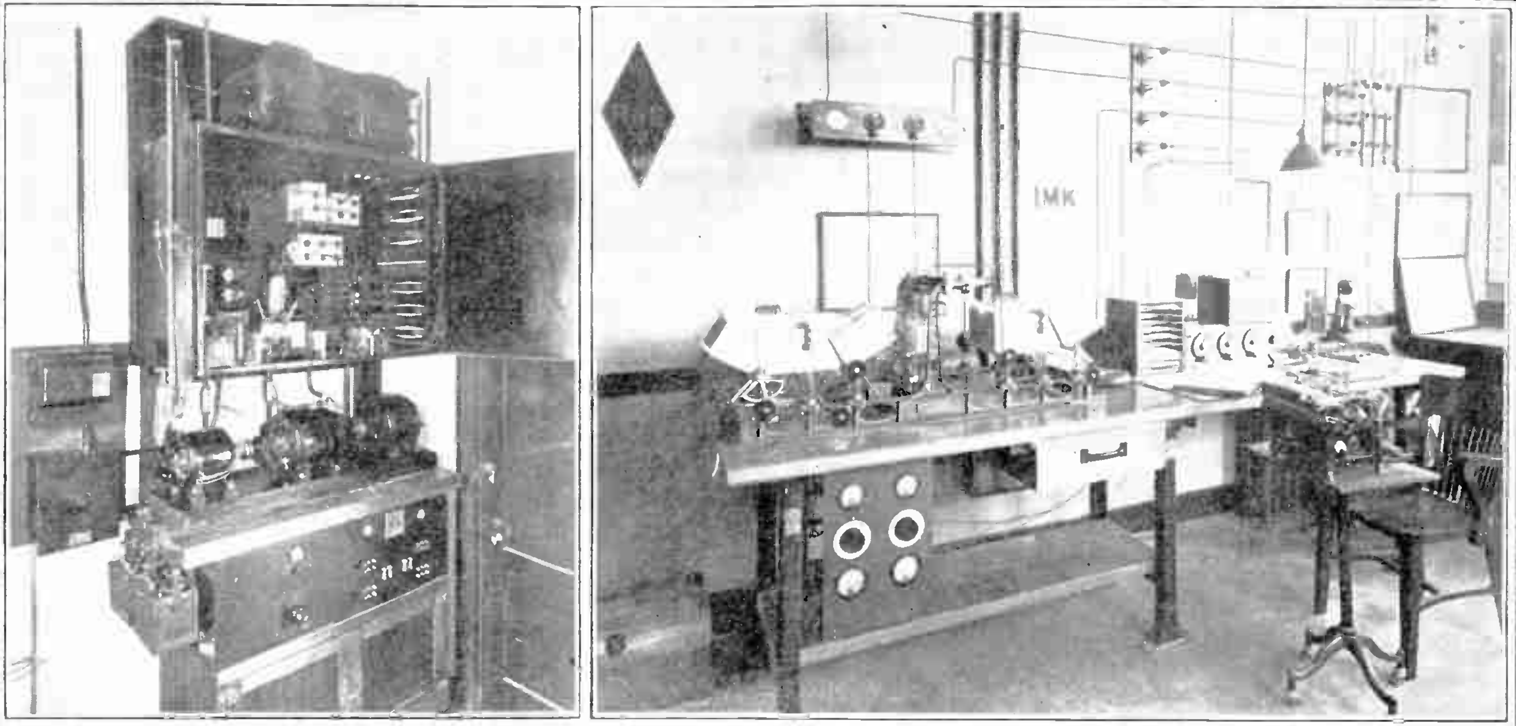
The Radio Amateur's Handbook

The RADIO AMATEUR'S HANDBOOK



W1MK, THE HEADQUARTERS STATION OF THE A. R. R. L. AT HARTFORD, CONN.

The power supplies and the operating position are shown. Note the neatness and accessibility of every feature of the station arrangement. High voltage d. c. to the main and auxiliary transmitters is obtained from a motor-generator and a mercury-arc rectifier and filter. Fuses, relays, batteries, charging equipment and the like are all in the power-supply room. The receiver is in front of the operator, key and controls at his right, and the message file box at his left. Ample space is provided for the monitor, frequency meter, and station log when not in use. Two-wire voltage (Zeppelin) feed is used to separate antennas for the different transmitters and there is a separate receiving antenna to facilitate "break-in" work. The Official Broadcasts to A. R. R. L. Members are sent simultaneously on 3575 and 7150 kc. The main transmitter unit has interchangeable coils of heavy tubing with compression-type threaded brass couplings and may be shifted quickly to any of the different amateur frequency bands. W1MK is a busy station but always ready for a call from any "ham". Operating schedules are published regularly in *QST*.

The RADIO AMATEUR'S HANDBOOK

A MANUAL *of* AMATEUR SHORT-WAVE RADIOTELEGRAPHIC COMMUNICATION

BY

FRANCIS EDWARD HANDY

COMMUNICATIONS MANAGER, AMERICAN RADIO RELAY LEAGUE

AND

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ASSOCIATE TECHNICAL EDITOR, *QST*
IN CHARGE, A.R.R.L. TECHNICAL DEVELOPMENT PROGRAM

SIXTH EDITION

HARTFORD, CONN.

THE AMERICAN RADIO RELAY LEAGUE

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FORWARD TO SIXTH EDITION

THE *Radio Amateur's Handbook* is intended both as a reference work for member-operators of the American Radio Relay League and other skilled amateurs and as a source of information to those wishing to take part in amateur radio activities but having little or no idea how to get started. The choice and sequence of material have been planned with particular thought to the needs of the beginning amateur but each subject has been developed and carried on to embrace the most modern amateur practice in that particular department of activity. The book is designed to be a practical rather than a theoretical work, and necessary theoretical discussions are made as simple and fundamental as possible.

This book is made available by the American Radio Relay League. the radio amateur's own organization. Written by amateurs, for anyone and everyone interested in amateur work, it is hoped that it will be a helpful manual to those active in amateur work and instrumental in helping beginning and prospective amateurs to get into the game and get the most that there is in the enjoyment of amateur radio by directing their efforts along the lines that bring results most quickly, surely and cheaply.

In 1925, Mr. F. E. Handy, now the League's Communications Manager, commenced work on a small manual of amateur operating procedure, at the direction of the A. R. R. L. Executive Committee. It was deemed desirable to include a certain amount of "technical" information, since an amateur's results are so greatly influenced by the disposition and adjustment of his apparatus. When Mr. Handy completed his manuscript he had written a considerable-size book of great value. It was published in 1926 and enjoyed an instant success. Produced in the familiar format of the League's magazine, *QST*, unusual as that is for a publication of this nature, it was possible to distribute for a very modest charge a work which in volume of subject-matter and profusity of illustration surpassed most available radio texts selling for several times its price. Several successive editions have been revised by Mr. Handy as reprinting became necessary, and the book is now one of the institutions of amateur radio. Its fame went around the world and "Handy's Handy Handbook", as it has come to be known, has become the bible of practical amateurs in every country on the globe.

The present edition has been extensively revised and concerning this a word of explanation is in order. In late 1927 a new international radio convention was adopted by the nations of the world, an international treaty making profound readjustments in every part of the structure of radio, taking effect at the beginning of 1929. Throughout the year 1928 all classes of radio users, all over the world, were studying and planning to meet the requirements of the new convention. Operating procedure was changed. New technical requirements made obsolete many practices which were satisfactory theretofore. Particularly were these things true of amateur radio, for the privileges allotted to radio amateurs were reduced by the new treaty, which meant a greater congestion in operating and the necessity for improving methods. Recognizing this condition the amateur organization, the A. R. R. L., during 1928 carried on a technical development program, under the direction of Mr. Ross A. Hull, for the development of apparatus and methods which would overcome the handicaps of reduced space in the radio spectrum and give assurance of continued successful operation. The beginning of 1929 really marked a separation between the old and the new in amateur radio. Our Handbook, then, needed an overhauling in its technical phases, not only to keep abreast of normal progress but to revise treatments which had been perfectly satisfactory in 1928 in terms of the new requirements of 1929. Mr. Hull, as the director of the League's technical development program, was the logical man to join Mr. Handy in the current revision, and the present work represents a collaboration between them.

The book continues to be based on Mr. Handy's earlier editions. Some of it has been retained intact. The chapters on operating practice have been revised by Mr. Handy in terms of modern procedure. The chapters on station apparatus and adjustment have been revised by Mr. Hull in terms of the results yielded by the League's technical development program.

Some of the material is taken from *QST*, contributions from members of the League, and to them we are indebted. The book becomes, however, increasingly a family affair of the A. R. R. L. headquarters staff. Its production is managed by the personnel which produces *QST*; the opening chapter, entitled "Amateur Radio", is from the pen of Mr. A. L. Budlong, assistant to the A. R. R. L. Secretary; and this already-too-long foreword by the League's Secretary.

K. B. WARNER.

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The Amateur's Code

I *The Amateur is Gentlemanly.* He never knowingly uses the air for his own amusement in such a way as to lessen the pleasure of others. He abides by the pledges given by the A.R.R.L. in his behalf to the public and the Government.

II *The Amateur is Loyal.* He owes his amateur radio to the American Radio Relay League, and he offers it his unswerving loyalty.

III *The Amateur is Progressive.* He keeps his station abreast of science. It is built well and efficiently. His operating practice is clean and regular.

IV *The Amateur is Friendly.* Slow and patient sending when requested, friendly advice and counsel to the beginner, kindly assistance and coöperation for the broadcast listener; these are marks of the amateur spirit.

V *The Amateur is Balanced.* Radio is his hobby. He never allows it to interfere with any of the duties he owes to his home, his job, his school, or his community.

VI *The Amateur is Patriotic.* His knowledge and his station are always ready for the service of his country and his community.

—PAUL M. SEGAL, W9EEA.
Director, Rocky Mountain Division, A.R.R.L.

The RADIO AMATEUR'S HANDBOOK

CHAPTER I

Amateur Radio

IT CAN hardly be expected that the buyer of this Handbook will read this chapter first, nor is he particularly urged to do so. It is more likely that practical considerations have governed the acquisition of the book and that the first rush will be to the "How-To-Build-It" chapters which follow.

We expect this to be so, nor would we have it otherwise. Learn the code—build your receiver and transmitter—put them into operation! Then, when the first flush of success has passed, come back to this chapter, and at your leisure, find out something of the history and development of the class to which you now belong.

Amateur radio to-day is an established institution. Thousands of people pursue it as a hobby; a powerful and prosperous organization bonds together these followers and protects their interests; an internationally-respected radio magazine is published solely for their benefit. The Army and Navy seek the cooperation of the amateur in developing communication reserves; the public depends on amateur services in major emergencies; the countries of the world recognize him as one of the established branches of the radio art and provide space on the air for him in writing up international radio treaties.

Thirty years ago amateur radio did not exist—the name, had it been used, would have meant nothing. All the development just mentioned, then, has taken place within the comparatively short time represented since the opening of the present century.

It is the purpose of this chapter to trace, briefly, this development.

WHO was the first amateur? Long familiarity with the breed has made possible a most likely assumption. It is probable that within a few days of the announcement by Marconi of the successful termination of his first experiments in radio communication, an ambitious young Italian with an insatiable curiosity had wormed himself into the confidences of the illustrious Senatore and acquired enough of the rudiments of the new art to attempt a duplicate of the original apparatus. He was the world's first amateur. Our conviction of his existence is in no wise lessened by the fact that history neglects to mention him.

History does come to our aid as soon as we turn to the American amateur. Prior to the advent of radio telegraphy there existed a class of young fellows whose hobby centered around "electrical experiments". They built electric motors and wet cells to run them; they assembled Wimshurst static machines; they constructed backyard telegraph lines.

When Marconi announced that it was possible to send messages without wire and proved it by transmitting the letter "S" across the Atlantic Ocean, the older heads murmured in awe and consulted their Bibles. Our youthful electrical experimenters, on the other hand, perceived immediately that here was something a hundred-fold more engrossing than "electricity". With one voice they asked "How does he do it?", and with one purpose of mind they proceeded to find out for themselves. At least one American amateur had a receiver built at the time of the first Trans-Atlantic experiment, nor was his enthusiasm in any degree dampened by its failure to perform.

Enter, Amateur Radio!

FOR ten years progress was slow, crude and fraught with difficulties. There were few books on the subject—none of a popular nature. There were no radio magazines. Much of an amateur's transmitting and receiving equipment was homemade, of necessity, the glorious era of ten-cent-store radio being some twenty years in the future. Only a few concerns in the country carried radio equipment of any kind.

But progress was made. The coherer and microphone detector gave way to the crystal, with its enormously increased sensitivity. The single-slide tuner displaced the straight aerial-to-ground hookup, and was itself displaced by the more flexible three-slide tuner. This, in turn, was superseded by the loose-coupler with variable condenser tuning. There were rumors filtering through of a new type of detector, the audion bulb, invented by DeForest, which was even superior to the crystal and which needed no adjustment.

The transmitters were all spark. The beginners used spark coils, straight spark gaps and—sometimes—a simple kind of antenna tuning. Their more wealthy brothers used high-voltage transformers. Power was limited by one's pocket-book, and some pocket-books did not stop short of the five-kilowatt mark.

Rotary gaps were developed and were pounced upon.

Wavelengths were to a certain extent accidental—but the aim was high. Unfortunates with limited antenna facilities had to be content with 250 or 300 meters; most of the big fellows were from 300 up—as likely as not, around 1000.

By 1912 ranges had increased to the point where the fellow with several kilowatts was sometimes heard three and four hundred miles, in favorable sections of the country. The average radio amateur, however, contented himself with more moderate distances, and used his set for the most part in conversing with friends on the other side of the city.

There must have been five or six hundred amateurs by the end of 1911. With the total Navy and commercial stations coming to only fifteen or twenty percent of this figure, the advantage obviously lay with the amateur when it came to dominating the air. If a commercial station wanted to do any work it was usually necessary to make a polite request to the local amateurs to stand by for a while. If the request was not polite or an amateur-commercial feud happened to exist, the amateurs did not stand by and the commercials did not work.

THE law came for the first time in 1912. Government representatives returned from an international radio meeting in London armed with detailed regulations to govern the newly-arrived industry and sundry announcements were immediately made to all amateurs as follows: Every amateur operator must take out a license for himself and his station. Amateurs would have to keep their power down to a maximum of one kilowatt. They could not operate above two hundred meters. Commercial and Navy stations now had definite rights, and were no longer fair game. Official call letters would be issued to each station and were to be used by it when transmitting. A few special licenses would be issued to operate on 375 and 425 meters.

Initial alarm in the amateur ranks at these pronouncements was soon allayed when it was found by experiment that if the matters of obtaining licenses and of showing consideration to the commercial and government stations were complied with, observance of the other features was not particularly necessary. "Two hundred meters" would cover anything from 250 to 375. "One kilowatt" could be stretched to two or three without too much fear of governmental admonishment. Regulation, in a word, was not accompanied by enforcement beyond the bare essentials, either in the amateur ranks or in any other branch of radio, in those first early days.

Under this happy state of affairs the amateur grew and prospered, and by the first part of 1914 had increased in number to about 2000. Except, however, for a slight increase in transmitting range to four or five hundred miles for the big fellows, and the use of audion bulbs—non-regenerative—by some of the more advanced stations for receiving detectors, the art remained in about the same state.

WE LIKE to think of destiny as—well, Destiny—advancing relentlessly despite the futile efforts of puny man. It perhaps would be more accurate to say that man, by taking advantage of every-day incidents, makes a hole through which Destiny can forge.

Destiny caught up with the amateur in 1914. The tale is tradition among old-timers, yet ever worth retelling. It was in the early part of this year that Hiram Percy Maxim, of Hartford, Conn., desiring to send a message to Springfield, Mass., with an amateur transmitter whose range did not extend to Springfield, conceived the idea of having it relayed by an intermediate station at Windsor Locks.

It was done.

Now, it is not claimed that this in itself was unusual. Ships were using the relay principle to get messages from mid-ocean to shore with the assistance of other ships. It is reasonable to assume that amateurs themselves had previously relayed messages beyond the limits of their own particular sets.

The act itself, therefore, has no great significance. The application of the act, however, has all the significance in the world. Maxim had for many months thought of starting a national amateur organization. He had not carried it further than the idea state because he could think of no prime moving force, no basic principle around which to rear the structure. Americans have always been great "joiners", but if an amateur organization were ever to progress beyond the paper stage it must offer something more than one's name on the rolls. In short, unless he could find something definite for such an organization to do, he could not justify its existence.

The morning after the Hartford-Springfield relay while his thoughts were harking back to the previous evening's success, the old ideas about the national organization wandered through his mind—something clicked—and Destiny had camped on the amateur's doorstep.

For here, without a doubt, was the idea around which the organization should be successfully and strongly built. The missing block in the puzzle had been found and fitted. The organization would be a *relay* organization. It would have as its object the developing of relay routes over all the country among all the amateurs, so that by this means an amateur in one part of the country could send a message hundreds of miles to an amateur in another part; perhaps even send a message from one coast to another!

WITHIN a week, a name had suggested itself suitable for this new organization, and a month later it was decided to start the ball rolling. Witness, then, in May 1914, H. P. Maxim and another Hartford amateur, C. D. Tuska, sitting down and writing a letter to each one of the amateurs listed at that time in the government call-book, announcing the formation of the *American Radio Relay League*, outlining its purposes, and soliciting membership. There were no dues; membership was free on application.

Response was immediate and enthusiastic. Applications came back in every mail. In the early summer of 1914 was issued the first publication of the American Radio Relay League—a little blue-bound call-book listing the names, addresses, calls, power, range, receiving speed and operating hours of three hundred League members. This sold for 50c.

By letter and radio the word was spread. Membership increased rapidly. In January, 1915, the League was incorporated under the laws of the State of Connecticut as a non-commercial organization with no capital stock. In March, 1915, a second call-book was issued, listing some six hundred members. In the meantime, through radio contacts and correspondence, attempts were being made to build up the relay routes for which the organization had been formed. Some success was being had in this line. In late summer of 1915, however, a serious difficulty loomed and demanded attention. It was proving a real task to acquaint the growing membership with the plans and schedules by means of letters only. Increasingly it became evident that a bulletin of some kind was necessary. The League, however, had no funds; membership was still free and the call-books were sold at cost.

What to do?

The answer came in December of 1915 when each member of the League received in his mail a sixteen-page magazine called *QST*. This, it was announced, was being published privately at the expense of Maxim and Tuska and was thenceforth to be the official publication of the League. League membership continued to be free. Any League member who wanted to get the magazine could have it by sending in $1.00 for a year's subscription.

Response was again immediate; *QST* continued, and, except for a period during the war, has since been published monthly as the official organ of the League.

HAVING now a journal in which to chronicle the activities of the membership, Progress rolled up its sleeves, hitched its belt and settled down to business. A member, discovering some new improvement for his apparatus, would write an article on the subject, and within a month everyone was benefiting by it. Manufacturers, invited to advertise, found a new and responsive field for their wares. Some of them began to manufacture apparatus peculiarly suited to amateur needs.

Early in 1916 a plan for an organized relay system was promulgated; by the end of that year six major trunk lines had been established and four of them were being actively developed under trunk line managers.

Earlier in the year—February 22, 1916—occurred the first attempt at a nation-wide relay test when Kirwan, 9XE, of Davenport, Iowa, inaugurated the first Washington's Birthday Relay with a message from Col. W. P. Nicholson, of the Rock Island Arsenal, addressed to the governors of every State in the Union. The Pacific Coast got the message fifty-five minutes after it had been started at 9XE; the Atlantic Coast, sixty minutes after; New Orleans had it in twenty minutes and Canada had it in twenty minutes. The success of this test, though far from 100%, created the greatest enthusiasm and led to a prediction in *QST* that a transcontinental message would eventually be sent with but two intermediate relays.

It was during the summer of this year, too, that Charles E. Apgar, an amateur at Westfield, N. J., copied on phonograph records all the transmissions of the supposedly neutrality-observing German radio station at Sayville, and thereby provided evidence for the Government to take it over.

As a fitting close to the year, two manufacturers brought out special amateur regenerative receivers—instruments which so marvelously increased the sensitivity and range of receiving apparatus that a trans-continental relay was immediately proposed.

Here, indeed was high adventure!

THE year 1917 had no more than dawned when an amateur message did cross the country. On January 27th three messages were started from the station of the Seefred brothers, 6EA, on the Pacific Coast, and passing by quick jumps through 9ZF, 9ABD and 2AGJ, ended up at Maxim's station, 1ZM. But this accomplishment was almost immediately over-shadowed by a greater one. On February 6th a message was started from the East Coast, relayed to the West Coast, and an answer returned in the record time of one hour, twenty minutes! Though the calls of most of the stations participating in this epochal event are now in other hands, mention of the routing is nevertheless justified. It was, starting from 2PM on the East Coast, through 8JZ, 9ABD, and 9ZF to 6EA, on the West Coast, and back via the same stations.

In this same month an important change took place in the A.R.R.L. For nearly three years Maxim and Tuska had been acting as self-appointed president and secretary, respectively. By 1917 the League had grown to such an extent that a more business-like organization was deemed advisable. On February 28, 1917, then, a group of amateurs met at the call of Mr. Maxim in New York. When they dispersed, after a two-day session, they had written and adopted a constitution that outlined the policies of the League, specified the machinery for the election of officers, divided the country into six divisions, to be supervised by division managers and assistants, and had elected by vote twelve A.R.R.L. directors and four officers. These officers were: president, Hiram Percy Maxim; vice-president and general manager, A. A. Hebert; secretary, C. D. Tuska; and treasurer, C. R. Runyon, Jr.

With a real organization now behind it, with trans-continental relays a reality, with manufacturers at last catering whole-heartedly to amateur wants, with the trunk lines beginning to move traffic regularly, with a report of a west coast station hearing an east coast station direct and with a League membership of nearly 4,000, organized amateur radio in early 1917 was poised for tremendous strides in development.

THOSE strides were never taken—not *that* year.

For, coincidentally with its declaration of war on Germany in April 1917, the United States Government placed a ban on the operation of all amateur apparatus. Amateur antennas were lowered; amateur transmitters were sealed; amateur receiving apparatus was ordered dismantled.

But wait a moment—

A representative of the Navy Department met with President Maxim and Vice-President Hebert in New York and requested the aid of the A.R.R.L. in enlisting its skilled relayers as radio instructors and operators for the duration of the war. The need, it was explained, was desperate.

"How many do you want?" asked Mr. Maxim.

"Five hundred!" replied Lt. McCandless.

"How soon do you want them?"

"Immediately!"

"Can you put that in terms of days?"

"Yes—we want them within ten days!"

Destiny again. . .?

A last broadcast went out over the League's relay routes. Within ten days the Navy had its five hundred operators!

Thereafter, deprived of its basis of existence and steadily losing members to the armed forces of the United States, the League kept on as best it could for the benefit of those who were too old or too young to enlist and to bring the able-bodied members into the service. Everything possible was done to keep going. Hope was held out during the summer of 1917 that the war ban would not prevent experimental work with dummy antennas. It was a vain hope. Further orders were issued, strictly prohibiting the use of radio apparatus for any purpose whatsoever. The order was a deathblow. *QST* stopped publication with the issue of September, 1917, after having been run for several months at a loss.

The League closed its desk, locked the office, hung a "Not In" sign on the door knob, and went to war.

Before it was over, three thousand additional A.R.R.L. members had followed those first five hundred pioneers.

THE war ended on November 11, 1918. Eleven days later the old Board of Direction met in New York, authorized President Maxim to attend a hearing on a proposed radio bill in Washington, and adjourned after agreeing to meet again for the purpose of getting the League started.

In February, 1919, the Board met again and listened to a report by Vice-President Hebert on the condition of the League. This report stated that all membership dues had lapsed, and that there was but $33 in the treasury. It ended by recommending that if the League were reorganized, a paid secretary should be employed, and that *QST* should be bought from its owner, Mr. Tuska, and become the property of the League.

That Board had nerve and determination. On the first of March it again met, and voted to reorganize the League. Further, it voted to purchase *QST* for the A.R.R.L. The fact that there was only $33 in the treasury and that the purchase price of *QST*, including several month's unpaid printing bills, was close to $5,000, did not deter it one whit. It appointed a committee to devise a financing plan, told them to go to it, and adjourned.

Before the month was up, another meeting was held, attended this time by several of the old members of the League temporarily in New York. The first action taken at this meeting was to draw up a new constitution. It was done. New officers were then elected as follows: president, H. P. Maxim; vice-president, R. H. G. Mathews; treasurer, C. R. Runyon, Jr.; secretary, C. D. Tuska; traffic manager, J. O. Smith. The last-named office was a new one created under the new constitution.

It was immediately determined to advise as many former League members as could be reached of the reorganization plans. Orders were given to the Secretary to print up a miniature two-page *QST* and send it out. When it was pointed out that to send out such a bulletin would cost nearly $100, the eleven men present stopped the meeting temporarily, dug down in their pockets, and in a few minutes had placed $100 on the table. The men who thus made possible the first step toward reorganization were: Victor Camp, H. L. Stanley, J. O. Smith, W. F. Browne, A. A. Hebert, K. B. Warner, R. H. G. Mathews, C. D. Tuska, H. P. Maxim, A. F. Clough, and H. E. Nichols.

When they met two weeks later, applications were beginning to come in. It was voted to resume publication of *QST*, and K. B. Warner, formerly of Cairo, Illinois, was elected the paid secretary of the League.

On May 3, 1919, the Board again met to listen to a plan proposed by the Finance Committee. Briefly, it was to borrow $7500 from former League members, issuing in return certificates of indebtedness payable in two years with interest at 5% per annum. The proposal was approved. It was also voted to purchase *QST*. Secretary Warner was instructed to lay plans immediately for the first issue of the magazine.

In July the first post-war issue of *QST* was printed with money loaned for the purpose by the printer himself, and the A.R.R.L. bond issue was advertised to the members. It was stated that if the League were to continue, $7500 must be subscribed by the membership. No security could be offered—the League had no assets. The loan would be a loan on faith only.

Amateur spirit is a very wonderful thing. If you don't believe it, consider this: as one man the old League members subscribed to that bond issue. The League went on.

THE A.R.R.L.'s first job was to get the ban on transmitting lifted. Eight months had passed since the termination of hostilitie but transmitting was still prohibited. The League sent protests, appeals and entreaties to Washington, but month dragged after weary month with no results. Amateur radio fumed, swore and turned to building long-wave receivers for diversion. It was a poor sop, at best.

October—and the ban was lifted! An immediate headlong rush to get on the air took place. Manufacturers were hard put to supply apparatus fast enough. Each night saw additional dozens of stations joyously crashing out over the air.

Gangway!

KING SPARK!

Grown now to full maturity, developed and perfected by years of pre-war and war experience, it reached its highest peak in the succeeding eighteen months. Glorious old sparks! Night after night they boomed and echoed down the air lanes. Night after night the mighty chorus swelled, by ones, by twos, by dozens, until the crescendo thunder of their Stentor bellowings shook and jarred the very Universe! A thousand voices clamored for attention. Five-hundred-cycle's high metallic ring. The resonant organ basso of the sixty-cycle "sync". The harsh resounding snarl of the straight rotary.

Character: Nervous, impatient sparks, hurrying petulantly. Clean-cut business-like sparks batting steadily along at a thirty-word clip. Good-natured sparks that drawled lazily and ended in a throaty chuckle as the gap coasted down-hill for the sign-off.

Survival of the fittest. Higher and higher powers were the order of the day.

The race was on, and devil take the hindmost.

Interference.

Lord, what interference!

Bedlam!

Well, it could not be Utopia.

BUT it was an era of progress. Records were made and broken, and broken again. A message was relayed from Hartford to Los Angeles and an answer returned in 6½ minutes. 6ZK in California was heard in New York City. 9ZN in Chicago was heard in Panama. 2RK in New York was reported by a ship operator at Gibraltar. Relay routes grew over night; traffic mounted higher and higher. It became necessary to make the position of Traffic Manager a paid job, and Fred H. Schnell, of Chicago, came to Hartford as the League's traffic official. The League paid off its bonded indebtedness, and began to put money in the bank. An official emblem was adopted—the now-familiar diamond. At the request of Canadian amateurs, A.R.R.L. operating territory was extended to include Canada, and four Canadian divisions were created. The Bureau of Standards at Washington requested and secured the co-operation of League members in a nation-wide fading test. The First National Convention of the League was held in Chicago (Aug. 30—Sept. 3, 1921) and was attended by four hundred amateurs from all over the country.

IN the latter half of 1921 the giant Spark, storming unmolested across the countryside, met a stripling in his path. Each instinctively recognized the other as an enemy. The stripling stepped aside, but a year later they were to meet again. This time there was no stepping aside. David met Goliath, and the giant fell. Let us anticipate that meeting by a year and bid the gallant old warrior farewell while he is yet in his prime.

The King is dead—Long live the King!

Hail C. W.!

CONTINUOUS Wave Transmission for the amateur was an outgrowth of his war experience. While serving in the Army and Navy he had seen five-watt tubes covering very respectable distances. Interesting stuff, this C.W. Something to think about.

An undercurrent of C.W. experimentation began with the resumption of post-war transmission in 1919. It was confined to a small group for one very excellent reason: power tubes were not yet commercially avaliable. Only a favored few were in a position to acquire government war-time tubes. The acquiring, it may be said, was done by devious methods.

Those experimenters made some highly interesting discoveries. C.W. traveled incredibly long distances with low power. It was sharp. It did not create vicious local interference. It cut through static.

Such decided advantages could not be overlooked. When power tubes became available commercially early in 1921, the A.R.R.L. started a campaign advocating the adoption of C.W. for amateur use. Conversion, however, proved a slow process. The rank and file remained loyal to the spark with its brute-force appeal, and refused to be stampeded on the slight evidence of the slide-rule minority. Argument had no effect. "Long live Spark" became their watch-word.

It was apparent that nothing short of a clean knock-out victory for C.W. would convince them. This, as we shall soon see, was not long in coming.

IN December, 1921, thirty American amateur stations were heard in Europe! It electrified the amateur world—but it was not an accident. All but three of those thirty stations were logged with American amateur receiving equipment operated by an American amateur who had been sent to England at the expense of the League solely for that purpose. Not that we doubted the ability of our British cousins to do a good job on the receiving end, but—well, safety first. They had had little experience with 200 meters. So Paul Godley was sent over, and put up an antenna at the very edge of the sea on a bleak moor in Scotland. For ten bitter cold rainy days he made his home in a drafty tent with the receiving equipment, while every American amateur who could get a set on the air shot signals at him. When he dismantled his apparatus at the conclusion of the tests it had been demonstrated for all time that amateur signals on 200 meters could span the Atlantic.

Something else had been accomplished, too. More than two-thirds of the signals that got across were from C.W. stations. Here was an argument that could not be laughed off. The spark contingent thought it over, sighed resignedly, and began poring through catalogues of C.W. equipment. From that time on, the future of tube transmission was assured.

C.W. proved a most accommodating playmate, and immediately started out to justify the faith placed in it by the amateur world. The excitement of the Trans-Atlantics had not yet died down when a young fellow named Dow wrote from Hawaii to say that he was having no difficulty at all in copying dozens of American signals. Within a few months two-way communication with Hawaii was taking place nightly, and in the Fall of 1922 all previous amateur records were shattered to bits when Maxim started a message to Hawaii and had an answer back in less than four and a half minutes! Only one intermediate relay station was needed to bridge the gap from Hartford to Hawaii. The year closed with another trans-Atlantic test. If further proof of the merits of C.W. were needed, this test supplied it. Three hundred and fifteen American calls were logged in Europe. What was more, one French and two British stations were heard on this side. Two-way communication with Europe loomed as a possibility.

Trans-Pacifics!

Hardly had the year 1923 opened when New Zealand amateurs reported logging stations from every district in the United States. In mid-summer of the same year this news was eclipsed by reports from Australia that they were hearing many American amateur signals from all but the eastern districts, and coincident with these reports word came that several ships in Chinese and Japanese waters had logged West Coast amateurs.

It was becoming just a bit bewildering to keep up with developments.

INERTIA is more than a name in the physics text book and a factor in mechanical problems. It is something to be reckoned with in many lines of activity—including amateur radio.

When Marconi began his communication experiments he chose long wavelengths because spark apparatus was easier to handle at long wavelengths. Followed a natural inference on the part of the radio world: long waves are best. The mistake, of course, lay in assuming that because the apparatus functioned better at a long wavelength the wavelength itself was a superior one for communication. The 1912 London Conference fostered this belief by doling out the longest waves to the long-distance services. As wavelengths got down around 1,000 meters, they were apportioned to services with more limited range requirements. When it came to our resulting United States law, the amateur, being more or less of a nuisance at the time, was limited to a maximum of 200 meters. It was the firm conviction of most folks that this would effectually prevent him from getting out any farther than his backyard.

To a certain extent, then, the amateur must be forgiven if for the first twenty years of his existence he persisted in a belief that the only way to get DX was to boost the wave as high as possible. Even after the law made its appearance in 1912 the majority continued on the high side of 240 meters. Grumblings and dark glances greeted moves on the part of the Radio Inspectors to get amateur stations down to at least 220 meters in 1921 and 1922. Nor did the overwhelming success of the 1922 Trans-Atlantics suggest to the amateur world generally that there might be a catch in this matter of wavelength. The Trans-Atlantic success was a success in spite of the wavelength, and that was all there was to it. To-day we say it was indeed in spite of the wavelength, but we mean it differently.

With such a frame of mind existing, it is little wonder that no particular attention was paid to a short item early in 1922 announcing that Boyd Phelps, then assistant editor of *QST*, had worked Boston on 130 meters with splendid signal strength. Nor was any particular excitement aroused by the statement of a small group of amateur experimenters early in 1923 that a series of 100-meter tests had shown better signals over given distances for this wavelength than for 200 meters.

THE needed jolt came on November 27, 1923. On this date Schnell, 1MO, and Reinartz, 1XAM, worked for several hours with 8AB, Deloy, in France, for the first two-way communication across the Atlantic. It was a great accomplishment, but the significant thing was this: all three stations used a wavelength in the vicinity of 110 meters.

First suspicions that it might have been a freak were dispelled when additional stations dropped down to 100 meters and found, somewhat to their astonishment, that they too could work two-way across the Atlantic. The exodus from the 200-meter region started.

In early 1924 the Hoover Radio Conference assigned amateurs bands at 20, 40 and 80 meters. It must be admitted that the move from 100 to 80 was made with misgivings by many. There was magic in 100! It speedily developed that there was just as much magic in 80—perhaps a little more. Many other European countries were worked two-way.

Thought turned to 40 meters. A pretty low wavelength, to be sure—but you never could tell about those short waves. What had worked once might work again. Forty was given a whirl, and responded instantly by enabling two-way communication with Australia, New Zealand and South Africa.

Surely this must stop somewhere! It stood to reason that 20 was too low for any use. But—it was given a try-out. No good? Almost immediately it showed undreamt-of possibilities by enabling an east coast station to work a west coast station direct at high noon. The dream of amateur radio—Daylight DX!

This capped the climax. Downward, ho! A year later, as far as the average amateur was concerned, a plugged cent would have bought the entire wavelength spectrum above 100 meters.

From this time to the present represents a three-year period of unparalleled accomplishment. The short waves proved a veritable gold mine. Country after country came on the air, until the confusion became so great that it was necessary to devise a system of international intermediates in order to distinguish the nationality of calls. The League began issuing what are known as WAC certificates to those stations proving that they had worked all the continents. Several hundred such certificates have been issued. Representatives of the A.R.R.L. went to Paris several years ago and deliberated with the amateur representatives of twenty-two other nations. On April 17, 1925, this conference formed the International Amateur Radio Union—a union of national amateur societies. We have discovered that the amateur as a type is the same the world over.

IT is usually difficult to conceive of improvement on the latest developments. The perspective, of course, is too close. A year ago amateur radio decided that at last the ultimate had been reached, and that there were now no more worlds to conquer.

No?

To-day amateurs are making unprecedented strides in the development of transmitting and receiving apparatus. A systematic study of circuits for good and bad features is proceeding as never before. Ten meters a year ago was definitely out of the picture as useless. Yet, as these lines are being written, an amateur beam station in Massachusetts is putting strong and steady ten-meter signals into California and New Zealand.

History alone should furnish sufficient proof of the fact that there exists no such thing as "the ultimate".

LEGISLATION has always been the arch enemy of the amateur. We have already seen that but for human erring on the part of the early lawmakers in 1912, the first encounter with this formidable antagonist would very likely have ended in virtual extinction.

Due to the intervention of the Great War, no further international threat was to be made until 1927. Meanwhile, however, plenty of trouble of this kind made itself felt within the borders of our own country. As the state of the art advanced, more and more attempts at radio legislation were fostered in Congress. Most of these in their original form were detrimental to the welfare of the amateur. To list the various bills and outline their histories would tire the reader and accomplish no useful end. Let this statement suffice: since the organization of the A.R.R.L. in 1914 there has never been presented in either House of Congress a single bill pertaining to radio legislation without the amateur cause being personally represented by one or more officers of the League.

A menace of another kind put in its appearance during 1926 and 1927. There appeared a tendency on the part of municipalities to create city ordinances restricting local amateur operation. For six months the League waged a battle in two States against the constitutionality of such ordinances, and in 1927 obtained a court opinion denying the right of municipalities to regulate or restrict amateur operation.

Perhaps the greatest crisis in all amateur history came in the Fall of 1927 when world delegates again met for an international radio conference at Washington, D. C. At this conference entire delegations from some of the most powerful nations on earth endeavored to have the amateurs forever ruled off the face of the earth. Only sustained effort on the part of League representatives, backed by the splendid support of the United States and a few other friendly delegations, made it possible to emerge from that conference with the amateur privileges we enjoy to-day.

In no field of amateur activity have the advantages of organization been more apparent than in that of legislation. Little influence is exerted by a single individual appearing at a Congressional hearing and speaking for himself as an amateur. It is another matter when several men appear and say "We speak for the 17,000 amateur operators in this country."

AMATEUR radio is one of the finest of hobbies, but this fact alone would hardly merit such wholehearted support as was given it by the United States delegation at the recent international conference. There must be other reasons to justify such backing. There are. One of them is a thorough appreciation by the Army and Navy of the value of the amateur as a source of skilled radio personnel in time of war. The other is best described by the words "public service".

We have already seen 3500 amateurs contributing their skill and ability to the American cause in the Great War. After the war it was only natural that cordial relations should prevail between the Army and Navy and the amateur. Several things occurred in the next few years to strengthen these relations. In 1924, when the U. S. dirigible *Shenandoah* made a tour of the country, amateurs provided continuous contact between the big ship and the ground. In 1925, when the United States fleet made a cruise to Australia and the Navy wished to test out shortwave apparatus for future communication purposes, it was the League's Traffic Manager, Fred Schnell, who was in complete charge of an experimental high-frequency set on the U. S. S. *Seattle*.

Definite friendly relations between the amateur and the armed forces of the Government were cemented in 1925. In this year both the Army and the Navy came to the League with proposals for amateur co-operation. The radio Naval Reserve and the Army-Amateur Net are the outgrowth of these proposals.

The public service record of the amateur is a brilliant one. These services can be roughly divided into two classes: emergencies and expeditions. It is regrettable that space limitations preclude detailed mention of amateur work in both these classes, for the stories constitute some of the high-lights of amateur accomplishment. As it is, only a general outline can be given.

Since 1919, amateur radio has been the principal, and in many cases the only, means of outside communication in more than sixteen storm and flood emergencies in this country. The most noteworthy were the Florida hurricane of 1926, the Mississippi and New England floods of 1927, and the California dam break and second Florida hurricane in 1928. In all of these amateur radio played a major role in the rescue work, and amateurs earned nationwide commendation for their resourcefulness in effecting communication where all other means failed.

In 1923 the American Railway Association sent a representative to the A.R.R.L. National Convention at Chicago to talk over plans for amateur co-operation in railroad emergencies. In 1924, 1925 and 1926 the League maintained an emergency network of some eighty stations for the benefit of a large eastern railroad. Five times this network rendered service when wires went down.

It was amateur radio which, in 1927, gave to the world the story of the tragic end of the Hawaiian flyer *Dallas Spirit*.

Amateur co-operation with expeditions started in 1923, when a League member, Don Mix, of Bristol, Conn., accompanied MacMillan to the Arctic on the schooner *Bowdoin* in charge of an amateur set. Amateurs in Canada and the United States provided the home contact. The success of this venture was such that MacMillan has never since made a trip without carrying short-wave equipment and an amateur to operate it.

Other explorers noted this success and made inquiries to the League regarding similar arrangements for their journeys. In 1924 another expedition secured amateur co-operation; in 1925 three expeditions benefited by amateur assistance; in 1926 five expeditions secured amateur co-operation; in 1927 this number increased to six, and in 1928 no less than nine expeditions were depending upon amateur communication for their contact with civilization. In practically all cases amateurs were taken along as operators, and in many instances the apparatus was of amateur construction.

On the Byrd Expedition now in the Antarctic, three of the four radio operators were recruited from the amateur ranks, and amateur stations in the United States are furnishing a great part of the communication with this country.

SO ends this story of amateur radio. It has been the aim to make it an accurate story, with no attempts to glorify the amateur beyond his just due, nor any effort to smooth over rough spots in amateur progress. If the amateur has at times seemed a happy-go-lucky sort of individual, with insufficient regard for regulations, it should be remembered that at those particular times the radio world was a far different one than at present; stations were comparatively few, broadcasting had not yet arrived, precise measuring instruments were not generally available, and the amateur was doing only what all radio services were doing.

Out of it all has emerged the amateur radio and the radio amateur of to-day. To-day the amateur's position is fixed forever in the radio world. He has a name for being a progressive, resourceful and capable type. He has a growing list of glorious accomplishments to his credit. He is, to-day, law-abiding to the extreme; the quickest critics of amateur off-wave operation are amateurs themselves.

The story as related has necessarily been brief. Many stirring incidents have gone unmentioned entirely, through lack of space; such incidents as have been included have been accorded only a sentence or two, where a chapter would be necessary to record all the absorbing details. Yet we hope that through it all the reader has glimpsed that indefinite and elusive something which always has and for all time will be an integral part of amateur radio, prized as one of its most cherished possessions—a something which casts aside all marks of rank, caste or creed and binds together amateurs the world over—a something which, for want of a better name, we call Amateur Spirit.

THE AMERICAN RADIO RELAY LEAGUE

The American Radio Relay League is to-day not only the spokesman for amateur radio in this country but is the largest amateur organization in the world. It is strictly of, by and for amateurs, is non-commercial and has no stockholders. The members of the League are the owners of the A.R.R.L. and *QST*.

The League is organized to represent the amateur in legislative matters. It is pledged to promote interest in two-way amateur communication and experimentation. It is interested in the relaying of messages by amateur radio. It is concerned with the advancement of the radio art. It stands for the maintenance of fraternalism and a high standard of conduct. One of its principal purposes is to keep amateur activities so well conducted that the amateur will continue to justify his existence.

The operating territory of the League is divided into thirteen United States and six Canadian divisions. You can find out what division you are in by consulting Chapter X of this book. The affairs of the League are managed by a Board of Directors. One director is elected every two years by the membership of each United States division, and a Canadian General Manager is elected every two years by the Canadian membership. These directors then choose the president and vice-president, who are also directors, of course. No one commercially engaged in selling or manufacturing radio apparatus can be a member of the Board or an officer of the League.

The president, vice-president, secretary, treasurer and communications manager of the League are elected or appointed by the Board of Directors. These officers constitute an Executive Committee to act in handling matters that come up between meetings of the Board, their authority being subject to certain restrictions.

The League owns and publishes the magazine *QST*. *QST* goes to all members of the League each month. It acts as a monthly bulletin of the League's organized activities. It serves as a medium for the exchange of ideas. It fosters amateur spirit. Its technical articles are renowned. *QST* has grown to be the "amateur's bible" as well as one of the foremost radio magazines in the world. The profits *QST* makes are used in supporting League activities. Membership dues to the League include a subscription to *QST* for the same period.

HEADQUARTERS

From the humble beginnings recounted in the story of amateur radio, League headquarters has grown until now it occupies twelve rooms in a new office building and employs more than two dozen people. Work at headquarters is divided into the following departments: executive and secretarial; advertising; editorial and technical; accounting; communications; information; and circulation. It is interesting to note that with one exception the head of each of the above departments holds an amateur license, and that eight other members of the headquarters staff also are licensed amateurs.

Members of the League are entitled to write to Headquarters for information of any kind, whether it concerns membership, legislation, or general questions on the construction or operation of amateur apparatus. If you don't find the information you want in this book, write to A.R.R.L. Headquarters, 1711 Park Street, Hartford, Conn., telling us your problem. All replies are directly by letter and no charge is made for the service.

If you come to Hartford, drop out to Headquarters. Visitors are always welcome.

W1MK

For many years it was the dream of the League officers that some day headquarters would be able to boast a real "he-station" and a permanent operator to run it. In 1928 this dream became an actuality, and the League to-day owns and operates the station shown in the frontispiece, operating under the call W1MK. The sole duties of one of the members of Headquarters are to operate this station day and night.

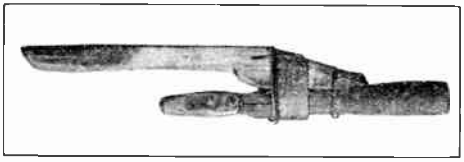
W1MK has two transmitters. The main one is that shown on the table and is a 500-watt tuned-plate tuned-grid transmitter with interchangeable coils for the different amateur frequencies. An auxiliary transmitter, shown under the table, is a 250-watt Hartley permanently tuned to a given wave in the forty-meter band. Both transmitters are keyed simultaneously on 40 and 80 meters when sending official broadcasts to the membership.

Full-wave and half-wave horizontal Hertz antennas are used respectively for 40-meter and 80-meter operation. Two Zeppelin feed-lines from the transmitters excite these antennas. A separate receiving antenna is used to facilitate break-in operation. The receiver is a shielded one of conventional type, using plug-in tube-base coils. Power-supply equipment is contained in a separate room and either motor-generator or mercury-arc supply is available by means of switches on the operating table.

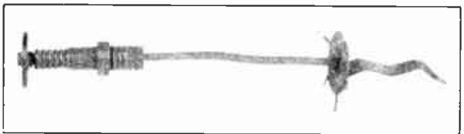
The current operating schedules of W1MK may be obtained by writing the Communications Department at Headquarters or by consulting *QST*.

TRADITIONS

As the League has come down through the years, certain traditions have become a part of amateur radio. Developments in radio have altered the apparatus used by amateurs a great deal in the last decade but through all the changes some personalities have stood out above the rest, typifying the spirit of the amateur.



THE WOUFF-HONG AND THE RETTYSNITCH
(Photographs are not to the same scale)



The Old Man with his humorous stories on "rotten radio" has become one of amateur radio's principal figures. His pictures of radio and radio amateurs are characteristic and inimitable. The Old Man sits in his "shack" and reflects on the "rottenness" of everything. He glares at "Kitty", spitting out his grouch to all who care to listen. There is much speculation in amateur circles concerning the identity of T.O.M., but in twelve years of writing he has not once given a clue to his real name or call.

The Wouff-Hong is amateur radio's most sacred symbol and stands for the enforcement of law and order in amateur operation. It came to being originally in a story by T.O.M. For some time it was not known just what the Wouff-Hong looked like, but in 1919 The Old Man himself supplied the answer by sending in to League Headquarters the one and only original Wouff-Hong, shown below. It is now framed and hangs on the wall of the Secretary's office at A.R.R.L. Headquarters.

The *Rettysnitch* another weird instrument of similar origin, is used to enforce the principles of decency in operating work.

JOINING THE LEAGUE

The best way to get started in the amateur game is to join the League and start reading *QST*. Follow the suggestions made in succeeding chapters of this book in getting started. Write the Information Service for help in any special problems that come up. An interest in amateur radio is the only essential qualification necessary in becoming a member of the League. Ownership of a station and knowledge of the code are not pre-requisites. They can come later.

Inquiries regarding membership should be addressed to the Secretary of the League, or you can use the convenient application blank in the rear of this book.

CHAPTER II

Getting Started

THE story of amateur radio has been briefly told for the benefit of the newcomer. It gives to many people a new breadth of vision. Enjoyment from broadcast reception alone is soon exhausted. The thrill of hearing programs from distant stations soon gives place to a search for better quality in local programs. The novelty of listening to broadcast speeches and music wears off in a matter of months.

To understand and enjoy radio in the fullest sense we ought to listen to all that takes place. The broadcast listener has but skimmed the surface of radio fun. He has no conception of the joy that will be his, once he has put his finger on the throbbing pulse of two-way radio. Long waves, set up by frequencies below the broadcast band, bring us a horde of flute-like signals. Press messages, storm warnings, and weather reports from all over the world tell their story to whomever will listen. Some stations speak slowly and leisurely so that even the beginner can read. Others race along furiously so that whole sentences are meaningless buzzes. Countless ship stations work near the broadcast band. Ships report their position daily. Hundreds of human-interest messages are sent to and from the shore stations every day. The communication activities conducted on the short waves, produced by electric currents at frequencies above the broadcast band, are most interesting of all. Numberless amateur two-way conversations, also transocean commercial radiotelegraph messages, short-wave broadcasting of voice and music, transmissions from government and experimental stations, and signals from expeditions exploring the far parts of the earth are among the attractions that lie here. The signals on both sides of the broadcast band of frequencies constitute new fields of interest for the broadcast listener to conquer. Perhaps for most persons the things going on in the more recently discovered and used high-frequency bands are more interesting than any other activities in the entire radio spectrum. It is certain that in this broader view of two-way radio, the new man may be assured of such a varied wealth of new experiences as he has never known in the narrower enjoyments offered by reception of broadcasting.

The greatest distances that have thrilled us with faint music are just beginning distances for our short-wave receivers. No continental limits confine the "DX" possibilities. Friendships in every corner of the world follow two-way communication. A short-wave receiver brings endless possibilities to light. A low-powered and inexpensive radio telephone may be built to use in talking with other stations over considerable distances. However, most amateurs prefer to learn and use the Continental telegraph code. Code signals will easily cover four or five times the distance possible for the same or more complicated radiophone equipment. The reliability of radio telegraph communication is vastly better than that of any voice work.

There is nothing difficult about building a receiver and transmitter. The parts are inexpensive; the construction is simple. In "getting started" the first step is to spend some evenings patiently learning the code. Before doing any operating it is necessary to obtain station and operator's licenses from the Department of Commerce. These are free of charge. Before we are ready to apply for licenses we must build the station, get the transmitter ready to operate, and learn the code.

MEMORIZING THE CODE

The easiest way to learn the code is for two or more people to practise together. As the writer learned by another method which is adaptable to a single person two methods will be outlined here.

In the appendix are the Continental Code characters. There are also phonetic symbols to help in learning quickly. The Continental Code is a dot and dash system used all over the world by radio operators and in Europe by wire telegraph operators as well.

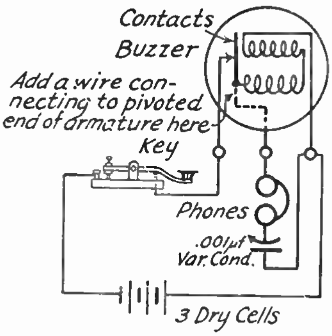
In receiving code signals each letter must be associated directly with the sound heard. The code must first be memorized. Learn the code, pronouncing the symbols "dit darr" rather than "dot dash". Do not visualize the letter "A" as a dot and a dash. Recognize the sound "dit darr" as "A" directly. Learn a few letters every day until the alphabet and figures have been mastered. Have a friend ask you the letters in non-alphabetical order. Repeat them in terms of "dit-darr" language until familiar with them all. Practise until you know the sounds as letters without pausing to think of them in terms of dots and dashes. Don't expect to learn it all in a day. Take things easy. Learn a few symbols at a time. Review each day the letters learned the previous day. Be optimistic. You will be surprised at your progress.

Here is one way to memorize code characters suggested by Mr. Howard R. Ward which may prove helpful to some. Several dozen small cards are procured. At the bottom of each card a letter of the alphabet, a figure, mark of punctuation or phrase that is much used in radio work is written. On the same side of each card and at the top edge is given the corresponding code symbol in dots and dashes. In use the cards are shuffled and reviewed by the individual who is learning Continental while either the top or bottom edge of the card is kept covered with the thumb or a blank card. Such cards may be readily carried about and used at odd intervals.

As soon as the code has been memorized, actual practise in using it (receiving) should be attempted. Proficiency in code speed is gained, as in other things, by constant practise. Good sending at moderate speeds is harder to learn than receiving. It is best not to use a key or try to send much until ten or twelve words a minute can be read and copied.

PRACTICING WITH A BUZZER

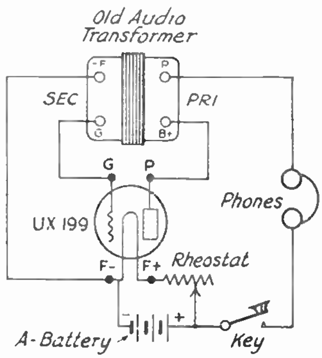
A buzzer practise set is one aid to learning code, especially if someone who is a good operator can help by sending to you. A buzzer, a telegraph key and a dry cell connected as shown in the diagram make a buzzer practise set. Using a head-set will give more nearly the conditions that obtain in actual radio receiving. It will keep out outside noises. A variable condenser of about .001 µf. max. shunted by another small fixed capacity (determine this value experimentally) can be used to control the audibility if desired. A high-pitched buzzer signal is helpful in learning the code. The small sum of money any apparatus for learning the code costs is a good investment.



CONNECTIONS OF A BUZZER CODE PRACTICE SET WITH A TELEPHONE HEAD SET
The intensity of the signal can be varied by changing the setting of the variable condenser. The phone and condenser are connected either across the coils of the buzzer or across the vibrator contacts. The condenser may be omitted and the tone may be changed by changing the number of dry cells.

ANOTHER GOOD CODE PRACTICE OUTFIT

The chap in cramped quarters whose roommate objects to buzzer practise for learning the code can use a 199 or 201-A tube connected as an audio oscillator. An old audio amplifying transformer with good windings, a pair of 2000-ohm headphones, a telegraph key, three No. 6 dry cells, a UX-199 tube and socket, and a 20- to 50- ohm filament rheostat are all the equipment required. A diagram explains the connections. The circuit is a Hartley. The "B" supply comes from the plus A terminal as shown. This means that it is important that the A-battery polarity be just as shown or the outfit will not work. The lead from the key can be connected to a point of lower positive potential on the A-battery or rheostat with about as good results. If nothing is heard in the phones with the key depressed after everything has been connected, reverse the leads going to the two binding posts at **either** Sec. or Pri. in case one of the coils on the transformer is reversed. Reversing both sets of leads will have no effect. Keying gives a fine signal in the phones without making any noise in the room.



CONNECTING AN AUDIO OSCILLATOR (HARTLEY) FOR CODE PRACTISE WORK

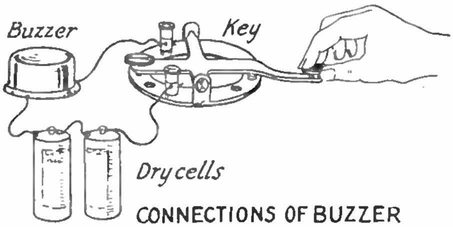
In picking out a key for a practise set some care should be taken to get a well-balanced, smooth-action key. A fairly "heavy" key with large contacts is best to use right from the start. It will save buying another key for the station later on. Good sending depends partly on the key.

USING A KEY

The correct way to grasp the key is important. The knob of the key should be about eighteen inches from the edge of the operating table and about on a line with the operator's right shoulder. A table of about thirty inches height is best. The spring tension of the key varies with different operators. A fairly heavy spring at the start is desirable. The back adjustment of the key should be changed until there is a vertical movement of about one-sixteenth inch at the knob.

Do not hold the key tightly. Let the hand rest lightly on the key. The thumb should be against the left side of the key. The first and second fingers should be bent a little. They should hold the middle and right sides of the knob respectively. The fingers are partly on top and partly over the side of the knob. The other two fingers should be free of the key. The sketch shows the correct way to hold a key.

A wrist motion should be used in sending. The whole arm should not be used. One should not send "nervously" but with a steady flexing of the wrist. The grasp on the key



CONNECTIONS OF BUZZER KEY, BATTERIES AND THE CATLIN GRIP

should be firm, not tight, or jerky sending will result. None of the muscles should be tense but they should all be under control. The arm should rest lightly on the operating table with the wrist held above the table. An up-and-down motion without any sideways action is best. The fingers should never leave the key knob.

The code is made up of different combinations of dots and dashes. The sending of intelligible signals depends on proper keying by the transmitting operator. The dots and dashes must be of the proper relative length. Suitable spaces must be left between letters and words. A dash is equal in length to three dots. The space between parts of the same letter is equal to one dot. The space between two words is equal to five dots. The exact time intervals depend on the rate of sending. Beginners key a bit stiffly, making a C like two N's. Muscle control improves with a few hours' daily practise.

RECEIVING

Now that we have memorized the code we must begin to practise sending and receiving using the code practise set. Someone who is already a good operator should be enlisted to send the first signals.

Go over the code and name the different letters as they are sent on the buzzer. The letters should be sent while you name them. Don't try to compare different letters. Learn each by its own individual sound. Each letter combination should be sent in a snappy way. A slow rate of sending should be secured by leaving long spaces between letters, not by dragging out the signals. Practise on letters and then on groups of letters. Write down what you receive to better co-ordinate the process of receiving and recording signals. Do not try to write down the dots and dashes; **put down the letters.**

Code groups are more valuable for ordinary practise than straight English texts. The frequency with which certain letters appear in common writing gives more practise on some letters than on others. Concentrate on the practise work and be patient. All the effort you spend in learning the code will repay you fifty-fold.

Always have the letters sent you for practise a little faster than you can comfortably receive. When the sending is so fast that you can copy just two out of every three letters, your mind will be speeded up and you will try to get that other letter.

SENDING

When sending do not try to speed things up too soon. A slow, even rate of sending is the mark of a good operator. Speed will come with time alone. Leave freak keys alone until you have mastered the knack of properly handling the standard-type telegraph key. Because radio transmissions are seldom free from interference a "heavier" style of sending is best to develop for radio work. A rugged key of heavy construction will help in this.

When signals can be copied "solid" at a rate of ten words a minute it is time to start

A	.-	N	-.
B	-...	O	---
C	-.-.	P	.--.
D	-..	Q	--.-
E	.	R	.-.
F	..-.	S	...
G	--.	T	-
H	....	U	..-
I	..	V	...-
J	.---	W	.--
K	-.-	X	-..-
L	.-..	Y	-.--
M	--	Z	--..
1	.----	6	-....
2	..---	7	--...
3	...--	8	---..
4	....-	9	----.
5	.....	0	-----

LETTERS AND FIGURES OF THE CONTINENTAL CODE

practising with a key in earnest. The paragraph on "using a key" and the diagram show just how to grasp a key. An experienced operator should be present right at the start to offer suggestions. Otherwise a wrong idea of spacing or of holding the key may develop into a habit that is hard to break. While learning to receive, you have become fairly familiar with good sending. Try to imitate the machine or tape sending that you have heard. This gives a good example of proper spacing values.

When beginning to handle a key do not try to send more than six or seven words a minute. A dot results from a short depression of the key. A dash comes from the same motion but the contact is held three times as long as when making a dot. A common mistake of beginners is to make it several times too long. There is no great space between the parts of a letter. An "S" is made by three up-and-down motions of the key in regular sequence. The letter "G" is made by holding the first two contacts and making the third one without any pause at the contact. Key practise should not be extended over too-long periods at first. The control of the muscles in the wrist and forearm should be developed gradually for best results.

Individuality in sending should be suppressed rather than cultivated. Sending is something like writing, however. Individuality is bound to show in all hand-sending. Unless the spacing is even and regular, reception becomes guess-work. The operator who practises on a buzzer until he has developed a good "fist" is appreciated by everyone he "works". His sending is legible and gets favorable attention.

A good rule in sending is never to send faster than you can receive. Then you can tell what your signals sound like to the operator who must copy them. Speed needs to be held in check. "Copiability" is what we want. Repeats waste valuable time. When you find that you are sending too fast for the other fellow, slow down to his speed. Attempting to send dots nervously in as rapid succession as possible is the first step in acquiring a "glass arm".

A word may be said about the "Vibroplex" and "double-action" keys. The "Vibroplex" makes dots automatically. The rate of making dots is regulated by changing the position of a weight on a swinging armature. Dots are made by pressing a lever to the right. Dashes are made by holding it to the left for the proper interval. A side motion is used in both types of keys.

These keys are useful mainly for operators who have lots of traffic to handle in a short time and for operators who have ruined their sending arm. Such keys are motion savers. However, a great deal of practise is necessary before readable code can be sent. The average novice who uses a "bug" tries to send too fast and ruins his sending altogether. The beginner should keep away from such keys. After he has become very good at handling a regulation telegraph key, he may practise on a "bug" to advantage.

LEARNING BY LISTENING

Another method of learning the code will appeal to some individuals. We all want to try our skill on some real messages when we have progressed this far. The next step after memorizing the letters is to put into practise on an actual receiving set what we have learned.

A number of high-power stations can be heard in every part of the world. Many commercial short-wave stations send on wavelengths below one hundred meters and can be copied with the simple receivers described in this book. A one-tube or two-tube receiver can be quickly and cheaply put together for long-wave code practise. Powerful transatlantic commercial stations send on wavelengths between 5,000 and 20,000 meters. Many of them use tape transmission. The sending is perfectly regular. Often words are repeated twice. Both understandable English and secret code (most excellent for code practise) are used in the text of the messages. These stations send at speeds depending on the reception conditions at the time of transmission. It is usually possible to pick a station going at about the desired speed for code practise. There is an increasing number of such commercial services now using short-waves so it is possible to "learn by listening" on short waves although there will be less confusion if we start out with the long-wave apparatus which will next be described.

After building a receiver and getting it in operation, the first step in "learning by listening" will be to hunt for a station sending slowly. Listen to see if you cannot recognize some individual letters. Use paper and pencil and write down the letters as you hear them. Try to copy as many letters as you can. Sometimes you will hear signals that you cannot interpret. Long-wave stations use keying systems that allow a signal to go out between the dots and dashes on a different wavelength. You will readily learn to distinguish between this "blacklash", as it is called, and the actual signals that you can copy. Whenever you hear a letter that you know, write it down. Keep everlastingly at it. Twenty minutes or half an hour is long enough for one session. This practise should be repeated three or four times a day. Don't become discouraged. Soon you will copy without missing so many letters. Then you will begin to get calls, which are repeated several times, and whole words like "and" and "the". After words will come sentences. You now know the code and your speed will improve slowly with practise. Learning by this method may seem harder to some folks than learning with the buzzer. It is the opinion of the writer, who learned in this way, that the practise in copying actual signals and having real difficulties with interference, static, and fading, is far superior to that obtained by routine buzzer practise. Of course that is of great value at first in getting familiar with the alphabet.

Many short cuts have been proposed for quickly memorizing the code for increasing speed of reception. Most of them have some good points. Learning the code is mostly a matter of getting practise, however. An omnigraph is of some assistance if a large number of records can be obtained. It is an expense that few can afford. Unless many different sets of "copy" are available one soon becomes familiar with the material and it is of no more value. Phonograph records of code signals can be obtained but have similar drawbacks. Examinations for operator's licenses are conducted using an omnigraph. Therefore it is desirable to become familiar with tape or omnigraph sending to insure easily passing the examination. "Machine sending" on long or short-waves is about as good as an omnigraph except that the speed cannot be controlled at will.

In "learning by listening" try to pick stations sending just a bit faster then your limit. In writing, try to make the separation between words definite. Try to copy the whole of short words before starting to write them down. Do the writing while listening to the first part of the next word. Practise and patience will soon make it easy to listen and write at the same time. Good operators can often copy several words "behind" the incoming signals.

It is largely a matter of individual choice whether one decides to build a simple short-wave receiver (see first receiver described in chapter on "Building a Station") to use in getting code practise from the high-power government and commercial stations now transmitting on high frequency (short-waves) or whether one should use the transmissions of long-wave stations for reception until proficiency is gained. The long-wave transmissions are free from interference, fading effects and the like, for the most part, and they are available practically 24 hours per day. Either type of receiver is inexpensive and easy to build. The constructional details of a reliable medium- and long-wave receiver will be described next in order. The tuning-in of long-wave stations is not usually as critical as in the case of the short-wave stations, which may make the long-wave receiver suggested best for the novice.

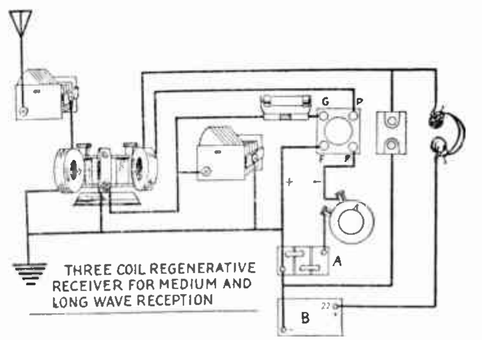
A MEDIUM- AND LONG-WAVE RECEIVER

For use in obtaining code practise an excellent receiver can be made by purchasing a couple of good variable condensers, a 3-coil swivel mounting, and a few honeycomb coils wound on 2½" forms. The "three-circuit" regenerative (primary-secondary-tickler) circuit should be used, giving flexible and selective tuning with no trouble in getting it to work. Such an all-wave receiver will work most efficiently on the long-waves. It will be inferior to a special receiver for short-wave and broadcast work, however.

Right here we will list the materials needed to construct such a long-wave code-practise receiver:

1 three-coil honeycomb mounting
2 good variable condensers (.001 µf. max.)
1 .00025 µf. fixed mica grid condenser
1 2- to 6-megohm grid leak
1 .001 µf. fixed mica by-pass condenser
1 30-ohm rheostat
1 good tube socket for 201-A or 199 tubes (Either type may be used successfully, choice depending on whether you prefer dry cells or storage battery filament supply.)
1 22½-volt block B-battery
1 pair headphones
10 feet of bus or stranded wire for making connections
1 baseboard, about 1" x 10" x 12" for mounting apparatus
1 6-volt storage battery (or 3 No. 6 dry cells)
1 terminal strip with five binding posts or Fahnestock clips
1 single-circuit jack (or use clips to hold phone-cord tips)
Brass angles to support variable condensers
3 honeycomb-wound coils (of 500, 750, and 1250 turns, respectively)

A three-coil mounting and coils to cover suitable ranges can be obtained from the



THREE COIL REGENERATIVE RECEIVER FOR MEDIUM AND LONG WAVE RECEPTION

Pacent Electric Company, 91 Seventh Ave., New York City, or Charles Branston, Inc., Buffalo, N. Y.

For the commercial ship and shore stations coils of 75, 100 and 150 turns may be purchased. The table of 3-coil combinations will indicate coil sizes to cover other services and frequencies (wavelengths). Various sizes of coils may be added as desired. By plugging them into the coil mounting, using the coil combinations suggested in the table, the set may be changed to be responsive to different kinds of radio transmissions on various frequency bands. You can then hear the different kinds of radio communication that we have mentioned by listening on the proper frequency for a particular service.

With coils of moderate size Arlington's Navy Press and coded weather, in addition to a great many lower-powered ship and shore stations, can be heard. However, we shall not want to listen to high speed ship-shore traffic handling at first. The press and weather reports sent broadcast at medium rates of speed will make excellent material for code practise. The transmissions on the longer wavelengths (lower frequencies) which may be received with the larger coils are more suitable for hour-after-hour of continuous code practise. The "tuning-in" of different stations is accomplished with the variable condensers. The tone of the incoming signal can be varied to suit the operator. In the circuit shown, 1,000-micromicrofarad variable condensers are used in the antenna circuit (A) and across the secondary coil (S). (1,000 μμf. = .001 μf. as specified in the list of materials.)

tickler (T) is on the right. The secondary coil is the one which really determines the wavelength band that can be covered with a certain size of secondary tuning condenser.

The dotted line means that equally good results may be expected with the filament circuit either grounded or ungrounded. The principal advantage in grounding the filament and connecting the movable plates of the variable condenser to this side of the circuit

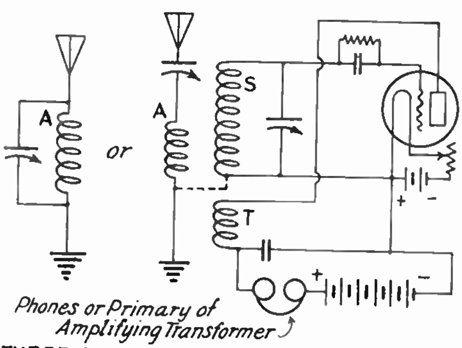
3-COIL COMBINATIONS FOR RECEIVING VARIOUS SERVICES

Service	Frequency in kc.	(Wavelength in meters)	Turns Ant. Coil	Turns Sec. Coil	Turns Tic. Coil	Antenna coil connection for .001 μf. variable condenser
Amateur & Broadcast	2150-850	(140-350)	35	25	35	Series
Broadcast & Com'l	1200-430	(250-700)	75	50	35	"
Com'l Ship-Shore	670-200	(450-1500)	150	100	75	"
Com'l and Navy	430-135	(700-2200)	200	150	100	"
Govt. & Com'l	270-75	(1100-4000)	300	250	150	"
U.S. & Foreign Arcs	130-62	(2350-4800)	200	300	150	Parallel
U.S. & Foreign Arcs	120-35	(2500-8500)	500	500	200	"
Com'l and Press	97-20	(3100-15000)	750	750	300	"
Same and NSS Time	50-14.3	(6000-21000)	750	1250	500	"

Such a three-coil outfit as described works best on frequencies below 400 kc. (wavelengths above 750 meters). It can be made to work within the broadcast range also but it will not be the most desirable form of receiver for frequencies above 1500 kc. (wavelengths below 200 meters).

The tickler should be at the grounded end of the secondary coil to avoid or minimize undesirable tuning effects.

All the parts for a one-tube set are shown properly connected in the picture diagram.



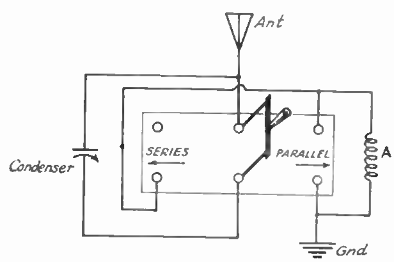
THREE CIRCUIT REGENERATIVE RECEIVER

By adding one or two more vacuum tubes as suggested by the dotted lines much louder signals may be obtained. It is assumed that phones will be used so that not more than two tubes will be desirable for most code-practice work.

The antenna coil (A) is the left-hand coil in the sketch while the secondary coil (S) is in the center of the co mounting and the

is that it minimizes the detuning effect of the hand when brought close to the condenser dial.

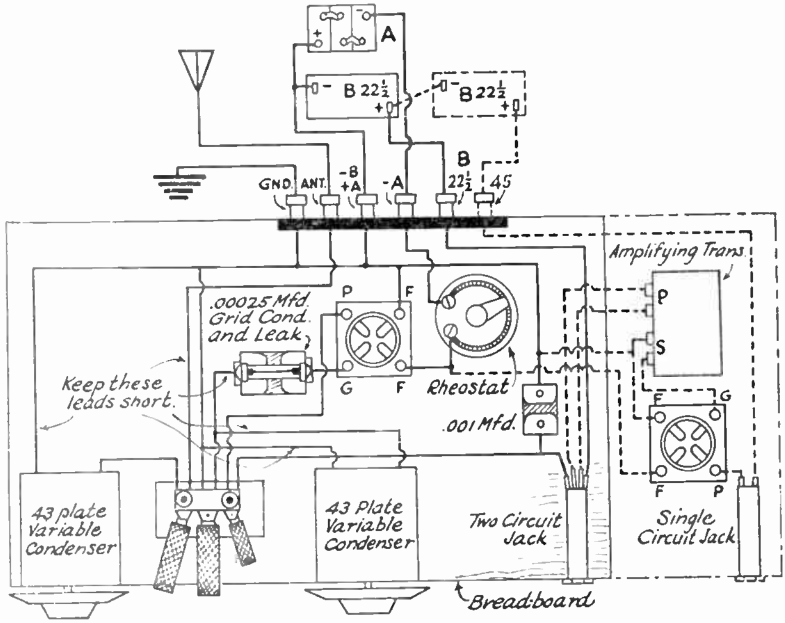
The schematic circuit diagram shows two methods of making the antenna coil connection. The "series" connection shown in all the diagrams may be used for *all* wavelengths



CONNECTING A DOUBLE-POLE DOUBLE-THROW SWITCH TO CHANGE THE ANTENNA COIL AND CONDENSER QUICKLY FROM A SERIES TO A PARALLEL ARRANGEMENT

but with the "parallel" arrangement shown at the left it will be easiest to tune our antenna circuit clear up to the twenty thousand meter wavelengths which will result in the best signal strength. A given primary coil can be made to cover a large band of wavelengths by using a series condenser for the shorter wavelengths and changing to parallel for reaching longer wavelength stations.

The farther apart we move the antenna and secondary coils, the easier the set will oscillate and the "sharper" the tuning. Different stations can be separated more easily when the coils are not too close together. Varying the position of the coils changes the "coupling" as explained elsewhere. The tickler should be brought up toward the secondary coil until a light click is heard in the phones. Then the set is oscillating and stations may be tuned in by the process of turning the dial of the secondary tuning condenser (the one across S). When a station is found, the tickler can be readjusted for loudest signal strength. Louder signals still can be obtained by bringing the antenna more nearly in tune by varying the setting of the antenna condenser, which will also make a slight readjustment of the tickler coil position desirable.



SKETCH SHOWING ARRANGEMENT AND CONNECTIONS FOR LONG-WAVE RECEIVER

and one-stage amplifier (shown dotted). Another stage may be added similarly for loudspeaker work if desired, but detector alone or detector and one step of amplification in any event gives ample signal strength for use with headphones.

READING DIAGRAMS

Schematic diagrams show the different parts of a circuit in skeleton form. Picture diagrams show the connections and apparatus as it actually appears in the station or laboratory. A little study of the symbols used in schematic diagrams will be helpful in understanding the circuits that appear in *QST* and in most of the radio books that we have mentioned. The diagrams are easy to understand once we have rubbed shoulders with some real apparatus and read about it. Schematic diagrams are used in all electrical work because they save so much space and time when discussing the various circuits. Picture diagrams are simpler to use but difficult to draw. Photographs of apparatus show the actual arrangement used better, but the wiring is not always as clear as in the picture diagrams. In building most apparatus a schematic diagram and a photograph will make everything clear. It is suggested that the beginner carefully compare a few picture and schematic diagrams if not entirely familiar with the latter.

We have not room in this book to include pages of pictures of apparatus giving the proper symbol for each device but a number of picture diagrams have been put in at different points so that a comparison of picture and schematic diagrams will enable one to understand what is intended in all the schematic diagrams here and elsewhere. In general, coils are indicated by a few loops of wire, resistances by a jagged line, and variable elements in the circuit by arrowheads. If a device has an iron core it is usually shown by a few parallel lines opposite the loops indicating coils or windings.

When you can draw and talk about circuits in terms of the various conventional symbols you are on what is familiar ground to every amateur and experimenter. Then you can meet the dyed-in-the-wool expert and understand what he talks about.

You may find a correspondence school course of some help. It depends on the individual's ability to absorb by mail. In any event, though, study things out from the information available in this book—then jump in and enjoy the experience. Learn by doing!

SOME TRANSMISSIONS USEFUL FOR CODE PRACTICE

Station Call	Location	Kcs. Frequency (Wavelength, meters)	Greenwich †Civil Time	Subject matter
NAA	Arlington, Va.	4015 (74.72)	0115	*Aviation weather and upper air reports
		68,112 (4412, 2679)	0300	Marine weather
		4015 (74.72)	0400	Weather b. c. to Europe
		112 (2679)	0700	Navy press broadcast
		4015,8030,12,045 (74.72,37.36,24.9)	1315	*Aviation weather and upper air reports
		112, 16,060 (2679, 18.68)	1500	Marine weather
		112 (2679)	1700	Hydrographic
		690 (435)	2045	Weather
		(All five frequencies)	0255-1655	Time signals
NPG	San Francisco, Cal.	4175,8350 (71.85,35.9)	1415-0215	Aviation weather
		42.8, 108, 8350 (7009,2778,35.9)	1530-0330	Weather, hydrographic *Aviation
		108 (2778)	0600	Weather, hydrographic
NSS	Annapolis, Md.	17.6 (17,045)	0700	Navy press
			0255-1655	Time signals
NAR	Key West, Fla.	102 (2941)	0300-1700	Weather, hydrographic
NAT	New Orleans, La.	106 (2830)	1600-2200	Weather, hydrographic
			1500	Weather
NPL	San Diego, Cal.	102 (2941)	0430-1630	Weather
		30.6 (9804)	1000	Navy press
NAH	New York, N. Y.	108 (2776)	1505-2200	Weather, hydrographic
NAJ	Great Lakes, Ill.	132 (2273)	0400-1545	Weather, hydrographic
			2200	" "
			1655	Time signals
NAM	Norfolk, Va.	122 (2459)	0100-0130	Weather
			1330-1545	"
			2045	"
NPM	Honolulu, T. H.	54 (5555)	0630-1830	Weather, hydrographic
			2230	" "
		26.1 ,106 (11,494, 2830)	2355	Time signals

The following stations may be heard transmitting press or commercial traffic. The list is given to aid in identifying the stations you may hear.

		Frequency in kc.	Wave length in meters
WAX	Miami, Florida	54, 138, 188, 500	(5552, 2175, 1599, 600)
WCC	Chatham, Mass	130, 136, 500	(2300, 2200, 600)
WII	New Brunswick, N. J.	21.8	(13,750)
WIK	Rocky Point, N. Y.	13,930	(21.5)
WIR	Rocky Point, N. Y.	4050	(74.0)
WIZ	New Brunswick, N. J.	6965	(43.07)
WNU	New Orleans, La.	90, 177, 500	(3331, 1700, 600)
WOP	Rocky Point, N. Y.	13,900	(21.55)
WQK	Rocky Point, N. Y.	18.2	(16,465)
WQM	Rocky Point, N. Y.	170	(1760)
WRQ	Marion, Mass	22.2	(13,505)
WSA	East Hampton, N. Y.	462	(650)
WSE	East Moriches, N. Y.	107	(2800)
WSO	Marion, Mass.	25.8	(11,620)
GBR	Rugby, England	16.7	(18,000)
GLC-GLJ-MUU	Carnarvon, Wales	21.2, 31.8, 67.8	(14,100, 9450, 4425)
POZ	Nauen, Germany	16.6, 97	(18,060,3100)
AGS	Nauen, Germany	23	(13,000)
AGC	Nauen, Germany	11,800	(25.5)
LCM	Stavanger, Norway	24.7	(12,140)
IDO	Rome, Italy	27.6	(10,850)
FL	Paris, France	30, 37.5, 41.2, 93.8, 113, 4000, 9380	(10,000, 8000, 7300, 3200, 2660, 75, 32)
LY	Bordeaux, France	15.8	(18,900)
YN	Lyons, France	19.6	(15,300)

Radio operators handle these circuits in some cases; in others "tape" or "machine" transmission and reception is used to speed up traffic handling to the limit fixed by relays and atmospheric conditions.

Most beginners are puzzled by certain abbreviations which are used right along on long-waves. Many code groups are sent by different commercial organizations to shorten the messages and to reduce the expense of sending messages which often runs as high as 25 cents a word. Unless one has a code book it is impossible to interpret such messages. Five and ten-letter cypher groups are quite common and make excellent practise signals. Occasionally, when receiving conditions are fine, a blur of code will be heard which results when tape is speeded up to 100 words per minute and photographic means are used to record the signals.

A prefix* is often used to show the class of traffic and the station to whom the message is going. The long-wave commercial stations number their messages periodically. Ship and shore stations start a new series of message numbers each day and with each new station worked. The commercial stations use "de" for an intermediate. Thus Tuckerton sending the 86th message for a certain period sends, "86 LCM de WGG." In case Bordeaux is sending, the prefix reads "F 86" or if the operator is just starting his evening's work, "Hr tfc F 86." meaning "Here traffic Bordeaux, France, number 86." Stavanger, Norway, uses the prefix "NW"; and POZ uses "PR".

Traffic is classed as "ordinary"; "deferred"; "urgent"; and "rush". "Ordinary" messages have a straight prefix as we have mentioned above. "Deferred" messages have "K" added to the prefix of a given station. "Urgent" messages have "D" added to the prefix. An "R" stands for rush.

When the receiving operator is uncertain of a word or part of a message, he asks a repeat from the transmitting station at the first opportunity. "RQ" is the prefix that tells what is meant. "RQ" is used when the receiver questions the message. "RQ F 271 irvingbank third" means, "What is the third word in the text of Bordeaux's number 271 addressed to the cable address Irvingbank?"

The answer to an "RQ" is a "BQ". If the third word of number 271 was "membership", LY will answer the "RQ" by sending, "BQ F 271 third membership."

When the public asks for information about a message, a service message is sent. The prefix "SG" is used for this. If the reply comes back with the prefix "SVC" (service), "SG", or in the form of a "BQ" showing the company to be at fault, the company does not charge for the service message. If "ST" is added to "BQ" the message in question was clear of errors the first time transmitted, and the service message is "by request". In this case the service message is paid for by the inquirer.

LCO and LCD in the prefix refer to the text as being "language of country of origin" or "language of country of delivery." RP means "reply prepaid."

It should perhaps be emphasized that the procedure described in the foregoing paragraphs is that of commercial usage, not amateur. Amateurs use a less complex procedure of their own, as will be explained later.

UNDERSTANDING TIME SIGNALS AND WEATHER REPORTS

Amateurs in the United States will probably find the time signals, weather and press reports from Arlington, Va., (NAA) and Annapolis, Md., (NSS) most useful and interesting in learning the code. Sometimes before sending the press NAA will request listeners to stand by (QRX) for a certain time while ship traffic is cleared. That gives us a chance to see how traffic is handled. Then the "U.S. Navy Press" will follow with interesting world-wide news items. A 12-to-15-word code speed is employed. After we have practiced so we can do several words per minute, some regular listening to NAA and NSS will soon enable us to copy letters, words and whole sentences.

The time signals start at 7:55 a.m. and 9:55 p.m., E.S.T., daily.† Every tick of the standard clock at the Naval Observatory is sent as a dot. The 29th second of each minute is omitted as well as the last five seconds of the first four minutes of time signals. The last ten seconds before the hour are omitted. The beginning of the dash which is sent at noon and ten p.m. is exactly the hour.

Weather reports go something like this: "CQ de NAA USWB T02081 DB01251 H00442 P99265," etc. This introduction means, "General call to all stations from Arlington, Va., United States Weather Bureau." The report gives conditions at various points two hours previous to the time of transmission. The key-letters refer to the different observation points. A few of the commoner ones follow:

T—Nantucket, Mass.
DB—Delaware Breakwater.
H—Cape Hatteras, N. C.
P—Pensacola, Fla.
B—Bermuda.
C—Charleston, S. C.
S—Sydney, Nova Scotia.
SF—San Francisco, Cal.
SE—Seattle, Wash.
K—Key West, Fla.
DU—Duluth, Minn.
G—Green Bay, Wis.
D—Detroit, Mich.
M—Marquette, Mich.

* These broadcasts are made in the regular Weather Bureau word code, which can be easily translated by means of Weather Bureau Code, 1924, W. B. No. 814, copies of which may be procured from the Superintendent of Documents, Washington, D. C., at $1.25. These broadcasts are made for the benefit of Army, Navy and commercial aviation fields, for marine services, business organizations and as a general public service.

† See index for reference to "time conversion" to translate this into your local time.

CH—Chicago, Ill.
V—Cleveland, O.
DI—San Diego, Cal.
WA—Washington, D. C.
AC—Atlantic City, N. J.
NF—Norfolk, Va.
E—Eastport, Maine.
JA—Jacksonville, Fla.
AT—Atlanta, Ga.
F—Buffalo, N. Y.
KC—Kansas City, Mo.
J—St. John's, Newfoundland.
SL—St Louis, Mo.
PB—Pittsburgh, Pa.
O—Omaha, Neb.
DA—Dallas, Texas.
TA—Tampa, Fla.
NO—New Orleans, La.

The weather reports from different naval radio stations follow the same form and all may be translated as will be explained. The first part of the bulletins is devoted to weather reports, the second part to weather forecasts and storm warnings. Useful weather maps may be prepared from the information contained in the first part of the broadcast.

The first three figures give the barometer reading. "P992" shows that the barometer at Pensacola reads 29.92 inches. "6" shows the direction of the wind:

0—Calm, no movement
1—North
2—Northeast
3—East
4—Southeast
5—South
6—Southwest
7—West
8—Northwest

The last figure gives the velocity of the wind in statute miles per hour. 1 nautical mile equals 1.15 statute mile. "5", for example, indicates "fresh breeze" according to the table below which is known as the Beaufort scale of wind intensities.

Figure	Air	Statute M.P.H.
0	Calm	Less than 1
1	Light air	1-3
2	Light breezes	4-7
3	Gentle breezes	8-12
4	Moderate breezes	13-18
5	Fresh breezes	19-24
6	Strong breezes	25-31
7	High wind	32-38
8	Fresh gale	39-46
9	Strong gale	47-54
10 (W)	Whole gale	55-63
11 (S)	Storm	64-75
12 (H)	Hurricane	76 or more

When several 5-unit groups of figures are given, the first two groups are surface observations at stations indicated by the key letters. Additional groups contain **upper air data** which can be interpreted in the customary way. When ship reports are included in the first part of the bulletin, these follow the reports from land stations. Following the call signal of the ship station are two groups of five figures each. The second group gives the barometric pressure and the wind direction and force as explained. The first two figures of the first group indicate the latitude of the reporting ship, and the other three figures give the longitude.

The Radio Service Bulletin which is issued monthly by the Department of Commerce may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 25c a year. This gives the up-to-date details about such stations.

Official Broadcasting Stations of the A.R.R.L. send the latest Headquarters' news **on amateur frequencies.** The messages are often interesting and they are sent slowly enough for code practice between 15 and 20 words a minute. Lists and schedules appear frequently in the membership copies of *QST*.

A word of caution: the U.S. radio communication laws prescribe heavy penalties for divulging the contents of any radiogram to other than the addressee. You may copy anything you hear for practise but you must preserve its secrecy.

SHIP-SHORE STATIONS

After a little proficiency in code speed has been developed it is interesting to become familiar with other radio services than the long-wave commercial stations that are so useful in giving regular code practise. Cables cross the oceans; telegraph and telephone circuits span the continents. The minute we set foot on a ship and get away from the offices and residences where our everyday life is spent, we are cut off from quick and easy two-way communication by telegraph, telephone and mail. Everything now depends on wireless telegraphy. The very ship on which we travel is protected by radio beacons. Warnings and weather reports are received every few hours. If we have important business to transact, it must be done by radiogram.

So the business handled from ship to shore is always varied and interesting. Its importance can hardly be sufficiently stressed in a few words. Steamers many days at sea keep in touch with the stock market quotations, and receive news of world-wide significance. They receive individual messages for their passengers. When storms are encountered, machinery becomes damaged, fires break out, or when there is trouble aboard ship, a simple SOS call brings assistance from the nearest point within just a few hours, depending on the nearness of assistance. The safety and confidence of everyone in the ocean travel of to-day depends in a large measure on the ship-shore telegraphic communication.

At one end of the broadcast band of wavelengths lies the amateur telegraph field and a number of communication services for fixed and mobile stations. At the other end of the broadcast band lies the ship-shore communication channels. Hundreds of ships have traffic to clear to shore daily. Often foreign ships sending in the broadcast band cause interference for which the amateur is unjustly blamed. Ship and shore station operators have highly developed time-saving procedure in order to handle many varied messages with a minimum of interference (QRM) with each other. So that the listener will know what to expect and so that he can understand what he hears we will give a few of the commoner abbreviations and their uses right here.

Using the 150-turn coil to listen to the ship-shore traffic between 500 and 1200 meters wavelength we may hear both "spark" and "tube" transmitters. The communication laws specify that a call shall be made by sending the "attention sign" once, the call letters of the station called three times, the intermediate "de" (meaning from) once, and following this with the call letters of the calling station three times. The full form of a call is like the following, "WSA WSA WSA de ITF ITF ITF." The answer, "ITF ITF ITF de WSA K", signifies that WSA is ready for traffic. Usually the note of WSA or any of the shore stations is quite distinctive. To save time he may say nothing but "ITF K". When the ship station is near the shore station, he shortens his call to "WSA ITF". If WSA is busy taking traffic from someone else he will ask ITF to "stand by", this way: "ITF QRX". Still shorter is "ITF .—. . ." (wait) which means the same thing.

A 600-meter wavelength is used for calling and 700 to 850 meters is used for working. 800 meters is used for naval radio compass work. The navy uses 952 meters as its calling wave, although some traffic is handled on it also.

When ITF says, "WSA ITF P" he means, "I have a *paid* message for you. The reply from WSA is usually, "ITF K 700". The operator at WSA then proceeds to listen on 700 meters or thereabouts and to copy the message. The prefix "P" in the message shows that it is a "paid" message. "TR" is the prefix to a position report which is sent daily showing the position of various ships for the information of owners and the public who await ship movements anxiously. "SVC" indicates that a service message is coming. The letters "GOVT" indicate that a government message will be sent. "GOVT S B", "GOVT W B", or "GOVT HYDRO" in the preamble indicate that the message to follow contains official business of the U.S. Shipping Board or Weather Bureau. "GOVT" is also transmitted as the first word in the address and is counted as one word. Other signs in the preamble indicate different classes of radiograms. A collated radiogram is indicated by "TC" sent in the preamble and as the first item of the address, and such messages must always be repeated back to the sending station for verification. "RP" is used for "reply prepaid", "POST" to show "delivery by mail" is desired, "GP" on radiograms to be called for at a post office, "TR" on those to be called for at a telegraph office and "TM" (with figure representing the number of addresses) on messages with one text but several addresses.

"W", "WDS", "CK", or "GR" refers to the number of words or the check of the message. "M" indicates routing via the Radio Corporation of America who control some of the large traffic-handling commercial stations. A short commercial message with a "radio" check might be sent from WLC to ITF as follows: "ITF WLC R HR P 1 W 11 CONEY ISLAND NY 217P 14 to WILLIAM RICHARDSON SS GENUARO MNEWLONDON —. . .— ADVISE WHAT NEW MACHINERY NECESSARY—. . .—TOMPKINS AR WLC K".

The time and date precede the address. Suppose the operator of ITF misses a few words; he may ask WLC to repeat: "RPT TXT". To ask for missing words, "WA" and "WB" refer to the "word after" and "word before" a specific word. In the appendix a table of "miscellaneous abbreviations" prescribed by the Washington International Radiotelegraph Convention may be consulted for the interpretation of other convenient operating procedure you may hear.

Ship stations send a "position report" daily or as may be required by the vessel's owners. The letters "TR" precede the report, which includes the distance from ship to the shore station in nautical miles, the position as briefly as possible and the next port of call. The speed of the ship is sometimes included. A sample report: "TR 150 OFF CAPE HATTERAS BOSTON 5 .—.—. ITF".

The presence of unnecessary capital letters, periods, commas or other marks of punctuation may alter the meaning of a text. For this reason commercial communication companies use a shiftless typewriter (capitals only). The texts of messages are typed in solid block letters (all capitals) devoid of punctuation, underlining and paragraphing except where expressed in words. In all communication work, accuracy is of first importance.

GAINING CODE SPEED

Code speed depends mostly on the amount of practice one gets. Any one can learn the code. A desire to learn, plus determination and persistence at the start, are the prime requisites a beginner should have.

As soon as the scattered letters begin to make words and sentences, the beginner is repaid a thousand-fold for his time and trouble. Low frequency, 20-60 kc. (or long wave 5,000-15,000 meter) flute-like signals have a charm all their own: the medium frequencies, 60-600 kc., (500-5,000 meters) contain the throbbing "human-interest stuff"; the broadcast band, 1500-600 kc., (200-500 meters) brings us music that entertains; the amateur short-wave, high-frequency signals, 30 mc. to 1715 kc., (10-175 meters) give us the thrills of local and world-wide two-way contacts with others just like ourselves. Each wavelength has its particular characteristics and the whole spectrum of radio activities is a field where we can explore and enjoy the findings when we will, not forgetting to keep the contents of messages secret as required by law.

OBTAINING A GOVERNMENT LICENSE

Before one can operate ANY form of transmitter he must have two government licenses. A license is required for the station and another license is required for each operator of the station. Happily, neither of the licenses costs anything to obtain.

The station license allows the station to be operated. The man who holds the license is responsible for the proper operation of the station under the terms of the license. The operator's license is proof of the ability of the operator. Some knowledge of the code and operation of the apparatus are necessary to get this license. There is information enough right in this book to enable anyone to get an amateur operator's license. No license whatsoever is necessary for the operation of any kind of receiving station. Operation of a transmitter of ANY SORT without a license is unlawful and a heavy penalty is imposed for such operation.

Application blanks for new amateur station licenses may be obtained from any one of the Supervisors of Radio. All licenses are of course subject to such general regulations as the Federal Radio Commission may issue from time to time.

Amateur operator's licenses are issued in three grades. Amateur Extra First Class Radio Operator, Radio Operator Amateur Class, and Temporary Amateur Operator's License are the names by which these licenses are known.

The Temporary Amateur License is given amateurs who do not live near the Supervisor's office, after they have passed a brief examination by mail. Anyone can get application blanks for operator's and station licenses from the nearest Supervisor by asking for them. Temporary Amateur Operator's Licenses are issued to be effective only until the applicant can appear to be examined in person which is required within a reasonable distance of the points where examinations are regularly given. When you have studied the code and are properly qualified, you can readily get one or two licensed operators in your vicinity to make affidavit to the fact that you can send and receive at 10 words per minute as required by the Secretary of Commerce. It is to be noted that this temporary license will authorize its holder to operate only a particular station, also that such licenses are issued for periods not exceeding one year.

The regulations are quoted as follows with regard to the license issued for Radio Operator, Amateur Class:

"Applicants for this grade of license must pass a code test in transmission and reception at a speed of at least ten words per minute in Continental Morse Code (five characters to the word).

"An applicant must pass an examination which will develop knowledge of the adjustment and operation of the apparatus which he desires to use and of the International Regulations and Acts of Congress insofar as they relate to interference with other radio communications and impose duty on all classes of operators.

"A percentage of seventy will constitute a passing mark.

"This license is valid for the operation of licensed amateur radio stations only."

The requirements for passing the amateur examination are not difficult. Information on all amateur station and operating rulings of the Federal Radio Commission and the Department of Commerce may be obtained on application to the Supervisors. Special attention should be given to the regulations concerning amateur stations.

Applicants are expected to be familiar with amateur receiving and transmitting equipment. The construction and function of each part of the apparatus should be studied. They should be able to explain the operation and elementary theory.

In the examination the applicant is required to tell what apparatus he expects to use, to draw a simple diagram of connections, and to explain the operation. The diagram should show switches and ground connections just as they are in the station. Applicants must be able to identify a distress signal (SOS) and to understand the signal used telling him to stop sending (QRT) when he is causing interference (QRM). Applicants who fail to qualify may be re-examined after three months from the date of taking their unsuccessful examination.

When existing operator's licenses expire, a renewal must be applied for and will be issued to all classes of operators (except commercial extra first class) without examination provided the operator has had three months' satisfactory service in the last six months of the license term. One year of such service out of the two-year license term may be accepted at the discretion of the examining officer.

To be eligible for the examination for an Amateur Extra First Class Radio Operator's License the applicant must have had at least two years' experience as a licensed radio operator and must not have been penalized for violation of the radio laws. The code speed requirement is 20 words per minute receiving and transmitting. Applicants must pass a special examination in which 75 per cent will constitute a passing mark. The possession of one of these "extra first" operator's licenses is a special mark of distinction and proficiency. The superior grade of license is a stimulus to better operating and should be the goal of every operator. The possession of such a license is a mark of achievement and every amateur is urged to apply for this form of operator's "ticket" as soon as he can qualify.

While any grade of amateur operator's license is sufficient for the operation of an amateur radio station, a commercial "ticket" is proudly displayed in many a "ham shack." There are three classes of commercial licenses, the Commercial Extra First Class, Commercial First Class, and Commercial Second Class. To obtain a Commercial Extra First Class license one must be able to take both Morse and Continental codes at high speed. Previous operating experience as holder of a commercial first-class license is necessary also. For the Commercial First and Second Class licenses code speeds of 20 and 12 words-per-minute in Continental code are required, respectively. Applicants desiring to operate broadcasting stations only will be given an examination pertaining specifically to broadcasting apparatus and the limitation will be specified on the second class license issued. Commercial first and extra first licenses authorize the holders to operate any licensed radio station. For passing the examination given in qualifying for any of the commercial classes of operator's license, advanced operating knowledge and theory are required. The examination includes questions under the headings of experience, diagram of receiving and transmitting apparatus, transmitting apparatus, receiving apparatus, operation and care of storage batteries, motors and generators, international and U. S. laws and regulations. Some excellent books are available if one desires to study them in order to qualify. See our recommendations in the appendix in this connection.

Request application blanks and information from the nearest Supervisor of Radio. The country is divided by the Department of Commerce into nine Inspection Districts. The addresses and territories of the different Supervisors follow:

First District: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut. Address, Supervisor of Radio, Customhouse, Boston, Mass.

Second District: New York (counties of New York, Staten Island, Long Island, and the counties on the Hudson River to and including Schenectady, Albany, and Rensselaer) and New Jersey (counties of Bergen, Passaic, Essex, Union, Middlesex, Monmouth, Hudson and Ocean). Address Supervisor of Radio, Customhouse, U. S. Sub-Treasury Building, Wall, Pine and Nassau Sts., New York City.

Third District: New Jersey (all counties not included in second district), Pennsylvania (counties of Philadelphia, Delaware, all counties south of the Blue Mountains, and Franklin County), Delaware, Maryland, Virginia, and the District of Columbia. Address Supervisor of Radio, Room 13, Customhouse, Baltimore, Maryland.

Fourth District: Alabama, Tennessee, North Carolina, South Carolina, Georgia, Florida and the Territory of Porto Rico. Address Supervisor of Radio, Room 524, Post Office Bldg., Atlanta, Georgia.

Fifth District: Mississippi, Louisiana, Texas, Arkansas, Oklahoma and New Mexico. Address Supervisor of Radio, Customhouse, New Orleans, La.

Sixth District: California, Nevada, Utah, Arizona and the Territory of Hawaii. Address Supervisor of Radio, Customhouse, San Francisco, Cal.

Seventh District: Oregon, Washington, Idaho, Montana, Wyoming and the Territory of Alaska. Address Supervisor of Radio, 2116 L. C. Smith Bldg., Seattle, Wash.

Eighth District: New York (all counties not included in the second district), Pennsylvania (all counties not included in the third district), West Virginia, Ohio and Lower Peninsula of Michigan. Address Radio Supervisor, 504-6 Commerce Building, Detroit, Mich.

Ninth District: Indiana, Illinois, Wisconsin, Michigan (upper peninsula), Minnesota, Kentucky, Missouri, Kansas, Colorado, Iowa, Nebraska, South Dakota and North Dakota. Address Supervisor of Radio, 2022 Engineering Building, Chicago, Ill.

When you receive the application blanks fill them out completely, answer all the questions and return the papers to the Radio Supervisor. If you pass the examination you will receive your license *unsigned*. Then take the license to a Notary Public. Execute the oath of secrecy of messages and return the licenses to the Supervisor, who will send them back to you after signing them.

Tube sets for C.W. telegraph work or for radiophone communication on certain amateur bands are readily licensed. Spark sets are no longer licensed to operate on amateur wavelengths. If an applicant lives near the Supervisor of his district it is only necessary for him to get in touch with the Supervisor. The necessary arrangements for taking the examination and getting a station license can be made in person or by mail.

The Federal Radio Commission licenses amateur telegraph stations to work in *any* or *all* of several frequency bands. If voice is to be used, the station must be built to work in the 1715-2000, 3500-3550, or 56000-60000 kc. (150-175, 84.5-85.7, or 5-5.36 meter) bands. Amateur transmission is prohibited in the United States between the hours of 8:00 and 10:30 P. M. local standard time, and on Sundays during local church services, if and when interference to other services exists. Interference to other services cannot be permitted. Quiet hours are prescribed when readjustments of the transmitter or alterations of a non-selective receiver will not do away with the trouble.

A.R.R.L. "Vigilance Committees" have been organized in a number of communities. Amateurs, broadcast listeners, and representatives of the local newspapers make up the committees. They investigate reports of amateur interference, put the interested parties in touch with each other, suggest ways of reducing or getting rid of the interference and see that the blame is placed where it belongs. When quiet hours are necessary, they are recommended. In cases where suggestions are disregarded, the interference is reported in detail to League Headquarters. In extreme cases the matter has to be turned over to the Radio Division, Department of Commerce. 98% of the interference experienced by broadcast listeners comes from power leaks and foreign ships who transmit in the broadcast band when near our shores. The Vigilance Committees have done much to educate the broadcast listener regarding the sources of interference and they have reduced what little amateur interference there has been to a negligible quantity.

To-day there is no excuse for amateur interference. The broadcast listener who uses a non-selective receiver (there are some such still on the market) has only himself to blame if he takes no steps to improve it and increase its selectivity. The amateur who interferes can always change his set to work on higher frequencies (reduce his wavelength), loosen the antenna coupling and improve the plate supply. The addition of a "key thump filter" will often be sufficient to permit non-interfering operation. Close proximity to a transmitting station often results in the setting up of forced oscillations in near-by receiving circuits. Placing antennas at right angles and using good "shielding" will eliminate even such troubles.

There should not be the slightest hesitation in constructing a station on the grounds that it will "interfere" or "draw lightning." A receiving or transmitting antenna properly grounded will "leak" off a charge gradually to ground, *preventing* the accumulation of voltage that might cause a disruptive discharge with danger to life and property. An antenna is a protection, not a hazard.

AMATEUR REGULATIONS

Amateur radio stations are authorized for communication only with similarly licensed stations and, effective Jan. 1, 1929, on wavelengths or frequencies within the following bands:

Kilocycles	Meters
400,000 to 401,000	0.7496 to 0.7477
56,000 to 60,000	5.00 to 5.36
28,000 to 30,000	10.00 to 10.71
14,000 to 14,400	20.83 to 21.43
7,000 to 7,300	41.1 to 42.9
3,500 to 4,000	75.0 to 85.7
1,715 to 2,000	150.0 to 175.0

The five last mentioned wavelength bands have proved most useful in carrying on actual communication over great distances. The purpose of the Government in assigning many wavelength bands to amateurs is to give the amateur the freedom which has always been his due. Only thus can knowledge of the behavior of the shorter wavelengths incidental to actual communication be developed most fully. The *experimenter* is most interested in the two first mentioned wavelength bands about which least is known.

Amateur stations must use circuits loosely coupled to the radiating system or devices that will produce equivalent effects to minimize key impacts, harmonics and plate supply modulations. Conductive coupling, even though loose, will NOT be permitted, but this restriction shall not apply against the employment of transmission-line feeder systems to Hertzian antennas.

Amateur stations are not permitted to communicate with commercial or government stations unless authorized by the licensing authority except in an emergency or for testing purposes. This restriction does not apply to communication with small pleasure craft such as yachts and motor boats holding limited commercial station licenses which may have difficulty in establishing communication with commercial or government stations.

Amateur stations are not authorized to broadcast news, music, lectures or any other form of entertainment. Spark transmitters will not be authorized.

No person shall operate an amateur station except under and in accordance with an operator's license issued to him by the Secretary of Commerce.

No person, firm, company or corporation within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto.

All persons who may have knowledge of the text or simply of the existance of radio telegrams, or of any information whatever, obtained by means of the radio service, shall be bound to maintain and insure the secrecy of correspondence.

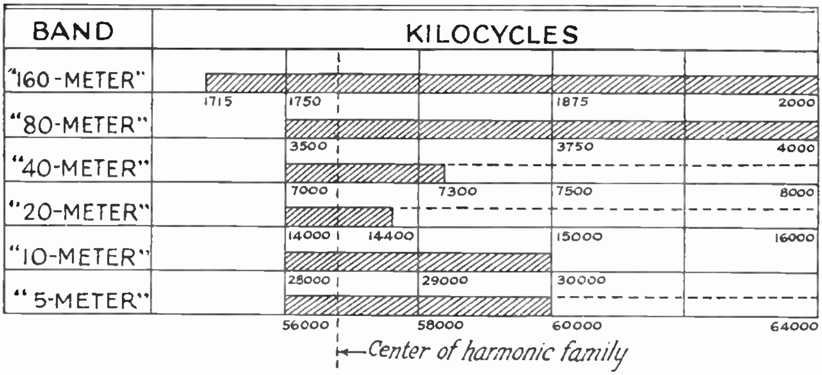
All amateurs should be familiar with the laws and regulations, especially those provisions and penalties respecting violation of terms set forth in station and operators licenses, secrecy of messages and malicious interference. A penalty of $500 fine for each and every offense is stipulated (in addition to other penalties provided by law) for conviction of a violation of any provision of the Radio Act or regulations made under that Act or of the provisions of treaties ratified and adhered to by the United States.

The Radio Act of 1927 provides for the licensing of radio operators by the Secretary of Commerce. Operators' licenses may be suspended by the Secretary of Commerce for a period of not more than two years upon satisfactory proof that the licensee (a) has violated any provision of any Act or treaty (or regulations made under such Act or treaty) binding on the United States which the Secretary of Commerce or the Commission is authorized by this Act to administer; or . . . (d) has transmitted superfluous radio communications or signals or radio communications containing profane or obscene words or language; or (e) has wilfully or maliciously interfered with any other radio communications or signals.

OUR AMATEUR BANDS

The amateur has accumstomed himself to many changes of different kinds in the last seven or eight years. Following each change in regulations there has been a readjustment to meet the new conditions. The number of stations working in our different amateur bands depends on the individual purpose, convenience and enjoyment each man finds in using a certain territory. The reliability of communication on a given frequency at a given time of day, the suitability of a given band for traffic or DX, the desires of the individual amateur in choosing his circle of friends with whom he expects to make contact on schedule, our own communication methods and practise a great many more contacts than this would seem to indicate can be managed, however. This comparison is made simply to give a practical idea of the width of each band.

The 7000-kc. and 14000-kc. (40-meter and 20-meter) bands have proved most generally useful for low-power work over long distances both day and night. 14000-kc. (20-meters) is the best frequency to use to cover great distances in daylight. At night many records have been made using frequencies of 1750 kc., 3500 kc., 7000 kc., and 14,000 kc. The 28-mc. band opened for amateur work by the Federal Radio Commission at the request of the A.R.R.L. early in 1928 has proved itself very



SHOWING THE RELATIVE WIDTHS OF OUR AMATEUR BANDS

the amount of interference to be expected at certain hours, and the time of day available for operating: all influence the choice of an operating frequency. Many amateurs can use any one of the several available frequency bands at will.

All our bands are in approximate harmonic relation, although the graphical representation shows that some bands are "wider" than others and that this relation is not exact and holds true for only certain sections of some bands. The bands are commonly referred to by amateurs as the 1750-kc., 3500-kc., 7000-kc., 14000-kc., 28-mc., and 56-mc. bands, so named for the portion common to each in this harmonic relationship.

The sketch showing the several amateur bands takes account of the fact that at double the frequency a signal occupies double room in the spectrum. It will be seen that the 56-mc. and 28-mc. bands are the same in practical width, that the 7000-kc. and 14000-kc. bands are narrower, but that the 3500-kc. and 1750-kc. bands are double these in width and widest in point of the number of stations that can be accommodated. A rating of our bands by "commercial channels" available shows 60, 52, 18, 13, 33, and 25 channels available, starting with the 1750-kc. (160-meter) band. By useful for long and moderate distance communication on different occasions. It is still too early to predict its ultimate field of usefulness. Our experimenters have obtained good trans-ocean communication on this frequency on several occasions and find it similar to 14000 kc. in some of its effects. We must look to them for information which will make this band of increasing practical use.

The 3500-kc. frequency is regarded as best for all consistent domestic communication. It is good for coast-to-coast work at night all the year except for a few summer months. It is recommended for all amateur message-handling over medium distances (1,000 miles for example). Much of the friendly human contact between amateurs is in the 3500-kc. band. It is the band from which we make excursions to the higher frequencies on occasions when we desire foreign contacts.

The 1750-kc. band contains many beginning amateurs, practising code by listening to transmissions arranged for their benefit. Many beginners may also be heard here making their first two-way contacts with each other. In addition to this, 1750 kc. is a popular band for the radiophone men, and to a few traffic pushers who keep schedules on this frequency. It is also open to amateur television and picture-transmission.

Using the higher frequencies, there is often difficulty in talking with stations within three or four hundred miles, while greater distances than this and also very short distances of ten or twenty miles can be covered with ease.

In summer, transcontinental and foreign daylight work is best accomplished using 28000 kc. and 14000 kc; 14000 kc. and 7000 kc. also may be used at night for the same purpose. 1750 kc. is good at night for moderate distances. Amateurs once conducted a great deal of foreign contact work on 3500 kc. in addition to the domestic work on this frequency, but this has been for the most part abandoned with the rush to the higher frequencies. The 1750-kc. frequency has the advantage that it is best for working with stations one or two hundred miles away. This band offers some excellent advantages to the chap who is getting started, due to less congestion and interference from other amateur stations, although there are lots of good things to listen to on the other frequencies.

CANADIAN REGULATIONS

Canadian amateurs wishing operator's licenses must pass an examination before a radio inspector in transmission and reception at a speed of ten words per minute or more. They must also pass a verbal examination in the operation of amateur apparatus of usual types, must have a working knowledge of procedure, and must have a little operating ability prior to taking the examination. Nothing is likely to be asked which is not covered in this Handbook. The fee for examination as operator is 50 cents and is payable to the Radio Inspector who examines the candidate.

The form of application for station license may be obtained either from a local Radio Inspector's office or direct from the Department of Marine and Fisheries, Radio Branch, Ottawa. This consists of a blank form with spaces for details regarding the station equipment and the uses to which it is to be put. The applicant must also sign a declaration of secrecy which, as a matter of fact, is executed at the time of obtaining the operator's license. The annual fee for station licenses for amateur work in Canada is $2.50.

CHAPTER III

Fundamentals

BEFORE we go on to study the problem of economically building a station and getting it working we should step aside just a moment to get some idea of how radio signals can be sent and received.

To understand fully all the things that happen in the process of sending and receiving radio impulses we ought to know something about electricity and the physical laws of electricity and magnetism that determine its behavior as we understand it. The books described and recommended in the appendix will cover the ground very well on this subject. However, we are going to mention some elementary principles that will help in getting a picture of what happens. A thorough groundwork of fundamental knowledge can be gained through consistent reading and through experience in handling apparatus.

ELECTRICITY

Almost everyone has rubbed a cat's fur and noticed the little sparks in it that can be seen in the dark. "Frictional" electricity is present. Sometimes lightning discharges take place between two clouds or between clouds and earth. This is another example of the liberation of "static" electricity which is manufactured by wind friction under certain temperature conditions.

We use electric lights, electric heaters, telephones, flashlights, street cars and motors and know that the mysterious agent that has been harnessed is "electricity." We call this "current electricity", as distinct from the other kind of electricity. Current electricity always manifests itself by heating effects and magnetic effects. All that is known about electricity is known by its effects when it is used in certain ways.

Every substance is made of mixtures or chemical combinations of different elements. Any chemical combination can be divided and redivided into smaller particles of the same chemical make-up. The chemist calls the smallest possible piece of any one such substance a "molecule". Molecules are in turn made of atoms of chemical elements. The atom of hydrogen, copper, or carbon combines with atoms of sulphur or chlorine to make "molecules" of different compounds which the chemist names appropriately. These atoms themselves are made of still smaller particles called electrons, which are of exceedingly small mass and size. The electron is negative electricity. A positive nucleus (center), surrounded by a group of electrons, makes up the "atom" or smallest particle of every element. So every substance is made up of millions on millions of electrons. The electron itself can be considered the smallest possible quantity of negative electricity.

THE ELECTRIC CURRENT

The everyday uses of "current electricity" we have mentioned. A free flow of electrons in any body constitutes an electric current. When the electrons in a body flow readily we say the body is a "conductor." If they do not flow quite so readily we say that the substance offers more "resistance" to the electric current. If the electrons hardly flow at all we say the body is an "insulator."

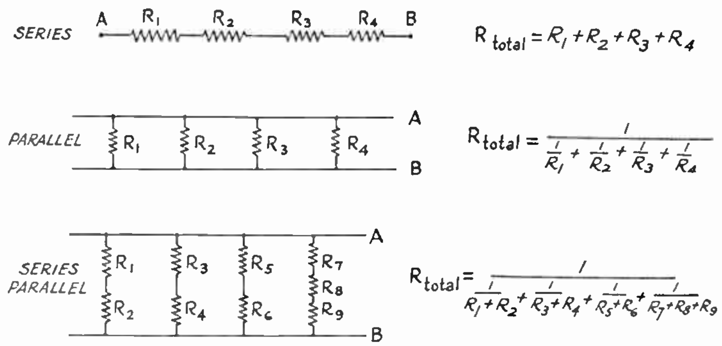
The "resistance" of most substances varies somewhat with temperature. Sometimes the variation is so great that a body ordinarily considered an insulator becomes a conductor at high temperatures. The "resistance" of metals usually increases with temperature. The resistance of liquids and of carbon is decreased with increasing temperature. Copper, silver and most metals are relatively good conductors of electricity while such substances as dry glass, mica, rubber, dry wood, porcelain, shellac and gutta percha are good insulators.

MAKING CURRENT ELECTRICITY

The ordinary electric cell and the electric generator are the sources of all our electric current. The electric cell may take the form of a so-called dry cell; it may be a wet cell; it may be a storage cell. In any case the source of current is a chemical source. In the first two forms mentioned the chemical action of the fluid (there is such a fluid in even the "dry" cell) tears down the structure of one of the elements or "poles" of the cell to supply the electric energy current. In the storage cell the chemical change is reversible and the cell can be "recharged." The heating, chemical and magnetic effects of the electric current have been briefly mentioned. These effects are reversible ones, too. The electric generator has wires moving through a magnetic field which generate the electric current that we are talking about.

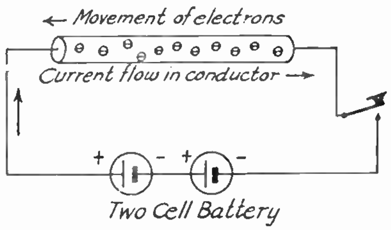
SERIES AND PARALLEL CONNECTIONS. E.M.F., CURRENT FLOW

A number of cells or generators grouped together as a source are termed a "battery." By connecting a number of cells together a more powerful current source is obtained than can be made by a single cell. Any high school physics book will explain about the different kinds of electric batteries. Certain chemical solutions and elements are best suited for making cells for certain jobs. Electric cells and in fact all pieces of electrical apparatus may be connected in "series" or "parallel" or "series-parallel" depending on which way is best for a given purpose.



RESISTANCES CONNECTED IN SERIES, PARALLEL, AND SERIES-PARALLEL

In any electric cell, there are two different chemical elements in a solution. Depending on the choice of elements and solution a certain *electromotive force* will be developed and maintained. One terminal will always be *positive* (+) while the other terminal will always be *negative* (—) with respect to it. When the two terminals are connected by a wire or conductor an electric current flows.



CURRENT FLOW

In the circuit *external* to a battery the "current" is said to flow from positive to negative. The electrons on the other hand are said to flow from the negative pole of the battery to the positive. Thus we must always think of the flow of negatively charged particles as an "electron flow", *toward* the positive terminal of the battery. The electric current is a "current flow" *away* from the positive terminal. The diagram shows what is intended. Only because the electron theory had not been advanced when the conventional definition of positive and negative was made do we need to make this distinction. The current flows in the same direction through every part of the circuit. If we examine conditions *inside* the dry cells shown in the diagram we find the flow just opposite from the directions indicated for the external circuit. When the key is closed the electric current flows around the external circuit from positive to negative. When the key is open there is an insulating medium or non-conductor between its contacts. No current of any consequence can flow. We speak of the conditions with the key closed as "closed circuit" conditions. When the key or any part of the circuit is open or broken we speak of the conditions as "open circuit" conditions.

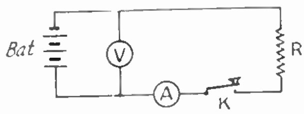
When a steady current flows in any electric circuit, the size or amplitude of the current is determined by the *electromotive force* in the circuit and the resistance of the circuit. The relations that determine just what current flows are known as Ohm's Law. In order that we may speak conveniently of electrical pressure, current and resistance, certain units of measure are used. The commonly accepted *unit of current* is the ampere. The *unit of electromotive force* or electrical pressure is the volt. The *unit of resistance* is the ohm. When one volt (e.m.f.) is applied in a circuit having one ohm resistance, a current of one ampere will flow.

When I is the current in amperes, E is the electromotive force in volts and R is the circuit resistance in ohms. A simple formula expresses Ohm's Law:

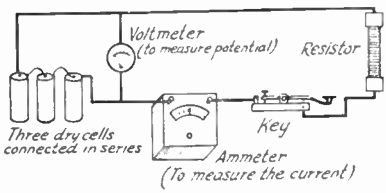
$$R = \frac{E}{I} \qquad I = \frac{E}{R} \qquad E = RI$$

The resistance of the whole circuit can be found by dividing the voltage by the current. The current can be found by dividing the voltage by the resistance. The e.m.f. is equal to the product of the resistance and current flowing. It is at once evident that if any two of the quantities are known, the other may be found by applying the formula.

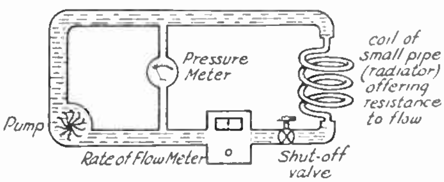
A good analogy can be made by considering for a moment some fluid acting in a



A - SCHEMATIC DIAGRAM



B - PICTURE DIAGRAM



C - MECHANICAL ANALOGY

THE ELECTRIC CIRCUIT AND MEASURING INSTRUMENTS

mechanical circuit. In Figure C the pump has a similar function to that of the battery.

A shut-off valve controls the current flow in the pipe similarly to that of the key in the electric circuit. The walls of the pipe offer "resistance" to the flow of fluid just as the atomic structure of the connecting wires and resistor hold back to the flow of electric current in the electric circuit. A water pressure meter and a "rate-of-flow" meter have the same uses in such a circuit that the voltmeter and ammeter have in measuring the electrical pressure and rate of current flow in the electric circuit.

The higher the "pressure" the more fluid will flow around the pipe. The smaller the pipe the greater its "resistance" and the less current will be permitted to flow.

USING OHM'S LAW

Every part of an electric circuit has some resistance. We have shown how cells can be connected in series, how resistances can be connected in series. Different electrical instruments can be connected in series in the electric circuit. In the diagram on the next page, the tubes, the rheostat, and the three cells of the storage battery make up the series circuit. The two vacuum tubes are connected in parallel, but they are in series with respect to the rest of the circuit. The rheostat is a variable resistance and is used to change the current flowing in the circuit by changing a part of the resistance of the whole circuit and therefore in effect changing the whole resistance which is the sum of all the parts. The rheostat has part of the circuit resistance, the exact value depending on the position of the rheostat arm and the amount of resistance wire that it includes in the circuit. The cells themselves have some "internal" resistance, depending on their condition. The filaments have an increasing resistance with increase in temperature. This in turn depends on the current through the tubes. The lead wires in the circuit resistances are so small that they can be neglected for practical computations. If the lead wires are of copper and have a large cross-sectional area (the kind of wire and the size wire used determine the "conductivity" [mhos] which is the reciprocal of the resistance in such a circuit) their resistance is so small that we need not consider it. If dry cells are used, their resistance may be neglected if they are new. Storage cells always have a very low internal resistance if they are cared for and kept charged.

VOLTAGE DROPS

When current flows through a resistance we have what is called a "voltage drop" across the resistance. The voltage drop is always equal to the voltage which causes the current to flow through the resistance. The voltage drop across the filament of a vacuum tube can always be found by Ohm's Law and is the "resistance" (of the filament) times the current flowing through it. The sum of all the voltage drops across the various pieces of apparatus in a series circuit is always equal to the voltage of the source (or the sum of the voltages in the circuit if there be more than one source). This law is known as Kirchoff's Law. So the combined voltage drop across the rheostat and the paralleled filaments will be always equal to the voltage of the storage battery (six volts).

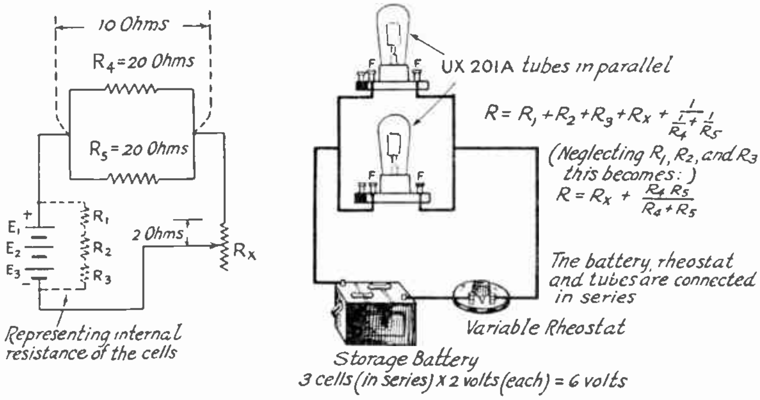
Keeping these relations in mind we can find the resistance of any part of the circuit. For example, we have a detector and one stage audio amplifier (standard equipment for amateur code work) using two UX-201-A tubes. What resistance (Rx) should we connect in the circuit to use a six-volt battery with this outfit?

On the box in which the tube came we find that the manufacturers specify a terminal voltage of 5 volts and a filament current of .25 (¼) ampere for each tube.

The resistance of the filament under any operating conditions can be determined by Ohm's Law or from facts about the tube supplied by the manufacturer. A five-volt tube which takes a filament current of one-fourth ampere has a resistance of 5 divided by ¼ or 20 ohms. When two tubes are connected in parallel the resistance of the combination is:

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{R_1 R_2}{R_1 + R_2} = \frac{20 \times 20}{20 + 20} = 10 \text{ ohms}$$

Now we can check the accuracy of our problem solution by using our answers and



SERIES-PARALLEL CONNECTION SHOWING HOW TO SOLVE FOR THE TOTAL RESISTANCE IN THE CIRCUIT

This then will be the voltage drop or terminal voltage of the tube under operating conditions. We have two tubes each requiring .25 amperes so our storage battery will have to supply 2 x .25 or .5 (½) ampere. If possible, always find the current and voltage (or the effective resistance) of the portions of the circuit in parallel before trying to find out about the series branches of the circuit.

Because the summation of the voltage drops equals the voltage of the source, the drop across the rheostat equals 6 volts minus 5 volts or 1 volt. We have assumed that the drops in the battery and leads are negligible, which is nearly true.

Now we know two things about the rheostat. The voltage drop across it must be 1 volt. The current through it is .5 ampere. By Ohm's Law the resistance is:

$$R = \frac{E}{I} = \frac{1}{\frac{1}{2}} = 2 \text{ ohms.}$$

The usual 0-6 ohm rheostat will give ample variation and should be chosen for this purpose.

the e.m.f. in the circuit and solving for the current.

$$I = \frac{E}{R} = \frac{6 \text{ volts}}{10 \text{ ohms} + 2 \text{ ohms}} = \frac{1}{2} \text{ ampere}$$

R=combined resistance of tubes plus resistance of rheostat at proper setting

The heating effect of the electric current is caused by the friction of the electricity flowing through the wire. The higher the resistance the more heat will be generated for a given length of time (seconds) and for a given amount of current and the greater will be the power loss or power spent in making heat.

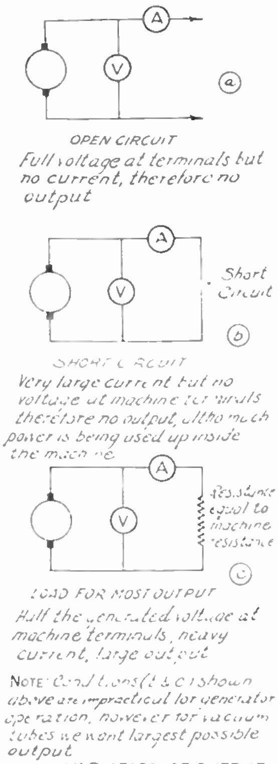
$$\text{Power (watts)} = I^2R = EI = \frac{E^2}{R}$$

$$\text{Heat (British Thermal Units)} = I^2RT\ (9.5 \times 10^{4})$$

If the current in a resistor and the resistance value are known we can readily find the power that is used. If the voltage drop across a resistance and the current through it are known we can determine the resistance value (from Ohm's Law) and also the power used (EI), which is always equal to the product of volts and amperes.

Maximum power in the load is spent in heating when the load resistance equals the internal resistance of battery or generator.

Magnetic effects are always present when a current flows in a circuit. Lines of magnetic force or influence surround the current carrying conductors. When a conductor is wound into a coil of many turns the *magnetic field* becomes stronger because there are more lines. The laws of the magnetic circuit are similar to those of the electric circuit but we do not use them as often in elementary work. The magnetic force is spoken of in terms of magnetomotive force (m.m.f.) which depends on the number of turns of wire, the size of the coil, and the amount of current flowing in the coil. If ten amperes flow in one turn of wire the magnetizing effect is 10 *ampere-turns*. If one ampere flows in ten turns of wire the magnetizing effect is also 10 *ampere-turns*.



VARIATION OF OUTPUT AS LOAD RESISTANCE IS CHANGED

The length of the magnetic circuit, the material of which it is made and the cross-sectional area, determine what "magnetic" current or *flux* (Φ) will be present. Just as the resistance of the wire determines what current will flow in the electric circuit, the *reluctance* (μ) of the magnetic circuit depending on length, area and material acts similarly in the magnetic circuit.

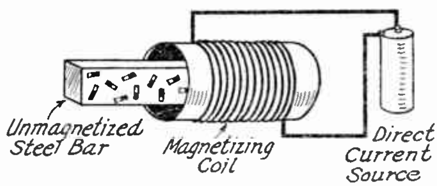
$$I = \frac{E}{R} \text{ in the electric circuit so}$$

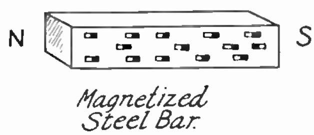
$$\Phi = \frac{\text{m.m.f.}}{\mu} \text{ in the magnetic circuit.}$$

The magnetic field about wires and coils may be traced with a compass needle or by sprinkling iron filings on a sheet of paper held about the coil through which current is passing. When there is an iron core the increased magnetic force and the concentration of the field about the iron is readily discernible.

Permeability is the ratio between the flux density produced by a certain m.m.f. and the flux density that the same m.m.f. will produce in air. Iron and nickel have higher permeability than air. Iron has quite high permeability, is of low cost, and is therefore very commonly used in magnetic circuits of electrical devices.

The permeability of iron varies somewhat depending on the treatment it receives during manufacture. Soft iron has low reluctivity, another way of saying that its permeability is extremely high. The molecules of soft iron are readily turned end to end by bringing a current-carrying wire or a permanent magnet near. When the influence is removed they just as quickly resume their former positions. When current flows around a soft iron bar we have a *Magnet*. When the circuit is broken so the current cannot flow, the molecules again

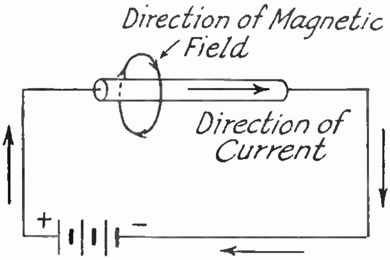




HOW PERMANENT MAGNETS ARE MADE

assume their hit-or-miss positions. Little or no magnetic effect remains. When a steel bar is subjected to the same magneto motive force in the same way, it has less magnetic effect. However, when the current is removed, the molecules tend to hold their end-to-end positions and we have produced a *permanent* magnet. Compass needles are made in this way. Permanent magnets lose their magnetism only when subjected to a reversed m.m.f., when heated very hot or when jarred violently.

The direction of the magnetic field can be found by what is called the right-hand rule. Grasp the wire in the right hand with the fingers around it and the thumb pointing



along the conductor in the direction in which the current is flowing. The fingers then point in the direction of the magnetic field.

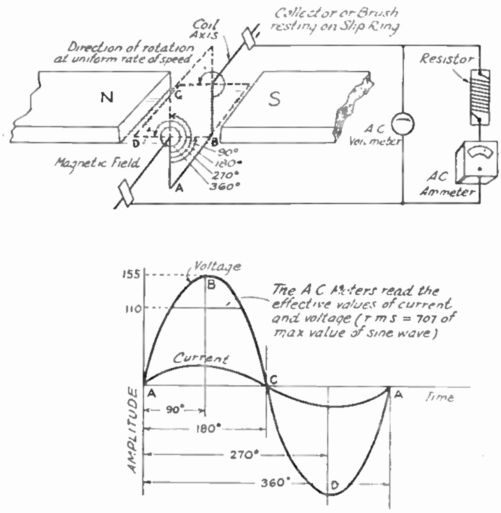
ALTERNATING CURRENT

Thus far we have considered current electricity as a flow of electrons in one direction around a circuit. This sort of a current is known as "direct" current (d. c.). In many applications to-day we have to think about "alternating" current (a. c.). Instead of a unidirectional current in the circuit, the current that flows goes first in one direction and then in the other. Instead of having a pump (dynamo with commutator) to make the water flow in one direction in a pipe, we now have a double-acting pump and the water (electrons) flow first in one direction and then in the other. The speed of the reversals depends on the time in which the pump acts in each direction before reversing. In an alternating current generator the number of poles in the magnetic field of the machine and the speed of rotation determine the number of alternations or reversals in current that take place in one second. A complete cycle has two alternations or reversals of current. The diagram shows the way in which a rotating coil cuts a magnetic field, and the changes in the direction of the current with time are indicated by the second part of the diagram, as well as the amplitude or size of current flow during different parts of the cycle.

We shall be much concerned with alternating currents, as all radio work is based on them. The number of cycles that takes place each second is called the "frequency" of an alternating current. Power circuits frequently use 25-cycle current. Electric lighting circuits are usually 60-cycle circuits. Ship radio generators are often wound for 500-cycle operation. Radio transmission circuits require energy at frequencies of 15,000 to several millions of cycles per second. These higher frequencies can be produced in several ways. We are concerned with the equipment that is necessary. High frequency alternators and "arc" sets can best be used to produce the lower radio frequencies. "Spark" transmitters have been in use for years for ship-shore communication. "Vacuum tube" transmitters are most efficient and inexpensive of all. They are widely used today for all sorts of radio services. The older equipment is interesting but we shall study the tube transmitter mainly.

INDUCTION

When current passes through a coil it sets up a magnetic field around the coil. The strength of this field varies as the current varies. Conversely, if a field of varying



SIMPLE ALTERNATOR CIRCUIT

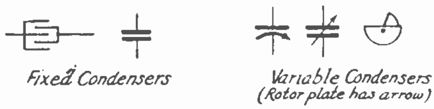
Diagram shows instantaneous values of current and voltage with electrical degrees of coil rotation – there are 360 electrical degrees for every pair of poles so that one complete mechanical revolution may correspond to more than one electrical revolution

strength passes through a coil an electromotive force is *induced* in the coil. If a permanent magnet is thrust in and out of a coil a voltage is induced in the coil. The time rate of cutting flux determines the value of the induced voltage.

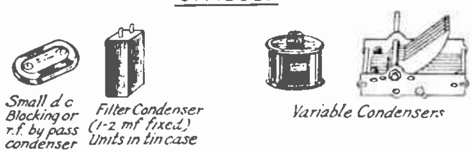
This principle is utilized in large direct-current and alternating-current generators, in transformers and in all sorts of electric motors and rotating electrical machinery. In generators and motors, magnets (or field poles) set up an electrical field which links conductors (armature coils). The relative motion of the field poles and the armature determines the rate of cutting flux and the voltage that is induced. In transformers the parts are stationary but the flux is alternating or changing in value and direction. The value of the induced voltage depends on the rate at which the magnetic field changes and on the number of turns in the coils. Changes in flux follow changes in current directly. All coils have that property known as "self-inductance", or electrical inertia. A decreasing current causes a decreasing flux. The decreasing flux induces an e.m.f. in the coil which tends to prevent any further decrease in current. The direction of the induced voltage always tends to prevent the change of current which makes the induced voltage. When changing flux links other coils which are near the coil in which a varying current flows, a voltage is set up in each coil, the value depending on the rate of change of the flux linking each coil and on the turns in the respective coils. The induction between coils is known as "mutual" induction.

Energy is stored in the magnetic field which surrounds a current-carrying coil.

Inductance is measured in "henries". This property of a coil depends on its number of turns, the diameter of the coil, and on the permeability of the magnetic material of



SYMBOLS



FORMS OF CONDENSERS

the core. In 25-cycle and 60-cycle work an iron path is usually provided for the flux. The permeability of iron is much greater than that of air at these frequencies. All iron and steel shows a "magnetic lag". The flux in the iron lags somewhat behind the current producing it. This phenomenon is known as "magnetic hysteresis". When the magnetizing force (H) is increased, the flux density (B) increases very rapidly at first if an iron core is used. However, for large values of magnetizing force, the intensity of magnetization becomes constant and the magnetic substance is said to have become "saturated". A further increase in flux density (B) can only be made by a disproportionate increase in magnetizing force (H). In radio-frequency circuits, iron introduces a hysteresis loss. The *higher* the frequency the lower the *permissible* flux density. The iron cannot follow the rapid changes in flux. It is worthless at the higher radio frequencies.

FIXED AND VARIABLE INDUCTANCE

Coils used in radio circuits are made having either fixed or variable inductance values. Fixed coils have a fixed self-inductance (L). Sometimes two coils are arranged in series so that they may be rotated with respect to each other. When the fields add, the mutual inductance of the combination (2M) can be added to the self-inductance of each of the coils. When the fields are opposed, the mutual inductance (2M) is subtracted from the self-inductance of the two coils. When the fields of the coils are at right angles, the mutual inductance is zero and the inductance of the combination is the sum of the inductances of the two coils. This arrangement is commonly known as a variometer.

CAPACITANCE AND CONDENSERS

The property of a dielectric between two conductors that makes it possible for the combination to become charged is known as capacitance. Coils have inductance; condensers have capacitance. Usually a number of metal plates of large area are separated by air, mica, glass or some other dielectric. The capacitance of a condenser depends on the number of plates, the area of the plates, the distance by which they are separated and the material between the plates which is known as the dielectric.

The "electric field", sometimes called the "electrostatic" field of the condenser, is concentrated mostly in the space between the plates. When the plates are connected to a direct current source, a heavy current flows for an instant, and decreases to zero. The condenser is said to be "charged" and if the dielectric is good, it will hold the charge for some time. If the current source is taken away and a wire connected across the plates, the condenser will discharge through the wire. A large condenser charged with several hundred volts will give a visible spark and discharge with a crash. It will also cruelly "jolt" one who plays thoughtlessly with its terminals.

Energy is stored in the electric field of a condenser just as it is stored in the magnetic field of a coil. The energy in the field of a coil or condenser is potential energy. Water stored in a tank high above the earth has potential energy due to its position with respect to the center of the earth.

Capacitances can be connected in series or in parallel like resistance or inductances. However, connecting condensers in parallel makes the total capacitance greater. In the case of resistance and inductance, the value is lessened by making a parallel connection. Capacitance is measured in "farads" or more commonly (in radio work) in the smaller units known as the microfarad or micromicrofarad.

CONDENSERS IN SERIES AND IN PARALLEL

The equivalent capacity of condensers connected in parallel is the sum of the capacities of the several condensers so connected.

$$C = C_1 + C_2 + C_3$$

The equivalent capacity of condensers connected in series is expressed by the following formula which can be simplified as shown when but two condensers are considered.

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \qquad C = \frac{C_1 C_2}{C_1 + C_2}$$

It is sometimes necessary to connect filter condensers in series, as this increases the breakdown voltage of the combination while it of course decreases the capacity available. Condensers of just the *same* size are most effectively connected in series for this purpose. Voltage tends to divide across series condensers in inverse proportion to the capacity, so that the smaller of two series condensers will break down first if the condensers are of equal voltage rating. High-resistance units are often used in such applications to equalize the voltage drops and protect condenser banks from unequal voltage distribution. As the resistors are placed directly across the terminals of each condenser and across the high-voltage line, they are necessarily wasteful of power. Before selecting filter condensers the operating conditions, voltage peaks and r. m. s. values should be carefully considered (See October 1928 *QST*, page 37.)

The formula for determining the equivalent capacity of two series condensers also may be used to advantage in designing a transmitter using the Colpitts circuit.

DISTRIBUTED INDUCTANCE, CAPACITANCE AND RESISTANCE

Thus far, we have considered three properties of electrical circuits and apparatus. Coils, condensers and resistors are all built to have as much of one of these properties as possible without having a great deal of the other two. These "lumped" properties can be connected in a circuit to produce a certain effect on the current and voltage distribution. Condensers will not permit the passage of a steady direct current. Radio frequency impulses act readily through a condenser, however. Choke coils and large inductance coils tend to prevent rapid changes in current. Radio frequency impulses do not act through properly built coils. Direct or continuous current, however, flows unhindered by the inductance of coils.

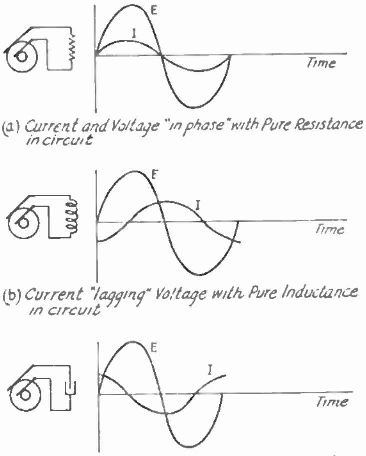
In every sort of coil or condenser and in every electrical circuit, we find not the one property for which the instrument was built but a combination of all the electrical properties we have mentioned. Most design work is a compromise, to approach nearest the ideal results we have in mind. Every coil and transformer winding has resistance and distributed capacitance between the turns as well as the inductance that makes it a useful device. Every condenser has resistance losses also. Power lines, telephone circuits, cables and radio antennas all have *distributed* inductance, capacitance, and resistance throughout their entire length. *Lumped* values are introduced at intervals and at the terminals to produce certain effects. The distributed properties have to be carefully considered also.

OHM'S LAW FOR ALTERNATING CURRENT

Alternating current behaves much the same way as direct current in circuits that contain resistance only. However, its behavior is somewhat changed by the addition of capacitance and inductance to a circuit.

We have mentioned the fact that the *rise of current* in a circuit containing inductance was somewhat *delayed*, that the inductance had the effect of electrical inertia. The effect of a lot of inductance is to tend to prevent any increase or decrease of current in the circuit. It is also true that current must flow into the plates of a condenser *before* any potential difference can exist between its plates. Because of these facts, we say that the current "lags" behind the voltage in a circuit which has much inductance and that the current "leads" the voltage in a circuit where capacitance predominates.

In a direct current circuit, containing either inductance or capacitance, the current increases to a maximum value or decreases to zero as the case may be, coming to a constant rate of flow after a few moments. In an alternating current circuit, the voltage is alternating in character



(a) Current and Voltage "in phase" with Pure Resistance in circuit

(b) Current "lagging" Voltage with Pure Inductance in circuit

(c) Current "leading" Voltage with Pure Capacitance in circuit

SHOWING AMPLITUDE-TIME RELATIONS OF CURRENT AND VOLTAGE FOR A COMPLETE CYCLE (360 Electrical Degrees)

as we have seen and the *instantaneous* values of current and voltage are constantly changing. Some curves show the amplitude-time relations of current and voltage in circuits where there is (a) resistance (b) inductance (c) capacitance.

Ohm's Law for alternating currents:

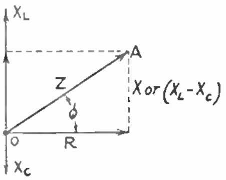
$$E = IZ \qquad I = \frac{E}{Z} \qquad Z = \frac{E}{I}$$

In an alternating current circuit, the current flow is determined by the voltage of the source and by the resistance (R) and re-

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$X_L = 2\pi fL$$

$$X_C = \frac{1}{2\pi fC}$$



THE IMPEDANCE TRIANGLE
(showing relations between impedance and its components, reactance and resistance)

actance (X) of the different parts (i.e., the impedance Z) of the circuit. R, X, and Z are expressed in ohms.

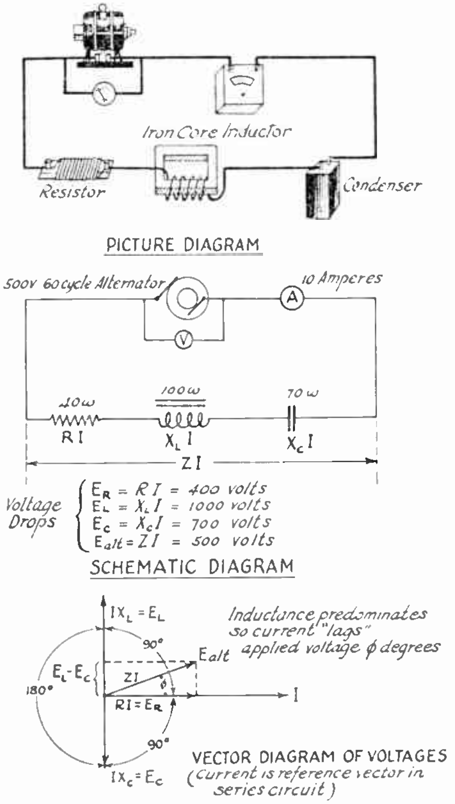
Sometimes it is useful to show the relations between R, X and Z in a vector diagram. The length of the lines in such a diagram can be made to represent the size or magnitude of the electrical quantities while the angles between the lines can show "lead" and "lag" in the circuit. In the impedance triangle shown, OA can be taken as unit radius of a circle drawn about the center O. Distances upward represent inductive reactance while distances downward from O show capacitive reactance. Either may predominate and govern the conditions in a circuit. X_L and X_C are always opposite in their effects and therefore can be subtracted directly if the values are plotted to scale.

Reactance is a property which we have not discussed before. Reactance is a property of a *coil* or *condenser*. It is that property depending on the frequency and inductance (or capacity) which determines the behavior of the coil (or condenser) in limiting the current that flows when an alternating voltage is applied. The reactance is but one component of the impedance. The inductive reactance of a coil is meant by the symbol X_L; the capacitive reactance of a condenser is meant by the symbol X_C. Some resistance is also always present in electrical circuits and must be taken into consideration.

We have spoken of "lead" and "lag". The relations of the voltage drops caused by resistance, inductive or capacitive reactance, and impedance can be shown in a diagram and will help in understanding these terms better.

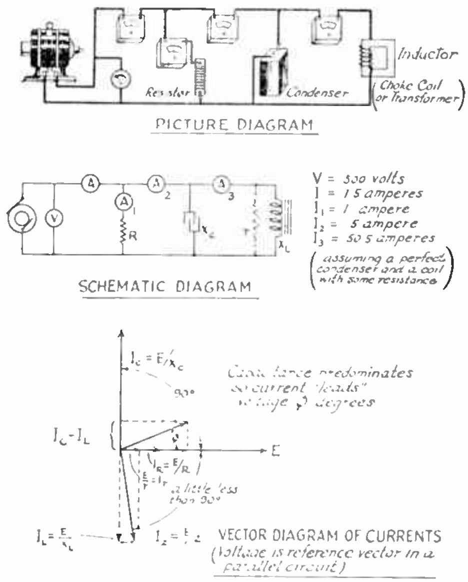
Alternating voltages and currents have thus far been shown on a magnitude-time chart. The values of amplitude are shown from instant to instant throughout the whole cycle (a complete cycle is 360 electrical degrees of rotation). A vector diagram can be used to show the angular relations and magnitudes at a given instant. In a series circuit, the current is the same through each piece of apparatus. In a parallel circuit the voltage of the source is common to each bit of apparatus connected in the circuit. Either a current vector or a voltage vector may be taken as a reference vector, depending on the particular circuit we are talking about.

The diagram shows a circuit containing resistance, inductance and capacitance *in series*. The vector (I) is the reference vector showing the *current* flowing in such a circuit. There is a "voltage drop" across each part of the circuit just as in the case of a direct current circuit. The algebraic sum of all the voltage drops around the circuit is equal to the voltage of the source. In an alternating current circuit some of the voltage drops may be positive and others may be negative. The voltage (E=RI) is effective in causing current to flow through the resistance of the circuit. It is "in phase" with the current. The voltage ($E_L = IX_L$) is effective in overcoming the inductance of the coil. It is 90° *ahead* of the current vector, for the current in a coil *lags* the voltage, and when the coil has pure inductance the angle is 90°. The voltage ($E_C = IX$) causes current to flow in and out of the condenser plates. It is 90° *behind* the current vector, for the current in a condenser *leads* the voltage. Right away one can see that voltages across coils and condenser in the circuit are about 180° out of phase. When they are *equal* in amplitude and *exactly opposite* in phase, the condition known as electrical "resonance" obtains. The current in the circuit is "in-phase" with the voltage. Its value is determined only by the resistance of the circuit. This is called "series resonance" or "voltage resonance". Sometimes the voltages across the condenser and coil in a circuit like this build up to values much higher than that of the voltage source. Then they become dangerous to both life and equipment. In a vector diagram where size and angle are correctly shown, the "in-phase", "leading" and "lagging" components of the voltage can be separated. The leading and lagging components are 180° apart. Subtraction gives the "effective" reaction vector. Combining this with the "in-phase" vector by the old law of triangles that "the square of the hypotenuse equals the sum of the squares of the other two sides" we can find the "impedance drop" which is the diagonal of the impedance triangle.



SERIES ALTERNATING CURRENT CIRCUIT

In the second diagram a circuit with resistors, coils, and condensers in parallel is shown. The voltage impressed on each device is common to all devices in the circuit. The current in each of the three paths is determined by the applied voltage and the "resistance" or "reactance" of the path we are considering. In the condenser branch, the current will "lead" the applied voltage; in the coil branch, the current will "lag" the applied voltage; and in the resistance the current will be in phase with the applied voltage. If the current in the coil and that in the condenser happen to be of the same value, the current supplied by the alternator will be the same as that taken by the resistance alone. A much higher current will be present in the leads between the condenser and coil. This condition is known as "parallel" or "current" resonance.



PARALLEL ALTERNATING CURRENT CIRCUIT

If we know the values of inductance, capacitance and the frequency, we can always figure out the "reactance" and find the current that will flow in the coil or condenser when a certain voltage is applied. If resistance, inductance and capacity are all present, they must *all* be considered in the proper relation. Complicated net works are hard to solve but usually we can divide the circuit into sections and treat each one independently.

When the resistance of a device is small in proportion to its inductance we can neglect the resistance and simplify calculation.

FIGURING SOME PRACTICAL PROBLEMS IN ALTERNATING CURRENT

It is assumed that we have a 40-meter transmitter. It is desired to connect a small condenser across the high-voltage plate transformer to protect the transformer windings from voltages that might build up across them if high frequency currents should leak back thru the r.f. choke and filter to any extent, a condition possible though perhaps unlikely. Remembering that the higher the frequency is, the lower the "reactance" of any condenser, we judge that a small condenser will probably do the trick. Finding a .02-microfarad mica-insulated transmitting condenser available, rated to withstand 2,000 volts, we decide to consider what may happen if we connect it across the high-voltage alternating current source.

First of all to see if it will be practical and accomplish the result we want, let's see (a) what the reactance of the condenser to the 40-meter (7,500 kilocycle) leakage will be and (b) what the reactance will be to the 60-cycle source. In the formula the units are cycles and farads so we must remember to use the proper conversion factors.

(a) $X_c = 1 \div 2\pi fC = 1 \div 6.28 \times 7{,}500{,}000 \times .02 \times 10^{-6} = 1 \div 6.28 \times 7.5 \times .02 = 1/.942 = 1.06$ ohms

reactance at 40-meters (a very low value which will readily by-pass R.F. and prevent any harmful voltages building up across the inductance of the transformer winding).

(b) $X_c = 1 \div 2\pi fC = 1 \div 6.28 \times 60 \times .02 \times 10^{-6} = 132{,}800$ ohms
reactance at 60-cycles.

The transformer is a small one and so we cannot be sure until we figure it out if the secondary current taken by the protective condenser and the set combined will be likely to overheat the transformer or not. The plate transformer we happen to have has a ratio of 10:1 and delivers 1100 volts (effective value) when run normally. The 60-cycle current through the condenser will be:

$$I = \frac{E}{X_c} = \frac{1100}{132{,}800} = .0083 \text{ amperes} = 8.3 \text{ ma.}$$

The transformer is rated at 100 watts (VA) which means that it will deliver

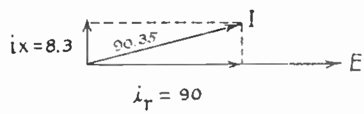
$$I = \frac{W}{E} = \frac{100}{1100} = 91.1 \text{ ma.}$$

The transformer output goes to a tube rectifier thru a filter which has a 70-henry choke in one lead. After keying in the negative lead the current passes through a 3-henry "keying" filter choke to the plates of two UX-210 tubes. There is a considerable voltage drop in the rectifier tubes and in the resistance of the two choke-coil windings. In addition to this, a resistor may be added in series with the keying choke winding to further drop the voltage so our tube will operate normally with about 400 d.c. volts in its plate circuit. The proper size of this resistor is quickly found by using Ohm's Law. If it is desired to produce a *drop in voltage* of about 100 volts, divide this value by the estimated plate current, let us say 100 mils or .1 ampere. (R = E/I)

$$\frac{100}{.1} = 1{,}000 \text{ ohms}$$

In purchasing any resistors be sure they are big enough to dissipate the heat that will be produced by the current they will have to carry. The power that must be dissipated in heating is $W = RI^2$ (watts) $1{,}000 \times .1^2 = 10$ watts (for such a resistor).

Each tube takes 45 milliamperes, 2 x 45 = 90 ma. which the set takes when correctly adjusted. The .02-mfd. condenser across our transformer takes a "leading" 60-cycle current of 8.3 ma. (assuming a perfect condenser with no leakage). There are filter condensers across the high voltage line. They are across *rectified* d.c., however, and do not affect the transformer current in quite the same way. Assuming that the transmitter operates at nearly unity power factor (current in phase with the voltage) the resultant current taken by the transmitter *and* condenser will be 90.35 ma.



This is easily computed by using the law of squares previously referred to.

$$I = \sqrt{(I_r)^2 + (I_x)^2} = \sqrt{90^2 + 8.3^2} = \sqrt{8169} = 90.35 \text{ m.a.}$$

So our transformer *will* operate at about full load with the condenser and transmitter load connected continuously. Transformers can be operated *intermittently* at 150% of rated load without much danger. Before connecting many different kinds of loads to a transformer we should figure out about what is going to happen. Suitable protective fuses should be installed.

FIGURING THE CAPACITANCE OF A CONDENSER

$$C = \frac{kA\ (n-1)}{4\pi\, d \times 9 \times 10^5}$$

$$= .0088\ \frac{kA}{d}\ (n-1)\ 10^{-5}\ \mu\text{fds.}$$

where A = area of one side of one plate (sq. cm.)
n = total number of plates
d = separation of plates (cm.)
k = specific inductive capacity of dielectric.

The Specific Inductive Capacity (k) is a property of the dielectric used in a condenser. It determines the quantity of charge which a given separation and area of plates will accumulate for a given applied voltage. The "inductivity" of the dielectric varies as in the following table. "k" is the ratio of the capacitance of a condenser with a given dielectric to the capacitance of the same instrument with air dielectric.

TABLE OF DIELECTRIC CONSTANTS

Dielectric	"K"	Kilovolts per cm. to puncture
Air (Normal pressure)	1.00	7.8-9.0
Flint Glass	6.6 to 10	900
Mica	4.6 to 8	1500
Paraffin Wax (solid)	2.0 to 2.5	400
Sulphur	3.9 to 4.2	——
Castor Oil	4.7	150
Porcelain	4.4	——
Quartz	4.5	——
Resin	2.5	——
Olive Oil	3.1	120
Gutta Percha	3.3 to 4.9	80-200
Shellac	3.1	——
Common Glass	3.1 to 4.0	300-1500
Turpentine	2.23	110-160
Dry Oak Wood	2.5 to 6.8	——
Formica, Bakelite, etc.	5 to 6	——

When the air dielectric in a variable condenser is replaced with some other fluid dielectric its maximum and minimum capacitance values are multiplied by "k" and the "sparking" potential is increased.

Fluid dielectrics repair themselves after a break-down unless an arc is maintained that carbonizes the oil. Dry oil is a good dielectric with quite low losses. When solid dielectric is used it should be borne in mind that dielectric strength (breakdown voltage) becomes lower as temperature rises. Breakdown is a function of time as well as voltage. A condenser that stands up under several thousand volts for a few seconds might break down when connected to a 2000-volt line for a half-hour.

Example of finding condenser capacitance: We have 3 plates, 3" x 5", in air. The plates are separated ⅛". 1" = 2.54 centimeters.

k = 1. A = 7.62 x 12.70 = 96.8 sq. cm.
d = .3175 cm. n — 1 = 2.

$$C = .0088\ \frac{1 \times 96.8}{.32}\ 2 \times 10^{5} = .00005325\ \mu f.$$

or 53¼ micromicrofarads.

If we put this in castor oil the increase in capacitance, owing to the greater value of K, will make our condenser have a capacitance of

53¼ x 4.7 = 250 micromicrofarads.

The air condenser might spark over at about

7.8 x .3175 c.m. = 2.475 kv. (2,475 volts)

In oil (castor oil) it would have 150/7.8 times the breakdown voltage of air.

$$\frac{150}{7.8} = 19.25$$

19¼ x 2475 = 47,600 volts

We can find the same value directly:

150 x .3175 cm. = 47,600 volts (peak).

Using the formulas for "reactance" we can find what the voltage drop across this condenser will be when carrying current at a specified high frequency.

$$E_x = X_c\ I \qquad X_c = \frac{1}{2\pi f\ c}$$

Where E_x is the reactance voltage drop.
C is the capacitance of the condenser (farads).
f is the frequency (cycles per second)
X_c is the reactance of the condenser in ohms.

Suppose we are using the 3-plate fixed air condenser in our antenna circuit, that a radio frequency ammeter is in series with it. We are operating on an 80-meter wavelength (3,750,000 cycles) and the meter right next the condenser reads 1.3 amperes. What is the voltage drop across the air condenser?

$$X_c = \frac{1}{2\ (3.1416)\ (3750000)\ (53.25)\ 10^{-12}}$$

$$= \frac{1}{1257 \times 10^{-6}} = \frac{10^6}{1257} = 797\ \text{ohms}$$

$E_x = (797)\ (1.3) = 1034$ volts (root mean square value).

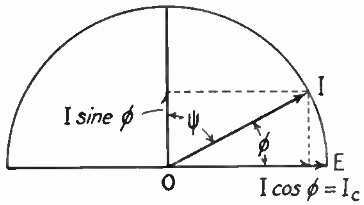
If the wave is a sine wave, this value multiplied by 1.414 will give the "peak" or maximum value.

1034 x 1.414 = 1462 volts (peak)

Our radio frequency ammeter measures the heating effect of all the instantaneous values of current during the radio-frequency cycle. The direct current, the square of which equals the average of the squares of all the values of alternating current over a whole cycle, produces the same heat as the alternating current. Alternating current meters generally used for a.c. switchboard work read the *effective* or *root mean square values* which we mention above.

POWER AND POWER FACTOR

In a direct current circuit the power in watts equals the product of volts and amperes (P=EI). In an a.c. circuit the



IN THE VECTOR DIAGRAM I COS Φ IS THE COMPONENT "IN PHASE" WITH THE VOLTAGE AND I SIN Φ IS THE "QUADRATURE" COMPONENT

The origin of vectors is indicated by O. Current and voltage vectors are shown with a full arrowhead while the components of the current have the half arrowhead.

instantaneous power equals the voltage times the current "in phase" with that voltage. P = E (I *cos* Φ).

We have mentioned the "leading" and "lagging" currents that flow electrically "ahead of" or "behind" the voltage. The angle between the current and voltage is called the "phase angle" (Φ). The cosine of this angle is the "power factor". In the diagram the current (OI) is shown leading the voltage (OE) by the angle (Φ). The cosine (in-phase component of the current) is OI_c. The sine or 90° out-of-phase component of the circuit is I sine Φ in the diagram. This is sometimes known as the quadrature or the "wattless" component of the current. I cos Φ = I_c. Any trigonometry text has tables of sines and cosines of different angles. Strictly speaking

the cosine is the ratio $\frac{OI_c}{OI}$. OI is taken as

unity radius for the semicircle so the cosine can be expressed as OI_c, some fraction of unity. The power factor is the ratio of the actual power dissipated in a circuit (watts) to the volt-amperes (combined power and wattless power.) The volt-ampere rating of a circuit is often known as the "apparent" power. When OI lies along the line OE, Φ = 0 and cos Φ = 1. This condition is referred to as "unity power factor" and when it obtains P = EI as in *direct* current circuits always.

PHASE DIFFERENCE OF A CONDENSER

The angle between voltage and current in a good condenser is nearly 90°. The power factor of such a condenser (cos Φ or cos 90°) is almost zero.

Ψ is the angle of phase difference. It is the angle expressing best the amount by which the condenser falls short of being a *perfect* condenser.

The better the dielectric of a condenser the lower the phase difference. The power factor of a condenser is the ratio of its resistance to its reactance. P.F. = R/X = 2 π f C R.

A condenser with imperfect dielectric behaves like a perfect condenser having a *low* series or a *high* parallel resistance.

DEFINITION AND CONVERSION OF RADIO TERMS

While a complete glossary of quantities and units, with conversion tables, is outside the main purpose of this handbook, the writer feels that some of the more commonly used terms and symbols encountered require definition. For com-

Metric Prefixes Often Used With Radio Quantities

μ	$\frac{1}{1,000,000}$	One millionth	micro-
m	$\frac{1}{1,000}$	One-thousandth	milli-
c	$\frac{1}{100}$	One-hundredth	centi-
d	$\frac{1}{10}$	One-tenth	deci-
	1	One	uni-
dk	10	Ten	deka-
h	100	One hundred	hekto-
k	1,000	One thousand	kilo-
	10,000	Ten thousand	myria-
	1,000,000	One million	mega-

plete and reliable information covering both terms and graphical symbols the reader is referred to "The Report of the Committee on Standardization", published by the Institute of Radio Engineers (New York), and to the "Standard Handbook for Electrical Engineers."

The practical unit of capacity is the *farad.* The ability of the dielectric between the plates of a condenser to become charged electrically determines the permittance or capacitance of a given condenser. A capacity of one farad is defined as that capacity which will have its plates charged to a potential difference of one volt when that quantity of electricity known as one coulomb (one ampere flowing for one second) flows into it. In radio engineering the farad is much too large for practical work so that sub-multiples are commonly used. The microfarad (μf) and micromicrofarad (μμf) are units used in common radio practise. The micromicrofarad (μμf) is sometimes referred to as a picofarad (pf), which is a simpler expression standing for the same electrical quantity. The centimeter is taken as the electrostatic unit of capacity (esu) in the C. G. S. (centimeter-gram-second) system and can be readily used by applying the conversion factor given below:

1 farad (f)	= 1,000,000 microfarads (μf)
1 microfarad (μf)	= 1,000,000 micromicrofarads (μμf) or picofarads (pf)
1 centimeter (cm) (esu)	= 1.11 micromicrofarads (μμf)
1 henry (h)	= 1,000 millihenries (mh) or 1,000,000 microhenries (μh)
1 microhenry (μh)	= 1,000 centimeters (cm) (emu)

The practical unit of electric pressure and potential difference is the *volt.* The electromotiveforce (e.m.f.) or voltage in a circuit is what causes the flow of current, just as pressure in fluids causes the flow of water or gas in pipes. Current always tends to flow from a point of higher to a point of lower potential. The C.G.S. units which equal one volt are the abvolt (10^{-8} emu) and the statvolt (300 esu).

The practical unit of the rate of current flow is the *ampere,* determined by a fixed rate of the electro-deposition of silver under specified conditions.

1 ampere = 10 absamperes (emu) = 3.33 x 10^{-10} statamperes (esu).

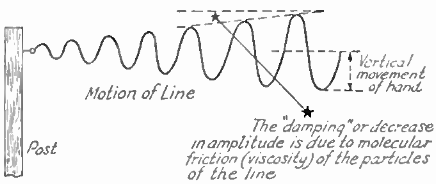
The practical unit of resistance is the *ohm,* defined as the resistance of a mercury column of certain dimensions under specified conditions. 1 ohm = 10^{-9} absohms (emu) = 9 x 10^{11} statohms (esu). An e.m.f of 1 volt is required to produce a current of 1 ampere in a resistance of 1 ohm.

Energy and power should be carefully differentiated. Energy is simply the capacity for doing work. Power represents the expenditure of energy and is a measure of the rate at which work is done. Power is measured in watts; work done is measured in watt-hours. Most electrical devices are rated by their power consumption in watts. One horse power (h.p.) = 746 watts.

CHAPTER IV

How Radio Signals Are Sent and Received

WHEN a pebble is thrown into a still pond, water waves are created which travel outward in circles from a common point. When a clothes line fastened to a post is shaken vertically, waves are set up which travel to the post and are reflected back to the hand.



WAVE MOTION

The waves are recurring displacements having amplitude, length, and frequency. They carry energy and spread outward from the source with a definite speed. Light waves and sound waves represent other forms of wave-motion. Radio waves are similar to water waves. They differ in velocity and frequency from other forms of wave-motion.

The velocity of radio waves is about 300,000,000 meters (186,000 miles) per second. There is a fixed relation between the velocity, frequency and length of radio waves. The velocity is constant and the frequency or wavelength may readily be found if either one is known.

$$f = \frac{V}{\lambda}$$

Where
f is frequency (cycles)
V is velocity of propagation (meters/sec)
λ is the wavelength (meters)

WAVELENGTH-FREQUENCY CONVERSION

shown on charts and tables in this book and elsewhere is based entirely on substitution in the above formula. V is a constant whose accurate value may be taken as 299,820,000 meters per sec. Using this and any desired wavelength, the corresponding frequency is quickly found. Dividing the result (cycles per sec.) by 1,000 gives the frequency in kilocycles.

Suppose we know the wavelength is 200 meters.

Then the frequency is $\frac{300,000,000}{200}$ = 1,500,000 cycles per second.

A radio wave consists of magnetic and electric lines of force. To create a water wave we can mechanically agitate the water. If we simply throw a pebble into the water, the wave will soon decrease in height, lose energy and be damped out. If we regularly hit the water at suitable intervals we can keep the wave going out continuously from the central point. To create a radio wave we must disturb the medium in which lines of force or radio waves can be set up. This hypothetical medium is usually referred to as the ether. A high-frequency electric current (radio frequency to-and-fro movement of electrons) is necessary for the production of radio waves. If this current is damped out, the radio wave will also diminish to zero value. Magnetic and electric lines of force go through the same variations as the current that sets them up. If we continually supply energy to keep the electrons in motion, a continuous wave (c.w.) will be sent out.

We are concerned with the manner of creating this high frequency energy. The apparatus used is of particular interest to us. The lower radio frequencies can be produced by rotating machinery (Alexanderson alternator). Resonant circuits having a natural period or frequency are made use of in converting ordinary direct current to high frequency current. In practice, the electric arc, the spark gap and the vacuum tube have all been used with resonant circuits for this purpose.

OSCILLATIONS

If we put a weight on a spring and release it, the weight bobs up and down for several minutes. The weight has inertia; the spring has elasticity. Coils have inductance or "electrical inertia". Condensers have capacitance or "electrical elasticity". Mechanical and electrical oscillations are very similar in most respects.

When a high voltage is free to act in a circuit containing inductance and capacity, the current surges back and forth in a transient oscillatory way, just as the displaced weight bobs up and down on the spring.

TUNED CIRCUITS

In all radio work tuned circuits are used a great deal. Radio receivers and transmitters alike make use of tuned circuits. "Tuning" a transmitter simply means changing the values of inductance and capacitance so that the "resonant" frequency of the circuit is the desired value. A transmitter is usually tuned to one wavelength (frequency) and the circuit adjusted for maximum effectiveness. If more than one wavelength is used, the adjusting is carefully done for each. The position of clips and condensers should be marked so that a change can be quickly made.

"Tuning" a receiver simply refers to the changing of the variable element (usually capacitance, but which may be either inductance or capacitance) to change the received wavelength.

A tube circuit may be adjusted for either maximum effectiveness or maximum efficiency or both if the controls of power supply and coil adjustment are flexible enough.

$$\lambda = 1885\sqrt{LC}$$

When L is the inductance in microhenries
C is the capacitance in microfarads
λ is the wavelength in meters

USE THIS FORMULA FOR DETERMINING THE WAVELENGTH, INDUCTANCE, OR CAPACITY

when the other two values are known. Inductance may be readily measured by using known capacities in a resonant circuit, finding the wavelength with a wavemeter, and substituting in the formula.

Simple calculations can be made directly from the formula. Knowing that inductance usually varies as the square of the number of "turns" (n) and as the square of the diameter of coils (d), suppose we wish to tap a coil to receive 7000 kc. (40-meter) signals, instead of 3500 kc. (80 meters) which a circuit happens to be working on. The coil is a space-wound affair and we will neglect the distributed capacitance, which is otherwise important. (The Greek letter "alpha" in the formula below means "is proportional to".)

$$\lambda \propto \sqrt{LC} \quad \textit{(from above)}$$

$$\frac{\lambda}{2} \propto \frac{\sqrt{L}}{2} \propto \frac{\sqrt{n^2}}{2} \propto \frac{n}{2}$$

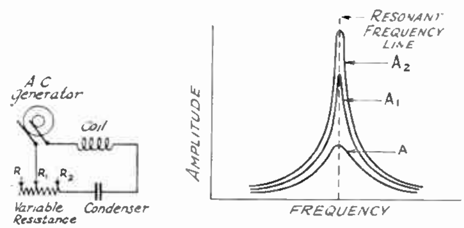
or

$$\frac{\lambda}{2} \propto \frac{\sqrt{L}}{2} \propto \frac{\sqrt{d^2}}{2} \propto \frac{d}{2}$$

Then neglecting distributed capacity, if we tap the coil in the center, the half-wavelength signals will be received. We might also build a coil of half the diameter, having the same number of turns as the original coil. The same variable condenser can be used successfully for tuning.

DAMPING, RESISTANCE, SHARPNESS OF TUNING

We can compare our electrical oscillations to the mechanical oscillations of a pendulum. Given one impulse, the number of times the pendulum swings back and forth depends on the medium around it. It will swing longer in a vacuum than in air. If it is placed in water, it will stop quickly. The work done in overcoming molecular friction slows it to a standstill. The "viscosity" of the water or air is the measure of this sort of friction. For a given impulse, the amplitude of swing will not be so great if the motion is hindered by some sort of friction. Loss of energy causes "damping". In an electrical circuit we meet "resistance" which has much the same effect on electrical oscillations as the "viscosity" of the medium has on mechanical oscillations. The "sharpness" of tuning and the "amplitude" of electrical oscillations are greatest when the "resistance" of a circuit containing a condenser and coil is lowest. The diagram shows a tuned circuit which has a variable resistance as well as a certain amount of inductance and capacity. The high-frequency generator G impresses a constant voltage in the circuit. The currents that flow vary in broadness and



HOW RESISTANCE IN A CIRCUIT BROADENS TUNING

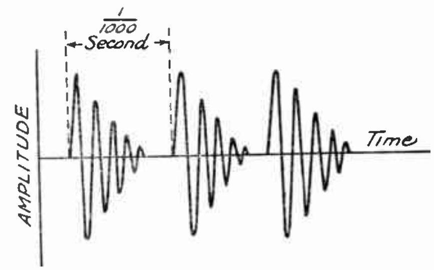
amplitude depending on the amount of resistance in the circuit.

We get the loudest signals with a receiver having low resistance circuits. If we are talking with a station whose note is very sharp and a trifle "wobbly" or if we are tuning for someone near a certain wavelength we can advantageously use a lumped variable non-inductive resistance in our tuned circuits. The note can be broadened and made more readable without materially decreasing its high intensity. Of course, our circuit does not tune as "sharply"; more interference from other stations may be noticed; a certain station will be heard, however, even if the set is de-tuned a trifle. The value of this arrangement depends altogether on the conditions for a given case. Add forty or fifty ohms to one of your tuning circuits and observe the action we have mentioned.

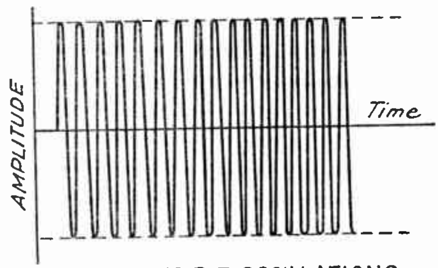
DAMPED AND UNDAMPED WAVES

When our pendulum receives but one impulse to set it in vibration, the oscillations soon die out due to damping. In radio this damping means that the current or oscillation gradually decreases in amplitude. After a few swings thru positive and negative values, the circuit is electrically in a state of rest. Then another discharge across our spark gap will set up another group of damped oscillations.

If energy is supplied in a series of "*timed pushes*" the oscillations will rise to a maximum value and hold that value continuously. There will be no groups of



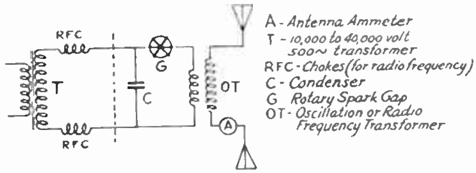
GROUPS OF DAMPED RADIO FREQUENCY OSCILLATIONS



CONTINUOUS R.F. OSCILLATIONS

damped oscillations. The wave will be a continuous wave (CW). The damping effect of the circuit will influence the decaying of oscillations when the circuit is broken as by keying. The energy supplied by each "push" will just make up for the amount lost thru friction (damping) and the amplitude of oscillations will be constant. The vacuum tube is the most common generator of continuous oscillations.

The spark transmitter creates such a highly damped wave as we have discussed in the second above paragraph. A condenser is charged to a high potential. It (C) stores energy. When charged, the condenser voltage breaks down gap (G) and oscillations take place in the LC (inductance-capacitance) circuit. These are coupled into the antenna thru the "oscillation" or "R.F." transformer (LL_1). The resulting electrical surges take place at the natural frequency determined by the values of inductance and capacity in the circuit. Just as a pendulum has a natural rate of



CIRCUIT USED IN A "SPARK" TRANSMITTER

swinging back and forth determined by its length and weight, every circuit has such an "electrical" period which depends on its inductance and capacity. Unless energy is supplied to electrical circuits to keep them "oscillating", the high-frequency currents are soon damped out by the resistance of the circuit just as molecular friction of the air stops the action of the pendulum. The escapement of a clock supplies energy from the spring to keep the pendulum in motion. In tube sets, the vacuum tube (like the escapement) provides energy from the plate supply source at the proper time intervals if the transmitting circuits are correctly adjusted.

THE ANTENNA

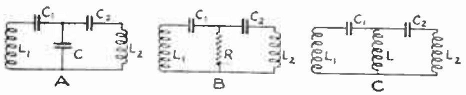
High frequency currents can produce radio waves. If these currents are *confined* to circuits containing lumped inductance and capacitance, they are not very effective in producing radio waves, however. An antenna-ground or antenna-counterpoise circuit has distributed inductance, distributed capacitance, and also a comparatively high "radiation" loss. Such a circuit is often referred to as a "radiator" or "radiating system." The physical dimensions are quite large and the lower the frequency the larger they have to be to "radiate" successfully.

The antenna or "radiator" is built expressly for the purpose of setting up the radio waves. Antennas have a number of shapes. The T, the inverted L, the V, the umbrella, and the coil or loop antenna are common types. The last named is very poor for most transmitting purposes but can be used effectively with the *very* short waves. Directional transmission is effected by building antennas of certain shapes. A loop radiates most energy in both directions along the plane of the loop. The inverted L transmits best in the direction opposite from that in which the horizontal part points. Radio waves like other kinds of waves can be reflected and refracted. Suitable reflectors make a "beam" transmitter that has marked directional characteristics. The short antennas used for high-frequency short-wave transmission do not have any marked directional effects and we do not have to worry about these.

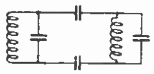
COUPLING

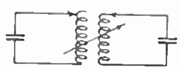
How do we get the radio frequency energy into our antenna, does someone ask? The energy transfer is accomplished by the use of *coupled* and *tuned* circuits. A pendulum has a certain natural period of swinging back and forth. We can move the pendulum back and forth at any rate we wish by applying enough force. By far the greatest response is shown when we pay attention to the natural rate of swing and *time* our application of force accordingly. If one of two pendulums of the same natural period is set in motion and there is a common link between them that transmits even a very tiny bit of energy, the other pendulum will gradually get in motion. Mechanical resonance exists when the two pendulums are tuned to the same natural rate of vibration. The pendulums are "coupled" by the common link which makes the energy transfer possible.

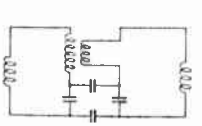
(a) When the common link in two electrical circuits is a condenser, we refer to the coupling as "capacitive" coupling. (b) When a resistor is used, we speak of "re-

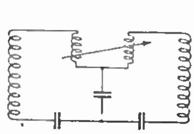


Direct coupling with condenser, resistor, or coil.


Indirect Capacitive Coupling


Magnetic Coupling


Magnetic and indirect Capacitive Coupling


Magnetic and Direct Capacitive Coupling

TYPES OF COMPLEX COUPLING

sistance" coupling. (c) When a coil is used, the coupling is "inductive" coupling. These three types of direct coupling are sometimes called "conductive", as shown in the diagram.

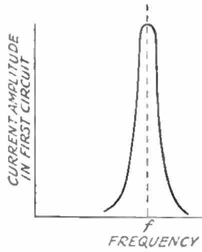
The "voltage drop" across the common link (C, R, or L) caused by current circulating in L_1 C_1 (C, R or L) is effective in producing currents in the L_2 C_2 (C, R or L) circuit. The L_1 C_1 current and the value of C, R, or L determine what takes place in the C_2 L_2 circuits.

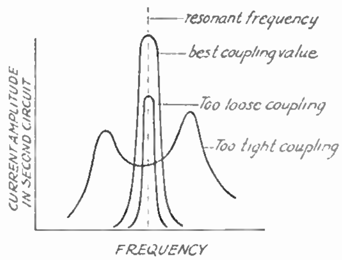
The circuits may also be coupled less directly as shown in the second diagram.

These methods of coupling are known as indirect capacitive coupling and magnetic coupling, respectively.

Most amateur stations using short wavelengths use "magnetic" coupling. In such an arrangement the coupling value may be changed by *changing the number of active turns in either coil* or by *changing the relative position of the coils* (distance or angle between them).

The value of the condensers and coils used for coupling and the value of high





SHOWING CURRENT VALUES IN PRIMARY AND SECONDARY FOR DIFFERENT VALUES OF COUPLING

frequency currents (causing a voltage drop across the first circuit) determine the power transfer between the two circuits. Whether the coupling is "inductive" or "capacitive" is determined by whether the two circuits are linked by a *magnetic* or an *electrostatic* field. Sometimes both kinds of coupling exist and this is known as complex coupling.

All of the above coupling schemes may be classified as either tight or loose. Coupling cannot, as is commonly supposed, be meas- in "inches" separation of coils. The separation between the coils (distance and angle between axes) *and* the number of turns in each determines the coefficient of coupling. Many turns in two coils very close together gives us *tight* coupling and a big transfer of power. Few turns at right angles or far apart give us *loose* coupling with little actual energy transfer.

When the coupling between two circuits

is very small the two circuits can be readily tuned to be resonant to the same frequency. As we increase or "tighten" the coupling, the mutual inductance increases. The circuits are no longer resonant to the same frequency but the combination is resonant to two frequencies, one higher and one lower than the first frequency. The quantity of power transferred is greater and greater as the coupling gets tighter and tighter. However, the power transferred on the *one* frequency that we are interested in, increases to a maximum and then begins to decrease. The peak values of the two frequencies are never quite as high as the one peak. We have a *broader* wave that creates interference. The range is somewhat decreased. With most transmitters there is a certain critical value of coupling that gives best results. With a tube set, too close (tight) coupling causes instability. The transmitting wavelength flops from one wavelength to another and the signals cannot be easily copied. With a "quenched" spark transmitter and with an "arc" set the best coupling value is somewhat critical. Too close coupling gives a big reading on the antenna ammeter but the wave is "broad" and the signals do not "reach out".

SENDING AND RECEIVING (DAMPED WAVES)

In transmitting, then, we use apparatus that generates radio-frequency alternating currents from a high-voltage commercial source. The radio-frequency energy is coupled into an antenna or radiating system. Here it sets up magnetic and electric lines of force that radiate in all directions.

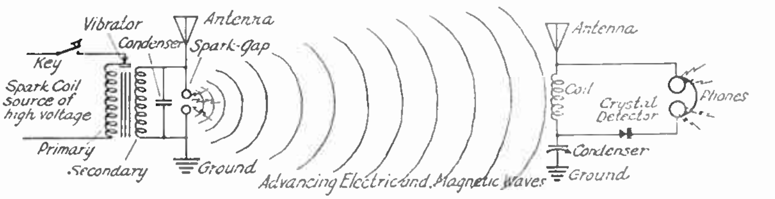
In receiving radio signals we may use apparatus similar to the sending equipment and reverse the procedure. Magnetic and electric lines from the radiator sweep across an antenna which we erect for the purpose. Radio-frequency potentials are induced in it. Our antenna has distributed inductance and capacitance. It therefore tunes to a certain frequency. We can add lumped inductance and capacitance if we please. The maximum response occurs when the antenna circuit is tuned to the incoming frequency. The small potential induced by the advancing electric waves causes oscillations to take place in the antenna circuit. The radio-frequency voltages in this circuit can be applied directly or indirectly to the grid of a vacuum tube or to a crystal detector. These devices have the property of conducting current better in one direction than in the other. Rectification takes place and the damped impulses from a spark transmitter or the modulated voice frequencies from a radiophone may be received. Continuous waves cannot be quite so simply received, however.

THE VACUUM TUBE

The usefulness of the vacuum tube is known to most of us. Its action as a rectifier or detector, as an amplifier, and as an oscillator is known but not so well understood.

A vacuum tube is familiar to most folks as an evacuated glass vessel containing three elements, filament, plate and grid. Small vacuum tubes are used for radio reception. Large tubes are used as amplifiers of speech or of weak radio-frequency signals. Every time we make a long distance telephone call hundreds of V.T. amplifiers are put into use for our benefit. Still larger tubes are used in making powerful radio-frequency currents for sending out radio waves of long and short length. The biggest tubes handle many kilowatts of energy. They sometimes have water jackets for cooling the plates which waste some power as heat. Any three-element vacuum tube can perform all three kinds of action if we use it properly.

All substances are made of electrons. When most metals are heated some of the electrons in their make-up "boil" off. The purpose of the *filament* in our vacuum tube is to give off electrons. Any light that it gives is simply incidental to the heating process. A tungsten filament has to be heated very hot before it gives up its electrons. It takes lots of energy to do this and much light is given off in the process.



SENDING AND RECEIVING *(damped waves) This sending arrangement causes interference and cannot be used by amateurs.*

Thoriated filaments are used in most modern tubes. A coating of barium and strontium oxides on a filament also parts readily with electrons. Such tubes do not take so much power for filament heating. Plenty of electrons are available and but little light is thrown off, as the temperature is not very high.

Electrons are negative particles of electricity. In a tube full of some fluid like air, electrons given off will fall back into the filament. When there is a vacuum around the filament the heated parts are protected from oxidation and the electrons easily boil out and fill this tube. The grid is next to the filament and if it is well insulated so the electrons cannot leak away it will collect electrons until it is negatively charged. Like charges repel and most of the new electrons coming off the filament will then fall back into it. Out beyond the grid is the *plate*. If we connect a battery between the filament and plate with the positive terminal next the plate, the positive plate will attract the negative electrons. As fast as the electrons come off the filament they fly over to the plate. Electrons in motion make an electric current. The amount of current depends on the size and temperature of the filament, the voltage of the battery and the resistance in the different parts of the circuit. The potential of the grid has a marked influence on the current, too. An ammeter or milliammeter anywhere in the circuit will measure the current that flows. A change in the voltage of the plate battery does not change the

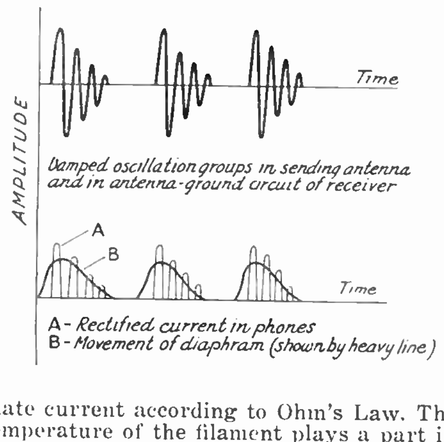


plate current according to Ohm's Law. The temperature of the filament plays a part in limiting the electron emission and possible current flow. The electrons come from the heated filament. The grid and plate are seldom hot enough to give off electrons under normal conditions. The current can only flow one way through the tube. If alternating current is applied in the plate of our direct current B-battery, the electrons will only be attracted to the plate during the parts of an alternating current cycle when the plate is positive. The tube is acting as a "rectifier". This action is similar to that of the "crystal" detector in receiving "spark" and "voice".

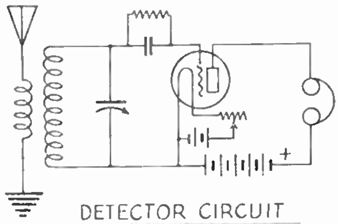
The *grid* is the controlling element of the vacuum tube. A two-element vacuum tube is a good rectifier. It can act as a "valve" in the circuit, allowing the current to flow in but one direction. It is good for little else, however. The grid is of open construction and it is placed near the filament. A battery (C) can be connected in the grid circuit (between the grid and filament) which makes the grid either positive with respect to the filament or negative with respect to the filament.

When the grid is positive, the negative electrons are attracted more and they get started away from the filament with more velocity so that more of them reach the plate. A plate current meter shows that the plate current has increased. When the grid is negative, the negative electrons are repelled and the plate current is decreased. The grid is near the filament and any change in grid potential has a large effect on the plate current. If the grid potential is varied while the filament current and plate voltage remains constant, the effect on the plate current varies as shown in the diagram. The filament temperature limits the emission of electrons causing the bend at the top of the curves, as saturation is approached. The bends in the curve (A B C D) can be used for detection. The straight section of the characteristic curve is useful for non-distorted amplification.

HOW A VACUUM TUBE "DETECTS"

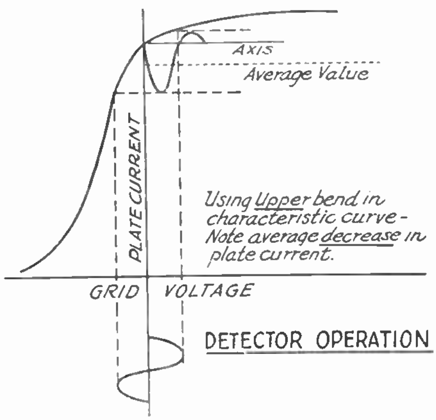
For simple detection the circuit shown is usually used. A tuned circuit is coupled to the antenna and connected through a small condenser which is shunted by a high resistance to the grid and filament of a vacuum tube. The whole connection is called the *input* circuit to our tube. The filament current is provided by a low voltage battery (the A-battery). The head phones and a higher voltage battery are connected between the filament and plate of the vacuum tube. This is the *output* circuit of our tube. The B-battery, as it is called, usually has a voltage between 15 and 25 volts.

The electric and magnetic field from a sending station set up voltages in the antenna causing oscillating high frequency currents in the antenna coil. The resulting field about this coil links the coil in the input circuit to our tube. This circuit is tuned to resonance at which point there is a maximum voltage across the condenser and coil. One of the terminals of the grid condenser connects to one side of the condenser and coil. This point becomes first positive and then negative at radio frequency. At a given instant let us say that this terminal of the grid condenser is positive. The other plate of the condenser takes on a negative charge of equal value



DETECTOR CIRCUIT

by robbing the grid of some of its electrons. This leaves the grid itself positive with respect to filament. The *resistance* of the grid leak is so high that practically no charge is lost through leakage in the very small time required for a half-oscillation. The positive grid attracts more electrons from the filament through a momentary increase in the plate current. As soon as the negative half of the radio frequency cycle comes along, the other plate of the grid



DETECTOR OPERATION

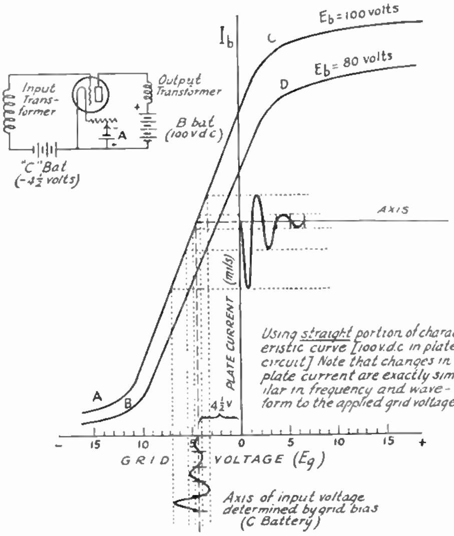
condenser becomes positive and the grid itself has a charge of electrons. The negative grid repels further electrons but *holds all that it has received.* It continues to gain electrons during each positive part of the radio frequency cycles that occur. The result of a continued damped or modulated group of oscillations is to make the grid more or less negative. This causes a dip in the plate current. Between every group of oscillations the negative charge has time to "leak" off the grid through the high resistance of the grid leak allowing the plate current to increase again. When receiving modulated speech the process becomes continuous and the variations in telephone current are therefore at speech frequencies.

A tube can detect without the grid condenser and leak by adjusting it to work on the "bend" in the curve. Radio-frequency changes in grid potential will make radio-frequency changes in plate current. The decrease in plate current when the grid is negative will be greater than the increase in plate current when the grid is positive (at that "bend" in the plate-current grid-voltage curve which comes just before saturation).

If we wish, we can leave out the grid leak and grid condenser, substituting a C-battery to put a negative bias on the grid of our detector tube. Just the right bias must be used so that the tube will detect *on the lower bend* of the plate-current grid-voltage characteristic curve. The set recovers quickly from static crashes when this is done. It is quieter in operation than a set with a poor grid leak can ever be. Slightly superior sensitivity on weak signals is claimed, due to the increased quietness.

HOW A VACUUM TUBE "AMPLIFIES"

A small change in grid potential always makes quite a large change in plate current. This makes it possible to apply cur-



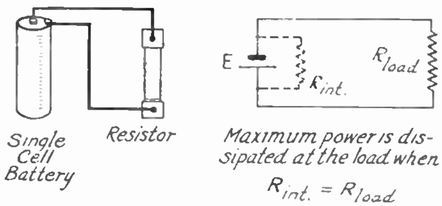
AMPLIFIER OPERATION

rents of any frequency to our grid and to use the effect of the varying plate current in a transformer or "coupler" of some sort to produce greater voltages and currents at the same frequency. The power of course comes from the local B-batteries and the grid simply controls that local power supply.

Several tubes can be used one after another in an amplifier. They are coupled by any of the methods we mentioned under the subject of coupling. Magnetic coupling is perhaps most commonly used. Radio and audio frequency transformers are the simplest examples of magnetic coupling for amplifying voltages of different frequencies.

The action of amplification is quite similar to detector action. No grid condenser or leak is necessary. To give undistorted amplification the tube must be connected in a circuit so that it operates on the straight portion of its plate-current grid-voltage curve. The grid voltage must be kept down below certain limits, and a C-battery or bias potential to shift the axis of the input voltages will often prevent distortion and save battery consumption, although not necessarily giving more amplification. The figure shows how undistorted amplification is secured.

Maximum voltage amplification is desired between tubes. Between the last



CONDITION FOR MAXIMUM POWER IN A CIRCUIT

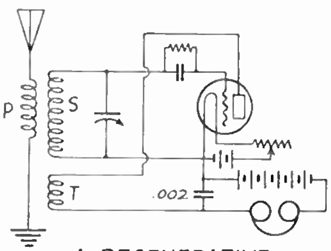
step of an amplifier and phones or loud speaker we want maximum power transfer. This is obtained by matching the tube impedance to the primary impedance of the output transformer. The secondary impedance of the output transformer is made equal to the impedance of the winding on phones or speaker to give best results. Just as in the case of the dry cell or generator, the maximum power is transferred when the load and internal impedance characteristics are matched.

HOW A VACUUM TUBE "OSCILLATES"

We have mentioned that vacuum tubes can and are used to generate undamped high-frequency currents. The production of undamped oscillations is accomplished by adding energy in "timed pushes" to each oscillation. A tube can be made to oscillate by coupling the input and output (grid and plate) circuits. The inductance and capacitance in the grid circuit usually determine the frequency of oscillation, although the values of inductance and capacitance in other parts of the circuit may control this. A coil in the plate circuit (tickler coil) sometimes couples a part of the plate circuit energy magnetically to the grid circuit, thus keeping the amplitude of oscillations unchanged despite the losses that tend to make them decrease. Every tube has some capacitance between the elements. When there is a coil in the plate circuit there is bound to be a "reactance voltage drop" across this coil. This voltage couples some energy back to the grid circuit through the grid-plate capacitance of the tube. Often a tube which refuses to oscillate can be brought into oscillation by adding a small condenser between the grid and plate. A few inches of insulated wire connected to each and twisted together will serve this purpose. Increasing the size of the coil in the plate circuit will do the same thing.

REGENERATION

There is always some feed-back through the tube inter-electrode capacity. Usually detection and amplification are accomplished in one tube. Oscillation takes place only when there is enough feed-back from the output to the input circuits so that the action is continuous as long as power is supplied and the coupling is sufficient, and where the feed-back is sufficient to compensate for the losses in the circuit. Whenever any energy is "fed back" to the input of the tube we refer to the process as "regeneration". A signal impressed in the grid circuit (SC) produces changes in the plate circuit (T) at the same frequency. These changes have greater magnitude than the impressed signal because they take



A REGENERATIVE DETECTOR CIRCUIT

power from the plate battery. Whenever some of the energy is led back to the grid circuit (or made to react on the grid circuit) we have "regeneration". The response to weak signals is greatly increased by using regeneration because the original voltage impressed on the grid is much increased by the feed-back. When there is sufficient "regeneration" we have "oscillation". By varying the tickler coupling, the capacitance across grid and plate, or the turns in any coils that may be in the plate circuit, we can control the amount of regeneration and the ease with which the set goes in and out of oscillation. In receiving "spark" and "phone" signals we want our tube to be adjusted for maximum regeneration *without* oscillation. To receive a continuous wave (c.w.) signal we want the set to just oscillate.

In a radiophone receiver we always want to prevent oscillation. "Neutralization" refers to any of the various methods by which oscillation is prevented. The coupling between grid and plate through the interelectrode capacity of the tube always feeds back some high frequency (h.f.) voltage to the grid circuit. To neutralize the effect of this we adopt some method to feed back another equal and opposite voltage (a voltage equal and 180° out of phase) to our input circuit. To get some regeneration is desirable, so we usually do not neutralize completely—the neutralizing voltage is opposite but not quite equal.

If a continuous wave is impressed on a detector tube having unilateral conductivity, rectification takes place. Since the waves are not modulated or damped, a change in the average value of the plate current takes place when we start to receive the continuous wave and no further change occurs until the continuous wave stops coming in. In our phones there is merely a click at the start and end, but no evidence of a signal being received as long as the amplitude of the incoming signal is constant. The impulses received change their direction at radio frequency and as such frequencies are inaudible we must look to other means to receive continuous wave telegraph signals.

HETERODYNE AND AUTODYNE C.W. RECEPTION

The best and most common way to receive continuous waves is to use a vacuum tube to produce weak oscillations of *nearly* the same frequency as the incoming continuous wave (c.w.). The local oscillations and the incoming oscillations are added together in the input circuit to one vacuum tube.

Two tuning forks of slightly different frequency "beat" upon each other, alternately adding to and neutralizing each other. The "beats" are of low frequency (the difference of the frequencies of each tuning fork) and the amplitudes of the two forks add so that the beat has first the sum of the amplitudes, then the difference (zero).

In radio work, continuous waves are ordinarily received by the "beat" method. Inaudible high frequencies are combined to produce an audible beat note. Millions of cycles can be generated locally in a small vacuum-tube oscillator. This oscillator is coupled to the grid circuit of a vacuum tube. The incoming oscillations are also coupled to this same circuit. The beats between the two frequencies are present in the output. The beat frequency equals the difference of the two frequencies. "Heterodyne" comes from two Greek words meaning "other force". When a tube is used especially to generate the local frequency, serving no other purpose but this, we have the heterodyne method of c.w. reception.

"Auto-dyne" means "self-force". The standard amateur regenerative tuner employs the autodyne method of reception. One vacuum tube generates oscillations. Incoming signals are coupled into the grid circuit of this same tube. A single tube thus acts as oscillator, detector, and amplifier.

RECEPTION—GENERAL

In all radio work, whether the apparatus is for sending out radio-frequency energy or whether it is for receiving weak impulses to amplify and convert into understandable characters, the business of tuning is important. Tuning is the process of adjusting the coils or condensers so that the circuit will respond to certain frequencies (wavelengths) which correspond to certain stations that we want to receive. When signals are to be received, the sending and receiving stations must have their apparatus and circuits tuned to the same frequency (wavelength).

Usually sending stations use some fixed wavelength while receiving stations "tune" for the station that is wanted. Either the condenser or the coil may be the variable element in the receiving circuit. Sometimes both are made variable. The proper ratio of capacitance to inductance in a circuit has long been the subject of controversy. Good receiving results are obtained over quite wide limits. Therefore, for simplicity of control just the coil or just the condenser is made adjustable.

Using a coil with a small variable condenser and a number of fixed condensers makes it possible to cover a wide range of wavelengths (frequencies) with the desired nicety of adjustment. When a big condenser is used a vernier knob or dial helps to give easy control. By using one small variable condenser and a number of removable coils it is possible to design a practical and efficient "tuner" that will cover any or all the frequencies (wavelengths) used by amateurs today.

Tuning controls should be few in number and easy to operate. Adjustments should stay put and body capacity effects must be avoided, especially so in a high-frequency (short-wave) receiver.

Almost everyone who reads this Handbook has seen, used, and perhaps constructed a receiver of some sort for broadcast or amateur wavelengths. There is little difference in the procedure followed in making a one- or two-tube broadcast receiver and in building a good short-wave tuner. In fact, the fundamental change that must be made is simply to reduce the size of both the coils and condensers used.

In broadcast reception we are careful to use amplifying transformers that do not amplify certain frequencies in the musical scale much more than others. In code reception we can use the same instruments if we please or we can pick out some so-called "distortion" transformers to give us more amplification on some one frequency. By heterodyning or autodyning the incoming signal to give a beat note of the desired frequency we can readily get maximum amplification from such a transformer. Static and signals of different frequency from that of the transformer "peak" will not be amplified to the same extent as the signal we want to read. The signal will stand out clearly against a background of little noise.

Most of the stations we hear will be continuous-wave stations. Our reception is accomplished by the autodyne method. Our local receiver oscillates. Our adjustment of the condenser-coil circuit determines the frequency of oscillation. The antenna circuit is coupled to the condenser-coil circuit. Oscillations are set up in the antenna circuit by the changing field from the transmitter. The field about the antenna coupling coil (if one is used) *links the coil in the tube circuit. The grid of the vacuum tube has impressed on it voltages of two frequencies. The output circuit of the vacuum tube contains the *difference* between these two grid-circuit frequencies. When the two frequencies (one from the antenna and one locally generated) are exactly the same, we have "zero beat" and *no* sound in the phones *unless* the incoming signal is modulated.

In receiving code signals the regeneration control is set so that the receiver oscillates over the whole range of frequencies that can be covered by the set. The tuning dial of the condenser-coil circuit is turned slowly while the regeneration control is moved just the little bit necessary to keep the tuner *on the edge of oscillation.* When the amplitude of the local oscillations is just equal to that of the incoming signals, the beat note will be strongest. In receiving signals the energy from the antenna circuit is always very weak. The best results (maximum sensitivity) are obtained with the regeneration control not beyond the point where oscillations begin in the local circuit.

Most vacuum tube receivers to-day utilize the principle of regeneration. Part of the energy in the output circuit (plate circuit) of the detector tube is coupled back to the input circuit (grid circuit). The feed-back voltage may be applied to the grid either through the plate-grid intra-tube capacity or by an inductive feed-back obtained by using a "tickler" coil.

MODULATION

When something that we do varies the amplitude of the current in a circuit, we have modulated the current. Speech modulation is usually accomplished by speaking into a microphone. Microphones for speech only are quite satisfactory when made of a stretched metal diaphragm in front of some carbon granules whose resistance varies, depending on the position of the diaphragm. For musical reproduction the condenser microphone and the Pallophotophone are quite useful even though they must work through a large amplifier before there is energy enough to control large amounts of power. The glow microphone gives uniform modulation over a wide band of audio frequencies.

Micophones and modulators vary currents by varying the resistance or impedance of the circuits of which they are a part.

Perhaps the simplest way to manipulate a continuous wave is to put a microphone in the antenna circuit (A). The antenna resistance can be varied by speaking into the microphone. This is a crude arrangement. The variation in antenna current is usually small, the modulation incomplete, the power loss considerable, the current a microphone will handle limited, the interference produced illegal.

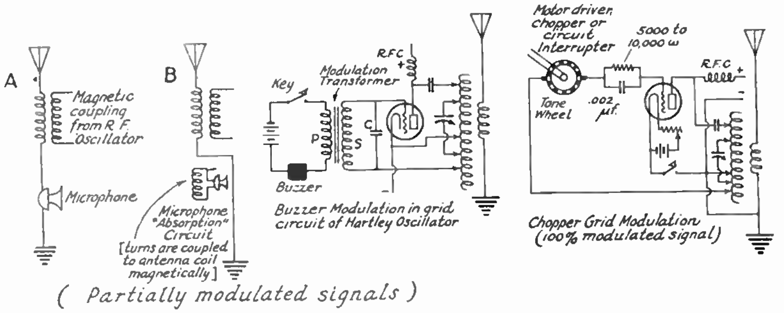
The absorption method (B) of modulating a continuous wave ("carrier" wave) is something of an improvement. A microphone is connected in an absorbing circuit coupled to the antenna. The amount of energy absorbed varies with the resistance in the absorbing circuit and the coupling used.

"Grid" modulation and "plate" modulation are accomplished by introducing the speech frequencies into the input or output vacuum tube circuits through suitable transformers (to isolate the high voltages and to match the impedance of the circuits).

* When the antenna is connected directly to the grid end of the condenser-coil circuit thru a small fixed condenser, the oscillations of the antenna circuit take place as usual and the voltage drop across the coil and condenser is applied directly to the grid of the detector tube.

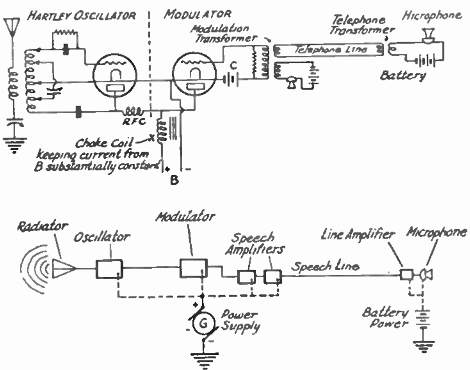
In modern radiophone transmitters the microphone works into a number of amplifiers, cascaded and coupled together to produce uniform amplification over the desired audio range. Sometimes part of the amplifiers are right at the microphone. The speech or music goes over telephone lines for some distance to the point where the station is located and there more amplifiers are used to get power enough successfully to "modulate" the strong "carrier" radio-frequency current which is used to set up the radio waves.

The oscillator works steadily and the radio frequency is coupled into the antenna circuit. A radio-frequency choke coil keeps h.f. current from leaking back into the modulator and supply circuits. The load which the modulator tube takes varies. As the grid voltage of the modulator tube is changed at speech frequencies, its plate current is made larger and smaller accordingly. The microphone and its amplifiers have complete control over the plate current of the modulator tube. The plate currents of the modulator and oscillator normally are about the same. When the microphone is spoken into, the modulator plate current can vary from nearly zero to about twice its average value. The reactance coil (X) keeps the current from the source and the voltage across both tubes practically constant. Therefore while the modulator plate current is varying from zero to twice its average value, the oscillator plate current must vary inversely from twice its normal value to about zero. The high-



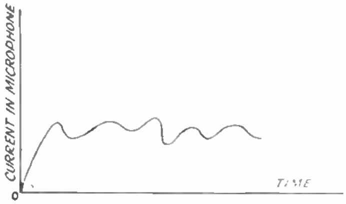
SOME MODULATION METHODS

The system of modulation most widely used in radiotelephone practice to-day is known as the Heising method. In such a transmitter we have two vacuum tubes. One is used to generate radio-frequency power to apply to the antenna. This is connected as an oscillator. The other tube is of equal size to the oscillator but is employed as a modulator tube. Both tubes are fed from a common plate supply source thru a large iron-core coil. The reactance of the choke coil (X) is so great that the current through it is practically constant and cannot vary at speech frequencies or higher frequencies. Thus when the transmitter is working the current from the source is constant. For this reason the Heising system is sometimes known as the "constant current" modulation system. The designer should allow about five times as much reactance in the choke coil as there is in the combined (joint) impedance of the paralleled modulator and oscillator tubes. The average speech frequency (about 800 cycles) is usually taken as a working value in designing this choke. The best practice is to use large tubes and amplifying transformers in the speech amplifier that can always operate underloaded giving practically no distortion—equal amplification at all frequencies.



A SIMPLE RADIOPHONE CIRCUIT
(with Heising Modulation)

frequency output of the oscillator varies directly with its input. Thus we have a high-frequency carrier wave completely modulated with a speech "envelope".



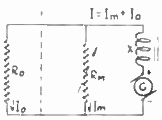
SPEECH ENVELOPE SIMILAR IN FORM TO VOICE CURRENT

Parallel (Heising) modulation, while excellent for 200 to 550 meter broadcasting work, is not in every case as desirable for short-wave phone operation. *No plate voltage changes should be permitted in the oscillator if we are to have the necessary constancy of frequency for short-wave work.* Modulation by varying the plate voltage of the oscillator is undesirable on short waves. One way around the difficulty is the use of a master oscillator tube followed by one or more stages of power amplification and introducing the modulation in the power amplifier. The size of the modulator can be kept at a minimum by modulating in the first power amplifier rather than in one of the stages nearer the point where the energy is coupled into the antenna.

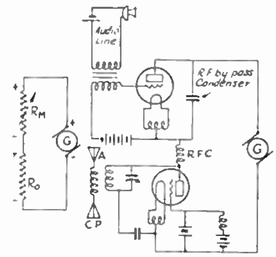
The Heising system will often give incomplete modulation if the modulator is arranged to work directly with an oscillator having piezo-electric frequency control. The oscillating crystal has inertia which tends to iron out modulation of any kind. By detuning the output circuit of the crystal tube, fairly good modulation can be obtained although there will be a tendency toward self-oscillation and some unsteadiness due to lessened control by the crystal.

Series modulation may be used successfully in such a case. The plate circuit of one or more modulator tubes is placed in series with the plate circuit of the oscillator. The modulator acts as a resistance in the plate supply line of the oscillator (a resistance variable at speech or musical frequencies) and modulates by varying the voltage applied to the oscillator. The proportions of the voltage drops across the modulator and oscillator will depend at any instant on the voltage applied to the grid of the modulator. While the plate resistance of the oscillator may vary slightly with the changes in its plate voltage, such variations will be small compared with the resistance changes in the modulator tube plate circuit. Series modulation involves running the filament circuit of either modulator or oscillator above ground potential, insulating the separate filament supply source required for one of the tubes for high voltages. The oscillator must be isolated from the modulator by suitable r.f. chokes. Good results may be obtained also by applying the series modulation to the power amplifier, which is the better arrangement unless crystal control is used (because it permits the oscillator to work with a steady plate voltage).

When we have a buzzer or a "chopper" connected in place of the microphone, we get "buzzer modulation" or "ICW" (interrupted continuous waves). For modulated telegraphy, however, the "constant current" system of modulation is not important. "Grid" modulation is less complicated and expensive, and perfect reproduction of the wave-form is not as necessary as when voice communication is intended.



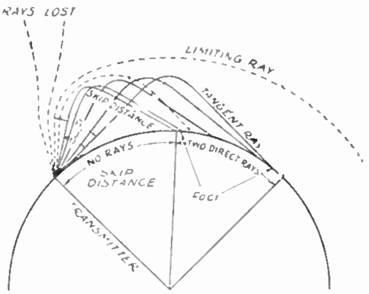
PARALLEL (HEISING) MODULATION SCHEME



SERIES MODULATION SCHEME

FADING AND SKIP DISTANCE

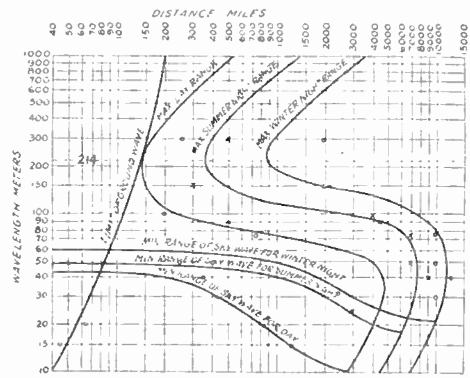
No discussion of amateur radio or of short wave phenomena can be complete without mentioning the more commonly accepted theory advanced in explanation of the things that have been observed in connection with short-wave transmissions. It appears that just as light waves can be reflected (by a mirror) and refracted (when passing into a medium of different density



θ_1 ANGLE AT TRANSMITTER CORRESPONDING TO THE FIRST CRITICAL ANGLE
θ_2 ANGLE AT TRANSMITTER CORRESPONDING TO THE SECOND CRITICAL ANGLE

SHOWING THE VARIOUS POSSIBLE PATHS OF RADIATION

The vertical and near-vertical rays penetrate the ionized layer and wander away. When one reaches the "limiting angle" the ray just does get bent enough to be kept from wandering away, but it continues to graze the layer and is after all worthless. Below this angle we have progressive reflection (or refraction) and the ray returns to earth. As the angle of departure from the transmitter is chosen flatter and flatter the energy strikes so far away as to miss the earth, possibly going out to the ionized layer again, and perhaps even being reflected down a second time if it has energy enough left.

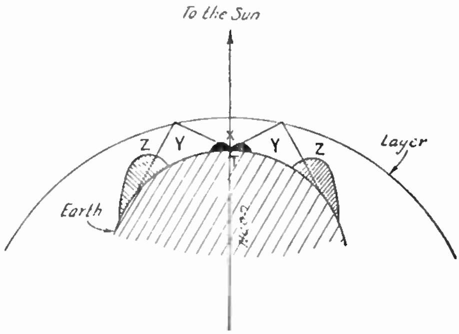


APPROXIMATE AVERAGE TRANSMISSION PERFORMANCE OF DIFFERENT WAVELENGTHS AT DIFFERENT DISTANCES

The received signal is assumed to have a field-strength of 10 microvolts per meter at the receiving point. The transmitter is assumed to have 5000 watts in the antenna. The chart is rather confusing but may be explained as follows. To the left of the line marked "limit of ground wave" it should be possible to receive at all times. After that, one must pick a pair of curves of the same sort (that is for the same time) and if the distance is between the curves one should hear the signal. Thus, a 30-meter wave should be reliable at all times to 70 miles for the conditions mentioned. From there to 400 miles its daylight performance will probably be uncertain while from 400 on it will gradually die down until at 1600 it will again be below 10 microvolts per meter. There are, of course, numerous exceptions where one does hear it when it should be absent. The curves are mainly from data by A. H. Taylor.

such as water) so it is with radio waves. The behavior of radio waves set up by different alternating current frequencies is harder to understand because these waves are not visible or audible except by artificial means of detection. The frequency spectrum used for radio communication is a wide one and the determination of what happens is further complicated by the continuous variations taking place in the medium traversed by the radio waves. The bending or refraction of radio waves is attributed to the presence of free electrons in the ionized portions of the earth's upper atmosphere. The ionization passes through a daily and seasonal variation depending on sunlight and changes in barometric pressure.

Changing reflecting and refracting properties of the Kennelly-Heaviside layer* are sometimes supposed to account for the min-



THE NATURE OF "SKIPPED DISTANCE" OR "DEAD BELT"

T—Transmitting point.
X—Local signal due to earth-bound or ground wave.
Z—Region of refracted or reflected signal.

ute-to-minute changes in the intensities of received signals (fading). Changes in the strength of vertical and horizontal components of radio waves due to varying polarization* also account for fading.

*The Kennelly-Heaviside layer is so named for the investigators who first suggested the existence of an ionized region above the earth's surface which might have an influence on the propagation of radio waves. It can be shown mathematically that such ionized layers can transmit an electromagnetic wave with a higher velocity than it would have when travelling through un-ionized space. There is a more or less increasing state of ionization in the higher levels of the earth's atmosphere. Explaining ionization we might say that it must be thought of as the breaking up of neutral gas molecules into positive and negative constituents by ultra-violet light from the sun and by direct bombardment of the outer layers of the earth's atmosphere by electrons thrown off from the sun—notably from sun spots.

Polarization refers to a change produced by the medium through which the radio waves travel by which the transverse vibrations in the medium are limited to a single plane. Near any transmitter the vibrations take place more or less indifferently in any plane about the line of propagation depending, to some extent, on the type of radiator used.

The third diagram explains what is commonly referred to as the "skip" distance, that distance that signals skip over. The signal decreases in intensity as we leave the transmitter due to spreading out and to energy absorption. It finally drops below a useful value, remaining out (Y) until we reach a great distance from the transmitter, after which it unexpectedly gets strong again, gradually dropping in intensity at still greater distances. Assuming radiation from a transmitter at a great many different angles, the first diagram shows the different directions in which radiation takes place. The signal may of course be received near the transmitter due to the ground wave and also in the area between the "two direct rays" shown. The skipped distance at night is much greater than in the day time. It gradually increases up to about midnight. The skipped distance also is known to be greater in winter than in summer which seems reasonable because the ionization should be less then, due to shorter periods of sunlight.

Fading is reported less violent at very long distances due to the fact that radiation can arrive by many routes, thus averaging conditions and giving a fair signal in spite of fading along some paths. Right at the edge of the skip distance interference effects may occur with very severe fading, while beyond this point the rays of high-angle radiation die out giving a better chance for a steady signal. In general short-wave communication results go to prove that the skip distance for any given time decreases with decreasing frequency or increasing wavelength. While skip-distance effects are important on our short wavelengths they are not as noticeable on the broadcast band and less important still on the longer wavelengths.

There is nothing absolute about any of the rules that different investigators have devised for determining whether a signal from a certain transmitter can be heard at a given point. However, some charts and rules are useful when studying the subject of transmission phenomena even though they are approximate. Such a chart is shown reprinted from *QST* with some explanation of what it means. It shows roughly what may be expected of different wavelengths in radio communication.

Amateur experience seems to indicate that the power of a transmitter is one of the less important considerations in short-wave work. Extreme distances are covered day and night with less than ten watts in the antenna using 14,000 and 7,000 kc. frequencies (20- and 40-meter wave lengths), and the signal strength of high and low powered stations is much the same. The conditions which obtain in the transmitting medium itself between two stations attempting radio communication are undoubtedly the most important factor in determining the results in each case.

CHAPTER V

Building a Station—The Receiver

TO GET the greatest fun and benefit from amateur radio work you will want to get into the game with a complete station. Perhaps some readers of this Handbook wish to "experiment" and to build equipment only for testing purposes. Some individuals get their chief pleasure in making measurements comparing the performance of apparatus by laboratory methods. Some are never happy unless they are continually examining different circuits, becoming familiar with their operation and tearing them down again. Advanced experimenters enjoy making series of actual transmitting tests to find out more about radio wave propagation as it varies with wavelength, distance, and time-of-day. However, if you are like most amateurs, you will probably prefer to put together a complete but inexpensive station and to get your enjoyment from its operation.

Perhaps you think that building a station involves many complicated pieces of apparatus, a special building, separate power supply, intricate circuits and, last but not least, a considerable investment of funds. Such an idea is quite erroneous. While a station may mean all these things if an individual is wealthy, it means nothing of the kind as a rule. Not more than four or five percent of the thousands of active radio amateurs in this country boast a quarter-kilowatt transmitting tube, not to mention the other equipment. The *average* amateur carries on both local and international communication with a solitary 7½-watt transmitting tube and rarely with anything larger than a 75-watter.

A "station" is nothing more nor less than a transmitter and receiver, correlated by suitable controls. Please do not get the impression from a hasty glance at the amount of material in the next few chapters that a lot of complicated equipment is necessary. This book covers much accessory equipment to a station in the endeavor to be as complete a handbook to the station owner as possible. In the first part of each chapter the simplest descriptions of equipment will be found. The beginner is asked to pay no attention to the paragraphs on crystal control, synchronous rectifiers, measurements of antenna resistance and the like. Those subjects can be looked into later. At the start one should pick out one of the simple receivers described in this chapter, build one of the low-power transmitters described in the first part of Chapter VI, and get information on power supply, keying, wavemeters, station arrangement and adjustment from the proper chapters. Then the sending and receiving sets may be properly installed on a table or in a desk in any convenient part of the home, in a way similar to that shown in the pictures of station arrangement and in the frontispiece. That's really all there is to building a station.

In building a station there is of course some constructional and experimental work to do. There is a great deal of satisfaction in the act of building, considered just by itself. The "good" station must have a "good" transmitter and an equally "good" receiver. The mechanical and electrical details of these instruments offer interesting problems to the beginning amateur. It is the purpose of this booklet to make the path a little easier for him.

Although we describe receivers and transmitters in detail, it is not necessary to follow our mechanical arrangements exactly to get good results. With a few parts and tools a great deal of ingenuity can be exercised. Some planning with pencil and paper, mixed with a little common sense, results in the "best" station at the lowest cost. A few hours spent in looking over the suggestions given here will save money and enable one to get started right.

GETTING MATERIALS

After the planning is done, the materials should be ordered. Your local dealer will have some supplies but probably he will not have them all. Condensers, coils, meters, insulators, transformers, batteries, tubes or whatever is needed are carried by some of the advertisers in *QST*. Advertisements containing false claims are refused. Good new apparatus is examined by the Headquarters staff. Editorial mention is only given when it appears that the apparatus is really worth calling to the attention of the members. "Ham-ads" always contain a variety of good used apparatus for sale or exchange. Once in a while complete receivers and transmitters are offered for sale in these columns. To get just what one wants and to save money, most amateurs prefer to "build their own."

When some article cannot be obtained locally or through *QST* advertisements you can write the League's Information Service for advice. A stamped self-addressed envelope insures an early reply. Be sure to include *all* the information about your circuit and tubes. If our Information Service man is to find just what you want, he must know all your needs to make a complete answer possible.

TOOLS

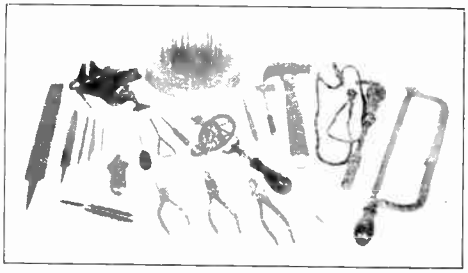
Before actual construction is begun we ought to have certain tools to aid in putting our material together. One or two pairs of side-cutting pliers with strong jaws, a pair of round-nosed pliers, a knife, two or three sizes of screwdrivers, a drill stock and some numbered drills, a soldering iron, scriber, reamer, file, small hammer, and perhaps, a little vise will be useful tools for the builder. All these are useful but not all are absolutely necessary. Most of us can probably scare up some tools by looking around the house for a few minutes.

EXPERIMENTAL LAYOUTS

In building apparatus for experimental purposes and for temporary use it is just as desirable to use system in laying out the apparatus and in wiring up as when the more permanent panel job is built. Some spare "breadboards", a bunch of General Radio plugs and jacks, Fahnstock clips, some scrap bakelite pieces for building terminal boards, angles for supports and a bunch of different sized brass machine screws, wood screws, nuts, and washers will make it easy to build up and try out new circuits or to wire up auxiliary apparatus to go with the transmitter. It is a good idea to keep some bus wire on hand and various sized spools of magnet wire will prove useful in doing temporary wiring if you are an experimenter.

A table of drill sizes giving the proper numbered drill to use for passing a screw through a panel or for tapping to take a certain size of machine screw is included in the Appendix for the convenience of League members who are continually building and who like to have such information in convenient form. Only the sizes most used in radio constructional work are given as too many tap sizes that are seldom of use might prove confusing. Wood screws also come in various sizes and lengths. Usually the numbers correspond to the drill-size numbers, the diameter given being that of the screw just below the head. The length of wood screws are stocked by most hardware stores to the nearest quarter inch of what you want. Round-head screws look best. Whether blued or nickled screws are used is mainly a matter of choice with the individual builder.

A small tap holder, a die holder and three or four taps and dies covering the 8-32, 6-32, and 10-32 sizes used most of all can be obtained from a hardware store at a reasonable cost. Sometimes the local 5-and-10-cent store will have these tools at a dime each. With the dies you can thread brass rod and run over threads that become "bunged-up" on machine screws. With the taps you can thread the holes that you drill so that they will take machine screws to hold the apparatus that you wish to mount.



TOOLS FOR CONSTRUCTION

All are convenient but not necessary. A set of small taps and dies, a circle cutter to use in mounting meters on panels, a bit brace and a set of socket wrenches will be useful in addition if regular construction work is planned.

SOLDERING AND WIRING

In wiring different pieces of apparatus a neatly soldered job will repay the builder in good appearance and reliable operation. Good connections may be made without solder but a well-soldered job has low contact resistances. A soldered outfit works quietly and uniformly over long periods of time. Soldering is worthwhile when properly done.

Making soldered joints is quite a simple matter. A few points should be kept in mind for best results. A hot well-tinned soldering copper, clean, bright surfaces, a *small* amount of rosin and a small amount of "half-and-half" soft solder will do the trick. Tinning the parts to be soldered before completing a point will be helpful.

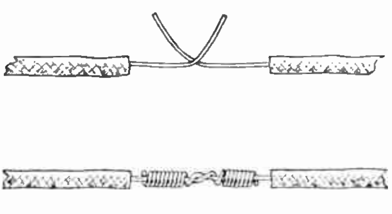
Soldering flux keeps the clean surface from becoming oxidized when heat is applied. Acid fluxes or soldering pastes made by the action of hydrochloric acid on zinc and supported in a low-melting base should especially be avoided. They are good for mending tin pans and gutter pipes. They cause corrosion of electrical connections. The melted "paste" can cause a set to operate poorly or to become inoperative by adding leakage paths across coils and condensers. Use lump or powdered rosin that can be obtained for a dime from any drug store.

"Half-and-half" simply means that the solder is an alloy, half tin and half lead. "Tinning" the soldering copper is done by filing the point bright and clean and rubbing it in hot solder with a little flux until the point is covered with clean solder. Scrape connections with a knife or file before soldering, to save time and make a joint good electrically and mechanically. The soldering copper must be re-tinned occasionally if it becomes overheated. It should always be used when very hot but not allowed to become "red hot." A hot copper makes soldering easy.

Bus wiring is neat and effective. The wires are laid out in straight lines running straight back, horizontally and vertically. The corners are made square. Hold bus wires firmly with pliers while a little solder "runs" into the joint.

Splicing wires is best done as shown in the diagrams. A little care makes a permament and strong splice of low resistance. In a twisted pair, "stagger" the splices to prevent them from hitting together and short-circuiting under any circumstances. Tape all splices carefully to avoid trouble.

Battery leads to the receiver may be bunched to good advantage. Radio-frequency circuits should have the leads well spaced. Wires should cross at right angles when crossing is necessary. Connections between coils and condensers should be as short as possible. However, coils and condensers must not be jammed together too much as this increases the effective resistance and lowers the sensitivity. Leads a couple of inches long are

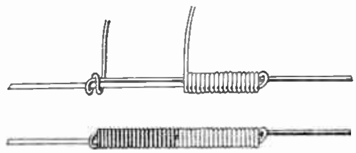


THE WESTERN UNION SPLICE

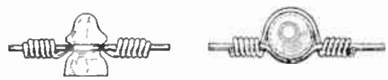
permissible and will allow us to keep the condenser out of the field of the coil, which is the main consideration.

The antenna lead and all the connections from the condenser and coil should be kept away from other wiring. The wiring in the audio amplifier can be spaced, and short leads are good, but they are not nearly as important here as in the detector and antenna circuits. To avoid undesirable feed-backs the plate and grid leads should be kept well separated.

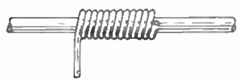
The transmitter should be wired neatly in such a way that it will be electrically efficient. At the same time, the power supply and high voltages must be taken care of in a way that insures safety to life



ANOTHER METHOD OF SPLICING WIRES



SUPPORTING A WIRE AT INSULATORS



A RIGHT-ANGLE SPLICE

and property. The insulation of lead-in and high voltage conductors should comply with underwriters' rules.

In the pages that follow we are going to describe in detail conventional short-wave tuners. Constructional "dope" for a moderately-priced transmitter with a world-wide range is also given. We have discussed some fundamentals of electricity. The diagrams and constructional information are quite complete. We suggest that the constructor study the books mentioned in the Appendix for more complete theory and general information. The descriptions of stations in *QST* frequently give good ideas on station arrangement. *QST* itself keeps us informed about new developments that are useful and noteworthy. The writer believes that knowledge of why a certain thing is done in a certain way is desirable before any work on a station is done. For that reason a number of pages have been given over to simple explanations of some of the things that happen in radio circuits.

UNDERWRITERS' RULES

The specific rules covering radio equipment are given in Article 37 of the National Electric Code, under the heading of Radio Equipment. Some states have adopted this code or a more strict version of it. Certain cities have adopted it, too, and they enforce their regulations through municipal inspectors. Before making an installation it is well to find out if the apparatus and wiring are subject to a state and city inspection as well as by insurance interests.

The following cities have adopted wiring codes of their own and, therefore, installations in these cities should be made in accordance with their special rules: New York City, Chicago, St. Louis, Denver, Portland, Ore.; Memphis, Tenn.; Macon, Georgia; Kansas City, Mo.; Jamestown, N. Y.; Newark, N. J.; Camden, N. J.; Sioux City, Iowa; San Diego, Cal.; Little Rock, Ark.; Hot Springs, Ark,; San Francisco; Gary, Ind.; Atlanta. Ga.; New Haven, Conn.; Chattanooga, Tenn.; Madison, Wis.; Wilkes Barre, Pa.; Moline, Ill.; Rock Island, Ill., Peoria, Ill., Detroit, Mich., and Louisville, Ky.

Electrical wiring in Maryland, the District of Columbia, Louisiana, Tennessee, Ohio, Minnesota, and North Carolina is subject to the approval of a state inspector.

"Approved" refers to devices designed for the purpose used in accord with recognized practice. The device must be acceptable to the Inspection Department having jurisdiction (there may be a City or State inspector in addition to the Insurance Rating or Inspection Bureau.) When there is no inspector for the city or state, insurance interests inspect through their rating organizations, one of which covers each part of the United States. Your local insurance agent can advise you in whose territory you are located so you can get in touch with the proper authority.

A conference with the Inspection Department *before* making an installation or change will save inconvenience and expense later. Your own interests and those of fellow citizens will be best protected from an insurance and fire hazard standpoint by having such a conference.

The wiring must follow the requirements observed in your particular community. In some instances a separate power line must be run directly to the watt-hour meter. A few feet of "BX" from the nearest outlet to a "Square-D" switch box, properly fused at the switch, will usually be satisfactory. The installation of high-voltage apparatus and wiring must be done in approved fashion. High-tension cable, supported on porcelain pillar insulators, keeping the high voltage away from all wood-work and neighboring conductors, is a safe type of construction.

A receiving antenna can be connected to ground before it gets to the set through either in-door or out-door type of lightning arrestor. Several approved types are sold by local dealers with complete instructions for installation. These arrestors are simply spark-gaps sealed in a vacuum to lower the voltage break-down. The ground can be made by scraping a water pipe or ground rod clean and bright with a file. A 10c ground-clamp will make a good connection to the pipe. A yearly inspection will insure a good ground. An approved lightning arrestor operating at a potential of 500 volts or less is required for *each* lead-in conductor of a receiving station. There are no requirements for indoor antennas, however.

Part 5 of the Fourth Edition, National Electrical Safety Code, classifies transmitting stations as those of low, medium, and high power. A low power station is one to which the power supplied is less than 100 watts and where the voltage supplied is less than 400 volts. A high power station is one requiring over 1,000 watts power supply or a supply voltage of over 2,000 volts. Medium power stations are classified as those not falling into either the low or the high power class. Most amateur radio stations fall into the low or medium power class, unless a voltage in excess of 2,000 volts is used.

The same requirements apply to both antenna and counterpoise wires. Antennas for receiving and low-power transmitting stations should be supported and insulated similarly to public service communication lines while for medium and high-power stations the requirements for constructing supply lines for transmitting electrical energy in like situations shall be met. Antennas should not cross over or under supply lines or telephone and telegraph wires nor should they run above and parallel to them in such a way that a falling antenna might come in contact with a live wire. Antennas should not cross railroad tracks or public thoroughfares. They should not be attached to poles owned and maintained by local public utilities for supporting power lines or communication cables or wires. In most cases local ordinances forbid such construction as a menace to the public welfare. When antennas are put up in such hazardous locations special precautions should be taken to have ample strength in the antenna wire and its support and ample clearances.

Antennas should not be supported on chimneys. When a tree is used there should be some provision for keeping the antenna from snapping when the tree sways in the wind. Any size of wire can be used for a receiving antenna. Probably No. 14 B. & S. (American Wire Gauge) hard-drawn copper wire, enameled to prevent corrosion, will have the best balance of electrical conductivity and mechanical strength for that purpose. Sending antenna and counterpoise wires for medium or high power stations should have a strength of not less than No. 10 hard-drawn copper wire and should be insulated with insulators having a minimum creepage distance of 10 inches or more. A clearance above ground of 10 feet is prescribed for receiving and low-power antennas where they cross foot paths and entrances to private garages. Above streets a clearance of 15 to 18 feet is required and this must be increased to 28 feet when an antenna or counterpoise for a medium or high-power sending station is contemplated. For spans over 150-feet in length these clearances must be increased. There must always be at least 10 inches clearance between antennas of such stations and the nearest combustible material. There should be at least a 10 foot clearance when the antenna or counterpoise of a medium or high-power station crosses under other conductors. The clearance required is less for receiving antennas and those of low-power stations and is specified as 2, 4 and 6 feet depending on whether communication lines, low-voltage or high-voltage (above 750 volts) conductors are crossed.

Transmitting antennas and counterpoises must be *grounded* by means of lightning switches. The switch shall be of the single-pole double-throw type having a minimum break distance of 4 inches and a blade of at least .0625 sq. in. cross-section. The switch should be in the most direct line between leadin and ground but can be located either outside or inside the station. Live parts of the switch must clear the wall (or other conductors) by 3 inches for a C. W. installation (5 inches for a damped-wave set). The switches must be connected so that the antenna and counterpoise leads can be disconnected from the set and connected to the ground wire whenever the station is not in operation.

The lead-ins must be made through approved lead-in bushings. A good but cheap way to bring in the antenna lead is to drill a hole in the center of a large window-pane. A brass machine screw with rubber gaskets will go through this and make an excellent lead-in. The lead-in insulator must have a 3-inch clearance beyond the wall of the structure. Antenna leads must never come within 5 inches of supply wires. A wooden board at the top or bottom of a window will make a good support for lead-in bushings under most circumstances. Pyrex bowls make good bushings. M. M. Fleron & Son, Trenton, N. J., manufacture an "approved" bushing of adjustable length. A "drip loop" prevents water from following the antenna wire into the station. Lead-in bushings or tubes must be rigid, noncombustible, nonabsorptive, and have good insulating properties.

An outside ground is recommended but not absolutely necessary for a transmitting antenna. The ground lead should be made of No. 14 hard-drawn copper wire or of wire having greater strength and conductivity. Its cross-section should not be less than that of the lead-in wires. The ground wire should be run in as direct a line as possible from the switch to a good permanent ground. A driven or buried ground or a waterpipe ground is satisfactory. Never ground to a gas pipe, though. For ground wires no insulating supports or insulation is necessary. The ground switch should have husky blades and jaws. They may be mounted on pillar-type insulators, on marble or water-proof bases. Slate bases and absorptive composition bases will leak electrically and decrease the effective output of the set. "Mud" lead-in insulators will act similarly.

Everyone who owns an amateur station or who plans to have one should send ten cents (not in stamps) to Superintendent of Documents, Government Printing Office, Washington, D. C., for the booklet, *Safety Rules for Radio Installations*, Handbook of the Bureau of Standards No. 9. This gives a great number of rules for installing amateur radio equipment.

STATION ARRANGEMENTS

A complete station consists of a transmitter, a receiver. a monitor and frequency meter, and suitable antennas for transmitting and receiving. The exact arrangement of these units is not usually of great importance as far as their electrical effectiveness is concerned but the matter is worthy of careful consideration in order that the station may be operated with the greatest convenience and comfort.

The items which are handled most frequently are the receiver, power switches, key and monitor. It is well, therefore, to group these so that they can be operated without the necessity of changing one's position. Perhaps the most popular practice is to place the receiver towards the left of the table or bench on which the apparatus is to be mounted. The monitor is located alongside the receiver on the right (where it is near enough to give a good signal in the receiver) and the key is screwed to the table slightly to the right of this and far enough back to give a good support for the operator's arm.

The filaments of the transmitting tubes must be lighted before the high voltage is applied and for this reason two switches are necessary—one in the primary of the filament transformer and one in the supply circuit to the plate supply apparatus. These switches can well be mounted under the front edge of the table in a position convenient for right hand operation.

Since the transmitter is left at one adjustment for much longer periods than the receiver, it is as well to mount it well clear of the other apparatus where it will not be influenced by the "body-capacity" of the operator or the vibration of keying. One possible scheme is to mount it on a shelf above the right hand side of the operating table. The transmitter should be near the antenna or feeder leads, however, and in some cases a different placement of the transmitter may be advisable. In order to reduce the vibrations reaching the transmitter it is often mounted on four rubber sponges or suspended on heavy rubber strips.

It should not be necessary to give the plate supply apparatus frequent attention and for this reason it can be on a shelf near the floor or, particularly if it is a generator, can be rigged in the basement. In the latter case, of course, particular attention must be given to the insulation of the high-voltage leads between the supply system and the transmitter.

There are scores of possible arrangements for the station and they will be varied in individual cases by the arrangement of the room, the size of the table or bench and the type of apparatus. It may be a good plan for the amateur to arrange the apparatus in not too permanent a fashion at first so that he can change things around when he has gained some experience in the operation of the station.

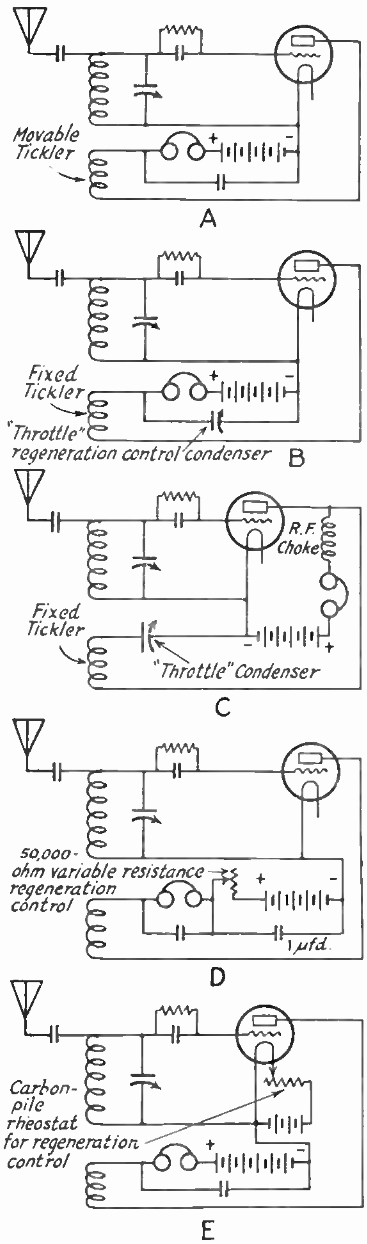
DESIGNING THE RECEIVER

The first apparatus to be built for our station should be a receiving set. Fortunately the short-wave receiver is not a complicated affair like the broadcast receiver. In its most practical form it may consist of two, three or four tubes but even a single tube can serve to receive amateur signals over long distances. The first requirement in the receiver is a detector tube connected to a tuned circuit and provided with a tickler coil in order that it may be caused to oscillate. A regeneration control must be provided so that the detector can be maintained in a condition of gentle oscillation for the reception of telegraph signals or held at the point just below oscillation for phone reception. Since the amateur frequency bands comprise five narrow slices of territory widely separated, it is not possible to cover them all effectively with one coil in the tuner. Present practice is to use a plug-in coil for each band. Many schemes have been evolved to provide suitable coils and coil sockets, the present trend being towards the use of a tube base or a special former of larger size plugging into a tube socket. Larger coils with a horizontal row of plugs fitting into a similarly arranged row of sockets also are used in some cases. The important requirements are that the coils should be readily changed; that the contacts should be positive; that the coils should be mechanically strong so that they will not be deformed in handling; and that the coils should be small in diameter in order to avoid the existence of an extensive field around them.

The variable condenser used to tune these coils is an important feature. It should be of solid construction and good electrical design. If the contact to the rotor shaft is not perfect or if it consists of a metal "pigtail" which rubs irregularly against the shaft or the metal end plate, noises will be generated in the receiver which will handicap reception seriously. Since the amateur frequency bands are of various widths, a single tuning condenser with a definite capacity range will not be very satisfactory, since if its capacity is suited to tune one of the lower-frequency bands across most of the dial the higher-frequency bands will be covered in small segments of the dial. This will make the tuning in these higher-frequency bands a very difficult process. In consequence it is very desirable to provide the receiver with plug-in condensers, or some other form of tuning capacity unit, the capacity range of which can be varied so as to give almost full-dial coverage for all bands.

The regeneration control is the next most important item in the short-wave receiver. It has been given much study during the last few years and several satisfactory schemes have been evolved. Almost any arrangement of the tickler coil and feedback control can be depended upon to give similarly loud signals but some of them have the advantage of permitting adjustment of regeneration without detuning the signal. This is very much to be desired. It is also a great advantage if the regeneration control is absolutely quiet in action; if it permits a gradual adjustment up to and past the point of oscillation; and if it permits the tube to oscillate gently all across the frequency band on which the receiver is working without the necessity of touching anything but the tuning control. The use of a variable resistor of 25,000 or 50,000 ohms in the lead to the detector plate probably gives these desirable qualities with the least trouble, and its use is recommended. It is important, however, that this resistor be of good quality if noisy operation is to be avoided. Even with the best resistors it is advisable to connect a fixed condenser of 1 μfd. or more across its terminals to reduce the possibility of noises being caused by poor contact between the movable contact and the resistance element.

In the systems using a rotating tickler coil or a throttle condenser it is usually desirable to make the tickler of much smaller diameter than the tuning coil in



FIVE METHODS BY WHICH REGENERATION CAN BE CONTROLLED IN THE DETECTOR CIRCUIT

In the arrangement shown in diagram A the regeneration or feed-back is varied by rotating the tickler coil which is mounted at the filament end of the tuning coil. In scheme B the tickler is fixed in relation to the tuning coil and the regeneration is controlled by variable throttle or feed-back condenser C2. Circuit C is a similar arrangement to the latter but with parallel or shunt plate feed. In scheme D, which

(Concluded at bottom of next column)

order to reduce the tuning effect of the regeneration control. In all of the methods it is essential that the tickler be mounted or wound at the filament end and not the grid end of the tuning coil.

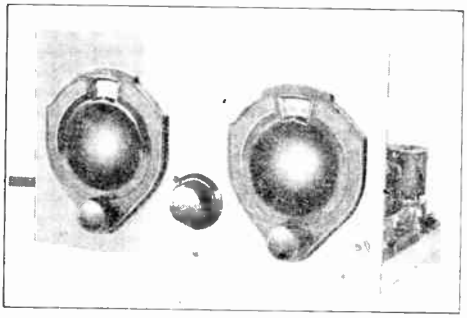
Though the short-wave receiver can consist of the detector tube only, with the phones in its plate circuit, an audio-frequency amplifier will be found to improve the readability of the weaker signals. If the audio amplifier is arranged to peak at some audible frequency—to amplify signals tuned to give a note of, say, 1,000 cycles to a much greater extent than signals giving other frequencies—it will be possible to improve the selectivity of the receiver. In the operation of a receiver fitted with such an amplifier the signal to be received is tuned so that its note is of the frequency at which the amplifier is peaked. This signal is then amplified to the full extent of the amplifier while signals of other frequencies are amplified to a much lesser degree depending on the difference between the frequency of the note produced by them and that produced by the signal being copied. In this way interference between stations on neighboring frequencies is reduced. If the receiver is to be used for phone reception, distortion would be produced by an amplifier of this type and it is therefore necessary to use audio transformers, chokes or resistances to couple the audio amplifier or amplifiers in the same way that they are used in broadcast receivers.

The arrangement of the parts in the receiver and the wiring of them are important matters. Many amateurs screw the apparatus on a wooden baseboard but this scheme has the disadvantage that dust and dirt soon collect on the condensers and coils and noisy operation results. A panel-mounted receiver fitted with a cabinet is really much preferable and need not be much more expensive. The panel and cabinet will afford protection to the apparatus and will give a much more pleasing appearance than the baseboard covered with apparatus and wires. In addition, the panel usually will permit a more convenient arrangement of the controls.

It is as well to spend some time in considering the lay-out of the parts so that the leads in the detector circuit may be reasonably short, without cramping the apparatus, and that the tuning coil is convenient to the tuning condenser and the detector tube without being too close to any large metal parts. It is difficult to specify

is the most popular of all, control of feed-back is affected by the variable resistance R in the detector plate lead. In arrangement E the tickler is fixed and regeneration controlled by adjustment of the filament heating a scheme giving excellent results when the feed-back value is so chosen as to give satisfactory regeneration at proper filament-current values.

definitely the separation that should be maintained but an approximate idea of suitable spacing can be obtained by studying the photographs of the receivers. The wiring in the detector circuits should be made with bus-bar or enamelled copper wire of



THE PANEL LAY-OUT OF THE TWO-TUBE RECEIVER

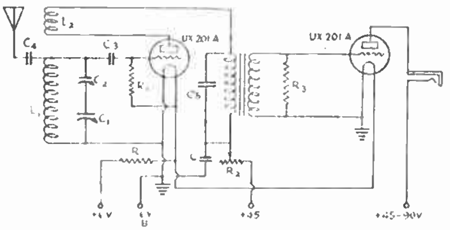
The vernier dial on the left is the main tuning control, that on the right-hand side being the regeneration control. The knob in the center controls the midget variable condenser which is set at predetermined positions for each band in order to permit full-scale coverage.

about 14 or 16 gauge so that it will not vibrate or shake and so "shimmy" the signals. In the audio-frequency amplifier the wiring can be done with rubber-covered flexible wire and the difficulties of bus-bar wiring avoided. Bus-bar can be used throughout, of course, if a neat appearance is desired. If the receiver is to be reliable and quiet in operation it is essential that all joints in the wiring be well soldered. When the wiring has been completed it should be checked over carefully before connecting any batteries. Before connecting the B battery the A battery should be hooked-up to make sure that the filaments can be lighted and controlled by the rheostat or switch. If all the tubes do not light the trouble should be found before proceeding any further. It is a good plan to connect a flash-lamp bulb in series with the lead to the negative terminal of the B battery so that any fault in the wiring which ordinarily would result in burning out the tubes will merely blow the bulb. If, when the B battery is connected, the bulb is blown the wiring should be checked with care and the fault located before another attempt is made. It is surprising the ease with which wires can be misplaced in such a way as to connect the B battery to the tube filaments. Even the most experienced amateurs make mistakes of this kind and the protection of the flash-lamp bulb should not be disregarded. When the phones are plugged in a loud click should be heard and a similar or louder click should be obtained when any of the connections to the B battery are made or broken. At this stage it should be possible to make the set oscillate by adjustment of the regeneration control. If this control is moved gradually the detector should go into oscillation with a soft thud. A rustling sound produced by static and miscellaneous electrical noises will show that the tube is oscillating. If there is any doubt about whether oscillation has been obtained or not, the grid terminal of the detector tube can be touched with the finger. If it is oscillating a "plonk" will be heard as the finger touches the terminal and another "plonk" as the contact is broken.

A TWO-TUBE RECEIVER

Now that we have mentioned the general requirements and considerations we can proceed with the description of actual receivers.

The two-tube receiver illustrated is one of the simplest types that can be built. It is, however, a thoroughly practical one which can be depended upon to give readable signals, when conditions permit, over even the longest distances. The wooden baseboard measures 11" x 6" x ⅞" thick and upon it is mounted all of the apparatus with the exception of the variable condensers and the variable resistor used as a regeneration control. These control elements are

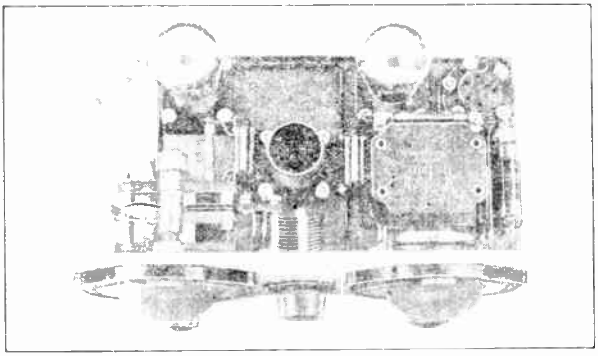


THE SIMPLE WIRING OF THE TWO-TUBE SET

Apparatus required:

Two UX-201-A or UX-199 tubes and sockets.
C—1μfd. by-pass condenser.
C1—50-μμfd. tuning condenser (straight line frequency).
C2—100-μμfd. midget variable condenser.
C3—100-μμfd. fixed grid condenser.
C4—Antenna coupling condenser two ½"-square brass plates about ⅛" apart.
C5—2,000 μμfd. fixed by-pass condenser.
R—½-ampere ballast resistor (Amperite).
R1—2 or 4 megohm grid-leak.
R2—50,000-ohm variable resistor.
R3—0.1 megohm fixed grid-leak type resistor.
L1, L2—Tube-base coils described under photograph.
One good audio-frequency transformer.
Baseboard measuring 11" x 6". Aluminum or bakelite panel 11" x 6½".
Phone jack, miscellaneous wood screws, machine screws, brass strip, etc.

mounted on an aluminum panel 11" x 6½" x ⅛" thick. Aluminum of this thickness can be obtained at most tin shops and hardware stores and should be cut to shape in the heavy shears with which these shops are usually equipped. The panel can be given a pleasing finish by stripping it in a strong solution of washing soda. When removed from the solution the aluminum will have a clean matt surface which can be preserved, after the panel has been well washed in clean water, by giving it a thin



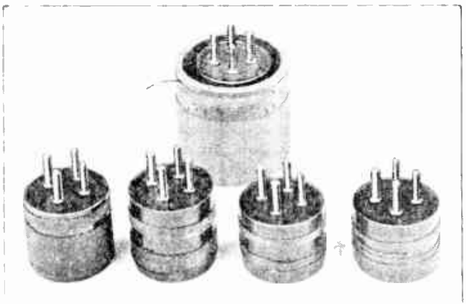
A PLAN VIEW OF THE TWO-TUBE RECEIVER

The main tuning condenser and the midget condenser can be seen at the left of this receiver. Between them is the antenna coupling condenser and behind them the tube-base coil, the grid condenser and leak and the detector tube. On the right-hand side is the variable-resistor regeneration control and its dial, with the audio transformer, amplifier tube and battery-connection socket behind them. On the extreme right is the filament ballast resistor.

coat of Duco lacquer. A metal panel of this type is useful in reducing the effects of "hand-capacity." A panel of bakelite or hard-rubber, which is preferred by some amateurs, can be used. In any event the panel can be secured to the base by three or more round-head wood screws in the manner shown in the front view of the set. When a metal panel is used it is necessary to insulate the frame of the variable resistor and the telephone jack from it. This can be accomplished by drilling holes large enough to give clearance between the panel and the resistor shaft and the jack and by using washers of thin card or other insulating material between the panel and the frame of the apparatus mounted on it.

From the circuit diagram it can be seen that two variable condensers are used in series across the tuning coil L1. The condenser C1 is the main tuning control and is a high-grade condenser of 50 μμfds. capacity. It is controlled by the dial on the left of the panel and can be seen on the left of the plan view of the set. The midget condenser C2 is of 100 μμfds. capacity and is controlled by the knob in the center of the panel. It is used in series with the main tuning condenser to reduce the capacity range of the latter so that almost full scale coverage can be obtained on any of the amateur bands. When the receiver is operated on the 1,715- or 3,500-kc. bands this midget is set near its maximum capacity, the exact position being determined experimentally, so that the capacity range of the tuning condenser will be limited to the value necessary to give full-scale coverage on those bands. For the 7,000, 14,000 and 28,000-kc. bands the midget condenser is set at lower values—each value being predetermined experimentally—so that the effective capacity range of the tuning condenser is progressively lower for the higher frequency bands. An understanding of the reason why a lower setting of the series midget condenser reduces the capacity range of the tuning condenser can be obtaining by studying the explanation of the action of condensers in series in Chapter III. This method of obtaining full-scale coverage for each band is only one of many possible schemes. The methods used in the other receivers described in the chapter could be incorporated in this two-tube set.

The tuning coils are wound on bases taken off burnt-out tubes. The approximate number of turns needed for the various bands is given under the illustration of the coils. The exact number of turns needed



THE TUBE-BASE COILS USED IN THE TWO-TUBE RECEIVER

Both grid coils and ticklers in these coils are wound with 21 gauge d.s.c. wire. The numbers of turns used are as follows:

Band	Grid Turns	Tickler Turns
1,715 kc.	49	8
3,500 "	33	7
7,000 "	15	6
14,000 "	6	5
28,000 "	3	3

No spacing is used between turns except in the grid coil for 28,000 kc. where the spacing is ⅛". As can be seen, the 1715-kc. coil is wound on a 2"-diameter bakelite tube mounted on a tube base.

will depend to some extent on the placement of the apparatus and the arrangement of the wiring. It is a good plan first to wind the coils with the number of turns given. Exact adjustment of the inductance can then be made by spreading out one or two of the end turns. When the correct adjustment has been found the turns can be held in place with a few spots of Duco cement or banana oil. The coils plug into an ordinary tube socket which can be seen in the plan view of the set near the center of the baseboard.

The antenna is coupled to the receiver through a very small capacity indicated on the diagram as C4. It consists of two pieces of brass about ½" square separated ⅛". This condenser can be seen in the illustration of the receiver between the two variable condensers. The two brass pieces are in the form of small angle pieces held with machine screws to a small piece of hard rubber. It is important that this condenser be mounted close to the lead from the end of the tuning coil to the grid condenser C3, and that its capacity be kept small. Some adjustment of its capacity may be found advantageous after the receiver has been put into operation. This can be accomplished by bending one of the brass pieces away from or towards the other.

The tickler coil L2 is fixed in its position with respect to coil L1 and is wound on the same tube base about ¼" from the filament end of L1. The number of turns used in this coil is not very critical but if the number specified in the list of windings does not cause the detector to oscillate with the regeneration control resistor R2 at about the half-way position, experiment with other values will be advisable.

Condenser C5 is the radio-frequency bypass condenser across the audio-frequency transformer. Its use is very important though its capacity is not critical. Without it the detector could be made to oscillate only by using an abnormally large tickler or very high plate voltage. The most satisfactory plate voltage for the detector is about 22½. It might be thought from the diagram that 45 volts is used in this set. This is not so, however, since the resistance of R2 at about half-scale setting is sufficient to drop the voltage to the point where only about 22½ volts are placed on the detector plate.

The fixed resistor R3 is connected across the secondary of the audio-frequency transformer to eliminate a howl or squawk which is often produced at the point where the detector starts oscillating. Experiment with the value of this resistor is desirable since in some receivers a very high resistance is all that is necessary. The higher this resistance is the less will its effect be on the volume of the signals. The resistor R is an Amperite or similar filament-ballast resistor used to hold the filament voltage at 5. It is used to avoid the necessity of a filament rheostat.

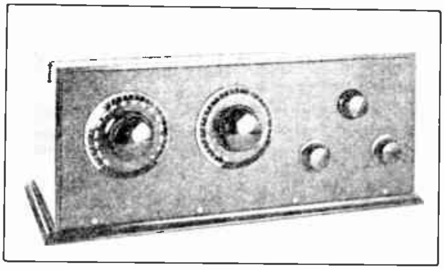
The UY-type tube socket, to be seen at the extreme right-hand corner of the baseboard, is used to provide connections to the A and B batteries. A standard battery cable (which can be obtained in most radio stores) is used, its wires, at the receiver end, being soldered to the prongs of a UY-type tube base. A battery plug of this type is very useful in permitting all batteries to be removed in a moment for experiment with the receiver without any danger of the tubes being burnt out.

In addition to the parts in the list given under the diagram it will be necessary to have an A battery and a B battery. The A or filament battery can be a storage battery of between sixty and one-hundred ampere-hours capacity for the UX-201-A tubes, but should UX-199 tubes be used instead the filament battery can well consist of three dry cells. It is not necessary to use a heavy-duty B battery for a receiver of this type since the drain from it is only of the order of a few milliamperes.

The operation and adjustment of this and other receivers will be described later in this chapter.

A THREE-TUBE RECEIVER

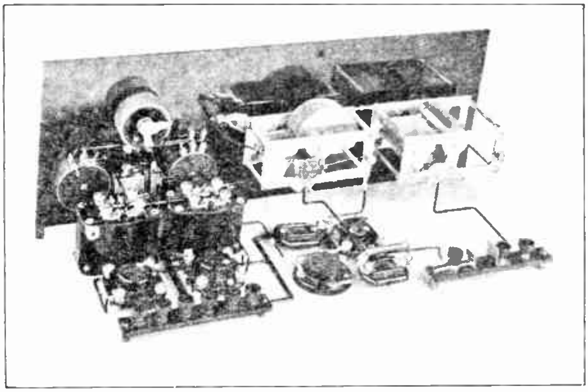
The three-tube receiver illustrated on this page involves several features different from those of the set just described. In the first place an antenna tuning unit is used.



ONE TYPE OF THREE-TUBE RECEIVER

The two large vernier dials control the main tuning condenser and a special antenna tuning unit. The three knobs operate the regeneration control, the filament rheostat and the volume control.

The condenser C1 and the coil L1 of this unit serve to tune the antenna so that the maximum available voltage appears at the antenna coupling condenser C3 and the grid of the detector tube. The arrangement does not work in quite the same way as an antenna tuning coil on a broadcast receiver, since for some frequencies the capacity of C1 would have to be decreased in



A REAR VIEW OF THE THREE-TUBE RECEIVER
At the right of the baseboard is the antenna coupling condenser, the detector grid condenser and leak, the detector tube socket and the tuning-coil socket. At the left are the two audio transformers, the audio-amplifier tube sockets and the battery terminal strip. The antenna tuning coil L1 is connected outside the receiver.

order to give the best signal when C2 (the main tuning condenser) has been increased. The tuning of C1, however, is never very sharp and it will not be difficult to find the correct adjustment under most conditions. If desired at any time the switch—shown in the diagram above L1, C1—can be opened and the antenna tuning coil disconnected.

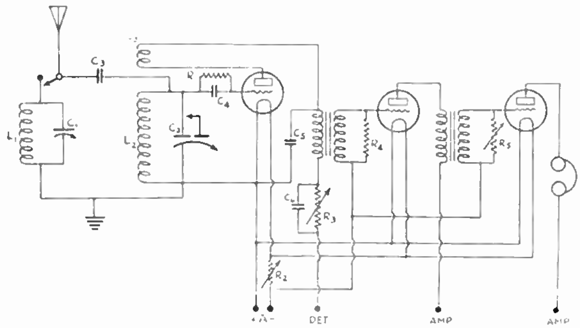
A different method is used in this receiver to spread out the various bands. The variable condenser C2 is a special double condenser which can be built from an ordinary straight-line-frequency condenser. In the particular condenser illustrated in the receiver the stator plates are removed and the rods supporting them are cut in half in order to support the two new stator assemblies that are to be used. One of these assemblies, which will be used alone for some of the bands, consists of a single stator plate which is exposed to a single rotor plate. The spacing between the plates will have to be varied so that this two-plate unit tunes the receiver over the 7,000-kc. band. The spacing probably will be equal to about 20 pages of this Handbook. The second unit of the condenser, the stator assembly of which is insulated from that of the first, also consists of one stator plate and one rotor plate with about half the spacing used in the first unit. This stator assembly is connected to the first one with a short flexible lead and a clip, so that the two condenser units are used in parallel for some of the bands.

The capacity of the larger unit should be adjusted by spacing the plates until the two units in parallel give open scale tuning over the 3,500-kc. band. The connections of these condensers are given in the table of coil sizes.

The arrangement of the apparatus in this receiver can be seen from the illustrations. A wooden baseboard is used to support the fixed apparatus, while the variable units are mounted on a bakelite panel. The rheostat, volume-control resistor and regeneration-control resistor can be seen grouped at the left side of the panel in the rear view of the set. The main tuning condenser and the antenna tuning condenser are on the right of the same illustration.

AN ALTERNATIVE THREE-TUBE SET

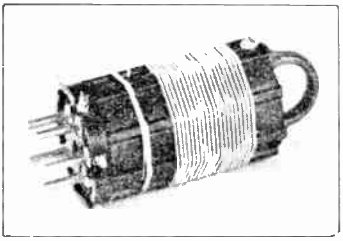
Some idea of the various forms that receivers can take can be obtained by comparing the three-tube receiver just described with this one. In this case an entirely different arrangement is used to spread out the various bands on the dial and the audio amplifier is changed greatly in order



THE WIRING OF THE THREE-TUBE RECEIVER

Apparatus required:
Three UX-201-A or UX-199 tubes and sockets.
C1—350-μμfd. variable condenser.
C2—Special double condenser described in text.
C3—Antenna coupling condenser similar to that described for two-tube receiver.
C4—100-μμfd. grid condenser.
C5—2,000-μμfd. by-pass condenser.
C6—0.1-μfd. condenser.
R1—7-megohm grid leak.
R2—10-ohm rheostat.
R3—50,000-ohm variable resistor.
R4—0.1 to 0.25 megohms.
R5—500,000-ohm variable resistor for volume control.
L1—Will vary to suit antenna. 6 turns 3" diameter will be approximately correct.
L2—Described under illustration of coil.
Two audio-frequency transformers, phone jack, bakelite panel, wooden baseboard, miscellaneous screws, wire, etc.

to make it amplify frequencies of 1,000 cycles to a much greater extent than any other frequencies. An amplifier of this type is called a "peaked" amplifier and in order to differentiate between this receiver and that just described we will call this the three-tube peaked-amplifier receiver.



THE TYPE OF COILS USED IN THE THREE-TUBE RECEIVER FIRST DESCRIBED

The number of turns used and the connections of the special double condenser are as follow:

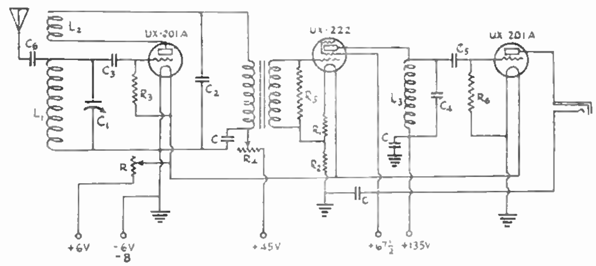
Frequency Band	Grid Turns	Tickler Turns	Condenser Sections
1,715 kc.	77	9	Both
3,500 kc.	37	6	Both
7,000 kc.	26.25	5	Smaller
14,000 kc.	9.25	4	Smaller
28,000 kc.	2.75	3	Both

The grid coils are wound with No. 26 d. c. c. wire with the exception of that for the 1,715-kc. band, which is wound with No. 30 s. c. c. This finer wire is used for the ticklers. No spacing between turns is used for the two lower-frequency bands but spacing equal to the diameter of the wire is used on the other bands. The tickler of the 28,000-kc.-band coil is wound between the grid turns. These dimensions possibly will vary in individual cases.

From the circuit diagram it can be seen that the arrangement of the detector tube is very similar to that of the two-tube set. Similar tube-base coils are used for L1 and L2 and regeneration is controlled in the same manner. The chief difference is in the tuning condenser C1 which is remodeled from a straight-line-frequency condenser in a manner shown in the detailed picture of this unit. All of the stator plates except one are removed and one rotor plate is clamped in a sliding collar made up from the parts of another similar condenser. This collar is fitted with a set-screw which holds the rotor plate to the shaft at predetermined spacing from the stator plate. In order to decide upon a suitable spacing for each frequency band the condenser should be set at minimum capacity and the coil adjusted so that the high-frequency end of the band can be tuned in near the bottom of the condenser scale. Then the condenser can be turned to almost the maximum dial setting and the position of the rotor with respect to the stator varied until the low-frequency end of the band can be tuned in. At this position a shallow hole should be drilled with the tip of a twist drill to accommodate the conical end of the set-screw. When the spacing has been determined for the other bands and the depressions drilled in the shaft the rotor can be moved from one position to another by loosening the set-screw and sliding the collar along the shaft. This adjustment of the condenser, when the coils are changed from one band to another, can be done quite rapidly.

The first audio-frequency amplifier in this receiver is a UX-222 screen-grid tube. It is used in this position since it is particularly suited to give a highly-peaked amplifier when a tuned audio circuit is connected to its plate. The filament of this tube operates at 3.3 volts and if the other tubes in the set are UX-201-A's the resistances R1 and R2 will be required to drop the filament voltage to the correct value. R1 is a fixed resistance of 10 ohms and R2 is 5 ohms. The secondary of the audio transformer is connected to the junction between them so that the grid of the tube will have a suitable grid bias.

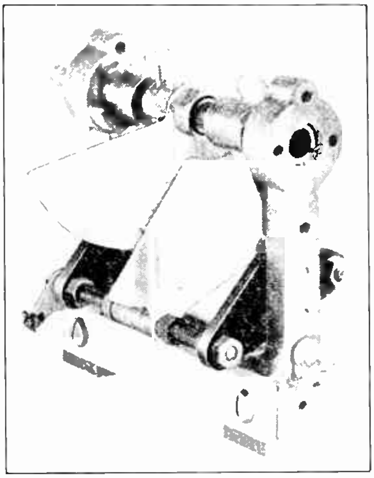
The coil L3 can be the secondary winding



SHOWING HOW THE THREE-TUBE PEAKED AMPLIFIER RECEIVER IS WIRED

Apparatus required:
Two UX-201-A and one UX-222 tube and sockets.
C—1-μfd by-pass condensers (3 required).
C1—"Sliding rotor" type variable condenser—see text.
C2—2,000-μμfd. by-pass condenser.
C3—100-μμfd. grid condenser.
C4—.01-μfd. audio tuning condenser (adjustable).
C5—.006-μfd. audio grid condenser.
C6—Antenna coupling condenser—see illustrations.
R—10-ohm rheostat.
R1—10-ohm fixed resistor.
R2—5-ohm fixed resistor.
R3—2-4 megohm grid leak.
R4—50,000-ohm variable resistor.
R5—0.1 megohm resistor.
L1, L2,—Tube-base coils similar to those used in two-tube set.
L3—Secondary winding of a Ford ignition coil.
One audio-frequency transformer. Aluminum panel 12"x6". Baseboard 12"x7". Various screws, brass strips, wire, etc.

of a Ford ignition coil with the primary and core removed. Such a coil shunted by a condenser C4, of about .01 μfds., will tune to approximately 1,000 cycles and will make the amplifier peak at this frequency. The exact capacity of C4 to give the peak at a suitable frequency had best be deter-



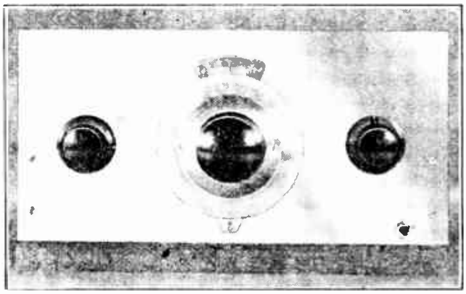
THE SLIDING ROTOR CONDENSER USED IN THE THREE-TUBE PEAKED-AMPLIFIER RECEIVER

The rotor plate is mounted on a collar fitted with a set-screw and hence can be moved to or from the stator plate and set at definite positions. This makes possible a number of different capacity ranges and enables any of the bands to be covered only by tuning across the whole dial.

mined by experiment. Several condensers in parallel make it easier to arrive at the correct value. In the plan view of the receiver they can be seen at the rear center of the baseboard immediately behind the tuning condenser and Ford coil secondary. The final audio amplifier is a UX-201-A tube. It is not needed to give additional amplification but its use is essential since the phones could not be operated satisfactorily in the plate circuit of the UX-222. The values of the apparatus are given under the circuit diagram. The panel of this receiver, like that of the two-tube set, is of ⅛″ thick aluminum. It measures 12″x6″. The baseboard is ⅞″ thick and is 12″x7″.

USING FOUR TUBES

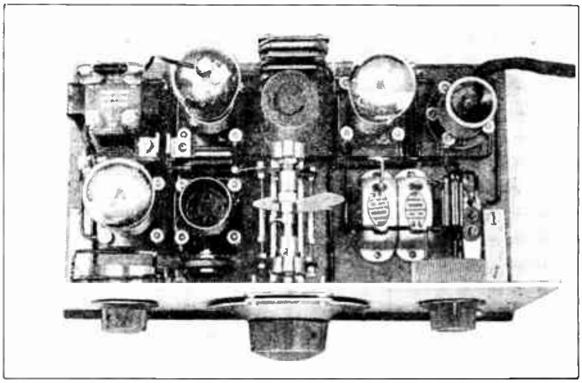
The receivers so far described are all capable of receiving amateur signals from the other side of the world when conditions are favorable and it may seem strange that there is any justification for more than the number of tubes used in them. For the amateur who is interested in obtaining the most effective communication possible over



THE THREE-TUBE PEAKED-AMPLIFIER RECEIVER

The vernier dial in the center is the main tuning control. The knob at the left controls regeneration, while that at the right belongs to the filament rheostat. The panel is of aluminum similar to that used for the two-tube set.

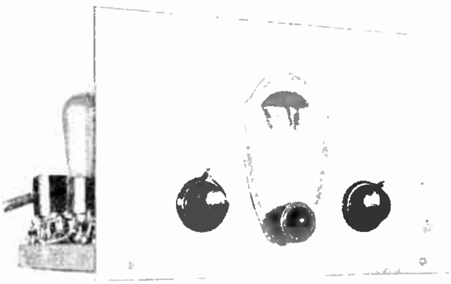
the longest distances, however, there are advantages to be gained by using a screen-grid antenna coupling tube or untuned radio-frequency amplifier. This tube gives an appreciable increase in sensitivity and eliminates any influence of the antenna dimensions over the calibration of the tuning circuit. Also it avoids radiation from the



A BIRD'S-EYE VIEW OF THE SAME RECEIVER

Immediately behind the regeneration-control resistor on the left is the detector tube and the tube-base coil in its socket. Behind these the audio-frequency transformer and screen-grid audio amplifier tube can be seen. In the very center of this group is the antenna coupling condenser consisting of two small brass angles mounted on a piece of hard rubber. The sliding-rotor tuning condenser is in the center, with the Ford coil secondary and its tuning condensers at the rear. On the right the last audio tube, the battery-connection socket, the filament rheostat and various by-pass condensers are mounted.

oscillating detector. In a receiver to be used for phone reception the use of such a radio-frequency amplifier is a distinct advantage since it greatly improves the sensitivity of the receiver when the detector is in a non-oscillating condition. This particular receiver is fitted with a peaked amplifier similar to that used in the three-tube outfit and so is suited for telegraph reception only. It could be modified for phone work, however, by fitting it with a two-stage transformer-coupled amplifier like that used in the first of the three-tube receivers described.

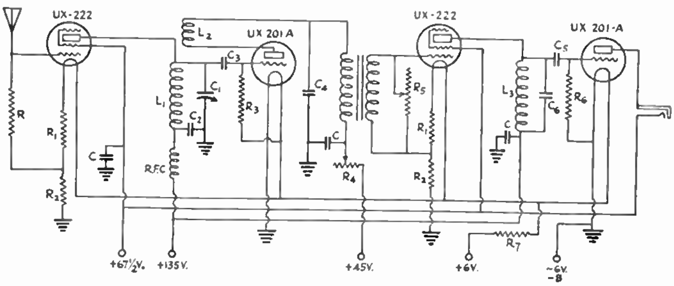


THE FOUR-TUBE PEAKED-AMPLIFIER RECEIVER

The drum dial in the center is, of course, the main tuning control. The knob on the left is the volume control while that on the right is for adjustment of regeneration. The phone jack is mounted on the baseboard near the rear left corner instead of on the panel.

From the diagram it can be seen that the grid circuit of the screen-grid radio-frequency amplifier tube is not tuned. A tuned circuit could be used in place of the resistor R but its use would mean a second major tuning control. The added amplification provided by such a tuned input circuit has not so far been shown definitely to justify the added difficulty in tuning introduced by the second control.

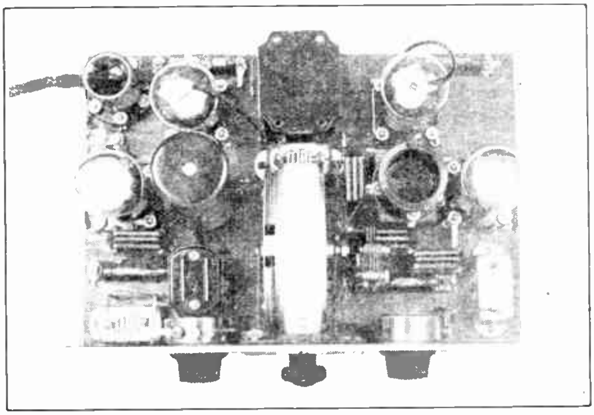
The plate of the UX-222 goes directly to the end of the tuning coil in the grid circuit of the detector tube. The plate voltage of the UX-222 is fed to it through this coil and consequently it is necessary to insulate it from the filament circuit with a fixed condenser C2. The detector circuit is arranged in much the same way as in the previous receivers but yet another alternative scheme is used to provide different capacity ranges for the tuning condenser C1 so that all the bands will have full-scale coverage. In this receiver, C1 consists of plug-in midget condensers which have had some of their plates removed until they are of a capacity suited to the band on which they are used. Three such condensers are shown in front of the coils with which they are used. Some idea of the arrangement of the sockets for these condensers can be obtained from the close-up of the receiver. The two G.R. sockets are mounted on a piece of hard rubber which is held to the frame of the drum dial by one of these sockets. It is important that these sockets be spaced accurately so that the condenser will plug in firmly and not rock as the dial is rotated. The fitting of the G.R. pins to the midget will depend upon the type of condensers used. With the condensers illustrated, the pin connected to the rotor plate was inserted in the



THE CONNECTIONS OF THE FOUR-TUBE RECEIVER

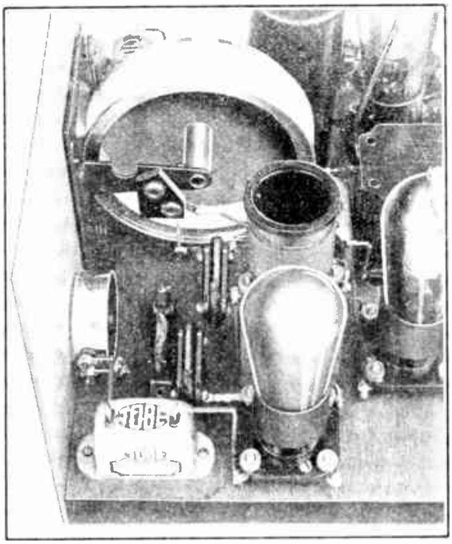
Apparatus required:
Two UX-201-A and two UX-222 tubes and their sockets.
C—1-μfd. by-pass condensers (3 required).
C1—Plug-in midget tuning condensers (see photograph).
C2—4,000-μμfd. fixed condenser.
C3—100-μμfd. grid condenser.
C4—2,000-μμfd. by-pass condenser.
C5—6,000-μμfd. audio grid condenser.
C6—.01-μfd. audio tuning condenser (experiment necessary).
R—10,000-ohm gridleak-type resistor.
R1—10-ohm fixed filament resistor.
R2—5-ohm fixed filament resistor.
R3—6-megohm grid leak.
R4—50,000-ohm variable resistor.
R5—200,000-ohm variable resistor for volume control.
R6—8-megohm grid leak.
R7—Filament ballast resistor for .75 amperes.
L1, L2—Plug-in coils—see photograph.
L3—Secondary winding of Ford ignition coil.
R. F. C.—Receiver-type short-wave radio-frequency choke.
Aluminum panel 12"x7½", baseboard 12"x8", drum dial, one audio-frequency transformer, phone jack, and a variety of screws, wire, etc.

bakelite end plate in place of the machine screw which ordinarily held the spring contact. For the stator connection a G. R. pin, the threaded portion of which had been sawn off, was soldered to the head of the machine screw which supports the stator plates of the condenser. When it is desired to change from one band to another



THE FOUR-TUBE RECEIVER IN PLAN

Behind the drum dial is the audio-frequency transformer. Beside the transformer and to the right of it is the screen-grid antenna coupling tube. In front of this tube is the tuning coil and the detector tube. The plug-in tuning condenser can be seen projecting from the shaft of the drum dial. The assembly to the left comprises the two audio tubes, the Ford coil secondary (which happens to be enclosed in an aluminum tube shield) and the fixed tuning condenser for this coil.



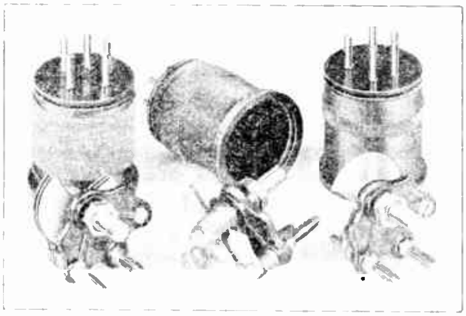
A CLOSE-UP SHOWING THE MOUNTING FOR THE PLUG-IN TUNING CONDENSERS

The two G. R. sockets are mounted in a piece of hard rubber. One of them serves to secure the assembly to the frame of the dial and at the same time make contact between the rotor of the condensers and the frame. The frame, of course, makes contact with the panel and this is connected to the copper sheet on the under side of the wooden baseboard. This copper sheet forms one side of the filament circuit and is indicated in the diagram as a ground.

the coils are first changed. Then the dial is set at 100 degrees, the set screw on the dial loosened and the condenser removed. The condenser to be used is then set at its maximum capacity and plugged into place, the set screw being tightened to hold the shaft securely. This plug-in condenser scheme is a thoroughly practical one. It could well be used in any of the other receivers providing a dial fitted with a suitable set screw was provided.

The coils for this receiver are wound on special coil forms which can be obtained at most radio stores. Tube bases could be used for the coil forms, or other approved types of coils could be substituted.

The audio amplifier of the receiver is arranged in the same manner as that of the three-tube peaked-amplifier receiver and provides a splendid degree of selectivity. The peak to be obtained with a Ford coil secondary as the coil of the tuned audio circuit is not by any means the sharpest peak that can be produced by the UX-222 amplifier. In fact a Ford coil is used simply because its resistance is sufficient to flatten the peak to a sufficient degree. With a more sharply peaked amplifier it is difficult and sometimes impossible to copy signals which are not extremely steady. Greater selectivity and a consequent reduction in interference between stations can be obtained by using a more pronounced peak. This may mean the sacrifice of some of the unsteady signals, however. To obtain a sharper peak the Ford coil secondary should be replaced by a coil of lower resistance. One suitable type of coil can be wound with 3,000 turns of 30 gauge s.s.c. wire "scramble"-wound in five ¾"-square slots turned in a wooden former of 2" outside diameter. Approximately .07 μfd. will be required across this coil to tune it to 1,000 cycles. Experiment with other forms of coils will be found of interest and value.



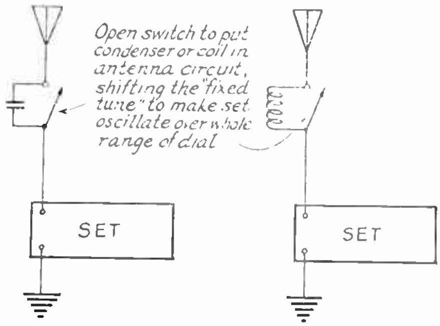
COIL-CONDENSER COMBINATIONS FOR THREE BANDS

Differing from present-day practice, a separate tuning condenser is used with each inductance in the four-tube receiver to give full-scale dial coverage for each band. The grid coils are wound with 20 gauge d. s. c. wire. As a rough guide it can be said that 6 turns are used for the 14,000-kc. band; 11 turns for the 7,000-kc. band; 31 turns for the 3,500-kc. band. The tickiers found suitable are of 30 gauge d. s. c. wire. 5 turns being used for 14,000 kc. 7 turns for 7,000 kc. and 9 turns for 3,500 kc. It is almost certain that these figures will vary in individual receivers.

OPERATING THE RECEIVERS

When the receiver has been completely wired and after the wiring has been checked, the batteries should be connected in the manner shown in whatever diagram is being followed. Always a flash-lamp bulb should be connected in the negative B-battery lead to act as a fuse to prevent the bulbs from burning out should anything be connected incorrectly. When the antenna has been connected, the filaments lighted and the phones plugged into the jack, the regeneration control should be turned towards its maximum position until the "live" sound of oscillation is obtained. For the reception of telegraph signals it will be found that the greatest sensitivity will be had at the point where oscillation begins. Hence for the reception of very weak signals it is usually advisable to "back off" the regeneration control until the detector is just about to stop oscillating. This critical adjustment is, of course, necessary only for the reception of the weakest signals. If the tickler coil has the correct number of turns in the four-tube receiver it will be found that the receiver can be operated for an entire evening on any one band for medium-distance work without the necessity of touching the regeneration control. In the other receivers, which have the antenna coupled directly to the tuning coil, some trouble may be had from "dead spots" on certain portions of the bands. Sometimes they can be eliminated by reducing the capacity of the coupling condenser but in other cases it is necessary to place a coil or condenser in the antenna lead.

Possibly it will be found that the receiver howls just as the detector starts to oscillate and that reception at this point is impossible. This "fringe-howl," as it is termed, can be cured by reducing the value of the resistance connected across the secondary of the first audio transformer. A resistance not lower than .1 megohm should cure the trouble completely but it should be kept in mind that the lower this resistance is the greater will be the reduction in amplification caused by it.



TWO WAYS OF SHIFTING THE "DEAD SPOT" ON A TUNER

When the receiver has been made to oscillate quietly, attention should be given to its calibration. If the coils have been wound according to the details given it probably will tune somewhere near the various bands. However, it is almost certain that a final adjustment of the coils will be necessary to make the edges of the bands come near the top and the bottom of the dial scale. As mentioned before, one simple method of adjusting the coils is to make them slightly larger than necessary in the first place, afterwards spacing one or two of the end turns until the correct value of inductance is obtained. It is not essential that the bands be tuned in across the entire dial but time spent in careful adjustment of the particular tuning system used, so that the band is spread between at least 15 degrees and 85 degrees, will be well worth while. The edges of the bands will not be hard to find. During the evening, when amateurs are busiest, the place on the dial where the amateur stations leave off and the commercial stations begin should be quite well defined. At most times the commercial stations located at edges of the amateur bands should be operating and should serve as a guide. These stations have been termed "commercial markers" on account of their usefulness in setting the location of the edges of the bands.

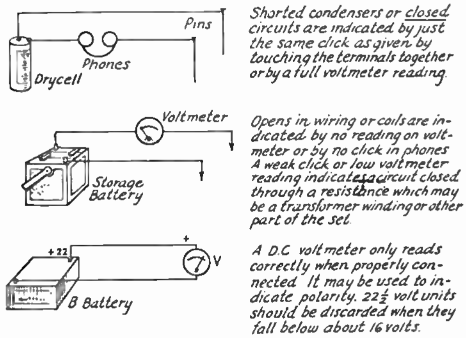
Just as soon as the tuning system has been adjusted, attention can be paid to the audio-frequency amplifier to make certain that it is operating correctly. If audio transformers are used in a "broadcast-receiver" type amplifier, there is very little that can be out of adjustment. In the peaked amplifier, however, it is quite possible that the tuned audio circuit of the screen-grid amplifier is not tuned to a suitable frequency. A check can be made by tuning in a steady signal with a pure note. As the beat note is varied from the lowest to the highest audible frequency—by tuning the receiver—the signal should increase in strength sharply at one point and then fall off sharply as this point is passed. The frequency at which this sudden increase in signal strength is obtained should be at about 1,000 cycles or some other frequency that is comfortable to read. If the peak occurs at a higher frequency than this, more capacity should be connected across the Ford coil secondary or the particular inductance used. If the peak frequency is too low the capacity across the coil should be reduced.

In the operation of any receiver it should be remembered that batteries must always be in good condition and that poor results are often caused by poor tubes. The batteries and the tubes should be given first consideration if the receiver becomes noisy or sluggish in operation. If all joints in the wiring have been carefully soldered, noises in the receiver will be caused by poor batteries and by poor contacts between the tube pins and the sockets. If the noise occurs only when the condenser is turned it is probably the result of dust between the plates or of poor contact between the rotor assembly and the lead to it. In some cases a noise of this type is caused by the shaft or the dial, if it is metal, rubbing against the panel or some other metal object. Yet another source of noise is the antenna system or outdoor wiring near the antenna. Any two wires in poor contact in or near the antenna can cause serious noises when they are blown about by the wind.

Quiet operation in the short-wave receiver is of extreme importance. It is well to aim at sensitivity and open-scale tuning but the value of these characteristics is nullified very greatly if there is not freedom from extraneous noise.

HUNTING FOR TROUBLE

A pair of phones, a dry cell, and a D.C. voltmeter are the most useful instruments for locating faults in the set. If the tube does not light, it should be tested for an open filament. Then the filament-circuit wiring should be traced carefully. The rheostat should be examined for an open wire, the socket for a sprung prong. With the B-batteries disconnected trace the filament wiring from the A-battery to the socket using either the click in the phones or the voltmeter across the 6-volt line. A



LOCATING FAULTS

couple of pins on the end of the voltmeter terminals will make it possible to pierce the insulation for testing purposes.

If a regular clicking sound is heard in the phones when they are connected to the set as in regular operation, it probably means that the grid leak is open or of too high value. A lower-resistance leak will remedy this condition. A pencil mark between grid and filament terminals on the bottom of the tube (or a line of carbonized India ink) will serve in an emergency. Two brass machine screws in a small piece of hard rubber or bakelite with the "leak" drawn between terminals will be a better arrangement.

If the filament lights but there is no sound in the phones, trace the plate circuit wiring carefully, paying attention to the jack to see that the phones are not shorted there. If there is a by-pass condenser across the phones, this should be checked with phones or voltmeter and battery to see that it is not shorted inside or by some solder across the terminals. The grid and plate terminals of the socket may be bent.

An open secondary coil or grid circuit lead may cause a clicking similar to that when there is no grid leak. The winding may be tested with the voltmeter or phones for an open circuit. If no signals come through and there is no "tuning", probably the variable condenser is not solidly connected across the secondary coil. Decreased signal strength may indicate that the antenna coil is open or that the antenna or ground are off. A shorted grid condenser may give the same effect. If no "clicking" is heard with the grid leak removed from the set there may be a shorted grid condenser, a soldering paste "leak" within the socket or across the grid condenser, or a poor tube (open grid). Try a new tube, test the grid condenser with the phones or voltmeter, or clean up any leaky paths that are found between grid and filament.

THE RECEIVING ANTENNA

A good antenna is desirable for the short-wave receiver though it will be found surprising how simple and crude the antenna can be without greatly hampering the operation of the receiver. Many amateurs use a receiving antenna consisting of some fine cotton-covered wire run along one side and end of the room on the picture molding. An antenna of this type is completely effective with a sensitive receiver such as the four-tube outfit described in this chapter. With the simpler receivers, however, an outdoor antenna usually is to be recommended. If the receiver is used in conjunction with a transmitter, the transmitting antenna can be employed by fitting an antenna switch to connect the receiver to some point on the leads from the transmitter to the antenna or feeder wires. If it is desired to work the station "break-in," a separate receiving antenna is necessary. With such an arrangement both the receiver and transmitter are in operating condition at the same time and all that is necessary to transmit is to press the transmitter key. To receive, nothing more is necessary than to release the transmitting key.

A satisfactory outdoor antenna may be made with a length of 14 or 16 gauge enameled copper wire strung between insulators at a height of between 10 and 50 feet above ground. The length of the wire in the antenna is not a very important consideration but the longer the antenna, up to a certain point, the louder the signals. Some amateurs find a very long low antenna, even 800 feet, of distinct advantage in obtaining a better ratio between the strength of the signals and the strength of static and other extraneous noises. When a separate antenna is used for receiving and transmitting they should be kept as far apart as possible and preferably at right angles to each other. This is necessary in order to reduce the amount of energy absorbed by the receiving antenna from the transmitter.

And now, when the receiver has been built, adjusted, and placed in satisfactory working condition it will be permissible to sit back and take a long breath. For the receiver is one of the two essential parts of an amateur station. If the receiver has been correctly built and if the location of the station is satisfactory it will receive as far as any transmitter can send. If it has open tuning scales; if it has lots of sensitivity and amplification; and if it is smooth and quiet in operation, it will be a very great comfort and a source of splendid pleasure.

CHAPTER VI

Building a Station—The Transmitter

THE transmitter is the more important half of the amateur station. Not only is it more difficult to build than the receiver and more needful of careful adjustment but it is more deserving of careful handling. If the receiver operates poorly and refuses to do the things it should, no one but the amateur himself need know about it. Should the transmitter perform badly, however, the whole amateur world can hear it and judge the amateur behind it accordingly. For there is not the slightest doubt about the fact that an amateur, these days, is known by the signal he owns. No amateur is anxious to have a wobbly signal, a creepy signal, a rough spluttery signal or any other sort of signal that blots out a section of the band wide enough to accomodate a half dozen really good signals. Aside from this, it is soon discovered that a clean steady signal is a genuine asset purely on account of its effectiveness. Through bad interference or over long distance the cleanest and steadiest signal usually will be the most readable one even if it is not the loudest.

HOW A TUBE OSCILLATES

Before going any further let us review briefly the manner in which oscillations are produced by the vacuum tube in a typical circuit. It will be a great help if we know just what makes the "wheels go 'round".

When the plate voltage is applied to the circuit the sudden shock causes some current to circulate in the condenser-coil circuit. The currents flow at the natural period of the circuit. The current flows in and out of the condenser at millions of cycles per second and there is a voltage drop across each of the turns of the coil due to the "reactance" of the coil. Reactance is a property of coils due to their inductance and depending on the frequency applied to the coil also. This current sets up a field linking all the turns of the inductance coil. Radio-frequency potentials exist between each of the turns of the coil.

The grid potential controls the flow of plate current within the tube. The D.C. plate potential is constant. There are two or three turns between the grid and filament clips (Hartley circuit). The radio frequency voltage across these turns is applied to the grid. The rapidly changing grid potential tends to cause changes to take place in the plate current at radio-frequency. While the plate current remains substantially constant, the internal impedance of our vacuum tube is changed at radio frequency (in effect). Changing plate impedance establishes a radio-frequency voltage between the filament and plate of the tube. The plate coil circuit is part of the condenser-coil circuit. Therefore the condenser-coil circuit receives more "timed shocks" which keep it oscillating at its natural period.

This voltage cannot cause the flow of radio-frequency currents back through the plate transformer, for the radio-frequency choke coils offer a very high impedance to high frequency currents. This radio frequency voltage is impressed across the condenser-coil circuit and causes high currents to flow in this circuit. The energy in this circuit is "stored" first in the electric, then in the magnetic field. Sometimes this circuit is called a "tank" circuit because of that fact. The current which flows in this circuit sets up a field about the inductance which embraces all the turns of the inductance. This field causes a voltage to be induced in the grid turns; this is applied to the grid circuit of the tube. As long as a sufficiently large "feedback" voltage is supplied to the grid there are continuous oscillations.

The tube is really a "converter" of direct current energy from your battery or other plate supply source to radio frequency energy which you want in the antenna. The clips are placed on the split coil in the same relative positions shown in our diagrams. The filament clip is that one in the center of the coil while the plate and grid clips are on either end. More turns are usually needed between the filament clip and the plate clip than between the filament and grid clip. The position of the clips from the variable condensers determines the wavelength. The higher the capacitance and the larger the inductance coil in the "condenser-coil" circuit the greater will be the wavelength (the wavelength varies as the square root of the product of inductance and capacity).

The portion of the coil between the filament clip and the plate clip may be referred to as the "plate" coil. The part between the filament clip and the grid clip is usually called the "grid coil".

When the filament is heated, electrons, negative particles of electricity, are boiled away from the filament. The plate of the tube is positively charged and the negative electrons from the filament are attracted to it. The grid is nearer to the filament than the plate and if a positive charge is put on the grid, it accelerates or speeds up the motion of the electrons from the filament to the plate and increases the flow of plate current. If a negative charge is placed on the grid it retards or repels the electrons so that most of them fall back into the filament and the plate current is small.

When the key is pressed and the tube is oscillating we have seen that there is a radio-frequency current in the condenser-coil circuit. This current sets up a magnetic field about the coil in which it circulates (the primary coil). Transformer action takes place and radio frequency voltage is induced in the antenna coupling coil (the secondary coil). This induced voltage is of course of the same frequency as that supplied by the tube circuit. The greatest current flows in the antenna when the antenna circuit is tuned to have the same period as that of the coil circuit – and a maximum reading on the antenna ammeter shows when this condition obtains. The coupling between the two coils depends both on the number of useful turns in primary and secondary and also on the relative position of the two coils. Coupling can be loosened by cutting down on the number of turns (of either coil), by drawing the coils farther apart, or by leaning one coil over at an angle with respect to the other.

Energy stored in the tube circuits may be likened to the energy stored in the flywheel of a gas engine. Circuits having less than twice the amount of energy stored that is wasted or lost tend to be erratic in action. On the other hand if too much circulating current is present in the condenser-coil circuit the "copper losses" will be high. Most of the stored energy should be in the plate circuit of the tube.

TRANSMITTER CIRCUITS

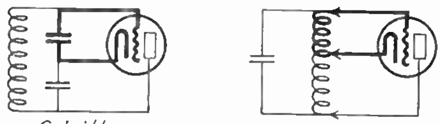
Fundamentally there are only two general divisions of oscillating circuits: those employing capacitive coupling (condensers) to feed back energy from the plate to the grid circuit, and those using inductive coupling (coils) for the same purpose. All circuits are modifications of these two general classes.

The choice of a transmitting circuit is not of great importance, for if the circuit is arranged to suit the particular tube or tubes used, and is adjusted well, similar results can be obtained with any of them. In every transmitter provision is made to tune the condenser-coil circuits to the required frequency, to tune the antenna circuit to resonance with the plate circuit, and to vary the amount of energy fed into the grid circuit from the plate circuit (the grid excitation). Other means are provided to adjust the grid bias, to match the impedance of the tube, and to adjust the antenna load to that value which will allow the most efficient transfer of energy from the plate circuit. Some method of making all of these adjustments is to be found in every satisfactory circuit. In fact a circuit is nothing more than a combination of the necessities for making such adjustments, the object in making them being to get the largest output into the antenna without exceeding the input rating of the tube and always maintaining a steady clean-cut signal.

The circuits in most general use are the Hartley, Armstrong or Tuned-Grid Tuned-Plate, Colpitts and Ultraudion. Also there is the Master-oscillator-amplifier circuit (which is an oscillator in one of the above circuits feeding a radio-frequency amplifier) and the crystal-control circuit (a crystal oscillator feeding one or more radio-frequency amplifiers).

In the Hartley circuit the plate tank circuit, which is a feature of all of the circuits, has its ends (or clips near its ends) connected to the grid and plate of the tube. The filament circuit of the tube also is connected to the coil at a point nearer the grid end of the coil than the plate end. In this way the coil is really divided into two sections, one in the grid circuit and a larger one in the plate circuit. Oscillations are maintained because of the inductive coupling between these two sections.

In the Tuned-grid Tuned-plate circuit there are two tank circuits, one connected between the grid and the filament of the tube and the other between the plate and filament. In the short-wave transmitter these two circuits are not coupled inductively and the capacity of the tube itself is utilized to provide the coupling between the grid and plate circuits which is necessary to cause oscillation.



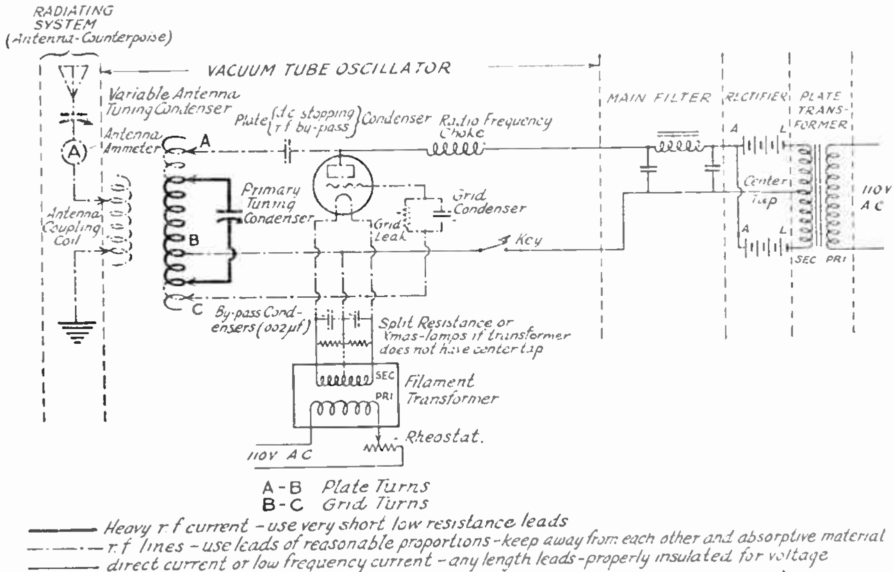
CLASSES OF OSCILLATING CIRCUITS

The Colpitts circuit is arranged so that the filament is connected to the junction of two condensers which are in series across the coil. In this way the grid and plate circuits share the voltage drop across the condensers, and oscillation is produced in this manner.

A great many variations of these fundamental circuits have been evolved and it is not surprising that the newcomer is often confused by them. It is well to remember that however complex or unusual the circuit may appear it can without doubt be "boiled down" to one of the fundamental arrangements. And, what is more important, when it has been adjusted carefully in every respect it will provide almost an identical performance to that of any other circuit.

The keynote of the whole circuit business is that it is not the circuit that matters, it is the way in which it is tuned and adjusted.

Of course the tube oscillator does not comprise an entire transmitter and the circuit looks much more complicated when the power supply system, the filter and the keying arrangement are added. The usual complete transmitter may be divided into five sections. In the example given (which is only one of many types) the first section is the power supply of 110-volt 60-cycle alternating current supplying the plate and filament transformers. The plate transformer steps the alternating current up to a voltage between 400 and 2,500 (depending on the tube used in the transmitter) while the filament transformer steps down the voltage to the rated value of the tube filament. Any variation of the high voltage usually is obtained by changing taps on the secondary winding. Adjustment of the output of the filament transformer is obtained by the use of a rheostat in the primary circuit of the transformer. From the secondary of the high-voltage transformer the alternating current is led to the rectifier—the second division—where it is changed into pulsating direct current. This current then goes through the third section—the filter—where the pulsations are smoothed out so that the current is now a steady direct current. This supply is then led to the tube oscillator which converts it into a very high frequency alternating current of the frequency to which the oscillator is tuned. The fifth section of the transmitter is the antenna system. It is tuned approximately to the frequency of the oscillator and takes its power from the plate circuit of the tube through an antenna coil inductively coupled to it. In this chapter we will consider chiefly the tube oscillator—the apparatus in the fourth section. The power supply, rectifier, filter keying and antenna systems will be discussed separately.



A TYPICAL CIRCUIT (MAGNETICALLY COUPLED HARTLEY)

For simplicity's sake the desirable meters have been omitted from this diagram; their location may be seen in the many diagrams which follow. The key similarly is shown in the simplest possible location, but better arrangements are available and are discussed in a following chapter. The antenna is shown working against a ground, as in receiver practice, to aid in understanding the diagram. Although an actual ground is becoming a rarity in amateur transmission the principles shown still apply, whether the antenna is operated against ground or counterpoise or whether the antenna coupling coil is part of the radiating system or part of a feeder system feeding a different type of antenna.

CHOICE OF TUBES

The type of tube to be used should be given consideration before a start is made with the construction of any of the apparatus for the transmitter. The design of almost every item in the transmitter will be influenced by the tube with which it is to be operated. The rating of the transformers, for instance, the current-carrying capacity of the filter, the rating of the fixed condensers, the type of variable condensers and the design of the inductances all will depend on the power and voltage rating of the tube.

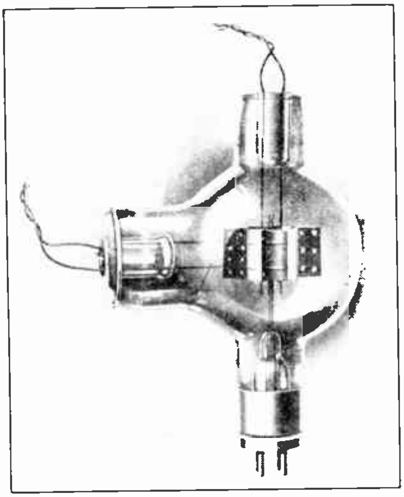
Fortunately there is a splendid variety of transmitting tubes to choose from. What is more, the tubes available are of high quality with satisfactory characteristics. If they are handled carefully and operated correctly they will give wonderful service.

The amateur usually uses the lowest-power transmitting tube—the UX-210—for his first transmitter and this practice is a good one. The use of low power enables the transmitter to be built cheaply yet providing full opportunity for the amateur to gain a knowledge of the operation and handling of a transmitter. Many of the most experienced amateurs actually prefer a low-power transmitter of this

Tubes	Fil. Volts	Fil. Amps	Plate Volts	Plate Milli-amps	Plate Impedance (ohms)	Mutual Conductance (micromhos)	Voltage Amplification Factor μ	Output Rating (Watts)	Use
UX-112A	5.0	0.25	90-157	2.5-8	8800-4800	890-1670	8.0	.040*-.195*	Power Amp.
UX-120	3.0	0.125	135	6.5	6600	500	3.3	.110*	Power Amp.
UX-171-A	5.0	0.25	90-180	10-20	2500-2000	1200-1500	3.0	.130*-.700*	Power Amp.
UX-199	3.0	0.06	45-90	1-2.5	16,500	380	6.25	.007*	Det.-Amp.
UX-201-A	5.0	0.25	45-135	1.5-2.5	11,000	725	8.0	.015*-.055*	Det.-Amp.
UV-203-A	10.0	3.25	1000	125 (osc.)	5000	5000	25	50	Osc.-Amp.
UV-204-A	11.0	3.85	2000	200 (osc.)	5000	5000	25	250	Osc.-Amp.
UV-206	11.0	14.75	10,000-15,000	135	225,000-115,000	300	34.5	1000	Osc.-Amp.
UX-210	6.0-7.5	1.1-1.25	350-425	60 (osc.)	5000	1550	7.7	1.54*-7.5	Osc.-Amp.-Mod.
UV-211	10.0	3.25	1000	125 (osc.)	1900	6300	12	50-100	Osc.-Amp.-Mod.
UX-222	3.3	0.132	135-180	1.5	850,000	350	300	....	S/G Amp.
UY-224	2.5	1.75	180 max.	4.0	400,000	1050	420	....	S/G Amp.
UY-227	2.5	1.75	45-180	4.0-6.0	9000	1000	9.0	.164*	Det.-Amp.
UX-240	5.0	0.25	90-180	0.3-2.0	40,000-60,000	500-900	30	....	Amp.-Det.
UX-245	2.5	1.5	250 max.	32	1900	1850	3.5	1.6*	Pwr. Amp.
UX-250	7.5	1.25	450 max.	55	1800	2100	3.8	4.65*	Amp.-Mod.
UX-841	7.5	1.25	350-425	5-9	23,000	1300	30	7.5	Amp.-Osc.
UX-842	7.5	1.25	350-425	14-28	2500	1200	3	7.5	Amp.-Mod.
UX-845	10.0	3.25	1250 max.	75	2100	2390	5	20*-50	Amp.-Mod.
UV-849	11.0	5.0	2000-3000	75-100	3200	6000	19	100*-350	Amp.-Mod.-Osc.
UV-851	11.0	15.5	2000-2500	300	1400	15,000	20	1000	Osc.-Amp.-Mod.
UX-852	10.0	3.25	2000	75 (osc.)	6000-9000	2000-1300	12	75-100	Osc.-Amp.
UV-860	10.0	3.25	2000	70	150,000	1350	200	75	S/G Pwr. Amp.
UV-861	11.0	10.0	3000	90-150	133,000	2250	300	500	S/G Pwr. Amp.
UX-865	7.5	2.0	500	21	200,000	750	150	7.5	S/G Amp.
WE-211A (G)	8.7-10	3.4	750	125	4000	......	....	50	Amp.-Osc.
WE-211D	10.0	3.0	750-1000	40-85	3500	3000	12	50	Amp.-Osc.
WE-212A (I)	10.75-12	6.25	1600	175	2000	....	....	250	Amp.-Osc.
WE-212D	14.0	6.0	1500	100-150	2000	8000	16	250	Amp.-Osc.
WE-215A (N)	0.8-1.1	0.25	20-90	0.2-0.7	35,000-25,000	260-180	6.5	....	Det.-Amp.
			(A.C. r.m.s. per plate,)						
UX-213	5.0	2.0	220	65	....	....	..	....	Full-Wave Rect.
UX-216B	7.5	1.25	550	65	....	....	...	....	Half-Wave Rect.
UV-217A	10.0	3.25	1500	200	....	....	...	....	Half-Wave Rect.
UV-217C	10.0	3.25	3000	150	....	....	...	....	Half-Wave Rect.
UX-280	5.0	2.0	300	125	....	....	...	....	Full-Wave Rect.
UX-281	7.5	1.25	700	85	....	....	...	....	Half-Wave Rect.
UX-866	2.5	5.0	5000 (inverse peak)	600 (peak)	....	....	...	....	Half-Wave Rect.
UX-872	5.0	10.0	5000 " "	2500 (peak)	....	....	...	....	Half-Wave Rect.
UX-874	Volt. Drop, 90 V. d. c.; Starting Volt., 125 d. c.; Max. Current, 50 mils.				......	....	...	....	Volt. Regulator
UV-876	Current rating, 1.7 amps.; voltage drop, 40-60.				....	....	...	....	Ballast Tube
UV-886	Current rating, 2.05 amps.; voltage drop, 40-60.				....	....	...	....	Ballast Tube

Many of the "U" tubes listed are duplicated in "C" numbers one hundred higher. *Asterisk indicates max. undistorted output as amplifier at proper plate and grid voltages. Where no (*) shows, power output shown is that as oscillator. S/G means screen-grid.

type, finding that they can readily communicate over many thousands of miles with them under good conditions. The distance that can be covered by a transmitter is, in fact, not very much dependent upon the power of the transmitter. Even a UX-199 tube in the hands of an experienced amateur can send across the world when conditions are very good. The higher-powered transmitters can send no farther than this but they have the advantage in being able to put signals with greater reliability and readability into far distant countries.



THE UX-852

In addition to the 7.5-watt UX-210 tube there is the UX-203-A (50 watts); the UX-852 (75 watts) and the UX-204-A (250 watts). The latter is the highest-power tube that is used for most amateur work. Many other tubes, including the screen-grid types, also are available to amateurs.

In choosing the tube it is well to remember that a really good performance and a clean signal can be obtained only if the tube is run at or under its rated power and only if the power supply equipment has an ample margin. In the early days tubes and power supplies were often heavily overloaded to the point where the plate of the tube was white hot and the transformer windings about to go up in smoke. In those days the whole idea was to get the highest possible antenna current. Modern practice is to operate the entire equipment well below its full rating. In this way, even if the antenna current is but a fraction of that available, the signals usually will be more readable at distant points because of their clear tone and steadiness. It is an undisputed fact that 7.5 watts of antenna power from a 75-watt tube can make an infinitely superior signal to 7.5 antenna watts from a 7.5-watt tube.

The output ratings and some other characteristics of the tubes readily available to amateurs are given in table form. With the exception of the UX-210, which can be bought at radio stores, the Radio Corporation transmitting tubes can be obtained only by ordering direct to the Sales Department of the company, Woolworth Building, New York City. The Western Electric tubes are not obtainable readily in this country. They can usually be bought in Canada from the Northern Electric Co.

PLANNING THE TRANSMITTER

The low-powered transmitter really can be considered as an oversize oscillating receiver. There are few essential differences in its arrangement and not much more difficulty involved in its construction. The chief thing to remember is that, whereas extremely minute currents flow in the tuning circuits of the receiver, very heavy currents flow in even the low-powered transmitter. This means that the first constructional difference between the transmitter and receiver is in the size of conductors used for the tuning coils and the leads connecting them to the tuning condensers. Heavy wiring is required in most other parts of the transmitter but it is of greatest importance in the tuning circuits, where the currents obtained are many times greater than those in any other portions of the circuit.

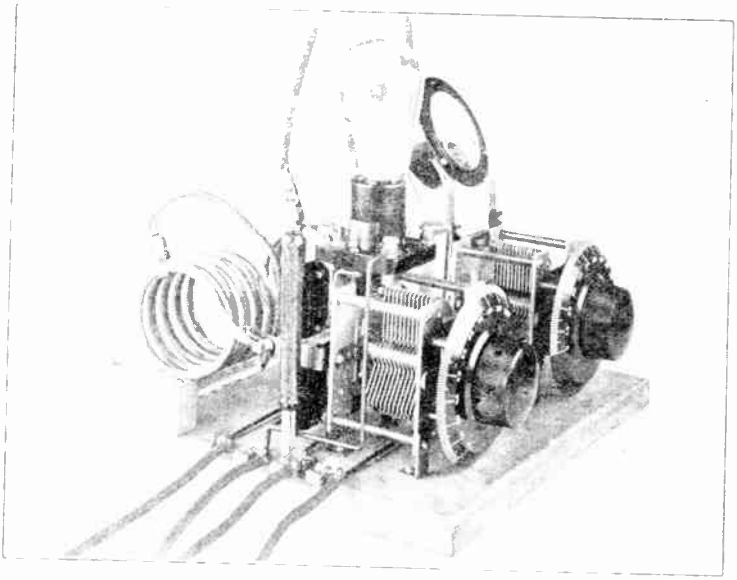
Another essential difference between the receiver and transmitter is that the fields around the coils and condensers of the transmitter are very much more intense than in the receiver. Consequently greater spacing between the coils and other apparatus is desirable and the elimination of unnecessarily heavy insulating-material supports inside the coils is important.

Yet another prime difference is that the voltages in the transmitter are of a much higher order than in the receiver. Insulation throughout the transmitter must therefore be given particularly careful consideration.

There is a splendid field for the exercise of thought and originality in the arrangement of the apparatus of the transmitter. The shortness of leads and the placement of the coils and condensers with respect to the other apparatus are matters of such importance that the amateur will always be rewarded for time spent in consideration of the problem. In the pages that follow some examples of satisfactory lay-outs will be given. These will serve to give a general idea of how the transmitter can be arranged. However, they are not the acme of perfection. Neither are they applicable to all types of apparatus. The use of even a different variable condenser than that shown in any one of the examples—a condenser with its terminals in a different place—may make some entirely different lay-out preferable. The amateur should not allow this discussion to dishearten him, however, for it cannot be denied that excellent results are being obtained every day in amateur stations all over the world with the apparatus arranged in quite a clumsy fashion.

Most of the transmitters to be described are mounted on a baseboard with all the apparatus exposed and readily accessible for adjustment or experiment. If desired, the apparatus can be mounted on a baseboard and a vertical panel in a manner somewhat similar to the receiver. Unless the apparatus is arranged with great care, however, this type of construction is likely to mean a sacrifice of convenience in making alterations and adjustments.

the leads in the oscillator circuit as short as possible, at the same time permitting the coil to be in a clear space by itself. The condenser C2 in the circuit diagram is that at the left of the baseboard on which the tube is mounted. The tube base is supported from the condenser by two small brass angles, one of which can be seen in the first illustration of the set. The tube is placed in this position so that the terminals on the socket are convenient to the apparatus to which they are connected and so that the tube itself is out in the open where



A SIMPLE LOW-POWERED TRANSMITTER
Using a UX-210 tube arranged in a Hartley circuit, this transmitter is an effective and reliable one for the beginner. When adjusted and tuned carefully it will produce very clean and steady signals—signals which any amateur would be proud to own.

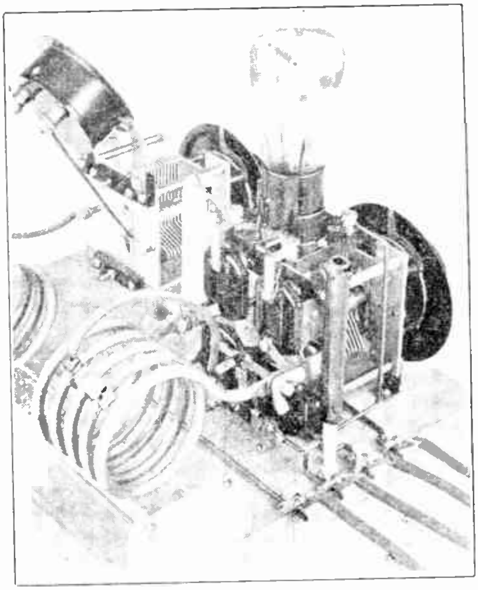
A LOW-POWERED TRANSMITTER

The construction of a simple transmitter can be accomplished in the shortest time and with the least difficulty by mounting the apparatus on a baseboard in somewhat the manner shown in the illustrations. We will use this transmitter as an example and describe in it detail. If the reader studies the circuit diagram, the photographs and the description carefully he will find that the transmitter is even simpler than it looks. If he understands just what it is all about he will find it easier to modify the arrangement to suit the particular apparatus at his disposal than to duplicate it laboriously in every detail.

The baseboard of this transmitter measures 10″ x 12″. The apparatus on it is grouped into two units—the tube and its associate equipment on the left and the antenna coupling coil, antenna condenser and ammeter on the right. Every effort has been made to make the heat developed in it can be radiated readily In operation the plate of a transmitting tube gets quite hot and on account of the expansion of the metal the capacity between the elements is changed. This change in capacity causes a change in the frequency of the transmitter wave. It is for this reason that so many amateur signals "creep" during transmission. The heating of the plate of the tube represents power lost and the greater the heating for a given input power the lower is the efficiency. Careful adjustment for greater efficiency therefore reduces the plate heating but it can never be reduced to the point where ventilation of the tube is not an important consideration.

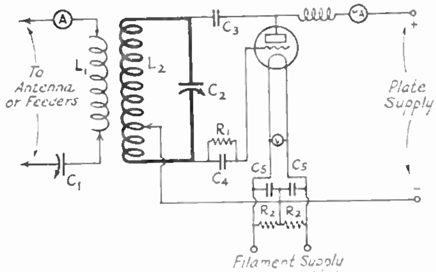
In the close-up view of the transmitter the condensers C3 and C4 can be seen connected to the grid and plate terminals of the tube socket with small angle pieces of brass strip. Below these are the two filament by-pass condensers indicated as C5 on the diagram. The purpose of these condensers is to provide an easy path for radio-frequency currents flowing to the filament of the tube which would otherwise have to go through the resistors R2. When the filament of the tube is lighted from alternating current these "center-tap" resistors are necessary to avoid having the alternating voltages on the filament reach the grid, for this would cause modulation or "ripple" on the transmitted signal. The voltage at the leads to the filament is constantly changing at the 60-cycle supply frequency but the voltage at the center point of the two resistors R2 is constant. Another method of accomplishing the same result is to use a center tap on the filament-supply winding of the transformer. The center-tap resistor arrangement is sometimes preferable, however, since it permits the use of a filament rheostat in the secondary of the filament transformer instead of the primary. Rheostats for the secondary winding are more readily available than the other type. In place of the resistors, Christmas-tree lamps or automobile headlamp bulbs can be used. They are equally effective.

The most important item of all is the tank circuit consisting of the coil L2 and the condenser C2. It is this tuned circuit that sets



A "CLOSE-UP" SHOWING THE HEAVY "TANK" LEADS AND SOLID CONSTRUCTION

The plate and grid fixed condensers are mounted immediately under the tube socket. Below them are the two filament by-pass condensers and the center-tapped filament resistor. On the far side of the tube socket is the plate choke supported from the plate terminal. On the near side is the grid leak pushed over a wooden peg in the base-board. Heavy flexible wire is used for the filament lead to the inductance, a clip being permissible in this case on account of the low current to be passed by it. Relatively enormous currents flow in the coil-condenser circuit and in this case connections between the two must be made with wing nuts, or some similar device, in order to avoid serious losses.



THE HARTLEY CIRCUIT USED IN THE LOW-POWERED TRANSMITTER

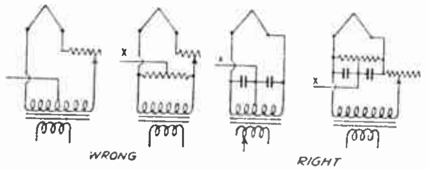
Material required:

One UX-210 tube and socket.
A—Thermocouple ammeter 0-1 amps. or automobile headlamp bulb.
V—Alternating current voltmeter 0-10 volts.
MA—Direct current milliammeter 0-100 milliamps.
C1—500-µµfd. receiver type variable condenser.
C2—500-µµfd. receiver type variable of good quality.
C3—500-µµfd. fixed condenser.
C4—250-µµfd. fixed condenser.
C5—2000-µµfd. fixed condensers.
(These fixed condensers should be high-grade 500-volt receiver type condensers or special transmitting type.)
R1—10,000-ohm transmitting grid leak.
R2—50- or 100-ohm fixed resistors or Christmas-tree lamps.
RFC—160 turns of No. 30 gauge d.c.c. wire on ¾"-diameter wooden rod.
L1, L2—Plate and antenna coils described under illustration.
Wooden baseboard 10"x12".
Two glass towel bars and wooden supports for same. Four terminals or Fahnstock clips, miscellaneous wood screws, machine screws, wing nuts, clips, copper strip for connections and brackets, 14 gauge enamelled copper wire for connections shown in light lines.

Power supply, antenna and keying systems for this and the other transmitters are discussed in separate chapters.

the frequency of the transmitter and it is the resistance of this circuit that influences to a very great extent the efficiency and general performance of the transmitter. Even with a 7.5-watt tube the radio-frequency current circulating in this circuit can be as high as 5 amperes, and the avoidance of clips or other poor contact or the use of small conductors is therefore essential. The transmitter can take very high plate currents, can operate unstably or can fail to oscillate at all just because there is a poor contact in this circuit or because the conductor is too small. In this transmitter the coils are wound of ¼"-diameter soft copper tubing which can be obtained at most hardware stores or automobile supply houses.

The coils can be wound on a piece of 2¾" outside diameter iron water pipe or on a wooden former of the same size. One end is first secured to the former by drilling a hole through the tubing and the former, if it is iron, and inserting a machine screw. In the wooden former, of course, a wood screw would be used. The winding is then accomplished by rotating the former in one hand, feeding the tubing to it with the other. The turns should be wound close together at the start and later spaced by inserting a piece of wood between the two end turns and working it spirally down the coil. This method makes the spacing more

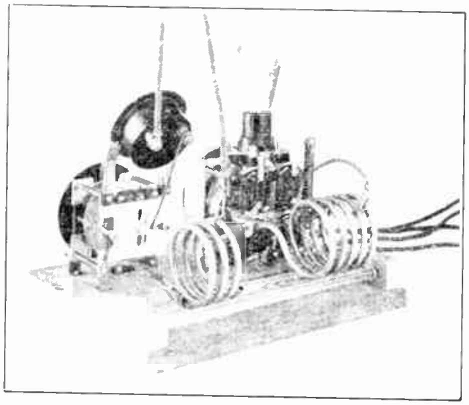


METHODS OF CONNECTING TO THE "ELECTRICAL CENTER" OF THE FILAMENT CIRCUIT

even than merely pulling the turns apart by hand. The ends of the coils are hammered flat and a piece is cut out of the flat portions so that they can be slipped under the heads of the wing-nuts which are to hold them in contact with the connector strips to the condenser.

The wing-nuts and the connector strips can be seen in the close-up view of the transmitter. The connector strips are of 3/8″-wide heavy copper. The lead from the coil to the center-tap of the filament circuit carries relatively little current. It is therefore possible to use a clip on the coil to permit adjustment. The gridleak R1 can be seen in the illustrations standing vertically alongside the variable condenser C2. It is pushed over a wooden rod which in turn is pushed into a hole in the baseboard. The radio-frequency choke is the only other item in the oscillator circuit. It can be seen on the opposite side of the variable condenser to the grid leak. This choke serves to prevent the radio-frequency current generated by the tube from getting back into the power supply. The operation of the transmitter is greatly dependent upon its effectiveness. The dimensions given under the diagram should make a satisfactory choke but it is advisable to experiment with slightly different values. A neon bulb is very useful in checking up on the performance of radio frequency chokes. If it is held by the glass portion and one of its contacts is held on a wire carrying radio-frequency current, the lamp will glow brightly. When such a lamp is touched on the lead from the choke to the tube plate it will therefore light. If the choke is operating properly there will be only a slight trace of radio-frequency current at the other end of the choke and when the lamp is put in contact with the lead from this end it will light very dimly or not at all. In a low-powered transmitter of this type the choke would not be considered effective if the neon tube lighted brightly enough to be visible in daylight. A wooden handled screwdriver can be used in a somewhat similar manner. When the screwdriver is held by the wooden handle and its metal end touched on a wire carrying radio-frequency current a spark will be seen as the contact is made or broken. An appreciable spark should be obtained at the plate end of the radio frequency choke and none at all at the opposite end.

The second section in the transmitter is the antenna coupling and tuning unit. It consists of the variable condenser C1 which sits alongside condenser C2; the 0-1 ampere thermocouple ammeter, which is mounted above the condenser C1; and the antenna coil L1, which can be seen resting on the two glass towel bars which run the length of the baseboard at the rear. These glass rods are used to prevent the coils from vibrating, to insulate them from the baseboard, and to permit the antenna coil to be moved away from or near to the plate coil, so varying the antenna coupling. The thermocouple meter is not an absolute essential. It can be replaced by an automobile headlamp bulb, the antenna current being estimated by the brilliance of the lamp instead of the reading of the meter.



A REAR VIEW OF THE LOW-POWERED HARTLEY

The tube socket being mounted on top of the plate tuning condenser, its plate and grid terminals are particularly convenient to the leads between the condenser and the coil on to which they are connected through the plate and grid condensers. At the left is the antenna tuning unit, consisting of a coil—which is moved along the glass rods for variation of antenna coupling—a condenser, and a thermocouple ammeter. The meter, though mounted on the condenser, must be insulated from it. The plate choke can be seen between the two variable condensers. Aside from their use in supporting the antenna coil, the glass rods also serve to prevent the plate coil from vibrating.

In the illustration of the coils for this transmitter, coils for five frequency bands are shown. This does not mean that all of them must be built. Though there are six frequency bands available to the amateur it is best for the newcomer to attempt operation in one of them only until he has mastered the adjustment and operation of the equipment. One reason for this is that the antenna system is quite a simple affair for any one band but becomes complex and difficult to adjust when an attempt is made to make it operate on several bands. Then, it is a little difficult to adjust the transmitter for maximum performance on any one band, let alone adjusting it for several. Any of the four lower-frequency bands are satisfactory for the first attempt, though of these the two higher-frequency bands—the 7,000-kc and 14,000-kc. bands—will permit of communication over the greater distances.

This transmitter is designed for use with a tube of the UX-210 type and it should be clearly understood that it will not prove satisfactory with a tube of higher power rating or widely different characteristics.

TUNING

The tuning of any transmitter is a matter of the greatest possible importance. The performance of even the best transmitter can be spoiled by the slightest misadjustment, and on the other hand almost any transmitter can be made to perform well by an amateur experienced in the work. Even the most experienced amateur, however, cannot tune the transmitter effectively unless he is able to listen to it as he adjusts the controls. The use of some sort of monitor to listen to the signal as the transmitter is tuned is essential. A detailed description of simple monitors will be found in Chapter IX. It should be studied and a monitor built before any attempt is made to tune the transmitter.

When the transmitter has been assembled; when the antenna and its leads or feeders have been tightened; when it has been found that the leads and coil, or the transmitter itself, will not vibrate, the filament supply should be switched on and the filament voltage adjusted to the rated value—7.5 volts. Now the filament clip should be adjusted to about the position shown in the illustrations where the ratio of grid to plate turns is about 1 to 4 or 1 to 5. A low plate voltage should be used for the first test, about 250 or 300 volts being a suitable value. The antenna coil should be taken off or coupled very loosely to the plate coil when this plate voltage is switched on, and the filament clip should be readjusted to give a plate current of about 20 or 25 milliamps. The plate current should be switched off before any readjustments are attempted, since a serious, perhaps fatal, shock would result from contact with wiring connected to the plate supply. Contact with other metal parts of the set while it is running probably would mean a bad radio-frequency burn. The frequency should now be checked by one of the methods described in the chapter on frequency measurement, and when it has been made certain that it is within the band the adjustment can proceed. The plate voltage can now be increased to normal. The antenna coil at this time can be coupled more closely and the antenna tuning varied until maximum current is indicated. The antenna coupling can be increased until the greatest possible antenna current is obtained. This value should be noted carefully as something to avoid using at all costs. Without delay the antenna coupling should now be backed off, returning the condenser as each adjustment of coupling is made, until the current is about 85% of the highest value. Now the antenna should be detuned until the current has dropped to about 85% of the last 85% value. Particular notice should be taken of the signal in the monitor as this detuning is done, as the signal probably will be much cleaner with the antenna detuned on one side of resonance than on the other.

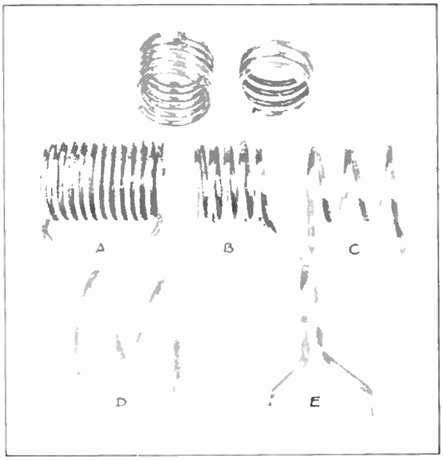


PLATE AND ANTENNA COILS FOR FIVE BANDS

Coils A, B, C, D and E are used for the 3,500-4,000 kc. ("80-meter"), 7,000-7,300 kc. ("40-meter"), 14,000-14,400 kc. ("20 meter"), 28,000-30,000 kc. (10 meter) and 56,000-60,000 kc. (5 meter) bands, respectively. They have an inside diameter of $2\frac{3}{8}$" and were made by winding the $\frac{1}{4}$" soft copper tubing over a length of $2\frac{3}{8}$" outside diameter iron water pipe by hand. To facilitate the winding process holes were first drilled in the pipe and the tubing, one end of the copper tubing being secured to the iron pipe with a machine screw before the winding was started. The ends of the coils are hammered flat and drilled to fit under the wing nuts which hold them to the condenser leads. Two antenna coils—to be seen above the plate coils—serve for use with coils A, B, C. and D. Their size will be determined to some extent by the type and constants of the antenna.

After a further check of the frequency, tests can be made to see whether the keying is clean and whether keying chirps exist. The various methods by which keying can be accomplished, and their adjustment, are treated in another chapter so we will not touch upon them here. At this stage of the adjustment process, however, the checking of keying is all that is necessary before the first CQ can be called.

Successful tuning is greatly a matter of experience and the amateur will soon find that many improvements in the signal can be made by slight adjustments here and there. Just so long as the signal is observed continually in the monitor, these adjustments and their effect will soon be found. When he has had some experience the amateur will find that he can anticipate the effect on the signal of every adjustment he makes.

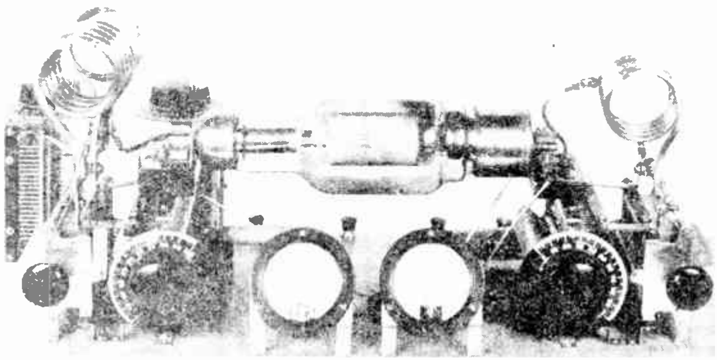
Summed up in a few words, the aim in all transmitter tuning is to get the steadiest and cleanest signal consistent with reasonable antenna power at the rated input to the tube.

A HIGH-POWERED TRANSMITTER

The chief differences between transmitters of low and high power are merely in the size of the conductors and the ratings of the condensers and other apparatus. The fact that the circuit of this 250-watt transmitter is the Tuned-grid Tuned-plate and not the Hartley does not mean that the other circuits would not be satisfactory for high power or that the Tuned-grid Tuned-plate would not be quite effective for low power. The circuit used in this transmitter was chosen because the long UX-204-A tube, with its grid terminal at one end and its plate connection at the other, lends itself particularly well to a circuit in which the grid and plate tuning units should be widely separated. Other circuits could have been used but they would not have permitted the same simplicity of lay-out or directness of wiring.

As in the previous examples the apparatus is arranged on a baseboard. The placement of the parts can be seen clearly in the plan view. The plate tank, indicated by L2, C3, C4 in the circuit diagram, is at the left front of the plan view. The grid tank, shown by L3, C3, C4 in the diagram, is on the right. The antenna tuning and coupling unit, L1, C1, C2, can be seen at the left rear corner of the base, the antenna coil L1 being mounted so that its coupling to the plate coil can be varied. The details of this mounting can be seen in the close-up view. Two variable condensers are used across the plate and grid coils simply because of the difficulty of getting a single transmitting condenser with the desired 500 or 600 μμfds. capacity. If single condensers of this capacity are available they should be used.

In the transmitter the two variable condensers—of the double-spaced transmitting type—are mounted on brass angles on the baseboard and are connected in parallel by heavy copper strips 1/2" wide which serve also as the mountings for the plate and grid coils.



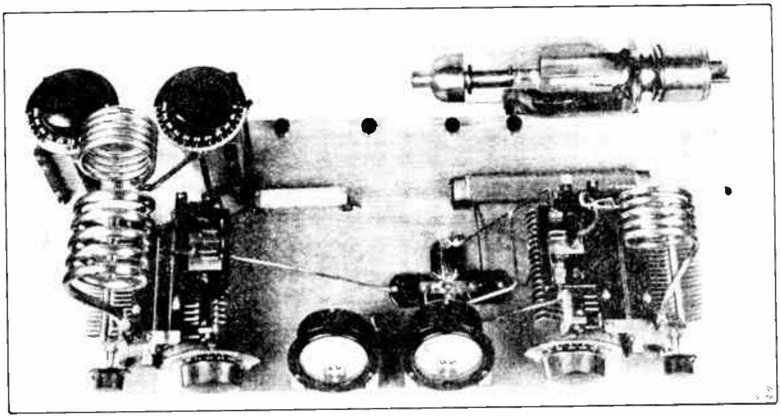
ONE POSSIBLE ARRANGEMENT OF A 250-WATT TRANSMITTER

In this case the tube is connected in the Tuned-grid Tuned-Plate circuit which permits a simple lay-out and short leads when used with a tube which has its plate connection at one end and its grid connection at the other. On account of the very heavy currents in the plate tank circuit, the plate inductance and the connections from it to the plate tuning capacity are made of large conductors. The apparatus is all mounted rigidly so that it cannot vibrate and spoil the signal.

The strips, after running between the terminals of the condensers, are bent up at one end and drilled to take 1/4" machine screws fitted with wing nuts. The lugs of the coils fit under these wing nuts, as can be seen in the close-up. Little difficulty should be had in following the other constructional details after the photographs and diagram have been studied. With the exception of the tank circuits, where all conductors are of 1/2"-wide copper strip or copper tubing of the sizes mentioned under the illustration of the coils, the wiring in the circuits of the tube is of 1/8" diameter copper tubing or wire. 1/4' tubing is used in the antenna circuit. It is not essential that the lay-out shown be duplicated in detail by anyone building a similar transmitter. This arrangement is only one of dozens of possible ones and, as in the previous transmitters, is given to provide the reader with a general idea of the way in which transmitters are assembled.

In tuning this transmitter the same general principles are observed as those described in the case of the low-powered transmitter.

Extreme care must be taken to avoid contact with any metal part of the set while it is running, since the plate supply in this set could easily result in a fatal shock. The dials and knobs can be adjusted when the set is operating, providing it has been made certain that continual checking of the frequency is necessary. The antenna coupling can now be increased until maximum current is obtained and immediately it should be reduced until the current is about 85% of the maximum value. It is at this stage that it is so important to



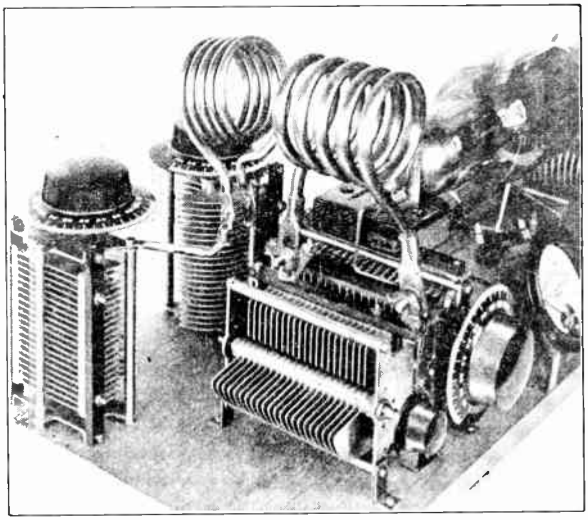
THE HIGH-POWERED TRANSMITTER AS SEEN FROM ABOVE

At the right is the grid unit comprising the tank circuit with its two variable condensers in parallel, and the heavy-duty grid leak immediately behind them. Of the four fixed condensers arranged in a group, that on the right is the grid condenser. On the left of the group is the plate circuit by-pass condenser, the remaining two serving as the filament by-pass. On the left side of the transmitter is the high-capacity plate tank, with its unusually heavy inductance, and the antenna tuning unit. To the right of this plate unit the radio-frequency choke can be seen.

the sets-screws in them do not protrude. The plate supply must be switched off before anything else is touched.

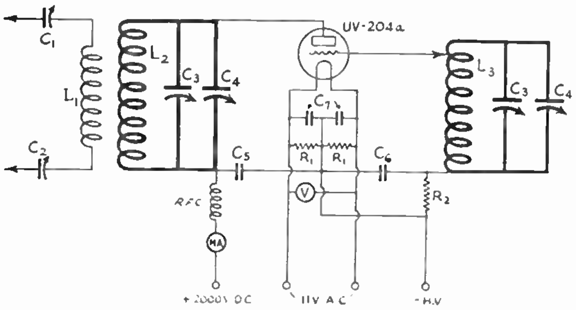
In transmitters employing this circuit it is well first to set the plate tuning condenser at about 75% of its maximum capacity, with the grid tuning condenser at zero. Then, with the antenna coil removed and the plate voltage lowered, the grid tuning capacity can be increased until the plate current dips and then rises to about 10% higher than the minimum. Now the frequency should be checked and if it is not within the band the same process should be repeated until it is.

At this stage the antenna coil can be coupled loosely and the antenna or feeder circuit tuned until maximum current is indicated. If the plate current at this point is still below the rating of the tube (when the plate voltage has been increased to normal) the grid capacity can be increased until it has climbed to the required value, at which time the antenna tuning should be readjusted. Each change in the grid circuit will mean changes in frequency, and



A "CLOSE-UP" OF THE PLATE TANK AND ANTENNA TUNING UNIT

In the immediate foreground is the 410-μμfd. variable condenser providing "lumped" capacity, adjustable for the various frequency bands. Behind it, and connected in parallel with it, is the main tuning condenser. Heavy copper strip is used for all connections in the tank, the inductances being attached to the tank condensers with ¼" machine screws and wing nuts. Coupling between the plate and antenna coils is varied by swinging the latter on its mounting.



THE CIRCUIT OF THE HIGH-POWERED TRANSMITTER

Apparatus required:

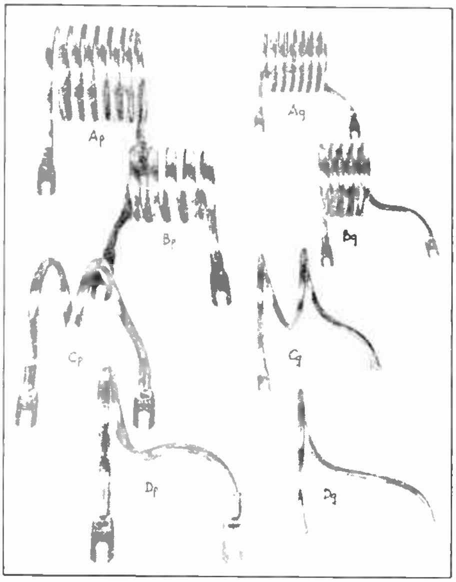
One UX-204-A tube and mountains.
C1, C2—140 μμfd. variable antenna or feeder condensers (transmitter type).
C3, C4—Double-spaced transmitting-type variable condensers having a combined capacity of 500 μμfds. or more. A single condenser can be used in place of the two if it has sufficient capacity.
C5—100 μμfd. fixed by-pass condenser (5,000-volt rating).
C6—100 μμfd. fixed grid condenser of same rating.
C7—2,000 μμfd. fixed filament by-pass condensers (preferably 2,500-volt rating, though 500-volt condensers usually will serve).
R1—100-ohm fixed resistors. A center-tapped filament transformer can be used instead.
R2—Heavy-duty 10,000-ohm grid leak. Leaks rated at 75 watts or less usually heat and cause frequency creeping.
RFC—160 turns of 26 gauge d.c.c. wire on ¾"-diameter form.
L1, L2, L3—Antenna, plate and grid coils described under illustration of them.
One or two antenna or feeder thermocouple ammeters 0-3 amps.
V—Alternating current voltmeter, 0-12 volts.
MA—Direct-current milliammeter, 0-250 m.a.
Wooden baseboard, four terminals, miscellaneous wood screws, machine screws, wing nuts, brass feet for condensers, copper connecting strip, ⅛" copper tube or wire for connections shown in light lines.

Suitable power supply, antenna and keying systems are given in later chapters.

observe the signal carefully in the monitor in order to decide on which side of resonance the antenna should be detuned to obtain the cleanest signal. Final check of the frequency and slight polishing of the keying and all adjustments with the aid of the monitor will now make the transmitter ready for the air.

A MASTER-OSCILLATOR-AMPLIFIER TRANSMITTER

This circuit is so named because the oscillator tube, instead of feeding the antenna direct as in the previous examples, feeds one or more amplifier tubes which in turn supply the antenna circuit. The circuit has the advantage of being able to maintain a much steadier frequency than those in which the antenna is fed directly from the oscillator. The oscillator of such a transmitter can be fitted with a very large condenser in its tuning circuit so that its frequency will be steady. The value of this condenser can be greater than that possible in a tube feeding the antenna, since the reduction in efficiency necessary to obtain a very steady wave in this manner is not important. The output power of the oscillator tube should be considerably more than that actually required to excite the amplifier but such a power can be obtained without trouble if the oscillator tube is of the same rating as the oscillator. Tubes of similar rating are desirable also because the oscillator can then be operated below its normal power input and the tube can be kept quite cool and in a stable operating condition. The important point to remember is that the output of a master-oscillator-amplifier transmitter will only be as steady as that of the oscillator. The extra equipment needed and the difficulties of its construction will not be justified unless the oscillator is made to operate very steadily by using a high-capacity tuning circuit and a tube of sufficiently high rating to permit it to be run well below its normal power. These points will be made clearer by describing an actual

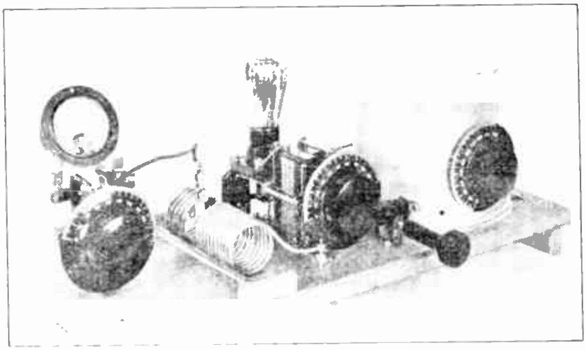


GRID AND PLATE INDUCTANCES FOR FOUR FREQUENCY BANDS

For the 3500 kc. band Ap and Ag are the coils used, Ap being 3½" inside diameter and Ag 2⅜". Bp and Bg serve for the 7000 kc. band, Cp and Cg for 14000 kc., and Dp Dg for 28000 kc. With the exception of coil Ap the coils are all 2⅜" inside diameter. The plate coils are of ⅜" outside diameter copper tubing, and the grid coils of ¼" tubing. All of them were wound by hand on pieces of iron pipe. This procedure is possible, however, only when the tubing is of the "soft drawn" grade.

transmitter in the design of which they were taken into account.

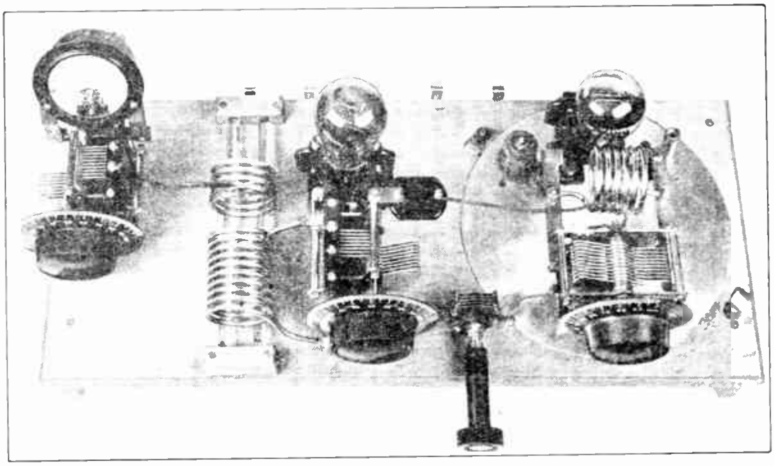
In the circuit diagram of this transmitter the oscillator is the tube on the right, arranged in a Hartley circuit. In the tank circuit of this oscillator—indicated by dark lines—a 500-μμfd. condenser (C2) is used as in the previous transmitters to aid in obtaining a capacity" of the operator moving near the set. The use of such a shield, however, hinders the ventilation of the tube and it is necessary to drill several ¼"-holes around its edge near the base and several in the top to obtain a circulation of air. Without these holes the tube would heat badly and the frequency would creep in consequence. The close-up



THE LOW-POWERED MASTER-OSCILLATOR-AMPLIFIER TRANSMITTER

The frequency of this transmitter is set by the stable oscillator contained within the aluminum shield. When the amplifier is correctly neutralized nothing outside the oscillator unit is capable of causing any appreciable shift in the transmitted frequency. The oscillator tube is of the same type as the amplifier, operated well below its power rating.

steady frequency. The oscillator unit is mounted on the right side of the baseboard on an aluminum disk and in operation it is enclosed in a shield consisting of an inverted aluminum kettle. This shield avoids changes of frequency which otherwise would be caused by the "body views again can be depended upon to give an idea of the mounting of the apparatus. In the oscillator the tube socket is mounted on the aluminum disk. The fixed grid and plate condensers are supported in a vertical position from the grid and plate terminals of



THE TRANSMITTER WITH THE OSCILLATOR SHIELD REMOVED

Mounted on an aluminum disk is the Hartley oscillator. Over it fits the aluminum kettle. The amplifier unit is mounted alongside the oscillator and between it and the antenna tuning unit. Glass rods are used to support the amplifier plate coil and the antenna coil, coupling between them being varied by sliding the latter along the rods. The neutralizing condenser—probably the most important control in the transmitter—is mounted between the oscillator and amplifier tuning condensers.

the tube socket, these condensers, in turn, holding the heavy copper strips that form the connections to the tuning condenser. At the center of these strips G.R. sockets are fitted and into these the tuning coils are plugged. The mounting of the apparatus and all the wiring should be perfectly stiff, since any vibration will make a steady-frequency output impossible.

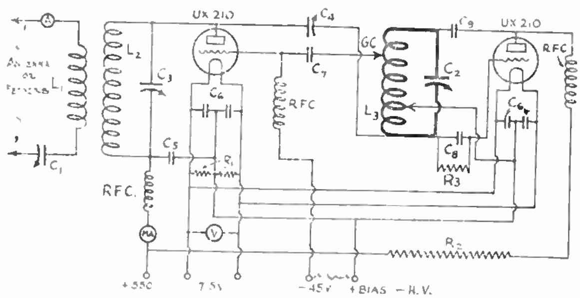
The grid of the amplifier receives its excitation through a coupling condenser C7 from the oscillator coil. The lead is made to a clip on the coil and this clip is varied in its position to vary the amount of grid excitation. The amplifier tube, which is of the same type as the oscillator, is mounted on small brass brackets from the amplifier plate tuning condenser. The plate tank of this tube has a smaller condenser and more turns than that of the oscillator, in order to get the highest possible efficiency. A high value of capacity is not necessary to stabilize the frequency, since this has already been effected in the oscillator.

From the circuit diagram it can be seen that if the oscillator tube were removed the circuit would be very similar to the Tuned-grid Tuned-plate, the amplifier tube having a tuned plate circuit L2, C3 and a tuned grid circuit L3, C2. The amplifier tube would therefore oscillate by itself unless special precautions were taken. The amplifier is prevented from oscillating by neutralizing it in much the same manner as the radio-frequency amplifiers of a broadcast receiver are neutralized. The neutralizing is accomplished with condenser C4 and is an extremely critical adjustment. We will tell of it in detail when we discuss the tuning process.

The placement of this neutralizing condenser and the apparatus in the amplifier can be seen in the plan view. The full plate voltage is across the neutralizing condenser and to avoid the possibility of shock and to reduce difficulties in adjustment introduced by "hand capacity", it is fitted with an extension handle.

The amplifier plate coils, like those in the oscillator, are fitted with G.R. plugs which fit into similar sockets mounted in copper strip extensions from the condenser terminals. The plate coils rest on two glass rods so that vibration is eliminated. On these same rods the antenna coil rests. Antenna coupling is varied by sliding the antenna coil near to or away from the plate coil. The antenna tuning condenser and ammeter are mounted on the extreme left end of the baseboard. The grid of the amplifier tube is maintained at a suitable operating voltage by a bias battery which is connected to the grid through a radio-frequency choke. This choke cannot be seen in the illustrations as it is under the amplifier tube socket. The choke in the positive high-voltage lead to the amplifier is that to be seen sitting in front of the tube in the close-up of the amplifier unit.

In tuning the oscillator of this transmitter the same process will apply as that outlined for the other transmitters. It is as well to have the grid lead to the amplifier attached when the tuning is done but the plate supply to the amplifier should be disconnected. Just as soon as the oscillator has been tuned to give the steadiest signal on the required frequency, with the plate input at about 10 watts, the preliminary neutralizing can be undertaken. For this work a two-turn coil connected to a flash-light bulb should be coupled closely to the amplifier plate coil. With the plate supply still disconnected from the amplifier but with the oscillator running, the neutralizing condenser should now be set at zero and the amplifier plate tuning condenser rotated until the maximum indication is obtained in the bulb. At this stage the neutralizing condenser should be adjusted until no such indication is obtained, even after slight readjustment of the plate tuning condenser. The plate voltage to the amplifier can now be connected and the amplifier plate circuit tuned until the lowest



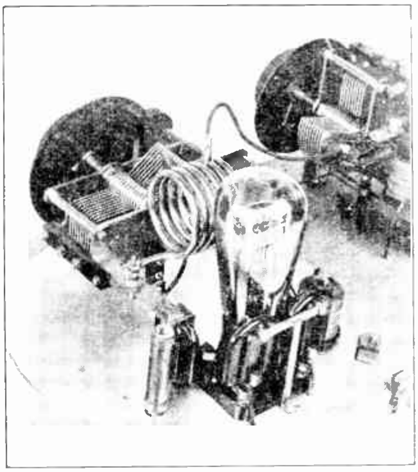
THE CIRCUIT OF THE MASTER-OSCILLATOR-AMPLIFIER TRANSMITTER

Apparatus required:
Two UX-210 tubes and sockets.
C1, C3—350 μμfd. receiver-type variable condensers
C2—500 μμfd. ditto.
C4—50 μμfd. midget condenser and extension shaft.
C5—2,000 μμfd. fixed by-pass condenser.
C6—1,000 μμfd. filament by-pass condensers.
C7—250 μμfd. fixed coupling condenser.
C8—250 μμfd. fixed oscillator grid condenser.
C9—1,000 μμfd. fixed oscillator stopping condenser.
R1—100-ohm. center-tap resistors or Christmas-tree lamps.
R2—100-watt 10,000-ohm grid leak to drop plate voltage for oscillator.
R3—10,000-ohm grid leak for oscillator (10- or 25-watt size).
RFC—Radio-frequency chokes each consisting of three sections of 50 turns of 30 gauge d.c.c. wire wound in ⅛"-slots in a 1"-diameter, wooden former and connected in series. The tubular chokes described before should be equally satisfactory.
L1, L2, L3—Antenna, plate and oscillator coils described under illustration.
Aluminum kettle and disk for oscillator shield, baseboard 9½"x 22", five terminals or Fahnstock clips, wood screws and machine screws, towel bars and wooden supports for same, brass angles, copper strip, and 14 gauge wire for connections.

The power supply, antenna and keying systems are treated in later chapters.

value of plate current is obtained. Antenna coupling and tuning can now be effected, keeping in mind that antenna coupling still plays the same important part in master-oscillator-amplifier transmitters as far as efficiency is concerned, and that it still has some influence of the frequency stability. When the coupling has been adjusted to give maximum antenna or feeder current, the coupling should be backed off until the antenna current is about 85% of its former value. No noticeable improvement in frequency stability or note will be obtained by detuning the antenna as in the other transmitters. Adjustment of the clip GC should now be made to give the best efficiency in the amplifier.

If the tuning has been followed in the monitor the signal probably will be clean and extremely steady. In most cases further improvement will be possible by further adjustment of neutralizing. This can be done effectively by listening to the transmitter in the monitor with little or no plate-supply filter and adjusting the neutralizing condenser until the cleanest note is obtained. As complete neutralizing is approached the character of the note will improve and at the exact point of neutralization it will be far superior to that obtained on

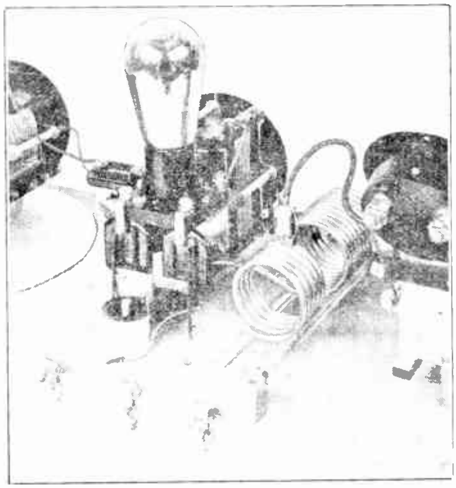


A "CLOSE-UP" OF THE OSCILLATOR UNIT

On the left of the tube is the grid leak and the grid condenser from which the combined connecting strip and coil mount is run to the variable condenser. A similar arrangement is used on the plate side of the tube. On the right side of the tube is the plate r.f. choke. The filament by-pass condensers can be seen mounted on the tube base in the immediate foreground.

either side. Neutralizing with the pick-up coil and flash lamp bulb is useful to obtain approximate adjustment but a final check with the monitor is very valuable.

In higher-powered transmitters of this type a similar lay-out and construction could be used, though heavier coils and wiring, together with condensers of higher voltage rating, would be necessary. The use of this circuit, as we have said, will not be justified fully unless the oscillator tube is of ample power rating. To control a UX-203-A amplifier a similar tube would be desirable as oscillator. A UX-203-A



THE AMPLIFIER UNIT IN GREATER DETAIL

The height not being limited by any shield, the tube, in this case, is mounted in a convenient position on brackets extending from the tuning condenser. Under the tube base is the plate-circuit by-pass condenser and dropped from it is the filament by-pass unit. Projecting to the left of the tube is the grid coupling condenser in the lead from the oscillator.

or a UX-852 would be effective as the oscillator controlling a UX-852, though two UX-852's would be a better combination since the same plate supply could be used for both. A UX-852 could be used to control a UX-203-A. In this case also the same plate supply could be used for both tubes.

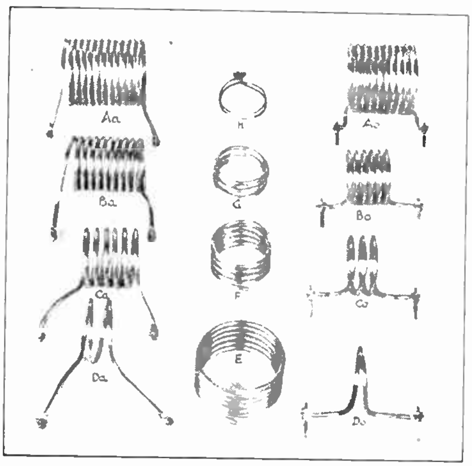
OTHER CIRCUITS—THE COLPITTS

There are several other circuits in which the apparatus described could have been arranged. The performance obtained with all of them would be almost identical once the adjustment had been mastered. Though it is impossible to describe in detail a transmitter with each circuit available, we will mention their different features so that their use will be understood.

In the Hartley circuit a magnetic feed-back from plate to grid causes oscillation. In the tuned-plate-tuned-grid arrangement a capacitive feedback from plate to grid is responsible for the action that takes place. The Colpitts circuit action is based similarly on a capacitive or electric feedback, though not through the inter-element capacity of the vacuum tube itself.

In the Hartley circuit the grid connects to one end of the coil, the plate connects to the other end and the filament goes in between the two. With r.f. currents flowing in the coil-condenser circuit there is a "voltage drop" across each section of the coil (due to its inductive reactance). This "voltage drop" always acts so that the grid voltage is exactly opposite to the plate voltage. When the r.f. **grid** voltage swings **up** the r.f. **plate** voltage swings **down**. The filament is between the grid and plate in potential.

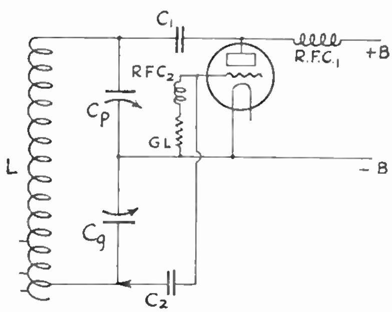
In the Colpitts circuit, coils and condensers have been swapped around so that in effect the filament is tapped to the center of a condenser with the grid and plate connections at the outside terminals. With r.f. currents flowing in the coil-condenser circuit there is a "voltage drop" across each section of the condenser (due to its capacitive reactance). This acts as above. The "voltage drops" of plate and grid circuits are exactly opposite in phase, with the filament in between the plate and grid as far as voltage is concerned. Hartley action is dependent on voltage drops across different parts of a coil. The Colpitts action is dependent similarly on voltage drops across different sections of a condenser.



OSCILLATOR, AMPLIFIER AND ANTENNA COILS FOR FOUR BANDS

Made of 3/16" outside diameter copper tubing and wound by hand on a piece of iron pipe, these coils serve for the four bands from 3,500 to 14,400 kc. in this particular transmitter. In a transmitter arranged differently some changes in the dimensions given may be necessary. Coils Aa and Ao are the amplifier and oscillator coils for the 3,500 kc. band. They have an internal diameter of 2½". Coils Ba and Bo are for the 7000 kc. band, Ca and Co for 14,000 kc., and Da, Do for 28,000 kc. For the last three bands the coils are wound to have an inside diameter of 1¾". Coil E is used in the antenna circuit for 3500 kc., F for 7000 and 14,000 kc. and G for 28,000 kc. The number of turns used can be seen on the illustration. Coil H, fitted with a flash-lamp bulb, is that used for the preliminary neutralizing process.

The differences in all circuits are principally in ease of adjustment and control. The Colpitts controls somewhat differently than the others. Output and efficiency will remain about the same, however. In looking at the circuit diagram the first thing we notice is that the grid-leak connects from the grid directly to the filament with a small choke in series to



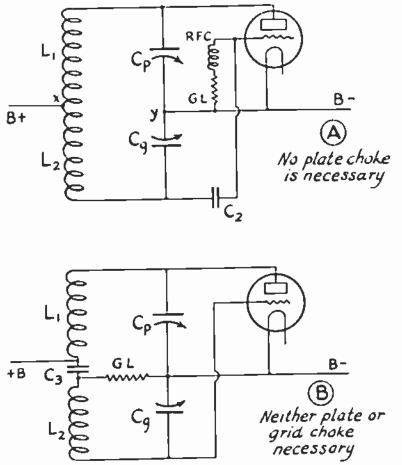
SIMPLEST FORM OF COLPITTS

keep r.f. leakage currents down. While we had some choice in the matter in the Hartley and T.P.-T.G. circuits, this connection of the grid leak is quite necessary in the Colpitts circuit. A leak connected across C_2 would be useless as C_g would not afford a return path to filament (C_g acting as a blocking condenser with infinite impedance as far as D.C. is concerned). Increasing the capacity of C_p raises the wavelength and increases the grid feedback. Increasing C_g also raises the wave but reduces the grid feedback. It is simply a matter of adjusting the proportion of voltage drops across the two condensers by changing their size (and therefore their reactance). A frequency change is also caused, because changing either condenser changes the effective capacity across the coil. To keep the grid excitation constant and change the frequency, C_g and C_p can both be increased or decreased together. A separate control of grid excitation can be had by making grid condenser C_2 variable or by adding a clip connection to L so that the lead from C_2 does not necessarily connect to the extreme end of the L-C circuit.

In using a practical form of the Colpitts circuit for transmitting the controls must be kept down to a reasonable number and so it may be desirable to forego separate clip connections for control of grid excitation, particularly as extra leads hung on a circuit at different points tend to bring in a double tuning effect at the higher frequencies we use.

By using a balanced arrangement and modifying our simplest form a little we can get rid of the necessity of using plate and grid r.f. chokes. This is a splendid idea for use in an outfit for work on different frequencies because one doesn't have to worry about plug-in chokes for the highest efficiency—a practical necessity if we plan to change our frequency over a very wide range. The Colpitts circuit as shown goes down to our shortest waves with ease. As soon as C_g and C_p have been put on the same shaft or otherwise coupled together mechanically the adjustments are as easy as with the other circuits and the wavelength can be changed with the grid excitation constant.

In the first paragraphs of our discussion of the Colpitts circuit attention was called to the fact that there is always a point of zero voltage between plate and grid, both between



SOME VARIATIONS OF THE HOFFMAN BALANCED COLPITTS CIRCUIT

the two ends of the coil and between the two condensers. That means that there is no r.f. voltage between points x and y (even though there is the entire d.c. plate potential between them). Sketch A discloses that the plate blocking condenser C_1 has been taken out and that the plate supply is being fed to the center of coil L_1-L_2. The high voltage is all over the coil and stator plates of both tuning condensers—but we have eliminated the necessity for a plate choke coil.

If C_g and C_p have the same capacity, L_2 and L_1 will be about equal in turns, but if C_g is larger as it sometimes is, the arrangement will be in balance again when the B feed point is moved down so that L_2 is smaller. The voltage node (zero) moves down the coil somewhat as the grid excitation is decreased by using a larger capacity at C_g without a proportionate increase in the capacity of C_p.

A good way to find the nodal point is to put an r.f. choke in the B-plus lead and to hunt r.f. voltage over the whole coil with a neon tube indicator or insulated metal object. Insulation is important here as the coil is alive and dangerous. Hands off! The connection for the plate feed should be made to the zero point on the coil when it is located. If it's not exactly right, leave the r.f. choke in the plus lead to keep what little voltage is present where it belongs. The choke is relieved of the major part of its regular job at any rate.

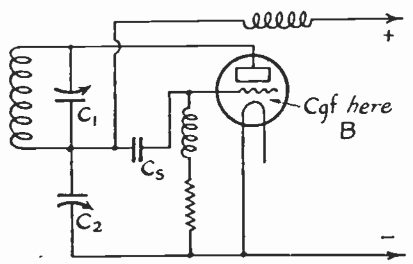
If a large capacity be placed at C_3 as shown in sketch B it will have very little effect on the distribution of r.f. voltages over the coil. It will give us two points at about the same r.f. voltage and insulated with respect to d.c. voltages. This condenser should be capable of withstanding the plate voltage and handling the circulating current and should be at least ten times the capacity of the tuning condensers. The grid-leak and B-plus leads may now be connected as diagrammed. No chokes of any description are left in our circuit. Neither is a grid condenser absolutely needed. C_3 keeps high voltage d.c. off the grid.

C_g and C_p both carry the circulating current and must be transmitting condensers or at least double spaced receiving condensers if much power is used. Remember that condensers in series have a smaller effective capacity than either condenser taken by itself. Two .0005-microfared condensers on the same shaft in series will behave like a single tuning condenser with a maximum of .00025 microfarads. Use the effective capacity value when determining coil sizes in designing a transmitter. C_g is often made the larger of the tuning condensers so that the voltage drop across it will be considerably less than the drop across C_p. C_g should have twice the capacity of C_p to make the grid excitation have the optimum value unless a small grid condenser is used to limit the r.f. grid voltage.

Having determined the equivalent capacity necessary to cover a certain frequency range, a trial value for C_g or C_p may be substituted in the formula for series capacities (see chapter on Fundamentals) and the value for C_p or C_g accurately determined.

THE ULTRAUDION

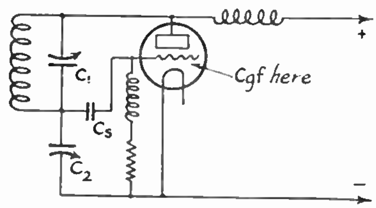
One popular arrangement is shown in the diagram referred to as the ultraudion circuit. The tuned circuit consists of the coil L1-L2 in series with the capacity between the plate and grid. The frequency can be increased by the simple process of cutting down the size of L1 and L2. When these coils are cut down to be mere connecting leads, tubes may be made to



A SERIES-FEED ULTRAUDION CIRCUIT
The condenser C2 is used to vary the grid excitation. C1 being the usual plate-tank tuning condenser. The antenna or feeder coil is coupled to the plate-tank inductance as usual.

oscillate nicely on frequencies as high as 300,000 kc., the limit depending on the size of the grid-plate tube capacity which is different in different tubes.

The distributed capacity in the plate choke very likely by-passes some r.f. energy to the filament by way of the power supply (filter condenser). This is avoided in the practical



A SHUNT-FEED ULTRAUDION CIRCUIT

and final arrangement of apparatus by moving the plate choke connection to the grid end of the tuned condenser-coil circuit as shown in the next diagram. This is in reality a change from shunt or parallel plate feed to series feed. The harmful distributed capacity is now in shunt with C2 where it does some good. There is also less r.f. voltage at the choke using the series arrangement, which is better. A variable high-resistance leak of 10,000 or 15,000 ohms will enable us to adjust the bias to the best operating value.

The plug-in coils for a practical ultraudion set are constructed just like the coils described in the first part of this chapter.

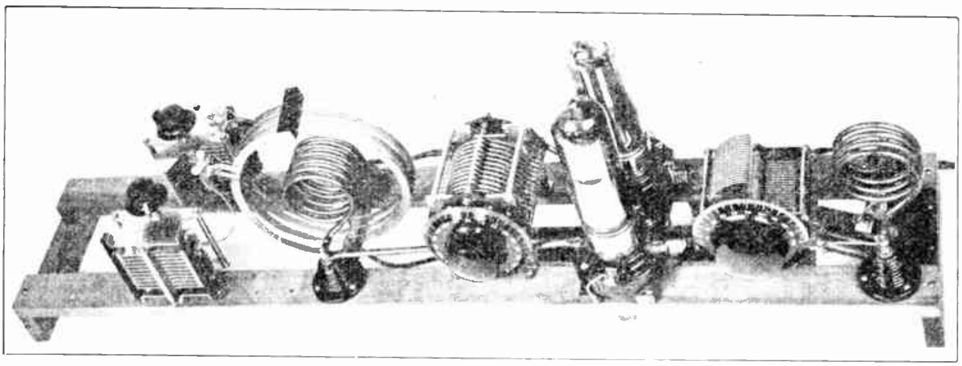
PUSH-PULL CIRCUITS

When two tubes are to be used together as oscillators or amplifiers they can be connected in parallel. It is much better, however, to arrange them in a push-pull circuit. The push-pull oscillator circuits have the advantage over single-tube circuits in that the effective tube capacity across the tuning circuits is reduced by half because the tubes are really in series across the tuning coil. It is this tube capacity that varies when the tube heats and causes frequency creeping. The push-pull circuits are therefore less susceptible to this trouble. This reduction of the effective tube capacity also results in less radio-frequency current flowing through the tube and reduced tube heating on that account.

The push-pull circuit can be a Hartley, a Tuned-grid Tuned-plate, or the tubes can be arranged as a push-pull amplifier. In all cases each tube operates on alternate half-cycles of the radio frequency in the same way as tubes in the push-pull amplifier in a broadcast receiver operate on alternate half-cycles of the audio-frequency current.

In operation the tuning circuits associated with the tubes are tuned in exactly the same manner as when a single tube is used.

One practical arrangement employing two UV-203-A tubes is illustrated. The tuned grid circuit is on the right of the tubes, the plate circuit being on the left. The construction of these circuits is similar to those of the transmitters described before. The antenna coil is the large coil surrounding the plate coil, the two feeder tuning condensers being mounted to the left of it. G.R. stand-off insulators are used for the coil mountings and ¼" copper tubing is used for the connections in the plate tank circuit and for the plate and grid coils. The values of these coils and the tuning condensers can be similar to those of the high-powered transmitter described, though it not necessary to use the ⅜"-diameter tubing for the plate coils since the power is so much lower. Other practical push-pull circuits are given.

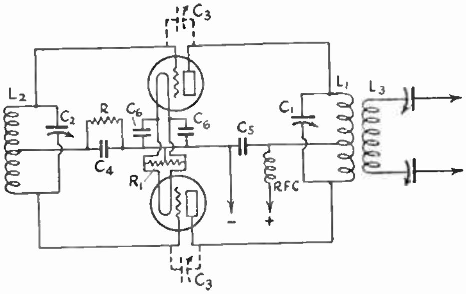


ONE SATISFACTORY LAY-OUT FOR A PUSH-PULL TRANSMITTER

From right to left can be seen the grid coil, grid tuning condenser, two UX-203-A tubes, plate tuning condenser, plate and antenna coils and the two feeder tuning condensers. The various fixed condensers and resistances are mounted underneath the frame.

CIRCUITS EMPLOYING SELF-RECTIFICATION

In order to avoid the necessity of a source of direct current for the plate supply, two tubes



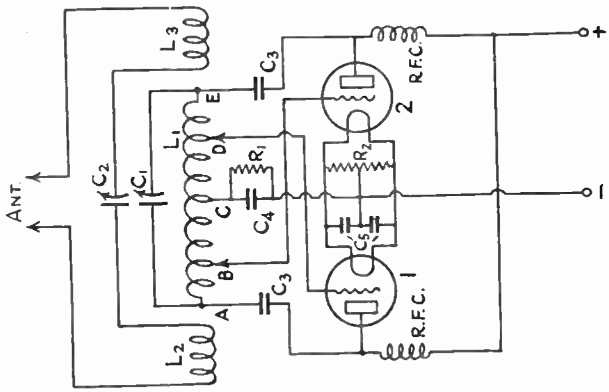
THE CIRCUIT OF THE PUSH-PULL TUNED-GRID TUNED-PLATE TRANSMITTER

C1—350 μμfd. transmitting-type variable condenser.
C2—1,000 μμfd. receiver-type variable condenser.
C3—25 μμfd. transmitting-type variable condensers, necessary only when low-capacity tubes such as the UX-852 are used.
C4, C5—300 μμfd. 5,000-volt fixed condensers.
C6—2,000 μμfd. receiver-type fixed condensers (500-volt rating).
L1, L2, L3—Plate, grid and antenna coils. The dimensions given for the previous transmitters will be suitable.
R—10,000-ohm grid leak.
R1—Filament center-tap resistor, 100 or 200 ohms.

can be connected so that when one lead from the high-voltage transformer is positive, during one half-cycle, one of the tubes oscillates; and when the other high-voltage lead is positive, during the other half-cycle, the second tube oscillates. Transmitters in which the oscillator tubes do their own rectifying in this manner are known as self-rectified transmitters. They have the advantage that a rectifier and filter system is unnecessary but they have the big disadvantage of emitting a heavily modulated signal which can cause a great deal of interference.

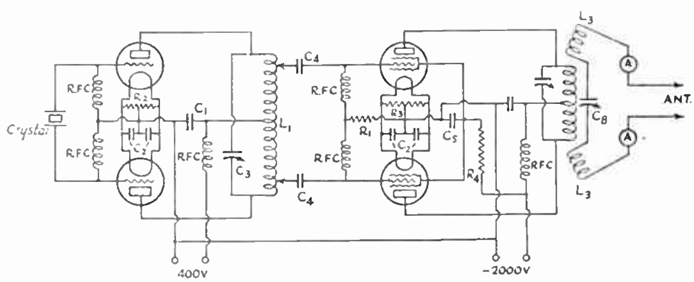
Any of the standard circuits can be modified to take two tubes operating in this manner, two plate by-pass condensers, two radio-frequency chokes in plate leads, and a center-tapped high-voltage transformer being necessary.

Should the amateur decide to use one of the self-rectified circuits it will be necessary for him to take extreme care in its tuning so that the signal will be the cleanest that it is possible to obtain from it. It is very easy to obtain a rough rattly note from a transmitter of this type and serious interference would be caused by it. With very careful tuning, however, the note can be given a clear musical quality and its interfering capabilities reduced considerably.



A PUSH-PULL HARTLEY CIRCUIT

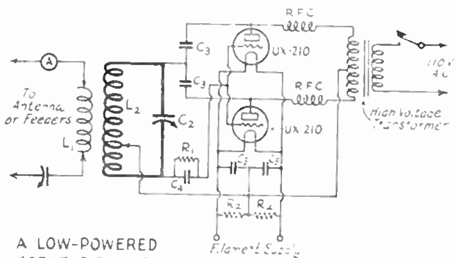
C1—500 μμfd. transmitting-type variable condenser.
C2—250 μμfd. transmitting-type variable condenser.
C3, C4—500 μμfd. 5,000-volt fixed condenser.
C5—2,000 μμfd. 500-volt fixed condensers.
R1—20,000-ohm grid-leak if UX-852 tubes are used.
R2—Filament center-tap resistor.



THE CIRCUIT OF A PUSH-PULL CRYSTAL-CONTROLLED OSCILLATOR-AMPLIFIER TRANSMITTER

In this particular circuit two UX-210 tubes are used as oscillators controlling two UX-860 amplifier tubes. The apparatus in the circuits of these tubes will be similar to that specified for the other transmitters. R1 is a variable grid leak with a maximum resistance of about 20,000 ohms. R4 has a resistance of 100,000 ohms and provides the proper screen-grid voltage. Any difficulties which may be experienced in understanding this circuit should be cleared up after a study of the section of this chapter dealing with crystal control work.

For more detailed information on this type of circuit than it is possible to include in this handbook, the reader is referred to an article on page 23 of *QST* for February 1929. This



A LOW-POWERED "SELF-RECTIFIED" TRANSMITTER

The symbols can be interchanged with those given in the circuit of the low powered single-tube transmitter

article deals particularly with the process of adjustment to obtain a good note and to avoid a "broad wave".

CRYSTAL CONTROL

In all of the transmitters so far described the frequency of the output has been set by a self-excited oscillator. The frequency of the radio-frequency current generated by such an oscillator is influenced by many factors and in this fact lies the chief disadvantage of all such transmitters. If the frequency of such oscillators were determined only by the tank coil and condenser values, little criticism could be leveled against them. Unfortunately, however, it is also influenced by variations in the antenna or output circuit, by heating of the elements of the tube, by changes in the filament voltage and by fluctuations in the plate voltage. Since these factors are never constants in the amateur station the frequency of the self-excited transmitter will always be unsteady to a more or less serious extent, depending upon the care with which the apparatus is built and adjusted. Then, aside from slow frequency changes, the self-excited transmitter will always be characterized by rapid frequency changes or frequency "flutter" unless the plate supply is a pure d.c. entirely free from any modulation or ripple.

It is because the crystal oscillator almost entirely overcomes these failings that its popularity is so rapidly increasing. The crystal—a thin piece of quartz, carefully ground—has the property of oscillating at a frequency which is determined almost exclusively by its thickness. When it is incorporated correctly in the transmitter circuits, the antenna can swing, the tubes can heat and the voltages fluctuate, but the output frequency will remain substantially constant. Ripple in the plate supply will cause a modulation in the amplitude of the transmitter output but it will not cause appreciable "fluttering" of the frequency. For this reason the note produced by the crystal-controlled transmitter, when it is adjusted correctly, will always be of a piercing musical character.

THE CRYSTAL

At present good crystals are no longer the very expensive and scarce items that they were a few years ago. Reliable and highly serviceable crystals are now generally available. With their coming much of the trickiness has gone out of crystal-control operation, and amateurs can now tackle the construction and operation of a crystal outfit without the fear (general at one time) that they were attempting something far above their heads—something that only the expert men could ever accomplish successfully.

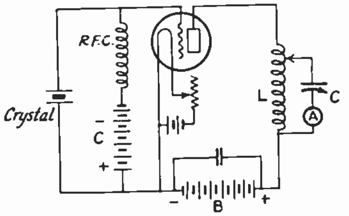
The cutting of oscillating crystals from the big quartz crystals is a process requiring much skill, experience and equipment. Some amateurs with the necessary facilities cut and grind their own crystals with a certain degree of success but the considerations involved are both complex and of great importance. For this reason it is assumed that the amateur will buy his crystal in its finished form, or, if he is particularly ambitious, in the form of a partially ground "blank".

The finished crystals are chiefly of two types—those cut in such a manner as to be susceptible to temperature changes to the least degree, and those cut and ground to permit them to be operated with the greatest possible power output. Those of the latter type are usually described as "power crystals". They are particularly suited for amateur work, where it is desired to obtain the highest power output for a given expenditure on tubes and their associate apparatus.

Tested "blanks" can be bought in various thicknesses much more cheaply than the finished crystals. Such "blanks" must be ground down with great care until they oscillate at the required frequency. Usually one side of the blank is "finished" and all grinding should be done on the reverse side in order to limit the probability of obtaining other than a flat surface. Grinding is usually accomplished by rotating the crystal in irregular spirals on a piece of plate glass smeared with No. 120 carborundum powder and water or kerosene. It is possible merely to bear down on the crystal with two fingers as the grinding proceeds, but there is a lesser chance of arriving at a concave or convex surface if the crystal is stuck to the underside of a small brass plate, the surface of which has been ground flat. Providing the brass surface and the "finished" surface of the crystal are both well ground, the crystal and the brass will adhere if both are moistened with kerosene.

It is possible to grid the crystal a little at a time and, by frequent checking in a test circuit, arrive at the desired thickness by the "cut and try" method. It is much better, however, to compute from the thickness factor (which will be supplied by reputable dealers in blanks) the approximate thickness which will be required to give the necessary frequency. Then, as the grinding proceeds, the thickness can be checked by means of a good micrometer such as the Starrett No. 218 C-½". This tool also can be used to make certain that the thickness of the crystal is the same at all points—that bumps or hollows are not being ground on it.

Even with this procedure it is desirable to check the frequency from time to time. The checking can well be done by inserting the crystal in a circuit similar to that labeled as the "Elementary Crystal Circuit". The output of the crystal oscillator can then be picked up in the receiver and its frequency checked against stations of known frequency in much the same manner as the frequency of the self-excited transmitter is checked with the aid of a monitor. A detailed explanation of this process will be found in Chapter IX. When the frequency of the crystal is found to be approaching the desired value it is well to use a finer grade of carborundum powder. The FF and FFF grades are suitable for the final grindings.



ELEMENTARY CRYSTAL CIRCUIT

MOUNTING THE CRYSTAL

Even the best crystals may operate poorly if the mounting is not all that it should be. The best crystals may be purchased ready-mounted in specially-designed holders. The specialists who grind and finish the crystals naturally are familiar with the requirements of the mounting and much trouble will often be avoided by purchasing the crystal and mounting complete.

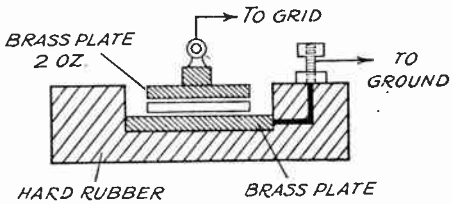
The simplest way for the amateur to rig his own mounting is to make up two flat brass plates, the crystal being placed on one of them and the other being arranged to rest on the crystal with no more pressure than that provided by the weight of the brass. The plates should preferably be turned flat in a lathe and then ground to a fine finish. Successful plates can be made, however, by cutting them with a hack-saw from ⅛"-thick brass plate, then grinding them in much the same way as the crystal would be ground. A suitable size for the plates is about 1" square.

Though it is possible to operate the crystal between such plates merely by arranging the plates and the crystal in the form of a sandwich on a piece of insulating material or on the table top it is a very much better plan to make up some form of holder out of which the crystal or plates cannot be jarred. The arrangement illustrated on this page is one suitable type. Connection to the upper plate can be made by means of a very light leaf of spring brass but a small spiral of very fine copper wire usually is more satisfactory. This wire can be soldered to the plate if care is taken to use an absolute minimum of heat in the soldering process in order to avoid warping the plate.

THE OSCILLATOR CIRCUIT

In operation, the two metal plates between which the crystal is mounted are connected between the grid and filament of the crystal oscillator tube. Bias is then supplied to the grid through a radio-frequency choke. The plate circuit of the oscillator consists of a coil and condenser so proportioned as to tune to the frequency of the crystal. In some arrangements in which the frequency of the crystal is to be doubled in a succeeding amplifier, an additional tank circuit is included in series with that just mentioned. This tank is tuned to twice the frequency of the crystal.

Probably the most generally-used tube for the oscillator is the UX-210. The UX-171-A, the UX-112-A and the UV-203-A or other oscillators of similar characteristics are also satisfactory under certain conditions. In cases where the voltage on the plate of the tube is of the order of 150, the UX-112-A probably is the most satisfactory tube. When a "power" crystal is operated with voltages between 300 and 400 the UX-210 is a splendid tube for the purpose. The UX-203-A is used with voltages between 400 and 500 in cases where a particularly good "power" crystal is available. Most crystals, under these conditions, would be fractured and so made inoperative. With a good crystal it is not difficult to obtain outputs from the crystal tube of the order of 5 to 25 watts depending on the tube used. The oscillator can therefore be operated to feed the antenna system direct for low-power work. Such an arrangement, however, has the disadvantage that the full output can be utilized only at the frequency of the crystal. Some output is available on the harmonics of the crystal frequency but it probably would be only a fraction of that to be obtained on the fundamental frequency. This energy can be put to service by tuning the antenna system to, say, the second harmonic, but it is very much preferable to introduce it into the grid circuit of an amplifier tube in which the power can be boosted before the antenna system is reached.



THE 4XE CRYSTAL HOLDER

The use of one or more amplifiers after the crystal oscillator is quite standard practice in crystal-control work. Not only do they permit the use of a high powered tube to feed the antenna system but they also make it possible to double the frequency of the crystal several times if necessary, so as to allow operation in any of the amateur bands.

POWER AMPLIFIERS

The amplifiers used after the crystal oscillator for amateur work can be considered as being of two types. Those in which the output frequency is the same as the input frequency are known as "straight" or "fundamental" amplifiers. In cases where the output of the amplifier is twice the frequency of the output of the preceding tube the amplifier is said to be a "frequency doubler" or merely a "doubler". Common practice is to use a crystal with a frequency within the limits of the 1,715-kc. or the 3,500-kc. band. The crystal tube is then followed by one or more fundamental amplifiers for operation at the frequency of the crystal. For operation on the higher-frequency bands the crystal tube is followed by a sufficient number of frequency doublers to increase the frequency to the required value and then preferably by a final fundamental amplifier to feed the antenna. It is usually unsatisfactory to operate the amplifier feeding the antenna as a doubler.

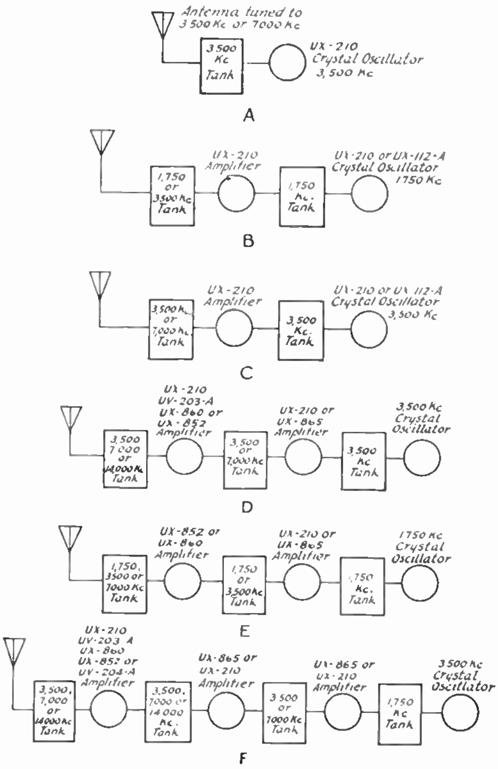
This practice of using a single crystal to permit operation in any band is somewhat limited by the fact that all the amateur bands are not in complete harmonic relation. From the chart of the amateur frequencies in Chapter II it can be seen that only small sections of the amateur frequency bands are harmonically related. The frequency of a crystal which will permit operation in any band must therefore lie between 1,750 and 1,800 kc. If operation is required on all bands except the 1,715-kc. band the crystal must have a frequency between 3,500 and 3,600 kc. In the discussion of possible combinations of tubes for operation on various bands it will therefore be assumed that the crystal used is one having a frequency determined by these considerations.

AMPLIFIERS

The amplifying tubes following the crystal oscillator can either amplify the fundamental frequency supplied to their grid circuits or one of the harmonic frequencies generated by the previous tube. When the amplifiers are operated as fundamental amplifiers they must be neutralized (unless screen-grid tubes are used), since the grid and plate circuits are then tuned to the same frequency. When they are operated as harmonic amplifiers, neutralization is not necessary but precautions must be taken to make certain that the harmonic content in the tank circuit from which the tube is excited is sufficient to give ample excitation.

Several possible combinations of tubes and tank circuits are given in the diagram so titled.

At *A* is shown the simplest practical form of crystal-controlled transmitter. It consists of a UX-210 crystal oscillator coupled to the antenna system without any intermediate amplification. The plate circuit of the tube must be tuned to the frequency of the crystal in order that it may oscillate. The antenna circuit, however, may be tuned either to the fundamental frequency or to the second harmonic, in this case, 7,000 kc. Of course, the energy available on the fundamental frequency will not be very great and that on the second harmonic much less. The transmitter would serve only for work requiring very low power.



SEVERAL POSSIBLE TUBE COMBINATIONS IN THE CRYSTAL-CONTROLLED TRANSMITTER

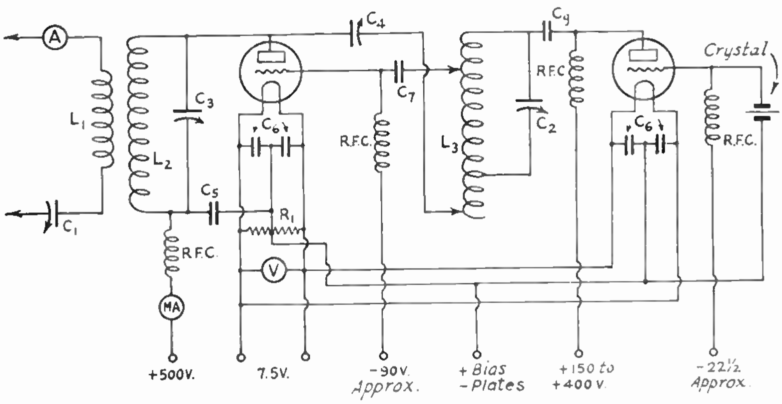
In the Diagram *B* the crystal oscillator is shown operating on 1,750 kc. The tank in its plate circuit is tuned to the crystal frequency but in this case it feeds the grid circuit of an amplifier. When this amplifier is to operate as a fundamental amplifier its plate tank is tuned to the crystal frequency, the antenna circuit also. Under these conditions the tube must be neutralized since otherwise it would oscillate on its own accord as a tuned-grid tuned-plate transmitter. For operation in the 3,500-kc. band the tank of the amplifier is tuned to that frequency, its grid being excited from the

3,500-kc. energy existing in the crystal-tube tank in the form of the second harmonic of the crystal frequency. The important point to observe is that when operating as a fundamental amplifier the tube has available for excitation all of the radio-frequency energy in the tank of the preceding tube; but when doubling its excitation is obtained only from the second-harmonic energy. The energy in this harmonic is dependent upon the arrangement and adjustment of the tube generating it and, consequently, when doubling, these adjustments are important ones if the excitation is to be held up to the desirable level. The most important of the factors influencing the harmonic content are the adjustment of grid bias and the ratio of inductance to capacity in the tank. In general, the highest possible value of inductance and the lowest value of capacity should be used in tank circuits feeding doublers. These points will be treated in greater detail in the discussion of adjustments and tuning.

doubler. As suggested on the diagram a UV-203-A, a UX-860 or a UX-852 could well be used in this position. For 14,000- kc. operation both the first and second amplifiers would be doublers and this, in all probability, would prove a disadvantage. As mentioned earlier, it is usually unsatisfactory to operate the tube feeding the antenna as a doubler. For 14,000-kc. operation the output tube would be operated in this manner.

Diagram *E* shows the same transmitter operating from a 1,750-kc. crystal. In this case operation is possible on the 1,750-, 3,500- and 7,000-kc. bands. As in the previous case the output tube will have to be a doubler for operation on the latter band.

In the arrangement shown at *F* the output tube is always operated as a fundamental amplifier. This is made possible by the use of an additional amplifier using a UX-210 or UX-865 tube. Operation in this manner has the added advantage that sufficient excitation



THE CIRCUIT OF THE OSCILLATOR-AMPLIFIER TRANSMITTER

described earlier in the chapter, modified for crystal control

The constants of the apparatus correspond with those of the self-excited oscillator-amplifier transmitter with the exception of C2 and L3, C2 can be of 250 μμfds., while the coil L3 will be large enough to tune, with that capacity, to the frequency of the particular crystal used. The wire used in L3 need not be heavier than about 12 or 14 gauge

To return to the diagram *B*, previously mentioned, we find that operation with it is not practical on other than the 1,750- and 3,500-kc. bands. The use of a 3,500-kc. crystal as shown in Diagram *C* makes operation possible on the 3,500- or 7,000-kc. bands but the arrangement still has the limitation of operation in two bands only. In addition, of course, it has the limitation of a low power output. The arrangement *D* indicates the manner in which an additional amplifier would be fitted to make operation possible in three bands. In this case the crystal frequency is 3,500 kc. and the bands in which operation may be had are 3,500, 7,000 and 14,000 kc.

The second amplifier may be a UX-210 but sufficient excitation will be available from the first amplifier, when it is correctly adjusted, to drive a higher-powered tube even if it is a

will be available from the tank of the second amplifier to drive a tube of any power up to about 250 watts, since the energy on the fundamental frequency of the tank is always used.

A great many tube combinations other than those shown are practical but it would be impossible to treat them all. From these few typical examples the amateur should be able to plan other arrangements to suit his own particular needs and the apparatus available to him.

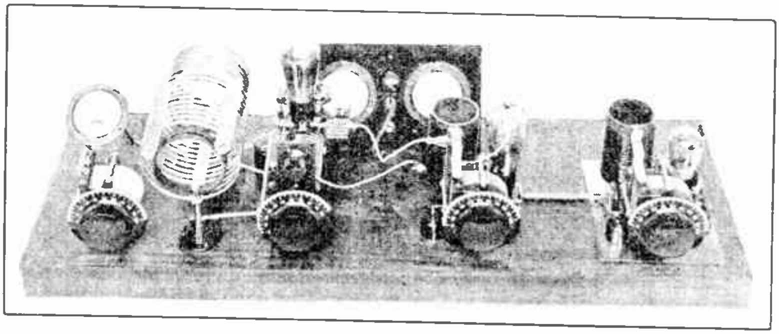
By the use of a "power" crystal and high voltages on the crystal tube, or by the use of special circuits, it is often possible to obtain sufficient energy in the crystal tank to drive a UX-852 or even a UV-204-A tube directly. Such arrangements, however, are limited to operation on one band only (possibly two) and have the disadvantage that the crystal is being overworked. Under these conditions the crystal, if it is not cracked, is at least likely to operate erratically. In other words, though the intermediate amplifiers shown in the diagrams are not always essential to provide excitation for the higher-power tubes they are necessary to permit the frequency doublings required for operation on the higher-frequency bands.

CONSTRUCTIONAL DETAILS

The structural arrangement of the crystal-controlled transmitter need not differ from that employed in any other type of set. The only important requirement is that the oscillator and each amplifier be treated as a separate unit, the inductances of which must not be coupled with those in other parts of the circuit. In the case of a low-powered transmitter the same construction can be followed as that described for the master-oscillator-amplifier transmitter earlier in this chapter. The circuit of that transmitter, modified for crystal control, is given. It can be seen that it differs only in the arrangement of the oscillator circuit.

With a 3,500-kc. crystal it would be possible to operate this transmitter on 3,500 kc. by tuning both tank circuits to that frequency and neutralizing the amplifier in the manner indicated on the circuit diagram. For 7,000-kc. operation the amplifier tank and antenna circuits would be tuned to that frequency, neutralizing then being unnecessary. With the amplifier operating as a doubler, however, (as would be the case under these adjustments) it is possible that the exciting voltage generated by the crystal tube on the second harmonic of its fundamental frequency will be insufficient to swing the grid of the amplifier tube fully. A power crystal operated with the normal plate voltage on the crystal tube would not be so limited but other crystals operated at lower voltages might be. In such cases the amplitude of the second harmonic can be increased and the operation of the doubler tube improved by using two tank circuits in the plate of the crystal oscillator—one tuned to the fundamental of the crystal and the other tuned to the second harmonic (twice the fundamental frequency). The voltages developed across the latter tank are utilized to feed the amplifier grid when doubling.

A transmitter of this type can be operated at four times the crystal frequency (the 14,000-kc. band with a 3,500-kc. crystal) by leaving the amplifier tank tuned to the second harmonic (7,000 kc. in this instance) and then tuning the antenna circuit only to the second harmonic of the amplifier tank frequency. If the amplifier is heavily biased there would be some worth-while energy available on this frequency (14,000 kc.) and the antenna could be excited by it. However, this energy would be only a small fraction of that available from the tube operating as a straight amplifier and the arrangement could not by any means be considered an efficient one. Much more desirable procedure is to add to the amplifier tubes in the transmitter so that the final tube can be operated as a straight amplifier with the antenna tuned to the frequency on which it is operating. One type of transmitter which permits such operation is that illustrated in the photographs which follow.

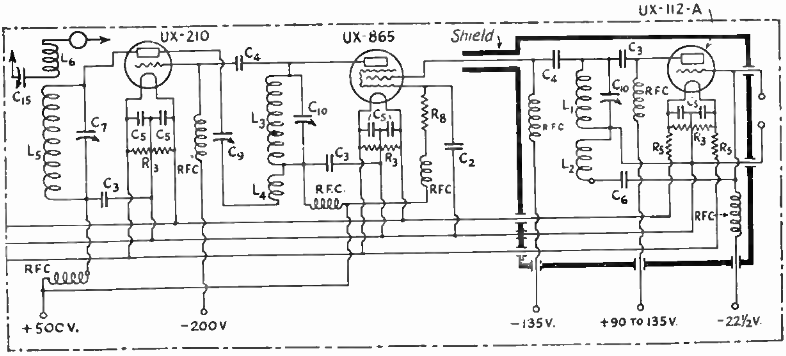


A CRYSTAL-CONTROLLED TRANSMITTER
which can be operated at high efficiency on at least three bands with any one crystal

The first illustration shows a three-tube unit comprising a crystal oscillator (which can be converted to a self-excited oscillator) and two amplifiers. The intermediate amplifier in this particular transmitter is of the screen-grid type—which does not require neutralization. A three-electrode tube may be used in its place if some neutralizing arrangement is provided whenever the tube is operating as a straight amplifier.

The constructional methods employed in this transmitter are similar to those shown and described earlier in this chapter for the oscillator-amplifier transmitter. The oscillator and each amplifier stage are assembled on the base-board as separate units, sufficient spacing being provided between the various inductances to avoid harmful coupling between their fields. All radio-frequency wiring in the transmitter is above the base-board while battery leads, after they have been by-passed and fitted with their radio-frequency chokes, run down through the base and thence to the terminals at its rear edge.

modates L1 and L2. For crystal operation of the oscillator, L2 is removed and a new L1 (without any additional shunt condenser) is plugged into place. Then the crystal is plugged into the two terminals shown at the extreme right of the diagram. When operating with the crystal the shield is not essential.

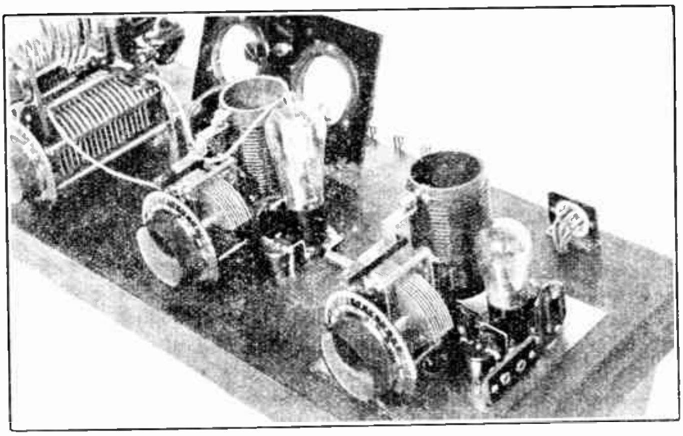


THE CIRCUIT OF THE THREE-TUBE CRYSTAL-CONTROLLED TRANSMITTER

C2—1000-μμfd. 500-volt fixed condensers.
C4—250-μμfd. 500-volt condensers.
C5—2000-μμfd. 500-volt condensers.
C6—500-μμfd. 500-volt condensers.
C7—350-μμfd. double-spaced transmitting-type variable condenser.
C9—23-plate midget condensers with plates double-spaced.
C10—350-μμfd. receiving type variable condensers.
C15—500-μμfd. receiving type variable condenser.
R3—100-ohm center-tapped resistors.
R5—5-ohm fixed resistors.
R8—25,000 ohm fixed resistor.

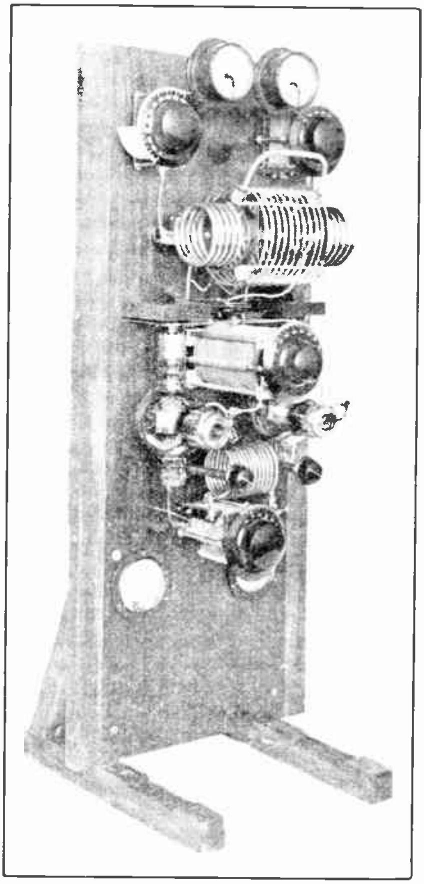
L1 and L3 wound on 3" outside-diameter bakelite tubing with 14-gauge enameled antenna wire. Approximately 18 turns will be required when the tank is tuned to the 3,500-kc. band; 10 turns for the 7,000-kc. band; 5 turns for the 14,000-kc. band. L5 may be wound for the different band in accordance with the specifications for the plate tank of the UX-210 in the self-excited oscillator-amplifier transmitter given earlier in this chapter. When the oscillator in this transmitter is self-excited L1 is of 6 turns of 14-gauge wire, L2 of 4 turns, and a 500-μμfd. fixed condenser is connected across those ends of the coils which run to grid and plate of the oscillator.

In studying the wiring diagram with the illustration of this unit it will be seen that the oscillator is at the right. When operating as a self-excited oscillator the inductances L1 and L2 are both in place and a shield (indicated on the diagram by the heavy line) is placed over the apparatus of the oscillator to avoid possible frequency changes resulting from body-capacity effects. A High-C tank is, of course, desirable for self-excited work and this is made possible by using a high quality mica-dielectric fixed condenser of 500 μμfds. connected between the grid and plate ends of the inductances. This condenser is permanently attached to the plug-in coil form which accom-



A CLOSE-UP VIEW
showing constructional details of the transmitter

The first amplifier is a UX-865, the lead to its control grid being run through a piece of 3/8″-diameter copper tube with which connection is made to the shield over the oscillator. The screen-grid amplifier is provided with the usual form of plate tank coil and condenser and differs from the amplifiers previously described only in the provision of a series



A HIGH-POWERED "PUSH-PULL" AMPLIFIER which can be excited by the three-tube unit described

resistance R8 to drop the plate voltage for the screen-grid, together with its associate by-pass condenser C2 and radio-frequency choke.

The third tube is a UX-210. In this particular unit it is provided with a double-spaced transmitter-type tank condenser and a tank inductance of heavy conductor. These precautions were taken since it was planned to Heising-modulate the tube for 'phone work, in which case the plate tank must withstand, during modulation, high voltages and high output power. The antenna or feeder tuning condenser and the antenna or feeder ammeter are mounted at the left of the base-board, the antenna coupling coil being fitted immediately behind the tank coil of the UX-210.

One very satisfactory arrangement of the meters is illustrated in this unit. The filament voltmeter and the plate milliameter are those to be seen on a small panel at the back of the base-board. Between them are three jacks connected in the plate circuits of the three tubes. The milliammeter is connected through a flexible lead to the plug, and the plate current of any of the tubes can then be read merely by placing the plug in the particular jack desired. The knob seen in the upper jack is fitted with a small length of bakelite rod. This rod is pushed into the jack in the plate circuit of the last amplifier in order to open the jack and disconnect the plate supply during the process of neutralization.

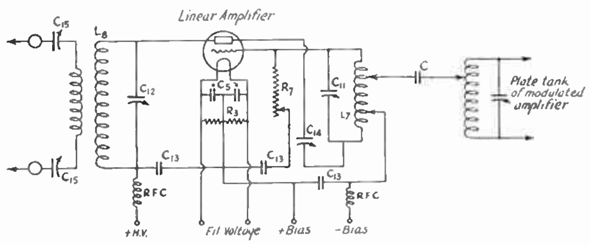
TUNING THE TRANSMITTER

The tuning and adjustment of a transmitter of this or any similar type is not the problem that some amateurs consider it to be. In fact, many amateurs now insist that the tuning of a crystal-controlled transmitter is much more simple and straightforward than the tuning of a self-excited transmitter. The most important aid to tuning a multi-tube transmitter is, without doubt, a tuning lamp—two turns of fairly heavy wire, about 3 inches in diameter, connected to a flash lamp bulb. This lamp, when its turns are coupled to one of the tank coils, is illuminated when there is current in the tank and the amount of the current can be well estimated by the coupling between the tuning lamp and the tank necessary to give a certain degree of illumination. At a fixed coupling the lamp will indicate the greatest current in the tank when it is illuminated to the greatest brilliancy.

The first step in the tuning is to switch on the oscillator and tune its plate tank condenser until the maximum current is indicated by the tuning lamp. If the crystal is of the type permanently fitted in an enclosed mounting it should oscillate just as soon as the correct tank adjustment is obtained. If, however, the crystal is mounted in the open and has been subjected to some handling, it is almost certain that it will require cleaning with carbon tetrachloride, "Carbona" or some other grease solvent. Also it may require "jiggling" into different positions between the plates of the holder. Aside from the tuning-lamp indication, it will be found that the plate current of the crystal tube takes a sudden drop when oscillation starts. Both of these indications can be put to service in obtaining the adjustments for correct operation of the crystal-oscillator unit. When the first amplifier is to be operated as a straight amplifier the adjustment of the oscillator tube bias is not of particular importance providing it is made sufficient to limit the plate current to a reasonable value. When the amplifier is a doubler, however, it is important to operate the crystal tube with the highest possible bias. It will be found that there is a certain bias value above which the tube fails to oscillate. It is desirable to operate as near to this point as possible in order to accentuate the second harmonic in the output.

The next step is the adjustment of the bias of the first amplifier. It should be made with the plate supply disconnected from the oscillator or with the "oscillator" so detuned that it is not oscillating. When the amplifier is to operate as a straight amplifier the bias may be increased only to the point where no plate current is obtained, but when it is to be a doubler the bias should be brought first to this "cut-off" point and then should be run to about twice that value. At this stage the oscillator should be switched on and by means of the tuning lamp, the plate tank of the amplifier should be adjusted until maximum tank current is indicated. At this point the plate current of the amplifier tube will be found to be the normal rated current if the plate voltage is normal and if the excitation arriving from the crystal tube is sufficient. Insufficient plate current under these conditions is definite indication that the excitation is low. In an intermediate amplifier, however, this may not be serious since the output of the amplifier may be ample to excite the next tube even if it is operating far below its normal rated power. With the high bias values used in doubling to accentuate the second harmonic, it is, indeed, rarely possible to drive the plate current of the intermediate amplifier to its rated value. It is quite possible, however, that the amplitude of the second harmonic is then higher than it would have been with a lower bias and higher plate current.

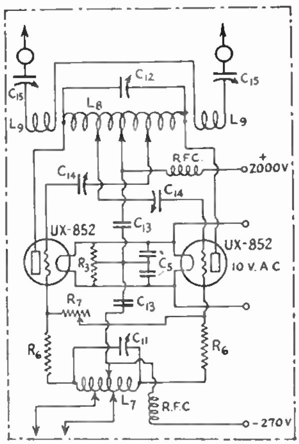
With the intermediate tank current at maximum, the third tube may now be neutralized. This is accomplished by opening the plate circuit of that tube and adjusting the neutralizing condenser and the tank condensers until



A SINGLE-TUBE HIGH-POWERED AMPLIFIER

The values of the apparatus in this unit also correspond with those given under the complete circuit of the radiotelephone transmitter

no tank current is to be detected in the output tank even when the circuits are in resonance. The process is precisely that described earlier in this chapter for the oscillator-amplifier transmitter. With the neutralizing accomplished, the bias on the third tube should then be adjusted. If the tube is to be used as a doubler, or if it is to be Heising-modulated, the bias should be run to the "cut-off" point and then doubled as in the previous tube. If it is to be operated as a straight amplifier, sufficient bias to bring the plate current to



THE CIRCUIT OF THE "PUSH-PULL" AMPLIFIER

The values of the apparatus in this unit will be found under the complete diagram in which this apparatus is utilized for radiotelephone operation

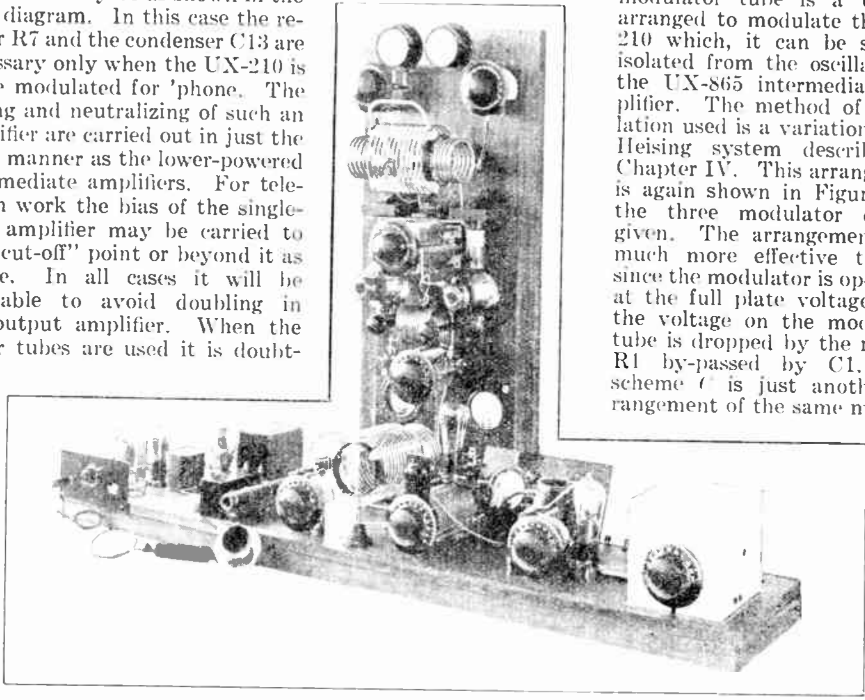
zero (to cut-off) is desirable. In this instance, as before, the bias is always adjusted with the oscillator switched off or taken out of oscillation.

HIGH-POWERED AMPLIFIERS

Aside from being a splendid low-powered transmitter operable at high efficiencies on at least three frequency bands with any one crystal, the unit just described will serve to excite almost any of the larger tubes available to the amateur. With the output amplifier operating as a straight amplifier (at the same frequency as the UX-210) a UV-204-A or a pair of UX-852 tubes may be excited to operate at high efficiency at their rated input. The arrangement of one type of amplifier suited for the work is shown in the illustration of the vertical panel holding two UX-852's arranged in "push-pull". The wiring diagram also is given. For telegraph operation the resistor **R7** is not required. Its use in 'phone work is to be detailed later.

In operation, the bias of such an amplifier is the first adjustment. With no excitation being supplied to the grids of the tubes, it is adjusted to "cut-off" or slightly beyond that point. Excitation is then supplied by connecting the antenna coil terminals of the three-tube unit to the taps indicated on the inductance L7 of the High-C tank L7-C11. The position of the taps on L7 and the coupling of the "antenna" coil to the plate tank of the UX-210 serve to provide adjustment of the grid excitation. It should be increased to the point where normal plate current for the tubes is obtained when all circuits are tuned.

When a single tube is used in the high-powered output amplifier the arrangement may be as shown in the next diagram. In this case the resistor R7 and the condenser C13 are necessary only when the UX-210 is to be modulated for 'phone. The tuning and neutralizing of such an amplifier are carried out in just the same manner as the lower-powered intermediate amplifiers. For telegraph work the bias of the single-tube amplifier may be carried to the "cut-off" point or beyond it as before. In all cases it will be advisable to avoid doubling in the output amplifier. When the larger tubes are used it is doubtful if the UX-210 would supply sufficient excitation to permit doubling at good efficiency at any time.



A COMPLETE MODERN AMATEUR 'PHONE TRANSMITTER

Though this outfit is much more complex than the average transmitter is likely to be, it serves to illustrate most of the principles discussed in the text

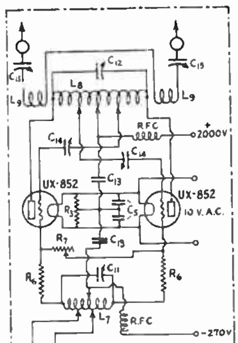
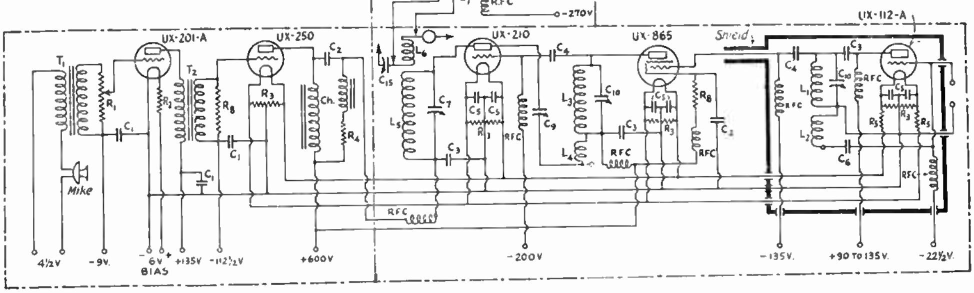
RADIOTELEPHONE TRANSMISSION

Any amateur transmitter with a d.c. plate supply and an r.f. output not appreciably modulated by it may be modulated for 'phone operation providing it is tuned to one of the frequency bands in which 'phone is legal. However, the self-excited transmitter and some oscillator-amplifier transmitters are not really satisfactory for this work. If the carrier of such transmitters is modulated at all fully, the frequency of the output varies with or is "fluttered" by the modulation. Bad distortion and serious interference usually result. For completely satisfactory 'phone transmission the frequency of the output should be set by an oscillator well isolated electrically from the tube being modulated, and the oscillator should preferably be crystal-controlled. The crystal-controlled transmitter last described provides an illustration of good modern practice in 'phone work when fitted with a modulator. The circuit of a complete radiotelephone transmitter is given. It comprises the three-tube crystal oscillator and intermediate amplifier unit, the "push-pull" output amplifier, and a modulator unit. The modulator tube is a UX-250 arranged to modulate the UX-210 which, it can be seen, is isolated from the oscillator by the UX-865 intermediate amplifier. The method of modulation used is a variation of the Heising system described in Chapter IV. This arrangement is again shown in Figure *C* of the three modulator circuits given. The arrangement *B* is much more effective than *A* since the modulator is operating at the full plate voltage while the voltage on the modulated tube is dropped by the resistor R1 by-passed by C1. The scheme *C* is just another arrangement of the same method, though a separate choke is provided for the modulator and modulated tube. The circuit *B* or *C* may be used with a great many combinations of tubes, some of these being shown in the full-page set of diagrams. In any of them the general arrangement of the apparatus and the adjustment and operation of it will be similar to that of the crystal-controlled transmitter described. The only important differences are in the adjustment of the bias and grid excitation of any tubes in the transmitter which come after the tube being modulated. Tubes amplifying the modulated energy must operate as linear amplifiers in just the same way that the audio-frequency amplifiers of a broadcast receiver operate. Also, the output of the final amplifier—if the modulated tube is before it—must have its output reduced to one quarter of the maximum value before modulation is applied. The output will have been reduced to one quarter when the antenna current has been halved and it is this halving of the antenna current which provides the most useful indication. In tuning the output stage the grid excitation is first increased to the point where maximum antenna current is obtained. The excitation is then decreased by decreasing the resistance of the grid resistor R7 until the antenna current has dropped to half of its former value. When the previous amplifier is then modulated fully, its output will swing from zero to four times normal. This means that the excitation of the final amplifier will swing between the same limits. The output power of the final amplifier will be able to follow this excitation and swing from zero to four times normal only if "normal" is one quarter of maximum power. This is why the output is reduced before modulation is applied.

If the final amplifier is operating after the modulated tube (as a linear amplifier) and if it is a single tube, its bias must be adjusted to a point where the plate current is the same irrespective of whether excitation is applied or not. This bias value, of course, will be considerably below the value used to give plate current "cut-off" as in telegraph work. When the amplifier is two tubes in "push-pull", the bias may be operated at "cut-off" for either 'phone or telegraph. A "push-pull" amplifier is capable of operating as a linear amplifier under these conditions.

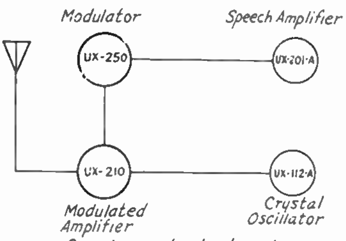
The adjustment of the modulator unit consists chiefly in varying the bias on both the speech amplifier and the modulator to the point where no appreciable flutter of plate current can be observed even when the microphone is spoken into loudly.

The microphone is an important item in any 'phone transmitter. The ordinary hand microphones usually are good enough for speech transmission but the more expensive "double-button" types are, of course, to be preferred. With any microphone, however, it is important to avoid speaking too closely or directly into it. It is desirable to adjust the speech amplifier circuits so that it is only necessary to speak in a low tone of voice to give full modulation in the transmitter. The condition of full modulation is difficult to gauge but one good indication is the antenna ammeter. With the modulation

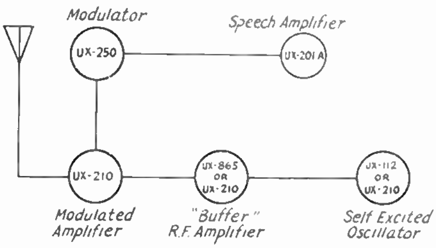
THE WIRING OF THE COMPLETE 'PHONE TRANSMITTER ILLUSTRATED

C1—1-μfd. 300-volt condensers.
C2—1-μfd. 1000-volt condenser.
C3—1000-μμfd. 500-volt condensers.
C4—250-μμfd. 500-volt condenser.
C5—2000-μμfd. 500-volt condensers.
C6—500-μμfd. 500-volt condenser.
C7—350-μμfd. transmitter-type variable condenser.
C9—A 23-plate midget condenser with plates double-spaced.
C10—350-μμfd. receiver-type variable condensers.
C11—1000-μμfd. receiver-type variable condenser.
C12—250-μμfd. "treble-spaced" transmitting condenser.
C13—1000-μμfd. 500-volt condensers.
C14—Receiver-type variable condensers cut down to 3 plates.
C15—500-μμfd. receiver-type variable.
R1—200,000-ohm potentiometer.
R2—4-ohm fixed resistor.
R3—100-ohm center-tapped resistors.
R4—5000-ohm resistor to carry 100 ma.
R5—5-ohm fixed resistors.
R6—100-ohm fixed resistors.
R7—10,000-ohm "Adjustat."
L1—16 turns of 14-gauge wire on 3" diameter tube, as plate coil for crystal operation, 6 turns of same wire for plate coil of self-excited oscillator.
L2—4 turns of same wire. When running as a self-excited oscillator, a 500-μμfd. fixed condenser is shunted across the extremities of L1-L2, i.e., from grid to plate.
L3—20 turns of 14-gauge wire space-wound on 3" diameter tubing.
L4—15 turns of 22-gauge d.c.c. wire on 2" diameter tubing mounted inside lower end of L3.
L5—3500-kc. inductance.
L6—6 turns of ⅜" outside-diameter copper tubing, turns 1" inside diameter.
L7—10 turns of 3/16" diameter copper tubing, turns 3" inside diameter.
L8—3500-kc. inductance.
L9—Each 5 turns of ¼" diameter copper tubing, turns 3" inside diameter.
T1—High quality audio transformer with new primary of 250 turns of 30-gauge wire. Any modern high-quality microphone transformer undoubtedly would be better.
T2—Audio-frequency transformer.
Ch.—Double "B-eliminator" choke.



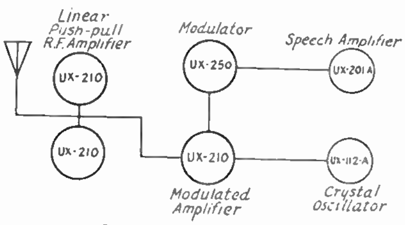
Carrier output 7½ watts
Peak modulated output 30 watts

A



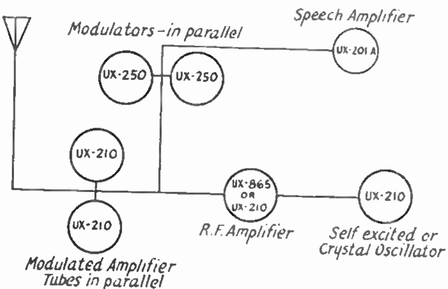
Carrier output 7½ watts
Peak modulated output 30 watts

B



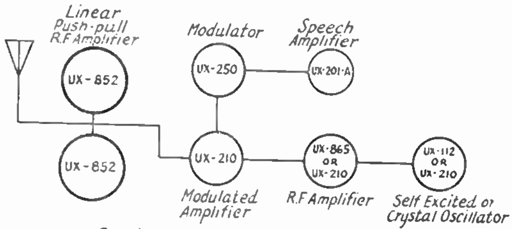
Carrier output 3.7 watts
Peak modulated output 15 watts

C



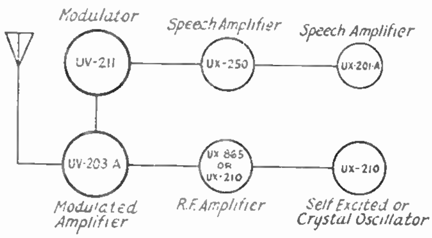
Carrier output 15 watts
Peak modulated output 60 watts

D



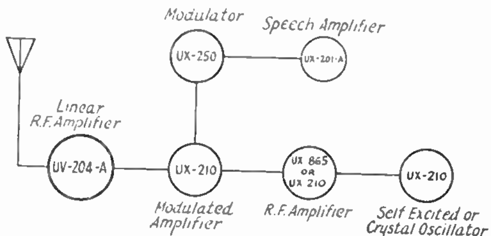
Carrier output 37 watts
Peak modulated output 150 watts

E



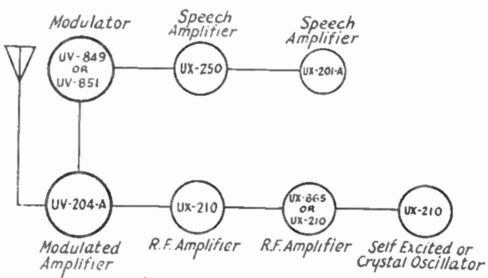
Carrier output 50 watts
Peak modulated output 200 watts

F



Carrier output 62.5 watts
Peak modulated output 250 watts

G



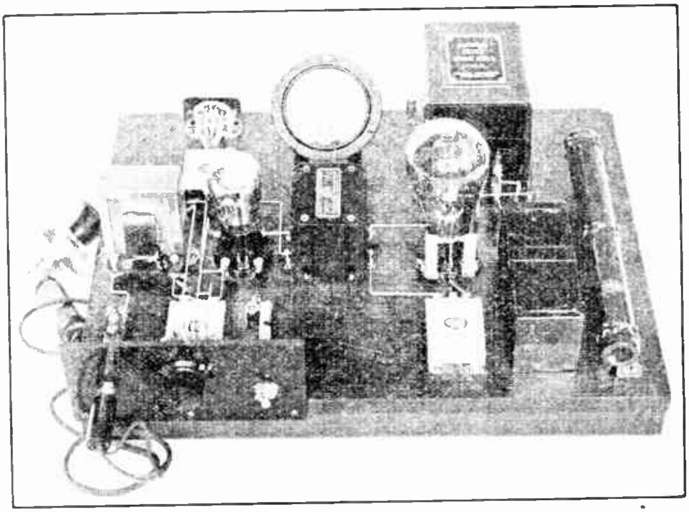
Carrier output 250 watts
Peak modulated output 1000 watts

H

systems discussed, the antenna current will rise by about 25% of its steady value when a note is hummed into the microphone providing the modulation is fairly complete and providing there is no serious distortion. Distortion is best detected by listening, inside the station, with a pair of 'phones connected in series with 20 or 30 turns of wire and a crystal detector. The coil of this 'phone monitor usually will give sufficient "pick up" if it is placed in the vicinity of the antenna or feeder leads.

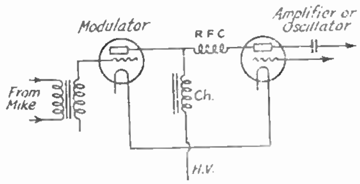
An excellent article on amateur radiotelephone transmission, with detailed explanation of the problems of modulation, appeared in *QST* for April 1929. Valuable information on adjustment appeared in *QST* for August 1929.

For successful amateur radiotelephone work it is very necessary that a suitable receiver be used. A receiver fitted with a "peaked" audio-frequency amplifier will be quite unsatisfactory on account of the distortion introduced by the "peaked" stage. Many amateurs have success with receivers of the type described in Chapter V fitted with good audio-frequency transformers and with bias on the audio tubes correctly adjusted for distortionless amplification. However, a high degree of radio-frequency selectivity is very valuable in amateur 'phone work. Though tuned radio-frequency amplifiers operating on the incoming frequency are not practical, the desirable selectivity can be obtained readily by the use of a super-heterodyne. A full description of one receiver of this type appeared in the March 1929 issue of *QST*.

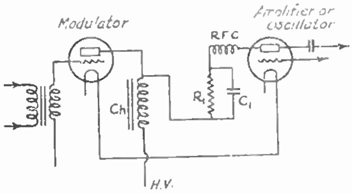


THE MODULATOR AND SPEECH AMPLIFIER UNIT

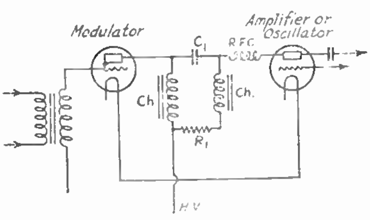
On the small panel is the microphone jack, the gain control and the microphone switch. Behind it, the microphone transformer and speech amplifier can be seen. The modulator tube with its associate apparatus is at the right.



A



B



C

CONSTUCTIONAL AND OPERATING HINTS

There is almost an infinite number of possible variations in the circuits, the apparatus and its arrangement in amateur transmitters. We could fill this Handbook with nothing more than description of effective transmitters and the methods of building and adjusting them. It is impossible, however, to give more than a few typical examples from which the amateur can gain a sufficiently general idea to enable him to make modifications to suit his own ideas or the apparatus available. We will now treat some miscellaneous considerations, ideas and methods but we cannot possibly cover the entire field. New schemes, apparatus and operating methods are being evolved constantly and if the amateur would be familiar with them and improve his station continually with their aid we can only suggest that he read and study the magazine *QST* each month.

TUBES IN PARALLEL

One vacuum tube is shown in most of the circuits we have drawn. This does not mean that only one tube can be used. Two or three tubes may be used in parallel to obtain greater power outputs than one tube can supply. Connecting tubes in parallel means connecting grid to grid, plate to plate and filament to filament. The efficiency of one tube is better than that of several, however. On the shorter wavelengths particularly it is better to use a single tube. With more than one tube we may get into difficulties with "parasitic" oscillations in the inductance of leads and the interelectrode capacities of the tubes. The use of one tube results in more certain operating, cooler tubes, and a steadier wave with fewer harmonics. The simpler our oscillator circuit, the easier it will be for us to get it working and to get the "bugs" out of it.

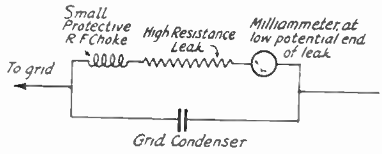
PARASITIC OSCILLATIONS

Parasitic oscillations usually occur when there is more than one tube operating in parallel or on very high frequencies where there are leads and distributed capacities in the circuit with a strong natural period of their own. Heating of the grid and plate leads inside the base is almost a sure sign of parasitic oscillations. A large input and low available output also lead one to suspect trouble of this sort. The current at ultrahigh frequencies may not show up on any meters at all but if it is there it is robbing the antenna of useful power. An R.F. ammeter placed in the grid lead may show a high reading—if parasitic oscillations are present.

Little grid chokes are used directly in series with the grid of each tube (if more than one tube is used) to cut down intertube H.F. currents and prevent loss of energy through parasitic oscillations. A resistance of about 100 ohms will do as well. Both are occasionally necessary. A few dozen turns of fine wire wound over and over on a ¼" diam. tube fastened down by a screw through it into the baseboard, will be effective. These chokes or resistors are in series with respect to the parasitic oscillations that we want to prevent between tubes. With respect to the main oscillating circuit the chokes are in parallel and have little effect.

METERS

The meters shown in the diagrams that we have discussed so far are really necessary to adjust the circuit properly for best efficiency. After the set is once adjusted and in operation, meters are useful but not necessary. We should have as many meters in the set as we feel we can afford. A filament voltmeter is of first importance. If we do not use a filament voltmeter or some indication of the operating temperature of the filament, the life of the tube may be much shortened by improper operation. An indicating device for the filament is, therefore, a matter of economy. Next we need an antenna ammeter. The antenna ammeter can be placed at the point in the antenna circuit where the antenna current is greatest (at the voltage node or current loop) but its indication will be useful wherever it is and the exact location is not extremely important. If we can afford it we should have a plate milliammeter of the proper range. All meters should be selected with regard to the tubes employed and the current and voltage that we may expect in the different circuits of the transmitter. With these three meters we can get along very well indeed in operating our transmitter. A plate voltmeter can be used if it is available but is not very useful after the circuit is once adjusted. Another milliammeter for the grid-leak circuit may be purchased after all the above have been obtained.



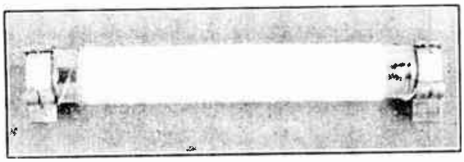
LOCATING THE GRID MILLIAMMETER IN A TRANSMITTER TO AVOID BURNOUT

RADIO-FREQUENCY CHOKES

Several ideas for mounting plug-in chokes will suggest themselves to the builder. The R.F. chokes can be wound on wooden dowels, each end of the winding being connected to some short right-angle brass pieces fastened to each end of the dowel. These brass angles should be mounted so that the projecting portions on each end are in the same plane. They will plug into the jaws taken from a discarded knife switch. Some glass tooth-brush holders from the "5 & 10" make even better forms that will mount nicely in large cartridge fuse clips. The aluminum caps clamp the wire and make good contact with the clips which should be mounted near the back of the transmitter frame where the chokes will be readily accessible when changing wavelength.

Radio-frequency choke coils should be constructed to work best on the particular wavelength to which the transmitter is tuned. Often one choke will work in the set for several frequency bands.

Every radio-frequency choke coil has a natural period of its own due to its inductance and distributed capacitance. When connected in a tube circuit the choke-period is changed. For every apparatus layout and tube equipment there will be a "best" choke. The best we can do is to specify what works best for our particular set. Mount the choke at right angles to the main coil and at a distance from it and everything else. Keeping coils away from each other and isolated as much as possible makes their losses lower and keeps induced voltages out of the argument.



ONE METHOD OF MAKING RADIO-FREQUENCY CHOKES

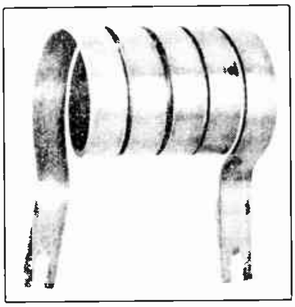
The former on which the wire is wound is a "5 and 10" glass toothbrush holder. The threaded aluminum caps clamp the ends of the wire and serve to make contact with the two large cartridge fuse clips which constitute the mounting. Such a choke can be replaced readily by others of different values when necessary.

For a short-wave transmitter the best chokes appear to be those that tune more sharply to a given frequency. Investigation usually proves that the chokes have standing waves on them under operating conditions. Single-layer coils, space-wound, not over three inches in diameter, seem to make the best chokes. Spacing the windings decreases the distributed capacity and, what is more important, raises the voltage break-down values at the end turns where the voltage-per-turn is always high in a sending set of any power.

In a choke the voltage at the end next the transmitter is highest (loop) while at the power supply end the voltage is minimum or zero (node). This may be checked with a Westinghouse Spark-C or any form of neon-lamp indicator. A screwdriver or other metal object with an insulated handle may be used likewise for making such an investigation of conditions as mentioned before.

COIL CONSTRUCTION

The tuning coils of the transmitter are extremely important items. Modern self-excited transmitters have large values of capacity across the coils to aid in obtaining a steady output frequency and in consequence the currents in the coils are of a high order. If the coils are made with a conductor which is too small, their resistance will cause serious losses in the circuit which will make themselves evident in the form of heat. In even a low-powered transmitter the coils can become too hot to touch if the coils are made with wire, tubing or strip which is too small. In such cases the transmitter usually oscillates unstably unless excessive grid excitation is used. It is quite common to hear the complaint that the plate current of the transmitter cannot be kept down to the rated value without the tube going out of oscillation. Almost invariable this is due to losses in coils which are not sufficiently heavy, or in high-resistance connections between the coils and their tuning condensers. In the transmitters described, heavy copper tubing was used for the coils but this does not mean that it is the only satisfactory conductor. It is, however, readily available, easy to wind, and it enables the construction of coils without the need of wooden, bakelite or hard-rubber insulating supports for the turns. It is absolutely essential that the coils be mechanically substantial—that they do not vibrate—since the slightest movement of their turns will mean variation in the output frequency of the transmitter. Coils made of copper or brass strip usually will vibrate unless the strip is very heavy or unless a supporting frame is used.



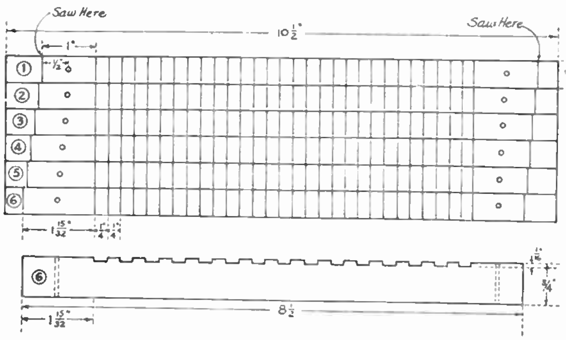
THE PLATE TANK INDUCTANCES

for a high-powered amateur transmitter can be made in this manner. The copper strip is 1/8" thick and 3/4" wide.

One satisfactory type of coil using strip is that illustrated. Copper strip 3/8" wide can be used for low-powered transmitters but 1/2"-wide strip is preferable for a power of about 50 watts. For a transmitter of 250 watts or more the self-supporting strip inductance could be used. In this case 3/4"-wide strip 1/8" thick is used.

The constructional details of the former for the smaller coils are shown in the sketches. The number of turns necessary for the various frequency bands will be approximately those specified for the copper tubing coils. Experiment will be necessary to determine the exact number, however, and for this reason the former-wound coils are not quite as practicable as the self-supporting type. With the latter coils the spacing of the turns can be varied until the required value of inductance has been obtained.

The first cut shows how the notched strips are laid out. All six oak strips can be sawed straight across in a miter-box to a depth of $\frac{1}{16}$". Then they can be staggered the right amount and the ends sawed off. The staggering will make the winding progress ahead the right amount from turn to turn. If a miter-box is not available each strip can be notched separately in a vise. Be sure to leave room on the ends for the mounting bolt and so that the ends can be sawed off the necessary amount.



LAYOUT FOR WOOD STRIPS FOR INDUCTANCE

The notches should be sawed a few thousandths of an inch wide so the strip will slip into place easily. When the strips are staggered the right amount strip number 1 can be placed next strip number 6 and the grooves will progress uniformly as shown by the dotted line.

The staggering is necessary in order to give the proper pitch to the winding that will be put on later. A hole is drilled one-half inch from the ends of each strip using a No. 27 drill. After soaking the strips in boiling paraffin for at least an hour they can be removed. Despite the fact that the paraffin is not visible on the surface of the wood, the wood is impervious to moisture and full of paraffin. Now you can bolt the wooden strips to the end rings which were previously drilled, taking care to see that they are put on in the correct order and that none of them is reversed in the process. It is a good idea to number the ends of the strips when they are first sawed to avoid trouble.

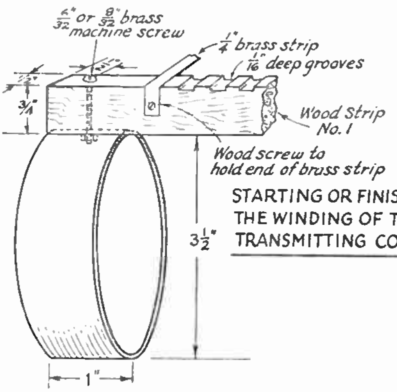
The brass (or copper) strip is next wound on after anchoring the end with a wood screw or a brass machine screw as shown in the diagram. If one strip is not available it will be necessary to solder shorter lengths together before starting the winding on the form. After the winding is completed, the small brass angles can be attached to hold the coil off the base in a horizontal position.

CONDENSERS

The performance of any transmitter can be impaired seriously if the insulation between points of high voltage is poor. A common location for trouble of this type is in the condensers. Without any external indication, there can be radio-frequency leaks through the insulation which will make it impossible to obtain a clean note from the transmitter. In some cases the signal emitted under such conditions is a rough "hash" and no amount of tuning will improve it. A great deal of trouble will be avoided if the best condensers available are built into the set at the start.

The variable condensers for transmitters operating from a plate supply of 500 volts or less may be of high-grade receiver type. For transmitters operating from higher voltages than these, special transmitting condensers are desirable. Several makes of such condensers are well advertised. They are available in many capacities and voltage ratings.

It is not necessary that the condensers specified for the transmitters described should be variable over the entire range, since they will be operated chiefly at values between 200 and 500 μμfds. Variable condensers of 200 or 250 μμfds. can be connected in parallel with fixed air-dielectric condensers of about the same capacity. Such fixed condensers can be bought but the resourceful amateur will find that they can be built up from copper sheet or aluminum dish pans supported with glass rods or glazed porcelain. Many possible constructional methods present themselves, the chief considerations being to keep down the size of the



STARTING OR FINISHING THE WINDING OF THE TRANSMITTING COIL

unit so that its field will not be too extensive, to reduce the supports to a minimum without sacrificing solidity, and to provide good contact between the plates and heavy conductors to them.

The fixed condensers in other parts of the set also are important. Mica or glass dielectric is satisfactory for these, and several types of suitable condensers are available. Receiver-type condensers, providing they are rated at not less than 500 volts, can be used in transmitters employing the UX-210 tube but special transmitting condensers will be necessary when higher plate voltages are used.

HIGH-IMPEDANCE TUBES

The transmitters described in this chapter were all designed for use with the tubes specified and they will not operate with the same efficiency if tubes of widely different characteristics are employed. Many of the European tubes and some manufactured in this country have a very high plate impedance and the circuits in which they operate most effectively may be different from those given. In the first place the high impedance of the tube makes it necessary to have a radio-frequency choke of very high reactance in shunt-feed circuits (such as that given for the low-powered transmitter) to attain reasonable efficiency. In practice, due to the difficulty of making high-reactance radio-frequency chokes, the shunt-feed circuits are often almost inoperable when used with the high-impedance tubes. No such difficulty is experienced when series feed circuits (such as that given for the high-powered transmitter) are employed. The large values of capacity specified for the tank circuits of the transmitters in this chapter also would result in low efficiency if used with high-impedance tubes. A greater number of turns and less capacity would be desirable. In addition, much higher-resistance grid leaks will be necessary. Some of the European tubes operate effectively with values even as high as 50,000 ohms.

TRANSMITTER ASSEMBLIES

As we have already mentioned, it is by no means necessary to arrange the apparatus in the transmitter in the manner shown in the illustration. Many other excellent schemes are possible. The board on which the apparatus is mounted can, for instance, be arranged in a vertical position, with the wiring, transformers, chokes, etc., behind it and the remaining apparatus is front. Alternatively the apparatus can be mounted chiefly on a baseboard, with the meters and controls on a vertical panel in front of it. The panel could be of bakelite or hard-rubber or may be made of well-dried wood. The important points to watch in arranging the apparatus are to make sure that the leads, particularly in the tuning circuits, can be short; to see that the coils are well clear of the condensers or other large metal bodies; and to arrange the parts in such a way that the controls are convenient and all apparatus is accessible.

UNSTEADY SIGNALS

One of the chief problems in transmitters other than those of the crystal-control type is to maintain a steady frequency. First there is the frequency creep due to heating of the tube or other apparatus in the set. This can be reduced to a minimum by tuning the set for greatest efficiency. The greater the antenna power for a given input the less will be the heating of the tube. The aim is, therefore, to keep the input at or below the rated value and to tune the set until the tube operates with the least heating. With a good antenna most tubes can be operated at the rated input without the plate showing any color. With any tube the plate should never be allowed to get hotter than a dull red. This is most likely to happen during the preliminary adjustment when the tube stops oscillating or is operating in an inefficient manner. For this reason, during adjustment, it is advisable to have the key or a convenient switch so arranged as to permit shutting off the plate power quickly when necessary.

The detuning of the antenna circuit mentioned in the paragraphs on tuning does not result in appreciably lowered efficiency in the tube. When it is said that the greatest antenna current should be obtained for a given input to keep the tube coolest it is meant that the greatest antenna current with the antenna detuned in the manner described should be obtained. When the antenna is detuned the plate current drops. The grid excitation should therefore be adjusted so that the normal plate current will be obtained with the antenna circuit in the detuned condition.

Another common cause of frequency instability is vibration or swinging of the antenna or feeders. The effect of such vibration or swinging is reduced considerably by the detuning of the antenna circuit but it is essential that the antenna be supported in such a way that it is steady even in a high wind. This point will be given consideration in the chapter on antennas.

Leaky insulation also is often a serious offender in this regard. Not only can a leak destroy the character of the note but it can be responsible for a wobbly frequency. Trouble of this type often can be detected by removing the antenna circuit and listening to the transmitter in the monitor. Sometimes the leak is visible in the form of a thin arc. If the leak is through bakelite a swelling on the surface of the insulation often will be noticed.

Perhaps the most common cause of all is vibration of the coils or wiring. A vibration which results in serious frequency instability often is too slight to be noticable. The coils and wiring should be watched very carefully during operation to make sure that the movements of keying, the humming of a transformer or the vibration of a generator are not transmitted to the set. The mounting of the set on rubber sponges often will aid in the elimination of the trouble.

It is only by careful and prolonged attention to such details that the performance of the transmitter can be maintained at a high standard. It is fine to aim at a neat station, an elaborate lay-out, or an imposing antenna. Of infinitely greater importance than these things, however, is the signal—the only part of the station that the whole world can examine.

CHAPTER VII

Power Supply, Keying and Interference Elimination

FROM the preceding chapter the impression could be gained that a transmitter consists merely of a tube and the tuning circuits associated with it. However, it must be understood that the transmitters described are not complete and cannot operate until they are provided with a power supply. This power supply, though involving only simple apparatus in some cases, is at all times of the greatest importance. Care expended in its installation and adjustment will be well rewarded by improvement in the signal and in the overall effectiveness of the transmitter.

The power supply system of any tube transmitter consists of two units—the supply for the tube filaments and the supply for the plate circuits. It is the latter to which we will give first consideration.

THE PLATE SUPPLY

In order for the oscillator tube of a transmitter to oscillate, or the amplifier tubes to amplify, it is necessary to maintain the tube plates at a high positive potential with respect to their filaments. If the tube is to function steadily and produce a pure unmodulated musical signal at the receiving end, the plate supply providing this potential must be a steady direct current. It is this point which is of such great importance. Rapid fluctuations in the plate supply voltage cause similarly rapid fluctuations in the antenna power. This, in turn, results in the production of side-band frequencies and added interference. What is much more serious, however, is that in the self-excited oscillator such voltage fluctuations cause not only power fluctuations but *frequency* fluctuations or frequency "flutter." The extent of this "flutter" can be reduced greatly by the use of a high value of capacity across the tank coils and by careful tuning adjustment (as described in Chapter VI) but, with the possible exception of the crystal-control transmitter, the "flutter," the mushy note and the interference which accompanies it can never be completely avoided unless the plate supply is a pure d.c. Slow variations in the plate voltage also must be avoided since these result in slow frequency changes or frequency "creep," making it necessary for the receiving operator constantly to retune his receiver in order to hold the signal. Yet another possible weakness in the plate supply, to be avoided, is poor regulation (to be discussed in detail later) which results in the plate voltage changing with every change in load on the plate-supply system. Trouble of this sort gives rise to a sudden frequency change—a frequency "chirp" —whenever the load is changed. It is when the transmitter is keyed that this effect becomes so serious.

POSSIBLE SUPPLY SYSTEMS

The simplest form of plate-supply system is nothing more than a bank of dry cell batteries or storage cells. For the low-powered transmitter such a supply is not only inexpensive but particularly desirable on account of its ability to provide a steady and quite pure direct current. For a transmitter of any appreciable power, however, both the installation and upkeep costs mount rapidly and its use is no longer practical.

For the medium and high-power transmitters there are two alternatives—to use a high-voltage generator of ample rating for the tube or tubes, or to step up the commercial alternating current to a suitable voltage, then converting it to direct current with a rectifier system and smoothing out the fluctuations or ripple with a suitable filter. The latter arrangement is probably the most generally used in amateur stations.

DRY CELLS AS PLATE SUPPLY

Dry-cell batteries usually can be obtained in 22½ or 45-volt units for plate-supply work.

The 22½-volt batteries (4" x 4¼" x 8") usually have about 5700 milliampere-hours capacity when discharged intermittently at rates not in excess of 30 milliamperes. 200 hours of operating use can be expected when using such batteries with a UX-210 transmitting tube. With 201-A tubes even longer life can be expected. Of course the thickness of the zinc shell, the sealing to prevent evaporation, the composition and disposition of the electrolyte, and the depolarizing elements used will have a great deal to do with this life. Our figures are merely representative of some of the batteries available from reputable manufacturers.

Battery capacity will be reduced if batteries are kept in too dry a place, especially if they are not sealed well, as the electrolyte will dry out. In damp climates there is apt to be leakage between the cells of high-voltage batteries if precautions are not taken. In cold climates batteries keep very well but may show a temporary loss of voltage as the activity of the chemicals is decreased by cold. In this case the voltage will rise as current is drawn from the batteries due to the heat generated inside.

The life and capacity depends on the size, weight, construction, on the adaptability to service and on care in installation and use. The ampere-hour capacity given above is representative of the average medium-sized 22½-volt 15-cell 5-pound B-battery. Of course the figures would be the same for a 45-volt 30-cell 10-pound battery made by the same firm. The exact battery dimensions are bound to vary somewhat, as these batteries have been manufactured in a variety of sizes and shapes to suit the many kinds of broadcast receivers brought out in the last few years. In general one can go best by the weight—the larger and heavier the battery for a given voltage, the longer it can be depended on to last if it is made by a well-known manufacturer instead of by some fly-by-night concern.

Dry-cell batteries are *not* suited for use with larger sets than those using one UX-210. The economy is rather poor beyond a 50-milliampere discharge rate.

The beginning amateur will have no trouble in starting off with a set using small tubes with a dry-cell battery of two or three hundred volts for plate supply. A keying filter may be used with battery plate supply to keep key-clicks or key-thumps from making the set a local nuisance.

B-BATTERY ELIMINATORS

In the last few years a number of substitutes for A and B batteries have been advanced. Of course these devices were made to use with vacuum-tube receiving sets but they enter the picture here because they can be used with low-powered transmitters.

These battery eliminators, of course, are designed to plug into your 110-volt alternating current circuit. There are many types on the market, all containing a step-up transformer, rectifier, and filter and differing from one another principally in the type of rectifier used and the means for determining and regulating the output voltages.

A few of the B-eliminators give a good direct current output at between three and four hundred volts with fairly decent regulation. Using one on a small *transmitter* gives excellent results.

The key may be placed in the 110-volt line or in the d.c. output leads. Both should be tried. The regulation of these eliminators is sometimes poor, which may give rise to "yooping" if the key is in the d.c. output. On the other hand if one tries to key in the 110-volt line to the eliminator the filter may not permit the d.c. voltage to rise and fall fast, so that the keying will not be clean-cut. The dots may even be *missing* entirely. When the keying is not quite right in either the output or the input, one is compelled to short-circuit some of the filter chokes of the B sub or else disconnect some of the condensers, tolerating some ripple for the sake of improved keying. Of course all this is useless if the transformer and rectifier of the B-sub are not fit to provide sufficient plate current for the transmitter. That should be investigated first.

REGULATION

When we speak of the voltage regulation of a transformer, generator, rectifier, filter, or rectifier-filter combination we are talking about the variation in the voltage the device delivers with the "load" that it handles.

A rectifier-filter delivers 350 volts, 45 m.a., to a UX-210 with the key pressed. We lift the key and the voltage at the output terminals of the filter rises to 500 volts. The regulation from full-load to no-load is the difference or 150 volts. Regulation is often expressed as a percentage. Voltage regulation is the ratio of the difference in full-load and no-load voltage to the rated load voltage.

$$\frac{150}{350} = 42.8\% \text{ regulation (rather poor)}$$

The tube load is not necessarily *full* load for this rectifier. If we design our rectifier-filter to give an output of 350 volts, 100 ma., (35 volt-amps or watts), and happen to be using it under-loaded, we have 42.8% as a value of regulation for about half-load. A regulation curve for the outfit can be plotted showing what the percentage regulation of volts delivered will be for different loads.

The regulation of mercury-vapor and mercury-arc rectifiers is very good. Big filters and transformers having lots of resistance and rectance have notably poor regulation. Kenotron or Rectron rectifiers and electrolytic rectifiers have quite poor regulation which has to be taken into account in building transmitters. The regulation of batteries depends on the internal resistance of the cells of which it is made up. This in turn depends on the depolarizer used, increasing with the age of dry cells. The internal resistance of storage cells is very low and the regulation correspondingly good (small).

Storage cells are expensive and many of them are necessary to give us high-voltage power. Either Edison alkaline batteries or lead cells can be used. Equipment must be provided for charging them. Distilled water has to be added to replace that lost from evaporation. In cold climates they must be kept fully charged to prevent freezing of the electrolyte. After a few years the storage cells must be rebuilt or replaced and so the up-keep is also quite high.

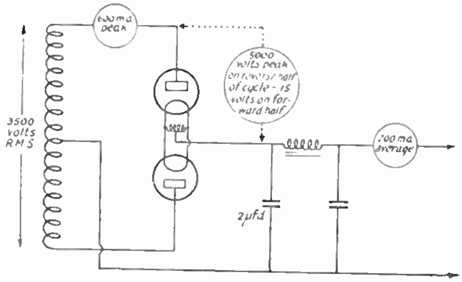
THE RECTIFIER-FILTER SYSTEMS

Assuming that alternating-current power is available at 110 or 220 volts, a very effective high voltage supply system can be built up from a high-voltage transformer, a rectifier system and a filter. The details of the transformer and the filter are to be given complete treatment later in the chapter and for the moment we will limit the discussion to the remaining unit, the rectifier system. Several types of rectifiers are available for use in the plate supply system, chief of these being the hot-cathode mercury-vapor tubes, the mercury arc, rectrons, and chemical rectifiers. Of these the most satisfactory is the mercury-vapor rectifier which, though low in cost, is simple, reliable, clean, highly efficient and capable of giving long service. Several rectifiers of this type are available at present, a typical one being that illustrated. All of them consist of an anode or plate and a cathode in a low-pressure mercury vapor. In some of them the cathode is a simple filament while in others the cathode is of the "heater" type, consisting of a metallic cylinder coated with the "emitter" and heated from within by a heater element in the manner of an "a.c." receiving tube.

A TYPICAL HOT-CATHODE MERCURY VAPOR RECTIFIER TUBE.

The ratings of tubes of this type usually are given in terms of peak inverse voltage—the voltage that the tube will stand in the direction opposite to that in which the current normally flows—and peak current. The peak current is dependent upon the emission available from the filament or emitter and in the operation of the mercury-vapor tubes the greatest care must be taken to see that it is never exceeded. The important point to take into consideration is that the peak voltage or peak current is much greater than the readings of the meters in the circuit. The peak voltage or peak inverse voltage, for instance, may be taken as 1.4 times the rated transformer voltage or the voltage indicated by a high-voltage meter. The peak current in the plate supply system is not so readily determined since it depends to some extent upon the type of filter into which the rectifiers are feeding. With a large condenser on the rectifier side of the filter as shown in the first diagram, the peak current per tube is roughly three times the load current from the two tubes. With a large choke on the rectifier side of the filter as shown in the second diagram, the peak current per tube is reduced to about 1.5 times the load current from the two tubes. It is for this reason that a choke ahead of the filter proper is desirable when the current to be drawn by the transmitter is heavy.

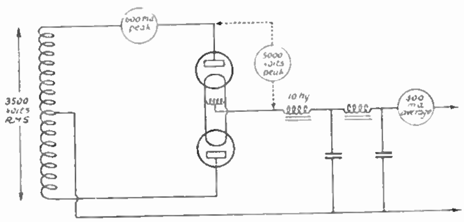
Some idea of the operation of a rectifier-filter type of plate supply can be obtained by studying the two diagrams mentioned. In each of them the high-voltage secondary of the plate-supply transformer is the winding indicated at the left. In order to permit full-wave rectification it is center-tapped. When, during one half-cycle of the supply frequency, the upper end of this winding is positive, current flows through the upper rectifier from plate to filament and out to the filter system from the center tap of the filament winding. The peak current which can flow without harming the tube (if it is of the type illustrated) is the 600 m.a. shown within the circle. The voltage drop across the tube on this half of the cycle is only 15 volts. At the time when current is flowing through the top tube the bottom end of the plate transformer secondary is negative and no current can flow through the



TWO TUBES USED IN A FULL-WAVE RECTIFYING CIRCUIT

With condenser input to the filter, the peak current through each tube is approximately three times the average output current from the two tubes. This filter arrangement should be used where the output voltage is relatively high and the output current is low.

lower tube. A voltage exists across the elements of the tube, however, and it is this voltage—the inverse peak voltage—which, with this particular tube, must not exceed 5,000 volts. On the next half of the supply cycle the upper end of the transformer secondary is negative and the lower end positive. Current then flows through the lower tube from plate to filament and out into the filter, while the upper tube is doing nothing but withstanding the inverse voltage which is now across



IN THIS CIRCUIT ARRANGEMENT, THE FILTER INPUT IS THROUGH A CHOKE

Here the peak current through each tube is only approximately one and a half times the average output current obtained from both tubes. A sacrifice in output voltage results, though, and this type of filter should be employed in cases where the output voltage may be low but where high output current is necessary.

its elements. In this way the tubes take their turn on each alternate half-cycle to pass current to the filter and at all times the current flows out through the center tap of the filament transformer. This lead is then the positive high-voltage connection, the center tap of the high-voltage transformer secondary becoming the negative connection. The output of the rectifiers drops to zero between each half-cycle but the current flow is always in the one direction. In other words the output is now a pulsating direct current. If applied to the transmitter directly from the rectifiers it would result in a transmitter output heavily modulated and, if the transmitter were self-excited, appreciably "fluttered" in frequency. The use of a filter between the rectifiers and the transmitter, however, makes it possible to smooth out the pulsations until the output is a smooth and steady direct current. The filter system, to be detailed later, constitutes a store-house in which some of the output of the rectifiers is retained during the peak of each half-cycle so that the transmitter will still have a supply even when the output of the rectifiers has dropped to zero between the half-cycles.

A table of rectifier-filter arrangements for use with various transmitting tubes is given. From this table it will be possible to obtain sufficient information to plan a plate-supply system for any of the transmitters described in the last chapter. In addition a complete diagram showing the connection of a typical plate supply to a typical transmitter is given on the next page.

In building up a plate-supply unit employing tubes of this type it should be remembered that the filament current is quite high. Not all tube sockets are suitable for currents greater than one or two amperes and if poor contact at the filament prongs, overheating of the connections, and possible tube damage are to be avoided, the socket should be selected with care. A further important point to watch is the filament voltage at which the tubes operate. Satisfactory service and a normal life are obtained only when the filament is held at the rated voltage.

In the mercury-vapor tubes having an exposed filament it is necessary to apply the filament voltage 20 or 30 seconds before the plate voltage in order to permit the filaments to come up to their normal temperature before operation starts. In the case of the "heater"-type tubes a much longer delay is necessary between the application of the filament and the plate voltage because the "emitter" is heated indirectly. In actual operation of the station this delay would be a decided disadvantage and general practice is now to leave the rectifier filaments running continuously during periods when the station is being operated.

OSCILLATOR			RECTIFIER			RECTIFIER DIAGRAM	⊗ FILTER
TUBES	VOLTAGE	AMPERE	TUBES	TOTAL TRANSFORMER VOLTAGE	PEAK PLATE CURRENT PER TUBE		
UX-210 ○	450	0.060	2 UX-866	1250	0.090 ★		120-VOLT DROP
UV-211 OR UV-203 A ○	1250	0.175	2 UX-866	3500	0.265		350-VOLT DROP
UX-852 OR UX-860 ○	2000	0.100	2 UX-866	3500	0.300		200 VOLT DROP
UX-852 OR UX-860	3000	0.100	4 UX 866	3500	0.150		200 VOLT DROP
UV 204 A	2500	0.275	4 UX 866	3500	0.400		550 VOLT DROP

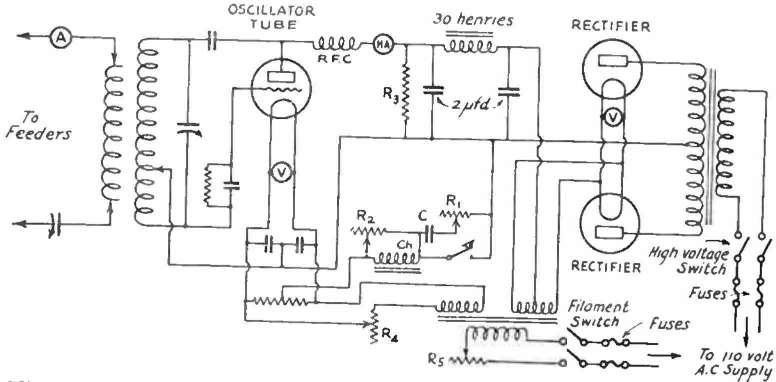
NOTES.
⊗ 1000 ohms chosen as resistance of typical choke.
★ Approximate values
○ Two tubes may be used in parallel without overloading rectifier.

The above table indicates a suitable rectifier and filter arrangement for transmitters employing six different types of tubes commonly used by amateurs.

MERCURY ARC RECTIFIERS

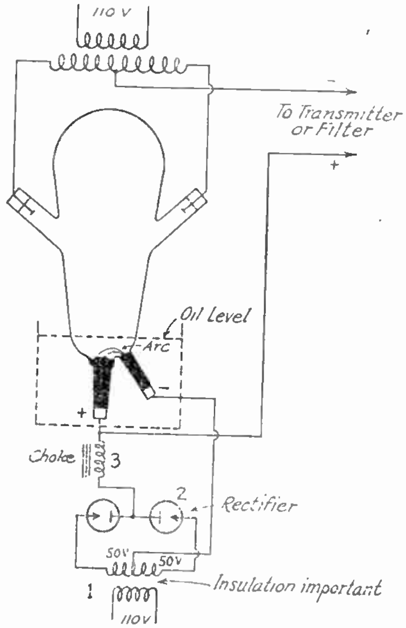
For high-powered amateur transmitters a popular rectifier is the mercury arc. Such rectifiers will handle over six thousand volts if necessary and are capable of withstanding very much higher peak inverse voltages and peak currents than the smaller types of mercury-vapor tubes available to amateurs. At a number of amateur stations tubes have been installed, obtained for little or nothing from the local electric-light company that discarded them after they began to operate unsteadily in a series street-lighting system. Such tubes will still serve as rectifiers for an amateur plate supply source for UV-203-A's or for a UV-204-A for years providing they are installed correctly.

The efficiency of such rectifiers is very high, there being a negligible drop in plate potential within the tube as in the case



SHOWING THE COMPLETE WIRING OF A LOW-POWERED TRANSMITTER

The apparatus in the circuits of the oscillator has been treated in the previous chapter. It will not be detailed here. R1, R2, R3, C and Ch. comprise the essentials of the keying system. They will be detailed later in this chapter. In adjusting the filament voltages the rectifier filaments are first brought to the right value by means of the primary rheostat R5. Then, the oscillator filament is adjusted with the aid of the rheostat R4. A rheostat is not used in the filament leads to the rectifiers since the current would be too heavy for rheostat of the ordinary type if mercury-vapor rectifiers were employed.

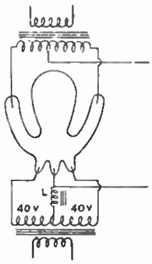


SIMPLEST FORM OF "KEEP-ALIVE" SYSTEM FOR MERCURY ARC RECTIFIERS

of the hot-cathode mercury-vapor tubes. The overall efficiency of course is lowered an amount depending on the "keep-alive" circuit used and the instantaneous load values on the tube. Mercury arc rectifiers are easy to filter, too. The device used for keeping the hot-spot on the mercury pool and the inductance for keeping the tube operating stably will be most of interest to Handbook readers.

The "keep-alive" circuit is necessary in using the mercury-arc rectifier with amateur transmitting sets for telegraph work. An auxiliary electrode near the base of the tube is ordinarily provided for use in starting the arc by an initial flash on the main pool—and this starting arc is kept in operation continuously by "keep-alive" circuits so that the tube will be kept filled with mercury vapor even when the key is up as in intermittent telegraph work. The auxiliary and main mercury pools are connected through an inductance coil (to steady the keep-alive arc and prevent it from going out) and a rectifier to a source of low-voltage alternating current (about 50 volts on either side of the center tap). Tungar or Rectigon tubes such as used in low-voltage battery chargers can be used or, lacking these, an electrolytic rectifier made up in two half-gallon battery jars will prove very satisfactory. In operating the tube the glass next the keep-alive arc gets hot so that one should take the precaution of mounting the mercury-arc tube in an oil bath to a level somewhat above the mercury pools to protect the glass. Use light gas-engine oil of any kind convenient for cooling purposes.

The transformer supplying the "keep-alive" circuit must be well insulated because just as in the case of the filament heating transformer for tube rectifiers, the filament circuit of the rectifier is at plate potential



CIRCUIT THAT CAN BE USED WHEN THERE ARE TWO AUXILIARY ELECTRODES (THREE MERCURY POOLS)

Note that no low-voltage rectifier is necessary for maintaining the "keep-alive" arc.

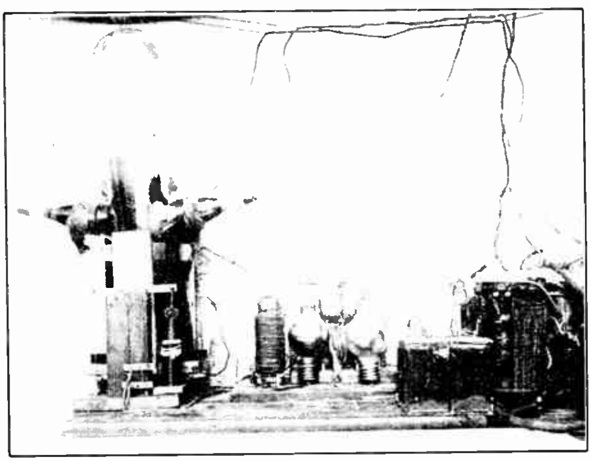
above ground. If no one-to-one-ratio transformer with a center-tapped secondary is available for the keep-alive circuit a 50-volt supply can be used with four large chemical rectifier jars connected in a bridge arrangement.

The choke can be easily built if a spare transformer winding of the necessary inductance is not available. Some resistance in series with the choke will help in limiting the current used in the "keep-alive" circuit to a value which will just keep the arc operating stably, preventing the wasting of power and getting away from the danger of overheating the glass at the auxiliary electrode. The primary of an R. C. A. 75-watt filament-heating transformer makes a good choke in an emergency. One amateur used a choke having about 800 turns of No. 18 or No. 20 wire wound on a closed core 1¼" square (cross-section). The primary of some transformer in almost every experimenter's "junk box" will be found to serve in an emergency. The voltage used and the necessary adjustments are not critical. About 2 amperes "keep-alive" current is necessary for stability.

The connections of the mercury-arc rectifier in transmitting circuits are just the same as those of any of the other rectifiers. The diagrams show several different "keep-alive" rigs. Most of the stations use the small 110-volt 10-ampere tubes successfully. So many styles and varieties of tubes are available that we cannot be too specific regarding any particular rectifier tube. In general, the tubes are not critical and a little careful experimenting will enable you to get one going at your station. At least one amateur has successfully operated one of the G. E. 10-kilowatt street-lighting rectifier tubes (Type 40525) without the low voltage rectifier for the keep-alive circuit. It is best to use a rectifier, as low-voltage *direct* current makes an arc stable.

In handling the tubes remember that mercury is heavy and it must be poured carefully to prevent cracking the tube. If a tube is defective due to a poor vacuum it will not operate. A tube having a good vacuum will give out a clicking sound when the mercury is shaken about carefully so that it splashes a little. If there is much air in a tube the mercury will oxidize on trying to start the arc. In mounting the rectifier tubes the glass should not be clamped so that there is any strain on it as it is almost sure to fracture after a few hours of operation if there is a strain on some part of the glass.

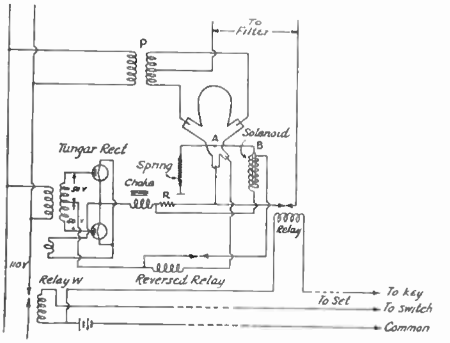
In one typical amateur installation the mercury-arc rectifier tube is mounted with the oil jar in a wooden frame and remote-controlled by the arrangement shown in the photograph and diagram. The tube with its frame is pivoted on a line through the center of gravity (Point A in the circuit diagram) in a second larger wooden sup-



TUNGAR "KEEP-ALIVE" ARRANGEMENT AT W3AB

Note the framework supporting the tube and the solenoid used for tilting it by remote control.

port. A rod B is fastened to the frame of the tube as shown, a coiled spring pulling down on one end of the rod and an iron solenoid armature of cylindrical shape arranged on the other end of the rod so that when the coil of wire (solenoid) around the armature is energized by the closing of the proper relay, the magnetic pull will tilt the tube. The low-voltage rectifier circuit supplies the current for operating the solenoid.



THE WIRING OF THE MERCURY-ARC INSTALLATION
shown in the photograph. In this case the tilting of the arc is accomplished by means of a remotely-controlled solenoid.

In the "keep-alive" circuit is a reverse-connected relay, the contacts of which are held closed whenever there is no current in the circuit leading to the auxiliary electrode. A storage battery controls the power and keying relays. When the switch closes the circuit to relay W, the power transformer P and the Tungar rectifier are connected to the 110-volt mains. The circuit through the solenoid being closed, the current goes through the solenoid windings, pulling down one end of the rod and tipping the tube. The mercury flows over, covering both lower electrodes and allowing current to flow in the "keep-alive" circuit. This energizes the reversed relay, breaking the solenoid circuit so the spring can pull the tube into an upright position, striking an arc as it does so.

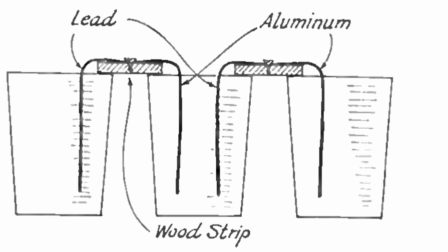
THE ELECTROLYTIC RECTIFIER

For an amateur station the electrolytic rectifier is bulky and sloppy but works well. Chemically pure aluminum is hard to obtain, but the lead or iron element is plentiful and cheap.

In designing a chemical rectifier one must be sure to use sufficiently large jars to prevent undue heating of the solution. Allow 50 volts to a jar and a current density of not over 40 milliamperes per square inch of aluminum sheet.

A dilute solution of sodium bicarbonate (baking soda) gives good results with low cost. A layer of transformer oil on top can be used to reduce evaporation, and creeping will not be as troublesome as when borax is used. Sodium-ammonium phosphate and sodium-potassium tartrate are good but more expensive. The use of borax requires a saturated solution. If baking soda is used there will be a heavy white precipitate formed at the aluminum electrode which will settle to the bottom. As this does not appear after the aluminum is formed, an old solution can be used for forming and the electrodes put into a clean solution after they are formed. Lead and iron are not satisfactory for use as auxiliary electrodes in an aluminum rectifier that has an organic solution, but they work well with a borax solution or with the dilute baking-soda solution. A carbon auxiliary electrode will be satisfactory if an organic rectifier solution such as citrate, acetate, or tartrate is used.

Diagrams of connections are shown. An example may help. We have 2 UX-210's that normally take 45 m.a. each of the plate current. That makes 90 m.a. the set uses. Our transformer gives us 550 volts on each side of the center tap. Assuming 100 m.a. maximum load, 100 divided by 40 gives us 2½ sq. in. of aluminum that must be immersed in each jar to carry the current. 550/50 makes 11 jars necessary for each leg of the rectifier (lower diagram). We should use 12 jars to give the necessary 10% factor of safety. Some jelly tumblers



SIMPLY-MADE ELECTROLYTIC RECTIFIERS FOR LOW-POWER SET

may be pressed into service to hold the solution. A small rack and some wooden pieces holding the aluminum and lead strips will complete the outfit.

In the bridge-connected rectifier S delivers 550 volts, two rows of 12 jars each being in parallel across S, 24 jars total number. There are four groups of six jars each. In the diagram showing the plate transformer with center-tapped secondary, S delivers 1100 volts (550 each side of center-tap in making computations. In this respect to the 1100 volts, showing that the same number of jars are required for either connection. In the case of a center-tapped transformer, use the voltage each side of center-tap in making computations. In this arrangement there are two groups of 12 jars each.

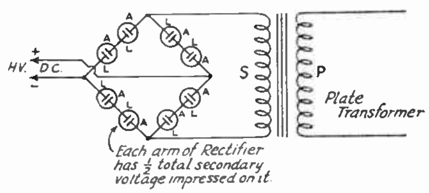
Two UX-210's will need a rectifier with the following parts:

28 Aluminum strips, 5" x 1" x 1/32" thick	$3.00
28 Lead strips, 5" x 1" x 1/16" thick	2.00
28 Glass tumblers, 2 for 5c	.70
4 2" x 1" wooden strips (7 jars long)	.30
1 gross 5/8" blued round-head wood screws	.20
2 packages "20 Mule Team" borax	.20
Total	$6.40

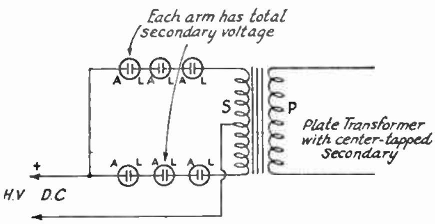
Special care must be used in first forming an electrolytic rectifier, especially if the cells are formed in series across a high-voltage transformer. When the circuit is closed it is almost a dead short circuit across the transformer secondary, and the current will be quite high until the film is partially formed. A resistance or bank of lamps should be placed in series with the input to the plate transformer. The unformed jars are not able to rectify effectively and so act as a short circuit across the high voltage winding. If fuses do not blow, the transformer probably will burn up. Putting lamps in series limits the transformer load to one it can stand. As the rectifier begins to form, the series lamps get dimmer and larger lamps or more of them can be used until the rectifier will withstand the full voltage.

The maximum current density should not exceed the normal operating density. The jars must not be allowed to heat as the film on the aluminum plates begins to break down at about 120° F. If there is sparking the rate must be reduced, as the film on the aluminum will be destroyed as fast as it is made. A well-formed aluminum electrode will be smooth and have a thin dull white surface. After several hours of forming the rectifier will keep in condition with occasional use. An aluminum-oxide film and a gas film as well are responsible for the rectifying action, and the gaseous film forms as soon as the jars are connected to the source. There should be no fireworks or scintillating sparks on the plates. That is a sign of too much voltage per jar and means that some other "dead" cells are not working. Each plate should have a uniform phosphorescent glow. A dark cell *may* be working. If there is enough voltage the phosphorescence will prove it is working. The current-carrying capacity of electrolytic rectifiers seems to be limited mainly by the heating in the cells. Quite high instantaneous currents can be rectified but unless artificial cooling of the aluminum electrode is possible it is necessary to follow the prescribed current density of 40 m.a. per square inch.

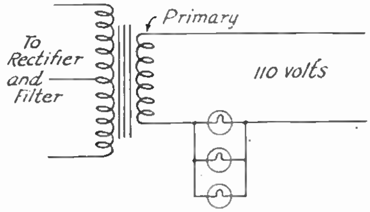
Tube	Plate volts (r.m.s.)	Plate milamps	Submerged aluminum plate area, per cell	Jars required for Bridge or center tap connection
UV-202	350	40	1 sq. in.	16
2 UX-210's	550	90	2½ sq. in.	24
UV-203-A	1000	120	3 sq. in.	44



BRIDGE-CONNECTED LEAD-ALUMINUM RECTIFIER



CONNECTIONS OF CHEMICAL RECTIFIERS



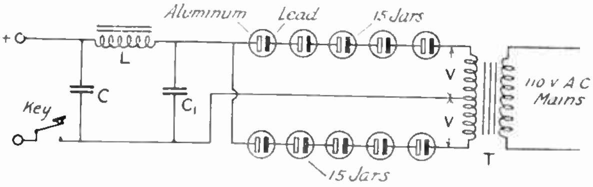
FORMING THE ELECTROLYTIC RECTIFIER

More lamps are screwed in as rectifier forms. When nearly formed, the lamp bank may be bridged by a wire. If there is appreciable heating, cut off the forming current until rectifier is again cool.

The rectifier must be allowed to form gradually. If the voltage is raised too quickly the cells will heat and operations should be suspended until they are cool again. Impure aluminum contains carbon, zinc or iron. Such plates will show brown spots. Cells containing poor aluminum will not form and new aluminum should be used. White petrolatum can be used for sealing the cells if desired. Lye can be used to clean the plates when it is necessary. A little ammonia can be added often to replace that lost by evaporation. Old aluminum lightning arrestor cones are a good source of pure aluminum. Sheet aluminum from the Aluminum Company of America and its agencies is satisfactory.

Test tubes, jelly tumblers, drinking glasses, and small and large preserve jars can be used to hold the different sized plates.

When a good large filter is used there is a "back-voltage" or counter electromotive force from the charge left in the filter condensers which has an effect in the rectifier circuit as soon as the key is up. This voltage is applied to the rectifier at the same time the transformer is applying high voltage alternating current to it. This may make the voltage-per-jar too high so that some of the aluminum films break down, sparkling and making a "noise" that does not filter out easily. A few more jars added to a rectifier usually will cure this trouble permanently. The transformer voltage that causes break-down is always the "peak" of the a.c. cycle, which is nearly one and one-half times the effective value of voltage at which a.c. circuits are rated.



POWER SUPPLY FOR A LOW-POWERED TRANSMITTER

Note electrolytic rectifier connections and polarity. T is the plate transformer. T1 is the filament transformer. The filter consists of 30- to 100-henry choke L together with C and C1 which are 2 microfarads or more each.

MOTOR-GENERATORS AND DYNAMOTORS

A direct-current motor-generator is an excellent source of plate power for any station. The rated output of the generator (watts) should be equal to the product of the plate voltage (volts) and plate current (amperes). The terminal voltage must match the rated plate voltage of the transmitting tubes. It is convenient but not necessary to have a "field" rheostat in the field of the generator to regulate the terminal voltage. The regulation of most of the motor-generators on the market is good. By using a series field winding or "compounding" a machine, an increase in load current makes the field in which the armature rotates stronger, which compensates for the several factors causing a drop in voltage. A machine having the same full-load and no-load voltages is known as "flat" compounded. If the full-load voltage is greater than the no-load voltage, the machine is "over-compounded." A motor-generator set is the simplest plate supply source but it is also probably the most expensive.

The motor that drives the generator can be direct-connected or belted. In any case it should drive the generator at about its rated speed. It should be rated at about 1¼ to 1½ times the generator capacity as it has to take care of its own and the generator's losses.

Motor-generators for radio work can be obtained from the Electric Specialty Company of Stamford, Conn., who will supply information on their products on request. An a.c. supply with a filter is cheaper. However, a motor-generator of the right size will save bother with big filters and rectifiers. A little filter to take out the commutator ripple may be necessary. A many-segment commutator will have little ripple and will not need to be filtered except for voice work (radio telephony). The motor-generator set is noisy which makes it impossible for some jobs. However, it is usually very convenient if one has the ready money to spend on power supply equipment.

Dynamotors, gasoline-engine-driven generators, storage cells or dry-cell "B" batteries are necessary for isolated lay-outs or semi-portable motor-truck outfits. Emergency communication must always depend on a local source of power, for commercial lighting and power are cut off in times of emergency.

A dynamotor is simply a two-winding machine, running on one winding as a motor driven from a six or twelve-volt storage battery. The high voltage winding delivers several hundred volts to the plates of our transmitting tubes.

SMALL TRANSFORMERS

A transformer is an electrical device for changing electrical power at one voltage and current to power at another voltage and current. A step-down transformer takes its power at a high voltage and small current, delivering a *lower* voltage and more current. A step-up transformer delivers *higher* voltage than it takes at its input.

Filament-heating, bell-ringing, distribution and welding transformers are examples of step-down transformers. Plate-supply systems and high-voltage transmission lines between cities are fed from step-up transformers.

The input winding connects to the source of supply and is called the *primary* winding. The output connects to the load and is called the *secondary* winding. Any transformer may be used for either step-up or step-down work. To avoid confusion it is always best to refer to transformer windings as high-voltage and low-voltage windings.

Most transformers that amateurs build are for use on 110-volt 60-cycle supply. The number of turns necessary on the 110-volt winding depends on the goodness of the iron on the turns per volt and the number of turns in the secondary winding. When the secondary is connected to a load, the induced voltage makes current flow in the load. The m.m.f. produced by this secondary current opposes the primary m.m.f. and tends to reduce the flux in the core. This results in lessened counter-e.m.f. in the primary. More current is taken from the supply line to keep up the flux value and maintain the secondary voltage under load.

The transformer uses a little energy to supply losses in the core and windings. Due to the resistance of the windings and to magnetic leakage paths, the voltage of the secondary may drop materially under load. Poor regulation, as this is called, is sometimes useful in a special transformer. In our filament-heating and plate-supply transformers we can arrange the windings compactly, make good solid joints in the core, use large low-resistance wire in the windings, and keep the length of the magnetic path fairly short and of good cross-section. This will keep the secondary voltage quite constant under load.

Input (Watts)	Full-load Efficiency	Size of Primary Wire	No. of Primary Turns	Turns Per Volt	Cross-Section Through Core
50	75%	23	528	4.80	1¼"x1¼"
75	85%	21	437	3.95	1⅜"x1⅜"
100	90%	20	367	3.33	1½"x1½"
150	90%	18	313	2.84	1⅝"x1⅝"
200	90%	17	270	2.45	1¾"x1¾"
250	90%	16	248	2.25	1⅞"x1⅞"
300	90%	15	248	2.25	1⅞"x1⅞"
400	90%	14	206	1.87	2 "x2 "
500	95%	13	183	1.66	2⅛"x2⅛"
750	95%	11	146	1.33	2⅜"x2⅜"
1000	95%	10	132	1.20	2½"x2½"
1500	95%	9	109	.99	2¾"x2¾"

core used and on the cross-section thru the core. Silicon steel is best and a flux density of about 50,000 lines per square inch can be used. This is the basis of the table of cross-sections given in this article.

The size wire used depends on the current expected. This will vary with the load on the transformer. A circular mil is the area of the cross-section of a wire one thousandth of an inch in diameter. When a small transformer is built to handle a continuous load, the copper wire in the windings should have an area of 1500 circular mils for each ampere to be carried. For intermittent use, 1000 circular mils per ampere is permissible.

Let us review the theory of transformer operation briefly. A small magnetizing current will flow in the primary winding at no load. This sets up a magneto-motive force (m.m.f.) and flux lines go around the magnetic circuit or core. The flux links both low-voltage and high-voltage windings. This flux induces a counter electromotive force in the primary winding just opposite to the applied e.m.f., which prevents much current from rushing into the primary. The flux induces a secondary voltage depending

In the primary of a transformer the current at no load (magnetizing current) lags with respect to the applied voltage by nearly 90°. As the load comes on, voltage and current are more nearly in phase.

A table is given showing the best size wire and core to use for particular transformers. The figures in the table refer to 60-cycle transformers. The design of 25-cycle transformers is similar. A slightly higher flux density is permissible. Because the frequency is much lower the cross-sectional area of the iron must be greater (or the number of turns per volt correspondingly larger). Otherwise the inductance of a certain number of turns will be too low to give the required "reactance" at the reduced frequency ($X_L = 2\pi f L$). If one builds the core so that its cross-section is 2.1 to 2.2 times the value of area worked out from the table, the same number turns of wire may be used in a primary coil for 25-cycle operation. If the same core and more turns of wire are used a larger "window" will be needed for the extra wire and insulation. Increasing both the number of turns per volt and the cross-section of the core gives the best-balanced design.

Most 60-cycle transformers will behave nicely on a 25-cycle supply if the applied voltage is sufficiently reduced. Up to 52 volts 25 cycles may be applied to a 110-volt 60-cycle winding without harm. Knowing the transformer voltage-ratio the output voltage will be known. The current-carrying capacity will be the same as at 60 cycles. The KVA (kilovolt-ampere) rating will be about half the 60-cycle value.

DESIGNING A PLATE TRANSFORMER FOR TWO 7½-WATT TUBES

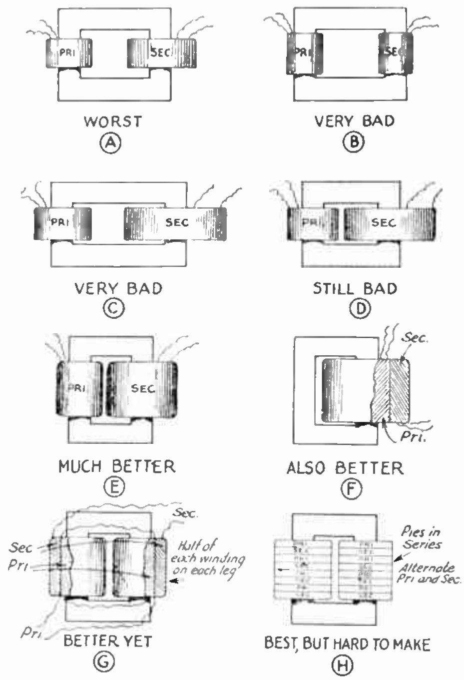
Suppose we want to build a plate transformer for 2 UX-210 (7½ watt) tubes. General amateur practise is to supply two of these tubes with about 100 milliamperes of 500 volts. Allowing 250 volts drop in the rectifier (not unusual in a chemical rectifier) we will need 750 volts at the secondary. A transformer built for this voltage can be used with a resistor to make additional voltage drops if it is necessary to work with just one tube or with lower voltages to prevent heating. With one tube the current required will be less and the regulation will be better. A 4,000-ohm resistor carrying 50 mils (.05 ampere) to one UX-210 will have 200 volts drop (RI), compensating for greatly improved regulation.

750 volts x .100 amperes = 75 watts transformer output.

The table gives us a probable efficiency of about 85 or 90% for small transformers of this size.

The number of turns in the secondary winding is governed by the number of turns in the primary and the desired secondary voltage (in this case 750). Before the number of secondary turns can be found out we must know how many *turns per volt* there are in the primary. This can be found by dividing the number of primary turns by the primary voltage and is given directly in the table. The number of turns for the secondary can now be found by multiplying this figure by the desired secondary voltage. As we have decided to build the 75 watt transformer (the one nearest the requirements of our problem) the number of secondary turns can now be found easily (750 x 3.95 = 2963 turns). The size of wire to be used for the secondary depends on the secondary current and the allowable current density, and can be found in the same way as for the primary wire from the wire table given in the Appendix. For this layout of equipment look for a size of wire for the secondary that will safely carry 100 milliamperes (.1 amp.). This is given in the wire tables as No. 30 B. & S. It is a good idea to add 3% to 5% of the number of secondary turns to the winding to make up for the voltage drop that will occur at full load due to the transformer losses and regulation. (105% x 2963 = 3110 turns).

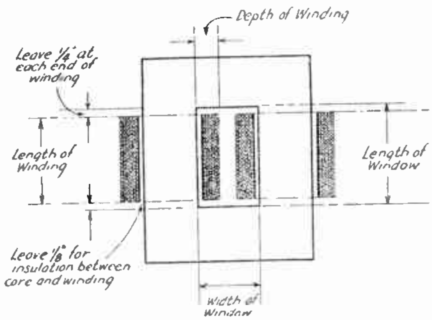
Usually a rectifier system is used that rectifies both halves of the cycle, using a separate secondary winding for each half cycle. This means that unless the bridge rectifier connection is used, two 3110-turn secondaries will be required. It is possible to use smaller wire in the secondary in view



HOW THE ARRANGEMENT OF THE CORE AND WINDINGS AFFECTS THE VOLTAGE REGULATION OF CORE TYPE TRANSFORMERS

of the fact that each winding is passing current but half the time, but it is better to stick to 1,000 circular mils per ampere and be safe. Using good-sized wire will help to improve the regulation. The core specifications and the number of turns to use in the primary are given in the table. Before we go ahead with the construction it is necessary to figure out the opening or *window size* that will be necessary in the core of proper cross-section in order to just get the windings on without wasting any space.

The best thing to do is to decide on a tentative length of winding, making a full-size drawing of the transformer on a sheet of paper. From the wire table find out how many turns of wire per layer can be obtained in the primary winding. Leave at least ¼" between the end of the winding itself and the adjacent leg of the core. Divide the total number of turns that will be needed in the winding by the number of turns per layer to find out how many



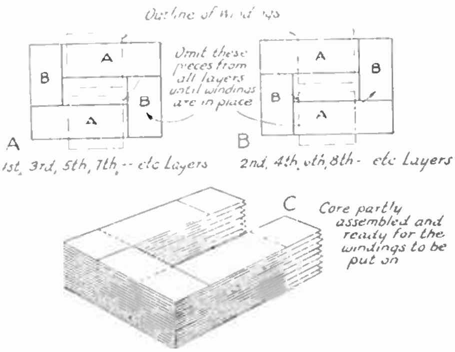
A FULL SIZE DRAWING OF THE TRANSFORMER should be made showing the space to be occupied by the windings and insulation. Be sure the window is large enough to get the windings on but do not make it a bit larger than necessary or the regulation will be impaired

layers will be needed to get the required number of turns on. The depth of the winding can next be ascertained. Be sure to allow ⅛" between the core and the inside layer of wire for insulation. Allow for insulation between layers if there is to be any, too. Having finished these computations, you can draw the outline of the winding in, just as it is going to look as it is shown in the diagram. The depth of the secondary winding can be figured in just the same fashion, using the same length of winding as was used in the primary. If enameled wire is used, allow for a layer of thin paper between each layer of wire. Although enamel-insulated wire has the best space factor, single-cotton-covered enamel is best to use. Double-cotton-covered wire can be used but is not so economical of space.

When the depth of both primary and secondary windings has been computed, their sum plus ¼" (for a factor of safety) will give the width of the window in the core. If the drawing begins to look like D instead of E (see the sketch showing different arrangements of core and windings), it will be necessary to try a different value for the length of the winding, figuring the size of the window all over again. A transformer with a large core and a relatively small amount of wire is best from the standpoint of the amateur builder because wire in smaller sizes is expensive while transformer iron is cheap. It is hard for most amateurs to wind many turns by hand unless a convenient winding jig is available.

After a little juggling with pencil and paper, the design of the transformer will be complete. The next step will be to obtain the materials and start the process of construction.

Any kind of transformer iron or silicon steel will make a good core. Sometimes an old power transformer from the local junk yard or from the electric light company can be torn down to get good and cheap core materials. The writer used the wire thus obtained from a wrecked compensator to put up a complete multi-wire antenna and counterpoise in the good old times when lots of wires were considered essential in an antenna system, making a transmitting coil and giving away a lot of wire besides, so there are other uses for junked transformers if you can get hold of one. It is not worth-while to try to cut out core materials yourself or to use ordinary stove-pipe iron as it will not lie flat. Laminations of about 28-gauge thickness should be used, as thicker iron pieces will give a large loss from eddy currents in the core and the heating in the core will be objectionable. The iron must be carefully cut so that good joints in the core can be made if the transformer is to have passably good regulation. L-shaped laminations are convenient to use in building a transformer but separate pieces for the four sides can be used if they are more readily obtained. The



HOW TO PUT A TRANSFORMER CORE TOGETHER

method of assembling a transformer core is shown in one diagram. Three sides of the core can be built up, the windings put on, and then the fourth leg of the core put in place one lamination at a time. All laminations should be insulated from each other to prevent eddy currents flowing in the core. If there is iron rust or a scale on the core material you have, that will serve the purpose very well—otherwise one side of each piece can be coated with thin shellac. It is essential that the joints in the core be well made, that the joints be square and even. After the transformer is assembled, the joints can be hammered up tight using a block of wood between the hammer and the core to prevent damaging the edges of the laminations. A cigar box with two adjacent sides knocked out and the cover removed will be helpful in building up the core evenly. When three legs are completed, the whole can be tied with string, clamped in a vise, and the legs on which the windings are to be slipped wound with friction tape to hold them firmly in place and to keep the iron from damaging windings and insulation.

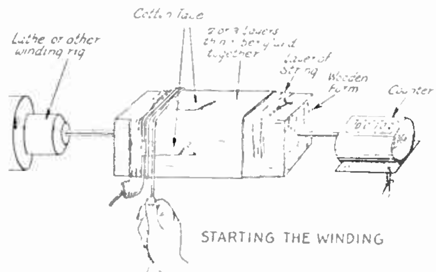
It is convenient to wind the coils on varnished fullerboard. At any rate the coils should be wound on a wooden form and if some fullerboard or pliable cardboard can be put over this it will make it easy to slip the finished coils from the form to the core without mechanical injury. The wires cannot get out of place when so wound and they are well-insulated from the core besides. The wooden block should be slightly larger than the leg of the core on which the winding is to be put and it should be a few inches longer than the winding. The block must be smooth and of just the right size. Several pieces fastened together with small screws at the ends will make a form of the right size which can be easily taken apart when the winding is finished.

Diagrams suggesting ways of starting the winding, finishing the winding and bringing out taps are shown to suggest the best procedure. If a lathe is not available for holding and rotating the form during winding, a bicycle, grinder, sewing machine or hand drill clamped in a vise can be adapted for the purpose. For secondary windings of many turns of wire a revolution counter should be used to make the work easy and to insure that the right number of turns are put on each coil. It is certainly exasperating to lose track of the number of turns when a winding is nearly finished.

If a solid block is used for a winding form, a layer of string should be wound over the form before the wire is put on. The ends of the string are fastened to tacks and this string can be removed as soon as the winding is finished, to leave room for slipping the winding off the form. The fuller-board, some thin fiber, or heavy fish paper goes over this string, serving as a permanent support for the winding and as insulation from the core. In high-voltage windings, some layers of Empire cloth (varnished cambric) should be included in addition and if a transformer to give very high voltage is built a micarta barrier will be necessary.

The winding itself is quite simple. The wire is wound on in layers as it takes least space when wound that way. Strips of paper between layers of small enameled wire are necessary to keep the turns of each layer even and to give added insulation. Too-thick paper must be avoided as it keeps the heat generated in the winding at full load inside so that the temperature may become dangerously high for the insulating materials, resulting in breakdown.

It is advisable to impregnate transformer coils after driving the moisture out, to make them permanently good. Manufacturers do this by putting the coils in a partial vacuum, heating, and then forcing insulating compound under pressure into the coils. Transformers built by the amateur for filament and plate-voltage supply can be painted with insulating varnish or waxed to make them rigid and moisture proof. A mixture of melted beeswax and rosin makes a good impregnating mixture. Melted paraffin can be used but it has too low a melting point. When possible, the transformer can be suspended in a tank of cooling and insulating oil, though this is not good for indoor use as the fire hazard must be considered. Double-cotton-covered wire can be coated with shellac as each layer is put on. However, enameled wire should never be treated with shellac as it may dissolve the enamel and hurt the insulation and it will not dry because the moisture in the shellac will not be absorbed by the insulation. Small transformers can be treated with battery-compound after they are wound and assembled. Usually a home made transformer that is varnished or protected from moisture by shellac can be mounted as shown in one diagram and will stand up indefinitely under the intermittent service of amateur radio work. Therefore a can of insulating varnish or shellac and a small brush with which to apply it will be made part of our transformer-building equipment.



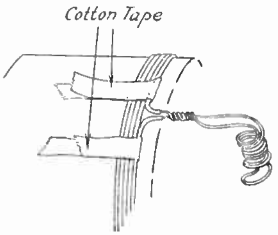
STARTING THE WINDING

In starting the winding, hold the loose end on each side of the winding form by folding a two inch piece of cotton tape around the first turn in such a way that the following turns hold the first one in place. Coil up enough wire on the end to provide a lead from the inside of the coil to the terminal board after the transformer has been mounted. After making a good start, the winding process can be speeded up. In winding the coil, feed the wire with a cloth over your hand about two or three feet away from the rotating form. Keep the wire as tight as possible without danger of breaking it. Wind the wire in even layers with no turns directly on top of each other to take best advantage of the available space.

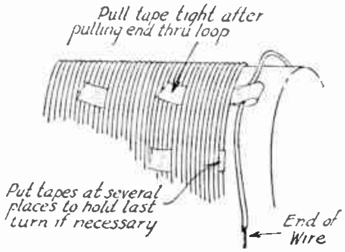
When about half an inch from the end of the first layer, lay on some more pieces of cotton tape to bend back under the second layer, thus holding the end turns securely in place. If very thin paper or no paper at all is used between layers the same thing can be done at the end of each layer. Using very fine wire with paper between layers no additional support for the end turns will be necessary, especially if the precaution of ending the layers about one eighth inch from the edge of the paper is observed. Where no paper is used, run the layers as near to the end of the form as possible, keeping the wire as tight as possible.

Keep watch for shorted turns and layers. If just one turn should become shorted in the entire winding, the low voltage to flow in it would cause a heavy current to flow which would burn it up, making the whole transformer useless.

Taps can be taken off as the windings are made if it is desired to have a transformer

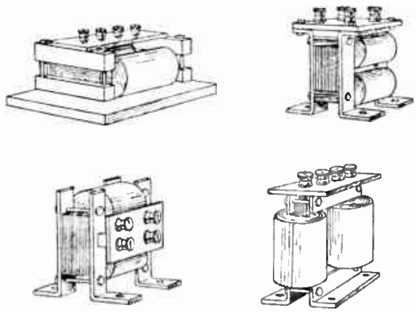


BRINGING OUT A TAP



FINISHING OFF THE WINDING

giving several voltages. The diagram plainly shows the method to be used in making taps and in finishing the winding. The more taps there are, the more difficult becomes the problem of avoiding weakened insulation at the points where the taps are made. Taps should be arranged so that they come at the end of the layers whenever possible. If the wire is very small, the ends of the winding and any taps that are made should be of heavier wire to provide a stronger lead. Unless the finished winding is well taped, a piece of fullerboard or heavy paper should be put over it to prevent the winding



WAYS OF MOUNTING TRANSFORMERS

from mechanical injury as well as to improve its appearance.

High-voltage coils should be taped with varnished cambric tape. Low-voltage coils can be taped with friction tape or with untreated cotton tape and varnished later. Always lay the tape on smoothly so that each turn advances half the width of the preceding one. Pull the tape tight but not so tight as to pull the winding out of shape.

The leads should be well insulated. High voltage leads can be run through varnished cambric tubing or the "spaghetti" that is on sale at the local radio store. Pieces of flat tubular shoe lacing are good enough to cover the low-voltage leads.

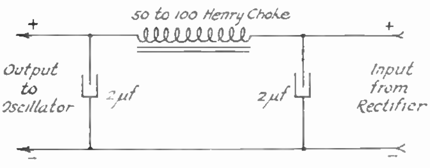
When slipping the coils on the partially assembled core, be sure that the leads do not touch the core. If the windings fit loosely some small wooden wedges should be driven in place at each end. Last of all, the other leg of the core is put in place and driven up tight. If the coils are wedged firmly and wound tightly and the core is taped, clamped or bolted between some strips of wood or bakelite, the transformer will not hum. It will operate with very little noise anyway if these precautions are observed. Last of all the transformer should be mounted. After leaving the primary winding connected to the line for several hours it should be only slightly warm. It it draws much current or gets hot there is something wrong and some short-circuited turns are probably responsible which will continue to cause overheating and fireworks later.

Some ⅛" x 1" angle iron, or pieces of iron strap of the right size, make an excellent mounting. The core is clamped tightly by several bolts at the corners. The terminal board should be of bakelite and situated so that there is plenty of room for the leads to come up under it from the windings below. Several ways of mounting transformers and putting on the terminal board are shown. Be sure to separate the terminals from the different windings as much as possible so that there is no danger of their becoming crossed. Ordinary binding posts, 8-32 or 10-32 brass or nickled brass machine screws, or even Fahnstock clips can be used on the terminal board for making connections.

FILTERS

With all the rectifier arrangements that have been described a filter is essential to improve the note and to suppress any a.c. hum that may get through from the supply source. Even with a motor-generator set a filter may be necessary to take the commutator ripple or "burr" out of the note unless the motor-generator happens to be supplying a crystal-controlled set. In some cases a suitable filter has been mentioned when discussing or diagramming a particular rectifier system.

A filter of the so-called "brute force" type using a 30-henry to 100-henry choke coil in series with the high-voltage leads from rectifier to set, and having a two-microfarad (or larger) condenser across the high-voltage line on each side of the choke will be satisfactory for filtering the output of almost any rectifier of the electrolytic, mercury-arc, Rectron (vacuum tube), or gaseous-conduction tube types. The condensers across the high-voltage line must always have a voltage breakdown high enough for safety under no-load conditions (when the voltage is highest).

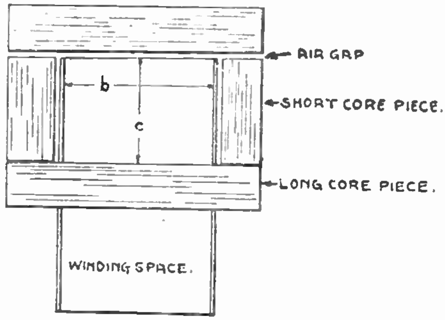


"BRUTE FORCE" FILTER CIRCUIT

DESIGNING AND BUILDING CHOKE COILS FOR THE FILTER

The design and construction of choke coils to use in filtering the plate supply of an amateur transmitter can be carried out in the same way that the building of a transformer was developed. The basic design principles are the same and the building of a choke coil is even simpler because no taps are necessary and only one coil is required on the core.

A full-page chart, reproduced from *QST*, shows the dimensions for building chokes that will meet most needs of the amateur for removing the commutator ripple from a d.c. generator or smoothing out the ripple in rectified 25-cycle and 60-cycle plate supplies. Of course the chokes must be used with suitable capacities to make effective filter. Though it is usually best to make chokes, the filter condensers can be purchased ready-made from any of the reputable condenser manufacturers. As this is a practical rather than a theoretical book, it is not possible to discuss the theory of high-pass and low-pass filters. Some good books on telephone transmission from the nearest public library will cover this theory for readers who want it. Chokes of inductances between the values given in the table can be made by using less turns of wire in the winding. Inductance varies about as the square of the number of turns so that using half the number of turns specified gives one fourth the inductance. More turns than those specified in the table must not be used as the core will become saturated. Dimensions *b* and *c* given in the table can be understood by reference to the diagram. The arrangement of core and winding is supposed to be that of the diagram, also.



ARRANGMENT OF INDUCTANCE COILS.

The best core material is the same as that specified for building transformers—silicon steel sheet. The laminations should be .014" (or less) thick, covered with shellac or rust to reduce eddy-current losses. Fine iron wire is excellent as a core material, also. While interleaved corners are almost a necessity for a good transformer core, the core of your choke coil should be made with a butt joint. An air gap is needed in any case to prevent saturation of the core and to offer a means for adjustment of the inductance. After the gap is adjusted the core should be clamped firmly so that the magnetic pull will not change the adjustment and to insure quiet operation. Besides clamping the core, a substantial "brass" air gap can be used or a wooden or cloth wedge inserted in the air gap to prevent vibration

DESIGN DATA FOR INDUCTANCE COILS WITH IRON CORES. *Weight of Steel taken as 480 lbs/cu ft = 0.28 pounds/cubic inches*

	Core Size: Cross Section	Inductance: Henrys	Equiv Gap (G)	*Actual Gap: Decimals	*Actual Gap: Nearest Fraction	No Turns (N)	⚘ Flux Dens (B) Lines to inch	Winding Form b	Winding Form c	Mean Turn inches	Feet of Wire	Resistance (D C)	Weight of Copper	Core Dimentions: Long Piece	Core Dimentions: Short Piece	Pounds Steel
All wound with No. 33 enamelled wire 206.6 ohms per 1000 ft 6591 ft. per lb. Carrying Capacity 0.05 amperes.	½×½	0.5	.040"	.017"	1/64"	1600	6500	0.42"	0.28"	3.0	400	82.5	1.0 oz	½×1.6"	½×.50"	0.30
		1.0	.041	.019		2300	9000	0.50	0.33	3.2	615	127.0	1.5 "	½×1.7	½×.55	0.31
		5.0	.043	.023		5200	20000	0.75	0.50	3.8	1670	345.0	4.0 "	½×1.92	½×.75	0.37
		10.0	.046	.030	1/32"	7600	27000	0.90	0.60	4.2	2640	545.0	6.5 "	½×2.1	½×.85	0.41
		15.0	.048	.035		9500	32000	1.00	0.68	4.5	3510	725.0	8.5 "	½×2.2	½×.85	0.43
	¾×¾	5.0	.043"	.023		3500	13000	0.62"	0.42"	4.5	1310	271	3.25 oz	¾×2.4	¾×.75	1.0
		10.0	.046	.030		5000	18000	0.73	0.49	4.75	2000	411	5.0 "	¾×2.5	¾×.75	1.0
		15.0	.048	.035		6300	21000	0.82	0.55	5.0	2630	544	6.5 "	¾×2.6	¾×.75	1.05
		20.0	.052	.044	3/64"	7600	24000	0.91	0.60	5.2	3280	678	8.0 "	¾×2.7	¾×.85	1.1
		50.0	.070	.100	7/64"	14000	33000	1.25	0.83	6.0	7000	1445	1 lb 1 "	¾×3.0	¾×1.0	1.25
	1×1	10.0	.046"	.030	1/32"	3800	14000	0.64"	0.43"	5.6	1760	364	4.25 oz	1×3.0	1×.75	2.1
		15.0	.048	.035		4800	16000	0.69	0.49	5.8	2310	478	5.5 "	1×3.0	1×.75	2.1
		20.0	.052	.044	3/64"	5700	18000	0.78	0.52	5.9	2800	580	6.75 "	1×3.1	1×.75	2.2
		50.0	.070	.100	7/64"	11000	25000	1.10	0.75	6.7	6130	1270	15.0 "	1×3.5	1×1.0	2.5
		100.0	.100	.250	1/4"	18000	29000	1.40	0.93	7.4	11000	2280	1 lb 10 "	1×3.8	1×1.1	2.75
	2×2	100.0	.100"	.250	1/4"	8900	14000	0.97"	0.65"	10.4	7700	1590	1 lb 3 oz	2×5.5	2×1.0	14.5
All wound with No. 30 enamelled wire 103 ohms per 1000 ft. 3287 ft. per lb Carrying Capacity 0.10 amps.	½×½	0.5	.040"	.017	1/64"	1600	13000	0.55"	0.38"	3.4	450	46	2.2 oz	½×1.6	½×0.63	0.31
		1.0	.041	.019		2300	18000	0.66	0.45	3.6	700	72	3.5 "	½×1.75	½×0.70	0.35
		5.0	.043	.023		5200	39000	1.00	0.68	4.5	1950	200	9.5 "	½×2.10	½×0.95	0.43
	¾×¾	1.0	.041"	.019		1500	12000	0.53"	0.37"	4.3	540	56	2.7 oz	¾×2.10	¾×0.63	0.87
		5.0	.043	.023		3500	26000	0.83	0.56	5.0	1470	151	7.2 "	¾×2.5	¾×0.80	1.05
		10.0	.046	.030	1/32	5000	35000	1.00	0.67	5.4	2250	230	11.0 "	¾×2.6	¾×0.95	1.12
	1×1	5.0	.043"	.023		2600	20000	0.71"	0.49"	5.8	1250	130	6.1 oz	1×2.8	1×0.75	2.0
		10.0	.046	.030	1/32"	3800	27000	0.86	0.58	6.1	1940	200	9.5 "	1×3.0	1×0.85	2.2
		15.0	.048	.035		4800	32000	0.96	0.65	6.4	2550	260	12.5 "	1×3.1	1×0.90	2.25
	2×2	10.0	.046"	.030	1/32"	1900	13000	0.60"	0.42"	9.5	1500	160	7.5 oz	2×4.66	2×0.60	11.5
		15.0	.048	.035		2400	16000	0.68	0.46	9.7	1900	200	9.5 "	2×4.75	2×0.66	12.3
		20.0	.052	.044	3/64"	2900	18000	0.75	0.51	9.8	2400	250	11.5 "	2×4.85	2×0.75	12.5
		50.0	.070	.100	7/64"	5300	24000	1.00	0.70	10.5	4600	480	1 lb 6.5 "	2×5.50	2×0.95	14.0
		100.0	.100	.250	1/4"	8900	28000	1.33	0.90	11.2	8300	860	2 lb 8 "	2×5.90	2×1.15	16.0
All wound with No 26 enamelled wire 40.75 ohms per 1000 ft 1300 ft per lb Carrying Capacity 0.25 amps	½×½	0.5	.040"	.017	1/64"	1600	32000	0.90"	0.60"	4.2	550	22.5	7 oz	½×2	½×.85	0.40
		1.0	.082	.120	1/8"	3200	32000	1.30	0.85	5.1	1350	55	1 lb 1 "	½×2.5	½×1.10	0.50
	¾×¾	0.5	.040"	.017	1/64"	1000	21000	0.72"	0.46"	4.7	390	16	5 oz	¾×2.3	¾×0.71	0.96
		1.0	.041	.019		1500	30000	0.90	0.58	5.1	640	26	8 "	¾×2.5	¾×0.83	1.05
	1×1	1.0	.041"	.019		1100	22000	0.75"	0.50"	5.8	530	22	6.5 oz	1×2.9	1×0.75	2.10
		5.0	.086	.170	11/64"	3700	35000	1.40	0.92	7.3	2260	92	1 lb 12 "	1×3.6	1×1.20	2.7
	2×2	5.0	.043"	.023	1/4"	1300	23000	0.82"	0.53"	9.7	1050	43	13 oz	2×4.9	2×0.80	12.7
		10.0	.050	.040	1/64"	2000	32000	1.05	0.68	10.5	1750	71	1 lb 6 "	2×5.2	2×1.0	13.8
		15.0	.096	.200	13/64"	3300	28000	1.35	0.86	11.1	3060	125	2 " 6 "	2×5.5	2×1.1	14.7
		20.0	.104	.280	9/32"	4000	32000	1.43	0.95	11.5	3820	156	2 " 15 "	2×5.6	2×1.2	15.2
	3×3	10.0	.046"	.030		1300	22000	0.81"	0.53"	14.0	1510	62	1 lb 3 oz	3×6.9	3×0.8	39
		15.0	.048	.035		1600	26000	0.90	0.60	14.2	1900	77	1 " 7 "	3×7.0	3×0.85	40
		20.0	.052	.044	3/64"	1900	30000	1.00	0.65	14.4	2300	93	1 " 12 "	3×7.1	3×0.9	41
		50.0	.140	.330	1/3"	5000	28000	1.60	1.10	15.9	6600	270	5 " 2 "	3×7.8	3×1.35	46
		100.0	.200	.600	19/32"	8400	34000	2.10	1.40	17.0	12000	485	9 " 3 "	3×8.3	3×1.65	50
All wound with No 23 enamelled wire 20.32 ohms per 1000 ft 648.4 ft per lb Carrying Capacity 0.50 Amps.	½×½	0.5	0.16"	.35	11/32"	3200	32000	1.80"	1.20"	6.4	1700	35	2 lb 10 oz	½×3	½×1.45	0.62
	¾×¾	0.5	0.08"	.170	11/64"	1480	30000	1.25"	.83"	6.0	735	15	1 lb 2 oz	¾×2.9	¾×1.1	1.26
		1.0	0.16	.35	11/32"	3000	30000	1.75	1.20	7.2	1800	37	2 " 13 "	¾×3.5	¾×1.5	1.6
	1×1	0.5	0.04"	.02	1/64"	800	32000	0.90"	0.60"	6.2	410	8.5	0 lb 10 oz	1×3.0	1×0.85	2.2
		1.0	0.082	.17	11/64"	1600	31000	1.30	0.85	7.1	945	19	1 " 8 "	1×3.5	1×1.0	2.5
		5.0	0.387	.75	3/4"	7800	32000	2.90	1.90	11.0	7000	143	10 " 14 "	1×5.2	1×2.2	4.2
	2×2	1.0	0.041"	.019		560	22000	0.75"	0.50"	9.8	460	9.4	0 lb 12 oz	2×4.9	2×0.75	12.7
		5.0	0.086	.17	11/64"	1800	32000	1.35	0.90	11.3	1700	35	2 " 10 "	2×5.5	2×1.15	15.0
		10.0	0.184	.40	13/32"	3800	33000	2.00	1.30	12.8	4100	83	6 " 6 "	2×6.2	2×1.5	17.3
	3×3	5.0	0.043"	.023		860	30000	1.00"	0.60"	14.2	1000	21	1 lb 10 oz	3×7.1	3×0.85	40.0
		10.0	0.092	.20	13/64"	1840	31500	1.40	0.92	15.3	2350	48	3 " 10 "	3×7.5	3×1.15	43.5
		15.0	0.130	.30	19/64"	2620	32000	1.65	1.10	16.0	3500	71	5 " 7 "	3×7.8	3×1.4	46.0
		20.0	0.175	.38	3/8"	3500	32000	1.90	1.25	16.6	4850	99	7 " 8 "	3×8.1	3×1.5	48.0
		50.0	0.432	.80	13/16"	8700	32000	3.00	2.00	19.2	14000	282	21 " 8 "	3×9.3	3×2.3	58.0
		100.0	0.900	1.50	1 1/2"	16700	31500	4.10	2.80	22.0	31000	620	47 " 5 "	3×10.5	3×3.1	68.0

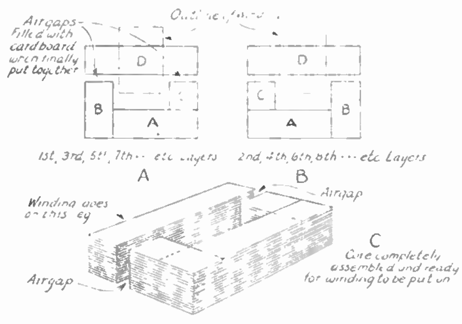
* The Actual Gap can only be an approximation owing to the many factors which may effect Fringing of flux, permeability of core, etc. It must be adjusted by trial until the proper value of inductance is obtained or better yet, until the set up operates at the best point.

⚘ The values of (B), the flux density, are those obtained with all D C & no A C, or the effective B if all A C. The maximum value in the latter case will be 1.41 × B as given. In the case of rectified A C applied to coil with no previous smoothing the maximum B may be 1.57 times the values given.

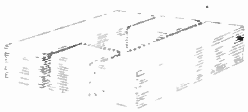
— HICK

and make the adjustment permanent. The total air gap, if there is more than one, will of course be the sum of the length of the separate air gaps.

Wire with thin insulation should be used to make an economical design. Large wire uses up a great deal of space without giving much inductance. It is best to wind directly on the core with just a single layer of tape between if possible. More insulation will be required for chokes that are to be placed in high-voltage plate supply lines but this



HOW TO PUT A CHOKE COIL CORE TOGETHER



ANOTHER METHOD OF BUILDING A CORE FOR A CHOKE COIL

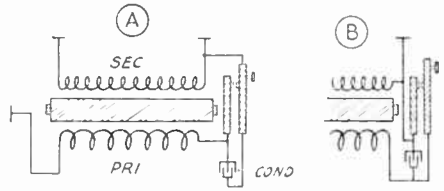
should not be any thicker than is absolutely necessary. Before starting the winding on the core, put some cotton strips along it and fasten some heavy cardboard or thin micarta end flanges in place. After winding the coil, the tape can be tied over the coil to keep the wire from spreading. Too much tape should not be put on or the choke will not keep cool under load conditions. The wire sizes in the table are conservative and 10% more current can be carried continuously and even more than this intermittently. If the winding is very deep, the cooling will be better if the coil is split into two sections to slip onto each long core piece. 10% more turns will then need to be added to each coil to make up for the magnetic leakage between coils which is increased by splitting the winding. Heavy flexible leads should be soldered to the ends of the coil and taped down to prevent their breaking off.

The action of a filter may be likened to that of a big flywheel that stores energy in the magnetic field of the chokes and in the electro-static field of the condensers placed across the line. The filter absorbs energy during the "peak" output periods of the rectifier, giving out this energy during the "zero" part of the a.c. cycle to keep the supply voltage substantially constant (unvarying). A large paralleled condenser alone (75 μfd.) helps a great deal. A large series choke with condensers across the line at either end seems to work best and this is commonly referred to as the "brute force" type of filter. The choke should be over 30 henries but it does not have to be adjusted to any particular value of inductance. Several parallel resonant circuits effectively eliminate one frequency. By means of a carefully-designed filter having high impedance to certain frequencies, the several fundamental and harmonic frequencies from the a.c. supply that are present in the output of a rectifier can be suppressed.

Windings from spark coils, amplifying transformers, or any old coils of many turns of small wire can sometimes be pressed into use for the plate-supply equipment for a low-power transmitter. All that is necessary is to mount them on the right sort of a core and to adjust the air gap. Any transmitter using a UX-210 or larger tubes should be provided with a good rectifier and filter using one of the choke coils whose dimensions are given in the table. Sets of lower power using receiving tubes can sometimes be filtered by making use of some old spark coils such as find their way into every experimenter's "junk" box.

FORD COILS AS FILTERS FOR LOW-POWER SETS

The connections of a Ford coil and the method of connecting two coils with their condensers as a filter are shown in the sketch. Such a filter as that described can be made from discarded coils obtained for almost nothing from local automobile repairmen. One coil will cut down the ripple somewhat and two of them connected as shown still have sufficient inductance to improve the tone greatly without reducing the plate voltage more than 20%.

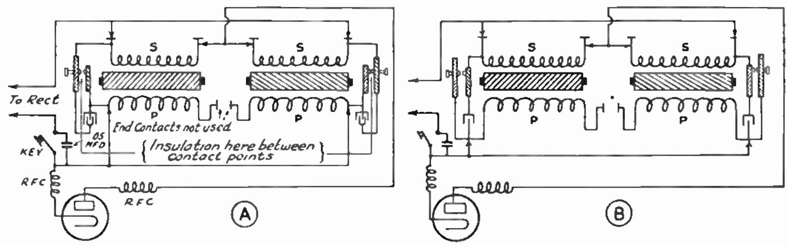


CONNECTIONS OF TWO TYPES OF FORD COILS

There is a condenser shunted across the vibrator contacts which has a capacity of about 1 microfarad and which will easily stand four or five hundred volts and this should be connected so it is across the output of the rectifier—it will *not* be as effective if placed next the tube. A thin piece of insulating material must be placed between the contact points of the coil and between the lower contact arm and the core but it is not necessary to tear the coils down to make use of them.

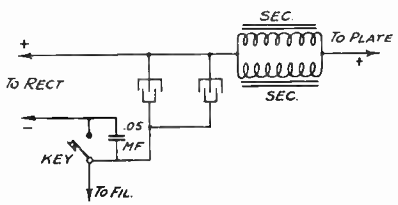
There are at least two types of coils, the one indicated in Circuit A which has a

steel is about 3,000 (average), the ratio of air to iron can be determined approximately but the iron varies so much that the exact value must always be decided by trial. For a core of 10" total length, an air gap of about .05" or a little less will meet average requirements.



METHOD BY WHICH TWO FORD COILS ARE USED AS A FILTER IN A LOW POWER TRANSMITTER

brass backing on the vibrator end and the one indicated in Circuit B which has a wooden end. The d.c. resistance of the many turns of small wire is rather high and so the secondaries of two spark coils must be connected in parallel as shown to secure best results. The primary winding does not



have much inductance and is of little value. The secondary of a Ford coil has a resistance of about 5,000 ohms which will reduce the plate voltage a good bit if used by itself.

ADJUSTING THE AIR GAP AND TESTING FILTER ACTION

The simplest way to adjust the air gap is to connect the filter to the load with which it is to work, changing the air gap until the best filter action is observed when listening to the output of the transmitter in the monitor. A too-large air gap will reduce the inductance and the choke will be ineffective. A too-small gap will allow the core to become saturated, and the choke will be just as ineffective.

The right value for the air gap is one that uses up about nine-tenths of the ampere-turns of the coil to maintain flux in the air gap. The rest of the magnetomotive force magnetizes the core. As the permeability of air is unity and that for sheet

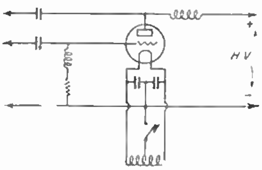
THE FILAMENT SUPPLY

The second division of the power supply for the transmitter is the supply to the filaments of the tubes used. Though batteries are sometimes used for this supply, alternating current obtained from the house current through a step-down transformer usually is more practical and more satisfactory. In some cases the filament-supply winding is wound over the core of the high-voltage transformer, thus eliminating the necessity for a separate filament transformer. This practice, however, is not to be recommended. The filament supply must be constant if the transmitter is to operate effectively, and with both filament and high-voltage supplies coming from one transformer this constancy is obtained only with great difficulty, since changes in the load taken from the high-voltage winding cause serious changes in the voltage obtained from the filament winding unless the transformer is operating well under its rating or unless special compensating apparatus is employed. Wherever possible the high-voltage and filament transformers should be separate units operating, if it can be arranged, from different power outlets.

The important points to observe in installing the filament supply are that a means is provided for a center-tap (as described in the preceding chapter); that a filament voltmeter is connected in the circuit as near as possible to the filament terminals of the tube; and that a suitable rheostat is provided for the adjustment of the filament voltage. Examination of any of the transmitter circuits will make it obvious that the filaments of the rectifier tubes must be well insulated from the filaments of the transmitter tubes. The filaments of the rectifiers provide the positive output lead from the plate supply system while the filaments of the transmitter tubes are connected to the negative side of the high-voltage supply. The fact that the two filament supplies must be insulated does not, however, mean that two transformers are required. The two windings can be on the same core, the necessary insulation being provided between them. Should the filament transformer be bought and should it have no winding suitable for the filaments of the mercury-vapor rectifiers, an extra winding usually can be fitted without difficulty. Two No. 12 gauge wires in parallel should be used for the winding, the number of turns being determined by the "cut and try" method. With most transformers only a few turns will be necessary to give the required voltage. The rectifier-filament winding can be center-tapped or a center-tapped resistor can be used across it in the manner described for the transmitter filaments.

KEYING THE TRANSMITTER

Naturally, in order to utilise the transmitter for telegraphic communication, it is necessary to be able to break up its output into long and short pieces which, at the receiving end, will give the desired dots and

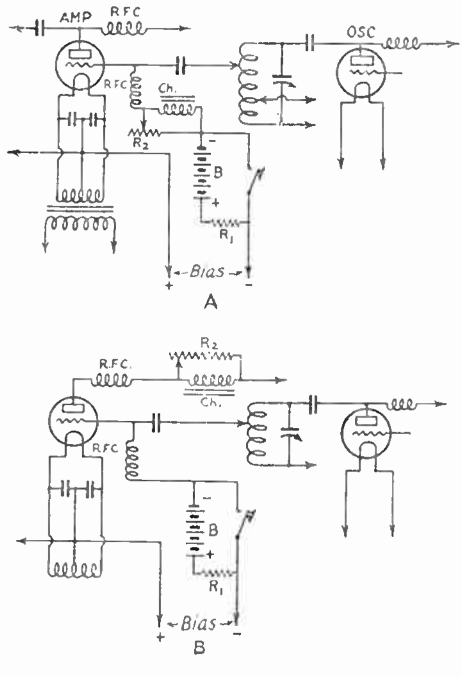


ONE OF THE SIMPLEST FORMS OF KEYING SYSTEM
in which the key is connected in the center-tap lead. This arrangement often results in interference from key-thumps.

dashes. There are many simple ways of so breaking up the output of the transmitter but careful adjustment both of the transmitter and of the keying system usually is necessary to avoid the production of key-thumps (which may interfere with broadcast reception) or key-chirps (which may make the signal very difficult to read).

Key-thumps will result if the transmitter is caused to start or stop oscillation suddenly. They will be made much more serious if the keying system is one which throws all load off the plate supply when the key is up. The reason for this is that with no load on the plate-supply apparatus the condensers of the filter system become charged to the peak voltage of the transformer. Then, when the plate voltage is applied to the tube, it not only starts oscillating suddenly but starts oscillating with abnormal force because of the peak voltage which accumulated in the filter. This peak voltage is, of course, soon reduced to normal but the result will have been a heavy key-thump.

In modern amateur transmitters it is considered good practice to have a load resistor always connected across the output of the plate-supply system. In this way, even if the transmitting tube is disconnected during keying, there is always a load on the filter and its condensers are never charged to high peak voltages. A practical value of load current through such a load resistor is about 25% of the tube plate current. In a transmitter employing a single UX-210 tube this would be approximately 15 m.a. The value of the resistance necessary to limit the current to this value is obtained from Ohm's Law, R = E/I. For a 500-volt supply it would therefore be 500 divided by .015, the



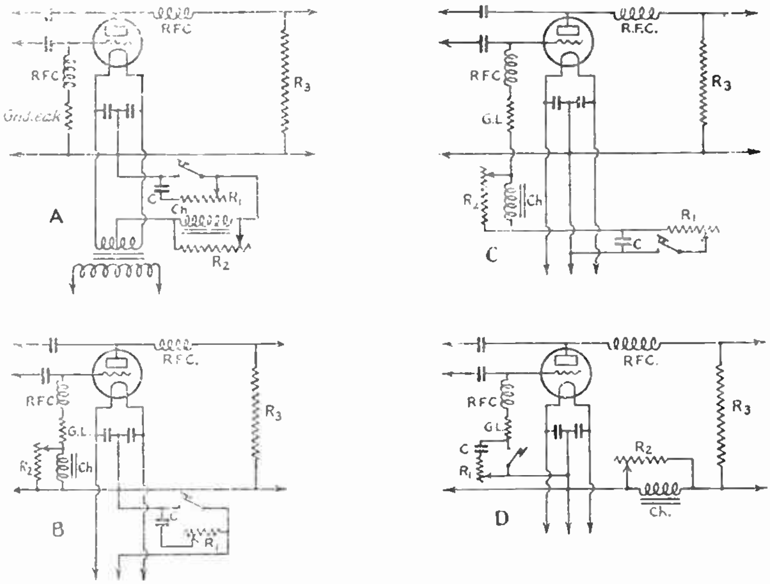
KEYING SYSTEMS PARTICULARLY SUITED FOR USE WITH M.O.P.A. OR CRYSTAL-CONTROLLED TRANSMITTERS

In the Circuit A the time lag unit is in the bias lead to the amplifier grid. In most cases the mere opening of the grid circuit will not prevent the flow of amplifier current and for this reason the battery B is included. Its purpose is to hammer the amplifier grid negative when the key is up. The resistor R1 is used to limit the current flowing from B through the key when it is down. A 5,000 ohm gridleak will serve when B does not exceed 45 volts. A proportionately higher resistance is required when B is of a higher voltage. B is adjusted with the key up until the amplifier plate current is zero.

The connection of the lag circuit in the high voltage supply to the amplifier as in Circuit B is desirable when medium or high power is used in order to provide a "cushion" against plate voltage surges during keying. Ch. and R2 are as specified under the larger figure.

result being about 33,000 ohms. In some cases, particularly if the mercury-vapor rectifiers are used, a greater drain current than this can be permitted. A resistor of 20,000 ohms, giving a drain of 25 m.a., would be

With some such means as this to prevent the building up of high voltages in the filter when the transmitter is not taking power, the keying problem is much simplified. In some locations, where the antennas of



SOME PRACTICAL KEYING ARRANGEMENTS INVOLVING THE USE OF AN INDUCTANCE TO PROVIDE A TIME LAG

At A the key and lag circuit Ch., R2 are connected in the center tap lead, so operating in both the plate and grid d.c. circuits. In this case the inductance Ch. must be capable of carrying the grid and plate currents without undue voltage drop. At B the key is in the center-tap lead while the lag circuit is in the d.c. grid lead. The inductance in this instance can be of much lower current rating than that used in A. The arrangement is therefore useful in cases where the available choke is not wound with sufficiently heavy wire to serve in the plate wiring. In the circuit C both key and choke are in the grid circuit a scheme which is particularly suited for high-current tubes with which key sparking, when the plate circuit is broken, is often difficult to eliminate. The arrangement D shows the key in the grid circuit and the lag circuit in the plate lead. This connection is well adapted for use with high-current tubes also since key sparking is readily eliminated and the lag circuit is in a position where it can play second part in reducing the possibility of sudden high voltage surges reaching the tube during keying. It is a useful arrangement when the available choke happens to be heavy enough for service in plate circuit. The resistor R3 (described in the text) performs a function essential to the successful operation of any of the circuits in reducing the peak voltage built up in the filter during the keying spaces.

R1—Variable resistor of wire wound or carbon-pile type, 400 or 500 ohms.

R2—When Ch. is of the order of 30-50 henries, 10,000 ohms. When Ch. is between 5 and 10 henries 5,000 ohms. For operation in the grid circuit or the plate circuit of low-powered transmitters resistors similar to the Bradleyohm are serviceable. For most plate circuits, however, wire-wound resistors or carbon-pile resistors similar to the Bradleyleak are necessary.

R3—Wire wound resistor between 20,000 and 80,000 depending on tube used. See text.

C—.5 or 1 μfd. fixed condenser, voltage rating of at least half plate voltage when used in grid or center-tap. Voltage rating equal to filter condensers when used in plate lead.

Ch.—Audio frequency transformer secondary for use in grid circuit of low powered transmitter. Good "B Eliminator" choke for grid circuit of medium or high powered transmitter. When used in center-tap or plate lead a choke rated well above plate current of tube is necessary. Inductances between 5 and 30 henries are suitable providing R2 is of the correct value. In some cases a smaller choke may be found effective without R2.

suitable for a UX-210 under these conditions. An inexpensive load resistor can be made up from "B-eliminator" voltage-divider resistors which are often available cheaply at "10-cent" stores. Transmitter-type grid-leaks are, of course, also suitable for the purpose.

broadcast receivers are not close to the transmitting antenna, the simple connection of the key in the center-tap to the filament transformer, as shown, may serve. In most cases, however, such an arrangement would produce interference on account of the key-thumps caused by sparking at the key and by the sudden starting and stopping of oscillation. In the diagrams that follow the key is shown shunted by a resistor and condenser. It is by the use of these units that the sparking at the key is kept at a minimum. Also it will be seen that a choke is shown in some part of the circuit, shunted by a variable resistor. The purpose of this choke is to introduce a time lag so that the tube will be caused to start and stop oscillating gradually. The resistor across the choke is provided in order to permit adjustment of the effective inductance of the choke. By means of this resistor the time lag can be adjusted so that it is just long enough to avoid a thump but yet short enough to avoid a "tail" or chirp at the beginning and end of each dot or dash. It will be seen that the choke or time-lag circuit is in some cases connected in the grid lead and in others the plate lead. The actual placing of the choke does not matter much but some of the chokes available, such as audio-frequency transformer windings, are suitable only for the low currents in the grid circuit, whereas others, with heavier wire, may be operable in the plate or center-tap lead. In some cases the amateur may find a choke which has just the right inductance to give him the desirable lag. Under these conditions the variable resistor R2 shown in the diagrams across the choke would not be necessary.

Though other circuits are shown for use with oscillator-amplifier transmitters, it must not be thought that these represent all the possible systems. Keying can be accomplished in a great many ways and the most effective scheme for one set of conditions is not necessarily the most effective under other conditions. Experiment with the wide variety of systems discussed from time to time in *QST* undoubtedly will lead to the installation of an arrangement suitable for the particular conditions existing in one's own transmitter.

CODE INTERFERENCE PROBLEMS

Amateurs are often unjustly blamed for code interference. Foreign ships and commercial radio telegraph services sometimes cause bad interference to radio telephone broadcasting. This may be cured in many cases by long-wave wave traps similar to those for short-wave work that will be described in detail. Power leaks from electrical distribution systems, disturbances from thermostats in heating pads, flatirons, and oil heaters, interference from street car lines, dial telephones, loose electric lamps, ignition systems, vibrating battery chargers, mechanical rectifiers, and violet-ray apparatus are other possible sources of interference, not to mention the neighbor who operates a "blooper" (an oscillating receiver which itself is a miniature transmitter without a license). Many of the broadcast receivers sold today are still not properly selective, especially when the antenna is connected to the "secondary" coil instead of coupled to it magnetically. All this points to the conclusion that the broadcast listener as well as the amateur concerned must approach the interference problem with an open mind and a broad viewpoint.

The best way in which a source of code interference may be definitely located is through the knowledge of someone who can copy code. An operator can instantly distinguish the source of many other kinds of interference, too, though his advice will be most valuable in code interference cases. If impossible to call in a local radio operator, it is often possible to bring loudspeaker or phones to the mouthpiece of a telephone and to call a radio station operator so that he may listen and make recommendations. Trouble from power leaks may be traced to its source directly or reported to the local officials of the lighting or power companies that are now taking an interest in such matters that affect the public welfare. They are equipped to hunt trouble, replace defective insulators, remove swinging wires, re-bond rails, etc., as may be required.

While the advent of short waves for transmitting has minimized code-interference, a possibility of trouble still exists when antennas are adjacent, when the power source for transmitter and broadcast receiver is the same, and also when certain types of power supply are used in the transmitter. If a transmitter is too tightly coupled to the antenna, local disturbances are likely to occur. A pure direct-current plate supply (B-batteries or motor-generator) is likely to cause "blanketing" by blocking the grids of the receiver with large amounts of r.f. voltage. In effect the broadcast signal is greatly reduced in strength or shut off altogether. The use of plate supply from a spark coil used with vibrator, grid (chopper) modulation, or keying of a direct current source without any cushioning inductance in the circuit, is likely to lead to certain difficulty.

The particular short-wave band that is chosen for operation will in a measure determine the amount of interference trouble to be expected. With suitable precautions operation in *any* amateur band can be carried on continuously without interference resulting. A *good* plate supply, a suitable transmitting circuit, correct keying for the arrangement used, and a location free from "single-circuit" broadcast tuners which are notably non-selective, are desirable. Work in the 150-175-meter band (adjacent to broadcast territory) is perhaps most likely to provoke local interference trouble. 80-meter operation is less likely to give trouble. Interference results most rarely from 20- and 40-meter installation.

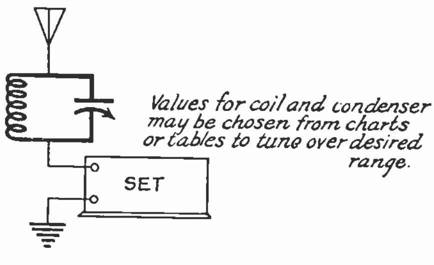
If an amateur transmitter operates on *any* wavelength in a self-rectifying circuit utilizing but half of the a.c. cycle and local broadcast listeners use A- or B-eliminators working from the same source (distribution-transformer secondary) interference is almost certain to occur. This is due to a voltage drop on just one half-cycle which "modulates" the source and affects as many people as may be supplied by a single transformer. The cure is to get an individual distribution transformer, to install another tube (or other device) working on the other half-cycle, or to put in a rectifier so that the power taken on both halves of the a.c. cycle will be constant.

Almost any other kind of amateur interference may be cured by installing radio-frequency chokes and by-pass condensers to prevent r.f. leakage back into supply lines, by placing adjacent antennas at right angles and as far apart as possible, by using key-thump filters to suppress key clicks and blocking effects, and by installing suitable wavetraps in antenna or ground leads of the broadcast receiver to improve its selectivity at the transmitting frequency.

WAVE TRAPS

Any tuned circuit coupled to a few turns of wire in series with the antenna of a broadcast receiver will act as an extremely high impedance at the frequency to which it is adjusted. Signals of that frequency will be excluded.

It is recommended that an inexpensive tuned circuit be built and installed in the antenna or ground lead whenever a set is not sufficiently selective. A *vacuum tube* receiver of any kind can be improved in this



manner. Even a single-circuit tuner (having direct instead of magnetic coupling to the antenna) can thus reduce or eliminate code interference even though the trouble is inherent in the design of such a receiver. Receivers *close* to a code station pick up forced oscillations in their coils and antenna unless properly shielded, but a trap-circuit will usually eliminate the trouble.

Here are some suggestions for the construction of a suitable wavetrap for eliminating short-wave code. Inexpensive parts may be obtained for $1.00 or less from any of the local radio retail stores which handle parts. (1) A coil and (2) a variable condenser, are the only parts needed in making an effective wavetrap. The coil can readily be home-made. The condenser need not be an expensive condenser—it need not even be of the straight-line frequency type because, once adjusted, further tuning of the wavetrap is unnecessary. A discarded 17-plate or 23-plate condenser of *any* kind will be suitable and many such condensers of the straight-line-capacity or straight-line wavelength type are available at 50c or thereabouts at local radio stores. While unsuitable for modern broadcast-set construction, they are entirely suitable and practical for wavetrap building.

The diagram shows just how the coil and condenser are connected. First the coil is connected across the condenser terminals.

Frequency of Interfering Signal	Coil (3" dia.)
1,715-2,000 kc.	20 turns
3,500-4,000 kc.	8-10 "
7,000-7,300 kc.	4-5 "
14,000-14,400 kc.	3 "

The antenna is then connected to one side of the coil-condenser combination, the lead to the broadcast receiver connecting to the other side. Too-long antennas often make an otherwise good broadcast receiver non-selective. (Over 100 feet is considered poor practise.) The number of turns to use in constructing wave-trap coils (of No. 16 to No. 20 B. & S. d.c.c. wire on a 3-inch form) is shown in the following table which assumes a .0003 microfarad (max.) variable condenser. For other sizes of coil or condenser a little experimenting will serve. It is well to mention in passing that the coil designed to tune to the 3,500-kc. band will also cover the 7,000-kc. territory when the condenser is adjusted to nearer minimum capacity. Several turns might be used in a 14,000-kc. wavetrap if the maximum condenser capacity were first reduced by removing several of the plates. It is convenient to buy some of the self-supporting coil material by the foot, chopping it up into sections having the right number of turns.

Install a wavetrap as shown. Then turn on the broadcast receiver and tune in the interference until it is loudest. Next, turn the dial of the *wavetrap* until the interference is brought down to zero—or minimum. As the dial is turned, the sound should *decrease* up to a certain point, beyond which an *increase* in volume of interference will be noticed. The dial should be moved back and forth slowly several times until the absolute zero or minimum is found. Leave the trap-circuit adjusted to this point. It will not be necessary to touch the wavetrap or readjust further unless it is desired to check the setting in case of further interference. It is a good idea to note the dial setting on a piece of paper so that it can be quickly re-set at the right point in case it becomes accidentally detuned.

Once the wavetrap is installed and adjusted, broadcasting stations can be tuned in as usual at any point on the dial of the broadcast receiver. The trap will *not* in any way influence either the *volume* or *tuning adjustments* of the broadcast receiver. Once adjusted for a locally-interfering code signal it will not be necessary to pay any further attention to it. A wavetrap is simply a tuned rejector circuit—tuned to say 3,500 kc. for eliminating code—to a broadcast frequency for separating interfering broadcasting stations. A code wavetrap will *not* work for the latter purpose—more turns of wire will be necessary in a coil for such a purpose.

In broadcast receivers of faulty design in which the antenna is connected directly to the tuning coil (as in a single-circuit receiver) wavetraps are helpful in adding artificial selectivity. When possible it may be better to get at the matter more directly by making a few simple changes in the receiver. It is an easy matter to add a coil of 10 or 15 turns of wire around the main tuning coil, then connecting this "antenna coupling coil" to antenna and ground. The looser this coupling is made the less danger of interference.

If a radio-frequency amplifier has one of its stages in oscillation it is possible for one of the higher harmonics of the broadcast tuner's oscillation to fall in an amateur band and receive a beat note with amateur signals. Similar troubles may be noted with superheterodyne receivers. To test for a direct pick-up between the coils of receiver and the transmitting antenna, disconnect the antenna temporarily. Shielding the receiver more thoroughly will help in cases of direct pick-up. If radio-frequency energy from a transmitter is leaking to neighboring receivers by way of the 110-volt line, some r.f. chokes of husky wire located right at the transmitter and a few by-pass condensers across the line or between line and ground may help. A change in antenna location will be necessary if the pick-up is found to be made inductively from the antenna. Running all house wiring in grounded BX should entirely get around such a trouble as this.

BREAK-IN OPERATION

In the chapter on operating practices, break-in is discussed. There are many advantages of such operation. "BK" sent once between short CQ calls invites anyone listening to answer immediately. While the transmitter is giving the CQ, the operator is carefully tuning over the band to listen for stations calling him. With break-in operation it is not necessary to wait until the end of a transmission to ask for repeats. A long dash will stop the other operator and you can ask him what you please. Commercial stations use break-in when working ships at sea by controlling transmitters many miles away over land lines using relays to start, stop, and key the sending set. It is not necessary even that the transmitter be very far away to take advantage of break-in work, though generally the more distant it is, the better the break-in system.

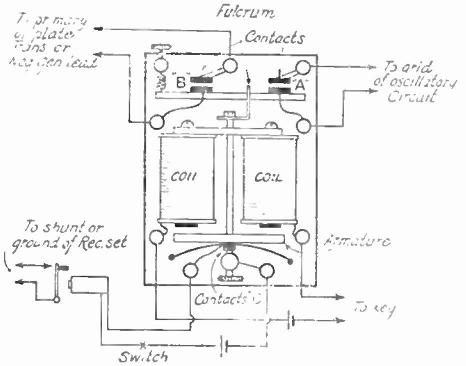


DIAGRAM OF A LEACH RELAY

Contacts at A close first before those at B close applying the plate power. The contacts at B open first (a few thousandths of a second before those at A). As both sets of contacts open positively there is dead silence in the phones because all oscillations are positively stopped. The auxiliary contacts at C open a trifle before those at A and B close, making it possible to use a 50-cent pony relay with reversed contacts to shunt or ground the secondary circuit of the receiver, keeping a high-powered outfit from burning out coils or condensers or making the grid leak noisy and positively preventing the receiver tubes from locking. The switch should be opened when listening for any length of time. Such relays may be obtained from J. H. Bunnell & Co., in New York City.

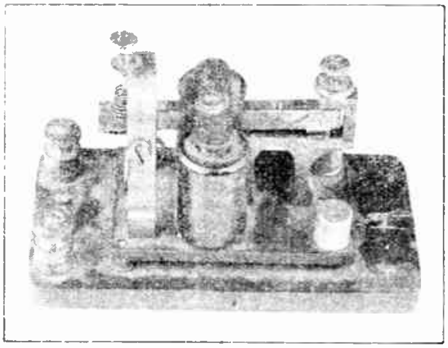
Listening on the receiver while sending constitutes the basis of every break-in system. A short antenna for the receiver may be put up at right angles to the sending antenna. Some magnet wire strung across the room or put behind the picture moulding will bring in the short-wave signals in fine shape and avoid the difficulties of changing over the antenna from the sending to receiving set. Often the signals can be picked up without any antenna at all if the receiver is unshielded or if there is some coupling to the transmitter due to its adjacent location. In this case there will be trouble in working break-in on frequencies close to that on which the sending set operates. If the transmitter is close and you key in the negative high-voltage lead, you may not be able to copy stations sending on your own frequency. There may be trouble even when the key is up from oscillations of the transmitting tubes caused by voltages from the filament transformer which come from an unbalanced center-tap arrangement. If this cannot be cured by putting in a true center-tap, it will be best to locate the transmitter farther away from the receiver and to use remote control. In this case a relay should be used to key the transmitter.

Any relay having two sets of insulated contacts and suitable adjustments will do. The Leach relay diagrammed is well suited for this use as it is so arranged that the grid circuit is closed first, the power being applied to the plate circuit through the other set of contacts a fraction of a second later. The process is reversed when the key is opened, the plate supply being cut off first. Keying the plate supply in the primary of the plate transformer is possible when the set is arranged for a.c. c.w. operation without a big filter and rectifier. The primary is always the best place to key when possible, as the inductance of the transformer windings cushions the putting on and off of plate voltage, preventing the likelihood of troublesome key-thumps. A really good filter will wipe out the keying, putting long tails on the dots and dashes due to the stored energy given up by the filter after the key is opened. Sets operating from rectifier and filter must be keyed in the plate circuit between filter and set. They often require the addition of a separate "thump" filter between the key and the oscillator to get rid of key thump.

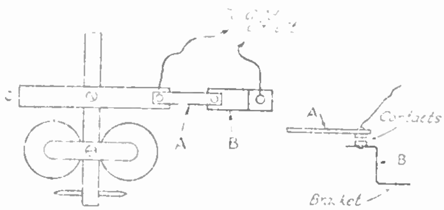
In an a.c. c.w. transmitter, a single-voltage source will sometimes fill the bill. A double-contact relay with one set of contacts in the plate and one in the grid circuit is guaranteed to give satisfaction.

MAKING A SUITABLE RELAY

A keying relay can be made easily of an old telegraph sounder. The photograph shows a single-contact relay made from a sounder. The brass sub-base should be removed and a piece of bakelite of the same size substituted. This can be drilled using the brass base as a template. Two additional binding posts should be added to the device to make it easy to connect to the contacts. ¼" x ¼" silver slugs 1/16" thick obtained from a jeweler make dependable contacts. These can be fitted into notches filed in the armature and frame of the sounder and soldered in place. A piece of copper braid or a thin brass spring should be connected between the U-shaped part of the frame and the armature so that the pivots do not carry any current. In addition it will be necessary to fasten a bit of insulation between the armature and the back-stop screw to keep the armature from closing the circuit when the key is open. This can be threaded and glued to the backstop screw itself or made a part of the armature. Such contacts are heavy enough to break the primary circuit of almost any amateur plate transformer. The relay will operate from the same storage battery that heats the filaments of the receiving tubes or from a separate battery. It can be adjusted to work well at almost any desired speed without bad sparking or sticking.



A GOOD SINGLE-CONTACT RELAY MADE FROM A TELEGRAPH SOUNDER



ADDING CONTACTS TO A TELEGRAPH-SOUNDER RELAY

The diagram shows how a set of contacts can be added to the sounder-relay to break the grid circuit. Remember that anything added to the armature must be as light as possible or the relay will be sluggish. The screw that holds the two parts of the armature together (also acting as a downward stop for the armature) can be taken out and a thin bakelite strip inserted just above the crossed metal pieces. Contacts for the grid circuit obtained from an old spark coil vibrator can be riveted to the end of a thin spring (A) which is fastened in turn to the bakelite arm. A small bracket bearing the lower contact and two flexible leads to suitable binding posts will complete the layout.

The spring (A) should be bent so that the A-B contacts close just before the main power contacts close and so that they open only after the power is off.

REMOTE CONTROL

If you live in an apartment house, you can dispense with the troubles of getting a one-wire or two-wire r.f. feed line in operation by putting the sending set right at the center of the antenna system on the roof. This will make it very easy to use break-in and save you from worrying about losses in poor dielectrics which are certain to be in the field of the lead-in if it is brought right down to the operating room.

In a remotely-controlled arrangement, relays can be installed in any one of several ways depending on the distance and on the combinations most desirable to fit the individual application. The problem is merely one of turning on and off the filament heating and plate-supply power with a switch and a key, using a minimum number of relays and as small an amount of wire as possible to give results.

For installations up to 100 feet distant it is probably best to use no special relays at all—but to run the power leads through switch and key to the points desired. Three wires will be necessary unless wires from the same power source can be tapped at a point near the sending set to obtain a common lead for filament and plate transformers, in which case but two wires will be required.

All relay contacts should be large enough to avoid the possibility of sticking if the set is remote-controlled. The outfit must be built substantially and adjusted to operate stably, too. There is a lot of pleasure in operating a set some distance away and the improved break-in work makes it well worth considering, especially if your radio shack is going to be a small one. A number of good relays can be purchased if you do not wish to fix them up yourself but usually it is necessary to substitute larger contacts than generally provided, for handling large amounts of current. If a motor-generator is used an automatic starting compensator operated by a suitable relay will be necessary for starting up the set. If a synchronous rectifier is remote controlled, a polarized reversing relay will be necessary to reverse the conditions to the primary of the plate transformer each time it starts with the wrong polarity at the output. Simple relays can be built as suggested or made from spare bell or buzzer magnet windings, using a soft iron core and a pivoted soft iron armature carrying the movable contact or contacts. The generator cut-out on a Ford can be made into a good relay using the fine winding in the keying circuits.

The beginner should limit his efforts to building a simple and inexpensive low-power sending set and a good receiver and not attempt to start off with a remote-controlled transmitter. The numerous "kits" of transmitting and receiving parts on the market make it especially easy to get started right at low cost. Remote control is not absolutely necessary to break-in work and it can always be added easily after the elements of a station have been built and are in operation. Remote control is the best possible thing for the fellow with the cold out-door shack or the radio room in the attic where the temperature hits the 100° mark in summer.

CHAPTER VIII

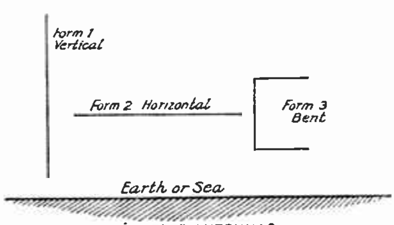
Antennas

WITH the short-wave receiver the antenna does not appear to be of very great importance. If the receiver is a good one signals can be heard from almost any part of the world with an antenna wire strung up in even the crudest fashion. In consequence, one is tempted to state that the amateur can afford to be careless about the receiving antenna. In severe contrast to this statement, however, it must be said with all possible emphasis that no such carelessness is possible in the design and construction of the transmitting antenna system. The performance of the transmitter in almost every respect will be approximately proportionate to the care that is taken in the planning, building and adjusting of the antenna system.

Before any attempt is made to explain how the transmitting antenna systems operate, or to describe their construction, it is necessary to differentiate between the terms "antenna" and "antenna system". The treatment of short-wave antenna systems in simple and absolute language is a difficult business at any time but at least it is simplified to some extent if we can talk of the antenna—meaning that portion of an antenna system which is provided to do the radiating of energy into space—and so separate it from the feeders and other adjuncts of the antenna system which would otherwise so complicate the discussion.

TYPES OF ANTENNAS

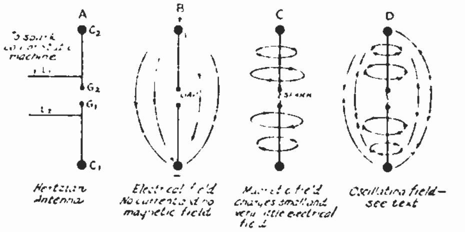
Notwithstanding the great variety of antenna systems to be seen in operation, the antennas



HERTZ ANTENNAS

are, for all practical purposes, of but two distinct types. Those in which the ground is an essential part of the radiating system are known as Marconi antennas. In some cases antennas of this type are connected directly to a ground system but in others the connection is obtained through the capacity to ground of an extensive counterpoise. The second type of antenna is the Hertz antenna, in the operation of which the ground does not play an essential part. The Hertz antenna is not connected directly to ground and, in its purest form, consists of a single wire suspended sufficiently high above the earth or earthed objects to have an inconsequential capacity to ground. The Hertz antenna, though it was originally used by the experimenter after which it was named nearly half a century ago, is now used almost exclusively for short-wave transmisson.

A single wire such as that comprising the Hertz antenna, irrespective of whether it is



THE ANTENNA FIRST USED BY HERTZ was like that shown in the diagram. The high-frequency voltages and currents in this antenna set-up electrical and magnetic fields which are at right angles in space. Both fields exist at the same time, one increasing as the other is decreasing.

vertical, horizontal or bent into a V or other shape, has inductance, capacity and resistance in much the same way as the tuning circuits of the transmitter have inductance, capacity and resistance. The Hertz antenna is therefore really a simple oscillatory circuit having a natural frequency in the same way that the tuning circuits of the transmitter have natural frequencies. The chief difference is that in the antenna the inductance, capacity and resistance are distributed throughout its length, whereas in the transmitter tuning circuits they are concentrated. The Hertz antenna is known as an open oscillatory circuit and has the ability to radiate effectively the energy oscillating in it. The tuning circuits in the transmitter are known as closed oscillatory circuits and have a very limited ability to radiate the energy in them.

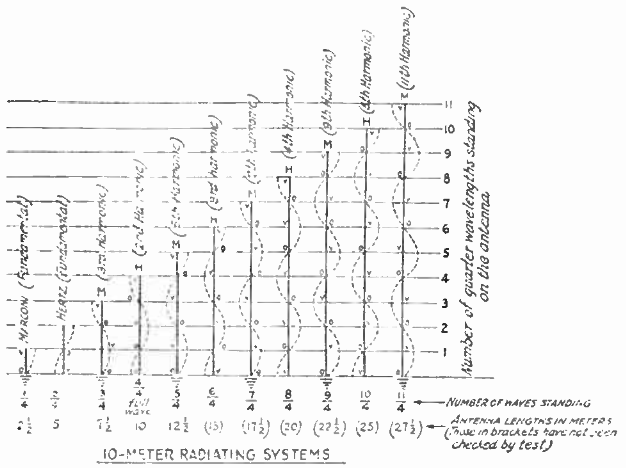
In order to calculate the natural frequency of a closed oscillatory circuit it is necessary to use a relatively complex formula (given in Chapter IV) in which the capacity and inductance in the circuit are involved. In an open oscillator of the type of the Hertz antenna, however, there exists a very simple relation between the natural period and the length of the wire. The natural wavelength of the wire (the highest wavelength at which it will oscillate) will be its length in meters multiplied by 2.1. This figure is by no means applicable to all the Hertz antennas which could be imagined but it serves for substantially all of those encountered in actual amateur practice. Its natural frequency (the lowest frequency at which it will oscillate) can be obtained by dividing 300,000 by the natural wavelength, the answer being in kilocycles. Speaking in terms of feet, the natural wavelength of the antenna will be its length in feet divided by 1.56. Its natural frequency will be equal to

$$\frac{300,000 \times 1.56}{\text{length of feet}}$$

the answer again being in kilocycles. From this it can be seen that the highest wavelength to which a Hertz antenna tunes—its natural wavelength—is approximately twice its length in meters. In other words, the length of the antenna is about half the wavelength to which it tunes. This simple relation makes it very useful to speak of wavelengths instead of frequencies when explaining the action of antennas, and this practice will be adopted in this chapter. At the same time the relationship between wavelength and frequency should be kept in mind continually.

The fact that a Hertz antenna is approximately half as long as its fundamental wavelength makes it convenient to refer to such an antenna, operated on its fundamental, as a half-wave antenna. This, however, is not the only way in which it can be operated. In the same way that the tuned circuits of the transmitter will oscillate at harmonics of their fundamental wavelengths or frequencies, so the Hertz antenna will oscillate at harmonics. An antenna with a fundamental wavelength of 84.46 meters (3,550 kc.) will be a half-wave antenna at that wavelength. However, it is also possible to make it oscillate on 42.23 meters (7100 kc.), when it will have two half-waves on it. It would then be said to be operated at the second harmonic. The same antenna would also oscillate on 21.11 meters (14,200 kc.), when it would have four half-waves on it. In this case the antenna would be working on the fourth harmonic. If it was fed from a transmitter tuned to 10.56 meters (28,400 kc.) this same antenna would still oscillate. It would then have eight half-waves on it and would be operating on the eight harmonic.

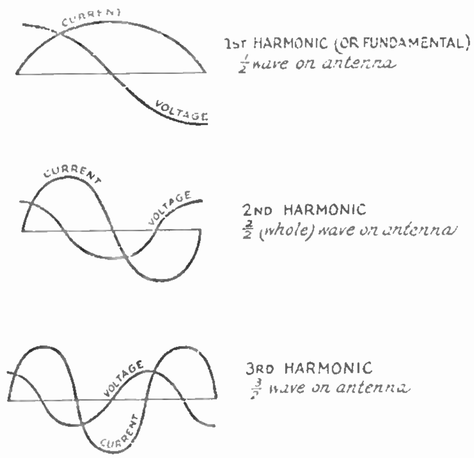
These statements may seem confusing at first but it is essential that they be studied until they can be understood if it is desired to appreciate just how antennas are designed and operated. It may help to examine the third diagram in which Hertz and Marconi antennas are shown operating at various harmonics. It will be seen that all the Hertz antennas have an even number of quarter waves on them while the Marconi types have an odd number. No particular notice need be taken of the Marconi types since they are rarely used in amateur work and will not be treated in detail in this discussion. The wavy dotted lines on this diagram indicate the distribution of voltage along the antenna. In the Hertz antenna there is always a point of maximum voltage and minimum current at both ends of the wire. This is shown more clearly in the next diagram in which both the voltage and current distribution are shown. It can be seen that wherever the voltage is highest the current is at a minimum and wherever the current is highest the voltage is at a minimum. The important point, however, is that in the Hertz antenna there is a point of highest voltage and no current at both ends. It is common practice to term the points of no voltage "voltage nodes" and the points of no current "current nodes." Conversely, the points of highest voltage or current are sometimes known as voltage or current "antinodes" or "loops".



28,000-KC. (10-METER) RADIATING SYSTEMS

drawn to illustrate possible methods of operating both grounded and ungrounded antennas. The grounded or Marconi systems are labelled M while the ungrounded or Hertz systems are marked H. The dotted lines show the voltage distibution. The points "O" are the voltage nodes or point of minimum voltage. They are also points of maximum current (current antinodes) and it is at these points that current-feed can be used to best advantage. Points "V" are points of maximum voltage. Voltage-feed systems are connected at or near these points. While the systems are shown vertical they can be operated in almost any other position.

It must always be kept in mind that there will be a definite number of half waves on the antenna when it is oscillating—there will be no odd quarter or eighth waves left over. This can be seen clearly in the diagram just referred to. When oscillating on its fundamental



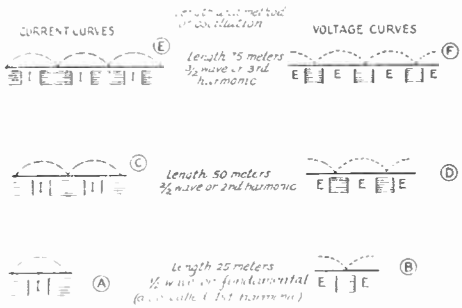
VOLTAGE AND CURRENT DISTRIBUTION OF ANTENNAS OPERATING AT HARMONICS

there is one half-wave along the antenna; on its second harmonic, two half-waves; on its third harmonic, three half-waves; on its fourth harmonic, four half-waves, and so on. If the fundamental of this antenna was 85.66 meters (3,500 kc.), the next requency at which it would oscillate would be the second harmonic. This would be twice the frequency, 7,000 kc., or half the wavelength, 42.83 meters. The next frequency at which it would oscillate would be the third harmonic, which is three times the frequency—10,500 kc.—or one-third the wavelength—28.55 meters. And this example could be carried on to the twenty-fourth or fourty-fourth harmonic if we had the space. In all of these cases, however, there would be points of highest voltage at both ends of the antenna. And since points of highest voltage are always points of lowest current, when the antenna is oscillating, these ends will be points of lowest current also. There will be other points of no current and high voltage along the antenna as can be seen from the same diagram to which we have been referring. A knowledge of the location of these points is of the greatest importance in the planning of the feeding system, as we shall see.

FEED SYSTEMS

We now have some idea of the manner in which a Hertz antenna can oscillate but it is certain that the antenna cannot be strung up in the air and be expected to oscillate of its own accord. It must be supplied with power from the transmitter. The process of supplying power to the antenna is termed "feeding" or "exciting" the antenna.

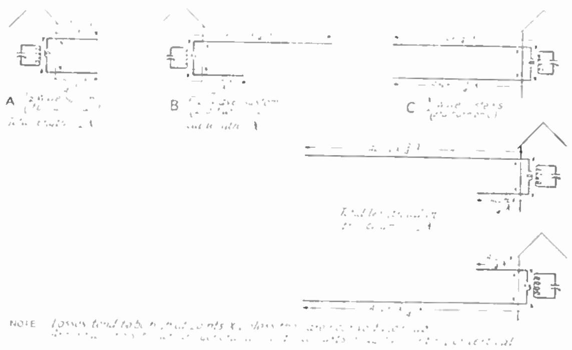
Primarily there are two types of feeding schemes—those by which the antenna is fed by a large current at low voltage to a point where we can have current in the antenna, and those by which the antenna is supplied with a high voltage at low current to a point where we can have voltage in the antenna. It is immediately apparent that we cannot attach a current feed system to the ends of a Hertz antenna because there is no current there. But reference to the two previous diagrams will show that there are other places in the antenna where there is high current and at any of these places a current-feed system could be connected. When the antenna is operating on its fundamental there is a point of highest current at the center and the feed system could well be attached at this point. Such an arrangement provides what is probably the simplest antenna system that the amateur can use. It is shown at A in the next diagram.



FEED POINTS ON 50 METER HERTZ ANTENNAS

The fundamental antenna—approximately one half-wave long—is bent so that its middle portion is within the station. At the center, the antenna coil is connected and coupled to the plate coil of the transmitter. If the antenna itself had a fundamental of the frequency on which it was desired to operate the insertion of the antenna coil would disturb it. Hence, in actual practice, a series tuning condenser is also inserted alongside the coil—or one on each side—so that it is possible to compensate for the loading effect of the antenna coil and tune the antenna to the required frequency. If the antenna is being operated on some harmonic there will be other places of maximum current at which the feed system could be introduced. Some of these are shown in the same diagram. It will be noticed that these points of maximum current are either one or an odd number of quarter-wavelengths from the ends of the antenna.

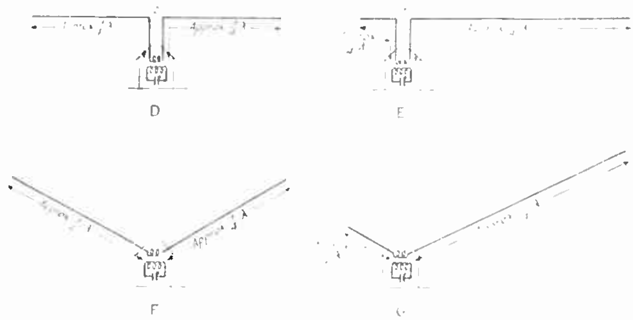
The antennas illustrated in this diagram, particularly at A and C, would not be very effective in practice on account of the manner in which the antenna is doubled back on itself. The trouble is that the current at a given point



CURRENT-FEED ANTENNA SYSTEMS

In the past, antennas of the type shown at A or C have been widely used by amateurs and referred to rather inappropriately as "antenna-counterpoise" systems. In reality they are just bent Hertz antennas. Their effectiveness usually is improved if the two portions are led from the station in opposite directions, so making the antenna in the form of a straight line or a wide "V". The important point is that in any such antenna system the coupling coil must be inserted at or near a point of maximum current. This will be at one or an odd number of quarter-wavelengths from the end. One or two variable condensers can be connected in series with the antenna inside the station to permit precise tuning of the system.

on one-half of the antenna is 180 degrees out of phase with the current at a similiar point on the other half. The field around one of the halves will therefore tend to cancel the field around the other half and the effectiveness of the antenna as a radiator will be reduced. It is very much preferable to arrange things so that a considerable portion of the antenna is out in the open away from the influence of the remainder. Other desirable schemes would be to fold only a small portion of the antenna or to arrange it in the form of an open V. In some stations, for instance, where the transmitter is in an attic, it may be possible to make the antenna a straight wire entering the room on one side and leaving it on the other.



OTHER POSSIBLE CURRENT-FEED ANTENNA SYSTEMS

The schemes so far described have the disadvantage that the antenna is brought into the station where its radiation can be absorbed by the building, and where it may be unnecessarily close to the ground. It is better to leave the complete antenna strung up in a place well clear of trees or buildings, feeding it with a feeder system which is purposely arranged to play no part in the business of radiating. The arrangements D and E in the last diagram are preferable to the others in this respect, for the portion between the antenna coil and the point Z really has been removed from the antenna and converted into a feeder system with little radiating ability. In order to reduce the radiation from the feeder to a minimum the two wires comprising it should be supported between 10 and 12 inches apart in the manner to be detailed later.

Should the flat-top portion of the antennas D or E have a fundamental frequency equal to that of the transmitter and should the point Z be at a point of maximum current, the flat-top portion can be made to operate alone as a Hertz antenna, the two wires from the point Z to the station being adjusted so that they are not oscillating in the manner of an antenna but are merely serving as a transmission line. They then carry the radio-frequency current to the antenna in the same way as the wiring in our house carries the alternating current to our lamps. There are no standing waves on the wires, with their nodes and anti-nodes, but instead there is just a gradual voltage gradient. In order that the feed wires may function in this way they must not tune to the transmitted frequency. They will operate most effectively when the impedance of the antenna into which they feed, and the impedance of the circuit supplying them at the transmitter end, both match their own impedance. In order to attain this condition a transformer should be used between the antenna and the feeder in addition to the usual transformer consisting of the plate and antenna coils at the station end. The transformer at the antenna end of the feeder can be eliminated but even then the arrangement is a difficult one to adjust.

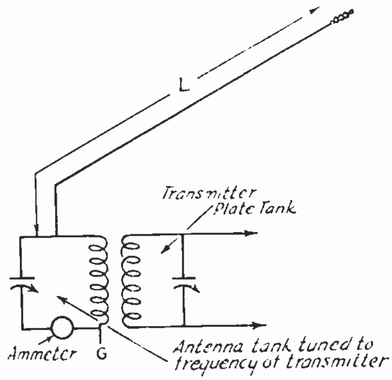
All of the methods so far discussed have been of the current-feed type—where the antenna is fed at a point of high current and low voltage. Some of the most practical amateur antennas are of the voltage-feed type, where feeding is accomplished at a point of high voltage and low current. We will proceed to a discussion of them.

A simple form of voltage-feed antenna system is that shown in the diagram so titled. In it one end of the Hertz antenna—which is a point of higher voltage—is brought into the station and connected directly to one end of the inductance L2 of the tuned tank circuit coupled to the plate coil L1. Alternatively, the antenna can be connected through a small condenser or choke direct to the plate coil, the position of the clip on the plate coil being varied for best results. Both of these schemes, however, have the same disadvantage as the first current-feed systems described, in that the antenna must be brought into the station. As in the current-feed systems it is possible to leave the antenna in the clear and feed it with a feeder system. This system can either be tuned, in which case it will have standing waves on it, or it can be adjusted to work as an untuned transmission line, in which case there will only be a voltage gradient along it. The former scheme is considered the most practical and is probably the most popular scheme of all for amateur work. In the untuned voltage feeder system a single wire only is necessary to run between the transmitter and the antenna. The adjustment of such an arrangement, in common with others, will be described later.

With the tuned feeder system two parallel wires 10 or 12 inches apart usually are employed for the feeder, these wires really constituting a folded-up Hertz antenna. Such a feeder, operated in conjunction with a Hertz antenna, usually is termed a Zeppelin antenna system, the name being derived from the fact that it was originally designed for use on dirigibles.

PLANNING THE ANTENNA

As we have seen from the discussion earlier in this chapter, the antenna—the radiating portion of the system—can readily operate on its fundamental frequency or on the harmonics. If, then, the antenna is of such a length that its fundamental is in a particular part of the 1,750-kc. ("160-meter") band, it can not only be operated on this frequency but also on any harmonic frequencies which happen to fall within the higher-frequency bands. Operation in all bands with one antenna system is, however, not nearly as simple as this statement would seem to indicate. There are two flies in the ointment. In the first place all of the frequencies in our bands are not in harmonic relation. The frequencies between 1,750 and 1800 kc. have harmonics in all other bands but all other frequencies in that particular band have harmonics which fall outside one or more of the higher-frequency bands. Of course this difficulty is not of great importance since it is only in very rare cases that the amateur has any need to operate one antenna system in more than two or, at the most, three bands. Also, the systems employing a Hertz antenna usually are sufficiently flexible to permit operation on frequencies within a band even if the actual fundamental or harmonic frequency of the antenna falls a little outside.



A SIMPLE BUT PRACTICAL VOLTAGE-FEED ANTENNA SYSTEM FOR OPERATION ON SEVERAL FREQUENCY BANDS

Should the length of the antenna L be 264 feet, the antenna could be operated on any of the amateur bands merely by tuning the transmitter and the antenna tank circuit to the required frequency. If the length L is 132 feet the antenna will have a fundamental of approximately 3,550 kc. (84.46 meters) and it could be operated on the 3,500-kc band or any of the four higher-frequency bands. When the antenna is approximately 66 feet long its fundamental will be at 7,100 kc. (42.23 meters) and operation will then be possible on the 7,000 kc. band or any of the three higher frequency bands. By connecting a good ground system at the point G the antenna system is converted to a Marconi type and operation can then be had at half the fundamental frequency of the antenna itself. Thus an antenna 132 feet long—with a fundamental of 3,550 kc.—could be operated on the 1715-kc. band in conjunction with a ground connection and on all other bands by disconnecting the ground and using the voltage-feed system. The antenna need not be bent as shown in the diagram. In some locations it could be made horizontal and in other vertical. Even if one portion is sloping, another part vertical and the remainder horizontal it will still operate. It should be as much in a straight line as well clear of trees and buildings as possible.

The more important difficulty is introduced by the feeder system on account of the fact that the voltage and current distribution along the antenna varies as the harmonic frequency on which it is operated is changed. Current feed could be used, for instance, when the antenna is operated on its fundamental, for there is then a half wave on the antenna and there is a point of maximum current at the center. For second-harmonic operation, however, there would be two half-waves on the antenna and the same current-feed system could not be used, since the center of the antenna would now be a point of minimum current. On the third or any other odd harmonic there would be an odd number of half-waves on the antenna and consequently a point of maximum current at the center. In these cases the original current-feed scheme would operate. On the even harmonics, however, it would not.

There are just two points on the antenna which are points of maximum voltage irrespective of the harmonic on which the antenna is being operated. They are at its two ends. Consequently any scheme which feeds at one of these points is likely to serve for operation on any harmonic. There are several such schemes available and it is not surprising that they are considered the most flexible and the most effective of all. Let us now plan, as examples, some antennas of this type suited for operation on two or more bands.

As we have said, the antenna, if it is fed at one end with a voltage-feed system, will operate on its fundamental or any harmonic frequency. For the antenna, then, all we need is a wire with a fundamental of the lowest frequency on which we wish to work. Let us assume that this frequency is 3,550 kc. (which happens to be the center of the band of frequencies on the 3,500 kc. (80-meter) band which have harmonics in all of the higher-frequency bands). In order to arrive at the necessary length of the wire in feet we can either convert the frequency to wavelength in meters (by dividing 300,000 by the frequency in kilocycles), then multiplying the wavelength by 1.56, or we can make one calculation out of it with the formula

$$\text{Length of wire in feet} = \frac{300{,}000 \times 1.56}{\text{Frequency in kc.}}$$

In simpler form this becomes

$$\text{Length of wire in feet} = \frac{468{,}000}{\text{Frequency (kc.)}} \text{ or } \frac{468}{\text{Freq. (megacycles)}}$$

If it is desired to work in meters instead of feet, the formula is then

$$\text{Length of wire in meters} = \text{Wavelength} \times .475$$

$$\text{or } \frac{300{,}000 \times .475}{\text{Frequency (kc.)}} \text{ which is } \frac{142{,}500}{\text{Frequency (kc.)}}$$

$$\text{or } \frac{142.5}{\text{Freq. (megacycles)}}$$

Since the required fundamental of the antenna is 3,550 kc., or 84.46 meters, its length in feet will be $\frac{468{,}000}{3{,}550}$ or 84.46 x 1.56. The answer in both cases is 131 feet 9 inches. This, then, is to be the length of our antenna from its far end to the very point at which it connects with the feeder system. Not many amateurs will be able to string this antenna in a vertical position but it will operate quite satisfactorily if it is horizontal. Quite possibly the location of the radio room will make it necessary to make a bend in the antenna or to run a portion of it vertically and the remainder horizontally. In almost every instance there will some such factor influencing the exact placement of the wire. The whole aim, however, is to arrange the wire as much in the open as possible and in the nearest approach to a straight line, irrespective of whether it is vertical, horizontal or sloping. The entire wire is radiating and for this reason it is desirable to run it directly into the open from the radio room and to avoid draping it down the wall or close to the roof. Except in special antennas where the angle of radiation is being considered particularly, the height above ground is not very important providing it is greater than a quarter-wavelength. Even this figure need not be adhered to strictly on the lower-frequency (higher-wavelength) bands—where it is so hard to attain—but it is well to provide such a height for operation on the higher-frequency bands.

Presuming that one end of this antenna runs into the station, its feeder system consists only of a tank circuit which can be made a replica of the plate tank of the transmitter. This tank is tuned to the frequency of the transmitter and the ammeter included in it indicates when the two tank circuits are in tune and when the frequency corresponds to the fundamental or the desired harmonic of the antenna. To change from the 3,500-kc. band to the 7,000-, 14,000- or 28,000-kc. bands it is merely necessary to tune the transmitter and the antenna tank circuit to the required frequency in those bands. Though the fundamental of the antenna is 3,550 kc., the antenna system is quite flexible. It could be operated with slightly reduced effectiveness anywhere in the bands mentioned.

If it was desired to operate only on the 7,000-, 14,000- or 28,000-kc. bands, the length of the antenna could be reduced so that its fundamental was in the 7,000-kc. band. The center of the harmonically-related areas in this band is at 7,100 kc. and an antenna having a fundamental frequency of that figure would be just half the length of the 3,550-kc. antenna, or 65 feet 10 inches. Similarly an antenna to be operated only in the 14,000-kc. and 28,000-kc. bands could have its fundamental at 14,200 kc. It would then be 32 feet 11 inches long. It might be pointed out that these lengths are the calculated values. It is extremely doubtful whether any difference in performance would be caused by making the antenna 33 feet long or, for that matter 33 feet 6 inches.

The losses involved in bringing this antenna into the radio room can be avoided at some sacrifice of simplicity by using a feeder system which would permit the antenna to be strung well up in the clear.

Quite the most popular system of this type, and probably the most effective, is the Zeppelin antenna system, the operation of which has already been described.

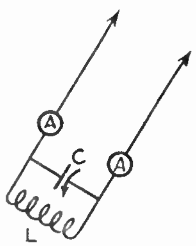
In the Zeppelin system the feeder consists of two wires connected at the station end to a coupling coil and tuning system. At the antenna end one of the wires is connected to the antenna, the other being left free. The feeder is really a folded-up Hertz antenna tuned to operate at its fundamental or an odd harmonic of the fundamental frequency. In other words the feeder should be half-wave, three-half-wave, or five-half-wave. The total length of the two feeder wires combined could therefore be determined in just the same way as the

APPROXIMATE LENGTH OF EACH WIRE, FEET	TUNING ARRANGEMENT FOR VARIOUS BANDS				
	1750 kc (160 m)	3500 kc (80 m)	7000 kc (40 m)	14000 kc (20 m)	28000 kc (10 m)
120	SER	PAR	PAR	PAR	SER OR PAR
90	PAR	SER	SER	PAR	SER OR PAR
60	PAR	SER	PAR	PAR.	SER OR PAR
40	(---)	PAR	SER	PAR	PAR.
30	(---)	(---)	SER	PAR	SER. OR PAR
15	(---)	(---)	PAR	SER	PAR.
8	(---)	(---)	(---)	PAR	SER

SER - *Series Tuning* PAR - *Parallel Tuning* (---) - *Not Recommended*

SOME SUGGESTED ZEPPELIN FEEDER LENGTHS AND RECOMMENDED TUNING METHODS FOR THE VARIOUS AMATEUR BANDS

length of an antenna would be determined, provision being made to compensate for the loading effect of the coupling coil by the insertion of series condensers. If the feeder is to supply the antenna on several bands, however, it must be of such dimensions and so provided with tuning facilities that it can be operated with an odd number of half-waves on it for each of the bands. The determination of suitable wire lengths is simplified by the provision of a table of lengths. A variety of lengths are given, one of which probably will suit under the limitations of the particular location in which the antenna must be erected.

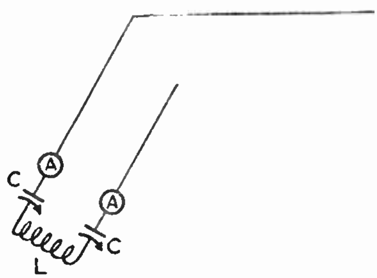


PARALLEL TUNING OF THE FEEDER

The effectiveness will be much the same with any of the lengths. A slight variation from the figures given is permissible since it can be taken care of in the tuning process. It will be noted that for some bands the feeder coil is used with a parallel condenser of about 350 μμfds. so that the feeder can be tuned to have that particular fundamental frequency which will permit an odd number of half-waves, while in other cases similar condensers are used in series with the feeder wires for the same purpose. The connections for these two arrangements are given.

The spacing between the feeder wires is not very critical, a value of 10 or 12 inches being satisfactory. It is very important, however, that the two wires should be of the same length. Then, in operation, the two ammeters will read the same with the parallel tuning connection and can be made to read the same with the series connection by adjusting the two condensers C to the same capacity. Under these conditions the current at points in one wire will be 180 degrees out of phase with and of the same value as the current in opposite points on the other wire. The fields around the wires will cancel, or almost cancel, and little or no radiation will result. In this way the losses in the system are reduced to a minimum.

The tuning of this system is not difficult. Supposing the antenna and transmitter are to be operated on the 7,000-kc. band and assuming that the feeder system is 60 feet long, it can be seen from the table that the feeder condenser should be in parallel with the coil. Observing the usual procedure for transmitter tuning, as described in Chapter VI, the various adjustments are carried out until the frequency of the transmitter is of the value desired. Then the feeder coil is coupled loosely to the plate coil and the feeder condenser

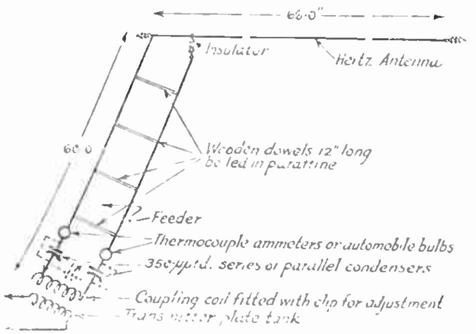


SERIES TUNING OF THE FEEDER

reduced from maximum until the highest reading is obtained in the ammeters A. When the coupling has been increased to give the highest current possible it is reduced until the ammeters read about 85 percent of the previous current and the condenser is then adjusted to detune the feeder until approximately a further ten percent reduction in feeder current has been obtained. The monitor should be used, as described before, to determine whether the better signal character is obtained with the feeder tuned above or below resonance.

Should the series feeder condensers be necessary for the frequency on which operation is desired, the same procedure is followed with just the difference that the two condensers are tuned down from maximum at the same time so that the values of capacity used are similar and the feeder currents therefore of the same order.

In place of the tuned feeder of the Zeppelin antenna system, an untuned feeder or radio-frequency transmission line can be used. In practice this can consist of a single wire running from a clip on the plate tank coil to a point of high voltage on the antenna. The chief difficulty is in the adjustment of the system, since if the position of the connection between the feeder wire and the antenna is not correct there is a tendency for the feeder to join forces



A PRACTICAL ZEPPELIN-FEED ANTENNA SYSTEM FOR OPERATION ON SEVERAL FREQUENCY BANDS

The length of the feeder is shown as 60 feet but it can be of any of the lengths given in the table. The condensers at the transmitter end of the feeder are arranged in parallel or series according to the instructions given in the table, so that the feeder may be adjusted correctly for the particular band in which the system is to be operated. With the antenna 66 feet long the system could be operated on the 7,000-kc., 14,000-kc. or 28,000-kc. bands. If it was 132 feet long operation could also be had in the 3,500-kc. band.

with the antenna in the role of a Marconi-type antenna working in conjunction with the ground. Another disadvantage is that the system serves with maximum effectiveness for one band only. It can be operated in several bands but this necessitates making the connection between the feeder and antenna at a point which serves fairly well for the various bands and not very well for any of them. When carefully adjusted for one band the system has been found satisfactory.

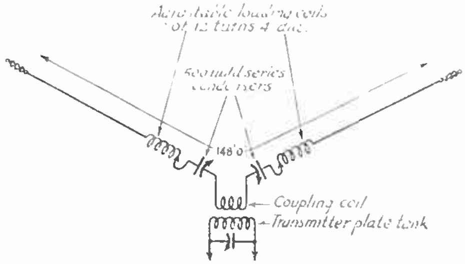
Since the feeder wire in this method is untuned and not a portion of the radiator, it can be of almost any length and located in almost any way with respect to walls or roofs providing it is a foot or so clear of them. The connection between it and the plate tank should be made through a variable condenser of about 150 μμfds. or through a choke of about 20 turns of 14 gauge wire 3 inches in diameter. It is advisable to arrange this choke so that the number of turns in the circuit is variable.

An important item for the adjustment of this single-wire feeder system is a thermocouple or hot-wire ammeter reading 0-1 or 0-2 amperes or an automobile headlamp bulb connected across two or three feet of the antenna at its center. This arrangement serves to indicate the condition when maximum antenna current is obtained. In adjusting the feeder its station end should be clipped on the plate coil about a third the distance between the filament and plate connections and its antenna end should be looped around the antenna a few feet from the center. Two strings should be tied to the feeder at this point so that it can be pulled towards or away from this point during adjustment. For each position of the feeder on the antenna the clip on the plate coil, the coupling condenser or the choke should be adjusted until minimum current is obtained in the feeder and maximum current in the antenna. These readings should be noted for various positions of the feeder between the center and one end, and that position should be chosen which gives the greatest antenna current with the lowest feeder current. When correctly adjusted the antenna current probably will be of the order of ten times the feeder current.

PLANNING THE CURRENT-FEED ANTENNAS

The problem of planning the current-feed antenna is chiefly the reverse of that involved in planning the voltage-feed systems since in this case we connect the feeder system at all times to a point of maximum current if the system is to operate effectively. As we have already stated several times there is a point of maximum current at the center of a fundamental antenna or of an antenna operated at any of the odd harmonics. We find that the simplest current-feed systems take advantage of this fact.

For an antenna that is to operate on one band only, there is really nothing to the problem. The length of wire necessary to give a fundamental of the frequency on which the transmitter is to be operated is first calculated by the formula given. Then it is cut in half. One half is led out from the station in one direction and the other half is led in the other direction,

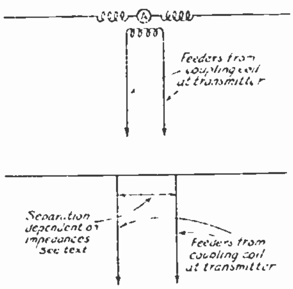


A PRACTICAL CURRENT-FEED ANTENNA FOR OPERATION ON THREE BANDS

For 3,500-kc. work the fundamental of the wire (which is about 3,157 kc.) is reduced to a frequency within the 3,500-kc. band by cutting out the loading coils and adjusting the series condensers. For operation on the 7,000-kc. band the loading coils and series condensers are adjusted until the system is tuned to 2,333 kc., when it is operated on its third harmonic. For 14,000-kc.-band operation the loading coils and series condensers are varied until the system tunes to 2,800 kc., when it operates on the fifth harmonic. The entire system radiates and for this reason it should be suspended as much in the clear as possible.

the two halves being kept at a reasonable height and as far from each other as possible. The introduction of the antenna coupling coil will load the system slightly and to compensate for this a series condenser or one series condenser on each side of the antenna coil are inserted. The antenna system is tuned to the transmitter with the aid of these condensers.

If it is necessary to operate such an antenna on several waves the complications shown in the diagram are necessary. The wire is first made of such a length that its fundamental is slightly below the lowest frequency on which operation is desired, say, 3,157 kc. (95 meters) for 3,500-kc.-band operation. The fundamental of this system is then reduced with the series condensers for operation on the 3,500-kc. band. For 7,000-kc. (40 meter) operation it is loaded to the third harmonic (2,333 kc. or 120 meters), when there will be three half-waves on it and a point of maximum current at its center. For 14,000 kc. the loading or the series capacity is reduced until the system tunes to the fifth harmonic (2,800 kc. or about 100 meters), when a point of maximum current will again exist at the center.



TWO CURRENT-FEED SYSTEMS WITH UNTUNED FEEDERS

This same type of antenna can be arranged in an almost limitless number of ways, some of them being suggested at the opening of the chapter. The only essential is that the antenna be operated at its fundamental frequency or some odd harmonic of its fundamental.

The current-feed systems in which the feeder is an untuned radio-frequency transmission line are difficult to adjust and lack the flexibility of some of the other systems. They are not particularly suited for amateur work and enjoy but little application by amateurs. Two possible arrangements are given in the diagrams, some device being shown at the antenna end of the feeder to permit the matching the impedances of the antenna and the feeder. The antennas can be operated without such coupling devices at some loss of efficiency but their adjustment then becomes even more tricky. Unless extreme care is taken the feeder and antenna will tend to operate with standing waves on the entire system, thus comprising the same folded current-feed Hertz described before. For operation on any one band the current-feed system employing the two widely-spaced feeder wires can be used. Even in this system care must be exercised to see that the feeders are not of a length which will permit them to tune to the frequency of the transmitter or a harmonic of it. Careful adjustment of the coupling coil at the station end is also necessary.

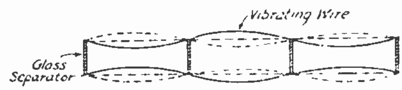
When feeders of these types are actually operating as untuned transmission lines it will be possible to run a neon bulb over the length of each wire without varying the brilliance of the glow in it to any appreciable extent. On the tuned feeders, of course, the bulb would light up brilliantly at points of high voltage and low current, and would be dim or entirely dark at points of low voltage and high current.

CONSTRUCTIONAL DETAILS

For the purpose of this discussion let us divide the antenna system into two parts—the conductors and the insulators. If the system is to operate most effectively the conductors must be of low resistance. On the other hand the insulators must be of the highest possible resistance. For low or medium-powered transmitters an entirely satisfactory conductor is No. 14 gauge soft-drawn enamelled copper wire. For higher-powered transmitters No. 12 gauge is preferable. Every effort should be made to make the wires in one piece so that the only joints are at the output terminals of the transmitter. Where joints cannot be avoided they should be thoroughly soldered. It should always be possible to make the Hertz antenna-portion in one piece.

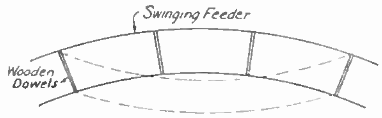
If the feeder system is of the tuned type the currents in it will be of the same order as those in the antenna and the same care in avoiding joints is necessary. In the untuned feeder system, however, the currents are relatively low and this consideration is therefore not as important. In these cases smaller wire can be used if necessary.

In building a two-wire feeder the wires should be separated by wooden dowels which have been boiled in paraffine. In this way the feeder is given a tendency to swing in windy weather as a unit. When heavy glass or porcelain spacers are used the tendency is for each wire to vibrate with respect to the other, so causing changes in the capacity between the wires and consequent changes in the emitted frequency. The wooden dowels can be attached to the feeder wires by drilling a small hole in the dowels, then binding them to the feeders with wire.



When heavy glass spacers are used in the feeder construction there is a tendency for the wires to vibrate as shown, so causing a wobbly frequency from the transmitter

The best insulation to use throughout the antenna system is pyrex glass. Glazed porcelain also is very good. It should be kept in mind that the ends of tuned feeders or the ends of the antenna are point of maximum voltage. It is at these points that the insulation is most important. A 12″ pyrex insulator is quite satisfactory for amateur transmitters of any power. For the low-powered transmitters one of the smaller sizes, or two in series, would be satisfactory.



The use of light wooden dowels in the feeder permits the system as a whole to swing. In this case the effect on the frequency of movement of the feeder would not be as noticeable.

Probably the most satisfactory method of leading the antenna or feeders into the station is through holes drilled in the centers of the window panes. The drilling can be accomplished by using an ordinary steel twist drill if plenty of turpentine is provided at the point of the drill. It is best to remove the panes before drilling is attempted, since it will be difficult to avoid breaking them if the work is done when they are in the window. Large pyrex bowls are also satisfactory as lead-in insulators, the bowls being mounted over large holes cut in a board of such a size that it fits snugly under the lower or above the upper sash when it is partially opened.

It is hardly possible to give practical instructions for the suspension of the antenna since the methods used will vary so widely in individual instances. In most cases poles are desirable to lift the antenna clear of surrounding buildings but in some locations the antenna is in the clear when strung from one chimney to another or from a chimney to a tree. Small trees are not usually satisfactory as points of suspension for the antenna on account of their movements in windy weather. If the antenna is strung from a point near the center of the trunk of a large tree this difficulty is not as serious.

In most locations a variety of possible arrangements will present themselves. It will be well for the amateur to try the antenna in different positions or to try different types of antenna. Time expended in such experiment undoubtedly will be well worth while

CHAPTER IX

The Frequency Meter—Radio Measurements

THE amateur may be guilty of failing to adjust his transmitter to give the cleanest signal, so causing unnecessary interference; he may fail to observe regular operating procedure and cause annoyance to all with whom he communicates—and for these actions he may be scorned by those fellow amateurs who hear him. There is one thing, however, which constitutes an unforgivable sin in amateur radio. It is that of operating the transmitter outside the boundaries of the amateur frequency bands. Every amateur must have some means of determining definitely whether the frequency of his transmitter is within the limits of the band in which it is to work. Without the facilities to do this he has no right in the world to send even a single dot.

It is fortunate that when the station has been equipped with a monitor the shielded oscillator which is indispensible in adjusting the transmitter correctly—it is also provided with what is probably the cheapest and most effective apparatus for setting the transmitter frequency within the band. Truly, the monitor is an essential part of the station equipment. Without it the amateur is about as handicapped as a blindfolded motorist would be if someone had run off with the steering wheel.

BUILDING A MONITOR

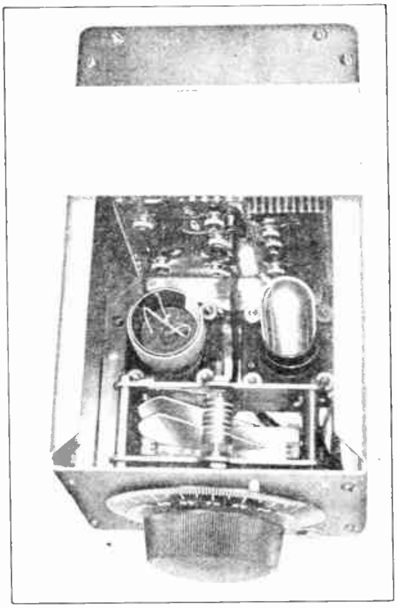
As we have said, the monitor need not be a costly or elaborate affair. Just how simple it can be is shown by the two examples illustrated. The constructional work probably would not occupy more than a Saturday afternoon.

The chief requirements of the monitor are that it oscillate steadily over the bands on which the station is to be active; that the bands be at least fairly well spread across the dial so that tuning will not be excessively critical; and that the pick-up of the head-phone cords be sufficiently mullified and the shielding complete enough to permit the monitor to sit near the transmitter and to beat with its fundamental frequency without producing more than a good readable signal.

The circuit used in both of the monitors illustrated is given. In it a UX-199 tube is connected in a split-coil series-feed Hartley circuit, the filament being supplied from a 3-volt dry battery source and the plate from a small 22½-volt unit.

The first monitor shown is built in an aluminum shield. This shield is built up of 1/16" thick aluminum, the bottom and front being of one piece folded, the sides and back of another piece folded and the top of two pieces, one of them hinged to provide an opening to change the coils, tube or batteries. The apparatus is assembled on the piece constituting the front and bottom and, when the oscillator is in running condition, the sides, back and top are fixed in place with small machine screws.

The tuning condenser for this monitor is built from an eleven-plate Cardwell condenser, plates being removed until one stator and two rotor plates were left. The rotor plates are treble-spaced in order to give just

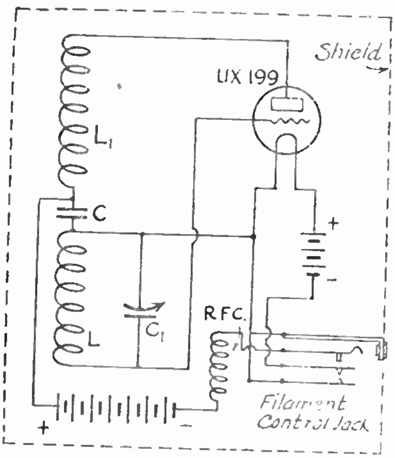


ONE POSSIBLE ARRANGEMENT OF THE MONITOR

In this case a "C" battery is used for filament supply, so permitting a compact lay-out. With a three plate treble spaced tuning condenser and coils wound on tube bases the number of turns used was as follows:

Band	Grid Turns	Plate Turns	Wire
3,500 kc.	43	18	30 gauge
7,000 kc.	19	13	26 gauge
14,000 kc.	7	7	20 gauge
28,000 kc.	3	3	20 gauge

sufficient capacity range to bring the 3,500-kc. band within the limits of the dial. No arrangement is made to reduce the capacity range of the condenser for the 7,000-kc. or higher frequency bands and tuning on these bands is therefore rather critical. The coils, wound on tube bases, are described under the photograph. To reduce the effect of the pick-up from the phone cords a receiver-type radio-frequency choke is inserted in one of the phone leads at the point shown on the circuit diagram. Without this choke the monitoring of the transmitter during



THE WIRING OF THE MONITOR

Apparatus necessary:

C—1,000-μμfd. by-pass condenser.

C1—In the first monitor a three-plate treble-spaced condenser is used. In the second monitor the main tuning condenser is a four-plate midget, in parallel with which is connected a 100-μμfd. midget as described in the text.

L, L1—Tuning coils described under the photograph of each monitor.

RFC—Short-wave receiver-type radio-frequency choke. 150 turns of 32 gauge wire wound on a ½"-wooden dowel would serve.

One UX-199 tube and socket.

One filament-control phone jack.

Aluminum shield or cracker tin of suitable size.

Filament and plate batteries, miscellaneous wire, screws, etc.

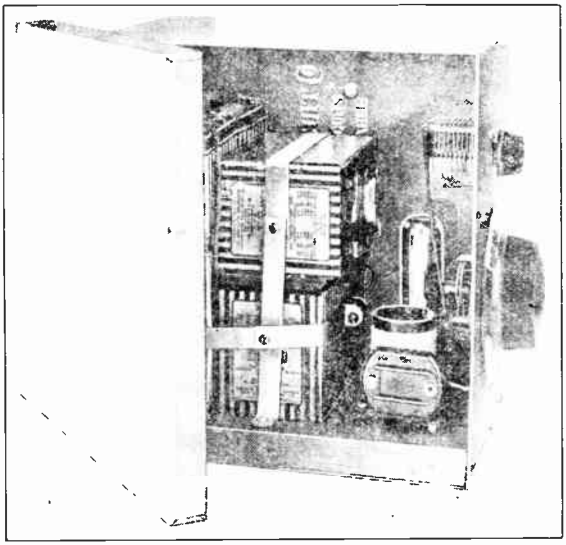
adjustment is made difficult by the fact that the tuning of the monitor and the strength of signal produced by it vary greatly in accordance with any movement of the operator's body in the vicinity of the transmitter.

The other monitor illustrated employs the same circuit as the smaller one but is fitted with large size dry cells for filament supply in order to make practical the continuous monitoring of all transmissions. It varies from the first one also in the arrangement of the tuning system. The main tuning condenser is a small vernier type with all but four plates removed. Its capacity is such that the 3,500-kc. band occupies almost the whole dial. On the 7,000-kc. and higher frequency bands the eleven-plate vernier, mounted above it and connected in parallel with it, is set at a predetermined value which reduces the effective capacity range of the main condenser to the point where the band occupies most of the dial. In order to do this, in this particular monitor, about half of the capacity of the larger condenser is added for the 7,000-kc. band and almost all of it for the 14,000 and 28,000-kc. bands. Either 22½ or 45 volts can be used on the plate, though the latter value was found desirable in order to give satisfactory oscillation on the 28,000-kc. band. The shield for this monitor is a Loose-Wiles biscuit tin measuring 8½"×9"×5½"—a size which just leaves reasonable breathing space after the larger batteries and the two tuning condensers have been installed. As can be seen from the photograph the apparatus, with the exception of the variable condensers, is mounted on a wooden base ¾" thick. When the leads to the condensers have been removed this base slides out of the shield, so facilitating the changing of batteries or the tube.

INSTALLATION AND ADJUSTMENT

In order to make the full use of the monitor it must be placed carefully with respect to the receiver and transmitter so that the signal in it from the transmitter is not too loud and so that the signal produced by it in the receiver also is of reasonable strength. If the receiver is located several feet from the transmitter a satisfactory location for the monitor will be found alongside the receiver on the side furthest from the transmitter. If the transmitter is a low-powered one it may be found necessary to place it on the transmitter side of the receiver in order to get enough pick-up. In any case it is essential that the monitor be so placed that it is in the immediate vicinity of the receiver and preferably so that its phones can be worn whenever the controls of the transmitter are adjusted without the necessity of moving it from its normal place in the station. If the receiver is across the room from the transmitter it will be necessary to move the monitor to a spot convenient to the transmitter whenever adjustments are to be made. Of course, the monitor can be placed alongside the receiver for frequency setting and monitoring of the transmitter during transmissions. It may be found that the pick-up with the lid of the shield closed is not enough to give a pleasantly loud signal. In such a case the lid can be opened until the required signal strength is obtained and left in that position for frequency checking or monitoring.

It is a very worth-while plan to fit the receiver with a small double-pole-double-throw switch so that the phones can be thrown from the receiver to the monitor. In this way it is possible to monitor all transmission simply by flipping over the switch when a change is made from the transmitter to the receiver. Ordinarily the transmitter makes a tremendous and very uncomfortable thump in the receiver phones during operation. If it is possible to throw the phones over to the monitor this thump is then replaced by a moderate signal which will be almost a replica of the signal that the other fellow has to copy. This makes for much snappier and more readable sending and provides a continuous check on the signal. Should anything go wrong with the transmitter or antenna to cause the frequency to change, the trouble is immediately apparent. For continuous monitoring in this way it would be as well to make the monitor (like the second example illustrated) large enough to accommodate standard-size dry cells for filament supply. Such cells should give months of operation without renewal.



AN ALTERNATIVE ARRANGEMENT SUITED FOR CONTINUOUS MONITORING OF THE TRANSMITTER

The use of two large dry cells for filament supply makes the monitor more bulky but permits it to give months of service without attention. Using a main tuning condenser of about 15 µµfds. and an additional 75 µµfd. condenser, adjustable to spread out the higher frequency bands in the manner described in the text, suitable coils were found to be:

Band	Grid Turns	Plate Turns	Wire	Added Shunt Capacity
3,500 kc.	10	15	30	None
7,000 kc.	12	13	26	Approx. 35 µµfd.
14,000 kc.	5	7	20	Approx. 75 µµfd.
28,000 kc.	3	3	20	Approx. 50 µµfd.

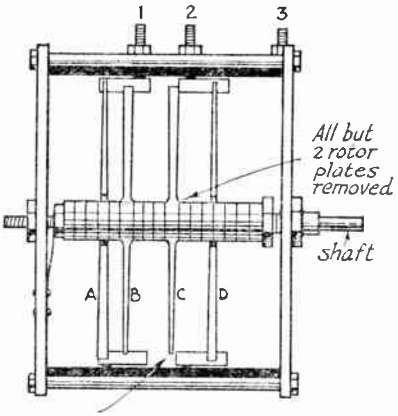
In this monitor also the coils are wound on tube bases.

CHECKING THE TRANSMITTER FREQUENCY

The simplest method of using the monitor for frequency setting is first to find a suitable place in the band with the receiver, transferring this frequency to the monitor by beating the receiver with the monitor and then putting the transmitter there by tuning it until it is heard in the monitor. This method does not provide the means for setting the transmitter on any definite frequency unless there is a known station there to mark it, but it does enable the transmitter to be tuned to, say, the center of the band, to a spot a quarter of the way from the top, or to any roughly estimated points. It is not often that the amateur finds it essential to tune his transmitter to within a kilocycle or so of a given frequency but if such is the case there are means involving greater difficulties which can be used. They will be detailed later. The prime requisite usually is to have the transmitter within the limits of the band and perhaps in some particular section of it. For this work the simple monitor is all that is necessary.

In order to put the transmitter frequency in its place it is first necessary to switch on the receiver and explore the band on which operation is desired in order to locate the commercial stations marking the edges of the band and to find the spot within the band which looks most desirable. When the spot has been decided upon the receiver is left running at that setting and the monitor tuning condenser is adjusted until the beat note between the monitor and receiver is heard. This beat can then be set at the zero-beat or silent point. The phones are now plugged into or switched onto the monitor, without disturbing its tuning condenser setting. Then the transmitter is switched on and its frequency adjusted until the beat note between the transmitter and monitor is heard. When this beat has been tuned to the silent point the transmitter frequency will be the same as that on which the receiver is set. At this stage the adjustment of the transmitter can be completed to give the cleanest and steadiest signal, the monitor being left at the same adjustment, and the transmitter frequency being held to beat with it all the time. With practice it will be found that the frequency variations caused by certain amounts of dial movement on the monitor can be estimated with fair accuracy and that slight adjustments of the transmitter frequency can be made without difficulty when the request is made to QSV to avoid interference.

Of course, the opposite procedure can be followed to find the approximate frequency of the transmitter. In this case the trans-



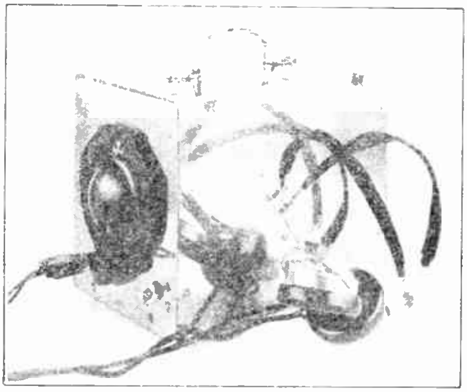
SHOWING THE REBUILT CONDENSER USED IN THE CALIBRATED MONITOR

mitter frequency is found in the monitor and then, with the transmitter switched off, transferred from the monitor to the receiver where it can be determined approximately from its relation to known points on the receiver dial. It might be explained that the usual receiver, even if it is shielded, cannot be used for this work (i.e., alone, without the monitor) since the pickup of the battery leads and external wiring is so great that the signal from the transmitter is nothing more than a heavy rumble across most of the dial. In some cases where both the receiver and its batteries are shielded the receiver can replace the monitor but even then the antenna lead to the receiver would have to be removed when the transmitter is checked, so disturbing any settings made from received signals of known frequency.

If an oscillating crystal is available, the fundamental frequency or harmonics of which fall within the bands in which the transmitter is to be operated, it can be used with a UX-201-A or UX-199 to provide a splendid monitor. With such an arrangement one can avoid the complications of crystal-controlling the transmitter, yet maintaining an almost perfect check on the frequency. Of course, if the transmitter is controlled by an accurately calibrated crystal the transmitter frequency-setting problem is at once solved. The monitor, however, is still a necessity for signal checking, since even the crystal-controlled transmitter can misbehave.

MORE PRECISE METHODS

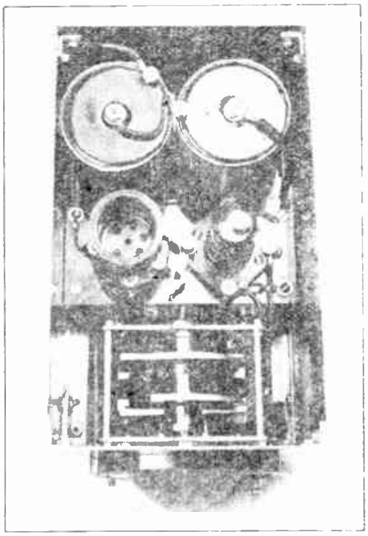
So far we have outlined the simple procedure necessary to determine definitely whether the transmitter frequency is within the limits of the band and roughly in what part of the band it is located. Some amateurs will be interested in knowing how a transmitter can be tuned to within a few kilocycles of a given frequency. For this work some calibrated standard will be necessary against which to compare the frequency of the transmitter. For approximate work the standard can be nothing more than the simple monitor which we have described. Indeed, if the monitor is solidly constructed it may well be used for quite accurate work providing the tuning condenser used is of a type likely to retain its calibration. The arrangement of the two midget condensers in the second of the two monitors is not satisfactory on account of the possible errors resulting from the re-setting of the condenser used to spread out the bands. The condenser in the first monitor can be used but in this case the disadvantage will be that some of the bands will be cramped



A CALIBRATED MONITOR OF THE TYPE DESCRIBED IN THE TEXT

within a few degrees of the dial and accurate readings will be difficult to make. One type of condenser which is particularly suited is that illustrated. It is made by the amateur from a 500-μμfd. Cardwell taper-plate condenser so as to provide a condenser which has three capacity ranges.

In order to build such a condenser, all except two stator and two rotor plates are removed. Then the brass mounting of the stator plates is cut as shown on the diagram so as to isolate the two stator plates. The unit then really consists of two condensers, the capacities of which can be altered by varying the spacing of plates B and C and by moving them on the shaft nearer to the stator plate A or D. When the coil is connected between the terminals 2 and 3 the capacity between the plates C and D is used. When the coil is connected from 1 to 3 the larger condenser constituted by plates A and B is used. If one end of the coil is connected to both 1 and 2 and the other end of the coil to 3, the two condensers are in parallel and a still larger capacity is obtained.

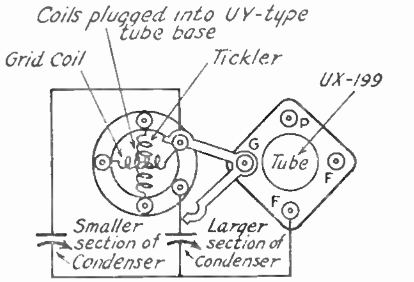


PLAN VIEW OF THE CALIBRATED MONITOR

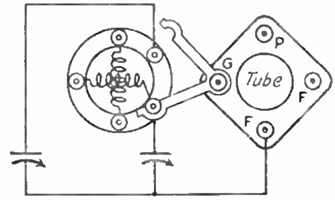
In this instrument particular care was taken to obtain mechanical rigidity and generally substantial construction. The switching arrangement for throwing in any of the three possible capacity values can be seen between the tube and the coil. The shield of this monitor is made of heavy copper plate built up on aluminum angle-pieces.

In the next monitor illustrated, this type of condenser is used so that each band can be spread out to occupy a large segment of the dial. A small switch is provided as shown in the diagram so that the different capacities provided by the condenser can be connected when required. For the 1,715- and 3,500-kc. bands the two condensers in parallel are used. For the 7,000-kc. band the capacity between plates A and B is connected to the coil. On the 14,000- and 28,000-kc. bands the plates C and D are brought into use.

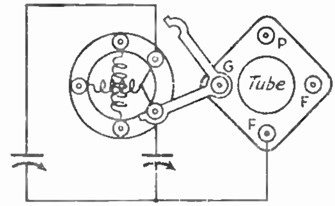
With a well-built monitor of this type, provided with a solid condenser of some such type as this, the calibration can be made directly on it. Probably the most satisfactory way of making the calibration will be to listen to the Standard Frequency Transmissions, of which the current schedules are given from time to time in *QST*. When the receiver has been tuned to the standard frequency signal, the monitor is tuned until the signal from it is at zero-beat with the receiver. The monitor dial reading is then noted along with the frequency of the standard frequency signal received. In a similar way the settings of the monitor dial are found for other standard frequencies. Some points outside the



Wiring of coil and setting of switch for the 14,000-k.c. band.



Wiring of coil and setting of switch to connect larger section of condenser across grid coil for the 7000-k.c. band.



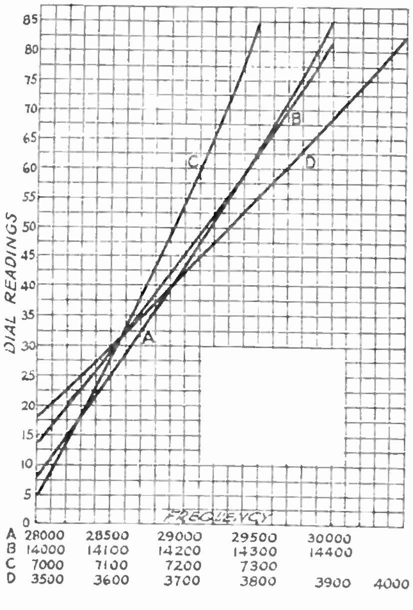
Wiring of coil which connects both sections of condenser in parallel for the 3,500 k.c. band. The switch can be in either position. In other respects the wiring is similar to that of the other monitors.

THE WIRING OF THE CALIBRATED MONITOR

Showing the switching device for connecting any of three possible capacity ranges to the coil. The coil plugs into a 5-hole UY-type tube socket. Two of the terminals provide for the tickler winding. One of the others is the filament end of the grid coil. The grid end of this coil is connected to one or the other of the remaining two prongs on the coil-form, depending upon which capacity range is desired in association with it. The two capacitances are connected to the corresponding terminals on the socket. There are thus two alternative connections from the grid, each connecting, through the switch, with the proper capacitance. When the combined capacitance of both capacity ranges is desired, the grid end of the coil is connected to both of these prongs, rather than to a particular one, and thus both capacitances are in circuit regardless of to which the switch is connected.

band can be found by checking against the commercial stations on both sides of the band. The frequencies of these stations are also given from time to time in *QST*. When several such points inside and at the edges of the band have been found on the monitor dial, the dial readings are plotted against the frequencies to give a calibration curve from which the frequencies at all other settings of the monitor dial can be found. With such a calibrated monitor the frequency of the transmitter can be found by locating it on the dial and finding from the calibration curve the frequency corresponding to this dial reading. Conversely, the dial setting for some definite frequency can be found from the curve, the dial set at this setting, and the transmitter tuned until its beat-note is heard in the monitor.

When the batteries or the tube in the monitor are replaced with new ones it is certain that the calibration will be upset to



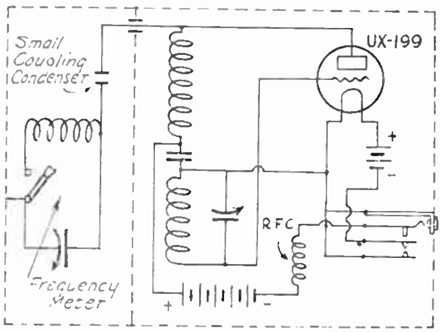
A TYPICAL SET OF CALIBRATION CURVES FOR A CALIBRATED MONITOR

These curves will not serve for any of the monitors described. They are presented only to show the method used in setting out the calibration. In order to avoid confusion it is usually advisable to make a separate curve on a separate sheet for each band.

some extent. Even the gradual decay of the batteries will introduce some error. For this reason it is as well to check the monitor against a few stations of known frequency from time to time in order to correct for any such changes.

A COMBINED MONITOR-FREQUENCY-METER

In order to attain a greater degree of calibration permanence, some amateurs prefer not to calibrate the monitor but instead to use it in conjunction with a coil-con-



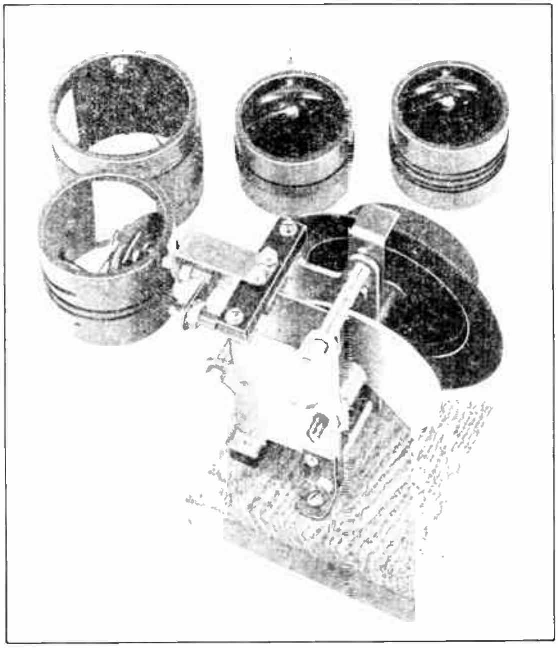
THE WIRING OF THE COMBINED MONITOR-FREQUENCY-METER

The shield can be made from two cracker tins soldered together or it can be specially built from aluminum or copper sheet. The switch in the frequency-meter circuit can be one of the miniature single-pole knife switches which are readily available at most radio stores. It can be mounted on the front of the shield near the condenser dial of the frequency meter.

denser forming a separate tuned circuit. This tuned circuit is not susceptible to the variations in tubes or batteries and its calibration is therefore less likely to vary. The wiring of such an instrument is given in the next diagram. The coil and condenser comprising the frequency-meter are in a compartment of the metal shield separate from that in which the monitor is built and the only coupling between the two units is that provided by a small fixed condenser consisting of two brass angles about ½" x ¼" and separated ⅛". The capacity of this coupling condenser is made as near permanent as possible, since variations in the coupling to the frequency-meter would result in changes in the calibration.

The coils and condenser for the frequency-meter unit can be similar to those shown in the next illustration. The condenser is made from a Cardwell taper-plate condenser by removing all except a single stator and a single rotor plate. The bands are spread out across a wide segment of the dial by putting fixed condensers across the coils. These condensers are mounted on the coils by spacing the pins so that they can be pushed through holes in the bakelite tube on which the coils are wound and screwed directly into the condensers. Sangamo condensers are suited for this purpose. The values used are given under the illustration. The number of turns given for the coils is only approximate and it undoubtedly will be necessary to adjust them so that they can be tuned across the bands.

The spacing of the two condenser plates also will have to be varied until a suitable value has been found. The wiring in this frequency-meter will have to be made very substantial and the turns of the coils will have to be held firmly in place with shellac or Duco cement. Otherwise the constants in this unit will not be of a permanent nature and the construction of the instrument will not be justified.



THE TYPE OF CONDENSER AND COILS USED IN THE COMBINED MONITOR-FREQUENCY-METER

The coils are wound on bakelite tubing of the diameter indicated below. The details of the windings are as follow:

Band	Turns	Dia. of Turns	Length of Winding	Fixed Shunt Capacity
3,500 kc.	40	2½"	1"	None
7,000 kc.	9	2"	5/16"	100 μμfd.
14,000 kc.	4	2"	1/2"	50 μμfd.
28,000 kc.	2	2"	3/16"	50 μμfd.

With the exception of the 3,500-kc. coil, which is wound with 24 gauge wire, 20 gauge double silk covered wire is used. These dimensions should serve as a rough guide but it is possible that they may have to be varied considerably if a tuning condenser of slightly different capacity range is used.

In making the calibration the stations of known frequency are first picked up in the receiver and the monitor is then tuned to the same frequency, with the switch in the frequency-meter circuit open. The beat note between the monitor and receiver is now adjusted with particular care until a dead zero-beat is obtained. At this time the switch in the meter circuit is closed and the variable condenser of the meter is varied slowly in one direction until the beat rises from zero, falls back to zero and then rises again. There will be a narrow segment on the dial of the frequency-meter condenser where the beat note is zero but where it rises sharply on each side. In the center of this zero-beat area is the setting corresponding to the frequency at which the receiver is set. The width of this zero-beat area will be influenced by the capacity of the coupling condenser between the frequency meter and the monitor. Before calibration starts its capacity should be adjusted to give the narrowest zero-beat area possible. Its capacity, from then on, should be untouched. The same process of picking up stations of known frequency on the receiver, setting the monitor to the same frequency with the meter switch open, and then "pulling" the frequency of the monitor with the frequency-meter circuit, should be repeated at as many places on the dial as possible. Then a curve of the dial readings of the frequency-meter against the frequency indicated can be drawn.

THE FREQUENCY-METER

In the past, when amateur frequency bands were much more extensive than they are now, the most common method of checking the frequency of the transmitter was with a wave-meter or frequency-meter consisting merely of the coils and condenser forming variable tuned circuits for the various bands. For each coil a curve of variable condenser settings against wavelength or frequency was drawn, so that the frequency of the tuned circuit for any condenser setting could be determined rapidly. In use, the coil of the meter was coupled to one of the coils of the transmitter and the variable condenser of the meter was varied until resonance between the meter and the transmitter was obtained. In some cases the condition of resonance was observed by watching for the sharp rise of the transmitter plate current which resulted from the meter circuit coming into tune with the transmitter. In another of the many methods a thermocouple meter or a small lamp was used in the frequency-meter circuit. Resonance was indicated when the greatest current was obtained in the thermocouple meter or lamp for any given degree of coupling between the frequency-meter and the transmitter. This type of frequency-meter can still be used at the present time but readings can be taken with a satisfactory degree of accuracy only if the meter is used under the same electrical conditions as those in which it was calibrated. The extreme difficulty in obtaining accurate results with such a frequency-meter when its coupling to the transmitter is a variable factor has led to the evolution of the combined monitor-frequency-meter in which the coupling between the meter and the oscillator is the same when measurements are made as it was when the instrument was calibrated.

ELECTRICAL MEASUREMENTS

The proper use of voltmeter and ammeter followed by a substitution of the scale readings in Ohm's Law makes the determining of many circuit constants possible. The simple measurements of resistance (d.c.) and impedance (a.c.) are most important.

Electrical measurements are based on the use of one or more calibrated instruments especially made for their application. These instruments vary in construction depending on whether they are for use with direct current, alternating current at commercial frequencies (25 or 60 cycles), or for radio measurements where you are dealing with frequencies of millions of cycles.

Two of the most important quantities to be measured are *current* and *voltage*. The instrument for measuring the rate of current flow is called an *ammeter* because the unit of current is taken as the "ampere". The unit of potential difference is the "volt" from which we name the instrument for measuring electrical pressure a *voltmeter*. Some instruments may be used for one kind of current only; others are suitable for both d.c. and a.c. Meters are built on various principles, each of which has a field of application and certain advantages and disadvantages. Most commercial instruments are built ruggedly and compactly. A pivoted movement carries a pointer moving over a scale which is calibrated directly in terms of volts, amperes, watts and so on, depending on the construction and circuit of the instrument. In most indicating instruments a fine spiral spring holds the pointer in its zero position when no current is flowing.

Many direct current instruments make use of a moving coil pivoted between two permanent magnetic poles. This type of instrument is known as the d'Arsonval type, taking the name of the physicist who first made use of the principle. The deflection depends on the current through the moving coil which is connected to the terminals of the instrument. When heavy currents are to be measured, metal shunts are connected across the terminals of the meter to pass some of the current. The scale of the meter can be calibrated to read the current directly when the shunt is built into the instrument. However, a sensitive voltmeter is often used for measuring current when a set of shunts of known resistance is available. The current value is figured out by knowing the resistance of the shunt, measuring the voltage drop across it when current flows, and applying Ohm's Law.

Voltmeters are made by connecting a high resistance in series with the d'Arsonval movement to limit the current flow and power consumption of the instrument to a small amount. The resistance is usually placed right within the instrument itself. The value of resistance, the size of the spring, the number of turns in the coil, and the strength of the magnetic field (which determines the torque for a given current) all have an effect on the range of the meter. Any low-reading d.c. milliammeter will make a good d.c. voltmeter when calibrated with a suitable external resistor.

If you have an instrument of the d'Arsonval type it can be used either as voltmeter or ammeter if separate calibrations are made with various external shunt and series resistors. An external resistor or "multiplier" placed in series with any voltmeter will increase the range of the meter so it may be used to measure higher voltages than given on the scale of the meter. The internal resistance of the voltmeter must first be found using Ohm's Law. Substitute the values for the current the meter takes (measured on a milliammeter) and voltage applied to the meter in Ohm's Law to get the resistance of the movement and series resistor. A fresh 22½-volt block B-battery will do for a source of voltage if only a rough calibration is necessary. If the *total* resistance in the circuit of the meter is doubled, the deflection will be just half the value for a given voltage that was obtained before adding the external resistor, so that the scale readings can be multiplied by two—which is the reason such an external resistor is called a multiplier. If it is desired to increase the useful scale of a voltmeter by adding resistors of unknown value, take two meter readings, one with the voltmeter "as is" and the other with the external multiplier in series with the meter and the same applied voltage. The ratio of the two readings is the figure by which any and all scale readings of the meter can be multiplied to give the correct results.

Any pocket voltmeter can be used as a milliammeter in connection with circuits whose resistance is comparatively high (compared to that of the meter). As the plate impedance of small vacuum tubes is high, such a meter can be connected right in series with the negative lead from the high voltage plate supply to a vacuum tube circuit. If one cares to alter the connections inside the voltmeter, bringing out an extra lead so that the movement can be used without any resistance in series with it, the meter will have less effect on the external circuit. One should take precaution never to overload the meter. A calibration curve may be made for the meter or the current figured out by writing Ohm's Law:

$$\text{Milliamperes} = \frac{(1000)\ (\text{reading in volts})}{(\text{resistance between meter terminals})}$$

Direct current instruments such as described using permanent magnets must never be connected in a.c. circuits. The permanent magnets will be weakened, ruining the calibration. The pointer will tend to vibrate but cannot follow the alternations. Direct current meters of the type described measure the *average* value of the current passing. This must be considered when a d.c. meter is used to measure fluctuating current such as that supplied to a self-rectifying vacuum tube oscillator. The average value of a complete a.c. cycle is zero.

The value of an alternating current ampere is based on its heating effect which varies as the square of the current. The square root of the average of the squares of all the instantaneous values of an alternating current over a half-cycle is called the *effective* or *root-mean-square* value which is a true measure of the heating effect. Taking the peak value of sine wave alternating current as unity, the *average* value (sum of all the instantaneous values divided by the number of values) is .637 while the *effective* value is .707. Thus the plate input to a self-rectifying circuit as measured on a d.c. meter does not give a true indication of the heating effect. Its readings are *average* readings and they must be multiplied by about $\frac{.707}{.637}$ or 1.11 to give the *effective value*.

Both alternating and direct current can be measured by instruments of the electrodynamometer type. Such instruments contain both a fixed and a movable coil, the fixed coil taking the place of permanent magnets. The calibration is in terms of the torque or force between the two coils through which the current is passed. As the fixed and moving coils are in series, the current reverses at the same time in both and the force of attraction between coils is always in the same direction. This instrument reads *effective* values of fluctuating current and voltage. Such meters are usually calibrated on steady direct current, but they are very accurate at all commercial frequencies as usually manufactured.

A third type of instrument has a moving iron plunger which is drawn into a solenoid by the current. If the soft iron plunger is well-laminated such instruments read equally well on a.c. or d.c. The better class of instrument utilizes a soft-iron vane mounted on the shaft in an inclined position. The vane tends to become parallel to the lines of force from the stationary coil which is inclined about 45° with the shaft. This instrument also reads *effective* values and the type is quite commonly used for pocket meters and switchboard instruments.

Induction-type instruments work by means of a split-phase alternating field. Indicating and recording ammeters, voltmeters, watt and watt-hour meters, power factor meters and so on base their use on this principle which is discussed in any good electrical engineering text book. It should not be necessary to add that they will work correctly only on alternating current of certain specified commercial frequencies.

Electrostatic voltmeters depend on the mechanical attraction between two charged surfaces at a difference of potential. They can be used for either a.c. or d.c. but are unduly bulky for use below 3,000 volts. For high voltage work they are quite accurate and they sometimes can be used in amateur work for measuring plate supply voltage. Condensers answer the same purpose for electrostatic voltmeters as do multiplier resistances for ordinary a.c. and d.c. voltmeters.

Hot-wire instruments are familiar to every amateur. The current to be measured heats a wire and the scale of the meter is calibrated to read amperes from the change in the length of the wire. Such instruments can be used with equal facility for direct current, low-frequency alternating current, and radio-frequency alternating current measurements. A hot-wire instrument calibrated with direct current will read true effective values of alternating current with the possibility of slight errors creeping in at radio frequencies due to the capacity between terminals and to the fact that radio-frequencies travel on the surface of wires rather than on the inside, thus raising the effective resistance of the meter.

Another meter familiar to the amateur is the thermo-coupled type. The current to be measured is sent through a small resistance or "heater" strip which warms a thermo-junction. This is connected to a sensitive galvanometer of the d'Arsonval type which is calibrated directly in amperes at 60 cycles for commercial purposes. For laboratory measurements a sensitive d.c. meter is used with several thermocouples and thermo-couple bulbs to cover different ranges. The couples are often sealed in a bulb full of dry hydrogen which protects the junctions from atmospheric changes and movements of the air, dissipating the generated heat at a constant rate. Properly constructed and calibrated, this sort of instrument will read *effective* values of alternating current at both radio and commercial frequencies. If the couple is separate from the heater the instrument will read equally well on d.c. However, the usual thermo-coupled meter sold for radio work contains a copper-Advance couple spot-welded to a manganin heater strip and unless the weld covers a very small area there is some likelihood that the direct current being measured will get through to the galvanometer causing its readings to vary from the correct ones. Unless the couple and the heater are intimately related, there is danger that much of the heat will be lost before it reaches the couple. Hot-wire and thermo-coupled meters can be calibrated in either terms of current or current-squared, so it is well to note the type of calibration before making any measurements. Current-squared instruments are usually called thermo-galvanometers.

There are certain qualifications of all meters that should be considered by the prospective purchaser. For most work at an amateur station, precision equipment is neither necessary nor desirable. Meters should be rugged, fairly accurate and not unduly expensive. *Permanency of calibration* is always the first requirement; extreme accuracy is secondary and dependent on permanency. Indicating meters should be shielded from stray magnetic fields, should have a suitable and legible scale, high sensitivity (low friction), and they should be dead-beat (the pointer should come to rest quickly). The springs and magnets should have as permanent qualities as good manufacturing conditions and processes can insure. Instead of using a large multiplying resistance with a.c. voltmeters, it is most economical to use an "instrument" transformer, to step-down the high voltage. By knowing the ratio of the transformer, the proper multiplying factor can be used. The scale may be calibrated directly in terms of the higher voltage if necessary. The resistance method is necessary for measuring high d.c. voltages though it is wasteful of power.

In applying meters to radio circuits, it is best to get meters which have a full-scale deflection at about double the value at at which you will ordinarily work. This brings the reading in the center of the scale and makes it possible to use the meters for lower or higher ranges. Always put plate ammeters in the *negative* high voltage leads when possible. This will keep them at low voltage (nearly ground potential) which makes them safe to handle and protects them from insulation breakdown as well.

A meter to measure the d.c. component of the grid current should be placed in series with the grid leak resistor and a small radio-frequency choke coil (to protect the windings from radio-frequency voltages that may otherwise build up across them.) A low-reading hot-wire or thermo-coupled meter in series with the grid condenser will show that the radio frequency component of the grid current of an oscillator is about proportional to the r.f. values elsewhere in the circuit. If it is necessary to put a d.c. meter in a radio frequency lead, be sure to protect it with a radio frequency choke of the right size and to by-pass high-frequency currents around the meter and its choke coil by shunting them with a condenser of ample capacitance. A radio-frequency meter placed in a lead carrying a current with both a d.c. and a.c. component will indicate both and the effect of the direct current must be subtracted out of the scale reading to give the value of radio frequency current. It is well to see that a small d.c. and a.c. current give the same (or proper) deflection on the meter, too, as a little d.c. getting through to the d'Arsonval movement may throw the reading away off. Multipliers for high voltage d.c. meters should be mounted where the live parts are out of reach, preferably in a grounded metal-incased box. The measurement of direct current quantities and even of alternating currents at commercial frequencies is comparatively simple compared to some of the measurements made at radio frequencies. About all anyone needs to know to measure direct current quantities is how to apply Ohm's law and how to connect the meters so they have little effect on the measurements themselves. The measurments of radio-frequencies should be thought of as simply an advanced application of ordinary alternating current laws, however. The construction and use of a wavemeter (or radio frequency meter) has already been described and now we are going to touch on some of the more common and useful measurements that anyone can make at a radio station.

MEASURING FILTER CHOKE-COIL INDUCTANCE

The approximate inductance of different choke coils at 60 cycles was given in tabular form in the chapter on power-supply apparatus. However, the inductance of choke coils is a variable quantity depending on the grade of iron used in the core and on the length of the air gap. When the core becomes saturated or the frequency varies, the inductance value will change somewhat, too. For all practical purposes a measurement of the inductance can be made that will be much better than the approximate figures of the table and closely approaching the inductance actually obtained under working conditions.

Two things about the coil must first be determined—the resistance and the impedance at a known frequency. Then the inductance can be found by solving a few formulas or by the still simpler process of referring to the chart reproduced in these columns.

Formula A (Ohm's Law) can be used to get the resistance. Formula B will give the impedance. Substituting these values in Formula C and solving for L will give the inductance in henries.

Four meters should be used for making the measurements if you can get them. The connections for making the measurements are shown in the diagram and a sample problem has been worked out to show how it is done. If the alternating current supply voltage and frequency are accurately known, the values can be substituted if no meters can be obtained for the purpose. A dry cell or storage battery can be connected to the choke to be measured through a d.c. milliammeter using only sufficient voltage to get a reading in the middle of the scale of the meter. The voltage across the coil should next be read. Dividing the voltage by the current (changed to amperes) gives the d.c. resistance in ohms.

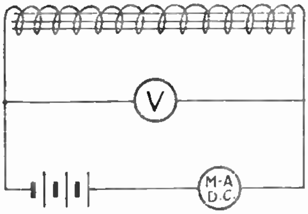
Next, the local a.c. supply is taken as a source of voltage and the same procedure is repeated—this time using *alternating* current meters. The result is the impedance in ohms at the frequency used. Now both the reactance and resistance of the coil come into play so that the current that flows into the choke does not increase as much as might be expected in view of the greater applied voltage. Usually the frequency is accurate to within a part of a cycle and anyone can find out what it is quickly enough by telephoning the local power house for information. Unless the coil was found to have a resistance of 20 ohms or more from the first set of measurements, it is not safe to connect it directly across the 110-volt mains. In any case it will be wise to put a small fuse in the circuit to protect the meters, the circuit and the choke itself. Suitable a.c. meters can be obtained from the high school laboratory or perhaps from the local electrican.

Now substitute the values in Formula C. The result can be obtained by working down through the eleven steps shown or by following the directions under the curve after R and Z have been found. If the number $(Z^2 - R^2)$ obtained lies between 1,421 and 142,100, the inductance will be in tenths of henries. If it is between 142,100 and 14,210,000 the middle lines of figures on the axis of the curves should be used. If the difference of the squares is between 14,210,000 and 14,210,000,000 the inductance will be found on the scale of 10 to 100 henries. If you wish to use the curve, it is of course necessary to measure the choke coil at one of the frequencies shown on the curve. The 25-cycle and 60-cycle curves are most convenient and the inaccuracy of the meters themselves will often result in a greater degree of error than that derived from use of the curves.

(A.) $R = \frac{E}{I}$

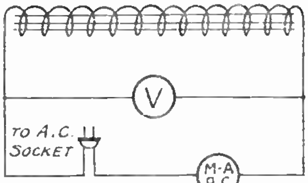
(B.) $Z = \frac{E}{I}$

(C.) $Z = \sqrt{R^2 + (2\pi fL)^2}$



(A.) $R = \frac{E}{I}$; $E = 6$ volts; $I = .150$ Amp.

1. $R = \frac{6}{.150} = 40$ ohms



(B.) $Z = \frac{E}{I}$; $E = 110$ V. $I = .13$ Amp.

2 $Z = \frac{110}{.13} = 846$ ohms

(C) $Z = \sqrt{R^2 + (2\pi fL)^2}$

3 $Z = \sqrt{(40)^2 + (2 \times 3.1416 \times 60 \times L)^2}$

4 $Z = \sqrt{1600 + 142{,}129 \times L^2}$

5 $Z^2 = 1600 + 142{,}129 \times L^2$

6 $Z^2 - 1600 = 142{,}129 \times L^2$

7 $(846)^2 - 1600 = 142{,}129 \times L^2$

8 $715{,}716 - 1600 = 142{,}129 \times L^2$

9 $142{,}129 \times L^2 = 714{,}116$

10 $L^2 = \frac{714{,}116}{142{,}129} = 5.02$

11 $L = \sqrt{5.02} = 2.24$ Henries

FORMULAS USED IN FINDING CHOKE COIL INDUCTANCE AND THE CIRCUITS FOR MAKING THE NECESSARY MEASUREMENTS

The problem can be worked out mathematically like the sample shown or the inductance can be more readily found by referring to the chart.

In the example worked out we got the values of R and Z as 40 and 846 ohms respectively. $Z^2 - R^2 = 714,116$. On the curves this number is in the middle row of figures. Following the dotted line from this point gives the inductance as 2.25 henries. The accuracy of measurement will depend mostly on the accuracy of the meters used and on the care in taking readings. The average of several readings can be used if especially accurate measurements are necessary. A d.c. milliammeter can be borrowed from the transmitter for taking the measurements necessary. Most hotwire and thermocoupled ammeters are calibrated on commercial frequencies and can be used for finding the impedance if they happen to be available in the right scale ranges. A moving-coil electrodynamometer type ammeter is best of all if it can be borrowed from some laboratory.

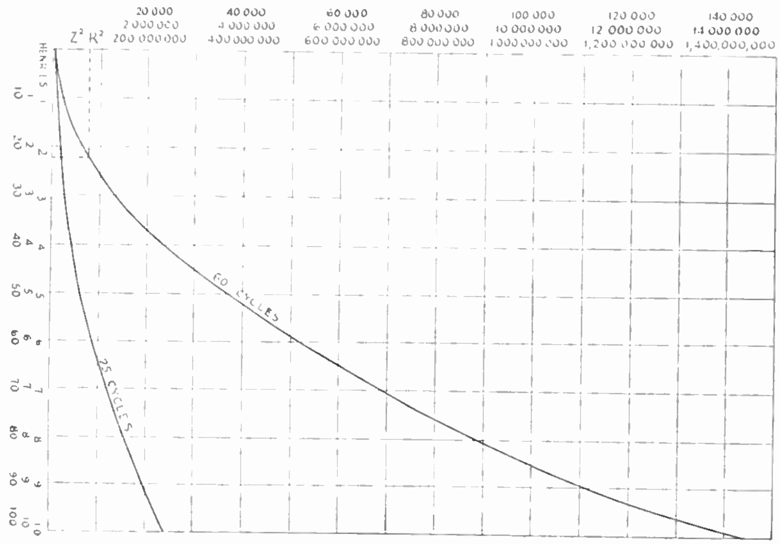


CHART FOR FINDING INDUCTANCE OF FILTER CHOKES

1—Find the resistance of the coil (R) by using Formula A.
2—Find the impedance of the coil (Z) by using Formula B.
3—Find $Z^2 - R^2$ by multiplying Z by Z and R by R and substracting.
4—Using the value found for $Z^2 - R^2$, refer to the 60-cycle or 25-cycle curve and find the inductance at the frequency you are interested in at the left given in henries.

Note: If the choke has too small a core or too small an air gap it may become saturated when carrying rectified alternating current, somewhat lowering the effective inductance. A very "skimpily designed" choke will lose nearly three-fourths of its inductance under such conditions.

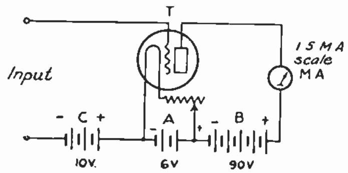
VACUUM-TUBE VOLTMETERS

By a vacuum-tube voltmeter we mean a combination of a tube, a sensitive milliammeter and the necessary batteries—this combination being so arranged that the reading of the milliammeter is an indication of the voltage impressed on the input of the vacuum tube.

The general connections of such a voltmeter are diagrammed. T is a vacuum tube of the usual 201-A type; MA is a milliammeter having a full scale range of about 1.5 milliamperes (such as is used in the grid circuit of drivers). Weston makes a small instrument having this range, which serves very well. For great precision we must use extremely accurate meters.

With the values of filament, plate and grid potentials indicated, the grid of the tube is operating at a point well down on the grid-voltage plate-current characteristic, and the plate current will be about one-tenth milliampere. If now an alternating potential is impressed on the input terminals, the grid will fluctuate periodically about this initial bias and, due to the shape of the characteristic, the positive loops in the plate current will exceed the negative loops, so that we have an increase in our average plate current, this increase varying with the impressed alternating voltage. In other words, our plate milliammeter will show an increased reading when the a.c. is impressed on the grid. For example, an input voltage of five volts with the constants shown will increase the plate current from about one-tenth milliampere to one milliampere.

If we calibrate such a vacuum-tube voltmeter by varying the input voltage and ob-



serving the reading of the plate milliammeter, we can plot a curve from which we may obtain the voltage for any reading of the milliammeter. A typical calibration curve for such an instrument is shown. While this is the general basic type of vacuum-tube voltmeter in actual practise, there are many refinements applied to fit it for various particular uses.

The big advantage of a vacuum-tube voltmeter over ordinary instruments used in electrical work is that no power is used in the meter itself in making the measurements. It is readily apparent that ordinary voltmeters and ammeters are unsuitable for making measurements of the tiny currents and voltages in radio receivers. A vacuum tube voltmeter may then be used for measuring voltages (and currents, too) without consuming any power from the source under measurement. This makes it possible to measure

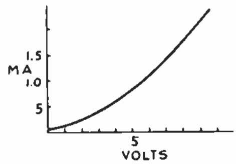


TABLE:

V	MA
0	.10
1	.15
2	.25
3	.40
4	62
5	.85
6	1.11
7	1.39

audio-frequency and radio-frequency amplification as well as many other quantities difficult to get at with clumsier instruments. There is a wide field of use for such a device.

CHAPTER X

The A.R.R.L. Communications Department

THE Communications Department is concerned with the practical operation of the stations of League members. The work of the department includes arranging amateur operating activities, establishing standard operating procedure, encouraging good operation, improving message relaying, and concluding tests to these ends.

The aim of the Communications Department is to keep in existence a network of League stations made entirely of privately-owned radio stations covering the entire continent of North America. One of its objectives is to create a body of skilled operators whose services and abilities will further the general knowledge of the art of radio communication. The relaying of friendly messages between different parts of the country without charge is one of the most important phases of the work coming under the supervision of the Communications Department. Amateur operators have also always been of great assistance to our country in times of any sort of emergency in which quick communication to a distant point has been a factor, especially when other methods of communication have failed.

These objects of our organization must be borne in mind at the same time we, as individuals, are getting the most enjoyment from the pursuit of our chosen hobby. Only by operating our stations with some useful end in view can we improve the service which we give others and increase the pleasure we get from amateur radio communication, at the same time justifying our existence.

The activities of the Communications Department are arranged and recorded through *QST* and by special correspondence. Tests and relays are arranged from time to time to develop new routes for traffic handling, to prepare ourselves to render emergency service in time of need, and to bring to light additional general radio information. In this way all members of the League benefit from the experience of certain individuals who excel along specified lines of work.

The policies of the Communications Department are those urging members to adopt uniform operating procedure and to use system in their station operating. The Communications Department constantly tries to make our communication system just as efficient as a non-commercial message-handling organization can be made. Compliance with government regulations, orderly operating, and co-operation with each other and with outside interests for the advancement of the art, are a part of the policies of the Communications Department. The first duty of the department to member-stations is to supervise operating work so well that the amateur will continue to justify his existence in the eyes of his Government. Then he will be allowed a continuance of the privileges which he has received as his due in the past.

Records of the worth-while traffic handling, of message routing, and of specific tests conducted between the different stations are kept in the files of the Communications Department and recorded in the Official Organ of the League, *QST*.

It is obviously impossible to distribute up-to-the-minute information in a monthly periodical. Therefore mimeographed circular letters are used on special occasions. The active stations are thus kept informed of the developments in such a rapidly progressing system. Through such letters, through *QST* and through a large volume of routine correspondence with individual members, the contact is kept good and the activities we have outlined are effectively carried out by the interested member-stations.

Official Broadcasting Stations have been appointed to improve on even the arrangement we have just outlined. Every day of the week at certain hours about one hundred stations send a telegraph broadcast that is copied by hundreds of members. The broadcasts carry the very latest information that is available from League Headquarters.

Official Frequency Stations, many of them crystal-controlled, have been selected to aid in maintaining the orderly and law-abiding operation which is in accordance with the policies of the League and of the Communications Department. The up-to-date list of calls and frequencies is printed in one of the recent numbers of *QST* for your benefit. The Official Frequency Stations are not appointed by A.R.R.L. Section Communications Managers as are all the other appointees. They are selected by the Official Frequency Committee. Communications should be addressed to the Official Frequency Committee, Chairman, Mr. D. C. Wallace, 109 West Third St., Long Beach, California. The O.F.S. are required to observe a high degree of precision in signing their frequencies after their call signal as they engage in two-way work, and in making reports on the transmissions of other stations. A deviation of not more than one-half of 1% of the correct frequency is permitted of the O.F.S.

From time to time Standard Frequency Stations also transmit different "standard" frequencies on schedules published in *QST*. Several frequencies are chosen for a given set of transmissions so that frequency meters may be calibrated, secondary standards checked, and the like. The Standard Frequency Stations endeavor to maintain accuracy within one-tenth of 1% which is materially better than can be held by most frequency-meters.

In these pages we are going to explain the organization of the Communications Department, the proper message forms to use, and some special practices which experience has proven best. We urge that you help strengthen amateur radio by studying the operating practise suggested and by adopting uniform operating procedure. Keep this book in your station for ready reference.

Everyone at League Headquarters welcomes criticism that is accompanied by constructive suggestions. In fact it is only through the boosts and suggestions which come from every member and operator that we can improve our service to others, thereby increasing the pleasure we ourselves get from our chosen hobby.

ORGANIZATION

The affairs of the Communications Department in each Division are supervised by one or more Section Communications Managers each of whom has jurisdiction over his section of a Division.

For the purpose of organization, the A.R.R.L. divides the United States (plus Cuba) and Canada (plus Newfoundland) into Divisions as follows:

ATLANTIC DIVISION: Delaware, District of Columbia, Maryland, Pennsylvania, that section of New Jersey within the Third Federal Inspection District, and that section of New York within the Eighth Federal Inspection District.

CENTRAL DIVISION: Illinois, Indiana, Kentucky, Michigan, Ohio and Wisconsin.

DAKOTA DIVISION: Minnesota, North Dakota and South Dakota.

DELTA DIVISION: Arkansas, Louisiana, Mississippi and Tennessee.

HUDSON DIVISION: The entire Second Federal Inspection District, consisting of certain counties of New Jersey and New York States.

MIDWEST DIVISION: Iowa, Kansas, Missouri and Nebraska.

NEW ENGLAND DIVISION: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont.

NORTHWESTERN DIVISION: Idaho, Montana, Oregon, Washington and the Territory of Alaska.

PACIFIC DIVISION: Arizona, California, Nevada and the Territory of Hawaii.

ROANOKE DIVISION: North Carolina, Virginia and West Virginia.

ROCKY MOUNTAIN DIVISION: Colorado, Utah and Wyoming.

SOUTHEASTERN DIVISION: Alabama, Florida, Georgia, South Carolina and the Island of Porto Rico, the Republic of Cuba, and the Isle of Pines.

WEST GULF DIVISION: New Mexico, Oklahoma and Texas.

MARITIME DIVISION: Newfoundland, Labrador, and the provinces of New Brunswick, Nova Scotia, and Prince Edward Island.

ONTARIO DIVISION: Province of Ontario.

QUEBEC DIVISION: Province of Quebec.

VANALTA DIVISION: Provinces of Alberta and British Columbia and Yukon Territory.

PRAIRIE DIVISION: Provinces of Manitoba and Saskatchewan, and the Northwest Territories.

Each United States Division elects a Director to represent it on the A.R.R.L. Board of Directors and the Canadian Divisions elect a Canadian General Manager who is also a Director. The Board determines the policies of the League which are carried out by paid officers at League Headquarters acting according to the instructions of the Board. When the Board is not in session, the officers of the League, constituting an Executive Committee, can act for the Board, subject to certain limitations.

The Communications Department has a field organization made of officials elected by the membership in a way similar to the Directors. Each Director and the Communications Manager at League Headquarters decide the proper sectionalizing of each Division, after which each Section holds an election for Section Communications Manager. These field officials are listed on page 3, while the names and addresses of the Directors are printed on page 6, of each *QST*.

It is for more efficiently collecting reports from the active stations and supervising the activities of the Communications Department that the operating territory is divided into Sections. In each Section there is a Section Communications Manager, who under the direction of the Communications Manager, has authority over the Communications Department within his Section. He is responsible to, and reports to the Communications Manager, except in Canada where he reports to the Canadian General Manager.

Whenever a vacancy occurs in the position of Section Communications Manager in any section of the United States, its island possessions or territories, or the Republic of Cuba, the Communications Manager announces such vacancy and calls for nominating petitions signed by five or more members of the Section in which the vacancy exists, and naming a member of the Section as candidate for Section Communications Manager. The closing date for receipt of such petitions is announced.

After the closing date, the Communications Manager arranges for an election by mail or declares any eligible candidate elected if but one candidate has been nominated. Ballots are sent to every member of the League residing in the Section concerned, listing candidates in the order of the number of nominations received. The closing date for receiving ballots is announced. Immediately after this date, the Communications Manager counts the votes. The candidate receiving a plurality of votes becomes Section Communications Manager. The Canadian General Manager similarly manages such an election for a Section Communications Manager whenever a vacancy occurs in any section of the Dominion of Canada, Newfoundland or Labrador.

Section Communications Managers are elected for a two-year term of office.

The office of any Section Communications Manager may be declared vacant by the Executive Committee upon recommendation of the Communications Manager, with the advice and consent of the Director, whenever it appears to them to be in the best interests of the membership so to act, and they may thereupon cause the election of a new Section Communications Manager.

COMMUNICATIONS DEPARTMENT OFFICIALS AND APPOINTMENTS

The following portions, relating to Section Communications Managers, Official Relay Stations, and Reports, are reprinted from the "Rules and Regulations of the Communications Department" and set forth the regulations which govern these matters within the department.

SECTION COMMUNICATIONS MANAGER

1. The Section Communications Manager is responsible to the Communications Manager at League Headquarters for the efficiency and co-operation of his personnel. His policies are the democratic policies of the League itself.

2. His territorial limitations are determined by the Division Director and the Communications Manager.

3. He recommends the appointment or cancellation of Official Relay Stations in accordance with the rules pertaining to the Official Relay Station Appointment.

The Section Communications Manager examines application and question forms, signing the prescribed certificate of appointment and forwarding it to the station owner when the appointment can be properly made. Form 4 appointment card bearing the certificate number is forwarded to League Headquarters with the questionnaire forms properly filled out by the applicant. Cancellations (Form 4C) are made for inactivity or for violations of any of the rules or provisions of the Rules and Regulations or of the Official Relay Station Certificate.

An applicant who fails to qualify may again apply for appointment after 3 months have elapsed.

4. He shall be responsible for the maintenance of the Official Broadcasting Station System within his Section, recommending such appointments (Form 4) or cancellations (Form 4C) as may be necessary. Due consideration shall be given the distribution of stations on the different frequency bands and the qualifications of stations and operators for this service.

5. He is responsible for the traffic activities of his Section. He shall appoint such assistants for specific work as may be deemed necessary by the Communications Manager, such as Route Managers and Official Observers. These officials will have full authority within the Section over the activities indicated by their titles. They will report and be responsible to the Section Communications Manager for their work. With the consent of the Communications Manager he may, if necessary, designate a competent Official Relay Station appointee or League member to act for him in a particular matter in any part of his territory. He shall be careful to instruct such an appointee properly in the duties he is to execute while acting for the S.C.M.

6. He shall conduct investigations of radio organizations and interference cases whenever such cases are referred to him by the Communications Manager or the Division Director.

7. He shall appoint Vigilance Committees in the centers of activity where amateur interference conditions appear to make such committees desirable in helping to lighten the load of complaints received by the Supervisors of Radio. (See April 1925 *QST*).

8. He shall have referred to him by his various appointees any correspondence that may relate to matters of general policy, or suggestions for improvements in conducting the affairs of the League.

9. He may requisition necessary Communications Department supplies provided

for making appointments and supervising the work in his Section. He may render an itemized postage expense account monthly. Section Managers are entitled to wear the distinctive A.R.R.L. pin with red background, similar in other respects to the regular black-and-gold A.R.R.L. membership pin.

10. He shall render a monthly report to Headquarters, consolidating all the reports by subjects into a comprehensive summary. This report shall reach Headquarters on or before the 26th of each calendar month. It shall be made up from all reports from O.R.S. and other active stations together with the reports from special appointees (5) and as mentioned under the subject of reporting.

THE ROUTE MANAGER

While the Section Communications Manager is the traffic executive of the Section, the Route Manager has the principal traffic station on his particular locality. There is generally one Route Manager to every twenty or twenty-five Official Relay Stations, depending on the radio population of the Section concerned and the amount of organized activity. Route Managers maintain good local radio contacts regularly so that stations can be lined up and routes developed and operated *by radio.* Route Managers co-operate actively with all active stations in their districts, so that each Route Manager is the nucleus of a communication net which he organizes himself, and for which he is responsible at all times to his Section Communications Manager. Route Managers arrange schedules for local traffic handling between the different towns and cities in their territory as well as keeping many schedules at their own station and keeping track of between-Section schedules, reporting monthly to the S.C.M. who in turn reports to A.R.R.L. Headquarters where work in all parts of the country is co-ordinated monthly.

OFFICIAL OBSERVERS

Each S.C.M. recommends for appointment a suitable number of Observers who report regularly to the S.C.M. on the off-frequency operation noticed, sending out notification forms (provided from Headquarters) to help amateurs in keeping within the assigned hands. Official Observers also make general observations on operating conditions, taking the proper action to bring about improvement, always reporting the action taken to the Section Communications Manager. The reporting forms from the observers are forwarded to Headquarters where a record is kept of reports on each off-frequency station so that suitable action may be taken in persistent cases for the general welfare of amateur radio.

THE OFFICIAL RELAY STATION

The Section Communications Manager shall recommend for appointment as Official Relay Stations such stations of League members as apply for and merit such appointment. The recommendation shall be based on the ability of the applicants to come up to a specified set of qualifications. The applicant shall have a loyal, co-operative attitude; he shall follow standard A.R.R.L. operating practices (understanding and using the proper message form, finish signals, service message, cable-count check on important messages, and so on); he shall have a transmitter and receiver capable of operation at any time; and he must be able to send and receive Continental code at a rate of at least 15 words per minute.

1. It shall be the duty of each Official Relay Station appointee to report monthly to his Section Communications Manager, to keep the station in readiness to operate, to use A.R.R.L. operating practises exclusively, and to take part in the activities of the League whenever possible. The message file must be held for three months ready for call by the S.C.M. at any time. *Reports are due on the 16th of* each month if the station is located on the mainland of the United States.

2. Each Official Relay Station shall receive an Appointment Certificate to be displayed prominently in the station, a quarterly bulletin newsletter from Headquarters, and Form 1 reporting cards on which to turn in the regular monthly reports to the Section Communications Manager.

3. When a station is of necessity inoperative for six months or less, the appointment may be held on an inactive list by the Section Communications Manager, providing the station owner has reported the facts of the case and requested that he be excused from active operating and reporting during this time. Inactive lists shall be turned in to Headquarters by the Section Communications Manager with his monthly report. O.R.S. appointments shall be transferable from one Section to another, with the consent of the Section Communications Managers concerned who must alter their records and notify Headquarters of such changes. Such appointments shall *not* be transferable from one station-owner to another.

4. The violation of the provisions made above for operating and reporting shall be sufficient reason for the Section Communications Manager to recommend cancellation of the appointment. The Section Communications Manager shall notify the Official Relay Stations that this action is pending when the first and the second report has

been missed. The appointment shall be cancelled automatically when the third consecutive report fails to come through on time. Such cancellations shall be classed as "complete." New application and question forms must be filled out and evidence of better performance submitted before reappointment can be considered. If an O.R.S. resigns his post after consistent work, an "honorable" cancellation shall be issued and reinstatements made *within one year* may be made on application without filing new papers.

REPORTS

Each Official Relay Station report shall include the number of messages originated, delivered, relayed, and the total. The Form No. 1 reporting card furnished by the A.R.R.L. shall be used when it is available but the non-arrival of this form shall not constitute an excuse for not reporting.

The Section Communications Manager shall condense all reports received, leaving out any "negative" information. His report shall not mention inactivity or non-reporting. Traffic figures shall be separately listed at the end of the report and shall not be included in the body of the report. The most consistent traffic stations and the ones doing most experimental and other useful work are the ones deserving credit and to whom space shall be given. When possible, the Section Communications Manager shall send in his report *typewritten and double-spaced.* Section Communications Managers shall not transmit the reports received by them to Headquarters except on a request to do so, but shall consider the reports as for their information and from them prepare a condensed report of the month's activities and the status of amateur affairs in the territory under their jurisdiction.

MORE ABOUT THE O.R.S. APPOINTMENT

The Official Relay Station appointment of the Communications Department deserves some further explanation. Telegraphing members who hold amateur licenses are most interested in this work.

Before the war our League was a much smaller organization than it is to-day. What traffic handling was done was performed in a very easy-going manner. Messages were not taken seriously by those who sent them or by those who handled them. Because there were fewer stations operating, it was harder to relay messages to their destinations. Deliveries were the exception rather than the rule.

As the League expanded more stations came on the air. It became increasingly possible to land messages right at the city of destination. More messages came our way from the public who began to realize that messages were actually being delivered and handled in good time. As the service improved, more people availed themselves of its use. Regular trunk and branch traffic routes were arranged so that messages could be handled reliably in almost any direction. However, with the advent of the war, this organization became inoperative with the closing down of all stations by the government.

After the war, the new organization went through some violent changes. New developments were principally along the lines of tube transmission. Next came the shorter wavelengths, making a complete revamping of our communication system necessary. The granting of appointments right and left, the increase in numbers of inexperienced operators, the new conditions under which we were operating (on several frequency bands), each left its mark on our communication system. Once a man could handle a certain number of messages a month, he was granted an appointment without much questioning. Before the war newcomers automatically got operating experience by listening to commercial and government long wave stations. By the time their stations were in workable shape to handle relay traffic, the necessary operating experience had been gained. After the war, newcomers threw sets together from the information then made available. Stations capable of communicating over thousands of miles on short waves were operated by operators whose tuners no longer reached wavelengths where good commercial traffic was being efficiently handled. Lack of this preliminary training was responsible for poor operators. Unreliable stations and operators, out for "DX records" only, slowed up traffic. Complaints were received on the unreliability of operators and on the poor delivery of messages everywhere.

Finally, it was decided to abandon the old system and to start fresh. The need of placing a greater responsibility on the traffic handling of stations was felt keenly. A class of stations that could be depended upon should be created! An iron-bound set of qualifications and a set of Rules and Regulations for Official Relay Stations were drawn up as a standard and a foundation for the present traffic-handling organization was built. Appointments under the new system of things are no longer given without investigation. A set of questions to be answered for Communications Department files and recommendations to the Section Communications Manager are necessary. The present system of Official Relay Stations, which has been in successful operation for over five years, is the result.

WHY YOUR STATION SHOULD BE AN OFFICIAL RELAY STATION

Official Relay Stations are the best regulated and the most active stations in League operating work to-day. Every Official Relay Station receives an attractive certificate of appointment. The certificate is a mark of distinction putting the operator in a class above the average "ham". The operators of Official Relay Stations are well-known as "reliable" operators and amateurs of good standing. The badge of honor carries some weight with everyone who visits the station, including the Radio Supervisor. Vacancies in the ranks of the League officials are filled from the ranks of the Official Relay Stations. Every owner of an Official Relay Station receives a bulletin letter from A.R.R.L. Headquarters quarterly with the latest schedules, news, and procedure hints and helps. Special reporting cards for the convenience of the Official Relay Station operators in reporting their traffic-handling work and records are sent out with the bulletin.

O.R.S. appointees are entitled to wear the distinctive *blue* A.R.R.L. pin which is similar to the regular membership pin except that it has a blue instead of a black background.

HOW TO BECOME AN O. R. S.

To secure an appointment as Official Relay Station is quite a simple matter if you have the qualifications and a little experience. After building the station and gaining some code speed, get in touch with your Section Communications Manager. Arrange some schedules for traffic-handling by writing a few letters to the best stations you hear consistently in different directions from your own station. Collect and handle some traffic regularly and don't forget to report your work to the S.C.M. on time each month for a few months. Then ask your local traffic official to furnish you with an application blank to become an Official Relay Station (or use the one printed for your convenience in the rear of this book). Fill out the application blank and send it to Headquarters.

You will get some question blanks to be filled out and returned to the S.C.M. If you have the necessary knowledge and qualifications the S.C.M. will be able to follow his instructions and make the appointment. In this event the information you have sent him will be turned over to Headquarters for Headquarters' files. If you cannot answer all the questions correctly or are not quite able to make the grade, your application may be tabled for two or three months in which time you can study and practice operating until you *can* make the grade. It may be that you miss out on some of the questions but get a nice letter from the Section Communications Manager explaining the answers and notifying you what action can or cannot be taken regarding an appointment.

Being recognized as an Official Relay Station is very much worth while. It is not difficult to obtain an appointment but certain requirements must be met and lived up to if the appointment is to be kept valid. Otherwise it would *not* be worth while. Cancellations of appointment follow failure to report for two successive months, continued failure to operate according to A.R.R.L. practices, failure to observe government regulations, failure to keep a receiver and transmitter in commission, and failure to comply with the spirit of the rules on the application form or certificate.

When a station is inoperative of necessity and the Section Communications Manager has been duly notified, the appointment is gladly held on an inactive list over a certain period of time. New operators are needed among the "reliables" every day. The appointment is one made with mutual advantage to yourself and to our Communications Department. Fill out the application form as soon as you can qualify!

CHAPTER XI

Operating a Station

THE enjoyment of our hobby usually comes from the operation of our station once we have finished its construction. Upon the station and its operation depend the traffic reports and the communication records that are made. We have taken every bit of care that was possible in constructing our transmitter, our receiver and monitoring equipment and in erecting a suitable antenna system. Unless we make ourselves familiar with some uniform operating procedure, unless we use good judgment and care in operating our stations, we will fall far short of realizing the utmost in results achieved. More than this, we will make ourselves notorious unless we do the right thing, because we may interfere with other stations if we operate improperly.

After a bit of listening-in experience you will hear both kinds of operators and realize the contrast that exists between the operation of the good men and that of "lids" and "punks" who have never taken the trouble to familiarize themselves with good practise. Occasionally you will pick up an amateur whose method of operating is so clean cut, so devoid of useless effort, so snappy and systematic, that your respect is gained and it is a pleasure to listen and work with him.

For efficient traffic handling, the transmitter should be adjusted for stable, satisfactory operation on two or three known lawful frequencies. Marked or tagged points on the coil with known condenser settings for definite frequencies will enable the operator quickly to change frequency (QSV) at any time. Whenever such a change is made, be sure to check the frequency accurately with a monitor beating against an oscillating receiver set on commercial or government stations assigned to the frequency channels which mark the edge of our amateur bands. There is no excuse for operating off frequency. Any frequency calibrations should be checked often to guard against variations.

The operator and his methods have much to do with limiting the range of the station. The operator must have a good "fist". He must have patience and judgment. Some of these qualities in operating will make more station records than many kilowatts of power. Engineering or applied common sense is as essential to the radio operator as to the experimenter. Don't make several changes in the set hoping for better results. Make one change at a time until the basic trouble or the best adjustment is found.

An operator with a clean-cut, slow, steady method of sending has a big advantage over the poor operator. Good sending is partly a matter of practise but patience and judgment are just as important qualities of an operator as a good "fist".

The good operator sends signals which are not of the "ten words per minute" variety, but they are slow enough so that there is no mistaking what he says. The good operator does not sit down and send a long call when he wants to work someone. He puts on the phones and listens in. He goes over the dial thoroughly for some time. The fellow that is admired for his good operating is the one who is always calling some particuliar station instead of using the "inquiry signal". Because he listens until he hears someone to work and then goes after him, our good operator gets his man nearly every time. A good operator chooses the proper time to call, he makes plain signals, and he doesn't call too long. A short call is sufficient because if a station does not get the call it is likely that he is listening to another station. A long call makes the receiving operator lose patience and look for someone else.

The adjustment of the receiver has much to do with successful operation, too. The good receiving operator notes the dial setting and when he has completed calling in proper fashion, he waits a moment and then tunes above or below the logged dial setting just in case something has shifted a bit in the receiver or transmitter. The best operator has patience and waits a few minutes in case of delay at the transmitter or in case fading signals make a second answer necessary.

COMMUNICATION

After all, communication has as its object the exchange of thought between two minds. Sometimes those minds are near together and it is possible for the individuals concerned to converse at length and exchange their thoughts freely. At other times and this is when radio communication is involved, the individuals are miles apart and the thoughts to be transmitted must be condensed to just a few words. Then these words must be relayed or passed on from mind to mind or operator to operator. When they reach their ultimate destination someone can interpret them fully if they have been properly and carefully handled by the intermediate operators.

Time is involved in making any exchange of thought. Because every man's life and experience is measured by time, this factor becomes important in everything we do or say. The number of messages handled, the number of distant stations worked, the number of records made at our station, all depend in some degree on the time available for our hobby. The more time we spend at the set, the more well-known we become and the greater the summation of our accomplishments.

As time is a factor, uniform practises in operating have become necessary to insure a ready understanding of what is going on in the minds of each operator. "Q" signals and abbreviations of various sorts have been devised and are in general use today just because of the time element involved, to enable every operator to exchange intelligible thoughts with as little waste effort as possible. So proficiency in the commonly-used abbreviations and in knowledge of uniform operating practises is to be desired. Proficiency comes with practise. In the Appendix are the "Q signals" and some abbreviations used by amateur operators. We will mention some of the time-saving things that have become standard practise among good operators and following that a few words about relay procedure will show how a station is operated to best advantage.

Accuracy is of **first** importance. Then speedy transmission and handling of radiograms must be considered. Very often, transmission at moderate speeds moves traffic more quickly than fast sending. A great deal depends on the proficiency and good judgment of the two operators concerned. Fast sending is helpful only when two fast operators work together.

OPERATING RULES AND REGULATIONS

The Official Relay Stations follow some general requirements for law-abiding operation which are mentioned on the appointment certificate. Some specific rules and regulations have been made to raise the standard of amateur operating. Official Relay Stations observe these rules carefully. They may be regarded as "standard practice."

Any actively-operating stations will do well to copy these rules, to post them conspicuously in the station, and to follow them when operating.

Here are the rules with an example of the use of each in actual operating:

1. The calling station shall make the call by transmitting not more than three times the call signal of the station called and the word DE, followed by its own call signal sent not more than three times, thus: VE9AL VE9AL VE9AL DE W1MK W1MK W1MK. In amateur practice this procedure may be expanded somewhat as may be necessary to establish communication. The call signal of the calling station **must** be inserted at frequent intervals for identification purposes. Repeating the call signal of the called station five times and signing not more than twice (this repeated not more than five times) has proved excellent practise in connection with break-in operation (the receiver being kept tuned to the frequency of the called station). The use of a break-in system is highly recommended to save time and reduce unnecessary interference to a minimum.

Stations desiring communication, without, however, knowing the names of the operating stations within range, may use the signal of inquiry, CQ, in place of the call signal of the station called in the calling formula. The A.R.R.L. method of using the **general inquiry** call (CQ) is that of **calling three times, signing three times, and repeating three times.** CQ is not to be used when testing or when the sender is not expecting or looking for an answer. After a CQ, the dial should be covered **thoroughly** for two or three minutes looking for replies.

The **directional** CQ: To reduce the number of useless answers and lessen needless QRM, every CQ call shall be made informative when possible. Stations desiring communication shall follow each three-times-sent CQ by an indication of direction, district, state, continent, country or the like. Stations desiring communication with amateur stations in a particular country shall include the official prefix letters designating that country after each CQ. To differentiate domestic from foreign calls in which the directional CQ is used, the city, state, point of the compass, etc., is mentioned only after the third CQ just before the word DE and the thrice-repeated station call. Until such time as the official prefixes used by amateurs of various countries are designated and become known, the older I.A.R.U. system of international intermediates may be used to designate continent and country. Examples follow. A United States station looking for any Canadian amateur calls: CQ VE CQ VE CQ VE DE W1MK W1MK W1MK. A western station with traffic for the east coast when looking for an intermediate relay station calls: CQ CQ CQ EAST DE W6CIS W6CIS W6CIS. A station with messages for points in Massachusetts calls: CQ CQ CQ MASS DE W3QP W3QP W3QP. In each example indicated it is understood that the combination used is repeated three times.

2. Answering a call: Call three times (or less); send DE; sign three times (or less); and after contact is established decrease the use of the call signals of both stations to once or twice. Example: W1BIG DE W1MK GE OM GA K (meaning, "Good evening, old man, I am ready to take your message, go ahead.")

3. Ending signals and sign off: The proper use of AR, K and SK ending signals is required of all Official Relay Stations. AR (end of transmission) shall be used at the end of messages during communication and also **at the end of a call,** indicating when so used that communication is not yet established. K (invitation to transmit) shall be used **at the end of each transmission when answering or working another station,** almost carrying the significance of "go ahead." SK (or VA) shall be used by each station only **when signing off,** this followed by your own call sent once for identification purposes. SK (end of work)

indicates to others **that you are through** with the station which you have been working **and will listen now** for whomever wishes to call. Never CQ after signing off until you have covered the dial thoroughly looking for stations calling you.

Example: (AR) G2OD DE W1AQD AR (showing that W1AQD has **not** yet gotten in touch with G2OD but has called and is now listening for his reply). Used after the signature between messages, it indicates the end of one message. There may be a slight pause before starting the second of the series of messages. If —.— (K) is added it means that the operator wishes his first message acknowledged before going on with the second message. If no "K" is heard, preparations should be made for copying the second message.

(K) ZL2AC DE W6AJM R K. (This arrangement is very often used for the acknowledgment of a transmission. When anyone overhears this he at once knows that the two stations are in touch, communicating with each other, that ZL2AC's transmission was all understood by W6AJM, and that W6AJM is telling ZL2AC to **go ahead** with more of what he has to say.) W9APY DE W3ZF NR 23 R K. (Evidently W9APY is sending messages to W3ZF. The contact is good. The message was all received correctly. W3ZF tells W9APY to **go ahead** with more.)

(SK) R NM NW CUL VY 73 AR ...—.— W7NT (W7NT says "I understand OK, no more now, see you later, very best regards, **I am through with you for now and will listen for whomever wishes to call. W7NT signing off.**")

4. If a station sends test signals to adjust the transmitter or at the request of another station to permit the latter to adjust its receiving apparatus, the signals must be composed of a series of V's in which the call signal of the transmitting station shall appear at frequent intervals.

5. When a station receives a call without being certain that the call is intended for it, it shall not reply until the call has been repeated and is understood. If it receives the call but is uncertain of the call signal of the sending station, it shall answer using the signal - - — — - - (?) instead of the call signal of this latter station.

6. Several radiograms may be transmitted in series with the consent of the station which is to receive them. As a general rule, long radiograms shall be transmitted in sections of approximately fifty words each, ending with - - — — - - (?) meaning, "Have you received the message correctly thus far?"

7. A file of messages handled shall be kept, this file subject to call by the Section Manager at any time at his discretion. Only messages which can be produced shall be counted in the monthly reports, and these under the A.R.R.L. provisions for message-counting.

In acknowledging messages or conversation: NEVER SEND A SINGLE ACKNOWLEDGMENT UNTIL the transmission has been SUCCESSFULLY RECEIVED. "R" means "All right, OK, I understand completely." When a poor operator, commonly called a "lid", has only received part of a message, he answers, "R R R R R R R R R R, sorry, missed address and text, pse repeat" and every **good** operator who hears, raves inwardly. The string of acknowledgments leads one to believe that the message has been correctly received and that it can be duly filed away. By the time this much is clear it is discovered that most of the message did not get through after all, but must be repeated. Perhaps something happens that the part after the string of R's is lost due to fading or interference, and it is assumed that the message was correctly received. The message is then filed and never arrives at its destination.

Here is the proper procedure to follow when a message has been sent and an acknowledgment is requested. When ALL the message has been received correctly a short call followed by "NR 155 R K" or simply "155 K" is sufficient. When most of the message was lost the call should be followed by the correct abbreviations (see appendix) from the international list,—when but a few words were lost the last word asking for a repetition of the address, text, etc. (RPT ADR AND TXT K). When but a few words were lost the last word received correctly is given after AA meaning that "all after" this should be repeated. AB for "all before" a stated word should be used if most of the first part of the copy is missing. BN two stated words asks for a fill "between" certain sections. If only a word or two is lost this is the quickest method to get it repeated.

Do not send words twice (QSZ) unless it is requested. SEND SINGLE unless otherwise instructed by the receiving operator. When reception is very poor, a QSZ can be requested to help make better copy. When conditions are even moderately fair, a QSZ is unnecessary. Few things are as aggravating as perfect transmission with every word coming twice. Develop selfconfidence in yourself by not asking others to "QSZ" to you unless conditions are rather impossible. Do not fall into the bad habit of sending double without a definite request from the fellows you work.

Be sure the transmitter is adjusted to give a **steady** signal that is copiable. Floppy wobbly notes are due to poor mechancial construction, improper circuit adjustments, or too close coupling to the antenna. See that the transmitter is built substantially. The apparatus should not move around or vibrate as you operate. Use few turns in the antenna coupling coil and keep it at a good distance from or at an angle with the coil which is in the "condenser-coil" circuit containing the oscillator tube.

Do not accept or start incomplete messages. Omission of the fundamental parts of a message often keeps a message from getting through to its destination. Official Relay Station appointments are subject to cancellation for failure to make messages complete enough.

CALLING PRACTICE

As we noted in Chapter II, our frequency bands are different numbers of kilocycles wide. It has been pointed out that the length of our calls should be determined somewhat in accordance with the width of a particular band, assuming that a receiving operator can cover all bands at a certain rate when looking for stations calling him. Because there is "more room" on some of our bands it is reasonable to conclude that if an operator is hunting for stations calling him with the thorough and systematic methods of a good operator, a longer period of time must be allowed to enable him to use the same care in covering the dial that he uses on the other, narrower, bands.

However, it does not follow that a blanket practise of making long calls should be adopted when working in the wider bands. We think that a modified practise, adopted with this situation in mind, will produce the best results in raising stations. It is seldom necessary to use a very long call to raise a station if we use our best judgment and refrain from doing any calling until we know that the receiving operator is "doing his stuff" and that our chances of raising him are best.

The League has never attempted to lay down any rules regarding the length of a call. The problem must be solved by the individual operators to fit the length of a call to the individual case under consideration.

We believe that the use of a "break-in" system at most of our stations will do much to obviate the necessity for long calls. We think that in any case where it is imperative that we raise a certain station, a long call is justified. We are strongly of the opinion that a one-minute call with a break in the sending long enough to listen for a reply from the station called, followed by more one-minute calls is much better than a long unbroken call. Such a calling scheme will eliminate much unnecessary transmission and result in raising a station as quickly as calls of great length.

In calling, the call signal of the calling station must be inserted at frequent intervals for identification purposes as explained under the head of operating rules and regulations. Repeating the call signal of the called station five times and signing not more than twice has proved excellent practise. This combination can be repeated as many times as necessary. Such a procedure allows many stations to log our station without turning away in disgust at a too-long call.

The operators who seem to be most successful in raising the stations they want are not the ones who use the longest calls. They are the operators who use the best judgment in selecting the time to call, and in deciding on the number of calls that will give the best results in the calling periods.

OPERATING NOTES

A real sensitive receiver is often more important than the power input to the transmitter in working foreigners. There is not much difference in results with the different powers used, though a 250-watter will probably give 10% better signal strength at the distant point than a UV-203-A or UX-210's, other factors being the same for the purposes of comparison. It will not do much better than this because the field strength drops so rapidly as we get away from the antenna of a transmitting station. In working foreign countries and DX stations you should be able to hear ten or a dozen stations before expecting that one of them will hear your call. In general, just hearing an occasional foreign station does not mean that that country can be worked at your own pleasure.

A common fault among amateurs that do not get in touch with DX stations readily is that their calls are too short. Often they do not send enough short CQ's indicating the country or place desired even when the receiver is sensitive enough to bring in several stations located at the desired spot. Of course the type of radiator can always be blamed or the antenna location but usually the operator has only himself to blame.

Sometimes when you are listening you will hear a long succession of dots sent with perfect regularity for six or seven minutes at a time. Usually these dots come from commercial "machine" or "tape" transmitters. When there is no tape with code characters going through the machine, the mechanical key automatically makes dots, the purpose being to enable the receiving station to keep tuned to the proper wavelength and to adjust his receiver for maximum sensitivity of reception. Such interruptions occur when the tape breaks, when it has to be taken out in order to repeat part of a message, or when there is no more traffic to be sent for the moment.

The signal "...-" (V) is sometimes sent for two to five minutes for the purpose of testing. When one station has trouble in receiving, the operator asks the transmitting station to "QRV" while he tries to adjust his receiving set for better reception. A decimal point is often sent by the letter "R". Example: 2.30 PM is sent "2R30 PM". A long dash for "zero" and the Morse C (.. .) for "clear" are in common use. An operator who misses directions for a repeat will send "4", meaning, "Please start me, where?" These latter abbreviations, like others in our present day practise, are hybrids, originating in wire practises and Morse usages.

Improper calling is a hindrance to the rapid dispatch of traffic. Long calls after communication has been established are unnecessary and inexcusable. Some stations are slow to reply to a call. However, the day of the station with dozens of switches to throw is past. Controls for both receivers and transmitters are simpler, fewer in number, and more effective. The up-to-date amateur station uses a "break-in" system of operation and just one switch controlling the power supply to the transmitter.

Poor sending takes the joy out of operating. There are stations whose operators are not able to send better and those who can send better but do not. The latter class believe that their "swing" is pretty. Some of them use a key with which they are not familiar.

Beginners deserve help and sympathetic understanding. Practise will develop them into good operators. The best sending speed is a medium speed with the letters quickly formed and sent evenly with proper spacing. The standard type telegraph key is best for all-round use. Before any freak keys are used a few months should be spent in practising with a buzzer.

No excuse can be made for a "garbled" text. Operators should copy what is sent and refuse to acknowledge messages until every word has been received correctly. Good operators never "guess" at anything. When not sure of part of a message they ask for a repeat. The "lid" operator can be told very quickly when he makes a mistake. He does not use a definite "error" signal and go on with his message but he usually betrays himself by sending a long string of dots and nervously increasing his rate of sending. The good operator sends "?" after his mistakes and starts sending again with the last word sent correctly. Unusual words are often sent twice. After the transmission "?" is sent and then the word is repeated for verification.

The international abbreviations for getting "fills" on incomplete messages provide a good workable system. Everyone knows the fellow who sends the whole message over to fill in one word. Nothing is quite so exasperating. When there is a check, reference to it reveals missing or superfluous words. The necessity for accuracy is really the reason for a check. Almost as aggravating as the repeating of a whole message unnecessarily to fill in a word is the sending of "words twice" when reception is perfect. Words should be sent more than once only when necessary and at the request of the receiving operator.

The law concerning superfluous signals should be noted carefully by every amateur, and individual conduct governed accordingly. Certain operators hold the key down for long periods of time when testing or thinking of something to send. Whenever this is done during operating hours, someone is bothered. Unnecessary interference prevents someone from getting in contact with (QSO) someone else, and if messages are being handled the copy is ruined. If you must test, disconnect the antenna system and use an equivalent "dummy" antenna (made of lumped resistance, capacity and inductance). Always send your call occasionally when operating with the antenna. You may be heard in Africa. If it is code practise that you must have, by all means use a buzzer or an automatic transmitter. Pick a time for adjusting the station apparatus when few stations will be bothered.

USING A BREAK-IN SYSTEM

A break-in system of operation makes it possible for us to talk back and forth with fellows we work just as one talks back and forth over a telephone circuit or telegraph system. Using a "break-in" we can interrupt the other fellow if we miss a word or do not understand him. With a telephone we stop talking as soon as the distant party speaks and interrupts us. In a telegraph office the operator who misses a word opens his key so that the sending is interrupted and cannot go on until the receiving operator has had his say and again closed the circuit. In a radio system using a break-in the receiving operator presses the key and makes some long dashes for the transmitting operator to hear. As soon as he does get the signal he stops transmitting and listens to what the receiving operator says, after which the sending is resumed.

A separate receiving antenna put up at right angles to the transmitting antenna makes it possible to listen to most stations while the transmitting tubes are lighted. It is usually necessary to pause just a moment occasionally when the key is up to listen for the other station.

Much useless calling and unnecessary transmission is prevented if a break-in is used. Two stations can use the system to mutual advantage. When messages are being handled, if some interference comes in or if a word is missed due to swinging signals, a few taps of the key will set things straight in a jiffy. "BK BK GA ROANOKE" (or whatever was the last word received correctly will save time and unnecessary sending. If the trouble continues, the sending station can "stand by" (QRX) or it can take traffic until the reception conditions at the distant point are again good.

For example, suppose W8SF has a message for New York City. He calls, "CQ CQ CQ NY DE W8SF W8SF W8SF", repeating the call three times and concluding with "AR". W2PF hears him, answering "W8SF DE W2PF bk me bk me." When W8SF hears W2PF, W8SF immediately holds his key down and makes some long dashes. W2PF, who is of course receiving "break-in" while he calls, stops sending when he hears the dash. W8SF then calls in the regular manner, saying "W2PF DE W8SF ge hr msg AR". Then W2PF gives him a "GA OM" and the message is sent without further preliminaries. Since both stations are using break-in, they can interrupt each other at any time when something goes wrong or a letter is dropped, and traffic can be handled in half the usual time. There is a real "kick" from working a "break-in" arrangement. After the fun is over there is a wholesome satisfaction in the knowledge of a job well done. Swift clean cut operation brings its own reward.

In calling, the transmitting operator sends the letters "bk", "bk in", or "bk me" at frequent intervals during his call so that stations hearing the call may know that a break-in is ni use and take advantage of the fact. He pauses at intervals during his call, to listen for a moment for a reply from the station being called. If the station being called does not answer, the call can be continued. If the station called answers someone else, he will be heard and the calling can be broken off until he has finished his business and is again listening for more stations to work.

EMERGENCY WORK

In the past, amateurs have given an excellent account of themselves in many emergencies of local and national character. In every instance, the amateurs who have considered the possibilities of an emergency arising before the trouble actually came to pass were the ones who must be credited with doing the most important work. They were ready, prepared for the crisis when it came. It behooves all of us to think upon these matters, to likewise prepare ourselves for doing a creditable job in each and every future opportunity for such work. The very least we can do is to study the history of such cases so that we may proceed correctly and systematically about our business without losing our heads and passing up glorious opportunities for service in any crisis.

Priority must be given messages from a stricken point asking for relief measures such as food, antitoxin, blankets, doctors, nurses and necessities of life. Next in order of importance (and also in order of transmission) are the press messages informing the outside world of all that has taken place, the extent of the disaster, perhaps containing public appeals for assistance if the authorities in the affected area believe this necessary. A third class of messages is between friends and relatives, messages of inquiry or messages of assurance to and from the stricken territory. In each emergency many amateur stations at as many different points all over the country get on the air with such messages from anxious friends on the outside. Of course it is necessary for stations with such traffic to stand-by until the relief and press messages are off the hook and opportunity is given for clearing such private messages.

During emergencies it is often possible to send broadcasts to the press generally (or addressed to U. P., A. P., N. A. N. A. etc.) between the transmissions of relief priority traffic. Invariably such messages are correctly delivered to local member-newspapers in such associations, the public kept informed, and amateur radio credited. Such broadcasts should be sent at regular intervals if possible. They have sometimes been overlooked in the rush. Perhaps the last duty of the emergency station is a full report of the work that was done so that the whole achievement can do its bit for amateur radio. Stations outside an "emergency zone" and in communication with relief stations in that zone are requested to inform Headquarters of this situation by telegram (to facilitate traffic movement and for the information of the press).

Considerations of an emergency power supply are of first importance in many cases where radio is destined to play a part. If local electric service mains are crippled one may have recourse to B-batteries, dynamotors driven from storage batteries and the like. In a serious emergency, communication is of first importance. By consulting with other amateurs and putting all the available facilities together in the most favorable location a station can be made operative in short order. An order from some competent authority will make supplies of batteries or temporary service from a public utilities company available for emergency stations. It is sometimes as easy to move the amateur station to a power supply as to collect a power supply together and bring it to the amateur station. This is especially true if the transmitter and receiver are built as independent units that may be moved about at will. In some emergencies B-batteries have been provided from local electrical supply stores. In other cases broadcast listeners have been called upon to contribute their individual batteries to the common cause.

It is impossible to tell just when or where will be the next call on amateurs to render service in an emergency. In the North, sleet storms and crippled wire service threaten public safety during at least three months of each year. Floods periodically threaten different sections of the country at different times of the year, due to melting ice and snow or to long-continued rainstorms. In the southeastern states, storms of hurricane intensity are common. The situation in all such emergencies is a serious one. The entire question is one of preparedness for the individual station. Shall we be ready or not, if and when an emergency arises? Be ready for the emergency call, QRR, when it comes. Jump into the breach with your station if feasible or stand by and avoid interference to those handling emergency traffic if this seems to be the right thing to do.

If you live along the line of a railroad you should get in touch with the local representative of the railroad so he will communicate with you in case amateur radio can help in an emergency. You should likewise make note of the address of Red Cross headquarters, of local military units, police departments, representatives of press associations and the like, if possible putting your station on record with such organizations and other competent authorities so that you will be called upon to assist when emergency communication appears to be necessary. When storms approach or disaster threatens it is best to keep in touch with the situation by radio and to again offer service to these agencies well in advance of the actual emergency. In some cases amateurs have kept hourly schedules in expectation of a coming emergency which did not materialize but in other such cases signal service was performed with credit to the individual amateur and amateur radio operators generally. Emergency work reaps big returns in public esteem and personal satisfaction, if we consider the history of such cases. Emergency work is of lasting benefit to amateur radio from whatever standpoint it is considered.

Every amateur should give some thought today to the construction and installation of a set capable of doing emergency work. A list of organizations and responsible individuals that will want to file priority traffic once radio communication supercedes (or is used in addition to) inadequate wire communication facilities should be prepared for emergency use. The people on the list should be informed of the nature of amateur radio work and invited to make use of our facilities in any crisis. Keep a workable emergency rig in readiness. Know where a power supply can be obtained for this set in case it is needed even if you do not have such a power supply at your station regularly. When the crisis arises, volunteer your services. Be prepared.

MESSAGE TRAFFIC

Amateur operators can engage in friendly conversation and talk about their stations and apparatus to their heart's content. Commercial operators are required to devote all their time to the handling of business. Amateur operators usually use abbreviations and short-cut methods of stating things so that a lot can be said in just a little while. When two operators are in touch, it is easy for them to understand each other or to ask for more complete wording if there occurs a failure to interpret all the abbreviations used.

One activity of the League that is quite important is the accepting and relaying of messages. Station owners may originate traffic going to any part of the United States or to such foreign countries as permit the handling of citizen messages by amateur operators. Messages may be accepted from friends or acquaintances for sending by amateur radio. Such messages should be put in as complete form as possible before transmitting them, and incomplete messages should not be accepted. As messages are often relayed through several stations before arriving at their destination, no abbreviations should be used in the text as mistakes are bound to happen when the text is shortened in this manner. To people not acquainted with radio abbreviations, messages written in shortened form are meaningless. Delivering stations must be careful to see that messages are written out fully.

In handling messages we are doing something really worth-while. We want to start only good worth-while messages from our stations. Our efforts should be directed to making the quality of our message service high. The number of messages we handle is of secondary importance. The kind of messages we originate or start from our stations and the speed with which the messages pass through our station and the reliability or accuracy with which the messages are handled are the things of paramount importance.

AMATEUR STATUS

It is most important that individually and as an organization we be most careful to preserve our standing as amateurs by doing nothing to harm that most precious possession, our amateur status.

No brief can be held for the amateur who accepts direct or indirect compensation for handling specific messages. This is in direct violation of the terms of the amateur station license, the regulations of the Federal Radio Commission and the agreements in regard to the use of vacuum tubes and equipment "for amateur and experimental use". Such violations may be responsible for not only bringing individual amateurs into great trouble but may even throw a shadow of disrepute on the good name and record of amateur radio considered as a whole. The penalties are too great and neither the violations nor the violators can be tolerated. Accepting compensation of any kind is dangerous business!

It is the purpose of these paragraphs to warn amateurs to avoid being "used" by commercial interests in unethical ways. An amateur asked our advice recently on accepting a whole set of fine station equipment from a business house—the only string being that he should consistently try to handle some traffic with a certain foreign point. A hotel on the Pacific Coast offered an amateur radio club a fine meeting place with free light, power and heat—provided the amateurs would establish an amateur station and relay messages for guests of the hotel. A certain newspaper planned to "organize an amateur radio club" and establish a "net" for the collecting of amateur news for the paper. It offered the amateurs a club room and the facilities of a powerful station that it would install as "net control station" in return for the things it could gain by making amateurs violate their amateur status! Not a month goes by without some case of this sort coming to the attention of League Headquarters. Interests finding difficulty in obtaining limited commercial licenses are trying to find ways to evade the rulings of the Federal Radio Commission and to "use" amateur stations and status to the detriment of the amateur's own best interests.

There are plenty of legitimate activities in which amateurs may participate. The League approves amateur coöperation with worthy enterprises, sponsors tests to show the utility of short-wave communication, encourages worthwhile service to expeditions in getting their messages from the far parts of the earth. Be assured that there is nothing wrong in accepting trophies and prizes of any sort for legitimate amateur competition in communication contests. Watch carefully and refuse to enter into any agreements or alliances through which you accept anything in the nature of a consideration for services rendered in connection with your amateur radio station. There is no question of the good intentions of the amateurs involved in the several cases cited. Very great damage can be done unless there is strict observance of both the spirit and letter of the regulations involving amateur status. Avoid sugar-coated promises and opportunities which might be construed as direct or indirect compensation and a violation of amateur status. Seek competent advice before you jump at chances to get something for nothing. Preserve your most valued possession, your status as an amateur.

The matter of what constitutes "commercial correspondence" may be viewed from many angles. The reader is referred to a legal opinion prepared by the League's General Counsel (page 13, July 1928 *QST*) for further discussion. Our right to handle friendly communications of worthwhile character and to engage in valuable work of all kinds in emergencies and with expeditions remains unquestioned. It is our notion privately that a "consideration" is absolutely necessary to establish the "commercial" nature of any traffic, however.

Recently a case came to our attention in which a station owner was reported to have accepted a prize (?) for originating a large quantity of messages of a direct advertising nature. The messages were of course of the "rubber stamp" variety so that they had to be thrown out of the totals in accordance with the A.R.R.L. policy expressed elsewhere in this book. It may be considered a violation of the best amateur ethics for an amateur operator and station to assist rigorously in an advertising campaign even when no compensation is passed, for the messages are neither friendly in character nor have they anything to do with experimental work or amateur radio as a hobby. Possibly it is all right for an amateur to handle such messages as long as he accepts no compensation—a legal opinion probably would substantiate the right of the amateur to handle this business under those circumstances.

MESSAGE FORM

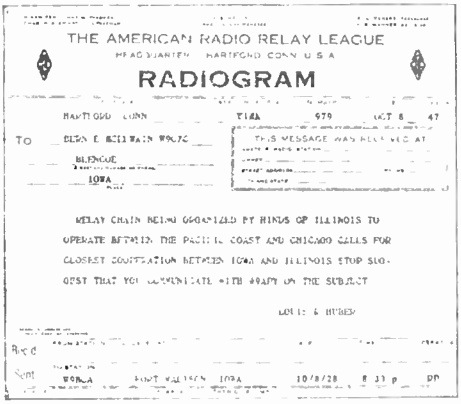
Each message originated and handled should contain the following component parts in the order given:

(a) City of origin
(b) Station of origin
(c) Number
(d) Date
(e) Check (optional)
(f) Address
(g) Text
(h) Signature

(a) The "city of origin" refers to the name of the city from which the message was started. If a message is filed at League Headquarters by someone in Hartford, Conn., the preamble reads, "**Hr msg fm Hartford Conn W1MK Nr 457 April 9,**" etc.

If a message is sent to your radio station by mail the preamble reads a little differently to show where the message came from and from what city and station it originated as well. If a message was filed at A.R.R.L. Headquarters and if it came by mail from Wiscasset, Maine, the preamble would run like this to avoid confusion, "**Hr msg fm Wiscasset Maine via Hartford Conn W1MK Nr 457 April 9,**" etc.

(b) The "station of origin" refers to the call of the station at which the message was


THE AMERICAN RADIO RELAY LEAGUE
HEADQUARTERS HARTFORD CONN U S A
RADIOGRAM
HARTFORD CONN 979 OCT 8
TO
BLENCOE
IOWA
THIS MESSAGE WAS RECEIVED AT
RELAY CHAIN BEING ORGANIZED BY HINDS OF ILLINOIS TO OPERATE BETWEEN THE PACIFIC COAST AND CHICAGO CALLS FOR CLOSEST COOPERATION BETWEEN IOWA AND ILLINOIS STOP SUGGEST THAT YOU COMMUNICATE WITH ON THE SUBJECT
Rec'd
Sent FORT MADISON IOWA 10/8/28

To emphasize properly the standard message form used by the A.R.R.L. we are illustrating a sample message herewith. It is a simple matter to record the date and time of receiving and sending a message if a calendar and clock are kept handy in the station. If these data and the calls of the stations concerned are placed right on the message blank itself, there is never any question about the routing or speed of handling messages that cannot be answered at once by reference to the message file.

filed and this should always be included so that a "service" message may be sent back to the originating station if something interferes with the prompt handling or delivery of a message. In the example of preambles just given "W1MK" is the station of origin, that call being the one assigned the League Headquarters Station by the Radio Division, Department of Commerce.

(c) Every message transmitted should bear a "number". Beginning on the first day of each calendar year, each transmitting station establishes a new series of numbers, beginning at Nr. 1. Keep a sheet with a consecutive list of numbers handy; file all messages without numbers; and when you send the messages, assign numbers to them from the "number sheet", scratching off the numbers on that list as you do so. Such a system will keep things straight and be very convenient for reference to messages originated.

The original number supplied each message by the operator at the originating station is transmitted by each station handling the message. No new numbers shall be given the message by intermediate stations. If a message is filed at W1MK on April 9 and when sent is given the number "nr 458" this same call and number is used by all stations handling this message. The number and date become a part of the city-and-station-of-origin identification used for the purpose of tracing.

The message started from W1MK reads, "Hr msg fm Hartford Conn W1MK Nr 458 April 9." No matter what station handles this message, the city and station of origin, the number and the date, remain exactly the same as in the original and should reach the addressee in that form. Only at stations where a message originates or is filed can a number be assigned to a message. Intermediate relaying stations neither change numbers nor supply new ones to messages.

(d) Every message shall bear a "date" and this date is transmitted by each station handling the message. The date is the "day filed" at the originating station unless otherwise specified by the sender.

(e) Every word in the address text and signature of a message counts in the check using radio cable-count. Words and abbreviations in the preamble are not counted.

In the address the names of cities, states, countries or other divisions of territory each count as one word regardless of the number of letters they contain. Proper names in the address and signature are counted at the rate of one word for each 15 letters or fraction thereof. The words "street", "avenue" "square" or "road" are always to be counted each as one word separately from the name of the street, etc., whether written with it or separately. Names of ships are counted as one word irrespective of the number of letters they contain. When there are two ships of the same name, the name and the call letters of the ship are together counted as one word. The name of the state is always counted as one word in addition to the name of the city. Initials in the address are counted each as one word. Each group of house or street numbers is allowed to pass as one word, however.

It is customary to omit the count of the name of a state in the check when it is written and sent in parentheses in the address.

If a telephone number is included in the address, the word "telephone" or "phone" counts as one word. The name of the exchange is an additional word in the check. Each group of five figures or fraction thereof counts as one word. A hyphen indicating the word "ring" may be substituted for one figure in a telephone number without increasing the check. "PHONE CHARTER 328-5" counts as 3 in the check. "26039" counts as 1 in the check. "2603-9" is a six character group and accordingly counts as 2 in the check. Mixed letter and figure combinations are counted as a word to each character. A house number followed by a letter counts as but one word, however.

Radio calls are often included in the address to make proper routing easy. "W5XAY" counts as one word in the address but as five words when it appears in the body or signature of the message.

In the text words are counted for every fifteen characters or fraction thereof if the message is a plain language message. A word containing from 16 to 30 letters counts "2" in the check. As English is the business language of the world, most messages are sent in English. Messages can be sent in any languages made up of the Arabic (26-letter) alphabet.

Names of cities in the address count always as one word while in the text they may count as more than one word depending on how written and transmitted. NEW YORK CITY counts as one word in the address but three words wherever it appears in the body of the message. NEWYORKCITY is counted as one word when written and sent without spacing between the parts.

Isolated characters each count as one word. Five figures or less in a group count as one word. Words joined by a hyphen or apostrophe count as separate words. A hyphen or apostrophe each counts as one word. However, they are seldom transmitted. Two quotation marks or parenthesis signs count as one word. Punctuation is never sent in radio messages except at the express command of the sender. Even then it is spelled out. In the text of messages, the names of ships are counted at the rate of 15 letters to a word if the names are written out separately. If all parts are joined to form one word each 10 letters or fractional part counts as one word.

Messages may be classed as plain language messages, coded messages or cipher messages. A plain-language message bears the same thought indicated by the dictionary meaning of the words used in the text. All ordinary messages are plain-language messages. Every 15 characters or fraction thereof counts as one word. Numerals are counted in groups of five or less. A fraction bar or decimal point counts as one character on figure. An underline counts as an extra word wherever it appears.

Examples (plain language):

		91 3/4	1 word
USS	1 word	396 3/4	2 words
ARRANGEMENT	1 word	2961	1 word
UNCONSTITUTIONAL	2 words	85772	1 word
X-RAY	2 words	171186	2 words

(the hyphen is not transmitted)

In coded messages the words are all pronounceable but their arrangement is not necessarily in sentences to express the thought. Several selected words or word groups express more extensive thoughts.

In code messages every ten characters or less count as one word. Either dictionary or artificial words may be used but all words must be pronounceable to take the ten-letter count. Words containing 11 to 20 letters count "2" in the check. When one has a copy of the simple and commonly used codes the business of coding and decoding is easy.

Examples (coded):

CAUSTIC	1 word
COMBINZUBIOUS	2 words
AVIABLOSKI	1 word
HOOTBAFF	1 word

In cipher messages the letters or figures in each uninterrupted series are counted at the rate of 5 (or fraction thereof) per word. Groups of letters are checked at the same rate as groups of figures. Mixed letters and figure combinations count a word to each character. "R4TG" counts as four words unless it is an established trade mark or trade name. Radio calls are always counted as cipher. "W1MK" counts as four words in the text or signature of a message (though but one word if sent "en group" in the address). For accuracy it should be written "watch one mike king". Abbreviated or misspelled words are counted at the "5-letter" rate in any message where they accidentally appear. A misspelled word with missing letters takes the same count as though it were correctly spelled.

Examples (cipher count):

XYPPQ	1 word
D6W	3 words
CXQPWL	2 words

If a message is written partly in plain language, partly in cipher, and partly coded, the words in plain language and code are counted at the "10-letter" rate while the other parts of the messages are checked at the "5-letter" rate.

When messages are written in plain language and cipher, the passages in plain language take the fifteen letter count and the passages in cipher take the five letter count.

Messages in plain language and code take the ten letter count.

When the letters "ch" come together in the make-up of a dictionary word, they are counted as one letter.

Either whole or fractional numbers spelled out so each group forms a continuous word may be checked at the "15-letter" rate. "FOB", "COD", "SS", "ARRL", "QST", and such expressions in current use, are counted five letters to a word wherever they appear. Each group must of course be sent and counted separately to indicate separate words. Groups of letters are not acceptable in the address but must be separated and checked as one word each.

Here is an example of a "plain-language" message in correct A.R.R.L. form and carrying the "cable-count" check:

(HR MSG FM HARTFORD CONN W1MK NR 83—217p May 3 CK 49 TO)
H W DENSHAM
140 WASHINGTON ST
COLLINGSWOOD NEWJERSEY

PLEASE COMMENT ON PROPOSED OLD TIMERS WEEK USING 3500 KILOCYCLES STOP BACK NUMBER OF QST WAS FORWARDED MONDAY STOP WHAT FREQUENCY IS MOST IN USE AT W3EH QUESTION 73 TO YOU AND NEW JERSEY GANG

(sig) ARRL COMMUNICATIONS MANAGER

The count on each part of the message is added to give the "check" shown. Address: 8. Text: 38. Signature: 3. The check is the sum of these three or 49 words. The parts of the message in parentheses are always transmitted but do not count in the check.

The following words that give most trouble in counting this message add into the "check" as follows:

H	1
W	1
140	1
St	1
NEWJERSEY	1
3500	1
QST	1
W3EH	4
73	1
NEW JERSEY	2
ARRL	1

The use of a check on amateur messages is optional. Where employed, however, it is a matter of courtesy to see that the check is correct and is handed on along with the rest of the message. Very important messages should be checked carefully to insure accuracy, and if an important message is received with no check, a check should be added.

(f) The "address" refers to the name, street and number, city, state, and telephone number of the party to whom the message is being sent. A "sufficiently complete" address should always be given to insure delivery. When accepting messages this point should be stressed. In transmitting the message the address is followed by a double dash or break sign (—...—) and it always precedes the text.

(g) The "text" consists of the words in the body of the message. No abbreviations should ever be substituted for the words in the text of the message. The text follows the address and is set off from the signature by another break (—...—).

(h) The "signature" is usually the name of the person sending the message. When no signature is given it is customary to include the words "no sig" at the end of the message to avoid confusion and misunderstanding.

FOREIGN TRAFFIC RESTRICTIONS

Amateur traffic may be handled freely between two countries only when so agreed between the two governments. Otherwise governments will permit experimental communication between their amateurs and those in other countries, at the same time prohibiting the handling of messages for third parties. Of course it must be understood that certain frequency bands are available by international agreement for amateur work, and any country may or may not permit its amateurs to use part or all these bands, as it desires.

In England, France, Germany, Belgium, South Africa, Spain, Ireland, Denmark, Madeira, S. India, Indo-China, and Uruguay only "experimental" traffic can be handled by amateur radio. Messages that would normally be transmitted by cable or commercial radio cannot be accepted by amateurs in these countries on penalty of losing the privileges they do have. Experimental traffic is usually defined as that which does not compete with or lessen government revenue from existing government telegraph and cable services. Messages between amateurs regarding the technicalities of station construction, adjustment or operation, messages regarding short-wave amateur tests, those concerning I.A.R.U. and A.R.R.L. activites—in short, messages that can be classified as relating to non-commercial business conducted by non-commercial organizations, can be freely handled, while personal messages and business messages either to or from anyone except an experimenter cannot be accepted by a foreign station. Only a partial list is given above as conditions in all countries of the world are not definitely known at this writing.

All kinds of amateur traffic may be handled between amateur stations in different parts of the United States, Hawaii, Alaska, Porto Rico, Philippine Islands, and an agreement to that effect is expected between the governments of the United States and Canada. It is hoped that similar arrangements will be concluded shortly with Australia and New Zealand by both Canada and the United States. Messages have been handled freely between our country and Brazil, Chile, and China in the past so that we may expect permission for amateur message handling to be forthcoming in some of these countries in the future also. There is thus a splendid opportunity for handling citizen radio as well as experimental messages not only in each of these localities but also between each country listed just above.

There is opportunity for some real service to local communities everywhere that an amateur puts up a station and gets on the air, and especially in time of emergencies. Excellent work in traffic handling comes to our attention regularly. Many expeditions and exploring parties go to the far parts of the earth—and now they always take short wave equipment along for contact work.

ORIGINATING TRAFFIC

Every message has to start from some place and unless some of us solicit some good traffic from friends and acquaintances there will be no messages to relay. A number of League members have made a special study of different simple methods of collecting messages and we want to mention those that have proved worthy and worked out well in practise. Of course the simplest way to get messages is to offer to send a few for friends, always reminding them that the message service does not cost them a penny and that no one can be held responsible in case a friendly message does not arrive at its destination or if it arrives after some delay, but that, after all, most messages do get through in good season so that sending them is really worth while.

A number of our most enthusiastic traffic handlers who are interested in handling messages in quantities have taken more aggressive steps to secure results. One man at least has advertised in the local papers that messages may be phoned him for transmission via A.R.R.L. radio stations. Another fellow we know has made arrangements to handle a daily report on live-stock and butter-and-egg market conditions. Radio stations at Madison and Milwaukee, Wisconsin, are responsible for conducting the first daily and speedy market service of its kind. A number of the amateur fraternity have distributed pads of message blanks to a number of local stores and business houses. A neatly typed card is displayed near-by explaining the workings of our A. R. R. L. traffic organization, and listing the points to which the best possible service can be given.

The time of collecting messages and the list of schedules kept may also be posted for the benefit of those interested. Wide-awake amateurs have always distributed message blanks to the nearest tourist camps during the summer seasons of recent years and lots of good traffic has been collected through a system of message-collection boxes placed in public buildings and hospitals. A sign prominently displayed outside the radio station has in some instances proved a good source of obtaining worth-while messages. Other similar ways of obtaining message traffic will occur to the station operator when he is ready to go out after something to do. When conventions or exhibitions come to a city there are always opportunities for getting a lot of real messages to send. Some hotels are glad to accept messages from guests to be sent through near-by amateur stations as a special free service to their patrons.

TROUBLES TO AVOID IN ORIGINATING TRAFFIC

Incomplete preambles seem to be the most common fault in message handling work. The city of origin, the station of origin, the number, the date, and the check are all a part of the preamble which goes at the beginning of every message. **The city and station of origin** are most essential. Without them it is impossible to notify the sender that his message could not be delivered and without this information it is not possible to route the reply speedily. All Official Relay Stations are instructed to refuse to accept messages without this essential information. Every station should demand an "office of origin" from stations who have messages, and traffic may be rightly cancelled (QSK) on failure to include it. Thus messages will never get on the air without a starting place.

Many messages carry an **insufficient ad-**

dress and cannot be delivered. Originating stations should refuse to accept messages to transmit when it is apparent that the address is too meagre.

NUMBER SHEET OF ORIGINATED MESSAGES AT RADIO STATION ________

Message Numbers	Sent to Station	Date	Message Numbers	Sent to Station	Date
~~1~~	8CWK	6/10/26	31		
~~2~~	5AUN	6/10/26	32		
~~3~~	4OA	6/11/26	33		
~~4~~	1BTG	6/12/26	34		
~~5~~	6BUR	6/12/26	35		
~~6~~	3BZ	6/13/26	36		
~~7~~	7LR	6/14/26	37		
~~8~~	8ASV	6/14/26	38		
~~9~~	6CGO	6/15/26	39		
~~10~~	8ADG	6/16/26	40		
~~11~~	8EU	6/17/26	41		
~~12~~	1BIG	6/19/26	42		
~~13~~	9BPY	6/20/26	43		
~~14~~	8ASV	6/21/26	44		
~~15~~	9ET	6/22/26	45		
16			46		
17			47		
18			48		
19			49		
20			50		
21			51		
22			52		
23			53		
24			54		
25			55		
26			56		
27			57		
28			58		
29			59		
30			60		

Some stations lose track of the messages which they accept for delivery or transmission. They use scratch pads to copy signals on and they never clean up the operating table or have a place for things. The remedy is to adopt a few of the principles of neatness and to spend about two minutes each time you are through operating to put things in order. Write messages on message blanks of a uniform size when they arrive at the station. Keep the messages to be sent together. A good system to use is to mark the state of destination in the upper right hand corner of each message, arranging the messages in a heavy clip so that the names of the states are in easy view. A file box may be similarly arranged. A simple log book, a good filing system, an accurate wavemeter and clock, are sure signs of a well-operated station. The apparatus on the operating table will tell a story without words.

NUMBERING MESSAGES

An accurate and complete log and a "number sheet" posted on the wall of the station or kept attached to the log sheet that is in use, will help in keeping the records straight and in avoiding possible duplication of numbers on messages. Guess work and confusion are eliminated in a station of either one or several operators if a "number sheet" is used. A "number sheet" system enables any operator quickly to tell just what number is next; it helps the operator in counting the number of messages originated in a given month; and it may also give a convenient check with the log in showing to whom each message was sent.

Take a blank sheet of paper and put a consecutive list of numbers on it starting with the current message number. Run the numbers in columns, ten numbers to each group or column, and allow sufficient space between columns for entering station calls.

File the messages in complete form except for the number and when you have a station ready to take a message, consult the number sheet, assign the next available number to the message, and when the station acknowledges the message, cross off the number used, putting the station call after this number and writing the number on the message blank.

A new number sheet can be made as often as necessary. A sheet that is in use looks something like the illustration.

Number 16 will be the next number originated at the station using this number sheet.

COUNTING MESSAGES

So that we can readily keep run of our messages and compare the number of messages originated and delivered each month to learn some facts about the "efficiency" of our work in handling messages, a method of counting messages is used that gives the desired information. Each time a message is handled by radio it counts one in the total.

A message received in person, by telephone, by telegraph, or by mail, filed at the station **and transmitted by radio** in proper form, counts as one message **originated**.

A message **received by radio and delivered** in person, by telephone, telegraph, or mail, counts as one message **delivered**.

A message **received by radio and sent forward by** radio counts as two messages relayed (one when received and again one when sent forward).

All messages counted under one of the three classes mentioned must be handled within a 48-hour (maximum) delay period to count as "messages handled" with but one exception. Messages for all continents except North America may be held one-half the length of time it would take them to reach their destination by mail if necessary to eliminate needless local passing about of long distance traffic. A "service" message counts the same as any other type of message.

The message total shall be the sum of the messages **originated, delivered** and **relayed.** Each station's message file and log shall be used to determine the report submitted by that particular station. Messages with identical texts (so-called rubber stamp messages) shall count once only for each time the **complete** text, preamble and signature are sent by radio.

EXAMPLES OF COUNTING

By following the above rules, the messages handled during the "message month" may be counted readily. A monthly report should be sent to the local traffic official of the A. R. R. L. as mentioned under the subject of "Reporting." The closing date of the "message month" is the 15th of each month, (the last of the month in Hawaii). Reports must go forward the next day.

Let us assume that on the 15th of the month one operator of a large amateur station receives several messages from another station. (a) Some of these messages are for relaying forward by radio. (b) Some of them are for local delivery. (c) There are still other messages the disposal of which cannot be accurately predicted. They are for the immediate neighborhood but can be either mailed or forwarded to another amateur by radio. A short-haul toll telephone call will deliver them but the chances of landing them nearer the destination by radio are pretty good. This operator's "trick" ends at midnight on the 15th and he must make out the report with some messages "on the hook" to be carried over for the next month's report.

(a) The messages on the hook that are to be relayed have been received and are to be sent. They count as "1 relayed" in the report that is made out now, and they will also count as "1 relayed" in the next month's report (the month during which they were forwarded by radio).

(b) By mailing the messages or phoning them at once, they can count as "1 delivered" for the current month's report. By holding them until the next day they will count in the next report as "1 delivered".

(c) The messages in this class should be carried forward into the next month. If they have to be mailed they will count in the next report as "1 delivered". If they are relayed, we count them as "2 relayed", "1" received in the preceding month being carried forward and added to "1" sent makes the "2 relayed." If the operator wishes to count this message at once (for the current month) it must be mailed promptly and counted as "1 delivered".

Some examples of particular counting problems follow:

The operator of Station A gets a message by radio from Station B addressed to himself. This counts as "1 delivered" by himself and by Station A.

The operator of Station A takes a verbal message from a friend for relaying. He gives it to Station B over the telephone. Operator A does not handle the message by radio. Station B and operator B count the message as "1 originated". A cannot count the message as he did not start it on the air.

The operator and owner of Station A visits Station B and while operating there takes a message for relaying. The operator and owner of B cannot operate for a day or two so the message is carried back to Station A by operator A who relays it along within a few hours. The traffic report of both station A and Station B shows "1 relayed" for this work. Operator A gets credit for "2 relayed" if he is entered in a message-handling contest and gives details of his work at both stations specially for the contest.

Messages originating at any station count only in the "originated" column. Messages received by radio and delivered, count only in the "delivered" column. The relayed column can contain either an odd or even number of messages, depending on the messages left over for next month, the circumstances in a given case, and so on. The total is the sum of the figures in originated, delivered, and relayed columns.

"RUBBER-STAMP" MESSAGES

Because, now and again, our stations fall into the habit of originating quantities of so-called 'rubber-stamp' messages with such texts as 'your card received will QSL', 'greetings by radio' and the like, the identical text being addressed to a large number of addressees (always more than one), it becomes necessary to re-affirm our policy with respect to such messages. The history of our organization shows the demoralizing effect of an influx of such stereotyped messages in quantity. Because such messages mean little individually and because there is much labor and little pleasure in handling such messages the result has always been a decrease in the delivery column while the totals of originated and relayed messages rise to unprecedented heights—that mean nothing at all. Because the net effect of encouraging rubber-stamp messages is to clog the hooks of traffic handling stations until these stations can no longer function, it was decided long ago to kill large quantities of such messages at their source by a rule which put a premium on delivering good messages promptly **and not counting the rubber-stamps when figuring out totals for the report under the honor system.** Several arguments in favor of 'greeting' messages have much in their favor. While there is nothing against and much in favor of handling individual friendly greeting messages which do have significance to the general public, it is necessary to maintain a firm policy with respect to counting rubber-stamp messages to further efficient traffic handling with a good percentage delivery in our national scheme of affairs.

Obviously, a station in handling a rubber-stamp message has to exert only a small amount of effort in receiving the text and signature once. Then by handling the address to different points en group a large number of messages (?) can be received and and transmitted in similar fashion with little expenditure of time and effort. The italicized statement regarding counting or not counting of rubber-stamps is herewith amplified to credit honest effort as it deserves while discouraging quantities of messages having identical texts. As has been explained, the League's system for crediting points for messages handled is based on giving one credit each time a complete message is handled by amateur radio, i.e., one credit for each originated message, one credit for each delivered message and two credits for each relayed message (one credit for the work in receiving it and one for the work in transmitting it). Only every message handled by radio with a complete preamble, address, text, and signature shall be counted under any of the classes of messages.

Example (showing a claimed and revised count on R.S. messages): A certain station takes an R.S. message to 10 addresses and relays it onward to another station claiming 'relayed 20' for his work. This station shall be credited with 'relayed 2', one for receiving a complete preamble, address, text, and signature, one for sending a complete message on its way. For receiving and relaying to three stations (requiring the complete message to be sent three times) a total of **four** might be justly claimed in the relayed column.

DELIVERING MESSAGES

The only service that we can render anyone by handling a message comes through "delivery". Every action of ours in sending and relaying messages leads up to this most important duty. Unless a message is delivered, it might as well never have been sent. Sure enough, we have had a lot of pleasure in sending it and many stations have been glad to acknowledge receipt and to forward it by radio, but without a delivery nothing has really been accomplished.

Right now, delivery conditions are pretty good. Periodically, however, we have an influx of new operators who are willing to get all the fun out of handling messages by radio and who are not willing to give anything in return. If a message comes their way, it gets filed or thrown in the waste basket. Often the man who sent the message expects an answer. Sometimes he writes to confirm his message or to inquire if his friendly message was received. It is then that our League gets a black eye because of the unreliability of some individual who has allowed a message to die at his station or who had been too lazy to deliver a message after it has been received and acknowledged.

There is no reason for anyone to accept a message if he has no intention of relaying it or delivering it promptly. It is not at all discourteous to refuse politely to handle a message when it will be impossible for you to forward it to its destination.

Occasionally message delivery can be made through a third party not able to acknowledge the radiogram he overhears. When a third party happens to be in direct contact with the person addressed in the message he is able to hand him an unofficial confirmation copy and thus to make a delivery much sooner than a delivery could be made otherwise. It is **not** good radio etiquette to deliver such messages without explaining the circumstances under which they were copied, as a direct delivery discredits the operator who acknowledged the message but who through no fault of his own was not able to deliver so promptly. With a suitable note of explanation, such deliveries can often improve A.R.R.L. service and win public commendation. An operator's oath of secrecy prevents him from giving out information of any sort to any person **except** the addressee of a message. It is in no manner unethical to deliver an unofficial copy of a radiogram, if you do it to improve the speed of handling a message or to insure certain and prompt delivery. Don't forget that there are heavy fines prescribed by Federal laws for divulging the contents of messages to anyone except the person addressed in a message.

There are several ways of delivering messages. When it is possible to deliver them in person, that is usually the most effective way. The telephone is the most serviceable instrument in getting messages delivered without undue labor. When the telephone does not prove instrumental in locating the party addressed in the message, it is usually quickest to mail the message.

To help in securing deliveries and making the relay game very much worthwhile to everyone concerned, here are some good rules to follow:

Messages received by stations shall be delivered immediately.

Every domestic message shall be relayed within forty-eight (48) hours after receipt or if it cannot be relayed within this time shall be mailed to the addressee.

Messages for points outside North America must not be held longer than half the length of time required for them to reach their destination by mail.

We are primarily a radio organization, and the bulk of our messages should go by **radio**, not by mail. The point is that messages should not be allowed to fall by the way, and that they should be sent on or delivered just as quickly as possible. When a message cannot be delivered, or if it is unduly delayed, a "service" message should be written and started back to the "office of origin".

Each operator who reads these pages is asked to **assume personal responsibility** for the accuracy and speed of each message handled so that we can each have reason to take personal pride in our operating work and so that we will have just cause for pride in our League as a whole. Do **your** part that we may approach a 100% delivery figure.

THE SERVICE MESSAGE

A service message is a message sent by one station to another station relating to the "service" which we are or are not able to give in message handling. The service message may refer to non-deliveries, to delayed transmission, or to any phase of message handling activity.

Whenever a message is received which has insufficient address for delivery and no information can be obtained from the telephone book or the city directory, a service message should be written asking for a better address. While it is not proper to abbreviate words in the texts of regular messages, it is quite desirable and correct to use abbreviations in these "station-to-station" messages relating to traffic-handling work.

The prefix "svc" in place of the usual "msg" shows the class of the message and indicates at once that a station-to-station message is coming through. Service messages should be handled with the same care and speed that is given other messages.

Suppose a regulation message is received by W3CA for someone in Roanoke, Va. Suppose that the message cannot be delivered because of insufficient address. The city and station of origin of the message are given as "Pasco Washn W7GE". In line with the practise outlined above W3CA makes up a service message asking W7GE to "give better address," of course obtaining the address from the party that gave him the message. W3CA will give the message to anyone in the west, of course trying to give it to the station nearest Pasco, Washington, and sending it over the greatest distance permitting reliable communication. The message looks something like this:

"HR SVC FM ROANOKE VA W3CA NR 291 Aug 19
To RADIO W7GE
L C MAYBEE
110 SOUTH SEVENTH AVE
PASCO WASHN —...—
UR NR 87 AUG 17 TO CUSHING SIG GICK HELD HR UNDLD PSE GBA —.. —
(sig) WOHLFORD W3CA"

ROUTING MESSAGES

Messages can usually be placed near their destination. In any case they should be relayed to the station nearest the location of the addressee and over the greatest distance which allows reliable contact.

OPERATING ON SCHEDULES

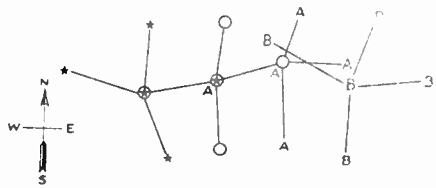
Traffic handling work can very advantageously be carried on by arranging and keeping a few schedules. By arranging schedules and operating the station in a business-like way, using an accurate frequency meter and a clock, it has been proven many times that a maximum amount of business can be moved in a minimum of time and effort. The message "hook" can be cleared in a few minutes of work on schedule and the station will be free for "DX" or "experimental" work.

Every brass-pounder is urged to write letters to some of the reliable and regular stations heard, asking if some schedules cannot be kept a few times a week especially for traffic handling. With reliable schedules in operation it is possible to advertise the fact that messages for certain points can be put through with speed and accuracy, and the traffic problem will take care of itself.

THE FIVE-POINT SYSTEM

To make our relaying more systematic the "five-point system" of arranging schedules was proposed and has worked out very nicely in many cases. After getting the station in good operating condition, each station's operator arranges to work four stations, one north, one east, one south, and one west. These directions are not exact but general. The distances are not too great but they must be distances that can be worked with absolute certainty under any conditions.

A good way to select the four stations is to listen-in and to pick out the stations heard most regularly, operating most consistently,



and in the right direction. It is a good scheme to "work" these stations a few times. Write them letters and get acquainted; then try to arrange some schedules. Short schedules are the best. A half or quarter hour each day is enough. Using our twenty- and forty-meter channels we can work right through the broadcast period.

There is no excuse for failure to keep a schedule. After a little while, keeping it will be a part of the daily routine, and when the arrangement has been made after careful consideration by the fellows involved it will prove no hardship but rather a source of pleasure. In an hour one can call the four stations, clear traffic, and be free to work other groups of "five-pointers" or to spend the time otherwise.

By referring to the sketch the idea may be seen at a glance. Five stars work together, five circles, five A's and so on, all over the country.

The system depends on the use of an accurate clock, wavemeter and log. When things stay the same from day to day the dial settings become memorized like telephone numbers and the importance of the three items named is not so great.

When there is no traffic, a few pleasantries are in order during the scheduled time of working. Several advantages of handling messages on schedule are evident from whatever angle the situation is approached. The use of several separate wavelength bands for amateurs has more or less divided us. By arranging schedules and working in a business-like way we can make full use of all our frequencies.

ACCEPTING AND TRACING MESSAGES

Messages that are not complete in every respect **shall not be accepted** for relaying. The city of origin, station of origin, number, date, address, text, and signature constitute a complete message. The fundamental parts of the message are regarded as the CITY and STATION of origin, a SUFFICIENT ADDRESS to insure delivery, a TEXT, and a SIGNATURE. All these parts are necessary to make a message of value to the recipient, to make possible to deliver the message and to route an answer back to the sender. The city and station of origin make it possible to send a service message back to the starting point in case of delay or trouble in making a delivery. The date and number are useful as the inclusion of a date speeds up the message and the number makes it possible to trace the messages easily.

Tracing messages is sometimes necessary when it is desired to follow the route of a message or to find where it was held up or delayed. Tracing is usually accomplished by sending a copy of the message and a letter requesting that the time, date, and station calls of the stations from whom the message was received and to whom the message was given, be noted in the proper place on an enclosed sheet. The letter asks that the sheet and message be forwarded in rotation to all the stations handling the message until it has overtaken the message, when the tracer is mailed back to its starting point with the information collected from all the logs along the route.

REPORTING

Whether the principal accomplishments of the station are in traffic handling work or along other lines, what you are doing is always of interest to A. R. R. L. headquarters. Our magazine, *QST*, covers the entire amateur field, keeping a record of all the messages handled in different sections of the country, giving mention of the outstanding work that is done in communicating over great distances using small amounts of power, and summarizing all the worthwhile activities in the sections of the magazine devoted to those particular activities.

We have mentioned the Official Relay Stations and the Communications Department organization. A special section of *QST* is devoted to the Communications Department. Each month a special form postal is sent the active stations in the relay system for reporting purposes. Blanks on the card are provided so that the number of messages originated, the number delivered, and the number relayed can be inserted, together with the message total. There is also space to tell about the most important traffic handled, the wavelength used during the reporting month, the "DX" worked, and other station records and activities, together with a list of the stations with whom schedules are kept. Items of general interest, changes in the set, and addresses of new amateurs also come in on this card.

This information is wanted from every operator of an active amateur station in the United States. Each month on the 16th (the 1st in Hawaii) the active stations send reports to their local officials. These officials forward all the reports sent them to Headquarters. They are next prepared for the magazine. Only representative space can be given each section of the country and almost every report received has to be squeezed in order to get it in. Reports must have the dead material edited out of them to allow room for as much active and interesting news as can be gotten in. Sometimes paragraphs have to be cut down or left out altogether to make the material fit the space it is allowed. Reports about what someone is "going to do next month" and about "burnt out tubes," "no traffic" or "non-operation" get deleted. The more worthwhile a report is, the more of it gets in print. If something comes in that is worth special mention, it gets more space in another part of the magazine. Traffic figures and calls of active stations always get full space. The readers of this Handbook are cordially invited to send in their reports to the local traffic official just as soon as they have a station in operation. Write the nearest traffic official whose name appears on page 3 of each *QST*. **Make your report as informative and interesting as possible.**

Especially important work that has a news value should be sent direct to League Headquarters at Hartford. Get in touch with your local man soon, and ask him just when he must get a report from you, so that he can include it with other reports on the day he makes up his official report. Be sure to make your report as full of information as possible, including some of the things we mentioned if possible.

Contributions to *QST* are welcomed by the Editors! Authors must remember that only a small percent of the received material can be printed and that it is impossible for an organization like ours to pay for articles. Ours is a "family" organization supported by and for the amateur. Contributions cannot be paid for due simply to the fact that the League is not a commercial or moneymaking organization like the ordinary magazine publishing house. By carefully selecting material the members get the best magazine that can be made. *QST* is noted for its technical accuracy. Getting into the reading pages of *QST* is an honor worth working for.

KEEPING A LOG

Every operator of an amateur station should keep a log of the operating work that is done as well as of the tests of an experimental nature that are carried out with the transmitter or receiver.

The keeping of a station logbook is important in making our station excel in every respect. The "log" is written up right at the time the station is in operation. Properly kept, it becomes a detailed and interesting history of station accomplishments and is frequently of great value in proving or disproving transmissions.

Reference to a well-kept log will usually disclose the number of the last message that was sent, so that we can quickly find the next number to use. The log will give us the whole story of the "where" and the "when" of every message that has passed through the station.

A faithfully-kept log gives absolute proof of the transmitting work that has been carried on and makes the history of the station always available, up-to-date, and complete. Every commercial and government station keeps a log because it is a necessity. Amateurs keep a log because of the ready-reference value in proving records and because of the pleasant recollections and associations that come from reviewing the history of friendly radio contacts and from displaying the record of the accomplishments of the station to interested visitors and friends. So by all means plan to start a log at the same time you start operating the station.

There are as many different kinds of logs as there are stations. Station owners all have opinions on the form that the log should take. The more elaborate the log is, the more time, care, and pains are required in keeping it. The value of the log does not increase as rapidly as the work of entering details mounts.

Still another column may be added for "Remarks". A, B, C, or D are often used to indicate the 1750-, 3500-, 7000- or 14000-kc. band. The letter can show which wavelength band or secondary coil was used. After this letter follows the condenser setting, "B-28" showing that W8BRC was using the 3500-kc. band and that the tuner condenser setting was on 28 degrees. At the end of the line the time of transmission may be noted. "1s, 2r" can be used to mean that one message was sent and two received from W8BRC.

DATE.	APRIL 10, 1927		WKD (X)	
3:25 P.M.	CALLED	CALLED BY	W8BRC	
E.S. TIME	CQ	ANS X	X	

FIGURE 1

Figure 2 shows a very detailed log which really gives a lot of information but which is somewhat harder to keep in good shape. W, H and C are used for "worked", "heard" and "called". A bar under the "R" in "RAC" may show that the note is well-rectified and fairly smooth. A line under the "AC" can indicate that the ripple is pronounced. Plenty of information will be available for stations wanting information when such a log is kept, no matter how late a date the request for information is received.

DATE	TIME	CALL	W H	My Freq.	His Freq.	His Note	My QSA	His QSA	Weather	REMARKS
Oct. 10	0310	W7ABB	H		3820	CW		R4	Rain	Cig CQ es W8AWJ
11	0120	G2NM	W	3700	1720	RAC	Fair	R3	Rain	He faded—swings too

FIGURE 2

Therefore, the simple log is best as we will get the biggest return from the time spent in keeping it up-to-date.

A loose-leaf notebook often proves useful in making our log. The sheets can be renewed each month and those used can be taken out and filed away with the cards and station records. A stenographer's ordinary notebook costing from ten to thirty cents and about 4½" by 8½", takes little space on the operating table and also makes a good log book.

A dozen pages may be ruled in advance with vertical lines. In the first column the DATE and TIME are noted. In the second column the calls of stations worked, heard, and called are put down. A circle, parentheses, or a line drawn under the call can indicate whether a station was worked, heard and called, or simply heard. A special designating sign or abbreviations before or after the call letters can show this information.

Figure 1 shows a more standardized form of log. The date is usually placed at the top in the center; the time is put in the first column at the left; the next two columns show the called and calling stations. In an additional column is placed an "X" when a station is called. If communication is established, a circle is placed around the "X".

In Figures 3 and 4 are shown some printed log sheets that are ready for use and in quite convenient form. The log sheet shown in Fig. 4 is stocked at A. R. R. L. Headquarters simply for the convenience of League members.

A log is of great value in a number of ways. A comparison of the operating results obtained

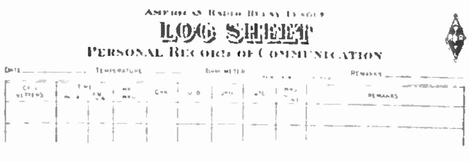


FIGURE 3

with different apparatus in use at different times is valuable. The "DX" or traffic-handling value of the various wavelengths over varying distances may be readily found from the log. The effect of weather or time of day may also be quickly found. **Every change made in either the transmitter or antenna system should be noted down in the log** so that results may be compared for dates before and after the date when a change was made. No matter how trivial the change, **put it down in the log.** Remember that only one change at a time should be made if the changed results are to be attributed to one definite cause.

We have shown several types of log sheets in these pages. There are advantages and disadvantages to each. Perhaps certain ideas from different log sheets can be embodied in your own station log. Perhaps some printed log sheets will be best for your work. Every reader will wish to start his station right by making up an individual station log. The simpler the form of the log is, the more of us can use it advantageously. We offer these forms of logs as suggestions, hoping that you will find them worthy of adoption. Keep a **station log!!!**

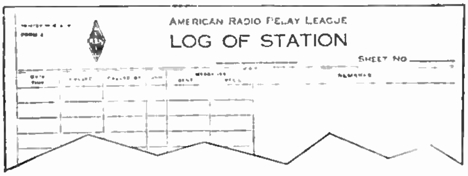


FIGURE 4

A simple form of log is shown above. What is worth doing is worth recording. The simpler the form is the more of us can use it advantageously. We simply offer this form as a suggestion, hoping that you will find it worthy of adoption. Every station should keep a log of transmissions and stations worked so that reports received can be verified from the log and so that the record of message-handling will be a complete one.

WORD LIST FOR ACCURATE TRANSMISSION OF SEPARATE CHARACTERS

When sending messages containing radio calls or initials that are likely to be confused and where errors must be avoided, the calls or initials should be thrown into the following code words:

A	ABLE	N	NAN
B	BOY	O	OBOE
C	CAST	P	PUP
D	DOG	Q	QUACK
E	EASY	R	ROT
F	FOX	S	SAIL
G	GEORGE	T	TARE
H	HAVE	U	UNIT
I	ITEM	V	VICE
J	JIG	W	WATCH
K	KING	X	XRAY
L	LOVE	Y	YOKE
M	MIKE	Z	ZED

EXAMPLE: W1BCG is sent as "WATCH ONE BOY CAST GEORGE" but put back into the first form by the operator who delivers the message.

A somewhat different list can be obtained from the local Western Union telegraph office and posted beside the telephone to use when telephoning messages containing initials and difficult words. The above list was made up of short words to save time in radio transmission while insuring accuracy. The W. U. list is best for voice work (radio-phone, telephone or dictaphone) as the words are selected to carry the proper sounds best while delivering messages by phone.

RELAY PROCEDURE

Messages shall be relayed to the station nearest the location of the addressee and over the greatest distance permitting reliable communication. Messages that are not complete in every respect shall not be accepted for relay. The city and station of origin, the number, date, address, text and signature constitute a complete message.

No abbreviations shall be substituted for the words in the text of a message. Delivering stations must be careful to insure that no confusing abbreviations are written into delivered messages.

Sending "words twice" is a practise to avoid. Use it only when expressly called for by the receiving operator when receiving conditions are poor. "QSZ" is the signal used when this is necessary.

Messages shall be transmitted as many as three times at the request of the receiving operator. Failing to make a complete copy after three attempts, the receiving operator shall cancel the message (QTA).

Let us assume that a station in Hartford, Conn., receives a message whose destination is Dallas, Texas. The message is at once written out on a message blank, filling in the city and station of origin, leaving only the "number", "rec'd", and "sent" spaces vacant

The operator is anxious to get the message started. He sits down in front of the set and listens. He does not hear any western stations so he decides to give a directional "CQ" as per A. R. R. L. practise. He calls, "CQ CQ CQ TEXAS DE W1MK W1MK W1MK", repeating the combination three times and ending with only .—.—.

He listens and hears W9CXX in Cedar Rapids calling him, "W1MK W1MK W1MK DE W9CXX W9CXX W9CXX .—.—."

Then he answers W9CXX indicating that he wishes him to take the message for Dallas. W1MK says "W9CXX W9CXX DE W1MK R QSP DALLAS? K"

After W9CXX has given him the signal to go ahead, the message is transmitted, inserting the "number" in its proper place, and assigning the next number indicated on the "number sheet". The message is sent in A. R. R. L. sequence.

"Hr msg fm Hartford Conn W1MK nr 247 Nov 11 ck 31 To Frank M Corlett W5ZC 2515 Catherine Street Dallas Texas —...— Communications Department supplies and membership list are going forward today please send your reaction to general number 372 our army file —...— sig Houghton .—.—. W1MK —.—"

W9CXX acknowledges the message like this: "W1MK DE W9CXX Nr 247 R K." Never should a single "R" be sent unless the whole message has been correctly received.

The operator at W1MK now writes in the number of the message, scratches off number 247 on the "number sheet", putting "W9CXX" after the number, and in the "sent" space at the bottom of the message blank he notes the call of the Cedar Rapids station, the date, time, and his own personal "sine". At the same time he concludes with W9CXX something like this: "R QRU 73 GB . . .—.— W1MK", meaning, "All received OK, I have nothing more for you, see you again, no more now, best regards, good-bye, I am through with you and shall at once listen for other stations who may wish to call me. W1MK is now signing off."

W9CXX will come back with "I R GB AR . . .—.— W9CXX," meaning "I understand, received you OK, good-bye, I am through." Then he will listen a few minutes to see if anyone is calling him. He will listen particularly for the Texas stations and try to put the message through W5ZC or a neighboring station. If he does not hear someone calling him, he will listen for Texas stations and call them.

GETTING FILLS

Sometimes parts of a message are not received correctly or perhaps due to fading or interference there are gaps in the copy. The problem is to ask for "fills" or "repeats" in such a way as to complete the message as quickly as possible—and with the minimum of transmission.

The standard abbreviations indicated by the International Radiotelegraph Convention enable us to get "fills" briefly and easily. Only familiarity with the list of abbreviations is necessary that the proper choice be made.

If the first part of a message is received but substantially all of the latter portions lost, the request for the missing parts is simply RPT TXT AND SIG, meaning "Repeat text and signature". PBL and ADR may be used similarly for the preamble and address of a message. RPT AL or RPT MSG should not be sent unless nearly every bit of the message is lost.

Each abbreviation **used after a question** (. .—. .) asks for a repetition of that particular part of a message.

When a few word-groups in conversation or message handling have been missed or received incompletely, a selection of one or more of the following five abbreviations will enable you to ask for a repeat on the parts in doubt.

? AA . . . . ., repeat all after . . . .
? AB . . . . ., repeat all before . . . . . .
? AL. repeat all that has been sent.
? BN . . . . AND . . . ., repeat all between . . . . and . . . . .
? WA . . . ., repeat the word after . . . . . .
? WB . . . ., repeat the word before . . . . . .

The good operator will ask for only what fills are needed, separating different requests for repetition by using the "break" sign or double dash (—. . .—) between these parts. There is seldom any excuse for repeating a **whole** message just to get a few lost words.

Another "interrogation" method is sometimes used, the question signal (. .- -. .) being sent **between the last word received correctly** and the **first word** (or first few words) received after the interruption. RPT FROM . . . . . TO . . . . . is a long, clumsy way of asking for fills which we have heard used by beginners. These have the one redeeming virtue of being understandable.

The figure four (. . . .-) is a timesaving abbreviation which deserves popularity with traffic men. It is another of those hybrid abbreviations whose original meaning, "Please start me, where?" has come to us from Morse practise. Of course ?AL or RPT AL will serve the same purpose where a request for a repetition of parts of a message have been missed. While these latter usages are approved, the earlier practise is still followed by some operators.

Messages are often transmitted as many as three times at the request of the receiving operator. Failing to make a complete copy after three attempts, the receiving operator cancels the message (QTA) and the transmitting operator tries to relay the message through another station.

AUDIBILITY

The International Radiotelegraph Convention has agreed upon a Q Code of abbreviations for all services, also. Audibility is indicated by sending a figure (1 to 5) after the appropriate Q signal, to show progressive signal strength. QSA means, "The strength of your signals is . . . . ."

Thus one might say "QSA 3", the exact and literal meaning of which is "The strength of your signals is fairly good; readable, but with difficulty". The scale:

1—Hardly perceptible; unreadable.
2—Weak; readable now and then.
3—Fairly good; readable, but with difficulty.
4—Good; readable.
5—Very good; perfectly readable.

OPERATING HINTS

Listen carefully for several minutes before you use the transmitter to get an idea of what stations are working. This will help in placing messages where they belong.

Use abbreviations in operating conversations. This saves time and cuts down unnecessary interference.

Stand by (QRX) when asked to by another station who is having difficulty working through your interference. It is equally courteous to shift frequency (QSV) to a point where no interference will be caused. Sometimes a change in frequency will help the station you are working to get your message through interference. Accurate frequency meters at both stations will make this change speedy and the contact sure.

Report your messages to the local traffic official every month ON TIME. Otherwise you cannot expect a report to reach *QST*. Reports sent to Headquarters are routed back to the local officials who make up the monthly report.

Don't tell a fellow his signals are QSA5 when you can just hear him.

Don't say "QRM" or "QRN" when you mean "QRS".

Don't acknowledge any message until you have received it COMPLETELY.

Don't CQ unless there is definite reason for so doing. When sending CQ, use judgment. Sign your call frequently, interspersed with calls, and at the end of all transmissions.

Abbreviated standard procedure deserves a word in the interest of brevity on the air. If you hear some old timers using it you will understand what is meant by reading the following paragraph. In handling lots of messages with a number of scheduled stations, most traffic can be cleared by holding all stations to 15-minute schedules. Several schedules should be arranged in consecutive order. To get several messages through in 15 minutes isn't an easy job but abbreviated practises help to cut down unnecessary transmission.

W1AUF DE W1BMS P meaning paid, personal, or private message (adopted from commercial procedure) is much quicker than HR MSG added to a call. N QSK is shorter than QRU CU NEXT SKED. Instead of using the completely spelled out preamble HR MSG FM AUGUSTA MAINE W1BIG NR 156 OCTOBER 13 CK 14 TO etc. transmission can be saved by using RDO AUGUSTA ME W1BIG 156 OCT 13 14 TO etc. One more thing that conserves operating time is the cultivation of the operating practise of writing down 156 W1UE 615P 11 13 28 with the free hand during the sending of the next message. It is hard to do at first, but all these little points added together make the total time saved on a message mean something. Of course only stations handling many messages regularly need to think of abbreviations to this extent. If one follows standard practises, he is most sure of being understood and it is not necessary to waste time in explaining too-abbreviated messages in detail. Make it a rule not to abbreviate unnecessarily when working an altogether unknown station.

Be courteous over the air. Offer suggestions for improving the other fellow's note or operating methods. Expect and ask for similar suggestions without expecting any praise. Constructive things can be said without being disagreeable or setting one's self up as a paragon. Be truthful but tactful.

CALL BOOKS

One useful addition to every station is a good call book. When stations are heard or worked, the first thing that interests us is the location. If we have messages to be handled, it is absolutely necessary that we know the location of stations that we hear so that we may route our messages correctly.

Several call books are available for small sums of money. However, no call books are ever quite up-to-date because new stations are continually coming on the air and old stations occasionally drop out of existence and some changes have taken place in just the short time while an up-to-date list of calls is being set in type by the printer.

"Amateur Radio Stations of the United States" contains a list of the licensed amateur radio stations of this country. Experimental station or "X" calls are also listed. This may be obtained for 25c (not in stamps) from Superintendent of Documents, Government Printing Office, Washington, D. C. The yearly June edition is usually available about October first.

"Commercial & Government Radio Stations of the United States" gives lists of the various commercial stations together with naval and government licensed calls. This publication may be obtained for 15c (not in stamps) from Superintendent of Documents, Government Printing Office, Washington, D. C.

A complete list of Canadian amateur station calls can be obtained for twenty-five cents from the Department of Marine and Fisheries, Ottawa, Canada.

The Citizens' Radio AMATEUR Call Book, listing amateur and commercial stations of the entire world, may be obtained from Citizens Radio Service Bureau, 508 S. Dearborn St., Chicago. Single copies $1.00 (foreign $1.10). This callbook now appears in September, December and March, with new calls added up to the date of issue. Yearly subscription (three issues) $2.50.

Appendix

THE CONTINENTAL CODE

Letter or Figure	Symbol	Phonetic
A	.—	Dit darr
B	—...	Darr dit dit dit
C	—.—.	Darr dit darr dit
D	—..	Darr dit dit
E	.	Dit
F	..—.	Dit dit darr dit
G	——.	Darr darr dit
H	....	Dit dit dit dit
I	..	Dit dit
J	.———	Dit darr darr darr
K	—.—	Darr dit darr
L	.—..	Dit darr dit dit
M	——	Darr darr
N	—.	Darr dit
O	———	Darr darr darr
P	.——.	Dit darr darr dit
Q	——.—	Darr darr dit darr
R	.—.	Dit darr dit
S	...	Dit dit dit
T	—	Darr
U	..—	Dit dit darr
V	...—	Dit dit dit darr
W	.——	Dit darr darr
X	—..—	Darr dit dit darr
Y	—.——	Darr dit darr darr
Z	——..	Darr darr dit dit
1	.————	Dit darr darr darr darr
2	..———	Dit dit darr darr darr
3	...——	Dit dit dit darr darr
4	....—	Dit dit dit dit darr
5	.....	Dit dit dit dit dit
6	—....	Darr dit dit dit dit
7	——...	Darr darr dit dit dit
8	———..	Darr darr darr dit dit
9	————.	Darr darr darr darr dit
0	—————	Darr darr darr darr darr

Sign	Symbol	Phonetic
Period (.)	.. .. ..	Dit dit dit dit dit dit
Question (?)	..——..	Dit dit darr darr dit dit
Break (double dash) (=)	—...—	Darr dit dit dit darr
Exclamation (!)	——..——	Darr darr dit dit darr darr
Received (O.K)	.—.	Dit darr dit
Bar Indicating Fraction (Oblique stroke)	—..—.	Darr dit dit darr dit
Wait	.—...	Dit darr dit dit dit
Comma (,)	.—.—.—	Dit darr dit darr dit darr
Colon (:)	———...	Darr darr darr dit dit dit
Semicolon (;)	—.—.—.	Darr dit darr dit darr dit
Quotes (" ")	.—..—.	Dit darr dit dit darr dit
Parenthesis ( )	—.——.—	Darr dit darr darr dit darr
Attention Call to precede every transmission	—.—.—	Darr dit darr dit darr
End of each message (cross)	.—.—.	Dit darr dit darr dit
Transmission finished (end of work)	...—.—	Dit dit dit darr dit darr
Invitation to transmit (go ahead)	—.—	Darr dit darr

—— - - - ——

A dash is equal to three dots.

The space between parts of the same letter is equal to one dot.

The space between two letters is equal to three dots.

The space between two words is equal to five dots.

FOREIGN LETTERS

Letter	Symbol	Phonetic
Ä (German)	.—.—	Dit darr dit darr
Á or Å (Spanish-Scandinavian)	.——.—	Dit darr darr dit darr
CH (German-Spanish)	————	Darr darr darr darr

É (French)

. . — . . Dit dit darr dit dit

Ñ (Spanish)

— — . — — Darr darr dit darr darr

Ö (German)

— — — . Darr darr darr dit

Ü (German)

. . — — Dit dit darr darr

TESTING POLARITY

If no D.C. voltmeter or ammeter of suitable range with the terminals marked plus or minus is available, some other simple tests can be applied if one is in doubt about the polarity of a direct-current source. The two wires may be dipped in a weak salt-water solution or in a solution of hydrochloric, sulphuric or nitric acid. The larger quantity of bubbles (of hydrogen) will come from the *negative* terminal.

Some test paper may be prepared by getting a small quantity of the necessary chemicals from the local drug store. Dissolve one gram (1/28 oz.) of phenolphthalein in a little alcohol. Add this solution to 100 cubic centimeters (3.5 fluid oz.) of a 10-per-cent solution of potassium chloride in distilled water. Filter paper or other absorbent paper of the same texture and color should be soaked in the solution and dried, then cut into strips. A piece of this paper moistened with water and placed in a contact with the two wires will be stained a bright red at the *negative* terminal.

HDQ. INFORMATION FOR MEMBERS

The latest *official* and *special broadcasts* are sent simultaneously on 7150 and 3575 kc. (41.9 and 83.8 meters, from Headquarters Radio Station W1MK at the following times (E.S.T.); 8 p.m. Sunday, Monday, Tuesday, Thursday and Friday; 10 p. m. Monday and Friday; Midnight: Sunday, Tuesday and Thursday.

Q CODE

We have a new Q Code which includes all those meanings which we find it necessary to express with clearness and brevity in communication work. It is much longer and more complete than the previous code. In many cases it assigns utterly different meanings to familiar abbreviations. The old code must be forgotten and the new one learned. Here are the new meanings. It is of course understood that an abbreviation takes the form of the appropriate question when it is followed by a question mark.

Abbreviation	*Question*	*Answer*
QRA	What is the name of your station?	The name of my station is . . . .
QRB	At what approximate distance are you from my station?	The approximate distance between our stations is . . . . . . nautical miles (or . . . . . . kilometers).
QRC	By what private company (or government administration) are the accounts for charges of your station liquidated?	The accounts for charges of my station are liquidated by the . . . . private company (or by the government administration of . . . .).
QRD	Where are you going?	I am going to . . . . . .
QRE	What is the nationality of your station?	The nationality of my station is . . . .
QRF	Where do you come from?	I come from . . . .
QRG	Will you indicate to me my exact wave length in meters (or frequency in kilocycles)?	Your exact wave length is . . . . . . meters (or . . . . kilocycles).
QRH	What is your exact wave length in meters (frequency in kilocycles)?	My exact wave length is . . . . meters (frequency . . . . kilocycles).
QRI	Is my tone bad?	Your tone is bad.
QRJ	Are you receiving me badly? Are my signals weak?	I can not receive you. Your signals are too weak.
QRK	Are you receiving me well? Are my signals good?	I receive you well. Your signals are good.
QRL	Are you busy?	I am busy. Or, (I am busy with . . . . . .). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by atmospherics?	I am troubled by atmospherics.
QRO	Must I increase power?	Increase power.
QRP	Must I decrease power?	Decrease power.
QRQ	Must I send faster?	Send faster (. . . . . . words per minute).

Abbreviation	*Question*	*Answer*
QRS	Must I send more slowly?	Send more slowly (........ words per minute).
QRT	Must I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Must I send a series of V's?	Send a series of V's.
QRW	Must I advise .... that you are calling him?	Please advise .... that I am calling him.
QRX	Must I wait? When will you call me again?	Wait until I have finished communicating with .... I will call you immediately (or at .... o'clock).
QRY	Which is my turn?	Your turn is No. .... (or according to any other indication).
QRZ	By whom am I being called?	You are being called by ....
QSA	What is the strength of my signals (1 to 5)?	The strength of your signals is .... (1 to 5).
QSB	Does the strength of my signals vary?	The strength of your signals varies.
QSC	Do my signals disappear entirely at intervals?	Your signals disappear entirely at intervals.
QSD	Is my keying bad?	Your keying is bad. Your signals are unreadable.
QSE	Are my signals distinct?	Your signals run together.
QSF	Is my automatic transmission good?	Your automatic transmission fades out.
QSG	Must I transmit the telegrams by a series of 5, 10 (or according to any other indication)?	Transmit the telegrams by a series of 5, 10 (or according to any other indication).
QSH	Must I send one telegram at a time, repeating it twice?	Transmit one telegram at a time, repeating it twice.
QSI	Must I send the telegrams in alternate order without repetition?	Send the telegrams in alternate order without repetition.
QSJ	What is the charge to be collected per word for .... including your internal telegraph charge?	The charge to be collected per word for .... is .... francs, including my internal telegraph charge.
QSK	Must I suspend traffic? At what time will you call me again?	Suspend traffic. I will call you again at .... (o'clock).
QSL	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM	Have you received my acknowledgment of receipt?	I have not received your acknowledgment of receipt.
QSN	Can you receive me now? Must I continue to listen?	I can not receive you now. Continue to listen.
QSO	Can you communicate with .... directly (or through the intermediary of ....)?	I can communicate with .... directly (or through the intermediary of ......)
QSP	Will you relay to .... free of charge?	I will relay to .... free of charge.
QSQ	Must I send each word or group once only?	Send each word or group once only.
QSR	Has the distress call received from .... been attended to?	The distress call received from .... has been attended to by ....
QSU	Must I send on .... meters (or .... kilocycles) waves of type A1, A2, A3, or B?*	Send on .... meters (or on .... kilocycles), waves of Type A1, A2, A3 or B.* I am listening for you.
QSV	Must I shift to the wave of ...... meters (or of .... kilocycles), for the balance of our communications, and continue after having sent several V's?	Shift to wave of ......meters (or of .... kilocycles) for the balance of our communications and continue after having sent several V's.
QSW	Will you send on .... meters (or on .. kilocycles) waves of Type A1, A2, A3 or B?*	I will send on .... meters (or .... kilocycles) waves of Type A1, A2, A3 or B.* Continue to listen.
QSX	Does my wave length (frequency) vary?	Your wave length (frequency) varies.
QSY	Must I send on the wave of .... meters (or .... kilocycles) without changing the type of wave?	Send on the wave of .... meters (or .... kilocycles) without changing the type of wave.
QSZ	Must I send each word or group twice.	Send each word or group twice.

Abbreviation	*Question*	*Answer*
QTA	Must I cancel telegram No. .... as if it had not been sent?	Cancel telegram No. .... as if it had not been sent.
QTB	Do you agree with my word count?	I do not agree with your word count; I shall repeat the first letter of each word and the first figure of each number.
QTC	How many telegrams have you to send?	I have .... telegrams for you or for ....
QTD	Is the word-count which I am confirming to you accepted?	The word count which you confirm to me is accepted.
QTE	What is my true bearing? (or) What is my true bearing relative to?	Your true bearing is .. degrees (or) Your true bearing relative to .... is .... degrees at .... (o'clock).
QTF	Will you give me the position of my station based on the bearings taken by the radiocompass stations which you control?	The position of your station based on the bearings taken by the radiocompass stations which I control is .... latitude .... longitude.
QTG	Will you transmit your call signal for one minute on a wave length of .... meters (or .... kilocycles) in order that I may take your radiocompass bearing?	I am sending my call signal for one minute on the wave length of .... meters (or .... kilocycles) in order that you may take my radiocompass bearing.
QTH	What is your position in latitude and longitude (or according to any other indication)?	My position is .... latitude .... longitude (or according to any other indication).
QTI	What is your true course?	My true course is .... degrees.
QTJ	What is your speed?	My speed is .... knots, or .... kilometers per hour.
QTK	What is the true bearing of .... relative to you?	The true bearing of .... relative to me is .... degrees at .... (o'clock).
QTL	Send radio signals to enable me to determine my bearing with respect to the radio beacon.	I am sending radio signals to permit you to determine your bearing with respect to the radio beacon.
QTM	Send radio signals and submarine sound signals to enable me to determine my bearing and my distance.	I am sending radio signals and submarine sound signals to permit you to determine your bearing and your distance.
QTN	Can you take the bearing of my station (or of ....) relative to you?	I can not take the bearing of your station (or of ....) relative to my station.
QTP	Are you going to enter the dock (or the port)?	I am going to enter the dock (or the port).
QTR	What is the exact time?	The exact time is ....
QTS	What is the true bearing of your station relative to me?	The true bearing of my station relative to to you is .... at .... (o'clock).
QTU	What are the hours during which your station is open?	My station is open from .... to ....

*Waves are classified as follows in Art. 4, General Regulations. A1: unmodulated continuous waves, varied by telegraphic keying. A2: continuous waves modulated at audible frequency, with which is combined telegraphic keying. A3: continuous waves modulated by speech or by music. B: damped waves.—Editor.

MISCELLANEOUS ABBREVIATIONS

The following miscellaneous abbreviations now have universal agreement and should no longer be employed in other than the meanings specified, nor should other than the specified abbreviation be employed to convey any meaning listed in this table.

Abbreviation	*Meaning*
C.......	Yes.
N......	No.
P.......	Announcement of private telegram in the mobile service (to be used as a prefix).
W......	Word or words.
AA.....	"All after ...." (to be used after a question mark to request a repetition).
AB.....	"All before ...." (to be used after a question mark to request a repetition).
AL.....	"All that has just been sent" (to be used after a question mark to request a repetition)
BN.....	"All between ...." (to be used after a question mark to request a repetition).
BQ.....	Announcement of reply to a request for rectification.
CL.....	"I am closing my station."

Abbreviation	*Meaning*
CS.....	Call signal (to be used to ask repetition of a call signal).
DB.....	"I can not give you a bearing, you are not in the calibrated sector of this station."
DC.....	"The minimum of your signal is suitable for the bearing."
DF.....	Your bearing at .... (o'clock) was .... degrees, in the doubtful sector of this station, with a possible error of two degrees.
DG.....	Please advise me if you note an error in the bearing given.
DI.....	Bearing doubtful in consequence of the bad quality of your signals.
DJ.....	Bearing doubtful because of interference.
DL.....	Your bearing at .... (o'clock) was .... degrees in the doubtful sector of this station.
DO.....	Bearing doubtful. Ask for another bearing later, or at ...... (o'clock).
DP.....	Beyond 50 miles, possible error of bearing can attain two degrees.
DS.....	Adjust your transmitter, the minimum of your signal is too broad.
DT.....	I can not furnish you with a bearing; the minimum of your signal is too broad.
DY.....	This station is bilateral what is your approximate direction in degrees relative to this station?
DZ.....	Your bearing is reciprocal (to be used only by the central station of a group of radio-compass stations when it is addressed to other stations of the same group).
ER.....	"Here ......" (to be used before the name of the mobile station in the sending of route indications).
GA.....	"Resume sending" (to be used more especially in the fixed service).
JM.....	"If I may send, make a series of dashes. To stop my transmission, make a series of dots" (Not to be used on 600 meters (500 kilocycles).
MN....	Minute or minutes (to be used to indicate the duration of a wait).
NW....	"I resume transmission" (to be used more especially in the fixed service).
OK.....	"We are in agreement."
RQ.....	Announcement of a request for rectification.
SA.....	Announcement of the name of an aircraft station (to be used in the sending of indications of passage).
SF.....	Announcement of the name of an aeronautic station.
SN.....	Announcement of the name of a coast station.
SS.....	Announcement of the name of a ship station (to be used in the transmission of indications of passage).
TR.....	Announcement of the request or of the sending of indications concerning a mobile station.
UA.....	"Are we in agreement?"
WA.....	"Word after ......" (to be used after a question mark to request a repetition).
WB.....	"Word before ......" (to be used after a question mark to request a repetition).
XS.....	Atmospherics
YS.....	"See your service advice."
ABV....	"Shorten the traffic by using the International Abbreviations." or "Repeat (or I repeat) the figures in abbreviation form."
ADR...	Address (to be used after a question mark to request a repetition).
CFM...	"Confirm" or "I confirm."
COL....	"Collate" or "I collate."
ITP....	"The punctuation counts."
MSG...	Announcement of telegram concerning ship service only (to be used as a prefix).
PBL....	Preamble (to be used after a question to request a repetition).
REF....	"Referring to ......" or "Refer to ......"
RPT....	"Repeat" or "I repeat" (to be used to ask or to give repetition of all or part of the traffic by making the corresponding indication after the abbreviation).
SIG....	Signature (to be used after a question mark to request a repetition).
SVC....	Announcement of service telegram concerning private traffic (to be used as a prefix).
TFC....	Traffic.
TXT....	Text (to be used after a question mark to request a repetition).

HAM ABBREVIATIONS

In amateur work the following abbreviations are also used together with many other abbreviated words, usually composed "on the spur of the moment". Study of abbreviations brings to light some methods that may be followed in coining abbreviations.

1. A method much used in formulating abbreviations of short words is to give the first and last letters only, eliminating all intermediate letters in the word.

Examples: Now, nw; check, ck; would, wd.

2. Another method uses consonants only, eliminating all vowels in the word.

Examples: Letter, ltr; bound, bnd; message, msg; received, rcd.

3. A third method consists of using phonetic spelling.

Examples: Some, sum; good, gud; says, sez; night, nite.

4. Replacing parts of a word with the letter "X" is a method occasionally used in abbreviating.

Examples: Transmitter, xmtr; weather, wx; distance, dx; press, px.

ABL	Able
ABT	About
AC	Alternating Current
ACCT	Account
ACCW	Alternating current C.W. (Not rectified before application to plate circuit of transmitting tubes)
ADR-ADS-ADSD	Address-addressed
AER	Aerial
AGN	Again
AHD	Ahead
AMP	Ampere
AMT	Amount
ANI	Any
ANT	Antenna
ARL	Aerial
ART	All right
AST	Atlantic Standard Time (1 hour later than E.S.T.)
AUD	Audible, audibility
AUSSIE	Australian amateur
B	Be
B4	Before
BCL	Broadcast listener
BD	Bad
BI	By
BK	Break, back
BKG	Bookkeeping, breaking
BLV	Believe
BN	Been, all between
BND	Bound
BPL	Brass Pounders' League
BTR	Better
BUG	Vibroplex key, amateur radio "fever"
C	See, correct, yes
CANS	Phones
CHGS	Charges
CK	Check
CKS	Chokes, circuits
CKT	Circuit
CL-CLG-CLD	Call-calling-called, closing (station)
CM	Communications Manager
CN	Can
CNT	Can't, cannot
COND	Condenser, condition
CONGRATS	Congratulations
CP-CPSE	Counterpoise
CRD	Card
CST	Central Standard Time
CUD-CD	Could
CUL	See you later
CUM	Come
CW	Continuous wave
CY	Copy
DA	Day
DC	Direct current
DFS	Disregard former service
DH	Dead head, service message
DLD-DLVD	Delivered
DLY	Delivery
DN	Done, down
DNT	Do not, don't
DPR	Day Press Rate
DSTN	Destination
DSTC	Delivered subject to correction
DUPE	Duplicate
DX	Distance

ER(E)	Here
EM	Them
ES	And
EST	Eastern Standard Time
EVBDI	Everybody
EVY	Every
EZ	Easy
FB	Fine business, excellent
FIL	Filament
FLD-FLT	Filed, filing time
FM	From
FONES	Telephones
FR	For
FREQ	Frequency-frequently
GA	Go ahead (resume sending)
GB	Good-bye
GBA	Give better address
GE	Good evening
GEN	Generator
GES	Guess
GG	Going
GM	Good morning
GCT	Greenwich Civil Time
GN	Gone, good night
GND	Ground
GQA	Get quick answer
GSA	Give some address
GUD	Good
GV-GVG	Give-giving
HA	Hurry answer
HAM	Amateur, brass-pounder
HD	Had, head
HI	Laughter, high
HR	Here, hear
HRD	Heard
HV	Have
HVY	Heavy
HW	How, hot wire, herewith
HWM	Hot wire meter
I	I understand
ICW	Interrupted continuous wave
INPT	Input
IMPT	Important
KNW	Know
LD-LID	"Lid," a poor operator, long distance
LITE	Light
LTR	Later, letter
LW	Low
MA	Milliampere
MANI	Many
MG	Motor-generator
MGR	Manager
MILS	Milli-amperes
MI	My
MIN	Minute
MIM	Exclamation
MITY	Mighty
MK	Make
MO	Month, master oscillator
MST	Mountain Standard Time
MTR	Meter
N	Nil, nothing, no
ND	Nothing doing
NG	No good
NIL	Nothing
NITE	Night
NM	No more
NO	Know
NPR	Night Press Rate
NR	Number, near, no record
NSA	No such address
NT	Not
NTG	Nothing
NW	Now (I resume transmission)
NZ	New Zealand
OB	Old Boy, Official Broadcast
OFS	Office
OM	Old man
OO	Official Observer
OPN	Operation
OP-OPR	Operator
ORS	Official Relay Station
OSC	Oscillate, oscillations
OT	Oscillation transformer, old timer old top
OW	Old woman

PRI	Primary
PSE	Please
PST	Pacific Standard Time
PT	Point
PUNK	Poor operator, lid
PUR	Poor
PWR	Power
PX	Press (news)
R	Are, all right, O.K.
RAC	Rectified alternating current
RCD	Received
RCVR	Receiver
RDO	Radio
RDS	Reads
RES	Resistance
RHEO	Rheostat
RI	Radio Inspector
RITE	Write, right
RM	Route Manager
RPT	Repeat, report
RUF	Rough
SA	Say
SCM	Section Communications Manager
SEC	Second
SED	Said
SEZ	Says
SHUD	Should
SIG-SG	Signature
SIGS	Signals
SINE	Sign, personal initials, signature
SINK	Synchronous
SITE	Sight
SKED	Schedule
SORRI-SRI	Sorry
SPK	Spark, speak
SUM	Some
TC	Thermo couple
TDA	Today
TKS-TNX	Thanks
TNG	Thing
TMW	Tomorrow
TR	There, their, position report
TRI	Try
TRUB	Trouble
TS	This
T	The
TT	That
TU	Thank you
U	You
UNDLD	Undelivered
UNKN	Unknown
UR	Your, you're
URS	Yours
V	Volt
VAR	Variable
VC	Variable Condenser
VT	Vacuum tube
VY	Very
WD	Would, word
WDS	Words
WN-WEN	When
WI-WID	With
WK	Work, weak, week, well-known
WKD	Worked
WKG	Working
WL	Will
WN	When
WO	Who
WT	What, wait, watt
WUD	Would
WV-WL	Wave, wavelength
WX	Weather
XMTR	Transmitter
XCUSE	Excuse
XPLN	Explain
XTRA	Extra
YDA	Yesterday
YL	Young lady
YR	Your
ZEDDER	New Zealander
73	Best regards
88	Love and kisses
99	Keep out
2	Two, to, too
2DA	To-day
4	Please start me, where?, for, four
8	Eight, ate

QST AND QRR

It should be noted that QST and QRR are now unassigned in the official international list. CQ is now specified for *all* "general" calls having no special or emergency significance. A number of League members have concerned themselves with the problem of differentiating a general message addressed to all amateurs from a CQ sent by any number of stations desiring to establish communication with other stations not already engaged in communication. The best solution of this difficulty is the adoption of special abbreviations to clarify the calls sent addressed to all amateurs under ordinary circumstances or in emergencies. At the same time Q abbreviations must not duplicate or conflict with any of those in the *international* list, which is prohibited to prevent general confusion. Please note carefully the following special abbreviations adopted by the A. R. R. L.:

QST	General call preceding a message addressed to all amateurs and A. R. R. L. members. This is in effect "CQ ARRL."
QRR	Official A.R.R.L. "land SOS." A distress call for emergency use *only*.

Z SIGNALS

The U. S. Naval Communication Service has a special parlance of its own. Z signals having similar and in some cases nearly identical meanings to the Q signals (which were authorized for use in commercial work by the Washington Convention) are used. A list is not presented here as it is outside the field of amateur radio work and chiefly of interest to members of the Naval Communication Service. The Radio Corporation of America's high power stations handling commercial messages over great distances have and use a similar set of Z signals to which different special meanings are assigned.

INTERNATIONAL PREFIXES

A complete list of the prefixes assigned to different countries by the International Radiotelegraph convention will enable one to identify the nationality of *all* calls heard on the air, with the possible exception of a few signals from those few nations of the earth not subscribing to the conference.

Nations are obliged to select some letter or letters from their assignment to use as a prefix to amateur calls. The remainder of the call commonly consists of a numeral and two or more letters.

Before amateurs were recognized by international conferences, a system of "international intermediates" was used between the call signals of the called and of the calling station, to indicate nationality. Each country where there were amateurs subscribing to the International Amateur Radio Union agreed to use a set of two-letter "intermediates." Each country's intermediate consisted of two letters, the first indicating the continent and the second the country within that continent.

Now that amateurs have official international recognition, these "intermediates" are being supplanted by the official prefixes, determined by international agreement. The prefixes supplement the previous arrangement just as fast as governmental action is taken in the different countries following the signing of the I. R. C. at Washington in 1927. The provisions of the convention were effective in all countries January 1, 1929. Occasionally one may still hear one of the old I. A. R. U. "intermediates" on the air, from some country which has not yet officially assigned a prefix to its amateurs, but all amateurs now use "*de*" for an intermediate and the old I. A. R. U. assignments, when now used at all, appear as the prefix to the call. Thus, for example, the government of China has not indicated what prefix its amateurs should use, and amateurs in China may still be heard using the letters "ac" as the initial letters of their calls, a relic of the old I. A. R. U. intermediate for that country.

In accordance with the calling practice given in the chapter on "Operating a Station," an example is given of the procedure used by an Alaskan amateur in calling a station in the continental United States, using the prefixes that have been listed. Note that the prefix W or K is always part of the call signal itself. Example: W7TX W7TX W7TX DE K7AER K7AER K7AER AR.

In the full list of countries which follows, the first column lists the allocation of call signals made in the Washington Convention. Every call of a nation must be taken from the block of letters assigned it. Thus this list is useful in identifying the nationality of any call heard, whether amateur or not. In the second column the amateur prefixes, the beginning letters of amateur calls, are listed. In most cases we know these prefixes to have been officially designated by the government concerned, but in some cases we have listed, of our own initiative, the proper prefix when there can be no choice about it. For instance, Haiti is assigned the calls from HHA to HHZ and therefore every Haitian call must begin with the letters HH, whether that government so proclaims or not. In a few cases blanks are shown, where there is some choice and the government concerned has not acted. For instance, one does not know, until Colombia acts, whether Colombian amateur calls will commence with HJ or HK. Where a prefix is shown in brackets, it indicates that that government has more than one assignment of initial letters and that the indicated letter will be found assigned, in another part of the list, to that country.

The list follows:

CAA-CEZ	CE	Chila
CFA-CKZ	[VE]	Canada
CLA-CMZ	CM	Cuba
CNA-CNZ	CN	Morocco, Algeria, Tunisia
CPA-CPZ	CP	Bolivia
CRA-CRZ	CR	Portuguese colonies
CSA-CUZ	CT	Portugal
CVA-CVZ	CV	Rumania
CWA-CXZ	CW	Uruguay
CZA-CZZ	CZ	Monaco
D	D	Germany
EAA-EHZ	EAR	Spain
EIA-EIZ	EI	Irish Free State
ELA-ELZ-	EL	Liberia
ESA-ESZ	ES	Esthonia
ETA-ETZ	ET	Ethiopia (Abyssinia)
F	F	France (including colonies)
	FI	French Indo-China
G		Great Britain
	G	Great Britain except Ireland
	GI	Northern Ireland
HAA-HAZ	HA	Hungary
HBA-HBZ	HB	Switzerland
HCA-HCZ	HC	Ecuador
HHA-HHZ	HH	Republic of Haiti
HIA-HIZ	HI	Dominican Republic
HJA-HKZ	---	Republic of Colombia
HRA-HRZ	HR	Republic of Honduras
HSA-HSZ	HS	Siam
I	I	Italy and colonies
J	J	Japan
K		United States of America
	K1	Philippine Ids.
	K4	Porto Rico and Virgin Ids.
	K6	Territory of Hawaii
	K7	Alaska
LAA-LNZ	LA	Norway
LOA-LVZ	LU	Argentine Republic
LZA-LZZ	LZ	Bulgaria
M	[G]	Great Britain
N	[W]	United States of America
OAA-OBZ	OA	Peru
OHA-OHZ	OH	Finland
OKA-OKZ	OK	Czechoslovakia
ONA-OTZ	ON	Belgium and colonies
OUA-OZZ	OZ	Denmark
PAA-PIZ	PA PB PC	The Netherlands
PJA-PJZ	PJ	Curacao
PKA-POZ	PK	Dutch East Indies
PPA-PYZ	PY	Brazil
PZA-PZZ	PZ	Surinam
RAA-RQZ	RA	U.S.S.R. ("Russia")
RVA-RVZ	RV	Persia
RXA-RXZ	RX	Republic of Panama
RYA-RYZ	RY	Lithuania
SAA-SMZ	SM	Sweden
SPA-SRZ	SP	Poland
SUA-SUZ	SU	Egypt
SVA-SZZ	---	Greece
TAA-TCZ	---	Turkey
TFA-TFZ	TF	Iceland
TGA-TGZ	TG	Guatemala
TIA-TIZ	TI	Costa Rica

TSA-TSZ	TS	Territory of the Saar Basin
UHA-UHZ	UH	Hedjaz
UIA-UKZ	[PK]	Dutch East Indies
ULA-ULZ	UL	Luxemburg
UNA-UNZ	UN	Kingdom of the Serbs, Croats and Slovenes (Yugoslavia)
UOA-UOZ	UO	Austria
VAA-VGZ	VE	Canada
VHA-VMZ	VK	Commonwealth of Australia
VOA-VOZ	VO	Newfoundland
VPA-VSZ		British colonies and protectorates
	VP	Kenya Colony
	VQ	Northern Rhodesia
	VS	Straits Settlements
VTA-VWZ	VT-VU	British India
W ·	W	United States of America continental
XAA-XFZ	X[1]	Mexico
XGA-XUZ	(AC)[2]	China
YAA-YAZ	YA	Afghanistan
YHA-YHZ	YH	New Hebrides
YIA-YIZ	YI	Iraq
YLA-YLZ	YL	Latvia
YMA-YMZ	YM	Free City of Danzig
YNA-YNZ	YN	Nicaragua
YSA-YSZ	YS	Republic of El Salvador
YVA-YVZ	YV	Venezuela
ZAA-ZAZ	ZA	Albania
ZKA-ZMZ	ZL	New Zealand
ZPA-ZPZ	ZP	Paraguay
ZSA-ZUZ	ZS, ZT, ZU	Union of South Africa

Note 1—Improperly assigned by Mexico. Should have two letters, to distinguish from China.

Note 2—Unofficial prefix, heritage from I. A. R. U. "intermediates," still used by amateurs in China. They would be better advised to use XG, which would establish nationality.

MEASURING DISTANCES ACCURATELY

Oftentimes it is interesting to know just how far away some station is located. In measuring distances it is customary to measure along the shortest path on the surface of the earth. This distance is along the arc of a Great Circle and for very short distances it is practically a straight line.

The only requirements are: the geographical positions of the two places; the ability to substitute these angles in the formulas that will be given; sufficient knowledge of Logarithmic and Trigonometric Tables to find the values of the functions given in the formulas; and finally, the comparatively rare ability to follow directions accurately, and to work without errors.

Geographical position is given as the latitude and longitude of the place expressed in degrees, minutes and seconds of arc. The seconds may be neglected in this kind of a problem. The latitudes, and the difference of the longitudes give two sides and the included angle of a spherical triangle, from which the side opposite the known angle can be computed; which is the distance between the places expressed in degrees and minutes. Since one minute of arc equals one nautical mile, (often wrongly called a knot), if the degrees are multiplied by 60 and the minutes added, we have the distance in sea miles; and since one sea mile equals 1.15 statute miles we have only to multiply again by this figure to get the answer we require.

There will be four possible cases:

1. Latitudes of the same name, that is, both north or both south, and the longitude difference less than 90°.
2. Latitudes of opposite names, one north and one south, and the longitude difference less than 90°.
3. Latitudes of the same name, and the longitude difference greater than 90°.
4. Latitudes of opposite names, and the longitude difference greater than 90°.

The first step is to find the longitude difference by subtracting the less from the greater if both are east or both west. If one is east and the other west, add them. If the sum is less than 180°, use it; if the sum is greater than 180°, subtract it from 360° and use the remainder.

Let a = the latitude of the place nearer the pole.
(You may work from either pole.)
b = the latitude of the other place.
C = the longitude difference.
c = the distance required.

CASE 1

It is required to find the distance between San Francisco, 37° 48′ North, 122° 23′ West, and an island in the Pacific at 14° 02′ North, 171° 20′ West. Here a = 37° 48′, b = 14° 02′, and C = 48° 57′.

$$\cos c = \sin a \sin b + \cos a \cos b \cos C$$

log sin 37° 48′ = 9.78739
" 14° 02′ = 9.38469

antilog of 9.17208 = 0.14862

log cos 37° 48′ = 9.89771
" 14° 02′ = 9.98684
" 48° 57′ = 9.81738

antilog of 9.70193 = 0.50342

The angle whose Nat cos is 0.65204 is 49° 18′.
Then (49 x 60) + 18 = 2958 nautical miles or 3406 statute miles.

CASE 2

Required: the distance between a point in 37° 48′ N, 139° 43′ W, and another place in 14° 02′ S, 171° 20′ E. The sum of the longitudes is 311° 03′, which subtracted from 360° leaves 48° 57′. Here the values of a, b, and C are the came as in Case 1, but because the latitudes are of opposite name the formula now becomes,

$$\cos c = \cos a \cos b \cos C - \sin a \sin b$$

log cos 37° 48′ = 9.89771
" 14° 02′ = 9.98684
log cos 48° 57′ = 9.81738

antilog of 9.70193 = 0.50342

log sin 37° 48′ = 9.78739
" 14° 02′ = 9.38469

antilog of 9.17208 = –0.14862

The angle whose Nat cos is 0.35480 is 69° 13′
Then (69 x 60) + 13 = 4153 nautical miles or 4782 statute miles.

If b and C become large enough, the second term will become larger than the first so that the difference will become negative. In this event the angle taken from the tables must be subtracted from 180° and this remainder will be the distance required. For example: if the two latitudes were 37° 48′ N and 37° 40′ S, and the longitude difference 85°, cos c would be –0.29808, the angle corresponding to which is 72° 39′ and this subtracted from 180° leaves 107° 21′, which is the distance required.

CASE 3

Required: the distance between a point in 52° 30′ N, 14° 50′ E, and another place in 18° 30′ N, 149° 20′ E. The longitude difference is 134° 30′. Our tables of functions of angles do not cover angles more than 90°, so that we must subtract 90° from this, which leaves 44° 30′ as the value of C in the formula. Also we must take out the sine of C instead of the cosine, and put the minus sign before this term in the formula. We have then, a = 52° 30′, b = 18° 30′, C = 44° 30′.

cos c = sin a sin b — cos a cos b sin C
log sin 52° 30′ = 9.89947
" 18° 30′ = 9.50148

antilog of 9.40095 = 0.25174

log cos 52° 30′ = 9.78445
" 18° 30′ = 9.97696
log sin 44° 30′ = 9.84566

antilog of 9.60707 = –0.40464

The angle whose Nat cos is -0.15290 is 81° 12′, which must be subtracted from 180° because of the minus sign, leaving 98° 48′. Then (98 x 60) + 48 = 5928 nautical, or 6826 statute miles, is the distance required.

CASE 4

Required: the distance between a point in 52° 30′ N, 14° 50′ E, and another place in 18° 30′ S, 149° 20′ W. The longitude difference is 164° 10′, from which 90° must be subtracted as in Case 3, so that C = 74° 10′ while a = 52° 30′ and b = 18° 30′. Since the latitudes have opposite names the sine term of the formula becomes negative, as in Case 2; and since the longitude difference is more than 90° the cosine term becomes negative, as in Case 3, and the formula now is,

cos c = -sin a sin b – cos a cos b sin C
log sin 52° 30′ = 9.89947
" 18° 30′ = 9.50148

antilog of 9.40095 = – 0.25174

log cos 52° 30′ = 9.78445
" 18° 30′ = 9.97696
log sin 74° 10′ = 9.98320

antilog of 9.74461 = –0.55540

The angle whose Nat cos is –0.80714 is 36° 11′, which must be subtracted from 180° as in Case 3, leaving 143° 49′. Then (143 x 60) + 49 = 8629 nautical, or 9936 statute miles, is the distance required.

All these formulas have been derived from the one fundamental sine-cosine expression of spherical trigonometry, transformed to suit the individual cases, as follows:

cos c = cos a cos b + sin a sin b cos C.

C is the angle at the pole between the two meridians that pass through the two places, a and b being the lengths along the meridians from the pole to the places; in other words, their polar distances. The latitudes, being measured from the Equator must be subtracted from 90° to get the polar distances, or, what is the same thing, we may use them as given if we take the complimentary function values from the tables, provided all the angles are less than 90°. Our formula for Case 1 therefore becomes:

cos c = sin a sin b + cos a cos b cos C.

In Case 2, we have one side greater than 90° by just the amount of latitude given. In this Case the angle C was at the north pole, and the south latitude was 14° 02′, which is distant from the north pole 90° to the Equator plus 14° 02′, or 104° 02′, and the cosine of 90° + 14° 02′ equals -sin 14° 02′; also sin (90° + 14° 02′) equals cos 14° 02′; and the formula becomes:

cos c = – sin a sin b + cos a cos b cos C.

In Case 3, the angle at the pole is greater than 90°. As stated in the preceding paragraph, cos (90° + x) = –sin x; hence 90° was subtracted from the longitude difference, sin (C – 90°) was taken from the tables, and the second term was given the minus sign, which made the formula:

$$\cos c = \sin a \sin b - \cos a \cos b \sin (C - 90°).$$

In Case 4, the first term is the same as that term in Case 2, and the second term is the same as that term in Case 3, for the same reasons. The formula then is:

$$\cos c = -\sin a \sin b - \cos a \cos b \sin (C - 90°).$$

By using these four formulas as directed, the distance between any two points on the Earth's surface can be computed.

Good maps are convenient for measuring distances quickly and with a fair degree of accuracy. A large map with circles drawn having radii suitable to the scale of the map and your own station as a center, is the best to use. When another station is located on the map, the distance can be estimated at once by noting just which circles it lies between.

TIME CONVERSION

From time to time we become interested in making and keeping schedules for tests or traffic handling with foreign amateurs, or with stations in some other part of our own great country. Test schedules are often printed or distributed in mimeographed form and the time specified is usually that of the place where the station doing the testing is located. Occasionally the time is changed to Greenwich Time. Perhaps it is stated in 75th Meridian Time. When we are listening to some of the long-wave arc and alternator stations we often pick up time signals sent on local standard time. So whatever we do, sooner or later we will need to convert schedules to or from our local time to take advantage of them.

For your use we are including a convenient conversion table which shows the time in different parts of the world. Every fifteen degrees of longitude corresponds to one hour time difference. The use of the table is self-explanatory.

Time is usually reckoned by the nearest meridian of longitude. Every 15° of longitude corresponds to one hour of time. The "zero" meridian passes through the Greenwich (England) Observatory and international time is usually in terms of "Greenwich Time". Government departments concerned with time designation usually refer tests to a specified time by using a "zone" system. Each 15° of longitude constitutes a "zone" starting with the "zero" meridian (Greenwich) as Zone 0. Eastern Standard Time is referred to as ZONE PLUS 5 time. Pacific Standard Time is ZONE PLUS 8 time and so on. In the Western hemisphere time zones are plus. In the Eastern hemisphere time zones are "minus". For convenience and to avoid confusion tests are sometimes specified on the basis of numbering the hours like the dial of an Italian clock, from "1" to "24". The day starts with midnight which is the "zero", 0000. One o'clock in the morning Eastern Standard Time (75th meridian time) is 0100 E.S.T. and 11:30 p.m. E.S.T. is 2330 E.S.T. by the same designation. As we travel eastward, we will meet the rising sun. Time gets later and later. When New York time is Friday night 2330 E.S.T., London time will be five hours later or 0430 Greenwich Time Saturday morning. The letters AST, EST, CST, MST, and PST stand for Atlantic, Eastern, Central, Mountain and Pacific Standard Time.

TIME AND DAY CONVERSION TABLE

Longitude	Place					TODAY													TOMORROW						
EAST 180	Fiji Islands	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11
165	New Zealand (*)	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10
150	Australia, east	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9
135	Japan	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8
120	China, Philippines	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7
105	Indo China, Straits Settlements	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6
90	Calcutta (**)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5
75		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4
60	Mauritus, Seychelles	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3
45	Aden, Somaliland, Madagascar	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2
30	South Africa	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1
15	Germany, Italy, Norway, Sweden	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0
0	England, France, G.M.T.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
15		23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
30		22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
45	Brazil, east	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
60	Agentina, Porto Rico	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
75	Washington, D. C., E.S.T.	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
90	Chicago, C.S.T	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
105	Denver, M.S.T.	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
120	San Francisco, P.S.T.	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
135		15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
150	Alaska	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13
165	Samoa, Hawaii (***)	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12
WEST 180		12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11

YESTERDAY TODAY

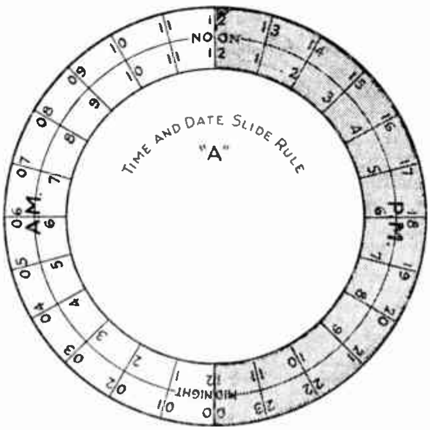
NOTES:—(*) Add one-half hour for New Zealand Time.
(**) Calcutta local time Subtract one-half hour for India Standard Time.
(***) Subtract one-half hour for Hawaiian Standard Time.

NOTES:—0 is midnight, 1 is 1.00 A.M., etc. 12 is noon, 13 is 1.00 P.M., 15 is 3.00 P.M., etc.
Read the figure columns vertically, thus:—when it is 12, noon on Monday in New York E.S.T., it is 3 00 A.M. on Tuesday in Melbourne, Australia.
Or again; 11.00 P.M. on Sunday in San Francisco is 6.30 P.M. on Monday in New Zealand and 5.00 P.M in Australia.
The hours of darkness—6 P.M. to 6 A.M. are shaded

CIRCULAR TIME-AND-DATE CHART

A method of comparing different times with each other and with G.C.T. (Greenwich Civil Time) is necessary to get time, weather, and press schedules, announced in almost every case in local time. In the chart shown, the two discs A and B should be drawn carefully and mounted on cardboard. When centered and pinned together we have a convenient device to use in working international schedules and in checking QSL-cards. The chart is based on the fact that time changes an hour for each 15° of arc.

To find local time from a given G.C.T. simply set the G.C.T. mark on the given time and read the local time directly at its mark. Let us take an example. Set the G.C.T. mark at 00 G.C.T. Then by direct reading it is 6 p.m. Chicago time or 9 a.m. Tokio time. If we in Tokio wanted to find what time it was in New York at 6 p.m. Tokio time we would set the Tokio pointer at 6 p.m. and read 4 a.m. for N. Y. time.



Finding dates: Suppose an operator in Los Angeles works a station in Tokio at 11 p.m. P.S.T. on June 10. Then the slide rule shows that it will be 4 p.m. Tokio time. The next thing is to find whether it is *today* or *tomorrow* in Tokio, that is June 10th or 11th. Now with the rule all set we run our eye around it in a *clockwise* direction *from* Los Angeles *to* Tokio. If at any point in that space the Midnight mark on disc "A" is encountered it is *tomorrow* in Tokio, i.e. June 11th. If the Midnight mark is not countered in this space it is *today* in Tokio. For example: Suppose the Los Angeles station works the station in Tokio at 1 a.m. P.S.T. June 10th. Then the Los Angeles operator will know from the slide rule that it is 6 p.m. June 10th Tokio time.

Let us work from the Eastern Hemisphere back to the Western. Suppose the operator at the Tokio station is doing the figuring. He works the Los Angeles station let us say at 9 p.m. June 15, Tokio time. He wants to know what time it is in Los Angeles and also what the date is. He sets the rule to 9 p.m. Tokio time and finds at once that it is 4 a.m. in Los Angeles. Now for the date. He reads around disc "B" From Tokio to Los Angeles in a *clockwise* direction. Notice that it is always clockwise from the local station to the distant station. If any place in that path the midnight mark is encountered it is *today* in Los Angeles, in other words June 15th. It would be 8 a.m. Los Angeles time, and since the midnight mark is not encountered between the two, in a clockwise direction from Tokio to Los Angeles, it is *yesterday* in Los Angeles, i.e. June 14th.

Now to find the difference in dates between two stations in the same hemisphere. Consider that half of the disc "B" and disregard the other half altogether. If the midnight mark does not come between them, within that semicircle, they are both *today*. If, however, the midnight mark comes in between them the one to the right is one day ahead of the one to the left, or inversely, the one to the left is a day behind the one to the right.

GOOD BOOKS

For further information on radio principles, for advanced theory, and for preparation for commercial licenses, we suggest reference to some good books that will prove both interesting and helpful.

Robison's Manual of Radio Telegraphy and Telephony contains more advanced information and data on tube transmission and reception than any other modern work;

it is an exhaustive and authoritative work. While originally intended as a Navy textbook, and therefore not treating specifically with station-building, it does cover thoroughly the principles that underlie radio communication. This book also contains good operating data and useful tables for the radio man. It is well worth the price of $4.00.

The Principles of Radio Communication, by J. H. Morecroft, has for years been a standard text for radio and tube theory. It is an engineering work primarily and the reader will need a fair amount of mathematics to assimilate it. The price is $7.50.

For the experimenter there is nothing to surpass the latest edition of Ramsey's *Experimental Radio,* which contains a wealth of information on radio experiments and measurements. The price is $2.75.

The man interested in obtaining a commercial license will find the necessary information in *Radio Theory and Operating* by Loomis, price $3.50; *The Radio Manual* by Sterling, price $6.00; and *Practical Radio Telegraphy* by Nilson and Hornung, price $3.00. The first two mentioned contain the 1929 regulations. All are excellent for the commercial radio operator, or the man training to be one.

Van der Bijl's *Thermionic Vacuum Tube* is the best text available for studying the theory of operation of vacuum tubes in various circuits. It is strictly an engineering work, and will hardly do for the beginner. The price is $5.00. Another good book on radio principles is *Radio Engineering Principles* by Lauer and Brown, priced at $3.50.

A good book on principles for the beginner at a low cost is *The Principles Underlying Radio Communication,* which can be obtained for $1.00 in coin or bill (no stamps or checks) from the Superintendent of Documents, Government Printing Office, Washington, D. C. *Radio Instruments and Measurements,* Circular No. 74 of the Bureau of Standards, can be obtained from the same source for sixty cents, and is a valuable reference work for radio formulas, measurements, etc.

Any of the books mentioned above (except the last two) may be obtained from the Book Department of the A.R.R.L. at the prices given.

QST is the official organ of the American Radio Relay League. It is published monthly, containing up-to-date information and telling all about the latest developments in amateur radio. *QST* is a magazine devoted exclusively to the radio amateur. Written by and for the amateur, it contains knowledge supplementary to the books we have mentioned. *QST* is found on the bookshelves of earnest amateurs and experimenters everywhere. Good books are a worth-while investment. A subscription to *QST* is equally valuable.

THE AMATEUR'S BOOKSHELF

INDUCTANCE CALCULATION

The lumped inductance of coils for transmitting and receiving is fairly easy to calculate.

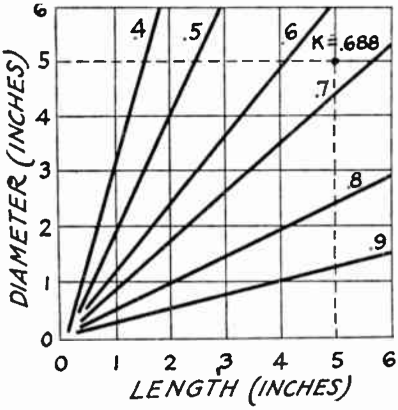
$$L = \frac{.0395\ a^2\ n^2}{b} K$$

(for single layer solenoids)

Where L is the inductance in microhenries
n is the number of turns
a is the mean radius of the coil (cm.)
b is the length of coil (cm.) = nD
D is the distance between the centers of two adjacent turns
K is the coil shape factor depending on the ratio 2 a/b (see chart).

Start with the given coil diameter. Using the overall length of the coil find a value for "K". If the diameter is 5" and the length 5" go to the right from "5" on the diameter scale. At the same time go "up" from "5" on the length scale. Notice where the two lines meet. They meet at "X" between the lines "6" and "7". We estimate the value of "K" at .688 and proceed.

Assume a transmitting coil having 10 turns of ¼" brass strip, flatwise wound,



FINDING "K"

5" diameter (6.35 cm. radius), and spaced ¼" between turns, making the overall length (nD) 12.7 cm.

$a = 6.35 \qquad \frac{2a}{b} = 1$

$n = 10.$

$b = 12.7$

K is about .688 (from chart)
(Dia. and length each are 5")

$$L = \frac{.0395\,(6.35)^2\,(10)^2}{12.7}\,.688 = 8.64 \text{ micro-henries.}$$

TUBE REACTIVATION

When the filament emission of "XL"-filament tubes becomes reduced from many hours of normal use or from operation at excessive plate voltage and plate current (this happens most often due to misadjustment or overloading of the transmitter) it is necessary to run the tubes at a higher filament voltage than normal for some time *with the plate voltage off* and the grid disconnected. This process tends to bring active thorium to the surface of the filament, renewing the available electron supply under operating conditions.

XL-filament tubes (having thoriated filaments) must be differentiated from tubes having oxide-coated filaments (Western Electric) which cannot be reactivated. In long-continued normal operation there is a gradual decrease in the plate current resulting in gradually decreasing output. The old types of tungsten-filament (bright) tubes have a more limited emission remaining constant until burn-out of the filament. XL-filament tubes may still glow at their normal dull brilliancy after continued use and after the electron emission is practically zero. They may be reactivated several times, doubling or tripling tube life.

Various "reactivators" on the market differ somewhat as to the flashing voltage and time and the subsequent ageing voltage and time. Tubes of similar type made by different concerns also differ somewhat in filament characteristics. The tubes must be connected in a circuit so that the cooking or ageing process at once follows flashing. While flashing and cooking are recom-

(Concluded on Page 197)

NUMBERED DRILL SIZES

Number	Diameter (mils)	Will clear screw	Drilled for tapping iron, steel or brass*
1	228.0	—	—
2	221.0	12-24	—
3	213.0	—	14-24
4	209.3	12-20	—
5	205.5	—	—
6	204.0	—	—
7	201.0	—	—
8	199.0	—	—
9	196.0	—	—
10	193.5	10-32	—
11	191.0	10-24	—
12	189.0	—	—
13	185.0	—	—
14	182.0	—	—
15	180.0	—	—
16	177.0	—	12-24
17	173.0	—	—
18	169.5	8-32	—
19	166.0	—	12-20
20	161.0	—	—
21	159.0	—	10-32
22	157.0	—	—
23	154.0	—	—
24	152.0	—	—
25	149.5	—	10-24
26	147.0	—	—
27	144.0	—	—
28	140.5	6-32	—
29	136.0	—	8-32
30	123.5	—	—
31	130.0	—	—
32	116.0	—	—
33	113.0	4-36 4-40	—
34	111.0	—	—
35	110.0	—	6-32
36	106.5	—	—
37	104.0	—	—
38	101.5	—	—
39	099.5	3-48	—
40	098.0	—	—
41	096.0	—	—
42	093.5	—	4-36 4-40
43	089.0	2-56	—
44	086.0	—	—
45	082.0	—	3-48
46	081.0	—	—
47	078.5	—	—
48	076.0	—	—
49	073.0	—	2-56
50	070.0	—	—
51	067.0	—	—
52	063.5	—	—
53	059.5	—	—
54	055.0	—	—

* Use one size larger drill for tapping bakelite and hard rubber.

WIRE TABLE

Gauge No. B.&S.	Diam. in mils.*	Diam. in m m.	Cross-sectional area Cir. mils	Sq. inches	Sq. m m.	Turns per linear inch D.C.C.	S.C.C.	Enamel	Feet per pound (copper) D.C.C.	S.C.C.	Bare	Resistance of wires (ohms per 1000 ft) Copper**	Advance (approx)	Copper wire carrying capacity (amperes) at 1000 C.M. per amp	at 1500 C.M. per amp
0000	460.0	11.68	211600	.1662	107.2	......	......	....	....	....	1.561	.0499	....	211.6	140.7
000	409.6	10.40	167800	.1318	85.03	......	......	....	....	....	1.968	.0629	....	167.8	111.3
00	364.8	9.266	133100	.1045	67.43	......	......	....	....	....	2.482	.0793	....	133.1	88.9
0	324.9	8.252	105500	.08289	53.48	......	......	....	....	....	3.130	.1000	....	105.5	70.3
1	289.3	7.348	83690	.06573	42.41	......	......	....	....	....	3.947	.1260	....	83.7	55.7
2	257.6	6.544	66370	.05213	33.63	......	......	....	....	....	4.977	.1592	....	66.4	44.1
3	229.4	5.827	52640	.04134	26.67	......	......	....	....	....	6.276	.2004	....	52.6	35.0
4	204.3	5.189	41740	.03278	21.15	......	......	....	....	....	7.914	.2536	....	41.7	27.7
5	181.9	4.621	33100	.02600	16.77	......	......	....	....	....	9.980	.3192	8.88	33.1	22.0
6	162.0	4.115	26250	.02062	13.3	5.44	5.60	....	....	....	12.58	.4028	11.21	26.3	17.5
7	144.3	3.665	20820	.01635	10.55	6.08	6.23	....	....	....	15.87	.5080	14.19	20.8	13.8
8	128.5	3.264	16510	.01297	8.36	6.80	6.94	....	19.6	19.9	20.01	.6405	17.9	16.5	11.0
9	114.4	2.906	13090	.01028	6.63	7.64	7.68	....	24.6	25.1	25.23	.8077	22.6	13.1	8.7
10	101.9	2.588	10380	.008155	5.26	8.51	8.55	....	30.9	31.6	31.82	1.018	28.0	10.4	6.9
11	90.74	2.305	8234	.006467	4.17	9.58	9.60	....	38.8	39.8	40.12	1.284	35.5	8.2	5.5
12	80.81	2.053	6530	.005129	3.31	10.62	10.80	....	48.9	50.2	50.59	1.619	44.8	6.5	4.4
13	71.96	1.828	5178	.004067	2.62	11.88	12.06	....	61.5	63.2	63.80	2.042	56.7	5.2	3.5
14	64.08	1.628	4107	.003225	2.08	13.10	13.45	14.	77.3	79.6	80.44	2.575	71.7	4.1	2.7
15	57.07	1.450	3257	.002558	1.65	14.68	14.90	16.	97.3	100	101.4	3.247	90.4	3.3	2.2
16	50.82	1.291	2583	.002028	1.31	16.40	17.20	18.	119	124	127.9	4.094	113.0	2.6	1.7
17	45.26	1.150	2048	.001609	1.04	18.10	18.80	21.	150	155	161.3	5.163	145.0	2.0	1.3
18	40.30	1.024	1624	.001276	.82	20.00	21.00	23.	188	196	203.4	6.510	184.0	1.6	1.1
19	35.89	.9116	1288	.001012	.65	21.83	23.60	27.	237	247	256.5	8.210	226.0	1.3	.86
20	31.96	.8118	1022	.0008023	.52	23.91	26.40	29.	298	311	323.4	10.35	287.0	1.0	.68
21	28.46	.7230	810.1	.0006363	.41	26.20	29.70	32.	370	389	407.8	13.05	362.0	.81	.54
22	25.35	.6438	642.4	.0005046	.33	28.58	32.00	36.	461	491	514.8	16.46	460.0	.64	.43
23	22.57	.5733	509.5	.0004002	.26	31.12	34.30	40.	584	624	648.4	20.76	575.0	.51	.34
24	20.10	.5106	404.0	.0003173	.20	33.60	37.70	45.	745	778	817.7	26.17	725.0	.41	.27
25	17.90	.4547	320.4	.0002517	.16	36.20	41.50	50.	903	958	1031	33.00	919.0	.32	.21
26	15.94	.4049	254.1	.0001996	.13	39.90	45.30	57.	1118	1188	1300	41.62	1162	.25	.17
27	14.20	.3606	201.5	.0001583	.10	42.60	49.40	64.	1422	1533	1639	52.48	1455	.20	.13
28	12.64	.3211	159.8	.0001255	.08	45.50	54.00	71.	1759	1903	2067	66.17	1850	.16	.11
29	11.26	.2859	126.7	.00009953	.064	48.00	58.80	81.	2207	2461	2607	83.44	2300	.13	.084
30	10.03	.2546	100.5	.00007894	.051	51.10	64.40	88.	2534	2893	3287	105.20	2940	.10	.067
31	8.928	.2268	79.70	.00006260	.040	56.80	69.00	104.	2768	3483	4145	132.70	3680	.079	.053
32	7.950	.2019	63.21	.00004964	.032	60.20	75.00	120.	3137	4414	5227	167.30	4600	.063	.042
33	7.080	.1798	50.13	.00003937	.0254	64.30	81.00	130.	4697	5688	6591	211.00	5830	.050	.033
34	6.305	.1601	39.75	.00003122	.0201	68.60	87.60	140.	6168	6400	8310	266.00	7400	.039	.026
35	5.615	.1426	31.52	.00002476	.0159	73.00	94.20	160.	6737	8393	10480	335.00	9360	.032	.021
36	5.000	.1270	25.00	.00001964	.0127	78.50	101.00	190.	7877	9846	13210	423.00	11760	.025	.017
37	4.453	.1131	19.83	.00001557	.0100	84.00	108.00	195.	9309	11636	16660	533.40	14550	.020	.013
38	3.965	.1007	15.72	.00001235	.0079	89.10	115.00	205.	10666	13848	21010	672.60	18395	.016	.010
39	3.531	.0897	12.47	000009793	.0063	95.00	122.50	215.	11907	18286	26500	848.10	24100	.012	.008
40	3.134	.0799	9.888	.000007766	.0050	102.50	130.00	230.	14222	24381	33410	1069.00	32660	.009	.006
41	....	.0711	7.841	.000006160	.0040	112.00	153.00	240.	17920	30610	42130	1323.00	....	.008	.005
42	....	.0633	6.220	.000004885	.0032	124.00	168.00	253.	22600	38700	53100	1667.00	....	.006	.004
43	....	.0564	4.933	.000003873	.0025	140.00	192.00	265.	28410	48600	66970	2105.00	....	.005	.003
44	....	.0502	3.910	.000003073	.0020	153.00	210.00	275.	35950	61400	84460	2655.00	....	.004	.0025

*A mil is 1-1000 of an inch **For hard drawn copper, increase resistance values 2%.

(Continued from Page 195)

mended for receiving tubes of the XL-type whose emission has fallen below manufacturer's ratings, cooking for longer periods (several hours in some cases) without the flashing process is to be preferred for transmitting, rectifier and power-amplifier tubes.

Tube	Flashing Volts	Flashing Time	Ageing Volts	Ageing Time
UV-UX-199 C-CX-299	12	1 sec.	4	5-8 min.
UX-201A-200A-171 CX-301A-300A-371	18	1 sec.	7	5-8 min.
UX-210-216B CX-310-316B	—	—	9	15-30 min.
UX-213 CX-313	—	—	6	15-30 min.
203-A	—	—	12	30 min.

The tubes should test up to manufacturer's ratings after reactivation. The grid and plate may be tied together and connected through B-battery, milliammeter and switch to filament for testing emission. Under these conditions the switch should be closed very briefly while the emission current is measured. 50-volts (not more) is a convenient B-value for 3- and 5-volt tubes. With filament normal at 5 volts the following *minimum* values may be expected: 200-A, 12 m.a.; 201-A, 25 m.a.; 171, 50 m.a. A UX-210 with 6 volts on the filament and 100 volts on the plate and grid should pass 100 m.a. Remember that the B-supply source must be of low internal resistance, however.

GREEK ALPHABET

Since Greek letters are used to stand for many electrical and radio quantities, the names and symbols of the Greek alphabet with the equivalent English characters are given.

Greek letter	Greek name	English equivalent
Α α	Alpha	a
Β β	Beta	b
Γ γ	Gamma	g
Δ δ	Delta	d
Ε ε	Epsilon	e
Ζ ζ	Zeta	z
Η η	Eta	
Θ ϑ	Theta	th
Ι ι	Iota	i
Κ ϰ	Kappa	k
Λ λ	Lambda	l
Μ μ	Mu	m
Ν ν	Nu	n
Ξ ξ	Xi	x
Ο ο	Omicron	ŏ
Π π	Pi	p
Ρ ϱ	Rho	r
Σ σ	Sigma	s
Τ τ	Tau	t
Υ υ	Upsilon	u
Φ φ	Phi	ph
Χ χ	Chi	ch
Ψ ψ	Psi	ps
Ω ω	Omega	ō

FINIS

INDEX

To Handbook Readers Who Are Not A. R. R. L. Members

Wouldn't you like to become a member of the American Radio Relay League? We need you in this big organization of radio amateurs, the only amateur association that does things. From your reading of this Handbook you have gained a knowledge of the nature of the League and what it does, and of its purposes. We would like to have you become a full-fledged member and add your strength to ours in the things we are undertaking for Amateur Radio, and incidentally you will have the membership edition of *QST* delivered at your door each month. A convenient application form is printed below—clip it out and mail it today.

..........................19........

American Radio Relay League,

1711 Park Street,

Hartford, Conn., U.S.A.

Being genuinely interested in Amateur Radio, I hereby apply for membership in the American Radio Relay League and enclose $2.50 (foreign $3.00) to cover one year's dues.*

It is understood that this entitles me to receive the league magazine "QST" for a similar period. Please begin my subscription with the

....................issue.

Send "QST" and my Certificate of Membership to the address below.

Name ....

....

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A bona fide interest in amateur radio is the only essential qualification; ownership of a transmitting station and knowledge of the code are desirable but not necessary.

Station call, if any..

Grade Operator's license, if any ....

Radio Clubs of which a member..

Do you know a friend who is also interested in Amateur Radio, whose name you might

give us so we may write him about the League?................................

.... Thanks!

* The dues are $2.50 per year in the United States and Possessions; Canada and all countries in the American Postal Union; in foreign countries not in the American Postal Union, $3.00.

TO HANDBOOK READERS WHO ARE ALREADY A. R. R. L. MEMBERS

For telegraphing members, who hold amateur licenses, and who are interested in Communications Department work, here is an application blank for an appointment as Official Relay Station. Copy this, or cut and fill it out, and send it to A.R.R.L. Headquarters for routing to the proper Section Communications Manager, if you are interested. The Communications Department operates only in the United States and its territories and possessions, Canada, Newfoundland and Labrador, Cuba and the Isle of Pines. Foreign applications from outside these areas cannot be handled.

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City .... County...............................

State ....

Transmitting wave-lengths specified on my license from.....................meters,

to.............meters. Actual wave-length in use.............meters.

In making application for appointment as Official Relay Station, I agree:
——to obey the radio communication laws of the country under which this station is licensed, particularly with respect to the regulations governing quiet hours and wave-lengths.
——to send monthly reports of station activities to the Section Communications Manager under whose jurisdiction this station comes.
——to handle messages in accordance with good operating procedure, delivering messages within forty-eight (48) hours when possible, mailing to destination whenever impossible to relay to the next station in line within a 48-hour period.
——to participate in every A.R.R.L. communication activity to the best of my ability, always trying to live up to those ideals set forth in "The Amateur's Code."

My membership in the A.R.R.L. expires ....
month year

I understand that an appointment as Official Relay Station may be suspended or cancelled at the discretion of the Section Communications Manager for violation of the agreement set forth above.

Signed.......................................

NOTES

NOTES

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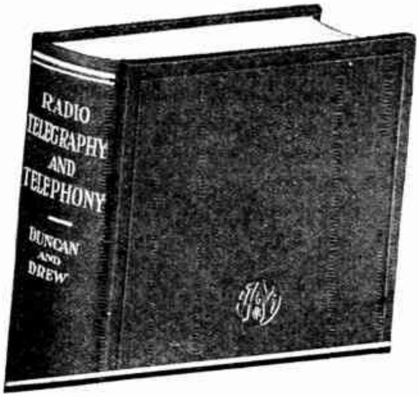

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Radio Telegraphy *and* Telephony

By **Rudolph L. Duncan**
Director, Radio Institute of America

and **Charles E. Drew**
Instructor in Radio, and in charge of Electrical Division Radio Institute of America

Published May 1929

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- Appendix

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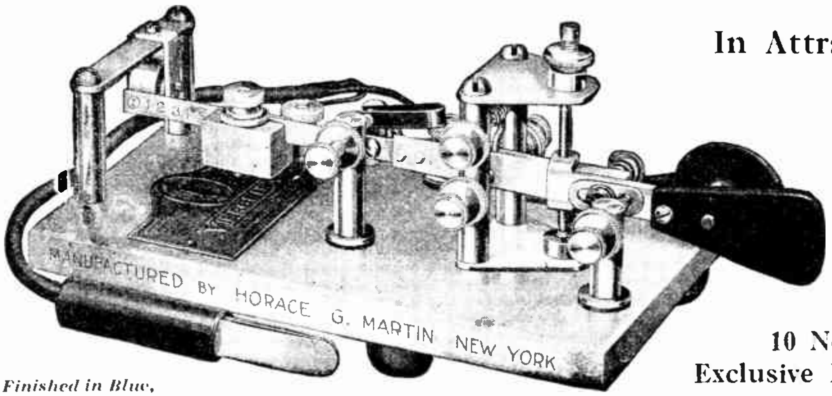

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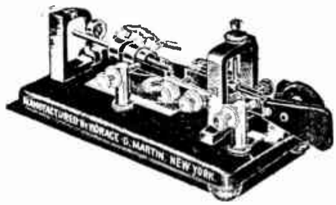

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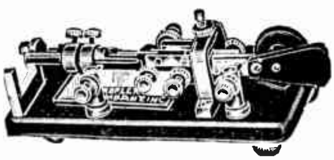

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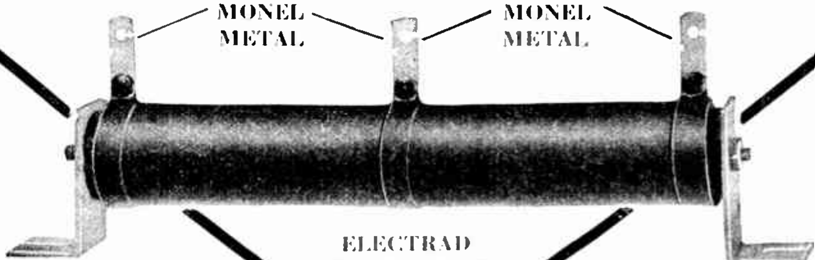

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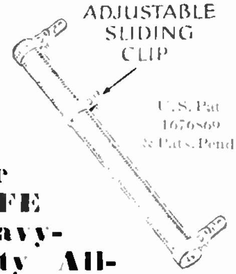

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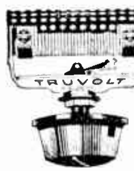

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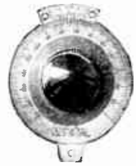

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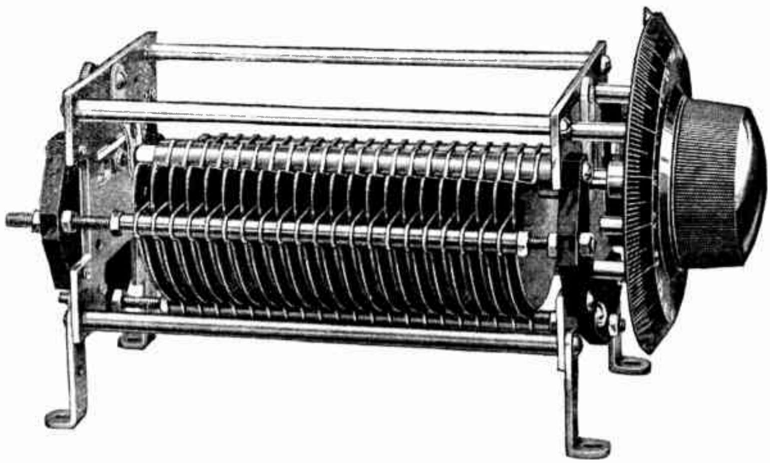
Precision Type N

Four-inch solid German silver NATIONAL Velvet-Vernier Dial, Type N, developed for use in radio equipment requiring the utmost precision of logging. *Real Vernier* makes accurate reading possible to one-tenth division. Mechanism is original and unexcelled NATIONAL Velvet-Vernier design. List price, each **$6.50**



National Transmitting Variable Condensers

THE NATIONAL Variable Transmitting Condensers have seen constant and satisfactory service in the hands of ARRL members and commercial broadcast transmitting stations, and certain types have been standard in the U. S. Navy for many years.

.0001 Mfd. — 23 Plate (3/8" spacing) . . . **$12.50**
.00015 Mfd. — 17 Plate (3/16" spacing) . . **$7.50**
.000235 Mfd. — 23 Plate (3/16" spacing) . **$11.50**
.00045 Mfd. — 43 Plate (3/16" spacing) . . **$16.50**

These prices include NATIONAL Velvet-Vernier "Type A" Dials. Condensers without dials, $2.50 less.

Standard insulation is Krolite or hard rubber. Micalex can be furnished on special order to those licensed to use it.

Note: **— Prices on Navy type Condensers for high voltage work will be quoted upon receipt of specifications. The Navy type Condenser, built to order, has a ball bearing rotor shaft and pyrex insulators.**

Made in wide range of capacities and special types not listed here. Prices and particulars on application.

NATIONAL CO. INC. *Est.* 1914 W. A. Ready, *Pres.*

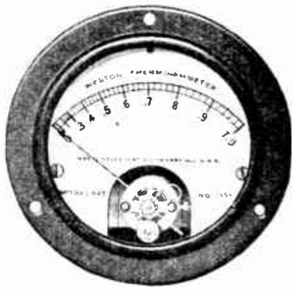
The Amateur's Goal— More Miles Per Watt

Typical transmitter with Weston Model 425 Thermo-Galvanometer and Thermo-Ammeter installed.

WITH aeroplanes the goal is more miles per hour, more miles without re-fueling, more hours in the air, altitude, etc., but with a radio amateur it is how many watts you are radiating and how many miles per watt.

Some of the problems which the radio amateur encounters and must answer are: The maintenance of resonance at all times; the protection of costly tubes; tuning the transmitter to within a few cycles according to the 1929 band requirements; and obtaining a true indication of the extremely valuable radio frequency current generated by the transmitter.

The Weston Model 425 Thermo-Galvanometer used in connection with a wave meter will enable you to tune your transmitter to come within the requirements, while the Thermo-Ammeter of the same model number in the oscillating (tank) circuit, gives you a reading which is the true indication of the R. F. current generated by the transmitter.



Model 425 Thermo-Galvanometer

The above illustration shows a typical transmitter with these instruments installed. They are of the popular 3¼" diameter type for flush panel mounting and in every way represent the highest Weston quality — accurate, dependable, and possessing unusual electrical characteristics for instruments of this size.

Weston instruments are on sale by all dealers. If you cannot conveniently obtain the required models and ranges write to the factory direct.

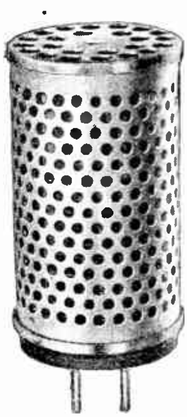
Weston Model 425 Thermo-Ammeter

Weston
PIONEERS SINCE 1888
INSTRUMENTS

WESTON ELECTRICAL INSTRUMENT CORPORATION

602 Frelinghuysen Avenue :: Newark, New Jersey





for that FINAL TOUCH

To you who delight in spanning hundreds and even thousands of miles with low-power transmitters and super-sensitive receivers, it is hardly necessary to go into details regarding precision methods. Suffice it to state that when you want precise resistance,

Remember- there's a CLAROSTAT *for Every Purpose*

For this is not only the name of a product or line of products, nor again the hall-mark of sound radio engineering: it is the name of a service dedicated to precision methods in radio transmission, reception and experimentation. CLAROSTAT translates ordinary guesswork into guaranteed success.

From the SUPER-POWER CLAROSTAT, capable of dissipating 250 watts and intended for the control of transmitters and motor-generator sets, to the GRID LEAK CLAROSTAT, with a resistance range of 1/10th to 10 megohms for receiving circuit applications, you will find a CLAROSTAT fitted to your every radio need.

Remember, too, that the CLAROSTAT is a combination adjustable and fixed resistance – *adjustable* to a hair's breadth in matching or balancing precise circuit conditions, and then *fixed* for all time if necessary, when it is set.

But the whole story cannot be told here. So please

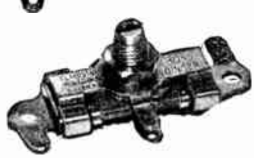
WRITE for technical data on the complete Clarostat line, or ask your dealer about it. Better still, send 25 cents in stamps or coin for "The Gateway to Better Radio" — the biggest quarter's worth you ever got in radio literature.

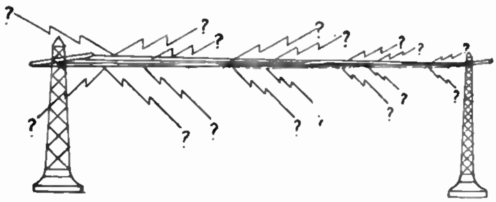
CLAROSTAT MANUFACTURING CO., INC.

Specialists in Radio Aids

283 North Sixth Street · · Brooklyn, N. Y.

Mem. R.M.A.

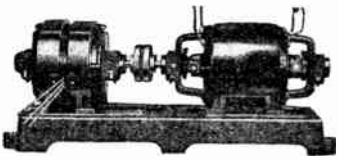



There is no question about the miles per watt with Esco — It is the maximum!

Put an "ESCO" power supply behind your set and increase your range—

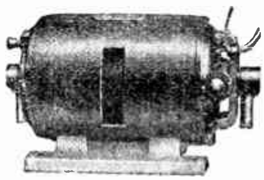
ESCO lists over 1,000 combinations for radio—Here are a few—

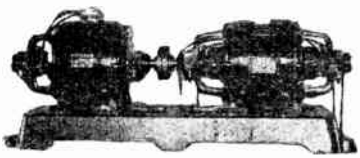
"ESCO" Dynamotors—small—compact—rugged and efficient. Commander Byrd has several in the Antarctic. Primary wound for 6 volts DC or higher. Secondary wound for high or low voltage AC or DC, 26 frame sizes to choose from.



"ESCO" four bearing motor generators are the power pioneers of the Radio Art. ESCO bulletins list over 250 combinations. The "ESCO" four bearing set shown to the left is Item No. 37 with a polyphase AC motor. It was this item which was used by Carlos Braggio of Bernal, suburb of Buenos Aires in establishing the first amateur radio communication between North and South America.

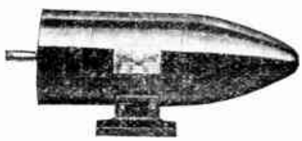
"ESCO" 2 bearing motor generator sets are very practical and economical where a single voltage is required. The secondary end may be wound for any voltage between 6 and 750 volts. These machines are excellent for crystal control equipment, grid bias on large sets, Neon tube supply for television or for small transmitting sets.





The cut on the left shows an "ESCO" 2 unit, 4 bearing motor-generator. The generator is double commutator high voltage, with a distributed and compensated field winding. This design permits greater overload, produces less ripple and gives more power output for a given frame size than the conventional type of generators. The MacMillan Arctic Expedition was equipped with four of this type.

Low wind resistance, light weight, non-corroding parts, ball bearings, tool steel shafts, steel shells, cast steel pole pieces, weather proof construction, many sizes to choose from, high voltage and low voltage windings to suit individual requirements, are a few of the many reasons for "ESCO" generators being the first choice.



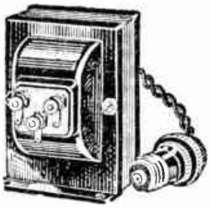
ELECTRIC ESCO SPECIALTY COMPANY

333 South Street, Stamford, Conn., U.S.A.

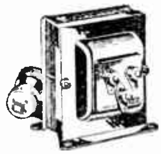
Manufacturers of Motors, Generators, Dynamotors and Rotary Converters for all purposes

THORDARSON

TRANSMISSION EQUIPMENT



T-2382
T-2383



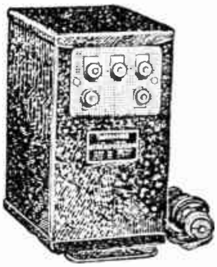
T-3680

Filament Supply Transformer
Completely Shielded

T-2382—80-VA. Sec. 6-6, Center Tap............$10.00
T-2383—175-VA. Sec. 6-6. Center Tap.......... 15.00
T-3680—For R. C. A. or Raytheon 866. 2½-V. Sec. Center Tap. 10-Amps.............. 12.00
50-60 Cycle—110-115 Primary

Line and Tube—Line to line Coupling Transformers

T-3474—Tube to Line Transformer..............$25.00
T-3475—Line to Tube Transformer.............. 25.00
T-3476—Line to Line or Mixing Transformer..... 25.00



T-2387
T-2388
T-2389

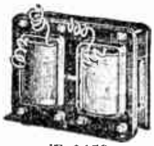
T-3474
T-3475
T-3476

Plate Supply Transformers

T-2387—300-V. A. Sec. 1000-1500, Center Tap... $22.00
T-2388—500-V. A. Sec. 1500-2000, Center Tap.... 30.00
T-2389—1000-V. A. Sec. 1500-2000, Center Tap.... 40.00
50-60 Cycle—110-115 Primary

Thordarson Double Choke Units

T-2099—E. 30-H, 130 Mils. D. C. 250-Ohms, Choke, Each..............................$14.00
T-3099—E. 30-H, 160 M. A. D. C. 190-Ohms, Choke, Each...................... 16.00
T-3100—E. 30-H, 200 M. A. D. C. 125-Ohms, Choke, Each....................... 18.00
T-2376—1,5-H, 200 M. A. 1600-V. Insul. Key, Filter. 5.00
T-2458—18-H, Ea. Choke. 250 M. A. D. C. 2000-V. Insul. 108.5-Ohms, Choke, Each....... 19.50

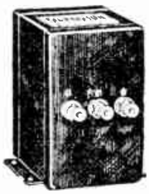


T-2458

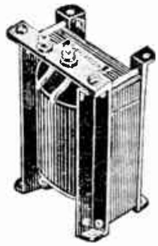
T-2099
T-3099
T-3100

Filter and Plate Reactors

T-2027—30-H, 300-M. A. 3000-V, Insul..........$22.00
T-2071—30-H, 150-M. A. 3000-V. Insul.......... 16.00
T-2073—30-H, 500-M. A. 3000-V. Insul.......... 30.00
T-2353—6-H, 150-M. A. 3000-V. Insul. Modulator Choke............................ 7.50



T-3180
T-3020



T-2027
T-2071
T-2073

Microphone Transformers

T-3180—200-Ohms, E. S. Ratio 27-1, Imp. 750-1..$20.00
T-3020—200-Ohms, E. S. Ratio 45-1, Imp. 2000-1. 10.00
T-2357—200-Ohms, at 500 Cycles, Ratio 64-1, Imp. 4000-1............................ 5.00

Combined Plate and Filament Supply Transformers

T-2098—130-M. A. 550-550-E. S. C. 7.5-V. Flmts..$20.00
T-2900—130-M. A. 610-610-E. S. C. 7.5-V. Flmts.. 20.00
T-2950—200-M. A. 675-675-E. S. C. 7.5-V. Flmts. All 50-60-Cycle, 110-115-Prim........ 29.50

T-2098
T-2900
T-2950

T-2357

Send for New "Ham" Circular

Thordarson Electric Manufacturing Co., 500 W. Huron Street, Chicago, Ill.

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The Home of RADIO

45 VESEY STREET

NEW YORK

New York's Headquarters for Transmitting Apparatus

When in Town Visit Our Store

Everything in

General Radio
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Fleron
Sangamo

Acme
Lynch
Signal
Pyrex

National Radio
Jewell
Electrad
Bradley
National Rectobulb

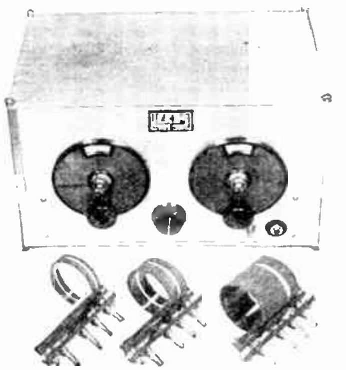
Always in Stock

NEW 1930

SHORT WAVE RECEIVER

The LEEDS 1930 SPECIAL

A short wave receiver that's got them all beat. Best circuit design and finest mechanical construction. Praised by "Hams" everywhere as the greatest short wave receiver ever made.



What some prominent users say — "More than delighted with its performance." 4PD "Far exceeded expectations." 2AFS. "Oscillation and tuning control far best I have ever seen." "Signal strength amazingly loud and response very clear."

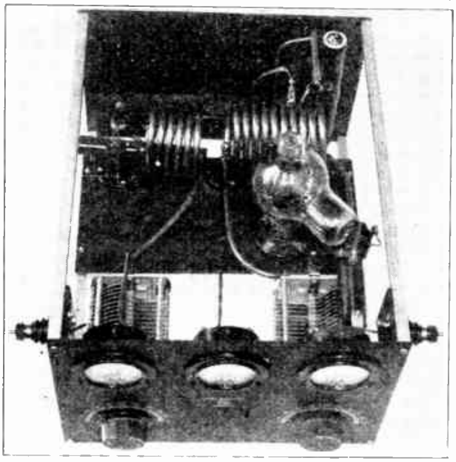
In use by a constant host of Hams from coast to coast. 3-tube Receiver — detector — 2 audio, using three 201-A tubes. Universal type, continuous range 15 to 100 meters; amateur type covers Ham bands 20-40-80 meters with generous spread on the dial.

List price $60.
Special Offer, net **$37.50***

SHORT WAVE X-MITTER

The LEEDS High-C 75 Watter

A real X-mitter for those who are satisfied only with the best. Incorporates all the latest developments of the past year, insuring highest efficiency. Size 10" x 14" x 17" overall; adjustments and operation very simple. Finest results are possible even in the



hands of a comparatively inexperienced operator. Hartley High-C circuit employed, insuring constant frequency stability. Employs one UX852 tube as an oscillator; wired almost entirely with copper tubing, still further adding to its electrical efficiency.

LEEDS RADIO LABORATORIES

Precision Custom Built Short Wave Receivers and Transmitters

This department under the supervision of the Short Wave Specialist Jerome Gross. We design, construct and advise on any material for the "Ham" Broadcasting station or laboratory. Write Jerry Gross for advice on any of your problems.

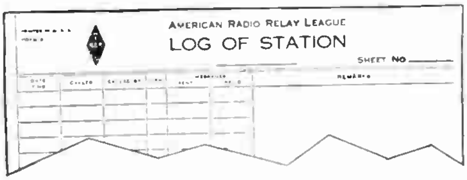
PLEASE PRINT YOUR NAME AND ADDRESS PLAINLY to AVOID DELAY

WRITE FOR SPECIAL PRICE LIST

MAIL ORDERS FILLED SAME DAY
10% Must Accompany All Orders

Every Transmitting Amateur Uses These Forms

They are essential to every well-conducted station

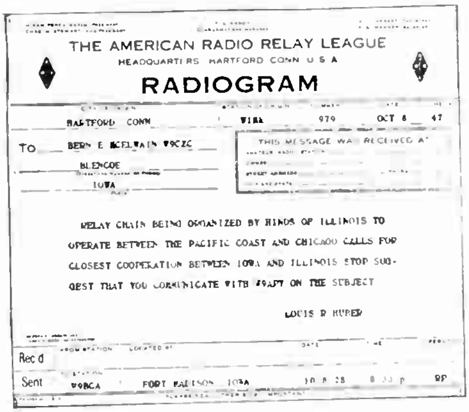


A. R. R. L. Log Sheets

Designed by hams for hams. $8\frac{1}{2}$ x 11 bond paper, punched for standard three-ring loose-leaf binder. 125 sheets postpaid for $1.00 or 500 for $3.50.

Members' Correspondence Stationery

Write your radio letters on League stationery — it identifies you. Lithographed on $8\frac{1}{2}$ x 11 heavy bond paper. Now available in one color (black) heading at greatly reduced cost — 100 sheets 50c; 250 sheets $1.00; 500 sheets $1.75. Postpaid.

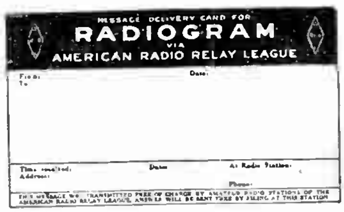


Official A. R. R. L. Message Blanks

Most convenient form. Designed by the Communications Department of the A.R.R.L. Well printed on good bond paper. Size $8\frac{1}{2}$ x $7\frac{1}{4}$. Put up in pads of 100 sheets. One pad postpaid for 35c or three pads for $1.00.

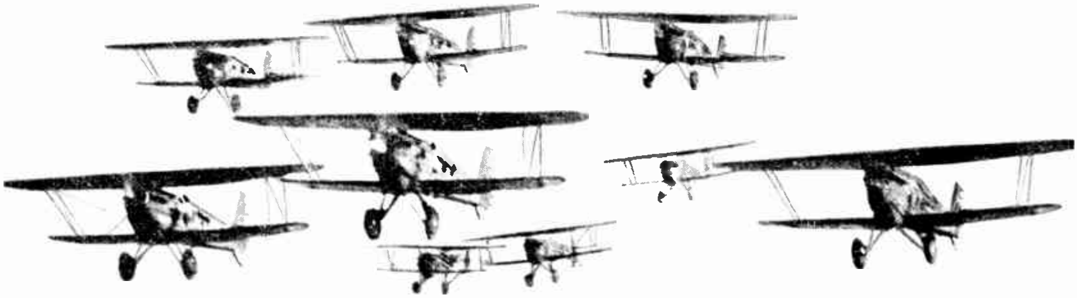
Message Delivery Cards

Neatest, simplest way to deliver a message to a near-by town. On U. S. stamped postals 2c each. On plain cards (for Canada, etc.) 1c each, postpaid.

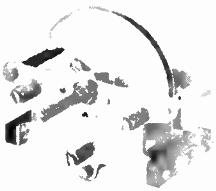


AMERICAN RADIO RELAY LEAGUE

1711 Park Street **Hartford, Conn.**

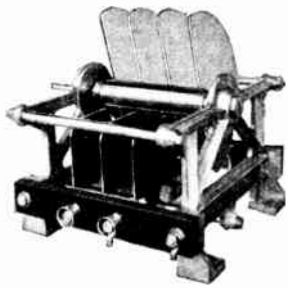


"In The Air" or "On The Air"
CLASS TELLS



Success may be judged by many standards, and you will discover how relative the term is, as applied to Radio, when you tie up with CARDWELL Condensers and compare Performance with what you considered was Success before.

The CARDWELL line is intended to, and does, meet a demand for the utmost in condenser value and efficiency. It includes transmitting condensers for broadcasting stations, commercial transmitters and amateur uses, and receiving condensers of several types and many capacities. The CARDWELL Taper Plate Condenser—unbelievably rigid and vibrationless—is incomparable for short wave receivers.



CARDWELL Condensers are not dressed up to delight the eye but are designed to do a job, and upon their preeminent ability to do that job is based the reputation of the CARDWELL.

CARDWELL CONDENSERS

"The Standard of Comparison"

THE ALLEN D. CARDWELL MANUFACTURING CORPORATION
81 PROSPECT STREET ✦ ✦ BROOKLYN, NEW YORK

TRADE **OHMITE** MARK

Reg. U. S. Patent Office

Vitreous Enameled *Radio Resistors*

RESISTORS FOR <u>*EVERY*</u> REQUIREMENT

TRANSMITTING GRID LEAKS

8 1-2" x 1 1-4" Furnished with brackets.

Size of Unit 4" x 5-8" Furnished with brackets.

OHMITE VITREOUS ENAMELED RESISTORS have been used in equipment made for the Byrd Antarctic Expedition, and are being used in many of the large broadcasting stations.

RESISTORS FOR CURRENT SUPPLY UNITS

2" x 5/8", 25 Watt

4" x 5/8", 45 Watt

Cartridge Type
1 13/16" x 1/2

Write for bulletin on complete line of resistors especially for Radio use. Large stock on hand at all times. Also carried in stock at our New York and San Francisco offices.

OHMITE MANUFACTURING COMPANY

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CHICAGO, ILL.

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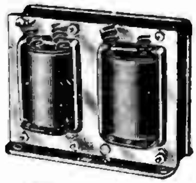
New York City

THORDARSON DOUBLE FILTER CHOKES

CONTAINS TWO 18 HENRY 250 MILL CHOKES



This Thordarson heavy duty, rugged double Filter Reactor is excellent for Filter Circuits in Transmitters, Power Amplifiers, "B" Eliminators and various other purposes.

Each Choke has a 2000 Volt insulation and the D.C. resistance of each Choke is 108.5 ohms.

When connected in series this Filter Reactor has a capacity of 36 henries at 250 mills, and when connected in parallel 18 henries with 500 mills carrying capacity.

Weight for shipment 14 pounds. Dimensions 3 x 7 x 5½ in. Equipped with mounting brackets.

SPECIAL $6.25

MODEL T-2458
List Price $19.50

TYPE PL 571
List Price $7.25

Dubilier HIGH VOLTAGE FILTER CONDENSER

4 MFD. D. C. WORKING VOLTAGE 600 V

These Filter Condensers are designed for use in filter circuits in Transmitters, and all high Voltage Socket power devices and Power Packs.

SPECIAL $2.25

SIZE 6" x 5" x 3½"

CAPACITY	RATED D. C. WORKING VOLTAGE
2.0 MFD.	1000 V
1.0 " "	800 V
1.	800 V
3.	400 V

AEROVOX OR Dubilier

7 MFD. HIGH VOLTAGE FILTER CONDENSER BLOCKS

Finest non-inductive High Voltage Filter Block ever made. Designed for use with UX-250 Power Tubes but can be used safely in filter circuits of transmitters or high power Amplifiers in any combination of capacities desired.

Each Unit is equipped with long, heavy, flexible leads, convenient for easy wiring, and also has mounting brackets. Latest design.

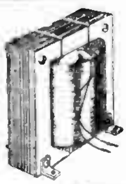
The insulation resistance of these Condenser Blocks is in excess of R.M.A. and N.E.M.A. standard requirements.

Due to the request of manufacturers of these Condenser Blocks we cannot divulge the high list price of same.

SPECIAL

$3.25

PER BLOCK



50 HENRIES

FILTER CHOKES

85 MILLS

These are very efficient Chokes for use in Filter Circuits for your Transmitter, A and B. Eliminators or Power Packs.

The Choke Coils are very well constructed and are made with air gaps to prevent magnetic saturation from direct current.

SPECIAL
$1.50

Faradon OR POLYMET

5 MFD. HIGH VOLTAGE FILTER CONDENSER BLOCKS

This condenser block is ideal for use in "B" eliminators, Power amplifiers and experimental work.

4 mfd. D. C. working voltage 400 v.
1 mfd. D. C. working voltage 600 v.

SPECIAL $1.50 PER BLOCK

AMERICAN SALES CO., 19-21 Warren Street, New York City

Glorious Adventure *awaits you in* RADIO

RADIO needs men just like you. Thousands of opportunities are now open for fellows who already know something about radio . . . who "*think*" radio, who "*play*" with radio, men who are "radio-minded" . . . radio amateurs! You, too, can use the knowledge you already have as a stepping-stone to success in radio. All you need is a little commercial training in order to make good in this fascinating profession. Others have done it and so can you. RCA Institutes actually trains you for success. It gives you the practical as well as the theoretical knowledge . . . the "how" as well as the "why" of radio. You study under the direction of nationally known experts . . . men who have made good in radio and can show you how you, too, can make your mark in this, the fastest-growing industry in the world today.

Get a Commercial Radio License

Radio needs you. Never before has there been such an opportunity for rapid advancement. On ship or shore, the constant demand is for men . . . more men . . . trained men! Large broadcasting stations, manufacturers, dealers, as well as steamship companies are continually asking for men who have the knowledge and the confidence to hold a well-paid position in Radio. You, too, can now get that knowledge . . . You can be trained for a good paying radio job.

This is the Only Course Sponsored by the Radio Corporation of America

RCA is the world's largest radio organization. It sets the standards for the entire radio industry. And the RCA Institutes' home laboratory training course enables you to quickly learn the secrets of radio. It enables you to obtain a thorough, practical education in radio in your spare time . . . You get the inside information, too, because you study right at the source of radio achievement. You learn radio by actual experience with the remarkable outlay of apparatus given to every student.

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> Newark, N. J. . 560 Broad St.
>
> Home study graduates may also attend any one of our resident schools for post-graduate instruction at no extra charge.

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Clip this coupon now . . . send for this free book. Or, if you wish, step in at one of our resident schools and see for yourself how RCA Institutes actually prepares men for success in radio. Come in and get this free book or send for it by mail. Everything you want to know about radio. Each page packed with pictures and descriptions about the amazing opportunities in this vast, world-wide, money-making profession.

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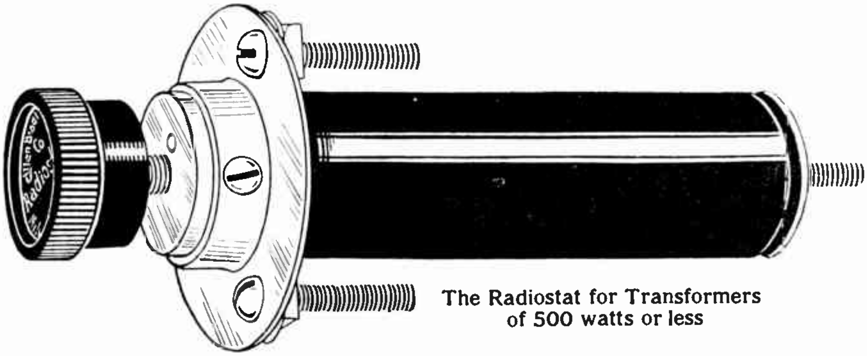
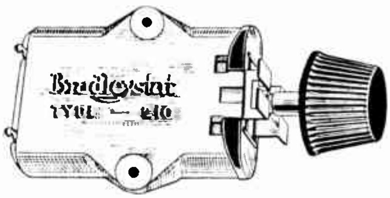


The Radiostat for Transformers of 500 watts or less



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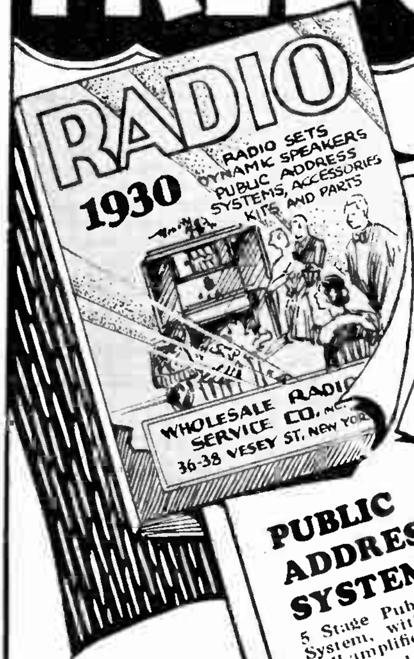

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