MAY 1929

RADIO BROADCAST

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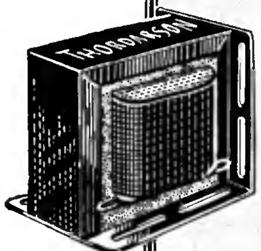

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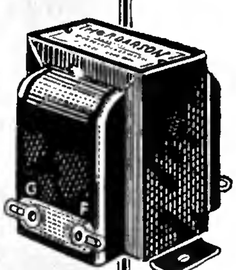

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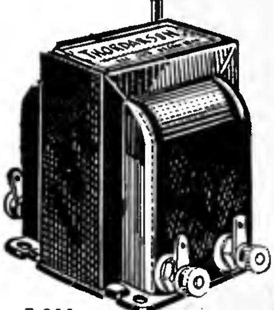

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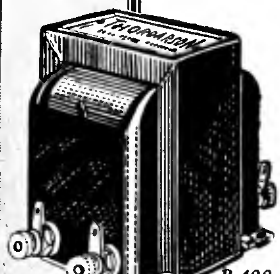

R-400 2nd Stage A. C. Audio Transformer $9.00

ONCE again Thordarson steps into the foreground, this time with three new audio transformers of unrivaled performance—fitting companions for the Famous R-300.

The R-100 is a quality replacement audio transformer for use by the service man in improving and repairing old receivers with obsolete or burned out audio transformers. The universal mounting bracket of this replacement unit permits mounting on either side or end, and is slotted in such a way as to fit the mounting holes of the old audio unit without extra drilling. List price $2.25.

The R-260 introduces a new standard of performance for small audio transformers. Wound on a core of Thordarson "DX-Metal" this audio unit is capable of reproducing plenty of "lows." It is entirely devoid of resonant peaks and performs with unusual brilliance over the entire audible band. List price $5.00.

The R-300 needs no introduction to the discriminating set builder. It is commonly recognized by set manufacturers and individuals alike as the peer of audio coupling transformers, regardless of price. The high frequency cut-off at 8,000 cycles confines the amplification to useful frequencies only. List price $8.00.

The R-400 is the first and only audio transformer built expressly for use with A. C. tubes. It is similar to the R-300 type in appearance and performance but possesses a better inductance characteristic when working under high primary current conditions such as are encountered in coupling the first and second stages of audio amplifiers using 226 or 227 type tubes in the first stage. List price $9.00.

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Transformer Specialists Since 1895
HURON, KINGSBURY and LARRABEE STREETS

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RADIO BROADCAST

VOLUME XV

MAY, 1929, to OCTOBER, 1929

GARDEN CITY NEW YORK

DOUBLEDAY, DORAN & COMPANY, INC.

1929

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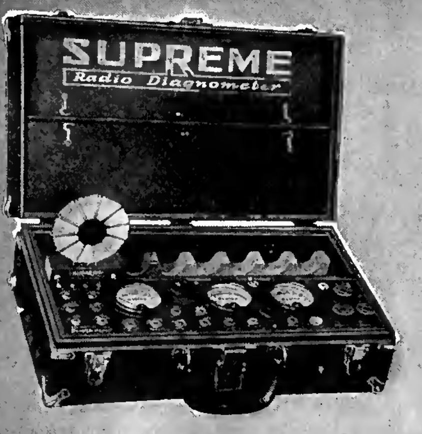
(*Illustrated Articles. Editorials in Italics)

AUTHORS

PORTRAITS



Model 400A Patents Applied For

What the Supreme Diagnometer Will Do

In addition to providing plate voltage readings, grid bias readings, filament voltage readings, and plate current readings, the SUPREME Diagnometer 400A provides oscillation tests of tubes — the best known method of showing normal, subnormal, and abnormal tubes. Gives direct full output readings of filament rectifiers. Tests screen grid tubes. Makes continuity tests without use of external batteries. Contains modulated radiator which takes place of broadcast stations for testing, and also furnishes signal for neutralizing and oscillator for synchronizing condensers, giving meter dip and speaker click at resonance. Has heavy duty rejuvenator. Bridges open stages of audio, alters outputs, tests fixed condensers, contains stages of audio, fixed capacities, 500,000-ohm variable resistance and 30-ohm rheostat. All meters and apparatus available for external use.

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Three Weston Meters and SUPREME engineering, combined with the finest of materials and workmanship, insure absolute accuracy. A Voltmeter of three scales, 0, 10, 100, 600, 1000 ohms per volt; a Millammeter of 125 mils and 2½ amps; and an A.C. Voltmeter, three large scales of 0, 3, 15, 150, are built into the SUPREME test panel and are housed in Bakelite cases.

All instruments are manufactured for 110 volts and 50-60 cycles. Instruments of other frequencies can be furnished special at slight increase in price.

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It has *Revolutionized* Radio Service

Radio Dealers Who Are Giving SUPREME Service Report Big Increases in Radio Sales and Service Profits

America's foremost authorities have proclaimed the SUPREME Diagnometer to be the greatest contribution to radio service and selling since the inception of radio. In one great stride this remarkable instrument changed radio service from "blind man's buff" to scientific analysis.

The day of hit-and-miss service methods supplemented with a few simple meter readings has passed. Only through complete, scientific service will dealers and service men be able to deliver the satisfaction their customers are demanding, and the SUPREME Diagnometer offers at this time the ONLY practical, convenient, proved means of obtaining a complete, scientific diagnosis of every working part of any radio.

The SUPREME Diagnometer must not be confused with set testers—those simple meter combinations which provide only plate voltage, grid bias, plate current, and filament voltage readings and nothing more. The SUPREME is a complete radio laboratory, in compact, handy, portable form, that provides all the elasticity and range of the most expensive stationary laboratory equipment. It is impossible to describe here all the tests and analyses it will make; but as you read the synopsis of its many functions in the extreme left-hand column of this page, you will realize how vastly superior the SUPREME Diagnometer is to any other or all other radio service instruments on the market.

Yet the SUPREME is simple to understand and operate. Its brass-bound carrying case measures only 18 x 10½ x 7 inches, and complete with the Diagnometer weighs only 25 lbs. The case contains ample and easily accessible compartments for carrying all necessary adapters and tools. A cushioned tube shelf that affords absolute protection for extra tubes is included. The instrument can be removed from carrying case for shop use.

Prices and Terms

SUPREME Diagnometers may be purchased either for cash or on the time-payment plan. Under our deferred payment plan, Model 400A can be purchased for $38.50 cash and 10 trade acceptances (installment notes) for $10 each, due monthly. Cash price, $124.65. All prices net, F. O. B. Greenwood. No dealers' discounts.

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Kindly send us more complete information on the Supreme Radio Diagnometers and the Supreme Service League.

Signed..

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RADIO BROADCAST

ENGINEERING · THE LABORATORY · SERVICING

WILLIS KINGSLEY WING . . . . *Editor*
KEITH HENNEY . *Director of the Laboratory*
HOWARD E. RHODES . . *Technical Editor*
EDGAR H. FELIX . . . *Contributing Editor*

VOL. XV. NO. 1

Contents for May, 1929

The contents of this magazine is indexed in *The Readers' Guide to Periodical Literature*, which is on file at all public libraries

. . . among other things

WE MUST apologize this month and all because the table of contents directly west, as your eye travels, must be set in smaller type than is our custom. But the 'orrible truth is that it had to be set smaller in order to get everything in. We hope the increased scope of the contents will make up for the slightly decreased legibility.

THIS May issue now before you covers a pretty wide range. For those interested primarily in merchandising, we have the leading article on the relation of sales and service; a description of a small successful radio shop in Washington, D. C.; an exclusive statement for RADIO BROADCAST by President Frost of the R. M. A. on the importance to the radio sales structure of good radio service; the very interesting article on page 15 on how to use technical facts in selling (this particular story is based on the Radiola 60), and finally, the special trade news section on page 45.

AN INDUCTANCE which has no appreciable external field is described by Emil Reisman on page 21 and it should be of great interest to our engineering readers. G. F. Lampkin of the University of Cincinnati details some interesting data he gathered on crystals (page 23). The articles by Prof. Terman of Stanford on detection have attracted wide attention and the last and perhaps the most interesting of the series is presented on page 37.

H. S. PARSONS, chief, Periodical Division, Library of Congress, Washington, asks our aid in completing the files of the Library of Congress. The following numbers of RADIO BROADCAST are missing from their files: Vol. 7, Nos. 2, 3, 4, 5 (June—Sept., 1925); Vol. 10, No. 2 (Dec., 1926). Any reader who is able to spare those copies should communicate with Mr. Parsons.

THE June issue of RADIO BROADCAST will be the Trade Show Issue and it will contain the most inclusive data on the way the radio world is going, written by those who are making radio industry history. The leading article, by Ralph H. Langley of the Crosley Company is a stimulating discussion of present trends in cabinet design, another deals with latent sales possibilities in phonograph pick-ups, another deals with how a radio dealer solved some of his most vexing problems in store management. Besides these there are many other special articles and all our regular departments, a description of an unusually interesting v.t. voltmeter, simple to build and unusually stable in its calibration, and a new method of presentation of our popular "Set-Data Sheets." We believe you will like the June issue.

—WILLIS KINGSLEY WING.

DOUBLEDAY, DORAN & COMPANY, INC., Garden City, New York

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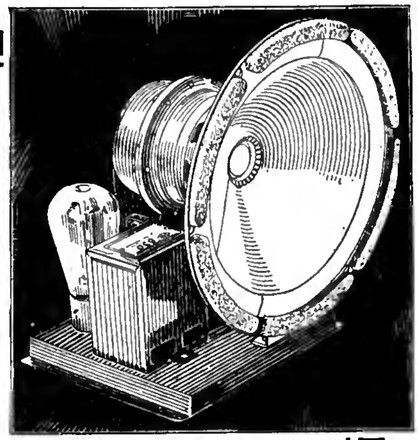
SM

Sweetest of Loud Speakers— It's a Real S-M!

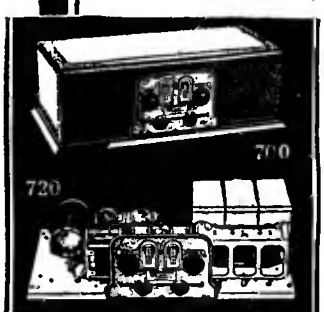


S-M 850 Dynamic Speaker
105-120 volts, 50-60 cycles.

ONLY two months old is the S-M dynamic speaker: yet already it has taken its proud place among S-M audio products—the acknowledged aristocrats of tone quality. . . "*Sweetness*" is taking on a new meaning for owners of S-M speakers. All the mellow flow of the "lows," as well as the brilliancy of of the "highs," come out smoothly on an S-M dynamic—with a surprising absence of all rumbles, roars and rattles. . . As always, there are underlying engineering reasons. Sound design in the speaker head is coordinated with similar mathematical correctness in the built-in S-M 229 output transformer, which has various taps to insure proper impedance matching for 171A, 210, 245, or 250 type tubes, singly or in push-pull. . . The 110-volt d.c. type (851), at $29.10 net, is ideal where the field winding is to be connected as a choke in a power circuit. . . The a.c. type (850), at $35.10 net, operates on 50 to 60 cycles, 105 to 120 volts. Thorough rectification of field current, with a 280 tube and a 2-mfd. filter condenser, reduces hum to the point of defying detection. . . Either type fits an 8½" baffle hole. . . Try an 850 or an 851 unit in the next set you build—and the S-M speaker will become *your* speaker!

720AC Screen-Grid Six

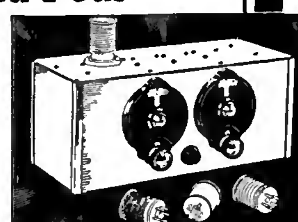
(*All-Electric*)



The 720AC is giving to experimenters everywhere a preview of radio as it will be in 1930—combining the sensation of the 1928 season—*all-a.c. operation*—with the sensation of 1929—*screen-grid r.f. amplification*—and with them the entirely new 1930 features of a screen-grid tube almost 100% better than the d.c. operated '22, and a *moderate-voltage* output tube (the '45) nearly as powerful as the high-voltage '50. And, with these, the S-M precision engineering which has brought in broadcasting from across the Pacific with six tubes—*and even with four*. S-M tone quality is the accepted criterion of the audio transformer industry. All these things in the 720AC (*licensed under patents of RCA and associated companies*), at only $70.20 net for the set completely wired in the 700 two-tone shielding cabinet, less tubes and power units. Component parts total $47.07 net; cabinet $5.55 net additional. S-M 669 power unit, furnishing all A, B, and C power required, wired complete $34.50 net. S-M 720 receivers can be changed over at slight cost to the 720 AC circuit; full directions in Data Sheet No. 10.

"Round-the-World Four"

(*Short-Wave Sets*)



Bigger and bigger grow the thrills that are coming in on the short-waves—biggest of all when received clearly on an S-M Round-the-World Four. One screen-grid r.f. tube is used, with regenerative (non-radiating) detector and two S-M Clough-system audio stages. Wired complete in the aluminum cabinet shown, (Type 730) with coils giving 17 to 200 meter range, $42.90 *net*—or as a two-tube adapter (Type 731) for use with any broadcast receiver, $30.00 net. Component parts also available, at $31.71 net for the 4 tube set, or $22.86 net for the 2 tube adapter.

New 810 Drum Dial

As beautiful an illuminated dial as you will find anywhere, in the highest-priced receivers. Smooth—absolutely quiet—rigid and accurate—a full 1/16" for each of the 100 dial divisions—and only 1 1/16" thick over all—truly a dial to delight the heart of the set-builder with modern ideas. Obtainable for condensers to *right* or to *left* of dial; 810R or 810L, price $2.25 net.

Are you getting the Radiobuilder, a monthly publication telling the very latest developments of the S M laboratories? No. 11 (Mar. 1929) gave the first details of the new 720AC All Electric Screen Grid Six, and the 669 Power Unit for the new a.c. screen grid and 245 tubes, with complete circuits. Send the coupon for free sample copy, or to enter your subscription if you want it regularly.

If you build professionally, but do not have as yet the S-M Authorized Service Station appointment, ask about it.

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For enclosed.............in stamps, send me the following:

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S-M DATA SHEETS as follows, at 2c each:

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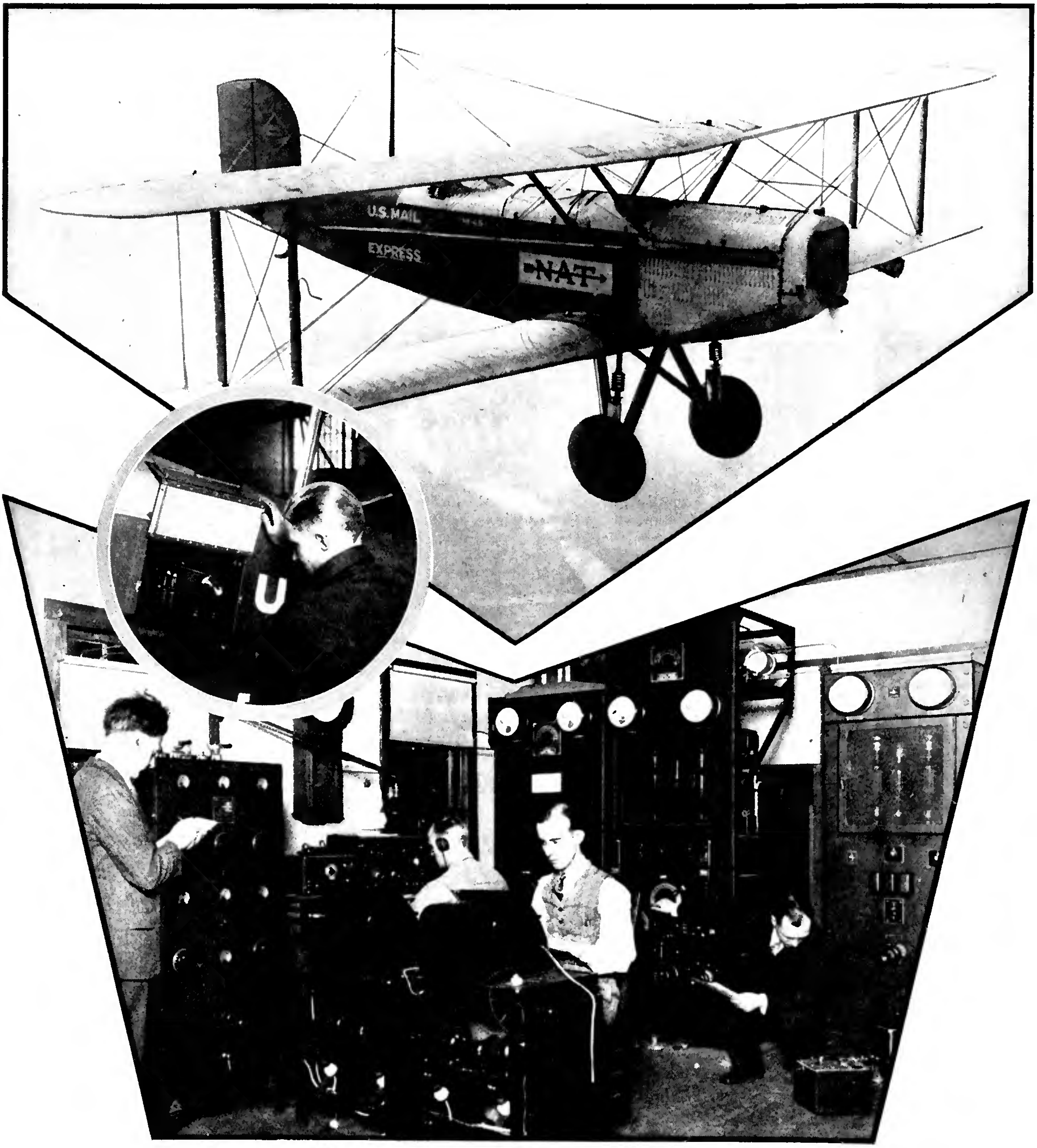
....No. 3. 730, 731, 732 "Round-the-World" Short Wave Sets
....No. 4. 223, 225, 226, 256, 251 Audio Transformers
....No 5. 720 Screen Grid Six Receiver
....No. 6. 740 "Coast-to-Coast" Screen Grid Four
....No. 7. 675ABC High-Voltage Power Supply and 676 Dynamic Speaker Amplifier
....No. 8. Sargent-Rayment Seven
....No. 9. 678PD Phonograph Amplifier
....**No. 10. 720AC All-Electric Screen-Grid Six.**
....**No. 12. 669 Power Unit (for 720AC)**

Name..

Address..



AIR-MAIL PLANES TO HAVE RADIO BEACON RECEIVING EQUIPMENT

Radio has been called upon to solve the problems caused by aviation's greatest foe—bad weather. As a culmination of over a year of intensive tests, all the airplanes of National Air Transport, Inc., operators of air-mail and express lines, are being equipped with radio receiving apparatus, and radio beacon stations are being constructed at the company's principal airports. The receivers on the planes will pick-up beacon signals and weather reports. The pictures on this page show (above) an N.A.T. radio-equipped plane with vertical antenna, (center) the receiving equipment which is installed to the rear of the pilot's cockpit and which is tuned remotely with the cable shown, and (below) an interior view of the transmitting station at the Cleveland airport.

Some Thoughts for Merchandisers

HOW SALES AND SERVICE ARE RELATED

By WILLIS KINGSLEY WING

THE radio dealer is primarily concentrating on the sale of a new radio set to his customer. He bends his chief efforts toward that end. When the immediate sale is consummated, the dealer looks to another new set sale and, in the main, is inclined to breathe a sigh of relief at the conclusion of the sale and to congratulate himself that it is out of the way. The customer who has just bought this new set, on the other hand, has a rather different point of view. He, the buyer, has just started his radio life. It has begun with the purchase and installation of his set. He looks on the dealer as the local representative of the entire radio industry structure. Only through the dealer can this interested customer attain good radio entertainment. The customer has bought a thing of wood and metal, whose technical working he does not understand, which promises him unlimited entertainment in his own home.

Having spent his good money, the buyer expects to receive continued return on his investment in the form of constant dividends of entertainment. In other words, although the buyer may not actually phrase it in his own mind in just this way, he expects his set to be serviced properly. The buyer regards his actual act of purchase as merely the first step in his radio experience. The continued good operation of his receiver is to the buyer the most important thing.

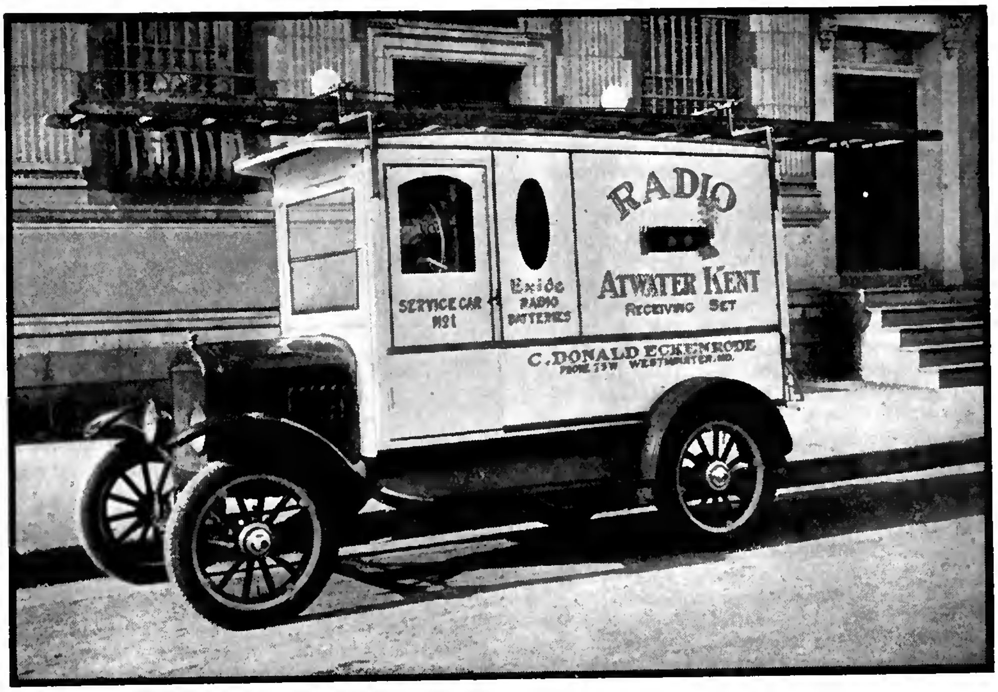
Here we have an interesting situation with the buyer and seller taking almost diametrically opposite points of view. The dealer looks toward new buyers to bring into camp—new sales, while the buyer looks toward continued and satisfactory service from what he has bought.

The dealer quite naturally is apt to feel that his chief job is sales. He knows that sets, being what they are—devices with the equivalent of electrical and mechanical moving parts—will require expert attention, occasional adjustment, and repair. This repair and adjustment branch of his business, however, is frequently regarded as the minor one. Service work is, then, a kind of necessary evil. The dealer realizes that technical men must be hired and their work supervised, testing equipment bought, and a shop equipped. So the sales side of the dealer's business looks more attractive, more potentially productive of results, than the service branch. And, in many cases, the dealer unconsciously separates these two chief activities.

If sales and service are separated in the dealer's outlook on his own business, isn't it because the dealer himself has made this arbitrary division? The customer surely has not. So it can be said fairly, that in extreme cases, the dealer and his customer are working at cross purposes. And it takes no massive brain to see that such a condition is not good for the dealer, the customer, the manufacturer, and the entire industry.

When the customer goes to his dealer with a service problem—which to the customer at the moment is just about the most important radio matter in the world—and he senses that the dealer is not nearly so interested in him now he has purchased his set, he is most dissatisfied and disappointed. The customer wants good service and wants it quickly. The dealer may be fidgeting to sell a new prospect in his display room at that precise minute. If he lets that customer feel that service is given grudgingly, then at that moment, the customer's confidence in the entire industry begins to be shaken. The customer looks askance not only at the dealer but at the manufacturer of his set as well.

The dealer is the ambassador of the industry to the customer. He is an ambassador when he sells the set, and he is no less an ambassador when the customer comes to him for service on that set.



A well-equipped service car is a great asset to a sales-service organization. Such a car makes it possible for the serviceman to take all necessary equipment with him on every job and it also has a favorable psychological effect on the customer. The car pictured above is an excellent example; it is fully equipped even to a ladder for erecting an antenna.

> *The basis for this article was an address delivered before the Retailers' Section of the Federated Radio Trades Association at their recent convention in Buffalo. Here we attempt to point out the important, and inseparable, relation between radio sales and service. Far too many dealers regard sales as the most important part of their activities and relegate service far, far down in the scale of things. Judging the retailing of radio as a whole, the weakest part of the structure is service. It has often been remarked that the radio industry can learn a great deal from a study of the progress of the automobile industry and certainly the automobile owner of to-day can get service of a high order on his car no matter where he may be. The radio dealer should render better service on the sets he sells, not only because it is better for the industry but also for the much better reason that through improved service he will make more money.*
>
> —The Editor.

Importance of Service

SERVICE rendered by the dealer is of increasing importance and it has a direct bearing on sales. In April, 1929, Radio Broadcast were published reliable figures on the sales of radio sets and radio tubes for the years 1927 and 1928. An appreciation of these figures is helpful in solving the problem under discussion.

In 1926, about 2,000,000 receivers supplied from all sources were sold. In 1927, nearly 1,800,000 sets supplied from all sources were sold. And in 1928, 3,000,000 sets from all sources were sold to the radio public.

The Department of Commerce figures of set sales in 1927—that never-to-be-forgotten year when battles were waged over the respective merits of the standard battery-operated sets and the new a.c.-tube receivers—indicate that about one a.c. set was sold to every three battery-operated sets. No such comparison is available for the year just closed—1928, but it is probable that the majority of sets sold in 1928 were socket-operated a.c. receivers.

Why did 1928 show such an astounding sale of sets? That figure of 3,000,000 is one to conjure with and the men responsible for sales can well be proud of it. Just two factors entered in. First, the public acceptance of the *new convenience* of radio. The light-socket-operated receiver hit their fancy. The a.c. set represented to them the "perfect radio" they wanted to own. Secondly, extraordinarily good broadcasting, represented by general programs of high quality and the astounding effect of the public interest in the broadcasting of all the events in the political campaign. There is much more to be said on these two points, but this will suffice.

It is no idle phrase to say that the a.c. set has been *accepted* by the public; the sales for 1928 demonstrate that. But in 1929 a.c. sets must be *sold* to the public. A radio set operating direct from the light socket is no longer a marvel to the prospective buyer. The phrasemaker who described radio as a seven-day wonder was more right than he knew and for all practical purposes might have been describing the sales situation last year. When the seven days were up, the a.c. set was *accepted*. From then on, it had to be *sold*.

Now those who bought a.c. sets last year, those represented in that 3,000,000 set market, bought a.c. receivers because they were the cream of the market. Radio for them had arrived and they bought it.

Radio set sales in 1929 will be more difficult. The cream of the market has been skimmed, as far as those interested in a.c. sets for their own sake are concerned. Now how can the tough sales problem in 1929 be licked? In just two ways: first by better, more intensive, more intelligent sales methods. The dealer cannot content himself with taking orders like salespersons in large and successful department stores; he must *sell*. How he must sell, is, as the saying is, another story. The second method by which the sales problem of 1929 can be conquered is in the improvement of *service*.

On January 1, 1929, there were 11,000,000 radio sets in use in the United States. Of these 11,000,000 not more than 3,500,000 are a.c. sets. That last figure is probably high, but will be accepted for the purpose of this discussion. Therefore, there remain 7,500,000 sets now in use which can be replaced with modern complete light-socket-operated receivers. Of course, a respectable quantity of these 7,500,000 sets are in homes which are not supplied with a.c. lines. But if a generous subtraction is made for all reasons, there still remain a tremendous number of battery-operated sets which can be replaced with the a.c. set of 1929.

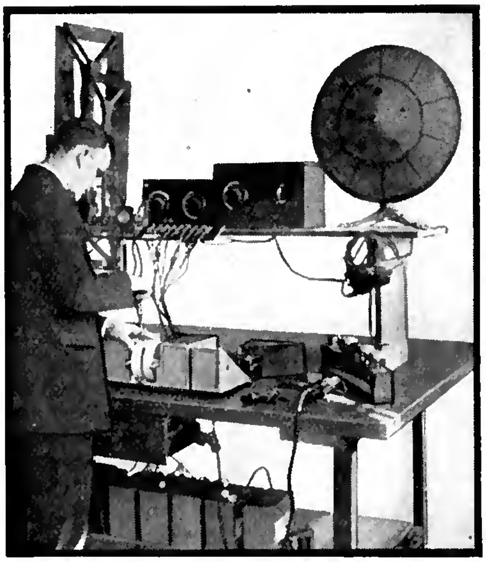
The Resale Market

IN CONSIDERING the 1929 market one cannot avoid the growing importance of the resale market. The dealer can and should sell new sets to people in 1929 who have never owned a radio before, but he also has an enormous prospect list made up of those who have sets, sets which are battery-operated, of poor quality of reproduction, expensive to maintain, and otherwise antiquated and unsatisfactory.

Now most of these present owners of unmodern, outmoded sets are in contact with a local dealer, And the chief contact the dealer has with them is through his service department. When it comes to salesmen everyone is pretty much the same; one does not willingly expose himself to a sales canvass if he is not absolutely convinced he wants what the salesman has to sell. But the dealer with a well-rounded organization has a great advantage. One branch of his organization is welcomed in the home of the prospect for a resale. *And the representative of that branch is the serviceman.*

The customer tends to hang on to his radio as long as he can. He reiterates that his radio is "a little old, but good enough." He loves to tell how his set still gets all the stations he wants, of its "fine mellow tone," and other phrases we all know so well. But when he calls in the dealer's serviceman, he establishes contact with the sales organization again. He asks to be sold service and he should get it. And if the dealer's sales and *service* organization function smoothly, the dealer can get an immediate line on whether or not that customer is a good prospect for a resale, through the report of his own representative—*the serviceman.*

Returning to the 1929 sales problem again, the relation of the resale market to the new sale possibility will be considered. John S. Dunham, president of QRV Radio Service, Inc., one of the largest and best purely service organizations in New York, has told the writer of a situation he has discovered. In a representative Riverside Drive apartment house where, with a total of 73 apartments, only 60 families owned radio receiving sets. That is the condition in one of the wealthiest sections of New York City, where the majority of families can well afford a radio receiver. Every one of these 60 families is a prospect



—F. A. D. Andrea, Inc.

In order to perform tests efficiently the dealer's shop must be equipped with well-designed testing apparatus. This picture shows a serviceman performing a continuity test on a Fada receiver in an approved fashion.

for a new and modern set in 1929, but it is going to take some expert selling to bring the 13 unequipped families into the radio fold.

The dealer is most certainly going to sell many of these families who have never owned a radio before the history of 1929 is written, but he should not lose sight of the ripe prospects among those who already own sets.

What is Good Service?

VOLTAIRE once said, "If you will argue with me, first tell me the terms of your discussion." And it is fair enough here to ask, "What is good service?" Good service is what keeps the customer *sold on radio*. The dealer must render satisfactory service during the period of the free guarantee in order that the set remain in the customer's home; the set must not come back. And barring earthquakes or other acts of God, the set can stay there to the customer's complete satisfaction during that time. If the dealer cannot keep the set sold through good service during that period, it is plain that the customer becomes completely unsold on radio, from the dealer right back to the maker of his set.

And what about the period *after* the free service guarantee has expired?

Here again, the dealer should render the best of service for the best of reasons. Through good service the dealer should keep the customer long enough to sell him another set. Through good service, the dealer can make a profit on service transactions and certainly on the sale of tubes and other accessories the purchase of which results from service calls. And here is a most important point: estimates indicate that about 10 per cent. of the total radio retail outlets are exclusively radio stores. In the case of the remaining 90 per cent., the other outlets, good service on the part of the dealer is going to retain customer confidence and satisfaction and make that customer come to his store for the other merchandise which that dealer handles. Furthermore, the dealer's main interest is in selling radio sets. He has to watch carefully the cost of *getting* his customers. Good service after the free service guarantee has expired means the difference between keeping a customer already acquired and going through the expensive process of getting a new one. Let's put that important point in another way.

If it costs a dealer $5 for each new customer and through poor service he loses half of them it means his year's new customers cost him $10 each. If he gets 100 new customers and poor service loses half of them, he must get 200 new customers to keep 100. So good service is closely connected with the dealer's new set sales, not only to those customers already in hand but to the friends of those customers. And the recommendation value of good service with customers already owning sets is no small factor in entirely new sales to the friends of the dealer's present customer. Almost every radio dealer, no doubt, recalls many instances in his own experience where satisfying his customer through accommodating and efficient service resulted in a good prospect and sale among one or more of that customer's friends.

Now is this good service which has been discussed too heavy a burden on the dealer? Well, the customer looks on the dealer as a means through which he can get good radio reception. Good broadcast reception is to the customer the only end. To the customer the dealer represents the chief source of radio information and expert ability. In the customer's eyes, the dealer sells him first, the mechanical-electrical means through which he gets the broadcast reception he desires, and through that same dealer he buys the continuance of the reception on which he insists. Good service on the dealer's part to the customer does not represent men or materials but only the restoration of good broadcast reception.

Service Requirements

GOOD service on the dealer's part requires: first good servicemen; secondly, a simple and easily maintained system of service records at the store; and thirdly, good testing and repair equipment in the hands of the servicemen.

Perhaps the average dealer, looking at his service problem as of secondary importance to his sales problem, has been prone to hire the cheapest men he could get, or to put it another way, has felt that servicemen were not worth a very large salary. It is probably true that the average serviceman makes little more than $25 or $30 per week. However, would it not be better for the dealer to hire fewer men and pay them more?

Even the simplest system of cost accounting applied to the dealer's service work will show that it is more economical to reduce the total number of service calls. For example, a mediocre dealer's serviceman makes two calls within ten days at a customer's house, each call involving in time alone a charge of not less than $1.50. The two calls cost $3.00. One call, which in the charge of an expert efficient serviceman at $3, is better economy. Economy from the dealer's standpoint, certainly from the customer's angle, and it is economy of the time of the serviceman himself.

It would be better from the dealer's position to hire one serviceman at $50 per week and expect topnotch performance than to hire two fair servicemen at $25 each. The dealer has a right to expect the very best of work from the good man, while he always knows in the back of his mind that the mediocre men cannot be expected to do really first-class work. The importance of having the service job done right the first time cannot be overestimated. And getting it done right means that a first-class man must do the work and must be paid well for doing it. And from the dealer's cost standpoint, it does not mean that he has to spend more money than he can afford. Good service done by the best possible serviceman is actually cheaper than "cheap" service.

Relation of Service to Sales

IN THIS discussion the serviceman has been considered as a different person, a different type from the sales staff of the dealer. But in the last analysis, and it is the honest analysis, the serviceman is a salesman just as much as anyone in the dealer organization is. The serviceman is *selling* service. If he is not, the dealer has deadwood on his hands. And service to the broadcast listener means only one thing—good broadcast reception. When the customer bought from the salesman originally, he was also buying broadcast reception and not merely radio furniture.

The good serviceman is really keeping radio sold and that is real salesmanship. The serviceman, it is true, differs greatly from the pure salesman in the radio store. But it must be remembered that after the customer has actually bought his set from the dealer, it is the serviceman who maintains that contact of the customer with radio reception.

Everyone is human and the good serviceman who enters the customer's home gets into as human a situation as can be found anywhere outside of a doctor's office. The patient goes to the doctor with an ailment and implicitly trusts the doctor to draw on his fund of medical knowledge and recommend and apply the cure. The radio owner, calling the radio serviceman in, is in exactly the same position. He is putting his trust in a technical expert to restore to him good reception.

Now the intelligent serviceman, backed up by a good system of customer-service records, goes into the home. He examines the set with practised eye and sure hands, using his test equipment surely and expertly, just as the doctor uses his thermometer and stethoscope to detect the patient's physical ailment. The good serviceman knows what will restore the set to working order, how much it will cost, and how long it should take. He does not talk circuit-diagram language, which the customer does not understand and, therefore, suspects. He tells the customer in words he can understand what his set needs. And he gives the customer's set that cure. But the good serviceman does more.

He returns to the shop and notes down on his service record—which should be available to the purely sales staff—his analysis. That analysis may show, as it often does, that the customer really needs, not a new set of tubes, or a new a.f. transformer to restore him to the enjoyment of good broadcast reception, but a new set. The serviceman does not try to sell that new set, but, while on the job and being entirely honest, he can in his analysis to the customer plant the seeds of desire for a new set and can give him reasons. The serviceman, as a sideline to his main task, is really a most important feeder of replacement sales to the retail shop.

In this connection it should be pointed out that only a very small number of the sets now in use are designed to give what we all know to-day to be good broadcast reception. The advances in design in the past 18 months or more have been too rapid. It is invariably true that the customer is satisfied with his present set until he hears something better. Servicemen of wide experience say that one of the most common complaints of owners runs something like this: "Please come out and fix my set. It still plays, but its quality doesn't seem to be as good as when I first got it." Now, barring such proper complaints as failing tubes and incidental circuit conditions causing temporarily impaired quality—which the serviceman quickly repairs—what is the true situation? Simply this: the set, after minor repairs, is as good as it ever was, but what has happened is that the customer has revised his ideas of what good quality is. His set, in other words, has not failed him, the set is no different, but the *customer* is different. His ideas of good quality have been revised without his knowing it.

How Servicemen Aid Sales

WHAT does the good serviceman do in this case? Does he merely tell the customer that his set is as good as it ever was? That, the customer will never believe because he *knows* in his heart that the set isn't. No, the good serviceman, working under proper direction from his chief, explains how reproduction has improved in new models, tells him of the merits of the new loud speakers, revises, in fact, for the benefit of the sales staff, the customer's ideas about modern radio. Of course, the serviceman can explain that he can install special high-quality transformers and a dynamic loud speaker but he can show at the same time that the $50 or $60 involved in materials alone in this improvement in his old set might better be put toward an entirely new and modern set which has all these improvements as an integral part. Or take another frequent situation. While the serviceman is making repairs in the home to an old set, the customer plies him with questions. "What do you think of this set of mine? Is the new X-phonic receiver all the advertisements say? How much does it cost to operate one of the a.c. receivers? What set do you recommend?" These questions and a lot more like them are fired at the serviceman, and, if he is good, he answers them honestly. And when he returns to the shop his analysis of that customer's possibilities can appear laconically in the remarks column: "customer's set repaired with set of new tubes; good prospect for new a.c. set."

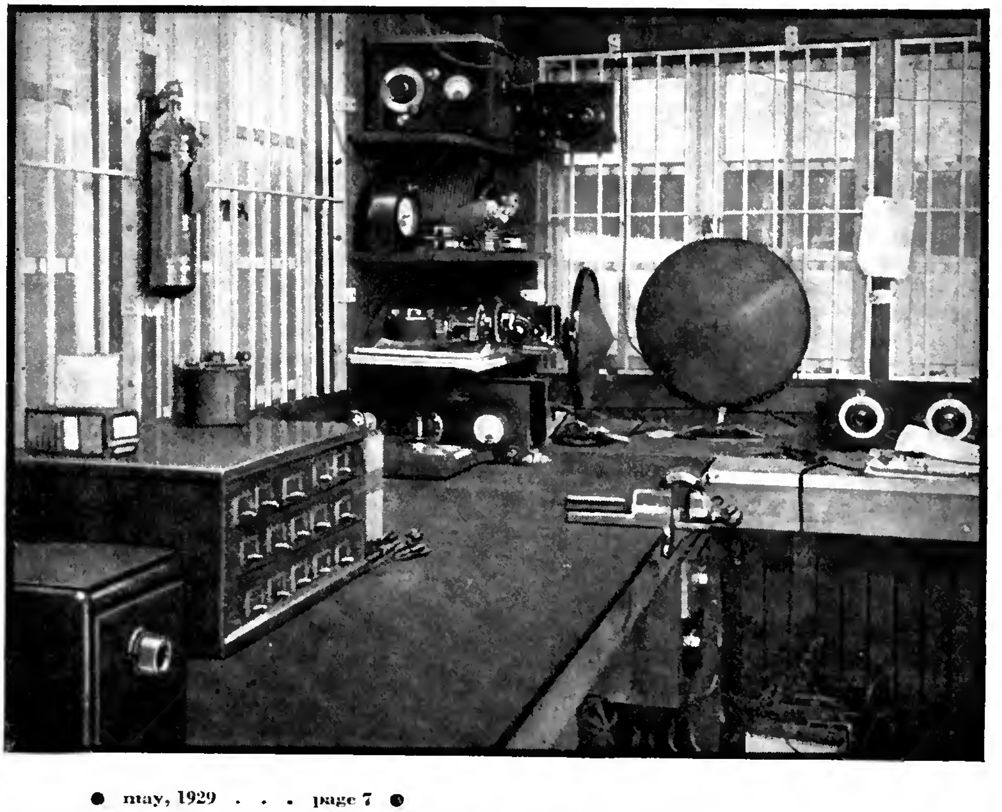
Here the dealer makes a profit on the service call, satisfies his customer, and gets absolutely invaluable information leading to the sale of a new set. Had his reputation for service been poor his competitor's serviceman would have been there, paving the way for a replacement sale. So is good service tightly linked to increasing sales.

Now where are good servicemen to come from? How much responsibility rests on the dealer and how much on the serviceman? Although an attempt has been made to show that the intelligent and alert serviceman, working in the customer's home, has a tremendous advantage in influencing new sales, he is not a salesman primarily. But if he is not used by making him an integral part of the sales plan, the dealer is leaving a big part of the store's sales possibilities untouched. During the regular sales meetings the dealer should help the serviceman to understand the importance of his part in the sales plan and should instruct him on how he should answer the customer's questions about new sets.

The dealer's main effort should be to improve his servicemen and that means leaving no stone unturned to see that he is getting every bit of technical information which will help him. He needs the best possible tools of his profession, to be sure; good meters, set-checkers, etc., but he needs the technical knowledge of how to use them, he needs background on radio generally, he must know what other manufacturer's sets are like, technical short-cuts in his work, etc. In short, he must study. The dealer sees that he is equipped with the proper meters—the tangible necessities—but he must also see that he has the intangibles—the knowledge based on study.

There are some textbooks which give servicemen the background they need or which help to develop that which they already have, there is a lot of excellent printed matter from various radio manufacturers which has lots of useful information, and there are periodicals which will help servicemen to keep abreast of the technical side of this rapidly moving industry. In this connection, one of the most encouraging signs which has been manifest is the deep interest of radio dealers and their service staffs in acquiring more accurate technical information on what is going on. Thousands of letters are received at Radio Broadcast from dealers and servicemen, and these communications are from men who are greatly interested in improving themselves with more information.

The serviceman's work bench should be well lighted and free from obstructions to permit most efficient work. Each tool should have a place and small parts should be stored in some orderly manner.



The MARCH OF RADIO

Will Synchronization Bring a Radio Panacea?

WHENEVER an experiment in the synchronization of broadcast station carriers is announced, articles appear in the press to the effect that, should the experiment be successful, the number of stations operating simultaneously in the broadcast band may be increased greatly. In most instances, this impression is entirely erroneous because only approximate carrier-frequency regulation is attempted. Only when absolute synchronization of both carrier and program signal is the objective is there any hope of increasing the number of transmitters which may operate simultaneously. Absolute synchronization has been accomplished successfully only when the stations are linked by wire lines and both carrier and program signals are supplied from a common originating point, as in the case of WBZ and WBZA.

However, there are definite limitations even to absolute synchronization. It is useful only when the signal received at any one point comes from but one of the two synchronized stations. A receiver, so located that it receives equal signals from both synchronized stations, is subject to serious distortion because the two signals are out of phase due to the differing time required to transmit them by wire and back through the air. Usually, because of fading and field-strength variations in the received signal, this phase difference is emphasized by a swinging effect. Consequently, undistorted reception with absolute synchronization is possible only when the signals of one of the stations predominate over the other at all reception points within their respective service areas.

We are informed of practical experiments conducted in Germany in the field of absolute radio program synchronization, employing wire distribution of both program and carrier. A definite interference pattern, which changed not only from day to day but hour to hour, was found to exist, due to the interaction of the signals received from two points simultaneously but out of phase. Reception, good at one point, would be found to be practically nil at another but a few score yards distant. This experience corresponds to theoretical conceptions of phase difference effects encountered in radio transmission from two different points. Authorities differ on these questions, it is true, but until we have actual demonstration of successful wire-line synchronization under the practical conditions of the present broadcast spectrum, glowing descriptions of this would-be panacea to broadcast allocation ills are rather the expression of a hope than a justified assertion.

In the case of approximate synchronization, attempted by means of independent crystals accurately matched, very serious limitations to its application exist which do not appear to be generally understood. The principal object sought in approximate carrier synchronization is to eliminate carrier whistle on regional channels. This is the most annoying type of interference, now widely experienced on all the crowded regional channels. For example, WCCO and WPCH, now engaging in a synchronization experiment, operate simultaneously only during the day. If their carriers are approximately synchronized, they may also operate simultaneously during such evening hours as the program service areas of the stations do not overlap. If the separation between these stations were reduced by 500 miles, approximate synchronization would still eliminate the carrier whistle, but the distortion due to the simultaneous reception of two programs and the effects of the sub-audible beat note, created by their carrier interaction, would cause disruption of the service of both stations. While a 50- or 60-cycle carrier heterodyne of approximately synchronized stations is not reproduced by the loud speaker, the sub-audible beat occurring interacts with the audio-frequency or program component, affecting musical quality. WPCH serves only a small area, surrounding New York, and, during the early evening hours, WCCO's signal is of such a low field strength that it would not produce an audible effect in WPCH's service area. At the same time, WPCH, being a low-powered station, would have no noticeable effect in WCCO's territory. But, as the later evening hours approach, and good transmission conditions prevail, WCCO may, under certain conditions, deliver sufficient signal in the New York area to affect the quality of WPCH's transmissions. The success of the WPCH-WCCO experiment, therefore, means only that, in certain instances, where a low- and high-powered station, widely separated, are paired on the same channel, their respective service may be somewhat improved at those times that their audio-frequency and carrier signals are of a widely diverse field strength within their service areas. Two or three hours' service in the early part of the evening is a valuable addition to WPCH's opportunity to serve its audience and the experiment of carrier stabilization is thereby justified. But station managements are warned that that is the maximum effectiveness of the experiment. Amateur allocation experts should realize that approximate synchronization will not increase the number of stations which may be assigned in regional channels.

The Federal Radio Commission has issued permission to the Continental Broadcasting Corporation of New York to attempt an experiment in synchronization of two broadcasting stations in Virginia. The frequencies assigned for the purpose are 3257, 3256, and 4795 kc. These high frequencies, when heterodyned, produce a 1539-kc. carrier, the frequency of the two stations in the broadcast band associated in the experiment. The employment of two or three high-frequency transmitters for generating a desired broadcast carrier frequency at several separated broadcasting stations by heterodyning may or may not have advantages over the distribution of a single frequency, which is stepped to the desired broadcast frequency by means of a frequency multiplier or harmonic producer. The latter method requires the use of but one high-frequency channel instead of two or three. The conclusion that a demonstration over short distances will make possible long-range synchronization of chain stations is unwarranted because it still remains to be proved that fading and noise effects do not cause instability in reception of the synchronizing frequencies and that skip-distance effects limit synchronization to very long spans only, so that amplifying such a signal to serve as the carrier for broadcasting is impractical.

Canada's High-Frequency Allocation

AN AGREEMENT has been reached between the State Department and the Canadian Government on continental high-frequency assignments, in accordance with the report of the majority of the American delegation at the recent conference at Ottawa. That report, with which ex-Commissioner O. H. Caldwell of New York dissented, gives the United States a total of 146 of the 228 general communications channels, of which 112 are exclusive and the remaining 34 shared with Canada and Newfoundland. Canada is allocated 38 exclusive channels, to be shared with Newfoundland, and 48 shared with other nations. Newfoundland received 17 channels, shared with the United States, Cuba five exclusive and 15 shared with Canada; Mexico and other nations, eight exclusive and 16 shared with Canada. Of the 65 channels below 3412 kilocycles, the United States holds 34, shared with Canada and Newfoundland; Canada has 48, shared with other nations; Newfoundland 17, shared with the United States; Cuba 15 shared with Canada, and other nations have 16 shared with Canada.

Apparently, the meetings leading to this agreement were not in the nature of a negotiation but rather a presentation of frequencies to Canada. With utter disregard of the future needs of the United States for essential high-frequency communication channels, an extraordinarily liberal award has been made to Canada. Considering that our population and habited area is roughly ten times that of Canada, there is no possible excuse for the present ratio, which gives Canada more than 70 per cent. of the number of frequencies assigned to the United States. Furthermore, the precedent established by this agreement will be pressed by Canada as applicable in the broadcast band. If our broadcast channels were divided in the same ratio, the American allocations would amount to approximately 48, the Canadian 34, and other neighboring countries 14. The same arguments which swayed the State Department into accepting the Canadian proposal for this disproportionately large share of high-frequency channels are certainly applicable to broadcast channels.

It seems to us that the only just basis upon which the 293 high-frequency channels can be divided among Canada, Newfoundland, Cuba, the United States, and the remaining countries in the North American continent is a scientific appraisal of their present communications and future needs. This requires that consideration be given to area, the determining factor in appraising the distances to be linked; population, determining the number of persons to be served, and any special factor which may be necessary to correct inequalities arrived at by this method. In the matter of area, Canada gains an undue advantage because a large part of its area is uninhabited and, therefore, requires little or no communication facilities. Although our population is larger, it is also growing at a rate which would make assignments on the basis of population quite fair. On the basis of area and population alone, Canada rates about one-tenth as many frequency facilities as the United States, although it is entitled to a better ratio than this because many small but important communities cannot be served by any other means of communication than radio. But this consideration does not justify the one-and-a-half-to-one ratio adopted.

Commission Permits Limited Picture Broadcasting

THE Federal Radio Commission has ruled that visual transmissions in the broadcast band will be permitted hereafter between 1 and 6 a.m. Seventeen companies have been granted high-frequency channels for experimentation in the field, including Westinghouse, Radio Corporation, General Electric, Jenkins, WAAM, Inc., Lexington Air Station, Pilot Electric, Chicago Federation of Labor, William Justice Lee, and Aero Products, Inc. Other applicants, while not denied licenses, were ordered to appear at hearings for the purpose of showing why they should be granted television-channel assignments.

This outcome of the visual broadcasting hearing should be encouraging to those interested in its development because it gives them opportunity to demonstrate the possibilities of the art both on high frequencies and in the broadcast band. It is perfectly proper to restrict visual broadcasting to obscure hours until its program value is demonstrated more fully. The present hours, however, should be modified slightly because station personnel is not available at the hours now specified. If the visual broadcasting period were moved forward to midnight instead of 1 a.m., and a morning hour, such as from 8 to 9 a.m., a silent period with most stations, added, much more effective work could be done without, at the same time, affecting entertainment audiences. However, if any progress is made at all, the Commission is likely to consider the merits of the case.

The consensus of those appearing at the hearing was that television and still-picture broadcasting should have opportunity to prove their prospective service value before any attempt is made to determine their future. Representatives of the Radio Corporation of America and allied interests were flatfooted in their statement that there is no place whatever in the broadcast band for television because there is no public interest in the subject. Other authorities, including Dr. Lee deForest, C. Francis Jenkins, and John V. L. Hogan testified that television and still-picture broadcasting may ultimately have real service value in the broadcast band. Broadcasting stations can be relied upon to radiate picture signals only if there are appreciative and responsive audiences. Therefore, there is no wisdom in arbitrarily preventing experimental progress in what may become a useful broadcasting service.

World Peace Via the High Frequencies

IN AN effort to conduct world-wide communication from the Secretariat of the League of Nations, arrangements have been made by that body for a series of high-frequency radio telephone transmissions, utilizing the Dutch station at Kootwijk. A similar attempt in May and June of last year resulted in 92 reports of successful reception in all parts of the world. This year, transmissions to the American continent will be attempted on Tuesday evenings, to Japan on Wednesday and Australasia on Thursdays. For point-to-point communication, this service is likely to meet the needs for diplomatic message exchange with the same reliability that obtains in all short-wave transmissions. If a world-wide broadcasting service is contemplated, however, no single station is likely to be of use. The bulletin, issued by the League's Secretariat, is rather naïve, indicating a somewhat incomplete knowledge of radio transmission phenomena. The only hope for a world-wide broadcasting system lies in the utilization of established broadcasting systems, linked by short-wave transoceanic networks of a nature now being tried by the National Broadcasting Company and the British Broadcasting Corporation. A great deal of time and money could be saved if the League took advantage of the experimental work being done by others.

The occasional rebroadcasting of foreign programs by established systems will undoubtedly do more to promote international understanding than all the lofty declarations of politicians and diplomats. Science is rapidly building the means of promoting peace among nations and, in so doing, is incidentally developing the agencies which will make warfare all the more effective and, therefore, the more destructive.

Municipal Regulation of Man-Made Interference

THE Federal Radio Commission, through its legal staff, has made an investigation of state and municipal regulations applying to radio communications. This body is prepared to give advice and assistance to municipalities and states desiring to formulate ordinances which will not conflict with federal regulation. Only one decision has been made in the courts, demarking the field of federal and state regulation of communication. In that opinion, rendered by the District Court of the Eastern District of Kentucky, Whitehurst V. Grimes, held that an ordinance, attempting to license radio stations, is unconstitutional on the grounds that "radio communications are all interstate."

The Board of Trustees of Boonville, N. Y., adopted an ordinance, providing that no person shall maintain or operate any electrical device or apparatus causing interference with radio receivers within the village of Boonville. No electric sign or other so-called blinking device whereby a make-and-break contact is maintained, shall be operated unless equipped with condensers properly grounded so as to limit interference, nor shall electric pianos or other similar machines be operated. Violet ray or other X-ray machines shall not be used between 6 and 10 p.m. except in emergencies. Anyone violating this ordinance shall be considered a disorderly person and subject to a penalty of a hundred dollars.

We learn from a correspondent of another proposed ordinance being considered by the Brandon City Council of Manitoba, Canada, prohibiting the use of electrical equipment which causes radiations of a type interfering with radio reception. There have been several attempts to pass similar municipal regulation in the United States and, in the few instances that such regulations have actually become ordinances, they have been found to be unenforceable. The attack on electrical interference does not lie in prohibiting the use of equipment of a radiating character. The solution of this problem, which is gradually becoming of greater and greater importance as other causes of interference with radio reception are eliminated, lies in compelling the manufacturers of electrical appliances to equip their devices with filter systems which prevent radiation. Those who cause interference are usually the innocent victims of the manufacturer of the device.

The Press Continues Bungling

THE National Radio Press Association, Inc., of New York City, has been formed for the purpose of supplying spontaneous news and sports reports exclusively for radio stations and, through them, to the radio public. It proposes to build stations in New York, Washington, Chicago, Cleveland, Columbus, Cincinnati, Detroit, Kansas City, St. Louis, New Orleans, Atlanta, Salt Lake City, San Francisco, Los Angeles, Seattle, Philadelphia, Dallas, and Minneapolis. It has made application before the Federal Radio Commission for twenty continental short-wave channels, to be taken from the channels assigned to the American Publishers Committee. There is not the slightest indication of the competence of the organization, but it has been said that Herbert Bayard Swope, former executive editor of the New York *World*, is behind the project.

John Francis Neylan, attorney representing the Hearst newspaper interests, has protested to the Federal Radio Commission about the distribution of the twenty frequencies assigned to newspaper use under the management of Joseph Pierson of the Chicago *Tribune* and president of the American News Traffic Corporation. Under the plan, the Hearst newspapers received three transoceanic channels and three intra-continental, while the United Press and the Scripps-Howard newspapers receive a total of six and a half wavelengths. In a telegram to the Commission, Mr. Neylan states that Mr. Pierson is without authority to represent any newspaper or news association of the Hearst interests and is without authority to speak for ninety per cent. of the press of the United States. The press continues to show marked incompetence in managing its radio affairs.

The Board of Directors of the Associated Press adopted a resolution to the effect that a member newspaper may not establish a chain by which a station in another city than the city of publication may broadcast news of the A. P., unless that member joins with and shares the credit with the originating newspaper. A member may not tie-up the broadcasting of Associated Press news with any advertising program. —E. H. F.

RUNNING A SMALL RADIO SHOP

By MARY TEXANNA LOOMIS

President, Loomis Radio College

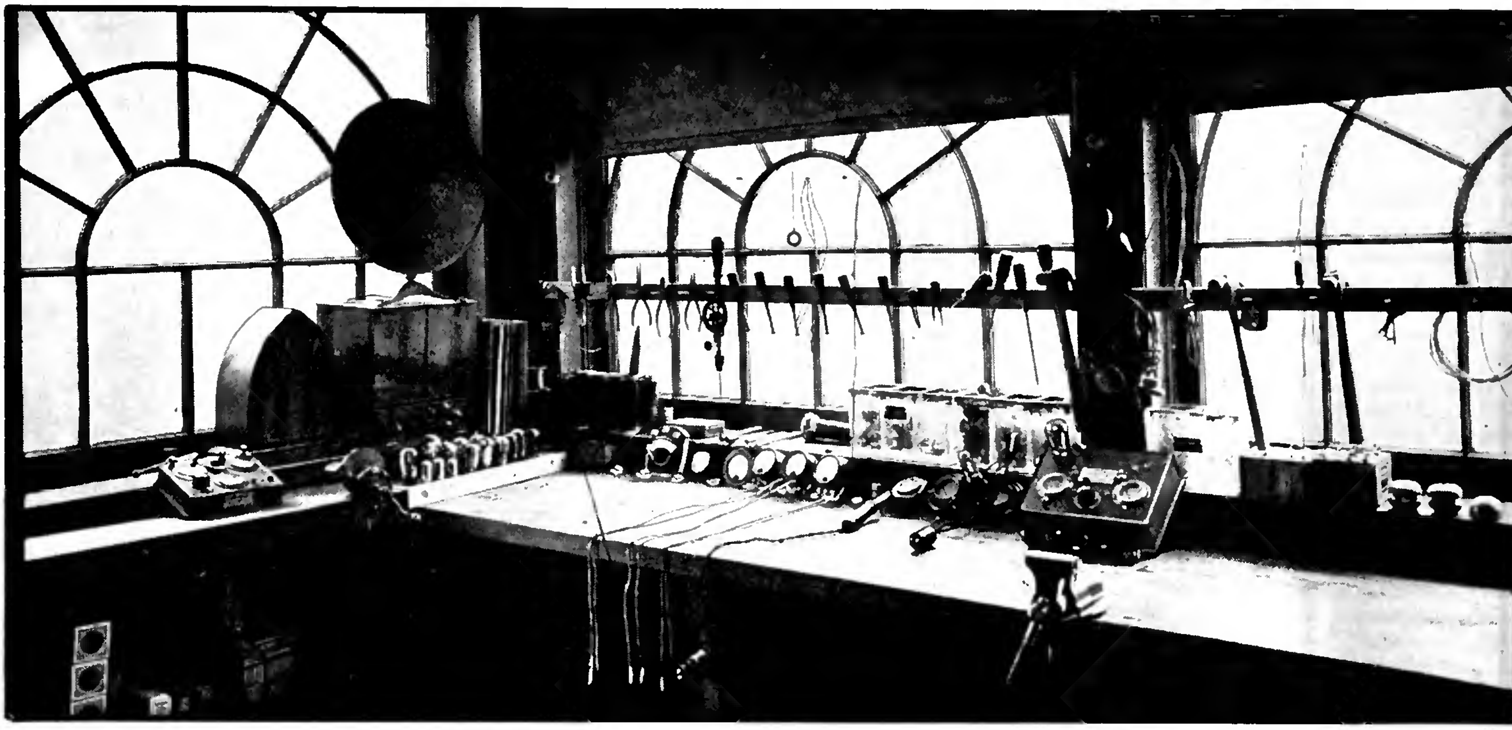


Fig. 1—A well-equipped work bench for the efficient servicing of radio receivers. Note especially the convenient arrangement of tools and testing equipment.

WHEN the editor of RADIO BROADCAST asked me to prepare an article giving details of a small radio retail and servicing business, it was obvious that the service-shop classroom of the Loomis Radio College did not answer this description, and that the most effective way of making such an article practical would be to pick out some prospering little shop as a model. Naturally the choice would have to be made from available material. I have chosen to describe the Capitol Radio Service, of the Mount Pleasant suburban section of Washington, D. C., hoping that the ideas gathered may be of assistance to persons contemplating going into a similar line of business.

The shop referred to is located in a remodeled house, giving two floor levels, as indicated in Fig. 3. Many such store buildings exist throughout the country, and this is mentioned merely to explain the drawings and pictures which accompany this article. The showroom, with a small array of high-class broadcast receiving apparatus, is shown in Fig. 2, and the service shop in Figs. 1 and 5. Several antenna-ground wall outlets, such as used in apartment-house installations, are arranged around the showroom and wired in parallel so that any set can be conveniently plugged into contact with the antenna and ground without having to move it.

The retailing branch of any radio store is a matter of buying wisely and selling at a reasonable profit. Most dealers have arrangements with two or more manufacturers of standard sets as their representatives in their localities. One high-priced and one low-priced set from different manufacturers need not conflict. All sets are purchased on either cash payment or short-time credit, with standardized discounts. Manufacturers of standard radio equipment will not release goods on consignment.

> *The author of this article looked into the shop of a typical dealer in Washington, D. C., and reports what was found. Particular stress is laid on the physical service equipment of this shop and how it is employed, and from this description dealers may compare their own problems and how they are trying to solve them with what the Capitol Radio Service organization is doing. Servicemen who find their businesses expanding to the point where they need a shop from which to operate will find this story especially useful.*
>
> —THE EDITOR.

Side Line Advisable

IT IS a good plan, especially in suburban districts, for the radio dealer to handle a small stock of electric lamps, flash lights, etc. Even a few standard automobile electrical devices may go well. The prospective radio merchant will profit by making a study of the location that he has chosen, to check up on the field that is likely to be open to him in electric side lines. In the matter of purchasing stock, the older experienced dealers could give valuable advice, if they could be induced to talk about their mistakes. They would no doubt tell newcomers in this field to proceed cautiously, without permitting conservatism to stand in the way of progress. One must always take a certain amount of chance in any business, but it is wise to avoid risking too much until the way ahead can be seen clearly. It is very easy to clog the stockroom shelves of a small radio store with a quantity of obsolete goods which only bargain sales at great sacrifice can move.

In the matter of receiving sets, and auxiliary equipment, the best goods, with the dealer's and factory's guarantees back of them, will pay best in the long run. Sets designed to meet the means of customers who can afford to invest only modestly may be as good, of their kind, as the more elaborate and costly apparatus. Often a large portion of the difference in price between two models from the same manufacturer may be due merely to the difference in design and finish of the cabinets or consoles. If the prospective customer cannot afford to buy beautiful furniture with his radio set, he should be advised to put his money into the "works."

The Service Department

THE service department of any radio store is the cause of its showings steady increase in business and profits. On the other hand, an inefficient service department is the cause of a store losing its business and finally, in extreme cases, of bankruptcy. The sets sold must be kept in working order, usually for people having only the vaguest of ideas concerning their operation. A short term of free servicing following a sale is standard practice. The dealer must deal pleasantly and patiently with his customers if he intends to make a success of his business. Therefore, the service department is a most important factor and worthy of careful consideration.

The first step toward installing a practical service shop is a list of apparatus to be used. As there are still a great many battery-operated sets in use as well as the various types of electric sets, adequate apparatus must be available for testing and repairing both types. All instruments should be purchased for their accuracy, convenience, and ruggedness. They will be subjected to hard wear.

An ample outfit, containing meters and tools which will enable any qualified radio serviceman to make any test required in locating set troubles, and for making all repairs, is suggested as follows:

The work bench: The design of this piece of equipment is most important. It should be 2 feet deep, 36 inches high, and made of heavy pine boards 2 inches thick. (Two 12" x 2" planks 12' long recommended.) The legs should be made of 4" x 4" lumber, so that it will be perfectly steady. The bench should be located in such a way that daylight comes in from the back, with each serviceman facing a window. There should be from 4 to 5 feet of bench room allowed for each man, and each man should have a drop light hung directly over his work. A stool of comfortable height should be provided each man for long jobs.

Shop servicing equipment: Electric soldering irons, capable of giving sufficient heat for extended work without burning out (One large electric shop in Washington uses the old-time plain irons, keeping several of them hot around a small gas ring.); wide assortment of well-constructed steel screw drivers; set of small open-end hexagonal wrenches; assortment of pliers and wire cutters of a good grade; set of hexagonal socket wrenches; assortment of fuses used in sets to be serviced; assortment of spring clips for making quick connections; several pairs of test prongs with wires; a small jaw vice; hydrometer; package of 00 sandpaper, and an electrician's steel knife.

Instruments needed: High-frequency oscillator; a.c. and d.c. tube tester; d.c. voltmeter with double-reading scale, 0–15 and 0–150; high-resistance voltmeter, 0–10 and 0–200; d.c. ammeter, 0–5; a.c. voltmeter, 0–3 and 0–5; and d.c. milliammeter, 0–100.

Power: All A, B, and C voltages for testing battery-operated sets should be wired to binding posts or clips on the work bench, as indicated in Fig. 4. There must also be a double outlet from the a.c. power line wired to the bench for use in testing a.c.-operated receivers. Where the shop is in the d.c. district of a city the most convenient method of handling the a.c. set problem is to install a motor-generator, running on d.c. and giving 110 to 115 volts a.c. output. The power rating of this generator depends on the load to be placed on it. A one-fourth-kilowatt generator is about sufficient for operating one a.c. set at a time. Two popular motor-generators, designed for this purpose and including filter, are the 250-watt, 115-volt, type BE-24, made by the Bodine Electric Co., Chicago, and the 500-watt, 115-volt, type LF-85, made by the Electric Specialty Co., Stamford, Conn.

Fig. 2—In this carefully planned showroom antenna-ground outlets have been installed in several convenient positions.

Antenna and ground: Erect separate antenna for shop, and wire to bench. Also wire good ground to bench.

Loud speaker: Place good loud speaker on a wall shelf, or other elevated position above bench for convenient plugging in. It is generally necessary to use an extension cord for this purpose.

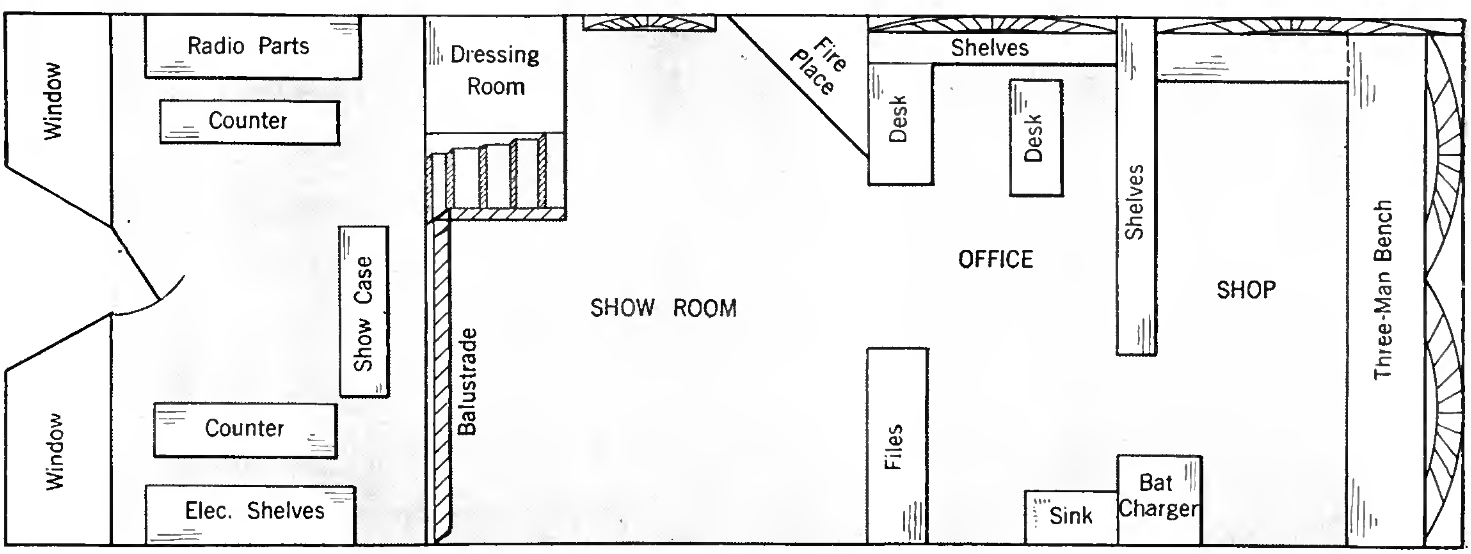
Outside serviceman's equipment: One oscillator voltmeter test combination; one test set, or assortment of meters with prongs or wires; such hand tools as are required for making minor repairs—screw driver, knife, hydrometer, pliers, soldering iron, phones, and a number of spare tubes of different types.

The equipment listed above should represent the initial outlay for a small radio service shop. Special tools may of course be added. Among these would be special wrenches, neutralizing tools which some sets require, etc.

Layout of Equipment

THE service shop should be located, when possible, in the rear of the salesroom, so that customers can be referred readily to the service department, using a minimum of the sales force time. The outside serviceman should have access to the serviceroom through the rear of the building. The shop should be well lighted, if possible by daylight. The lighting shown in Fig. 1 is ideal. Glass jars, seen in the photograph on the wide window sill, are used for holding spare parts for repairs. Adequate shelf room must be provided for holding incoming and outgoing sets, and a carefully handled system of tagging and filing is necessary in order to avoid confusion concerning ownership of the sets, their history, etc. Stout paper shipping

Fig. 3—Diagram showing the floor plan of the Capitol Radio Service Shop, Washington, D. C.



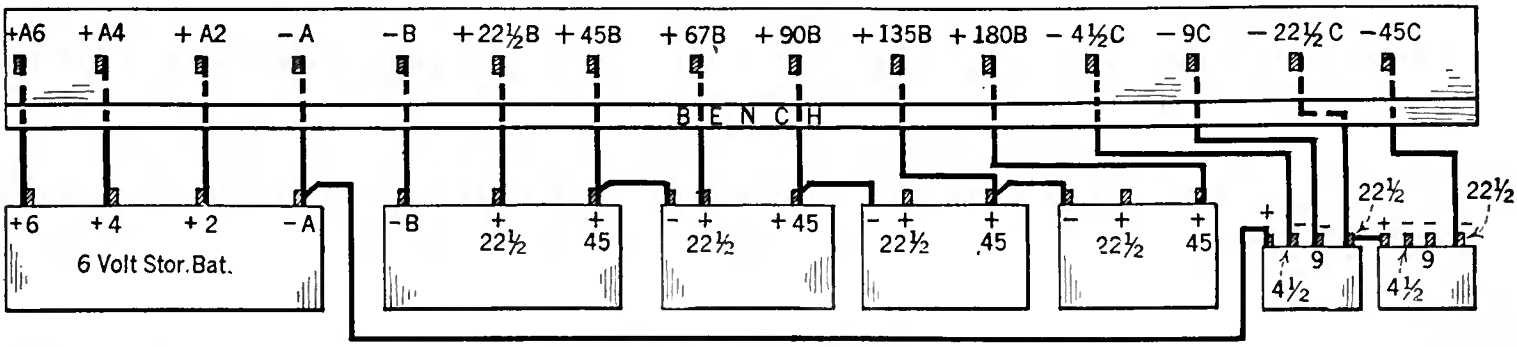


Fig. 4—Diagram showing the arrangement of battery clips on the work bench pictured in Fig. 3. As indicated all potentials are provided by batteries, thus assuring best results.

tags with fine stout twine are useful in labeling the incoming sets.

After placing the major equipment in the shop, the arrangement of instruments and tools on the bench is the next consideration. The hand tools most frequently used should be placed in a definite location, as shown in Fig. 1. The old adage, "Have a place for everything and everything in its place," will save much friction and loss of time. The bench beneath a radio set which is being serviced must, of course, be clean and free from tools. We have seen some servicemen actually working with a radio set placed on top of a pile of tools and débris on the work bench. Both radio set and tools suffer from such treatment.

All testing meters should be placed in a definite location, and supplied with long test leads. In some servicing shops the meters are mounted on a wooden or bakelite panel. However, as the leads must reach any set on any part of the bench, and be in such a position as to be easily read while putting the test leads to different parts of the set under test, this may not be found as convenient in practice as might be supposed. It is often found desirable to install a single-throw switch, or a locking push-button, in the lead from each meter, this will prevent accidents to the meters from picking up the wrong leads, if the switch is kept open except when the meter is in use.

The location of the tube rack, or racks, is a matter of personal preference in the individual shop. Safety from dropping objects and jolts is a point to consider in planning this.

Fig. 4 shows battery terminals as wired to the work bench in the Capitol Radio Service Shop. Fahnestock clips are located at the rear of the bench and permanently wired to the batteries under the bench. They could also be wired to a power unit in the same location. These clips are located between and in front of the meters, as pictured in Fig. 1. It will be noticed that the —B post is separate and requires a separate wire. This is intentional, as some of the battery-operated sets are designed for —B and —A together while others require connecting —B and +A together. This row of connections makes available the voltages required for all sets of battery type and also for connection in series with any meter for continuity tests.

Fig. 5—Making a continuity test on a radio receiver under ideal conditions with plenty of daylight and the proper test equipment.

Choosing Servicemen

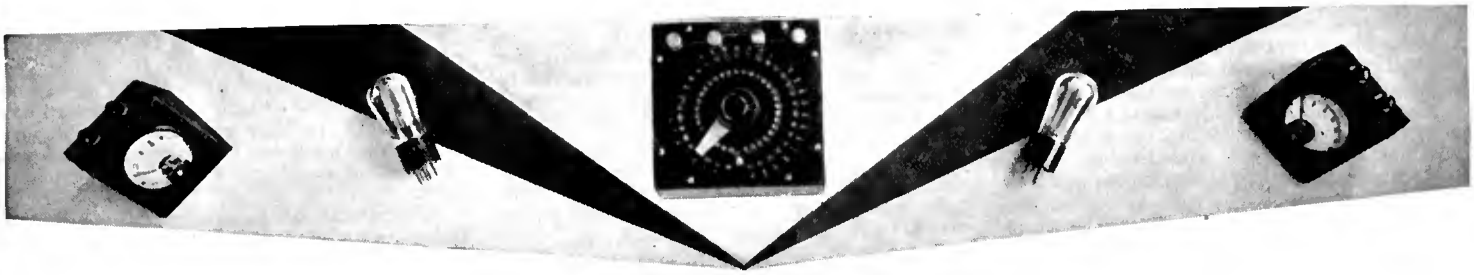
WITH comparatively simple and inexpensive equipment, a capable serviceman can accomplish more than can a poor man with all the apparatus on the market laid before him. The servicemen who do outside work are representatives of the shop employing them, and customers are generally inclined to judge the shop and its proprietor by the class of servicemen employed. An efficient serviceman must be sufficiently well educated in radio to understand technical instructions and drawings, and to be able to converse with customers on technical points, explaining the theory intelligently and giving concise advice to customers as to the operation of their apparatus. He must be backed by radio, mechanical and electrical experience. In many cases the serviceman is called upon to refer to the lighting circuits in a house or to make simple connections to them. "Radio tinkerers," who have "just picked it up," and who not infrequently advertise themselves as "radio engineers," should not be eligible to employment in a first-class radio servicing shop. The fact that many such people have been permitted to work on the public's radio sets has done considerable harm to the business by creating a feeling of suspicion and distrust on the part of many set owners. Efficient and honest dealing with the customer is invariably the surest road to real success. It is well known that many servicemen have, in times past, made a practice of condemning various parts of a set, the favorite parts being audio-frequency transformers, and of selling new ones for replacement, when the parts condemned were not really damaged. Such practices must sooner or later come back on people who are guilty of them, or who permit their employees to be guilty of them. There are a few pioneer schools in broadcast radio servicing and the prospective employer will profit by selecting his servicemen from the graduates of such training classes, or from men who have been practical commercial radio-telegraph operators. There are many ex-seafaring operators available, who have kept up with the times in broadcast receiving apparatus and who, for various reasons, wish to remain ashore and find work where their experience in radio will count.

The outside radio serviceman must have a good personality and a neat appearance. If he is gifted with diplomacy, he can often keep customers and make friends, when conditions might otherwise lose their business. If the volume of business requires, two servicemen are employed, one for shop and bench work and one for outside calls, with the understanding that if necessary either one will help the other. The larger shops, of course, employ many more servicemen than this.

Naturally, good men, coming up to the requirements given, cannot be hired for a pittance. If they are really well-trained and experienced men who can prove that they know their business, they are well worth a reasonably high salary. The proprietor of the small radio shop will find that he will make more sales and have a better paying business if his servicemen are able to add continually to his list of pleased customers.

Articles which have been published in recent issues of RADIO BROADCAST should be of great assistance to the dealer who is faced with the problem of engaging men for his service staff. In particular, the article, "An Examination for Radio Servicemen" by J. F. B. Meacham, on page 405 of April, 1929, RADIO BROADCAST will be found of value. This article includes the examination for radio servicemen which has been used with success for a number of years by one of the largest service organizations in New York City. This examination has been designed to determine the general radio knowledge of the applicant as well as his ability to service radio receivers and it has been found that the man who can pass an examination of its scope is usually quite efficient in the field as a serviceman. The examination is divided so that fifty credits are given the questions on servicing and fifty credits for general information. The subjects considered in the various sections of the examination are fundamentals, tubes, batteries, power units, diagrams, and servicing.

[The second of this series of articles will deal with the technical problems encountered by the serviceman and the most effective methods for handling them, with diagrams and descriptions of testing apparatus. *Editor.*]



STRAYS *from* THE LABORATORY

Distortion of Broadcast Harmonics

LISTENERS on short waves who occasionally run into telephone conversation or broadcasting which they cannot "clear up" may wonder what kind of stuff it is. The material is probably a harmonic of some broadcasting station and the "sour" quality is the result of the following phenomenon. The oscillator of the broadcasting station generates harmonics as well as the fundamental frequency. These harmonics are modulated as well as the fundamental, but the chances are that the amplifiers following the oscillator do not have linear characteristics as regards the harmonics. Let us consider only the second harmonic. If the fundamental is modulated with a frequency of 1000 cycles and at a modulation percentage of 60 per cent.; the second harmonic will have sidebands corresponding to the original modulation, i. e., 1000 cycles, and in addition a carrier of twice the original frequency with sidebands of double the original modulating frequency. This in itself would not account for the horrible garble that may often be identified as the harmonic of an otherwise well-thought-of broadcasting station. The additional distortion results from the fact that the percentage modulation on the second harmonic is doubled—and if the fundamental is modulated 60 per cent. the second harmonic will be overmodulated and, of course, distortion is inevitable.

The mathematics on this subject will be found on page 95 of February *Experimental Wireless and the Wireless Engineer* in a communication from A. B. Howe of the British Broadcasting Corporation.

Cut-off of Dynamic Reproducers

WHERE does a moving-coil loud speaker in a baffle-board cut off? In other words what is the lowest frequency to which it will respond with any degree of efficiency? Consider Fig. 1. A sound wave originates at the rear of the baffle as well as at the front. If these two waves come together at the correct phase, they will interfere, and the resultant sound to the listener will be less than if the radiation from the rear of the cone were suppressed. The purpose of the baffleboard is to increase the path through which the air waves must travel from front and back before they can interfere.

The distance from front to back via the shortest mechanical path must be at least one quarter the wavelength of the lowest tone desired. Sound in air travels at about 1110 feet per second. A frequency of 110 cycles, then, has a wavelength of 10 feet from the familiar formula—useful at radio or audio frequencies—that the wavelength is equal to the velocity divided by the frequency. Thus, if the shortest mechanical path is one quarter the wavelength, $10 \div 4 = 2.5$ feet, and so the distance from the center of the hole in the baffle around to the back must be at least 2.5 feet. This means that if the moving coil is in the center of a square board, this board must be 2.5 feet across. For 55-cycle reproduction the board must be 5 feet on a side and so on. A board three feet on a side will give good reception to all tones now being broadcast from the majority of stations.

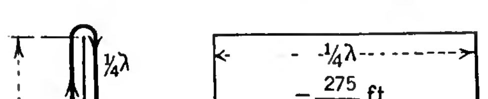


Fig. 1.

The following are among the subjects discussed in "*Strays*" this month:

Simplifying Filament Transformers

INTRODUCTION of the 2.5-volt power tube, the UX-245, will make unnecessary more than one winding on filament transformers. This is one step in doing away with the 1.5-volt winding and the center-tapped 5-volt winding. Thus, the introduction of a single tube standardizes and simplifies the construction of filament transformers. The winding for the rectifier tube, however, must be distinct from the filament winding. Will not someone develop a rectifier tube which can be operated from this same 2.5-volt winding? The solution seems to be a heater-type tube—but can someone develop a tube which will not break down under the comparatively high voltages?

An Argument on Power Vs. Energy

MR. HUBERT WOODS, of Riverside, California, takes us to task in the following vein:

"Under 'Strays from the Laboratory' in your issue of February, 1929, your first remarks are concerned with power, energy, and efficiency, and are well taken, in general.

"You define power as the 'rate of doing work.' Accepting this definition, how can you possibly 'consider a tube, such as a 171, feeding power into a load, etc.,' as you attempt to do in a subsequent paragraph? Do you mean that the tube feeds 'a rate of doing work' into a load?

"What the tube really feeds into the load is electrical energy, not power, nor work. Work is the final result.

"It seems to me you are guilty of the same lack of discrimination against which you properly protest.

"The units of energy and work are the same, but are not those of power, which is a rate, according to your definition. My company purchases electrical energy, which we convert (most of it) into work immediately, by use of motors. We do not purchase power (per your definition) although each motor has a certain power rating, because it can do work at a certain rate.

"If you had not burned your bridges behind you by defining power in one way only, you might possibly be justified in your usage of the term, since a common definition of power makes it synonymous with energy (ability to do work)."

Data on Series-Filament Circuits

READERS who have written this office for data on series-filament receivers will be interested to know that a collection of blueprints has been prepared by the Raytheon Company on how to wire well-known makes of receivers for series-filament operation. These diagrams may be had by applying to the Raytheon company, but it is earnestly requested that something more than curiosity be the basis of writing to this company for them. The diagrams will tell a serviceman how to rewire a receiver for series-filament operation, or will give him service data on a receiver of a given type that is already wired in this manner.

Sensitivity of Carborundum Crystals

THE curves in Fig. 2 were taken in the Laboratory by measuring the current through a Carborundum Company detector as the voltage across the crystal was changed. Several readings were taken in an effort to show the effect of varying the pressure of the con-

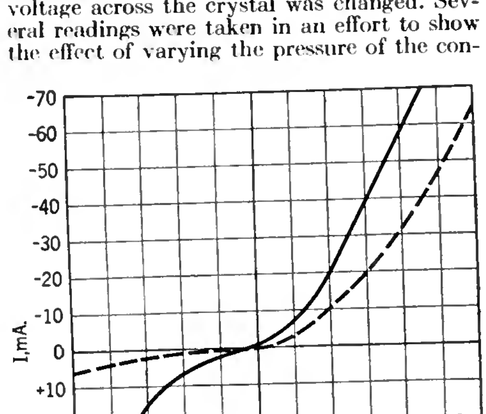


Fig. 2.

tact point. The weakest pressure on the crystal gave the best detection—that is, the greatest variation in current on positive and negative half cycles of input voltage. Of course, a weak presure indicates an unstable one, and so if, as on shipboard, one wants stability a comparatively heavy contact is used. The experimenter can have considerable excitement by plotting a.c. voltage waves and the rectified current waves as various a.c. voltage waves are placed on such a diagram. The effect of sliding the average value of the input a.c. voltage wave up and down the curve will show how such a rectifier detects.

Movie Recorders Make a Discovery

SOUND-Movie recorders have discovered that audiences are not very critical regarding the quality of the miscellaneous sounds that make up a picture. That is, if the villain shoots a revolver, it is not necessary to shoot a revolver in the studio, provided someone whacks something at the exact moment. In one test case there were several kinds of airplanes on the screen, and, while great efforts had been made to simulate the distinct sounds emitted by the individual planes, only a small percentage of the audience admitted they knew the difference. Half of this percentage were aviators. And so now, when you hear a talking moving picture, note how little difference it makes to you if a series of revolver shots sounds like someone throwing a bucket of coal down the cellar stairs—provided the sounds and sights are synchronized properly.

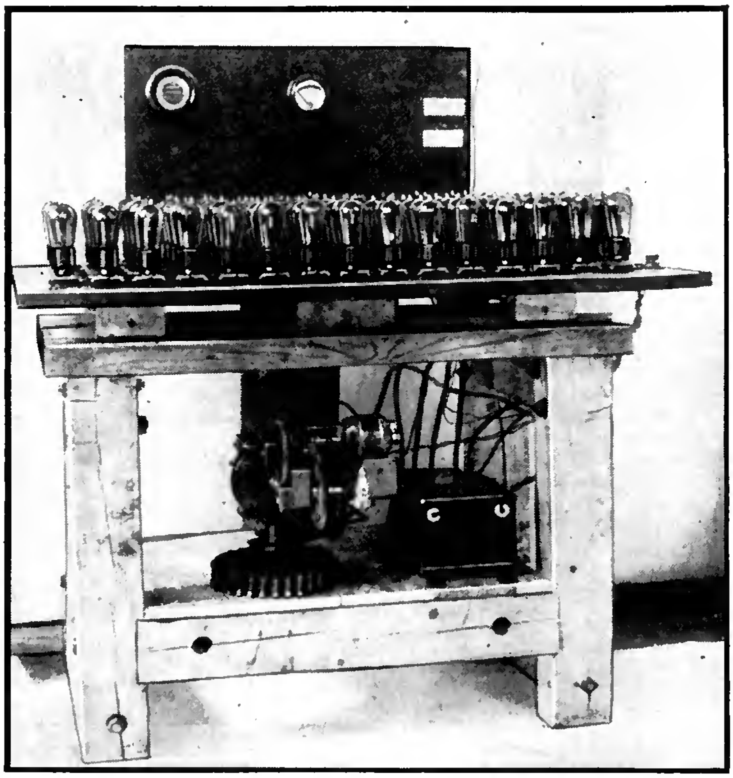
Power Output Required

MANY READERS take exception to our statement that a single 171-type tube provides sufficient power output for home reception. Many state that this is the maximum power output that can be used with the majority of cone-type loud speakers and several state that when they changed from a 171- to a 210-type tube (twice the power output) the difference on a cone-type loud speaker was barely noticeable. The fact that many loud speakers rattle if you put 1.5 watts of audio power into them is irrelevant. Our contention was that the sound output from a good loud speaker when less than one watt of electric power went into it was sufficient for home reception.

It is certain that, as the response to low frequencies is built up, either by using amplifiers with a hump at some low frequency, or by using a flat amplifier with a moving-coil loud speaker, the power output required increases. It is probable that an output of a full watt is desirable, and this may be obtained easily with the new power tube (the 245-type) that is now on the market.

The difference between a single 171-type tube and a single 210-type tube is only 3 DB, which is scarcely noticeable to the ear, and if a loud speaker or amplifier, or both, is used which does not reproduce the bass, the difference is not worth while. It is on the low notes, 150 cycles and less, that considerable power output is desirable—and there is no use in providing this power unless there are frequencies of this order to be reproduced, or if the loud speaker will not respond to the fundamental of such frequencies.

This seems to indicate that with cone-type loud speakers which do not respond to low frequencies, and which do not show distortion in the amplifier until this distortion is excessive, a power output of less than a watt is sufficient. With a moving-coil speaker in a three-foot ballleboard, or larger, an output of a watt is probably necessary, and more power than this will make less remote the possibility of overloading. We have operated a single 250-type tube with about 250 volts on its plate, which indicates a power output of less than one watt, but on loud low-frequency notes it does overload. Boosting the plate voltage to 300 or 350 will give all the power that is needed for home reception.



The vacuum-tube test rack pictured above was designed by Herbert H. Chun, of the Arcturus Radio Tube Company. The rack is vibrated by an eccentric cam and at the same time the tubes are turned on and off by an automatic switching arrangement. Any defect in a tube becomes apparant within thirty minutes when treated in this manner.

Now will the adherents of high-powered receivers come forward and tell us that we are still old-fashioned, and that two or three watts is absolutely necessary for modest home reception? We may, in time, be forced to admit even this!

One reader, Fred D. Pinkham, of Topsham, Maine, points out that the problem for the listener far from stations is decidedly different from that of the listener within the shadow of a local station. We admit this but cannot agree with his contention that the receiver must have sufficient power output to handle the following case. Suppose the volume control is fixed so that when a station which fades badly, is at a minimum, it is delivering an audible signal. Then the power output must be sufficient so that when the station "fades in" to a maximum the amplifier will not overload. Let us suppose the minimum signal that is satisfactory is one milliwatt. A station can fade at least 60 DB which represents a power ratio of one million. When the station fades in 60 DB the power output from the set must be *one kilowatt*—which is considerably in advance of the most hardened user of power tubes. If the maximum power output is one watt, which is reasonable, the least signal that will be heard, if there is a 60-DB fade, will be one microwatt, which is pretty far down. It is our hunch that even with one watt output, there must be a time when a fading signal will be inaudible—or will overload when "fading-in." The following from R. J. Kryter, Engineering Department, Prest-O-Lite Storage Battery Sales Corp., Indianapolis, gives some interesting data on this problem of power output necessary. It checks very closely the data taken by the Everyready engineers a year or so ago. This test determined that a 171-type tube was about all that anyone needed for home reception. It was before the days of moving-coil loud speakers, however.

"Some time ago the writer conducted a series of tests in which the signal currents and voltages occuring in the loud speaker circuit were measured for various types of music and with various types of loud speakers. The music was supplied both by phonograph and radio and included concert orchestra, jazz orchestra, military band, various trios, violin and piano, solo piano, singing voices from bass to soprano, and speaking voice. The loud speakers included short-horn, orthophonic-horn, magnetic-cone, and dynamic-cone types. The input to the loud speakers was supplied by a high-quality push-pull 210-type amplifier. The listening tests were made by persons of widely differing tastes and musical accomplishments.

"The results of these tests were as follows:

(1) "Low" volume was produced with an average signal voltage of 8 volts and an average current of 1.7 mA., corresponding to an output of 14 milli-voltamperes.

(2) "Normal" volume was produced with 18 volts and 3.8 mA., or 68 milli-voltamperes.

(3) "Loud" music was produced by 40 volts and 10 mA., or 400 milli-voltamperes.

(4) "Very loud" music was produced by 120 volts and 24 mA., or 2900 milli-voltamperes.

(5) The extreme limits were: Minimum 0.4 volt and 0.5 mA.; Maximum 195 volts and 55 mA.; maximum power ratio, 53,000. It is of interest to note that both the minimum and maximum values occurred in concert orchestra music, although the maxima were closely approached by the piano.

(6) The "average frequency" of music and speech as determined by correlating the average impedance calculated from the above figures with the impedance curves of the loud speaker units was 380 cycles.

(7) The impedance of the various loud speakers averaged about 3000 ohms at 50 cycles, 7200 ohms at 400 cycles, 13,000 ohms at 1000 cycles, and 25,000 ohms at 3200 cycles, ranging all the way from 1500 to 60,000 ohms in the 50–5000-cycles band.

"You will note that the power is given in milli-voltamperes rather than in milliwatts because the measurements were taken on actual loud speakers rather than on a fictitious resistance load. Calculations made by the writer, however, indicate that the distortion occurring in a vacuum tube feeding into a reactive load will be determined by the volt-amperes rather than the actual watts expended in the output.

"This data lends further weight to your conclusion as to the adequacy of the 171-type power tube for average home use. At the same time it demonstrates in startling fashion the great increase in power necessary for a given increase in sound output. Also, it is to be noted that peak values were frequently twice and sometimes three times as great as the above average values. Therefore, if overloading is to be avoided on sustained bass passages or on sudden fortissimos, an output stage capable of supplying 1 to 2 watts is justified."

—KEITH HENNEY.

How to Use Technical Facts in Selling

IF I WERE A SALESMAN

By AN ENGINEER

If I WERE a salesman and a prospective customer wanted to know why the Radiola 60 was "the one receiver that is built for all broadcasting conditions"—to quote from an advertisement in the *New York Evening Post*—I should use the following sales argument. The points are somewhat technical because all matters relating to what is inside the cabinet of a radio receiver concern technical matters, just as talk about the vermiform appendix, the dorsal fin, the intake manifold, or wing struts concern technical things, and naturally must be couched in technical jargon.

"There is little use in telling you as a customer that you need a selective set if you have listened-in at all, or have read or heard the tirades against the present overcrowded condition of the radio channels. There is no use to remind you that the multiplicity of stations, many of them on very high power, the general increase in high-quality programs more hours per day, and the more general use of high-quality loud speakers mean simply that the receiver must be designed for conditions that were undreamed of four years ago. What you want to know is how the Radiola 60 meets these problems.

"The Radiola 60 is a combination tuned radio-frequency receiver and a super-heterodyne. These two receiver systems are fundamentally different. The majority of receivers now made are tuned radio-frequency sets only. Some receivers are super-heterodynes only. This receiver is a combination of both of them. The object is first to gain selectivity, second to gain voltage amplification, and third to secure these essential receiver characteristics without destroying the fidelity with which the receiver will translate radio signals into audible sounds.

"The tuned radio-frequency receiver first picks up the desired signal from an antenna, amplifies it, separates the audio modulations from the inaudible radio or carrier wave, and then amplifies these audible tones. Now here, in this complicated process which may involve six or more tubes and a corresponding number of electrical circuits, distortion must not occur.

"Radio stations are now put on channels which are 10 kilocycles apart, just as keys on a piano are stationed along the keyboard a certain number of tones apart. When one wants to listen to one station, he does not want to listen to several others, but at the same time he wants to get all the desired station is transmitting—all tones from the highest to the lowest. He must select a certain radio signal but not select it so well that he loses part of the desired signal in the process.

"The usual tuned radio-frequency amplifier is inherently more sharply tuned at low frequencies—at the left-band end of the usual radio keyboard—and broader at the other end. Thus, it is more difficult to separate two stations that occupy adjacent channels at the high frequencies. At the same time the amplification at the high frequencies is higher than at the low end of the keyboard. And these two difficulties work together to make the problem of the radio-frequency-amplifier-design engineer anything but pleasant. The ideal condition would be to make the amplification and selectivity the same all along the radio keyboard.

"The usual radio-frequency amplifier is composed of a tube and a transformer which connects this tube to the following tube. This transformer has a few turns on the primary and many turns on the secondary. The primary tends to resonate at some frequency higher than any to which the secondary is ever tuned. This tendency to resonate at some high frequency makes the receiver have greater amplification and less selectivity on the high frequencies.

The Radiola 60 receiver in a table-type cabinet.

"The Radiola 60 uses large primary coils instead of small ones, so that the primary tends to resonate at a lower frequency than any to which the receiver will be tuned. This tends to bring up the amplification at the lower radio frequencies, and to prevent such selectivity at these frequencies that part of the audio tones are cut off.

"The direct result of making the primary of the transformer large instead of small is, first, an increase in amplification at low radio frequencies, second, prevention of 'side-band cutting' at low radio frequencies, and third, the amplification over the whole keyboard of radio channels is even. Fig. 1 shows what this amplification is.

> *Believing the importance of using technical facts in selling radio receivers was being overlooked by the majority of salesmen, the Editors asked an engineer to write the article which appears here. The data for it were taken from a paper presented before the Institute of Radio Engineers, March, 1929, by G. L. Beers and W. L. Carlson, which are the result of the development work on the Radiola 60 series.*
>
> *Although the facts used here apply only to this particular receiver, similar presentations of sales points could be prepared on any other receiver—and in our opinion ought to get many salesmen out of tight places when the prospective customer demands facts, instead of glib phrases about excellent tone quality, extreme selectivity, and perfect "DX."*
>
> —The Editor.

"Such is the radio-frequency amplifier of the Radiola 60. It is followed by a detector, just as in any receiver, but into this detector is introduced another frequency coming from a tube acting as a miniature transmitter, the oscillator tube. The frequency at which this tube oscillates is varied automatically at the same time that the radio-frequency amplifier is tuned to the desired signal and the frequency it introduces into the detector always differs from the incoming signals by 180 kc. The modulations which are separated from the radio wave in this detector are impressed on this 180-kc. signal and modulate it. Thereupon amplification takes place again at 180 kc. instead of the frequency to which the receiver is tuned.

"So the Radiola 60 in addition to amplification at broadcast frequencies amplifies again at 180 kc. Finally these 180 kc. signals are fed into a second detector which separates the audio frequencies.

"The 180-kc. frequency to which the second or intermediate-frequency amplifier is tuned was chosen for the following reasons. If this frequency were low, it would amplify audio tones and any noises appearing in the preceding tubes; that is, microphonic bongs, tube hiss, etc., would be passed through and amplified in the intermediate-frequency amplifier. If the frequency were made too high, trouble from oscillation, and lack of amplification would occur. The 180 kc. is a compromise frequency.

"Let us look into this mixing of frequencies in the detector tube. Suppose the intermediate frequency is 50 kc. If we are receiving a 1000-kc. station we can set the oscillator at either 1050 kc. or 950 kc. and still have the desired 50-kc. intermediate frequency modulated by the audio tones. For this reason we can receive a 1000-kc. wave at two points on the oscillator dial. Again let us suppose we have the oscillator tuned to 1000 kc. and that two stations equally powerful are transmitting on 950 and 1050 kc. Both of these signals enter our first detector and with the 1000-kc. oscillator frequency produce a 50-kc. wave modulated with the audible tones of both stations. The result is hash; both stations are spoiled.

"If the intermediate frequency is 180 kc. such trouble cannot possibly take place at frequencies lower than 1140 kc. Suppose the

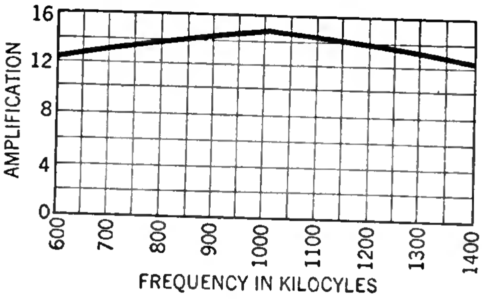


Fig. 1.

oscillator is set at 1160 plus 180 kc. or 1340 kc. The only other station that could produce the 180-kc. intermediate frequency in the first detector would be 1340 plus 180 or 1520 kc.—and the broadcasting keyboard extends only to 1500 kc.

"Here again is a virtue of the radio-frequency amplifier ahead of the intermediate-frequency amplifier. This first amplifier builds up the desired signal and discriminates against the unwanted, so that even if two stations offer equal signals at the antenna, one of them desired and one of them not, the undesired will be reduced—compared to the desired—by the amplification of the radio-frequency amplifier and when the two signals get to the first detector or mixing tube, the unwanted signal is already reduced so far it does not bother the listener.

"So far the result is a tuned radio-frequency amplifier of such a design that all stations scattered over the radio keyboard can be received with equal facility; the quality of reproduction from these stations will depend only upon the stations—there is inappreciable loss of quality in the receiver; after amplification at the frequency of the stations, the signals are changed in frequency and amplified again. The first amplifier acts not only as a kind of filter letting in only the desired signals, but it gives some amplification too.

"The intermediate-frequency (180-kc.) amplifier is of the type that has attracted considerable attention from radio editors. It is a band-pass amplifier which means simply that it is tuned so broadly on the top of its response curve and so steep on its sides that all desired audio tones are admitted and amplified, and others are rejected. This result is secured by tuning both primary and secondary of the intermediate-frequency transformers (the usual transformer has only the secondary tuned). The response characteristic is shown in Fig. 2A. The overall characteristic—which shows how the intermediate-frequency amplifier discriminates against unwanted signals is shown in Fig. 3.

"And so the intermediate-frequency amplifier not only amplifies but selects as well. The Radiola 60 amplifies, selects, and detects twice.

"The second detector is the increasingly popular 'power detector,' which means, so far as the layman is concerned, that it eliminates the distortion and noise that frequently occur in the first stage of a.f. amplification. It does this by eliminating the first stage of a.f. itself. Such elimination is possible by the great amount of amplification that has taken place in the preliminary amplifier and in the intermediate-frequency amplifier.

"This power detector is adjusted so that it overloads at the same time the power tube does. When the detector overloads its output decreases as shown in Fig. 6.

"Some of the Radiola 60 series (the 64 for example), have automatic volume controls. It is this device which makes the receiver suitable for reception in a transmitter-cluttered neighborhood, or out in the rural areas far from stations. Once the listener sets the volume-control dial to the maximum output he desires he cannot get a louder signal no matter how powerful the station is that he tunes to. In a local area this is of undoubted advantage. In the country the automatic volume control will tend to build up weak signals to the desired level. Of course, if the weak signal is surrounded by noise—static, arc lights, X-ray machines, etc.—the volume control cannot eliminate the noise and get the signal, and so the noise background comes up along with the station. But on a good night when the noise level is down all stations that deliver a certain minimum signal to the antenna will deliver a certain maximum output loud speaker signal, this output always at the control of the listener. The effectiveness of the control at the output levels A and B compared to no control, C, is shown in Fig. 4.

"This receiver has eight tuned circuits. One's first reaction to such a statement is that there would be no high audio frequencies at all—but a look at Fig. 5 shows that such is not the case. The large primary winding of the first amplifier transformer, the band-pass effect in the intermediate or second amplifier, and the characteristics of the a.f. amplifier are such that undue suppression of the high audio notes does not take place. In other words, *it is a high-quality receiver*."

If I were a salesman, I should use technical facts to back up my sales arguments. I should state that this particular receiver is selective because of the radio-frequency amplifier and because of the selecting effect of the second or 180-kc. amplifier. It is sensitive because amplification takes place at three different frequencies, first the frequency of the incoming signals, next at 180 kc., and finally at the audio or audible frequency. It has a power detector which eliminates some noise and some distortion. It is a high-quality receiver because its radio-frequency amplifier does not cut "sidebands," because its intermediate-frequency amplifier employs the band-pass idea, and because its a.f. system is good. In addition to all these advantages, the Radiola 64 has an automatic volume control which keeps down strong local signals, and boosts weak distant signals.

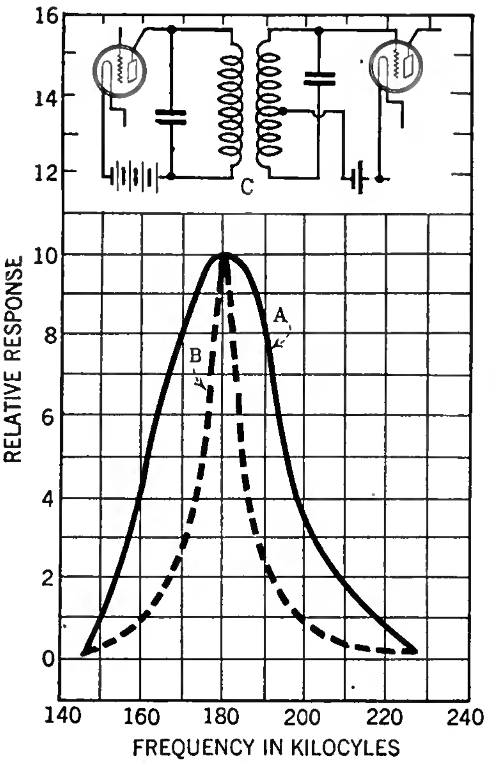


Fig. 2.

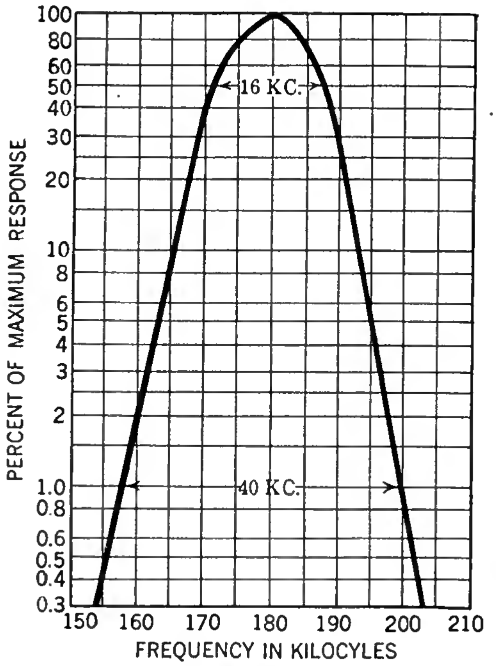


Fig. 3.

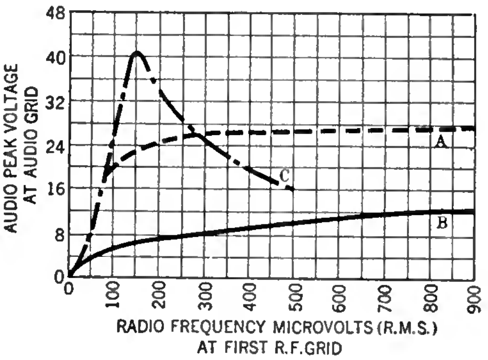


Fig. 4.

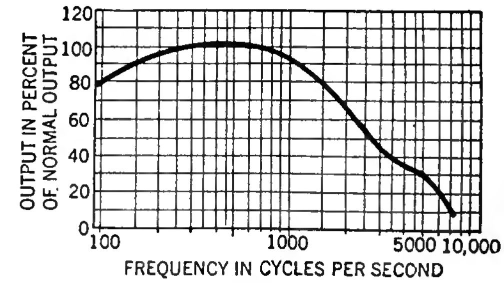


Fig. 5.

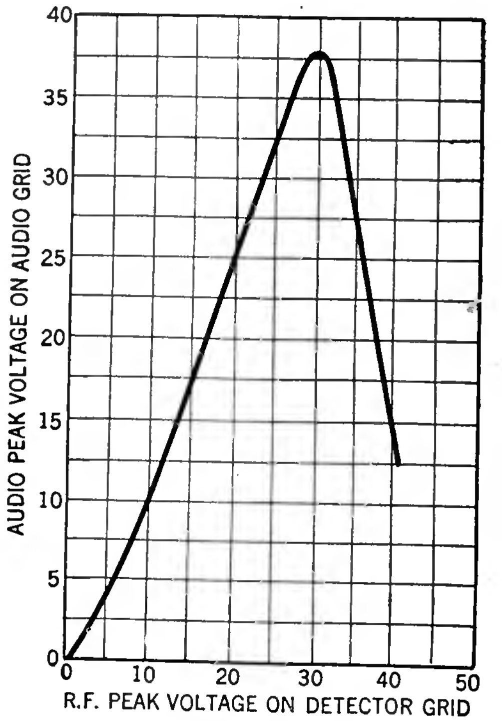


Fig. 6.

Defining the Scope of the Serviceman's Job

RADIO AMBASSADORS OF GOOD WILL

By HERBERT H. FROST

President, Radio Manufacturers Association

"The serviceman is not only a trained mechanic, but he must also have sales ability, personality, and tact."

"In the long run, it is not the cost of giving service that is to be considered, but the expense in not giving it."

Herbert H. Frost

"A SATISFIED customer is your best advertisement." That is an old statement, but it's especially true in radio.

In this industry, there are many ways of interesting a customer, but no matter what sales talk may be given him, what promises may be made, or how good-looking the radio set may be, unless it continues to function properly and to his satisfaction, you have anything but a satisfied customer. Here enters the *serviceman.*

He is to-day different from the serviceman of the past, as he is not only a trained mechanic, but he must also have sales ability, personality, and tact to allow him to meet unexpected situations in his work.

The importance of a serviceman having these qualifications is becoming more pronounced each year, and the capabilities of these men are advancing in accordance with advances made in the radio art. It has been proved repeatedly that when a dealer sells a radio set without having a capable serviceman, it results in the set being installed in a haphazard fashion. Eventually the customer has cause to become dissatisfied. He reports his dissatisfaction to the dealer, but finds no success. The ultimate result is that this disgruntled consumer tells his friends about the dealer, and before long that dealer realizes he has a poor reputation, which finally results in the closing of his store because he has lost his patronage.

Traveling public officials are sometimes called "ambassadors of good will." I believe that a field serviceman, whether he comes from the dealer, the distributor, or the manufacturer, is in all truthfulness an ambassador of good will, as he is never called upon unless there is some sort of trouble to be straightened out, and if he is successful it most assuredly results in good will. Who is more appreciative than an ardent radio fan whose balky receiver is once more playing merrily?

The reason for stressing the importance of a dealer maintaining an adequate and efficient service department, rather than having his service work done by his distributor or manufacturer, is because he is familiar with the conditions surrounding that particular sale. If the service is handled by a jobber or manufacturer, all personal touch between the dealer and his customer is lost.

In the long run, from the standpoint of the dealer, it is not the cost of giving service that is to be considered, but the expense in not giving it. Of course, there are some people who demand excessive service, and again this brings out the desirability of having the dealer handle the situation, as he alone knows that particular consumer's peculiarities.

The distributor and manufacturer should also maintain adequate service personnel, as the dealer looks to them for technical information and necessary spare parts material.

The more assistance that the jobber and manufacturer give the dealer in the form of instructions, the less that dealer is apt to call for assistance, and the more willing he is to maintain his own service department, as, having a thorough knowledge of the merchandise, he then realizes how easy it is to accomplish the normal service repairs.

There is a growing tendency on the part of the manufacturer to maintain a staff of traveling men, whose main duty is to give instructions to various groups of dealers, supply the dealer with a complete and easily understood service manual, and to assist the dealer in every possible manner to enable him to help himself. It has been found that most dealers prefer to handle their own service problems.

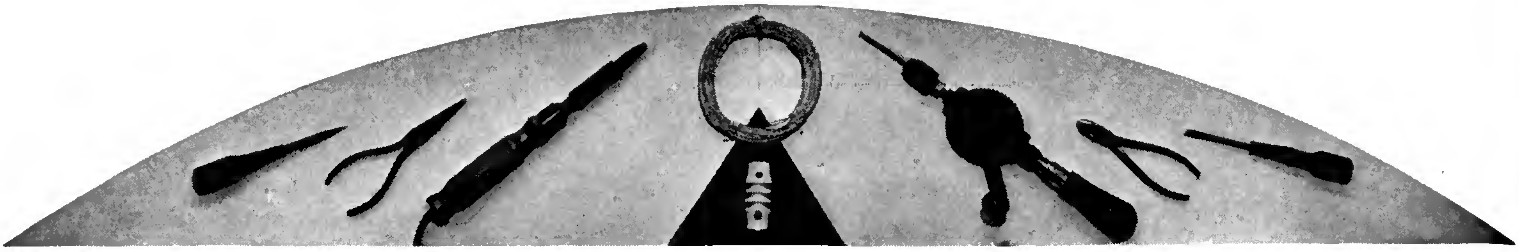
A service manager has to be farsighted enough to study the products being sold by his organization and to be prepared to eliminate any defect which may present itself in the merchandise, in the course of the year. His clear directions on how to handle these possible difficulties are an important part of the service manual which makes a large number of minor service calls unnecessary.

New Standard

SEVERAL manufacturers, distributors, and dealers were called upon not long ago, by the Vocational Training School Board of Essex County, New Jersey, to give the qualifications for a successful serviceman. Following this, a general course of instructions was made up, covering a three-year period of instruction for a selected group of young men, as it was the opinion of everyone that the efficiency of the average serviceman must be increased and expanded beyond that of an ordinary mechanic.

A great deal of good can be accomplished by service companies, formed by a group of servicemen, to handle the service work of various small dealers, who are not in a position to maintain their own department, but unfortunately they do not have that much-needed close contact with the sales, the merchandise, and its acceptance by the consumer.

The field of service work is fast increasing in its responsibilities and as soon as the responsibilities are recognized and advantages of a capable service department are appreciated fully by the dealer, jobber, and manufacturer, then will the sale of radio receivers increase still more rapidly. At the same time, the profits will increase, a result to which no objection has ever been found.



THE SERVICEMAN'S CORNER

IN "The Serviceman's Corner" we are endeavoring to group contributions on related subjects. Aside from the convenience of future reference, the expression of half a dozen minds on one subject is generally of more value than an isolated opinion. So you will find this month, and in future editions of this department whenever the number of related contributions justifies it, a symposium of service information on one particular receiver. Such considerations will not necessarily reduce publication of comments on unrelated and interesting items in service routine, nor should they be taken as indicative of an unusual amount of trouble with the receivers made the subject of group discussion.

Your comments on this, as well as our handling of other phases of radio servicing, are always welcomed by the department editor.

Test Set Reduced to Lowest Terms

THE necessity for radio voltage and current testing equipment, along with the high cost of the same has presented a problem to many servicemen that has often echoed its way to this department in the form of a request for data on inexpensive and reliable test equipment.

As a matter of fact, the entire gamut of d.c. tests, requiring milliammeters covering ranges from one milliampere to a hundred and high- and low-resistance voltmeters reading A, B, and C potentials from batteries or power-supply arrangements, can be covered with adequate accuracy with one meter in conjunction with an inexpensive assortment of wire-wound fixed resistors used in a combination of series and shunt connections. A satisfactory meter which may be used for this purpose is a standard 0-1 milliammeter.

Differences in voltmeters and ammeters of various ranges are principally differences in the resistance characteristics of the instrument, based on the simple and fundamental statement of Ohm's law: viz, voltage equals the current in amperes multiplied by the resistance in ohms. More simply, $E = I \times R$.

The fundamental circuits of a milliammeter employed as voltage and current indicators are shown respectively in Fig. 2 (A and B). Resistors R are connected exterior to the meters. In the circuit of Fig. 2 (A) R is always so much higher than the internal resistance of the meter, that this latter resistance may be neglected in all calculations.

If a source of unknown voltage is connected across the terminals of the circuit, Fig. 2 (A), the voltage will be equal to the resistance of R in ohms multiplied by the number of amperes indicated on the meter. In the specific cases under discussion, R will always be so high that the combination is a so-called high-resistance voltmeter (it may be used for measuring B and C potentials furnished by a B-power supply unit) and the meter will be a milliammeter, preferably having a range of from zero to milliampere. The voltage will then be the resistance of R, divided by one thousand, multiplied by the reading on the meter (in factions of a milliampere).

The following table indicates the proper values of resistors for full-scale deflection on the indicated voltages when using a 1.0-mA. meter.

VOLTAGE	RESISTANCE
5	5000 ohms
10	10,000 ohms
100	100,000 ohms
500	500,000 ohms

Any fraction of full-scale deflection indicates a similar fraction of the full-scale voltage. For instance, if the one-milliampere scale is broken up into 20 equal divisions, and an unknown voltage is measured with $R = 100{,}000$ ohms, ten divisions (0.5 milliampere) indicates a potential of 50 volts, 12 divisions, 60 volts and so on.

An ideal instrument for this purpose is the Weston type 301 milliammeter, zero to one milliampere range, which lists at $12.00. Daven "Super-Davohms" are economical resistors, sufficiently accurate for the purpose of voltage multipliers.

The calculation of the resistor values required as shunts in Fig 2 (B), to increase the current range of the instrument, is a bit more complicated, so that only the results will be indicated.

The following table shows the current for full-scale deflection on a 1.0-mA. meter with the indicated resistor shunts.

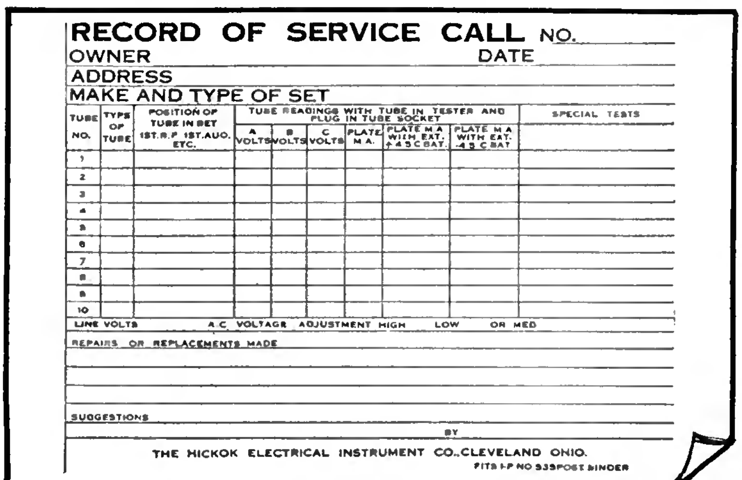
CURRENT	RESISTANCE
1 mA.	no shunt
50 mA.	0.57 ohm
100 mA.	0.27 ohm

As with the voltmeter arrangement, any fraction of full-scale deflection indicates a similar fraction of full-scale current in milliamperes. (These current multiplier figures are based altogether upon a 0 to 1 milliammeter having an internal resistance of 27 ohms, the characteristics of the Weston type 301 already recommended. While the *voltage-multiplying* resistors will be correct for any zero to one milliammeter, the current shunts will apply only to a meter of the characteristics indicated.)

It should not be difficult to secure the proper resistors for the current shunts. A simple way is to secure the winding from a one- or two-ohm rheostat, determine the resistance of the wire per foot, and cut off the correct amount.

A simpler way of obtaining various shunts is as follows. So adjust the circuit including the milliammeter to a predetermined value, preferable full-scale deflection. Now shunt any low-range variable resistor across the meter and, vary the resistor until any convenient fraction of the original current is shown on the meter. Leaving this resistor so connected, the same fraction will hold true for any indicated current.

It is obviously possible to arrange a zero to one milliammeter, by means of suitable resistors and switches, so that the voltages and currents generally encountered in radio testing and servicing can be measured conveniently on the one instrument. An arrangement of this type was described by G. F. Lampkin in RADIO BROADCAST for June, 1928. Fig. 1 suggests a neat and convenient method



RECORD OF SERVICE CALL NO.

OWNER DATE

ADDRESS

MAKE AND TYPE OF SET

TUBE NO.	TYPE OF TUBE	POSITION OF TUBE IN SET 1ST.R.F 1ST.AUD. ETC.	TUBE READINGS WITH TUBE IN TESTER AND PLUG IN TUBE SOCKET: A VOLTS	B VOLTS	C VOLTS	PLATE M.A.	PLATE M.A. WITH EXT. +4.5 C BAT.	PLATE M.A. WITH EXT. -4.5 C BAT	SPECIAL TESTS
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

LINE VOLTS A.C. VOLTAGE ADJUSTMENT HIGH LOW OR MED

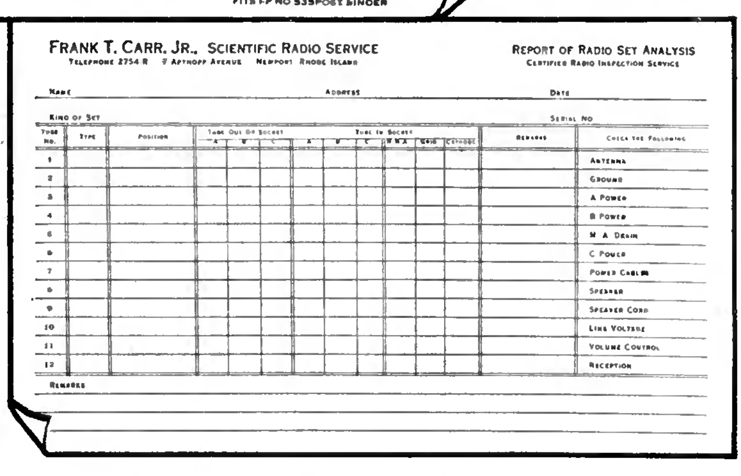
REPAIRS OR REPLACEMENTS MADE

SUGGESTIONS

BY

THE HICKOK ELECTRICAL INSTRUMENT CO., CLEVELAND OHIO.

FITS I-P NO 535 POST BINDER



FRANK T. CARR, JR., SCIENTIFIC RADIO SERVICE

TELEPHONE 2754 R 7 APTHORP AVENUE NEWPORT RHODE ISLAND

REPORT OF RADIO SET ANALYSIS

CERTIFIED RADIO INSPECTION SERVICE

NAME ADDRESS DATE

KIND OF SET SERIAL NO

TUBE NO.	TYPE	POSITION	TUBE OUT OF SOCKET: A	B	C	TUBE IN SOCKET: A	B	C	M.A.	GRID	CATHODE	REMARKS	CHECK THE FOLLOWING
1													ANTENNA
2													GROUND
3													A POWER
4													B POWER
5													M. A. DRAIN
6													C POWER
7													POWER CABLES
8													SPEAKER
9													SPEAKER CORD
10													LINE VOLTAGE
11													VOLUME CONTROL
12													RECEPTION

REMARKS

Service record charts that contribute efficiency to the service business by facilitating a check up on repeat calls.

of mounting and adjusting a combination volt-milliammeter of this design.

AN INEXPENSIVE TEST SET

R. K. Wheeler, of the Wachstetter Radio Company and General Radio Laboratory, of Indianapolis, Ind., solves the equipment problem of the serviceman in a similarly economical manner. He writes:

"Many excellent suggestions have been made in reference to radio set testing and servicing. However, all have employed comparatively expensive apparatus, and there are, no doubt, many servicemen, and set owners, who would be glad to have an inexpensive, reasonably accurate outfit, such as I have been using for the past year. The entire test set cost less than $8.00, and it will do practically everything that the more expensive ones will do.

"The main item of the test set is a combination tube tester, milliammeter, and two-range voltmeter, Figs. 3 and 4, composed of the following parts:

One Readrite 0–25 mA. meter	$1.00
One 2000-ohm resistor, Bradley	.50
One 250-ohm resistor, wire-wound	.25
Four Binding posts	.20
One Wood case, home-made	
One tube base, UX-type	.35
TOTAL	$2.30

"This is wired as per diagram, Fig. 3 and is plugged directly into a receiver to test tubes. The 0—6- and 0–50-volt taps are provided for battery checking and continuity tests, and are, of course, worthless for power-pack testing. However, for this purpose an excellent plug-in meter is made by Beede, 0–300-volt range, which shows voltages at the various sockets and is also a good check for continuity of the various plate circuits. This meter is sold at the local Kresge store for $1.75, and, while readings cannot be made with an exactness of 2 or 3 volts on account of the 0–300-volt scale, the writer's meter has been checked several times with Weston and Jewell high-resistance meters and found sufficiently accurate for the serviceman's purpose.

"The other item in this kit is a Beede, 0–7.5 a.c. voltmeter, (price $1.00), also plug-in type, for checking filament voltages at the socket. This meter has been found accurate and has been an important item in the writer's kit. As the voltage reading at the filament is one of the most important considerations, it was not felt necessary to invest in an 0–150 a.c. voltmeter."

Service Hints on Radiolas

When receivers are as widely circulated, as the various models made by the R. C. A., it is logical and inevitable that the service problems should increase in some way proportionate with their popularity. The serviceman will find it worth while jotting down this page number for future reference.

Frank M. Coates, with the McGraw Electric Company, Sioux City, Iowa, has run into the following interesting cases:

"Probably the most baffling troubles in radio receivers are those which do not affect the normal voltages at the tube sockets. The following are very peculiar and interesting cases of this nature which I have found in service work.

"1. The antenna lead of a Radiola 18 became pinched in such a way that the wire broke inside the insulation which was intact. The trouble was located by connecting the antenna to the volume control where the antenna lead terminates.

"2. On a Radiola 60 it was found that by moving the oscillator grid resistor the set would work. Inspection showed that where the bus wire lead connects to the tube socket the paint had not been removed, and this insulated the wire from the solder around it. As the oscillator tube has zero d.c. grid voltage, a meter test would be useless in this case.

"3. Another case of intermittent trouble on the model 60 was an open connection to the output condenser. The metal tab became broken under the insulating cover. The trouble was found by connecting a good 0.5-mfd. condenser across the two terminals of the output condenser.

"4. The most freakish case I have seen was a power unit that was connected to a light line which was struck by lightning. The transformer, choke, and filter condensers were not damaged but the flexible wiring had the strands fused into little globules inside the insulation which was not burned in the least."

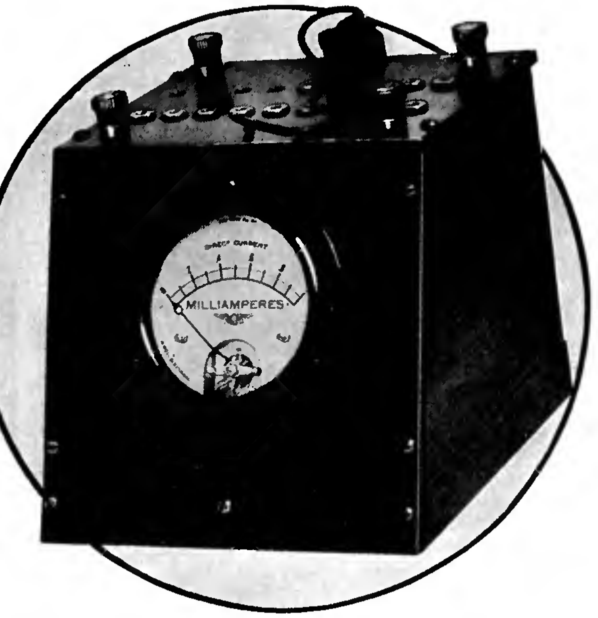


Fig. 1—A neat and efficient mounting arrangement for a universal volt-milliammeter.

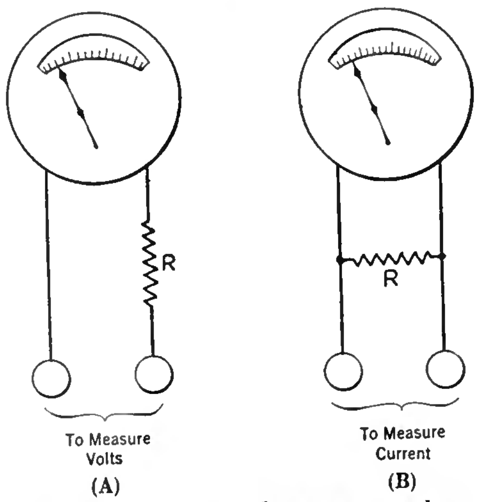


Fig. 2—(A) An elementary voltmeter consisting of a low-range milliammeter with a series resistor. (B) A low-range milliammeter, with a series of shunt resistors, R, can be made to cover a variety of high-current ranges.

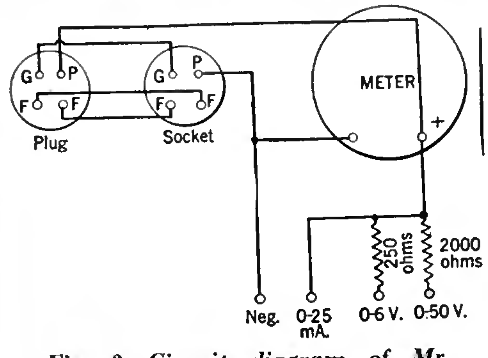


Fig. 3—Circuit diagram of Mr. Wheeler's test set costing $2.30.

HELP FROM THE G. E. COMPANY

M. G. McCarroll, with the Radio Engineering Department of the General Electric Company at Schenectady helps the cause along:

"I have run across the following trick faults while trouble shooting radio receiving sets. One of the commonest causes of 'no signals' in a Radiola 60, super-heterodyne, is found in a short circuit between one of the r.f. coils and a socket prong. The coils, not being mounted very rigidly, get pressed over sometimes so that when the tube is inserted in the socket there is a contact made between the socket prong and a terminal lug on the top of the coil. It usually is the coil located under the sixth socket from the left end of the set, and sometimes a person can reach down behind the chassis and with his fingers move the coil away from the socket prong without removing the chassis from the cabinet.

"The hardest case ever encountered of a loose connection was on a Radiola 60, and after exhaustive searching, in which everything checked out ok. it turned out to be a faulty tuning condenser on one of the intermediate-frequency transformers. The screw holding the plates of this small condenser had come out and while the set operated fairly well, the scraping sound of a loose connection was present with any slight vibration. The variable condenser tab had to be removed in order to get the i.f. transformer out of the chassis for repair, the small defective condenser being located inside the case of the i.f. transformer.

"Another unusual incident on Radiola 60's was a case of extreme fading on local signals. The volume would go clear down and then gradually come back to full strength, repeating this several times a minute. The trouble was a dirty contact on the potentiometer used as a volume control. Since the r.f. and i.f. tubes get their bias through this potentiometer it is obvious that when poor contact occurred with the arm the grids of these tubes were left free and consequently caused the fading mentioned above."

DATA FROM N. Y. C. SERVICEMAN

A categorical source of trouble in the Radiola 17 has been located by J. C. Yaegar, man-

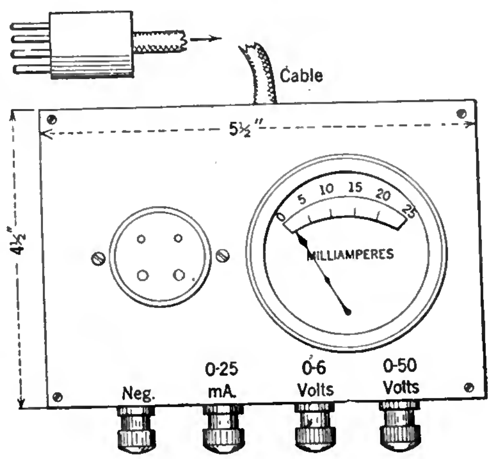


Fig. 4—Constructional details on another single-meter test set.

ager, Domestic Radio Service, New York City, as follows:

"What causes a set to have 'no volume' when all the circuits test ok., all the parts appear to be, and test, in good mechanical and electrical condition, tubes of known performance are used, and a power supply furnishing standard operating voltage is connected?

"Some R. C. A. 17's suffered from this trouble last summer in the territory along the eastern coast states and the cause and correction is now fairly well known over this territory. The forms on which the radio-frequency coils were wound in some cases absorbed sufficient moisture to cause a high r.f. loss in the amplifier circuits. The popular remedy has been to remove the radio-frequency coil assembly and dry it out thoroughly in a moderately heated oven, or to dry it out less quickly by placing the whole set in a warm dry place, for a few days. In almost every case, the original performance has been obtained after this treatment."

This condition will be met with in many other types of receivers. A simple method of cure is to increase the plate voltage applied to the r.f. tubes, feeding it through a by-passed high-range variable resistor, which functions as an auxiliary volume and regeneration control.

A BAFFLING PROBLEM

A. J. Barron, radiotrician and electrician of Shawnee, Okla., hit upon the same trouble and solves a little less easily:

"When you are called on to service a Radiola 17 and give it more volume on weaker stations and find that all of the tubes test ok., you will probably wonder what to do. My method is to get at the grid suppressors and unwind 10 or 15 turns of the resistance wire on them to lower the oscillation point in the r.f. circuit: it seems that after the r.f. coils season a while they raise the original oscillation point and the only remedy is to unwind some of the resistance wire from the grid suppressors or put in some of a lower resistance."

NOISY RECEPTION

Carlton W. Croteau, of Mount Carmel, Conn., goes into some detail:

"Being called upon to locate the cause of considerable noise in a Radiola 30, I soon found out that it was not interference. Walking near the receiver would create a terrible scratch and snap. This naturally sounded like a loose connection. The receiver was taken out of the console and checked thoroughly for loose and poorly soldered connections. None was found. Taking hold of the catacomb and holding it perfectly still would stop the noise. On top of the catacombs are several screws that keep the bakelite socket assembly in place. Two or three of these screws were found to be loose. When these were tightened the noise disappeared and even pounding on the receiver with the fist would not produce the noise.

"A dealer called me in to service two Radiola 18's that oscillated persistently regardless of where the compensating condensers were set. Touching the stator plates of the first r.f. condenser would stop the oscillating and the stations would tune in normally. By bending the two outside rotor plates in toward the stator of the first condenser the trouble was cured. In the second receiver, however, it was necessary to add more capacity than was needed in the first. To add this capacity it was necessary to take a piece of 0.010" brass about 1⅜" x 2" and fastening it on to the stator by means of the (2) screws that hold the stators to the bakelite strip.

"The method is shown in Fig. 5.

"Another Radiola 18 had a case of a short in the plate circuits of every tube, except the 171A. All plate voltage was at zero value with the exception of that on the plate of the 171A which was down to about 100 volts. After checking for shorted by-pass condensers the trouble was found to be in the third coil. In the center of this coil there is a small honeycomb coil wound with enamelled wire. It is mounted on a bracket made of brass which is grounded to the frame. A portion of the wire had worked its way against the bracket and was causing the short.

"Receiving nothing but a local station was the complaint I received from a dealer. The receiver was a Radiola 60. Every circuit was tested and found to be ok. with one exception. The oscillator tube did not draw any plate current. Other tubes were tried but the results were the same. With the tube out of the socket the local station came in with the same volume. After testing various parts of the oscillator circuit I found the oscillator series or grid condenser to be leaking. When this condenser was tested it was found to be passing about 0.1 volt. The replacement of this condenser cleared up the trouble and the receiver was restored to normal operation.

"Another Radiola 60 that was intermittent in operation required considerable time to locate the cause. This set would play for days at a time and then suddenly cease. By taking out most any one of the 227-type tubes and then inserting it into its socket the set would again function normally. This was most discouraging as then there was a long wait for it to stop again. I had taken it out of the cabinet by this time and finally it ceased to function. Then taking a lead pencil and by pushing and prying different connections I came upon the trouble. It was in the third i.f. transformer. Pushing down on one of the terminals would start the set. Releasing the pressure would cause it to stop. It was necessary to remove the transformer from the chassis and also take it out of the brass case. A high-resistance connection was found where one of the fine wires from one of the coils soldered to a small terminal within the assembly. Soldering this wire remedied the difficulty and after re-assembling the transformer the receiver worked normally and has continued to do so since."

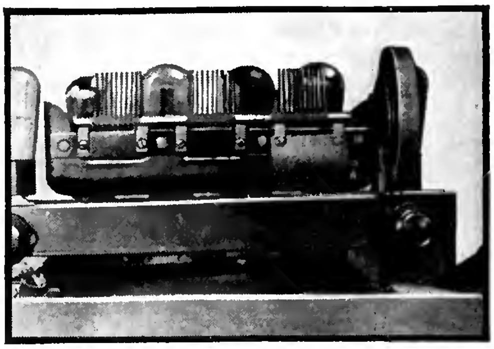


Fig. 5—Adding additional capacity to one section of a Radiola condenser to stabilize the circuit.

This month "The Serviceman's Corner" is inviting contributions on the use and servicing of relays. Relays, intelligently applied, should contribute greatly to the convenience and ease of operation in many radio installations. The use of relays is by no means limited to controlling the power-supply device and trickle charger. The possibilities of relays suggest themselves in all but the most simple installations in the way of receivers remotely controlled, either by hand or clock. In the more simple arrangements, the relays may be used merely to turn on and off a receiver, and in conjunction with phonograph pick-ups; more elaborate arrangements will control volume from a distance, while still more ingenious installations may effect a certain amount of station selection by remote control.

—The Editor.

POOR LOCATION

And concluding this little symposium on the eccentricities of Radiolas, the following comes to us from Indianapolis, Ind.:

"I made a service call on complaint of the owner of a Radiola 28, on account of poor volume, and no reception of distant stations. A check was made of tubes and batteries and all were found good. There was nothing in the set to suggest trouble, and a loud speaker of known efficiency was substituted, thinking that perhaps part of the trouble lay in weak magnets in the original loud speaker, but this made no difference. As the neighbor next door was getting excellent reception at that time on the same model set and loud speaker, the trouble could not be reasonably be blamed to the location. Finally I asked the owner where his furnace was located, and, as I suspected, he pointed directly below the set. We then moved the set across the room, and the first station tuned in was WPG, Atlantic City, with enough volume to necessitate turning the volume control back slightly. As the owner had had the set for several months, with such poor reception, it is needless to say he was not only surprised but delighted."

R. K. Wheeler, Wachstetter Radio Company and General Radio Laboratory.

Frank M. Coates (right) takes a day off from Radiolas.

Items of Interest

THE use of report sheets, describing the electrical characteristics of a receiver, tubes used, correct voltages, results under average good conditions, etc. are finding favor among systematic servicemen. We reproduce elsewhere in this department two good samples of these forms, one used by Frank T. Carr, of Newport, R. I., and the other supplied by the Hickok Electrical Instrument Company, of Cleveland, Ohio, for use in conjunction with their test equipment.

A Recent Technidyne Development

A SELF-SHIELDED RADIO INDUCTANCE

By EMIL REISMAN
Technidyne Corporation

THE coil described in this article, because of its self electrostatic shielding and absence of external magnetic field, requires no shielding when used in multistage radio-frequency amplifiers. The advantage of this feature may be appreciated better when it is understood that heretofore it has generally been found necessary to carefully shield all coils used in radio-frequency circuits in order to prevent interstage feedback. Where such shielding has not been used, methods of preventing oscillations due to interstage coupling have been resorted to. Practically all such methods involve the introduction of losses in the circuit to such an extent that oscillations cannot be sustained. While such methods of preventing parasitic oscillations are effective and quite easily applied, the loss in efficiency in such a circuit is quite a serious matter.

To help prevent oscillations caused by interstage coupling, individual shielding of every radio-frequency stage in the set is becoming quite a common practice. In addition to the shields, coils having a fairly small external electromagnetic field are sometimes used. Among such coils may be mentioned the toroid, binocular, and double D. It is found, however, that even such methods are insufficient to prevent intercoupling of the various stages of a multistage amplifier. In spite of seemingly inpregnable shields and windings having small external fields, it is found that electromagnetic and electrostatic fields do link adjacent and even distant stages of the radio-frequency amplifier; sometimes to such an extent that oscillations are produced. Many inductances having so-called "concentrated" fields are found to have fields which are not so concentrated. It is also found that shielding is not always as effective as it looks.

Shielding, even at its best, introduces losses in the circuits where it is used. As the effect of shielding depends upon the setting up of eddy currents in the metal of the shield, the radio-frequency resistance of the shielded circuit must necessarily be comparatively high. High-resistance circuits in a receiving set make for insensitivity and poor selectivity.

Proof of Immunity

THE self-shielded coil described in this article is one of the recent developments of Lester L. Jones, of the Technidyne Corporation. This coil has no external field to speak of and hence does not require shielding. The coil is self shielded electromagnetically and electrostatically, and may be placed in close proximity to other apparatus and even to similar coils of the amplifier without disturbing the balance of the system. A set made by a mid-western manufacturer utilizing self-shielded coils is perfectly stable and shows no traces of feedback even though the coils are all mounted in the same plane and are placed less than two inches from one another.

This coil is so immune to outside influences that a heavy band of copper may be wrapped tightly around the coil, and the ends soldered together with no detuning effect while the coil is in a sharply tuned circuit. The losses introduced under such conditions are practically negligible. Under similar conditions all other coils would be completely detuned; and almost all of the energy dissipated in the short-circuited copper band.

In Fig. 1 is shown a cross-section view of the self-shielded coil. It is seen to consist of an inner coil section, A, and an outer coil section, B. The coils are so related to each other that the outer coil, B, forms a magnetic and electrostatic shield for the inner coil.

Coils A and B are connected in series in such way that the magnetic fluxes produced by the coils oppose each other. Such an opposition of fluxes is accomplished by having both coils wound in the same direction and connected together at the same ends. The free end of the inner coil is the high-potential end and would normally go to the grid or other high-potential part of the apparatus in which it is used. The free end of the outer coil is the low-potential or ground end and would be connected to ground or low-potential part of the circuit.

Many attempts have been made to develop coils which require no shielding. In other words, inductances that have no external field have occupied the thought of a number of engineers. Some coils of this type have been developed, but in the process other faults arise which vitiate the advantage of the small external field. For example, one such coil that was tested in the Laboratory had no means of getting current into or out of it! The coil described in this article was invented by Lester Jones of the Technidyne Corporation. It is a low-loss, low-external-field coil. It can be used without shielding.
—THE EDITOR.

In the diagram it may be seen that the ground end of coil section B overlaps the high-potential end of coil section A. This is done mainly to improve the electrostatic shielding of the high-potential end of the coil.

The principle of the self-shielded coil is based upon careful mathematical design. It has been found that the ratio of the turns of the inner and outer coils must bear a very accurate relation to the ratio of the areas of the two coils. The product of the area and the number of turns on one coil section must be equal to the product of the area and number of turns of the other coil section. When this condition is realized, the external magnetic field due to the coil is at a minimum and is practically zero, because the field produced by the inner coil section neutralizes the field produced by the outer coil section. Conversely, magnetic disturbances in the vicinity of the self-shielded coil cannot affect the coil because the voltage induced in the inner coil section is of the same magnitude and opposed to the voltage induced in the outer coil section; therefore, the resultant voltage is zero.

Electrical Design

IN order to produce the electrostatic shielding of the coil, it is required that the self inductance of the outer section be equal to the mutual inductance between both coil sections. This condition is obtained when the product of the area and number of turns on one coil section is equal to the product of the area and number of turns on the other coil section. The requirements, therefore, for maximum electromagnetic and electrostatic shielding are identical.

In a properly built self-shielded coil a curious effect will be found to exist. By measurement it will be found that there is no potential drop across the outer coil. This may seem absurd to some, but, when it is considered that the voltage drop across the outer coil due to its inductance is neutralized by an opposing voltage induced by the inner coil, it may be realized that in effect the entire surface of the outer coil is at one potential. The reason for the balance of potentials in the outer coil is that the self inductance of the outer coil is equal to the mutual inductance between the inner and outer coils.

To produce self-shielded coils having high efficiency, the ratio of the area of the winding of the inner coil and the outer coil should bear a given relationship. It has been determined that for producing coils of greatest efficiency, the ratio of areas should be about 2, 2.1, and 2.2 for coils having ratios of outer coil diameter to length of 1.26, 1.58, and 2.1, respectively. When these area ratios are used, a high degree of static shielding with low distributed capacity is obtained in addition to maximum inductance with minimum radio-frequency resistance. In order to comply with these ratio requirements it may be found necessary to bank wind the inner coil or use a small size wire. The outer coil section in most cases will have to be space wound, or wound with large diameter wire.

The radio-frequency resistance, determines the efficiency of an inductance at radio frequencies. The high-frequency resistance of a coil is due to the combined effects of the skin effect in the wire of the coil, the d.c. resistance, eddy-current losses, distributed capacity in the coil, and mutual induction between the coil and neighboring circuits.

Efficiency of Coil

THE efficiency of the self-shielded coil as compared to other coils is quite high. It is superior to other coils having concentrated fields, such as the toroid, binocular or duo-solenoid, and the double-D. The self-shielded coil is not as efficient as a well-designed single-layer solenoid, which is perhaps the most efficient type of inductance in use. It is, though, far superior to a single-layer inductance of approximately the same size when the inductance is completely shielded with copper, and when the shield has about three times the volume of the coil. (It is obvious that the efficiency of a copper-shielded solenoid becomes greater as the size of the shield is increased, due to the decrease in eddy-current losses.)

A self-shielded coil having an inductance of about 125 microhenries has a distributed capacity of about 5 micromicrofarads. This is a slightly higher value than that for a corresponding single-layer solenoid, but is lower than that of the metal-shielded solenoid or the toroid.

It should take but little imagination to realize how wide the range of application of the self-shielded coil really is. A coil of this type can be used to great advantage in tuned radio-frequency circuits, neutrodyne circuits, radio-frequency oscillators, and, in fact, in any type of circuit where it is required that the coupling between coils and other apparatus be at a minimum.

Very compact sets may be built incorporating these coils without being troubled by excessive oscillation. As stated previously, self-shielded coils may be placed quite close to each other and at any desired angle without harmful coupling effects; hence they are ideal for use in compact sets.

In tuned radio-frequency sets when self-shielded coils are used, less than the usual amount of oscillation may be expected. In fact, such a tuned radio-frequency set when carefully built will, in many cases, operate like a neutralized set in that almost complete freedom from internal oscillation will be experienced.

Also, as these coils are not susceptible to outside influences, the individual coils will not pick up near-by broadcasters as other coils often do, thereby causing much interference.

Radio-frequency oscillators require that no energy be radiated by the tuning coils of the oscillator. Radiated energy will cause serious interference when radio-frequency measurements are in progress. Self-shielded coils will be found to be ideally suited for oscillators, because the energy radiated by the coil is almost negligible in comparison with that radiated by the usual type of inductance.

For short-wave work the self-shielded coil should give very satisfactory results. At short waves especially, magnetic and static coupling between coils and other parts becomes very strong. This is the cause of much of the energy loss and inefficiency on short waves.

Design Data

THE design of a self-shielded coil will be found to be more involved than the design of a single-layer solenoid, but by following these instructions the experimenter who can work out the constants of the single-layer coil will be able to determine the constants of a self-shielded coil of the desired inductance.

The first step in the design of any inductance coil is to determine the inductance needed. This may be calculated from a fundamental formula much used by radio engineers:

$$L = \frac{\lambda_2}{3.55 \times 10^6 \times C}$$

where L = inductance in microhenries.
λ = wavelength in meters.
C = capacity in microfarads.

In this case, where the inductance of a coil which is to be used with a variable condenser is desired, λ is the highest wavelength to which it is expected to tune, and C is the full-scale capacity of the condenser. In order to compensate the effects of distributed capacity in the coil, and other capacities such as the tube input capacity, several microhenries may be deducted from the inductance of the coil just calculated.

The outer tube diameter should now be decided on. For reasons of economy of space small diameters may be used, but from the viewpoint of efficiency a larger coil is preferable. Coils for covering the broadcast band may have an outside diameter of from $2\frac{1}{4}$ inches to $3\frac{1}{2}$ inches. The length of the outer coil winding should be within 1.2 to 2.2 times its diameter in order to maintain high efficiency.

The dimensions of the inner tube depend upon the area and length of the outer tube. As stated previously in this article, the length of the inner winding should be a little less than the length of the outer winding. It was also stated that for high efficiency and good shielding, the ratio between the areas of the inner and outer coil windings should be 2 when the outer winding has a ratio of diameter to length of 1.26, 2.1 when the ratio of diameter to length is 1.58, and 2.2 when the ratio is 2.1. The diameter of the inner tube may be calculated easily from the area and length of the winding.

After determining the dimensions of the inner coil winding, calculate the number of turns needed on the inner tube to give about one third more inductance than desired for

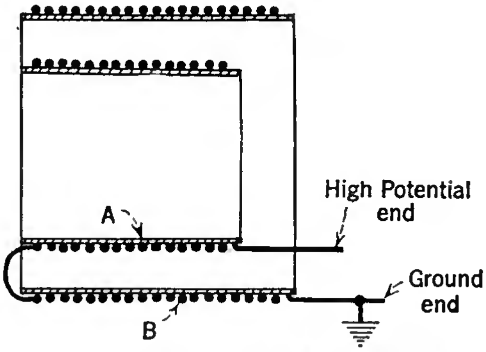


Fig. 1—Detail of the self-shielded coil.

the completed coil. For this calculation Nagoaka's formula may be used. This formula for the calculation of inductance of solenoids may be found on page 252 of the Bureau of Standards Circular No. 74, *Radio Instruments and Measurements.*

The number of turns needed on the outer tube is based on the ratio of the turns and areas of the inner and outer coil windings. The following formula gives the number of turns to be used on the outer winding:

$$N_1 = \frac{A_2 \quad N_2}{A_1}$$

where N_1 = number of turns on outer tube.
N_2 = number of turns on inner tube.
A_1 = area of outer winding.
A_2 = area of inner winding.

After the number of turns on the outer tube has been determined, calculate by means of Nagoaka's formula the inductance of the winding. Subtract the inductance of the outer winding from that of the inner winding, and the result is equivalent to the total inductance of the coil. In the self-shielded coil it is permissible to subtract the inductance of one

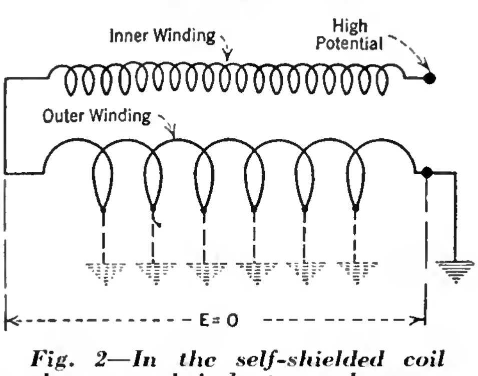


Fig. 2—In the self-shielded coil the mutual inductance between the inner and outer coil sections effectively neutralizes the self inductance of the outer coil; therefore, the outer coil is at the same potential throughout and has no external magnetic field. For the same reason the outer section serves as an excellent electrostatic shield for the inner coil.

winding from the other to obtain the total inductance, because the inductance of the outer coil is equal to the mutual inductance. This may be clearly demonstrated by means of the formula for the inductance of coils in series:

$$L_0 = L_1 + L_2 + 2M$$

where L_0 = total inductance.
L_1 = inductance of coil No. 1.
L_2 = inductance of coil No. 2.
M = mutual inductance between both coils.

In the self-shielded coil, L_1 is numerically equal to M; and, as M is negative because the fields of both coils are opposed, therefore, the formula may be rewritten:

$$L_0 = L_1 + L_2 - 2L_1$$

Reducing the formula we have

$$L_0 = L_2 - L_1$$

This is true only in a properly designed self-shielded coil.

In order to obtain the desired inductance for the coil, it may be found necessary to repeat the calculations several times, using a different inductance for the inner winding each time until the proper inductance for the entire coil is obtained. It will not be necessary to make more than three calculations for a given coil if good judgment is used.

When the entire inductance has been calculated properly a wire table should be consulted, and the size of wire to be used for the inner winding decided upon. The wire size used is limited only by the number of turns which must be wound within a given space. The outer winding may be space wound with No. 18, 20, or 22 wire. To obtain higher efficiency the coil should be constructed of litz wire throughout, and the inner winding bank wound. Extreme care should be taken that each strand of litz is unbroken, and is properly soldered at the ends.

Broadcast-Band Coil

THE following data may be used for constructing a coil which is to be used in conjunction with a 0.00055-mfd. condenser for covering the broadcast wave band:

OUTER COIL SECTION	
Diameter	$2\frac{3}{4}''$
Length of winding	$1\frac{5}{8}''$
No. of turns	33
Wire	No. 20 double silk covered

INNER COIL SECTION	
Diameter	$1\frac{1}{2}''$
Length of winding	$1''$
No. of turns	72
Wire	No. 32 double silk covered

If instead of winding the inner coil with fine wire, a heavier wire is used and the coil bank wound, a higher efficiency will be obtained. The bank winding should cover the same area and have the same number of turns as the winding specified in the above table.

The outer coil should be arranged in respect to the inner coil section so that it slightly overlaps the high-voltage end of the inner coil in order to produce more thorough shielding. Also, the inner coil section must be concentric with the outer coil. Both coils must be wound in the same direction and connected in series at one end as shown in the diagram.

For coupling purposes a few turns of wire may be wound over or near the low-voltage end of the inner coil. When such a winding is used, the end farthest away from the high-voltage terminal of the inner coil should be connected to the plate of the preceding tube or to the antenna. The other end of the winding goes to the plate battery or to the ground.

The author leaves the constructional details of the self-shielded coil to the builder's judgment. No doubt, many ways will be devised for fastening the coil sections together, and for mounting the completed coil.

Unlike other forms of "concentrated-field" inductances, the self-shielded coil just described is unique in that it is electrostatically shielded, and has an extremely limited magnetic field; while other coils having concentrated fields are not shielded statically.

OPERATING DATA ON QUARTZ CRYSTALS

By G. F. LAMPKIN

THE manner of obtaining quartz crystals from the raw quartz has been covered rather thoroughly in numerous publications. The article in December, 1928, RADIO BROADCAST (pages 85–87) by R. C. Hitchcock, gives valuable data on this subject. The manner of their application to oscillating or transmitting circuits has also been the subject of several writings. Data on the operating characteristics of quartz crystals themselves, however, have not been brought forward so frequently. One item which is of pressing interest is the accuracy to which the crystals can be made to hold their frequency. The present-day crowding of broadcasting stations, their wandering from assigned frequencies, heterodyning of carrier waves, and so on, make it necessary that the accuracy of crystal control be determined definitely. A more recent reason is concerned with determination of the number of practicable channels available among the short waves.

It is the purpose of this article to record a few data concerning the operation of crystal oscillators, including some notes on frequency variation of crystals. The work was done at the University of Cincinnati in connection with the development of a 50–100-meter, crystal-controlled transmitter for duplex radiophone communication. The advantages of single-sideband, or double-sideband, eliminated-carrier transmission over ordinary transmission are several, including power saving, duplexing, more uniform reception, and so on. Either system requires reintroduction of the carrier at the receiver. In the case of single-sideband transmission, the carrier, which is replaced at the receiver, must be within some 50 cycles of the carrier frequency which was suppressed at the transmitter; in double-sideband transmission, the carrier must be replaced within 1 or 2 cycles, in order that reception may be reasonably intelligible. For a single-frequency radiotelephone system using one of the above types of transmission, each station would require a matched crystal both to control the transmitter frequency and to supply the carrier at the receiving end. Successful operation of such a system, of course, is dependent on the constancy of frequency from the matched crystals.

Types of Short-Wave Crystals

THE data given below are not particularly comprehensive—for one thing, they cover only a restricted wavelength range—but they will serve to indicate what may be expected in crystal operation, and may stimulate other investigations. In order that better comparison, or judgment, may be made of the results, brief descriptions of the apparatus and methods used in measurement will be given.

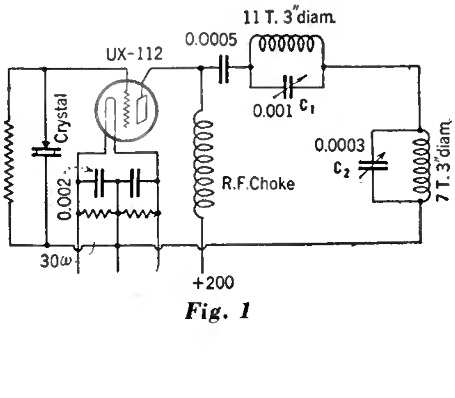


Fig. 1

The usual method of cutting a blank from the raw quartz yields a slab whose surfaces are perpendicular to one of the prismatic faces of the crystal. This section is shown at (A) in Fig. 3. An alternative method is to cut a slab parallel to a face of the prism, as at (B). A crystal cut in the first method has a wavelength constant of 104 meters per millimeter thickness; or, in everyday units, 2.64 meters per thousandth inch of thickness. The parallel-cut crystal has a fundamental wavelength of 3.87 times thickness in thousandths of an inch. Apparently any slab cut at an intermediate angle between the two above will also oscillate. Wavelength constant, temperature coefficient of frequency, and magnitude of fundamental and harmonic radio-frequency outputs, are quantities, among others, that vary with the angle of cutting. However, only crystals from the parallel- and perpendicular-cut slabs were ground and measured. In the table of Fig. 3 are listed some of the crystals that were completed. It may be seen that the wavelength constant varied from 2.59 to 2.66 in the one case, and from 3.85 to 3.89 in the other. For any given wavelength, the parallel-cut section produces a crystal that is thinner than the corresponding perpendicular-cut crystal.

> *It is commonly thought that a properly cut slab of quartz crystal will hold an oscillating tube to the exact desired frequency regardless of the mounting, plate and filament voltages, and other tube variables. Mr. Lampkin shows how these factors, as well as pressure on the crystal, temperature, etc. influence the frequency generated by the quartz-controlled transmitter.*
>
> —THE EDITOR.

The blanks were sliced from the raw quartz by a muck saw of 0.022" steel, 6" in diameter, motor-driven at 300 or 400 r.p.m., and fed with No. 90 carborundum and water. The finishing grinding was done by hand on a cast-iron plate with No. 200 carborundum and water. The surfaces of the crystal were not polished smooth, but had the appearance of ground glass.

Some of the crystals, particularly No. 1 and one of the 159-meter matched crystals, oscillated strongly when the two surfaces lacked as much as 1 or 1.5 thousandths inch of being parallel. As a rule, however, the tolerance was only one or two ten thousandths of an inch. Crystal No. 5 was surfaced closer than could be measured on the micrometers and would not oscillate; then putting a smooth, rounded bevel on all the edges brought it into strong oscillation. Crystal No. 6 would not oscillate at all unless its temperature was within a certain critical range. When a hot soldering iron was placed under the crystal holder, oscillations began and their strength, as shown by a vacuum-tube voltmeter, increased as the temperature of the crystal went up; they passed through a maximum, and then decreased with further increase of temperature. When the soldering iron was removed, the oscillations again rose to a maximum as the crystal cooled through the critical temperature, and then dropped off.

Harmonic Operation

CRYSTAL-CONTROLLED transmitters whose outputs are much below 80 meters usually operate on a harmonic of the crystal. Crystals whose fundamentals are less than 80 meters become too thin to handle conveniently. In grinding, if the surfaces of a 160-meter crystal must be parallel within a ten thousandth inch, the tolerance for an 80-meter crystal is only five hundred thousandths inch. An 80-meter crystal is thin enough that pressure on one spot in grinding will hollow out that part more than the surrounding surface—the crystal actually gives and bends. A crystal with a 40-meter fundamental is very fragile, being no thicker than a heavy piece of paper. These disadvantages of the short-wave crystals do not work extreme hardships, however. It is feasible, and comparatively easy, to employ the harmonics of 100- to 200-meter crystals to produce crystal-controlled outputs from 100 meters down. The usual method is to impress the output of the crystal oscillator on a heavily biased radio-frequency amplifier, and to tune the amplifier output to a harmonic of the crystal Ordinarily the second harmonic is picked out, so that the tube works as a combined amplifier and frequency doubler. The process is repeated, if necessary, until the desired wavelength of output is secured.

In order to determine what strength of harmonics could be obtained directly from the crystal oscillator, the circuit of Fig. 1 was set up. It may be seen to be the usual hook-up except for the extra tuned circuit in the output. A 112-type tube with plate voltage at 200 and filament voltage at 5 was the oscillator tube. Other dimensions are included in the figure. Trap circuit, L_1C_1, was tuned to the fundamental of the crystal. To measure the magnitude of radio-frequency voltage across this circuit, L_2C_2 was shorted out. A vacuum-tube voltmeter was connected across L_1C_1, and for each setting of the condenser the voltage was read. This voltage, of course, was at the fundamental wave of the crystal, or 159 meters. The values, plotted against dial reading, are given in Fig. 5, curve E_1. As the resonant wave of the tank circuit, L_1C_1, approached the fundamental of the crystal, from below, the magnitude of radio-frequency voltage increased steadily, until, just as the tuned circuit passed the crystal wave, the oscillations broke sharply. Maximum strength of fundamental radio-frequency voltage output was obtained just before the crystal ceased operating.

To measure the harmonic voltages, the short on tank circuit, L_2C_2, was removed and the vacuum-tube voltmeter was connected across it. Circuit L_1C_1 was kept tuned to the

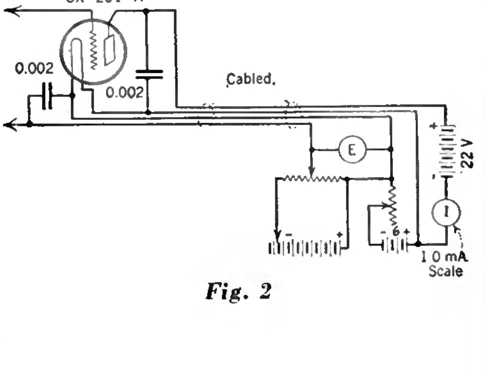
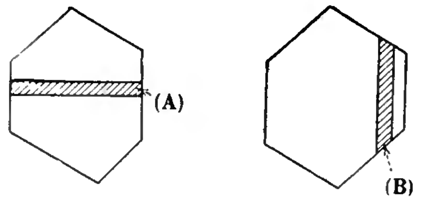


Fig. 2



NO	THICKNESS	WAVE	METERS/MILL
1	0.0515"	198.0	3.85
2	0.0642"	167.5	2.61
3	0.0410"	159.0	3.88
4	0.0410"	159.0	3.88
5	0.0575"	155.0	2.66
6	0.0367"	142.8	3.89
7	0.0535"	139.0	2.60
8	0.0535"	139.0	2.60
9	0.0480"	124.0	2.59
10	0.0460"	120.0	2.61

Fig. 3

fundamental of the crystal, in order to keep it oscillating. The second circuit was first tuned to 79.5 meters—the crystal's second harmonic. The point of maximum voltage occured at only one point on the dial of C_2, for any one position of C_1. However, the magnitude of the second-harmonic voltage did vary, as C_1 was tuned, in the manner of curve E_2 of Fig. 5. As the condenser in the fundamental tank circuit was brought up to the crystal wave, the second harmonic voltage at first increased, reached a maximum, and then dropped off until the oscillations again broke. The interesting point is that maximum harmonic voltage is not obtained at the same setting of the fundamental circuit dial as gives maximum fundamental output. When the trap, L_2C_2, was tuned to the third harmonic of the crystal, the same type of radio-frequency voltage output curve, E_3, resulted. The curves for a perpendicular-cut crystal, No. 7, were in no way dissimilar to those for the parallel-cut specimen.

Parallel Vs. Perpendicular Cuts

THE maximum voltages obtainable at the optimum tuning of both condensers, for harmonics up to the fifth, were determined. In Fig. 6, the curves show for four crystals, two parallel-cut and two perpendicular-cut, how the strengths of harmonic and fundamental voltages compare. The fundamental was measured across circuit L_1C_1, and the harmonic voltages were measured across circuit L_2C_2 when it was tuned to the given harmonics.

Under the test conditions, the parallel-cut crystals gave a greater magnitude of radio-frequency voltage than did the perpendicular-cut plates. Also, any given harmonic of the parallel-cut crystal was a greater percentage of the fundamental than was the corresponding harmonic of the other type. In either case,

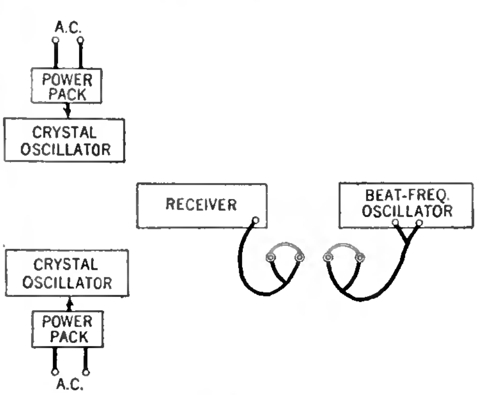


Fig. 4

harmonics that are a goodly proportion of the fundamental can be obtained directly from the crystal oscillator, so that it is possible to eliminate one or more frequency multiplying amplifiers in a transmitter layout. It may be noted that a grid leak was used on the oscillator tube. The relative strength of harmonics could probably be changed, and favorably, by using grid bias. A more intensive study on the matter of harmonics should certainly prove fruitful.

Radio-frequency voltages across the tuned circuits were measured, instead of reading the tank-circuit currents, because the voltages are more indicative of the true output of the oscillator. Voltage, only, is useful in feeding the next amplifier. The tank-circuit current for any one harmonic could be made to vary widely by merely changing the ratio of inductance to capacity, so that readings of current would mean little. The radio-frequency voltages were measured by impressing them on the grid of a vacuum tube, and then bucking out with direct voltage until the plate current returned to its initial value of 100 microamperes. The direct voltage, minus a small correction for initial bias, was, of course, equal to the peak of the radio frequency. The voltmeter tube was fitted with long leads to the battery and meter assembly, so that it could be brought right to the tuned circuit which was to be measured. By-pass condensers to filament were connected at the tube. The picture on the next page and the diagram of Fig. 2 give further details of the electrical and mechanical designs of the meter.

Frequency variation in crystal oscillators

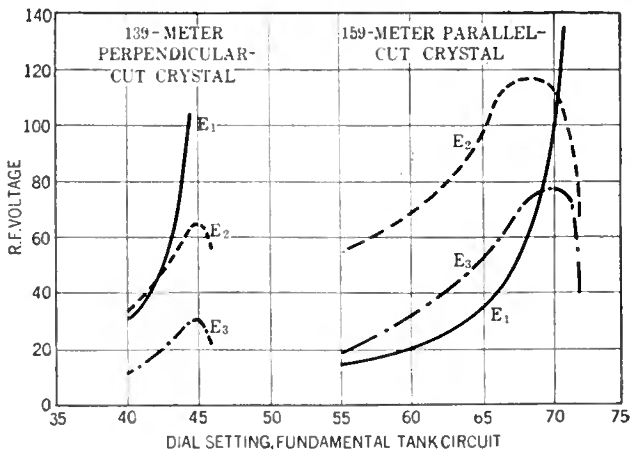


Fig. 5

is a problem whose difficulty of solution varies directly with the frequency. That is, a broadcast station on 500 kc., having to maintain its frequency within 500 cycles of that which was assigned, has to work within limits of 0.1 per cent. A station assigned a frequency of 1500 kc., and required to hold that within 500 cycles, has to maintain an error of less than 0.033 per cent. Thus, as the operating wavelength of the station goes down, the percentage accuracy which has to be maintained for a given permissible frequency variation increases.

The use of harmonics of a crystal oscillator does not improve matters in this respect, except indirectly. If the frequency variation of a 400-meter crystal is 50 cycles, say for a certain change in temperature, the frequency variation of its fourth harmonic, at 100 meters is 200 cycles. A 100-meter crystal whose temperature was changed the same amount would have exactly the same frequency variation—i.e., 200 cycles. The change of frequency with temperature is due to the expansion of the crystal; and the above conclusions are evident from inspection of the equations for thermal expansion. Indirectly, however, frequency stabilization is aided by using crystal harmonics, because the thicker

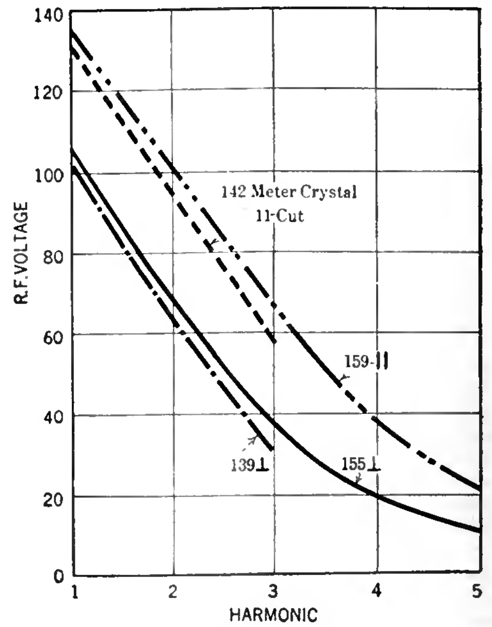


Fig. 6

crystals are much easier to handle and to mount.

Matching Crystals

TWO pairs of crystals were cut and ground to approximately zero beat. One pair, crystals No. 3 and No. 4, were cut parallel to a face of the raw quartz. By careful hand grinding with fine carborundum, and continual checking against each other as oscillators, the frequencies of the crystals were brought within one or two hundred cycles. The fundamental wavelength of the two was 159 meters. Two other crystals, No. 7 and No. 8, cut perpendicular, were ground and matched in the same way at a fundamental wavelength of 139 meters.

In order to measure frequency variation of the crystal, the layout depicted in Fig. 4 was utilized. The second harmonics of the crystals in the 50-to-100-meter band were to be used for controlling the transmitter, so the receiver was tuned in this band to the second harmonics of the two crystals. The crystal oscillators were spaced some 15 feet across the room, and were run from entirely separate A and B supplies. The frequency of the audible beat note, present at the receiver output, due to the two harmonics, was measured with a beat-frequency oscillator. For this purpose a 10-mmfd. semi-circular plate condenser was used as a vernier on the beat-frequency oscillator. When calibrated against a Western Electric 8A audio oscillator, a linear frequency variation of slightly more than 300 cycles was had over the dial. Thus, by beating the sound output from the receiver against that from the calibrated audio source, changes in frequency of one cycle in the crystal oscillators could be detected. One of the oscillators was left

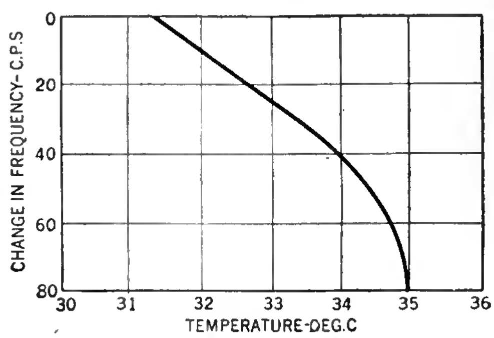


Fig. 7

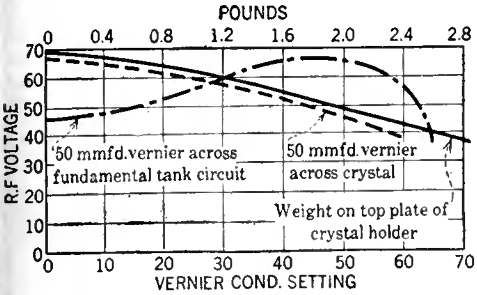


Fig. 8

untouched during a test run, while a variable on the other was changed. Then the variation in beat note between the two crystals was due solely to the change in the variable on one crystal. Since variation in frequency of the second harmonic was measured, the values given are twice the variation that occurred in the fundamental frequency.

Because the crystal oscillators were to be supplied with operating voltages from a 60-cycle a.c. source, the parallel-cut and perpendicular-cut types were compared as to frequency variation when the line voltage changed. The oscillator tube was supplied with 5 volts a.c. on the filament, and 200 volts d.c. from a B-power unit. Both these voltages had as their source an a.c. supply which could be varied from 110 to 130 volts. In the case of the parallel-cut crystal this change in line voltage caused an average frequency shift of 20 cycles. The same test applied to the perpendicular-cut crystal caused the frequency to change 35 cycles in two or three seconds, and then drift slowly to a total change of 92 cycles in some three minutes—again average values of several trials. This comparison, coupled with the fact that the parallel-cut plates gave a higher radio-frequency output, was the reason for confining subsequent measurements to this type of crystal.

Variations Possible

IN FIGS. 8 and 9 are shown the frequency variations that may be obtained by three means of intentional tuning. In the dash curve a small semi-circular plate condenser of 50 mmfd. maximum capacity was connected across the crystal itself. Variation of this capacity caused a nearly proportional change in crystal frequency. The total variation in frequency when the capacity went from 0 to 30 mmfd. was 450 cycles. At the same time, however, the second harmonic output voltage dropped from 67 to 38 volts, peak.

The variation of frequency resulting when the vernier condenser was placed across the fundamental tank circuit was determined, and is given in the dot-dash curve. The total change in frequency with tuning of the main condenser, from the point where the oscillations started to where they broke, was some 800 cycles. (For the perpendicular-cut crystal, this figure was 250 cycles.) The frequency varied in much the same manner as did the fundamental voltage, in curve E_1, Fig. 5. That is, the change in frequency was slight at first, then became greater until, at the point of oscillation cessation, the frequency change per increment of setting was a maximum. The dot-dash curve in Figs. 8 and 9, then, is a small portion taken from this larger curve that would be obtained were the main condenser varied. The hump in the second-harmonic output-voltage curve is also a portion of the larger curve E_2, Fig. 5.

Variation of pressure on the crystal surface constitutes another means of shifting the crystal frequency. The total change experience when the weight on the top plate of the crystal holder was run up to 2.8 pounds was 845 cycles. This represents a greater change in frequency for a given drop in output voltage than either of the other methods of tuning. The relation between pressure and frequency increment is nearly linear, so that tuning in this manner is better than, for instance, the use of a 50-mmfd. vernier across the fundamental tank circuit. Another ad-

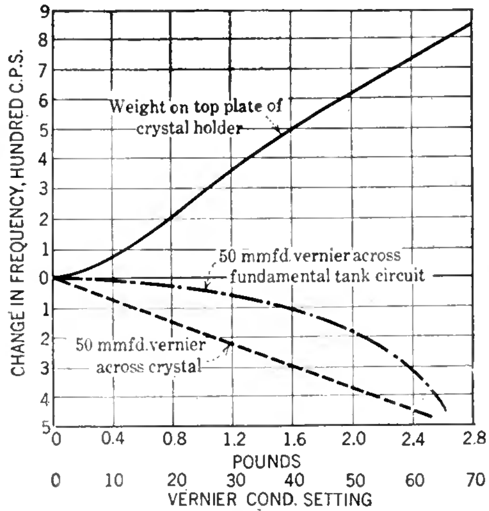


Fig. 9

vantage incurred by the use of pressure on the crystal is that it makes for stability. Jars or bumps suffered by the crystal and mounting are not so likely to disarrange the holder.

The latter point was one of the most troublesome in bringing and keeping the two crystals to zero beat. For each slightly different position of the holder plate, the crystal took up a new oscillation frequency that was possibly two cycles, or as much as two thousand cycles removed from the original. It is physically impossible to grind the two surfaces of an 80-meter crystal parallel within five or ten "cycles." A ten thousandth of an inch on such a crystal represents some 13,000 cycles. It seems that for each new position of the plate a new portion of the crystal has a major effect on the frequency. It was neces-

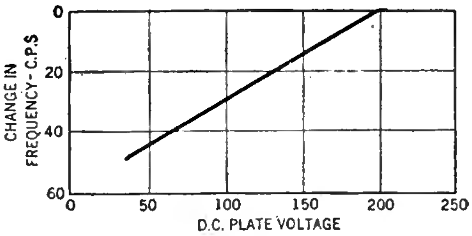


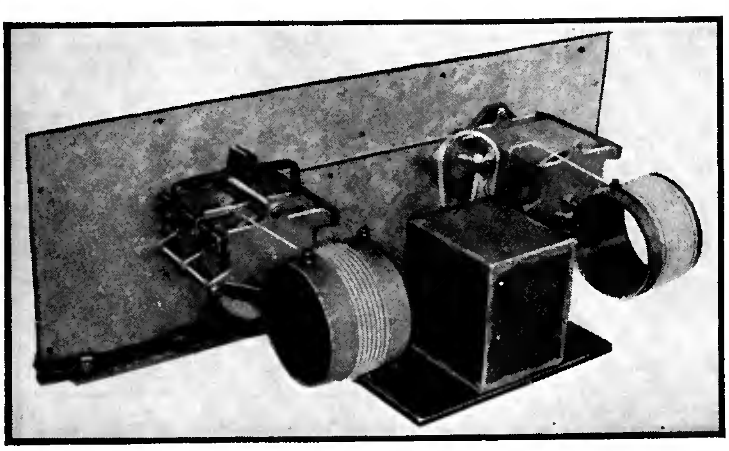
Fig. 10

sary to place and replace the top plate of the mounting till the frequency of one crystal came within a hundred or so cycles of that of the other. A holder designed to maintain the relative positions of the crystal and plate within close limits; or one designed to give intimate electrical contact over both crystal surfaces, should aid in overcoming the difficulty. In the case of the longer-wave crystals, it is possible to operate them with no contact whatsoever between plates and crystal.

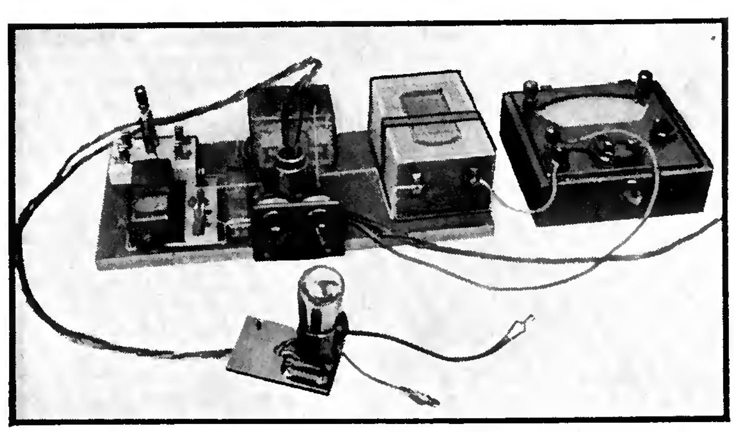
Maintaining Frequency Constant

THE frequency shift which occurred when both the filament and plate voltages on the oscillator tube were changed has been mentioned. In Fig. 10 the change in frequency that is due to plate voltage variation alone is shown. To maintain the frequency constant within one cycle the plate voltage must not be allowed to vary more than 1.5 per cent. To hold the frequency invariant to the same degree, temperature variation cannot exceed 0.66 degrees Centigrade. Thus, the major problem in frequency stabilization is that of temperature control. Other factors such as operating voltages and circuit constants can be fixed so that frequency shift due to them becomes negligible when compared with that due to temperature variation. Fig. 7 contains the points, plotted, which were obtained when the temperature inside the container for the crystal mounting was increased slowly by means of a resistance heater. Readings of temperature and frequency were taken at intervals of five minutes over the period of 45 minutes which the curve data cover.

Over the straight-line portion of the curve the frequency changed 15 cycles per degree Centigrade. The lower bend in the curve furnishes another example of the discontinuities encountered in crystal operation. As the temperature slowly approached 35° the frequency began to change more rapidly, and at that point the beat note suddenly jumped to 2973 cycles, where it had been 429 cycles previously. For no apparent reason the frequency shifted 2544 cycles. Thus, not only must the crystal temperature be held within extremely close limits, but the absolute value of the temperature is important. It is not safe to calibrate the crystal in one range of temperature, and assume that the frequency in another range can be obtained by application of the temperature coefficient of frequency.



The author's crystal-oscillator unit



The vacuum-tube voltmeter shown schematically in Fig. 2

ROUTINE TESTING OF FILAMENT CIRCUITS

By JOHN S. DUNHAM

QRV Radio Service, Inc.

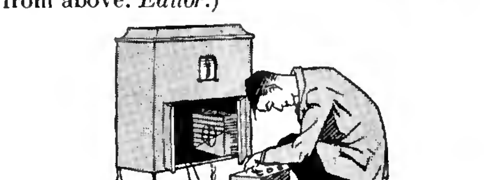
> *One of the primary interests of radio dealers who write us about servicing seems to lie in determining the best methods of going about service problems in general. In the April* RADIO BROADCAST, *Mr. Dunham wrote the first of a series of articles on routine testing of radio sets. This was most favorably received and this article which deals with routine tests of the receiver in the customer's home presents some interesting thoughts on routine tests for filament circuits. The table at the end of the article should be especially useful.*
>
> —THE EDITOR.

THE chart which is reproduced as part of this article describes a *method* of testing the continuity of filament circuits in radio receivers. It does not apply to any particular make or model of receiver, but is intended only to apply to the three commonly used *types* of filament circuit. It does not pretend to contain all of the tests which may be necessary on a given receiver, but was designed to serve as a guide in developing an orderly, thorough, and rapid system of testing. There may be variations of the order given which will save more time. It is certain that precisely the same order cannot always be followed, because there is such wide variation of physical construction of receivers in use to-day. The important thing is that *some* carefully designed order of testing must be used consistently in order to gain at once the two-fold advantage of thoroughness and rapidity.

Socket Trouble

STARTING at the sockets, it is always well to ascertain visually the state of cleanliness, or dirtiness, of the socket prongs before inserting the diagnoser plug for testing. If they are not bright over the area in which contact is made with the tube prongs, they should *always* be cleaned before going farther. Many a no-charge call has been the result of failure to perform this simple operation, a fact especially true when servicing old sets with open, flat-prong sockets. Fortunately, it is less prevalent with the newer types of socket. In the old types, scraping the prongs with the end of a screw-driver is the easiest and quickest method of cleaning them, after which process it is usually advisable to bend them upward to insure proper tension.

With the newer type of construction which does not readily permit visual inspection of the socket prongs, moving the top of the tube, in any socket, along the circumference of a small circle will produce noise from the loud speaker if the contacts are not clean and tight. That test may have to be deferred because of other troubles, but it should always be made. Such socket prongs may be cleaned from the top by the use of a piece of No. 14 solid antenna wire, bent over slightly at the end and sharpened, somewhat like an automobile carbon scraper. If the tension of the prongs has become insufficient, it usually can be remedied only from underneath the tube panel. However, the type of prong that is used in the Radiola 25 and other models may be tightened up from above with a special tool provided by RCA for that purpose. (Some servicemen always carry a crotchet needle in their kit as this may sometimes be used as a tool for the repair of sockets from above. *Editor.*)



On every service call the battery terminals should be carefully examined.

Continuity Tests

WITH the diagnoser plugged into a socket, if filament voltage is not obtained, the next place back along the line of supply which can be tested readily is usually the terminal strip of the set. If filament voltage is obtained there, it establishes the continuity of the remainder of that supply circuit, and at the same time narrows down the search for trouble to that portion of the circuit which lies between the terminal strip and the socket prongs. Each of the two legs of that portion may then be analyzed separately. Speaking of a parallel d.c. circuit, for example, if voltage is obtained by testing from the negative strip terminal to the positive socket prong, the continuity of the positive leg of the circuit is established, thus further narrowing the search down to the negative leg. If the filament-control rheostat is in that leg, testing for voltage from the positive strip terminal to the rheostat will determine whether the trouble is there, between there and the strip, or between there and the socket. When the open has been located definitely in a small portion of a circuit by such an orderly process of elimination of other parts of the circuit, then in most cases it may be found quickly by visual examination.

When the trouble is not a complete open, but is a partial break or a resistive contact, as indicated by low voltage, or fluctuation of voltage, at the socket, but with steady voltage of the proper value appearing at the terminal strip, the parts of the circuit in which the trouble does *not* exist may be eliminated by the same process. Then, if visual examination does not disclose the fault, it may be found by watching the voltage across the tube in the diagnoser socket, with the diagnoser plug in the set socket, while vigorously moving and pulling the particular length of wire to which the trouble has been traced.

Rheostats are the most common source of noise and fluctuation of voltage in d.c. filament circuits, as are any continuously variable resistors in any receiver circuit. If turning a filament rheostat—whether it be the common control for all tubes, or simply used as a volume control affecting only a few tubes—produces noise from the loud speaker, that rheostat should be thoroughly cleaned. Fine sandpaper is the best thing with which to clean the contact arm and the surface of the resistance wire on which it rides. If it cannot be reached easily to use sandpaper, in those sets which are designed without apparent thought to the difficulties of servicing them, a pipe-cleaner, dipped in alcohol, will sometimes suffice. If cleaning the end of the arm and the surface on which it makes sliding contact does not entirely eliminate the noise, then the rheostat should be dismantled and the sliding contact which connects the shaft to one terminal lug of the rheostat should be thoroughly cleaned, as well as the stationary part of that contact. Oil should never be used on the shaft bearings of a rheostat, for oil happens to be an insulator, a fact which seems to be ignored by a good many servicemen who ought to know it. There is one exception to the statement that oil should not be used on rheostat bearings. There is one manufacturer of rheostats in the United States (there may be a few others, but the author has never seen their product) who makes rheostats with a pigtail connection from the shaft to the terminal. Oil may be judiciously used on the bearing of that most excellent job. If you have not guessed it, the name of the wise manufacturer mentioned is the Yaxley Mfg. Co. Long may they prosper!

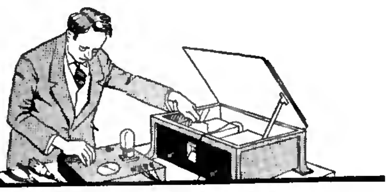
Still using the battery-operated set as an example, if proper voltage is not obtained at the terminal strip, the next logical test point is the terminals of the A battery. If normal voltage appears there, it is obvious that the trouble exists between that point and the set terminals. If no voltage at all is obtained at the set terminals, one of the two filament leads in the cable must be broken at some point. The continuity of the positive one may be determined by a voltage test from its terminal strip end to the negative battery terminal, and that of the negative lead from its terminal strip end to the positive battery terminal.

Corrosion on Terminals

IF THE more usual trouble of slightly fluctuating voltage at the terminal strip is observed, the most probable cause is corrosion on the battery terminals, creating a varying resistive contact between them and the cable lugs or clips. On every service call, the storage-battery terminals should be examined carefully, and if the contact is not perfect they should be thoroughly cleaned and thickly coated with vaseline. Also, if battery clips are not being used, or if those used are small and have weak springs, then large clips with very strong springs should *always* be put on. Failure to do those things is another prolific cause of no-charge calls and dissatisfied customers.

Oil should never be used on the shaft bearings of a rheostat for oil happens to be an insulator.

A few words about lead-cell storage batteries may not be amiss at this point. A voltage reading taken across the terminals of such a battery without the set load is valueless for the practical purpose of determining its condition and state of charge. The no-load voltage may be high, but the voltage with even the small load of the tube filaments may be very low. Neither is a voltage reading under that load a *sufficient* indication of the state of charge. The change of terminal voltage, even under normal load, is not a linear function of the change in ampere-hour capacity. During discharge, for example, the voltage curve is only a gradual slope downward until



After the fault has been localized it may be found by watching the voltage across the tube in the diagnoser socket, with the diagnoser plug in the set socket, while vigorously moving and pulling the particular wires to which the trouble has been traced.

nearly the end of the discharge, when it finally begins to fall rapidly. It is possible for the terminal voltage to be high enough to supply five volts at the tubes when the battery is more than three-quarters discharged and, therefore, in need of recharging.

Likewise, a hydrometer reading alone is not a sufficient indication of the condition of a battery. A cell may be reversed, or contain damaged or shorted plates without giving any indication of that condition by the specific gravity of its electrolyte. Therefore, a voltage test under the set load should be made and the state of charge should also be determined, either by measuring the specific gravity of the solution with a hydrometer, or by employing one of the various ammeters put on the market for that purpose which place a comparatively heavy load across the cell and measure the current on a scale which is roughly calibrated to show the approximate state of charge. The latter is preferable for the practicing serviceman. While not as accurate as the hydrometer, it is sufficiently so, and it is more compact, does not break easily, *and cannot drip acid solution.*

Trickle Chargers

WHEN a trickle charger is used, its rate of charge should always be measured by inserting the one-ampere range of the diagnoser ammeter in series with one of the leads between the charger and the battery. If the rate is adjustable, a good deal of possible future trouble can be avoided by adjusting it to approximately the rate which is needed for that particular set. Careful questioning will usually extract from the customer a fairly good estimate of the average number of hours the set is used daily. If he is not home to be questioned, and in the absence of other evidence, an average of four hours is a safe assumption. Multiplying that figure by the current drain of the tubes gives the number of ampere-hours taken from the battery every twenty-four hours. Dividing that figure by the remaining hours of each twenty-four, during which the battery is being charged, gives the rate of charge needed to replace the same number of ampere-hours. That figure plus 30 per cent. is the rate to which the charger should be adjusted. The computation may be expressed in the following formula:

$$\frac{\text{hours of drain} \times \text{drain in amperes}}{\text{hours of charge}} + 30\% = \text{charging rate.}$$

If the charger is adjustable in steps instead of continuously, it is better to use the rate which is a little higher, instead of the one which is a little lower than the desired rate.

If the rectifier is one of the wet types, and does not give the output which is necessary, the only reasonable remedy is to throw out the inexcusable thing and substitute for it a good dry rectifier replacement unit, such as Elkon or Kuprox, made especially for that particular charger. Dry rectifiers do not, of course, last forever—because it they were made that way the manufacturers' future replacement market would not exist—but at least they may be replaced, when exhausted, by others of the same make and type without causing the serviceman that feeling of guilt which he has when he supplies any accessory or part which he knows to be inferior. A similar dry type is also made to replace Tungars, and is preferable because of its economy in operation and life, and its quietness.

Charger Connections

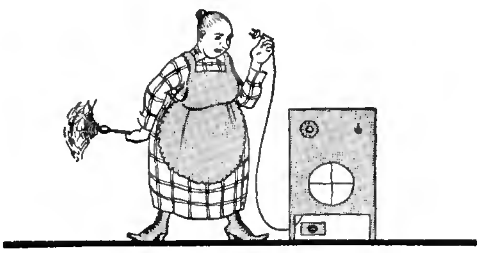
IT IS rather important to remember that the positive terminal of the charger must be connected to the positive terminal of the battery. If that order is reversed the battery will be discharged rapidly, and then very slowly charged again in the opposite direction, a process which materially shortens the life of both the battery and the charger. When a storage battery using a trickle is found to be fully discharged, or partially or fully charged with the polarity reversed, it is well to be sure of that point. The foregoing would seem to be information of the kindergarden variety, but the number of times QRV servicemen have discovered exactly the described state of affairs is amazing. When the condition is found, the only remedy is to have the battery sent to a battery service station for proper recharging.

When an ammeter test does not show any output, or an intermittent output from a trickle charger, a very probable place of trouble is at the points of the relay. Those points are slightly burned by sparking each time contact is broken, and, therefore, require cleaning occasionally. A very few strokes with fine sandpaper or a very fine file, held flat against the points by closing them against it, will suffice to clean them properly. The relay switch arms can get out of adjustment, so that they do not close firmly in one or the other direction, and may need bending back into their original shape. The spring against which the switch arms work may gradually lose its tension and require shortening. The tension should be adjusted so that good firm contact is made to close the charging circuit, but still light enough to permit the arms to be pulled sharply, and held

In series-filament circuits much time may be saved by testing the continuity of each tube filament separately with a C battery.

firmly, against the opposite points when the magnet is energized.

We have spoken so far only of a.c. trickle chargers. There is no difference in method of testing or connection where d.c. is the supply, but there is one caution about such equipment which is important. Whenever a d.c. trickle charger is installed, fixed condensers of any convenient value larger than 0.001 mfd. should always be put in both antenna and ground leads, *between* the set and the lightning arrestor, *before the charger is connected to the line.* This is also essential when installing d.c. sets, with the exception that the manufacturer usually takes care of putting a suitable capacity in the ground lead, within the set or power pack. If there is none for the antenna within the set, then it can be connected externally by the installer. Observance of that rule will avoid the evaporation of relay switch points, parts of primaries of antenna input transformers (in the event of a grounded antenna or shorted lightning arrestor), parts of tube filaments, and lighting circuit fuses, at a cost which is compara-



A common cause of "dead" d.c.-powered receivers is ignorance on the part of the housemaid concerning the manner in which the plug should be placed in the wall socket.

tively low. If you don't know the reason for those possibilities, draw a circuit diagram starting at the line, going through the relay, charger and battery to the filaments, showing the antenna-ground system with its connection to the filaments, remembering that either side of the line may be grounded and that, when the relay switch is in the charging position the points do not open until *after* the set has been turned on at the filament switch. The same situation exists with a set operated from the d.c. line.

Perhaps some enterprising manufacturer will put a variable-rate d.c. trickle charger on the market before battery-operated receivers become obsolete. Until that time, in cases where the rate of the present manufactured article is not reasonably near that required, and where the battery and charging equipment can be kept entirely out of sight, a good substitute for it is a porcelain lamp socket screwed to a wooden base, into which may be put a size of lamp which has approximately the right resistance to give the desired rate. Then, if it becomes necessary to change that rate, a different size of lamp may be substituted easily.

Series Filament Circuits

THE testing of series d.c. filament circuits is just as easy and may be done just as quickly as the testing of parallel circuits, if a logical routine is followed. When the tubes are not paralleled with resistances, there is but a single series circuit extending from one filament terminal on the strip to the other filament terminal, and consisting of alternate sections of tube filaments and single wires connecting those filaments, like a string of sausages. There may also be a section at one end consisting of a rheostat. Testing for voltage from the negative end (negative terminal on the strip) first to the positive end, and then successively to each joint between sections, will quickly disclose the point at which the open occurred.

While it would be just as effective to use the positive end as the point in the circuit from which to start testing, it saves time to get into the habit of always starting at the same point, and the negative end is preferable as the base of operations for all circuit tests, except when testing a.c. circuits—which obviously have no polarity to an a.c. meter.

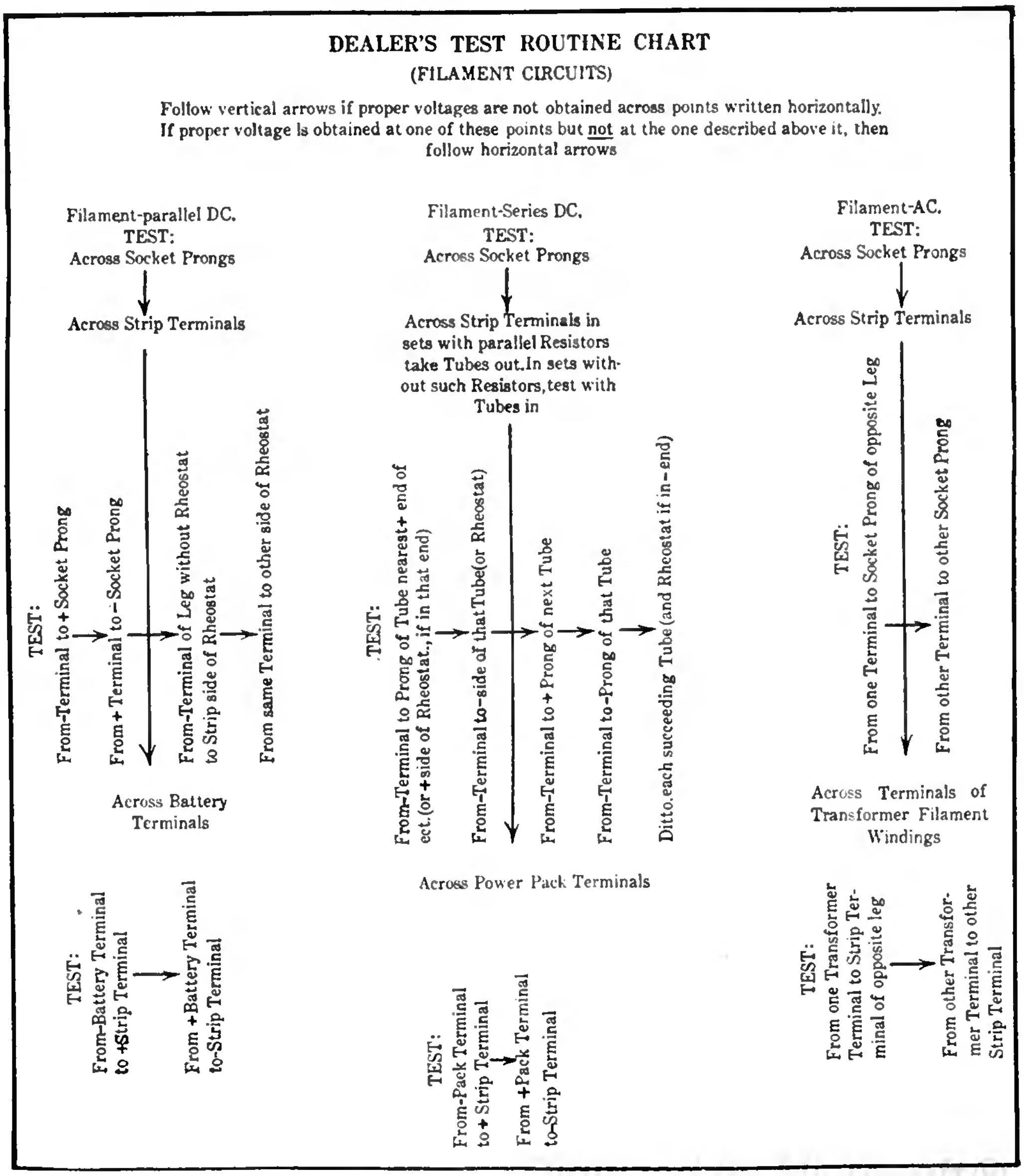
It is, of course, necessary to keep the tubes in the sockets when testing such single series circuits, and get at the contacts elsewhere. If the construction of the set is such that the socket contacts cannot be reached from above the panel when the tubes are in the sockets, time may be saved by testing the continuity of each tube filament separately with a C battery. If none of the tubes is open, then, to get at the socket contacts before removing the chassis from the cabinet, a piece of stiff wire bent into U shape may be substituted successively for each tube by inserting it across the filament prongs of each socket. After testing at one socket, the tube should be replaced in that socket, and the wire moved to the next socket to permit test there.

Radiola 28 Circuit

WHEN each tube in a series arrangement is paralleled with a resistance, such as in the Radiola 28 when operated from the 104 loud speaker, there are two series circuits which are parallel to each other throughout the length of the filament circuit, and are connected to each other between each tube. It should, therefore, be tested for continuity with the tubes out, but otherwise in the same order used when testing a single series circuit. As the continuity of the part of the whole circuit across which a tube filament is connected does not depend solely upon that tube, but depends also upon the parallel resistance, the opening of one filament is self evident because the others do not thereby go out. Similarly, if one section of the resistance opens, but the tube across it does not, the continuity of the whole circuit remains unbroken. In that particular case the tube filament will be carrying very nearly the current which was divided between it and the resistance section before the latter opened, so that it will be burning with abnormal brilliancy, a fact which is usually evident visually and hence removes the necessity for continuity testing.

Special Cases

IN SOME sets a series-parallel arrangement of tubes is employed. That is, in a set using six tubes, for example, there will be two series circuits containing three tubes in each, and the two circuits connected in parallel across the supply. Continuity testing of each of those circuits may then be done separately. That type of filament circuit is sometimes used in sets operated from a d.c. lighting supply. The serviceman should be very careful to refrain from changing tubes in that type with the power switch on, unless he is familiar enough with the circuit diagram of that particular model to know that it can be done without damaging other tubes. In some models there is but a single resistance used to drop the line voltage down to the voltage required for the two filament circuits. In such atrociously designed jobs, if one of the filament circuits is opened by removing a tube, or in any other way with the power on, the current drain is halved, the IR drop across the single resistance decreases, thus increasing the voltage across the remaining filament circuit. That increase of voltage in turn increases the current through the filaments, resulting in paralysis of all of them and often the burning out of one of them.



General Rules

WHATEVER type of filament circuit is used, if proper voltage is not obtained at the set terminal strip, the next logical place to test is at the filament terminals on the power pack, regardless of what type that may be. If proper voltage is secured at that point, each leg of the supply from there to the set terminals should be analyzed separately as previously described in this article. If proper voltage is not obtained at the terminals of the power pack, then it becomes necessary to trace back through that supply unit. If the supply is d.c., one side of it goes back from the terminal strip of the pack directly to the line, while the other side goes back to the other side of the line through a fixed resistance, or a variable resistance, or both in series. One may, therefore, test for voltage from the terminal of the side which is connected directly to the line, to each end of the resistor or resistors in the other side and to any other joints which may exist.

It is assumed in outlining these filament tests in receivers supplied from either a.c. or d.c. lines that the serviceman knows he has "juice" at the outlet used. When servicing any socket-powered receiver, if both filament and plate voltages are noticeable by their absence at the first socket from which a test is made, and there is no evidence of voltage at that outlet such as a lighted standing lamp supplied from it, then a voltage test should be made before resuming the regular routine.

A common cause of "dead" d.c.-powered receivers is ignorance on the part of the housemaid, and often the customer, that when the little black plug which goes into the outlet is removed for any reason, it should be put back in *exactly* the same position. All servicemen who work in d.c. neighborhoods should carry small tags with them to be tied to the cord close to the plug, on which can be written: "*Always replace plug with the notched side up.*" Then a small notch can be cut into the edge of the plug with a knife or file. The same thing applies to d.c. trickle chargers. If the polarity is reversed, the same thing will happen that happens when the polarity of the output of an a.c. trickle is reversed in its connection to the battery. The average customer is loath to pay a service charge to have a serviceman do nothing but reverse a plug in an outlet, especially if the call happens to follow closely one made to cure other trouble. No matter how carefully he may have been cautioned by previous servicemen about that particular thing, such is the nature of humans that in many cases the customer will not only commit perjury by definitely denying that he was so instructed, but he will also complain about the gross negligence of those preceding servicemen for their alleged failure to do so.

As the d.c. supply for series filaments obtained from a.c. power packs is closely associated with the plate supply, testing of such supply between the power pack terminals and the line will not be considered in this article, but will be discussed in some detail in a future installment.

The testing of parallel a.c. filament circuits differs from d.c. filament circuit testing only in that fewer stops are required. There are no rheostats to worry about, and in many sets the only point at which joints in the supply are not permanent soldered connections is the terminal strip to which the lugs on the cable from the power pack are screwed. When voltage tests made successively at the socket, set terminal strip, and transformer winding terminals to which the cable leads are soldered do not reveal voltage, then there can be only one trouble and one practical remedy (assuming, as before, that line voltage is getting to the primary of the transformer). The trouble is an open (or possibly shorted) transformer winding. The remedy is to replace the transformer.

No. 21 — *Radio Broadcast's Home-Study Sheets* — May 1929

THE USE OF A BRIDGE

THE usual method of measuring the inductance of a coil is to compare it with a coil whose inductance is known—either having been calculated, or compared to some other standard. One method by which this comparison may take place is indicated in "Home-Study Sheet" No. 15. Another, and more often used method, is to employ a Wheatstone bridge by which the unknown inductance, or capacity, may be compared directly to a known inductance or capacity.

Such a bridge may be a simple affair, like the one illustrated in this "Home-Study Sheet," or it may be much more complicated and costly.

As this piece of apparatus probably has a more varied field of usefulness than any other single piece of equipment in the laboratory, the experimenter will be well repaid for any effort expended in its construction.

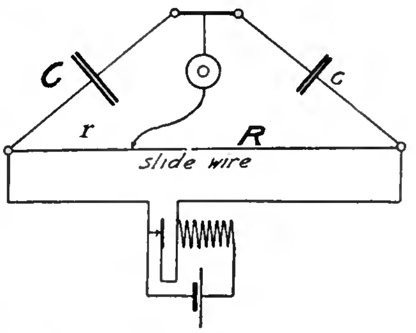


Fig. 1—Connections for a simple slide-wire bridge.

The simplest form and one with which a great deal of practical work may be done is the slide-wire bridge—a type that is greatly improved by the use of a wire of one of the modern high-resistance alloys, such as number 36 nichrome, which has a resistance of about 25 ohms per foot.

The reader is doubtless familiar with the connections as set forth in Fig. 1, in which condenser C is being compared with condenser c, the relation being expressed by the simple proportion $\frac{C}{c} = \frac{R}{r}$. It is, of course, unnecessary to know the absolute values of R and r. If, for example, the scale has 300 uniform divisions, and the sound in the telephone receiver vanishes at a point on the wire 100 divisions from the left, the $\frac{R}{r} = \frac{200}{100}$ or 2, which tells us that the capacity of C is twice that of c.

Practical work may be done by using about two feet of the wire referred to above, stretching it between metal connecting blocks and providing a paper scale. If the scale has twenty divisions to the inch, under proper conditions, it should be readily possible to read to the nearest division, which means a possible accuracy of a fraction of 1 per cent.

Those who have had some experience in lettering and drafting will have no difficulty in producing an accurate and professional-looking scale. Procure a piece of durable and smooth-surfaced card. Mark out the lines for the scale, but do not cut off the required strip until the work is complete. To subdivide, use a steel rule, holding it on edge and running the sharp point of a hard pencil down each engraved division line. This procedure will result in a series of fine dots, more accurately spaced in this mechanical manner than could possibly be done were the pencil point directed by the eye. A straight edge may now be placed parallel to the length of the scale, and, by using a small triangle against it, just as a T square is used against the edge of a drawing board, the division lines may be drawn in readily with a right-line pen and waterproof drawing ink. When the numerals have been lettered, the scale may be given a coat of transparent radio varnish or lacquer.

The chances of error due to inequalities in the wire, which are never very serious, can be reduced greatly by dividing the wire into two equal parts as shown in Fig. 2. When a reading has been taken, connections A and B may be reversed and another reading taken. If the two results differ materially, one or both wires should be replaced. When approximately the same reading is obtained on either side, it is evident that a mean between the two will be quite accurate.

For the measurement of resistance where inductance is also involved, as in the case of a coil, direct current must be employed, and a galvanometer used to locate the zero point on the slide-wire. For capacity measurements, alternating current is required and should also be used for non-inductive resistance determinations (e.g., grid leaks), as the telephone receiver is much more sensitive and more convenient than the usual galvanometer. For practical work a very satisfactory source of alternating current is a fairly high-pitched buzzer. In Fig. 1 the bridge wire is connected across the two contact points. Another method is to connect it directly across the buzzer coil, and sometimes the bridge, battery, and buzzer are all placed in series. For any given buzzer the best plan may be determined by using the bridge to compare two variable air condensers, preferably of the same make or type. The buzzer connection that results in most completely eliminating all residual sound from the telephone receiver when the bridge is balanced is the best. Make the test in a quiet room at different adjustments of the buzzer tone and at different points on the slide-wire.

It is very important to have a buzzer that will produce practically no residual sound under the foregoing conditions, as it enables one to identify defective condensers. If one of the air condensers referred to is replaced with a small fixed condenser which may have a poor dielectric, the sound in the telephone receiver cannot be made to disappear completely when the bridge is balanced, and the amount of this residual sound is a measure of the quality of the dielectric. The faint note that remains in the telephone receiver is simply due to what is termed *phase difference*. This may be made clear by referring to the mechanical analogy illustrated in Fig. 2, "Home-Study Sheet" No. 19, in connection with which it was pointed out that the spring had its maximum velocity at the moment when it was free from all stress, and that the stress was at a maximum when the velocity was zero. Representing the complete cycle of the spring, one extension and one compression, as 360°, it will be evident that velocity and stress are 90° out of phase. Similarly, in a perfect air condenser, the voltage and current are said to differ 90° in phase. In the mechanical analogy a perfect spring is assumed—one that responds instantly to any difference in pressure. If, however, the spring were made of a sluggish or faulty material that required a little time to conform to the pressure, the phase difference would no longer be exactly 90°. Similarly, with a poor dielectric, the phase difference is not precisely 90°, as it is in a perfect air condenser. When a condenser with a poor dielectric is balanced against an air condenser, the bridge will determine the point at which the opposing voltages balance, but as the phase of the current on one side is not exactly the same as on the other side, there will be a slight but unavoidable flow of current. After the experimenter has become familiar with the action of his bridge, he will be surprised to note the marked differences in fixed condensers, not only in regard to the quality of the dielectric, but also as to their stated capacities.

Fig. 3 illustrates a slide-wire bridge which, though it may be somewhat more elaborate than the reader may care to construct, will be described briefly, as certain features may prove suggestive. It is built on a strip of wood ⅞" thick, 3" wide, and 21" long. On one end is a buzzer and on the other a galvanometer. One or two dry cells are used, and, by throwing the six-arm switch, the telephone receiver and buzzer are disconnected and the galvanometer and battery are connected directly to the slide-wire.

The slide-wire is in two sections, which are connected through two brass blocks and a taper plug. By removing this plug, two large equal and non-inductive resistances may be placed across the binding posts indicated at R-R, thus greatly increasing the resistance of the bridge at the 1:1 ratio. This ratio is very generally used in measuring capacities within the range of a calibrated variable condenser, the balance being accomplished by varying the latter. The use of the high resistance in the two arms adds greatly to the sensitivity of the bridge.

At the two free ends of the slide-wire is a switch, which reverses the arms of the bridge, so that a mean of two readings may be used.

The movable contact should have a fine point and be mounted in an insulating handle, and is connected through a flexible conductor to a small binding post at A, which is in connection with a small switch arm. When the bridge is being used at the 1:1 ratio, this switch is placed on the inner contact point, which makes the desired connection to the mid-point permanent.

At B, provision is made for throwing in a high resistance in the lead to the galvanometer in order that the deflections will not be violent while attempting to find the point of balance. When this has been determined approximately, this resistance may be switched out. A piece of card heavily coated with pencil lead will answer and may be slipped readily under a pair of spring clips.

The wiring is all done on the underside, appropriate grooves being cut for the necessary leads. These should not be larger than No. 22 or 24 wire, except for the two short connections between the reversing switch at the end of the slide-wires and the two binding posts, which connections should be made with No. 14 or 16 wire in order that no extra resistance will be interposed beyond the points where the current divides.

The galvanometer used will be referred to later when the subject of galvanometers is taken up, and the necessary resistance units will be considered in a separate "Home-Study Sheet."

Using the Bridge

In practice one lead of the unknown capacity, inductance, or resistance is attached to the binding post X, one lead of the standard to which this unknown is being compared is connected to the post Y, and the remaining two leads are both attached to the post to the right of these two posts. Then the slider is moved until silence is secured in the head phones—it may be necessary to use an audio amplifier between the phones and the bridge if the room is noisy—the value of the unknown resistance or inductance is equal to the standard times the ratio of the two resistances, thus,

$$L_x = L_y \times R/r \text{ and } R_x = R_y \times R/r$$

but if two capacities are being compared, the ratio of the resistances (the lengths of the slide wire on either side of the slider) must be inverted; thus

$$C_x = C_y \, r/R$$

because the larger the capacity the smaller its reactance.

Fig. 2—A double slide-wire tends to eliminate error.

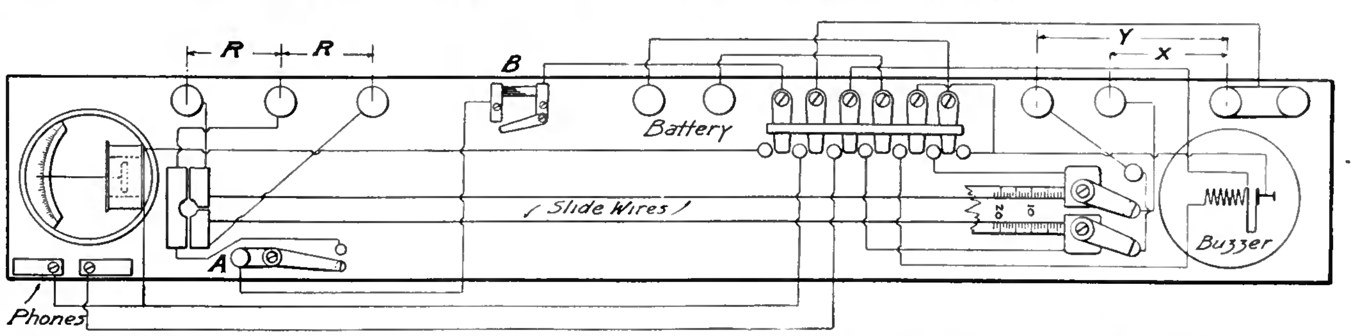


Fig. 3—Diagram of a reversible slide-wire bridge which may be used with either direct or alternating current.

No. 22 *Radio Broadcast's Home-Study Sheets* May 1929

RADIO-FREQUENCY AMPLIFIERS

A RADIO-FREQUENCY amplifier consists of a tube and some means for connecting that tube to an output circuit. In this "Home-Study Sheet" we shall learn how to design a single stage of radio-frequency amplification.

The circuit diagram of such a stage is shown in Fig. 1. Evidently there are several variable factors. We can use a low- or high-mu tube; the number of turns on the secondary, the size of the tuning condenser, the number of primary turns, and the coupling to the secondary are all variable and at the control of the designer.

Tuning Capacity

The size of the tuning condenser and the secondary inductance are related definitely to the frequency band to be covered. The present broadcasting band covers a range of from 200 to 550 meters, or about three to one. If the wavelength varies as the square root of the tuning condenser capacity, what range in capacity must be available to tune from 200 to 550 meters? As shown in "Home Study Sheet" No. 19 the wavelength is proportional to the square root of the product of L and C. That is, 600 meters = $1.884\sqrt{LC_1}$ and 200 meters $=1.884\sqrt{LC_2}$ where the two values of C (in mmfd.) are the capacities required to tune the fixed inductance (in μh) to 200 and 600 meters. Dividing one equation by the other we get $3 = \sqrt{\frac{C_1}{C_2}}$ or $9 = \frac{C_1}{C_2}$ which states that the capacity for 600 meters must be 9 times the capacity for 200 meters.

This is the first design problem. We must be able to use a condenser that has a capacity ratio of at least 9 to 1. If the maximum capacity is 0.00035 mfd., the minimum must not be greater than 0.000039. Because of (a) the input capacity of the tube, (b) the capacity of leads to the coil and to the tube, and (c) the distributed capacity of the coil to which the condenser is attached, all of which are in parallel with the condenser, the minimum capacity of the condenser must be less than this amount by at least 30 mmfd., or it must be as small as 9 or 10 mmfd. If it is larger, or if the distributed capacity of the coil is high, the lower wavelengths cannot be reached.

A large-diameter coil with large wire closely wound will have a large distributed capacity. This is one reason why commercial manufacturers use small coils wound with fine wire carefully spaced. A short single-layer solenoid has a distributed capacity in mmfd. nearly equal to 7 per cent. of its circumference in centimeters. (Breit, *Physical Review*, Aug. 1921.)

Secondary Inductance

The greatest percentage of the amplification factor of a tube will be obtained when the load into which it works is high. The effective resistance of a coil-condenser combination at resonance (see "Home-Study Sheet" No. 12) is equal to

$$R_{eff} = \frac{L^2\omega^2}{r} = \frac{L}{Cr}$$

Where L is the inductance of the coil
ω is 6.28 times the frequency
r is the series high-frequency resistance of the coil.

This shows that the effective resistance, which is the load presented to the tube, increases as the square of the inductance, and so if we can keep the resistance of the coil fairly low, a large inductance is better than a small one.

The selectivity, S, of such a tuned circuit is proportional to Lω/r, and the width of the resonance curve, at a point where the response is 0.707 of the value at exact resonance, is related to this ratio, i.e., $S = \frac{L\omega}{r} = \frac{fr}{f_2 - f_1}$ (see Fig. 2) which is another reason for using as large a coil as possible.

Problem 1. Assume a fixed capacity of 50 mmfd. across which the condenser is to be placed. This includes the minimum capacity of the condenser. Calculate the inductance of the coils to be used to cover the broadcasting band if the maximum capacity of the condenser is 250, 350, and 500 mmfd.

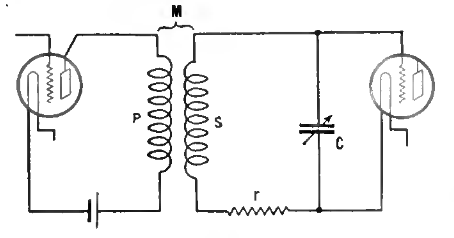


Fig. 1

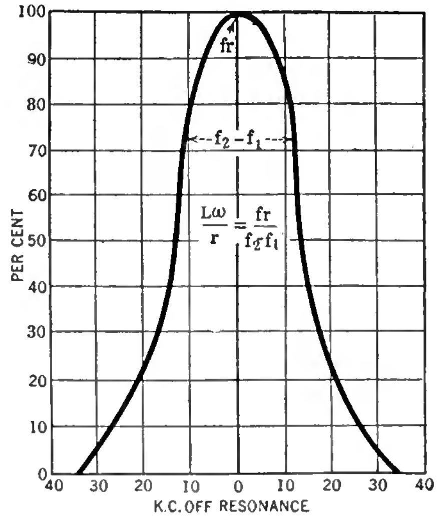


Fig. 2

If they have the same resistance (assume 20 ohms) at 1000 kc., calculate the effective resistance, or the load presented to the tube in each case. Calculate the width of the resonance curve and the selectivity factor, S.

Coupling to Previous Tube

How shall we couple the coil-condenser combination to the previous tube? One way is by means of a transformer. At first let us use an auto-transformer as in Fig. 3. Also, let us for the moment consider a tube with an amplification factor of 8 and a plate resistance of 6000 ohms (a 112-type tube), and connect it across the entire coil. What is the amplification and effect on selectivity?

The voltage amplification of such a tube and coupling device cannot be greater than the mu of the tube, and will be more nearly equal to it the larger the effective resistance of the tuned circuit becomes compared to 6000 ohms. As a matter of fact the voltage amplification will be equal to $G = \frac{\mu \times R_{eff}}{R_{eff} + R_p}$; in this case it will be equal to

$$\frac{8 \times R_{eff}}{R_{eff} + 6000}$$

so that, if the effective resistance of the tuned circuit is 50,000 ohms, the voltage amplification, G, will be about 7.3.

What happens to the selectivity of the tuned circuit? We have placed directly across this circuit, which has an effective resistance of 50,000 ohms, a 6000-ohm resistance. The resistance of these parallel resistances is now equal to (50,000 × 6000) ÷ (50,000 + 6000) ohms or 5860 ohms. Now what resistance added to the series resistance of the tuned circuit would reduce its effective resistance to this low value? Let us put down two equations, assuming the series resistance equal to 20 ohms

$$\frac{L^2\omega^2}{20} = 50{,}000 \quad . \ . \ . \ . \ (1)$$

$$\frac{L^2\omega^2}{20 + R} = 5860 \quad . \ . \ . \ . \ . \ (2)$$

dividing (1) by (2) we get $\frac{20}{20 + R} = \frac{5860}{50{,}000}$

from which R (added resistance) = 150 ohms so the total series resistance is now 170 ohms and the selectivity is $\frac{L\omega}{170}$ where it was equal to $\frac{L\omega}{20}$ for the coil-condenser alone. From this we learn that the selectivity has been reduced 170 ÷ 20 or a factor of 8.5.

Many investigators have experimented with this problem and the solution is to use a two-winding transformer with a primary of such an inductance and so coupled to the secondary that the effective resistance of the tuned circuit is stepped down so that it "looks," to the tube, like a resistance equal to the plate resistance.

What is the result? We can see that, if the tuned circuit is shunted, not by 6000 ohms but by its equivalent, 50,000 ohms, the selectivity has been decreased only by a factor of two, and we get some voltage step-up because of the transformer. Whereas it was possible to get an amplification of only 7.3 without the transformer, it is now possible to get more than the mu of the tube. Where the selectivity was cut down by a factor of 8.5 it is now reduced by a factor of only 2.

What should the turns ratio be? From transformer design theory the proper turns ratio is $N = \sqrt{\frac{R_{eff}}{R_p}} = \sqrt{\frac{50{,}000}{6000}} = 2.9$ for the given conditions. The voltage gain, so far as the tube is concerned is, as before, mu times the ratio between the load resistance (as stepped down by the transformer) and the sum of the load and plate resistances. This voltage gain is stepped up by the turns ratio of the transformer and becomes

$$G = \frac{\mu \times R_{eff}/N^2}{R_{eff}/N^2 + R_p} = \frac{8 \times 6000}{6000 + 6000} = 4 \times 2.9 = 11.6$$

$$= \frac{\mu L\omega}{2\sqrt{r} \times \sqrt{R_p}}$$

Problem 2. Consider a coil of 180 microhenries inductance and a high-frequency resistance of 15 ohms at 1500 kc., 10 ohms at 1000 kc., and 7 ohms at 505 kc., and a 112-type tube. Calculate the proper turns ratio for maximum voltage gain at 1500 kc., 1000 kc., and 550 kc. Assume that the proper ratio for maximum amplification at 550 kc. is employed. Calculate the voltage gain at this frequency, and using the same turns ratio, calculate the voltage gain at other frequencies in the broadcast band. Then, remembering that the resistance across the secondary is the tube plate resistance times the turns ratio squared, calculate the increase in series resistance of the tuned circuit at this frequency and the selectivity factor, Lω/r. Calculate the width of the frequency band at the 0.707 point at 550, 1000, and 1500 kc. Plot all of this data against frequency in kc. Do you see why most tuned r.f. receivers do not have equal amplification at all frequencies? Why the selectivity is poor at high frequencies, the gain low at low frequencies?

Problem 3. Repeat using at 201A tube, a 240 tube, and a 222 tube. The constants are for the 201A, μ = 8, R_p = 12000 ohms; for the 240, μ = 30, R_p = 150,000 ohms, and for the 222 screen-grid tube, μ = 200, R_p = 200000 ohms.

Problem 4. A 600-turn honeycomb coil has an inductance of 20 millihenries. A variable condenser is placed across it, and the circuit is coupled to a 40 kc. circuit. The voltage across the coil is measured as the tuning condenser is varied. Then a pair of steel wire cutters is placed near the coil and another resonance curve is plotted. The results are given below.

In such a circuit the high-frequency resistance can be obtained when the capacity is the variable factor, just as when the frequency is variable. It is only necessary to plot the resonance curve showing response against capacity and to ascertain the two values of capacity which make the response 0.707 of its value at resonance. Then, if C_r and C_2 are these two capacities and C_r is the capacity at resonance,

$$\frac{2\pi fL}{R} = \frac{2\ C_r}{C_2 - C_1} = \frac{L\omega}{r} = \frac{fr}{f_2 - f_1}$$

Plot the results given in the table, and find out the resistance of the coil in the two cases; calculate the width of frequency band passed at the 0.707 response point; calculate the value of the circuit's effective resistance, $L^2\omega^2/r$; calculate the proper turns ratio if this coil is to be tapped and used between a 227-type tube and the grid-filament input of a following tube; calculate the voltage gain at 40 kc. Would such an amplifier be a high-quality unit?

f=40 kc.

C mmfd.	E	E when pliers are near coil
780	0.40	
760	0.68	0.45
750	1.43	0.82
740	2.30	1.26
735	1.53	1.22
720	0.60	0.60

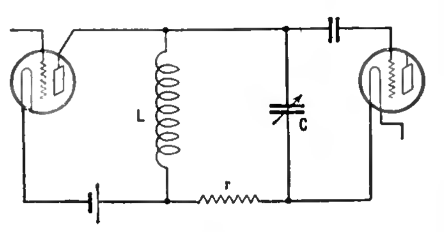


Fig. 3

Vibration Tests on Vacuum Tubes

THE EXPERIMENTER'S ARMCHAIR

By ROBERT S. KRUSE

LAST month we seemed to be giving the transmitter the most consideration. By way of evening up matters, we begin this time with a pure receiving story, having to do with the things that cause trouble in radio sets on airplanes and likewise in the ordinary home broadcast receiver.

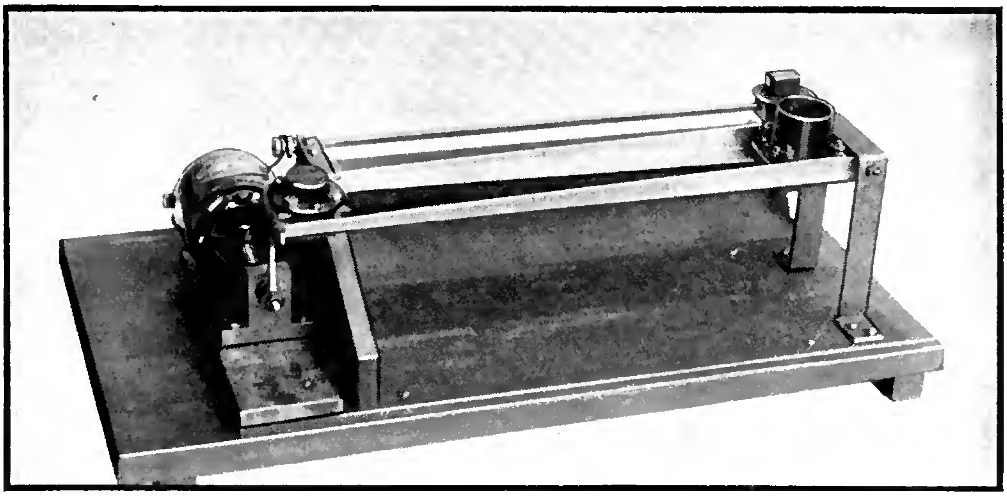
Mr. H. A. Snow, of the Radio Frequency Laboratories, Inc., Boonton, New Jersey, now has the floor.

Vibration tests were made on several vacuum tubes to study microphonic noises produced in amplifiers when one or more of the tubes are jarred, or vibrated, by sound waves set up by loud speakers. These tests were made to determine at what frequencies in the audible range such microphonic noises occur and to determine the source of the noise. At that time (January, 1928) studies were made on only the 201A- and the 222-type tubes.

The method of study was as follows:

The tube was mounted on a specially constructed vibrator unit adapted from a Western Electric loud speaker unit. The mounting of the tube was such that it received vertical and horizontal components of vibratory force produced when the vibrator unit was energized from a variable audio-frequency beat-frequency oscillator and power amplifier. The tube was connected as a detector in a typical two-stage amplifier such as used in broadcast receivers so that sounds produced in the amplifier by mechanical vibrations of the tube could be observed aurally by means of phones in the amplifier output. The tube under test was also observed visually by means of a magnifying lens system to determine just what element was vibrating and causing the sound in the amplifier.

In examining a tube, the audio frequency supplied to the vibrator unit was slowly varied and the tube watched closely to observe element vibrations, and the sound produced by such vibrations observed by means of the head phones. Quantitative measurements of sound produced were not attempted, but the



A motor-driven tube shaker used to produce vibrations of low frequency in testing microphonic vacuum tubes.

A vibrator unit employed in tests to determine the conditions under which vacuum tubes are microphonic.

vibratory periods of various elements were measured accurately. It was found that elements of different tubes of the same type had different natural periods, as might be expected. However, the following series of natural periods of the 201A type tube was found to be representative:

TUBE ELEMENT	VIBRATING DIRECTION	FREQUENCY (cycles)
Plate and supports (as unit)	Lateral	150
Filament and supports (as unit)	"	280
One leg of filament	"	*360
Second leg of filament	"	*370
Plate	—	1700
Grid (*as unit*)	Lateral	330

*At normal filament voltage. These frequencies vary with filament temperature.

At the frequencies shown above, each corresponding element would vibrate with considerable amplitude and produce a corresponding sound in the a.f. amplifier. The greatest amplitudes of vibration occurred laterally (considering tube held vertically).

In addition to the vibrations listed above the individual grid wires each had natural periods which were difficult to observe separately but resulted in a considerable series of resonance vibrations in the neighborhood of 1000-2000 cycles. Also, there were many smaller vibrations of the elements in different modes that could be heard in the amplifier output but could not be observed in the tube with the crude lens system used. It was interesting to note that the natural period of the filament legs varied over a considerable range as the temperature was varied, due, no doubt, to the changing elasticity of the filament.

TESTS WITH 222-TYPE TUBES

Type 222 tubes were also examined, but in this case it was more difficult to attach a resonance frequency to one particular element because the tube structure is such that several elements are attached together at the top more or less rigidly so that at the natural period of any one element the entire system vibrated. There were, as a result of this, a number of combination natural periods, due not only to one element, but to the combination of several.

The most pronounced amplitudes of vibration in the 222-type tube were at 130, 150, 220, and 500 cycles.

The greatest amplitudes in most of the tubes examined were in a lateral direction; that is, with the tube held vertically, vibration of the elements occurred laterally.

The conclusions reached from tests made are that the greater part of microphonic noises set up in tubes occurs from lateral vibrations of the various elements at their natural periods and that in the types of tubes studied, these vibration frequencies range from as low as 150 cycles to about 2000 cycles or higher, there being a large number of natural periods in each tube. Since so many natural periods exist in the audible range, it is a difficult matter when using a sensitive amplifier to prevent sound from a loud speaker being fed back into a tube and vibrate one or more of the elements at its natural period and so set up a howl, without radically changing the structure of a tube, or thoroughly shielding it from external vibrations by using some type of "shock-proof" mounting. The latter method is the only one available for sensitive amplifiers with the present tubes.

In some recent broadcast receivers the effects of microphonic noise have been reduced greatly by eliminating one audio stage and using a high-voltage detector, thus reducing the audio amplification in the set which reduces the sound produced by tube vibration.

It is interesting to hear the actual sounds produced when a tube is vibrated by means of the above unit over the audio range. The effect heard as the frequency is varied is as if the audio oscillator were producing its sound in a large hall made of sheet tin and half filled with tin cans, sheet metal, and other similar materials having a large number of resonant frequencies.

For low-frequency vibrations there was also made a motor-driven tube shaker, which is shown in one of the accompanying pictures. An adjustable eccentric on the motor shaft and moveable sockets permit changes of stroke and the motor speed-control rheostat provides frequency change. The speed could be determined by comparing the pitches of

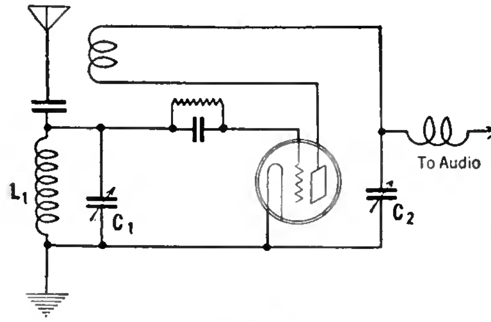


Fig. 1

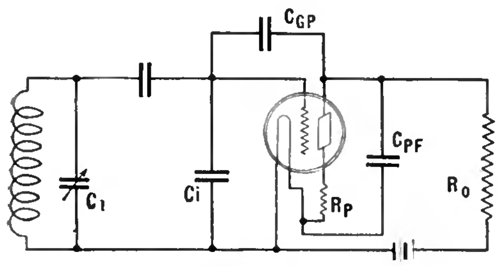


Fig. 2

tuning forks with the audio-frequency output of the tube.

THE USUAL COMMENT

Speaking as interlocutor permits me to say that immediately after seeing Mr. Snow's apparatus I went home and repeated his work in a slightly different manner. One thereby gains new understanding of R. A. Heising's remark that "A vacuum tube is something that hasn't anything in it and out of which you get a lot of things you don't expect."

One of these unexpected things is the tiresome tuning effect of everything about a short-wave receiver that is moveable or changeable. In most tuners, especially for code reception, this is deliberately made worse by using very small tuning capacity in an attempt to spread the scale. Intelligent use of lumped capacity accomplishes the same thing and in addition washes out some disagreeable effects. Concerning a method of doing this we will now hear from Mr. L. W. Hatry, of Hatry and Young, a radio service organization at Hartford, Connecticut.

A Stabilizing Device

Since the war the short-wave amateur has had trouble with the tuning effect of his regeneration control. The effect has received generous attention but to my knowledge no theory of its possible cause has been used as a weapon in overcoming it.

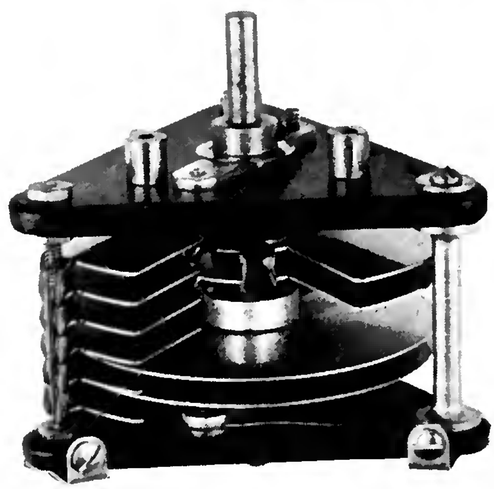
In speculating toward the cause amateurs have suggested inductive and capacitive changes due to moving parts. A marked improvement resulted from making the tickler small and putting it at the low-potential end of the tuned grid circuit. Likewise, improvement resulted from making the coil stationary and controlling regeneration by variation of a "throttle" in the shape of a variable bypass condenser. Thus, the speculations were to a degree confirmed and the effect of the regeneration control reduced until a c.w. beat note did not disappear (above audible pitch) with one degree of movement of the regeneration control but stayed in for ten or more.

The circuit for throttle regeneration control used in the majority of short-wave detectors to-day is shown in Fig. 1. Guesses as to the cause of the tuning effect of C_2 must have died nascent, for few reached print and the oral discussions seemed to equate to zero. One point seemed accepted, that L_1, C_1, being the frequency-determining circuit, must suffer a change in constants when C_2 is varied. But how? Since the tickler is fixed, coupling changes between the coils seem unlikely. With no change in L_1 we are left with the probability of such a change in C_i. Capacity effects between the rotor of C_2 and other parts of the set can be considered but a simple sheathing experiment eliminates that explanation. Thus we are referred back to the tube for the explanation.

The input capacity, C_i, of the tube is in shunt with C_1 and, therefore, is of importance. The simplest formula offering an explanation is:

$$C_i = C_{gf} + C_{gp}\left(\frac{\mu R_o}{R_o + R_p} + 1\right)$$

This means that C_i can be several times as large as C_{gp} if the load resistance, R_o, (See Fig. 2) is several times larger than R_p, the plate resistance of the tube. The simple formula applies only to a pure resistance load but illustrates the point. Usually R_o is replaced by a reactive load of which C_2 is a part, therefore, the load changes with changes in C_2 and we have at hand a plausible explanation of our effect.



The General Radio type 557 band-covering variable condenser.

The increased effect shown by a relatively small increase in C_{gp} lead to other attempts involving the use of a 199-type tube and eventually a 222-type tube as a detector because of low values of grid-plate capacity. The screen-grid tube when correctly wired gives less tuning effect of the regeneration control than any other equally well-designed set-up. However, the 222-type tube has disadvantages on short waves since the large plate-to-screen (and therefore to filament) capacity prevents oscillation, sometimes even at 20 meters. A special screen-grid tube might be devised as a short-wave detector and for the further confusion of the innocent.

A refinement of Fig. 1 outwits the tuning effect. Fig. 3 gives the diagrams. In (A) the minimum capacity of C_1 is made large so that the variations of C_i have little effect on the total capacity. The added capacity can be fixed and attached to the plug-in coil; an old trick that is too little used for band-covering tuners. Likewise it may be built into the tuning condenser as shown in one of the pictures. This condenser has a maximum of 70 mmfd. but the minimum is over one half as great—namely 43 mmfd. In Fig. 3 (B) the input capacitance of the tube is swamped by a condenser on the tube side of the grid condenser and the grid condenser is made as small as 0.000025 mfd. The only other detail to be observed is to keep the grid and plate leads apart.

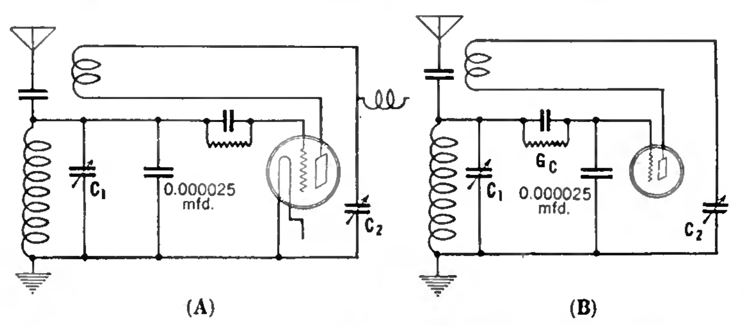


Fig. 3

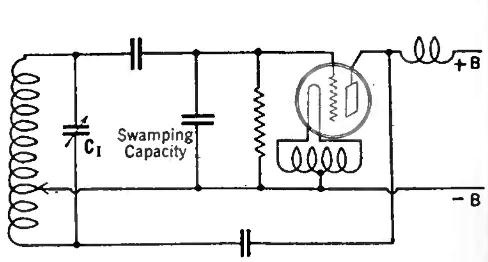


Fig. 4

As a test of this scheme such modifications were made in a commercial kit set with an especially bad tuning effect from the regeneration control. The 0.0002-mfd. grid condenser was replaced by the smallest available (0.00004 mfd.), which in itself made an improvement. The effect of a 0.000025-mfd. (25-mmfd.) swamping condenser was then tried on the tube side and condenser side of the grid condenser. As expected it had about 4 times as good an effect on the tube side and the tuner became a thoroughly workable one.

AS TO TRANSMITTERS

Just as the short-wave oscillating detector suffers from frequency changes not under control of the tuning circuit so does any other oscillator. In the transmitter no frequently varied oscillation control is used: the unit is required to generate a steady frequency and changes cannot be blamed on an altered condenser in the plate circuit. However, changes in frequency can be proved to occur with changes in plate voltage or tube temperature. Changes in plate voltage, E_p, result in changes of plate-to-filament resistance, R_p. In the formula, R_p is important when R_o is small and fixed, both of which are true in a transmitter or test oscillator. Accordingly, variations in E_p vary C_i. Thus, the high-capacity tuned circuits of the present vogue are seen to be good logic as well as good practice.

High-capacity tuned circuits have certain uncomfortable disadvantages, especially at high powers, and beside they should not be the only fruit of the seed of knowledge. Input capacity variations can be swamped out in a transmitter as has just been shown in receivers. For instance, in Fig. 4 we have a transmitting application of Fig. 3. This circuit has demonstrated its ability but neither it nor the so-called "H_i-C" arrangements are of much use if the builder permits parallel or lengthy plate or grid leads to augment the grid-plate capacitance.

I am not insisting that C_i is the entire theoretical flea in the ointment, but practice supports the theory's implications. We have here also an explanation of the popularity and success of the tuned-grid tuned-plate transmitter circuit. The TGTP circuit is different from the Hartley circuit in one large respect, the larger reactive plate load. By formula, if R_o is high enough, variations of R_p are swamped out and C_i variations cannot occur harmfully. Accordingly, the TGTP circuit should be stable without "H_i-C" complications. Don't try to reverse my earlier tricks and apply this to a tuned-plate receiver for there you *vary* your large R_o and acquire critical detuning like that which made the 1920 variometer tuner such quicksilver in the band.

TECHNICAL DATA

SOUND MOTION PICTURES

BY CARL DREHER

Magnitudes in Reproduction

THE principal job of the engineer in any field is to know quantitative relations. The purpose of this article is to discuss the usual light intensities, energy levels, and degree of amplification in sound motion picture reproducing systems. Some of this material has been presented from one viewpoint in the February issue of this department under the heading of "Further Data on Photo-Cell Characteristics." Much of the additional data given below is from the paper by Arthur C. Hardy, "The Optics of Sound Recording Systems," published in Vol. XII, Number 35, of the *Transactions of the Society of Motion Picture Engineers.*

Given a point source of light (one which is relatively small compared to other dimensions in the optical system) the intensity in a given direction depends on the amount of radiation from the source per unit of solid angle in that direction. If the source radiates *L* lumens in the solid angle *w*, the intensity, *I*, is given by

$$I = \frac{L}{w} \qquad (1)$$

When the light from a point source of intensity, *I*, falls on a surface placed at right angles at a distance *d*, the illumination is given by

$$E = \frac{I}{d^2} \qquad (2)$$

The above equations differ in some respects from their analogues in radio transmission, but only because of practical differences resulting from the order of dimensions in the two fields and the technique used in transmission, pick-up, and measurement. The lumen, the unit of light radiation or flux, is analogous to the watt, but it is a narrow unit, applicable only to radiation of a certain kind, i.e., visible radiation, while the watt is a general energy unit. In the region of maximum visibility a lumen corresponds to about 1.5 milliwatts. Light intensity as expressed by (1) above is expressed in terms of energy in a given solid angle, while radio field intensity is expressed as a potential (volts per meter) because of the method of pick-up used, involving an antenna.

The unit of light intensity is the candle, corresponding to one lumen per unit of solid angle. Illumination may then be expressed in foot-candles, meter-candles, or centimeter-candles. The last, as may be noted from a further inspection of (1) and (2), is the same as lumens per square centimeter. The latter is a good practical unit to keep in mind.

If the source of light is too large to be considered as a point, the concept of *brightness* must be introduced. Brightness may be defined as intensity over a given area. It is, therefore, measured in candles per square centimeter. Since one candle is, by definition, a radiation of one lumen per unit solid angle, it follows that a surface of unit brightness, as an incandescent lamp filament, sends out in a given direction one lumen per unit solid angle for each square centimeter of its area.

Professor Hardy, in the paper cited, sums up the photometric units in the following table:

Table of Photometric Units

QUANTITY	UNIT	SYMBOL
Flux	Lumen	F
Intensity	Candle	I
Illumination	Lumen per square centimeter or centimeter candle	E
Brightness	Candle per square centimeter	B

In reproduction from film the track is run at a constant speed past a thin rectangle of light, which shines through the film onto the window of a photo-electric cell. In its simplest form the mechanism may consist of a slit about 0.001 inch in width close up against the film and brightly illuminated. Such a system is shown in Fig. 1. The light rectangle on the film must be narrow compared to the highest frequency it is proposed to reproduce, so that 6000 cycles, for example, with one cycle occupying 0.003 inch on the track, requires an 0.001-inch slit close up against the film (say the same distance) to prevent the light from spreading out between the slit and the film. The area of such a slit is roughly 0.0005 square centimeter (0.001 inch in the direction of travel of the film by 0.1 inch transversely, corresponding to 0.00254 cm. by 0.254 cm.)

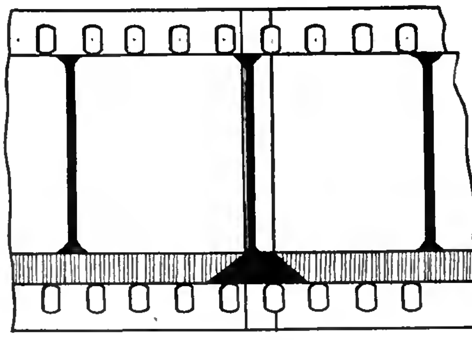
A good commercially available photo-cell may have a sensitivity of 10 microamperes per lumen. (See "Sound Motion Pictures," February, 1929, RADIO BROADCAST, page 244). It is not desirable to operate with a photo-cell output of less than 1.0 microampere, because of noise interference considerations. It follows that we have to get at least 0.1 lumen of light into the cell. This necessitates illuminating a slit with the above dimensions with not less than 200 lumens per square centimeter, which, as the lumen per square centimeter corresponds to the centimeter candle, may be secured from a 200 candle-power lamp at a distance of one centimeter. Because the bulb of the lamp would be in the way if this were attempted, the lens system shown in Fig. 1 is employed. By this means the lamp may be moved away a convenient distance and the light focussed on the slit. It is found that the filament must be operated at a brightness of 1200 candles per square centimeter to meet these conditions. This is about the limit, in practice, at which a reasonable life may be expected.

The close-up slit shown in Fig. 1 is not practicable for actual use in theatres, since an opening 0.001 inch wide up against a rapidly moving film cannot be kept free from foreign matter for any length of time. The optical expedient shown in Fig. 2, which, like Fig. 1, is copied from Hardy's paper, is accordingly adopted. The slit is moved away from its exposed position near the film, sealed within a lens system, made considerably wider and longer (say 0.004 by 0.4 inches), and then optically reduced to a light rectangle 0.001 by 0.1 inches on the film. With proper design of the optical elements the results are equivalent to the close-up slit system.

With the light levels assumed above the photo-cell receives 0.1 lumen and, with the stipulated sensitivity of 10 microamperes per lumen, will yield an output of 1.0 microampere through the anode resistance of 2 megohms, corresponding to an output of 2.0 microwatts. If this is amplified by 70 DB, or 10,000,000 times in energy, the amplifier output in, let us hope, undistorted audio energy, will be 20 watts. This output is, in fact, required to fill the average theatre of about 2000 seats. Assuming that the loud speakers have an efficiency of 20 per cent., we get four watts of sound energy out into the house after all the transformations of the system.

Splicing Sound Films

A VALUABLE article of a practical nature appearing in the January 5 *Movietone Bulletin* concerns the method of making a splice in a sound-movie film. If the splice is not properly treated a lamentably loud thump startles the audience in the theatre, as a result of the electrical impulse sent into the amplifier by the discontinuity in the sound track. Fig. 3, reproduced here from the drawing in the *Movietone Bulletin*, shows how this is obviated. The light is gradually shut off by a triangle painted with black or red lacquer (India ink is sometimes used) onto the sound track. The base of the wedge should be about ⅜ inch long along the line of sprocket holes, while the apex is at the splice on the inner edge of the sound track. If the splice is covered by too short a triangle the change in light intensity will remain abrupt and more or less noise in reproduction will result. If too long a triangle is painted, on the other hand, enough of the track may be obliterated to cause an interruption in the record. Some care is, therefore, necessary. The painting is done on the celluloid side of the film.



(A) Correct splice, quiet

Fig. 3.

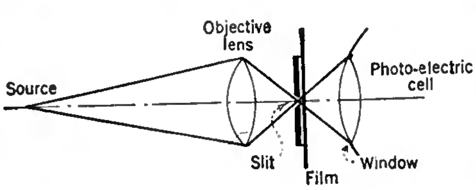


Fig. 1.

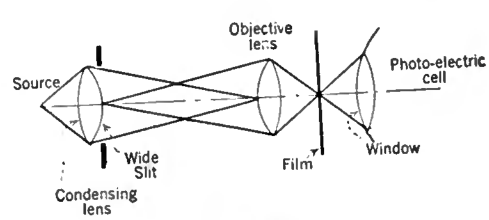


Fig. 2.

NOTES ON A. F. TRANSFORMER DESIGN

By J. KELLY JOHNSON

IT IS the purpose of this paper to present in a simple, practical form the general considerations involved in the design of audio-frequency transfer apparatus. The curves accompanying this article are first hand, except when specified otherwise, are solely for illustrative purposes, and are intended to show comparative rather than absolute values. They have been taken in the radio laboratory at Columbia University with the coöperation of the Engineering Department of the Pacent Electric Company.

In this article are presented considerable valuable data on audio transformers, showing how the conditions under which the transformer is measured affects its characteristics. The frequency characteristic, for example, is shown to vary widely with the load into which the device works, the value of the a.c. measuring voltage, and the d.c. current in the primary. The definite quantitative figures given by Mr. Johnson will be found very useful.

—THE EDITOR.

Measurement of Output Voltages

THE measurement of output voltage of voltage transformers must be done without excessive loading. This eliminates ordinary a.c. instruments. The electrostatic voltmeter might be used but the voltages to be measured are normally too small and the internal capacity of the meter too large. The vacuum-tube voltmeter in some of its many circuit variations is very satisfactory.

Regardless of the accuracy of the measuring voltmeter or its sensitivity, true curves cannot be obtained unless actual operating conditions obtain, or are simulated.

With normal grid bias on an amplifier tube the loading of the transformer by grid conductance is far greater than it would be with a one-tube V.T. voltmeter load. The grid conductance changes sufficiently with a.c. voltage applied to make it quite desirable to specify actual loading conditions, when making the test. The one-tube voltmeter circuit falls down from the very start.

The diagram in Fig. 1 shows a circuit which has been used with most satisfactory results by the writer. To avoid any error in calibration of the voltmeter, a comparison method is used. This permits of a very high degree of accuracy without extreme care in setting the input voltage. An accuracy of 1.0 per cent. is easily obtainable.

In the input circuit, the applied voltage, d.c., and equivalent tube resistance may be adjusted to simulate any type of tube. The current, I, through R_1 is set to give the desired voltage on the primary of the transformer. With the switch down the reading at I_p is noted. Then the switch is flipped up and R adjusted until the same reading is obtained. By rapid flipping of the switch and a low-inertia meter a very accurate setting may be made.

Figs. 3, 4, 6, and 8 show the effect of variation in applied a.c., d.c., load, both resistive and capacitive, and grid bias of the loading tube on the characteristic curve. They supply ample evidence to justify the specification of measurement under actual load conditions.

Fig. 8 was taken with a single-tube voltmeter using the method of comparisons which greatly increases the obtainable accuracy. The high bias used rendered the effect of grid conductance negligible. The improvement in the transformer characteristic with increase of applied voltage is quite pronounced. To make characteristic curves on transformers comparable, therefore, the same a.c. voltage must have been applied to their primaries.

In Fig. 3 is shown the effect produced by d.c. passing through the primary coil. The dotted curves show that a transformer with a heavy silicon-steel core was not much affected, while the curve for the high-permeability alloy core transformer was badly damaged by the d.c. The value of current used was about normal for a d.c.-type tube and considerably less than those encountered with the new a.c. types. The transformers were recommended by their respective manufacturers for use in the same point in the circuit.

Fig. 4 shows the effect of a resistive load placed on the secondary of a transformer. The peak voltage at resonance is cut down appreciably by even a load of very low conductance. The next, Fig. 6, shows the effect of grid conductance in flattening out the transformer curve. Although the grid did not swing positive, the conductance caused sufficient regulation to flatten the curves as shown. It must be noted that the previously mentioned effect of increased voltage applied on the primary raised the low-frequency portions of the 0.5- and 1.0-volt curves and lowered their peaks.

Special Test Apparatus

MEASUREMENTS on power audio-frequency transformers may be made using the same apparatus as described above. Ordinarily, however, the actual loading conditions require the employment of higher voltages than are conveniently measured with this layout.

The fact that these are power-transfer instruments immediately suggests the use of standard alternating current voltmeters, ammeters, and wattmeters. But the power required to operate the average a.c. ammeter is often as high as 5.0 watts, and the voltmeters are but slightly more sensitive. Wattmeters, partaking of the characteristics of both voltmeters and ammeters, consume about twice this power. Thus, it is seen that ordinarily the total output of the transformer under normal loading is insufficient to operate the meter alone. In addition, the inductance of the iron vane, or dynamometer type of meter movement is quite appreciable, and would give very great variation in indicated voltage values with frequency. The ordinary meter is not accurate beyond one-hundred-twenty cycles.

The circuit used in Fig. 5 is probably the simplest and the first to suggest itself. It requires a thermocouple meter and resistor to fix the input voltage, and another to measure the output voltage. This makes necessary a "mark" reading or requires an oscillator of a high degree of stability and high power output.

The V. T. voltmeter comparison method can be used to advantage, a single-tube voltmeter with a direct indicator in the plate being sufficient, as the output voltage of the transformer is high, and the added loading of the measuring device low enough to be neglected. It is possible that an inverted V. T. voltmeter might be evolved which would simplify measurements.

As regards the simulation of loads for power transformers, the curves of Fig. 5 show how a characteristic is altered by the secondary load. At the low frequencies the load reflected from the loud speaker would give a very low-impedance load on the tube, while at high frequencies the opposite is true. A resistive load, on the other hand, will not have unpredictable resonance points as shown on the loud speaker

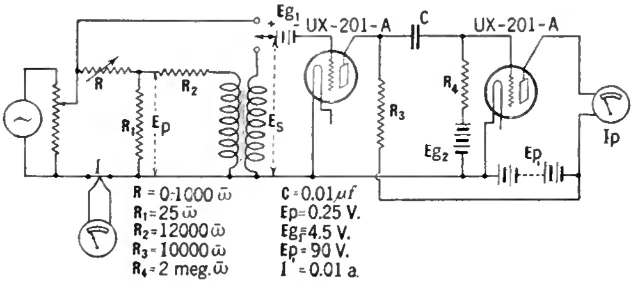


Fig. 1.

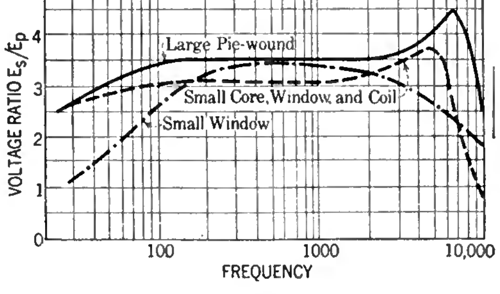


Fig. 2.

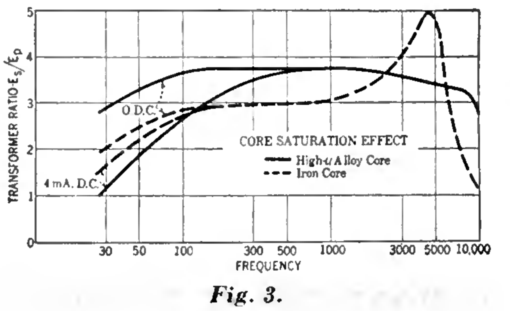


Fig. 3.

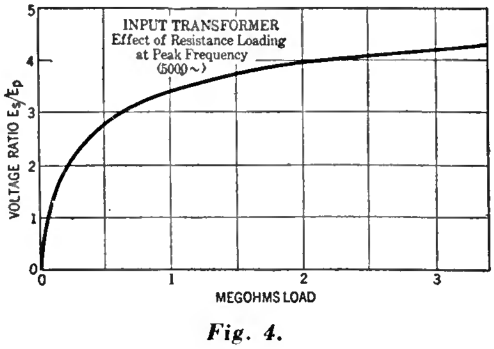


Fig. 4.

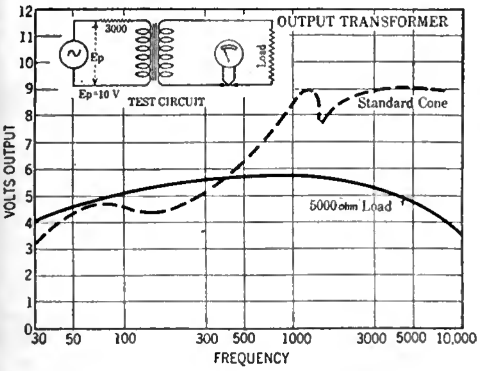


Fig. 5.

curve and will give a fairly constant reflected load. In view of the fact that many types of loud speakers might be used, any of which might well vary with time or change of manufacturing conditions, it is probably best to use a resistive loading, preferably one of twice the a.c. tube resistance, for a one to one transformer. This will facilitate the comparison of various transformers against a standard.

Two Kinds of Distortion

WAVE-SHAPE distortion may be caused either in the tube, or the transformer. A curved tube characteristic or d.c. saturation in the transformer will produce even harmonics of the initial wave, and a.c. saturation in the transformer core will produce odd harmonics. Tubes are usually worked on as straight a portion of their curve as possible, or are connected in push-pull so as to eliminate the effect of the even harmonics. The only remedy for distortion introduced by transformer saturation is to run the transformer core at low flux densities, i.e., at values of d.c. plate current and a.c. signal voltage which will not cause the core to become saturated.

Amplitude distortion may be divided into two classes. In the first, the output voltage of the amplifier is not directly proportional to the input voltage. At low frequencies low voltage inputs will not be amplified as much as higher ones due to the change of inductance of the transformer primary. The second class is that of frequency discrimination. Certain characteristics of the transformer and associated circuit cause it to pass some frequencies with less loss than others.

In Fig. 9 are shown the actual circuit diagram, the equivalent diagram, and the vector diagram of the loaded transformer. The effective alternating current plate impedance of the tube must be added to the effective primary resistance of the transformer. As shown in the vector diagram, the leakage reactance causes a voltage drop in quadrature with the effective resistance in both the primary and secondary which causes voltage regulation. The greater the load, the greater the regulation from these causes. It is therefore desirable to have the effective tube, primary, and secondary resistances as low as possible in order that the voltage output may be proportional to the voltage input.

Fig. 5 shows a curve of output voltage against frequency for a resistive load. With a constant voltage input the curve drops off at both ends. The drop at the high-frequency end is due to the leakage reactance whose effect increases with frequency. The drop at the low end is due to the increasing magnetizing current causing magnetic saturation of the core, and increased IR drop in the primary circuit. The leakage reactance can be neglected where this effect comes in.

The cone loud speaker load curve introduced on the same sheet shows the effect of an impedance load which is low at low frequencies and high at the high ones.

Apparent Losses

FIG. 7 illustrates the effect on the apparent resistance and inductance of the primary circuit of a voltage transformer, of the addition of a secondary circuit. The added losses are very noticeable, the added capacity lowers the resonant frequency, and the loading lowers the effective low-frequency inductance. A coupled circuit effect produces an added

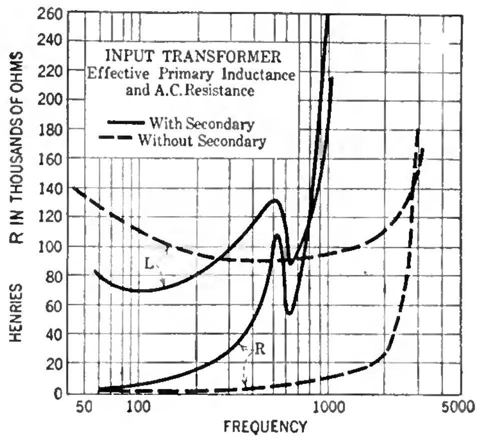


Fig. 7.

jag in the curve about midway, and there is some parallel resonance effect at low frequencies. This curve illustrates the way a voltage transformer load looks to the tube which is feeding it.

Therefore, the actual and equivalent circuits of the voltage transformer must include the distributed capacity of the secondary to enable a correct design to be worked out. In the equivalent circuit the leakage reactance is in series with the effective resistance and the distributed capacity of the secondary and the associated circuit. Of this associated capacity a large portion is formed by the effective tube capacity.

At some frequency the circuit will be in series resonance and will give a high voltage drop across the capacity due to the resonant current. This produces a peak on the characteristic curve of frequency vs. ratio, as was to be noted in several of the figures. If the effective reactance and capacity can be made small enough the peak may be moved out of the normal range of transmitted modulation frequency. If the effective resistance is increased sufficiently the resonant current can be reduced to a value which will not produce a prominent peak.

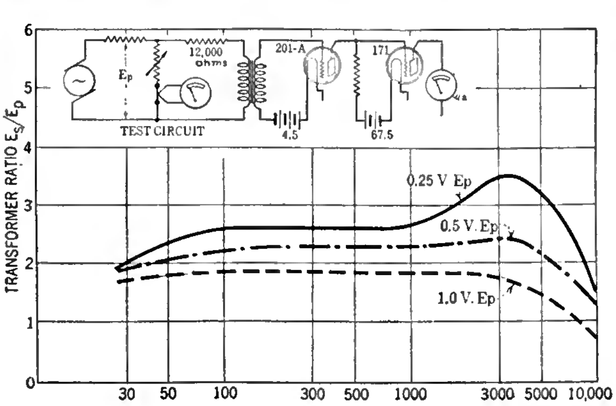


Fig. 6.

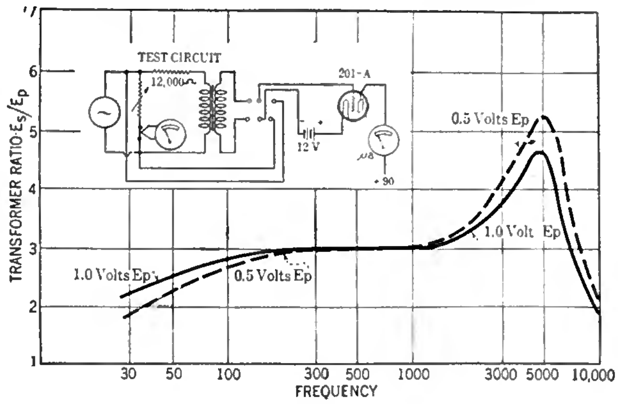


Fig. 8.

In Fig. 2 are shown curves for various improved designs of audio-frequency voltage step-up transformers. By pie winding, sufficiently low distributed capacity and leakage reactance are obtained to put the resonance frequency peak above the normal range of the radio-frequency band-pass of a receiving set.

The curve shown for the transformer with a small window is an example of the tendency toward improvement in transformer design. This had a comparatively small core weight and a high primary inductance, but showed practically no tendency to saturate with normal d. c. applied.

The small type transformer whose curve is shown, is interesting chiefly because of the method of manufacture. It is wound with a high space factor so that the turns in a layer bunch up during winding. This automatically short circuits enough turns to iron out the resonance peak. The cheapness of the core, winding and assembly enables this transformer to compete successfully with a much higher grade product.

A carefully designed voltage transformer with a value of primary inductance to give a 3.0 per cent. drop at 60 cycles with a 10,000-ohm tube, that is, 110 henries, can be made with such a low leakage reactance that it will peak at above 7000 cycles. If the core laminations are so made that the eddy currents are large, they will increase the effective resistance sufficiently to flatten the resonance peak completely. This will not affect the gain over the lower frequencies, however. Such a transformer is fully sufficient for covering the range of frequencies from 30 to 5000 cycles which is considered as perfectly satisfactory for the reproduction of voice or music.

In conclusion, the writer wishes to express his appreciation of the assistance in compiling this data rendered by the Engineering Department of the Pacent Electric Company.

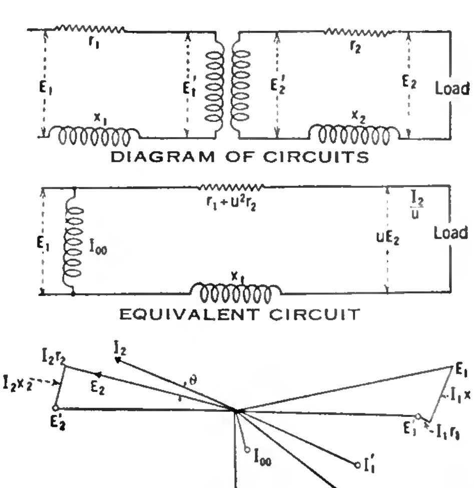


Fig. 9.

BROADCAST ENGINEERING

BY CARL DREHER

Power and Current in Modulation

Although the theory of modulation of a radio-frequency wave by a tone was quite completely worked out by R. A. Heising in 1920, it still remains obscure to many broadcast operating engineers. The references, for those who want to go into the problem thoroughly, are Heising, "Modulation in Radio Telephony," *Proc.* I. R. E., Vol. 9, No. 4, August, 1921; and Kellogg: "Design of Non-Distorting Power Amplifiers," *Journal*, A. I. E. E., May, 1925. Edward L. Nelson, has some less technical discussion on the subject in the December, 1928, I. R. E. *Proceedings* (Page 1776).

Modulation in radio telephony consists in varying the amplitude of a sustained radio-frequency current in accordance with the signal which it is desired to transmit. Mathematically the combination of radio- and audio-frequency currents is represented by the equation

$$i = A \sin \omega t \, (1 + K \sin \psi t) \qquad (1)$$

In this equation both waves vary according to a sine law, A is the average sustained amplitude when no signal is impressed on the carrier, ω and ψ are the angular velocities (2π times the frequency) of the carrier and the modulation tone, respectively. Since the expression shows the variation of current with time, t occurs twice. K is the modulation constant; it is a measure of the extent or "depth" of modulation. Its maximum value is unity, corresponding to complete modulation. When the carrier is unmodulated K equals zero, whereupon (1) becomes,

$$i = A \sin \omega t \qquad (2)$$

which is the usual expression for a sine wave alternating current.

The power corresponding to (1), in a circuit of resistance R, is

$$i^2R = RA^2 \sin^2 \omega t \, (1 + K \sin \psi t)^2 \qquad (3)$$

Integration gives a value for the power

$$p = \frac{RA^2}{2} (1 + 2K \sin \psi t)^2 \qquad (4)$$

$$= \frac{RA^2}{2} \left(1 + 2K \sin \psi t + \frac{K^2}{2} - \frac{K^2}{2} \operatorname{Cos} 2\psi t\right)$$

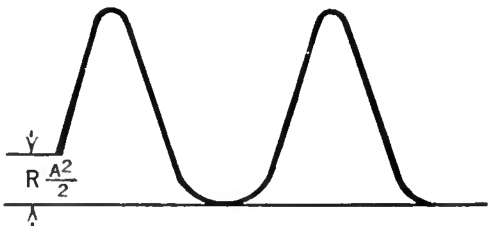
When the carrier is blank ($K = O$) the power is seen to be $RA^2/2$. When modulation takes place single- and double-frequency audio components ($\sin\psi t$ and $\cos 2\psi t$) are present. If the carrier is completely modulated integration over an audio- or signal-frequency cycle gives

$$P = \frac{3}{2} \times \frac{RA^2}{2} \qquad (5)$$

Comparing this result with the power $RA^2/2$ for no modulation, we note that the power of a completely modulated wave is $\frac{3}{2}$ that of an unmodulated wave of the same average current. The effective radio-frequency power rises to a peak value 4 times the non-signalling power level, as shown in Fig. 1.

This mathematical description supplies an answer to the question frequently asked by broadcast operators—whether the antenna ammeter reading should change when the wave is modulated. The answer is that the reading will increase with modulation, since the power in the antenna is actually greater when modulation is in progress than when the carrier is blank. If the modulation is 100 per cent., the power increase is given by the factor 1.5, but as the antenna ammeter reads the effective value of the current, and not the power, the reading will increase by the multiplier $\sqrt{1.5}$, or 1.226. A radio-frequency ammeter in the antenna of a fully modulated radio-telephone transmitter will therefore swing at syllable frequency to a reading about 20 per cent. higher than the unmodulated reading.

The received signal depends, in general, on the variation in the amplitude of the transmitted wave. Under the two conditions of K = 1 and K = 0.5 the antenna ammeter reading will be the same when there is no modulation, and almost the same even when modulation is impressed at these two levels, there being a little more swing, merely, under the complete modulation condition. But, even though the transmitting antenna current readings are practically identical, the received signal energy corresponding to K = 1 will give four times the received signal energy of K = 0.5



EFFECTIVE POWER IN ANTENNA-
COMPLETE MODULATION

Fig. 1.

Or, putting it another way, doubling the percentage modulation of a transmitter is equivalent, in improving reception, to holding the modulation constant and multiplying the carrier power by four. These results follow from the fact that the received radio-frequency current is directly proportional to the transmitting current at each instant.

In modern broadcasting, however, this must be accomplished without distortion. The early broadcast transmitters were defective in this respect. A high-quality transmitter, by 1924 standards, rated at 500 watts output, usually consisted of two oscillators and two modulators, each rated at 250 watts—as an oscillator. That was the nigger in the wood-pile. The two oscillators drew about 400 milliamperes plate current at 2000 volts, or 800 watts, putting somewhat less than 500 watts into the antenna. The two modulators, running on the same plate source, drew something like 80 milliamperes when the microphone was inactive. Under this condition they were getting only 160 watts, or one-fifth as much plate power as the modulators.

The design engineers, and some of the operating engineers as well, became cognizant of the defect outlined above quite early in the game, and as soon as the transmitter investments could be amortized—and some of them were amortized with horrifying haste from the economic standpoint—they took a step in advance. This consisted of increasing the number of modulators, in proportion to the oscillators, and running the two banks so that equal plate power was fed to each set.

The ideal design would appear to be one in which modulation can be carried to 100 per cent. without distortion, the peaks being allowed to hit this level. Actually, high modulation runs into a quality defect of another sort in that a second harmonic becomes prominent after detection and may be annoying with a combination of a good receiver and a critical ear. Also, some margin must be kept in order to prevent over-modulation and kicking off of the transmitter. In practice, the broadcasters work up to the distortion point and drop back four or six DB for a peak operating level. This also provides protection against over-modulation. If, therefore, the transmitter does not distort until the full modulation stage is reached, it will be run at not over 80–85 per cent. peaks in any case, and this also limits second-harmonic distortion to a permissible level, in view of the evils of low modulation operation, such as low service area in proportion to heterodyning potentialities, noise amplification by the carrier, etc. Thus, the best solution appears to be a transmitter which retains quality up to full modulation, and is run with peaks 15 or 20 per cent. lower.

The difficulty in producing such a design economically lies in the low efficiency of "proper", non-distorting power amplifiers. The output stage of a high-quality audio amplifier chain used in public address or sound motion picture work may take about 50 watts plate power. In that case the undistorted audio power output is not likely to be over 10 watts—a practical efficiency of 20 per cent. In the usual Heising scheme of modulation, where both the audio- and radio-frequency plates are fed through a common choke and the plate voltage for both banks is the same, complete undistorted modulation is impossible, since the modulator would have to produce an undistorted alternating voltage equal to the direct voltage supplied to it. Complete modulation is secured when this a.c. peak, added to and subtracted from the direct voltage from the rectifier or generator, swings the r.f. plates from double the latter voltage to zero, at the signal frequency. The only way of getting such a swing without distortion is to run the modulator at a higher voltage than the r.f. tube which it controls. This method is used in modern practice as a more or less fundamental element in design. As the efficiency of the modulator, working as a distortionless audio amplifier, is likely to be only of the order of one-fourth that of a good oscillator, a formidable assemblage of tubes must be provided if modulation is to take place in the power stages, as in the output of the transmitter. This may be obviated by modulating at low power; for example, a 50-watt radio-frequency amplifier along the line may be modulated by a 250-watt (oscillator rating) modulator run at a higher plate voltage. The saving, however, is not all that appears at first glance. The modulated radio wave, it must be again recalled, contains additional power to the extent, for complete modulation, of peaks four times the non-signalling power, and an average value $\frac{3}{2}$ the non-signalling value. The modulated radio-frequency stages following the low or intermediate power modulation stage must be designed with sufficient power to handle these increments. The design problem reduces, in effect, to the question of whether it is best to build a large audio amplifier or a large radio amplifier.

Part III—Practical Aspects

GETTING THE MOST OUT OF A DETECTOR

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This final article in a series of three on detection summarizes the advantages of the grid leak-condenser type of power detector. Inasmuch as none of the receivers now using power detection employ this type of detector, the Editors hope that the proponents of C-bias detection will step forward and present their side of the discussion. The other articles in this series concerned themselves with weak-signal detection by the grid leak-condenser detector and power detection.

—THE EDITOR.

THIS article is devoted to a discussion of the practical aspects of detection which come up in connection with broadcast receivers, in contrast with the first two articles, which went into the theory of detection. Problems which the set designer must answer are: Should plate or grid detection be used? Is a power detector advisable? How should the detector be adjusted for best results? How much audio-frequency output will the detector give? It is to questions of this type that an answer will be attempted.

Detection and Rectification

IN STARTING off it will be well to devote a little time to considering what detection is, and why it is necessary. A typical radio-frequency signal is shown in Fig. 1A, in which the amplitude of the signal varies in accordance with the sound that is being transmitted. A radio-frequency wave of this character will not produce any effect on a telephone receiver because, in the first place, the receiver will not respond to such a high frequency, and second, even if the telephone receiver diaphragm could vibrate at the signal radio frequency, the vibrations would be too high pitched for the ear to hear.

Since the amplitude of the signal varies in accordance with the sound being transmitted, what is desired is a current through the telephone receiver that is proportional to the amplitude of the radio signal. Such a telephone current can be obtained by rectifying the radio frequency, as shown in Fig. 1B, in which the negative half cycles of the signal current have been suppressed. The rectified current of Fig. 1B has the average value indicated by the dotted line. This average current is seen to vary in proportion to the strength of the signal, so in passing through the phones or loud speaker it will produce a response that is the same as the original sound being transmitted. If the signal is not rectified, the average value is zero, and there is no response in the loud speaker. *Detection is the name that has been given to the process of rectifying radio-frequency signals in order that the received energy may be converted to a suitable form for operating audio-frequency reproducers.*

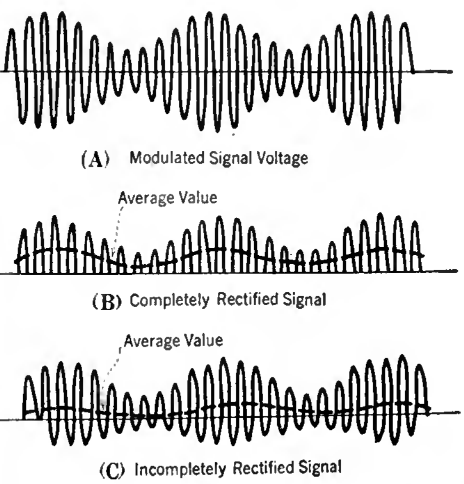


Fig. 1—These graphs illustrate the difference between completely and incompletely rectified signals.

The rectification (i.e., detection) shown in Fig. 1B is complete, which is to say that the negative half cycles are completely eliminated. It is possible for the rectification to be partial, as shown in Fig. 1c, in which the negative half cycles are present, but are smaller than the positive loops. The average value in Fig. 1c is indicated by the dotted lines, and is seen to be smaller because of incomplete rectification.

Grid Detection

IN GRID detection the radio-frequency signal is rectified in the grid circuit. The relation between the grid current and grid voltage of a typical vacuum tube is shown in Fig. 2. When adjusted to the point "O," the grid circuit will act as a very good rectifier, because when a radio-frequency signal is applied and the grid voltage alternately becomes more positive and more negative than "O," there will be considerable current flowing when the grid is on the positive half cycle, while on the negative half cycle there will be only a small grid current, or perhaps none at all. If the radio-frequency signal is a few volts in amplitude the grid current will be substantially as given in Fig. 1B, indicating complete rectification, while if the signal is less than a few tenths of a volt the grid current will be as shown in Fig. 1c, because the rectification is then incomplete.

The grid detector utilizes the rectified grid current to affect the plate current of the tube. Referring to Fig. 2, the rectified grid current must flow through the grid-leak grid-condenser combination. The rapid radio-frequency variations of this rectified grid current that are superimposed on the average get through the grid condenser very easily, but the average of the rectified grid current has great difficulty in getting through the leak-condenser combination, and accordingly produces an appreciable voltage drop across it. This voltage drop exists between the grid and filament; it is thus applied to the grid and is amplified in the plate circuit by the tube acting as an audio-frequency amplifier.

Plate Detection

IN PLATE, or C-battery, detectors the rectification takes place in the plate circuit of the vacuum tube. The relation that exists between grid voltage and plate current in a vacuum tube is given in Fig. 3. Rectification is possible if the grid and plate voltages are adjusted so as to put the operating point within the shaded region. Take the operating point "O," for example, and consider the result of applying a radio-frequency signal to the grid. On the positive half cycles the plate current will be considerable, while on negative half cycles the plate current stays zero most of the time. If the signal is large the rectification is substantially complete, while if the signal is only moderate in strength the rectification will be only partial. In either case, the rectified plate current that is produced flows through the phones, or whatever audio apparatus is present in the plate circuit of the detector, and the effect desired is produced by the average rectified plate current.

The important practical question is not how plate and grid detection take place, but which is best. In this regard grid rectification starts off with the initial advantage in that it rectifies the signal in the grid circuit but obtains the power output in the plate circuit. In this way the grid rectifier can be adjusted to give the most complete rectification possible in the grid circuit without regard to the amount of rectified grid power available, and can then obtain a large output power by suitably adjusting the plate circuit.

In the plate rectifier, on the other hand, the power output is obtained directly from the rectified plate current, and as a result it is not possible to obtain simultaneously complete rectification and high power output. The operating conditions giving most complete rectification are those in which the plate current is low, giving a plate resistance from five to twenty times the value under usual conditions.

The writer has made approximately 1000 measurements of grid detection constants and about 500 measurements of plate detection constants, and *not a single case was found where a tube properly adjusted for grid-leak detection would not put out at least four times as much audio-frequency voltage with weak signals than would the same tube operating under optimum conditions as a plate detector.* In most cases the grid detector will put out ten to twenty times as much audio-frequency voltage as the plate detector when both have the same signal voltage applied. From the point of view of sensitivity to weak signals it is obvious that plate detection has no justifica-

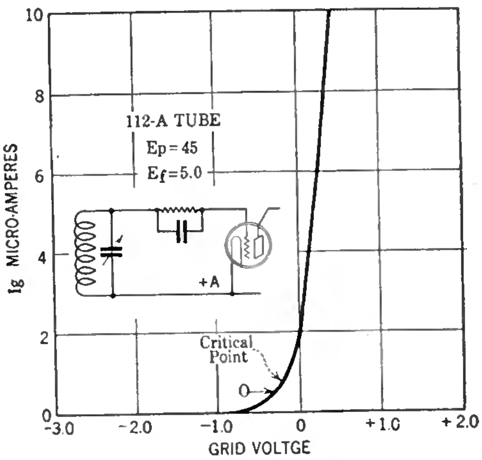


Fig. 2—Relation between grid voltage and grid current.

tion. From the point of view of quality there is no difference, as with small signals both types have a square-law characteristic (i.e. an audio-frequency output voltage proportional to the square of the signal voltage.)

The lack of ability to operate satisfactorily with large signal voltages usually attributed to the grid leak detector *is due to improper use of this method of detection, and not to any defect in the method itself.* In fact, in every case which the writer has examined, power grid-leak detection properly used was found to be from two to five times as sensitive as plate detection with the same tube. That is to say, the grid-leak power detector will give the same output voltage as the plate detector when the signal voltage is only 20 to 50 per cent. as great. Not only is the grid rectifier more sensitive, but it can also put out from two to four times as much undistorted audio-frequency power as the plate rectifier, when both are operating at the same plate voltage. In addition to this, the grid-leak power detector, *when properly adjusted,* will give *less distortion* than the plate power detector.

Fig. 4 gives the rectified plate current of a 210-type tube when operated as a power grid-leak detector and as a power plate detector with 247 volts on the plate in both cases. It is apparent that grid rectification is superior in sensitivity (because it gives more rectified current with the same signal), in power capacity (because it can give more rectified current), and in distortion (because its characteristic is closer to a straight line).

The answer to the question "Plate or grid detection?" is clear in the light of the points that have been considered. Grid-leak detection is superior to plate detection in respect to sensitivity, power capacity, and distortion, and should be used for both weak and strong signals. In view of its all-around inferiority, plate detection need not be given further consideration.

The usual receiver when not using power detection has one stage of audio-frequency amplification between detector and power tube. This stage generally gives a voltage amplification of about twenty-five times. If this tube is removed, and the detector made to supply directly the input to the power tube, an increase in the radio-frequency amplification of fifteen times will about make up for the loss in the audio end. Again, if the power tube is removed and the detector itself is made to supply the power, it will be necessary to increase the r.f. amplification an additional fifteen times, or to a total increment of 200–300 times, in order to keep the volume from the loud speaker the same.

The advantages in putting all possible amplification in the radio end are that the power detector has a straight-line characteristic, and that with each added radio stage one gains additional selectivity that in many cases is badly needed. On the other hand, audio-frequency amplification, while giving no selectivity, also requires no tuning adjustments, needs no shielding, and is relatively stable.

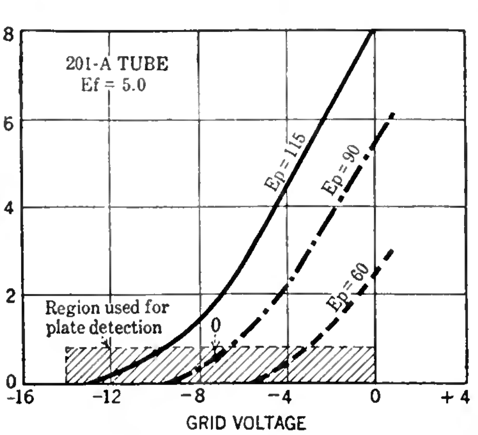


Fig. 3—Relation between grid voltage and plate current in a typical vacuum tube.

In the final analysis the decision as to whether or not to use power detection is determined by how easy it will be to get the extra radio-frequency amplification. If this can be obtained by making the tuning coils a little more efficient and using a little higher plate voltage, as will frequently be the case, then power detection should unquestionably be used. This is also the case when the r.f. amplifier is sufficiently stable to allow an added stage without introducing oscillation troubles, or when the amplifier already has more amplification than is necessary with the usual amount of audio-frequency amplification. A power detector is particularly desirable in the case of screen-grid tubes, where the stable amplification is so great that it is easy to get sufficient voltage to operate the power detector, and at the same time it is necessary to use at least three stages to obtain satisfactory selectivity, even though two stages often give all the amplification required for the weak-signal detector.

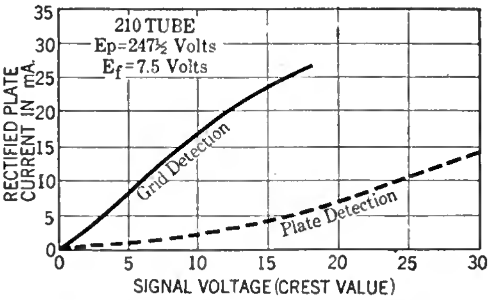


Fig. 4—Rectified d.c. plate current produced by an unmodulated signal applied to the grid of a 210-type tube acting as a plate and as a grid power detector.

Detection of Weak Signals

When the signals to be rectified are weak, which means about 0.1 volt or less, the detector sensitivity and quality are the factors to be considered in adjusting the circuit. The things that have a bearing on these matters are type of tube, grid-leak resistance, grid-condenser size, and plate voltage.

With small signals the rectification will only be partially complete, and will depend upon the operating point on the grid-current curve.

With all types of tubes the rectification is best at small grid currents, but the completeness of rectification is the same for all grid currents below a certain critical value. Adjustment of the detector so as to operate at grid currents greater than this critical value results in loss of sensitiveness. The dividing point is indicated on Fig. 2.

The actual point on the grid-current characteristic used for detection is determined by the grid-leak resistance, as explained in an earlier article. The greater the leak resistance, the smaller will be the grid current at the operating point. Thus, a low-resistance leak causes operation with large currents, and results in poor rectification. On the other hand, all leaks having a resistance sufficient to place the operating point below the critical value of grid current will give the same completeness of rectification of the small signal no matter how small the current is and this degree of rectification will be the maximum obtainable with that particular tube.

Values of grid-leak resistance that will put the operating point at the critical grid current have been determined for various standard tube types, and are tabulated in the fourth column of Table I. Resistances lower than those tabulated give poor sensitivity (i.e., poor rectification), while values much higher than those indicated will tend to cause distortion.

The grid-leak type of detector will reproduce the low notes better than the high ones unless properly adjusted. The loss in sensitivity on the higher notes is due to the fact that when the average value of rectified grid current (see Fig. 1B) is varying at a high audio frequency, this average current will be more or less short-circuited by the grid condenser, and so will not produce much audio-frequency voltage across the leak-condenser combination. The reproduction of the higher notes is improved by using the smallest possible grid condenser, and by operating with the lowest possible grid-leak resistance (in order to put the operating point where the grid current is high and the grid resistance correspondingly low).

The best value of grid-leak resistance to use is approximately that tabulated in Table 1, which is correct to give maximum sensitivity and a minimum of distortion. If the leak resistance is as given in the table, and the grid condenser capacity is that in the last column of Table I, then the detector will have the greatest sensitivity possible with that tube, and at the same time will reproduce 5000-cycle notes 70 per cent. as well as the lower pitches.

The detector characteristics with different leak and condenser sizes are shown in Fig. 6. The effect of using large grid condensers, or large grid leaks is shown and it is evident that such changes increase the distortion. It must be remembered that grid condensers much smaller than 0.0002 mfd. use up signal voltage and reduce sensitivity.

Slightly improved quality with lower leak resistance is gained at a very great loss in sensitivity, while the effect of too high a leak resistance is the same as a big grid condenser, namely, poor reproduction of the high notes.

In general, whenever the grid-leak resistance recommended in Table I is exceeded, the grid condenser capacity should be correspondingly less than the tabulated figure if the high notes are to be preserved. On the other hand, if the grid capacity used is smaller than that given in the table the grid-leak resistance can be proportionately higher without loss of quality or sensitivity.

The completeness of rectification obtainable with a grid-leak detector when small signals are applied is inversely proportional to a tube constant called the "grid-voltage constant," values of which are given in Table I. The audio frequency that is applied across the grid and filament of a grid detector by the rectification process is inversely proportional to the "grid-voltage constant." Thus, reference to Table I shows that a 227 heater-type tube will have 47/23 as much audio voltage on the grid as a 201A-type tube for the same signal. The best rectifiers are tubes with oxide-coated filaments having high electron emission. The 112A tube is about twice as good a rectifier as the 201A tube, and so is preferable for detector use in storage-battery sets.

The mu of the detector tube, and the plate voltage, determine the amount of amplification given the audio-frequency voltage produced on the grid, and have no effect on the rectification itself. With transformer coupling, a moderate-mu tube and a rather high plate potential (45 to 90 volts) are best, while with resistance coupling it is desirable to use a high-mu detector, and the highest possible plate voltage. With impedance coupling it is best to use a high-mu detector with a moderate plate voltage.

When the detector is adjusted according to the recommendations of Table I, it is a simple matter to compute the approximate detector performance. The effect of applying to the detector grid a radio signal having the carrier wave peak value of E_s and modulated to a degree m, is to produce a modulation-frequency voltage between detector grid and filament very nearly equal to mE_s^2/V_g audio volts, where V_g is the detector grid-voltage constant, and is given in Table I. This rule holds almost exactly for the lower frequencies of modulation, while for the high notes the output will be a little less. This audio frequency applied to the detector grid by the grid rectification of the modulated signal is then amplified by the mu of the tube and impressed upon the a.f. amplifier in series with the plate resistance of the tube.

Power Detection

WHEN a radio-frequency signal of at least several volts amplitude is applied to a suitably adjusted grid-leak detector the action taking place in the grid circuit with the signal voltage of Fig. 1A is as shown in Fig. 5. The rectified grid current charges the grid condenser negatively and causes the average grid potential to have the value shown by the dotted line in Fig. 5. This average value is always such that the positive crests of the signal make the grid go positive a small amount. Each time the grid goes positive grid current flows, and makes up for the current that leaks off through the grid leak during each cycle.

At times when the signal amplitude is decreasing in size, it is necessary that the grid leak allow the grid condenser charge to leak off at a rate that will cause the average grid potential to reduce at least as fast as the signal amplitude is changing. This requirement calls for values of grid condenser capacity and leak resistance smaller than usually used.

The explanation of the action that takes place in the grid-leak power detector is exactly the explanation usually given of grid-leak detection, i.e., charging the grid condenser and letting the charge leak off through the grid leak. In the detection of weak signals, the situation is somewhat different, because with weak signals the grid condenser charge can leak off through the detector grid filament resistance, thus complicating and changing the action. With large signal voltages the average grid potential is so very negative that the grid current flows only at the positive crests of the radio frequency, and during the rest of the time no grid current can flow.

If high-quality output is to be obtained from the grid-leak power detector it is necessary to have the proper grid leak and condenser combination. Suitable values for any tube are a grid leak of about ¼ megohm and a 0.0001-mfd. grid condenser. With these proportions the average grid potential will be able to change as fast as the signal amplitude up to modulation frequencies of 5000 cycles.

The overloading point of the grid-leak power detector is reached when plate rectification starts to take place. This is because plate rectification causes increase of plate current while grid rectification causes decrease of plate current. Plate rectification thus neutralizes the grid action and causes distortion.

As the maximum amplitude of a fully modulated wave is twice the carrier amplitude, a particular tube will handle half as big a carrier wave acting as a power detector as it can amplify, using the same plate voltage in both cases. Thus, a 201A-type tube with 90 volts on the plate usually uses a 4½-volt C bias. The crest amplitude of carrier wave that can be handled at a plate voltage is one half of this, or about 2¼ crest volts. In the case of the 210 tube of Fig. 4, the normal amplifier C bias for 247½ plate voltage is 18 volts, so that the crest amplitude of carrier that can be handled is 9 volts. Fig. 4 shows distortion beginning at 18 volts, or approximately the maximum signal amplitude when the 9 volt carrier is modulated 100 per cent.

The maximum audio-frequency power output obtainable from the grid-leak power detector is slightly over one fourth of the undistorted power the tube can give as an amplifier at the same plate voltage and a suitable grid bias. Thus, the 210-type tube at 247½ plate volts will put out 340 undistorted milliwatts as an amplifier, and will put out about 100 undistorted audio milliwatts as a power detector.

The approximate audio-frequency output of a grid-leak power detector can be obtained by a simple computation. It is apparent from Fig. 5 that the average grid voltage of the power detector follows the modulation of the signal. This variation in average grid

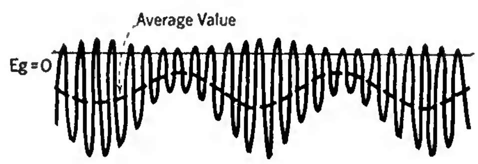


Fig. 5—Curve showing instantaneous and average grid voltages while a modulated signal voltage is applied to a grid-leak power detector.

potential applies an audio-frequency voltage to the grid of the detector tube, and it is this audio-frequency grid voltage when amplified by the tube acting as an amplifier that constitutes the audio-frequency output of the detector.

In the ideal detector the audio-frequency voltage applied to the grid would be equal to the modulation voltage in the signal. If the degree of modulation is m, and the carrier amplitude is E_s, the ideal amount of modulation voltage is mE_s. The actual power detector is only about 75 to 85 per cent. perfect, and will apply to the grid an audio-frequency voltage about 75 to 85 per cent. of mE_s. The percentage tends to rise slightly as the signal amplitude becomes large, but is surprisingly near constant at this approximate range for all tubes under ordinary conditions.

Tubes for Power Detection

IN ORDER to put out power the detector tube must operate with a high plate voltage. At the same time, the grid bias of the grid power detector is approximately zero except when the signal is coming in, and so the allowable plate current sets a limit to the plate potential. Tubes such as the 201A, 112A, 227, and 226 can operate as power detectors with 90 to 135 volts on the plate, and under such conditions will put an audio-frequency voltage of at least two volts on the detector grid without distortion. The 210-type tube can safely operate at zero grid with 250 to 300 plate volts, and will put out from 100 to 150 undistorted milliwatts in the plate circuit, enough to run an efficient loud speaker directly without an audio amplifier.

If the grid return lead of the power detector is brought back to the proper potential the same adjustment that is satisfactory for large signals will give from 50 to 75 per cent. as much output with weak signals as the best adjustment for small signals, and will give this result with excellent quality. The potential for the grid return lead to accomplish this is best determined by experiment. In some cases it will be the positive leg of the filament, in other cases the negative side, while more often it will be a potential intermediate between these. If the detector is to be used only for strong signals the return can be to either side of the filament, with the negative likely to be the best by a small margin.

When the signal voltage has a value between one quarter and one volt it can hardly be classed either as a strong or a weak signal. Such signals will be detected satisfactorily with either a weak-signal or power detector, the latter giving slightly better quality and slightly less sensitivity than the former. The amount of audio-frequency voltage obtainable on the grid with these moderate signal strengths is usually from 20 to 50 per cent. of the ideal value, that is, 20 to 50 per cent. of mE_s.

Receiver Design

IT IS possible, by computing detector performance, to determine just how much radio- and audio-frequency amplification is necessary in a radio receiver to give full output with a given field strength of signal. In order to show how this is done, and to make clear how detector computations are made and used, three typical examples have been worked out.

Case 1: It is planned to use one audio-frequency amplifier feeding a 171A-type power tube with a plate voltage of 135 and a grid bias of —27 volts. A 227-type tube is used as a detector, and it is assumed that the detector and the audio-frequency amplifier each give an amplification of 25 times. How much radio-frequency amplification is required to give full power output from a signal field strength of 1 microvolt per meter (which is about the minimum useful signal)?

The maximum audio-frequency voltage that can be applied to the power tube has a crest value of 27, and this is obtained when $27/(25 \times 25) = 0.043$ volts is applied to the detector grid by the detection process. The detector obviously must be a weak-signal detector, and this 0.043 audio volts is the output when the signal is fully modulated ($m=1$). Calling E_s the crest value of the radio signal that produces the required output of 0.043 volts, and noting that Table I shows $V_g = -0.23$, then when $m=1$, a formula already given shows that $\frac{1 \times E_s^2}{0.23} = 0.043$ and solving for E_s shows the required radio signal on the detector grid to be $E_s = 0.10$ crest volts, which, when fully modulated and applied to the detector grid, will put the maximum allowable audio input on the grid of the 171A-type power tube.

If the receiving antenna is 10 meters (about 33 feet) high, a signal field strength of 1 microvolt per meter (crest value) will induce 10 microvolts in the antenna. If a tuned input to the grid of the first r.f. amplifier is used this will be stepped up perhaps 15 times, applying a voltage of 150 microvolts to the first r.f. grid. To bring this up to the 0.1 volts (or 100,000 microvolts) required

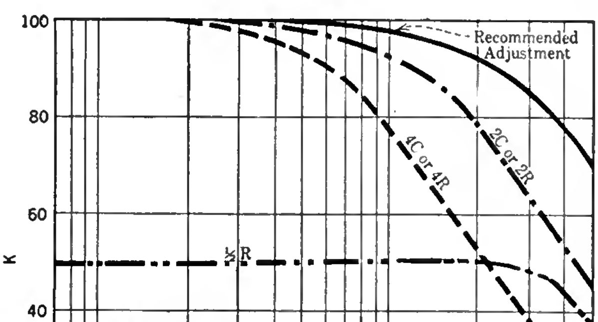


Fig. 6—Effect of grid condenser capacity in grid-leak detector operating with small signals.

by the detector grid requires an amplification of 100,000/150 = 667 times. If the induced antenna voltage had been applied directly to the first r.f. grid through a resistance to ground, the required r.f. amplification would be 100,000/10 = 10,000 times.

Case 2: A 227-type tube power detector with 90 volts on the plate is used to feed a 250-type tube which has a plate voltage of 300 and a grid bias of —54 volts. How much radio-frequency amplification is required to give full output when the signal field strength is 1 microvolt per meter?

The maximum audio voltage that can be applied to the grid of the 250-type tube is 54 volts, and assuming the 227 tube amplifies its audio grid voltage 25 times, the power detector must have 54/25 = 2.16 audio volts produced on its grid by the detection process. With complete modulation (m = 1) and assuming 80 per cent. of ideal detection, then according to the formula already given $0.80 \times 1 \times E_s = 2.16$ and the required radio signal is $E_s = 2.7$ volts, which is a value that can just be handled at 90 plate volts without undue distortion. If the antenna is 10 meters and a tuned antenna circuit with a step-up of 15 is used, the radio-frequency amplification required to put 2.7 volts on the detector grid is 2,700,000/(10 × 15) = 18,000 times. This could be obtained easily with three screen-grid stages. Without a tuned antenna the amplification needed is 15 times as much, or 270,000 times.

Table I

DETECTION CHARACTERISTICS OF THREE-ELEMENT TUBES

Type	Mu	Detector Voltage Constant V g	Leak Resistaace Recommended	Ceff for 70% reproduction of 5000 cycles
201A	9	—0.47	3.20 megohms	0.000212 mfds.
240	30	—0.47	3.20	0.000212
199	6	—0.50	1.50	0.000255
120	3	—0.45	1.67	0.000255
171A	3	—0.28	7.20	0.000160
112A	8	—0.26	5.8	0.000212
226	8	—0.29	1.6	0.000212
227	8	—0.23	7.8	0.000318
12	6	—0.27	8.0	0.000318

Note: Values of V_g are averages for a number of tubes.
Values of effective grid condenser capacity, C_{eff}, are values of grid condenser capacity plus tube input capacity to audio frequencies, which is usually about 0.00007 mfds. for tubes with a mu of about 8.
The recommended values of grid leak are such as to make the detector input grid-filament resistance at least 100,000 ohms.
All tubes are R.C.A. or Cunningham.

Case 3. A 210-type tube with 300 volts on the plate is used as a power detector and operates the loud speaker directly from its own power output. How much undistorted power is obtainable, and how much radio-frequency amplification with a 1 microvolt per meter field is needed to give this power?

A 210-type tube used as an a.f. amplifier at 300 volts would require a grid bias of —22½ and would put out 600 undistorted watts. As a power detector the tube will handle a fully modulated carrier wave of about 12 radio-frequency volts (which is just more than half of 22½) and will then put out about 600/4 = 150 undistorted audio-frequency milliwatts. This 12 volts of radio frequency will put about 0.85 × 12 = 10.2 audio volts on the grid of the detector to produce the 150 milliwatts output, and, with the 10-meter tuned antenna with a step-up of 15, will require a radio-frequency amplification of 12,000,000/(15 x 10) = 80,000 times. This could be supplied readily by three good stages of screen-grid radio-frequency amplification.

N. E. M. A. ATTACKS SERVICE EDUCATION PROBLEM

THERE has been a general recognition on the part of the radio industry that satisfactory radio reception requires more than the making of good radio receivers. If it is to give the consumer the utmost satisfaction the receiver must be installed in a manner which assures the maximum performance in its particular location with respect to selectivity, sensitivity, and tone quality. While the potentiality of maximum performance in these respects may be built into the receiver by proper design and construction, only when the installation is intelligently and scientifically made is there assurance that the customer will enjoy the highest standards of reception.

The mere realization that the dealer must learn the practical aspects of installation and maintenance is no solution of the complex problem of raising the standards of service rendered the consumer both with the initial purchase and the subsequent maintenance and attention required. The difficulties of dealer education by the manufacturer are increased greatly by the fact that he often has thousands of outlets distributing his product, so that there is no practical way of establishing contact with all of those having a hand in making the radio receiver perform in the ultimate purchaser's home. Many manufacturers issue service bulletins of great value to trained men but they do not fulfil the broad function of teaching servicing.

With a view to meeting the problem of service education the Radio Division of the National Electrical Manufacturers Association has issued a course especially for servicemen and dealers responsible for installations. This course was prepared in collaboration with the Radio Institute of America, a pioneer organization in training men for the various branches of the radio field. Four booklets giving the sort of practical information required in servicing, periodic examinations which are marked and rated, and direct correspondence help are included as a part of the course. The text covers not only installation but all the details of repair and maintenance of radio receivers. It discusses how to hunt for trouble with a view to conserving the time required with each service call. Scores of diagrams of commercial receivers are included in the text so that repairs can be made in the minimum of time by a study of the circuits of all popular models of radio receivers. While the subject of installation is treated in a very thorough fashion, the course does not place undue emphasis on that phase of the radio serviceman's work. Repair problems, trouble hunting and similar questions are presented in a comprehensive manner.

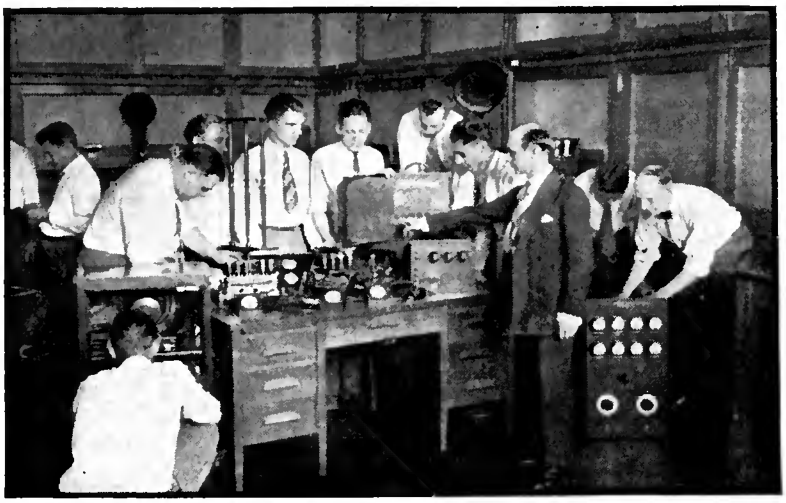
The first of the four textbooks discusses the fundamental principles of electricity involved in broadcasting and explains the magnetic field, electromagnetic induction, transformers, condensers, oscillatory circuits, audio-frequency amplification, and reproduction by the loud speaker. This volume also gives definitions and standard radio symbols for all parts used in radio reception and required of servicing, as well as an outline of the general types of radio receiver including tuned and untuned radio-frequency sets, regenerative detector circuits, super-heterodyne systems, and all types of audio amplifiers.

The second volume contains a discussion of direct-current receivers and the associated battery supply, and it goes into the subject of a.c. receivers exhaustively; also repairing magnetic and dynamic loud speakers. Among many other subjects is that of the installation of a broadcast receiver. This text also includes the construction of a testing set for general repair and test purposes and a modulated oscillator for shop tests.

Servicing, trouble shooting, vacuum tubes, and the elimination of electrical interference are some of the important questions taken up in the third text.

Book four is unique in that it contains complete circuit diagrams of all the leading models and makes of radio receivers on the market. This is the first encyclopedia of radio circuit diagrams which has been prepared to aid the serviceman in the application of the practical service methods explained in the first three text books.

In preparing this service course for the radio industry, the National Electrical Manufacturers Association has endeavored to achieve a high degree of practicability and the widest possible distribution by enlisting the coöperation of the Radio Institute of America which has devoted itself since 1909 to training men for work in all branches of the radio field.

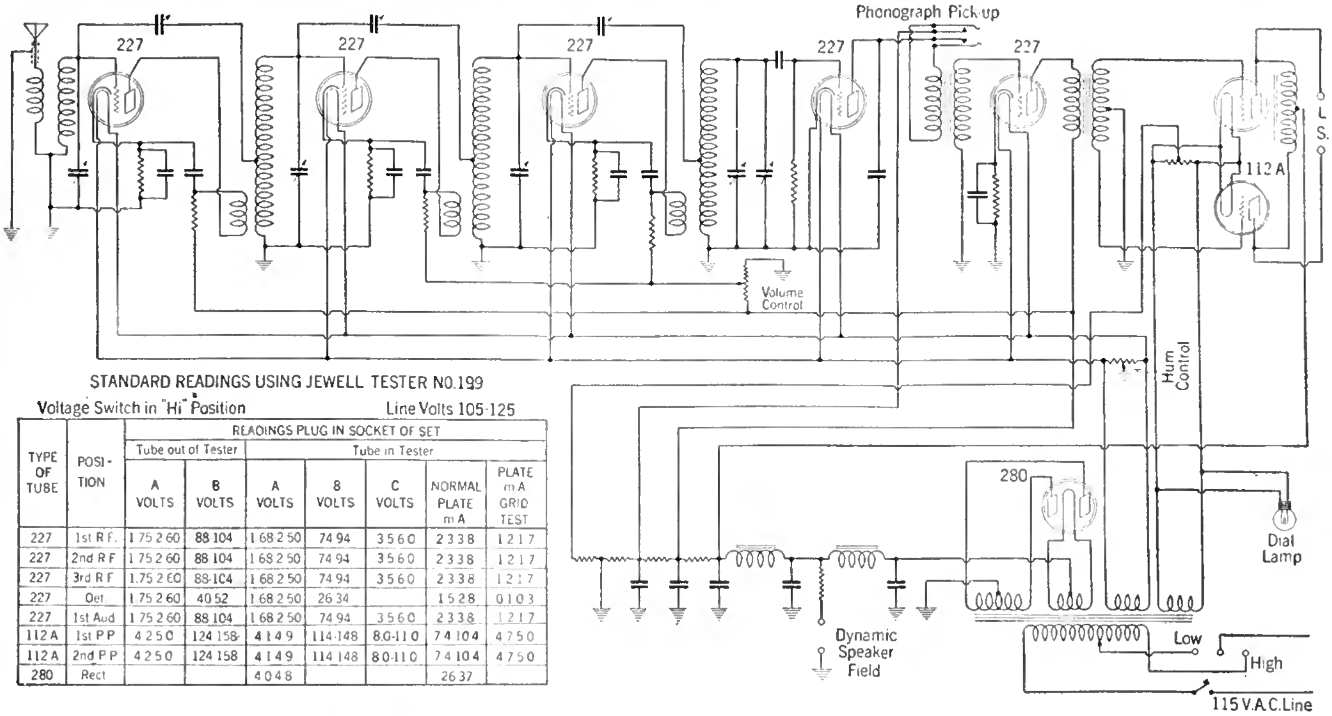


Students receiving instruction in servicing at the Radio Institute of America

No. 23 — *Radio Broadcast's Set Data Sheets* — May, 1929

THE BALKITE RADIO RECEIVERS, MODELS A-3, A-5, AND A-7

This completely light-socket-operated receiver uses five 227-type tubes and two 112A-type tubes in push-pull in the output. The use of 227-type tubes in all the sockets preceding the power stage somewhat simplifies the wiring since only one filament winding is required to supply all of them. Also the use of 227-type tubes results in less hum output. The volume control varies the plate voltage applied to the r.f. tubes.



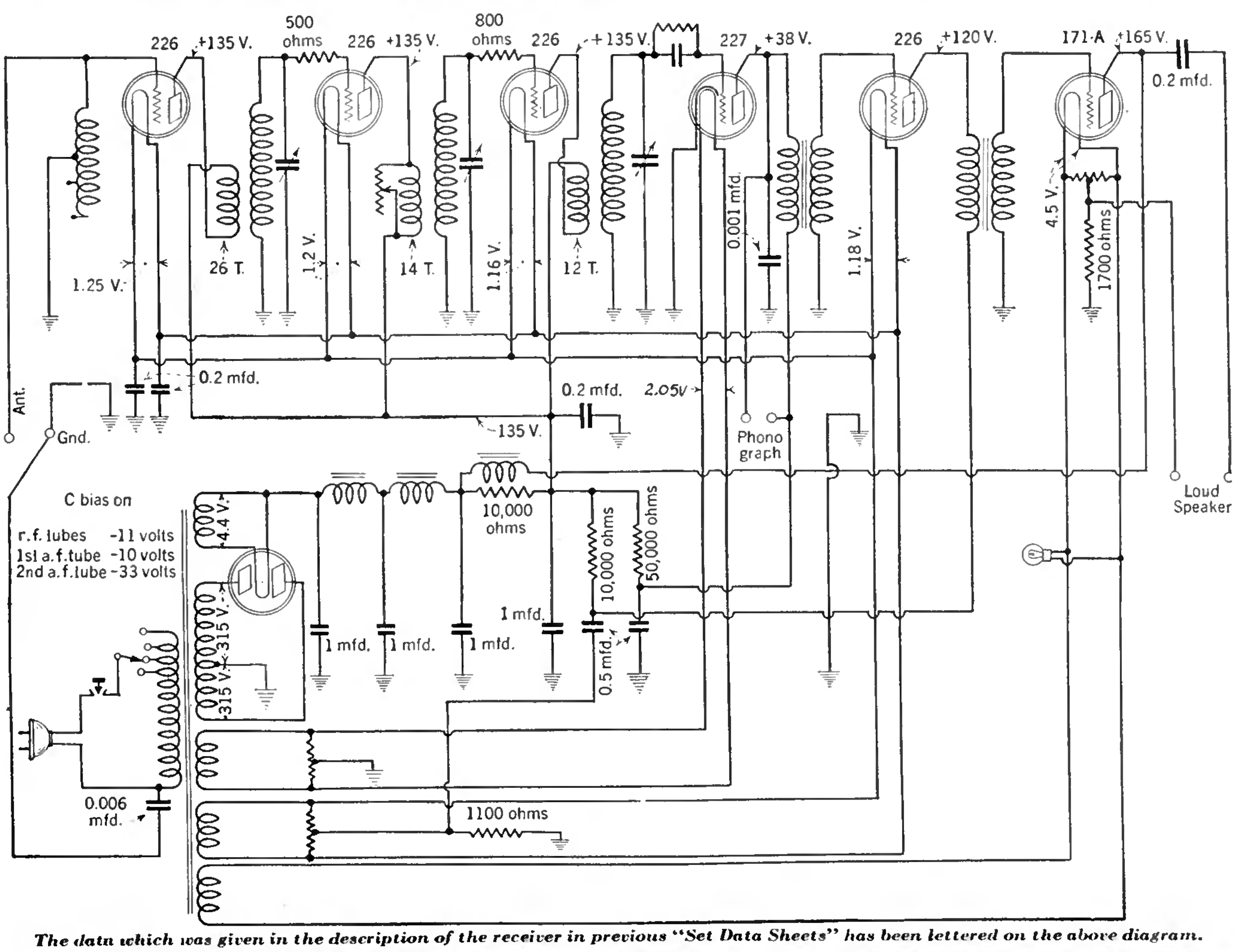
STANDARD READINGS USING JEWELL TESTER NO. 199

Voltage Switch in "Hi" Position — Line Volts 105-125

TYPE OF TUBE	POSI-TION	READINGS PLUG IN SOCKET OF SET: Tube out of Tester — A VOLTS	Tube out of Tester — B VOLTS	Tube in Tester — A VOLTS	Tube in Tester — B VOLTS	Tube in Tester — C VOLTS	NORMAL PLATE mA	PLATE mA GRID TEST
227	1st R.F.	1.75 2.60	88 104	1.68 2.50	74 94	3.5 6.0	2.3 3.8	1.2 1.7
227	2nd R.F.	1.75 2.60	88 104	1.68 2.50	74 94	3.5 6.0	2.3 3.8	1.2 1.7
227	3rd R.F.	1.75 2.60	88 104	1.68 2.50	74 94	3.5 6.0	2.3 3.8	1.2 1.7
227	Det	1.75 2.60	40 52	1.68 2.50	26 34		1.5 2.8	0.1 0.3
227	1st Aud	1.75 2.60	88 104	1.68 2.50	74 94	3.5 6.0	2.3 3.8	1.2 1.7
112A	1st P.P.	4.2 5.0	124 158	4.1 4.9	114-148	8.0-11.0	7.4 10.4	4.7 5.0
112A	2nd P.P.	4.2 5.0	124 158	4.1 4.9	114 148	8.0-11.0	7.4 10.4	4.7 5.0
280	Rect			4.0 4.8			26 37	

THE STEINITE MODEL 261 ELECTRIC RECEIVER

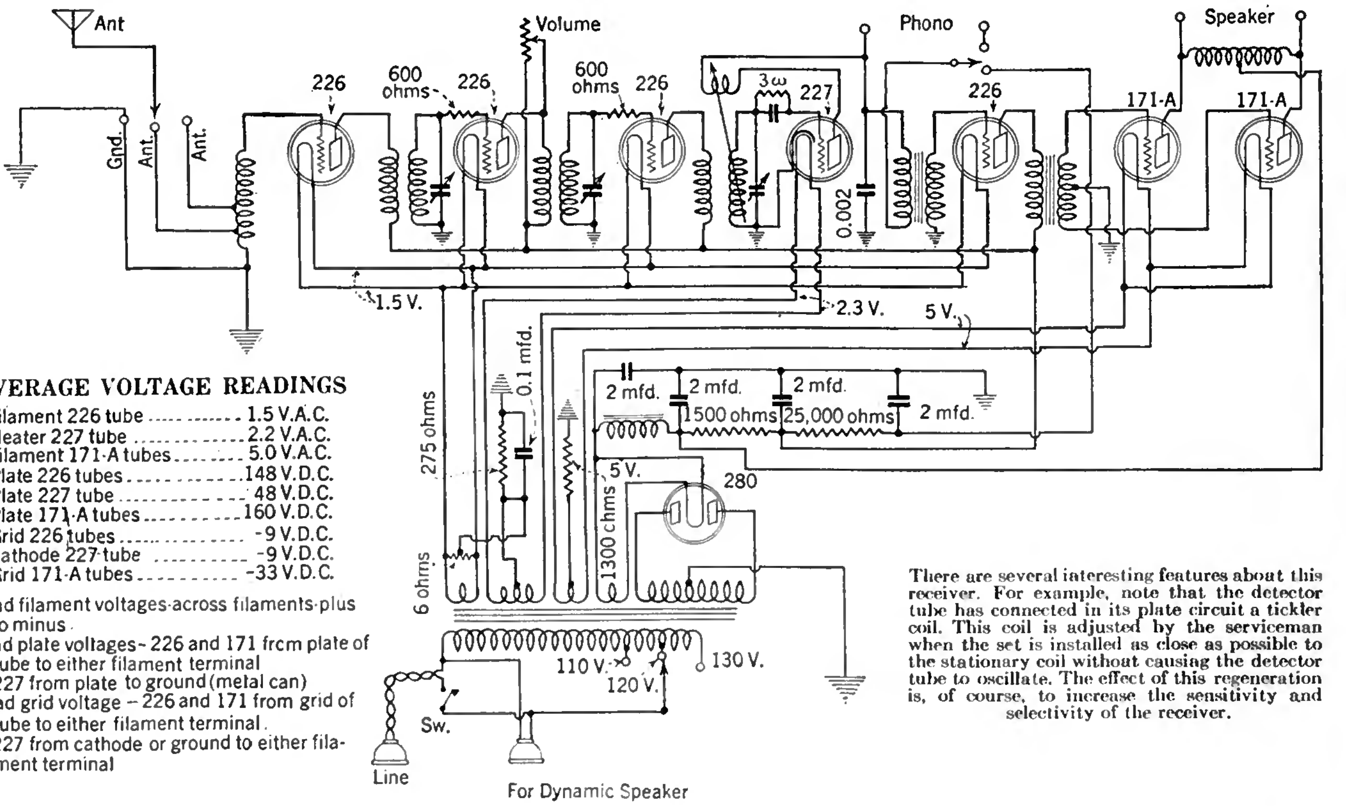
The circuit diagram published here indicates three taps on the antenna coil. This is correct for all receivers distributed previously to September 20th, 1928. Since that date the number of taps has been increased to seven, controlled by a seven-point switch located near the volume control. This circuit is incorporated in all Steinite receivers, models 261 to 266 inclusive.



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

No. 24 — *Radio Broadcast's Set Data Sheets* — May, 1929

THE ARBORPHONE MODEL 45 RECEIVER



AVERAGE VOLTAGE READINGS

Filament 226 tube	1.5 V.A.C.
Heater 227 tube	2.2 V.A.C.
Filament 171-A tubes	5.0 V.A.C.
Plate 226 tubes	148 V.D.C.
Plate 227 tube	48 V.D.C.
Plate 171-A tubes	160 V.D.C.
Grid 226 tubes	-9 V.D.C.
Cathode 227 tube	-9 V.D.C.
Grid 171-A tubes	-33 V.D.C.

Read filament voltages across filaments plus to minus.

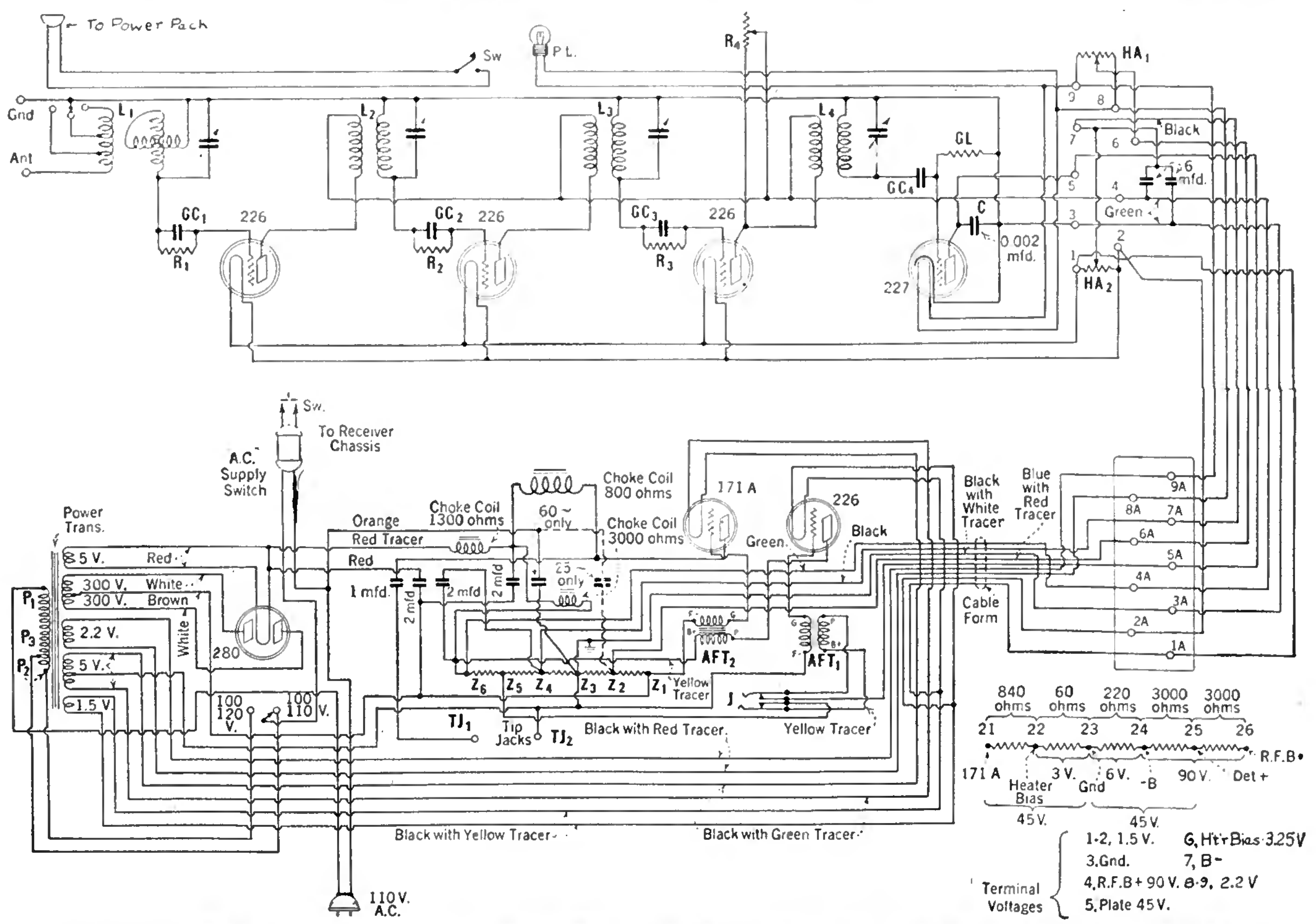
Read plate voltages – 226 and 171 from plate of tube to either filament terminal
227 from plate to ground (metal can)

Read grid voltage – 226 and 171 from grid of tube to either filament terminal.
227 from cathode or ground to either filament terminal

There are several interesting features about this receiver. For example, note that the detector tube has connected in its plate circuit a tickler coil. This coil is adjusted by the serviceman when the set is installed as close as possible to the stationary coil without causing the detector tube to oscillate. The effect of this regeneration is, of course, to increase the sensitivity and selectivity of the receiver.

THE KOLSTER RECEIVERS, MODELS K-20, K-22, K-25, AND K-27

These models consist of a three-stage tuned radio-frequency amplifier, a detector, and a two-stage transformer-coupled audio amplifier. Type 226 tubes are used in the r.f. and first a.f. stages and a 171A-type tube is used in the output stage. When a phonograph pick-up unit is used it should be plugged into jack, J. Note that a variometer is used in the first tuned circuit and also the taps are provided on the antenna coil.



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

Design and Construction Data

A SUPER-SENSITIVE SHORT-WAVE CIRCUIT

By THOMAS A. MARSHALL

Office of Fleet Radio Officer, Pacific Fleet, U. S. N.

This article describes a receiver that is more sensitive than the average short-wave set. The author has built a number of such receivers for the Navy where they enable the operators to get down to much weaker signals than with conventional receivers. The model of the set illustrated schematically on these pages was built by Herbert M. Isaacson of the QRV Radio Service. His conclusions, after constructing and operating the receiver, are that it is more sensitive than usual receivers for the high frequencies, and, although not adapted for the usual amateur traffic, it would "prove in" where an operator desired to communicate with a few transmitters whose positions have been located on the tuning dials, and then charted.

—THE EDITOR

THE short-wave receiver described in this article has several unique points of interest and advantages which clearly distinguish it from the commonplace. The circuit, in its most sensitive form, consists of a single-stage tuned radio-frequency amplifier followed by an autodyne detector and a two-stage transformer-coupled audio-frequency amplifier. In the radio-frequency amplifier and detector modified push-pull circuits are used because of the ease in generating oscillations and because of the low circuit losses on frequencies up to as high as 80,000 kilocycles (3.75 meters).

The conventional types of receiver circuits as developed in the past have been incapable of giving amplification in the upper frequency bands due to the relatively low input impedance of the tubes and the relatively low L/C ratio. The low input impedance is due to the relatively high grid-to-filament capacity which, under actual operating conditions, may be several times the geometrical capacity.

The capacity between the grid and filament markedly affects the input impedance which fact is of importance in determining the input power and the signal voltage impressed on the tube elements. The input impedance of the tube may be represented by a capacity with a high resistance in series. This resistance causes the absorption of power in the input of the tubes to become very high.

In Fig. 1 the value of R_g in ohms is very small compared with the reactance of C_g in ohms. Neglecting the slight effect of R_g we can say that the current will divide between the tuning condenser, C, and the parallel circuit, C_g, in direct proportion to the capacities of C and C_g. The current, I_g, flowing to the grid is obtained by the formula:

$$I_g = \frac{C_g}{C + C_g} \times I$$

The power, P_g, dissipated in R_g may be calculated by the formula:

$$P_g = I_g^2 R_g$$

The power dissipated in the push-pull circuit, as shown in Fig. 5, is approximately one half the value calculated for the circuit shown in Fig. 2.

Features of Push-Pull

FIG. 2 shows a three-electrode tube and its associated circuits as used in single-tube circuits. The points G, F, and P represent the three electrodes, the grid, filament, and plate. The capacities between them are represented by C_1, C_2, and C_3. Fig. 3 shows a similar tube and associated circuits as used in a push-pull receiver, Fig. 5. The inter-electrode capacity, C_1, and the grid resistance, R_g, are in series across the input circuit. Thus, the capacity is halved while the resistance across the input circuit is doubled, giving a much lower conductance for the input grid circuit. The same arrangement of capacities and resistances applies to the output or plate circuit.

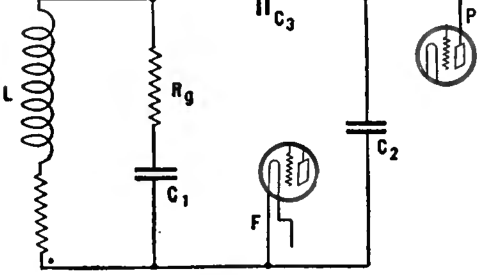


Fig. 2

In ordinary circuits, as shown in Fig. 2, the fixed capacity, C_1, across the coil system

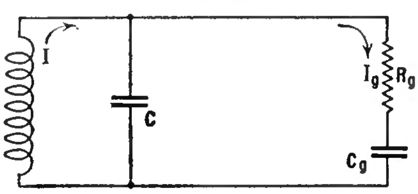


Fig. 1

restricts the tuning range. The circuit as shown in Fig. 5, due to reduced inter-electrode capacity, permits a relatively large L/C ratio, thus giving considerably more inductance than the single-tube circuit. The increased value of inductance with which to couple the tickler feed-back gives stable oscillations over the entire range of frequencies.

By the arrangement as shown in Fig. 5, the intra-electrode tube capacities are reduced by using the two split condensers, C_1, which are in series and by connecting the two tubes so that each grid-to-filament capacity is across one of the series sections. The total effective tube capacity upon the tuned circuit is halved. The two tube grid-to-filament circuits are across each half of the tuned circuit input voltages which decreases the grid-to-filament conductance to half value for each tube. Since the two reactances are in series the total conductance across the tuned circuit is one quarter the value of that in the usual circuit. It is, therefore, quite apparent that the input impedance of the new circuit is increased, making it possible to maintain a much higher signal-voltage potential across the tuning condenser terminals.

The circuit has been operated successfully in the 10-meter band. Reception of second harmonic values from distant stations such as IIJG, WIK, WEKQ, NPG, and WGT have often been accomplished during day time. KWE on approximately 1,600 kilocycles may be heard on 32,000 kilocycles, and WIK on 13,930 kilocycles may be heard on 27,860 kilocycles which is very close to the upper limits of the 10-meter band.

The circuit does not radiate energy due to the employment of the tuned radio-frequency amplifier and to the minimum antenna coupling. The antenna circuit within the receiver consists of a small series inductance, L, which is coupled to the amplifier tuned input inductance. These inductances are wound with fixed relationship to one another so that the calibration of each coil system will remain fixed. The receiver may be operated from an antenna of any length from a few feet up to several wavelengths, such as a Beverage system. A doublet type of antenna or a directional loop may be used. European stations may be heard by using a single-turn loop about one foot square and connected directly to the coil jacks. The loop coil will act as an antenna and inductance system. Fig. 4 shows the circuit for loop reception. Note that the circuit preserves symmetry which is so essential to efficient and stable operation of a loop system. Due to symmetrical operation of the loop system, no compensating capacities are required to keep the loop balanced capacitively on each side of the earth.

The second inductance, L_1 of Fig. 5, is connected to the tuning condenser, C_1, and feeds to the grids of the two tubes through the coupling condensers, C_2 and C_4. The grids obtain a negative bias through the one-megohm leaks, R_1 and R_2, which are connected to the battery end of the resistance, R_5, thus giving a bias potential of approximately 1.6 volts which is obtained by utilizing the voltage drop of the series resistance.

Special Apparatus Used

THE condensers C_{10} and C_{12} are shown as having two series sections and a common rotor. This device may be made by cutting the bus bar which holds the stator, thus separating it into two parts. The rotor is connected to the plus filament and is grounded, in this way eliminating hand effect in tuning. It will be observed that the grid coils have no center connection. These coils are permitted to find their own electrical center which may be different from the apparent center due to electrical irregularities existing in the circuits. The choke, L_6 and L_7, isolates the junction

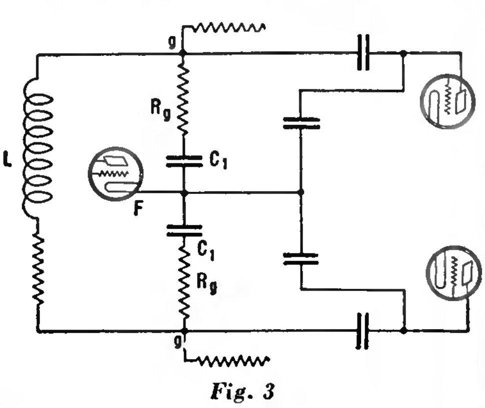


Fig. 3

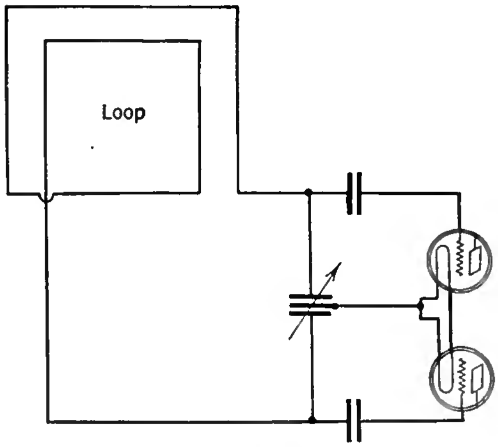


Fig. 4

of the two plate coils which tends to keep radio-frequency currents out of the B-battery supply circuits.

Three-element tubes may be used in the radio-frequency stage with a fair degree of success and Fig. 6 shows the circuit for standard three-element tubes. C_3 and C_4 are neutralizing condensers.

In order to obtain the greatest amplification possible it is essential that the external plate-circuit impedance be kept high. For this reason, greatest efficiency may be obtained by using a tuned plate circuit as shown in the dotted lines of Fig. 5. In this case L_3 should be a center-tapped coil tuned by C_{10} and C_4 in parallel, thus making possible a high-impedance load in the plate circuit. The effective resistance at resonance of this combination, $\frac{W^2 L^2}{R_1}$, may be much higher than the impedance of standard r.f. chokes which may be used (untuned) in place of L_4

The radio-frequency amplifier couples to the detector circuit through two 25-mmfd. condensers, C_5 and C_6. These capacities are made small to prevent reaction of the amplifier on the oscillating detector circuit.

The detector circuit is similar to the radio-frequency circuit. The potentiometer, R_7, is 100,000 ohms and serves to control oscillations by varying the voltage on the plates of the detector tubes. It is bypassed by a 2-mfd. condenser which prevents noise from irregular contacts as experienced with some volume-control potentiometers.

For ruggedness, selectivity, and elimination of vibration and microphonic noises, the receiver box should be built with heavy aluminum shields. If the proper care is taken microphonic noises, due to mechanical vibration, will be eliminated. Rigid bakelite tube sockets should be used rather than the cushion type. The receiver should be mounted upon a shock-absorbing pad such as a sponge rubber pad about one inch in thickness. The plate circuit of the radio-frequency amplifier may be shielded easily by arranging the two tubes so that each plate connection is near the shield and as short as possible. It will, therefore, not be necessary to use copper cylinders for each tube. If the proper care has been taken in mounting and wiring all the parts, the receiver will have a very low noise level, much lower than found on conventional types of receivers where the detector circuit is connected directly to the antenna system.

The condenser C_4 is 25 mmfd. which is sufficient to take care of the difference in tuning of the condensers C_{10} and C_{12} which may be operated on the same shaft.

Construction of Coils

COILS for this receiver may be made on Silver-Marshall plug-in forms. The following data are only approximate, but furnish a good starting point.

Band (Meters)	Ant. (L)	Grid r.f. (L_1)	Plate r.f. (L_3)	Grid det. (L_4)	Plate det. (L_5)
10	3	4	4*	3	4
20	3	8	4	6	6
30	4	15	6	12	6
40	4	17	7	14	6

*One half inch in diameter. Cut off top of coil form so that leads will not be too long.

In winding the coils, No. 16 enamel-covered wire should be used for grid coils and No. 22 enamel-covered wire for plate and tickler coils.

The two small coupling condensers, C_5 and C_6, between amplifier and detector may be made from small metal plates, about the size of dimes, and should be arranged so that the capacity of each may be varied slightly.

If the a.f. transformers are ungrounded, an unpleasant squeal may be heard in the phones. This may be eliminated by connecting an 0.05-mfd. condenser between grid of the last stage and the transformer frame. This will not reduce the signal strength.

List of Parts

THE following is a complete list of the apparatus employed by the writer in the construction of this receiver. Other parts may, of course, be substituted with discretion if the parts listed below cannot be obtained.

C_1, C_{12} Two Hammarlund condensers, 11-plate;
C_7, C_3, C_8, C_9 Four Dubilier condensers, 100-mmfd.;
C_4 One Hammarlund Junior 9-plate condenser, 25-mmfd.;
C_5, C_6 Two condensers, 25-mmfd. maximum. (See construction notes);
C_7, C_{11} Two Parvolt by-pass condensers, 1.0-mfd.;
C_{10} One Hammarlund 7-plate condenser (not used if L_3 is no r.f. choke);
C_{13} One Parvolt by-pass condenser, 2.0-mfd.;
L, L_1, L_2, L_3, L_4, L_5 Six coils (see coil table for data);
L_6, L_7 Two Samson r.f. chokes, 125-mh.;
R_1, R_2 Two Durham grid leaks, 1.0-megohm;
R_3, R_4 Two Durham grid leaks, 0.5-megohm;
R_5 One rheostat or fixed resistance, 25-ohm;
R_6 One rheostat or fixed resistance, 6-ohm;
R_7 One Carter volume control, 100,000-ohms;
R_8 One Yaxley potentiometer, 200-ohm;
Six Benjamin sockets, four-prong;
Three Benjamin sockets, five-prong;
Two Thordarson transformers, R200;
One Jewell Voltmeter, Pattern-135:
One on-off switch;
Two National dials.

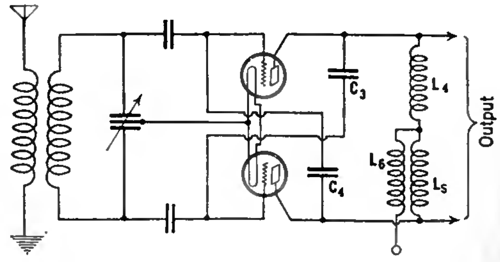


Fig. 6

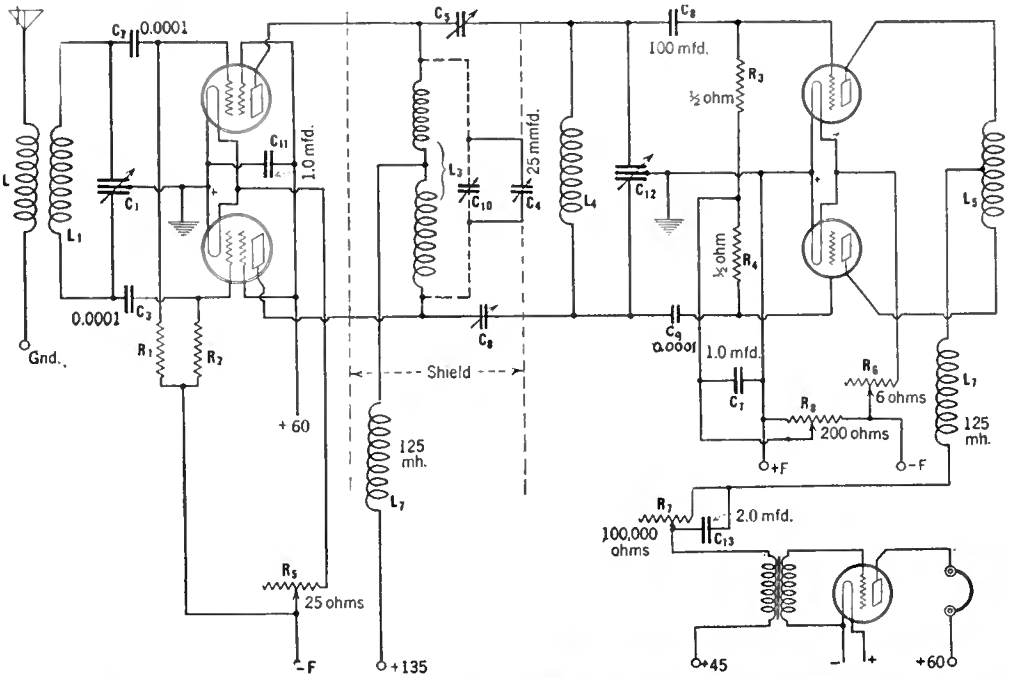


Fig. 5—Complete schematic diagram of the author's short-wave receiver.

SOUND-MOVIE MANUFACTURERS

OF INTEREST to workers in the sound motion picture field is the following list of practically all of the prominent manufacturers making acoustic apparatus for use in sound-movie installations:

LOUD SPEAKERS

Silver-Marshall—Dynamic cone—Silver-Marshall, Inc., 874 W. Jackson Blvd., Chicago, Ill.
Racon—Exponential horn—Racon Electric Co., Inc 18–24 Washington Place, N. Y. C.
Jensen—Dynamic cone—Jensen Radio Mfg. Co., 338 N. Kedzie Ave., Chicago, Ill.
Peerless—Dynamic cone—United Radio Corp., Rochester, N. Y.

DISC REPRODUCER INSTALLATIONS

RCA Photophone, Inc.—411 Fifth Ave., N. Y. C. (Dynamic cones, synchronous and non-synchronous turntables, amplifiers.)
Vitaphone—Electrical Research Products, Inc., 250 West 57th Street, N. Y. (Dynamic horn, synchronous and non-synchronous turntables, amplifiers).
Duotone—Western Electric Piano Co., 850 Blackhawk St., Chicago, Ill. (Dynamic horn, amplifier, non-synchronous turntables).
Motio-Tone—Gates Radio and Supply Co., Quincy, Ind., (Dynamic cone, or horn, turntables, amplifier)
Oganovox—National Sound Reproducing Co., 653 Clinton St., Milwaukee, Wisc. (Non-synchronous turntable, amplifier, dynamic loud speakers).
Good-All Orchestrola—Good-All Electric Mfg. Co., Ogallala, Nebraska. (Dynamic horn, amplifier, non-synchronous turntables).
Duplex-O-Phone—Nelson-Wiggen Piano Co., 1731–45 Belmont Ave., Chicago, Ill. (Amplifier and turntables only, for dynamic reproducers).
Han-A-Phone—Hanaphone Co. of America—6010 38th Avenue, Woodside, L. I.
Sonora—Bristolphone, 50 West 57th Street, N. Y. C.
Pacent Reproducer Systems—Pacent Reproducer Corp., 250 West 39th St. N. Y. C. (Dynamic cone, synchronous turntables, amplifiers).
Cinetone—S and S Enterprises, 46 Church St., Boston, Mass. (Dynamic cone, non-synchronous turntables, amplifier).
Phototone—Phototone Co., North Vernon, Indiana. (Cone, synchronous and non-synchronous turntables, amplifier).

SOUND–ON–FILM INSTALLATIONS

RCA Photophone Inc.—411 Fifth Avenue, N. Y. C. (Dynamic cones, amplifiers, sound reproducer equipment).
Movietone—Electrical Research Products Inc. (Western Electric) 250 West 57th Street, N. Y. C. (Dynamic horns, amplifiers, sound reproducer equipment).
De Forest Phonofilm—General Talking Pictures Corp., 218 West 42d St., N. Y. C. (Loud speakers, amplifiers, sound-reproducer equipment).

IN THE RADIO MARKETPLACE

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

Industry Briefs

Dr. Frank A. Rafferty has joined the staff of Zenith research engineers. Dr. Rafferty was formerly director of the radio research laboratories of Villanova College, Villanova, Pa.

The Laboratories of the Hazletine Corporation have been removed from Hoboken, N. J., to 333 West 52nd Street, New York City. W. A. MacDonald heads the staff of engineers at the laboratories.

The Radio Division of the Fansteel Products Company, makers of Balkite radio sets, has been incorporated in a separate company operating under the name The Balkeit Radio Company. Their address remains the same as before, North Chicago, Illinois.

Two New Radio Corporation licensees under receiving set and electrical phonograph patents are the Colin B. Kennedy Corporation, 231 South La Salle St., Chicago, Ill., and Silver-Marshall, Inc., 846 West Jackson Boulevard, Chicago, Ill.

J. H. Pressley who made a reputation as designer of an excellent super-heterodyne in years gone by, is now chief engineer of the United States Radio and Television Corporation, 1338 South Michigan Avenue, Chicago, Ill. Other officers of the company are: W. C. Perkins, president; H. T. Roberts, vice-president and sales manager; Arthur E. Case, vice-president and manager of plants; Douglas deMare, director of production; Don Pieri, sales engineer, and A. G. Messick, chairman of the board.

The La Salle Radio Corporation is now installed in a new plant at Ogden, Frontier, and Blackhawk Streets, Chicago, Ill. This company, headed by P. C. Dittman, president, makes a complete line of radio tubes.

Another Vacuum-tube manufacturer has entered the field. The new company will be known as the Triad Mfg. Co. with headquarters at Pawtucket, R. I. George Coby is president, Ely Egnatoff, treasurer, H. H. Steinle, vice-president and general sales manager, and William Cepak, secretary. Officers of the company have long been associated with the tube industry. The new company will make, in addition to a standard line of radio tubes, photo-electrical cells. Distribution of the Triad line will be through franchised jobbers only.

John M. Redell, a well-known figure in the radio sales field, has been appointed Chicago sales representative of the Sonatron Tube Company. Mr. Redell is secretary of the Midwest Radio Trades Association and a member of the executive board of the Federated Radio Trade Association.

Two Branches of the Edison Distributing Corporation, the wholesale distributing organization for Edison radio sets and Edison records have recently been opened, one at Boston and a second at Minneapolis. C. V. Chisholm is manager of the Boston office at 96 South Street. The Minneapolis office at 608 First Avenue, North, is headed by J. W. A. Henderson.

The Empire Electric Company, 25 East Juneau Ave., Milwaukee, Wis., has been appointed Central Wisconsin distributor for the Chas. Freshman Co. The appointment of distributors by the Freshman company is a new policy due to the new president, C. A. Earl. Distribution previously was made directly to dealers.

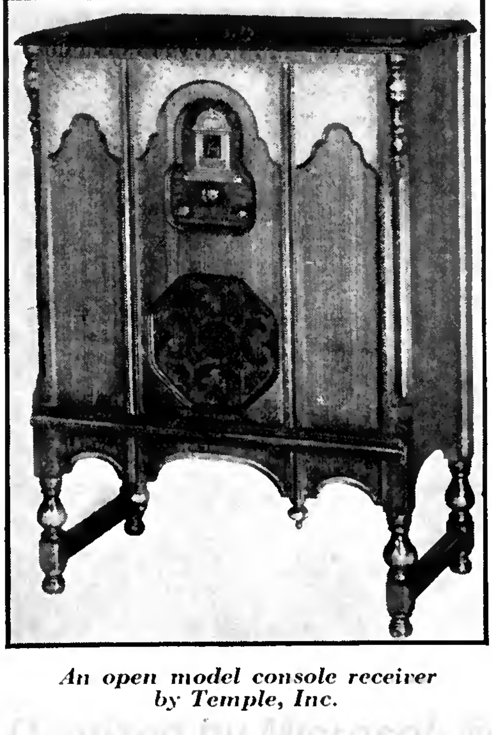
New Receivers Announced

The New Temple Receivers are available in two console models. The large console is equipped with a fourteen-inch dynamic loud speaker and the complete set sells for $189.00. The smaller console lists at $149.00 and it is equipped with a nine-inch dynamic loud speaker. The receiver circuit in both models is the same. Both sets use six 227-type tubes, a 250-type power tube, and a 281-type rectifier.

The First Set offerings by Silver-Marshall, Inc., of Chicago, as an RCA licensee will include console lowboys and highboys at approximately $149 and $189 list. These models, with identical chassis, will use the new a.c. screen-grid tube in the r.f. stages and the new intermediate power tube in the output stage. These receivers will be marketed through exclusive distributors.

Early in May, S-M expects to occupy a new factory on the west side of Chicago with a capacity of 1000 to 2000 sets per day.

The Kolster Radio Corporation through its subsidiary company, The Brandes Corporation, has entered the low-price set field. Three Brandes receivers are being manufactured, the Model B-10, a table-type receiver listing at $85, the Model B-11, a console set listing at $135, and the Model B-12, a console at $165. All three models use the same circuit which consists of three stages of r.f., detector and three stages of a.f. amplification. Type 227 tubes are used throughout except for the power tube and rectifier, the former being a 171A and the latter a 280. The Models B-11 and B-12 have built-in dynamic loud speakers. The sets are being manufactured at the plants of the Kolster Radio Corporation in Newark, N. J.



An open model console receiver by Temple, Inc.

Aero Products, Inc., of Chicago, Illinois, manufacture a short-wave adapter, the "Aero-Call," designed for use in conjunction with a standard broadcast receiving set to permit the reception of short-wave stations. This is a completely assembled short-wave tuning unit and the tuning range is from 15 to 90 meters with three coils supplied with the unit. Additional coils are available to extend the tuning range up to 550 meters so that all wavelengths from 15 up through the broadcast band can be covered by the use of interchangeable coils. The set is made in two models, one for use with a.c. receivers and one for use with d.c. receivers. Both models list at $25.00.

Miscellaneous New Parts

The National Company's new B-Power Unit, type 7180, was designed especially for use in conjunction with the new 245-type power tube and will deliver 250 volts to the plate of this tube and also supply the necessary 50-volt grid bias.

The Raytheon Manufacturing Company has designed two new high-voltage rectifiers, the Ray-s, $25.00 and the Ray sx-866, $12.50. The Ray-s rectifier is designed to supply up to 300 milliamperes of direct current at 2000 to 3000 volts. The type sx-866 supplies up to 250 milliamperes at 1500 to 2000 volts. Both tubes are designed to supply plate and filament current to the various types of transmitter tubes.

The Arcturus Radio Tube Company offers two new tubes, the type 145 power tube having a maximum output of above 1.8 watts and the type 122 screen-grid a.c. tube. Both tubes are the heater type, the heaters being designed for operation from a 2.5-volt a.c. source.

The Potter Dynamic loud-speaker filter, a product of the Potter Manufacturing Company, is designed for use in conjunction with a.c.-operated dynamic loud speakers to decrease the hum. To install the device it is simply necessary to connect the two leads from the filter across the field of the loud speaker. The price of the device is $7.50.

Items of Interest

The Tore Deutschmann Corporation have available some excellent bulletins on the subject of radio interference and its prevention. These bulletins can probably be obtained by those having anything to do with the installation of interference-preventing devices. The most recent pamphlet we have received takes up in detail the subject of preventing interference from oil burners. It is written by W. K. Fleming, chief engineer of the company.

Television Programs of an experimental nature are being transmitted regularly from 7 to 9 p.m. by station W2XBS of the Radio Corporation of America. The channel assigned to W2MBS is from 2000 to 2100 kilocycles (142.8 to 149.9 meters). A power of 250 watts is employed at present, although this will probably be increased shortly. Pictures are 60 scanning lines high and 72 elements wide. Twenty complete pictures are transmitted every second. Scanning is in such a direction that looking at the received picture the scanning spot moves from left to right and from top to bottom.

"Present transmissions consist of pictures, signs, views of persons, and objects," said Dr.

THE RADIO DEALER'S NOTE BOOK—NO. 3 TESTING INSTRUMENTS

*Free—Complete Information**

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

Good instruments are essential if receivers are to be serviced properly. In this connection, the table below lists the offerings of a few of the prominent instrument manufacturers. A dealer or serviceman ordinarily can make use of two instruments; one instrument is useful for checking the performance of all types of a.c. and d.c. receiving tubes and rectifiers and the other, a set-tester, for checking the performance of a receiver.

Whether a simple or a complicated set-tester is purchased depends upon one's personal preference. Some servicemen prefer the simplest possible instrument. The idea back of this is that if the set only requires a slight repair, it can be done on the job, but if considerable work must be done on the set, it is best to take it back to the shop where complete facilities for testing and repairing receivers are available. Other servicemen, however, prefer to complete the job on the spot and to such servicemen a very complete instrument of tests is probably essential.

In any event, whether or not you have a set-tester and tube-checker, data on all the available instruments should be in the hands of dealers and servicemen.

**As a service to readers, the Editors have arranged that dealers may obtain complete information on all the devices listed in the table by writing to the Service Department of* RADIO BROADCAST *and asking for data on testing instruments. All requests* must *be written on a business letterhead or a card must be enclosed to identify the writer as a dealer or serviceman.*

MANUFACTURER	DEVICE	TYPE No.	PRICE	MILLIAMMETER	VOLTMETER	REMARKS
Jefferson Electric Co.	Tube Rejuvenator	175	$ 4.50			For 50 to 133 cycles 100–120 volts a.c.
		180	6.00			For 25 to 40 cycles
Hoyt Electrical Instrument Co.	AC–DC Set Tester	600	65.00	0-30,120	0–12, 120, 600 d.c. 0–3, 9, 150 a.c.	A complete set tester
	Tube Tester	400	22.50	0–10, 50	0–3, 9 a.c. and d.c.	Tests all types of a.c. and d.c. tubes
	A.C. Attachment	101	15.00		0–3, 9 a.c. and d.c.	A device for use with d.c. tube testers to make possible the testing of a.c. tubes
	D. C. Set Tester	300	48.75	0–25, 100	0–10, 500 d.c.	For testing d.c. sets only
Jewell Electrical Instrument Co.	Tube Tester	210	65.00	0–100 and special scale	A.C. line voltage indicator	A tester for all types of tubes, including double-plate rectifiers
	A.C. - D.C. Set Tester	199	97.50	0–15, 150	0–7.5, 75, 300, 600 d.c., 0–4, 8, 16, 160 a.c.	A complete instrument for testing all types of sets
	Test Panel	580	212.00	0–15, 150	0–7.5, 75, 150, 300, 750 d.c., 0–4, 8, 16, 150, 750 a.c.	A special test panel for use in the shop. Contains special meter to measure condensers capacity up to 15 mfd.
	Tube Checker	150	38.00	0-15	0–4, 8 a.c.	Tests all types of a.c. tubes
Sterling Manufacturing Co.	Tube Tester	R–510	35.00	0–15, 100	0–15 a.c.	Checks performance of all types of a.c. and d.c. tubes. For 115 volts, 60 cycles a.c.
	Tube Tester	R–520	37.50	0–15, 110	0–15 a.c.	Same as R–510 except for 25 cycles a.c.
	Tube Checker	R–514	13.50			Special meters indicate short and low emissions in all types of a.c. and d.c. tubes
	Set and Tube Tester	R–522	67.50	0–10, 100	0–150 a.c. 0–3, 15 a.c. 0–10, 125, 500 d.c.	Tests all a.c. and d.c. sets; also a.c. and d.c. tubes, including screen-grid type. Binding posts for separate use of meters.
Supreme Instruments Corp.	Set Tester	400–A	124.65	0–125 0–2½ ampere	0–10, 100, 600 d. c., 0–3, 15, 150 a.c.	An a.c. and d.c. set tester complete with full sets of tools. Contains a modulated oscillator, tube rejuvinator, etc.
	Set Tester	99–A	97.65			A set tester lacking a few of the features of the larger model 400–A
Weston Electrical Instrument Corp.	Set Tester	537	100.00	0–30, 150	0–4, 8, 150 a.c. 0–8, 60, 120, 300, 600 d.c.	A complete a.c.-d.c. radio set tester
	Tube Checker	533	67.50	0–20, 80	A.C. line voltage indicator	For use by dealers in checking tubes at time of sale
Hickok Electrical Instrument Co.	Set Tester	AC-4600	$135.	0-20,200	0.-300, 600 d.c. 0–7.5 d.c. 0–3.3, 15 150 a.c.	A complete set tester
General Radio Co.	Test Oscillator	320				A modulated oscillator for receiver testing

A. N. Golsmith, vice-president and chief broadcast engineer of the Radio Corporation of America.

"Experimental work on such subjects as fading, picture quality, and other phases of television problems is being carried on by W2XBS."

Dr. Goldsmith continued by saying that this will in due course evolve in a service to the public on a basis similar to sound broadcast, and of like high quality.

THE SUPREME INSTRUMENTS CORPORATION, of Greenwood, Mississippi, manufactures a test set, model 400A, capable of making a very large number of tests on tubes and receivers. The device contains several special devices among which are a modulated oscillator which can be used in aligning the various tuning condensers in a single-control set and it also contains apparatus for rejuvenating tubes. The instrument is equipped with Weston meters, and sells for $124.65 list. It can be purchased on the time-payment plan. The down payment is $38.50 to be followed by ten monthly payments of $10.00 each. This company also makes a smaller service instrument, the model 99A, which lists for $97.65. If purchased on the deferred-payment plan, the down payment is $28.50 followed by eight monthly payments of $10.00 each.

THE J. E. JENKINS AND S. E. ADAIR COMPANY, of Chicago, are manufacturers of high-grade, audio-frequency apparatus such as audio-frequency transformers, gain controls, mixing controls, etc. The type GL-35 gain or volume control consists of nichrome-wire resistor units and the total resistance of the device is 350,000 ohms. The various steps give a logarithmic increase in resistance, each step giving a gain of about 3 DB.

THE UTAH RADIO PRODUCTS COMPANY has announced an automatic remote-control tuning device for radio receivers. The remote-control device, by means of which the radio set is operated from a distance, contains two knobs, one a station selector and the other a volume control. The control is small enough to hold in the palm of one's hand. The control box is connected by wires to an electric motor which is fastened to the radio receiver. The control box functions to turn on the set, tune it, and turn it off when the dial on the control box is turned to the "off" position.

DYNAMIC LOUD SPEAKERS in various models are manufactured by Wright-DeCoster, Inc., St. Paul, Minn. The models 105 and 106 are designed for operation from a storage battery, the models 107 and 108 have self-contained rectifiers, and the models 105x and 106x should be supplied with current from the filter circuit. The latter two models normally require a current of about 100 milliamperes. A model 107 loud speaker has been in use in the Laboratory for some time and comparatively it has much less hum than many other a.c.-operated dynamic loud speakers which we have tested. Its frequency response range is excellent.

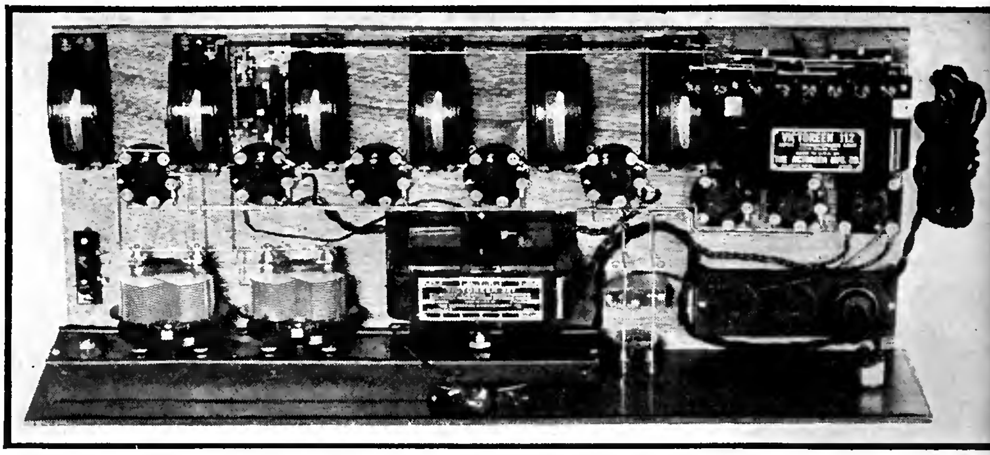
R C A Licenses First Tube Company

THE Raytheon Manufacturing Company has been granted a license to manufacture vacuum tubes under the patents of the Radio Corporation, it was announced by RCA on March 26.

"The license signed by the Radio Corporation and the Raytheon Manufacturing Company is a decided step toward stabilization in the radio tube industry," said L. K. Marshall, president of Raytheon. "Raytheon," continued Mr. Marshall, "through extensive laboratory research, pioneered in the developments that have resulted in electric power sets and made valuable contributions in producing effective tubes for use in B-power units. Recent Raytheon improvements are

another contribution to the tube's part in better radio reception. It is fitting that the Raytheon Company which has rendered so much engineering service to the radio industry, should be the first to take a license from the Radio Corporation, which will insure a close coöperation between the laboratories and should result in benefit to the radio industry in general."

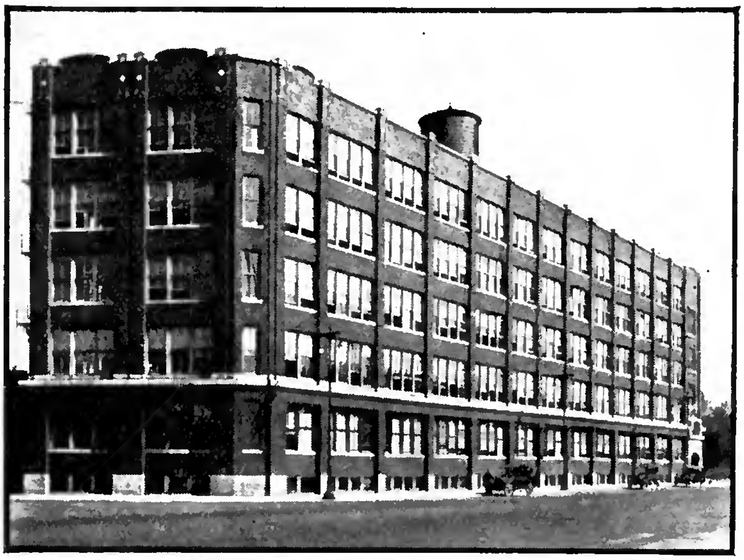
It is understood that licenses under RCA tube patents may be granted to other tube manufacturers. As extensive a family of licensed tube manufacturers may grow up as a result of this new RCA policy as has developed in the set field where there are now more than 31 companies producing receivers under RCA licenses. The first RCA set license was granted to Zenith on March 10, 1927. It is interesting to note that the first tube license was granted in the same month, just two years later.



Baseboard view of the New Victoreen kit receiver.

The 1929 Victoreen Kit Receiver

One of the Most Popular of the superheterodyne kits is the Victoreen 1929 A.C. receiver. We have received from the George W. Walker Company a description of this a.c. receiver and the following paragraphs describe its major characteristics.



The new tube manufacturing plant of the La Salle Radio Corporation, Chicago, Ill.

In designing the 1929 circuit, it was considered advisable to redesign the intermediate-frequency transformers and peak them slightly below former types. Each i.f. unit contains a variable condenser which is tuned to a standard frequency and then sealed at the factory. By this method any four transformers may be used together without the necessity of matching them in sets.

With the new r.f. transformers there has also been designed a special oscillator. The oscillator and antenna circuit tune together throughout the broadcast range, although the circuits naturally operate at different frequencies. Very little compensation is, therefore, required.

For tuning this receiver a single dial control using two 0.0005-mfd. Remler condensers are used. This single dial control unit has no backlash and requires a 360° back-panel-illuminated dial. Vernier capacity adjustments are provided for by a small 0.0001-mfd. variable condenser.

Plate rectification is used in the 1929 Victoreen AC receiver and in a measure this is responsible for the fidelity obtained. Both the second detector and first a.f. tubes operate with the same grid bias. A plate potential of 90 volts is used on the detector and the first a. f. tube operates from 180 volts.

The new Victoreen 327-type filament transformer has been designed to supply the standard a.c. tubes with power at slightly below their rated voltage. As now designed, it is standard only for 50- to 60-cycle current from a standard 108- to 112-volt line. This transformer comes equipped with the leads all attached to facilitate the wiring. It is designed to supply up to five 227-type tubes from each $2\frac{1}{2}$-volt secondary and two 112A-type tubes from the 5-volt secondary.

This circuit uses the 227-type tubes throughout the receiver. They reduce the hum to an imperceptible value and also eliminate variation in volume caused by voltage fluctuations.

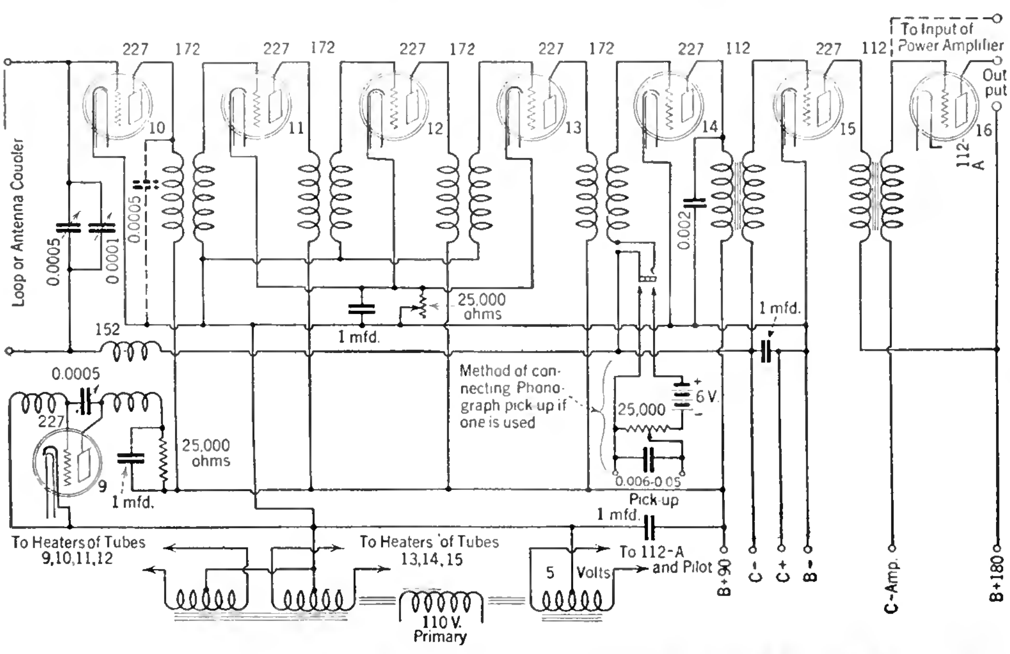
The volume control in the 1929 a.c. circuit consists of a resistor in the common plate return of the i.f. stages. This variable resistor's function is not only to decrease the plate potential but also to provide a high negative bias. This volume control does not change the tuning due to change in the voltage relation in the different circuits and, therefore, readjustment of the dials when the volume is changed is not necessary.

The circuit is adaptated for use with a phonograph pick-up unit which is placed in series with the grid return of the second detector. This receiver is also adaptable both for loop or outside antenna. If an antenna is used it is only necessary to remove the loop leads and connect the antenna coupler secondary to the loop posts. In using an antenna, fifty feet including lead-in should be more than ample.

The Victoreen power supply is a most important essential with the 1929 Victoreen a.c. circuit as it provides the 90- and 180- volt circuits with voltage regulator tubes.

The construction of this receiver is a very simple matter and free blueprints are available giving complete details. These include a point-to-point wiring description and a full-size template which may be used for laying out the parts.

The complete kit of parts for the 1929 Victoreen kit is available from the George W. Walker Co., Cleveland. Price: $141.30.



Schematic of the Victoreen 1929 A. C. Super-Heterodyne.

A CORRECTION

In the List of Books which was included in Mr. Dunham's article, "What the Serviceman Should Study," March, 1929, Radio Broadcast, page 295, two errors in price occurred. The correct price of H. F. Van Der Bijl's *Thermionic Vacuum Tube* is $5.00, and *Practical Radio Construction and Repairing*, by Moyer and Wostrel, lists at $2.50. Both books are published by the McGraw-Hill Book Co., Inc., New York City.

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 stages 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.
POWEL CROSLEY JR., Pres. CINCINNATI, O.
Owners of WLW, the Nation's Station
West of Rockies Prices Slightly Higher

ONLY *CENTRALAB*
makes resistances like these

The construction and design of a variable resistance is of as great importance as the mere fact that it possesses a certain resistance and will carry a specified current load. *CENTRALAB* design is such that the resistance unit not only will handle the power but also vary it in a manner so as to derive the greatest efficiency from the receiving set or power unit.

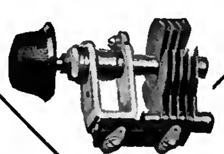
CENTRALAB RADIOHMS
In following resistances: 0-2,000 ohms, 0-50,000 ohms, 0-100,000 ohms, 0-200,000 ohms, 0-500,000 ohms. List price...**$2.00**

The following features distinguish *CENTRALAB* variable resistances of the Graphite Disc type:

Rocking Disc Contact — Noiseless, smooth and easy adjustment
One turn of knob gives complete variation — Constant resistance
Insulated shaft and bushing — Rigidly built; fully guaranteed

Made in two and three terminal units to be used as Volume Controls, Radiohms and Potentiometers. Special resistance tapers can be had for any circuit. Send for interesting booklet "Volume and Voltage Controls—Their Use."

CENTRAL RADIO LABORATORIES
24 Keefe Avenue — Milwaukee, Wisconsin



The MIDGET *of Many Uses*

"HAMMARLUND, JR." has all of the family characteristics—it is as carefully designed and well made as its bigger brother the famous Hammarlund "Midline" Condenser. For neutralizing R.F. circuits; for balancing the units of a multiple condenser; for vernier tuning; for antenna selectivity — and many other places in modern receivers, here is the biggest little condenser value you can buy. Five sizes: $1.50 to $2.25.

Write Dept. R B 5 for descriptive folder showing diagrams of uses.

HAMMARLUND MFG. CO.
424-438 W. 33rd St., New York

For Better Radio
Hammarlund
PRECISION
PRODUCTS

SHORT CIRCUIT AND 2,000 OHMS

sound alike in the phones when you're making a circuit continuity test by the "click" method. How would you tell the difference?

The progressive serviceman knows the answer. He uses the General Radio Direct-Reading Ohmmeter.

Bulletin 931-T Describes It.

GENERAL RADIO COMPANY

30 State Street, Cambridge, Massachusetts
274 Brannan Street, San Francisco, California

MANUFACTURERS' BOOKLETS

A Varied List of Books Pertaining to Radio and Allied Subjects Obtainable Free With the Accompanying Coupon

1. FILAMENT CONTROL—Problems of filament supply, voltage regulation, effect on various circuits, and circuit diagrams of popular kits. RADIALL COMPANY.

5. CARBORUNDUM IN RADIO—Pertinent data on crystal detectors with hook-ups, and information on the use of resistors. THE CARBORUNDUM COMPANY.

12. DISTORTION AND WHAT CAUSES IT—Hook-ups of resistance-coupled amplifiers with standard circuits. ALLEN-BRADLEY COMPANY.

17. BAKELITE—A description of various uses of bakelite in radio, its manufacture, and its properties. BAKELITE CORPORATION.

22. A PRIMER OF ELECTRICITY—Fundamentals of electricity with reference to the application of dry cells to radio. Constructional data on buzzers, automatic switches, alarms, etc. NATIONAL CARBON COMPANY.

23. AUTOMATIC RELAY CONNECTIONS—A data sheet showing how a relay may be used to control A and B circuits. YAXLEY MANUFACTURING COMPANY.

30. TUBE CHARACTERISTICS—A data sheet giving constants of tubes. C. E. MANUFACTURING COMPANY.

32. METERS FOR RADIO—A book of meters used in radio, with diagrams. BURTON-ROGERS COMPANY.

33. SWITCHBOARD AND PORTABLE METERS—A booklet giving dimensions, specifications, and shunts used with various meters. BURTON-ROGERS COMPANY.

37. WHY RADIO IS BETTER WITH BATTERY POWER—What dry-cell battery to use; their application to radio, wiring diagrams. NATIONAL CARBON COMPANY.

46. AUDIO-FREQUENCY CHOKES—A pamphlet showing positions in the circuit where audio-frequency chokes may be used. SAMSON ELECTRIC COMPANY.

47. RADIO-FREQUENCY CHOKES—Circuit diagrams illustrating the use of chokes to keep out r. f. currents from definite points. SAMSON ELECTRIC COMPANY.

48. TRANSFORMER AND IMPEDANCE DATA—Tables giving the mechanical and electrical characteristics of transformers and impedances, together with a short description of their use. SAMSON ELECTRIC COMPANY.

53. TUBE REACTIVATOR—Information on the care of vacuum tubes, with notes on reactivation. THE STERLING MANUFACTURING COMPANY.

57. FILTER DATA—Facts about the filtering of d. c. supplied by means of motor-generator outfits used with transmitters. ELECTRIC SPECIALTY COMPANY.

58. HOW TO SELECT A RECEIVER—A common-sense booklet describing what a radio set is, and what you should expect from it, in language that anyone can understand. DAY-FAN ELECTRIC COMPANY.

67. WEATHER FOR RADIO—A very interesting booklet on the relationship between weather and radio reception, with maps and data on forecasting the probable results. TAYLOR INSTRUMENT COMPANIES.

69. VACUUM TUBES—A booklet giving the characteristics of the various tube types with a short description of where they may be used in the circuit; list of American and Canadian broadcast stations. RADIO CORPORATION OF AMERICA.

72. PLATE SUPPLY SYSTEMS. Technical information on audio and power systems. Bulletins dealing with two-stage transformer amplifier systems, two-stage push-pull, three-stage push-pull, parallel push-pull, and other audio amplifier, plate, and filament supply systems. AMERICAN TRANSFORMER COMPANY.

73. RADIO SIMPLIFIED—A non-technical booklet giving pertinent data on various radio subjects. Of especial interest to the beginner and set owner. CROSLEY RADIO CORPORATION.

76. RADIO INSTRUMENTS—A description of various meters used in radio and electrical circuits together with a short discussion of their uses. JEWELL ELECTRICAL INSTRUMENT COMPANY.

78. ELECTRICAL TROUBLES—A pamphlet describing the use of electrical testing instruments in automotive work combined with a description of the cadmium test for storage batteries. Of interest to the owner of storage batteries. BURTON ROGERS COMPANY.

88. SUPER-HETERODYNE CONSTRUCTION—A booklet giving full instructions, together with a blue print and necessary data, for building an eight-tube receiver. THE GEORGE W. WALKER COMPANY.

89. SHORT-WAVE TRANSMITTING EQUIPMENT. Data and wiring diagrams on construction of all popular short-wave transmitters, operating instructions, keying, antennas; information and wiring diagrams on receiving apparatus; data on variety of apparatus used in high-frequency work. RADIO ENGINEERING LABORATORIES.

90. IMPEDANCE AMPLIFICATION—The theory and practice of a special type of dual-impedance audio amplification. ALDEN MANUFACTURING COMPANY.

95. Resistance Data—Successive bulletins regarding the use of resistors in various parts of the radio circuit. INTERNATIONAL RESISTANCE COMPANY.

98. COPPER SHIELDING—A booklet giving information on the use of shielding in radio receivers, with notes and diagrams showing how it may be applied practically. Of special interest to the home constructor. THE COPPER AND BRASS RESEARCH ASSOCIATION.

99. RADIO CONVENIENCE OUTLETS—A folder giving diagrams and specifications for installing loud speakers in various locations at some distance from the receiving set, also antenna, ground and battery connections. YAXLEY MANUFACTURING COMPANY.

101. USING CHOKES—A folder with circuit diagrams of the more popular circuits showing where choke coils may be placed to produce better results. SAMSON ELECTRIC COMPANY.

102. RADIO POWER BULLETINS—Circuit diagrams, theory constants, and trouble-shooting hints for units employing the BH or B rectifier tubes. RAYTHEON MANUFACTURING COMPANY.

104. OSCILLATION CONTROL WITH THE "PHASATROL"—Circuit diagrams, details for connection in circuit, and specific operating suggestions for using the "Phasatrol" as a balancing device to control oscillation. ELECTRAD, INCORPORATED.

105. RECEIVING AND TRANSMITTING CIRCUITS. Construction booklet with data on 25 receivers and transmitters together with discussion of low losses in receiver tuning circuits. AERO PRODUCTS COMPANY.

108. VACUUM TUBES—Operating characteristics of an a.c. tube with curves and circuit diagram for connection in converting various receivers to a.c. operation with a four-prong a.c. tube. ARCTURUS RADIO TUBE COMPANY.

112. HEAVY-DUTY RESISTORS—Circuit calculations and data on receiving and transmitting resistances for a variety of uses, diagrams for popular power supply circuits, d.c. resistors for battery charging use. WARD LEONARD ELECTRIC COMPANY.

113. CONE LOUD SPEAKERS—Technical and practical information on electro-dynamic and permanent-magnet type cone loud speakers. THE MAGNAVOX COMPANY.

114. TUBE ADAPTERS—Concise information concerning simplified methods of including various power tubes in existing receivers. ALDEN MANUFACTURING COMPANY.

115. WHAT SET SHALL I BUILD?—Descriptive matter, with illustrations, of fourteen popular receivers for the set-builder. HERBERT H. FROST, INCORPORATED.

118. RADIO INSTRUMENTS, CIRCULAR "J"—A descriptive manual on the use of measuring instruments for every radio circuit requirement. A complete listing of models for transmitters, receivers, set servicing, and power unit control. WESTON ELECTRICAL INSTRUMENT CORPORATION.

120. THE RESEARCH WORKER—A monthly bulletin of interest to the engineer and home builder. Each issue contains special articles on radio design and construction.

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163. THE BURT CELL. Description of the electrical characteristics and uses of photo-electric cells. R. C. BURT SCIENTIFIC LABORATORIES.

164. CHARACTERISTICS OF RADIO VACUUM TUBES. Chart giving average characteristics of standard a.c. and d.c. tubes. THE DAVEN CORPORATION.

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. 278 — Radio Broadcast Laboratory Information Sheet — **May, 1929**

Inductance-Capacity Products

THE formula for determining the frequency to which a circuit will tune is

$$f = \frac{159,000}{\sqrt{LC}}$$

where f equals the frequency in cycles per second
L equals the inductance of the coil in microhenries
C equals the capacity of the circuit in microfarads

It is evident from this formula that the frequency to which a circuit tunes is not determined by the inductance or the capacity alone but by their product. Tables of LC products are to be found in many textbooks, and in "Laboratory Sheet" No. 279 is given a table of LC products covering the broadcast band. The usefulness of this table will become evident from the following examples.

Example 1: Suppose we have a radio receiver which uses 0.0005-mfd. tuning condensers and which tunes-in a station broadcasting on 525 meters at 100° on the dial, i.e., with the condenser plates all in. What is the inductance of the tuning coils used in the set?

Answer: From the table the LC product for 525 meters is 0.0776. Therefore, L times C equals 0.0776. We know that C is 0.0005. Therefore, 0.0776 divided by 0.0005 gives 155 microhenries as the inductance of the coil.

Example 2: Suppose we wanted to rebuild this set to use 0.00025-mfd. condensers? What would the inductance of the coil have to be? The LC product must remain the same, 0.0776. Therefore, 0.0776 divided by 0.00025 gives 331 microhenries for the coil inductance.

Example 3: The receiver described in example No. 1 will tune down to only 230 meters. Therefore, what is the minimum capacity of the circuit and what must it be reduced to to permit the set to tune down to 200 meters?

Answer: The LC product for 230 meters is 0.01489. From example No. 1 the inductance of the coil is 155 microhenries. Therefore, 0.01489 divided by 155 gives 0.000096 mfd. as the minimum capacity of the circuit. To tune down to 200 meters the capacity must be reduced to 0.01126 (the LC product for 200 meters) divided by 155 microhenries. The quotient is 0.000073 which is the minimum capacity (in mfd.) the circuit must have if the set is to tune down to 200 meters.

No. 279 — Radio Broadcast Laboratory Information Sheet — **May, 1929**

Inductance-Capacity Products

THIS table gives the inductance-capacity products to tune to various frequencies throughout the broadcast-frequency band. L is in microhenries and C is in microfarads. The use of the table is explained in "Laboratory Sheet" No. 278.

Meters	f	L × C	Meters	f	L × C
200	1,500,000	0.01126	410	732,000	0.0473
210	1,429,000	0.01241	420	715,000	0.0496
220	1,364,000	0.01362	430	698,000	0.0520
230	1,304,000	0.01489	440	682,000	0.0545
240	1,250,000	0.01621	450	667,000	0.0570
250	1,200,000	0.01759	460	652,000	0.0596
260	1,154,000	0.01903	470	639,000	0.0622
270	1,111,000	0.0205	480	625,000	0.0649
280	1,071,000	0.0221	490	612,000	0.0676
290	1,034,000	0.0237	500	600,000	0.0704
300	1,000,000	0.0253	505	594,000	0.0718
310	968,000	0.0270	510	588,000	0.0732
320	938,000	0.0288	515	583,000	0.0747
330	909,000	0.0306	520	577,000	0.0761
340	883,000	0.0325	525	572,000	0.0776
350	857,000	0.0345	530	566,000	0.0791
360	834,000	0.0365	535	561,000	0.0806
370	811,000	0.0385	540	556,000	0.0821
380	790,006	0.0406	545	551,000	0.0836
390	769,000	0.0428	550	546,000	0.0852
400	750,000	0.0450			

more Mu from Screen Grid Tubes!

ARE you getting full value from screen-grid tubes? Most likely not, for 99 out of every 100 radio men run these marvelous tubes at very low efficiency. Why?

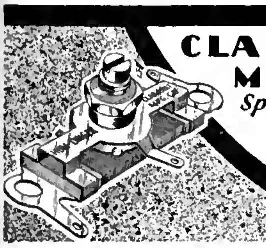
The main reason is failure to bias the control grid at 1½ volt negative potential. Of course that's troublesome if you must use a dry cell in ground lead. Other methods are equally awkward. But now you can use a better way. And here's how:

Try the Clarostat Hum-Dinger as a combination filament resistor and grid bias. Connect between negative A and filament, with center tap to ground side of antenna tuning unit. Adjust for proper grid bias by means of screwdriver, and leave it alone.

Oh boy! What a difference! And if you want to know why, just look up the characteristic curves of the screen-grid tube.

Of course the Clarostat HUM-DINGER is primarily an improved hum-balancer. Use it with your A-C filament tubes, and forget hum.

WRITE for data regarding the Hum-Dinger and other Clarostat products. There's a Clarostat for every purpose—adjustable, variable; fixed and even automatic. Ask your dealer about Clarostats.

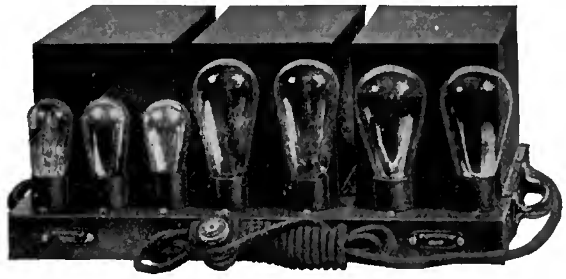


CLAROSTAT MFG. CO., Inc.
Specialists in Radio Aids
284 North Sixth Street
BROOKLYN, N. Y.

GENERAL AMPLIFIERS

For Use with Radio Set or Electric Phonograph Pick Up

Model GA 20



List Price (less tubes) $225

A self-contained, rugged, all electric, three-stage power amplifier employing two UX-250, two UX-226, two UX-281 and one UY-227. Will deliver approximately 14 watts of undistorted energy to the speaker. The use of dual push-pull makes for extremely quiet operation. Designed for 110-120 volt, 50-60 cycle alternating current operation.

The General Amplifier Company specializes in the design and manufacture of amplifiers to meet specific requirements. Your problems in the field of power amplification are solicited.

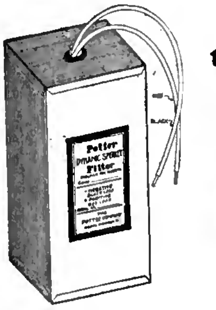
Bulletin RB-1 will be sent on request.

General Amplifier Company
27 Commercial Avenue — Cambridge, Mass.
Makers of High Grade Power Amplifiers

Potter

DYNAMIC SPEAKER

Filter



REDUCE the hum in A. C. operated dynamic speaker using low voltage rectifier

The installation of a Potter Dynamic Speaker Filter is easily made by connecting the two leads provided across the field of the speaker.

List Price $4.75

POTTER FILTER BLOCKS

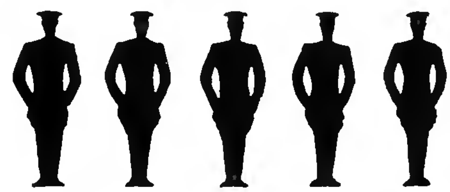
T-2900	Condenser Block for the single 250 type tube amplifier......	$20.00
T-2950	Condenser for the push-pull 250 type tube amplifier......	$22.50
T-2098	Condenser Block for single 210 type tube amplifier......	$20.00
T-280-171	Condenser Block for power pack with 280 type tube rectifier	$18.00

The Potter Co.
North Chicago, Illinois
A National Organization at Your Service

Stop that hum!

Install a De Forest Audion, No. 427, in your A. C. set and give it a real chance. Look for the name and number on the base.

DE FOREST RADIO CO.
JERSEY CITY — NEW JERSEY



Cunningham RADIO TUBES

Uniform Quality

since

1915

The high standard maintained in their manufacture is reflected in their quality performance.

Make every tube a Cunningham

E. T. CUNNINGHAM, Inc.
NEW YORK — CHICAGO — SAN FRANCISCO
DALLAS — ATLANTA

No. 280 RADIO BROADCAST Laboratory Information Sheet **May, 1929**

Characteristics of the Ear

THE ear is undoubtedly the most commonly used of acoustical devices and the curves on "Laboratory Sheet" No. 281 illustrate a very important and interesting characteristic of the ear. These curves are known as curves of "equal loudness," for each curve shows the pressure required at different frequencies, to produce sounds of equal loudness.

The lowest curve marked "threshold curve" is sometimes called the curve of minimum audibility and it indicates the pressures which will produce sounds *just audible* to the average ear. This curve shows that at minimum audibility the ear varies greatly in sensitivity, at different frequencies. The upper curve, which indicates how the sensitivity of the ear varies with loud sounds, shows the ear to be almost equally sensitive throughout the entire range of frequencies.

These curves have a definite relation to the reproduction of radio programs and indicate why we seem to lose the bass when the volume is cut down very low and why a loud speaker seems to boom (too much bass) when the volume is increased greatly. Sounds must be reproduced at a normal volume level, i.e., that level at which we are accustomed to hear music, if the reproduction is to sound natural. Even though the intensity of all the tones in the music are amplified equally well the curves indicate that a relatively increased effect on the ear will come from the bass portion if the sounds are too loud and a relatively increased effect from the treble if the sounds are too low in intensity.

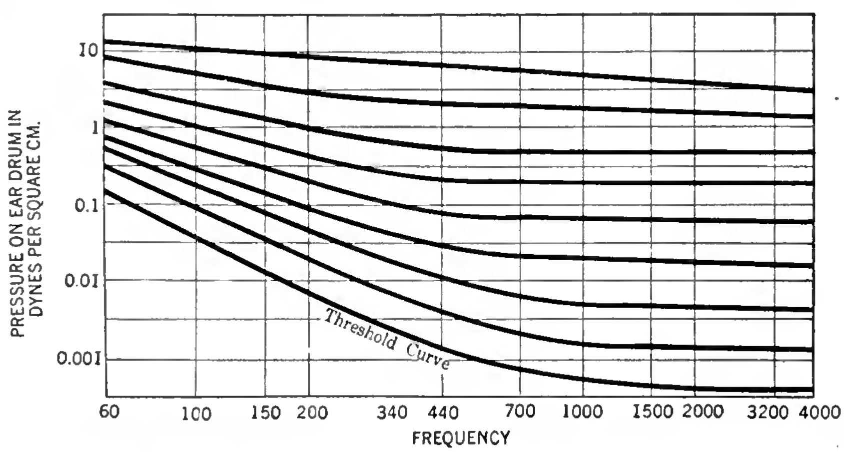
The data from which these curves were plotted was obtained from experiments made in the Bell Telephone Laboratories. The subjects listened to pure tones from a telephone receiver driven by current from an audio oscillator. The listeners compared different tones, two at a time, as to loudness and adjusted the intensity of the two tones so that they were equally loud. All of the apparatus was calibrated carefully and the engineers were able to determine from the setting of the adjustment the sound pressure in dynes per square centimeter.

Some additional data on this same subject will be found in "Laboratory Sheet" No. 109 in the July 1927, issue.

No. 281 RADIO BROADCAST Laboratory Information Sheet **May, 1929**

Characteristics of the Ear

THESE curves show the sound pressures which, acting on the ear, give sensations of equal loudness. They were prepared from data obtained from experiments made in the Bell Telephone Laboratories.



No. 282 RADIO BROADCAST Laboratory Information Sheet **May, 1929**

Amplifier Input Circuits

POWER amplifiers such as are coming into prominent use in auditoriums, theatres, dance halls, etc. may be employed to produce entertainment by connecting the input of the amplifier to a regular receiver, by making connections to a phonograph pick-up so that phonograph records may be played, or, in other cases, by connecting a microphone to the input. The amplifier may be used in any of these ways with practically no change in the circuit—the only change necessary is at the input to adapt the circuit to the source from which the signals are to be obtained.

These amplifiers are arranged normally so that they may be used with either a radio receiver or a phonograph pick-up. Appropriate terminals for these two devices form an integral part of the amplifier. In case the amplifier is designed for use only with a radio receiver, a phonograph amplifier may be used readily by connecting the two terminals of the pick-up across the primary of the first a.f. transformer of the amplifier. However, when it is desired to use a microphone at the input of such an amplifier a change is necessary since the microphone requires direct current for its operation and also the microphone is a low-impedance affair whereas the phonograph pick-up and radio receiver have high output impedances. With a microphone it is necessary that a special microphone transformer be used to adapt the impedance of the microphone to the input impedance of a tube. The primary of the microphone transformer should be connected across the microphone and in series with a few dry-cell batteries or a storage battery, the latter being preferable because of its greater capacity. The secondary of the microphone transformer is connected to the grid of the first a.f. amplifier tube. Microphone transformers are made by most of the well-known transformer manufacturers and complete instructions regarding their use can be obtained easily.

It should be realized that the above notes do not apply to all power amplifiers since some of them are equipped with three sets of input terminals so that either pick-up, radio, or microphone may be used. Obviously, the thing to do when purchasing such an amplifier is to decide what is to be used to supply the input signals and to then make certain that the amplifier under consideration is arranged with the proper input connections.

This sheet is the result of several letters received at the Laboratory from readers who have been under the impression that it is possible to obtain good results by simply connecting microphones across the input of an amplifier originally designed for use with a phonograph pick-up unit or radio receiver.