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BREAKING INTO RADIO SERVICING

Simple Instructions and Procedure
for Starting a Profitable Radio
Business of Your Own

By Robert Eichberg



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RADCRAFT PUBLICATIONS, INC.
99-BR HUDSON ST. NEW YORK, N. Y.

BREAKING INTO RADIO SERVICING

**Simple Instructions and Procedure
for Starting a Profitable Radio
Servicing Business of Your Own**

By **ROBERT EICHBERG**



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NEW YORK, N. Y.

Introduction

Do you want a business of your own—a job you cannot lose? Are you interested in radio? Are you willing to work?

If so, there should be a good place for you in servicing. It is a type of work which permits a man to name his own hours and his own price—a career in which there is no "sameness", no routine. Each job is a new adventure—and, if properly handled, a profitable one.

In this volume, the author, who has taught radio servicing to hundreds of men, takes you behind the scenes—tells you how to get business and give satisfaction—how to go about doing the actual service work—how to cash in on what you know about radio.

THE AUTHOR.

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BREAKING INTO RADIO SERVICING

CHAPTER 1

Can You Become a Service Man?

In order to succeed at servicing, you need certain equipment—not merely tools and meters, but mental, physical and moral equipment.

Before going into the business, take stock of yourself. Ask yourself these questions and then decide whether you are cut out for servicing. It's a business that depends largely upon your ability to analyse; your first job is to analyse yourself.

1. Have you some knowledge of radio?
2. Do you think you know it all, or are you willing to keep on studying in order to keep up with new developments?
3. Have you the patience to bother with details?
4. Do you enjoy tracking down a symptom of trouble in a receiver until you learn the cause—and the cure?
5. Have you business ability?
6. Are you able to "get along with" strangers, or are you too timid or too aggressive?
7. Can you work and work hard without a boss to stand over you?
8. Can you collect the money that people owe you—without hurting their feelings?
9. Are you resourceful?
10. Are you conscientious?

I do not need to tell you what the "right" answers to these questions are. Read them and take an honest inventory of yourself. If you honestly think that you will be a good service man, you will be a successful service man.

Any amateur set builder can take a friend's set and tinker with it until it works better than it did, but to succeed at servicing, you must be able to take strangers' sets and repair them so well that your bill will be paid gladly, and so quickly that you can make a fair profit at a reasonable charge. This book will attempt to show

you not only how to become a radio service man, but how to make good money at it.

GETTING STARTED

First pick your location. If you have not much working capital, you can work out of your home. You will need space for a small work bench, tools and testing instruments. You need not, however, worry about a reception room for your customers; they need never see the shop. Indeed, most of your work will be done in your customers' homes, though sets which puzzle you will be brought back to your shop for further study and the necessary repair work.

You will also need some neatly printed business cards and letter heads. Incidentally, a good form of advertising is to print a "Certificate of Guarantee" (See Fig. 1) in which you warrant the work you have performed (not necessarily the entire set) to be free of defects for a 1-year period.

The phrase "*All Work Guaranteed in Writing*" on your business card and letter head gives the customer faith in you. It brings you repeat business, which is the lifeblood of the service shop. It does not add appreciably to your expense, because any job you do—any new part you install—is rather more than likely to last a year. If something goes wrong in a set that has been repaired, it is not likely to be the part or circuit which has received attention.

YOUR REPAIR KIT

The first essential of your kit is a set-and-tube tester. This can be made in your shop, as shown in a subsequent chapter, or can be bought complete for a few dollars more than it will cost you to build. The tester, with a complete set of adapters to take all tubes and to fit all sockets, is a real necessity. Don't start work until you have one.

The next necessary part is a radio frequency oscillator. There was a time when this instrument was a luxury, but in this

day of superhets which must be peaked for optimum performance, the R.F. oscillator must be in your shop. It is not expensive, nor is it difficult to make, as a glance at Fig. 42 will prove. It should be made with plug-in coils, so that it will obviate the necessity of having a separate intermediate frequency (I. F.) oscillator, and the way that this is done, together with all constants, is described in its proper place.

The case of your analyser should be large enough to hold the minimum equipment which you are likely to want on the job. This includes:

- 1 complete set of tubes for the set you have been called to service;
- 1 small, light monkey wrench;
- 1 hammer;
- 1 pocket flashlight;
- 1 dentist's hand mirror;
- 1 roll lead-in wire;
- 1 ground clamp;
- 1 electrician's knife;
- 1 pair diagonal cutting pliers;
- 1 pair long nose pliers;
- 1 pair 6-inch side-cutting pliers;
- 1 non-metallic screw driver;

- 1 large screw driver;
- 1 small screw driver;
- 1 electric soldering iron; rosin-core solder;
- 1 roll of friction tape;
- Assortment of nuts, bolts, screws, etc.;
- 1 roll solid No. 18 push-back wire;
- 2 non-metallic socket wrenches;
- 1 set small open-end wrenches;
- 1 Scratch Remover kit;
- 1 piece #000 sand paper;
- 1 small, fine file.

This kit will enable you to fix most of the jobs you will be called in on, if you also carry a few of the more popular sizes of fixed resistors and fixed condensers.

So that you do not have to carry a regular store stock of those parts in your pocket, have a circuit manual in your shop and refer to it on every job. A loose-leaf manual is preferable, so that the sheet can be removed and taken with you on your call, to be replaced *as soon as you return*. When you get the call, always ask the make and model of the set that is to be fixed and look up the diagram before you go. It will save you hours of time.

1414 MAIN ST.

MAIN 1423

FRANK JONES
RADIO SERVICE
— GUARANTEE —

The repairs made to the Filter Condensers

in the Radiola Model RAE, 84#16, 439

owned by John Smith

464 Main Street, Centerville, O.

on March 16, 1938 are hereby guaranteed.

Any further repairs necessary in this part of the set within 60 days from the above date will be made without further charge

Signed. Frank Jones

In many cases, your customer will be unable to give you the information; a large number of people know the makes of their sets, but no more. In that case, you will have to go it blind. But even that is not so bad, for there are certain fundamental principles which hold good in every case. The figures on using an analyser will prove helpful.

Don't fool around too much with the set in the customer's home; to do so makes him lose confidence in you. Unreasonable though it is, the average set owner expects you to be a wizard. He expects that you will locate the trouble inside of fifteen minutes and tell him what has to be fixed and how much it will cost. You must not disappoint him—and you need not, as will be told in the chapter on outside jobs.

HOW TO GET STARTED

Every owner of a radio set is a prospect for you. The people with the oldest sets are the best prospects.

If you can make a deal with a dealer, so much the better. This is not so difficult with the smaller dealers in the large cities or with any dealer at all in the smaller towns. The usual arrangement is to give him a very low cost on all servicing to be done on new sets; that is, sets which require servicing within their original free service guarantee period. Sometimes it pays to service such sets without charge to the dealer, provided he turns over all other service calls to you, and gives you a list of owners of all older sets he has sold.

If you charge him for servicing his guaranteed sets, you will certainly have to give him a commission ranging from 10% to 25% on all the other work you get through him. If you do not so charge him, you may get away without paying him such commissions. He will get his benefit out of the money and trouble you save him.

Your local telephone directory, either the regular or the classified, is a good advertising medium and is not too expensive, except in the bigger cities. If you have your listing under your own name, take two other listings in addition. It will cost you only a few cents a month, but it will bring you more business from the people who do not already know you—the new prospects who will become your steady customers if you treat them right. These listings should be

under *Radio Servicing* and *Servicing, Radio*. Use the former if you can afford only one extra listing; if you can afford three, take another under *Repairs, Radio*. People have learned to look in the telephone books when they want almost anything; make it easy for them to find you there.

If it is permissible in your city and your building, hang a sign out, the bigger and clearer the better. All that you want on it is:

**GUARANTEED
RADIO REPAIRING
MAIN 1423**

or whatever your telephone number is, in the most easily-read lettering you can get.

You may have a car; if so it will be very convenient in making your calls and taking sets back to your shop. When you use it for business, put cards bearing the same information in the two side windows of the tonneau; it will be a moving billboard for you.

In addition to this, you may be able to take a small ad at a low rate in the program of your neighborhood movie theater, or (if you live in a small town) in your daily or weekly paper. If the advertising rates in these publications are high, though, you can eliminate this advertising; it will pay only if the week's cost is no greater than the profit you are likely to get from a single service job.

Another tried and true method of advertising is by means of throw-aways. You

CALL	KC		CALL	KC
WEAF	660	F	WBZ	990
WOR	710	R	WTIC	1040
WJZ	760	A	WPG	1100
WABC	860	N	WBIL	1100
WMCA	570	K	WHAM	1150
WHN	1010	J	WCAU	1170
WINS	1180	O	WHBI	1250
WNEW	1250	N	WTNJ	1280
WGY	790	E	WEVD	1300
WLW	700	S	WHAZ	1300
WAAT	940		WDRG	1330
WOV	1130	R	WBNX	1350
WICC	600	A	WNBC	1380
WIP	610	O	WSAN	1440
WPRO	630	I	WHOM	1450
WJAR	890	S	WNLC	1500
WEAN	780	E	WBNX	1530
WELI	900	R	WQXR	1550
		A		
		O		
		I		
		N		
		1		
		4		
		2		
		3		

Fig. 2.

can have a printer run off a thousand or so small cards which list the call letters, wavelengths and frequencies of the most important stations heard well in your area, together with your name, telephone number, and the line about guaranteed servicing. A suggested layout is seen in Fig. 2. Containing, as it does, valuable information for any set owner, it is likely to be kept near the radio. And when the set goes wrong, your telephone number is right at hand.

If you offer a "free inspection service," you are almost certain to get the call. Even if you don't, you are more than likely to get it, for people are notoriously lazy and are apt to call the man whose number is at hand—as yours will be.

(Free inspection offers are frowned upon by the servicing fraternity, nor are they, in the long run, good business, for they often harm the *prestige* of the man who offers them.)

These means can be supplemented by telephone canvassing, door-to-door canvassing, and direct-mail advertising.

TELEPHONE SOLICITATION

If your telephone is furnished you on an unlimited call basis, the first is quick and economical; somewhat more costly if you are charged for each call. In any case, however, it is well worth trying. But know what you are going to say before you take the receiver off the hook; there is nothing worse than hesitating or stammering or groping for words in a canvass of this sort.

Here is a sample conversation, as was published in an article on selling service, which appeared in *Radio-Craft*, the service man's magazine.

Hello Mr. Brown this is Frank Jones, the radio man. I have just started in the radio service business and in order to become acquainted with the people in town I am offering a *free (or bargain) radio inspection*. I will be glad to come to your home and inspect your radio, test tubes, and check the antenna and ground installations. How long have you had your radio, Mr. Brown?

You say your set is a year and a half old? By the way, Mr. Brown, have you had the tubes tested lately? You know that sometimes you can get better reception if you rearrange the tubes in

your set, without buying any new ones. I will be glad to stop up and test the tubes for you and try to get the best reception possible. I am doing this just as a sample of my work, so that when you do need service you know where to call.

Impress upon him that your charges for testing the set are extremely moderate, if any—that, in fact, it may not even be necessary for him to buy new tubes.

Eight times out of twenty-five, he will agree to let you come and look at the set, and about half of these sets will require tubes or some minor adjustments.

The other seventeen persons whom you call will tell you that they know their sets are all right. Do not be persistent for that would annoy them. Instead, simply say,

Well, Mr. Robinson, I am glad to hear that your radio is working satisfactorily and, so that you will know where to call, if you ever do have any trouble with it, I am going to mail you my telephone number and address.

And be sure you send out your card or your throw-away (which should be printed on a light card) the very same day. This will convey the impression that you are prompt—a highly desirable trait in a service man.

THE PERSONAL CALL

As to the door-to-door canvass, that is another matter. Be sure you look neat and clean before you start out; nobody wants to let a grimy or suspicious-looking character into the house. Ring the doorbell, and stand with your hat in one hand and your analyser in the other while you wait for the bell to be answered. Smile pleasantly when the door is opened.

Begin your conversation right off with something free and follow up with another offer. This is a good way:

"I just dropped around to give you one of these station logs to go on your radio." And as you say it, put down your analyser and hand in your throw-away, continuing without a pause, "You see, I'm Frank Jones, and I've just started a radio service shop, and maybe some day, you'll need a little repair work. What make and model set have you, if you don't mind telling me?"

Take out a note book and a pencil. It's ten to one the person to whom you are speaking will not be able to tell you more than the make—if that. So you continue, "Do you mind if I come in and just glance at it? I'd like the information for my records."

If the person says "Yes," assume it means, "Yes, come in"; if "No," that it means, "No, I don't object." In either case, start forward. The chances are that you will be allowed to enter; if not, smile, say, "Well, keep me in mind if anything goes wrong with your set," and leave.

But if you are allowed in, look at the set, and remark that it is a good one. If the owner has any trouble with it, he'll tell you so right away, and that will give you the best possible excuse to test it with a view to fixing it. If not, he'll tell you that, too.

In either case, you want to hear the set and, should it sound less than perfect to you, test it. So if you are familiar with it, ask permission to turn it on; if not, ask the owner to turn it on, so that you will not appear ignorant through fumbling around.

Should it be weak at certain frequencies, should the controls be noisy, the tone distorted, or other symptoms of trouble be present, you can offer to make a test so that you can give an estimate on repairing the fault.

If, on the other hand, it works perfectly, or the owner does not want to switch it on, you will have gotten some idea of its age, and can then bring up the question of tube replacement, much as was outlined in the telephone conversation.

At all events, you will have made a contact, and will have planted your name, business and phone number in your prospect's mind. If you have made a good impression, you will have a customer whenever the set demands attention.

The house-to-house canvass takes time, but the results usually justify it. You need waste few calls, for antennas identify most radio homes, and should you call on a non-radio family, you will be told so promptly.

You can easily know the name of the person living in every house you call upon, simply by getting access to a copy of the city directory and looking up the street and number of every antenna-equipped home that you have noticed. This will enable you to address the prospect by name, which

always flatters people and makes them feel friendly toward one.

DIRECT MAIL

As to the direct mail, make your letters simple, clear, and short. No one is going to wade through a lengthy letter and, unpleasant as it may seem, no one is interested in *you*. People are selfish; they are interested in themselves. For this reason, use "I" as little as possible; the magic words are "*you*" and "*yours*."

Sample letters follow, the first being a follow-up to be sent precisely two weeks after a telephone or personal call which did not result in your being permitted to inspect the set.

Dear Mr. Smith,

Your radio was working satisfactorily when last you spoke to me. Perhaps it still is; I sincerely hope so.

But please do not hesitate to call on me if you need service. An inspection will cost you little, and moderate charges are made for parts and repair work if any is necessary.

You would be surprised to learn how little such jobs usually cost. Often all that a set requires is some minor adjustment, which I shall be happy to make at a purely nominal charge.

It's not really "something for nothing"; it is merely my way of advertising. I want to prove that I am an expert service man whose charges are moderate, and this is the best way to let you know it.

A card is enclosed for your convenience, if I can be of help to you.

Sincerely yours,

Frank Jones.

With that letter you enclose a card like this

<p>You may call to make an inspection of my (Make)..... (Model #)radio set at M. on (Date)..... This does not obligate me in any way to employ you to repair the set. Name Street & No. Town & State</p>

This should be a printed post card, and your name and address should be printed on the other side, with a place left for a stamp. Do not send out stamped cards; it is wasteful and unnecessary. If the prospect is at all interested, he will spend a penny to bring you in.

Do not simply make one phone call or send one letter to a prospect. Keep after him until you get him as a customer. Remember, the constant drip of water wears away the hardest stone, and persistent advertising wears away the strongest resistance.

You are doing business in a highly competitive world, and must take the jobs away from the other service men who are already established. You can do this only by getting the set owners to give you a trial—and you can keep the business you get only if you can do it both promptly and well.

Compete on *service*, not on price. If you have to charge a dollar or two more than your competitors, this will not harm your business—*provided that you do a better job, and that you keep your word*. If you promise to call for a set at 2:00 P. M., be there at 2:00 P. M.—not at 3:00 or even 2:15. Punctuality is a rare thing; it is therefore valued highly.

Likewise, if you promise to have a set repaired by Wednesday morning, have it ready, even if you have to work all Tuesday night to do so. Don't disappoint your cus-

tomers if you want them to remain your customers.

But getting them in the first place is your earliest problem, and you must be systematic to do this, as well as to hold your business.

To do this, you should have two card files of prospects and customers. The first file is arranged chronologically by dates, and should cover three months, with three sets of cards, numbered from 1 to 31.

Make out a 3x5 inch filing card for each prospect you write to, or telephone, or call upon. At the top of this card, write his name, address, phone number, and any information you can get on the make, model, age, condition, etc., of his set.

Down at the bottom of the card, fill in the data on what you have done to sell him, and what results, if any, you have had. (See Fig. 3). Bring the card up to date every time you get into touch with him by mail or by telephone, and each time you do so, move the card back four weeks in the file.

By checking each day's date every morning, you will automatically cover your list regularly. The first letter seldom gets a sale—but the follow-ups get plenty! They are important; do not neglect them. Keep adding to your list, making it a rigid rule to make at least ten new contacts a day—more if you have the time. In this way, you cannot help but build up a worthwhile business if your work is at all satisfactory.

John Smith	RCA-RAE-84
1414 Main St.	
Centerville, O.	Center 0606
Phoned 1/16/38 -	not interested
Wrote 2/14/38 -	no reply
Wrote 2/28/38 -	Reply 3/13/38 -
	call for test

Fig. 3.

Once you have been permitted to inspect a set, make out a second card on it and put it in the alphabetical file, under the owner's name. This card likewise bears his name, address, phone number, and full information about the set, including its condition and what work, if any, was done on it, together with your charges.

It is a good idea to get some flat brass paper clips, and to affix one to the upper edge of each card that represents a job you have done—not merely an inspection, but a job.

Then, when you get another call, you can find the card readily, and have all the information you need right at hand. The reason for putting on the information about how the sale was made is to guide yourself in your future selling; for example, if 75% of your jobs are secured by the house-to-house canvass method, you will want to soft pedal your other methods and concentrate upon this one, as most productive of results.

In your date file, use one clip to mark the cards of the sets you have tested; two clips to mark those of the sets you have serviced. Make a regular phone call to these places once every two months.

In the first instance, simply say,

"Hello, Mr. Smith, this is Frank Jones, the radio man who tested your set (*mention make*) on (*Date*). I was just wondering whether it was still working as well as when I was there. Has any noise developed, or any trouble with weak stations or poor tone? Do you get (*mention the weakest station in the vicinity*) all right?"

If the set is working well, note the call on his card and move it along in the file; if not, make a date to go out and look it over.

If it is a set that you have repaired, your conversation will go more like this,

"Hello, Mr. Smith, this is Frank Jones, the man who repaired your set (*mention make*) two months ago. You remember I guaranteed that job? Well, I'm just calling to make sure it is still satisfactory; I want to make sure that my work is standing up."

If the set is all right, you have made a favorable impression as a conscientious man who takes a real interest in the job and is willing to stand behind his guarantee. If it is not all right, mention the work you did (replacing volume control, erecting new antenna, etc.) and state that you will be out and fix it again without

charge if that part has again proven faulty.

When you get there, the chances are 100 to 1 that it will be some different trouble, not covered by your guarantee, and for which you can fairly charge.

At all events, move his card along in the file for another check-up in sixty days, whether his set is all right or not.

BILLING AND COLLECTING

One great cause of friction between service man and customer is misunderstandings over charges. This is easily avoidable. Make it clear just what your charges are before you undertake a job.

If you do not know how long a job will take and your price is \$1.00 or \$1.50 or \$2.00 an hour for working time, explain this, but agree that your total charges will not run above a certain price. Even though you may have to put in a little more time than you figured on, see that your charge is somewhat *below* the maximum you have given. This makes an excellent impression. Charge for parts separately from labor. You can use any of three methods: (1) Charge for parts at list, with your regular time charge; (2) Charge for parts at a discount—possibly 20%—below list, with your regular time charge; (3) Charge for parts at list, with no—or a nominal—time charge, but with a minimum price for the job. Be consistent; decide upon which method you want to use in order to assure yourself a fair profit, but on a basis to compete with other service men. Then use the same method in all your dealings. The one you use will have to depend upon local conditions—upon what is customary in your city.

Agree with your customer not only upon *what* he is to pay, but *when* he is to pay. Explain that your prices are based upon cash transactions and that you want to be paid when the set is repaired and working in his own home. Then, when you bring it back and hook it up, you and he listen to it, you get your money and give him his receipt and guarantee, and you go.

The receipt is important. Many men starting in business are a little embarrassed when it comes to asking for money. But if you have your bill already written out and in your pocket, you simply take it out after the set has been tried and remark, "Well, I may as well make out the receipt now," and show it to him. If the bill is for an

odd amount, carry change with you. Householders do not always have the exact sum, and you may have to cut your bill or let your customer owe you part of it if you are not ready to change his bills.

Should he not have the money on hand, you can do one of two things: (1) You can refuse to leave the set—and probably lose a customer; or (2) You can smile understandingly and say, "I understand. It's quite all right. I'll be in the neighborhood tomorrow and I can stop by for it whenever it will be most convenient for you." The second method is by far the better. Although you may be gyped once in a great while, you have put him on the spot by making him tell you that he will pay you at a certain time, and you have held him to a date—tomorrow. Don't tell him to mail you the money; that is likely to lead to long delays.

When you get back to the shop, make a record on his card, showing what you did for the set, his degree of satisfaction with the job, what parts you used and their cost, what time you spent on the job, how much you got for the work, and whether the customer stalled in paying you, as above. Refer back to Fig. 4 for these notations.

SELLING EQUIPMENT

In some instances, you can add appreciably to your income by selling radio equipment. This ranges all the way from toy

"home broadcasting" mikes to remote loud speakers, remote controls to complete sets and, of course, includes such customary staples as tubes and antenna outfits.

Tubes are sold on demonstration. One of the most successful service men in the east, Mr. George K. Graham, makes a practice of carrying a complete set of tubes, as advocated earlier in this chapter. Citing his own experience, he says, "When you are in the customer's home, ask how long they have had the receiver, what previous trouble they have had, etc. This will give you a general idea of what may be wrong.

"The first thing to do is to examine the machine in its present condition. Take the customer's tubes out of the set, and place them to one side; then insert the full new set of tubes, explaining to your customer that you always check the set with new tubes known to be perfect. After you have tested the machine and rectified any difficulties that may have been present, take your tube tester and test the customer's tubes, carefully noting any that may be weak.

"Now, with your own tubes in the set, tune in one of the weaker stations. Then remove your tubes, one by one, replacing them with the customer's tubes. If he has any weak tubes, he will immediately see that there is a difference in results with good tubes in the set and the task of selling him new ones will be much lighter. Remember that the manufacturer designed

John Smith	RCA-RAE-84
1414 Main St.	Good
Centerville, O.	Center 0606
Replied to 2nd letter. - Test made 2/15/38	
I.F. out of line - religned at shop -	
delivered 2/16/38 - chg. \$5.00 - pd.	
Satisfied - also sold 2-58's & 1-55.	

Fig. 4.

the set to work with perfect tubes and it is your duty to see that the set has them. Your customer will thank you after he sees the difference in results. As ninety percent of the radio public have been sold on the idea that tubes are the most important part of a radio, you can capitalize the idea and make it pay you handsome dividends.

"The practice of having the tubes with you will bring you many a sale; because sometimes while you are running back to the store the customer gets a chance to change his mind, and may decide to run the set just as it is. Get the job done as quickly as possible and cash in on the interest the customer has in his set at the moment. Later on, something else will capture his attention. Remember the old adage of chain and department stores—'They never come back.' Very few of the customers who say they will call when they can afford the tubes will call you back. But, if you are tactful and persistent, you can sell them the tubes while you are right on the job."

Do not try to sell tubes to a customer unless he really needs them, and above all, *do not take his old tubes away with you* when you leave. To do so may give him the impression that they have some value, or that you are not above selling second-hand merchandise. Leave all old parts with him, or if he does not want them, put them into his wastebasket for him; prove to him that they are of no value to you.

The same goes for old parts, even if the set is taken to your shop for repair. If you replace an old, broken part, bring the part with you when you return the set. Hand it to him and tell him that it is what was causing the trouble. Otherwise there may always be in the back of his mind, some thought that you soldered a joint or cleaned a contact and charged him for something you did not actually put into the set. This seems like a little thing, but it is upon such small details that success is built.

Incidentally, when you take a set out for shop repairs, do not take the tubes with it unless you have tested them and found them all perfect in the presence of the owner. Leave any defective or untested tubes with him. Otherwise he may suspect you of taking good tubes and giving him defective tubes in exchange should you later

tell him that some are not up to standard. People are suspicious; it's too bad, but they are.

MONEY IN ANTENNAS

As you know, there are five very likely spots where noisy reception may be caused: (1) Tubes; (2) Sockets; (3) Tuning condenser contacts; (4) Volume control arm; (5) Antenna-ground circuit.

The latter is most quickly tested, simply by removing the antenna and ground from a noisy set and listening to see whether the trouble stops. If it does, there is usually a poor contact in the antenna and lead-in hook-up or in the ground and ground-clamp circuit. Often, too, the placement of the antenna proper may be such as to make it peculiarly susceptible to interference, or the lead-in may be run close and parallel to electric wiring, and thus pick up man-made static from the line.

If this is so, installing a doublet antenna with twisted-pair lead-in right to the set often cuts down interference appreciably. A zep antenna with either twisted-pair or good shielded lead-in is also very satisfactory. But be sure to use a good impedance matching transformer at the antenna and another between the set and lead-in or (as it is also called) transmission line.

In using shielded lead-ins, don't be afraid of grounding the shield too often. Ground it as close to the antenna end as possible, as close to the set end as possible, and at a couple of places in between if you want to keep the strays out. Though many service men do not bother, it often really does make a difference when a shielded ground wire is used in addition. It seems ridiculous, but it is a fact.

Incidentally, the antenna should be located as high as conveniently possible (at least ten feet above the roof) and at right angles to power lines, if that can be done. The insulators used to support it should be at least three feet from the supports. All joints in the circuit should be soldered, and the wire stretched tightly enough not to sway in the wind. The lead-in should likewise be supported—"Nail-it" knobs every ten or twelve feet will be adequate.

If you think it possible that you may find it necessary to make a new antenna installation, carry with you:

- 2 glass or Pyrex insulators;
- 12 "Nail-it" knobs;
- 1 roll 7/22 or larger enameled antenna wire;
- 1 roll lead-in wire (shielded or twisted pair);
- 1 approved lead-in strip;
- 1 approved lightning arrester;
- 1 approved ground clamp;
- 1 small blow torch.

That will enable you to do the job as soon as you sell the customer the idea that he needs it done. If you have to go back to the shop for the components, he may change his mind and phone you not to bother. Strike while the prospect is hot.

FIXING CONTROLS

You will test tone, volume and tuning controls by manipulating them, to see if they are noisy in certain positions, or when being turned.

Most modern condensers use wiping contacts, and when these become dirty, noise results. Sometimes, if they are very bad, they cause motor-boating. This is cured by sandpapering the contacts, and afterward flushing out any dust that remains with a few drops of alcohol, squirted in with a medicine dropper.

Unless the chassis is so constructed that the condenser may be reached easily, it is best to take the set back to the shop.

TONE AND VOLUME CONTROLS

These become noisy through dirty or corroded contacts, which may be cleaned much like the wiping contacts in the condenser. The same advice applies.

It does not pay to undertake a big job in the customer's home. In the first place, it is not pleasant for him to have a mechanic hanging around for hours. In the second, he is apt to think that you are unskillful if you take more than a few minutes to find the trouble. And it is a fact that you cannot do your best work with someone hanging over your shoulder and watching your every move.

TESTING SOCKETS

This, too, is one of the easy tests to perform. You simply move the tube gently while the set is in operation; if the contact is poor, noise will result.

While bending a socket prong is a small job, it is not good to do it. It is, for two reasons, better to replace the socket with a new one. Primarily, the spring may be weakened, which would mean that the trouble might soon come back. Second, you could not charge a fair price for so small a job.

By the way, you must not undercharge. Remember that you must be paid for your knowledge as well as for your time. The following story is to the point, and is told here because it sometimes can be used by service men whose customers think their price a little high.

The story is:

There was a factory out west that was rushing to fill some orders when one of the big 10-horsepower electric motors stopped.

They called all the mechanics in the plant, but none of them could fix it—and production was at a standstill. So they called a master mechanic from the next town.

He came, looked at the motor, took a small hammer from his pocket and tapped one of the bearings gently, then told somebody to turn on the switch. The motor ran perfectly.

When he presented a bill for fifty dollars, the plant manager went up in the air. "It's ridiculous to charge that much money for just tapping with a hammer," he raved. "I won't pay it."

The master mechanic smiled and said, "Let me itemize the bill. Ten cents for tapping with hammer. Forty-nine dollars and ninety cents for knowing where to tap."

Like this mechanic, you must be paid for what you know, in addition to what you do.

PERSONAL CONTACT

If you want your customers to keep on with you, there are certain acts of courtesy which you must observe. They seem small, but they will prove their importance. Some of them have been given you earlier in this chapter and will not be repeated.

1. Wipe your shoes before you enter the house. No woman wants to clean up after you.

2. Take off your hat before you enter. A gentleman is always respected and can command higher wages.

3. Do not smoke on the job, even though your customer is smoking and

invites you to join him. Let him see that his work is getting your undivided attention. Your abstinence also obviates any danger of your damaging his set or rug with your cigar or cigarette. If he offers you a cigar as you leave, it is well to take it and to show your appreciation. People always like those who appear grateful.

4. Do not go to a job with liquor on your breath. Refuse any drink while at the job. Smilingly explain that you don't drink during working hours, but do not say it as though that put you on a high moral plane.

5. Carry a large piece of paper or cloth with you, and work over it to avoid soiling the home. Clean up neatly when you have finished.

6. Have a large piece of soft heavy cloth (such as an old blanket) with you if you expect to cart a set away to your shop. This will keep the cabinet from being scratched. If you mar his furniture, you will not be called again.

7. Answer all questions seriously and respectfully, no matter how silly they may seem. Make your answers short, and do not get into long explanations or any arguments at all. Don't try to show off your knowledge.

8. Avoid personal remarks. Even well-meant compliments may strike some persons as "freshness." Do your job with as little conversation as possible.

9. Don't get annoyed—or if you are annoyed, don't show it. Let the dog sniff your ankles or the kid come nosing around. You can get rid of either of them simply by mentioning that something is hot, or that there is danger of a shock—and mentioning it just loudly enough for your customer to hear.

10. When you leave, thank your customer for the job, but not too effusively. Express your conviction that the set will be all right, and your hope that you will be called again if anything goes wrong. This can best be done when getting your money and giving your guarantee.

THE RETAINER SYSTEM

There is another service selling kink that works out well, too, but you must be willing to take a gamble. That is the retainer system.

You charge a flat fee of fifty cents a month, to be paid you whether anything is the matter with the set or not. This service is offered only on sets you have checked and found in good condition or, if defective, only after they have been repaired.

The owner pays you 50¢ a month, or can save ten per cent by paying you \$5.50 in advance, and taking a year's contract. The contract covers the one set only, but any time anything goes wrong with it, you repair it at no extra charge.

What's Wrong With Your Radio?
BY J. P. KENNEDY,
Instructor of Radio and Service Engineers.

Profit by Experience
OF 2,000 OTHERS, CALL
J. P. Kennedy's
Radio Service
Ph. 3-2414. 418 W. LaSalle

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If We Can't Repair Your Radio Set
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What's Wrong With Your Radio?
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Ph. 3-2414 418 W. LaSalle

My Grebe set was one of the first electric outfits using an A and BC eliminator. The set has stopped though the tubes light gets very hot. When an eliminator tube gets hot or shows a purple glow around the metal plate ways mount out in the power supply block etc.

What problems are likely to be met with in moving a set to a lake resort and installing it there? First, if it is an electric, the same voltage and frequency current supply you employ in the city must be available. (Vicinity near Grand Rapids, Mich. and Gary, Ind., may be 25-cycle supply instead of the 60-cycle supply.)

Fig. 5. A combination publicity-and-advertising campaign, using small ads with frequent insertion. The publicity can be had only if your local papers will print a radio column under your signature.

The average set of today is a pretty dependable instrument, and you are not likely to have to do more work than the fee covers in any year's period. If you do, the sets which require no servicing should more than make up the difference. Two hundred such accounts, obtainable through the solicitation methods previously described, assure you of business amounting to \$25.00 a week, and it is nice to have an assured income.

The contract need not bind your customer to continue the service for any period of time, for not only would it make him less willing to sign it, but it would not be worth your while to sue him in case he defaulted. It should, however, provide that you are to be paid regularly, and that the contract is void if the customer gets behind in his payments.

A suitable form is:

AGREEMENT

In consideration of the fee of fifty cents (50¢) to be paid me monthly as a retainer, I, Frank Jones, of 123 Main Street, Centerville, Ohio, do hereby contract to make all necessary repairs to the *Radiola 78, Serial number 123456, owned by Mr. John Smith, 1414 Main Street, Centerville, Ohio.*

The fee is to be paid upon my acceptance of this contract, and upon the 6th of every month thereafter.

The contract shall be automatically terminated, releasing both parties from any and all liability should *John Smith* default in any payment, and is also terminable by Frank Jones upon thirty (30) day notice in writing to *John Smith*.

It is understood by both parties that the payment of such monthly fee entitles *John Smith* to any and all necessary repairs to the set described, and that no further charges for labor or parts shall be made. This paragraph, however, does not include radio tubes nor damage resulting to the set when outside of the specified premises, nor if its ownership is transferred, nor to its cabinet, nor to damage due to flood or fire.

Accepted and effective this 6th day of April, 1938.

Frank Jones
123 Main Street
Centerville, Ohio
John Smith
1414 Main Street
Centerville, Ohio

(Note: The contract may be typewritten or printed, the italicised words being filled in by typewriter or by hand.)

As you see, it can be cancelled by either party at will, though you are bound to give any service for which you have been paid. You need not offer the service, however,

DANGER
from
LIGHTNING
Striking your radio aerial eliminated. Special this week only, a regular \$1.50 lightning arrester installed for only \$1.00. Comply with your FIRE insurance requirements. (All sets we have installed are protected.)
YOU CAN LAUGH AT LIGHTNING
If you phone
3-2414
J. P. Kennedy's
RADIO SERVICE

Your Wife and Family Deserve Lightning Protection
Lightning Arrestors Installed
This Week Only
\$1.00
J. P. Kennedy's
RADIO SERVICE
Regardless of where you bought your radio, employ
J. P. Kennedy's
RADIO SERVICE
Phone 3-6297
418 W. LaSalle.

19 Doctors, 12 Lawyers, 4 Presidents
Of local corporations, and many other prominent men, noted for their discriminating judgement, consistently employ
J. P. Kennedy's
Radio Service
418 W. LaSalle
Phone 3-2414
For Economical Results.

Fig. 6. The "scare" ad at the left was less successful than the "human interest" ad in the center, or the "prestige" ad at the right. The small ad was used to keep the name before the public.

except on sets which appear to be in good condition.

SUMMARY

These, then, are the essentials of becoming a service man. With them in mind, you can get started and, if your ability is at least average, should begin making a fair living almost from the very start.

Do not let a few bad days discourage

you; the good days will come, too. And have the ability to forget your business worries after business hours. Do not let the memory of a "crabby" customer make you short with the person you meet on your next call. It takes all sorts of people to make a world, and you will find that the pleasant, appreciative ones far outnumber the grouches.

Run your business like a business, and it will pay you. Neglect it, and you have no chance for success.

Color:	Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
Body	0	1	2	3	4	5	6	7	8	9
End	0	1	2	3	4	5	6	7	8	9
Dot	.0	0	00	000	0000	00000	000000			

Example: Red body with green end and yellow dot means 250,000 ohms.

Color Code for Fixed Resistors

Dear Mr. Smith:

Is your radio working satisfactorily—or is it just working?

Perhaps you have been using your radio for the past six months or so without having it checked. It may be that just a tube or some minor accessory is standing between you and complete radio enjoyment.

No matter what make or model of radio receiving set you own—no matter if it be old or new—your receiver does require periodical attention. Perhaps we can be of service to you; and we will appreciate your consideration.

I am a radio service specialist with sufficient knowledge and sincerity of purpose to insure your complete radio satisfaction. I deal in radio facts instead of radio promises and hopes. I am a capable radio engineer and my radio knowledge is at your disposal.

Let me look out for your radio interests. Call Main 1423. Inspection and advice cost you nothing. Why not call now and have your radio set inspected before trouble develops?

At your service,

Frank Jones.

An introductory letter, such as has been used to start a mail campaign.

Fig. 7.

Dear Mr. Smith:

Have you ever had a person who sold you merchandise or service take a personal interest in your satisfaction after he secured your money?

A few months ago, I had the pleasure of repairing your Bremer-Tully radio.

Not hearing from you since, I presume your set has been working satisfactorily, but really it should be carefully gone over at least once a year. Tubes don't last forever. Improvements are available, such as static modifiers, better known as tone controls, new quick heating tubes and more efficient antenna systems.

I am interested in your satisfaction. Without knowing of these improvements you might be talked into buying a new set, while your present set can be brought up to date at a fraction of the cost of a new machine. I want your friendship and the good will of your friends. This can only be obtained by serving your interests to the best of my ability. In other words, I want to check your radio again, without charge. If you will fill out the enclosed card, I'll be glad to come at your convenience.

Frank Jones

A letter used to revive dormant customers, and "re-activate" them.

Fig. 8.

CHAPTER 2

Expanding Your Business

Operating your own servicing business, as described in the preceding chapter, you will have little expense and few worries. You will not make a great fortune, but by dint of hard work, you should make a fair living if you are capable.

Being ambitious enough to start out for yourself, you will be too ambitious to continue in a small way, but will wish to expand.

Do so slowly!

Do not move from your ten-foot square office-workshop into an elaborate establishment occupying large space in one of the best locations in town. Instead, do your first growing in your original premises.

And do not try to expand until you are getting more work, week after week, than one man can handle conveniently. There is no sense in adding to your expense unless you are positive that doing so will add to your income, almost from the very start.

When you do add a man, make him an employee, not a partner. The laws of partnership are strange and wonderful things, and a dishonest or incapable partner can put you into the poorhouse in a very few weeks.

Choose your employee more carefully than you would choose a wife, for upon him depends your bread and butter.

It is best, when expanding in this way, to take a man who can both sell and service, and to pay him a salary and commission. The salary may be small, but pay it regularly; if it is due on Saturday, pay it on Saturday, for nothing takes the heart out of an employee more than to suspect that there is not enough money in the treasury to take care of him. He cannot do his best work if his mind is beset by financial worries.

The salary should be paid for doing such jobs as you turn over to him. In addition, he can receive a commission on all jobs which he brings in. You may give him a section of the town and let him work it when he is not busy on the jobs you have secured, for example.

I cannot suggest what salary is fair, for that depends upon living costs in your community. The best method is to interview several applicants, learn what they can do, and how much they want to be paid. Decide which is the best man that you can afford, and do not try to beat down his price, for if he is getting what he thinks (and you think) he is worth, he will be satisfied and will work his head off to give satisfaction in turn.

As to the commission, that depends upon what margin of profit you get on the jobs and upon what it costs you to sell, figuring your selling time at whatever rate you charge for service work. Less than 10% of the total fee will seem too small; more than 25% would be too large.

After your man has worked for a few weeks, you will know how good he is, and whether he is better at selling or servicing. If he excels you in either branch, have him put the greater part of his time in on it. If he is no good, tell him that business has fallen off, and that you will not need his services for a while. Then hire someone else.

Incidentally, be neither too fast nor too slow in raising wages. A five dollar a week increase shows a valuable employee that his services are appreciated, but if it comes too quickly other rapid raises will be expected.

Unless you have made some special deal involving a specified trial period at a very low wage, you had better not give the first increase until at least four months have elapsed.

But a good man—one upon whom you can depend at all times—is valuable and can take much of the work off your shoulders, giving you time to devote to building the business bigger.

You must continue to take care of the records and the billing, for it does not do to let any employee, however good, know too much about the inside workings of the business. You had to learn it from the start, so don't make it too easy for him to quit and go into competition with you. You

might better even keep your card file locked away in a drawer in your desk, for such a prospect and customer list is the heart of any business.

CHOOSING A SHOP

Eventually your business will outgrow your first shop, and you will want to take a bigger place. If you have but little capital, an upstairs room in some loft building will do very nicely, as most of your business will still be done by telephone.

If, however, you can spread yourself a little, a store on a busy street in a predominantly residential district will advertise your business to every passer-by, and will bring in customers you might not otherwise reach.

A store-shop becomes essential if you plan to sell sets as well as to service them.

Go into the neighborhoods where you think you are likely to get business. Look at the roofs and see whether many antennas are up, though almost all districts are now thoroughly populated with set owners. Also look at the people and see whether they look as though they can afford to have their sets serviced, and if there are many of them on the streets.

For your purpose, an upper-middle class neighborhood will be best. The very poor can not afford to hire you; the lower-middle are nearly in the same class; the upper-middle spend freely; and the very wealthy are not only few in number but are often slow pay and hard to satisfy.

Having picked your neighborhood, find several empty stores in it and inquire their rents. Decide which two or three are best suited to your needs from the viewpoint of space, layout, appearance of building, and distance from competitors. Then station yourself at each store and count the number of people that pass by it. Obviously, the more people that pass the store, the more will be attracted by your sign and displays.

All things being taken into consideration, then choose your store, but remember that the class of people living in the vicinity will determine the charges that you as the store-owner must fix. If the neighborhood houses a poor class, the charges must be small in order to obtain business. This means you can afford only a very small overhead. If the neighborhood is an exclusive one, then the rates must be increased in proportion, to take care of the overhead.

In large cities, exclusive and non-exclusive apartment houses may be adjacent to one another so that the line of demarcation may not be very great. In general, however, a medium-class section is to be preferred, as stated above.

Before finally taking a store, read the lease carefully. See what the rental includes, such as light and heat; make sure that it permits you to operate a shop as well as a store, and that you are permitted to erect an antenna. There have been cases where service men have rented locations and then found their leases such that they could not conduct their businesses, though they were bound to pay rent for the full term.

FIGURING OVERHEAD

Your overhead includes such fixed charges as light, heat, power, salaries, furniture, fixtures, tools, instruments, stationery, postage, telephone, rent, textbooks and technical magazines, and advertising. These must all be estimated as closely as possible, and figured against the amount of business it is probable the shop will do. In making the latter estimate, you will draw upon your experience as service man, analysing the number of jobs done and the total receipts as compared with your net profits, for a period of several months preceding. You will also estimate the increased business which your expansion should bring you. Be very conservative in making these estimates, so as to avoid over-expansion.

The new costs can be calculated with a fair degree of accuracy, also. You know what the rent and telephone will cost, and can figure that the charges for light, power, etc., will rise proportionately with the amount of work done. You know what tools and instruments will require, and how much they will cost you, and salaries can also be fixed. In calculating these, include a salary for yourself; anything made over and above these charges is your profit.

The tax system being what it is, you will have to keep accurate books. It will pay you to have the system set up by a certified public accountant and checked at least every three months by him. He will often be able to show you how to save enough money to pay his salary.

If you discuss the matter with him before you take your first step, he can frequently be of considerable help to you in choosing

a location, for he does work for numerous enterprises and may be able to tell you how good the location you have in mind really is. Further, he will tell you about what percentage of your estimated gross income should logically be allotted to each expense. For example, not over 20% to the rent is customary, light and heat being included in that amount.

That is, if you estimate that the business will take in about \$500 a month in a given location, the most rent you can afford to pay for it is \$100 a month, for your profits and other expenses must come out of the remaining \$400. Therefore, if you can get an equally desirable place for only \$50 a month, your profits will be increased by \$50.

Figure your equipment as an expense, and do not fail to allow for depreciation. Say that a new test panel will cost you \$60. Consider that money as an investment. If you estimate that the panel will have to be replaced and modernized in a year, charge of 1/12 of the investment each month, putting the monthly \$5 into a fund to be spent for replacing the panel. Do the same with tools and instruments.

Be liberal in estimating your overhead and stingy on trying to keep it low. Most businesses that fail do so because of excessive or incorrectly estimated overhead. Remember that you are in business to make money for *yourself* and not for your landlord, your help, or the telephone company. Incidentally, make it a firm rule that the telephone is to be used for business calls only and obey that rule yourself. Not only do outgoing personal calls cost you money; incoming calls block the line and may prevent some customer's reaching you to give you a job. If your line is always busy, he will not bother to keep on calling you, but will call someone else. Should you be able to afford it, it often pays to have one line for outgoing calls and a separate one *for incoming calls only*. This, of course, is done only if the amount of business warrants.

METHODS OF PAYING HELP

Methods of paying help were discussed briefly earlier in this chapter, when the expansion of your business in your own home was taken up. In the shop, you will have more business and need more help. This brings up new problems. You can pay (1)

straight salary; (2) salary and commission; (3) straight commission; (4) cooperative.

(1) The service men are hired at so much per week, which they receive regardless of how few or many calls they make, or how much or little equipment they sell.

This may sound unfair to the service man, but it really is not. When some firms hire a man, they expect him to do everything within his power to further the interests of the company. They believe that just because a man works late for a few nights, he should not demand additional remuneration, for when legal holidays arrive the man does not work, but receives pay for it just the same. There is a great deal of merit in this reasoning.

Most technical men want an assured salary, regardless of how much or how little they work. Such men are also aware that if they prove valuable to the organization, they will be rewarded by an increase in salary. If they are not valuable, the concern cannot make money, and they will find themselves out of jobs.

With the straight salary method of payment, a man who is exceptionally good receives about the same salary as one who is just passable. A firm cannot expect to have a number of men all of the same calibre. An average of excellence must be struck, and this average must be high enough so that the firm can make a reasonable profit. When business is slow, and it becomes necessary to lay off some of the men, the best ones will remain.

(2) The salary and commission method, outlined earlier, is one of the most satisfactory to employees as well as employer. It has one drawback; an unscrupulous service man will try to add to his income by selling useless apparatus, replacing perfect tubes, and making unnecessary repairs. When this is discovered he will, of course, be fired, but in the meantime his actions will have harmed the company's reputation.

On the other hand, as the service men are paid a small salary and a commission on all apparatus they sell, plus a percentage of the price of each service call, there is an incentive toward getting more work done per man than would be obtained without the bonus. Of course, there are some men who do as much as possible all the time, regardless of the method of payment. Such men, however, are hard to find, and as a consequence, the salary-plus-commission method has been adopted by many concerns.

(3) The payment of straight commission, without salary, looks like a way for the company to save money, but does not always work out that way. True, when business is slack, there is not much going out, but when it is rushing, the commission expense more than equals what salaries would have been, for the rate of payment must be averaged up.

Unless there is enough work to keep the men busy, they will soon quit. Nor are they likely to be "on tap" all the time when wanted, their time not being bought and paid for. It is impossible for the shop to give satisfactory service if it cannot tell when the men are coming in.

A variation is used by some concerns which maintain no men on the regular staff. The names and addresses of men living in widely scattered sections of the town are on file, and when a call is received from a certain locality, the man nearest the service call is informed either by telephone or telegraph. In this manner the customer is assured of speedy service, the firm is assured of a low overhead expense and, last but not least, the Service Man makes money.

Payment may be made on the total sale of equipment plus an additional fixed fee for the call, or a flat percentage of the total job. However, a very large number of competent Service Men must be had on file and these men must be available on short notice. Each man must carry a stock of apparatus either his own or the property of the firm, in anticipation of a reasonably complex service job.

With slight changes to fit local conditions, however, the plan may be made very profitable for all concerned.

(4) The cooperative method is merely a group of service men using a single shop, telephone and advertising campaign, each his own boss, but working under a manager—you.

The service is advertised and incoming calls from new customers are given to the individual service men in turn, so that over a period of time each receives the same number of calls.

You rent the shop and charge each so much a month to cover his share of the rent, advertising, and other overhead or sundries on a monthly basis. In addition, the men are required to buy their parts from you.

The card file system described in the first chapter fills a new need here, for once

a man has serviced a set for a customer, that customer is *his* and is not to be referred to any of the other men. Using a different colored card for each of the service men is the easiest way to keep their accounts separate. The men should not be required to pay you any commission on repeat calls, though you may reasonably demand a percentage on all new customers.

There is another source of profit for you if the men are not completely equipped, but must rent analysers, etc., from you.

In order to keep the shop running smoothly, monthly meetings are held, during which the policy of the company is discussed. Only suggestions may be made to the owner, since he may be considered the manager, but reasonable suggestions are adopted if the majority wishes.

Technical meetings are also held, and the opinion of the various members, concerning problems, customers, etc., are obtained. This has proven to be a very valuable asset in some cases.

With this method every man is his own boss, but if the calibre of his work or his character is such as to be detrimental to the company he may be "fired" by a three-quarters vote.

LITERATURE AND FILES

With new sets continually coming out, it is absolutely necessary for the service man to have a file of circuits on hand. It is also needful for him to read the technical magazines, to keep abreast of the times.

One of the shop's most valuable possessions will be a service manual, containing diagrams and data relevant to a wide number of makes and models of sets. It should be kept in one place and returned there immediately after use, never being taken from the shop. Two or three men might have to use it while another had it out. Some shops have two manuals—one to remain on the bench, the other for use out on jobs. It is a good idea if you have the money to spare.

Get every catalogue, pamphlet, magazine and text book that you can buy or otherwise secure. Many highly valuable booklets are distributed by tube and parts manufacturers either free or at cost. File them either by subject or manufacturer so that they can be found without delay when wanted.

Magazines may be filed complete, or may be cut apart for ready reference. If they

are clipped, the clippings should be put into folders or large envelopes and filed according to manufacturer's names, and set model numbers.

ADVERTISING

The methods of advertising suggested in the preceding chapter still hold good for the larger shop. However, there are some additional means possible.

First, your sign may be electric or neon, to attract wider notice.

Second, your window offers so wide a field for advertising that it shall be given a separate section. However, remember that it should bear in large letters the name of your company and your telephone number.

Third, the company name should be short, should show what you do, should be easily remembered and easily pronounced. *The Krszchnik Radio Company*, for example, would be bad from all standpoints. (Incidentally, watch the law on selecting a company name. You cannot call yourself a Corporation or use the letters *Inc.*, unless you are legally incorporated. Nor, in most cities, can you call yourself *Frank's Radio Service* unless you file a "certificate of doing business under an assumed or trade name" at the city hall or county clerk's office.) It is well to have the firm name begin with *Radio* or *Service*, to make it easier for customers to find in the telephone book. *The Radio Service Co.* or simply *The Radio Servicicers* are two good names.

NEWSPAPER SPACE

In the large cities, newspaper advertising has not been used to any great extent by any but the largest shops. This is mainly because a service man serves only his immediate vicinity, and therefore a city-wide advertisement, while it would be helpful to a large organization, costs too much for the small man. He must adopt a less expensive means of advertising. Certain newspapers have weekly pages or sections that are devoted exclusively to news of radio broadcasting. The man who wants his radio serviced is likely to look there for the nearest repair shop. Such advertising is recommended for any organization, regardless of size, that intends to increase its business. A small box, telling the people what you do, when you do it, and how much

you charge, is sufficient for all practical purposes, though the larger your ad, the better its chance of attracting attention.

Advertising rates in smaller cities are lower, and it is usually profitable for the service man to take space regularly. This is especially true of the weekly and semi-weekly papers.

PRINTED ADVERTISING

Circulars or cards may be sent out by mail or distributed by small boys. The latter are not entirely reliable as, paid according to the number of circulars they pass out, they are sometimes inclined to get rid of a few hundred in the nearest ash-can.

This defect can usually be overcome by assigning each of the youngsters a territory in which he is to distribute and giving a bonus to the one whose territory sends in the most business.

The throw-away previously described is good advertising for the larger shop as well as the beginner, and if printed in large quantities does not cost much.

One service shop uses this as his only method of advertising. The owner has the cards run off at the rate of 20,000 a printing and pays boys from 50¢ to \$1 per thousand to distribute them on Saturdays, holidays, and after school hours. The results are about 2%, which is sufficient to keep him busy all year round. When business is slow, he distributes a large number, but when it picks-up again, he reduces the distribution. In this manner he manages to keep business at an even level without the necessity of constantly hiring and firing Service Men.

Form letters, too, are a good method of soliciting business, as has been said. These can be printed, mimeographed, multigraphed, hektographed or typed. Prices vary with the different methods, and while multigraphing is not the cheapest, it will be found most satisfactory when everything is considered. It can be run in a type that closely matches your typewriter, so can be "personalised" by filling in the name and address of the customer or prospect. Most multigraphing concerns are equipped to handle the whole job for you; you need only supply the list of names, the stationery and the copy for the letter. Some will even help you to write it, if you want.

You must go into these mailings on an appreciable scale, if at all. Send out several hundred letters a week, and use dif-

ferent forms for your follow-ups. While your first letter to a prospect may go unanswered, he is likely to become a customer at the second, third or fourth.

Remember, too, that customers must be circularised as well as new prospects, for it is essential that you hold onto business once you get it. A way in which to follow up your customers has been suggested in the preceding chapter. Letters may be used in addition to (or instead of) phone calls.

WINDOW DISPLAY

Your show window is your best advertisement, for it actually demonstrates your work. It can be used in a number of ways.

First, if your business is principally service, you can put a test panel and work bench right in your window. There is nothing more like better than watching others work, so such a display invariably attracts attention. One highly successful shop in New York does this, having each of its shop men dressed in a uniform working smock, which conveys the idea of scientific efficiency. Of course you have to keep the bench neat if this is done, but it is easier to work on a clean bench, anyway.

One or two small signs in your window are enough—one to say that you do free tube testing and another to state that you guarantee all work, or give free inspections, or make a charge of \$1 or \$1.50 for an inspection at the customer's home. Do not clutter up your window with the ads of local movies unless you get far more than a few free tickets in return. Your window space is valuable; use it yourself.

Should you plan to make most of your income from the sale of merchandise rather than services, the window should contain a well arranged display of receivers and accessories that are attractive, each item having a neat placard indicating the price, make, and a brief description of its function. The window should have enough apparatus in it to afford good selection, but should not be over-crowded.

All items should be arranged so that they are clearly visible from all angles. A window blocked with bargain signs instills skepticism and is not in accordance with good business practice. In a transient location it is good, but where one must depend upon repeat business, it is not advisable.

ILLUMINATION

To attempt to save money by cutting down on window lighting is false economy. There is nothing more attractive than a well lighted window radiating its cheerfulness into the street. Window lighting does more to attract attention than anything else. Once a person is attracted, he is a prospective customer. Poor lighting actually drives away customers. The window should be kept spotless at all times and should give the appearance that business is excellent, although you may be on the verge of bankruptcy.

The same holds true of the internal lighting of the shop. Keep it bright, for a dingy place is depressing, and customers avoid it.

The work room will, of course, have to be well lighted, for obvious reasons.

STUNT ADVERTISING

You can do a number of stunts which will not only advertise your shop but, in many cases, bring in some revenue besides. One such is to buy a truck and equip it with microphone, amplifiers and loud speaker, for rental to political clubs at election time, to motion picture theaters, to stores wishing to advertise sales, and to other businesses.

When not rented, such a truck may be used by the shop, a radio receiver output being connected to the public address (PA) amplifier to reproduce broadcasts of public interest, such as Presidential speeches, sports events, and the like. The shop advertising is put across by having large signs on the truck.

The truck itself may be purchased second-hand, its price depending upon its age and condition. The other equipment need not run more than \$150. However, before making any investment, inquire as to local ordinances governing the use of sound trucks; some municipalities prohibit their use, others require that a special permit be secured. The investment can soon be earned back, for such trucks can be rented out at prices ranging from \$20 to \$50 per day.

The rent of public address systems to dance halls, churches, sports arenas, etc., is a very profitable source of income. The necessary apparatus consists essentially of one or two microphones, a double turntable, phonograph records, an amplifier, loud-

speakers and hook-up cables. All the equipment may be connected by means of plugs and jacks so that an installation can be made in a very short time. Installations of this type bring in as much as \$50 a day, depending upon the length of time the apparatus is to be in use, the size of the room or rooms, difficulty of installation, etc. This phase of radio certainly should not be neglected.

Although phonographs are fewer than they were before the advent of radio, there is a marked resurgence of interest in these instruments. You will not want to carry records as a side-line, as this calls for a rather large stock. But very little space is necessary if you wish to offer a recording service. You can, using a microphone, amplifier, turntable and pick-up, make a good recording of a customer's voice on a pre-grooved record. Such records are made for prices ranging from 50¢ to \$2.50, depending upon their length and the quality desired. Customers use them as "voice letters" to friends in other parts of the country.

In summer beach resorts a very excellent business may be done, and the profit, with the prices quoted above, is enough to make one sit up and think. Sound recording apparatus may also be used to record weddings, speeches, important broadcasts, etc., at special prices.

SHOP LAYOUT

After renting the store, the next problem is one of fitting it up.

If you are running a service shop, you have your choice of two good layouts. In the first, the work bench is in the window, but is fenced off from the body of the store by a railing or counter which divides it from a small reception room, where customers are interviewed. The use of a counter here makes the sale of parts, sets and accessories casier. At the rear, a partition divides off a smaller space used as office and stock room, where files and parts are kept.

A second good layout devotes the store proper to a small office, with the workshop and stock room out of sight behind a partition.

Should your shop be devoted largely to sales, put both office and workshop behind the partition, but keep as much of the stock accessible on the shelves as they will accommodate.

While an elaborate layout is very impressive, the cost is excessive in comparison with the income. When a customer enters a service shop, he does so for the sole reason that he wants his set repaired, and if your shop has a professional air, it need not be elaborate. In a store that specializes in sales, a man enters because he wants to buy something, and it is up to you to sell him. An impressive store is therefore absolutely essential. A neat, well-equipped appearance is all that is necessary for a service station.

Whether your workshop is visible to the customers or not, make it an ironclad rule to keep both shop and bench scrupulously neat. It will pay to do this, because it will result in a great saving of time on every job, as you should know from personal experience. Set a time—usually just before closing—for the workshop to be cleaned in preparation for the next day's work. Spending fifteen minutes in doing this will save each man who uses the shop many times as many minutes on the following day. This nightly clean-up includes clearing off the bench, turning off all switches, and putting each tool and part in its proper place. One man can be assigned the job and paid for it, or you can do it yourself, or it can be made the responsibility of whoever is the last man to use the bench.

PARTS IN STOCK

Your stock will have to depend upon your business, for a small shop cannot afford to carry as much replacement and other apparatus as a larger, busier shop will need.

While it is well to use manufacturers' original parts when replacing I.F. transformers, antenna coils and similarly critical components, such items as fixed condensers, fixed resistors and the like can be of any good make, provided they are of the proper value and approximately the same physical dimensions as those they are used to replace. A.F. transformers, tuning condensers and power pack parts are best when made by the set's manufacturer, as far as the service man is concerned, for they are adapted to mount in the places provided in the chassis, without need for redrilling or cutting.

You will need, therefore, a knowledge of supply houses which can deliver special parts promptly on short notice.

You will also need a complete stock of fixed resistors in various wattage ratings

and all common values, a complete stock of fixed condensers in all common capacities and various voltage ratings, a complete stock of modern tubes, a line of volume controls and tone controls, a complete line of sockets, plenty of push-back wire for connections, some screen-grid caps, several types of antenna kits, some 3-amp. toggle switches, assorted nuts and screws, a cabinet touch-up kit, some dial cable, and other sundries.

Here is a good place to give a bit of advice. When replacing resistors, use a higher wattage one than the one which burned out; when replacing condensers, use a higher voltage one than the one which broke down. It costs you no more, for the customer pays for the parts, and it will be more likely to stand up than the unit which caused the trouble before. In fact, whenever in doubt as to what wattage or voltage rating to use, use the greater. Your ability is judged by your work—if trouble does not recur, you are satisfactory; if a replacement part goes bad, you are considered a poor service man.

Incidentally, there arises the problem of what to do with old parts, salvaged from remodeled sets. My advice is to give them away to some school or boys' club, for the youngsters to play with. Some service men test all such parts and salvage the perfect ones for use in their work, but this is not good practice, no matter how common it may be. If you replace a part, use a new part, charge for a new part and get paid for a new part. If you use a second-hand part, but charge for a new one, you may be found out sooner or later, and your reputation (and, therefore, your business) will suffer accordingly. Using old parts increases the chance of having trouble recur. The only legitimate method is to charge less when using a second-hand part, and even this is not so good, for it causes the customer to think that perhaps you may use old parts and charge for new ones upon some other occasion. That is why I stress again that old parts should be thrown away in the presence of the customer, or given away *publicly*.

As to your portable analyser, one can be bought or built with comparatively little difference in cost.

You need not install all your instruments at first, but can begin with whichever one you need most to take care of your particular class of trade. The others can be added as the need for them increases—and your

finances permit. Diagrams and constructional data appear in subsequent chapters.

SUMMARY

You would not invest your money in a car unless you had been permitted to test it; do not invest your money in yourself (i.e., opening your own business) without testing yourself. This means that you must prove, either by operating your own radio servicing business out of your house, or by working as service man for someone else, that you can sell enough service jobs to keep you busy, and that you can do them well enough to keep your customers satisfied. You must prove this before you sink several hundred dollars in rent, decoration, fixtures, stock and equipment, or you are likely to lose your money.

This book stresses the ways in which you can become an independent service man rather than how to get a job with some service company because independence is every American's goal. If you want a job as service man as a means of gaining experience, that is okay, but work for yourself a while anyway, before you open a shop. Even the best service man cannot make a living unless he has the ability to find customers, just as even the best salesman cannot be a service man if he knows nothing about radio.

You need not be an electrical engineer to be a success as a service man, but you must keep well up on new developments in the set and tube fields. A course in radio at a residential school or from a correspondence school will prove valuable, but you can get along with knowledge acquired from reading text books and technical magazines, if supplemented by experiments or work. The courses, however, get you more knowledge—more quickly and more easily than you can pick it up yourself.

If you combine salesmanship with servicing ability, or can hire men who are expert in your weaker branch, you should succeed.

But remember, do not let overhead eat up all your profits. And do not expect that a large part of your gross income will remain as net profit. Rent, salaries (including your own), advertising, depreciation of equipment, broken parts, etc., will cost money. If at the end of your first year, you have drawn a regular salary, a profit of 5 or 10% above this is encouraging.

CHAPTER 3

Radio Receiver Fundamentals

While you need not be an electrical engineer in order to succeed as a service man, some knowledge of radio apparatus is necessary.

The fundamentals of radio have not changed since the "boom" of the early 1920's, but circuits have become more complicated and tube types so diverse that the student service man must be referred to special works on such varied branches as the design of superhets, methods of automatic tuning, vacuum tubes and their characteristics, et cetera.

In the old days, when the three-element and four-element tubes were the only ones in general use, and sets were predominantly T.R.F. or regenerative, basic knowledge of these circuits, their combinations and variants, sufficed the service man. Now it is virtually a necessity to have a book showing the circuit diagram of every make and model of set likely to be serviced.

None the less, the functions of the various stages in a set must be understood in order to have a thorough knowledge of servicing, and an hour's time spent in familiarising oneself with the principles will save many hours of time later.

PRINCIPLE OF RADIO

An alternating current, when applied to a coil, creates a fluctuating magnetic field, which can be transferred by inductance to another coil not too far away.

Similarly, when applied to the plates of a condenser, an electrostatic field is created, and this may be transferred capacitatively to another condenser not too far away.

The aerial and ground of a broadcasting station are the first "condenser"; the antenna and ground of a broadcast receiver form the second "condenser."

The electrostatic waves radiated by a transmitter are of various lengths, determined by the number of times per second the current used to generate them alternates. The number of alternations (from

zero to "maximum positive" to zero to "maximum negative" and back to zero) is the *frequency* of the station's signal.

Hundreds of stations are on the air; their signals—of many different frequencies—reach the antenna of the radio receiver, which must be provided with tuning units to select the frequency of the station which one desires to hear and to reject all other frequencies.

That is one function of the R.F. and I.F. stages of a receiver.

But there is another function of equal importance, and that is to build up the infinitesimally small energy, which reaches the antenna, up to the point where it can be used to actuate the diaphragm of a loud speaker—in reality, a powerful air-pump!

The waves radiated by a broadcasting station are by no means simple waves of constant amplitude (unvarying height of peaks). They are modulated by audio frequencies.

Audio frequencies are those vibrations lying between about 30 and 14,000 cycles per second—in the *audible range*. They are vibrations in the air—they can be heard.

At the station, they are converted into electrical impulses at the microphone, amplified, and used to shape or *modulate* the radio-frequency wave—the electrical wave which *radiates* from the station.

This modulated wave, then, is picked up on the antenna and built-up—strengthened—*amplified*—in the R.F. stages of the set. But if you put a pair of phones across the output of an R.F. stage, you could not hear the A.F. signal, for it is high frequency A.C., the peaks forming a practically continuous curve, so that the diaphragm of the reproducer unit is not caused to vibrate.

In order to make the signal operate the reproducer, it must be rectified or *detected*, half the wave being cut off, making the current unilateral. A reproducer connected across the output of the detector will convert the audio frequencies from electrical impulses back into sound waves, and per-

mit their being heard, though not very loudly.

It is the function of the A.F. (audio frequency) stages to build up the weak D.C. pulsations in the detector stage output, adding to their strength until they can move the diaphragm of the loud speaker with sufficient force to cause it to set up strong vibrations in the column of air which rests upon it.

That, basically, is the function of the various stages in the radio receiver.

Modern sets, however, are often more complicated than this. In the super-heterodyne, for example, the incoming signal is fed into a first detector (or mixer) stage, and a locally generated R.F. is impressed upon it from the oscillator stage. A *heterodyne*, or beat frequency, results, and this is amplified in the I.F. stages, which are carefully peaked for maximum efficiency at the intermediate frequency thus generated. The second detector performs the usual detector function.

Other modern sets have automatic volume control (A.V.C.), which, by controlling the bias on the grids of the R.F. or I.F. tubes, keeps powerful stations from blasting through, and builds up the volume of the weaker stations. It also decreases fading to an appreciable extent.

A further refinement of this is quiet automatic volume control (Q.A.V.C.), which, in addition to functioning as an AVC, cuts the set's sensitivity except when a carrier wave (i.e., signal) is tuned in. This practically eliminates background noise between stations during tuning.

Automatic frequency control (or A.F.C.) is a still newer feature, which tunes the set electrically to perfect resonance when it has been mechanically or manually tuned to approximate resonance. Such AFC is an essential of any good set with automatic (push-button) tuning.

As the public—your potential customers—grew more critical of the tonal values of radio receivers, other circuits have also come into use. The familiar tone control is the oldest and simplest of these, being merely a method of attenuating the highs and/or lows in the A.F. stages of the set.

There are also circuits which give increased fullness to various frequencies, such as bringing up the bass in soft passages, and so forth. These are not common.

Many higher priced sets likewise afford some degree of high-fidelity reproduction, which is simply a way of saying that they

reproduce a wider range of audio frequencies than do older or less costly sets. As yet, comparatively few stations radiate full high fidelity signals (i.e., all modulating frequencies from about 30 to 14,000 cycles). Sets which tune sharply can not receive all the audio frequencies in this range; those which tune broadly enough to do so sometimes fail to tune out powerful local stations on adjacent channels. This is overcome by adding a selectivity control to high fidelity models.

You will not, however, encounter many such sets in your work, for which you should be duly grateful.

CIRCUIT COMPONENTS

In order to make all circuits function, numerous parts are needed. These can be divided into three general classes—inductances, capacitances and resistances.

Inductances comprise all the coils in the radio set, whether they be antenna coils, IF, RF, or AF transformers, oscillator coils, RF or AF chokes, loading coils or what have you. They are simply coils of wire. If two such coils are placed in inductive relation, so that there is a transfer of energy between them, they become a transformer.

Capacitances are the condensers in the set, whether fixed, variable, or of the trimmer type. The variable condensers are used to tune RF circuits to resonance with the incoming wave, to tune oscillator circuits, and for similar purposes. The fixed condensers may be used to tune other circuits which need not be continually varied, but are more frequently employed to bypass undesired frequencies past a circuit, or to afford an easy path to certain frequencies, or to couple certain circuits. The latter use will be treated at greater length under audio amplifiers.

Electrolytic condensers use a liquid or a non-conductive material moistened with *electrolyte*—a chemical solution. They are normally polarised, offering a high resistance to the flow of direct current in but one direction. Their capacity is usually comparatively high.

Condensers of the trimmer type are variable (usually by means of a screw driver fitted into a slot on the control) but, once adjusted to the correct point, are left alone until re-adjustment (a job for the service man) is needed. They are used to balance

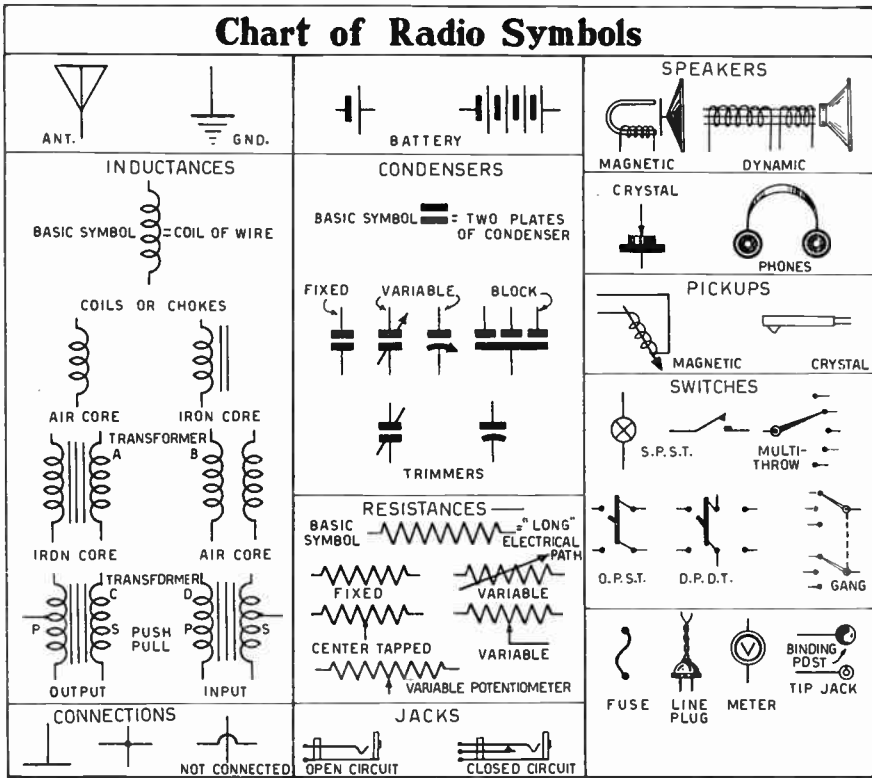


Fig. 9.

the sections of a ganged condenser, to align the IF stages of a superhet, and for similar purposes where a fixed condenser would be employed if its capacity could be determined with sufficient accuracy.

Resistances are resistors, either variable or fixed. The former are used principally to control volume and tone and, in sets with QAVC, sensitivity. They are also used in "mixers" where two or more mikes and/or phonograph pickups are used with a public address amplifier, and to control filament voltage in battery-operated receivers. The latter will be considered shortly. Fixed resistors are employed to "tap off" required voltages from a power pack, and to afford correct bias in various circuits.

BATTERY SETS

The earliest form of radio sets which used tubes, drew the required electrical energy from batteries. Such sets are still in use in isolated areas, where no electric

power lines are available, and for boat and auto radios. Save in the latter rather specialised applications, they are now rarely found, but the fact that, except for power source, they are like AC, DC and AC-DC sets warrants their full consideration.

For the sake of simplicity, then, battery operated receivers will be used to explain the basic operation of circuits, and considerable material will be quoted from a previous book, "How To Become a Radio Service Man," in the present volume. Acknowledgement is hereby given to its author, Mr. Louis Martin.

Fig. 10 shows several means by which the aerial of a set may be connected to the first R.F. amplifier tube. At A, a resistor is connected directly between the aerial and ground. When a current of electricity flows through a wire, this wire offers a certain amount of opposition or resistance to the flow of current. Silver, for instance, offers the least resistance of any metal, copper offers the next-least, while such metals as iron, german-silver, and carbon offer

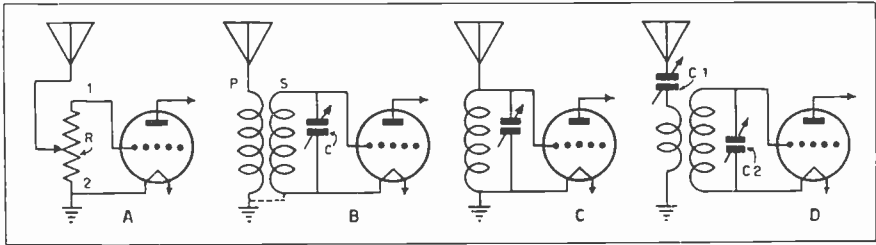


Fig. 10.

greater resistance than either silver or copper.

All signals "on the air" flow through the resistor to the ground. When the arm is at point 1, the signal is greatest and when it is at point 2, it is weakest (nearly zero), as it is obvious that the more resistance there is in either branch of the circuit, the less current will flow through it. In this case the branches are from the switch to 1 or to 2. By moving the arm between points 1 and 2, the strength of the signal may be varied at will. It will be noticed that this means of coupling (transferring energy) has no provision for separating one station from another. This is its main disadvantage, but it provides a very easy and effective means of varying the strength or volume of a signal after it is once tuned in.

At B, is shown another means of transferring the broadcast's station energy to the first R.F. tube. The energy of the station flows through the primary coil P (the primary is the coil to which energy is applied) which sets up a voltage, exactly similar to the broadcast wave, across coil S, which is the secondary (the secondary is the coil from which energy is taken).

A tuning condenser C, connected across S, tunes the circuit to resonance with the incoming wave, and thus selects the station desired. This method has the distinct advantage that only the desired signal gets past the first tube, assuring a degree selectivity. (Selectivity is the ability of a set to separate one station from another.) This circuit, with slight modifications, is used in the first stage of many modern receivers.

At C, a single-circuit tuner is shown. At one time, this arrangement was considered the most sensitive available. It still is used occasionally in the first RF stage, but because of its direct connection in the antenna circuit, it is very broad (receives one station over a large portion of the tuning dial).

At D, the condenser C1 is in series with the aerial and coil P. It is used when the aerial is very long and an additional control is not a disadvantage. Many present-day short wave sets have such a circuit.

Which of the above types one should use depends upon the taste of the particular designer, but it would be well for the experimenter to build a small receiver and try each for himself.

THE DETECTOR

It has been previously stated that in order for a signal to be heard, the speech or music must be separated from the carrier wave. (The carrier wave is that portion of the signal upon which the speech or music is superimposed. The speech or music is referred to as the audio-frequency signal.) Vacuum tubes are used for that purpose—the detection of broadcast signals. Without a detector, no signals could be heard regardless of their strength; therefore, it is an essential part of every radio receiver.

In its simplest usable form, the detector may be a crystal of galena, iron pyrites or even a chunk of coal! One contact to it is well made electrically; the other is an extremely light contact, generally made with a thin wire called a *cat's whisker*. Figure 11 shows, at A and B, two types of simple crystal circuits.

You will seldom, if ever, be called upon to service sets of this type, but the construction of one will be a good first step, for practice. The coil in A and the secondary in B are 60 turns of No. 20 dcc wire wound on a form 2 inches in diameter. The primary in B is 30 turns of the same wire, wound on the same form and in the same direction as the secondary.

Vacuum tubes, being far more efficient, sensitive, and stable, and furnishing infinitely greater output (signal strength) than crystals, have replaced these more primitive

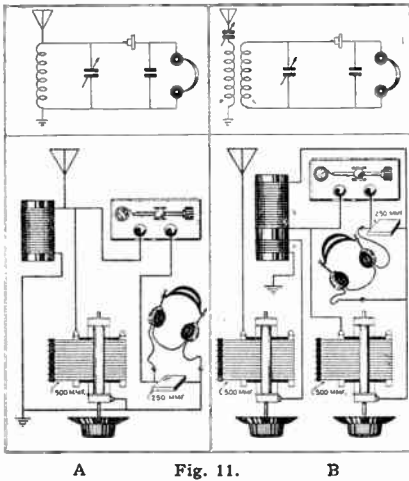


Fig. 11.

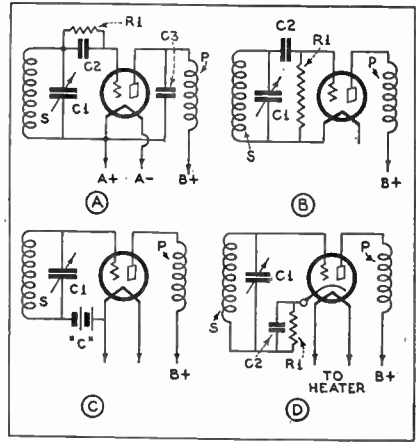


Fig. 13.

devices everywhere, save in a few sets still manufactured and sold, principally to children.

You will run across an astonishingly large number of battery-operated receivers in your practise, and as you progress in this volume, you will find data on various circuits.

First, however, we will consider some

simple tube detectors, as shown in Fig. 12 and 13. A, B, and C show the connections for battery-operated tubes; D is a common connection for A.C. tubes of the heater type, such as the 27.

At A the tuning coil, which may be the secondary of an antenna coil or an R.F. transformer, is connected to the detector tube through a condenser C2 and a resistor

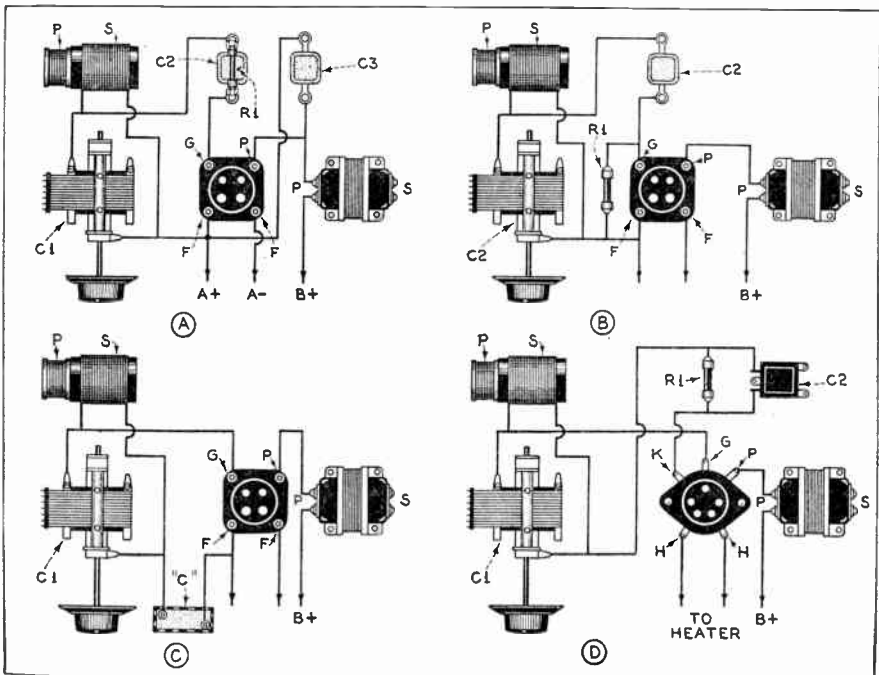


Fig. 12.

R1. This method of connection is known as the grid-leak and grid-condenser method, so called because during the operation, an electric charge is accumulated in condenser C2 which leaks off through resistor R1. This method of detection is one of the most sensitive known and reigned supreme for many years. It has several disadvantages which restrict its present use. It is sensitive on weak stations, but on the stronger ones it distorts considerably. The tone quality depends upon the value of C2 and R1; with use, the values change, especially with poor parts, and the receiver suffers accordingly. With present-day highly sensitive receivers, the signal strength applied to such a tube would give results that are unrecognizable from the original.

At B the same arrangement is employed but the grid-leak R1 is connected from grid to filament instead of across the grid condenser.

The value of C2 is usually about .00025 mfd. and R1 about 2 megohms (2 million ohms) in both A and B.

At C is shown an entirely different detector circuit. A small "C" battery is so connected that detection of the signal takes place without the use of condensers or resistors.

At D is shown a variation of the method used at C, which is called a power or linear detector. The quality of output is better for strong signals than that for the methods described above and therefore is more suitable for present receivers.

THE AUDIO AMPLIFIER

An R.F. amplifier is necessary in order to increase the sensitivity and selectivity of a receiver, and a detector is used for obtaining the signal to be heard from the broadcasting station wave. In order to make the signal to be heard as loud as desired, an *AUDIO AMPLIFIER* is necessary.

A complete discussion of audio amplifiers will be given in the latter part of this book, but suffice it to say that it is undesirable to use too many stages of such amplification since distortion is bound to occur. In fact, few present receivers use more than two stages of audio amplification fed from a power detector of the type described above.

To the man who knows a little about electricity, theory is not essential in order to service some receivers, so that more

time will be devoted to a discussion of the various parts of a radio set, and, which is far more important to the beginner in radio, how one may recognize one part from another.

Practically every diagram intended for use of service men is a *schematic* diagram. Complicated as these may appear to the beginner, they are far easier to read when one has had a little practice, for they show the circuit stripped to its essentials. Each part is shown in the same form at all times, with no confusion due to different shapes used by various manufacturers. Fig. 9 shows the more frequently used symbols.

On the next page there is a figure devoted to tubes, of which there is now an almost infinite variety. Refer to Fig. 14 for a chart showing their model numbers and uses.

New models of tubes are produced almost monthly, and it is a good plan to write to the leading tube manufacturers, requesting that you be put on their mailing lists, to receive data on all new tubes, as they are put on the market.

Incidentally, many leading manufacturers of resistors, condensers and inductances issue bulletins regularly, in which servicing tips and similarly useful information are given. These bulletins will be sent you on request. But be sure to mention that you are a service man, when writing for them. Use your business letterhead, and you are more likely to receive prompt attention.

THE VACUUM TUBE

The simplest tubes in general use are the three-element tubes, consisting of filament, grid and plate, encased in an evacuated glass bulb and mounted in a base which is provided with prongs, to make contact in a socket. Such tubes are used in certain stages of most battery-operated receivers, and in some electric (line-powered) sets. An explanation of their functions will give you an idea of what goes on in this important part, which has frequently been termed "the heart of the radio set."

The tube, in England, is called a "valve"—a really excellent description of its function. The filament is composed of a metal which, when heated by the passage of an electric current (the "A" supply), emits electrons (tiny "particles" of negative electricity). Being negative, the electrons are attracted by positive charges—and the plate of the tube is maintained positive by means

of the "B" supply. If no other factors entered into the tube operation, there would be a constant, uniform flow of electrons from the filament to the plate; consequently, the current flowing in the circuit (the plate current) would be uniform. It would not vary at any time—and the diaphragm of the loud speaker would therefore fail to vibrate.

But the tube has a grid interposed between the plate and the filament. If this grid is negative, it repels the electrons, greatly retarding their flow. If it is positive, it gives them added impetus on their journey to the plate. Thus when an incoming signal is fed to the grid of the tube, it controls the potential (charge) of the grid. As a slight change in grid potential means a comparatively great change in plate current, the tube acts as an amplifier, as well as fulfilling its function as a detector, even when but a single tube is used in the set.

There are two types of three-element (or triode) tubes. The first, using a filament, is a direct heater; that is, the element which is heated by the passage of the current is made of the substance which emits the electrons.

The second type is the indirect heater. It has a heater element much like the filament of the tube just mentioned, save that it is not of an electron-emitting material. Instead, it is placed close to the electron-emitting substance, which is called the *cathode*. The heater heats the cathode, which then emits electrons, just as the filament did in the tube previously described.

The reason for the use of this extra component in the tube is simple. When tube filaments are heated by batteries, the current is smooth—it does not fluctuate. Therefore, the rate at which the electrons are emitted is constant. But when the tube is heated by current from the A.C. or D.C. lines, the current, in the first instance, fluctuates through a complete cycle 60 times a second; on D.C. line operation, there is a different irregularity, known as commutator ripple. Either of these currents, if fed directly to the electron-emitting substance, would cause the electrons to be given off in accordance with the current, and this irregularity of emission would produce a terrific hum. However, the cathode in the tube has a characteristic known as *thermal lag*; it does not get hot so rapidly nor cool off as fast as does the heater. It therefore maintains a fairly constant tem-

perature, and emits its electrons in a steady, non-fluctuating stream. (Fig. 19).

For this reason, the earlier stages of electric (line-voltage operated) sets all use heater-type tubes. The hum is so low in relation to the built-up signal strength, however, that direct heater tubes are frequently used in the last audio stage.

Before going on to the more complex, but more efficient, tubes which contain more than the three essential elements, a further exposition of the three-element tube is not amiss. A cutaway view of a direct-heater three-element tube in shown in Fig. 15A, a plan view at 15B, and a diagrammatic circuit at 15C, while 15D illustrates the socket in which such a tube is used.

The filament or *cathode* is the V shaped thread of metal, the grid is the circular or oval arrangement of wires, and the plate or anode is the piece of sheet metal surrounding the other two elements. The grid and filament together form the input circuit while the plate and filament combined form the output circuit; the signal is fed into the tube via the grid and filament, and is fed out from the tube via the plate circuit. All apparatus connected to the input of the tube is called the *external input circuit* and all apparatus connected to the plate is called the *external plate circuit*. In most cases it is quite clear that only the external circuits are under consideration, so they are usually referred to merely as the plate circuit or the grid circuit.

The filament is heated by means of a battery or transformer which is connected to the tube through prongs at the base of the tube. In order to facilitate connections

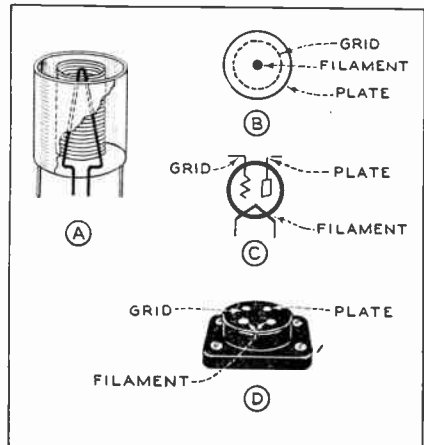


Fig. 15.

and to support the tube, a socket is used which is similar to that shown in Fig. 15D. The battery is connected to the socket as indicated in Fig. 16A and shown schematically in 16B. The "A" battery is the one that heats the filament; it is connected in series with the filament through the resistor R which is used for regulating the filament voltage to compensate for variations in the battery's charge. When a transformer is used, as in Fig. 13D, no rheostat is needed. A.C. circuits, being somewhat more complex than battery-operated, will not be considered in detail until a later chapter.

The external grid circuit must be connected to the grid and filament of the tube as stated above; the socket connections are shown in Fig. 17A, a schematic diagram in Fig. 17B. If an antenna and ground and a pair of telephone receivers be connected as shown in dotted line, a one-tube receiver will have been built.

Particular attention should be paid to the fact that there is a "B" battery inserted in the circuit. In order for a tube to function properly, it is necessary always to connect a voltage between the plate and the output circuit as indicated; furthermore, the plate should always be connected to the positive side of the battery and the filament to the negative. The tube will not function if the "B" battery connections are reversed and if the "B" battery is connected where the "A" battery should be, the tubes will be immediately destroyed. The polarity of "A," "B" and "C" batteries is one of the first points to check when trouble-shooting on a battery-operated radio set.

Advances in the vacuum-tube field have brought forth the four and five element tubes. The physical construction of the four-element tube is the three-element described above, with the exception of the insertion of another grid, interposed be-

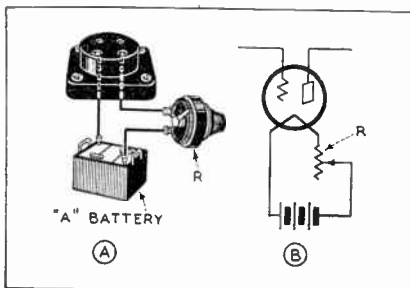


Fig. 16.

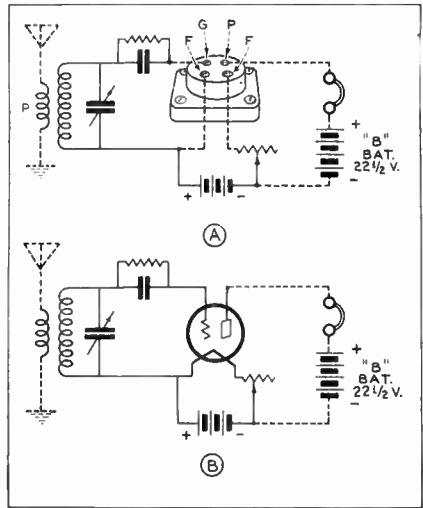


Fig. 17.

tween the input or control grid and the plate.

In a three element tube, the grid is placed between the filament and the plate so that all the electrons must pass through the grating of the grid in order to reach the plate. When the grid is made positive it increases the flow of electrons to the plate and when it is made negative, it decreases the flow of electrons. It is clear, then, that the condition of the grid (whether it is positive or negative) determines the amount of electrons flowing to the plate. Because of this controlling action of the grid which is connected to the input circuit of the tube, it is called the control grid. In other words, that grid in the tube which is connected to the input circuit is called the control grid, regardless of where the other grids connect.

To aid the tube, an initial voltage, obtained by means of a battery or the voltage drop through a resistor, is applied to the grid. This voltage is very important and determines whether the tube is an amplifier or a detector. This voltage is called the "C" voltage or "C" bias.

The arrangement of the elements in a screen grid tube is depicted in Fig. 18A, and its schematic circuit in Fig. 18B. The tube is so constructed that the control grid connection is made to a small cap on the top of the tube, the *screen grid* (between the control grid and the plate) connection being made to the same prong of the socket as the input grid of the three-element tube.

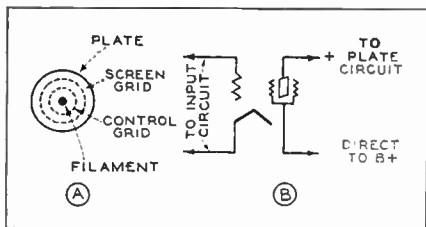


Fig. 18.

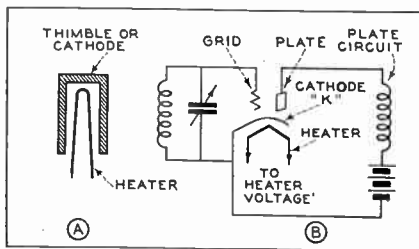


Fig. 19.

Such tubes are called four-element tubes, or *tetrodes*.

Like the triodes described before, these tetrodes are likewise produced in A.C. models, with heaters separate from the cathodes.

This heater may be used in three-, four-, or five-, six-, or seven-element tubes depending upon the design. Five-element tubes are constructed much the same as the four-element described above, with the addition of a third grid internally connected to the filament. Its presence, therefore, does not directly change the outline above. Other new tubes contain additional grids, or, at times, two complete sets of elements inside the same bulb. Their adaptation can be understood best by studying the particular circuits in which they are employed.

From the above, it will be realized that no extensive theoretical knowledge is necessary in order to construct or service some receivers because the fundamental circuit is similar in most receivers. This point will be discussed further later on.

The purpose of the vacuum tube, as stated, is to amplify or detect a signal, depending upon its connections. It will be instructive now, to discuss the R.F. units used in radio sets and then the A.F. units used in audio work.

R.F. AMPLIFIERS

Some degree of signal strength is necessary to cause a tube to function as a detector, and not every signal reaches the antenna with sufficient strength to cause this detector action to take place if fed directly into a tube.

For this reason, some form of radio frequency (R.F.) amplification is used. R.F. amplification builds up the strength of the signal before the incoming frequencies are fed into the detector stage. One or two such stages are common in all present sets, except the midgets. They are employed

even in the majority of the super-heterodyne receivers.

Fig. 20 shows a schematic diagram of a battery operated two stage R.F. amplifier using triodes, which directly precedes the detector tube. All filament and "B" battery connections have been omitted for the sake of simplicity but they are given in another section of this book.

An examination of the input circuits (the circuits which are connected between grid and filament) of the tubes will show that they are all somewhat similar to the aerial circuits previously discussed. If a type B (Fig. 11) antenna coil is used, the primary P is usually wound with about 10 turns of No. 22 wire either at one end or spread over the entire secondary. The secondary S is wound with about 60 turns of the same size wire on a 2 in. diameter tube. The only thing that connects the primary to the secondary is air, no iron being used in R.F. transformers. Fig. 21 shows a pictorial layout of a typical R.F. transformer, connected in the one-tube set described above. The transformer is light, small, and is usually mounted above and away from any metal parts of the set. In some cases it is enclosed in a can or shield in order to isolate it electrically from the rest of the receiver. In this respect, R.F. transformers are easy to recognize. They may vary slightly in size or shape, but their general appearance and the notable absence of iron distinguishes them from any other parts of the set.

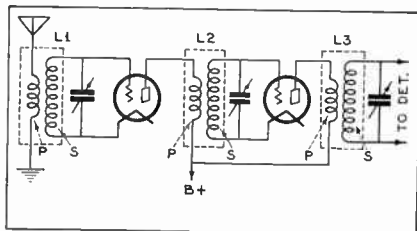


Fig. 20.

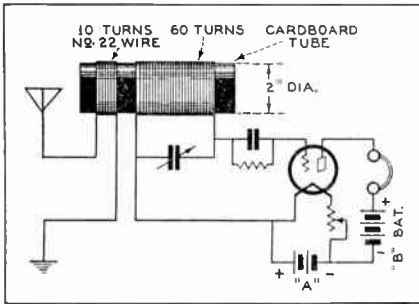


Fig. 21.

The primaries P of transformers L2 and L3 look exactly the same as the antenna coil L1 described above, with the exception that the numbers of primary turns are different (usually not quite as many). These coils may be purchased in sets of three and are accurately matched in order that the tuning condensers, connected across each, may be "lined up."

THE TUNING CONDENSERS

The tuning condensers used in radio work consist essentially of a set of spaced stationary plates (called the *stator*) between which are meshed a similar set of rotary plates (known as the *rotor*) as shown in Fig. 22. As the shaft is turned in one direction, more and more of the plates mesh and the greater the capacity; the opposite is true when rotated in the other direction. Connection to the grid of the tube is made from the stationary or stator, and to the filament from the rotor. Such tuning or

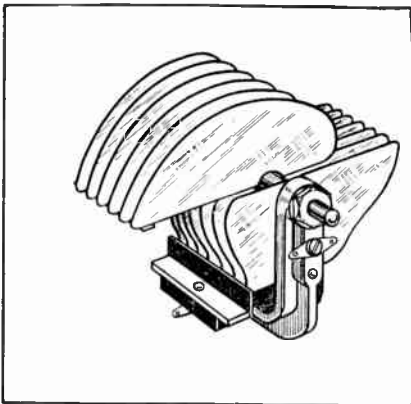


Fig. 22.

variable condensers are always associated with R.F. coils in any radio set.

RESISTORS AND FIXED CONDENSERS

The small fixed resistors and fixed condensers (non-variable, they have a fixed resistance or capacity) are the same in appearance, though they may differ in value, regardless of where they are used. Consequently, besides stating that the resistors are usually an inch or more in length, one-quarter inch in diameter and of different colors (see standard RMA color code reproduced elsewhere in this book) little need be said of them here. They are usually made of carbon or else are wire wound: either may be used, depending upon the

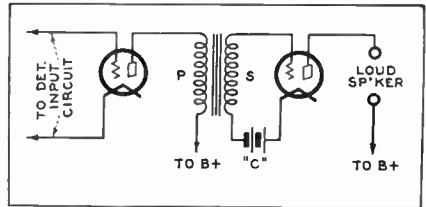


Fig. 23.

type specified by the manufacturer. Wire-wound resistors are used where appreciable current must be carried.

The fixed condensers are usually about one inch square, have two metal lugs, one projecting from either end for connection, and have their capacity stamped on the face or are color coded, like the resistors.

A. F. UNITS

The mode of connection of A.F. units is much the same as for the R.F. units described above. A.F. transformers are used to couple one tube to another in the manner shown in Fig. 23. The similarity is apparent. No tuning condenser is necessary across the secondary of this transformer since the station has been tuned-in by the R.F. unit, and it remains for the A.F. unit to amplify all of the signal that is applied to it by the detector.

Such transformers are usually wound on an iron core as shown in Fig. 24. The primary is wound with several thousand turns of very fine wire, just a little thicker than a hair. Directly over the primary

and insulated from it, is wound the secondary which consists of about two or three times as many turns, and is wound with still thinner wire. Such units cannot be constructed at home with the expectation of securing satisfactory results. An A.F. transformer is generally completely covered with a metal shield. The various terminals P, +B, G, and F, are clearly marked in some models. In others, a simple test on the ohmmeter will reveal which winding is the primary (lower resistance) and which the secondary (higher resistance). No trouble should be experienced in recognizing this unit. Its representation in diagrams is always accompanied by thin, straight lines indicate the presence of an iron core.

CHOKE COILS

There are two types of choke coils, usually just called *chokes*. One is the R.F. choke, which does not permit the passage of radio frequencies; the other, the A.F. choke, which blocks audio frequencies from passing. Each has its distinct uses. R.F. chokes are generally used in the R.F. or detector stages, to keep R.F. components from "leaking through" circuits in which they are unwanted. Such chokes are also frequently used in "line noise filters," to keep R.F. interference out of the set.

A.F. chokes are used for certain types of coupling between audio stages, and are widely employed in power packs, to smooth out the audio components of the rectified current. Sometimes the field of a dynamic speaker is used as an A.F. choke—but more of that subsequently.

The *henry* is the unit of inductance. A.F. chokes have iron cores which greatly increases their inductance; they usually rate from 10 to 30 henries. R.F. chokes are smaller and have an air or wooden or some other non-metallic core. As usually used, their inductance is about 1/1000 that of the common audio chokes; i.e., about 10 to 30 millihenries.

CONSTRUCTION OF R.F. CHOKES

While good R.F. chokes can be bought for a few cents each, it is sometimes necessary to make one in an emergency.

An R.F. choke consists of several hundred turns of very fine wire. If a 1-inch form is used, about 250 turns of No. 30 dsc

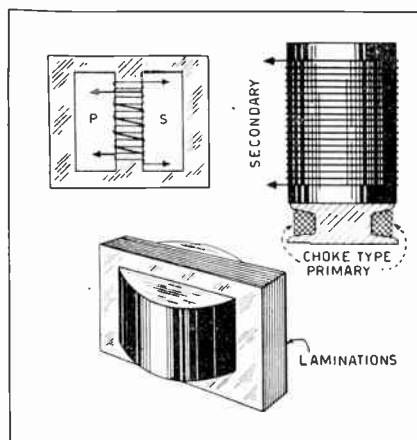


Fig. 24.—Left, Windings of A.F. Transformer; Right, R.F. (choke type) Transformer; Bottom, A.F. choke.

wire will be adequate for most circuits. The necessity for an R.F. choke is always indicated in the diagram of the set.

CONSTRUCTION OF A.F. CHOKES

Audio-frequency chokes are heavy, massive affairs wound with several thousand turns of enameled wire on a thick (about one square inch in cross-sectional area) core. It, too, has two terminals from which connections may be made, but there can be no confusion between this and an R.F. unit. If confusion does arise, it is between an A.F. choke and transformer. One may tell the difference between them, however, by the fact that a choke has but two terminals while the transformer has 4 or 5. Also, of course, a reference to the circuit diagram of a receiver shows where each unit is connected. A pictorial view of a typical A.F. choke is shown in Fig. 24. The method of connection will be described during the course of the book.

THE POWER UNIT

Ever since the advent of electrically operated receivers, there must be connected or housed in the set certain pieces of apparatus that are used to take the place of the "A" and "B" batteries formerly used. These pieces of apparatus, when built in a unit, are called the power unit or *power pack*.

Since ordinary radio sets require "B" voltages of from 20 to 500, means must be

provided to raise the ordinary 110-volt light-lines to the required value. To accomplish this, a device called a power transformer is used. In its essential form it consists of a large core of iron wound with several coils of wire. One coil connects directly to the light line, and therefore is called the primary. Another winding, with many more turns of finer wire, is wound directly over the primary. From this winding the high voltage necessary for the "B" supply is obtained, for if a secondary has three times as many turns as its primary, it delivers thrice the voltage at 1/3 the current (amperage). This winding is called the high-voltage secondary. To supply the voltage necessary for the heaters of certain tubes, smaller windings (called low-voltage secondaries) are used. A pictorial representation of these windings is given in Fig. 25A and a schematic diagram in Fig. 25B. In certain cases a tap (another word for a connection) is taken from the center of the high voltage winding as shown.

Now that the proper voltage has been obtained for the "A" and "B" supply, the next problem is to convert the high voltage A.C. into high voltage direct current (D.C.). This is accomplished by means of a rectifier tube. A power rectifier tube, unlike the three element tube previously described, has no grid—just a filament and a plate. The filament is lit by means of a low-voltage secondary of the power transformer and is connected as shown in Fig. 26A.

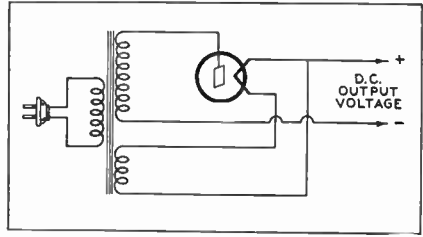


Fig. 26A.

In its normal operation, the voltage across the secondary of the transformer changes from positive to negative 60 times per second. Thus, 60 times a second the plate of the tube is positive and 60 times a second it is negative. As you learned when considering the triode, a positive plate is needed for current to flow in the tube. The result is that the voltage has one part of it chopped off—that part that is applied to the tube when the plate is negative. Since

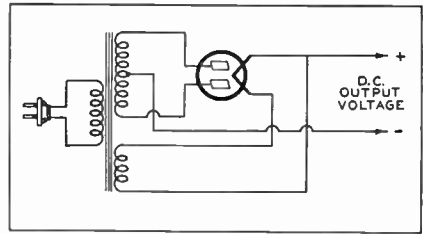


Fig. 26B.

only half of the voltage is used, the circuit is a half-wave rectifier.

To utilize all of the voltage that is applied to the tube, a slightly different type of tube is generally used. It has two plates instead of one—and is connected as indicated in Fig. 26B. The outside terminals of the high-voltage secondary connect to both plates of the tube and the center-tap is the negative of the D.C. voltage output. With this arrangement, when one plate of the tube is positive, the other plate is negative, and vice versa. With this connection, both halves of the voltage are used.

THE FILTER UNIT

Since the output voltage of the rectifier varies in strength, some means must be used to smooth it out, or make it unvarying in amount, so that it is equivalent to the batteries which it is replacing. Otherwise

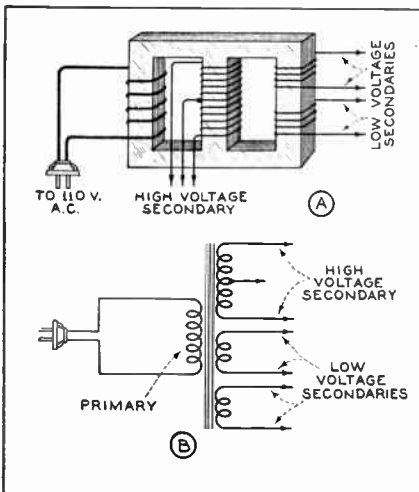


Fig. 25.

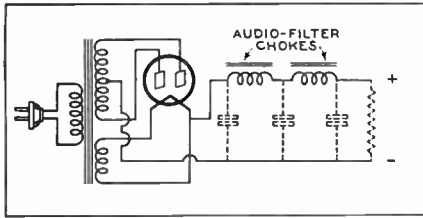


Fig. 27.

a loud hum would be heard in the loud speaker. In the discussion of A.F. chokes, it was stated that they are used whenever A. C. or varying currents are to be suppressed. They are, therefore, used to advantage as shown in Fig 27. To further increase the smoothing or filtering action, large condensers are connected as shown in dotted line. In order to make the voltage output stable, a resistance is connected from the "+B" to the "-B" as shown dotted in the same figure. This resistor is called the bleeder resistor and taps taken from various points along its length provide different voltages, between 0 and the maximum provided by the power pack. If the total voltage is 250, that at the mid point will be 125, and so forth, in proportion.

The entire action may be graphically illustrated by reference to Fig. 28, which is self-explanatory. With the above apparatus, it is possible to obtain an output which is substantially the same as that obtained from batteries.

THE LOUD SPEAKER

It is clear that if sound is to be heard, there must be some unit present in the radio

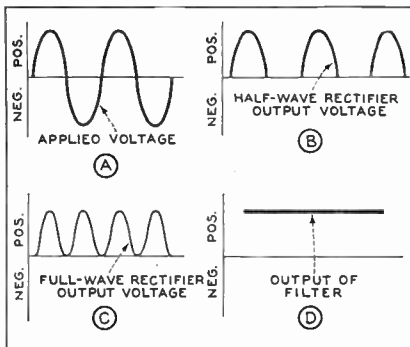


Fig. 28.

set to generate the sound and emit it. This is the purpose of a loud speaker.

Sound is nothing more than a motion to and fro of the air, between a vibrating body and the ear. The rapidity with which the air moves determines the pitch or frequency of the sound, while the amount of air motion determines the loudness or volume of the sound. A loud speaker, then, must be capable of taking the output of a radio set and causing the air to move in a to and fro motion in accordance with the signal to be heard. That part of the speaker which moves the air back and forth is called the diaphragm.

Probably the simplest speaker with which all are familiar is the telephone receiver used in the home or office, a cross-section of which appears in Fig. 29A. A permanent magnet (similar to an ordinary bar magnet)

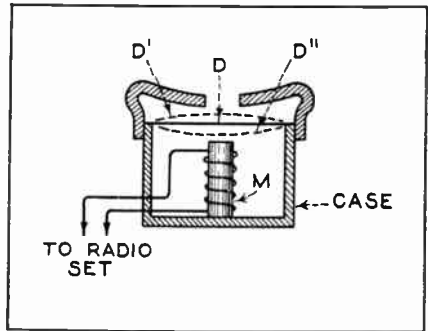


Fig. 29A.

is mounted vertically as indicated by M. Stretched over this, and separated from it by a few thousandths of an inch, is the diaphragm D. A coil of wire is wound over M and connected to the output of a radio set as indicated in previous diagrams. The effect of the signal is to magnetize and demagnetize (which means making stronger and weaker) the magnet M above and below the strength it has when no signal is received. This attracts the diaphragm to a greater or lesser extent in direct relation to the signal, as indicated by D' and D''. Since the diaphragm is a disc about 2 inches in diameter, it pushes the air in front of it back and forth, so that when the ear is placed directly in front of a small opening in the case, sound is heard. The same principle applies to the magnetic speakers which are nothing more or less than the simple receiver described, but with a large paper diaphragm. The large diaphragm

pushes more air, and hence gives a greater volume of output. It should be recalled though, that to get more sound output, more power must be applied, so that the telephone receiver must be used when weak signals are being received.

THE DYNAMIC SPEAKER

The speaker unit described above has several disadvantages. In the first place, when a strong signal is being received, the diaphragm vibrates so much that it hits the magnet and "rattles." Second, the permanent magnet may lose its magnetism after a time, and cause the speaker to weaken, necessitating replacement. Third, the quality of the music or speech is not very good with strong signals. To obviate the above defects, another type of speaker has been

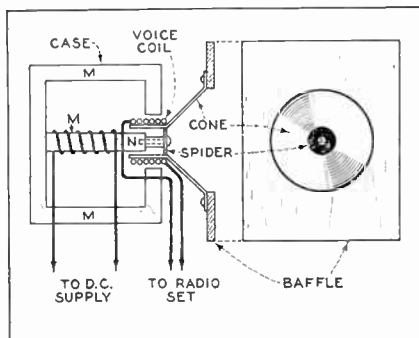


Fig. 29B.

developed and is used to the exclusion of the other type in most present receivers; it is the dynamic speaker.

A cross-section of such a unit is shown in Fig. 29B. A case (M) is built in the form of a cylinder with a large center core or pole piece MN. Over this many turns of fine wire (similar to that of an A.F. choke) are wound. The terminals of this coil connect to a D.C. source of supply. This source may be batteries, a separate rectifier, or in many cases this winding (called the field) is used as one of the chokes in the filter of the set's power pack. In any event, the core MN is magnetized. Over one end of the core, but separated from it by a gap, is placed a small coil, wound with a few turns of fine wire. This coil is called the voice coil and connects directly to the output of the radio set, through a step-down transformer, often built into the speaker. When a signal is impressed

across the terminals of the voice coil, it generates a magnetic field (exactly similar to that of the field coil); this field varies according to the variations of the signal and reacts with the steady field to produce motion of the voice coil. Rigidly attached to this voice coil is a large cone-shaped piece of paper which is called the cone; this cone moving with the voice coil produces sound.

A signal of almost any strength may be applied to such a speaker, the limitations only being the horizontal distance the voice-coil can move, which is about one-eighth of an inch. The quality obtained from such a speaker is excellent on large volume and there is freedom from the rattle inherent in the magnetic speakers described.

The cone is centered on the bar by means of a spider, as shown in the figure; if the cone is off center, the speaker will rattle. The easiest way to center a cone is to loosen the screw in the center of the spider and move the voice-coil from side to side until the rattle stops on the strongest signal that can be tuned in.

Three paper shims, spaced equidistantly around the core or pole, and between it and the voice coil may be temporarily inserted to facilitate the job.

In order to increase the response of the very low notes, a large board is attached to the cone by means of brackets as shown in the right-hand sketch of Fig. 25. This board should be at least one foot in length on each side in order for it to be effective. This board is called a baffle and is to be found on every radio set using a dynamic speaker.

The cabinet, of course, is the best possible baffle from a practical viewpoint.

In the past few years, with the development of new highly magnetic alloys, permanent magnetic dynamic speakers have come into use. These combine the advantage of both the magnetic and dynamic speakers, for they use the moving coil which characterizes the dynamic, yet avoid the need for the field coil.

However, they are seldom as sensitive as the dynamics which make use of the field coil, and are somewhat more likely to distort on extremely powerful signals. Their principal advantage is a saving in weight in portable sets, or the fact that they are thoroughly satisfactory on battery operated models, where high voltage or considerable current is not so readily available as in the electric (line operated) sets.

CHAPTER 4

Servicing Data

No matter how well designed and constructed a radio receiver may be, sooner or later it will call for your attention. Set failures are based upon a number of factors; (1) the natural tendency of moving parts to wear; (2) the tendency of certain parts to deteriorate with age and use; (3) accident or careless operation; (4) abnormal operating conditions; (5) semi-defective apparatus.

In your practice, you will find that point number two is the cause of most of your calls. It is really surprising how many set owners call the service man when the trouble is simply due to tube failure—a trouble the customer could rectify himself, simply by taking the tubes out and having them tested. However, his loss is your gain. He needs your knowledge to locate the fault, and he expects to pay for it.

Depending upon the type of customer, he will or will not expect to pay much of a service charge when your sole task is to replace a tube. Sometimes you will be able to collect your minimum service charge plus the list price of the new tube. But at other times, you will find it wiser to please the customer by making your service charge and giving him the tube at a discount, or by selling him the tube at list and making no service charge, or by charging for the call, but making him a present of the tube. It all depends upon a number of factors, chief of which is your ability to sell. You should be able to get paid for both the call and the tube without making the customer feel that he is being overcharged.

Antenna trouble will be another frequent cause of calls. This is true in many cases of noisy reception, where the cause is likely to be a swinging lead-in which may have an occasional partial ground, a defective lightning arrester, a poor ground-clamp, or a bad joint (all should be well soldered and taped) anywhere in the antenna-ground circuit.

You will always be able to collect your full service charge plus the price of any

necessary new parts for making repairs of this sort. In cases of much trouble here, it is well to put up an entirely new antenna-ground system, for if the person who did the original job was careless in one detail, it is likely that others will go bad sooner or later—and you will be blamed, as having been the last to handle the installation.

Electrolytic condensers are not unlikely to deteriorate with age and, when they do, must be replaced. Tests for defective condensers will be given later. Condensers, by the way, are impressive to the average set-owner, and no trouble is usually experienced in collecting for work done on them.

The same holds true of resistors, which are also easily tested.

In replacing resistors which must carry any appreciable current, or condensers which must withstand any degree of voltage, it is wise to allow a liberal factor of safety. Thus if a condenser is across a unit of 450 volts potential, a condenser rated at 600 volts working voltage is more likely to give satisfactory service over a long period of time than one rated at 450 volts. Similarly, if a resistor must carry 1 watt, a 2-watt resistor will stand up longer than a 1-watt one, which might overheat in continuous operation.

Figuring wattage is easy, for it is merely voltage multiplied by amperage. That is, if there is a current of $\frac{1}{2}$ ampere at a potential of 10 volts, a 5-watt resistor would be needed. Remember that a milli-ampere is $\frac{1}{1000}$ of 1 ampere (or .001 ampere). Then if the voltage across the resistor is 500 and the current 40 milli-amperes, the wattage is 20. Or if the voltage across the resistor is 125 and the amperage .015, the wattage is 1.875. In the latter case, a 2-watt resistor would be the smallest possible to use, and a 3-watt one would give a better margin of safety.

Any variable unit in the set is also a likely source of trouble, for wherever there is a moving contact, dirt or corrosion may

cause poor or intermittent contact, with resulting noisy or intermittent reception, especially when the control is manipulated. The wiping contacts on variable condenser rotors are places where this is apt to occur. Tone and volume controls are other places, and so are the points of band-switches. It is possible to clean these contacts with fine sand paper, the dust then being washed away with alcohol or a good grade of cleaning fluid. It may be blown away, if preferred.

The joints between tube prongs and tube sockets are also wiping contacts. If they are loose or dirty, the set may play noisily or intermittently, the trouble being most noticeable when the receiver is jarred. Dirty sockets can sometimes be cleaned simply by removing and inserting the tube a number of times, after the offending one has been located by swaying the tube gently with a fingertip. But if the contact is poor, it is wiser to replace the socket with a new one than to bend the contact tighter, for the contact spring may have lost some of its elasticity, and in that case would soon become loose again.

The prime requisites for the successful service man, then, are a broad general knowledge of radio principles and the ingenuity to know what to do to locate the trouble and to correct it when it has been found.

In most radio sets, defective parts, when located, may be easily replaced with similar units, but there are instances where similar replacement parts are not available, and it is in such cases that the ingenuity of the Service Man is called into play. He must possess the knowledge to recognize the problem at hand, decide on a solution and predict the results. At times, when the problem is strictly a servicing one, the solution is not difficult, but when it involves a mixture of psychology, salesmanship, engineering, economics and time, the term "Service Man" is misleading. His technical decisions must conform with accepted practice, and oftentimes the finished repair job is better than the original.

The service man's task, you see, is one which no man need feel is beneath him. And, important as it is today, it will grow even bigger as the time passes.

PRESENT POSSIBILITIES

Radio, phonographs, and home talking movies are the three main sources of reve-

nue for the Service Man, for the reason that every outfit sold requires attention at one time or another. A radio receiver is no longer a luxury but a necessity, and as such, a consistent demand for service men has been created.

Home television and facsimile are said to be "just around the corner" and while this statement has been made for years, it appears that we are nearing that corner, by the recent developments.

During the years since the early 1920's, the public has become educated to the possibilities that the future holds in store for them and, consequently, refuses to accept television in its present stage. However, television manufacturers are doing considerable laboratory and field work at the present time, which indicates that it will not be long before it becomes one of the major industries in the electrical field. Service men will do well to acquaint themselves with the advances made in television. When it is generally accepted, it promises to be a tremendous source of income for those engaged in its manufacture, sale or service.

Talking pictures swooped down upon the theatre with amazing rapidity, displaced the silent picture and also to some extent the legitimate stage. It is only natural then, that talking pictures in the home should be desirable. At the present time, small 16 mm projectors are available with and without sound accompaniment. The output of the pick-up (sound on disc or sound on film) usually connects directly to the audio amplifier of the radio set, so that it becomes the business of the Service Man to possess a knowledge of sound recording as well as radio in order to complete his radio education. At least one manufacturer has placed on the market a 16 mm. projector with sound on film. This product should stimulate the sound talking pictures in the home to a greater extent than the former method. A slight knowledge of optics, screens, illumination, etc., should be added to the Service Man's store of knowledge in order to effectively service home talkie equipment.

The phonograph has, of course, except for a few of the cheapest portables, gone completely electronic, using magnetic or crystal pick-ups, radio type A.F. amplifiers and loud speakers instead of the old sound boxes, tone arms, tone chambers and horns of past years.

you most plainly the path of signals and electric currents, and enables you to study out the function of each part in the set.

Although it is easy to point out how a particular diagram should be read, it is impossible to explain how all radio diagrams should be read unless general rules are laid down.

Fortunately, the input circuit of any vacuum tube is generally the same regardless of whether it is an oscillator, amplifier or detector. Stripped of non-essential details, the input circuit of any tube may

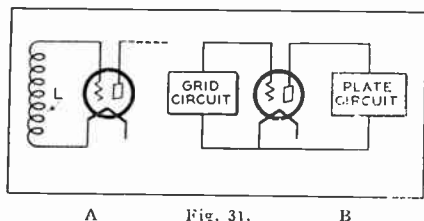


Fig. 31.

be represented by Fig. 31A. It is seen that a coil *L* is connected directly between the filament and the grid. Whether the coil has a condenser across it or not has nothing to do with the interpretation of the diagram immediately, the fact remains that between the grid and the filament of the tube there must be connected a circuit; whether this circuit is a resistor or an inductance has nothing to do with the fact that there must be a continuous circuit between the grid and filament. This point is extremely important and should be carefully borne in mind when tracing diagrams.

The same requisite is true of the plate circuit; regardless of what path one must trace through the plate circuit, there must be a complete circuit between plate and filament. It is evident that in a three element tube the filament is the common point from which all voltages are measured. In pictorial form, the grid and plate circuits may be shown as in Fig. 31B. With a true appreciation of the above statements, one is able to fathom the most complex radio receiver diagrams used in modern receivers.

In previous diagrams, as a reference to the symbol chart shows, the antenna and ground connect to the two ends of a coil marked *P*. This is the primary coil of the radio-frequency transformer *T*₁. All the energy collected by the antenna passes through the coil *P*. By induction it generates a voltage across the secondary coil *S*; this voltage operates the detector tube

*V*₁. In order to obtain the greatest amount of response, the coil *S* must be tuned to resonance with the signal, and this is accomplished by the condenser *C*₁.

In America, the broadcast stations cover the band from 550 to 1500 kc. (kilocycles), and therefore it is necessary to have coil *S* and condenser *C*₁ (Fig. 30) of such size that they can tune over this band easily. The antenna coil (or primary coil) *P* is merely used for the purpose of collecting sufficient energy to actuate the tube; if it is too large, the set will tune "broad" and if it is too small, it will produce a weak signal. Just how the primary is designed depends upon the particular receiver in use, and it is not the purpose of this book to enter into design considerations. All that it is necessary to know (so far as reading diagrams is concerned) is that the primary is not ordinarily tuned. The secondary coil and variable condenser *C*₁ (called the tuned circuit) connect to the grid and filament of the tube through the grid-condenser *C*₃ and the grid-leak *R*₂, which are necessary in order for the tube to act as a detector. It is the presence of *C*₃ and *R*₂ that indicate tube *V*₁ is a detector tube in this circuit. (Other circuits may use different means of detection.)

The plate of the tube connects through a coil to the primary of the audio-frequency transformer *T*₂. In simple terms, the tickler coil has two connections, one of which connections goes to the prong of the tube socket marked "*P*" and the other to the

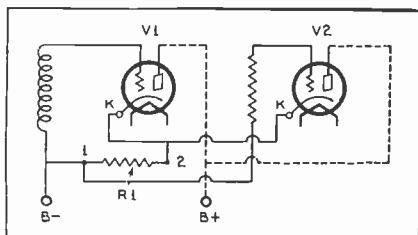


Fig. 32.

terminal of the A.F. transformer marked "*P*," the primary.

Notice that the grid and plate circuits in (Fig. 30) are continuous, as previously stipulated. Trace them with your pencil point. Starting with the grid of *V*₁, pass through *R*₂ (and of course *C*₃, although *C*₃ does not offer a continuous path for D.C. and therefore should not be considered) then through winding *S* of the R.F.

transformer T1 and back to the filament. Thus, the first pre-requisite is satisfied. From the plate of V1 pass through the primary of the A.F. transformer T2 to the "B" positive tap, through the "B" battery and resistor R1 to the filament. Thus, the second prerequisite is satisfied. Continuing with tube V2, pass from the grid through the "C" battery to the filament; from its plate through the phones and "B" battery, through R1 to its filament. In all of the above cases, it is absolutely essential that the circuit from the grid of a particular tube to its filament and from the plate to its filament be complete. In this manner each tube, with its associated parts, may be considered a distinct and separate unit, and may in general be studied in detail without reference to any other tube. (Fig. 32).

ADVANCED CIRCUIT STUDY

The simple circuits of Figs. 31 and 32 are the foundation upon which all additional data rests.

One problem with which most service men have difficulty is the determination of just what resistor or resistors are used to obtain "C" bias for a given tube. Again apply a simple rule, which if followed, will make the solution of the most complex circuit relatively easy. The voltage included between grid return and the filament (or the heater in the case of heater type tubes) constitutes the "C" bias for that tube. Thus in the circuit of Fig. 33, resistor R is the grid circuit, 4 being the grid lead, 3 being the grid return; lead 3 connects directly to point 2. Since the "C" bias is the voltage between the grid return and the filament, then the bias must be the voltage

across R1, or between points 1 and 2. The plate current flows between plate and filament and hence point 1 is positive with respect to point 2, or point 2 is negative with respect to point 1. The same holds true for the filament current and hence the grid return is negative with respect to its filament. In ordinary operation, no current flows in the grid circuit and hence through R. Therefore there is no voltage across R. The potential of the grid is thus the same as its grid return, with the result that the actual grid voltage ("C" bias) is the drop across R1. If the polarity of the "A" battery were reversed, the grid would be positive with respect to the filament, since the filament current is usually far greater than the plate current. In modern A.C. powered receivers, the "C" bias is determined solely by the plate current, so that the direction of filament current has no effect.

When you have studied and understood the foregoing you are ready to consider a more complex circuit, such as that illustrated in Fig. 34. The plate currents of both V1 and V2 must flow from "B" positive through the tube to the cathode (heater tubes being shown now as they are in more general use) and then through R1 (from point 2 to point 1) in order to reach the "B" negative. The "C" bias for both tubes is the voltage drop across R1 and is equal to the value of R1 in ohms multiplied by the sum of the plate currents of both tubes.

It is now very easy to understand how a modern automatic volume control functions. When a signal is too loud, it may be reduced by making the grids of the amplifier tubes more negative. This is done automatically by causing the plate current of a diode (two element) detector to flow through a resistor, and having this resistor in series with the grid return leads of the amplifier tubes. This is illustrated in Fig. 34.

The plate currents of both V1 and V2

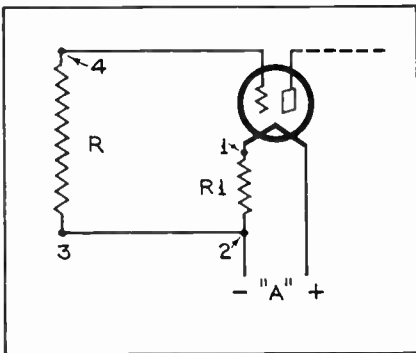


Fig. 33.

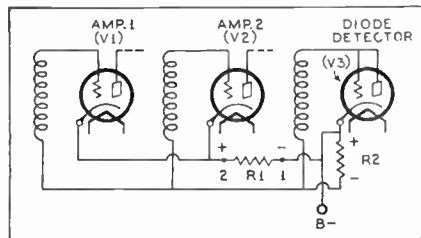


Fig. 34.

must flow through R1 in order to reach "B" negative, as R1 is between the cathode and the "B" supply. The current through the diode, when a station is tuned in, must flow through R2 as well as R1. The "C" bias for any tube is the voltage between the grid return and its particular cathode. Tracing through the grid returns of both V1 and V2, you will see that the total voltage between their grid returns and their cathodes is the sum of the voltages across R1 and R2. The voltage across R2 varies directly as the signal strength, and hence a smooth control of volume is automatically secured. Other systems use a separate tube to secure the desired result, but the fundamental theory of operation is the same.

It should be particularly noted that the way in which the automatic volume control functioned and an analysis of the grid circuits of three tubes were studied by merely following the simple rule outlined above. The plate and power circuits were omitted for the sake of clarity. In analyzing diagrams only one circuit should be investigated at a time so the simplified diagram shown in Fig. 33 is indicative of what one should concentrate on when studying radio diagrams.

GRID FILTERS

Resistors have another important use in A.F. amplifiers. In those of better qual-

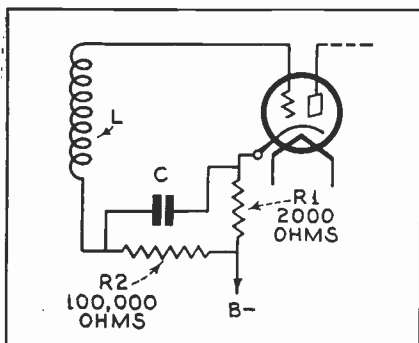


Fig. 35.

ity, it is desirable to keep the signal actuating any given tube entirely within the tube's associated grid and plate circuits. This is especially useful in high-gain amplifiers where the slightest feed-back may cause oscillations.

In Fig. 35, the grid-bias resistor is R1;

its resistance is, say, about 2000 ohms. The signal impressed across the coil L actuates the tube and therefore should be as great as possible. The effect of the grid-bias resistor is to reduce the signal voltage applied between the grid and cathode, so that it is necessary to shunt the resistor R1 with a condenser whose reactance (the opposition to flow of alternating or pulsating current through a condenser) at the lowest frequency to be received is about one-tenth the value of R1. If the circuit were unaltered, this would mean the use of a very large (and consequently expensive) condenser. But if a large resistor R2 is inserted in the circuit as shown, the condenser may be made very much smaller because the resistance of the path from the grid return to the cathode is deliberately made higher by the insertion of R2.

Since the value of the reactance of the condenser should be one-tenth the value of the resistance R1, it can then be made a mere fraction the capacity that it would have been, had R2 not been added. The frequencies in the grid circuit are blocked from entering the plate circuit via "B" negative, due to the resistors, yet are passed easily to the cathode (functioning as part of the grid circuit) through the condenser C. Resistor R2 does not contribute to the "C" bias because the plate current does not flow through it; the plate current returns to the "B" minus immediately upon leaving R1. It should be pointed out that the grid circuit of the tube consists of L, C, and R2. The plate circuit may also have a filter for the same reasons as discussed for the grid circuit.

In servicing receivers, where rewiring is necessary, remember that all leads (and especially those in the grid and plate circuits) should be kept as short and direct as possible. Further, grid and plate leads should not be allowed to be close to and parallel to each other, or feed-back, with resulting oscillations, often manifested as howling or whistling, is likely to occur. It is also well to keep the grid leads of one circuit well away from those of another circuit, and the same is true of the plate leads. The reason for this is the same as above.

Power supply leads, from which R.F. and A.F. components have been filtered by means of condensers in combination with chokes or resistances, do not need this care, even though they may be carrying current for grids and plates.

All A.C. leads, such as those carrying current for tube heaters or filaments, should be "twisted pair"; i.e., two wires twisted together. Otherwise the magnetic fields set up by the A.C. are likely to radiate from the leads throughout the receiver, causing severe hum. When the leads are twisted, however, the field of one neutralises that of the other, and the effect is greatly minimised.

In repairing A.C., D.C., or A.C./D.C. sets, the placement of the power pack, which is built-in, need cause you no concern, but

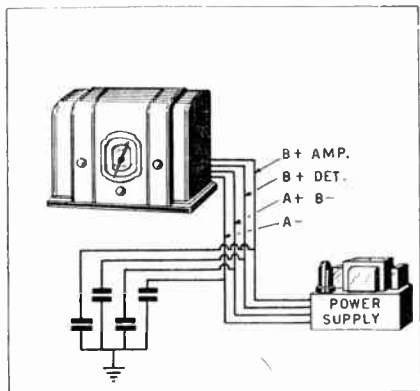


Fig. 36.

in adding power packs to battery operated receivers, keep the pack well away from the set, so that the 60-cycle will not feed into the R.F. or A.F. stages. If either the set or the pack is shielded, ground the shields. And if leads more than three feet long are used, it is well to by-pass each of them to ground with a separate .2-mfd. condenser, of adequate rated voltage, connected at the set end of the cable, as in Fig. 36. This minimises the chance of interstage feed back through the pack.

USE OF SIMPLE TEST INSTRUMENTS

Equally as important as knowing what to do when the trouble is located, is knowing how to locate the trouble.

The irreducible minimum of test instruments with which a professional service man can "get by" are a high resistance multi-range voltmeter and a milliammeter. These may be combined in one instrument, to save cost and for convenience, as shown in Fig. 37. Here is an item where you will

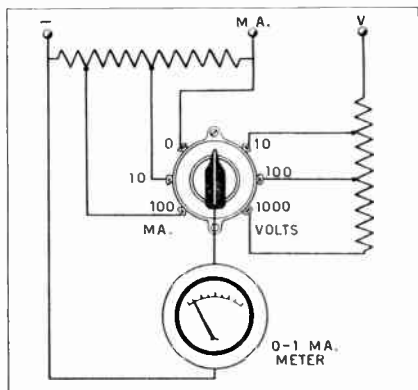


Fig. 37.

want the best that money can buy, for inaccurate instruments give readings which are utterly meaningless. The maximum tolerable inaccuracy is 2%. That is, a 100-volt meter, when placed across a potential of 100 volts, must not read less than 98 volts nor more than 102.

As the same meter, if placed across a 10-volt source, would read somewhere between 8 volts and 12 volts (still only 2% error when considered in relation to full scale deflection, though 20% out in relation to the voltage read) you will see the need for having a multi-range instrument, each scale of which is guaranteed to be within 2% of perfection.

The need for a high resistance instrument is obvious, for you will recall what you have read concerning potential drop obtained through the use of grid resistors. A practical illustration of this follows.

To attempt to describe a simple tester without illustrating in some detail the theory upon which it functions would be impossible. Therefore we will devote some time to a discussion of some of the problems encountered in measuring work and then proceed to show how they may be solved.

Suppose it is desired to measure the grid voltage of a tube connected as shown in Fig. 33. Grid voltage is measured between the grid and the filament (or the cathode in heater-type tubes) and therefore it is necessary to insert the voltmeter between points 1 and 4. If this is done, a reading will be obtained, but not a precise reading. The reason will be apparent when the same circuit is redrawn as in Fig. 38. The "C" bias resistor has been replaced by the battery E which, let us say, has a voltage of 6.

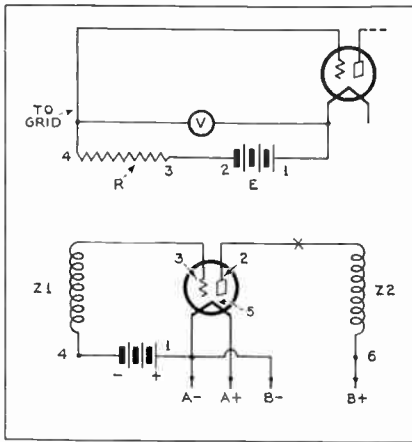


Fig. 38 top.
Fig. 39, bottom.

If the voltmeter is read correctly, it too must read 6 volts. Usually the resistor R has a value of about 1,000,000 ohms; if the grid circuit is that of an audio amplifier, the resistance of the secondary of the transformer may be about 100,000 ohms. Let us assume the latter figure.

If a low resistance voltmeter is used (100 ohms per volt), then the meter will have a resistance of only 1,000 ohms if the 10-volt scale is used. The current flowing in the circuit would be 6 divided by 101,000 or .000059 amperes. The voltage drop across R is 5.9 volts, leaving a voltmeter reading of only .1-volt. If a high resistance meter is used, with a value of 1,000 ohms per volt (a total resistance of 10,000 ohms for the 10-volt scale) the reading of the voltmeter would be .55 volts. It is seen then, that the higher the resistance of the meter, the more accurate the reading obtained.

It is not practical to make meters with a resistance greater than 1,000 ohms per volt, so that in circuits having a high resistance, the correct bias can never be measured with any of the usual meters. In R.F. and detector stages, where the secondary of the transformer has practically no resistance, it is possible to obtain correct readings. In cases of circuits having a high resistance, the grid bias may be accurately measured by removing the chassis and connecting the voltmeter across the bias resistor R_1 in Fig. 32.

The same holds true for the plate circuit—perfectly precise readings can never be obtained if the circuit under test has a

high resistance. The percentage of drop in voltage in the plate circuit will never be as great as in the grid circuit; for instance, if the true plate voltage (measured from plate to filament—or cathode) is 100 volts, and the voltmeter reads 75 in a fairly high resistance circuit, then it may be assumed that the plate voltage is correct. Extreme precision is not absolutely essential in service work—accuracy of about 10 percent is close enough for all purposes though 2% is far better.

From the foregoing, it is clear that for idea voltage measurements, the resistance of the voltmeter should be much higher than the resistance across which it is connected. A good rule to remember is that the resistance of the meter should be at least ten times the resistance of the circuit being measured. Precise measurements, irrespective of resistance in the circuits measured, are obtainable with meters that draw no current, such as the vacuum tube voltmeter. This, however, is not really necessary.

THE AMMETER

Just as the voltmeter is used for measuring potential, or voltage, the ammeter is used for measuring current, or amperage. The movements of the meters are the same, the only difference being that a high resistance is connected *in series* with the movement in the case of the voltmeter, and a low resistance connected *across* the movement when it is to be used as an ammeter. This point will be discussed in greater detail later on.

As the ammeter is a low resistance unit that is connected in series with the circuit through which flows the current to be measured, it might seem that its position in the circuit is unimportant. This is only true when its resistance is low as compared with the rest of the circuit; when the current through the circuit is small; and when, if a voltmeter is used, the current that is consumed by the voltmeter is not recorded by the ammeter.

The above paragraph regarding the placement of the ammeter is not greatly important in radio service work, but it accounts for some of the errors that occur in some types of measuring instruments.

D.C. ammeters are seldom used in radio servicing, though occasionally an A.C. ammeter may be used to check up on filament current and the like. Such an instrument,

often just a D.C. meter used in conjunction with a small rectifier, with which it has been calibrated, is not essential if an A.C. voltmeter is present, though it is convenient as an output indicator. The A.C. voltmeter, likewise, may be a D.C. voltmeter combined with a small rectifier. While it is a nice instrument to have for checking line voltage, output of power transformers, and filament voltage, you can get along without it. Filament voltage is usually either present and correct, or totally absent; it is seldom high enough or low enough to make the variation from normal worth measuring.

Line voltage can generally be assumed to be correct if other apparatus on the same line functions normally. Thus, if a lamp plugged into the circuit appears to burn with proper brilliance, and if electric clocks or vacuum cleaners run as usual, the line voltage is indicated to be correct.

As to power transformer output, this can be measured with a D.C. voltmeter *after* it has passed through the rectifier tubes. If the tubes are okay and the voltage is below normal, the chances are that a partial short somewhere in the set or power pack is drawing enough current to cause the drop. This can be determined quickly by making a measurement with the pack disconnected from the set; if the voltage comes back to normal, the trouble is in the set; if not, it is in the pack—and is usually due to a defective filter condenser.

THE MILLIAMMETER

While most of your measurements will be made with a D.C. voltmeter, a milliammeter is likewise necessary. As previously stated, this can be a single meter, provided with a switching system to put various resistances in shunt or series with it. Figure 37 shows how this is done.

A milliammeter is simply a very sensitive ammeter; it measures currents so small that they would scarcely stir the pointer of an ammeter. A 0-1 mil. meter—one which has full-scale deflection when passing a current of 1/1000 (or .001) ampere—can be provided with external resistances which will permit it to read currents up to 1000 mils (1 ampere) or more, and voltages from 0 to 1000 or more. Its resistance, when used as a voltmeter, will be 1000 ohms per volt, which makes it an excellent instrument. A little further along,

you will be given a diagram showing you how to build a multi-range volt-milliammeter.

Incidentally, when making calculations into which milliamperes (usually abbreviated as mils or ma.) enter, take care that the decimal point is in the proper place, else erroneous results will be obtained. For example, when using 6 milliamperes in a calculation, it always should be written 6/1000 amp. or .006 amp.

Very little can be said regarding the location of the milliammeter in any radio circuit other than that it is placed in series with the circuit through which flows the current that is to be measured. Its resistance is usually small compared with the remainder of the circuit, hence no appreciable error is encountered in its use. As a preliminary step toward constructing a simple analyzer, learn how voltmeters and milliammeters are made, how the two instruments mentioned are used to locate trouble in a simple radio set.

LOCATING TROUBLES WITH METERS

Meters are used in service work for the purpose of locating trouble. This does not imply that the meters indicate precisely in which particular part the trouble lies, but they help vastly to localize the search. Modern radio sets are so complicated that unless a means is used to suggest the source of trouble, the Service Man will find himself guessing; and guess work is one of the most frequent causes of unsatisfactory service work, besides being a tremendous time-waster.

It will first be shown how meters are used in a single stage amplifier, then in a complete radio set, and finally how they may be incorporated in a simple tester.

Suppose that, in servicing a receiver, a particular amplifier stage, illustrated in Fig. 39, is to be tested. Only six possible measurements may be made; first, plate voltage; second, plate current; third, grid voltage; fourth, grid current; fifth, filament voltage; sixth, filament current. If all of the above measurements conform with the values stated by the manufacturer, then the trouble does not lie in the plate, grid or filament circuits, and the attention of the Service Man should be concentrated elsewhere.

PLATE VOLTAGE MEASUREMENTS

To measure plate voltage, all that is necessary is to place the negative terminal of the voltmeter at point 1 and the positive terminal at point 2, or between the cathode prong and plate prong of the socket, in A.C. sets. Data sheets, provided by the manufacturers and in hand books, tell between what points to test, and what readings should be had on specific sets. The meter should indicate this certain value. (In all voltmeter measurements, the use of a high resistance meter will be assumed.) If the reading of the meter is far below the value recommended by the manufacturer of the set, the resistance of Z2 should be measured independently, and the results checked with the value specified by the maker. If the resistance of Z2 does not conform (within about 10 percent) with the rated value, it should be replaced at once. If it does conform, then in all probability the current drain of the voltmeter is sufficient to reduce the reading of the meter although the actual value, when the meter is not connected, is correct. It is evident at this point that correct interpretation of the meter reading is of paramount importance, as an erroneous interpretation may cause the Service Man to perform additional unnecessary tests.

If the stage being tested is one of the R.F. amplifiers, the actual voltage will be about the same as the read voltage; if it is an audio stage, the actual voltage may be from 10 to 75 percent greater.

If no voltage reading is obtained then either the "B" power is not connected or is defective, or the load resistance Z2 is open. The power supply may be tested by connecting the voltmeter across points 1 and 6. If a reading is obtained, then Z2 is open and should be replaced. It is wise to check the continuity of Z2 separately at this point, to check the previous tests.

Obviously, if the voltage reading is correct, the attention of the Service Man should be directed elsewhere. Certain manufacturers have sufficient foresight to realize the problems of the Service Man and publish the voltage readings as they are read, assuming a definite meter resistance.

PLATE CURRENT MEASUREMENTS

Assuming that the plate voltage is cor-

rect, the plate current should then be measured. This may be done by connecting the milliammeter in series with the plate circuit, as shown in Fig. 39 at point X. The meter should then read normal plate current. If the reading conforms with the current specified by the maker of the set, the plate circuit measurements are finished. If not, (1) it may be too high or (2) too low.

If the plate current is incorrect, with normal plate voltage, the "C" bias may be wrong, the filament voltage wrong (in battery operated sets), or the tube defective. Tests to ascertain which of them is causing the trouble will be given in their proper sequence.

GRID VOLTAGE MEASUREMENTS

To measure grid voltage, connect the positive terminal of the voltmeter to point 1 and the negative terminal to point 3. It should be noticed that the polarity of the voltmeter is the reverse of that used when measuring plate voltage.

The interpretation of the meter reading is exactly the same as for the plate voltage measurement above. To check for the actual value of bias, connect the terminals of the meter to points 1 and 4. In the case illustrated, since a battery is used for the bias, the actual value can be measured. In A.C. sets, the data sheet will show what voltage the meter should indicate.

While the measurement of control grid current is desirable, it is not essential to good servicing. With the proper negative bias on a tube, it should not draw current; if it does, the value of current means nothing to the Service Man, except that the tube is defective and must be replaced. This, however, may be determined just as rapidly, although with more inconvenience and less expense by testing the tube separately. Screen and suppressor grid voltages and currents are measured in the same way; i.e., from cathode to the element undergoing test.

FILAMENT VOLTAGE MEASUREMENTS

Very little can be stated regarding the measurement of filament voltage. The terminals of the meter should be connected across points 1 and 5. Voltage may then

be adjusted (in battery receivers) by merely varying the rheostat setting.

Filament current measurements are usually not required, as the proper emission may be obtained (or nearly so) by keeping normal filament voltage applied to the tube.

In A.C. sets, the filament voltage is A.C., and can be measured only with an A.C. instrument, although the plate and grid voltages, having been rectified in the power pack, are D.C. However, there is little to go wrong in a filament circuit, and it is usually safe to assume that if an A.C. tube lights, the voltage is correct, though there is sometimes a defective center-tapped resistor across a filament, this is more apt to show up as an audible hum heard through the loud speaker than as an incorrect voltage. Other flaws in the filament circuit generally show in tests from filament (or cathode) to grid or plate.

In D. C. sets, filament voltage may be tested as in battery sets. Here incorrect voltage may be caused by defective ballast tubes, line cord resistor, or other fixed resistors. A high filament reading due to any of these would be present on all tubes, as they are connected in series. A low or zero reading on one tube with high readings on the filaments of the others would indicate a partial or total short circuit in that tube's filament circuit.

SUMMARY

While six different measurements are possible, only four are usually needed; namely, plate voltage and current, grid voltage and filament voltage. The latter may generally be omitted on A.C. sets. Before a test is made, the Service Man should determine from service manuals, previous experience, etc., just what the results of the test should be. The tests are made for the sole purpose of ascertaining whether voltages and currents are or are not normal.

It should be particularly noted that the meter readings indicate where the trouble lies, but only indirectly. They are an aid to finding the cause of the trouble.

METER SCALES

One fact should have been apparent to the reader by this time. Voltage and current measurements were made and no mention was made of the scale of the meter. The grid voltage may be about 20 volts,

while the plate voltage may be 300; the plate current of a certain tube may be 2 ma. while that of the adjacent tube may be 35 ma. It therefore becomes necessary to adopt means of changing the range of the meter for different tubes, circuits, etc. It is also possible to use one meter as both a voltmeter and a milliammeter, the change from one to the other being effected by switches.

Multipliers are used for the former purpose, *shunts* for the latter. Briefly, a multiplier may be defined as the resistance that is inserted in series with the movement of a meter in order to read voltage, and a shunt may be defined as the resistance that is connected across the movement of a meter in order to read current. Thus, in Fig. 37, by manipulating the switch the meter may be made either a voltmeter or a milliammeter.

To obtain different ranges, various multipliers are connected in the circuit, each corresponding to a different range. The same holds true for the various milliammeter scales. Thus three or more ranges of voltages and currents may be read with a single meter.

The values of the resistance used depends upon the resistance of the meter with which they are employed, as well as its full scale deflection. Many manufacturers will supply the necessary data for adding multipliers and shunts to convert their meters to various ranges.

The 1-mil meter, with an internal resistance of 27 ohms, is quite common, and the following table indicates what resistances must be added *in series* to make it a multi-range *voltmeter*.

Range (Volts)	Ohms Added in Series	Multiply Present Scale By
0-10	10,000	10
0-50	50,000	50
0-100	100,000	100
0-250	250,000	250
0-500	500,000	500
0-1000	1,000,000	1000

Fig. 40.

To use the same meter as a multi-range *milliammeter*, use the following table, remembering that the resistors must be added *in shunt* (or parallel) with the meter instead of in series with it.

Range (M.A.)	Ohms Added in Shunt	Multiply Present Scale By
0-10	3	10
0-50	0.551	50
0-100	0.272	100
0-500	0.0541	500

Fig. 41.

In making the multi-range voltmeter, each resistor must be capable of carrying 1 ma. without overheating. In making the multi-range milliammeter, each resistor must be capable of carrying the current which the corrected scale reads, without overheating. For example, the 0.0541-ohm resistor must be able to carry 500 mils, or 1/2-ampere.

ANALYSER CONSTRUCTION

All that a set analyser is, is one or more meters, together with a number of switches by means of which they can be quickly and easily connected in series or parallel with various circuits of the set.

There are two principal types. The first, shown in Fig. 37, is the simpler. Its leads, equipped with test prods, may be held across any point in the circuit if the chassis is out of the set, and the shielding removed from the chassis (or if the chassis is open underneath). It is extremely simple to build and to use, provided that the

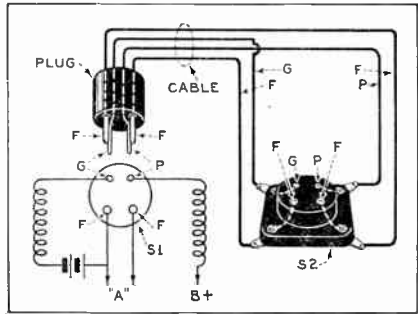


Fig. 43.

set on which it is to be used has its various leads exposed. If, however, the set to be serviced is in the cabinet, each tube must be removed in turn, and the test prods thrust into the tube sockets in order to test the various circuits. As the drain of the tube obviously cannot take place while the tube is removed from the socket, the service man is limited; he cannot, for example, get a plate current reading, nor can he learn what voltage there would be between any two tube elements *with the tube in use*. The voltage may vary considerably with the tube removed, particularly if the tube is defective. And he cannot use this instrument alone to test the tube.

A somewhat more complex analyser is needed to afford the other measurements. As illustrated in Fig. 42 it has a socket on its panel, and a cable with plug to en-

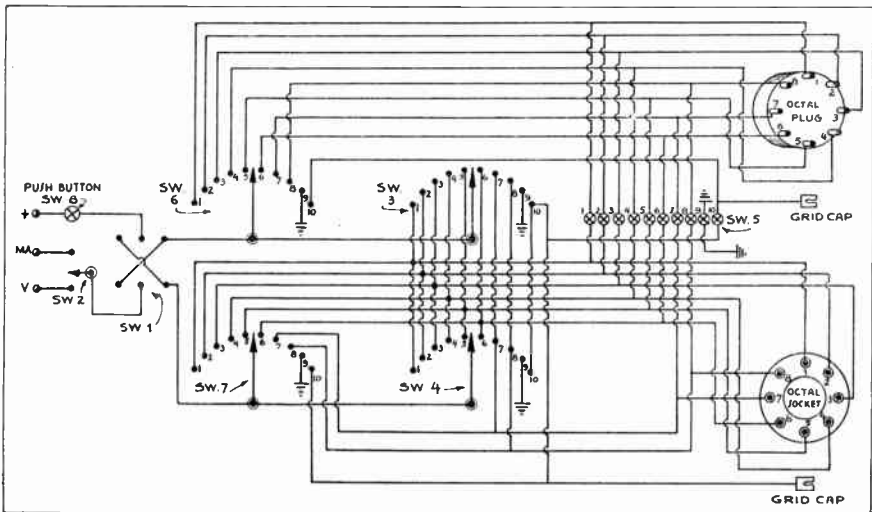


Fig. 42.

able it and the tube to be connected into the circuit at the same time. Fig. 43 illustrates the principle. The meter, by means of multi-point gang switches, is connected in series or parallel with the various circuits, the correct shunts being put into series or shunt with it by means of separate switches, or by a single multipoint switch, as in Fig. 37. It is also possible to have the resistances controlled by the circuit-selector switch, so that the meter is automatically turned to the right range when put into any circuit, and many commercial analysers are built in that way. As it involves exact calculations of a greater number of resistors, it is not suggested as a construction project for the novice.

In order to test all types of sets and tubes, the analyser should be constructed with an octal (eight-prong) socket and plug, with separate lead for both large and small grid-caps. If it is used with sets using 4-, 5-, 6- or 7-prong tubes, adapters are necessary for two purposes; to fit the analyser plug into the set socket, and to fit the tube from the set into the socket of the analyser. The separate lead has a spring clip at the set end, to attach to grid clips and a double end (large and small) grid clip, to use on the tubes in the analyser.

The schematic of this analyser, requiring a minimum number of parts, is indicated in Fig. 42. Designed to be used in conjunction with the multi-range meter shown in Fig. 37 it uses only:—

- Two 10-point switches;
- One 10-point, 2-gang switch;
- One push button;
- One double-pole double-throw toggle switch;
- One single-pole double-throw toggle switch;
- Ten single-pole single-throw toggle switches;
- One octal socket;
- One octal plug;
- One set adaptors;
- One double grid cap; two spring clips, wire, panel, hardware, and case.

As is seen in the figure, three leads are connected to plug into the multi-range meter, and a double-pole double-throw toggle switch is arranged to reverse the polarity of the connections to the meter. The single-pole double-throw switch SW1 permits the service man to use the meter for voltage or current readings without changing any connections. The meter ranges

are selected by means of the switch SW2 mounted with the meter, as shown in the earlier diagram.

The octal socket is mounted on the analyser panel, and each of its lugs is connected to four separate points. For example, socket lug 1 connects to Point 1 on SW3, SW4, and SW7, and to one side of toggle switch 1, in the SW5 group. Similarly, lug 2 connects to Point 2 on all the above multipoint switches and to one side of Toggle 2 in the SW5 group. And so forth until all the socket lugs have been connected.

A separate lead is extended above the panel, with the grid cap connected to its end. This is 9 in the figure, and is similarly connected.

The ground wire, G, is likewise connected.

Still open are the remaining connections to all the toggle switches. Each of these connects to a wire in the plug cable, and to one of the points in SW6. *Great care must be taken to connect 1 in SW5 to 1 in SW6 and to the cable wire that corresponds with Prong 1 of the plug, when that plug is inserted in the octal socket.*

The switch, SW1 is cross-wired, as shown, and one side connected to the arms of SW3 and SW6; the other side to the arms of SW5 and SW7. One of these leads is through the push button, SW8.

The analyser is now completed and ready for use.

USING THE ANALYSER

First turn all switches to the OFF positions, except those in group SW5, which should all be ON. Remove a tube from the socket in the set which you wish to test and, using the needed adapters, plug the tube into the analyser socket, and the analyser plug into the set socket from which the tube was removed. Attach the grid cap connections, if the tube has them, and clip the analyser's ground lead to the chassis of the set. Make sure your multi-range voltmeter is correctly connected to the analyser and proceed.

Suppose, for example, that the tube is a 6A8.

First set the meter-range switch on the highest voltage range, to avoid damage to the meter. Refer to the tube chart earlier in the book and see what elements are in this tube. You will see that it is a penta-

grid converter. Set SW4 on ground and SW3 on 1, press the button—no reading. Leaving SW4 unchanged, turn SW3 to 2. Press the button—no reading may mean trouble, for that's the cathode, and the diagram printed by the manufacturer of the set you are servicing shows it should have a potential of, say, 3 volts as compared to the cathode, which your diagram shows to be grounded. But slow up! You're going too fast! You could not expect to read 3 volts on a 1000-volt scale. Turn the multi-range meter switch. When you get it to the 10-volt scale, there's your reading. Put it back to the 1000 volt range and proceed with your third test. Look at that needle kick! 150 volts, and the set data sheets says it should be 100 volts. What's the trouble? Better check the plate current. To do this, turn SW3 and SW4 to OFF, turn SW6-7 to 3, and open switch 3 in the SW5 group. The meter kicks; turn the multi-range switch to the highest milliamperage scale—a barely perceptible reading. Advance it to the next highest scale—something radically wrong here, for it's still way low. And as you keep on advancing to lower scales, the needle fails to register plate current in spite of the excessive plate voltage.

What could cause that? If the resistors in the tube's external plate circuit were open, there would be no current and no voltage. If their resistance had risen for some reason, both plate current and plate voltage would have dropped; if resistance had fallen, current and voltage would have risen. But if the tube was bad, the cathode emission might be down, with a consequent drop in plate current, and this higher internal resistance of the tube would cause the plate voltage to rise somewhat. Maybe that's the cause. It seems logical, so try a new tube.

The set works, and your only remaining task is to disconnect your analyser, pocket your fee, and hustle along to your next job.

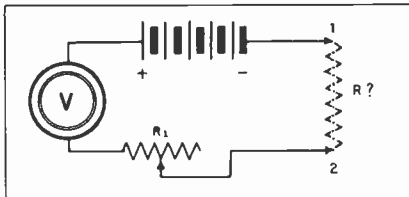


Fig. 44.

There are, of course, other possible tests at the other lugs and in the separate grid lead, but these will be self-explanatory from the diagram and the foregoing explanation. The push-button is in the meter lead so that the meter can be instantly disconnected if the pointer goes off scale. It reads only when the button, SW8, is pressed. If it flies off scale to the right, choose a higher range; if to the left, reverse its polarity with SW1. And be sure to use only the voltmeter for voltage readings, and always to start with the highest ranges in both current and voltage tests. Even though you are testing what you know to be a low voltage circuit, start with the high voltage range; maybe that's the trouble with the set.

SW4 does not appear to be a necessity, and in many tests, it is not. But there is sometimes reason to measure voltage between two grids, or between grid and plate, and in this case SW4 is well worth the few extra cents it costs.

With the voltage and current readings obtained, the function of the tester is completed and it remains the problem of the Service Man to interpret the results. No intelligent interpretation is possible without a wiring diagram of the receiver on hand. When a particular voltage is too low or too high, the diagram should be consulted immediately. In testing a tube, a very low voltage on the plate may be obtained. After deducting the probable voltage drop in the primary of the external plate circuit, the reading may still be too low to be normal. A test of the supply voltage and all soldered joints may show nothing wrong. The man without a diagram would, at this point, be "stuck" but the one who had foresight to procure the diagram of the receiver before testing it, will immediately see that a partially shorted plate bypass condenser will cause a considerable drop in voltage.

TESTING THE COILS

There are two types of coils used in radio sets, air-cored and iron-cored. Either type may be open, partially shorted or entirely shorted. Now most analyzers have, as an integral part of the device, a continuity tester or ohmmeter. This is nothing more or less in its essentials than a voltmeter V connected in series with a small battery, and a rheostat, R1 as shown in Fig. 44.

With terminals 1 and 2 shorted, and R1 properly adjusted, the voltmeter reads the battery voltage which is the same as the full-scale deflection of the meter. If an unknown resistance R_x is inserted between terminals 1 and 2, the voltmeter reads less than the battery voltage, because of the voltage drop in R_x , the resistance being measured. The more resistance between 1 and 2, the less the meter reads. This makes it possible to mark or calibrate the scale of the voltmeter directly in ohms, so that, when a resistance is connected between points 1 and 2, the meter reads a certain figure which is the value in ohms of the resistance so connected.

The coil to be tested is connected to points 1 and 2 of the ohmmeter. If the meter reads nothing at all (0), then the coil is open. If the meter does read, it is difficult to tell whether the coil is partially shorted or is good, unless the resistance of the coil is known. For instance, an R.F. transformer is wound with only a few turns of wire, and consequently its resistance is low. An ohmmeter test then, can only indicate when the coil is open or closed.

On the other hand, a large iron-cored coil is usually wound with many turns of wire and may have a resistance of several hundred or several thousand ohms. In this case, the Service Man cannot tell the difference between a partially-shortcd coil and a good one, unless he knows the approximate resistance of the coil when good. This may be usually found in the service notes of the radio set, or, if there is a similar coil in the same or another set, the resistance of one may be compared with the resistance of the other. Coils should be tested, not only for shorts and open circuits, but also for a "ground" (short circuit) to cores.

Fortunately, however, when a coil in a radio set is defective, it usually is either open or has a dead short.

TESTING CONDENSERS

When a fixed condenser is good it should do two things: (1) it should not allow D.C. to pass through it; and (2) it should therefore accumulate and hold a charge, when its rated D.C. voltage is applied. When a condenser is leaky it allows D.C. to pass, so that, to test for a leak in a condenser, all that is necessary is to connect the terminals of the condenser to the ohmmeter. The needle of the ohmmeter should move

a little (due to the flow of current into the condenser necessary to charge it if the capacity is large), and then return to its normal position and stay there. If it does not return to its normal position, but stays somewhere on the scale, the condenser is leaky and should be discarded.

The above statement applies only to condensers of large capacity, about $\frac{1}{4}$ to $\frac{1}{2}$ mf. and larger. For the smaller sizes, the continuity test described above is sufficient, being enough to determine whether the condenser is shorted or not. It is perfectly possible for a condenser to open, even though it is a rare occurrence; an open condenser is one which passes neither D.C. nor A.C.

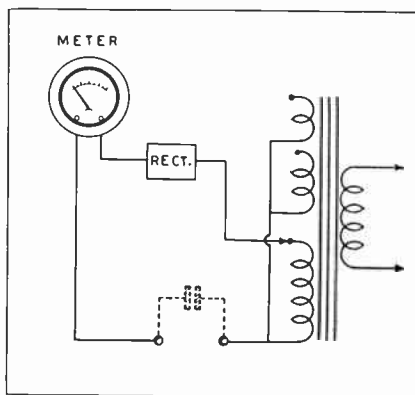


Fig. 45.

For the electrolytic type of condenser, the rated D.C. voltage may be applied. A milliammeter connected in series with the condenser and the source should read not more than .5 ma. per microfarad capacity of the unit. Thus an 8 mf. electrolytic condenser should have not more than 4.0 ma. passing through it, if it is to be considered O.K.

It is very useful to be able to measure condenser capacity. This may be done very easily by connecting a small copper-oxide rectifier in series with a D.C. meter and a source of A.C. potential. The condenser to be measured is also connected in series with the arrangement. The greater the capacity of the condenser, the greater the reading of the meter. In this manner the scale of the meter may be calibrated to read directly in microfarads, provided that the same A.C. source of potential is always used. See Fig. 45.

Testing resistors involves only the measurement of the value of the resistance.

CHAPTER 5

Advanced Servicing Information

The set analyser described in the preceding chapter will enable you to test all receiving tubes, and get readings on every stage of any set of standard make.

It will not, however, enable you to align the stages of a super-heterodyne, and as this is now the most popular circuit, the additional equipment needed for such tests will be described.

You are urged to buy an accurately calibrated R.F. and I.F. oscillator, and a sensitive output meter that is provided with sensitivity control. Your oscillator *must* be accurate and dependable, and unless you are an exceptionally careful and accurate constructor, you are warned against attempting to build it. A poor oscillator is worse than useless; it is misleading. It must show on its dial precisely what frequency is being emitted, so that the receiver being aligned can be peaked and made to track correctly.

It should have provisions for modulating the R.F. with an A.F. signal of constant amplitude, yet capable of attenuation. In other words, it must be a modulated R.F. signal so that it can operate an output meter, and it must be capable of being weakened so that the meter gives but a faint indication.

For complete servicing of all-wave receivers, it should be capable of tuning from 10 to 1700 meters, though complete coverage

of every band is not needed. Fig. 46 shows this type of circuit, battery-powered for ease of construction.

One of the most important features of the oscillator illustrated in the above-mentioned figure is its utter simplicity. It is portable, using a '30 type tube, a small 22½-volt battery for plate potential and a 2-cell flashlight "A" battery. The entire arrangement may be placed in a single case, the inside of which should be thoroughly shielded to prevent radiation (giving off energy) from the coil itself. It is designed to cover any desired bands, its range being governed by the coils and condensers used. The particular wave length desired may be obtained by merely rotating the tuning condenser C1, with the switches cutting in the required capacity, and the proper coils plugged in. The output of the oscillator may be adjusted by varying the arm of the 5,000-ohm potentiometer. This adjustment will be found to be particularly useful when testing receivers of different sensitivities.

The broadcast band coil consists of 60 turns of No. 20 or 22 silk or double cotton covered wire wound on a 2 inch diameter form tapped at the center. The coil should be raised a reasonable distance above the shield in order to prevent excessive loss and a consequent loss of efficiency. Under no circumstances should the "B—" terminal be connected to any of the "A" terminals, for this would short circuit the feed back coil and cause the oscillator to stop functioning. An R.F. choke is placed in the plate circuit of the tube in order to keep the radio-frequency power in the oscillator itself, and not let it wander out into the "B" battery leads from which radiation might take place.

Referring to Fig. 46, you will notice that a fan-switch enables you to cut in or out a number of condensers—C1 variable, the others fixed. Their capacities are: C1, .00014; C2, .0001; C3, .0002; C4, .0004 mfd.

For 10 to 200 meters, all three switches, SW1, 2 and 3 are left open. The 10-20 meter band is covered by a 10-turn center-

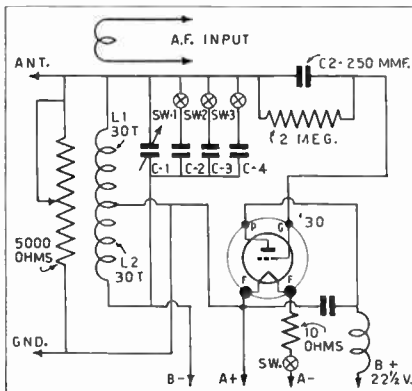


Fig. 46.

tapped coil of No. 22 dsc wire on a 1¼-inch form. Using the same wire and same size form, the 20-40 meter band requires a 22-turn center-tapped coil, the 40-80 meter band a 46-turn center-tapped coil, and the 80-200 meter band, a 106-turn center-tapped coil.

For the broadcast band, close SW4 and use the 200 meter coil.

For 175 kc. I.F., close all switches and use two 450 microhenry chokes, placed in inductive relation.

CALIBRATING THE OSCILLATOR

The oscillator described is a very stable one and the output will not change appreciably with different tubes, although it is a good idea to keep one tube for the oscillator alone.

The oscillator may be marked or calibrated in the following manner: Tune a radio set to a broadcast station of known frequency (most newspapers give the frequency of broadcast stations in the vicinity), and then disconnect the aerial and ground from the set. Start the oscillator by closing the filament switch SW and connect the ANT. and GND. posts of the oscillator to the receiver. Then turn the tuning knob (leaving the tuning of the set constant) until the note of the oscillator is heard in the loudspeaker. The number on the dial of the oscillator corresponds to the frequency of the broadcast station. This operation is repeated for stations of different frequencies. A curve is then plotted, the horizontal lines corresponding to the dial setting of the oscillator and the vertical lines to the corresponding frequency of the broadcasting stations. In this manner the frequency of the oscillator for any setting of its dial may be determined at a glance.

THE AUDIO OSCILLATOR

The possession of an audio oscillator seems to be the ambition of a great many Service Men. Why they do not possess one is beyond the comprehension of the author, since many interesting experiments and tests may be made with one. The diagram of connections is shown in Fig. 47.

Coils L1 and L2 are the secondary and primary, respectively, of an ordinary low-ratio audio transformer, the grid leak R1 should be made variable from 0 to 10 megs.,

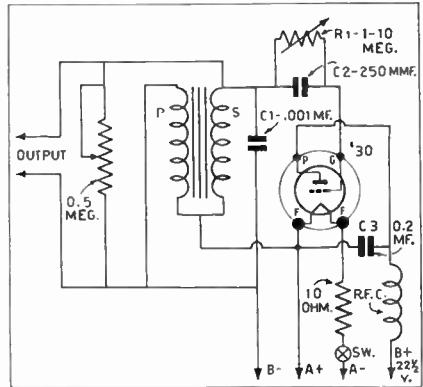


Fig. 47.

the choke R.F.C. should be increased to 15 henries, pot. should be increased to 500.-000 ohms, and the bypass condenser C3 should be changed to 2 mfd. Variation of the audio frequency pitch is secured by merely varying the size of the grid leak. Almost any range of audio frequencies may be secured by changing the size of either C2 or R1, the greater either one is made, the lower the frequency generated.

The output of the A.F. oscillator may be fed directly into the A.F. amplifier of a radio set which is under test or, better, may be put in through the R.F. oscillator. It is caused to modulate the R.F. oscillator's wave by having its output connected across the coil marked "input" on the R.F. oscillator diagram.

In setting up the stages of a super, especially one with AVC, a modulated R.F. signal is needed. This signal is fed into the set through the antenna and ground connections (or otherwise, if the manufacturer's data sheet so instructs) and the set adjusted until the highest output is obtained.

A very simple output indicator may be made as shown in Fig. 48, the transformer

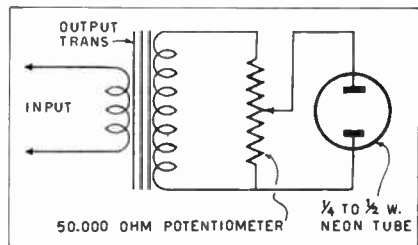


Fig. 48.

being a high-ratio output one, with a 50,000 ohm potentiometer wired across its secondary, as shown. In use, it is adjusted so that the neon tube barely glows from the signal, when the transformer primary is connected to the output of the receiver being serviced. As the set is aligned, the tube glows more brightly, and is again reduced in brilliance, through adjustment of the potentiometer, the procedure being followed as each stage of the set is brought to most perfect resonance.

Sometimes, however, a more easily read output indicator will be wanted, such as a meter.

THE OUTPUT METER

For frequencies above 100 cycles, the ordinary A.C. meter is useless. There are, however, small, dry rectifiers that are capable of handling very small currents efficiently. Several of these may be obtained and connected in a bridge arrangement as

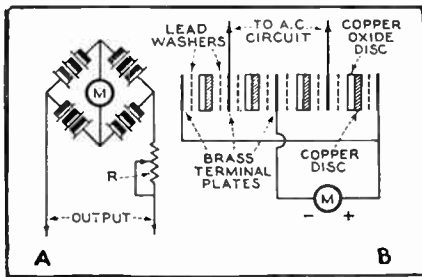


Fig. 49.

shown in Fig. 49A. The resistance R is adjusted until the meter reads full scale with a loud signal impressed. In most cases it has a value of 5,000 ohms.

Many manufacturers make their dry disc rectifiers with an internal bridge connection. In such cases, the meter should be connected as shown in Fig. 49B. The meter M is a D.C. milliammeter. The advantage of this method of connection lies in the fact that if the arrangement is to be used for reading current, the resistor R is short circuited and the terminals are connected in series with the circuit through which the current is to be measured.

Hot-wire ammeters are frequently used for R.F. measurements.

ALIGNING THE R.F. TUNING CONDENSERS

With present model radio sets, single-control tuning is used to the exclusion of all others. It is therefore necessary, in order for maximum signal strength to be obtained and for a minimum of interference to be received, that all the tuning condensers in the receiver be tuned precisely to the same frequency at any setting of the dial. Receivers that are out of line are bothered with interference, tune broadly and in some cases receive the same station at two or three points on the dial. This latter condition must not be confused with the "double-peak" reception which occurs when the volume control is turned too high on some types of screen-grid receivers. For the purpose of lining the tuning condensers in a set, there are connected across the tuning condensers small auxiliary or "trimmer" condensers. These are adjusted, by the method to be described later, until the signal is loudest. This type of adjustment does not hold for any setting of the condenser, so that many manufacturers construct the last plate in the tuning condenser in sections.

Each section is adjusted for a particular setting of the condenser, and, consequently, the tuning elements may be "lined-up" at all settings of the dial. Do not fool around with the plate segments; setting them is a factory job. Confine your efforts to the trimmers.

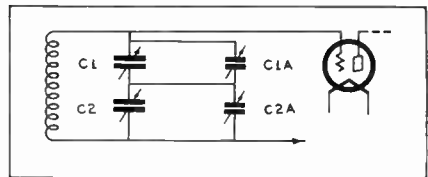


Fig. 50.

Another method that is used to some extent is a "bridge" arrangement depicted in Fig. 50. The tuning condenser is $C1$, while $C1A$, $C2$, and $C2A$ are adjusting condensers. With low settings of $C1$, the parallel effect of $C1A$ is large, and therefore $C1A$ is used to line the unit at the low wave lengths, say 1500 kc. At the higher wave lengths, $C2A$ is adjusted ($C2$ being fixed), since it is in series with the tuning condenser.

In lining up any set, especially a super-

het, follow the manufacturer's data sheet. He tells you the best way to adjust his particular set. You cannot improve upon his methods.

But if no data sheet is available, there is one general method in "tuning up" R.F. stages. The antenna and ground are removed from the set, and the ANT. and GND. posts of the R.F. oscillator are connected to the receiver. The plate lead to the detector (first detector in a superheterodyne) is broken and a low range (0-2ma.) D.C. meter is inserted. The set is tuned to a low wave length, and then the oscillator dial is turned slowly until the meter shows the highest reading (in the case of a grid-leak and grid-condenser detector, turn the oscillator dial until the reading is at minimum). Adjust the signal output of the oscillator until the meter reads half scale, and then retune the set carefully until a maximum reading is secured. This latter precaution is taken in order to be sure that the set is tuned to the same frequency as the oscillator. The proper balancing condenser is now turned slowly until the reading is maximum (or minimum, depending upon the detector). The balancing or padding condensers on the second, third, etc. stage are then adjusted in the same manner. If at any time the pointer of the milliammeter goes off scale, then the output of the oscillator should be reduced. This procedure should be gone over at least twice in order to secure satisfactory results. The dial of the set should now be tuned to the high wave bands and exactly the same routine followed. In cases where only one padding condenser in each R.F. stage is present, only one wave-length adjustment is possible, and the dial of the set should be tuned to the middle of the scale and the balancing done there.

If it is inconvenient to break the plate lead, an analyzer may be used, the lowest scale on the meter being employed. If the Service Man has an output meter or neon indicator, it may be connected across the primary of the output transformer, and used in exactly the same manner as the milliammeter described above.

THE POWER UNIT

The power unit of any receiver consists essentially of a power transformer, a rectifier tube, one or more chokes, filter condensers, and a bleeder resistor, as indicated

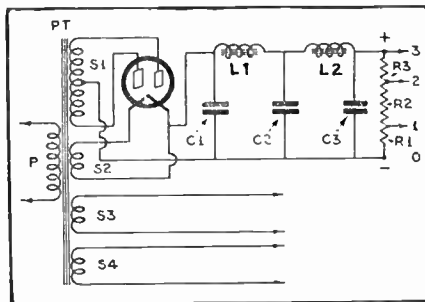


Fig. 51.

in Fig. 51. Several taps may be taken from the resistor as shown. Suppose that trouble is suspected in the power unit. How should one test it? The defects may be outlined in the following manner:

Defective Tube

Low or 0 voltage. Replace tube. If trouble persists, proceed as follows.

R1 Shorted

Set not connected to power unit, no voltage between 0 and 1; all other voltages higher than normal with set connected or not connected to power unit.

R1 Open

Set connected, voltage from 0 to 1, higher than normal; set disconnected from power unit; voltage from 0 to 1, very high; 0-2, high; 0-3, high.

R2 Shorted

Set connected, voltage between 1 and 2 zero; set disconnected from power unit; voltage between 1 and 2, zero; all other voltages high.

R2 Open

Set connected, voltage between points 1 and 2 high; set disconnected from power unit, voltage between points 1 and 2, very high; 0-1, zero; 0-2, high; 0-3, high.

R3 Shorted

Set connected, voltage between 2 and 3 zero, all other voltages high; set disconnected from power unit; voltage between 2 and 3, zero; all other voltages high.

R3 Open

Set connected, voltage between 2 and 3 high; set disconnected from power unit; voltage between 2 and 3, high; voltage from 0-1, zero; from 0-2, zero; from 0-3, high.

C1 Shorted

No voltage in set, L.1 and L.2 cool, rectifier tube very hot, transformer very hot.

C2 Shorted

No voltage in set, L.1 hot, L.2 cool, rectifier tube red, transformer hot.

C3 Shorted

No voltage in set, L.1 and L.2 hot, rectifier tube red, transformer hot.

L1 or L 2 Partially Shorted

Voltages in receiver high, A.C. hum apparent.

L1 or L2 Grounded

Symptoms the same as for when C2 or C3 is shorted.

L1 or L2 Open

No voltage in set; voltage high between center tap of power transformer and filament of rectifier tube.

SUPERHETERODYNE RECEIVERS

There are at least two main reasons for the superheterodyne. One is that low frequency R.F. (called I.F.) can be more efficiently amplified without causing the tubes to break into oscillation than can higher frequencies. The other is that an amplifier may be peaked more efficiently at a single frequency than over a wide range of frequencies.

That is exactly what happens in a superhet. The signal is picked up on the antenna and amplified by one or two stages of R.F. amplification, then fed into a "first detector" or mixer tube, where it is heterodyned ("mixed") with a locally generated frequency.

A heterodyne (or "beat frequency") results. This new frequency is controllable by the oscillator tuning condenser, usually ganged with the signal tuning condenser of the set. Thus the heterodyne frequency (the "intermediate frequency" or I.F., being lower than the R.F., yet higher than the A.F.) is kept constant. It is amplified tremendously in the I.F. amplifier stage or stages, and is then detected in the second detector, after which it is amplified at audio frequencies in the A.F. stages.

In order for a resultant low frequency to be generated, the frequency of the local oscillator must differ from that of the desired signal by an amount equal to the low-frequency at which amplification is to take place. This low frequency is called the intermediate frequency and is abbreviated I.F. A distinct advantage of such a receiver is the fact that the intermediate frequency may be kept the same regardless of tuning of the set over the broadcast band, and consequent-

ly no variable tuning condensers are required in the I.F. amplifier stages. In this manner the number of variable elements may be reduced to a minimum, although the number of fixed-tuned I.F. stages of amplification is large.

HOW TO LINE THE I.F. STAGES

Again let me repeat that in all cases where manufacturer's data sheets are available, the instructions they give should be followed.

If you cannot get such sheets, then and then only, follow the procedure given below.

First, remove the oscillator and all the R.F. tubes from their sockets, leaving only the first detector, the I.F., the second detector, and, if desired, the audio amplifier tubes in their sockets. Connect the two terminals of your separate I.F. oscillator to the grid and cathode terminals of the first detector, after first disconnecting the secondary of the R.F. transformer of the first detector tube. A milliammeter is next connected in series with the plate of the second detector, or an output meter may be connected across the terminals of the output transformer as previously described under "Lining up the R.F. Stages."

The Oscillator is tuned to the I.F. frequency the "trimmer" condensers are tuned on each of the I.F. transformers in turn, until the reading of the meter is a maximum (or a minimum if a grid-leak and grid-condenser detector is used). This process should be repeated at least twice in order to insure accuracy. In cases where it is inconvenient to remove the secondary of the transformer feeding the first detector, the two terminals of the oscillator may be connected to a small coil of about five turns, and this coil coupled closely to the grid coil of the first detector.

With the I.F. transformers correctly lined, the tubes may break into oscillation (even at 175 kc., especially if three-element tubes are used as in old sets.) The next procedure is to neutralize each stage in the manner described for R.F. stages. When this is completed the lining-up process should be repeated. The entire routine may have to be gone over several times before the amplifier is acting normally, but the effort will be compensated by the very stable results secured.

LINING THE OSCILLATOR CONDENSER

With the I.F. units in line, the next procedure is to adjust the R.F. tuning condensers; which is accomplished in the manner previously described. It is apparent that when the I.F. units and the R.F. condensers are in line, maximum signal strength will be obtained when the oscillator frequency is separated from the signal frequency by exactly 175 kc.

This intermediate frequency (175 kc.) may be obtained either with the oscillator 175 kc. above or below the signal frequency. Modern practice dictates that it shall be tuned above the signal frequency in order to minimize interference.

The milliammeter is again connected in the plate circuit of the second detector, all the tubes in the receiver are inserted, and

time to be sure of a maximum deflection of the meter.

The oscillator trimmer condenser in the receiver is readjusted for maximum response. Two points on this condenser will be found. *Choose the one with the minimum capacity—"widest open."* The same procedure is repeated for a higher wave length—about 600 kc.

The receiver is now "lined up" and "ready to go."

THE AUDIO AMPLIFIER

There are two principal types of audio amplifiers, of which Figs. 52 and 53 are typical. The former is transformer coupled; the latter, resistance coupled.

If properly designed, and if cost is not a major factor, the former is preferable, for it affords higher gain per stage and better

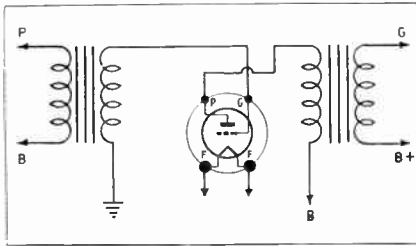


Fig. 52.

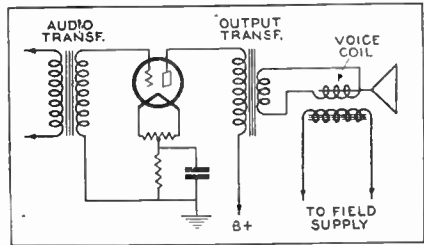


Fig. 54.

the R.F. oscillator terminals connected to the ANT. and GND. posts of the receiver in the usual manner. The receiver is tuned to a low wave length (about 1400 kc.), the set oscillator trimmer condenser is adjusted until maximum response on the meter is noted. The R.F. tuning condensers are then rotated slowly to determine if there is any increase in response, and should be left at the maximum point. It might be wise to tune carefully the external oscillator at this

tone quality. But if price must be kept down, a resistance coupled amplifier will give better results than a transformer coupled one of equal cost.

The servicing of an audio amplifier is far simpler than that of a radio frequency or intermediate frequency one, for balancing (tuning) does not have to be done. A quick check-up with the analyser described will reveal the faulty circuit. The defective part is replaced with an exact duplicate, and the set is okay again.

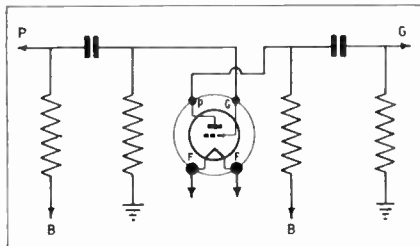


Fig. 53.

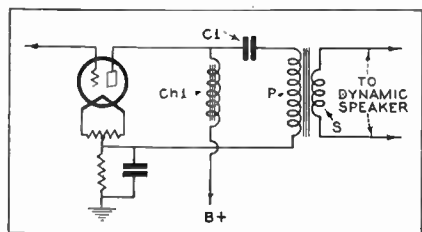


Fig. 55.

CONVENTIONAL AUDIO AMPLIFIERS

Practically all audio amplifiers are equipped with output transformers. Their use is necessary, not only because the D.C. component of the plate current flows through the transformer instead of the speaker, but also because the impedance (combination of resistance and reactance) of the voice coil of the usual dynamic speaker is far too low to be inserted directly in the plate circuit. A transformer must be used to raise this impedance to the required

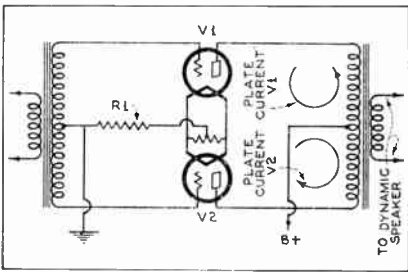


Fig. 56.

value—twice the tube's impedance in three-element tubes and one-fifth the impedance in pentodes. The schematic diagram of the usual amplifier is indicated in Fig. 54.

In certain cases where it is desirable to tune the amplifier in order to increase the response of a certain frequency, a choke is inserted in the plate circuit as indicated in Fig. 55. The value of condenser C1 together with the inductance of the primary of the output transformer is tuned to the resonating frequency. Another advantage of this method of connection is the fact that the D.C. component of the output does not flow through the transformer. This is distinctly advantageous where a slightly excessive amount of flux (magnetism) in the

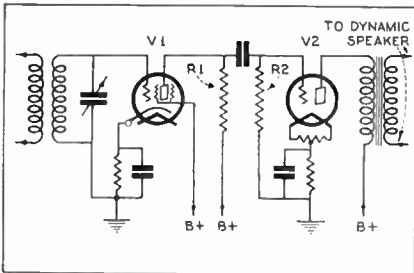


Fig. 57.

core is liable to cause saturation of the core, with a consequent reduction in inductance, manifested as distortion.

A push-pull connection, Fig. 56, is very popular at present due to the fact that the even harmonics generated in the tube when it is distorting, cancel out; consequently, the load impedance may be made equal to

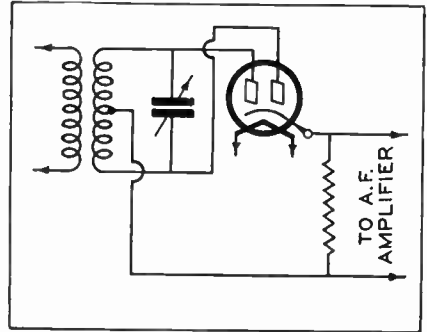


Fig. 58.

the tube impedance and greater output secured. It should be noted that the plate currents of each tube flow in opposite directions through the output transformer and therefore the D.C. flux in the core is always zero. This prevents the undesirable core saturation which is possible when D.C. flux is present.

DETECTORS

In some types of receivers the output of a linear detector feeds directly into the power tube as shown in Fig. 57. This is a resistance-coupled stage and is used when a screen-grid tube is the detector. It is more economical to use a coupling transformer when a three-element tube is the detector because of the additional gain that is secured. The remainder of the circuit is self-explanatory.

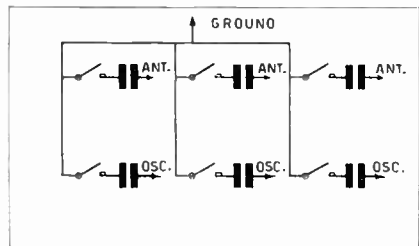


Fig. 59.

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The widely used Duo-Diode was introduced a few years ago. The schematic circuit is depicted in Fig. 58. It is simply a full-wave rectifier similar to the '80 type used in the power unit.

AUTOMATIC TUNING

There are, at the present writing, two chief means of achieving automatic tuning or "push-button" control. The first and simplest, shown in Fig. 59 is merely a group of trimmer condensers, each pair being put into its circuit by means of a push-button, *no two of which are possible to depress simultaneously.*

The first push-button is pressed and the trimmers it controls are adjusted until one station is heard with maximum volume. Then the next button is pressed and a second station is similarly tuned in. The procedure is repeated for the rest of the buttons.

More complicated is the motor driven tuner. In this case, a button starts a motor which drives the tuning control, releasing it through the action of a clutch at the predetermined setting. No more will be said about the mechanical means here, as it varies considerably in sets of different manufacture.

AUTOMATIC FREQUENCY CONTROL

Automatic frequency control is a highly ingenious and rather complex action, a good description of which has been given by C. P. Mason, associate editor of Radio-Craft, the magazine which publishes so much of interest to the service man. The following is quoted from an article by Mr. Mason, in that publication.

If an A.F.C. set is tuned to within 7

kilocycles of a strong signal, it will adjust its oscillator's tuning until the signal is brought within 500 cycles. A weak signal can be pulled in from, say, 3 kc. away; in each case, the final accuracy is increased as the receiver is more correctly tuned. So, in A.F.C. sets, tuning by hand, and then cutting-in the A.F.C. circuit with a switch, results in a correction which improves the quality. Of course, if one should set an A.F.C. receiver half-way between two strong signals, say 10 kc. apart, and turn on the A.F.C. control, the set might be puzzled to choose, like the donkey between two loads of hay; but this is not a common condition. In some new receivers, when the tuning control is turned to "preset" stations, the A.F.C. is cut out automatically until the dial stops rotating.

Every circuit is tuned by the presence of a certain amount of capacity and inductance (as well as resistance, which can never be entirely eliminated); the higher their product, numerically, the higher the wavelength, and the lower the frequency. The combined action of the capacity, pulling electricity ahead, and the inductance, holding it back, determines the frequency which will build up the greatest voltage in the circuit from a given signal.

If we put two inductances, side by side, in an electrical circuit, the two will present less obstruction (less reactance) to a current. Similarly, if we put a resistance in parallel across an inductance we lower the effective reactance; just as though we had decreased the inductance.

If we put a resistor across the coil, we draw current when the inductance should hold it back, thus weakening the effect of the inductance. But, on the next quarter-cycle, the resistor would pass current when the inductance was also forcing it along, instead of bucking the inductance. The same would be true, in the case of

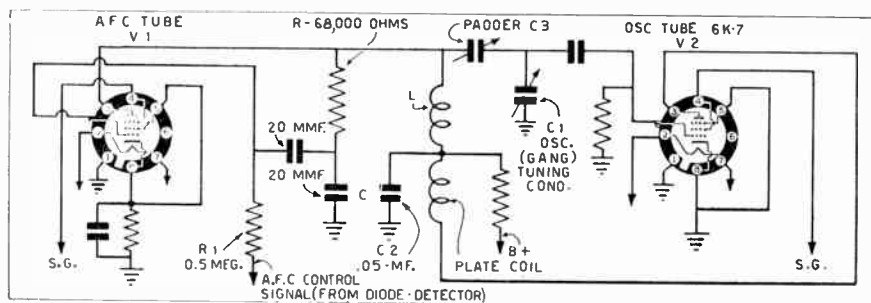


Fig. 60.

a vacuum tube uniformly biased (positively) which can also be considered a special form of resistance.

But the trick of the A.F.C. is to make the tube V1 alter the frequency at which the circuit of tube V2 (Fig. 60) oscillates, regardless of the setting of the oscillator circuit L-C1-C2-C3. By making the tube act either in opposition to or together with, the tuned grid inductance L, the effective inductance of the circuit is raised (lowering the frequency) or lowered (raising the frequency) so far as the R.F. voltage on the control-grid of V2, and its consequent voltage output, are concerned. And this, correspondingly, affects the I.F.

In order to do this, it is necessary to make the plate voltage of V1 oppose the oscillator control-grid voltage, set up in in the oscillator tuned circuit, whenever the receiver's I.F. amplifier is getting signals "off peak." This is done by feeding the regulatory signals to V1 from the resistance-capacity voltage divider R-C, which is across the oscillator coil. The presence of the small condenser C "lags" the voltage behind the current (just the reverse of an inductance's action), and the output of the tube V1 thus opposes the action of the tuned coil (L), the voltage of which is also applied to the control-grid of V2. (If the amplification of V1 were sufficiently high, it would completely neutralize the oscillation; but it is not.) This carefully-made adjustment, and the action of the diode-detector of the receiver, biasing V1, change the frequency of V2, just as though we were turning the rotor of a variometer coil in parallel across L.

SOURCE OF A.F.C. VOLTAGE

The next question is, where does the regulating voltage for the grid of V1, come from? We turn to Fig. 61, which shows at A the standard double-diode detector of a receiver. As will be seen, the output of the I.F. amplifier is across the plates of this diode, which serves as a full-wave rectifier, one plate and cathode functioning on each half-wave. If the signal received is converted to the proper I.F. by the action of the oscillator, the waveform passed through the tuned I.F. amplifier comes out symmetrical (Fig. 61B) as it is a product of the signal carrier wave and the equally symmetrical wave from the oscillator tube. But, if these two waves do not blend to

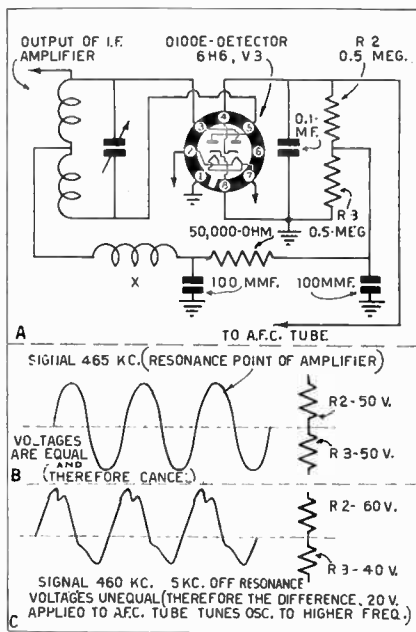


Fig. 61.

make one, which the I.F. amplifier is peaked to handle, there will be distortion—as shown at Fig. 61C, which represents the figure shown in an oscilloscope.

The result when the two halves of the waves rectified respectively by the two diodes P1-C1 and P2-C2 of the detector tube, are unequal, is to build up different voltages across their corresponding resistors, R2 and R3 (Fig. 61A). Now, when the waveform is symmetrical, these voltages are equal and opposite and therefore cancel each other. But if they are unequal, either a positive or a negative total voltage results, and this is fed from the upper end of R2 to the control-grid of the A.F.C. tube V1 as shown in Fig. 60.

When a positive R2-R3 voltage (as the result of the unequal detection of V3) reduces the bias on the control-grid of V1, the A.F.C. tube, V1 draws more current. This is equivalent to having a smaller inductance across the oscillator tube, V2, and the frequency of its oscillations will rise. This, in turn, will increase the frequency of the mixed signal which is passing through the I.F. amplifier.

If the I.F. signal frequency is, instead, too high, the difference in voltage becomes greater on the negative side.

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