Tenth Year of Service

RADIO ENGINEERING

Vol. X DECEMBER, 1930 No. 12

IN THIS ISSUE

Sold only by subscription
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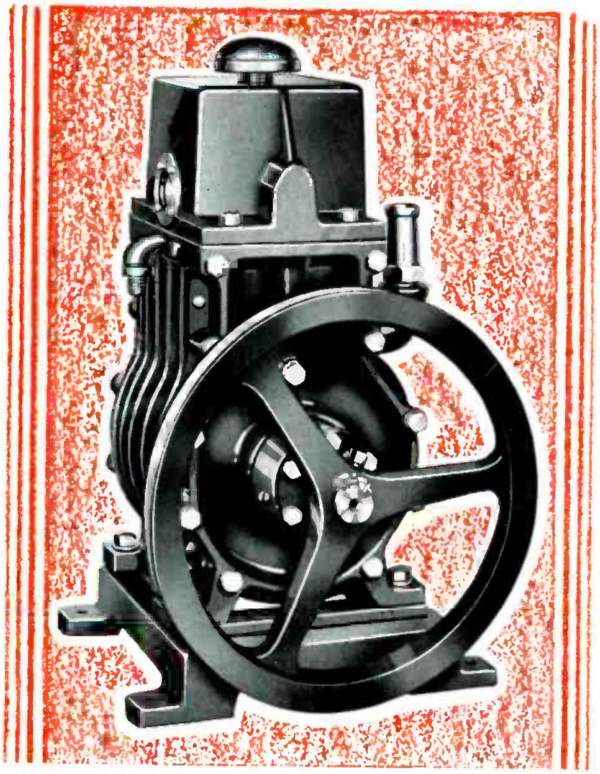
The Journal of the Rac



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Editor
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Western Editor
ULMER G. TURNER

Vol. X — DECEMBER, 1930 — Number 12

Contents

THE STENODE RECEIVER

THE Stenode (narrow path) radio receiver brought over from England by Mr. J. Robinson some weeks ago has been exhibited in New York to various groups of engineers. In this issue of RADIO ENGINEERING we publish the technical paper read by Mr. Robinson at a meeting of the Radio Club of America, New York, in November.

The advent of the Stenode in England, in 1929, was accompanied by an interesting discussion in the press relative to the existence or non-existence of the hitherto widely exploited sidebands of radio transmission.

A study of the circuit arrangement of the Stenode, and observation of the receiver's performance on test, discloses achievement along engineering lines suggesting improvement in selectivity. The rejection of interfering carrier waves is accomplished by various types of receivers, the utility of which is related to the lower limit of the intensity of the interference. In other systems proposed where sidebands are "trimmed" the reception results have not been good.

Manufacturers of broadcast receivers intended for sale to a public demanding simplicity of apparatus, and year-round dependability, may be expected to be less enthusiastic about this receiver than the inventor probably hopes for.

In the January issue of RADIO ENGINEERING will be published one or more articles written by American radio engineers dealing with the theories involved in the Stenode system.

Published Monthly by

Bryan Davis Publishing Co., Inc.
52 Vanderbilt Ave.
New York City

Publishing
AVIATION ENGINEERING
RADIO ENGINEERING
PROJECTION ENGINEERING

Publication Office—North Broadway—Albany, New York
Chicago Office—333 N. Michigan Ave.—Charles H. Farrell, Mgr.
Cleveland Office—10515 Wilbur Avenue—James C. Munn, Mgr.
St. Louis Office—505 Star Building—F. J. Wright
Kansas City Office—306 Coca Cola Building—R. W. Mitchell
San Francisco Office—318 Kohl Bldg.—R. J. Birch
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Entered as second class matter at the post office at Albany, N. Y., January 9, 1925, under the act of March 3, 1879.

Yearly subscription rate $2.00 in U. S. and Canada; $3.00 in foreign countries.

Editorial

December, 1930

THE LEVEL OF INDUSTRY

IN the industrial readjustments which have taken place during the past twelve months foresighted manufacturers have done a lot of discounting. It would have been better, of course, if the practice of lopping off percentages had been begun a year earlier.

The past twelve months have disclosed that mass production while it may solve price problems, brings in its train difficulties which may possibly outweigh some of the advantages.

This situation is not peculiar to the radio industry alone. Many other industries have discovered that as a tool for achievement mass production is but one item of the kit necessary to build for permanence.

All-embracing cooperation between the many industries to the end that there may be an unbroken circle of markets, by the year and by the decade may some day be organized. In the meantime—1930–31, it would appear that manufacturers might well conclude that the present, existing market is the one on which they are to keep the works going and make money. Benefits cannot fail to materialize in those instances where manufacturers discount largely the hope that within a year markets will expand to the dizzy proportions of the markets of 1928–29.

Real economy in manufacture, elimination of wasteful practices and methods, and liberal planning to procure a due share of the present business, are the factors which will provide the degree of prosperity possible at the present time.

▲

WHERE RADIO RECEIVERS ARE SOLD

SO far as radio sales are concerned there is an advantage creditable to the passing period of lessened purchasing power. From the beginning of popular radio service until recently the multitude of irresponsible sales outlets has been a scourge to responsible merchandizing.

There is evidence now, however, that a change is taking place. Improved, completely equipped receivers, low retail prices and better servicing are factors forcing change.

So long as top prices for standard sets prevailed over a period of only two months each year and so long as dumping was practiced by manufacturers, the fire sale, cut price, Bedlam Street type of radio sales outlet flourished.

Today the prospective radio purchaser can enter a regulation radio shop or a music store and purchase a first class receiver at a reasonable, a low, price. Under present conditions there is an insignificant margin between regulation retail prices and what a "gyp" store must sell for in order to pay rent.

If the radio manufacturing industry can in the future avoid large scale dumping there is little doubt that a degree of year-round stability may be reached comparing favorably with the experiences of other industries of similar magnitudes.

▲

TEN YEARS OF SERVICE

WITH this issue, RADIO ENGINEERING passes into its eleventh year of service to the industry. Although it had a predecessor in the form of a small, but popular, technical sheet, RADIO ENGINEERING began its task in 1921 when radio emerged from the development stage and took its rightful place among the major industries of the world.

The advent of large scale broadcasting, in 1920, opened for radio the field of one-way radiophone communication destined to set up new systems of entertainment, of news distribution, of publicity, of advertising and of public addresses on a national and international scale.

Throughout the past ten years RADIO ENGINEERING has conscientiously served the best interests of executives, engineers, research workers, constructors, servicemen and students. The editorial policy of the journal has avoided sensationalism; has avoided journalistic exploitations planned to capitalize the undeveloped—the unknown; dealing with scientific advance rather than prophecy.

Through its wide contacts this journal has been able to confirm that the most fruitful service—the service desired by engineers and executives—is that of monthly presenting complete, authoritative papers dealing with actual technical accomplishments. That this policy is sound is attested by the fact that the paid subscribers to RADIO ENGINEERING number more than the combined subscriptions total of this journal's two nearest competitors.

Donald McNicol

Editor.

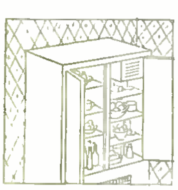
14 leaders cooperated *in preparing this book* for you

Presents facts and figures on fastening methods which have proved particularly advantageous.

TO help you attain greater fastening economy this interesting and informative booklet has just been published. It was prepared with the cooperation of fourteen of the most prominent manufacturers in their respective fields, who permitted a nationally known firm of engineers to enter their plants and make studies of fastening methods which have proved particularly advantageous.

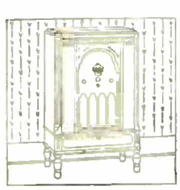
Certified facts and figures from those studies make up the booklet. Every production executive who is interested in attaining faster, easier, more economical assembly of a product made wholly or partly of metal should read with great interest such accounts as:

Servel saves $64,120 a year . . .



by assembling the exterior metal sheathing of their refrigerator cabinets with Hardened Self-tapping Sheet Metal Screws. This story of fastening economy is told by one of Servel's engineers, who describes the former methods of making the assembly, as well as the present method which eliminates a skeleton frame-work of wood with a saving of $1.00 per cabinet.

44 tapping operations eliminated on Philco Radio

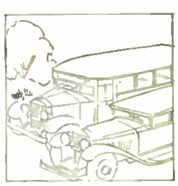


by fastening parts to the chassis with Hardened Self-tapping Sheet Metal Screws. The details of this achievement are particularly interesting since few products require more assembly work than a radio receiver. This report also explains the severe tests by which Philco determines the security of a fastening.

50% saving made by Doehler . . .

through the use of Self-tapping Screws on both vending machine and metal furniture assemblies. In this fastening study, the Chief Engineer of Doehler Die Casting Co. discusses alternative methods of fastening to die castings and of assembling sheet metal.

Enormous savings effected in auto production . . .



where fastening devices are selected with utmost care. That such effort pays, is proved by an account of the way a great builder of auto bodies saved $150.000 in a year by using Self-tapping Sheet Metal Screws for making fastenings to sheet metal.

Every study is worth reading!

All of the fastening studies in this book are interesting. Other contributors include: Zenith-Detroit, Gilbert and Barker, Stout. Edison and Simmons.

Any plant executive concerned with design or production may obtain "Fastenings" by using the coupon.

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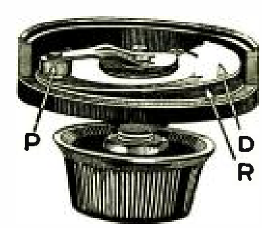
In millions of radio receivers CENTRALAB volume controls are helping to reach out across space to bring in noiseless, sputterless, reception.

. . . . here also is a case of delicate control.

Our engineers stand ready to help you with your resistance problems.



This shows the exclusive rocking disc construction of Centralab volume control. "R" is the resistance. Contact disc "D" has only a rocking action on the resistance. Pressure arm "P" together with shaft and bushing is fully insulated.

Centralab

CENTRAL RADIO LABORATORIES
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Send 25c for VOLUME CONTROL Guide showing how to service old and new sets with a small stock.

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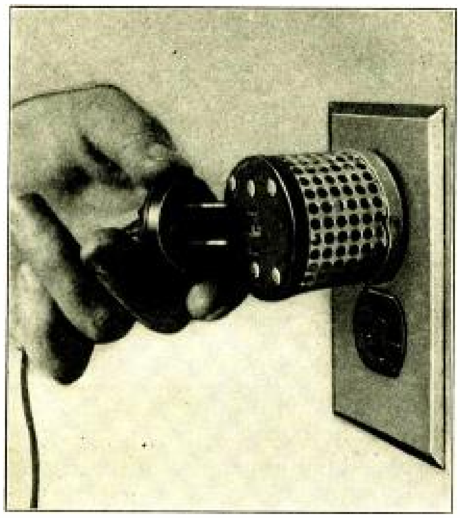

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An increase in the line voltage puts a serious strain on these smaller transformers and filters. Therefore normal applied voltage is absolutely essential.

The CLAROSTAT Automatic Line Voltage Regulator is designed to plug in between the socket and the radio—and it protects the set AUTOMATICALLY on line voltages between 110 and 140 volts.

It saves your product and your reputation but does not add to the list price of the receiver. It's an accessory to be sold with tubes.

Time tested and proven by its long use with standard size sets.

MANUFACTURERS, JOBBERS, DEALERS AND SERVICEMEN are all in a position to profit by the sale and recommendation of this guaranteed life saver to the overloaded midget.

Write or wire for literature and prices on this and other Clarostat products.

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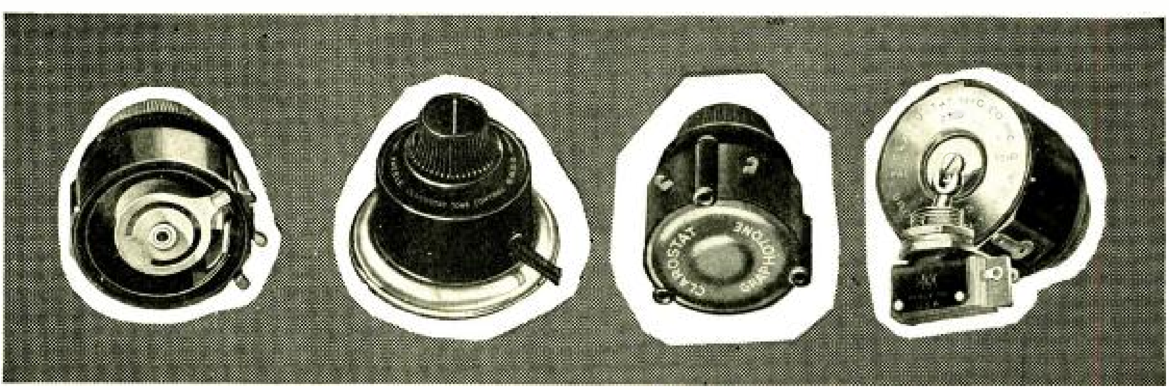

VOLUME CONTROL (Open Type—P58) | TONE CONTROL (Portable Model) | TONE CONTROL (Panel Mounting Type) | VOLUME CONTROL (Switch Type)

Impressions and Expressions

By AUSTIN C. LESCARBOURA

Tube Economics

THE intensive competition that prevails in the radio tube industry has brought about some queer and even disquieting conditions.

First, most tube manufacturers today are producing only the four a-c. types, namely, the -27, -24, -45 and -80 tubes. Such manufacturers by concentrating their entire energies on just four popular types, can steal a march on the few manufacturers who still keep faith with owners of old battery sets and with experimenters and engineers interested in the entire field of radio tubes.

Secondly, some tube manufacturers see fit to sell their "seconds" and even plain junk, while the most conscientious tube manufacturers produce just one grade of tubes. The market is not being helped by dumping the "seconds" and the hopeless rejects at any price.

Thirdly, some tube manufacturers are doing business without profit, to dispose of tremendous inventories. Better that they ran their plants at a more rational pace and sold their reduced output at a profit than to be ruining the game for all concerned.

The only bright spot is that the number of tube manufacturers is constantly shrinking. We now have about one-third the number of two years ago. A few more good squeezes and we shall be down to the really substantial manufacturers, provided that they can survive the unholy competition now going on.

▲

Tube Replacements

THE idea seems to be gaining ground among the unscrupulous radio public and trade that the purchase of a tube should mean a radio tube service forever more. In other words, the tube replacement policy is being taken for one awful buggy ride, and we can see a terrible outcome one way or another.

It is by no means exceptional for even the most reputable tube manufacturers to replace up to 20 per cent of the tubes they sell, in the case of certain customers. On the other hand, the exact same tubes may cause only 5 per cent replacement when sold to other customers. Why the discrepancy? Simply because some customers are only too ready to take advantage of a tube replacement policy, riding it to death.

Some day the tube manufacturers are going to quit using the liberal tube replacement policy as a means of coaxing in business. They are going to have their tubes tested by some impartial, outstanding organization, which will report on the uniformity, reliability and all-round worth of the general run of their tubes. Exhaustive tests conducted by those testing organizations will disclose a full one thousand hours of peak efficiency. Then the radio tube manufacturers are simply going to say to trade and public alike, "Gentlemen, here's a full one thousand hours of real service. We guarantee that because we know we've got it. But we are not going to replace tubes forever and ever. We know the tubes are right when they leave our factory, but we do not know what you do with them, so we shall take our own word as for their goodness."

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Better Programs

AFTER all, it's radio entertainment we are selling. Talk as we may of sets and circuits and tubes, in the final analysis the public is interested solely in the entertainment which those items make possible in the home.

So we are frankly happy to learn that the broadcasters are exerting every effort to pack more good things into the broadcast air. The broadcasters are securing the absolute peak of entertainment for the listeners-in, and even such artists as Jascha Heifitz, celebrated violinist, heretofore refusing to go before the microphone, have condescended to take part in radio programs to the end that our great industry might appeal as never before to the public at large. Sporting events are being harvested on a vast scale. International news events are being brought to our networks. Radio playlets of remarkable power are being scheduled.

What excellent roads have done by way of stimulating automobile sales, irresistible programs are now going to do for radio sales.

▲

Interference

BEFORE these lines are read, the Federal Radio Commission will have held a hearing for the purpose of granting or refusing the requests of radiovision broadcasters. One thing is certain, and that is the need for more satisfactory frequencies with which to broadcast radiovision programs. At present the radiovision art is seriously hampered by conditions obtaining on the air. Several transmitters are operating on approximately the same wavelengths, resulting in serious interference. The young art has enough to struggle with as it is, and this interference comes at a most inopportune time. It is to be hoped that the Federal Radio Commission, despite the many requests constantly heaped before it, will see its way clear to provide the necessary elbow room for the radiovision broadcasters now pioneering in what is certain to be a vast industry some day.

▲

The Shortest Season Yet

THINGS really didn't get started in the radio industry much before the first of October. And as these lines are being written, late in November, the season seems just about over, so far as manufacturing activities on a normal scale are concerned.

Imagine a production season of just two months! We pointed out a short time ago that the feverish activity in some quarters, particularly among certain parts manufacturers, was simply the intensified production season boiled down to a few months. Our guess was a good one. We have boiled an average six months' business down to just two months.

It becomes more and more apparent that our radio industry, as set up, simply cannot make a real go of the present radio business. We must go into other lines. We must diversify. Perhaps now is no time to be attempting new lines in the face of subnormal buying; but at least we should be giving thought to the future, and now is the time to think and think hard. Lately we have come across a loudspeaker diaphragm manufacturer working on a new line of novel toys, a radio set manufacturer developing electrical refrigerators, a condenser manufacturer putting out electric clocks, and so on. And more will follow along that same path of diversification.

What are 1931 Tubes?

IT'S easy to identify 1931 tubes among the general run of tubes. Meters and performance rather than labels and claims soon separate the sheep from the goats. Briefly, and for your guidance, the 1931 radio tube features are:

POSITIVE CHARACTERISTICS because of the doubling of the diameter of some support wires and better bracing, together with tightened tolerances.

IMPROVED TONE QUALITY resulting from greater rigidity and therefore minimum microphonic effects, together with suppression of distortion arising from undesirable regeneration.

QUIET BACKGROUND brought about by DeForest research into causes of hum and crackle, resulting in one-fiftieth the noise level heretofore considered standard practice, together with lower gas content made possible by unique DeForest exhaust units now in use.

LONGER SERVICE LIFE brought about by important improvements in filaments, cathode insulators and emitters, insuring a full thousand hours of peak efficiency.

GREATER VOLUME through the increase of the mutual conductance in power tubes, yet maintaining full interchangeability with usual tubes of lower output.

QUICK HEATING averaging about 10 seconds, due to patented DeForest notched cathode insulator, without sacrificing life, reliability or quiet operation.

HIGHER R. F. AMPLIFICATION with screen-grid tubes, or 60 instead of usual 30 per stage, while more uniform grid-plate capacity permits of maximum stability or minimum regeneration for the highest gain with least distortion.

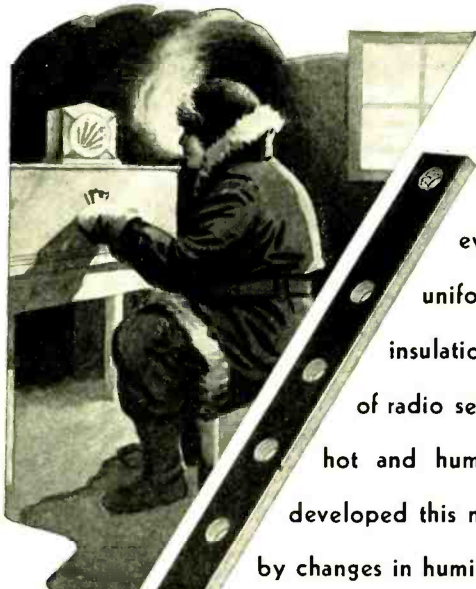
de Forest
AUDIONS
RADIO TUBES

The foregoing 1931 radio tube features are not to be found in tubes produced six months ago, much less those a year or two old, taken from large inventories. DeForest research and engineering—the heritage of a quarter century of pioneering—is rapidly translated into everyday terms by a production positively geared to the demand, bringing these latest features to you in fresh DeForest Audions.

DE FOREST RADIO CO.
PASSAIC NEW JERSEY

TEXTOLITE LAMINATED

Preserves the original tuning regardless of the weather



RIGHT on the premises of Uncle Sam, the whims of weather vary between seasons (and between localities) from arctic frigidity to tropical humidity. ¶ In every season and atmosphere, radio listeners expect uniform performance from their radio sets. Where the insulation used is Textolite, the original precise tuning of radio sets is preserved through dry and cold, and hot and humid weather. General Electric research developed this material, which is so slightly affected by changes in humidity that it possesses a practically constant power-factor. ¶ Besides the radio-frequency grade, there are available many other grades of Textolite for the needs of radio manufacturers. ¶ The eastern and western fabricators of Textolite are equipped to furnish advice or specifications regarding your problems. There is also a Textolite specialist in your nearby G-E sales office.

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GENERAL ELECTRIC

SALES AND ENGINEERING SERVICE IN PRINCIPAL CITIES

RADIO ENGINEERING

Production, Administration, Engineering, Servicing

DECEMBER, 1930

An Undeveloped Radio Market

By S. R. WINTERS

As in the United States the Organization of Radio Service Stations Should Open a New, Large, Rural Market in South America

WILL radio service stations spring up in great numbers in the future, paralleling the present ever-increasing automobile service stations? Just as the latter retail tires and tubes and sell gasoline, the new radio service station will sell vacuum tubes and radio parts but it will engage primarily in trouble-shooting—a sort of hospital for sick and crippled receiving sets. These will be legion among the all-electric receivers during the next twelve months—probably exceeding a million outfits subject to repair.

This trend of thought is suggested by a report from Buenos Aires, Argentina, to the United States Department of Commerce, in which it is indicated that this country is having its radio progress impeded by lack of servicing. The rapid expansion of the industry—with one model of radio receiver succeeding another in rapid succession—has eclipsed the need for repairs and adjustments in the outfits previously installed. As a result, recent recruits to the great international pastime of twirling the dials are complainants because of this absence of servicing and unless remedial measures are advanced the industry in Argentina will suffer a setback. In this South American country, not unlike the present opportunity in the United States, there is an inviting bid for the establishment of radio service stations, paralleling the prevalency of automobile service stations.

Promising Outlook for Sales

Despite this and other handicaps which we shall see presently, "the future sales outlook" for receiving sets and radio parts "is promising," according to Assistant Commercial Attache James S. Burke. Interference because of a superabundance of broadcasting stations is a difficulty of threatening proportions but the Government is attempting a solution of the problem by requiring a division of time between stations operating on interfering frequencies." Government control of the assignment of wavelengths is forecast as a future probability. The radio programs, we are told, are not especially attractive but this is believed to be only a temporary condition.

Battery-operated receiving sets, batteries, and radio-receiver parts are being purchased in increasing numbers in Argentina—a sales' invitation to American radio manufacturers who are not already utilizing this marketing opportunity. However, we are told that the sale for American-made vacuum tubes is not appreciably large—due to the competition with tubes of foreign make, particularly a Dutch product. Yet, the exports of radio apparatus to Argentina from the United States during last year reached a surprising total of $1,513,693, compared with $1,229,554 in 1928. The distribution of radio exports from this country to Argentina during 1929 included $482,371 worth of complete receiving sets and $583,335 worth of radio-receiver parts. The exports for the first four months of this year amounted to $550,686, including $217,939 worth of complete receiving sets, $114,985 worth of radio-receiver parts, $120,476 worth of batteries, and $93,166 for loudspeakers.

Parts Sales

The art of assembling sets has not been lost in this South American country; small electrical manufacturers buying the parts and joining them in orderly arrangements into complete receivers. This practice, however, still operates to the disadvantage of American radio manufacturers in some instances; inasmuch as cheap radio parts are imported from Germany, France, England, and Italy. Primarily, Argentina is an American market for complete receivers and radio parts. "The greatest hope," points out Assistant Commercial Attache Burke, in suggesting a possible expansion of the radio industry, "seems to be in extending the market in country districts. The large centers of rural population are within easy broadcasting distance of the cities, and dealers equipped to sell and service these outlying communities will undoubtedly find a new field as yet relatively unexploited."

Unwittingly, this representative of the Department of Commerce, located in Buenos Aires, has probably correctly visualized an opportunity that is even more insistent and extensive in scope in the United States—the marketing of receiving sets in the countryside. One has to but travel through vast stretches of rural territory without seeing any housetop antennas to realize that the great potentialities of radio have not been scratched. If there are rich rewards in radio, they are to be found on farms, ranches, and in the great open spaces.

Prospects For Radio

A READING of these statements discloses that the Radio Industry proposes to profit from Lessons Learned.

What Some of the Leading Manufacturers Think About the Experiences of the Past Year, and of the Future.

▲

Mr. H. B. Richmond, director of the engineering division, Radio Manufacturer's Association, believes the upturn has set in. Mr. Richmond's reply reads:

"IN reply to your request I am giving below a brief statement regarding radio industrial conditions.

"It is the weakest structures that fall first. Radio a year ago was in a very weak industrial position. This position was brought about by unwarranted expansion in the industry, based on excessive optimism, and also the unfortunate use of the radio industry as a medium for stock sales promotion plans. The radio industry has probably been outstanding in the rapidity and thoroughness with which it has liquidated its position.

"There is today every evidence of a decided upturn over the dull conditions which existed during the summer. This, of course, is after making due allowance for seasonal fluctuations. It is most probable that the number of sets sold during this fall and the holiday season will approach the number sold a year ago. They are, however, of a very decidedly different style. The small set is this year's outstanding item. This will mean that the unit price is lower than last year, so that the dollars of sales will decline, even if the number of sets sold remains the same.

"The outstanding lesson to be learned from the drastic liquidation period of the radio industry is the necessity for production control. Operating plans must be such that they can be kept in close harmony with selling conditions. More than ever has the necessity for research, both as to market and technical problems, been emphasized."

▲

Ray H. Manson, vice-president and chief engineer of the Stromberg-Carlson Telephone Manufacturing Company gives his views on the subject of midget receivers versus larger units. Mr. Manson states:

"IN answer to your invitation to contribute a statement, regarding the future business situation, for use in the December issue of RADIO ENGINEERING, I am attaching a short statement covering some of the subjects that I am personally acquainted with.

"We have complete faith in the future of the radio industry, but feel that the American public is in need of more education along the lines of appreciating the high quality of programs and the high quality of transmission of these programs which are now available to every owner of a radio receiver. I have reference particularly to the big public acceptance of the so-called midget radio receiver which from the standpoint of audio reproduction is a step backwards, as the reproduced program from most of these receivers is of a very inferior order and equivalent to that obtained with receivers of the vintage of 1925. It is true that these receivers are capable of giving greater volume than the earlier broadcast receivers and earlier loudspeakers, but the audio-frequency range is very short and in that respect there is little, if any, improvement. For example, a high grade electrodynamic speaker, which is capable of covering the useful audio range, when mounted in one of these midget cabinets, omits all of the fundamental frequencies below middle C on the piano. Also, the high frequency end of the scale is badly cut either intentionally or through the necessity of low-cost design, with the result that a high quality broadcast signal is poorly reproduced.

"Personally, I doubt if the public will continue to be satisfied with this kind of reproduction and that this situation will right itself in the near future. On the other hand, the regular lines of radio receivers of all makes have been greatly improved during the last twelve months as regards selectivity and better audio reproduction and we can expect continual gradual improvements in radio equipment following the same plan of development which has occurred in the automotive industry."

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Mr. Morris Metcalf, president of the R. M. A. and vice-president and treasurer of the American Bosch Magneto Corporation, analyzes accurately the causes of the passing depression in the radio industry. Mr. Metcalf's statement for RADIO ENGINEERING *follows:*

"IT is customary in these days to blame the general depression for our troubles and low sales. The radio industry, however, has internal causes which have far more effect on its prosperity than general business conditions. Youth is forgiven much, but the radio business is reaching an age when childish conduct is exacting its punishment, and the youth and rapid growth of the industry is no longer a valid excuse for the continued rejection of sound business practice and precedent.

Little or No Cooperation

"Radio manufacturers, with a few notable exceptions, are having a bad year; much worse, in fact, than there is any necessity for, or than is justified by general conditions. Manufacturers, jobbers and dealers seem bent on engaging in every bad practice known to the merchandising world. An almost complete lack of cooperation in matters vital to success, and a general disregard for the fundamentals of sound business, have created a situation which can only result in the failure of many companies, or the correction of their methods.

"Perhaps the most important factor in the continued growth of an industry is its ability to interest capital.

Receiver Sales

The automobile industry is an excellent example. The radio business, on the other hand, is so conducting its affairs as to repel financial interests and cast suspicion upon the soundness of its investments and its future.

"The principal causes of our woes and worries have been over-production and ineffective selling methods. The greatest restraint upon over-production which our laws permit is the collection and dissemination of the vital statistics of an industry. The common knowledge of production, sales and stock on hand is so generally recognized as a governing factor in operation that it is amazing to find this barometer completely ignored by most radio manufacturers. While this might be expected in the case of small or inexperienced concerns, it is, unfortunately, the larger ones who, through jealousy, fear or egotism are unwilling to contribute their figures to a central bureau. In my opinion, it is this fact more than any other which has accounted for the continued discrepancy between production and consumption, and all the evils attendant upon the consequent dumping of surplus merchandise. Again citing the automobile business, what is it that for twenty years has kept their production within reasonable bounds? It is the accurate knowledge that they have available, almost from day to day, of the production, inventory, and sales to dealers and customers of every member of their trade associations. Many other large industries have the same, but the radio business has no reliable information of this character, notwithstanding the earnest efforts of the R.M.A. for several years to provide this service.

Selling Methods

"As regards selling methods, I could not ask for space to describe them, but as a single instance one has only to consider the enormous waste and ineffectiveness of radio advertising to realize how far behind the times we are in modern methods. In my opinion, if half of the money spent by individual companies in misleading and unappealing advertising had been devoted to making the public radio conscious and acquainting them with the benefits and pleasures to be derived from the ownership of a radio set, it would have absorbed our overproduction. Such a campaign has pulled many an industry out of the mud, but I will venture to say that not five out of twenty of the larger radio manufacturers would subscribe to such a movement today.

"With the greatest advertising medium of all time at their command, and notwithstanding the greatest of obligations to the source of their being, there has been, up to date, no concerted support of broadcasting by the radio manufacturers.

"Engineering advance, research developments and manufacturing methods have far outstripped the commercial phases of our business, and not until the latter undergoes a marked improvement can radio take its place in the front rank of American industry."

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In response to RADIO ENGINEERING'S *request for a statement on the present business situation Powel Crosley, Jr., president of the Crosley Radio Corporation, telegraphs as follows:*

"THE radio industry is in a new business era where sanity, straight thinking, sound merchandising and advertising practices will rule those companies which are successful. The hectic years of rapid growth with their circus stunts, ballyhoo, extravagance, waste and foolish business methods which made it resemble a street show, are past. We feel that the policies of our company with its freedom from over-production, its growth, its honesty with dealers and distributors, and the ability of our executives to analyze the market demand and produce merchandise that has sold in large volume, has created for it a foundation for continued growth in this new business era. We have had a reaction that makes us face the future with great optimism. During the past few weeks reports from distributors indicate excellent volume for last quarter of year. Manufacturers in all lines who provide attractive, well-made merchandise at prices people can afford to pay, should have a satisfactory year."

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Mr. E. E. Shumaker, president, RCA-Victor Corporation, believes causes of slump are removed. He says:

"IT is said that an optimist is a man who can see a light where there is none and that a pessimist will blow it out. I have also heard that some men are such dyed-in-the-wool optimists that they will buy hair tonic from a bald headed barber.

"Ever since we inaugurated the 'Back to Work' movement in Camden, I have frequently been asked why I was an optimist. My reply was that I am not an optimist but that by nature I am a pessimist. I am like the old man who said he had many troubles but most of them never happened.

"Because by nature I am pessimistic and, therefore, inclined to look on the dark side of things, I have delved deep during the past months looking for trouble and, in so doing, discovered that down beneath the troubled surface, down among the fundamentals, conditions were much better than I anticipated. I found, at least to my satisfaction, that the causes for the depression of 1930 have been removed and that what the people and business of our country now need is confidence, in order that we may have an early recovery.

Cause of the Depression

"In arriving at this conclusion, it was necessary in the first place to determine the principal cause for the depression which I think you will agree was over-confidence and the belief on the part of the public and industry generally that the boom times of 1927, 1928 and 1929 would last indefinitely. This over-confidence resulted in over-expansion, over-production and all the attendant evils to which there was but one answer—we had to slow down. A depression was the result which was aggravated and has already continued longer than the cause warranted, largely because of the complete change in our state of mind.

"Business, after all, reacts very much like a human being. When a man is perfectly well, he frequently lives at a rapid pace. He is over-confident of his strength and lays the foundation for ill health while he is well. In due course, the inevitable happens. He becomes ill and is put to bed. The cause of his illness is now removed and nature does the rest. He feels well again but has learned a lesson. He is cautious and lacks confidence. By and by, however, he gains faith. His confidence is restored and he lives properly for a time. As a result he again glows with health and strength, becomes careless and passes through another cycle. . . .

"I find that the wealth of the country has not been impaired. We as a nation have just as many resources and have the same desires and propensities we had a year ago. I find that there is nothing wrong with the country. We are still turning out enough wealth each day to maintain the highest standards.

"I believe that the cause of our recent business illness has now been removed and that we are recuperating but much more slowly than need be because of not only our own fears but because of the preaching of pessimists and because of many bad examples that are constantly before us, such as closed factories, breaks in the stock market, and idle working men. Recuperating business is not as fortunate as the recuperating man to which I referred. Man can feel himself getting better and his doctor encourages him. He is not dependent upon anyone else for his complete recovery. When the business of a whole nation is ill, however, we are dependent upon each other. . . ."

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Parts manufacturer optimistic. Francis R. Ehle, president of the International Resistance Company, writes:

"I BELIEVE that the radio industry is being extremely fortunate this year as compared to many other industries suffering from general depression.

"While there are fewer radio manufacturers this year than last, those few seem to be reasonably busy. In our own case, the increasing number of resistors used per radio set gives us a normal amount of business: in fact, our sales this year are considerably ahead of last year.

"There have been so many statements issued by thoroughly competent statisticians and economists that I am sure what few words I would have to offer would have absolutely no bearing upon industrial conditions. We are going ahead here trying to increase our sales, manufacture a worthy product, and spending no more than is necessary to accomplish these objects."

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McMurdo Silver, of Silver-Marshall, Inc., expresses his views on the radio sales situation. To quote Mr. Silver:

Improvement Will Be Gradual

"TO assume that for the balance of this season the course of the radio industry will differ materially from the trend of general business is, of course, rather absurd; yet there are certain factors operating within the radio industry and peculiar to itself which have been affecting, and will continue to affect, it particularly, without any great regard for the course of general business. In reference to business conditions, it has been said during recent months that when business is flat on its back, it has no place to look but up, and circumstances apparently indicate that business in general is definitely on the verge of looking up: It is not logical, however, to believe that there will be any wide-spread improvement in the tone of general business during the coming few months, other than what might be termed a normal seasonal increase over what has been done in the past eight to ten months.

"Considering the progress of business during the last eight or ten years, it is interesting to note that, in terms of industrial production, business has operated upon an eighteen month, or, perhaps, what might be more properly termed a thirty-six month, cycle: that is, an upward trend for eighteen months and then a downward trend for eighteen months. The last peak of industrial production was reached in June of 1929 and, upon the eighteen month cycle theory, the bottom of the valley should be reached in December of 1930. On the other hand, the factors cited by a number of industrial authorities would seem to indicate that the bottom of the valley may have been reached in August or September of 1930, and that we may now be on the up-grade. In any event, it would seem reasonable to anticipate the beginning of the next upward trend in the early part of 1931, to continue into the middle of 1932.

"For the radio industry this may mean that only a fair season will be experienced for radio manufacturers, distributors, and dealers, during this last quarter of 1930, with the hope that a better than normal continuation of the season may be anticipated in 1931 with the radio business continuing upon a favorable basis well up into April or May. That is, it might be anticipated that the radio business will be better during the first half of 1931 than might reasonably be expected in the light of the last half of 1930.

Fewer Manufacturers Now

"The mortality rate among radio manufacturers within the past year has been very high—approximately 50 per cent of all R.C.A. licensees having gone out of business or suspended active operations. Whether or not there will be any such mortality during the remainder of 1930 and the early part of 1931 is, of course, yet to be seen. Although general indications would not appear to point to a high mortality rate, yet certain factors operating within the industry may result in a number of failures. In particular, the release of superheterodyne supplemental licenses by R.C.A. to its licensees in July of 1930 has upset the radio set market to an extent not fully appreciated by manufacturers.

"Since a considerably better radio receiver can be built for a given amount of money by employing the superheterodyne system rather than the tuned radio frequency system; since, from the days of wide-spread home set-building, the superheterodyne system enjoys an almost mysteriously favorable reputation with the public and the trade; and because very considerable amounts of money are being, and will be, expended to further popularize this system, in my opinion the market for t.r.f. receivers is largely a thing of the past.

"At the present time it would appear that from four to six, or possibly more, midget sets are being sold for every large receiver sold and in the large set range between $100 to $150, superheterodynes are selling in good volume. This means that the market for the t. r.f. sets introduced at the June, 1930 Trade Show is not large and that radio manufacturers merchandising t.r.f. receivers in this particular market will suffer somewhat.

Over-Production

"Looking back upon this depression which (and this is said advisedly) we appear to have just gone through the old bugaboo of over-production stands out as a dominant note. However, since over-production was prevalent in practically every line of business, there seems to be no special moral which can be pointed out to the radio industry alone. The fact remains, however, that had fewer high pressure sales methods been employed in 1929, and had production been regulated, not by rampant and stupid optimism, but upon the results of careful analyses of the business conditions of the country as a whole, the over-production which has faced the radio industry during the past year would never have existed. But so long as the world endures, there will always be optimists—plenty of them."

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Asked what the prospects of the radio tube industry were, George Lewis, vice-president of the Arcturus Radio Tube Company, stated:

"IT is estimated that the tube industry will sell for the current fiscal year 84,000,000 tubes. It is also prophesied by the economists in this industry that this total will be divided so that approximately 66⅔% will be diverted to replacement business, while 33⅓% will be sold as initial equipment with radio sets.

"With the total yearly sales constantly increasing and with a decrease in the number of tube manufacturers, which totalled over 120 in 1926–27 and now number some fifty odd, one can readily see that prospects for the tube manufacturer have been greatly enhanced the past few years.

"Add to this the many diversified uses of vacuum tubes in aviation, radio systems, industrial applications, sound talking pictures, miscellaneous machine control systems, sorting and counting arrangements, alarm systems, etc., and we have a total business that should place the radio tube industry up among the nation's leaders. And each day finds some new use which further increases the total volume sales.

"Summarizing, I might say that the prospects for tube sales for 1930 are very good, and are even brighter for 1931 and the succeeding years."

The "Stenode"

By J. ROBINSON, Dsc., PhD.
MIEE, F. Inst. P.

This paper on the Stenode radio receiver was presented at the November, 1930, meeting in New York, of the Radio Club of America. The principle of this ingenious system is now being widely discussed by engineers and no doubt its place in the family of radio receivers will become plain when its practical uses are understood.

THE Stenode system was conceived as the result of a desire to use the most selective circuits for communication purposes. It has been the constant endeavor of radio engineers and of communication companies to improve selectivity ever since Sir Oliver Lodge introduced the conception of the tuning of circuits. By making circuits more and more selective, it has been possible to increase the number of services which could operate simultaneously and as the tuning of circuits was improved, progress has always been very pronounced as regards freedom from mutual interference, as well as from general disturbances such as atmospherics.

Since radio telephony became prominent, however, it has been considered that no further advantage would be obtained by increasing the selectivity and, in fact, opinion has been universal that it would be incorrect procedure to do so. The application of Fourier's principles to modulation has shown that when continuous waves were modulated by speech or music, the complicated waves can be resolved into a series of continuous waves of different frequencies, there being thus apparently a large number of frequencies transmitted. Thus to receive one telephony service, it was considered necessary to receive frequencies over a comparatively wide band, and in order to be free from distortion, the receiver should be sufficiently flatly tuned to receive all these frequencies uniformly.

Similar views apply to telegraphy, and a state of affairs was reached where wireless services are allocated by international agreement in such a way that the Fourier frequencies or sidebands of neighboring stations should not overlap. Each telephony service should have 10 kc. allocated solely for its own use. A restriction of this nature obviously places a limit on the use to which radio can be put. Under these conditions the time was soon reached when it was impossible to find a convenient frequency band for any new service.

When there is a complicated modulated waveform, as in the case of speech or music, there are many terms of various frequencies up to a maximum of say 5000 cycles per second. The effect can thus be shown as a series of frequencies extending from n− 5000 to n+ 5000. It is to be remembered that this band changes constantly during the performance of orchestras or during any conversations which are employed to modulate the waves of frequency n and thus what are usually called sidebands change as regards the distribution of frequencies and of relative energy in these frequencies, although it can be stated that they are all included in a band whose width is $2p_m$, where p_m is the maximum modulation frequency. It has been assumed, therefore, that as modulated waves can be considered to consist of the transmission of a series of waves extending over a comparatively wide band, it is necessary to receive in an equal manner each of these various frequencies and thus a limit has been placed on the selectivity of receiving circuits. It has been considered essential to have a receiver with a resonance curve which is sensibly flat over this wide range of frequencies, normally 10,000 cycles for broadcasting.

Fourier Theories Investigated

It appeared to me to be of importance to investigate whether the generally accepted deductions from the Fourier theories were of universal application in radio and the first aspect to be studied was whether the restriction on selectivity hitherto regarded as indispensable need necessarily apply.

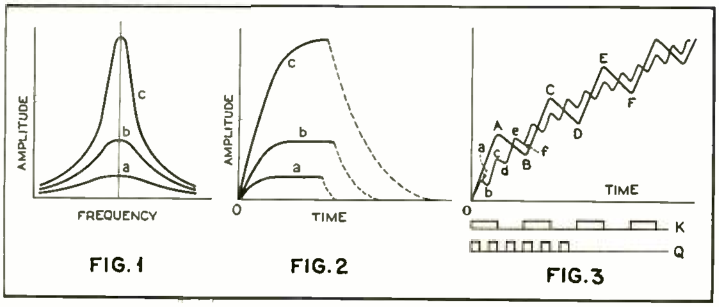
The universally accepted opinion was that if we employ a receiver with a resonance curve whose effective width is smaller than the frequency range of the sidebands, we should be, in popular phraseology, "cutting off the upper sidebands." If a receiver with an effective width less than 100 cycles were employed, the foregoing common expression obviously implied that we should eliminate all the sidebands of music and speech and leave practically only the pure continuous wave component.

Something was wrong in this generally accepted view, because if one considered a very selective receiver such as one employing a quartz crystal to be acted upon by waves of its own frequency, this crystal would build up to a steady state when the waves were of continuous waveform. It is obvious that if a transmitter were keyed at a very slow rate, we should obtain the complete response of the quartz crystal to the transmission, and if the rate of transmission were one signal per second, we should obtain the rise and fall of the response. If the frequency of signaling increased there would still be change of response, but yet general radio opinion stated that if the signaling speed were at the rate of 5000 signals per second, there would be no change in the response as the upper sidebands would be cut off.

There can be no discontinuity in the nature of the physical response as we go from a signaling speed of one per second to 5000 per second, and it is thus essential to examine the whole phenomenon from an entirely different point of view.

Decrement

Let us consider a resonant circuit which can be obtained in three different conditions as regards the logarithmic decrement, the remaining condi-



Figs. 1, 2 and 3. Damping, amplitude and response curves, respectively.

tions being constant. Fig. 1 shows resonance curves for these three conditions, the resonance curve a relating to the case of the highest damping and c to that of the lowest damping. We shall examine these conditions by plotting the rate of rise of the oscillations which arrive at the circuits. This is shown in Fig. 2 where we plot the amplitude of the oscillations in the circuit against the time when continuous waves arrive. We find that for the curve a the oscillations build up to a comparatively low steady state, whereas in the case of low damping, c, a large steady state is finally obtained. The amplitude of the steady state in fact is inversely proportional to the resistance in the circuit.

Another very important fact emerges from these curves which is that although the curve c eventually reaches a higher amplitude than that of curve a longer time is required for it to reach its steady state. In each case here we are considering the waves which arrive to be in tune with the receiver. When the incoming waves cease, the receiver is in a state of oscillation and these oscillations will commence to die away at a rate depending on the logarithmic decrement. In each case we have an exponential fall of the oscillations and for the case of high damping the receiver comes very quickly to rest, whereas for the case of low damping (curve c) a considerable length of time is required for the receiver to come to rest.

Suppose that we make a signal at a transmitter and that we wish the receiver to respond to its full extent and to die down to zero again, it is obvious from these curves that the length of the signal which we can use depends on which of the curves a, b or c, we employ. In the case of curve a, a comparatively short time is required to build to the maximum value and a comparatively short time to die down to rest again, whereas in the case of curve c, a very much longer time is required for the receiver to build up to its maximum value and to die down to rest again. Hence if we make the condition that the receiver must always be allowed to rise to a maximum value and must always come to rest again for any one signal, we arrive at the conclusion that the lower the damping of our receiving circuit, the lower must be the signaling speed of the transmitter.

High Signaling Speed

Let us now examine what would happen if we actually do employ very high signaling speeds for these circuits of exceedingly low damping. In Fig. 3 we again plot the amplitude of response of a very selective circuit against the time, and the actual response of such a receiver to telegraphic signals of two different speeds is also shown.

First of all, we shall consider signals as shown at K and we must assume that these signals are made so that the transmitter is active and at rest for equal intervals. For the first active portion, the amplitude of oscillation will build up to the point A. When the incoming waves cease, these oscillations will tend to die away, and as a comparatively long time is required for this process, it is obvious that we cannot afford to ignore the exponential effect, which in fact becomes of very great importance. In the period of rest, however, the receiver will only die away to the point B and it will still be in a state of oscillation when the next signal arrives. This will now (provided we arrange for it to start in the correct phase) build to the amplitude of oscillation of the point C, when the signals again cease. Again, the amplitude falls to the point D in the period of rest when the signals again arrive.

Thus for the signals K we find that the receiver continues to build up according to the curve OABCD, finally reaching a steady state with the amplitude varying according to the signals.

Consider now that the signaling speed is increased as shown at Q. The build up curve becomes oabcd, again the amplitude building up to a steady state with a fluctuation, the rate of fluctuation corresponding to the signaling speed but the amplitude of the fluctuation being smaller than in the case where the signaling speed was lower.

Fig. 3 is sufficient to show that no matter what telegraphic signaling speed is employed, provided that this is lower than the frequency of the carrier waves, we shall have the amplitude of the receiver fluctuating with the signals, the amount of fluctuation depending on the signaling speed.

In place of telegraphic signals as shown at K and Q, it is obvious that we could employ signals of trigonometrical form, instead of being square-topped as shown at K and Q. Similar reasoning will apply, and this means that instead of transmitting telegraphic signals of square-topped form, we are transmitting signals of trigonometrical form which, in fact, are equivalent to a trigonometrical modulation of the carrier waves. Thus we find that when the carrier waves are modulated by any frequency, we have the amplitude of oscillation fluctuating at the same rate as the modulation, but the amount of the fluctuation depends on the modulation frequency, being greater for a lower modulation frequency.

The important deduction to be drawn is that in this very selective circuit, all modulation frequencies, or all signaling frequencies are present, although not in their original proportions. We can, in fact, deduce a general principle, which is that when modulated waves impinge on a receiver. the percentage modulation is changed after going through the receiver to an amount which depends upon the logarithmic decrement and also on the modulation frequency. Thus no matter how selective we make a circuit, all modulation frequencies are still present, although they are not necessarily present in their original relative intensities. For extreme selectivity it was apparent that the response of any signaling frequency would be approximately, if not exactly, inversely proportional to the signaling frequency.

The Receiver

Having reached this very important deduction, the way was shown to the construction of a suitable receiver, by employing a very selective device and arranging for the correction of the modulation frequencies so that they should appear in their desired proportions. For instance, one method for bringing this about is to pass the modulated waves through a highly selective circuit, such as a quartz piezoelectric crystal, then to rectify the effects and pass the result through a low-frequency amplifier which has the characteristic of amplifying the frequencies so that the amplification factor is proportional to the frequency.

Thus it is seen that there is no necessity to place a limit on the selectivity of a circuit.

Magnitude of Modulation Response

The conclusion that has just been arrived at that the percentage modulation is reduced as the selectivity increases, helps us to appreciate that the magnitude of the modulated response is not small. Although the percentage modulation has been diminished, the total response of the circuit at resonance has increased as some resistance has been cut out of the resonant circuit to produce the selectivity. Hence although the percentage modulation is diminished, the absolute value of the modulation is not necessarily lowered.

Examining the curves of Fig. 2 it can be seen that the absolute magnitude of the modulations is in fact not smaller for the highly selective circuit c than for the damped circuit a. In each case the amplitude builds up to a steady state where the input of energy into the circuit just balances the dissipation of energy. For curve c, the rate of input of energy is given by the tangent of the angle AOT, Fig. 4. This angle gives the rate of loss of energy at the point P, and thus when the input of energy ceases, the energy will fall away along a line PQ where the angle QPK=AOT.

The modulated signal is given by the amount of fall from the point P, and in a given small interval it will fall through PK, which equals the amount of rise of amplitude which we would obtain in this circuit when starting from rest. Obviously this is greater for the selective than for the non-selective circuit.

We thus have the following results:

1. No matter how selective a circuit may be, all modulation frequencies are present.

2. From a quantitative point of view the signals need not be weaker than they are in a highly damped receiver.

3. We can now employ selectivity as high as is practically possible and there is no need to place a limit to progress as regards selectivity. We should expect that as the selectivity is improved, such annoying factors as spark and atmospheric interference should be diminished.

4. The percentage modulation of waves is changed after they pass through a very selective device by a factor which is approximately proportional to the logarithmic decrement and approximately inversely proportional to the modulation frequency.

Practical Methods

Having established the fact that no matter how selective a receiver may be, it is still possible to receive all modulation frequencies, we shall consider certain practical methods for utilizing these principles in radio.

Highly Selective Receiver with Equalizing Amplifier

It is known that when a quartz crystal is cut in a special manner it has a definite frequency and that it can be employed as a resonater. Professor Cady has shown that when such a quartz crystal is connected in parallel across a resonating circuit, and when the resonance curve is plotted, the normal curve is obtained with the exception that at a very definite frequency a crevasse M appears in the resonance curve as shown at Fig. 5. This crevasse M occurs because at or near this very definite frequency some of the oscillating energy is constrained to pass through the crystal.

Such a resonator is obviously very selective and our object is to employ it not in the form of a crevasse in another resonance curve but merely as a resonator of its own accord. We thus need to obtain our indications actually in the quartz crystal circuit itself and for this purpose the crystal is connected between one end of the resonance circuit and the grid of a tube of Fig. 6. The crystal is shown as Q. Such an entirely new departure in radio reception brings forward a number of peculiar problems, one of them being the fact that it is usually necessary with the crystal to employ electrodes or plates, thus providing a capacity which is capable of passing high-frequency energy. It is necessary to correct any such effect, and one method of doing so is to employ a small condenser C connected to the opposite end of the resonating inductance, the filament of the tube being connected to a center point of the inductance.

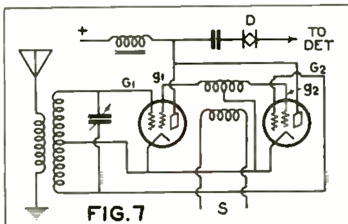
Thus in effect we provide a bridge circuit by means of which undesirable effects of any capacity of the quartz mount can be compensated. Effective reception with such a crystal obviously only occurs for a narrow frequency band and thus in order to employ one such crystal for a range of frequencies it is suitable to employ the supersonic principle, in order that incoming waves can have their frequency changed to that of the crystal.

It is not essential to describe in detail these supersonic portions of such a receiver, as this principle is well known. Following the quartz crystal, rectification is effected, after which a low frequency amplifier is used which is designed to amplify in proportion to the frequency.

Certain special features of rectification are introduced because the percentage modulation is low, although the actual amount of modulation may be quite normal.

Reversal of Phase Method

Another interesting method of employing a highly selective device in a different manner in order to obtain complete modulation frequencies is as follows: Referring to Fig. 2 it is seen that with such a selective device a considerable interval of time is required for the receiver to build up to its maximum amplitude, and at the same time this maximum amplitude is very high. It is, however, not



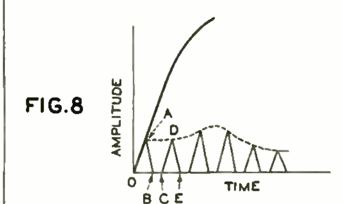
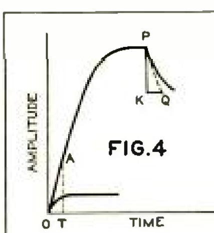
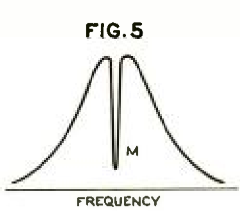


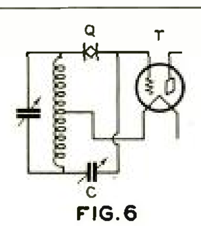
Fig. 7. Incoming signals led to two tubes. Fig. 8. Selectivity—does not affect modulation frequencies.

necessary to allow the receiver to reach its maximum amplitude and after a short interval of time when the receiver has built up to a comparatively small value, it is possible to bring it to rest again. This can be done by reversing the phase of the incoming signal. To show how this can be done a diagram is given in Fig. 7, a description of which appeared in *The Wireless World*, London, of December 11, 1929. In this case, incoming signals are led in opposite phase to the grids g_1 and g_2 of two tubes which are made alternately active at a lower frequency which would normally be supersonic when telephony is being received, by leading an alternating voltage of this lower frequency from a source S, Fig. 7 to second grids g_1 and g_2 in the two tubes.

In this way in the combined anode circuit of the two valves we obtain trains of waves with opposite high frequency phases in the successive trains which are led to the highly selective device D. We thus obtain a series of pulses as shown in Fig. 8, OAB, CDE, etc. The amplitudes of these pulses depend on the instantaneous intensity of the incoming waves. After rectification the envelope of these pulses corresponds to the form of the low-frequency waves, so that such a







Figs. 4, 5 and 6. Curves illustrating energy transfer.

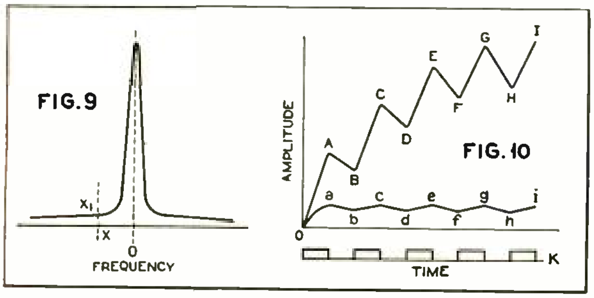


Fig. 9. Typical resonance curve of highly selective circuit.

Fig. 10. Telegraph signal impulses.

receiver although exceedingly selective will still indicate all the modulation frequencies.

Interference with the Stenode

Once it has been appreciated that all modulation frequencies are present in a receiver of this nature no matter how selective it may be, certain deductions can be made.

The opinion has been universally held that the ideal receiver for broadcasting reception should be able to receive equally waves over a frequency band of ten kilocycles and receivers have been designed employing band-pass filters to eliminate waves whose frequencies are outside of such frequency band. Such designs have concentrated on methods for obtaining equal response within the required frequency band of ten kilocycles.

In this connection it is important to point out that when the high frequency circuits of a radio receiver are designed to respond to a wide band of frequencies, such as, 5000 cycles, either side of the carrier frequency, there is an inevitable loss of the efficiency which comes from utilizing the principle of resonance to its best advantage.

One important result of the work on the Stenode system is the advancing of a definite group of principles hitherto entirely unrecognized, which may be employed by the application of sound engineering to bring about results considered up to now as entirely impossible.

Interference

It is now necessary to consider in what manner interference will be caused by waves of frequencies different from that to which the selective receiver is tuned.

We must consider what will happen if the interfering frequency is nearer than ten kilocycles. The general conception of the sideband theory appears to be that when the carrier frequency is nearer than ten kilocycles, interference should be experienced.

A general discussion on the nature of sidebands took place in the pages of *Nature* early in 1930, and various scientists, particularly Fortescue and Glazebrook recalled the fact that simple modulated waves, i.e., waves of frequency n modulated at frequency p do actually give resonant response in a receiver at the three frequencies n, n+p and n—p. Because of this it might be considered that if the interfering carrier frequency is 1000 cycles away and has a modulation of 1000 cycles, one of the sidebands so produced will fall directly on the resonance curve of our receiver and will thus produce considerable interference.

While there is no doubt that under such conditions the receiver would be excited, no interference is actually produced because this interfering sideband is purely of continuous wave-form and it will operate in conjunction with the desired carrier wave to determine the maximum amount of build up in the receiver. The preceding discussion has shown that the desired signals are the variations of this maximum build up.

The probability that we should obtain an interfering station with a prolonged note of such frequency that it produces a sideband accurately on the resonance curve of the receiver is very small with the Stenode and this probability diminishes as the selectivity of the receiver is increased.

A more general case is that the interfering station will have a modulation frequency of variable intensity which produces a sideband accurately on the resonance curve of the receiver and in this case intensity of this sideband is very much lower than when one constant note is being produced. The variation of intensity in this case is at a very slow rate being controlled by the speed of manipulation of musicians and is thus at a rate of the order of one per second.

We must thus look to other causes for any possible interference and we shall now consider what interference is obtained from the carrier wave of a neighboring station. Fig. 9 may be taken as a typical resonance curve of a highly selective circuit, and it is seen that an adjacent station at X will produce an effect on the selective receiver even though this effect is small. In most of the experiments up to date, it is found that such a carrier does produce a small interference and, although this does not form part of the present paper, means can be employed to remove this interference.

For the moment, however, we shall discuss the nature of this small interference of a carrier frequency. Let us consider the build up effects that are obtained in our selective receiver by an interfering station at X in a similar manner to that in Fig. 2.

In the first place, if the interfering station is of continuous waveform of frequency n, we have the build up of the signals as shown at oaceg, whereas for a signal of the same intensity actually in tune, i.e., of frequency n_0, the build up for continuous waves is OACEG. Let us now consider that we modulate the signals and employ telegraphic signals as shown at K Fig. 10. For the interfering station we have a low maximum value for the amplitude. Consider the case at the point e when a signal has just ceased. We have here the case of forced oscillations which have built up a small amplitude. At the time given by e the receiver is actually being forced to oscillate at a frequency n_2, which is different from the natural frequency of the circuit n_0. When the input of energy ceases, the receiver will continue to oscillate in its own natural frequency n_0 and the oscillations will die away according to an exponential curve determined by the damping of the oscillating circuit.

As the initial amplitude of the oscillation at e is small and as the damping is minute, we shall have the receiver dying away to the point f in the spacing interval, when there is no incoming energy. This exponential curve is of the same family of exponential curves as that given at EF and the slope of ef is further, very much lower than that of EF.

When the next signal arrives at e the receiver will build up to the point g (provided that the phase of the incoming signal is correct) and the total result is that the incoming signals give a maximum oscillation which is small, with a variation of amplitude which is still smaller. Thus the interfering station, when of continuous waveform produces energy given by oaceg and when this interfering station is modulated, we still have this same energy with a small variation of amplitude corresponding to the signals, i.e., oabcdefg. In fact, qualitatively, it is apparent that the percentage modulation of the interfering signals is of the same order as that for the signal which is in tune with the receiver.

The result has thus been obtained that when we have waves of a frequency n_0 modulated by speech, music or the like, and when we employ a very selective receiver, the modulation response is a maximum when the receiver is tuned accurately to the frequency of the incoming waves and that this response rapidly diminishes as the receiver is progressively detuned from this frequency. By making a receiver of the highest possible selectivity, the modulation response of a transmission whose frequency is less than 5,000 cycles away from that of the receiver can be made negligible.

This result is in accordance with our earlier conceptions of tuning, but at first sight, it appears to be a contradiction of the sideband theory. This latter theory is an application of the Fourier analysis to radio, and in consequence it has been considered to be a correct interpretation of all facts of modulation.

It is, however, very significant that there are certain phases of radio analysis where it is customary to employ the actual modulated waves instead of the Fourier components, such as for instance in problems of rectification, and it begins to be a case for consideration, whether the sideband theory as at present formulated, being merely a statement of Fourier's analysis, gives a complete statement of the case.

The case has not been completely analysed so long as problems of rectification and detection have been omitted. Then again it must be remembered that the Fourier components are changing in amplitude and frequency for the general case of modulation, such as for speech, music, telegraphic signals or television. Another consideration is that the Fourier analysis gives values for the amplitudes, frequencies and phases of the various components, and the question of phase shows that we cannot apply simple arithmetical addition to these various components.

This becomes of great importance in the case of the Stenode where the receiver is exceedingly selective. Still another factor which must be considered in the case of the Stenode is that we must take into account free oscillations which are given by the exponential term in the solution of the basic differential equation for oscillating circuits. With ordinary receivers, it is usually unnecessary to consider the exponential term as it is of small importance, but with the Stenode it cannot be ignored.

There is one other very important consideration in connection with the exponential term. The effect of this term is large in the Stenode and it is not easy to subject it to mathematical computation. Its value at any instant depends on the actual amplitude of oscillation in the selective circuit and as this amplitude is changing for modulated waves the value of the exponential term is also changing. When one attempts to apply the sideband analysis to the Stenode, the question arises as to the vectorial addition of various sideband effects. Such addition is permissible provided that each term is entirely independent of the other terms but when the exponential term is of large importance the sideband effects are not independent of each other and thus simple addition cannot be applied.

These considerations show that the application of the Fourier analysis to the complete radio equipment is not quite simple, and that when new facts are brought forward as in the present case of the Stenode, the application of the Fourier analysis must be made in a manner to include the whole of the phenomena.

Summary

The Stenode system is a departure from hitherto universal practice, where it was considered necessary to employ a widely tuned receiver in order to receive all the sidebands of the transmitting station. In fact, the Stenode system makes it possible to increase selectivity to the utmost practical limit and still obtain all modulation frequencies. While employing selectivity of a much higher order than normal it is possible to obtain all modulation frequencies and to apply a low frequency amplifier which may be designed according to a clearly defined law that the amplification factor is proportional to the frequency and thus to obtain fidelity. Another result arrived at is that there is a large improvement possible in the ratio of signal to interference whether the latter may be from natural or other causes. From a quantitative point of view, the signals are at least as strong as they are in the normal highly damped receiver. Some of the effects of the Stenode system can be expressed in the form that the percentage modulation of waves is changed after the waves pass through a selective device by a factor which is proportional to the logarthmic decrement and inversely proportional to the modulation frequency. It further brings out the possibility that modulated stations can be placed considerably closer than 10 kilocycles apart without interference and with perfect fidelity.

PRIVATE DIARIES OF DR. de FOREST GIVEN TO PUBLIC

In recognition of the twenty-fifth anniversary of the invention of the famous Audion tube, of radio and sound projection in motion pictures, The Smedley Press of 10 East 43rd street, New York, announces a limited edition of 450 copies of an historical volume, under the title "The Life and Works of Dr. Lee de Forest," with an Honor Roll of radio and sound motion pictures pioneers.

In this biography will be found, it appears, the first published excerpts from the private diaries of the inventor, who in his periods of stress, kept a daily record of happenings in the world of wireless. The biography is by C. S. Thompson, a lifelong friend of the inventor, and for many years publicity director of the de Forest Radio Company, holder of the original Audion tube patents.

Two fortunes in wireless were won and lost by de Forest, according to Mr. Thompson, before public acceptance of radio broadcasting made it possible for the inventor to climb the ladder of success for a third time, although frequently jeopardized by court decisions, which in the end gave him full credit for his invention of the three-electrode vacuum tube, as a telephone relay, amplifier oscillator, and regenerator of radio currents.

It was in the Clinton street, Chicago, shops of the Western Electric Company that de Forest first went to work as a shop helper — a company which it is said afterward paid him a total of $400,000 for patent rights, made doubly valuable, it appears, through the use of the de Forest amplifier tube as an integral part of sound projection in motion pictures theatres.

Interspersed in the diaries, says the biographer, are many rare gems of poetic feeling descriptive of nature, jotted down by the inventor in his leisure time devoted to tramping through the woods, or in watching the beauties of sunsets on Lake Michigan, in the tropics or at sea. The publishers announce that this limited edition, commemorative of the twenty-fifth anniversary of the birth of the Audion tube, will not be put on public sale. Publication will be made in January.

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COMMUNICATIONS—UNITED STATES, 1930

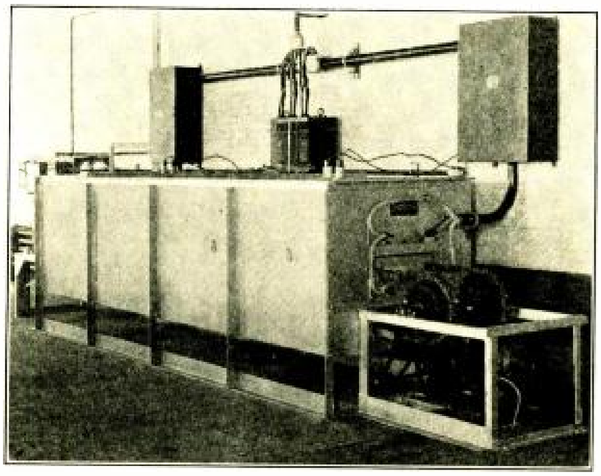
Telephone investment, estimated	$4,227,000,000
Telephone employees	430,000
Telegraph investments, estimated	412,000,000
Telegraph employees	90,000
Radio investments, estimated	3,250,000,000
Radio employees	210,000

E. E. SHUMAKER SAYS

E. E. Shumaker, president of the RCA-Victor Company, says:

"To talk prosperity means nothing. We must provide work for the individual. Labor must be usefully employed, and prosperity will follow."

Resistors---Wire Wound On Porcelain, Enamel Coated



Enamel baking oven for continuous operation.

By JOHN DUNSHEATH

IN THE huge and ever growing radio industry, porcelain enamel resistors are playing a more and more important part. In fact, they are in many instances replacing other types of wire-wound resistors. This trend is due to the superiority of enamel over other materials, for this purpose.

Porcelain enamel is of a glass base. This means that it is an excellent dissipater of heat, which is the chief purpose of a resistor of any type. Furthermore, the glass-base enamel is successful in excluding moisture from the coil. This latter factor is especially important in damp climates.

Enamel fused on a wire-wound resistor forms a complete insulation about the wire itself, at all times.

Vitreous enameled resistors have been repeatedly tested against other resistors identical as to interior construction, but covered with materials such as cement, refractory compositions, paint enamels, and lacquers. Invariably, the porcelain enameled resistor has proved superior, due to the points enumerated above.

The Manufacture of Resistors

The process of coating wire-wound resistors with vitreous enamel has been known and used for over forty years. In manufacturing a resistor of this type, the first requisite is that all the materials which go to make up the finished product must have coefficients of expansion as nearly equal as possible.

The base tube should be of a semi-vitreous refractory, with approximately 6 per cent porosity, depending upon whether the resistor is to be sprayed with or dipped in the enamel. In some cases the tubes are scored, to make the wire-winding operation easier.

The leads, or terminals, must be of a high grade acid pickled copper. There are several types of leads: plain sheet band, plaited wire, and pigtail type. It is very important that they be free from all dirt or grease, as enamel will not adhere to these foreign materials.

The wire should be bare nichrome carefully space-wound in advance so that it never crosses or makes contact with its own coils, as this will cause an incorrect reading in testing. The wire must be fastened securely to the terminal, and coated with a high temperature silver solder at the point of contact.

The enamel[1] is then prepared and checked for proper consistency, which is determined by weight. The tubes are then either dipped in or sprayed with the enamel, and started immediately into the continuous furnace. The furnace is divided into two heat chambers: a drying, or preheating zone, the temperature of which is about 700° F., and a firing zone with a temperature of from 1325° to 1350° F. The speed of the conveyor through the furnace is determined by the size of the resistor and the thickness of the tube. The enamel will not fuse properly until the tube on which the wire is wound is thoroughly heated, and has reached the same temperature as the fusing point of the enamel.

[1] *Information procured from the Porcelain Enamel & Mfg. Company, Baltimore, Md.*

After firing, the resistor is carried through the cooling chamber, so that it will slowly cool off to room temperature. If cooling takes place too rapidly either the tube or the enamel may crack.

If the wire is not properly fastened to the lead, the enamel may fuse between them. In this case, its high insulating properties will cut off all possible contact. When the enamel is not applied properly, a honeycomb effect results instead of the solid glass coating. Should the burning temperature be too high or the time too long, the wire may move during the operation. This will cause a short circuit, and consequent "out" reading. When the enamel is properly prepared a boiling condition is frequently encountered. When a gas fired furnace is used any leak in the muffle will produce a similar boiling effect.

The average number of coats per resistor is from 2 to 3. Where care is exercised the rejects will be 5 per cent or less after testing. Vitreous enamel resistors are usually worked to a tolerance of from 5 per cent to 10 per cent plus or minus, though many are made with a 1 per cent plus or minus tolerance.

In recent years the development of a leadless resistor enamel has been of great advantage as the absence of lead precludes any trouble from free lead spots, which sometimes develop after the resistor is in use. Furthermore, of course, the contention that employees may receive lead poisoning is entirely eliminated.

Porcelain enamel resistors are now obtainable in every size and ohmic capacity. They are invading the field especially where the even dissipation of high heats is necessary. The use of porcelain enamel resistors has increased about 500 per cent in the past five years.

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Dependable Resistance Units Are Essential for Trouble-Free Performance of Radio Receivers

Characteristics of Dry-Electrolyte Condensers

By HAROLD ROSS

DURING the past few years a continually increasing number of radio set manufacturers have made use of electrolytic condensers in the filter circuits of power units in receivers. The rising popularity among radio engineers of the electrolytic condenser in comparison with paper condensers is due to a number of factors of which cost is one of the most important; electrolytic condensers are much cheaper than paper condensers of equivalent voltage rating and capacity. But cost is by no means the only factor, for properly designed electrolytic condensers have a number of advantages that should appeal to the radio design engineer. These advantages are possibly not generally realized (due to the comparative newness of the high voltage electrolytic condenser) and for this reason is presented, in the following discussion, some data on the important characteristics of electrolytic condensers, together with notes on their practical use in the filter circuits of radio receivers.

Condensers for Receivers

The choice of a condenser for use in a radio receiver is governed by both technical and economic considerations. When judging condensers the engineer is interested in voltage rating, efficiency, life, ability to withstand momentary overloads, etc. If the condenser meets the technical requirements of the circuit, we are then interested in the space it requires, its weight, ease of mounting, appearance and cost. Let us first consider the technical characteristics of the electrolytic condenser.

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Laboratory Examination of Dry-Electrolyte Condensers show characteristics for Radio Receiver operation.

The operation of an electrolytic condenser depends on the formation around an aluminum electrode of a thin film having a very high resistance to the flow of current in one direction, although its resistance to the flow of the current in the opposite direction may be quite low. This thin film acts as a dielectric between the aluminum electrode and the electrolyte, so long as the voltage impressed across the cell has a polarity such that current tends to flow in the direction for which the film has a very high resistance. It should be obvious that the cell, when placed in an alternating-current circuit will act as a rectifier, since it has the essential rectifier characteristic of high resistance in one direction and low resistance in the opposite direction to the flow of current. If the device is to be used as a condenser it is necessary that it be used only in circuits where the potential across the cell always has the same polarity. This restricts the use of the ordinary electrolytic condenser to pure d-c. and pulsating d-c. circuits, such as exist in the filter systems of plate voltage supply circuits of radio receivers.

The maximum safe voltage which can be impressed across an electrolytic condenser is determined by the breakdown voltage of the film around the aluminum electrode. In the case of one[1] dry electrolytic condenser, the electrolyte film-forming characteristics are such that voltages somewhat in excess of 500 volts can be impressed across the condenser without any danger of breakdown; however the condensers are rated at 500 volts peak to give them a factor of safety.

[1] *Aerovox Hi-Farad type.*

Voltage Rating

The voltage rating of electrolytic condensers is determined by the materials used in construction and the voltage at which the film is formed. If, in operation, voltages in excess of the rated value are applied the leakage current through the condenser becomes excessive and if the voltage is sufficiently high the film will break down. If the overload is applied for a short time the film will automatically reform soon after the voltage returns to normal. If the excessive voltage is applied for a long time the condenser may be permanently injured. In the laboratory, groups of electrolytic condensers rated at 500 volts have been placed across 800 volt circuits for one minute without permanent injury to any of the condensers. In an extreme case 27 condensers were placed across 800 volts for twenty minutes, after which the voltage was reduced to normal, or, 500 volts. All but two of the units completely recovered from this severe overload, regaining rated capacity and normal leakage after operation for a short time at 500 volts. The ability of an electrolytic condenser to stand such abuse depends largely upon the characteristics of the electrolyte. The dry electrolyte used in these condensers has a high boiling point and it could therefore withstand the high temperatures developed during these tests. These condensers are recommended for operation at temperatures not in excess of 120° F. although the electrolyte will not dry up at temperatures as high as 175° F. If the 500-volt condensers are operated at less than 500 volts peak, the following temperatures are the maximum safe values.

Voltage (peak)	*Temperature Fahrenheit*
475	125°
450	130°
400	135°

The fact that these condensers are rated at 500 volts peak makes it possible to use them in all sections of plate voltage filter systems in radio receivers. Since the peak voltage across the first condenser of a filter circuit may reach values as high as 1.4 times the a-c. voltage on the plate of the rectifier, it follows that transformer voltages as high as 357 r.m.s. per anode may be used. Actually it will be found that in most circuits there is always some load on the rectifier which results in a voltage drop in the rectifier tube, making it possible to increase the transformer voltage by an amount equal to the minimum drop across the rectifier, without obtaining in excess of 500 volts across the first filter condenser.

It cannot be stressed too strongly, however, that the actual voltage developed across the first filter condenser will vary almost directly with line voltage. Most sets are designed for 115-volt operation and line voltages as high as 140 volts are quite common in certain parts of the United States. If excessive voltages are not to be developed across the first filter condenser with line voltages in the order of 140 volts, it is necessary that an automatic line voltage regulator be used, or that the transformer primary tap be set for the *highest* line voltage, or that the *normal* peak voltages across the first condenser be somewhat lower than 500 volts. With paper condensers one would also have to consider the possibility of surges, but since electrolytic condensers are not harmed by surges, surges may be neglected when the latter type of filter condenser is used.

As a Filter

In judging the merit of an electrolytic condenser an important factor is its efficiency as a filter. The effectiveness of a given condenser as a filter is largely determined by its series resistance. A high series resistance means poor power factor and low filtering efficiency. The series resistance of electrolytic condensers is determined by the specific resistance of the electrolyte and the length of the conducting path between the cathode and anode. It would appear desirable therefore to use an electrolyte of low specific resistance, but many tests have proven that the lower the specific resistance the greater is the chemical action between the electrolyte and the film, with the result that the life of the film is shortened. For long life an electrolyte of high specific resistance must be used, and the only way to keep the series resistance low is by reducing the length of the conducting path between anode and cathode. With proper construction an electrolyte of high specific resistance can be used to give long life and still hold the effective series resistance of the condenser at a low value.

It has been determined by many tests that the dry electrolyte used in the Aerovox condenser has no harmful effect on either the film, anode or cathode. The fact that the electrolyte does not attack aluminum also makes it possible to construct anode, cathode, and can of this material and thereby eliminate galvanic action, always likely to occur if two dissimilar metals are placed in contact with the same electrolyte. Samples, tested for 10,000 hours at maximum rated voltage—a test equivalent to about six years of normal use—have been disassembled and examined miscroscopically without locating any defect in either film, cathode or anode.

It is thought by many that the leakage current in the electrolytic condenser is an important factor—actually such is not the case. Losses in electrolytic condensers are due to dielectric hysteresis, electrolyte resistance, and film leakage. Ordinarily the latter loss is negligible for the leakage current is usually in the order of 1 to 2 ma. per 2 mf. section. The major loss is due to the resistance of the electrolyte and this loss has been reduced to a comparatively small value by a design which makes the conducting path very short. That the effective series resistance has been reduced to a low value is indicated by the fact that these condensers have an average power factor of only 8.2 per cent, which is some four times lower than was obtained in preliminary designs using certain types of construction with wet electrolytes. The importance of low power factor, if efficient filtering action is to be obtained, was proven by means of tests on a typical filter circuit. Electrolytic condensers were used in the first section of the filter system and the ripple voltage across the condenser measured by means of an oscillograph. The following figures were obtained.

Power factor of condenser	*Ripple voltage*
8.2	29.7 volts
16.1	39.6 volts
33.0	46.5 volts

These figures, determined by actual experiment, indicate how important is low power factor for efficient filtering. As nearly as can be determined by oscillographic tests a low power factor electrolytic condenser is practically equivalent per microfarad to a paper condenser.

If a filter condenser is to satisfactorily meet the requirements of the radio set manufacturer, it must be capable of withstanding rough handling, it must not be injured when subjected to the heat of summer or extreme cold of winter. Electrolytic condensers, if properly designed meet these requirements.

The extreme thinness of the dielectric film in the electrolytic condenser makes it possible to obtain large amounts of capacity in a small space. This is an important advantage, since space in the modern radio receiver is quite limited.

Besides being light in weight, the high capacity readily obtained in the electrolytic condenser makes it possible to reduce the size of the filter choke coils and thereby obtain a further reduction in weight of the chassis.

In summary: electrolytic condensers have a number of characteristics that make them suitable for use in radio receivers. Their voltage ratings can be made sufficiently high to permit their use in all sections of filter circuit. If punctured by a surge they heal themselves. If designed to have a low power factor they are equivalent per microfarad to paper condensers. If a dry electrolyte is used they can be mounted in any position and there is absolutely no danger of leakage. They can be designed to withstand all temperatures to which a receiver would normally be subjected. They are light in weight, small in size and low in cost.

BOOK REVIEW

"THE ELEMENTARY PRINCIPLES OF WIRELESS TELEGRAPHY & TELEPHONY" by R. D. Bangay, Third edition. Revised by O. F. Brown B.Sc., published by Iliffe & Sons Limited, Dorset House, Tudor Street, E. C. 4., London. Price 10/6 net, by post 11/-.

For many years this volume has been a standard book of instruction for wireless beginners and students. The progress of wireless during recent years has made necessary the new (third) edition which has been revised by O. F. Brown, B. Sc. The book covers the subject in a clear and simple style and deals thoroughly with modern developments. Many new chapters have been added and descriptions of modern circuits have also been included.

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"THE HANDBOOK OF TECHNICAL INSTRUCTION FOR WIRELESS TELEGRAPHISTS" by H. M. Dowsett M.I.E.E. F. Inst. P. M. Inst. R.E. Demy 8vo 478 pages. 459 Diagrams and Illustrations. Price 25/- net, by Post 25/9d.

This work constitutes a complete text book for the use of wireless telegraphists and others interested in the subject. In addition to dealing fully with general theory the book describes in detail the various types of marine wireless equipment, and gives also much practical information on maintenance. The subject matter of this new edition has been entirely recast and the scope of the book has been widened to meet the more exacting requirements of the operators' duties of today.

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PRACTICAL TESTING SYSTEMS, by John F. Rider, Radio Treatise Co., New York. 147 *pp., cloth,* $1.00.

For a long time there has been a need for a book of this kind. Mr. Rider has produced a very useful book, dealing with testing methods and systems as required by radio laboratorians and by servicemen. This book should be in every radio shop.

A New Frequency-Stabilized Oscillator System†

By Ross Gunn*

Engineering Attack on the Channel Limitation of Present Radio Systems Encourages Engineers to Hope for Successful Channel Separations of 100 Cycles.

THE economic value and importance of constant-frequency radio transmitters under the present congested condition of the ether can hardly be overestimated. The limit to the number of continuous-wave transmitters that can be placed within a given band is determined primarily by the stability and constancy of the transmitted frequency and by the purity of the emitted wave. It is hardly necessary to point out the technical advantages that would result from an oscillator system capable of producing a strictly constant frequency. Such oscillators are not yet available but approximate constancy can be attained. The writer can plainly forsee the time when successful high-frequency channels will be separated by not more than 100 cycles and the art must be developed to a point where such frequency intervals are a commercial fact. Piezoelectric and magnetostrictive constant-frequency oscillators have been the subject of much study in the past few years, and while the idea of "sawing a certain number of cycles out of a quartz crystal or steel ingot" appeals to one's imagination, it leaves a great deal to be desired from many points of view. Oscillators of this type are inflexible and are limited in the frequency range over which they will operate. As a result, modern radio transmitters are greatly complicated by the use of multiple-crystal systems and many stages of frequency-multiplying units which add needless complication to the technical problems involved. The inherent disadvantages of piezoelectric and magnetostrictive oscillators led the writer to undertake the development of numerous self-oscillating circuits which are found to be satisfactory constant-frequency oscillators for frequencies up to 20,000 kc.

In 1923 the United States Army Air Service undertook a series of experiments on radio control in which harmonic selectors were employed, and it fell to the writer to provide a suitable audio-frequency modulating source for the control circuits whose frequency would stay satisfactorily constant under the trying conditions that must be encountered in portable aircraft equipment. Ordinary self-oscillating circuits for audio frequencies were entirely out of the question, primarily because of frequency shifts arising from variations in the filament current or emission and from plate-battery fluctuations. Tuning-forks were tried but were entirely unreliable and unsatisfactory because of temperature effects and because large accelerations of the aircraft in certain directions tended to stop their vibration.

Various methods were adopted to compensate for frequency shifts in an ordinary oscillator arising from the variation of the plate voltage and filament emission but no truly satisfactory system could be devised. It was recognized early in the work that some new fundamental principle would be necessary if the problem were to be solved in a simple manner. The necessity for such a principle led to a test of an oscillator which was first described by the writer over six years ago,[1] but for reasons which will appear, the system was only of use as a constant-frequency source in the audible-frequency range, and it remained for later development to perfect it for use at radio frequencies.

Causes of Frequency Variation

In any self-oscillating vacuum-tube circuit the accidental changes in the generated frequency arise in general from two major causes. The first, and perhaps the most troublesome, source of difficulty arises from the fact that the generated frequency depends somewhat on the internal tube impedance. If the mean value of this quantity changes for any reason a change in frequency takes place. Changes in the internal impedance of a tube may arise from many sources of which we may name the following as important:

(a) changes in plate potential.
(b) changes in the mean grid potential
(c) changes in filament potential
(d) changes in emission due to causes other than (c)
(e) changes in spacing of the tube elements
(f) keying of the circuit

The second major difficulty is largely mechanical, since it is evident that changes in the mechanical arrangement of any part of the oscillating circuit will change the effect capacities and inductances which in turn will produce a change of frequency of the oscillator. Perhaps the most important causes of these variations are:

(a) changes in temperature
(b) vibration of mechanical forces
(c) electric or magnetic forces

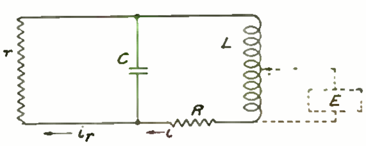

Fig 1

Equivalent circuit.

In the common vacuum-tube oscillating circuits employed up to the present time, moderate amounts of energy must be transferred from the plate to the grid circuit for excitation purposes. It is found that the generated frequency produced in such circuits is a complicated function of the internal impedance of the tube and that the law of the variation depends (often critically) on so many factors that compensation by simple means is practically impossible. The circuit theory of the common oscillators taking into account

† *Presented at the Toronto Convention of the Institute of Radio Engineers, Aug. 19, 1930.*

* *Naval Research Laboratory, Washington, D. C.*

1 *Gunn, Jour. Opt. Soc. and Rev. Sci. Inst., pp. 545, April, 1924.*

the effect of the tube impedances cannot be worked out here, but in the new circuits, which we shall consider presently, the grid coupling to the succeeding tubes is so small that the excitation circuit can be neglected. The resulting equivalent circuit represented in Fig. 1 is simple, and the frequency relations are readily obtained. In this circuit we shall consider only one symmetrical half of the entire oscillator and take no account of the special properties of the new circuit. In Fig. 1, let r represent the internal plate resistance of the tube which we shall assume has the properties of an ordinary conductor, and let L, C, and R represent the inductance capacity and

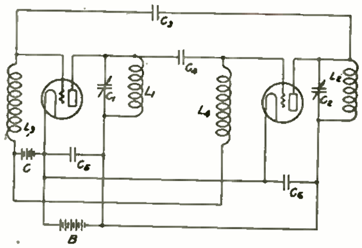

Fig 2

Fundamental scheme of the new oscillator.

equivalent series resistance of the associated tuned circuit. The differential equation connecting the circuit constants and the resulting current i for a free oscillation is

$$\frac{d^2i}{dt^2} + \left(\frac{R}{L} + \frac{1}{Cr}\right)\frac{di}{dt} + \frac{1}{LC}\left(1 + \frac{R}{r}\right) i = 0 \qquad (1)$$

This linear equation is solved by the usual methods and it is found that for values of L, R, and C encountered in radio work, the instantaneous oscillating current is given by

$$i = I_0 e^{-\alpha t} \sin \omega t \qquad (2)$$

where α is given by

$$\alpha = \frac{R}{2L} + \frac{1}{2rC} \qquad (3)$$

and

$$\omega = 2\pi f = \sqrt{\frac{1}{LC} - \frac{1}{4}\left(\frac{R}{L} - \frac{1}{rC}\right)^2} \qquad (4)$$

where f is the frequency of the resulting oscillations. Equation (4) may be put in the form

$$\omega = \omega_0 \sqrt{1 - \frac{LC}{4}\left(\frac{R}{L} - \frac{1}{rC}\right)^2} \qquad (5)$$

where ω_0 is 2π times the frequency which would be generated were L and C resistanceless inductances and capacities and were the shunt resistance r absent. Since r represents the internal tube resistance and since, as we have seen, this is a quantity that is subject to change in any practical circuit, the circuit constants should be so chosen that the effect on the frequency of the variations of r are a minimum. Inspection of (5) shows that the effect on the frequency for a change in r is a minimum when r is infinite or if

$$r = \frac{L}{RC} \qquad (6)$$

The internal resistance r of a vacuum tube is not equivalent to the constant resistance we have assumed since the tube resistance has unilateral conducting properties and is a function of the instantaneous plate potential but to a crude approximation, (6) specifies the relation that should exist between the various quantities. The mean value of the internal plate resistance of a shield-grid tube can be varied over a moderate range by adjustment of the filament and shield potential which allows a moderately wide selection of the ratio of L to C in so far as this particular requirement is concerned. In any flexible oscillator the relation is not readily satisfied for all adjustments, but within the limits set by the following design considerations the circuit constants should be so chosen that (6) is approximately fulfilled.

Another factor is still more important in the design of the tuned circuits; for it is clear that the more sharply tuned the elements of a filter chain the more effective is the selective action of the filter. The prime requisite of a simple tuned circuit for such use is that the sharpness of resonance shall be a maximum. That is, the quantity

$$G = \frac{1}{R}\sqrt{\frac{L}{C}} \qquad (7)$$

should be made as large as possible. In an earlier experimental investigation,[2, 3] relating to the design of high-frequency inductances it turned out that this factor was nearly constant with ranges of L to C varying by as much as two to one, for it was found that the equivalent series resistance of the circuits changed just enough to maintain G approximately constant. Thus considerable latitude is given in the selection of the quantities and for certain adjustments it is relatively easy to satisfy (6) and (7) simultaneously. These adjustments of the electrical circuit to fit the tube aid materially in the production of constant-frequency oscillations but the adjustments alone fail to give the great stability which is readily attained by the method employed in the new circuits and must be considered simply as a refinement necessary only when extraordinary stability is required.

Frequency changes arising from changes in the mechanical positions of the associated conductor systems arise primarily from temperature changes and vibration, although electrical and magnetic forces do occasionally cause trouble. Vibrations of the tube elements can cause difficulty, especially in aircraft, but with better and more rigid tube construction this difficulty will vanish. In a Navy aircraft transmitter employing the circuit to be described, no frequency modulation from vibration was encountered. Perhaps the most troublesome source of frequency shifts arising from mechanical causes originates in thermal expansion and contraction of the parts. The present series of experiments showed that changes in temperature of the tuned circuits might or might not produce changes in frequency, but in no case was the frequency shift of the new oscillator system larger than twice that produced by the same change in temperature in a circuit employing a quartz crystal. Moreover, it was found that the geometrical position and arrangement of the circuit elements were important and, by judicious choice, the temperature shifts could be kept to small values. The change in frequency is undoubtedly caused by the expansion of the mechanical parts which changes the effective spacing of the condenser plates, the individual turns of the inductance, etc. It is easy to design special forms of the inductances and condensers which have very small temperature coefficients but this is not necessary for compensation is more readily effected. A simple method has been employed to compensate for changes in frequency due to changes in temperature. The compensating device is simply a small condenser whose capacity is arranged to be a function of the temperature, and consists of a fixed plate and a movable plate made of a stiff bimetallic sheet. This is connected, most simply, across the main tuning condenser, and as the temperature of the device changes the spacing of the plates changes in a manner appropriate to compensate for frequency changes. It is evident that the fractional change of the total capacity can be controlled by the separation of the plates, and that the direction of the change can be reversed by simply turning over the biemetallic plate. Until

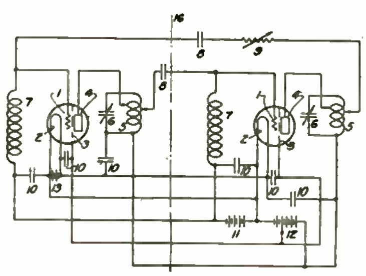

Fig. 3

Circuit suitable for all but very high frequencies.

one gains some experience, the adjustment is rather laborious but it is quite effective and it was found possible in certain cases to keep the frequency constant to within 85 cycles in 15.-000.000 when the temperature was changed 10° C. Temperature changes and expansion inside the tube have not been the subject of much study but it seems clear that no particular difficulty will be encountered from this source unless for some special reason series tuning is attempted.

[2] *Gunn, Radio Broadcast, page* 40, *May,* 1927.

[3] *Gunn,* Proc. *I. R. E.,* 15, 797; *September,* 1927.

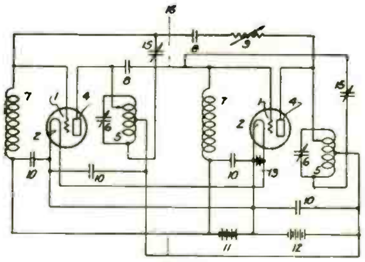

Fig. 4

Typical system, back coupling derived from overhang turns, and coupling condensers.

Fundamental Principle of New Circuits

The fundamental idea underlying the new circuits may most easily be understood by reference to Fig. 2, which shows the circuit that the author described some years ago, and is suitable for low frequencies well within the audible range. In this circuit L_1C_1 and L_2C_2 are nearly identical tuned circuits which approximately set the frequency of oscillation. The resultant frequency is also slightly dependent on the resistance of the tuned circuits, on the internal tube plate resistance and on the input coupling units to the succeeding tubes. The circuits L_1C_1 and L_2C_2 are sharply tuned and their parallel impedance is high for the particular frequency to which they are tuned and is low for all other frequencies. Now if a suitable change in potential be applied to the grid of the first tube, the variation is amplified, its phase reversed, and it is passed on to the second grid. The magnitude of the potential passed on the second grid will depend on the magnitude of the original change of potential and equally on the apparent impedance of the tuned circuit L_1C_1 since this circuit is effectively across the grid and filament of the second tube. Since the two tubes stand in identical electrical relation to each other, the second tube will repeat the process in precisely the same manner, and the initial pulse will be returned to the first grid amplified or attenuated and approximately in phase with it. When the returning pulse is larger than the initial one it is evident that oscillations will set in, in both the circuits L_1C_1 and L_2C_2 since these will be assumed to be tuned to identical frequencies. The oscillations will be impressed on each grid successively and if the interstage coupling is correct, those frequencies corresponding to a high parallel impedance in the coupling units will be amplified and pass through the system again and again and give rise to a steady oscillation. On the other hand, those frequencies corresponding to a lower parallel impedance in the coupling units will be less amplified and in the process of passing through the tuned systems again and again will be attenuated to such an extent that they will vanish from the system. It is then easily seen that the reëntrant circulation of oscillations through such a system simulates with great accuracy the selective effect of a filter system having a very great number of sections. Indeed, if oscillations are suppressed in the circuit of Fig. 2 by reducing the plate potential or the interstage coupling, the system makes an extraordinarily selective filter system. It is readily demonstrated that the output from a filter of a great number of sections can be made to approach a single frequency as closely as may be desired by proper design and use of as many sections as required. This demonstration is hardly necessary since the average radio engineer is perfectly familiar with the properties of such filter systems. The present system differs, however, from a filter unit of a great number of sections in that oscillating energy may be introduced constantly at each section. By proper adjustments and design of the coupling units, which may in themselves be very complicated types of filter sections, the system will oscillate freely at but one frequency and with difficulty, or not at all, at all other frequencies. Actual test shows that this is the case. The first oscillator that was built employing this principle oscil-

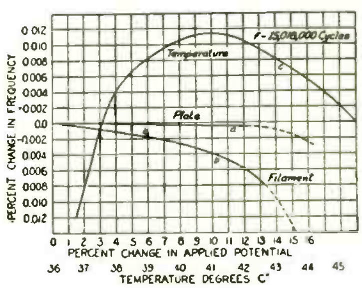

Fig. 5

How plate potential affects frequency changes.

lated at 1000 cycles and showed a frequency shift of less than one cycle when the plate potential was changed 50 per cent. Still greater frequency stability can be obtained by increasing the number of sections used, and extraordinary results have been secured by the use of four stages or more.

Application to Radio Frequencies

Initially the circuit failed to show great frequency stability at high frequencies and development on this phase of the problem was temporarily suspended. Later work made it clear that the difficulty with the operation of the circuits at radio frequencies was not with the fundamental idea of reëntrant circulation of the oscillation but was directly traceable to the fact that some of the control oscillation energy was fed back locally through the plate-grid and other stray capacities and couplings and the circulation was not complete. Bridge and balanced circuits were employed to correct these discrepancies and satisfactory results were obtained at moderate frequencies. However, the constant re-balancing and adjustment of the circuits which were necessary when the frequency was changed, robbed the circuit of perhaps its greatest asset—complete flexibility. It has since been found experimentally that any type of circuit that insures the complete circulation of oscillations through the tuned coupling elements again and again will make a satisfactory constant-frequency oscillator at radio frequencies. In the super-frequency band certain circuits and special adjustments become highly desirable. A universal circuit suitable for operation on all but the extremely high frequencies is shown in Fig. 3. In this arrangement screen-grid tubes are employed and these have been found most convenient since no balancing adjustment is necessary over nearly the entire frequency range. In this circuit it has been found absolutely essential to shield most carefully the different parts of the system, for it has been found that a slight coupling potential which reaches a grid from its own plate or plate circuit defeats the entire plan of reëntrant circulation of the oscillations. In all the systems to be described the plate circuits are shielded carefully from the control-grid circuits. This is most easily accomplished by incorporating the tuned plate circuit, the coupling condenser, and the grid choke to the succeeding tube, in one shielded compartment with the tube whose plate belongs to the tuned plate circuit and in another compartment an identical system is set up which works in conjunction with the first (see Figs. 8 and 9). By the careful location of the grid connections between compartments and by careful matching of the two halves, such an arrangement yields an oscillator of extreme stability. On the other hand, if the system is carelessly shielded it is found that energy is invariably led back from the plate circuit of the tube to the grid circuit of the same tube through stray couplings and slight variations produced in the frequency become cumulative. The resulting oscillations are then very sensitive to alterations in the plate and filament power supply.

Referring to Fig. 3 in detail a pair of electron tubes are shown connected in the oscillator system. Each tube stands in exactly the same electrical relation to its mate and each tube has associated with it nearly identical

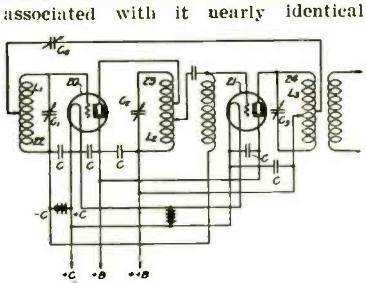

Fig. 6

Convenient arrangement when power amplifier is used in connection with small master oscillator tube.

circuits as shown. The circuit elements are represented in the standard manner. The variable capacity, 6, and inductance, 5, constitute a tuned circuit which determines the frequency of oscillation, and must be so chosen that the product of L and C are substantially the same in both circuits. These tuned coupling units are connected to the amplifier-oscillator tubes by means of the coupling condensers, 8, although this is not a necessary arrangement, and coupling may be accomplished by the use of a suitable inductance coupled magnetically to the plate inductance, 5, or by a combination of these methods. When shield-grid tubes are employed the shield is carefully maintained at ground or filament potential by the use of by-pass condensers, 10. This circuit is especially suitable for use as a master oscillator or as a heterodyne frequency meter, but when so used, it should be arranged to work into a shield-grid

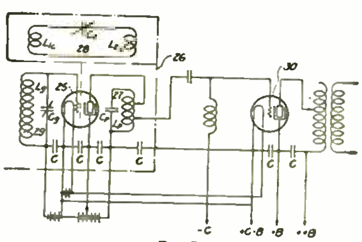

FIG. 7

This system is essentially a tuned-plate, tuned-grid oscillator circuit with link coupling.

output tube whose control grid is coupled to either tuned circuit of the master in the manner indicated in Fig. 8, making sure that the plate and plate circuit of the amplifier are shielded from all the master-oscillator circuits. The load is connected to the plate circuit of this output tube and it has been found that changes of any kind in the load produce negligibly small frequency shifts in the master. An essentially similar arrangement is shown in Fig. 4 which makes use of the standard 3-element tubes. With this type of tube it is necessary to balance out the plate-grid back coupling and any standard method can be employed so long as the compensation is carefully carried out. The circuit of Fig. 4 illustrates a typical system whereby the back coupling is compensated by a potential derived from a few overhanging turns and coupling condensers, 15. This circuit has not been found especially convenient for the higher radio frequencies. The variable resistance, 9, is introduced to control the amount of energy fed back to the original amplifier which in turn controls the oscillation current. Perhaps a better manner of controlling the feedback is by a variable tap on the plate coil in the manner indicated in the diagram. It has been found most satisfactory to keep the plate coupling rather large (especially in using shield-grid tubes) and the grid coupling to the succeeding tube as low as possible. The desirability of using low grid coupling arises from the reëntrant circulation of the oscillations which is of such a nature that certain frequencies are amplified and other frequencies are attenuated, the amount depending on the apparent impedance of the tuned circuits and the grid coupling. As the coupling between filter units is reduced the attenuation for all frequencies is increased and a critical point will be found where they all die out. A slight additional coupling brings the level up to a point where only the one frequency for which the circuits are adjusted is amplified and all others attenuated. This adjustment obviously is the one which gives rise to the most stable oscillations. A circuit which is properly adjusted will not oscillate except at one point on the tuning condenser, and the resonant point is as sharply defined on the condenser scale as in a quartz-crystal oscillating circuit. For example, in a certain circuit operating normally at 10,000 kc, oscillations had ceased completely when one circuit had been detuned to such an extent that the frequency shifted to 10,022 kc. or to 9,977 kc.

Performances

In order to determine what factors produced the greatest changes in frequency a series of standardization tests were run on an oscillator of the type shown in Fig. 3, and operating at 15,018 kc. These tests showed that the circuit is extraordinarily stable and the frequency stability of the oscillator compares favorably with a piezo-electric crystal-controlled oscillator maintained at a constant temperature by means of a thermostat. Rather complete tests have been conducted on the effect of changes of plate and filament potential on the frequency, and on the lilt produced by keying in different parts of the circuit. Changes in plate potential of 10 per cent produced a change of frequency of but 45 cycles. This change in frequency amounts to but 0.0003 per cent of the fundamental and is so small as to cause no difficulty whatever in any normal radio circuit. A curve showing how the frequency changes with the plate potential is given in Fig. 5. Perhaps the greatest changes in frequency are produced in a vacuum-tube oscillator by changes in the filament potential. With the present circuit such changes are relatively small and amount to but 400 cycles for a change in filament potential of 8 per cent. A curve typical of the performance in this respect is given in Fig. 5(*b*). Keying of the entire circuit in the plate lead gave rise to no lilt that could be detected until the frequency was pushed up to 20,000 kc., and even then the shift in frequency due to keying was just noticeable. The foregoing data are typical of the performance that may be expected from an oscillating system similar to Fig. 3, when properly adjusted to the desired frequency. It has been found that the operation of such an oscillator is subject to a very small drift in frequency over long periods of time due to permanent changes in the filament emission unless the precautionary adjustment specified by (6) is made. A curve showing how the frequency changes with the circumambient temperature is given in Fig. 5(*c*). In this particular run no attempt was made to compensate for temperature changes, but over a narrow range of a degree or so the frequency changed but slightly and this region would ordinarily have been selected for operation. The shape of this curve depends markedly on the particular arrangement of the parts, and Fig. 5(*c*) is given only as an illustration of what may be expected. When the circuits have been in adjustment the writer has never observed changes in frequency with temperatures which amounted to more than 60 parts per million per degree. By compensation this can very easily be reduced to about 10 parts per million per degree over a range of two or three degrees. In special cases the change was as small as one-twentieth of this value. The present circuits are therefore comparable in stability to a piezo-electric oscillator in respect to temperature variations, for crystal oscillators show changes of about 22 parts per million per degree.

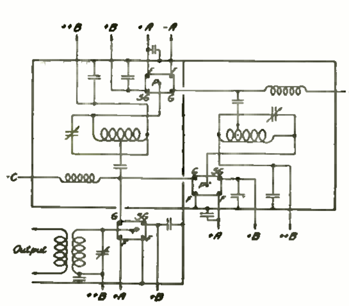

FIG. 8

Completed connections to output.

It should be emphasized at this point that the above performance data apply to a laboratory oscillator whose power supply for all parts of the system was steady direct current. Moreover, as has been found in other types of constant-frequency oscillators, it is essential that the tubes be lightly loaded when great stability is required. Dr. A. Hoyt Taylor of this laboratory has subjected the circuit to many tests in his transmitting laboratory and has not found the circuit quite as stable as the foregoing paragraph indicates. In his tests the tubes were worked at their rated output, and alternating current was supplied to the filaments. The effect of alternating current on the filaments was found especially unfavorable since the internal impedance of the tube varied over a considerable range at a frequency twice that of the heating current. This variation can undoubtedly be cured by the use of special non-inductive filaments but so far special tubes have not been made up. In general, it is recommended that the circuit be worked lightly and any power that is required be taken from a power amplifier associated with the master. When the master oscillator is keyed in preference to the power amplifier, it is still more desirable to work the system lightly, for thermal equilibrium is never attained under such operating conditions.

Special Circuits

Many variations of the fundamental circuits are possible without departing from the basic principle of reëntrant circulation which property gives rise to great frequency stability. The circuit of Fig. 6 is a convenient arrangement when a power amplifier, 21, is to be used in connection with a small master-oscillator tube, 20. The circuit has not been found quite so stable as the circuit of Fig. 3, since large changes in the load of the power amplifier changes appreciably the effective circuit constants of the tuned circuit L_3C_3 and the generated frequency is slightly changed. The change in frequency is kept small by designing the tuned circuits L_1C_1 and L_2C_2 so that these circuits are very sharply tuned. These two circuits are depended on primarily to stabilize the circuit by their filtering action, and the circuit L_3C_3 serves only as a broadly-tuned coupling unit to the load and to the input circuit of the master tube.

A degree of stability may even be attained by the use of a single tube. Such an oscillator shown in Fig. 7 is essentially a tuned-plate tuned-grid oscillator circuit with a link coupling circuit $L_{1c}L_{2c}C_{2c}$, which also serves as a tuned filter section. The three tuned circuits are all adjusted to substantially the same frequency and oscillations circulate continuously through the system. Complete circulation is insured by carefully reducing the plate—control-grid capacity coupling to an absolute minimum. This is accomplished by the use of a screen-grid tube and by placing a comb-like electrostatic shield made of copper wires between the plate coupling coil and the inductance L_{2c} with a similar shield between the grid coupling coil and the inductance L_{1c}. Any residual electrostatic coupling can be partially neutralized by slight grid coupling back to a few overhanging turns of the plate coil L_p. The circuit is not particularly recommended for ordinary use as it is very difficult to secure the stability which is readily attained with the other multiple tube circuits here described.

An examination of the operation of the circuit given in Fig. 3 shows that the potentials of the two control grids are about 180 deg. out of phase when the two halves of the oscillator are nearly identical and the oscillating currents in each are the same. The oscillator then makes an ideal master for a push-pull amplifier as the control grids of the two amplifier tubes are simply coupled to the two plate circuits by any suitable means and the correct phase relations are immediately established. A word of caution may not be amiss in this connection. It is to be noted that unless the circuits are laid out carefully the coupling to the push-pull amplifiers may serve to couple the two oscillator units and much of the frequency control may be lost due to the lack of complete circulation. It has been found desirable to shield the grid circuits of the two push-pull amplifiers from each other and by careful adjustment make sure that the radio-frequency ground potential of the two amplifier filaments is exactly the same as that of the oscillator filaments. At the highest frequencies this may be difficult.

Conclusion

The circuits which have been described all make use of the reëntrant circulation of oscillations in such a manner that oscillations of a single frequency are produced. A study of actual oscillator performance has shown that the new circuits when properly adjusted are capable of producing oscillations which are as stable as other oscillator systems employing tuned mechanical systems. The new system has the advantage of extreme flexibility and has been found to be valuable in naval aircraft radio communication problems. It should find broad application wherever a flexible and stable oscillator is required, although its flexibility probably precludes its use as a secondary standard of frequency.

Summary—A new vacuum-tube self-oscillating system having extraordinary frequency stability which depends on the reëntrant circulation of oscillations through tuned filter or coupling units is described. The reëntrant circulation through the filter sections attenuates all but a single frequency in a manner analogous to the attenuation produced by a filter system having an infinite number of sections. The unattenuated component having a single frequency is amplified at each passage through the system and constitutes the single-frequency oscillation. The methods and necessary precautions for attaining stability are given. Frequency shifts due to ordinary variations of plate potentials, filament current, or keying are found to be of the order of one-thousandth of one per cent. The extreme flexibility of the circuits permit the construction of satisfactory radio transmitters operating from the lowest frequencies up to 20,000 kc. without the use of frequency-doubling stages. The oscillator system has found wide application in commercial and naval aircraft radio communication problems.

INTENSE HEAT IN A-C. HEATER TUBES

PRESENT-DAY heater type a-c. tubes mark an achievement of the highest order in the development of severe service materials. For one thing, the insulator tubing in most tubes must have a fusion point above 2270° C., as contrasted with 1820° which is the fusion point of porcelain. What is more, the insulating tubing must not warp, shrink, break, decompose or interact with the tungsten wire at this temperature. It must remain a good dielectric at glowing temperatures. Meanwhile, the tiny holes throughout the length of the tubing no larger than the lead of an ordinary lead pencil—holes hardly visible to the naked eye—must be accurate in size and evenly spaced at all times.

The short life of earlier a-c. tubes has been traced to several causes. In the first place, materials originally employed for the heater insulator were quite unsatisfactory. The severity of the service conditions was not realized. Impurities resulted in brokendown insulation. There was frequently a chemical interaction between insulating material and tungsten wire. A common cause of failure was the fusing of insulator and wire, with early breakage of both tubing and wire, due to unequal rates of expansion and contraction. Porcelains, fused quartz, alumina and other materials were tried in turn, only to prove incapable of fulfilling the extremely trying conditions.

The remarkable life and performance of present-day heater type tubes, according to Henry L. Crowley of West Orange, N. J., are due to the introduction of magnesia. This material eliminates the heretofore critical exhaust conditions and high shrinkage in tube production, and provides the desired operating conditions. The crolite magnesia insulated tubes now available on the market have a life of several thousand hours, and, what is more, are capable of withstanding severe voltage overloads without materially decreasing their useful life, thus solving the problem of fluctuating line voltage faced in many sections of the country. In fact, it is now possible to obtain heater type tubes superior to the filament type, due to the successful solution of the insulation problem.

▲

TELEGRAMS PER PERSON IN VARIOUS COUNTRIES

New Zealand occupies first place with 4.7 telegrams per head. Next to Australia comes the United States with 1.9 telegrams per head per year. The figures for Britain are only 1.2. France sends 0.9 and Germany 0.5. Of the Australian states, Western Australia sends 4.7 telegrams per head, equalling the proportion of New Zealand; Queensland sends 3.15; South Australia, 2.7; New South Wales, 2.55; Victoria 2.45; and Tasmania, 2.3

Rectifier Type Instruments

By W. N. Goodwin, Jr.*

Herein Is Described a Practical Method of Measuring Alternating Currents of Low E. M. F.'s

General

THIS type of instrument is used principally for the purpose of measuring alternating currents of such small magnitude that they cannot be measured readily by means of the ordinary types of a-c. instruments such as thermal, soft iron and electrodynamometer types.

It is also useful where accuracy is not of so much importance as ruggedness and ability to withstand heavy overloads without damage.

Construction

It consists of a sensitive direct-current permanent magnet movable coil instrument used in connection with a rectifier made of four sets of copper oxide discs arranged in the four arms of a Wheatstone bridge circuit, the instrument being connected as the usual galvanometer in the bridge circuit. The copper oxide discs are so arranged that both halves of the a-c. wave pass through the instrument in the same direction as shown in Fig. 1.

Principle of Operation

As stated above, each half of the a-c. wave is rectified and passes through the instrument in the same direction, and since the instrument is a permanent magnet movable coil type the indications are proportional to the simple average value of the wave, and not to the squares of instantaneous values as is the case in a-c. instruments of the ordinary type, which are universally calibrated in root mean square values (r.m.s.).

As it is very desirable, however, to measure alternating currents in the conventional r.m.s. values, the rectifier instruments are calibrated by using an alternating current having a pure sine wave shape, and the scale figured in r.m.s. values.

It is obvious, therefore, that if the alternating current to be measured has any other shape than sinusoidal, errors will result, since the relation existing between r.m.s. and average values for sine waves in general is quite different from the corresponding relation for other wave shapes. This and other sources of error will be considered.

Accuracy

The principal sources of error in the rectifier type instrument are temperature, frequency, waveform, and the fact that the resistance of the rectifier varies with the amount of current passing through the discs. In addition to these, there may be permanent changes which may take place in time, but which experience thus far has not fully established.

Temperature Errors

Errors due to temperature changes depend upon the resistance of the circuit and upon the current passing through the rectifier. In voltmeters this is equivalent to stating that temperature errors depend upon the range in volts and upon the resistance in ohms per volt.

Temperature errors are the result of two changes which occur in copper oxide. When the temperature increases, the rectifying property diminishes, or stated technically, the rectification ratio is reduced, and at the same time the resistance of the rectifier is reduced. These two effects are in opposite directions upon the instrument indications, and fortunately, in most practical instances, actually neutralize each other near room temperature.

For voltmeters of the usual resistance of 1,000 or 2,000 ohms per volt, and for ranges from 1.5 to 20 volts, if used between temperatures of 18° C. to 35° C. (64° F. to 95° F.), errors due to temperature alone will probably not exceed 2 per cent.

For ranges above 20 volts, and for milliammeters, the temperature range may be 18° C. to 30° C. (64° F. to 86° F.) without exceeding an error of 2 per cent.

As the temperature effects increase rapidly for temperatures outside the above limits, it is very desirable to make all measurements within the temperatures stated.

These errors are of course in addition to the usual scale calibration and adjustment errors.

Frequency Errors

Up to 35,000 cycles per second the instrument indications decrease at a substantially uniform rate of approximately ½ of 1 per cent for each 1000 cycle increase in frequency. For example, at 4,000 cycles per second the instrument would indicate 4 x ½, 2 per cent low.

Errors Due to Change in Current Density

The resistance of a given rectifier depends upon the magnitude of the current passing through it, or in other words, upon the voltage drop across it. The resistance increases as the current density or voltage drop decreases. An instrument, therefore, has a lower resistance for full scale current or voltage than at any lower part of the scale.

In voltmeters, this resistance change is calibrated into the scale and, therefore, results in no error as far as the instrument indications are concerned. However, since the resistance changes, the instrument acts as a varying load on the circuit tested and if the circuit has a relatively high resistance, the instrument resistance variations may effect the terminal voltage in the circuit being tested, although the instrument will correctly measure the actual voltage applied to its binding posts.

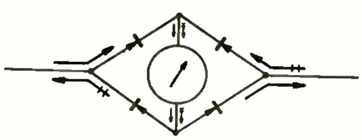

Fig. 1. Circuit arrangement.

When a rectifier type milliammeter is connected in a circuit, it affects the circuit conditions on account of its added resistance like any other type of instrument except that the effect depends upon the magnitude of the current passing, and the error will depend upon the total resistance of the circuit including the instrument, and also upon the current, that is, upon the scale indication.

For example, the rectifier usually

* *Chief Engineer, Weston Electrical Instrument Corporation.*

employed in a 500 microampere instrument of the 3½ inch size (Model 301) will have a resistance of approximately 710 ohms including the d-c. instrument at full scale, 500 microamperes, and 1540 ohms at 0.3 scale or 150 microamperes.

If the circuit resistance is relatively very high then this change will result in negligible errors. If, however, the circuit under test has a low resistance, say 1000 ohms, then the total circuit resistance for a current of 500 microamperes would be 1000 + 710 = 1710 ohms and the current indicated will be 1000/1710 x 100 = 58.8 per cent of that which would have resulted if the instrument had not been in circuit. For a current of 150 microamperes, the circuit resistance would be 1000+1540 = 2540 ohms and the current indicated is therefore, 100/2540 x 100=39.4 per cent of that which would have resulted had the instrument not been in circuit.

It must be remembered, however, that the instrument correctly indicates the actual current passing at any time, but the magnitude of this current depends partly upon the presence of the instrument in the circuit, as in the case of any other type of milliammeter.

Another effect produced by the varying resistance of the rectifier is to slightly distort the waveform of the current in the circuit, which may cause a slight error.

As a guide in estimating the effects of the varying resistances of the rectifier type instrument, the following tabulated values are given for Model 301 instruments.

TABLE I

Range	*Approx. Res. at Full Scale Ohms*	*Approx. Res. at 0.3 Scale Ohms*
500 Microamperes ..	710	1540
1 Milliampere	440	930
2 Milliamperes ...	290	590
5 Milliamperes ...	180	325

Waveform Errors

As stated above, since a d-c. instrument is used, the rectifier type instrument actually measures the average values of the rectified wave.

The conventional manner of designating alternating currents or voltages is to state them in terms of their root mean square (r. m. s.) or effective values, for the reason that the ordinary a-c. instruments indicate these values, and power is proportional to these values.

For this reason, rectifier instruments are calibrated with currents or voltages having a sinusoidal waveform and the scale is figured in r. m. s. values. It is obvious, therefore, that the instrument indicates correctly only if the currents or voltages measured have sine wave shapes. For other wave shapes errors will result, of varying magnitudes depending upon the variation from the true sine wave shape.

TABLE II

Harmonic	*Magnitude in Per cent of Fundamental*	*Phase Displacement*	*Ratio of Indication to True R.M.S. Value*
Third	10	180	0.961
Third	20	180	0.927
Third	30	180	0.862
Third	33⅓	180	0.840
Third	33⅓	0	1.052
Fifth	10	180	0.970
Fifth	20	180	0.943
Fifth	30	180	0.900
Third and fifth.........	30 & 30	0 & 0	1.063
Third and fifth.........	30 & 30	0 & 180	0.952
Third and fifth.........	30 & 30	180 & 0	0.877
Third and fifth.........	30 & 30	180 & 180	0.775

As a simple illustration to show the possible magnitude of errors due to waveform, consider the rectangular wave shown in Fig. 2A. This shape of wave is that which would be produced by commutating the voltage of a battery or other d-c.

From simple inspection it is seen that the maximum, r. m. s. and average values of the rectified wave are all equal and equal to V.

If, however, a voltage of this waveform is measured on the rectifier instrument it will indicate the r. m. s. value of a pure sine wave which has the same average value V that the actual wave has. Now it is well known that the r. m. s. value of a sine wave, whose average value is V, is 1.11 V so that the instrument will indicate about 11 per cent too high for this waveform.

Any waveform can be expressed as the sum of a series of pure sine waves consisting of a fundamental and of harmonics, the harmonics having frequencies of 2, 3, 4, 5, etc., times the fundamental frequencies.

Pure a-c. waves can consist of the odd harmonics only, 3, 5, 7, etc.

For example, the above mentioned rectangular wave consists of a fundamental wave of a magnitude of say 100 per cent, and the following series of harmonics, 33 1/3 per cent third, 20 per cent fifth, 14.3 per cent seventh, etc.

The errors produced by distorted wave shapes depend not only upon the magnitude of the harmonic, but upon its phase relation. The effective or r. m. s. value of any distorted wave is equal to the square root of the sum of the squares of the r. m. s. values of the fundamental and each harmonic, that is

$$V = \sqrt{v_1^2 + v_3^2 + v_5^2 + \ldots\ldots}$$

whereas the average value of a rectified distorted wave is the average value of the fundamental plus or minus the value of each harmonic averaged over a half fundamental cycle, depending upon the phase.

The tabulated values in Table II give some idea as to the magnitude of errors produced in measuring distorted wave shapes.

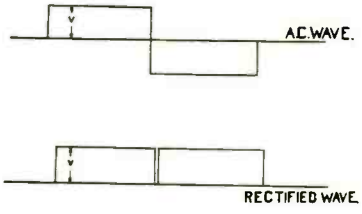

Fig. 2. Waveforms.

Conclusion

It is quite evident from the above discussion that among the errors which may be encountered in the use of rectifier type instruments, those resulting from waveform are the most serious.

There is also the possibility that a permanent change may take place in time in the copper oxide itself, but observations to date indicate that such changes are small, probably of the order of 1 per cent or less.

In general it may be stated that if the instrument is used on waveforms closely approximating sine waves, such as found on lighting circuits, and if used at room temperature, the indications may be relied upon to within about 5 per cent of full scale value. Errors due to frequency can be corrected.

▲

NICKEL-IRON ALLOY CORES FOR INSTRUMENT TRANSFORMERS

In the course of a discussion on a paper dealing with recent developments in connection with instrument transformers, attention was directed by a number of the speakers to the high standard of performance regularly obtainable from transformers having cores of nickel-iron alloy, e. g., "Mumetal."

J. G. Wellings and C. G. Mayo.—"*Instrument Transformers.*"

Jnl. Institution of Electrical Engineers, June, 1930, p. 704–735 .

▲

LESLIE F. MUTER SAYS

Leslie F. Muter of Utah Radio Products Company says: "Radio will smooth out to a normal course shortly."

A Proving Laboratory For Radio Receivers

Mr. Marconi Tunes-in a Modern Radio Receiver.

Description of a New Laboratory as a Link Between Sales, Development and Production.

By L. W. REINKEN*

In Newark, New Jersey, the Radio Department of Westinghouse maintains a small but complete radio laboratory, which is unusual from a functional standpoint. It is a link between the factory, the development laboratory and the sales department. It translates the ideas of the sales and publicity departments into engineering terms for the development laboratory, keeps in close touch with development and after development has been completed, maintains an engineering sampling inspection of production.

One of its most important functions is a daily sampling check on quality of factory production. By this check, it is possible to anticipate grief in the field and have possible sources of trouble corrected at the factory.

* Westinghouse Electric and Mfg. Co.

The production sample receivers are chosen at random from the final assembly line at Camden—about eighty miles away—and shipped via daily motor truck to Newark. At the laboratory they pass through the routines shown in Fig. 1. The apparatus used in the following routines is described later in the article.

Production Check

After unpacking, the shook, skids, balsa wood blocks, tubes and separately packed items are inspected for defects, and the shook inspected for improper marking.

The receiver is given a mechanical inspection for poor finish, damaged finish, missing parts, damaged knobs, grille, etc.

An air test is made on the receiver just as it would be made in a dealer's store. The receiver is tested with its own tubes on standard line voltage, and a listening test made for sensitivity, selectivity, fidelity, hum and power output. In addition, the operator looks for such faults as noisy volume controls, binding shafts, backlash—in fact anything that detracts from perfect operation of the receiver.

The phonograph operations are further tested for noisy or scraping turntables, defective automatic starts or stops. A listening test is made on record reproduction, home recording, radio recording, etc.

After the air test has been made and any necessary repairs have been performed, the voltage test with standard tubes follows. All voltages and the plate current of each tube are meas-

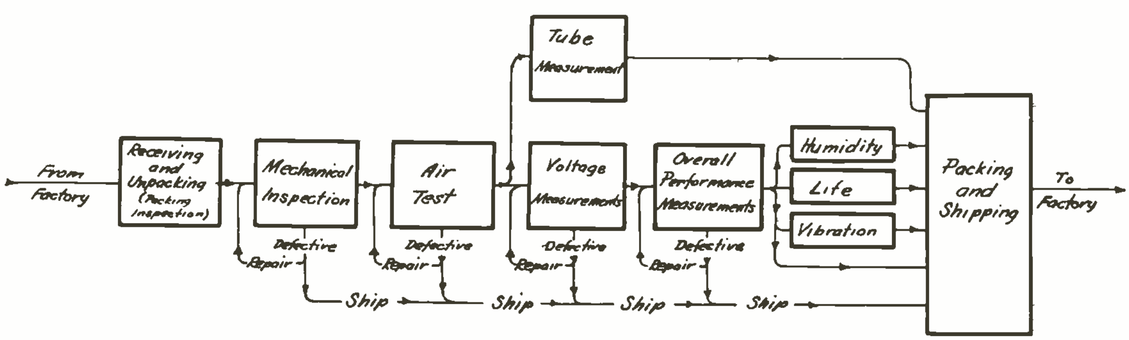

Fig. 1. Production Sample Test Routine.

ured. The voltage at two feeder points in the socket power unit and the hum voltage are also measured.

The tubes are individually tested. The mu, plate impedance, and mutual conductance of each tube is determined at standard voltages. Tubes not meeting factory limits are noted on the test report.

Overall performance measurements are made with standard tubes and standard line voltage in a completely shielded room. Here sensitivity, selectivity and fidelity are measured and compared with factory limits. Causes of out-of-limit characteristics are determined and noted, and if necessary a detailed investigation is made.

Temperature and Humidity Tests

Occasionally a set, after completing all other tests and found normal, is placed in a chamber capable of maintaining approximately 110 degrees Fahrenheit and nearly 100 per cent humidity. Periodical measurements indicate parts susceptible to moisture. After drying the receiver, and restoring to normal, the defective parts are replaced with parts of different design or treatment and the receiver again subjected to humidity. These tests supply data on which are based specific suggestions to the factory for changes in impregating materials, etc.

A normal set is connected to the power supply source and is allowed to run continuously—checking at regular intervals for signs of breakdown or deterioration. A more valuable form of life test for power supply units is a device which turns the set on and off repeatedly, subjecting the condensers to surges and the transformer and chokes to heating and cooling strains.

Periodically a normal set is placed on a vibrating machine and shaken until something breaks down. Sometimes it takes days of continuous vibration before any change is determined. This test is much more severe than any but the most unusual shipping conditions encountered.

Competitive daily reports and weekly summaries are sent to the New York Office. From these reports is prepared a weekly letter to the factory commenting on production from an unbiased, engineering, standpoint.

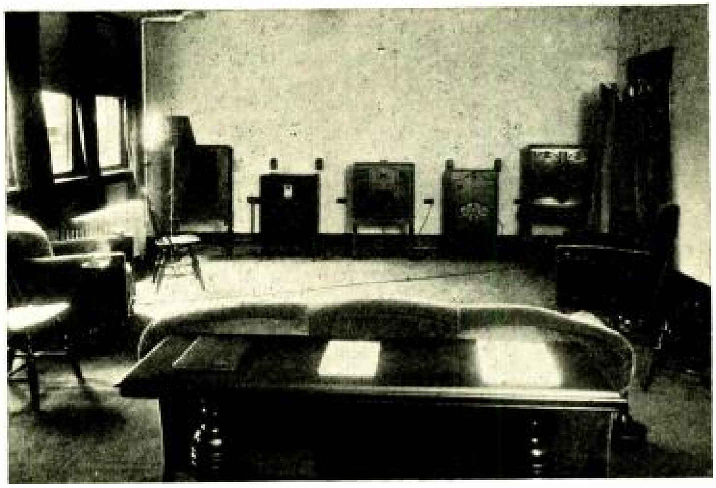

Fig. 2. Living Room Conditions.

Development

In addition to the production check briefly outlined above, the Proving Laboratory performs several other functions.

It maintains a keen interest in competitive receivers in general—and particularly in the relative performance of competitive receivers and of Westinghouse receivers under home conditions. Listening tests are conducted in a listening room furnished to reproduce the acoustics of a living room, and equipped with relays to permit rapid comparison of receivers.

These listening tests are supplemented by field engineers' reports on tests made by distributors and dealers, and by overall performance measurements of competitive receivers.

All of the men in the laboratory have had experience in radio development laboratories, and some have had additional experience in radio factories. This experience, coupled with close contact with the field, and with the merchandising section, permits the laboratory to specify accurately the performance requirements for new models under development.

Development samples are submitted to the Proving Laboratory for criticism. They are put through their paces —compared with present competitive merchandise, and checked against the performance requirements originally set up. Criticisms are obtained from members of the sales department, and the combined engineering and sales comments are sent to the development laboratory.

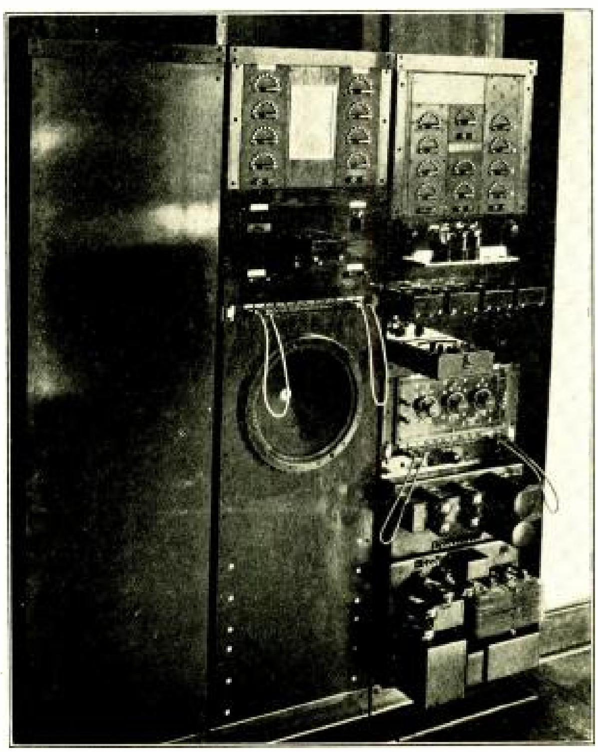

Fig. 3. Transmission Rack.

Other Functions

The laboratory contacts with distributors through field engineers. Service bulletins, service problems, special installations and distributor demon-

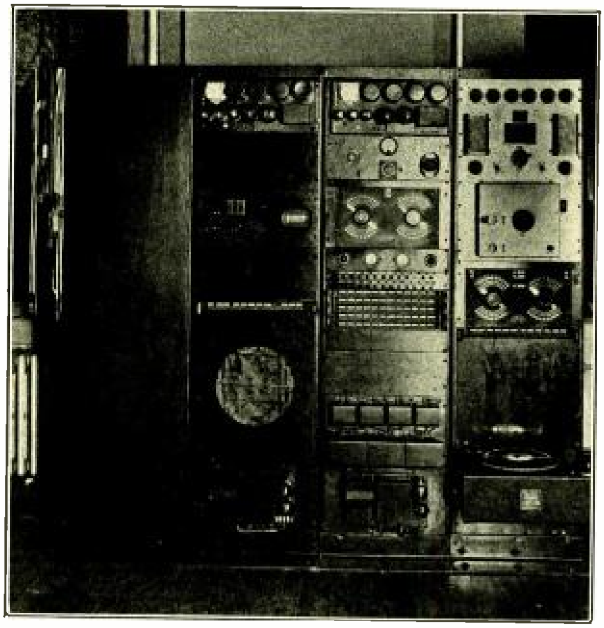

Fig. 4. Bridge Rack.

strations are some of the field jobs with which the laboratory is concerned. This is the field engineers' province, of course, but the laboratory finds intimate contact with the field to be of importance in formulating ideas to be incorporated in receivers.

Rack Apparatus

Most of the larger units in the laboratory are mounted on standard steel racks 72 inches high and 19 inches wide. The units associated with each set of racks terminate on a central jack panel. Patch cords enable any desired set-up to be obtained on the rack. With the aid of circuits running to other parts of the laboratory it is possible to set up combinations of apparatus located at separated positions.

The transmission rack, designed primarily for audio frequency studies, is the largest in the laboratory. At the present time it contains push-pull 250 amplifiers, a heterodyne oscillator, variable attenuators, volume indicator, loudspeaker, low-pass filters, a phonograph turntable of the centralized radio type and a cathode ray tube. The rack is equipped with two rows of pilot lamps associated with the power supplies of the various units and with battery chargers at a remote point. Above the pilot lamps are voltmeters and multi-switches for reading the voltage of the battery feeders. Space is provided for a complete centralized radio installation, consisting of a superheterodyne receiver for broadcast frequencies, a short wave adapter, amplifiers, power supply and clock control.

One of the unique pieces of apparatus on this rack is the cathode ray. The tube is the Western Electric 224-B, mounted parallel to the rack panel. It is viewed by means of an aluminum mirror mounted at a 45 degree angle, and is completely controlled by the switches and knobs on the panel. The controls cover filament supply, plate supply, focusing, spot-centering, viewing horizontal ordinate only, viewing vertical ordinate only, and viewing both ordinates simultaneously. This piece of apparatus will later be supplemented by a sweep-circuit device, which will make it possible to view the output of any piece of apparatus as an actual sine wave. This will be of use in studying amplifier overloading.

At the present time the transmission rack is capable of measuring gains, frequency characteristics, overload characteristics and losses. In addition, radio or phonograph programs, or heterodyne oscillator supply are available for testing amplifiers or loudspeakers.

To facilitate loudspeaker study a stroboscope is being designed to permit obtaining a "slow-motion picture" view of loudspeaker parts while vibrating. In addition a padded room and condenser transmitter and volume indicator are available for sound pressure measurements.

The three-rack bay (bridge rack), shown in Fig. 4, contains the following apparatus:

A miller bridge for measuring tubes.

A ratio-of-transformation bridge for transformer study.

Amplifiers and loudspeaker for use with the bridge in securing an audible null balance.

This rack will measure the mu and plate impedance of all receiver tubes, including 224's. Circuits from the transmission rack appear on this rack for patching together the units of the separate racks.

The bridge rack also has a blank panel anticipating future apparatus. One of the advantages of rack mounted apparatus is flexibility of expansion, as well as flexibility of operation.

A single rack, not shown in the accompanying photographs, is used in the voltage test routine in production sample check. This rack is equipped with a step-up transformer, and voltage regulator for maintaining receiver supply voltage constant. Mounted meters measure the supply voltage, current, and wattage. A commercial test kit has been modified for rapid measurement of all the voltage in the receiver.

Also mounted on this rack is an a-c. driven vacuum tube voltmeter for measuring hum voltage at the output of the receiver under test.

Performance Measurements

The shielded room in which performance measurements are made has an inner and an outer shield of copper screening, insulated from each other, and grounded at a common point. The signal generator and attenuator are mounted outside the room and are controlled by bakelite shafts passing through the two copper walls. The room is equipped with a modulating

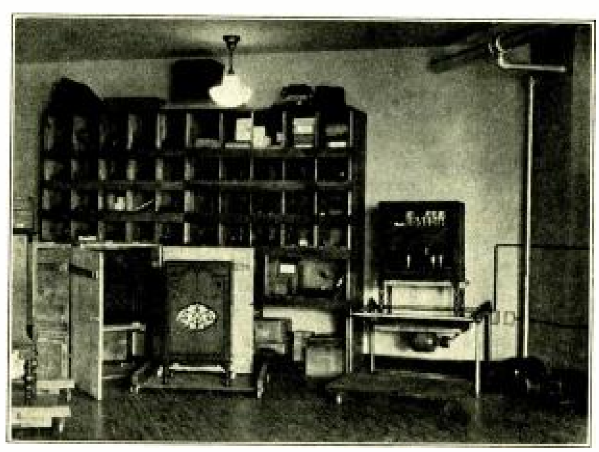

Fig. 5. Stock bins. To the right, the vibrator.

oscillator, output meter and monitoring loudspeaker. A voltage regulator is employed to maintain constant supply voltage for the receiver and measuring devices.

The present overall measuring equipment will eventually be replaced by overall measuring equipment calibrated to read directly in kilocycles, microvolts, modulation frequency, percentages modulation and milliwatts output. This apparatus will probably be rack mounted to conform with the other units in the laboratory.

At the right of the stock bins, in Fig. 5, is shown the vibrator. This consists of a spring suspended platform, vibrated by means of a motor and eccentric flywheel mounted beneath the platform. (The two units to the right of this instrument constitute a 25-cycle and d-c. motor-generator, and have no connection with the vibrator).

In Fig. 6 are shown the humidity chamber, storage batteries and chargers. The humidity chamber is large enough to accommodate the largest receiver in the Westinghouse line. It is equipped with a motor driven centrifugal sprayer, heating resistors, and thermometers for indicating temperature and humidity in the chamber.

In addition to the above major units, the laboratory maintains the usual stock of meters, decade boxes, resistors, standards, batteries, tubes, tools, etc. Among the portable instruments are an audio oscillator and amplifier, a Wheatstone Bridge, a megger, a capacity bridge, a receiver test kit, a radio frequency oscillator and a wave meter.

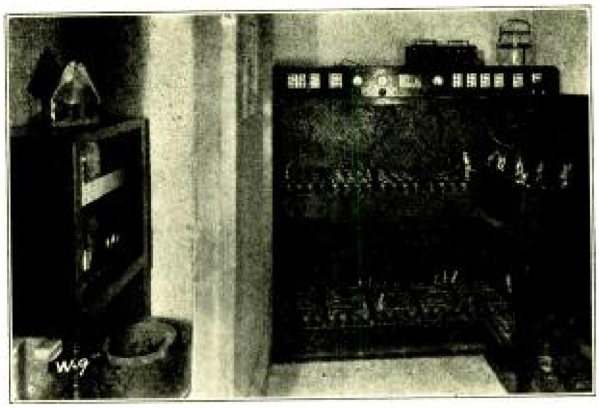

Fig. 6. Humidity chamber and battery charging equipment.

Power Supply

The fundamental power supply for the laboratory is 110 volts a-c. Power supply for d-c. and 25-cycle receivers is obtained from the motor-generators previously referred to. Outlets for 60-cycle, 25-cycle and d-c. supply, appear at numerous places in the laboratory and listening room.

Necessary voltages for the transmission racks are obtained from the battery banks. Two plate supply banks are provided, one of 300 volts for the cathode ray and one of 180 volts tapped at 130. Filament supply is also obtained from two banks, 6 volts for the cathode ray and 24 volts tapped at 12 and 6.

Mercury vapor rectifiers are used for charging the plate batteries, and Rectox chargers for the filament batteries. Pilot lamps associated with the charging circuits appear on the transmission rack. The voltage of any battery tap may be read at the transmission rack by switching voltmeters mounted for that purpose. These meters, in combination with the charger pilot lamps, minimize the possibility of allowing batteries to run down. Fuses for all battery voltages, and a-c. supply, appear on the transmission rack. This facilitates safe repair of rack apparatus.

Machine Shop

The laboratory maintains a small machine shop, equipped with a lathe, drill press, brake, shear, grinder, filing machine and of course, tool makers' instruments and woodworking tools.

The machine shop, in addition to maintenance, builds new apparatus designed by the laboratory. This method of obtaining apparatus has been found economical as well as technically satisfactory. Assembly or modification of purchased instruments into such devices as the cathode ray previously referred to, make it possible to secure useful apparatus not commercially available.

FRENCH RADIO COMMUNICATIONS

THE French system of radiotelegraphy is relatively well-developed and comprises:

1. State-operated system: A system exploited by the State, using material furnished entirely by the national industry, notably by the companies affiliated with the Compagnie Generale de Telegraphie Sans Fil. This system, through the principal centers of Lyon and Bordeaux, place Paris in direct communication with the following countries and cities: Portugal, Poland, Sweden, Russia, Lithuania, Bulgaria, Hungary, Cairo, Banako, Brazzaville, Tananarive, Djibouti, Java and Hanoi. In collaboration with the French companies which exploit the Guiana-West Indies and Saigon-France-Noumea-Tahiti systems, its network covers satisfactorily the French colonial empire.

2. Privately operated system: A system owned by the companies affiliated with the Compagnie Generale de Telegraphie Sans Fil, exploited under State control in collaboration with foreign companies. This network, operating through the stations at Sainte-Assise-Villecresnes, places France in direct communication with London, Madrid, Oslo, Prague, Belgrade, Bucharest, Vienna, Beyrouth, New York, Buenos Aires, Rio de Janeiro, Osako, Mukden and Shanghai. The network is completed by the transpacific Saigon-Honolulu and Saigon-San Francisco service.

The average daily number of words transmitted by the privately operated Sainte-Assise-Villecresnes station is 30,000, of which 14,900 are to European stations. The average daily number of words received is also 30,000 of which about 20,900 are from stations in Europe.

The Compagnie Generale de Telegraphie Sans Fil was founded in 1919. It has a capital of 100,000,000 francs (about $4,000,000) and controls the activities of a number of affiliated companies, its principal operating subsidiary being Compagnie Radio-France. This latter company has its transmission center at Sainte-Assise, its receiving station at Villecresnes and its head office in Paris.

WCLO

THE Janesville, Wis., Gazette has purchased radio station WCLO, formerly located at Kenosha, Wisconsin, and has moved it to Janesville. Entirely new equipment throughout, of the very latest type, has been installed in both the studios and transmitting station. High-grade talent has been employed by WCLO. Operating power is 100 watts, 249.9 meters—1200 kilocycles, licensed to operate full time. The studios are located at 204 E. Milwaukee Street, on the third floor of the Gazette building. The transmitting station is on the Milwaukee road, one mile east of Janesville. H. H. Bliss, publisher of the Janesville Gazette, is president of WCLO Radio Corporation.

What is Static?

By CHAS. J. HIRSCH

Here is a Mathematical Explanation of the Difficulties in Eliminating from Receivers Effects of Undesired Oscillations

FROM the first days of radio communication down to the present time static has disturbed radio receiving apparatus. Not only does it mar enjoyment of broadcast problems, but it represents a large economic loss by decreasing the range of effective communication and tying up expensive equipment.

As the nature of static becomes better known, the possibility of its elimination seems more and more remote. What then is this thing called static?

In the last analysis, static is so much like the desired signal that when we get rid of one we also get rid of the other. It is of the form of an electrical shock and can be caused by a large number of things: such as local or distant lightning, the accumulation and discharge of electrical charges by air currents, the closing of a switch, man-made sparks, in fact, by anything which disturbs the electrical characteristics of space. Its waveform may vary widely. The shock may occur once or repeat itself.

How can a shock which occurs only once disturb a radio set which is tuned to a million oscillations per second? A mechanical analogy will prove useful to illustrate this point. Let us consider the case of a simple pendulum. If we strike the pendulum, it will oscillate at a frequency determined by its length, and no matter what this length is it will oscillate. If there is appreciable friction, it will come to rest quickly. The pendulum is very much like a tuned circuit. If we shock the circuit electrically, it will oscillate at a frequency determined by the circuit's electrical constants. If it has high resistance, these oscillations will die down quickly. At first thought it would appear that this might be used to decrease spurious oscillations. Unfortunately, however, the signal is cut down equally.

There is another, more helpful method of looking at the electrical shock. Let us consider the electrical wave shown in Fig. 1. An equation for a wave of this type has been derived by Fourier. It is of the form:

$$E = A_o + A_1 \sin \frac{2\pi}{T} t + A_2 \sin 2 \left[\frac{2\pi}{T}\right] t + \ldots + A_n \sin n \left[\frac{2\pi}{T}\right] t + \ldots + B_1 \cos \frac{2\pi}{T} t + B_2 \cos 2 \left[\frac{2\pi}{T}\right] t + \ldots + B_n \cos n \left[\frac{2\pi}{T}\right] t + \ldots \quad (1)$$

In this equation, E represents the instantaneous voltage, t is the time, and T is the time required for a complete oscillation. The frequency, f, is of course equal to 1/T, so that we can rewrite equation (1) in its more usual form:

$$E = A_o + A_1 \sin f.2\pi t + A_2 \sin 2 f.2\pi t + \ldots + A_n \sin n f.2\pi t + \ldots + B_1 \cos f.2\pi t + B_2 \cos 2 f.2\pi t + \ldots + B_n \cos n f.2\pi t + \ldots \quad (2)$$

We see from this that any periodic wave, which is continuous and has no sudden changes of slope, can be expressed as the sum of an infinite number of simple sine waves, the frequency of each wave being a multiple of the lowest frequency. These simpler waves can be removed by tuned circuits. This is an experimental confirmation of Fourier's theorem.

Let us now suppose that this wave recurs ten times a second. Substituting this in equation (2), we get:

$$E = A_o + A_1 \sin 10 [2\pi t] + A_2 \sin 20 [2\pi t] + \ldots + A_n \sin 10n [2\pi t] + \ldots + B_1 \cos 10 [2\pi t] + B_2 \cos 20 [2\pi t] + \ldots + B_n \cos 10n [2\pi t] + \ldots \quad (3)$$

Here we note that each component is separated from the next by ten cycles. This frequency spectrum is illustrated in Fig. 2A.

Let the wave slow down so that it recurs only five times instead of ten times a second. Equation (2) then becomes:

$$E = A_o + A_1 \sin 5 [2\pi t] + A_2 \sin 10 [2\pi t] + \ldots + A_n \sin 5 [2\pi t] + \ldots + B_1 \cos 5 [2\pi t] + B_2 \cos 10 [2\pi t] + \ldots + B_n \cos 5 n [2\pi t] \quad (4)$$

Notice that the components in the frequency spectrum are separated by only five cycles instead of ten as before and the lowest frequency is now five cycles instead of ten.

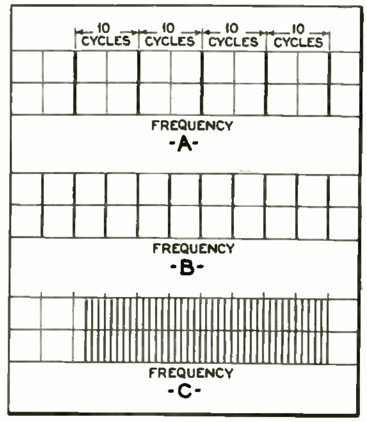

Figure 2.
A. Frequency distribution of a general irregular wave recurring every tenth of a second, i.e., of ten cycles. Note that the components occur every ten cycles.
B. Frequency distribution of a general irregular wave recurring every fifth of a second. i.e., five cycles.
C. Frequency distribution of a general irregular wave recurring every second, i.e.. one cycle.

Let us carry this even further. Let us suppose that the wave recurs once a second. Equation (2) becomes:

$$E = A_o + A_1 \sin [2\pi t] + A_2 \sin 2 [2\pi t] + \ldots + A_n \sin n [2\pi t] + \ldots + B_1 \cos [2\pi t] + B_2 \cos 2 [2\pi t] + \ldots + B_n \cos n [2\pi t] \quad (5)$$

We see now that the components of different frequencies are only one cycle apart and the fundamental is one cycle. If the wave recurred only once in a hundred seconds, the components would occur once every hundredth cycle and the lowest frequency would be one hundredth cycle.

This shows that, as the wave recurs less and less frequently, the fundamental frequency becomes lower and lower and the components crowd more closely together. Let us now carry this to the limit and assume that the wave occurs only once. We see that the lowest frequency is zero or at least infinitesimally small and the components merge into each other to form a continuous spectrum, each component being separated from the next by an infinitesimal frequency difference.

Then if the shock occurs only once, it contains every conceivable frequency. The amplitude of these will vary in accordance with a law that is determined by the wave shape. Often

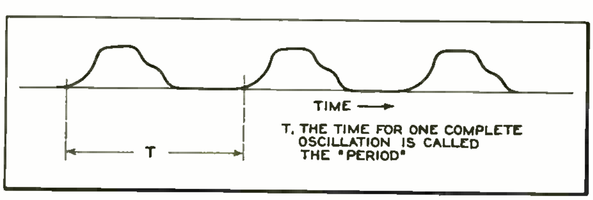

Fig. 1. Example of distorted wave which can be analyzed by Fourier's series.

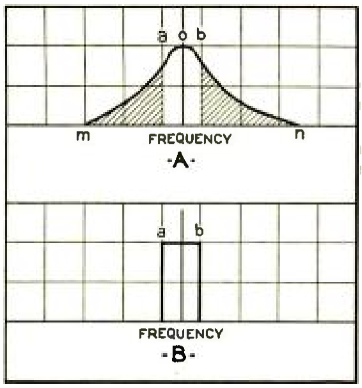

Figure 3.

A. Lines a and b represent the limiting frequencies which must be transmitted through the receiver for good reception. Curve m o n represents the selectivity curve of the set. We see from this that the area under m a and the area under b n do not contribute anything to the signal but allow noise frequencies to pass through the circuit. In an ideal receiver, the shaded portions of the resonance curve would be eliminated.

B. Resonance curve coincides exactly with limiting frequencies required for good reception. The only outside noise frequencies transmitted through the receiver are those occuring under a b. We cannot eliminate these frequencies without also eliminating the desired signal. This curve represents the limit that can be obtained in reducing noise by selective means.

most of the energy will be concentrated in certain frequency bands. However, if the energy is in that part of the spectrum where the signal is, we cannot separate it from the signal. Filtering it out will also filter out the signal.

From this consideration it will be seen that static cannot be completely tuned out. Of course some improvement can be obtained by making the receiver more selective. This is another way of saying that the receiver must not allow a greater band width to be transmitted through it than is absolutely necessary for good reception. If the signal requires a band width of 10 kilocycles and the set allows a band width of 20 kilocycles to pass through, it will allow static to be transmitted on frequencies which do not contribute anything to the reception of good signals. This is shown in Fig. 3A and Fig. 3B.

The amplitude of each component when a sustained d-c. voltage is suddenly applied is given by:

$$E = \frac{E' df}{\pi f}$$

Where E is the maximum amplitude of the component, E' is the amplitude of the impressed voltage, f is the frequency of a frequency increment df wide.

CHANNEL DESIGNATIONS BY FEDERAL RADIO COMMISSION

At a session of the Federal Radio Commission held at its offices in Washington, D. C., on November 14, 1930, the Commission amended General Order No. 88 as follows:

That in the frequencies exceeding 1500 kc. per second, a channel of radio communication shall be regarded as a band of frequencies, the width of which varies according to its position in the spectrum. The width of these channels increases with the frequency according to the following table:

Frequency (*kc.*)	*Channel Width* (*kc.*)
1500–2198	4
2200–3313	6
3316–4400	8
4405–5490	10
5495–8202.5	15
8210–10980	20
10990–16405	30
16420–21960	40
21980–32780	60

Note: A visual broadcasting channel shall not be more than 100 kc. in width. A commercial telephone channel below 3313 kc. shall be regarded as 6 kc. in width. A relay broadcasting channel between 6000 and 9600 kc. shall be regarded as 20 kc. in width.

In granting licenses, the Federal Radio Commission will specify the frequency in the center of the particular channel licensed to be used, but the licensee may occupy the center frequency and in addition such adjacent frequencies (within the limit indicated on the above table) as may be permitted by the frequency maintenance tolerance and required by the type of emission the station may be authorized to use, all of which will be specified in the instrument of authorization.

Licensees of fixed stations who have been granted the use of a channel for communication with specified points, upon application to the Commission for licenses may be granted the use of the same channel for communications with other points on the condition that the public interest, convenience, and necessity will be served by such a grant.

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HOW THE TERM "GRID" ORIGINATED

In 1906, when Dr. deForest gave the three-electrode vacuum tube the name Audion, some scientists objected to the coining of new words for electrical devices. The word "stuck," however, and the world over the tube is known as the Audion.

With reference to the first use of the terms plate and grid it is recalled by Frank Butler, an early technical associate of Dr. deForest's, that the term grid came into use in the old laboratory in the Parker Building, New York. Mr. Butler says:

"It was characteristic of Dr. Lee deForest, to call every new item discovered or utilized by a simple, homely name which is significant of its action or the thing it resembles. Most of the names coined by Dr. deForest many years ago are still in use today. It may be interesting to learn how the name 'grid' happened to be selected for that all-important part of a vacuum tube. It received its name in the old Parker building on Fourth Avenue, in New York City, where the audion was born. The first vacuum tubes were made in the form of a glass bulb, about four inches high, with a small candelabra base for the filament circuit, at the bottom, and two wire leads protruding at the top. One wire was green, the other red. The 'wing', now called the plate, was a flat piece of metal about ⅜ inch square, to which was attached the red wire, while the green wire led in a zigzag length of wire beside it. In the first tests it was customary to refer to the 'metal terminal' or the 'wire terminal of the tube, when referring to plate or grid, respectively. One day Dr. deForest told us to call those things by name, adding quickly the suggestion that we call one the 'wing', and the other the 'grid', because, as he said, 'that's what the thing looks like—just like a roaster grid.' And in order to avoid mistakes in the future by way of audion connections, a plainly stenciled card was posted above the workbench, bearing the slogan: "Remember, boys—Green to Grid, always!'"

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COOLING SYSTEM FOR KDKA TRANSMITTERS

Station KDKA, Pittsburgh, has recently installed a modern water softening system to be used in connection with the cooling system for the gigantic vacuum tubes used in radio transmitters.

There is a practical reason for this installation, because these giant tubes are expensive, and unless properly protected, their useful life period is limited. Therefore, anything that can be done to increase their life constitutes a saving in costly replacements.

According to E. B. Landon, chief operator of the Westinghouse East Pittsburgh transmitting station, the water must be tested frequently to protect the tubes and the cooling system. Ordinary city water cannot be used because it contains lime and other minerals which form harmful scale in the coils. The well-known soap test, consisting primarily of partially filling a test tube with water to which is added a drop of liquid soap, is used to determine whether the water is hard or soft. If the water becomes soapy when shaken it is soft and is suitable for use in the cooling system.

At the KDKA station this ultra-soft water is pumped to an outdoor cooling pool before going to the cooling coils and the tubes. Hot water coming from the station circulatory system enters the pool through a fountain-like spray. After cooling in the pool, it is pumped through the same circuit again.

Common Difficulties in Receiver Measurements

By Ralph P. Glover

The Dissemination of Incorrect Data on Receiver Performance Causes Serious Servicing Difficulties

In spite of its youthful age of four years or so, overall receiver measurement is seemingly being taken for granted by the radio industry at large. Practically every radio manufacturer worthy of the name possesses equipment for this purpose of greater or lesser range. Some radio magazines are replete with characteristic curves of each new receiver as it comes on the market, the data supplied by the manufacturer or obtained from measurements made in the radio journal's laboratory. Some set makers have already used measurement data in the form of curves or charts in their paid advertising.

What is seldom mentioned, outside the inner circle of those actually engaged in receiver measurement work, is that innumerable difficulties and painstaking care are involved in obtaining significant data; that the final value of any such data depends on careful interpretation of results, tempered by due consideration for the inherent limitations of the apparatus and methods.

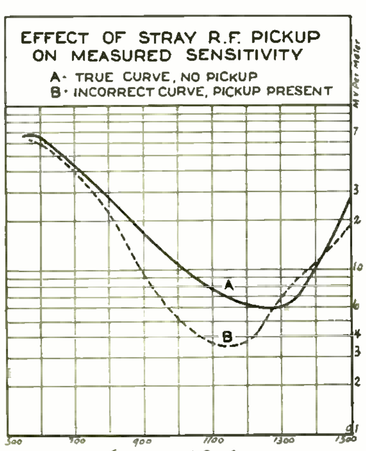

Figure 1.

Misleading Information

The writer recalls having seen a sensitivity curve, published in a radio magazine not long ago, which showed values of an entirely different order of magnitude than were obtained in another laboratory on a receiver of the same type. Investigation disclosed the fact that the receiver was equipped with three antenna taps and the published data had been taken on the most unfavorable of the three. There was no statement made in the magazine as to the test conditions which, as a matter of fact, were not at all representative of those encountered in actual service. Yet, this misleading information had a large circulation among dealers and servicemen who read that particular magazine and who were in no position to question or verify the results.

Fortunately, such occurrences are not common, but the example serves to emphasize the care and accuracy which must be exercised, especially when technical facts are presented to a public having as yet only a bowing acquaintance with receiver measurements.

Needless to say, the design and construction of receiver measuring equipment is an art in itself and results depend in no small measure on the correctness of the electrical design of the apparatus. For example, in Fig. 1 are shown two sensitivity curves taken on the same receiver. Curve A represents the true sensitivity of the receiver while curve B was taken with an auxiliary piece of apparatus connected to the signal generator and fed through a high-level r-f. lead. The effect of stray field, or pickup, from the lead is quite apparent. The lead was thoroughly shielded and had caused no trouble until this particular discrepancy was noticed. Rearrangement of the apparatus, eliminating the troublesome lead, solved the difficulty.

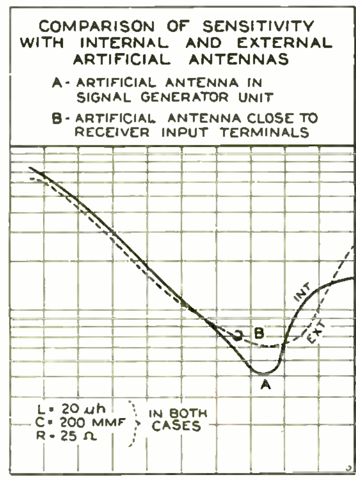

Figure 2.

Stray pickup, in all its various forms, is perhaps the greatest bugbear of the receiver measurement technician, especially when receivers having a sensitivity corresponding to one microvolt per meter are being dealt with. It should be remembered that the qualities of ease of operation and accessibility for maintenance are of paramount importance in measuring apparatus and perhaps rank next to accuracy in order of desirability. Unfortunately, apparatus for receiver measurements, designed with all these factors in mind, often presents the most difficult problems in pickup elimination. The designer is often forcibly reminded that short, heavy pieces of copper busbar by no means provide impedanceless access to the ground point at radio frequencies. Balanced-bridge effects and peculiar potential gradients are frequently a source of worry in perfecting a grounding system on a particular piece of equipment. Experience, good judgment and hard work are the most useful tools in running down troubles of this sort.

Method of Receiver Measurement

There is another type of difficulty which is frequently encountered in receiver measurement work and for which there seems to be no definite answer at the present time. This is best illustrated by a case in point. It is customary to divide receiver measuring booths into two compartments; the signal generator is located in one compartment and the receiver under test in the other. The signal is fed through the receiver through a standard artificial antenna[1] which may be built into the signal generator or placed close to the receiver. Both practices seem to be equally common, yet Fig. 2 shows quite plainly that somewhat different measured sensitivities may be obtained on the same receiver for these two conditions. Curve A of Fig. 2 was taken using an artificial antenna which was built into the signal generator: curve B was obtained on the same receiver, but the artificial antenna was located close to the antenna and ground terminals of the set. Both antenna systems were composed of circuit elements of the prescribed values and care was taken that all other test conditions were identical for the two measurements. Such discrepancies are not difficult of explanation and would not ordinarily be noticed where one system or the other is in constant use. They do, however, serve as a reminder that some allowances must necessarily be made in comparing data from different sources.

Characteristics of Tubes

Correct operation of the receiver is no less important than correct design of the measuring equipment. This applies particularly to all of the auxiliary apparatus which enters into the measurements, such as vacuum tubes, speaker fields, load impedances and the like.

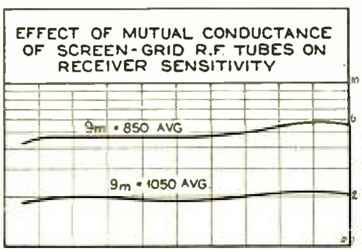

Figure 3.

As might be expected, the constants of the tubes used in the receiver have a great bearing on the results which are obtained. Each tube should have characteristics which represent the arithmetic mean value as regards filament emission, plate current, plate resistance, amplification factor and mutual conductance for each particular type used in the receiver[2].

The selection of tubes having these characteristics is a task of no mean proportions when the laboratory must rely on regular production tubes for its supply. Since no tolerances are given[2], it would probably be necessary to inspect literally thousands of tubes of each type in order to find a sufficient number complying literally with this requirement. However, most laboratories of necessity content themselves with tubes of correct mutual conductance and plate resistance, or with some such similar compromise. Fig. 3 shows the results of sensitivity measurements on a receiver using low and average mutual conductance screen-grid r-f. tubes. Little need be said about these curves except the simple statement that there is no routine more important in receiver measuring equipment maintenance than frequent and accurate checks on the characteristics of the tubes used in the receivers and all tubes should be maintained at the standard values in so far as this is feasible, economically. The reason for this is self-evident after a glance at Fig. 3.

Need for Tubes Having Average Characteristics

It is to be hoped that some day tubes of average characteristics will be available from the tube manufacturers for this purpose.

These are only a few of the many difficulties which are commonly encountered in measurements of receiver performance. That they are by no means insurmountable difficulties, however, has been proven in many receiver development laboratories.

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EXPERIMENTING WITH THE LIGHT SOCKET AERIAL

DISCUSSION relative to the light socket aerial has been going on for years. Some like this form of antenna; some do not; some have had excellent results with it, some have not; and so on. A great deal has been said yet no very definite conclusions have been drawn.

It is interesting at this time, therefore, to hear the comments of Harry W. Houck, chief engineer of the Dubilier Condenser Corporation, which has long specialized in a device of this nature, known as the Dubilier Ducon.

"You can no more throw together a light socket plug antenna and apply it to any house, than you can prescribe the same pair of eye glasses for everybody," states Mr. Houck. "Conditions vary in every house, and, as the light socket aerial makes use of the house wiring system as an aerial, the plug should be adapted to the requirements of the house, just as the eyeglasses should be suited to the condition of the individual.

"There are, of course, unusual cases where a light socket aerial will not function, generally due to the house wiring circuit grounding out a large percentage of the radio-frequency energy of the signals, or again in the case of buildings with steel framework generally completely grounded. These cases are the exception rather than the rule, and do not form a serious argument against the light socket aerial.

"In our antenna socket plug," states Mr. Houck, "we have endeavored to meet the requirements of the average house. We have succeeded not only in that aim, but also in securing good reception in houses that are decidedly not average. In our aerial plugs we have incorporated not one but two coupling condensers, thus giving a choice of three different capacity values. These three values balance practically every type of house-wiring installation encountered. The terminals of these two condensers come out in two binding posts on the end of the plug. By connecting the radio antenna connection post to one of these binding posts, a comparatively small condenser is employed, for use on a very long aerial of house wiring system. The other binding post provides a condenser of medium capacity and proves adequate for the average installation. Where the house wiring installation is unusually limited, both binding posts may be connected together and run to the set. This gives a maximum transfer of energy and brings the reception up to standard.

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A-C. OR D-C. RESISTANCE?

THE phenomenon known as *skin effect*, or the peculiar property of alternating current especially at high frequencies to travel only through the outer portion and not through the core of a conductor, is generally ignored in figuring resistance values for radio purposes. Thus the radio worker is frequently puzzled by the fact that a given solid resistor, rated at a given resistance, actually has considerably higher resistance value in actual use. He may hasten to blame the resistor manufacturer, whereas he has only a well-known electrical phenomenon to blame. A solid conductor offers considerably greater resistance to high-frequency current than to direct current, due to the skin effect.

It is for the above-mentioned reason that the metallized resistor is finding more and more applications in radio work. Such a resistor, having a metallic coating deposited on a glass filament, presents a virtually uniform resistance to either a-c. or d-c. energy. Since there is no core to such a resistance unit, the a-c. or d-c. energy flows through practically the same thin film or skin. Therefore, the resistance value is the same in either case, and there is no chance for error as when using solid resistance units.

[1] *Standardization Report for* 1928, *Yearbook of the I. R. E.*, 1928; p. 108.
[2] *Standardization Report for* 1928, *Yearbook of the I. R. E.*, 1928; p. 117.

Motor-Generators, Dynamotors, and Rotary Converters for Radio Uses

By E. W. Berry *

MUCH of the residential sections of New York, Boston, Chicago, Baltimore, and a number of small isolated towns are supplied with direct current only. Also there are many farms and perhaps boats or camps that depend upon 32 volt or 110 volt d-c. "farm lighting units" for their power supply. These conditions have often presented an obstacle to the sale and use of radio sets. There are several solutions. There is the use of the battery-operated set, the use of the direct-current set, and the use of a converting unit to change the direct current to alternating current. Inasmuch as the d-c. tube has not been developed to the perfection of the a-c. tube, and being in the minority of use, to stock and service the d-c. set would be quite a problem for the dealer. Also the choice of a set from a large assortment would be denied the user. The best solution of this problem seems to be the use of the converting unit.

These units are made to a great many specifications: that is: rotary converter, dynamotor, and motor generator; with filters and without filters; high speed and low speed; ball, wool packed, ring oiled and wick oiled bearings; primaries wound for the standard voltages of 6-12-32-100 and 220, or for special voltages. The secondary windings are generally 110 volts, 60 cycles, but may be wound up for 220 volts, 50 cycles, or most any other combination. The purpose of this article is to discuss the merits and applications of the many specifications.

Types of Units

The rotary converter consists of a unit with a single field winding for both the alternating and the direct current. The armature likewise has a single winding which is common to both primary and secondary. This is, practically speaking, a motor armature with two leads tapped on to the commutator at different points and the two leads carried through the motor core and connected to slip rings at the end opposite the commutator. In this simple combination "full voltage" is not obtained at the a-c. end.

Field for A-C. Tube Receivers Extended by Installation of Machine Converters.

That is, if 110 volts d-c. were used at the primary end only about 78 volts would be obtained at the secondary end. This is overcome by the use of a *booster winding* where higher voltage is wanted, and by the use of a *bucking* winding where less voltage is desired. These auxiliary windings are in series with the tapped leads and are wound in the same slots of the armature as the primary or motor winding. A *booster* winding would be used in a 110-110 volt converter and a *bucking* winding on a 220-110 volt machine.

As there is a direct electrical connection from the d-c. commutator to the a-c. collector rings this type of machine is difficult to filter and is generally used for the operation of phonograph motors and amplifiers only.

The dynamotor has a field common to both the primary and the secondary. In this respect similar to the converter but differing in the armature. Here there are two separate windings independent of each other. The primary winding is connected to the commutator and the secondary winding to the collector rings. This secondary winding is wound in the same slots as the primary, but is insulated from it entirely. The use of the two separate windings in the dynamotor requires more insulation and winding space than in the rotary converter. Therefore, the power output of a dynamotor is about two-thirds that of a converter of the same size. To more than compensate for this the dynamotor requires less filtering, gives less interference and is free from uneven commutator wear due to grounding effects and heavy currents as the tapped connection points come under the brushes.

The motor generator has two separate and distinct fields and two separate armature windings wound on different cores. That is, the primary consists of a field and an armature and the secondary of a different field and armature. In the smaller machines the two fields are generally placed in the same frame or shell. The armature in this case is of the two bearing type, with the two cores on a common shaft. In the larger machines separate motor and generator frames are used. This type set is four bearing with the two units mounted on a common cast-iron sub-base and connected by a flexible coupling.

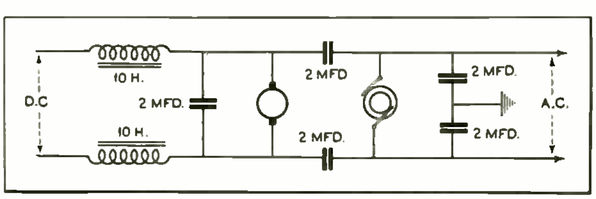
The advantage of the motor-generator set over the dynamotor is that the voltage of the motor-generator secondary may be closely controlled by means of a rheostat in the generator field. This type of control is far superior to the use of a line resistor. Another advantage of the motor-generator unit is that an alternating current motor operating from odd frequency or voltage such as 110/220 volts—25 cycle may be used, thus producing 110 volt, 60 cycle or any other desired combination.

From the above brief summary of types we may well draw the following conclusion:

For the phonograph amplifier unit

(*Continued on page 46*)

Ripple Suppressor Circuit



**Engineer, Electric Specialty Company.*

only, (no radio) the rotary converter may be used with good results.

For the radio or combination radio-phonograph the dynamotor is more satisfactory unless accurate voltage control is wanted, or a conversion of odd voltage-frequency to a standard is wanted in which case the motor generator should be used.

Filtering

Experience has proven that in most cases the converter will operate a phonograph amplifier satisfactorily without any filter. Slightly better operation is obtained with the use of a filter. The radio on the other hand requires filtering. Much time and money have been spent by manufacturers on this problem. From several years of research and the sifting of complicated systems there has been developed several simple and most effective filters. Until recently improved one of the most popular filters on the market consisted of five 2 mfd. condensers so placed that they effectively quieted the noises caused by the slight sparking of moving contacts. Recently this filter has been improved upon by the use of choke coils to iron out the disturbances coming in over the d-c. supply lines, in addition to quieting the machine disturbances.

High Speed vs. Low Speed

For a given outside diameter and length the two-pole machine has a smaller armature diameter, turns at a high rate of speed, and is capable of much more power output than the four-pole machine. The four-pole dynamotor has a larger armature diameter but turns at half the speed. The advantages of this slow speed machine are the longer brush wear and to a smaller extent the longer bearing wear. and the fact that it runs more quietly mechanically. The brush wear is not a serious consideration. These are inexpensive and easily changed, but of course are a source of more or less inconvenience in the case of the high speed machine. Bearing wear is hardly worth considering as the modern type bearings properly taken care of, or better said, properly left alone, will probably in either the high or low speed unit outwear the associated apparatus. The noise problem is worth considering, for in spite of dynamic balancing, used by progressive manufacturers, the high speed machines are better placed in out of the way rooms, cellars, and closets while the slow speed machines may be placed in the same room as the other equipment. The mounting of any type of machine in a cabinet has not to date been satisfactory.

Bearings

In the bearings of a machine it is desirable to have long wear, quietness and freedom from fussy attention. The principal types of bearings now available are the ball bearing, wool pack bearing, ring oil, and the wick oil.

The ball bearing gives long wear, needs little or no attention, but it is noisy in operation and is the most expensive.

The wool pack bearing gives long wear, needs little attention, and is quiet. This is medium priced.

The ring oil bearing will probably give longer wear than any other type. It is quiet in operation. Must have a good supply of oil. The ring may stick to the side in cold weather or with dirty oil, or if mounted in a tipped position. In other words it has to be watched to make sure it is working. This type is medium priced.

The wick oil bearing depends upon the oil feed through a wick. This is often insufficient in cold weather, or in aged felt wicks. At best it is not to be compared with the oil feed of the ring oil or the wool pack. Its life is apt to be short, and it should be watched. It is quiet in operation. This is the least expensive type.

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BROADCAST STATION LICENSES

ALL requests for assignment of radio broadcasting licenses are being most carefully scrutinized by the Federal Radio Commission, and its various divisions, to determine the financial responsibility of the new applicant for a license, his standing in the community and the necessity, if any, for continuing the station.

So many applications for change of ownership of stations have been filed recently that it appears trafficking in radio licenses is a new form of speculation developing in this country.

Section 12 of the Radio Act provides that no station license shall be transferred or assigned either voluntarily or involuntarily without the consent in writing of the licensing authority.

Emphasis is placed on the fact that all privileges granted under a license expire at the end of a license period, that the license is a franchise which cannot be sold.

Another apparent effort to take advantage of the Commission is the fact that numerous stations licensed to broadcast daily for short periods for the benefit of schools and churches are making application for the assignment of their licenses to commercial corporations. In most cases the request is accompanied by an appeal for more time on the air.

It is common knowledge that the Commission, in its desire to promote educational features and to carry church programs to the homes of the people, have been most liberal in granting licenses to those groups of applicants.

A few stations licensed to conduct charitable and altruistic work have been commercialized and now insist on more time to take care of advertisers.

All applications for assignment of such licenses will be carefully studied by the Commission and its investigators, and a real necessity for a commercial station must exist before such transfers are authorized.

It is likely that the Commission, in many cases, will find it advisable to cancel these licenses, rather than add to the overloaded channels. It would be a fine, patriotic service for these licenses to retire voluntarily from the field, if there is no longer any need of radio in their service, thus aiding the Commission in relieving some of the congestion in the air.

The Commission has just authorized an investigation of reports that the harmonics emitted by some broadcasting stations are causing much interference with reception on some frequencies used largely by commercial stations.

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DIAPHRAGM CENTER DESIGNS AND THEIR MEANING

By Clifford E. Stevens

MOST of us have observed the different forms of center constructiion for the usual dynamic speaker diaphragm or cone. Some have a solid center member, perhaps formed by a continuation of the diaphragm material itself, and frequently with a center screw. Others have the integral center member, but with many holes about the center screw. Still others have a metal spring member or "spider" for the center. Again there are those without center member, so that the pole piece of the pot magnet is visible.

Diaphragms with intact center member, are capable of exceptionally high-frequency response. The solid center member serves as a radiator of high notes. On the other hand, the diaphragm without center member permits of appreciable air leakage, reducing the general volume quite as well as the higher frequency response. The use of the spider or center spring suspension, is for the purpose of driving the diaphragm in a straight line, while getting away from the higher frequencies caused by a solid center. In some designs the spring suspension is around the apex of the diaphragm, at the rear and out of sight, so that the pot magnet pole pieces are visible at the center.

A compromise design which is gaining popularity includes an integral center piece formed of the impregnated cloth or burtex diaphragm itself. This center member may be without holes, or again with a single hole taking the centering screw which threads into the pole piece of the pot magnet, or again with the centering screw and a number of other holes to permit of air leakage and the cutting off of the higher frequencies.

ANACONDA COPPER COMPANY STAFF CHANGES

H. W. Simpson has resigned from the Chicago office of the Anaconda Wire & Cable Company. J. P. Davis has been transferred from the Pittsburgh office to the Chicago office where he will direct the western sales of Anaconda magnet wire. J. W. Mullally has been appointed district manager at the Pittsburgh office. He was formerly attached to the New York office. C. A. Heiser has been appointed district manager in the Dallas office. H. W. Thomasma has joined the New York office.

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ELECTRIC CLOCK CORPORATION

The Electric Clock Corporation of America, located at 500 S. Throop Street, Chicago, has issued its new 1931 catalog illustrating a complete and varied line of Lincoln electric clocks and clock motors. Wholesalers and dealers who have seen this catalog describe it as containing the most thorough line of electric clocks they have seen. There are 22 different models of Lincoln electric clocks.

The Electric Clock Corporation is specializing on clocks for the radio manufacturer who wants to install electric clocks as a merchandising feature of his own line. Each of these clocks is equipped with a dependable synchronous motor—designed to operate on 60-cycle, 105-120 volt a-c. Individual dials, hands, and lenses, as well as motors complete with housings, may be had.

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NORMAN M. SIMONS HOME FROM EUROPE

Norman M. Simons, of M. Simons & Son Co., Inc., 25 Warren Street, New York, exporters, has returned from a four months' trip abroad during which time he visited eighteen countries in the interest of American manufactured products. Mr. Simons reports having made arrangements whereby a satisfactory volume of business will result during the coming year.

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"AQUADAG" RETARDS SECONDARY EMISSION

If the grid of a tube and in some instances the plate, are provided with a black coating of an inert material, the number of secondary electrons is greatly reduced. One of the most efficient materials for forming such a coating is "Aquadag" graphited water—a concentrated colloidal solution of electric-furnace graphite in distilled water.

When applied to metallic surfaces by means of a spray or brush, it forms velvety black coatings which radiate heat very effectively thus keeping the tube parts to which it may have been applied at a relatively low temperature.

Surfaces formed with "Aquadag" tend to prevent the permanent alloying of particles from activated filaments with metal thus reducing to a considerable extent, "back emission" from grids which have become over-heated or which are so charged as to be subjected to the impact of primary electrons.

Graphite, an allotropic form of carbon, possesses the desirable property in this instance of providing very little secondary emission when bombarded with electrons from the filament and is very poor photo-electrically. The ease with which graphite in the colloidal state may be applied to tube parts before assembly makes it highly desirable.

"Aquadag" graphited water as marketed, is a truly colloidal product containing 22 per cent electric-furnace graphite (Acheson process). It may be used in any desired dilution by the addition of distilled water. "Aquadag" should not be subjected to extremely low temperatures as freezing destroys its colloidal properties.

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ALLIED DIE CASTING CORPORATION

H. B. Kilroe has been appointed the representative of the Allied Die Casting Corporation of Long Island City, New York, for the southern Ohio territory covering Dayton, Columbus and including Indianapolis. Mr. Kilroe's headquarters are at 507 Dayton Industries Building, Dayton, Ohio.

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H. S. TENNY ANNIHILATES DISTANCE

Henry S. Tenny, president of the Ilola Company, with plants in Cleveland, Ohio, and Oakland, California, has at last solved the problem of bringing the two factories closer together with the recent purchase of a Stinson Junior Cabin Plane. Mr. Tenny holds a private pilot's license and has been an aviation enthusiast for many years.

P. A. Engholm, vice pres., and Leon Golder, sales manager of the company, greeted Mr. Tenny recently on his arrival at the Cleveland airport.

USL ANNOUNCES NEW RADIO "B" BATTERY FOR AUTOMOBILE SETS

The USL Battery Corporation of Niagara Falls, N. Y., has expanded its manufacturing and merchandising field to include a new line of Special "B" batteries for motor-car radio sets. The new battery, which is expected to have a continued increasing demand because of the growing use of radios in automobiles, has been perfected by USL experts after exhaustive laboratory and practical tests.

The USL organization has already been awarded a contract to furnish these batteries as standard equipment for one of the leading motor car radio set manufacturers.

In addition to the growing use of radio sets in privately owned cars, the more recent moves of police departments to equip their cars with receiving sets will also provide another outlet for these batteries.

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RADIO SALES IN 1931

H. H. Eby, radio parts manufacturer, of Philadelphia, Pa., returned on November 26, from an extended trip to all parts of the United States, during which he discussed with radio manufacturers requirements for 1931. Mr. Eby reports prospects very bright for next year's radio sales. It is his observation that surplus stocks of receivers will be largely used up by the end of this year, and that all properly organized manufacturers will do a satisfactory business in 1931.

Mr. H. H. EBY

On his trip to and from the West Coast Mr. Eby made extensive use of airplane service.

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WARD LEONARD APPOINTMENT

The Ward Leonard Electric Company, Mount Vernon, N. Y., announces the appointment of R. C. James as sales representative in the Seattle district. Mr. James' organization will be located at 2321 Second Avenue, Seattle, Washington.

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AN IMPROVED SPOT WELDING MACHINE

A quick-break contactor and adjustable pressure are two unusual features incorporated in the new American B-5 spot-welding machine which has just been announced by the American Transformer Company, of Newark, N. J. The former, a semi-automatic device which opens the primary circuit at will, permits the weld to freeze under pressure and prevents arcing at the electrodes. Because the pressure is adjustable for various types of work and is applied by a heavy spring rather than the operator, the machine may be used for welding copper and brass, resistance soldering, and applications requiring heavy pressure.

The AmerTran type B-5 is a bench-type unit mounted in a compact sheet-steel case requiring a space of only 12 by 14 inches. It stands 28 inches high and has two electrodes which protrude 15 inches from the front of the case. The device operates from a standard 220-volt, 50/60 cycle circuit and is available in three sizes 5, 7½ and 10 kva. Standard equipment includes a foot-pedal control and a six-point primary switch for adjusting the welding current to the value needed for the particular job.

Various electrodes are available, the type supplied depending upon the character of the work. In all cases the space between the points is adjustable, and, where the welder is to be used continuously, water-cooled electrodes are provided. The transformer employed is of the high-efficiency, short-coupled type; that is, the secondary leads have been made as short as possible to reduce heat losses to an absolute minimum.

The machine is capable of welding two sheets of steel of 3/16" thickness or less, or two sheets of copper or brass of 1/16" thickness — ¼" spot weld in each case.

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NATIONAL UNION ANNOUNCES NEW DISTRIBUTORS

Henry A. Hutchins, general sales manager of National Union Radio Corporation, announced upon his return to the New York office, after a trip covering the eastern seaboard and the middle west, the appointment of fifteen new distributing outlets for National Union Radio tubes.

The new accounts are: Billings Hardware Co., Billings, Montana; Southern New York Electrical Supply Co., Binghamton, N. Y.; Sargent Faker, Inc., Rochester, N. Y.; Standard Battery & Electric Co., Cedar Rapids, Iowa; Baumgardner & Co., Toledo, Ohio; Bush & Lane, Holland, Mich.; Wattydyne, 4 Rue Bernard Pallisy, St. Etienne, France; The York Supply Co., Dayton, Ohio; Hudson Valley Asbestos Corp., Albany, N. Y; Crason Electrical Supply, New York City; R. K. Carter & Co., New York City; Friedman Electric Company, Easton, Pa.; Collins Piano Company, New Orleans, La.; Messrs. Rencoret Y Cia, Santiago De Chile; Dixie Drug Company, Goldsboro, N. C.

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MUNGER DIRECTOR OF NORTHWEST ASSOCIATION

The Northwest Radio Trade Association, in announcing its organization for 1931, has included as a member of the board of directors, Rex L. Munger, district sales manager of the National Union Radio Corporation. Mr. Munger, who has been actively engaged in sales work throughout the northwest territory for the National Union Radio Corporation since its formation in September, 1929, makes his headquarters in Minneapolis, Minn.

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NEW RADIO SERVICE ORGANIZATION

The International Society of Radio Engineers, with offices in Indianapolis, Ind., now affiliated with the Societe Internationale Della Radioario, announces a new policy in relation to radio manufacturers.

In the past the information service of the society has supplied its hundreds of thousands of inquirers with all information on new radio releases, inventions, patents, etc.

In the future, the International Society will supply information only on devices tested in its laboratories, and will apply this rule not only to American manufacturers, but through its foreign bureaus also.

Dr. Dennis P. O'Kennedy, formerly of the Royal Radio Commission is the new director-general of the laboratories of the society, in addition Dr. Hiro Natuchi, of Tokyo, and M. Andre DuViver of Paris, have taken over such administration of the society in Japan and France as was formerly administered from headquarters.

Statistics, data, information, lists of accredited agents are available through the central bureau of the society, and the bureau of translations can translate not only correspondence, but technical data, bulletins, catalogs, etc.

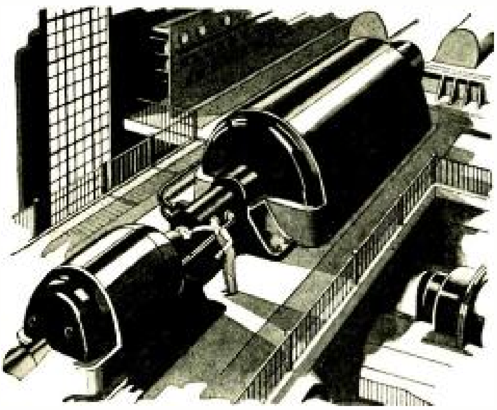
The latest extension bulletin is on Soviet Russia, with a very authoritative summary of European Russia, with Siberia and the Asiatic provinces briefly treated.

Thinking in the right material

The right workabilities, right functioning, right appearance, right possibilities for simplification of design, production, assembling and inspection. For some companies these have meant everything, for success against competition. Men who want ideas, for betterments and economies, should study closely every product in which NVF or Phenolite is used.

What they can learn

from Generators and modern Power Plant Equipment



HIGH speeds, high voltages, terrific pressures. . . . Think what properties a material must possess to withstand all of these destructive forces. Unusual properties you'll admit. In fact, so unusual that were it not for such materials as NVF and Phenolite these super-power plants would be an impossibility. Since the birth of commercial electricity, designers of generating and transmitting equipment have turned to National for materials whose dielectric and structural strengths are definite and calculable. With each year the demands upon these materials increase, yet each advance in design, each increase in size and output of the machines finds NVF ready with a formula that has anticipated the new specifications.

●

We make ten standard kinds of vulcanized fibre including Peerless Insulation and Leatheroid—for electrical insulation and for mechanical uses. We also make Phenolites (reinforced laminated bakelite materials) of many special formulae. Direct NVF representatives in principal cities of the United States, Canada and Europe.

NATIONAL VULCANIZED FIBRE CO.
WILMINGTON, DELAWARE

NVF

Every advancement, great or small, in ANY manufactured product, depends on

thinking in the right material

NEW Weston MODEL 566

Low price test set for radio servicing

THIS new Weston test set is designed for radio service men and dealers who specialize in servicing radio receiving sets in the home.

These men will find this new two meter test set ideally suited for their requirements because it combines the highly desired Weston dependability of operation with low cost.

Servicing Scope

Weston Model 566 checks all type tubes under the same conditions as exists when in their sockets, giving readings quickly, conveniently, and accurately. Model 566 furnishes adequate measurements for testing all models of receiving sets—checking power transformers; line voltage; heater voltage, and plate current and voltage at power pack; battery voltages, resistance and continuity of circuits, condensers and speaker coil currents.

EQUIPMENT Model 566 contains two 3¼ inch standard high quality Weston meters with scales specially calibrated for convenience and ease in reading. The meter on the left is a nine range A.C. Model 476 for 1,000/200/-16/8/4 volts, 8/4 amperes, and 100/20 milliamperes. The meter on the right is a 10-range D. C. Model 301 for 1,000/-250/100/25/10 volts, 0-100,000/0-10,000 ohms and 100/25/2.5 milliamperes. The various ranges of the D. C. Volt-ohm milliammeter are controlled by a 23 point Bi-polar switch. The ranges of the A. C. meter are controlled by a dial switch. A polarity reversing switch is provided; also binding posts, leads and tester plugs for use in taking external readings.

For more complete information write for Circular HII.

WESTON ELECTRICAL INSTRUMENT CORPORATION
612 Frelinghuysen Avenue,
Newark, N. J.

Weston
PIONEERS SINCE 1888
INSTRUMENTS

LINE VOLTAGE REGULATION

After years of research. the engineers of the Sola Corporation have perfected a voltage compensator which they claim will deliver regulated voltage to the a-c. radio receiver and any other applications of vacuum tubes and relays without a break or jerk. and will maintain the incoming line voltage within the narrow limits necessary for satisfactory reception. This device will lengthen the life of vacuum tubes because the tubes will operate on voltages within the safety limits as allowed by the manufacturer and will also protect condensers from early breakdown and reduce costly replacements of or repairs to the power compact. Line disturbances which are caused by high frequencies such as are generated when lights are switched on or off. when motors on household appliances are in operation, or when certain types of oil burners are started will be unknown in installations where the voltage compensator has been placed between the line and the radio receiver.

The compensator is light in weight (7¼ lbs.) and is exceedingly compact, being 3¼ inches by 4 inches

by 3½ inches overall. Many other applications require regulated voltages, such as photoelectric cell equipment, film printing lamps, synchronous sound equipment, relay applications and signaling devices, some of which require compensators having special degrees of regulation. Descriptive circular with line voltage curves may be obtained by readers of RADIO ENGINEERING by addressing the Sola Corporation. 2525 Clybourne Avenue. Chicago, Illinois.

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THOMPSON BREMER APPOINTS REPRESENTATIVES

The Thompson Bremer Company, 1750 Carroll Avenue, Chicago, Illinois, manufacturers of Everlock washers and terminals, announce the appointment of W. Burt Knight as West Coast representative. Mr. Knight has opened offices at 1646 West Adams Street, Los Angeles. California. The appointment of an eastern representative is also announced. Mr. J. Ramsey Reese, who is well and favorably known in the radio and electrical industries, has opened offices at 110 West Thirty-Fourth Street. New York City.

Announcement of additional items to the line of Everlock washers already manufactured by the Thompson Bremer Company, will be made shortly.

▲

MICROPHONES

Chauncey L. Delano of 274 Grove Street, Waltham, Mass., announces his resignation last July from the General Industries Corporation of the same city. He has organized a new company under his own name, and is manufacturing a new and improved line of microphones for all purposes, including a new two-button hand type for announcing purposes; a superior quality two-button type for all purposes; another model of the same microphone with a built-in pack filter another two-button type for speech only, and very shortly will have two types of condenser microphones ready. One of the hanging type which can also be mounted on a stand, and a new style for desk use. Several territories are still available for expert representation. Inquiries are solicited from manufacturers' agents selling associated equipment.

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SPECIAL SCREEN-GRID TUBE FOR MIDGET SETS

In the design of the midget set in which a less number of tubes are used for reasons of compactness and cost, it is most essential that the screen-grid tubes provide as much voltage gain as possible. With this requisite in mind, the DeForest engineers have developed and placed in production a special screen-grid tube of much higher amplification constant than the ordinary screen-grid tube. Tubes of this new type have been checked in a number of midget sets, and it has been found that the sensitivity of the average midget set can be doubled by using the new type tubes. For instance, if a set has a gain of 20 microvolts per meter, with the usual screen-grid tubes, the sensitivity may be increased to 10 microvolts per meter with the new type tubes.

Although the new type tubes were essentially designed for use in midget sets, they are interchangeable with the standard 24 tubes and can be employed in any of the present-day radio sets for the purpose of doubling the sensitivity.

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SELF-TAPPING SHEET METAL SCREWS

In a new booklet issued by the Parker-Kalon Company, 200 Varick Street, New York, the following information appears:

"The famous Philco balanced unit radio chassis is scarcely delayed a moment along the assembly line as part after part is securely attached. Assembly time and trouble have been reduced to the minimum by wise production heads of the Philadelphia Storage Battery Company.

"Tapping was once an obstacle to production economy and speed. Philco engineers sought a way to overcome it. They tested hardened self-tapping sheet metal screws and adopted them for six trial fastenings formerly made with machine screws. So successful and economical did these unique screws prove that in a short time the 6 fastenings grew to 10 . . . 18 . . . 30. And now 44 self-tapping sheet metal screws are used in place of machine screws! Forty-four tapping operations have been eliminated on each chassis! And the saving of time and labor amounts to thousands of dollars annually."

▲

LISTENING IN ON CONDENSER PAPER IMPERFECTIONS

The long strips of paper tissue that go into the making of a filter or by-pass condenser must be relatively free from metallic or foreign particles. Every speck of conducting material imbedded in the tissue is a potential source of trouble, since the electrical charge in the condenser concentrates its full force on the weak spots in the long dielectric that separates the two conducting tinfoil plates. Unfortunately, however, the troublesome specks are usually too small to be detected by the naked eye.

Some troublesome specks can be seen by means of a high-power microscope, appearing very much like lumps of coal. Other specks are invisible, irrespective of magnification. There are, however, two positive methods of detecting and counting the metallic particles per unit area of condenser tissue, which have been developed by the Dubilier condenser specialists. The first method is a chemical one, in which the tissue is chemically treated so as to bring out the metallic specks in the form of large discoloration spots readily visible to the eye. This method, however, renders the tissue unfit for use, although it serves as a representative test of an entire lot of tissue. This method detects only metallic particles. The second method is a "listening-in" process and does not render the tissue unfit for use, so that the tissue actually used in a condenser may be tested for weak spots. Briefly, the condenser tissue roll is placed in a device which comprises winding and unwinding rolls and contact members. In passing from one roll to another, the paper tissue passes between two brass contact rolls in circuit with a direct-current source and a pair of headphones. The pressure between the contact rolls may be adjusted. The operator, slowly turning the winding crank, listens by means of the headphones to the clicks caused by metallic or conducting specks, and determines the number per unit area, which must fall below the tolerance set for that grade of tissue. A further development is an automatic counter which keeps score of the number of electrical weak spots per unit area of the tissue being inspected.

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NEW RADIO TUBE WRAPPER

A practical application of the simple principle of "suspension packing" is seen in the Holed-Tite radio tube wrapper, a product of Holed-Tite Packing Corp., New York.

As shown in the illustration, the depressions on the sides of this light weight moulded pulp wrapper

grip the tube like an encircling hand. The tubes also are held firmly in place at the base. Suspension packing not only protects the tube from actual breakage but saves it from the shocks which might distort its elements. Tubes can be tested without removing from carton and when inspected the wrapper is not torn or defaced.

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THE MIDWAY CONDENSER

The Midway is a new, small and compact variable air condenser, manufactured by the A. D. Cardwell Mfg. Corpn., 81 Prospect Street, Brooklyn, N. Y., which should find considerable application for many purposes where extremely light weight and reduction of bulk are desirable in receivers, transmitters and oscillator-amplifier outfits. Condensers of this description having a breakdown rating of 3000 volts may be had in capacities as high as 150 mmfs. A panel surface of only 2¾ inches by 2⅛ inches is required and the condenser weighs from five to seven ounces, as compared to the usual standard transmitting condenser of equivalent capacity requiring a panel surface approximately 4 inches by 4 inches and weighing from fifteen to eighteen ounces.

Extreme lightness of weight is made possible because of the use of aluminum throughout, with a few minor exceptions, and the voltage breakdown is materially increased by reason of the use of polished plates, with rounded edges, in the transmitting models.

Several advantages are apparent—although fully adequate in replacing full size transmitting condensers of capacities up to 150 mmfs, the Midway condensers are only slightly larger and heavier than many so-called "midget" condensers, at the same time having the same solid and substantial construction and rotor shaft bearings found in the full size Cardwell transmitting and receiving condensers. They may be fitted into small spaces, allowing more room between components, thus reducing capacity field effects without substantially increasing the bulk of the complete instrument as would be necessary were full sized condensers used.

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LAMINATED BAKELITE

The laminated form of bakelite is used in radio for front panels, sub panels, coil forms, insulating bushings, and many small punched parts. In the manufacture of the laminated materials, sheets of paper or cloth are first impregnated in a solution made by dissolving the initial bakelite resin in a suitable solvent. The solvent is then evaporated and when the sheets have been thoroughly dried they are piled one upon the other, and are subjected to heat and pressure in hydraulic steam-heated presses. The product of this operation is a strong rigid plate with lustrous surface finish. Both the electrical insulation properties and the finish of this material are absolutely permanent. Time or exposure to air will not in any way affect it.

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TUBE CHECKER

Model 19 Supreme tube checker, manufactured by Supreme Instruments Corpn., Greenwood, Miss., provides an accurate test of all types of tubes at the correct filament voltages, and without the aid of adaptors. It is extremely simple in operation and exceptionally speedy in its testing work, thus being ideal equipment for the dealer or serviceman. Full size transformers are used, and the meter is a 3½ inch General Electric copper-oxide type with two scales of 80 and 8 milliamperes, affording easily discernible readings. Separate sockets are employed for each type of tube and average characteristics and rejection points are indicated on the panel alongside of each socket.

The Model 19 tube checker provides a very accurate and dependable test of screen grid tubes, and in addition, tests pentode and the new 2-volt, '30 series tubes. It is furnished with an on and off toggle-switch, and is encased in a handsome polished hardwood case, making it exceptionally durable. The portable model is equipped with hinged cover, snap catch, leather handle, detachable flexible cord, and is suitable for either counter or portable work.

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WIRE WOUND RESISTORS OF EXTREME ACCURACY

A large and varied line of precision resistors is announced by the International Resistance Company, Philadelphia, Pa. These units are intended for applications calling for precise resistance values, positively maintained at all times.

The International Resistance precision wire-wound resistors are of unique design. The wire is of nickel alloy, carefully gauged, specially enameled and subjected to a high insulation voltage test through mercury contacts. Contrary to common practice, the wire is the largest possible size consistent with the size of the resistor. This overcomes insulation problems and provides a more rugged unit. The wire is wound in the sections formed by the finned ceramic form. A high quality ceramic is employed, which has a low coefficient of expansion, low moisture absorption, extremely high resistance, and very close mechanical tolerances. Its low coefficient of expansion prevents breakage of wire under operating conditions. The wound resistor is impregnated in a special varnish which hardens with higher temperatures instead of softening as the wax coated forms do. The exclusive winding process employed gives unbroken insulation throughout. The units are tested by means of a five-minute flash load at double normal wattage, which locates the slightest flaw. The units are then tested on accurate bridges to the tolerance required, which may be 1 per cent, ½ of 1 per cent, or ¼ of 1 per cent.

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VEALE TO GOAT

Well known in the tube end of the radio industry is R. Clifford Veale, until recently with the General Electric Company, representing that company for its tube bases. Mr. Veale has become the sales representative for the numerous radio tube parts manufactured by Goat Radio Tube Parts, Inc., at Bush Terminal, Brooklyn.

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TOBEY ELECTED DUBILIER VICE-PRESIDENT

At the last meeting of the Board of Directors of the Dubilier Condenser Corporation, N. S. Tobey, sales manager, was elected executive vice-president of the company. Mr. Tobey, who has been busily engaged in building up the radio and industrial sales of the Dubilier organization during the past year, is going to devote a considerable portion of his time from now on to production and other phases of the business.

Buyers Directory of Materials and Apparatus

Readers interested in products not listed in these columns are invited to tell us of their wants, and we will inform the proper manufacturers. Address Readers' Information Bureau.

Addresses of companies listed below, can be found in their advertisement—see index on page 62.

ALUMINUM:
Aluminum Co. of America
Fairmont Aluminum Co.

ALUMINUM, SHEET, FOIL:
Fairmont Aluminum Co.
Johnson Tin Foil & Metal Co.

AMMETERS:
General Electric Co.
General Radio Co.
Weston Elec. Instrument Corp.

AMPLIFIERS, POWER:
American Transformer Co.
General Radio Co.
Samson Elec. Co.

ANTENNAE, LAMP SOCKET:
Dubilier Condenser Corp.

BASES, SPEAKER:
American Felt Co.
Booth Felt Co.
Western Felt Company

BASES, VACUUM TUBE:
(See Tube Parts)

BINDING POSTS:
General Radio Co.

BRACKETS, ANGLE:
Scovill Mfg. Co.

BRASS:
Scovill Mfg. Co.

BROADCAST STATION EQUIP'T:
American Transformer Co.
Cardwell, Allen D., Mfg. Co.
General Radio Co.
Jenkins & Adair, Inc.
Littlefuse Laboratories

BUTTS:
Scovill Mfg. Co.

CABINETS, METAL:
Aluminum Co. of America

CASTINGS:
Fairmont Aluminum Co.

CELLS, PHOTOELECTRIC:
National Carbon Co., Inc.

CEMENT, LOUD SPEAKER:
Maas & Waldstein Co.

CENTRALIZED RADIO SYSTEMS:
American Transformer Co.
Samson Elec. Co.

CHASSES:
Aluminum Co. of America
Metal Specialty Co.

CHOKES, AUDIO FREQUENCY:
American Transformer Co.
General Radio Co.
Meissner Mfg. Co.
Polymet Mfg. Co.
Thordarson Elec. Mfg. Co.

CHOKES, RADIO FREQUENCY:
Cardwell, Allen D., Mfg. Co.
General Radio Co.
Hammarlund Mfg. Co., Inc.

CHOKES, POWER:
American Transformer Co.
Dongan Elec. Mfg. Co.
General Radio Co.
Polymet Mfg. Corp.

CLAMPS, GROUND:
Clarostat Mfg. Co.
Scovill Mfg. Co.

CLIPS, SPRING:
Electrad, Inc.
Scovill Mfg. Co.

CLOCKS, ELECTRIC:
(See Electric Clocks)

CLOTH, WIRE:
(See Wire Cloth)

COIL FORMS:
General Mfg. Co.
General Radio Co.

COIL WINDING:
Acme Elec. & Mfg. Co
Automatic Winding Co.
Concourse Electric Co.
Dudlo Mfg. Co
Easton Coil Company
General Mfg. Co.
Inca Mfg. Co
Polymet Mfg. Corp.

COILS, CHOKE:
Acme Elec. & Mfg. Co.
Dudlo Mfg. Co
Easton Coil Company
Polymet Mfg. Corp.

COILS, IMPEDANCE:
Dudlo Mfg. Co.
Easton Coil Company
General Mfg. Co.
Polymet Mfg. Corp.

COILS, INDUCTANCE:
Cardwell, Allen, D., Mfg. Co.
Easton Coil Company
General Radio Co.
Hammarlund Mfg. Co.
Inca Mfg. Co.

COILS, MAGNET:
Acme Wire Co.
Dudlo Mfg. Co
Easton Coil Company
Inca Mfg. Co.
Polymet Mfg. Corp.

COILS, SHORT WAVE:
Easton Coil Company
General Mfg. Co.
General Radio Co.
Hammarlund Mfg. Co.

COILS, TRANSFORMER:
Acme Wire Co.
Dudlo Mfg. Co.
Easton Coil Company
Polymet Mfg. Corp.

CONDENSER PARTS:
Aluminum Co. of America
Henry L. Crowley & Co.
Scovill Mfg. Co.

CONDENSERS, BY-PASS:
Aerovox Wireless Corpn.
Amrad Co.
Condenser Corp. of America
Dongan Electric Mfg. Co.
Dubilier Condenser Mfg. Co
Igrad Condenser & Mfg. Co., Inc.
Polymet Mfg. Corp.

CONDENSERS, ELECTROLYTIC:
Aerovox Wireless Corp.
Amrad Corporation
Condenser Corp. of America
Polymet Mfg. Co.

CONDENSERS, FILTER:
Aerovox Wireless Corpn.
Amrad Co.
Condenser Corp. of America
Dongan Electric Mfg. Co.
Dubilier Condenser Corp.
Igrad Condenser & Mfg. Co., Inc.
Kingston Products Corp.
Polymet Mfg. Corp.

CONDENSERS, FIXED:
Aerovox Wireless Corpn.
Amrad Corporation
Condenser Corp. of America
Dongan Electric Mfg. Co.
Dubilier Condenser Mfg. Co.
Polymet Mfg. Corp.

CONDENSERS, MIDGET:
Cardwell, Allen D. Mfg. Co.
General Radio Co.
Hammarlund Mfg. Co.
Polymet Mfg. Corp.
Scovill Mfg. Co.

CONDENSERS, MULTIPLE:
Cardwell, Allen D. Mfg. Co.
Hammarlund Mfg. Co.
Scovill Mfg. Co.

CONDENSERS, NEUTRALIZING:
Hammarlund Mfg. Co., Inc.
Polymet Mfg. Corp.

CONDENSERS, VARIABLE TRANSMITTING:
Cardwell, Allen D. Mfg. Co.
DeJur-Amsco. Corp.
General Radio Co.
Hammarlund Mfg. Co.
Jenkins & Adair, Inc.

CONDENSERS, VARIABLE:
Cardwell, Allen D. Mfg. Co.
Concourse Elec. Co., Inc.
Frost, Herbert H., Inc.
General Radio Co.
Hammarlund Mfg. Co.
Scovill Mfg. Co.

CONNECTORS:
Cornish Wire Co.
Scovill Mfg. Co.

CONTAINERS, BATTERY BOX:
George F. Mitchell & Sons Co.

CONTROLS, CURRENT:
Central Radio Laboratories
Polymet Mfg. Corp.
Shallcross Mfg. Co.

CONTROLS, VOLUME:
American Transformer Co.
Central Radio Laboratories
Clarostat Co.
Ferranti, Inc.
Polymet Mfg. Corp.

CONVERTERS:
Cardwell, Allen D., Co.

COPPER:
Scovill Mfg. Co.

CORDS, EXTENSION:
Anaconda Wire & Cable Co.
Polymet Mfg. Co.

COUPLINGS, FLEXIBLE:
Chicago Gear Works
Hammarlund Mfg. Co., Inc.

CUSHIONS, SPEAKERS:
Aetna Felt Co.
Western Felt Co.

DIALS:
Crowe Nameplate & Mfg. Co.
Hammarlund Mfg. Co.
Scovill Mfg. Co.
United Scientific Laboratories

DIALS, DRUM:
Crowe Name Plate & Mfg. Co.
Hammarlund Mfg. Co.

DIE-CASTINGS:
Allied Die-Casting Corp.

DIES:
Thomas & Skinner Steel Products Co.
Willor Mfg. Corp.

DRYER-IMPREGNATORS:
F. J. Stokes Machine Co.

ELECTRIC CLOCKS:
Electric Clock Corp. of America

ESCUTCHEONS:
Crowe Nameplate & Mfg. Co.
General Etching & Mfg. Co.
Scovill Mfg. Co.

EXPORT:
Ad. Auriema, Inc.

FADERS:
Clarostat Mfg. Co.

FELT, ACOUSTICAL:
Aetna Felt Co.
American Felt Co.
Booth Felt Co.
Western Felt Co.

FELT, PACKING:
Aetna Felt Co.
American Felt Co.
Booth Felt Co.
Western Felt Co.

FILAMENTS:
(See Tube Parts)

FILAMENT CONTROLS, AUTOMATIC:
Amperite Corp.
Polymet Mfg. Corp.

FLEXIBLE SHAFTING
S. S. White Dental Mfg. Co.

FOIL:
Aluminum Co. of America
Johnston Tin Foil & Metal Co.

FUSES, INSTRUMENT:
Littlefuse Laboratories

FUSES, LOW RANGE:
Littlefuse Laboratories

GALVANOMETERS:
General Electric Co.
General Radio Co.
Westinghouse Elec. & Mfg. Co.

GEARS:
Chicago Gear Works

GENERATORS:
Electric Specialty Co.

GETTER MATERIAL:
(See Tube Parts)

GRAPHITE
Acheson Oildag. Co.

GRID LEAKS:
(See Resistances, Fixed)

HANDLING EQUIPMENT:
Nat'l. Vulcanized Fibre Co.

HINGES:
Scovill Mfg. Co.

HORNS:
Amplion Co. of Amer.

INDUCTANCES, TRANSMITTING:
General Radio Co
Jenkins & Adair, Inc.

INSTRUMENTS, ELECTRICAL:
General Electric Co.
Westinghouse Elec. & Mfg. Co.

INSULATION LAMINATED
Formica Insulation Co.
General Electric Co.
National Vulcanized Fibre Co.
Synthane Corp.

INSULATION, MOULDED:
Bakelite Corp.
Henry L. Crowley & Co.
Formica Insulation Co.
General Electric Co.
General Plastics Co.
National Vulcanized Fibre Co.
Synthane Corp.
Westinghouse Elec. & Mfg. Co.

INSULATION, REFRACTORY:
Henry L. Crowley & Co.
The Stupakoff Labs.

JACKS:
General Radio Co.

KITS, TESTING:
(*See Testing Kits*)

LABORATORIES, TESTING:
Electrical Testing Labs.

LACQUER, WOOD:
Maas & Waldstein Co.

LACQUER, METAL:
Maas & Waldstein Co.

LACQUER, ENAMEL:
Maas & Waldstein Co.

LAMINATIONS:
Thomas & Skinner Steel Products Co.
Willor Mfg. Corp.

LAMPS, MINIATURE:
National Carbon Co., Inc.

LAMPS, PANEL:
National Carbon Co., Inc.

LEAD-INS:
Clarostat Mfg. Co.
Electrad, Inc.

LOCK WASHERS:
Shakeproof Lock Washer Co.
Thompson-Bremer & Co.

LUBRICANTS, RADIO:
Acheson Oildag Co.

LUGS:
Scovill Mfg. Co.
F. R. Zierick Mfg. Works

MACHINERY, TUBE:
Arrow Mfg. & Machine Co., Inc.
Central Scientific Labs.
Eisler Electric Co.
Int'l. Machinery Works, Inc.
Lepel High Frequency Labs.

MACHINES, SPECIAL
Willor Mfg. Corp.

MAGNESIA, TUBES:
Henry L. Crowley & Co.

MAGNESIUM:
Aluminum Co. of America

MAGNETS:
Thomas & Skinner Steel Products Co.

METALS, RARE:
Fansteel Products Co., Inc.
American Electro Metal Corp.

METERS:
General Electric Co.
Weston Elec. Instr. Co.

MICROPHONES:
Amplion Co. of America
Ellis Electrical Laboratory
Jenkins & Adair, Inc.
Kellogg Switchboard & Supply Co.
Universal Microphone Co.

MOLDING MATERIALS
(*See Insulation, Moulded*)

MOUNTINGS, RESISTANCE:
Polymet Mfg. Corp.

NAILS:
Clamp Nail Company

NAMEPLATES:
Crowe Nameplate & Mfg. Co.
General Etching & Mfg. Co.
Scovill Mfg. Co.

NICKEL SILVER:
Gilby Wire Co.

OHMMETERS:
General Radio Co.
Weston Elec. Instr. Co.

OSCILLOGRAPH:
General Radio Co.

PACKING PADS, CABINET:
Aetna Felt Co.
American Felt Co.
Booth Felt Co.
Kimberly-Clark Corp.
Western Felt Co.

PACKING MATERIAL:
Holed-Tite Packing, Inc.
Kimberly-Clark Corp.

PACKING AND SHIPPING:
Kimberly-Clark Corp.

PANELS, METAL:
Aluminum Co. of America
Scovill Mfg. Co.

PAPER, CONDENSER:
Peter J. Schweitzer, Inc.

PHONOGRAPH MOTORS:
The Hammond Clock Co.

PHOSPHOR BRONZE:
Baltimore Brass Co.

PHOTOELECTRIC CELLS:
(*See Cells*)

PICK-UPS, PHONOGRAPH:
Amplion Co. of Amer.
Jensen Radio Mfg. Co.

PLATES, OUTLET:
Howard B. Jones

PLUGS, ATTACHMENT:
General Radio Co.
Howard B. Jones
Polymet Mfg. Corp.

PORCELAIN TUBING:
Henry L. Crowley & Co.

POTENTIOMETERS:
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Central Radio Laboratories
General Radio Co.
Polymet Mfg. Corp.
United Scientific Laboratories

POWER UNITS, A-:
Thordarson Electric Co.

POWER UNITS, B-:
Dongan Elec. Mfg. Co.
General Radio Co.
Thordarson Electric Mfg. Co.

POWER UNITS, A-B-C:
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Dongan Elec. Mfg. Co.
General Radio Co.
Thordarson Electric Mfg. Co

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Dongan Elec. Mfg. Co.
General Radio Co.
Polymet Mfg. Corp.
Thordarson Electric Mfg. Co.

PUBLIC ADDRESS SYSTEMS:
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Amplion Corp. of America
Samson Elec. Co.

PULLEYS:
Chicago Gear Works

PUMPS, HIGH VACUUM:
Arrow Mfg. & Machine Co., Inc.
Central Scientific Co.
Eisler Elec. Corp.
Int'l. Machine Works, Inc.

PUNCHINGS:
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George F. Mitchell & Sons Co.
Scovill Mfg. Co.
Soreng Manegold Co.

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Scovill Mfg. Co.

REFRACTORY SPECIALTIES:
Henry L. Crowley & Co.

REGULATORS, VOLTAGE:
Amperite Corp.
Central Radio Laboratories
Clarostat Co.
DeJur-Amsco Corp.
Polymet Mfg. Corp.
Soreng Manegold Co.
Ward Leonard Elec. Co.

RELAYS:
Cardwell, Allen D., Mfg. Co.

RESISTANCES, FIXED:
Aerovox Wireless Corp.
Central Radio Laboratories
Clarostat Mfg. Co.
The Daven Corp.
DeJur-Amsco Corp.
Frost, Herbert H.
General Electric Co.
Polymet Mfg. Corp.
The S. S. White Dental Mfg. Co.
Ward Leonard Elec. Co.

RESISTANCES, VARIABLE:
Central Radio Laboratories
Clarostat Mfg. Co.
DeJur-Amsco Corp.
Easton Coil Co.
Frost, Herbert H., Inc.
General Electric Co.
International Resistance Co.
Polymet Mfg. Corp.
Shallcross Mfg. Co.
Ward Leonard Elec. Co.

RESISTANCE WIRE:
(See Wire, Resistance)

RHEOSTATS:
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Clarostat Mfg. Co.
Frost, Herbert H.
General Radio Co.
Polymet Mfg. Corp.

SCREW MACHINE PRODUCTS:
Aluminum Co. of America
National Vulcanized Fibre Co.
Scovill Mfg. Co.
Synthane Corp.

SCREWS, HARDENED SELF-TAPPING:
Parker-Kalon Corp.

SCREWS, DRIVE, HARDENED METALLIC:
Parker-Kalon Corp.

SEALING COMPOUNDS
Candy & Co.
Cochrane Chemical Company

SHEET METAL PARTS:
George F. Mitchell & Sons Co.

SHIELDING METAL:
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Hammarlund Mfg. Co., Inc.
Radio Products Corp.

SHORT WAVE APPARATUS:
Cardwell. Allen D., Co.
De Forrest Radio Corp.
General Radio Co.
Hammarlund Mfg. Co., Inc.

SOCKETS, TUBE:
Central Radio Corp.
Henry L. Crowley & Co.
Frost, Herbert H.
General Radio Co.
Howard B. Jones
Soreng Manegold Co.

SOLDER:
Kester Solder Co.

SPAGHETTI:
(See Wire, Spaghetti).

SPEAKERS:
Amplion Corp. of Amer.
Jensen Radio Mfg. Co.
Rola Co., The
Transformer Co. of Amer.

STAMPINGS, METAL:
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George F. Mitchell & Sons Co.
Radio Products Corp.
Scovill Mfg. Co.
Thomas & Skinner Steel Prod. Co.

SUBPANELS:
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General Radio Co.
National Vulcanized Fibre Co.

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Soreng Manegold Co.

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Johnson and Johnson

TAPE, INDUSTRIAL:
Johnson and Johnson

TAPE, LOUD SPEAKER:
Johnson and Johnson

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Shallcross Mfg. Co.

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Thompson-Bremer & Co.

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TESTERS, TUBE:
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Radio Products Co.
Weston Elec. Inst. Co.

TESTING INSTRUMENTS:
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General Radio Co.
Radio Products Co.
Westinghouse Elec. & Mfg. Co.
Weston Elec. Instrument Corp.

TESTING KITS:
General Radio Co.
Weston Elec. Inst. Co.

TESTING LABORATORIES:
Electrical Testing Labs.

TIN COATED METAL:
Baltimore Brass Co.

TIN FOIL:
(See Foil.)

TOOLS:
Willor Mfg. Corp.

TRANSFORMERS, AUDIO:
Acme Elec. & Mfg Co.
American Transformer Co.
Dongan Elec. Mfg. Co.
Easton Coil Co.
General Radio Co.
Samson Elec. Co.
Thordarson Electric Mfg. Co.

TRANSFORMERS, B-POWER UNIT:
American Transformer Co.
Dongan Elec. Mfg. Co.
General Radio Co.
Kingston Products Corp.
Samson Elec. Co.
Thordarson Electric Mfg. Co.

TRANSFORMERS, BROADCAST STATION:
American Transformer Co.
Jenkins & Adair, Inc.
Samson Electric Co.

TRANSFORMERS, FILAMENT HEATING:
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Dongan Elec. Mfg. Co.
General Radio Co.
Thordarson Electric Mfg. Co.
Transformer Corp. of America

TRANSFORMERS, OUTPUT:
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Dongan Elec. Mfg. Co.
General Radio Co.
Samson Elec. Co.
Thordarson Electric Mfg. Co.
Transformer Corp. of America

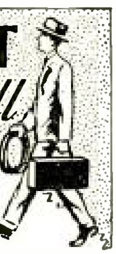
TRANSFORMERS, POWER:
Acme Elec. & Mfg. Co.
American Transformer Co.
Dongan Elec. Mfg. Co.
Easton Coil Co.
General Radio Co.
Kingston Products Corp.
Polymet Mfg. Co.
Samson Elec. Co.
Thordarson Electric Mfg. Co.

TRANSFORMERS, R. F., TUNED:
Cardwell, Allen D. Mfg. Co.
Hammarlund Mfg. Co., Inc.

TRANSFORMERS, STEP-DOWN:
American Transformer Co.
Amplion Corp. of Amer.

TUBE MACHINERY:
See (Machinery, Tube.)

TUBE, PACKING:
Holed-Tite Packing, Inc.




TUBE PARTS:
Acheson Oildag Co.
American Electro Metal Corp.
Buffalo Wire Works Co., Inc.
Cleveland Wire Cloth & Mfg. Co.
Henry L. Crowley & Co.
Fansteel Products Co., Inc.
General Plastics, Inc.
Gilby Wire Co.
Juno Fasteners, Inc.
Lepel High Freq. Labs.
Newark Wire Cloth Co.
Radio Products Corp.
Synthane Corp., Inc.
(See Parts, Tube.)

TUBE TESTERS:
(See Testers, Tube)

TUBES, A.C.:
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De Forest Radio Co.
National Carbon Co., Inc.
National Union Radio Corp.

TUBES, RECTIFIER:
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De Forest Radio Co.
National Carbon Co., Inc.
National Union Radio Corp.

TUBES, SCREEN GRID:
Arcturus Radio Co.
De Forest Radio Co.
National Carbon Co., Inc.
National Union Radio Corp.

TUBES, TELEVISION
See *(Cells, Photoelectric.)*

TUBING, NICKEL:
Gilby Wire Company

TUBING, PAPER & FIBRE:
Paper Tube Co.

TUBING, REFRACTORY:
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Stupakoff Labs, Inc.

TUBING, VARNISHED:
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TUNING DEVICES:
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UNITS, SPEAKER:
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Jensen Radio Mfg. Co.

VARNISH:
Maas & Waldstein Co.

VOLTAGE REGULATORS:
(See Regulators)

VOLTMETERS, A. C.:
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General Radio Co.
Weston Elec. Instrument Corp.

VOLTMETERS, D. C.:
General Electric Co.
General Radio Co.
Weston Elec. Instrument Corp.

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Aluminum Co. of America
Booth Felt Co.
Scovill Mfg. Co.
Synthane Corp.
Thompson-Bremer & Co.
Western Felt Co.

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Cochrane Chemical Company

WAXES, INSULATING:
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WAXES, SEALING:
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Cochrane Chemical Co.

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Anaconda Wire & Cable Co.
Dudlo Mfg. Corp.
National Vulcanized Fibre Co
Roebling, J. A., Sons Co.

WIRE, BARE & TINNED COPPER:
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Dudlo Mfg. Corp.
Roebling, J. A., Sons, Co.
Spargo Wire Co.

WIRE CLOTH:
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Gilby Wire Co.
Newark Wire Cloth Co.

WIRE, COTTON COVERED:
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Alpha Wire Corp.
Dudlo Mfg. Corp.
Gilby Wire Co.
Polymet Mfg. Corp.
Roebling, J. A., Sons Co.

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Anaconda Wire & Cable Co.
Dudlo Mfg. Corp.
Polymet Mfg. Corp.
Roebling, J. A., Sons Co.

WIRE, FILAMENT:
American Electro Metal Corp.
Callite Products Co., Inc.
Fansteel Products Co., Inc.
Gilby Wire Co.
Radio Products Corp.

WIRE, HOOK-UP:
Alpha Wire Corp.
Cornish Wire Co.
Dudlo Mfg. Co.
Roebling, J. A., Sons, Co.

WIRE, LITZENDRAHT:
Dudlo Mfg. Corp.
Roebling, J. A., Sons Co.

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Inca Manufacturing Co.
Polymet Mfg. Corp.

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Callite Products Co., Inc.
Fansteel Products Co., Inc.

WIRE, PIGTAIL:
Dudlo Mfg. Corp.
Roebling, J. A., Sons Co.

WIRE, RESISTANCE
Alloy Metal Wire Co.
Anaconda Wire & Cable Co.
Fansteel Products Co., Inc.
Gilby Wire Co.

WIRE, SILK COVERED:
Alpha Wire Corp.
Anaconda Wire & Cable Co.
Cornish Wire Co.
Gilby Wire Co.
Radio Wire Corp.
Roebling, J. A., Sons Co.

WIRE, SPAGHETTI:
Alpha Wire Corp.
Cornish Wire Co.

WIRE, TANTALUM:
Fansteel Products Co., Inc.

WIRE, TINNED COPPER:
Alpha Wire Corp.
Anaconda Wire & Cable Co.
Dudlo Mfg. Corp.
Roebling, J. A., Sons, Co.

ZINC:
St. Joseph Lead Co.

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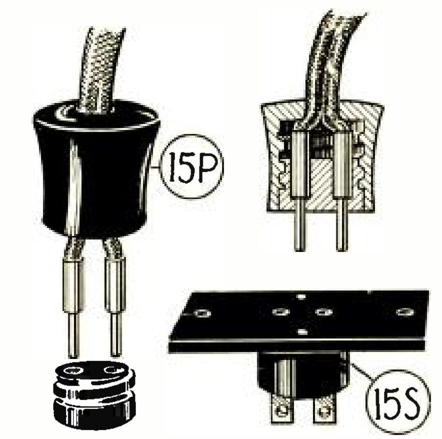

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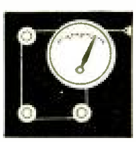
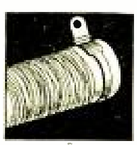
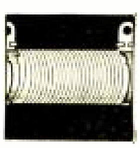
The pitchrod determines the accuracy of winding wire on tubes



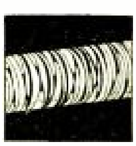
The tension of the wire must be correct



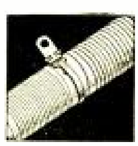
Lack of accuracy in pitch or tension will cause shorted turns or



If a perfect winding like this is to result



"Swimming" of wire after one coat of enamel is fused on



Control of these factors is perfect. Two wire sizes are often wound on one tube.

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