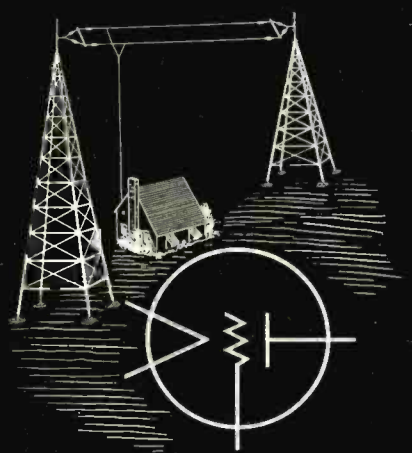
AUGUST, 1932

Radio Engineering



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By G. R. Brandt and H. L. Smith

THE DESIGN OF PORTABLE SPEECH INPUT EQUIPMENT FOR REMOTE CONTROL BROADCASTING
By Ray S. Lyon

PHOTOELECTRIC RELAYS
By W. R. King

TWELFTH YEAR OF SERVICE

The Journal of the Radio and Allied Industries

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SALES PROSPECTS FOR COMING MONTHS

THE gradual rise in stock exchange quotations for industrial securites has had an important effect upon the increase in the negotiable value of millions of dollars worth of stocks and bonds in the hands of the public and which have been held intact throughout the past three years.

Increase in the value of equity, even though it is not sold, means the thawing of frozen assets. The holders of securities once more gaining in value usually are early participants in new buying waves. There are hundreds of thousands of such persons so circumstanced in this country.

Stock market gains thus are of the utmost importance as an element of industrial recovery.

In the radio industry during the past three weeks there has been a distinct increase in manufacture and in sales. One factory we know of is now operating day and night shifts in order to fill orders in hand.

One division of the radio receiver market certain to prove profitable during the coming months are the 9,862,637 homes, largely rural, located beyond the services of electric power.

Various responsible commercial agencies now report conditions improving in practically all sections of the country. It is generally believed that radio sales during the Fall and Winter months—1932-33—will considerably exceed the gross for the same months of 1931-32.

A factor to keep in mind is that general business will experience healthy gains long before any manufacturer, jobber or dealer will stage a celebration marking the return of prosperity.

BRYAN S. DAVIS, *President*

JAS. A. WALKER, *Secretary*

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Editorial

AUGUST, 1932

VERTICAL ANTENNAS FOR BROADCASTING

ALTHOUGH WSM, Nashville, will use its present antenna system to radiate from its new 50,000 watt transmitter, the station expects to have ready by September its new 878 foot vertical type antenna.

This new antenna will be about 200 feet higher than the vertical tower of WABC. So moves forward the attack upon sky wave suppression while improving the outward thrust of the ground wave component of fewer variables and vagaries.

It is reported also that WCAU, Philadelphia, will install a 500 foot vertical antenna for broadcast purposes.

▲

THE RADIO CONFERENCE AT MADRID

THE radio conference of 1927, held in Washington accomplished about as much as was possible in view of the uncertainties of the entire subject at that time.

In the United States during the past five years progress has been made along the road toward regulation and control without unnecessarily placing obstacles in the way of further technical development.

At the Madrid radio conference to be held in September, this year, there will be deposited in the laps of the delegates from all countries, problems which in number and intricacy may rival those of Lausanne.

The popular broadcast phase of radio has made such great strides since 1927 that it is probable the demands of the broadcasters the world over will receive more consideration than was accorded them at Washington.

So-called government services and point-to-point services had rather the best of the allotments in 1927, but, in view of what in this country at least, has been learned during the past three years about the dependence of prosperity upon tax paying industries, there seems to be reason to hope that the economics of the situation will have sensible consideration this year.

European countries represented at the conference will no doubt bring to Madrid much of the international distrust, and lack of cooperation so evident in the various economic, tariff and political conferences which appear to run on continuously and arrive nowhere.

How different the situation is in America. Frequency schedule adjustments between the United States and Canada are made promptly, harmoniously and with mutual consideration.

The discouraging plight of the railroads in our country—large tax payers—largely because competitive truck transportation services have been provided with highways free to them, but which cost the taxpayers hundreds of millions of dollars in capital investment and as much more for maintenance, may be a parallel to what will happen to established communication companies unless economic considerations are recognized in the distribution of available message carrying channels in space.

Much depends upon the experience, the economic grasp, and the service background of the men our Government sends to Madrid to submit viewpoints as of the year 1932.

▲

POLICE RADIO

THE gratifying increase in the number of police radiophone installations throughout the country has given the forces of crime detection a new facility the effectiveness of which is now widely recognized.

The second stage of the development of this service may well take the form of either discouraging eavesdropping on the part of persons not properly concerned with the broadcasts, or of rendering the service secretive.

Donald McNicol

Editor.

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Western Electric 9A Speech Input Equipment . . .

Single panel assembly . . . Moving Coil Microphones . . . all A. C. operation . . . low operating cost

The Western Electric 9A is a complete, efficient, high quality speech input equipment designed primarily for use with the new series of Western Electric radio transmitting equipments (100 to 1000 watts). It may be used also with other transmitters and is admirably adapted for remote points requiring flexible pick-up facilities.

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The 9A Speech Input Equipment typifies the progress made in the design of broadcasting equipment. Its simple, practical design makes possible compact and convenient installations at studios, stations and remote locations.

Single Panel of the Western Electric 9A Speech Input Equipment; size 12" x 20" x 83"

Western Electric

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Graybar Building, New York, N. Y.

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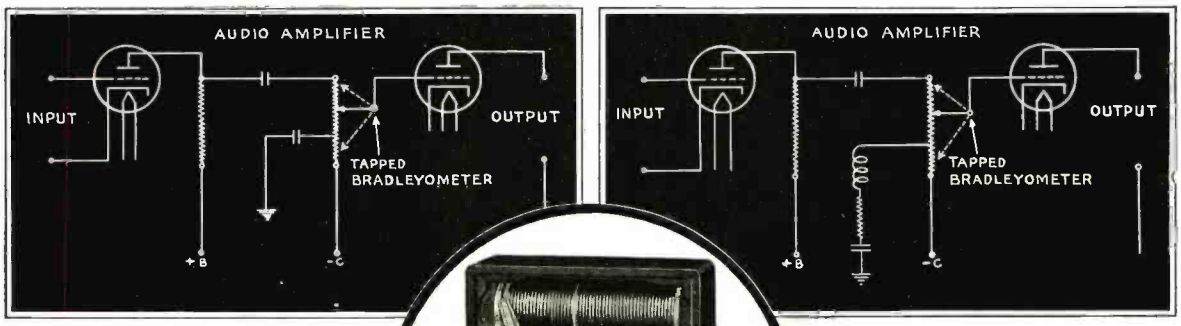
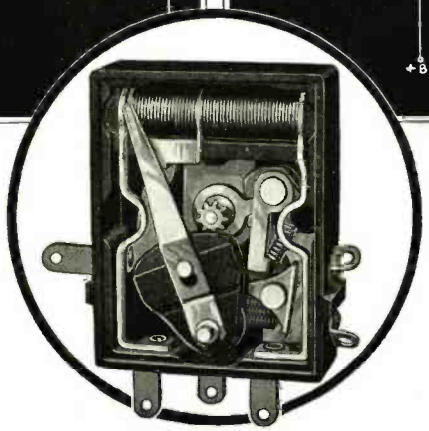
The New Tapped Bradleyometer



A tap on the resistance element is brought out to a fourth terminal. The network necessary to provide tone correction is usually connected between this tap and the grounded or low potential end of the Bradleyometer. (See above diagrams.)



A single-pole line switch approved by the Underwriters' Laboratories and the Hydro Electric Power Commission of Ontario with a rating of 2 amperes, 125 volts, can be provided within the Bradleyometer and is operated by the regular control knob.

for

Automatic Tone Correction with Volume Control

The sound pressure representing the threshold of audibility varies greatly with the frequency and is a great deal higher at low and high frequencies than in the middle register. Therefore, the volume control unit must vary the frequency characteristics of the audio amplifier so that the apparent quality

of reproduction remains the same for all volume control settings. The new tapped Bradleyometer achieves this result in any one of several audio frequency networks and automatically accomplishes tone correction with volume changes. Write for complete data on the new tapped Bradleyometer.

Bradley Suppressors are special solid molded resistors, used by prominent car manufacturers to provide individual resistors for each spark plug and for the common cable to the distributor on radio-equipped cars.

They increase the resistance of the high tension ignition system and minimize the disturbing oscillations in the ignition circuit which interfere with the radio receiver in the car. When used with suitable by-pass condensers in other parts of the circuit, shielded ignition cables are unnecessary. Write for data, today.

Bradleyunit Resistors are made in five sizes, with or without leads, and are R.M.A. color coded for resistance value identification. These solid molded resistors are accurately calibrated and have great mechanical strength.

Bradleyunit Resistors are used by the world's largest radio manufacturers, because their resistance value is stable under varying conditions of load, temperature, and moisture. Don't risk the reputation of your receiver with poor resistors. Get an Allen-Bradley quotation on your next order.

Allen-Bradley Co., 126 W. Greenfield Ave., Milwaukee, Wis.

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RADIO ENGINEERING

Production, Administration, Engineering, Servicing

VOL. XII AUGUST, 1932 NO. 8

Special survey of the radio industry

prepared by the
Research Department of R. G. Dun & Co.

THE radio industry is barely fifteen years old. This is the mere infant stage in terms of industrial life. Yet, in this brief span it has emerged from a toy into a product of value which contributes more than $500,000,000 annually to the national wealth, pays out each year around $350,000,000 for operating expenses, and provides entertainment and instruction for nearly 17,000,000 homes scattered from Maine to California. For entertainers alone, broadcasting stations will spend about $40,000,000 during the current year.

The total investment in the industry, is approximately $1,800,000,000. Of this sum, $150,000,000 represents investment of radio manufacturers; $250,000,000 the investment in radio broadcasting; $1,600,000,000 in listeners' sets; and $25,000,000 the investment in commercial radio stations. It is the universal acceptance of the radio that is its best guarantee of continued popularity. To millionaire and laborer alike, it brings the vocal and instrumental genius of the world's foremost artists, reports of sporting events, political occurrences and the news of the world.

That retail sales of radio products have fallen from the record peak in the last two years is not an indication of waning popularity for the instrument, but rather a sign of intense preparation for a period of great achievement. In fact, the drop in sales in 1931 to $309,270,000, which was a 38 per cent decline from the total of $500,951,500 recorded for 1930, and a decrease of 63 per cent from the $842,548,000 in 1929, which was the record year for the industry, is regarded as the natural sequence of the tumbling prices caused by the hectic activity during 1928 and 1929, when volume and volume alone was the aim of the industry. The recession surely cannot be attributed to any abatement of interest, as the desire to enjoy the benefits of the radio takes little heed of unfavorable economic developments or of those adverse influences which congest distributive channels.

Firmer Basis Reached

For a time, at least, the gold rush stage of the industry has passed. It now has settled down to the planning and thinking stage where sales drives must be worked out and production economies effected just as in every industry that is to endure. The members of the trade who are conducting their establishments with full regard for these elementary factors are making a profit even if it is below expectations. Sensational demand is absent, but it has been replaced by a healthier demand, which can be met more profitably by reliable merchandise on which a fair mark-up can be obtained.

More Radio Advertising

Despite the many adverse influences, radio broadcasting has been somewhat better during the last few months, due to the willingness of many advertisers, national and local, to give the audible advertising medium at least a trial. Instead of losing renewal accounts, or being unable to acquire new ones, many broadcasters report business on the increase, particularly those situated strategically for serving favorable markets.

This increase was rather unexpected during the Summer, but it appears that the radio is proving itself an efficacious advertising medium throughout the entire year. It is just as valuable for the exploitation of Summer merchandise as it is for calling attention to Winter articles. The prospects for the broadcaster now seem brighter than they have been for many years.

Now a World Industry

Of the 35,000,000 receiving sets installed in homes throughout the world, almost half, or 17,000,000 are operated under licenses. Subscription licenses, part or all of which are allocated to the support of broadcasting, are paid by 13,500,000 owners. The total population of radio-licensing countries is 370,000,000, approximately three times that of the United States. These nations have one-half as many stations as the United States, and one-third of these are operated under extra-monopoly arrangements.

The sum of licenses paid totals between $60,000,000 and $70,000,000 annually. This is largely an assumptive estimate, but it is as near as can be obtained. Not only do licenses vary within the country as to cost, dependent upon distances and licensee's income, but large numbers of free licenses are issued to schools, hospitals and the disabled.

There are 73 countries now broadcasting in various parts of the world. Broadcasting is supported in whole or

▲

While low-priced sets have led the demand thus far this year, the current trend is decidedly toward the better grade of units. Some manufacturers are discontinuing the midget models to concentrate attention on the consolettes. Many merchants are sustaining volume by making a special drive for replacement business, the number of obsolete receivers now in use being approximately 4,500,000

in part from licenses in 31 of these. In 24 of the 55 countries requiring licenses, and in 18 of the non-licensing countries alike, broadcasters are left to find their own means of carrying on. About the same proportion of non-broadcasting as of broadcasting countries collect annual receiving-set fees, which average approximately the same in specified amount.

During the past year there was an increase of nearly 25 per cent in the number of receivers in use. The increase was world-wide; few countries showed a decline—none of any consequence. The method of supporting broadcasting stations seems to have had little effect on the result. Every continent, and almost every country participated.

There now are 1,423 radio broadcasting stations in the world, an increase of 33 since July, 1931. Of this number, 806 are foreign stations, operating in 70 countries, and 617 in the United States and its possessions. Of 607 located in Continental United States, New York takes first place with 52 broadcasting stations, and California second place by virtue of its 43. Pennsylvania comes third with 40 stations, and Illinois, which formerly held second place on the list, now is fourth, with a total of 36. Texas is fifth, with 34 stations, while Navada, which for a long time was the only State in the Union without a radio voice, now has 2 stations. At the bottom of the list stands Wyoming, with only 1 radio station to its credit. Nearly one-half of the broadcasting stations in the country are in seven states, Iowa and Washington ranking sixth and seventh, with 26 and 22, respectively. The complete list of States, with the number of broadcasting stations located in each, follows:

BROADCASTING STATIONS IN U. S.

New York	52	Alabama	8
California	43	Mississippi	7
Pennsylvania	40	North Carolina	7
Illinois	36	Arizona	7
Texas	34	North Dakota	6
Iowa	26	Idaho	6
Washington	22	Montana	6
Ohio	20	Maine	5
Michigan	19	Rhode Island	5
Missouri	19	Vermont	5
Indiana	16	Kentucky	5
Wisconsin	16	West Virginia	5
New Jersey	15	Maryland	5
Massachusetts	14	Connecticut	4
Tennessee	13	South Carolina	3
Colorado	13	New Mexico	3
Oregon	13	Utah	3
Virginia	12	Dist. of Columbia	3
Oklahoma	12	Delaware	2
Nebraska	11	New Hampshire	2
Georgia	10	Alaska	2
Louisiana	10	Hawaii	2
Arkansas	9	Nevada	2
Florida	9	Puerto Rico	1
Minnesota	9	Wyoming	1
South Dakota	9		
		Total	607

The invested capital in these 607 broadcasting stations runs in excess of $50,000,000, as technical equipment, generators, transmitters, and antenna account for approximately $25,000,000 and the balance represents good-will, real estate, furniture and fixtures. The annual expenditures for talent, programs, employees, equipment and miscellaneous charges run to nearly $80,000,000. The invested capital in broadcasting ranges from $15,000 for a ten-watt station to $200,000 for a fifty-kilowatt installation. Some idea of the extent of the investment can be gained from a partial list of he stations and the wattage employed:

Number of Watts	Number of Stations	Capital Invested
Under 100	33	$288,202
100	191	4,107,502
Over 100	54	2,396,354
500	123	6,659,645
750	1	20,500
1,000	95	9,889,802
Over 1,000	4	200,455
5,000	31	5,221,464
Over 5,000	26	8,061,119

The transfer of the Radio Division of the Department of Commerce to the Federal Radio Commission, authorized by Congress in the recent economy bill, is expected to lead to the extension of the nation-wide inspection force of the Radio Division.

Municipalities Use Radios

Long recognized as an invaluable weapon of the police, the radio also has become important to other phases of civic government in a number of American cities. As a result, municipalities throughout the United States are studying the numerous public services rendered by the radio and are spending millions of dollars for transmitters and receivers for various civic purposes.

In New York City alone, 250 radio equipped motor-patrol cars cruise through the city's streets, constantly alert for alarms and instructions from police headquarters. Radio-equipped fire boats steam through the nation's busiest harbor and its surrounding waters protecting vessels and waterfront property. A non-commercial broadcasting station is operated by the city. Radio is listed as a major subject in the municipal technical high schools, with up-to-date equipment on hand for student experiments. Numerous schoolrooms are equipped with receivers for educational broadcasts. Radio weather reports are invaluable aids to aviators leaving and arriving at the municipal airport.

Costing in the neighborhood of $100,000, the New York police radio has by far the greatest radio system in the world. Since it has been in use, many attempted felonies and disturbances have been thwarted and quelled by the quick motor-patrol response to broadcast alarms. Frequently, but a few minutes elapse between the broadcast and the actual report of the arrest. In the operation of the automobile-radio system, the New York Police Department has continued the use of its long-established station for harbor communication.

The New York Fire Department has conducted numerous radio telephone tests for two-way communication between fire-boats and headquarters. Sets are installed on fire-boats and satisfactory results have been reported. The fire-boat radio systems provide for transmission of alarms and instruction to the floating engines as they steam through the harbor. Formerly it was necessary for the boats to return to the dock to receive instruction to proceed to a fire near a point that had just been passed.

Some 70 police radio services have been installed by as many cities and States during the last three years.

Current Sales Heavier

Although sales of radios attain their greatest volume during the months of October, November and December, fully 40 per cent of the total sales of the year being made during this three-month period, there has been an unexpected increase in demand since the early part of June. This has been attributed to the political conventions at Chicago, and the preparations that are being made to get the full benefit of the broadcasts to be made during the presidential campaign in the Fall, and the many unusual sports events, including the Olympic Games. All of these are to be broadcast both nationally and internationally.

Replacement sales have been heavy, as there are approximately 4,500,000 obsolete sets in use, and retailers are offering to accept these as part of the initial payment on modern instruments, with their increased capabilities of reception and tone quality. As a radio set is so constructed that in many cases a minor part at fault can cause considerable havoc with reception, parts must be renewed constantly if the best results are to be obtained. While such repair work brings no immediate profits of consequence, merchants are cultivating it this season more than ever, as it gives them an opportunity to keep in contact with customers and prospects. Vacation needs also are helping to sustain current sales.

The midget sets evidently are losing their appeal, as buyers are replacing these with larger sets, and manufacturers who formerly specialized on midgets are turning to consolettes. Most of the new receivers are equipped with two dynamic speakers. Some manufacturers, in fact, have announced three speakers. That is, one is centered on the front panel; the other two are placed angularly so as to reflect sound from the sides of the cabinet.

As manufacturers have been matching production rather closely with

sales, there has been almost no distress merchandise on the market, as compared with the situation during the first six months of 1931. While this condition has meant reduced sales volume for both wholesaler and retailer, it has resulted in greater profits. Besides, it is teaching all branches of the trade how to sell regular merchandise that carries a fair mark-up, instead of rushing wildly to attain volume and then find at the close of the season that there is nothing remaining to show for their work.

As many of the retailers note a decided shift to higher-priced merchandise, if a popular range in prices from $50 to $100 can be established during the Fall season, when buying is at its peak, it may be possible for total sales to reach the level of 1931, when the value of radio products sold at retail dropped to $309,270,000, which was the lowest point touched since 1923, according to the compilation made recently which shows:

TOTAL SALES OF RADIO PRODUCTS AT RETAIL

Year	Value
1922	$60,000,000
1923	136,000,000
1924	358,000,000
1925	430,000,000
1926	506,000,000
1927	425,000,000
1928	690,550,000
1929	842,548,000
1930	500,951,500
1931	309,270,000

That is, the 51,000 retailers of all kinds that handled radios in 1931 had total sales that were only slightly in excess of the $296,066,224 recorded for the sales of the 10,915 exclusive radio and electrical shops in 1929. Despite the decrease in sales during the last two years, however, the number of sets in operation has continued the steady gain which started back in 1925. With an estimated total of 16,800,000 in use on June 30, 1932, the United States leads the world in the number of receiving sets in operation, a gain of nearly 5,000,000 in the two-year period.

For the apparent popularity of radios, Denmark outdistances all other nations, with 133.9 radio sets per 1,000 inhabitants, leaving the United States in second place, with 133.1 radios per 1,000 persons at the end of 1931. This was an increase of 34.8 during the year, as there were 98.26 radios in the United States for each 1,000 inhabitants on December 31, 1930.

Retail Outlets Numerous

Retailers of radios exclusively are responsible for only 30 per cent of the total sales, the remainder of the volume being sold by music dealers, department stores, automobile dealers, tire and battery shops, electrical merchandise stores, and in a total of 72 types of retail establishments, including barber shops. It is interesting to note the different types of retail outlets which now sell radios:

Fred D. Williams, President, Radio Manufacturers' Association

Type of Dealer	Per Cent
Exclusive Radio	30
Music	12
Furniture	11
Automotive	9
Department	8
Power Companies	6
Electrical	6
Hardware	5
Contractors	3
Drug	1
Grocery	1
Jewelry	1
Miscellaneous	7
Total	100

Most of the sales in the radio retail trade are made on the installment plan, in the form of small weekly payments. Of the firms selling on the deferred payment plan, 73 per cent finance themselves, 21 per cent use the services of financial companies and 6 per cent use the services of financial companies and their own money. Radio sales per dealer are heavier in the large cities than in the small communities. Sales per dealer in cities of 3,000,000 or over average $55,000. The sales per dealer in communities of 25,000 to 30,000 average $18,792.

More Automobile Radios

The radio for the automobile now has become a fixed part of the industry. Automobile makers are installing radio receivers as standard equipment in selected models, which thus gives the final stamp of approval and endorsement. Since a year ago wide strides have been made in current design for such receivers. Manufacturers of radio tubes also have contributed heavily to the progress by introducing new types of tubes and perfecting the old standards.

With nearly 17,000,000 homes already equipped with radio sets. the next great outlet is expected to be the automobile. Of the 23,000,000 automobiles now on the American highways, it is estimated that at least 2,000,000 cars will be sold during the current year. Thus, with 25,000,000 automobile owners as prospects, it should not be difficult for the 125,000 automobile sets sold last year to be increased at least 300,000 before 1932 will have come to a close.

Price Trend Steadier

While prices for some of the new sets are higher, the fractional increase gives the buyer nearly twice the value for his dollar that he received a few years ago. That is, more tubes, more speakers, a better cabinet, and a tremendous improvement in radio quality. This is a step in the right direction as it means that there is a better chance for the retailer to make more money in the radio business this season.

This will be a welcome change, as during the hectic career of this young industry all the worries thus far have been borne by those engaged in making and selling the sets. The public has been the gainer at all times. No other dollar which the public has spent since the first tiny crystal sets were sold has worked so patiently to return an overflowing measure of entertainment, interest, and instructions as the radio dollar.

Although prices fluctuated considerably during the greater part of 1931, varying according to the district and the class of merchandise handled, it was possible to purchase most sets from 5 to 30 per cent under the quotations at which they had been offered during the year preceding. There was a predominance of distress merchandise on the market particularly during the last six months of 1931, largely the result of the overproduction of the year preceding. Much of the price-cutting, however, would have been done, even if the public had not been economizing, because there were more radios than could have been sold at the list prices, even with continued prosperity.

During the first six months of the current year, the situation has been cleared, to some extent, as stocks of manufacturers and retailers are the lowest they have been in years, and distress merchandise has become less of a retardative influence to sales than it was at this time a year ago. That the trend has become somewhat steadier is reflected in the current average price of $60 for a radio set, as compared

(*Concluded on page 28*)

Construction details of a 50 kw. broadcast transmitter

VERNE V. GUNSOLLEY

THE design and construction of a large transmitter entails few different problems than for a small one, but since the stability of the radio-frequency amplifier becomes an increasing problem, somewhat out of proportion to the increase in size, the principles of design need to be applied with far greater precision. Obviously the presence of grid circuits in a field intensity capable of covering the better part of the United States means that the shielding, balancing and by-passing must be something more than a mere gesture.

It is not the intention of this article to go into all the details of construction, but since this transmitter may be of considerable interest, especially to those intending to build one, photographs and descriptions are given.

The problems of locating the transmitter in the best place for city coverage were not met, for, the new transmitter was to be located next to the old transmitter so that the latter could be conveniently used for standby service.

In the matter of building construction, the sole consideration of the backers was utility. Therefore, while every effort was made at neatness and appearances, the buildings are constructed along the usual industrial lines. Furthermore, this station had been holding a building permit for some fifteen months. The Federal Radio Commission refused to extend the time further than the expiration of the last renewal, and building and transmitter construction had to be accomplished in record time. These conditions caused the most rapid transmitter construction on record for one of this size. Some idea of this rapidity can be gained from the fact that although the transmitter had to be in by March 20, ground had not been broken nor plans decided upon until close to January 1, allowing therefore but about twelve weeks for the entire construction program. Obviously no more time than necesary was spent on the building construction. By February 1, it was nearly completed ready for the transmitter.

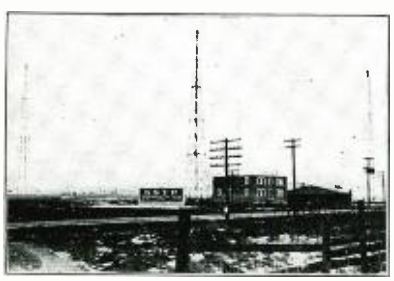

Fig. 1. General view of old and new transmitters. Insulated towers in background.

The exterior of the building is finished in stucco, on metal lath. The interior is cement finished on metal lath also, with the exception of the control booth and the sleeping rooms which are finished in acoustic plaster. All metal lath is bonded to give electrical continuity and to make it more effective as shielding.

The tuning house is of the same kind of construction as the main building, but the power plant housing the Deisel is of concrete block construction.

Power Supply

Obviously, the location of an industrial unit should be accompanied by some consideration of the availability of power as well as the matter of signal strength, available lands, and transportation. Unfortunately, the location of the old transmitter which was not so bad in this respect, due to the small amount of power (60 kw.) required, was not so good when it came to the question of some 250 kw. For the power company to build such a special heavy line entailed the expenditure of $40,000 on their part for which they demanded guaranties that were burdensome on the broadcasting company, and still none too profitable to themselves. The problem was further complicated by the fact that the station though permitted to build for 50 kw., was not permitted to broadcast on more than 10 kw. for the time being, and even then could not hope for an increase of power to more than 16 kw. Since the broadcast company was gambling on the chances of getting a 50 kw. license, it was plain that if they did not get it the guarantees imposed by the power company for a line heavy enough for 50 kw. operation would be excessive and unbearable. The existing line was too light for even 10 kw. transmitter operation since the old transmitter employed about 25 per cent modulation while the new was to use 100 per cent. Thus the old power line was too light and the new one, for the time being would be too heavy in the matter of cost. To meet this problem an unusual solution was found.

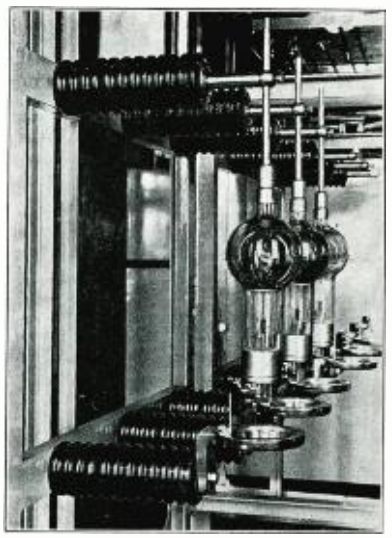

Fig. 2. Rectifier, closeup view, three tubes in place.

After much careful consideration and many misgivings it was finally decided that a Diesel engine would solve the problem. It would be able to carry the load alone under the present power permit, and, due to its characteristics, at an efficiency close enough to full load efficiency. Then, if the 50 kw. license were ever granted, by synchronizing with the old power line, sufficient power would be available without further investment.

Some of the misgivings were in the matter of voltage regulation, simplicity and reliability of operation, frequency stability, noise and vibration. Other Diesel plants were visited and records showed a reliability of operation that was higher than that inherent in the transmitter itself, thereby justifying its selection from that score. The matter of voltage regulation was superior to that of long lines. The reliability to date has fully justified its selection. The noise level is negligible. As to the vibration effects on tubes sufficient data is not available. This could be solved, if a problem, by locating the power plant further away from the transmitter. It was so slight as to justify taking a chance on locating the plant so it would be handy to the operator in any emergency. In fairness to the Deisel it must be said that it is quite as

easy to operate as an electric motor of equal power.

This problem had not met with much previous consideration. So decision was delayed in the matter until it was necessary for the engine company to have the engine installed, capable of operation, in 19 days. Installation was almost complete before the foundations were well set or the power house completed. The engine was therefore carefully realigned shortly after the foundation was permanently set.

Cooling System

For a short time some thought was given to the matter of combining the cooling systems of the transmitter and Diesel. Sufficient time was not at hand to work out such a system, and practice indicates that it would be no small problem due to the nature of the water required for the transmitter as compared to the lower grade of water that may be used in the Diesel. The transmitter is therefore equipped with a separate cooling system.

The blower for this system is a 42-inch rotary fan into the ducts of which are placed two copper fin and tube radiators. The circulating water going through these radiators is thus kept in relatively pure condition. The cooling system is mainly of iron. The air to the cooling fan and the exhaust may be circulated either inside or outside the building according to the season by means of suitable by-pass doors in the ducts. The transmitter may thereby be used to heat the building.

Rectification

The 3-phase, 480-volt output of the Diesel generator is fed to a six-wave rectifier through the medium of three 85 kva transformers. The amount of the rectifier is approximately 17,000 volts. It is equipped with six hot-cathode mercury-vapor tubes. One of the practical

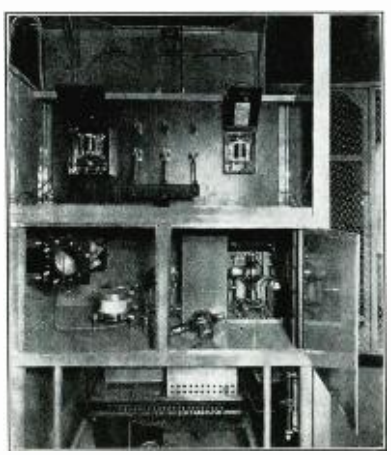

Fig. 4. Crystal gear and 860 stage during test.

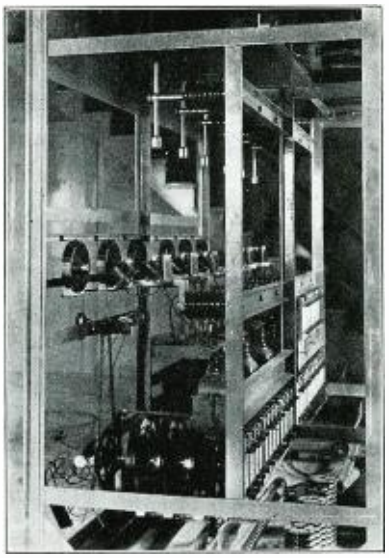

Fig. 3. Closeup of rectifier assembly before wiring.

features of this layout is the socket. The 204-A socket may be removed to receive another type of rectifier tube which at that time was not on the market, but soon expected. Fig. 3 shows a stripped view of the rectifier with the rheostats for filament control and the meters in place. Also the floor bushings and the fusing scheme is shown in back. By inserting the fuses in the proper clips, the desired taps of the transformers may be put in use. Overhead may be seen the voltage dividers for some of the first stages of the transmitter.

The rectifier voltage may be adjusted by the taps on the transformers. Considerable voltage control is offered by means of the exciter and generator fields on the Deisel unit. Further, a large resistor was designed for absorbing the shock of flashbacks in the rectifier, and it is possible to use this for working on about one-third full power for testing purposes. In the automatic starting process, the rectifier is started through this one-step resistance. Should a flashback occur, a suitable relay drops the load back on this resistor which limits the flashback current to full-load current until the faulty tube cleans up, after which the relay serves to cut out the resistance again. Thus a flashback instead of throwing the entire transmitter off the air merely causes a slight sinking spell in the program that is often not noticeable.

The tubes have a rating of 20,000 volts inverse peak, and a peak current rating of 5 amperes. For 50 kw. operation the tubes having a rating of 20 amperes at 20,000 volts will be used.

Crystal Control

At the time orders were given for the construction of the transmitter, no particular thought had been given to the design of a crystal gear. Sufficient time was not at hand to design one that would assuredly come up to the standards it was desired to set in the matter of frequency stability, so it was decided to save time on this part of the equipment by purchasing one already built. The claims of the makers are for stability to within 2 cycles in 1,460 kc. This has not been demonstrated for periods longer than the period of test so it is not known how closely it complies for continuous, 19 hour daily, operation. It is known, however, that the constancy is reasonably well within average for the best types of crystal control available. The bottom section of the rack in Fig. 4 shows the rear of the gear and a full view of terminal strip which may be pulled out to permit withdrawal of the crystal unit as a whole. The gear has no adjustments on the front panel, but a door may be dropped down for purposes of observing the thermometer or adjusting the controls. The gear has but one heater chamber, but two crystals, either one of

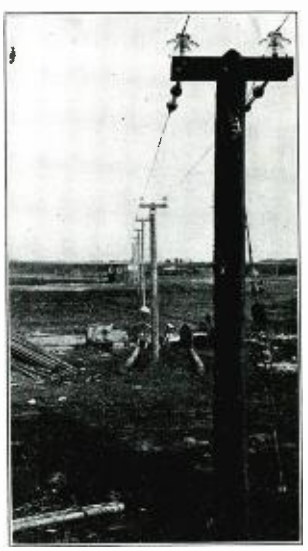

Fig. 5. View of transmission line from transmitter end.

which may be switched into operation in a moment's notice.

In this gear are contained the 210, and the two 865 tubes.

In connection with the water-cooled tube it may be mentioned that one of the useful features is a split gland ring that makes possible easy removal of the tube when occasion requires.

In all of the system assembly accessibility for prompt replacement of parts was kept in view.

Under the effects of a standing wave during tests, before the impedance of the line had been fully matched, the top of an insulater cracked permitting arc-over to the pin and thence to the braces across to the other pin and back through the other insulator to the opposite line. Cross-arm construction was changed to that shown in Fig. 5, thereby making full use of the cross-arm insulation; and the impedance watched before full power used.

The Antenna

The antenna is a straight vertical, nearly quarter-wave type. Although many antennas were experimented with, when the power was alike in all, the practical signal strength was the same; the effects of changing the pattern being noticeable but immaterial. With the percentage of modulation changed from 25 per cent to 100 per cent, while there is a very great actual difference at the receiver, the public still wants to know when the station is going on the air with the new transmitter. This is a most eloquent argument for permission to use 50 kw. Certainly increases of but 40 per cent or so as claimed for certain patented antenna systems seem to not justify any great expense for their installation.

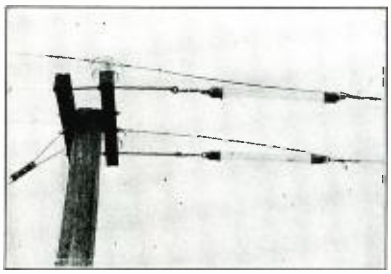

Fig. 6. Transmision line dead ending detail.

Towers

The new towers are shown as the first and third from the left in Fig. 1. They are considerably higher than the old towers and are insulated as shown in detail in Fig. 6. The capacity to ground is 38 $\mu\mu$f through each insulator, or a total for the four, 152 $\mu\mu$f. At 1,460 kc. the insulator impedance is thus about 720 ohms. One undesirable feature of this installation is that the insulation is only about 8 inches off the ground, necessitating maintenance during the winter snows.

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Grids for tubes

By F. L. HUNTER*

SINCE De Forest produced his first crude Audion, molybdenum has been an accepted material for grids. Tube manufacturers have many times believed they were rid of the expense of purchasing this rare metal.

By the winter of 1931 nearly all of the tube manufacturers had installed equipment which could produce satisfactory grids using base metal wire of .005 and .006 inch diameter. They were about to discharge moly.

The advent of the —56, —57, and —58 type tubes, however, brought about a change. The old faithful material could again be depended on to do the new job quickly and with certainty.

Manufacturers agree that the electrical characteristics of the common grid metals are not sufficiently different to dictate the choice. Their chief concern is with the mechanical properties; those which permit volume production and the maintenance of accuracy and uniformity. Since the wires used in these tubes are only as large as hairs (.003 inch, .0035 inch and .004 inch), the natural properties of the metal are highly important. Those required are:

1. Strength.
2. Natural stiffness.
3. Ductility.
4. Resistance to change in the temperature range encountered.

The strength must be great enough to withstand the abuse of high speed machine winding without breaking or stretching. The grid must be held as a compact unit exactly as wound or set and withstand the abuse of storage, mounting, and exhausting. Finally, it must endure the shocks and jolts of transportation and repeated handlings.

Inherent stiffness is also essential for meeting the conditions enumerated.

Setting the grid to accurate dimensions requires a high degree of ductility. Whether it is stretched or "bumped," the wire must be capable of being deformed without breaking and taking a permanent set in the desired form.

Often grids are subjected to a firing process in an atmosphere of hydrogen at temperatures ranging from 700° C. to 1,100° C. They should emerge from this as nearly unchanged as possible—neither soft and flabby nor hard and brittle. Since the stretching or setting operation is done after firing, it is essential that the metal retain its strength and ductility. During the bombarding process the grids are subjected to temperatures ranging from 600° C. to 1,000°C. Here the fine wires must neither soften nor warp from the settings they have previously been given.

The basic reasons for the difference between the behavior of molybdenum and base metal wires lie in their crystalline properties, and the temperature regions in which certain forms are stable.

All solid pure metals are composed of crystals cemented together by a non-crystalline or amorphous form of metal. The strength and elasticity of the crystal portion is different from that of the amorphous portion and these properties change relatively with temperature. In most metals the crystals are soft and ductile at normal atmospheric temperatures while the cementing material is relatively hard. At elevated temperatures the amorphous portion is plastic and relatively weaker than the crystals. The two substances are mutually con-

Engineer, Fansteel Products Company, Inc.

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Mechanical properties of material used are important in volume production.

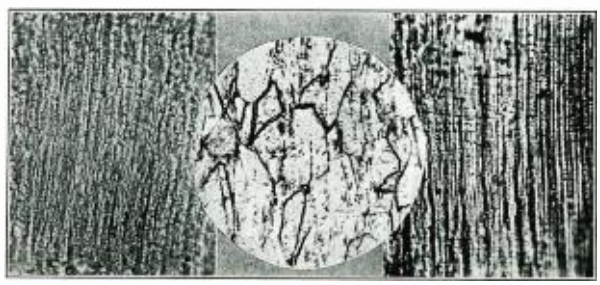

Fig. 1. — Annealed molybdenum wire.

Fig. 2.—Hard drawn nickel wire.

Fig. 3.—Hard drawn molybdenum wire.

Fig. 1. Fig. 2. Fig. 3.

vertible into each other, the crystals forming amorphous material at any place where they are squeezed or bent beyond the elastic limit, and the amorphous material being absorbed into the crystals whenever the temperature is raised to that region which permits crystal growth. The temperatures at which the crystals start growth differ greatly between metals and are widely influenced by impurities. The process may be compared to some living tissues which if wounded while in a dormant state produce a hard scar to seal the broken surface, but upon being brought into active conditions, absorb the scar tissue and replace it with normal, living cells.

Since this article is concerned only with grids, the discussion will be restricted to the use of molybdenum.

The fact that molybdenum is generally made by pressing fine powder into bars and sintering to form the starting ingot need not be considered a material difference from the process of casting nickel, say, from the molten state. It has been melted and cast in suitable equipment without showing any marked difference from the sintered product. Both the sintered molybdenum bar and nickel ingot may be so treated as to have the desired crystal structure after cooling. Both bar and ingot must be hammered or rolled while hot to compact the grains and make a dense, workable metal.

It would be outside the scope of this article to discuss the metallurgy of the entire process to the finished wire. It must suffice to set forth the structures of fine wires and their differences in nature and behavior.

Figs. 1 and 2 show the micro-structure of an annealed molybdenum wire and of a nickel wire which has been subjected to severe cold working. Both pictures show the elongation of crystals in the direction of working. In the case of nickel, however, they are shorter and non-fibrous. This nickel wire was stiff, hard, and fully as strong as the molybdenum wire. Its ductility or capacity to stretch was, however, zero. The long fibrous crystals of the molybdenum were so disposed as to minimize the effect of the cementing material.

The high strength of the nickel wire results from distortion and disruption of the crystals in cold working. They have been pulled out in the direction of drawing and compressed in the transverse direction. Many have been broken up into smaller units with the consequent formation of amorphous material.

The fibrous structure of the molybdenum wire was started during swaging of the rod and kept from reverting to the random or equi-axed condition by working at temperatures well below the conversion point. The cold drawing simply continued and intensified this thread forming process. Fig. 3 shows the structure at the end of cold drawing.

Fig. 4. Re-crystallized molybdenum wire.

Fig. 5. Re-crystallized nickel wire.

Fig. 6. Annealed molybdenum wire re-heated to 1100° C.

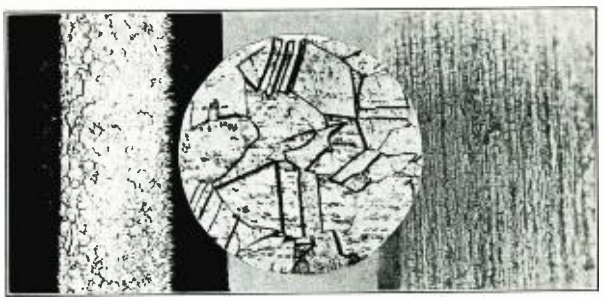

Fig. 4. Fig. 5. Fig. 6.

The wire of Fig. 3 was converted into that of Fig. 1 by raising its temperature to that at which the tiny fibers could absorb the surrounding amorphous material and mutually incorporate. The larger fibers absorbed their smaller neighbors and grew until they met on a basis of equality. Growth would continue until only one or two crystals occupied the entire cross section of the wire if it were not stopped at the appropriate point. Fig. 2 shows the optimum growth. The wire is strong yet perfectly ductile.

Crystal Structure

Figs. 4 and 5 show the crystal structures of completely re-crystallized molybdenum and nickel. The physical properties of these wires have now been reversed, although the appearance of their crystal structures is similar. The molybdenum is now hard and brittle but possesses only moderate strength and no ductility or stretch. The nickel wire has little strength or stiffness, but great ductility. Re-crystallization of the molybdenum wire produced small block-like crystals bound by weak, hard, and brittle cement. The individual crystals are as ductile as ever, but they are no longer interlocked. Any deforming strain must be transmitted to them through the surrounding walls of amorphous substance which is too weak and inelastic to hold the mass together until the crystals can stretch. The case of the nickel wire is the reverse. The crystals have rearranged themselves into unconstrained positions. Different boundaries now outline blocks and plates set at random. It is as though each had sought the most comfortable position and in doing so had absorbed all smaller competitors. The total amount of cementing material is now small compared to crystal areas and its hardening effect has been correspondingly reduced. The strength of the crystals is lower than that of the cementing substance so that they will break or "slip" before the wire can fracture along a sufficient number of adjacent crystal boundaries to completely rupture the wire.

The most important matter in connection with these photomicrographs, however, is the temperatures at which these crystal changes take place. The wire depicted in Fig. 2 was heated to 800° C. for 3 minutes to produce the structure shown in Fig. 5. The structure of Fig. 1 developed from that of Fig. 3 in 20 seconds at 1,350° C. That of Fig. 4 grew from wire similar to Fig. 1 after several minutes of heating at 2,000° C.

Fig. 6 shows the structure of the wire of Fig. 1 after re-heating to 1,100° C. for 20 minutes. The physical properties of the wire remained unchanged as might be deduced from the micrograph.

Authorities agree that nickel commences to re-crystallize at temperatures as low as 550° C. and that the speed of crystal growth increases rapidly with the temperature. At 800° C. re-crystallization is almost instantaneous in fine wires. Any grid made of .003 inch or .004 inch nickel wire may lose its strength and rigidity during bombarding, even if pre-firing is omitted. Molybdenum wound grids, will, however, emerge from the ordinary exhaust treatment unchanged. Even if excessive temperatures are used in bombarding the molybdenum laterals will become stronger and more rigid.

The performance of these tubes in sets is directly dependent upon the grids.

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NEW BEAM WIRELESS TO BE INSTALLED AT SHANGHAI

AN agreement has been signed between the Ministry of Communications, Imperial and International Communications Company, and the Marconi Company for installation on the outskirts of Shanghai of a beam wireless for international radio telegraphic communication, particularly with Great Britain. The Marconi company is supplying equipment including radiotelephony apparatus, according to Reuter, Nanking, June 25.

A chronological history of electrical communication —telegraph, telephone and radio

This history was begun in the January, 1932, issue of RADIO ENGINEERING, and will be continued in successive monthly issues throughout the year. The history is authoritative and will record all important dates, discoveries, inventions, necrology and statistics, with numerous contemporary chronological tie-in references to events in associated scientific developments. The entries will be carried along to our times.

Part VIII

1864 (298) The construction is begun of a submarine cable line to connect England with India, the Indian government backing the enterprise.

(299) Paccinotti publishes a report of his work in developing a commercial type of dynamo.

1865 (300) A better organized attempt is begun to lay a transatlantic cable (July 23) when the *Great Eastern* leaves the Thames for Valencia Bay. On August 11, after 1,186 miles of cable had been laid, the cable broke. Recovery abandoned. The contract price of the cable was $3,000,000, part cash and part in shares of the company. The cable is of seven copper wires surrounded by coatings of guttapercha, in turn surrounded by ten Bessemer steel wires. Where the break occurred the sea is 11,000 feet deep.

(301) Heinrich F. E. Lenz dies. (Born in Germany 1804.)

(302) Jeptha H. Wade, portrait painter and pioneer telegraph builder, is appointed president of the Western Union Telegraph Company, July 26. (Remained until July 10, 1867.)

(303) The Franklin Telegraph Company is organized, November 30.

(304) The Atlantic and Pacific Telegraph Company organized, December 2.

(305) Professor Clifton gives a demonstration of Reis' telephone before the Manchester, England, Literary and Physical Societies.

(306) The Collins expedition begins construction of an overland telegraph line between America and Europe via Behring Strait and Siberia. Franklin L. Pope and Ralph W. Pope were engineers identified with this undertaking. Lines were built north 850 miles through British Columbia to connect with American lines overland eastward. (This project was abandoned in 1867 after it became apparent that the submarine cable across the Atlantic was a success.)

1866 (307) The Atlantic Telegraph Company is reorganized as the Anglo-American Telegraph Company, with Cyrus W. Field still the main support of the enterprise to lay a transatlantic telegraph cable. On July 13 the *Great Eastern* commences laying a new cable twenty-seven miles north of the 1865 cable. The ship arrives at Trinity Bay, Newfoundland, on July 27, establishing successful communication across the Atlantic. At first the speed of operation was eight words per minute; later being increased to fifteen words.

(308) William H. Preece, in England, transmits signals between parallel grounded wires forty miles apart (August).

(309) Wilde develops a dynamo machine with separately excited field windings.

(310) The *Great Eastern* commenced, on August 9, picking up the abandoned 1865 cable, 604 miles from Newfoundland. Recovery made on September 2, splice made and cable extended to Newfoundland, communication being established to Ireland on September 8. Two Atlantic cables now in successful operation.

(311) The United States Telegraph Company and other independent telegraph companies consolidate with Western Union Telegraph Company, the general offices of the latter being moved from Rochester, N. Y., to New York City.

(312) Col. Robert C. Clowry is appointed district superintendent of the Western Union Telegraph Company in charge of lines in the southwest, with headquarters at St. Louis, Mo. During the war (1861-1865) he had been in charge of the military telegraph lines in the same territory.

(313) Edwin Rogers, associated with John N. Gamewell, invents improvements in fire alarm automatic signal boxes and repeaters. An installation of the new apparatus is placed in service at Mobile, Ala. (Rogers' repeater patent granted in 1870.)

1867 (314) Werner Siemens and Charles Wheatstone simultaneously bring out shunt and series self-exciting direct-current generators.

(315) The Callahan three-wire stock ticker is introduced.

(316) Clerk Maxwell, in England, announces the electromagnetic theory of light.

(317) A. E. Dolbear, in America, invents an electric gyroscope.

(318) Ladd dynamo exhibited at the Paris Exposition.

(319) William Orton, lawyer and ex-commissioner of Internal Revenue at Washington, becomes president of the Western Union Telegraph Company, July 10. (Remained in this position until April 22, 1878.)

(320) Cromwell Varley, of England, is brought to the United States to investigate and make a report on the condition of the lines of the Western Union Telegraph Company. His report, dated December 20, makes many recommendations for betterment.

(321) Michael Faraday dies. (Born in England 1791.)

1868 (322) The Dominion Telegraph Company is organized in Canada, with a capital of $700,000.

(323) The Franklin Telegraph Company's line, New York to Boston, is opened on March 9, using a duplex system invented by Joseph B. Stearns.

(324) Hamblet, in Boston, constructs the first electric clock.

(325) A second cable is laid between Malta and Alexandria, in the Mediterranean, and is successful.

(326) S. F. B. Morse writes a letter to Austin Goodyear Day, of the Kerite Insulated Wire & Cable Company, commending the use of Kerite for telegraph use. The original Kerite works was established at Seymour, Conn., in 1850, by Mr. Day.

(327) Charles G. Page dies. (Born in the United States 1812.)

(328) The rotating mirror method of observation of the oscillations of the alternating-current arc developed by Jamin and Rogers.

(329) Georges LeClanche, in France, invents the salamonniac primary battery.

(330) Thomas A. Edison's first patent granted, October 31, for an electrographic vote recorder.

(331) A fast-sending telegraph tournament is held by telegraphers in Boston, Mass. Among the contestants were: William E. Kettles, P. H. Burns, W. D. Gentry, Walter P. Phillips and W. R. Plum.

(To be continued)

The theory of rectification in hot cathode mercury vapor tubes

By G. H. Brandt and H. L. Smith

INDUSTRY is taxing the intelligence of its engineers to the utmost in the development of new methods and apparatus that may be used in the manufacture of products designed to survive the keen competition of the present day. This is particularly true in the radio industry. As a result of this tendency the hot cathode mercury vapor tube is coming into favor as an efficient rectifier and its widespread popularity makes a review of the mechanics of its operation desirable.

Since this rectifier is an electronic device its action must be explained from that standpoint. It is well to mention at this time that the concept of an atom as consisting of electrons traveling in definite orbits around a positive nucleus is only an assumption and portrays in a simple and logical manner the events that are probably taking place. This concept may be as far from the truth as is that of "lines of force" in a magnetic field but it is a concrete and useful picture in helping to keep in mind the changes that occur in transferring from one atomic state to another.

As its name implies, this rectifier comprises a hot cathode and a cold anode immersed in a gas at low pressure, in this case mercury vapor, the whole being contained in an envelope, usually of glass, with suitable connections brought to the outside.

Ionization of Mercury Atoms

Suppose now that a small positive potential is placed upon the anode. Electrons from the space charge (that sheath of electrons immediately surrounding the cathode) will be accelerated in the direction of the anode by the action of the electric field. Collisions will occur between these moving electrons and the mercury atoms. These collisions are of two kinds: elastic and inelastic. Elastic collisions are those in which the normal atom receives no energy from the colliding electron, while inelastic collisions are those in which the atom is raised from one state to another of higher energy. With the former collisions we are not concerned.

Inelastic collisions produce either of two states within the atom: excitation or ionization. Excitation occurs when the colliding electron strikes the atom with sufficient force to cause one of its electrons to move from a lower to a higher orbit. The minimum energy possessed by the colliding electron must be that amount acquired by having fallen through at least 4.9 volts. This is called the resonance potential for mercury and it imparts to the electron an amount of energy given by the equation

$$eV = 4.77 \cdot 10^{-10} \times \frac{4.9}{3 \cdot 10^{2}} = 7.79 \cdot 10^{-12} \text{ ergs,}$$

where e = electronic charge and V = voltage drop of the colliding electron. This value is also the product of Planck's constant and the frequency of the first line of the mercury spectrum. The excited atom in returning to its normal state radiates this amount of energy. Ionization occurs when the colliding electron strikes the atom with sufficient force to cause one of its electrons to be knocked from any orbit to infinity, i.e., outside of the influence of the nucleus of the atom. The colliding electron must have fallen through at least 10.3 volts to acquire sufficient energy to produce this condition. This voltage is called the ionization potential of mercury.

The ionized atom now having a dearth of electrons is positively charged and moves toward the negative cathode relatively slowly due to its comparatively greater mass. Due to their small mass, the colliding and the newly liberated electrons are accelerated rapidly toward the anode and may experience frequent collisions with other atoms of the gas before giving up their charges to it.

Recombination

In its travel to the cathode, the ion may collide with gas atoms or free electrons. Collisions with the former cause no change to either the ion or the atom because of the low kinetic energy possessed by the slowly moving ion. If the ion comes into close proximity with a free electron, the latter will be attracted to the nucleus, due to their unlike charges. Thus the electron neutralizes the positive charge of the ion; there is again the allotted number of electrons about the nucleus and a stable mercury atom results. This process constitutes recombination. At the time of recombination there is an amount of energy emitted in the form of light, equal to the energy imparted to the gas atom by the colliding electron at the time of ionization. This radiant energy may, if the recombining electron drops to the innermost orbit, possess all the lines of the mercury spectrum. This light is the characteristic blue glow seen within the tube while in operation.

The ion may also fail to recombine with an electron until the cathode is reached. Here recombination will occur with an electron from within the filament itself. During the passage of the ion through the space charge, it has the property of nullifying the effect of a great number of free electrons that help make up this sheath, thus allowing the anode to attract many more electrons than would otherwise occur were the gas not present. This fact accounts for the low voltage drop within the tube and is the sole purpose for the introduction of the gas.

Until the anode has reached a positive potential of ten volts, the current is limited by the space charge and is practically the same as though no mer-

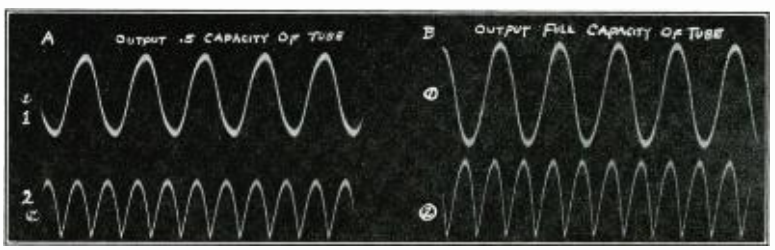

Fig. 1. Input and rectified output at half and full load from a full-wave rectifier.

Left: A1—Unrectified current input.
A2—Rectifier current output.

Right: B1—Unrectified current input, 60 cycle supply.
B2—Rectifier current output, resistance load, no filter.

cury vapor were present, for no ionization of the gas occurs. However, after ionization begins (10.4 volts) the current increases directly as the anode voltage and much more rapidly than would occur in a good vacuum. Therefore it is not until a voltage of 15 to 25 volts is reached, depending upon the vapor pressure and the geometry of the tube, that the saturation value of the current is obtained corresponding to that particular cathode temperature. In this latter state of current flow practically the whole of the voltage drop from filament to plate is concentrated in the cathode sheath in which there is now also a positive ion sheath neutralized by the low velocity or "ultimate electrons" accumulating in this space to a concentration many times greater than that of the primary electrons emitted by the cathode.[1]

Effect of Gas Pressure

Until the ionization potential has been reached, the current will be independent of the gas pressure since the electrons are unable to acquire sufficient energy to produce ionization. Above the ionization voltage the gas pressure has a very marked effect upon the current. A curve of current plotted against gas pressure shows first an increase as the pressure is decreased and then a decrease of current as the pressure is further decreased until the current corresponds to that in a high vacuum tube.

With high gas pressure the mean free path of the electron or the average distance traveled between collisions is so small that the electron is unable to acquire sufficient energy to produce ionization. As the pressure is decreased, the mean free path increases inversely as the pressure until some electrons travel far enough to acquire sufficient energy to ionize atoms upon collision. As the pressure is decreased further, more and more ions are produced until a point may be reached when all electrons are able to cause ionization. Increased reduction in pressure beyond this point increases the mean free path and also the energy of the moving electron but reduces the number of gas atoms so that collisions are less frequent and total ionization begins to drop off. This decrease in pressure may continue until there is practically no gas in the tube. The limiting current value will then be that due to the electron stream from cathode to anode of a high vacuum tube.

Rectification

As long as a positive potential is maintained on the plate there will be a flow of electrons to it and a passage of current in the opposite direction. If the plate is connected to the filament by an external circuit, the electrons will return to it and replace those previously emitted.

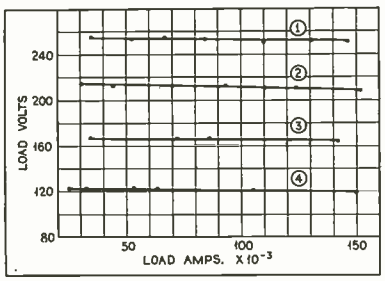

Fig. 2. Regulation curves of mercury vapor rectifier.

1. 272 v. per plate.
2. 227 v. per plate.
3. 182 v. per plate.
4. 136.5 v. per plate.

Were an alternating voltage impressed between filament and plate, during those halves of the cycles when the plate is positive, a current flow would occur as explained. During that time when the plate is negative, there will be no current flow because the negatively charged plate repels the free electrons, the filament now positively charged causes a collapse of the space charge and as the cold plate emits no electrons, there can be no ionization of the gas, hence no current flow. This accounts for the unidirectional or rectifying action of the tube when an alternating voltage is impressed upon its terminals. It can be seen that this arrangement permits only half of each cycle of the alternating current wave to be utilized, e.g., a half-wave rectifier. Two pairs of elements may be combined in one tube, forming a full-wave rectifier. Fig. 1 shows an oscillogram of the unrectified input and the rectified output current from a full-wave rectifier. It can be seen that there is no noticeable change in wave shape from half to full-load capacity of the tube.

Fig. 2 shows the regulation obtained from this rectifier for various plate voltages. Compared with other types of electronic rectifiers its superior regulation is at once apparent.

Precautions and Limitations

Were a positive potential applied to the anode before the filament was brought to proper incandescence and the space charge formed, ions attracted to the filament might attain sufficiently great velocities to dislodge active material from it. By virtue of the space charge, the voltage gradient between it and the anode is so changed and reduced that the positive ions are unable to attain velocities great enough to damage the filament.

The current output capacity of the tube is limited by the electron emissivity of the filament and is given by Richardson's fundamental equation for thermionic currents between a hot cathode and a cold anode:

$$i = A\theta^{1/2}\varepsilon^{-\frac{b}{\theta}}$$

where i = the current, θ the absolute temperature and A and b constants for a given substance. An increase in tube voltage above about 25 volts results in increased current but only at the expense of very greatly decreased life and even destruction of the filament.

The maximum inverse peak voltage is a function of the gas pressure and the geometry of the tube. It is well to remember this is the peak and not the r. m. s. value of the alternating voltage and that it should not exceed the value imposed by the tube manufacturers.

It should be further born in mind when incorporating the hot cathode mercury vapor tube in apparatus designed to use high vacuum rectifiers, that for the same power transformer the output voltage will be higher on account of its inherently lower internal voltage drop. For this reason it should be ascertained that the insulation of condensers and associated equipment is sufficient to withstand the stress of the resulting higher voltage.

▲

PLANE PILOTS WHIP FREAK "SKIP DISTANCES"

AN atmospheric peculiarity known as "skip distance" recently played tricks with short-wave telephony from airplanes of United Air Lines. The voice of a pilot of a night air mail-passenger plane flying between New York and Chicago was heard clearly at Ft. Worth, Tex., a thousand miles distant, when the ground station operator at Chicago could not hear him. Another pilot flying over Redding, Calif., was heard at Des Moines, approximately 1,900 miles away, when his voice could not be distinguished by the dispatcher at Oakland, only 300 miles distant. The voice of a flier over Kansas City was heard more distinctly at Spokane, Wash., than at Moline, Ill., and a pilot flying over the eastern part of the state of Washington picked up the voice of another air mail flier reporting his position to Oklahoma City.

Provision is made to counteract these unusual atmospheric conditions by having the pilots covered not only by the home station but by distant dispatchers who can serve as middle men between the pilot aloft and his designated station.

[1] *Langmuir, Phys. Rev. vol. 33 June 1929. pp. 954.*

The design of portable speech input equipment for remote control broadcasting†

By Ray S. Lyon,*

THE use of telephone lines for the transmission of radio programs from a remote point to the main studios or transmitter is nearly as old as broadcasting itself.[1] These were first utilized in the days when broadcasting studios were small and not adapted to the performance of large orchestras. Program talent was also scarce and an orchestra playing in a hotel grill-room or restaurant made ideal program material.

Many of the now famous orchestras and their leaders received their first publicity through the medium of remote control broadcasting. This type of service is a necessary requirement of broadcasting today and if a radio station is to be up to the minute it must necessarily be supplied with all the equipment that is required to pick up and transmit a program from practically any point outside the studios whether the connecting medium be a telephone cable or a radio channel.

In the early days of radio broadcasting this equipment was heavy and bulky. Some of the best equipment available was in the form of trunks and was extremely heavy It was, nevertheless termed "portable" by virtue of the fact that a carrying handle was provided.

This type of equipment, due to its obvious disadvantages, was soon superseded by a smaller type of unit which, while it was reduced in size and weight, did not fulfill all the requirements. The apparatus was limited as to the number of microphones that could be accommodated and soon went into obsolescence. It then became a problem for the engineers connected with the various radio stations to solve as best befitted the operating requirements of their particular station. Considerable development work was carried on by the individual station staffs and a wide variety of portable equipment resulted, some of which is still in use. For this and other reasons comparatively few commercial models of portable speech input equipment which meet all the requirements of modern broadcasting are to be found on the market today.

When the double-button carbon microphone was almost exclusively used, mainly because its frequency response was considered at that time to be satisfactory for broadcasting purposes and because its output level was fairly high (of about the order of —30 db.)[2] the amplifiers used were designed to have sufficient gain only to raise this level to the conventional zero or plus 2 db. level for transmission over the telephone circuits and to have a frequency characteristic comparable to that of the microphone. The condenser microphone which, in addition to having a lower output level and therefore requiring more gain in the amplifier, also required a high polarizing potential. Redesign of the portable equipment eventually became necessary. A remote amplifier had to be capable of handling the output of both types of microphones and the additional battery requirement of the condenser type made changes in the battery supply units necessary.

These changes in most cases were in the form of additional units which had to be carried by the operator and in many instances an additional stage of amplification was built into the existing amplifiers.

Now a third type of microphone has made its appearance in the field and its output level is still lower than that of the condenser type. Much has been written and said of the dynamic or moving-coil microphone[3] and a discussion of it is not within the scope of this paper. Let it suffice to say here that it is well adapted for use with portable equipment because of its excellent electrical characteristics, its small size and its comparatively light weight.

Inasmuch, therefore, as many radio stations have heavy investments in all three of the types of microphones mentioned it is really necessary to possess portable speech input equipment which is capable of handling all three types with a minimum of complexity. A type of equipment with such capabilities has been designed and built by the development staff of WOR and will be described later on in this paper.

Let it be said at the outset that no claims for originality of circuits nor for any outstanding features of construction beyond those already known to the art are made by the designer. This paper is presented solely for the purpose of bringing out the various considerations involved in the design of what has seemed in the opinion of the writer to be a type of equipment which apparently meets all the present day requirements of remote control broadcast operation.

General Design Factors

In the design of portable speech input equipment which is to be used for remote control broadcasting there are six major factors which must be carefully considered. These factors may be listed as follows, in the order of their importance:

1. Electrical characteristics.
2. Flexibility.
3. Simplicity of operation.
4. Mechanical design.
5. Weight.
6. Physical proportions.

The Amplifier

Of course, the first point to consider is the electrical circuit design of the amplifier and associated microphone mixing system.

The amplifier must obviously have sufficient gain for raising the microphone output to a +2 db. level for transmission over the telephone circuit.[4] This overall gain must take

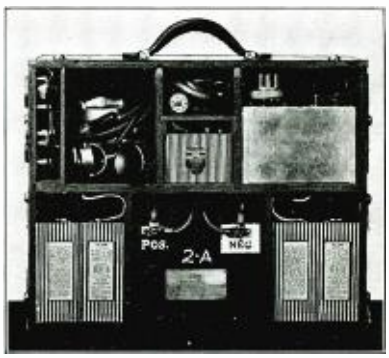

Fig. 1. Rear view of battery supply cabinet used with 30-A equipment. Note how small amplifier fits into compartment. Also note space for accessories.

†*Delivered before the Radio Club of America, June 8, 1932.*

**Development Engineer, Radio Station WOR, Bamberger Broadcasting Service, Inc., Newark, N. J.*

into consideration any losses involved in the microphone mixing network. If the mixer is properly designed, however, such losses may be kept at a minimum.

In addition to the necessary gain and maximum undistorted output the amplifier must be designed to have a flat frequency response from at least 40 cycles to 8,000 cycles.[5] The amplifier must be designed around tubes, which, in addition to being highly non-microphonic, require a minimum of filament and plate current. Since it has been pointed out that the amplifier unit may be used with microphones of various types, each type having a different output level, it is well when using microphones having relatively high output levels such as the carbon type, to provide an intermediate gain control within the amplifier itself in order that the overall gain may be reduced. This insures greater flexibility of the gain controls and minimizes tube microphonics and inherent amplifier noise. This gain control may be located in the circuit of the second stage of amplification and its control should be accessible to the operator at all times.

If it is assumed that the overall gain of the amplifier will be set at the proper level prior to the beginning of a program the attenuation may be variable in steps of 5 db. and should be designed to give a total attenuation of approximately 25 db. This value of attenuation is, of course, dependent on the total gain in the amplifier and the gain in the second stage.

Plate currents and filament voltages are fairly critical in this type of equipment and a means of controlling and measuring them is a necessity. Rheostats should be provided in the filament circuit instead of fixed resistors. The type of service in which this equipment is used is rather irregular and there is a possibility that the battery supply may be called upon to run the equipment over a long period of time without recharging. In that case it is a great convenience to the operator to be able to use his filament battery supply as long as he can by cutting out resistance in the filament circuits.

A voltmeter should also be connected across the filament circuits in order that the correct filament voltage may be visually determined, thereby insuring maximum tube life and constant operating characteristics at all times.

Plate current jacks and a suitable milliammeter should also be provided for measuring the plate current of each tube.

The correct meter readings for each circuit measurement may be indicated by means of red lines on the meter scales. This facilitates the rapid checking of the various circuits.

All jacks, rheostats and voltmeters should be plainly designated in order to preclude any possibility of error in their use.

Level Indicator or Output Meter

A most important accessory to a portable broadcast amplifier is the volume indicator or output level meter. This instrument is used to check the average output level delivered to the telephone line. Inasmuch as space and weight are at a premium in the design of equipment of the type under consideration, the type of output meter or volume indicator chosen must necessarily be one which is light in weight and requires minimum space. The copper oxide rectifier level indicator meets the requirements of both portability and accuracy and is admirably suited for the purpose.[6]

This output meter as supplied by the manufacturers has a scale which is calibrated in decibels, and levels of the order of —10 and +6 db. may be read directly on the scale. For service in portable remote equipment the meter may be used without an attenuation network as it is necessary only to read levels of the order —10 and +6 db.

Correct readings are obtainable with this type of meter only when it is bridged across a resistance of 500 ohms. It is therefore advisable, in order to insure correct meter readings regardless of the characteristic of the telephone circuits used, to provide a low attenuation network having an input and output of 500 ohms between the output transformer of the amplifier and the output terminals of the equipment. The level indicator meter should then be bridged across the output transformer secondary, which now has an output impedance of approximately 600 ohms regardless of the characteristic of the line.

It is obvious that if the meter is thus connected its indications of output level will be as many decibels higher than the actual level on the line as the number of decibels attenuation in the output network. This condition if allowed to exist would prove to be confusing to the operator in that the purpose of the meter is to check the actual level being applied to the telephone line. A compensating resistor should therefore be connected in series with the meter circuit. This will increase the effective resistance of the meter to a point where it will read as many decibels low as the attenuation in decibels of the output network. The indications of the meter will now represent the actual level being delivered to the telephone circuit without any correction on the part of the operator.

The output impedance of the amplifier is usually 600 ohms, that impedance being in conformity with standard transmission line practice which is well established.[7] The input impedance of the amplifier is dependent on the type of microphone mixing network decided upon, although the input impedance may be determined regardless of mixer design if a mixer output transformer is used. It is, however, desirable to design the mixer so as to eliminate any additional coils, thereby keeping weight and bulk at a minimum while reducing electrical losses.

Summarizing the amplifier design considerations then, we have seen these major factors to be important:

1. Vacuum tubes having a special vibration proof construction and requiring minimum filament and plate current should be chosen. The primary stages in which voltage amplification takes place require tubes having a fairly high amplification factor. The output or power stage tube should be one which will give safely a maximum undistorted output of at least 50 milliwatts but not necessarily more than 120 milliwatts which represents respectively power levels of +6 and +10 db.

2. The frequency response characteristic should be in conformity with present-day standards of broadcast practice.

3. Intermediate control of the amplifier overall gain should be provided.

4. Controlling and metering devices should be conveniently located in order to adjust and measure all voltages and currents.

5. A suitable output or level indicator meter should be included and

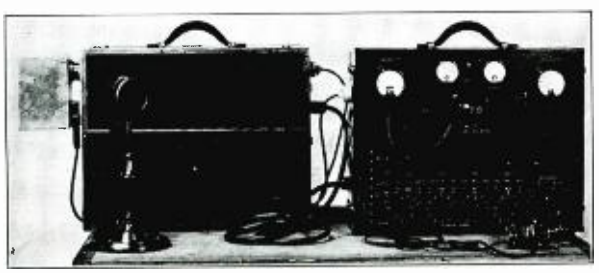

Fig. 2. Showing the 30-A equipment set up for use with dynamic microphone. Note the pre-amplifier plugged into condenser receptacle.

connected in the output circuit of the amplifier and should be properly adjusted to read the actual level being delivered to the telephone line.

6. A termination network having, preferably, a low order of attenuation should be inserted between the secondary of the output transformer and the line terminals of the equipment for properly terminating the amplifier. The output impedance of this network is normally designed to be 500 ohms, thus insuring proper termination of the amplifier regardless of line characteristics.

These are the major factors only and any other considerations which may be encountered are those attendant to the standard practices followed in good design of any type of amplifier for high quality speech input service.[8]

General Design Factors
Microphone Control Circuits

The design of the microphone mixer circuit should be governed by the following factors:

1. The various types and the number of each type of microphone for which operating facilities are to be provided.

2. The output impedance of each type of microphone.

3. Possible grouping requirements of all types of microphones used.

4. Simplicity and ease of operation.

5. Attenuation or fading requirements.

6. Variable level control with minimum change in frequency response independent of the settings of the attenuators or faders.

For many well-founded reasons the use of a single microphone is recommended for broadcast studio work for best results.[9] This practice, while it may be followed in studio operation, is not always adaptable in the field of remote activities. Due to poor room acoustics and other peculiar physical difficulties encountered in securing good pickup of various types of remote programs, it becomes necessary at times to use more than one microphone. Two are generally used, one for the program and one for the announcer. It has been necessary, however, in some cases, to use as many as 8 microphones for the pickup of as many speakers at a banquet. In one case this number of microphones was used in order to avoid any confusion which might result from the necessity of having to move one or two microphones from place to place as the program progressed. Let it be said, then, that the use of a multiplicity of microphones is not generally required. However, as it is impossible to predict the conditions under which a remotely controlled program may have to be set up, the provision of facilities for the simultaneous operation of a multiplicity of microphones is worthy of consideration when designing portable equipment for broadcasting purposes.

Since flexibility is a desirable feature, provision should be made for the operation of the three standard types of microphones. These types and their various output impedances should be taken into consideration. They have been mentioned before and their characteristics are well known. The double-button carbon microphone has an impedance of about 200 ohms, the condenser microphones in use may have either 50 or 200 ohms impedance, while the dynamic or moving-coil microphone has an impedance of approximately 25 ohms. Provision for correctly matching these impedances to the amplifier input transformer is therefore obviously a necessary requirement of the equipment. It may also be desirable at times to use two or more different types of microphones at the same time. In the event of such a requirement it is easily seen that provision must also be made for correctly matching their several outputs to the amplifier regardless of the number of each type used. Thus, for instance, it should be possible to use carbon, condenser and perhaps dynamic microphones simultaneously in any grouping that may be desired.

Fader Requirements

In order to make it possible to set the output level of each microphone independently of the others and at the same time raise or lower their combined outputs collectively, the output of the mixing network should be controlled by a variable master attenuator or gain control. Such a gain control is invaluable when a multiplicity of microphones is used, as it is often necessary to fade out all microphones simultaneously. In the design of mixer circuits the ideal arrangement is one in which the following conditions are satisfied:

1. The impedance at the amplifier input transformer primary terminals should be a known constant value for all positions of any one of the controls.

2. The attenuation of the volume controls should be logarithmically graduated in steps of not more than 2 db. each.

3. Each control should be independent of the other, which is to say that as any one control is varied from the "off" position to the full "on" position it should have no effect on the volume out of the amplifier from any of the other microphones being used.

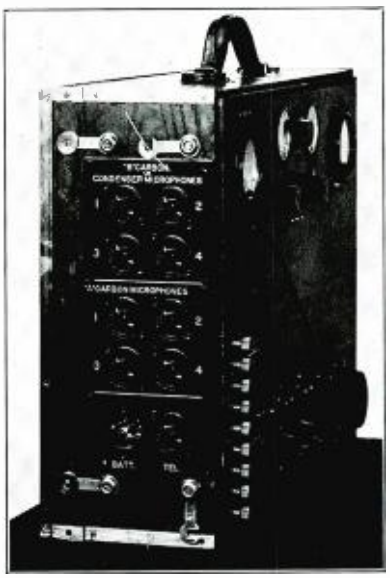

Fig. 3. End view of 30-A portable amplifier showing the two groups of microphone receptacles.

Two arrangements of mixing units are in general use:

(1) The parallel system, and (2) the series system[10]. The series type mixer is the later development, and while it has one or two disadvantages it possesses advantages which go far in recommending it.

In the parallel type of mixer the faders or control units are connected across the output of the individual microphone repeating coils and the output terminals of each of the fader units are connected in parallel. It is easily seen that such an arrangement can not satisfy the conditions mentioned above, for when one control is being operated at full "on" position the impedances in the circuit are poorly matched and the several controls are not independent of each other.

The series type of mixer has one disadvantage. Should an open circuit develop in any one of the control units the entire system would be rendered inoperative. The possibility of such an occurrence, however, can be reduced to a minimum if care is exercised in the selection of the control units or, as they are commonly called, faders.

A careful study of mixing circuits will show that the design of such circuits depends largely upon the degree of fidelity of frequency response and operating flexibility required. The choice of either one of the two types of mixing circuits rests solely with the designer, who should be thoroughly familiar with the conditions under which the equipment is to be used.

Output Switching Requirements

Radio broadcasting technique has advanced to a degree of perfection where any slight imperfection becomes at once a source of annoyance to the listener. The "show" must stay on the air and endless precautions have been taken to insure against failure of any of the electrical components used between the microphones in the studios and the antenna of a broadcasting station.[1] Breaks in the transmission of a radio program usually bring in many criticisms from the listening public. In the studios such breaks are usually of very short duration because centralization of equipment facilitates rapid location and clearing of any troubles that may arise.

In the case of a remotely controlled program the connecting link between the point of broadcast and the main control board or transmitter is usually a telephone circuit. This type of line service has been raised to a high standard of dependability and line failures are few. There remains the fact. however, that failures do occur now and then. When they occur the listening public is "returned to the studios." If this happens during a program of great interest, the effect on the radio audience is unpleasant and Mr. Public immediately tunes to another station. In view of this it is desirable to reduce the possibility of such occurrences to a minimum and it is customary to provide emergency telephone circuits between the remote point and the main studio control board.

Counting, then, the private telephone circuit which is always installed between the main control board and the remote point for purposes of communication between the operators. there are usually three connecting links between the portable equipment and the main amplifying system.

Any one of these three circuits can be utilized for program transmission should the necessity arise, and a means of rapidly switching the remote amplifier output from one circuit to another is an important feature that should be built into the portable unit. At the main control this changeover is easily and quickly effected by means of patch cords. It should be possible to switch lines at the remote point with the same ease and rapidity.

Of course provision must be made for monitoring the outgoing program at all times. In addition to this some method of switching should be included which makes it possible for the remote operator to listen in on a program cue which may be fed to him from the studios over either the emergency radio circuit or the intercommunication telephone line, or if no emergency line is installed, over the radio line which is to be used for the program, provided these lines do not pass through repeaters which prohibit two-way use.

If the equipment is to remain at the remote point of broadcast, as is often the case where programs are transmitted at regular intervals from the same point, a convenient means of leaving a short circuit on the radio line is essential for purposes of resistance measurements.

From experience and knowledge gained by close contact with all the various phases of remote control operation a switching system such as that just described has been found to be indispensable.

Simplicity of Operation

Simplicity of operation should unquestionably be a feature of design to strive for, because portable equipment may have to be operated under circumstances which make it difficult to handle even simple equipment. All of the features of design which have been discussed should therefore be electrically and mechanically combined in such a manner as to minimize their complexity, either inherent or apparent. This can be done by carefully planning the circuits, by judicious selection of electrical and mechanical components and by locating all controls on the equipment so that maximum convenience of operation is assured.

Mechanical Design Factors

Practically all of the electrical requirements of a portable broadcast speech input amplifying unit have been outlined and if the unit is to be built to meet these requirements the problem of good mechanical design is one of greatest importance.

Let us consider these requirements much in the same manner as we did those pertaining to the electrical design.

Briefly itemized, they may be listed as follows:

1. Durability or ruggedness.
2. Weight.
3. Physical proportions.
4. Quality of the component units.
5. Simplicity and minimum number of machine parts, castings, etc.
6. Ease of access to all electrical and mechanical components.
7. Interchangeability of units.
8. Symmetry of exposed equipment.

The term "portable" as applied to speech input equipment for broadcast purposes implies the necessity of its being quickly and easily transported from place to place. Practically all such equipment is carried by the operator from the studios to a taxicab at the curb, not always gently handled when time is limited, then hauled out again at the destination, set up and placed in service. At the conclusion of the broadcast it is disconnected, packed up and returned to the studios. This procedure is carried on day in and day out so it is at once evident that the equipment must be built to withstand hard service. The constant succession of shocks to which portable units are subjected makes it necessary to construct them ruggedly. All of the component parts must be substantially mounted in such a manner as to preclude the possibility of any one of them becoming loose or broken. The carrying cases should be substantial and all corners and joints reinforced. If the cases are constructed of metal they should be as light as possible without a sacrifice of mechanical strength and any large surfaces should be ribbed to prevent denting or buckling. The metal should be either non-corrodible or treated to protect it from the elements. If the cases are made of wood the wood chosen for their construction should be preferably one which combines comparatively light weight with great strength. Wooden cases should have metal protecting edges and corners as well as metal buttons on the bottoms to protect them against undue breakage and wear in transit.

Each unit of portable equipment should not weigh more than 50 lbs. Thus it is evident that the problem of mechanical design is one which calls for ingenuity on the part of the designer in order to provide maximum durability with a minimum of weight.

Physical Proportions

The average sized suitcase is built to be carried with a maximum of ease, the weight depending upon the contents, and is therefore of such physical proportions as to make it an ideal model after which to pattern portable apparatus carrying cases. Even so small a feature as the shape and construction of the carrying handle should be considered carefully. One which will provide the best grip without chafing the hand should of course be chosen and should be of a good grade leather reinforced with a steel center. Since the physical proportions are determined by the size of the contents let it suffice to say that the units should be as compact and therefore as small and light as is in keeping with good mechanical design.

Quality of Component Parts

The greatest insurance against trouble in portable units, aside from good mechanical assembly of the various parts, may be obtained through the careful

choice of the component parts used in the assembly. Vacuum tube sockets, fixed and variable resistors, jacks, meters, switches and especially the microphone faders should be of the highest quality obtainable. The wiring of the units should be so laid out as to be self supporting where possible and should be supported where necessary to eliminate vibration which might in time cause connections to break off. Loops should be left at each connection so as to make repairs possible in case of a break. Flexible wire may be used but is not necessary. Microphone faders and gain control units should be as nearly mechanically and electrically perfect as it is possible to make them. Operating in the low level circuits, they should be free from noise-generating imperfections. Contacts and sliding arms should be constructed of like metals, preferably any one of the well-known corrosion-resisting alloys. If the stationary contacts and the sliding arm are of dissimilar metals a minute voltage may be generated due to thermoelectric phenomena when the arm is rotated. This voltage when amplified shows up in the form of objectionable noise and is not tolerable when condenser or dynamic microphones are used, due to the extremely low output level of these instruments.

The resistance units which make up the variable networks or faders should be impregnated with a suitable moisture proofing material as any moisture which may accumulate between the windings may in time cause electrolysis and eventually destroy them. This also applies to all resistors used throughout the equipment.

All gain control units should be enclosed in individual metal shields or cans which are easily removable. In addition to protecting the unit against mechanical injury the can should serve as an electrical shield. Such a cover also helps to keep out dust and dirt which would otherwise accumulate on the contact surfaces and in time cause noisy operation.

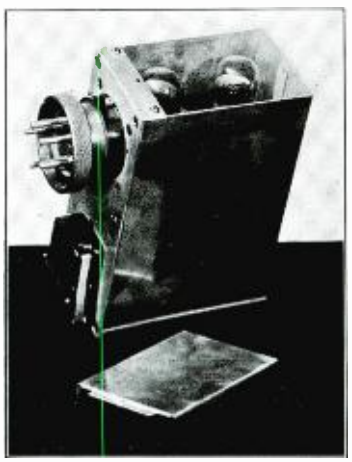

Fig. 4. Pre-amplifier for use with dynamic microphones. Top cover removed.

Battery and microphone receptacles should be of good quality and design. Contact springs and terminals should be preferably of phosphor bronze and should be designed to withstand hard service without appreciable wear or fatigue.

Meters which are built ruggedly and are accurate and reliable should be chosen. In short, all that is necessary to remember when selecting components is that the entire assembly is only as reliable as its individual parts.

Simplicity and Minimum Number of Machine Parts, Castings, Etc.

In assembling apparatus such as terminal strips, jacks, keys, etc., a certain number of small machine parts are necessary. These are usually in the form of studs, brackets, spacers, etc. Effort should be made to simplify these various machined parts wherever possible and to design them in such a way as will permit of easy duplication or replacement. Such items as spacers, studs, etc., can be designed to have universal use throughout the assembly. Castings or complicated bent or pressed parts should be avoided. These recommendations are applicable, of course, to any well-designed assembly but they are especially applicable to the equipment under consideration because repairs or replacements may have to be made rapidly and usually with limited facilities. If replacement parts therefore can be easily duplicated, much time may be saved and the equipment can be returned to service in short order.

Specially built equipment should be avoided wherever possible because of the excessive cost usually involved in its manufacture and the necessity of stocking duplicates of the special parts as insurance against delay in securing them when needed.

Ease of Access to All Electrical and Mechanical Components

It has been pointed out in another section of this paper that the equipment should be as compact as is in keeping with good mechanical design. While compactness is highly desirable it should not be accomplished through a sacrifice of accessibility to the various component parts.

Should any trouble develop or should any component part become defective, replacement or repairs should be simple operations to perform. Resistors, tube sockets, condensers and any other elements wherein lie possibilities of trouble regardless of their quality should be so mounted or placed as to permit of easy access should testing or replacing them become necessary.

Apparatus such as faders and gain controls which require periodical inspection and cleaning, should be mounted so as to simplify these operations.

It is desirable, therefore, that an assembled unit should be carefully planned so as to utilize, advantageously, a minimum amount of space and at the same time preserve maximum accessibility.

Interchangeability of Units

A desirable feature of mechanical design is the standardization of units. If the amplifier and mixer are built as separate units electrically interconnected by means of a suitable cable and terminal arrangement, the panels should be standardized so as to permit of interchangeability. Thus, if a remote amplifier and mixer are mounted in one carrying case it should be possible, in the event of failure of either unit, to quickly remove the faulty one and replace it with a perfect duplicate. This would eliminate the necessity of removing the entire equipment from service and the defective unit could be tested and repaired at the convenience of the repair department.

Symmetry of Exposed Equipment

The appearance of the completed unit should bear witness to the amount of forethought and planning that has been involved in its design. If a reasonable amount of care is exercised in laying out the equipment on the panels, a fair degree of symmetry can be retained without any appreciable loss in efficiency of operation. As a matter of fact, symmetry of appearance may add appreciably to the ease with which the apparatus can be operated. Exposed component parts such as controls, jacks, switches and meters can be located in such a manner that they present a symmetrical appearance. Panels may be plainly finished. A satin gloss bakelite panel or egg-shell enameled metal panel is easy to keep clean and always presents a neat and pleasing appearance.

Control knobs can be chosen which in addition to being convenient in size and shape, are plain and attractive. The necessary engraved designations on the panels can be of such size and character as is not obtrusive. Exposed metal parts should be either plated or lacquered to protect them against corrosion.

The mechanical beauty, however, should not be limited to the exterior of the equipment. Much eye value can be incorporated on the inside as well. The metal parts may be plated or lacquered, wiring can be laid out symmetrically,

neatly cabled and laced. and the whole layout done in a manner which will make it attractive as well as efficient.

Carrying cases should be neat in design and finish. They should be of such proportions as will readily combine beauty with utility. The exterior finish of the cases should be one that will not readily show mars or scratches, which may be received during transportation from place to place.

Summary of Design Factors

Only the outstanding factors that enter into the design of what apparently is the ideal type of portable speech input equipment have been given in more or less detail and an attempt has been made to present them in a manner that will be helpful to designers of such equipment. The requirements that have been set forth as being necessary are based on actual operating conditions that have been encountered during several years of close association with remote control activities.

Portable speech input equipment designed to meet all the requirements of portability and flexibility that have been described in this paper is an indispensable accessory to any broadcasting station. Two types of remote control equipment so designed are now exclusively used by station WOR and thus far, after a period of 6 months, during which time they have been subjected to tests for durability and dependability, have been found to be entirely satisfactory in all respects. A brief description of these two types of equipment may be of interest inasmuch as they embody practically all of the features necessary for reliable and efficient remote control broadcast operation.

The WOR Type 30A Portable Broadcast Speech Input Equipment

The problem of designing a complete complement of portable speech input equipment for the remote control department of station WOR was turned over to the development department of that station. The problem was considered from the various angles that have been set forth in this paper. There were many limitations as to what could be done with the facilities at hand. There was no machine shop to rely upon for construction. The space available for the development work and construction was limited to one room.

In view of these and other limitations it was necessary to design the equipment so as to utilize readily procurable components and simple assembly parts. There is only one specially made unit in the assembly. That is the output transformer which was not stocked by the manufacturer from whom the rest of the transformers were purchased. All parts, such as tube sockets, receptacles, jacks, keys, transformers, chokes, gain controls, etc., are of standard manufacture and can be readily purchased on the open market. The various resistors used were wound to order by a manufacturer specializing in that work and as the units are low in cost a small stock is kept on hand should they be required for replacement. The few necessary machined parts which were required were made up at a local shop and they are so simple in shape that the cost of manufacture is exceedingly low. All panels, which are of bakelite, were cut and drilled to order by a firm specializing in that work.

The cabinets or carrying cases are of well seasoned white oak and are brass bound as a protection against breakage. All joints in these cases are dove-tailed and reinforced to strengthen their construction.

The cases were designed to be constructed of wood for three reasons: They are easy to replace if broken; the initial cost is low and from experience it has been found that wood cases afford the greatest amount of protection per dollar against breakage; and that they will stand much abuse without becoming shabby in appearance.

The battery case, concerning which little has been said thus far, is of the same general construction and is exactly the same size as the amplifier and mixer case. In it are provided compartments for holding the necessary batteries as well as spare tubes, headset, spare microphones, etc. Connections from the battery supply to the amplifier are made by means of a rubber covered six conductor cable fitted on each end with a suitable plug. Receptacles are located on each box to receive the battery cable plugs. This cable and the plugs and receptacles are also of standard manufacture.

Western Electric condenser and dynamic microphones are standard equipment at present in WOR. It is necessary therefore that these types of microphones be accommodated as well as the carbon type. Four condenser microphone 5-pole receptacles are mounted at one end of the battery box and the necessary battery supply connected directly to them. The microphone output terminals of these four receptacles are connected to four corresponding 3-pole receptacles located on the opposite end of the box. When condenser microphones are used their cables are plugged into the 5-pole receptacles and they at once receive the necessary voltages required for their operation. The output is connected to the amplifier by means of three conductor cables or jumpers fitted with 3-pole plugs which are inserted in the receptacles provided for that purpose. If the use of a moving coil microphone is desired, a small two-stage amplifier is provided. This unit is small enough to be carried in one of the compartments in the battery box and is very light in weight. It is fitted with a 5-pole plug and a standard Western Electric moving coil microphone receptacle or jack. This amplifier is plugged into any one of the condenser microphone receptacles and automatically receives its required battery voltages therefrom. The output is delivered to the amplifier in the same manner as that of the condenser microphones. The moving coil microphone is of course connected to the pre-amplifier unit by means of the jack provided for it.

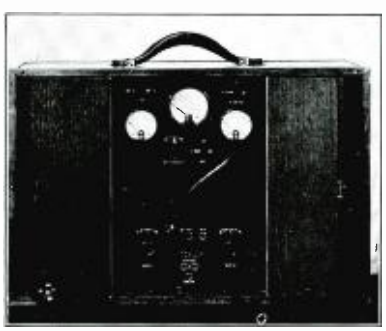

Fig. 5. Front view of 31-A equipment. Doors open showing control panel.

It was considered advisable to introduce this primary or pre-amplifier between the dynamic microphone and the main amplifier in order that the overall gain in the latter could be reduced. The extremely low output level of the moving coil microphone made it desirable to operate the main amplifier at a lower gain thereby minimizing tube microphonic and inherent amplifier noises. In this way the advantages afforded by mixing at a higher level are gained.

The filament voltage is supplied by a 6-volt 19-ampere-hour storage battery and the plate voltage is taken from a set of standard light duty B batteries. Grid biasing voltage is taken from batteries also. The rate of discharge of the B batteries places their average useful life at about 100 hours. The storage battery can be charged without removing it from the cabinet by connecting the charging voltage to any one of the condenser micophone receptacles since the filament terminals of these receptacles are connected to the battery at all times.

Electrical Design

The amplifier itself is an individual unit and consists of one impedance capacity coupled and two transformer coupled stages. The transformers used were selected because of their excellent frequency characteristics, proven uni-

formity of quality and because they are procurable on the open market. They were designed for zero d-c. in the primaries and in order to obtain the frequency response desired it was necessary to supply the plate voltage for the vacuum tubes through chokes.

Intermediate Gain Control

An intermediate gain control is located in the grid circuit of the second stage tube. This is in the form of a voltage divider and has a total value of attenuation of 25 db. variable in 5 steps of 5 db. each. In operation the overall gain of the amplifier is adjusted by means of this control before the broadcast program begins and the coarse graduations of control are therefore permissible.

Vacuum Tubes Employed

In the first and second stages of amplification, 864 type tubes are employed. Because of the rigidity of its element assembly, this type of tube is practically non-microphonic. In fact the particular tubes used are quiet enough in operation to eliminate the necessity of cushioning their sockets.

The output stage employs a 112A tube. This is capable of delivering a maximum undistorted output of 120 milliwatts, or a +10 db. level. The filaments of the three tubes are operated in parallel from a 6-volt supply and the necessary voltage drop for each type of tube is obtained by rheostats. There are two rheostats, one for the two 864 tubes and one for the 112A tube.

The two different filament voltages are thereby independently controlled and the correct operating value in each is indicated by means of individual voltmeters permanently connected across them. A jack is provided in the plate circuit of each tube and a milliammeter is conveniently mounted on the amplifier panel for measuring both the plate current and the current flowing in the carbon microphones.

Electrical connection to the meter is made through a flexible cord of suitable length fitted with a standard plug of such physical shape as to permit it to remain in any jack when the carrying case covers are in place.

Level Indicator

An output or level indicating meter of the copper-oxide rectifier type is mounted on the amplifier panel in such a position that it is directly in front of the operator when he is seated at the equipment. The meter is connected across the circuit between the amplifier output transformer and a balanced "H" type network having a low value of attenuation. Suitable compensation is introduced in the meter circuit so that the readings taken from the meter are indicative of the actual level being delivered to the telephone line. The 112A tube has a maximum undistorted output rating of 120 milliwatts which corresponds to a power level of approximately +10 db.

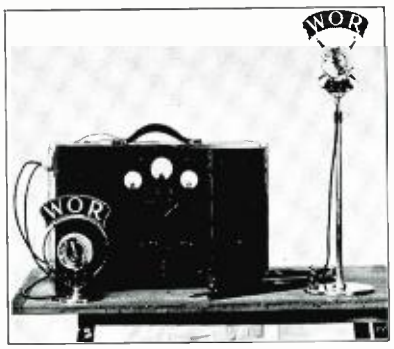

Fig. 6. The 31-A equipment set up ready for use. Note folding tripod to form a concert or floor type microphone stand.

An artifical line attenuates this level 4 db. It is at once seen that the actual undistorted level which can be delivered to a line is of the order of +6 db. As this level is in excess of absolute requirements a fair margin of safety is thus afforded. The H type network serves to properly terminate and isolate the amplifier at all times.

Electrical Characteristics

The total voltage gain as measured from microphone input to the mixer to the output terminals of the amplifier is 18,400 or approximately 85 decibels. The overall frequency response characteristic of mixing circuit and amplifier does not vary more than 2 db. over the audio frequency range from 40 to 9,000 cycles. At any setting of any of the several volume controls in the equipment greater variations than 2 decibels in the frequency characteristic are not involved.

The Microphone Control and Mixing Circuit

A maximum of flexibility is provided with a fair degree of simplicity in the design of the microphone mixer and control circuit. Facilities are provided for the operation, simultaneously, of any combination of four microphones regardless of the types used in the combination.

By means of standard lever type keys which may be operated and locked in any one of three positions, the circuits in the mixer can be changed so that a correct impedance relationship of microphones to amplifier input is established at all times. This correct relationship is maintained regardless of the dissimilarity of microphones used. Four such keys are provided and their positions are plainly indicated as "condenser," "carbon A," and "carbon B." They are mounted in a horizontal position so that the levers may be thrown to the left, center or right position. The left positions are for condenser or dynamic microphone operation. In this position the repeat coil used for carbon microphones is out of the circuit and the condenser microphone outputs are fed directly into the 50-ohm faders. In the center position the faders are connected across the secondaries of the repeat coils and the A group of four carbon microphones may be used. The right hand position of the keys permits the use of the B group of carbon microphones in the same manner as the A group. Thus it is evident that any combination of eight microphones of three different types may be set up for a broadcast and controlled at will.

The mixer is a series arrangement of four modified "T" type variable networks or as they are commonly termed "faders." In order that the output impedance of this combination be kept as low as possible, each fader has an impedance of 50 ohms, making a total of 200 ohms at the output. Each has a total attenuation value of 30 db. The attenuation is variable in 20 logarithmically graduated steps of 1.5 db. each. The faders control the output level of the individual microphones and since it is often necessary to fade out all microphones simultaneously the output of the four 50 ohm faders in series is controlled by a master gain control. This is a variable 200 ohm to 200 ohm T type network affording a maximum attenuation of 30 db. between the mixer and the amplifier input transformer, the attenuation in this network as in the 50-ohm faders, is variable in 20 steps of 1.5 db. each.

With such a combination of variables the microphone output levels may be controlled individually by means of the faders or collectively through the use of the master gain control without perceptibly changing the value of the amplifier input transformer primary impedance. In the full "off" position of the master control the primary of the amplifier input transformer is short-circuited, thus completely isolating the microphones from the amplifier. This feature adds to the convenience of operating. The operator may set all individual microphone levels and with the gain control set to the "off" position await the cue from the studios. Upon receipt of the cue he may start "fading in" the program without any other operation being necessary. This is also the case in fading out a program. When the "off" position is reached he knows

definitely that the program is "off the air."

Jacks are provided in the carbon microphone battery supply circuits for measuring the current flowing in each. The microphone battery supply is controlled by a switch independent of the amplifier filament supply.

Amplifier Output Switching and Monitoring System

Two lever type keys, similar to those used for microphone switching, are mounted at the left end of the mixer panel so that their levers swing in a vertical arc. They operate in three positions, "up," "center" and "down." The key on the left is the line selector or transfer key and the key on the right is the amplifier output control key.

The line transfer key is simply a switching device for connecting the output of the amplifier to the line used for program transmission. In the "up" position the emergency radio circuit is connected. in the center the regular radio line is in use or, if the key is thrown to the down position, the telephone or "order" circuit may be used for program transmission. This feature is very valuable in the event of line failure. Should the regular line in use fail or become noisy the operator can instantly change to the emergency line or if no emergency line is installed, the order wire.

The amplifier output control key when in the "up" position short circuits the telephone, radio, or emergency line depending upon the position of the line transfer key. In the center or normal position the amplifier output is connected through the line transfer key to the output terminals on the equipment. When the key is thrown to the "down" position the amplifier output is cut off from the line transfer key. This feature is desirable when a local test or check on the output is desired without feeding the test on the line. If the key is held in this position the operator may, by inserting the headset plug in the "line" jack, listen to a "cue" program fed from the studio over either the regular or emergency radio line or even over the private telephone line. This of course necessitates throwing the line selector or transfer key to the position required. In this way the operator may listen to the finish of the program preceding and the station identification. After the required interval of time the output key is released and at once the remote program is on the air. Monitoring of the remote program may also be taken from the "line" jack.

An important adjunct to remote control operation is the private telephone circuit or as it is commonly called the "order wire." It is desirable for the operator at the remote point to be in touch with the main control operator at all times. This is accomplished in the 30A equipment in the manner herewith described.

The order wire proper is connected to the binding posts marked "Tel." on the amplifier mixer units and the subset is then connected to the binding posts marked "SUB-SET." The three terminals provided on the subset for instrument connections are connected to a 3-wire cable fitted with a polarized plug. This plug is inserted in the receptacle marked "Telephone" on the amplifier unit. A standard breast telephone set is used by the operator and the plug inserted in the jacks designated as "Tel." Instead of the regular double receiver headset ordinarily used for monitoring, a single receiver is used. The other receiver is replaced by the telephone set receiver. In this way the operator is at all times in touch with both the main control operator and the program being transmitted.

As was stated earlier in the paper ten sets of this equipment have been in constant service over a period of from 6 to 7 months without having once been serviced (such routine service as cleaning gain controls and faders being excepted). One of these sets has during that time been shipped by express to a midwest city and returned. Upon its return it was unpacked and connected up and found to be in perfect working order.

The WOR—32A Amplifier

The small pre-amplifier used in dynamic microphone operation in conjunction with the equipment just described may deserve some detailed mention because of its novel design.

The approximate output level of the dynamic microphone being of the order of —80 decibels, it was considered advisable to introduce at least 20 or 25 decibels of amplification between the microphone and the mixing circuit of the portable equipment. This is desirable from both the standpoints of mixing level and additional amplification. The overall gain of the main amplifier being 85 db. it is evident that practically all of that gain would be required to raise the output level of a dynamic microphone to the required limits. Due to the extremely low output level it is desirable to mix and control the output of such microphones at a higher level than —80 db. in order to minimize fader contact noises if any exist.

It was to these ends that the type P-32-A pre-amplifier unit was designed and constructed. It is electrically a two-stage resistance-capacity coupled amplifier employing two 864 type tubes. The input impedance is 25 ohms and the output 50 ohms. The frequency characteristic is comparable to the 30A amplifier and the gain is 25 db. Mechanically it is a compact unit 2 inches by 6 inches by 6 inches in size and two of them may be readily carried in one of the compartments of the battery box when used in conjunction with the standard portable equipment. The unit is fitted with a standard 5-pole condenser microphone male plug and a standard Western Electric moving-coil microphone jack. A protecting shield or case covers the assembly and a removable top cover permits of access to the tubes.

In operation this unit is plugged into one of the condenser microphone receptacles on the battery box. It receives all necessary filament, plate and bias voltages from the receptacle in the same manner as a condenser microphone amplifier. The moving-coil microphone cable is plugged into the jack provided for it. Two of the units may be used at one time with the portable equipment. Thus has the dynamic microphone been adapted to the standard portable equipment. These units are also used in studios equipped with condenser microphones only. Such standardization of equipment is extremely desirable in view of the varied requirements placed on modern radio broadcasting facilities.

The 31A Portable Amplifier

The third and last development of the WOR laboratory may be described as a "last minute pick-up" unit. It consists of one carrying case only in which are contained the amplifier and two microphone mixers, all necessary battery supply, two carbon microphones, one concert or floor type microphone stand, one banquet type stand and one announcer's microphone stand. One hundred and ten feet of microphone cable and one set of spare tubes are also carried in this single unit which weighs 68 lbs. This weight is above the desirable limit, but in view of the fact that a complete set of equipment is contained in one unit the weight is not objectionable.

The amplifier consists of three stages employing the '30 and '31 type low current filament tubes. The filament supply is furnished by four dry cells connected in series parallel. The plate supply batteries are of the same type used in the 30A units. The 31A unit is designed to accommodate carbon microphones only and has an overall gain and frequency characteristic suitable for use with that type of microphone.

The microphones, stands and cables are all carried in the rear cover of the carrying case and are quickly and easily removed and set up for operation.

The microphone stands are specially

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A new exhaust pump for high vacuum

By H. V. CADWELL*

THE commercial production of highly exhausted products, such as radio tubes and X-ray tubes is dependent for economical production more upon the exhaust system than any other equipment used in their production. The vital need for efficient, dependable high vacuum pumps has caused vacuum engineers to lay their problem before companies having a background of experience in the production of precision instruments and, particularly, really high vacuum pumps. Through cooperation with vacuum engineers in the radio tube industry, there has been developed the Megavac pump, which originally was guaranteed to attain a vacuum as low as 1 micron of mercury pressure. Later refinements in the method of manufacture improved these pumps to an extent that enabled the manufacturers to guarantee the attainment of a vacuum of 0.1 micron mercury pressure. The introduction of high speed production methods soon made the Megavac pump inadequate from the standpoint of capacity. A new pump of increased capacity, yet of approximately the same physical dimensions was developed to meet the new demands. The new pump known as the Hypervac had a volume displacement of approximately five times that of the Megavac pump, yet through the employment of special precision machines in its manufacture, a new degree of vacuum (0.05 of a micron mercury pressure) was attained. This development represented a considerable forward step in the development of high speed production methods in highly exhausted products. However, as the size of the exhausted products increased and as their internal construction increased in volume, the need for still more rapid removal of the large volume of gas evolved during the outgassing procedures was apparent. As the limit had apparently been reached in the attainment of high vacuums by mechanical oil-sealed pumps with the production of the Hypervac pump, a new means of increasing the speed of exhaustion and reducing the final pressures still further was required.

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The Gaede Pump

The Gaede diffusion pump and the Langmuir condensation pumps, employing a rapidly moving stream of mercury vapor in a vacuum, seemed to be the only solution of the new requirements. These pumps are well known for their high speed of exhaustion and theoretically there is no limit to the degree of exhaustion they will attain. However, in commercial practice a definite limit of a few hundredths of a micron mercury pressure was seldom surpassed. Since these pumps require water for cooling and must be fitted with traps employing either solid carbon dioxide or liquid air, and since a very close adjustment must be made of the heat input for efficient operation, these pumps are expensive and difficult to employ in production work. Undoubtedly a better means of attaining commercially lower vacuums than were possible with the mercury vapor pump in commercial practice and yet free from their objectionable features was highly desirable. The engineers engaged upon a research project based upon the discoveries of Gaede which became known as the "molecular drag" principle.

Gaede found that when a vacuum was attained at which the mean free path of the gas molecule was greater than the diameter of the tube being evacuated, the rapidly moving molecules would travel from one wall to the other of the confining vessel. Upon striking the walls of the vessel there was a momentary condensation of the molecule, after which it again left the wall surface in a new direction not necessarily at the angle of reflection. Gaede conceived the idea that if a tube could be constructed which was divided longitudinally so that half could be held stationary and the other half moved at a rate of speed higher than that at which the molecule was traveling, its direction of travel upon leaving the surface would be that of the moving half of the tube and after some few minutes of this procedure, the molecules would pile up in the end of the tube towards which they were projected. If a high vacuum mechanical pump was connected to this end of the tube, these molecules would be removed and would not diffuse back in the direction from whence they came and the vessel would, therefore, be rapidly evacuated. Gaede solved the problem of the moving tube by cutting a groove in a cylinder which fit within a housing between which there was very little clearance. These pumps would exhaust to very low pressures with remarkable speed. Their performance was short-lived, owing to the fact that the slightest wear in the bearings would cause the rotating cylinder to drag upon its housing, which resulted in reducing the speed to such an extent that it would no longer pump. Improvements in the original Gaede pump were made by Holweck and Siegbahn, but even these pumps were not dependable for any length of time.

Cylinder Replaced by Disk

By substituting an accurately balanced disk for the cylinder of the previous investigators and through the employment of specially constructed ball bearings, the engineers of the Central Scientific Company have now produced a pump based upon the molecular drag principle, which not only is capable of attaining vacuums of a higher degree than previously possible, but has unusually high speed of exhaustion. Life tests upon these pumps have proven that this pump is dependable over periods of time that will justify their cost. This new pump, reaching as it does the highest degrees of vacuum, is now known as the Cenco Aristovac pump, the name Aristovac coming from the Greek word "aristos," meaning highest or best. The pump possesses many unique features. The motor is entirely enclosed within the housing of the pump. When a vacuum of 1 micron or less is applied

(*Concluded on page 28*)

The electron†

By KARL TAYLOR COMPTON*

A summary of the present scientific understanding of electronic theory presented briefly in non-technical language.

THE electron, as is commonly known, constitutes the smallest known division of matter. Science has shown it to be a peculiar combination of mass (minute though it is) and electrical charge, and that its inherent characteristics exhibit a singular combination of rotation and wave motion. All electrical phenomena are directly dependent upon the workings of countless numbers of these infinitesimal particles. A stream of them flowing along a wire constitutes a flow of electric current; millions of them boiling off hot metal filaments give us modern radio and the talkies; still more millions of them are active in our luminescent electric signs, while television is providing still another job for these "nimble servants."

In 1899 experiments on the striking luminous and electrical effects accompanying the discharge of electricity through vessels containing gases at reduced pressure led to the discovery that in these phenomena, the primary agent which we now know as the electron is a negatively electrified particle 1,846 times lighter than the lightest entity then known, the hydrogen atom, and bears an electric charge which is a natural indivisible unit of electricity. Electrons are affected in various ways by a wide variety of agencies, such as heat, light, chemical action, and shock. In some cases they are ejected from bodies spontaneously; in other cases they are pulled out by intense electrical fields. Spontaneous emission of electrons is one of the three phenomena shown by radioactive substances, and it occurs in the process of actual transmutation of one chemical element spontaneously to another.

These properties of the electron were discovered by Sir J. J. Thomson and his pupils immediately following the year 1899. About 12 years later Millikan and his pupils made much more accurate measurements of the magnitude of the electric charge on an electron. As a result of this work it may be said truly that although no one ever has seen or ever will see an electron, and although it is the smallest charge and has by far the smallest mass of anything which is known, nevertheless its mass and its charge have been measured experimentally with an accuracy far beyond that with which materials ordinarily are weighed or measured.

Magnetic Properties

Light produced by the motions of electrons in atoms has been found to be affected in a peculiar way by the presence of a magnet. By means of a magnetic field the light which may be given out at a certain definite wavelength and appear as a certain definite color or line in the spectrum may be split up into several components, some of longer and some of shorter wavelength, and having peculiar properties of polarization. This effect is so small that it can be observed only under the influence of powerful magnetic fields; and even then it is so small that it must be examined with a magnifying glass. This phenomenon is known as the "Zeeman effect." It has led to the proof that an electron, besides being an electric charge, also is a tiny magnet of perfectly definite strength, and that therefore the electron may be oriented one way or another by the application of a magnetic field.

Magnetic effects are produced, of course, by electric currents and any circuit in which an electric current is flowing behaves like a magnet. This suggests that every electron is really a tiny electric circuit; or, in other words, that it consists of a rotating or revolving electric charge the revolution of which is equivalent to a current in an electric circuit. This suggests that the electron is a spinning electric charge, and therefore that in addition to having mass and electric charge, it has a definite magnetic moment and an angular momentum.

Wave Properties

The electron also has the properties of a wave. The phenomenon of interference is widely known as characteristic of all types of wave motion, including light, heat, ripples, elastic vibrations, radio waves, and similar phenomena; but G. P. Thomson, son of Sir J. J. Thomson, was the first to show that when electrons pass through tiny apertures, there are phenomena of interference exactly similar to the phenomena of interference occurring when light passes through similar small apertures. This is perhaps the most striking demonstration of the fact that an electron has the properties of a wave. The same conclusion had been reached by a different interference phenomena a short time earlier by Dr. Davisson and Dr. Germer of the Bell Laboratories.

This wave nature of the electron is of a peculiar kind, in that the wave appears to be associated with it, directing it in its motion. There is a sort of indeterminism in the motion of any individual electron, but the probability or statistical likelihood of definite direction of motion can be determined from the properties of the wave which is associated with it. The wave furthermore has the peculiar property of a wavelength varying inversely as the momentum of the electron.

Current Flow Explained

Long before the existence of electrons was suspected it was found that the amount of current flowing in any given metallic circuit was exactly proportional to the voltage. This is the relationship as stated in the familiar Ohm's law. From the scientific standpoint it has been of great interest and until recently, a great puzzle as to just what determined this proportionality between current and voltage. According to the presently accepted ideas the more loosely bound electrons in the atoms which make up the metal are, under the influence of neighboring atoms, detached from their original parent atoms and are free to move somewhat at random throughout the metal. This motion is governed in part by temperature, since, on the average, the higher the temperature the more rapidly these electrons will move. The motions of the electrons are not all alike in velocity or direction, but are distributed at random according to a certain law of probability given by what is known as the Fermi statistics. These electrons are interfered with in their motion in various directions by collisions with each other or with atoms. When a voltage is applied, however, there is a constant force impelling them on the average to drift in the direction of the voltage, and it is this drift which constitutes the electric current.

In the earlier theories, the collisions just referred to were conceived of as if with atoms which behaved like hard, resilient spheres; but this was obviously too crude an approximation to fit the facts; an apparently satisfactory picture is the recent one credited to Sommerfield and his pupils, according to

†*From an address delivered at a special session of the A. I. E. E. winter convention, New York, Jan. 28, 1931.*

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which the motions of electrons in metal are governed by the interference of their waves in passing through the lattice-like structure of the atoms. According to this idea the deflection of an electron at collision means simply that the electron wave has been bent or diffracted out of its original path.

All this has brought about a very close analogy between some problems in electrical conduction and some problems in the propagation of light; and underlying this whole subject is a new branch of mechanics called "quantum mechanics." According to quantum theory, mechanical or electrical phenomena involving particles of electronic or atomic dimensions have to be treated by "wave mechanics," whereas phenomena occurring between larger bodies of a tangible size are treated by the ordinary electrodynamical methods; in other words, ordinary electromechanical concepts represent the special form which the quantum mechanics takes when applied to large bodies.

Electron Motion in Gases

Conduction of electricity through gases, which was the phenomenon that originally led to the discovery of the electron, still supplies perhaps the most complicated and intriguing problems in electricity. In such phenomena there must be considered the electron which is moving rapidly under the influence of the applied voltage and making frequent collisions with gas molecules; there must be considered also the heavy positive ions which result when electrons are knocked out of molecules, and which move relatively sluggishly in the opposite direction. Due to concentrations of one or the other kind of these electric charges in different parts of the gas, there is produced a very irregular distribution of the voltage through the gas, which accounts for some of the striking optical and electrical peculiarities of gas discharges.

Another peculiarity of electric currents in gases is that as the current increases, the resistance of the gas decreases. Because of this fact electric currents in circuits containing a path through a gas show many remarkable peculiarities, such as electric oscillations and discontinuous changes. Familiar forms of these phenomena include sparks, electric arcs, and the great variety of sign-lighting devices, such as neon tubes and mercury arcs. Lightning and aurora borealis are examples of such currents in cosmic phenomena.

Another interesting phenomenon is the thermionic emission of electrons. As already mentioned, the average speed of electrons in metals is controlled by the temperature of the metal, and if this temperature is raised sufficiently high an appreciable proportion of the electrons which strike the surface of the metal from the inside will be moving fast enough to escape entirely from the surface in spite of forces which tend to pull them back. It is these evaporated electrons which constitute the electric currents in radio tubes. There the hot filament is the source of electrons which are evaporated into the surrounding space and are drawn to the plate subject to the controlling action of the voltage impressed upon the intervening grid.

Electrons Respond to Light

When light, particularly ultra-violet light, falls upon metals, electrons may be ejected from the metals. The stronger the light the more electrons are ejected; and the shorter the wavelength of the light the greater the velocity with which they emerge. This phenomenon was accidentally discovered nearly 50 years ago, although its exact nature was not then understood. One of the most important contributions which Einstein has made to science was brought out in 1905 in his application of the quantum theory to explain the relation between the wavelength of the light and the velocity of ejection of the electron.

At the present time these so-called photoelectric currents are perhaps the most sensitive means in existence for the detection of light. They are used in stellar photometry and are the heart and soul, so to speak, of all television apparatus. This photoelectric phenomenon, too, is capable of a great variety of applications. For example, it permits electrical registration to be made of visitors entering a door; it permits automatic sorting of cigars, fruit, cloth, or other objects according to color; it enables the U. S. weather bureau to make a continuous electrical record of the brightness of sunlight; it performs innumerable important laboratory functions.

The Electron in Chemistry

A most interesting series of lectures was delivered at the Franklin Institute in Philadelphia a few years ago by Sir J. J. Thomson concerning the electron in chemistry. It has become evident now that the so-called "chemical forces" or valence forces which the chemist has used to account for the sticking together of atoms to form all the multitudinous varieties of molecules are nothing more or less than electric and magnetic forces existing between atoms and caused by the space distribution motion of electrons. Thus the whole field of chemistry on the interpretive side is turning into a study of electronic effects.

One of the most effective ways to investigate any object which cannot be seen or handled is to stir it up in some way and then try to observe and interpret what happens; this is exactly the process of research in modern atomic physics and interpretive chemistry. Atoms and molecules can be stirred up in a variety of ways—by heat or by electrical currents. Emission of light is the most frequently observed result of such agitation and from a spectrum study of that light it is possible to infer a great deal as to what went on in the atoms and molecules themselves. In principle this method has been the basis of all present knowledge of the structure of atoms and molecules and the fundamental electrical nature of matter.

Fundamental to, and inherent in, every aspect of mechanical and electrical properties of matter, there is the electron—always present and always active.

▲

FRENCH OVERSEA WIRELESS TELEPHONE TRAFFIC UNPROFITABLE

ACCORDING to *Les Echos*, a French financial daily, fiscal results of the first experiments with oversea telephone communications have proved unsatisfactory. In order to effect savings it has been found necessary to combine the direction of this branch of radio activity with that of the radiotelegraph service. Some figures reported on traffic in both directions follow: Traffic with North America—82 minutes per day with net collections of 1,930 francs per day. Traffic with South America—Argentina, 22 minutes per day in 1929, 18 minutes per day in 1930 and 18 minutes per day in 1931; with Brazil—4 minutes per day in 1930 and 2 minutes in 1931. Net collections with Argentina, 160 francs per day; and with Brazil, 16 francs per day. Traffic with Indo China, 18 minutes per day in 1930, 15 minutes in 1931; net collections, 11 francs per day. (One franc equals approximately $.0392.) The cost of installation of a transmitting radiotelephone station is given as about 10,000,000 francs, the operating and upkeep expenses amount to several hundred thousand francs a year, making it apparent that receipts therefrom are insufficient. The French Parliament has considered it necessary to exercise close supervision over the wireless organization and in that connection has disallowed the credit of 100,000,000 proposed for the installation of new lines which would probably be less productive than those already in operation. (*Vice Consul David B. Lewis, Paris, France*, 4/22/32.)

NEW INTERNATIONAL LIST OF RADIO STATIONS AVAILABLE FROM BERNE BUREAU

THE International Bureau of the Telegraph Union, Radiotelegraph Service, Berne, Switzerland, now has available for distribution the January, 1932 (third) edition of the international list of radio stations in order of frequencies, at 35 Swiss gold francs ($6.76), including supplements to the end of the current year and postage. Remittances should be made direct to the Berne Bureau by international money order.

▲

SPECIAL SURVEY OF THE RADIO INDUSTRY

(*Concluded from page* 9)

with $62 at this time in 1931, and $87 in 1930. A radio set today can be purchased for about one-half the price paid in 1928, when the average stood at $118, and less than one-half the price paid in 1929, when the average reached a record high of $133.

General Collections

While collections with wholesalers are in fairly good shape, as they are fully cognizant of the value of selling only to accounts with a good rating, during the last few months, many retailers have not been taking advantage of cash discounts, but are permitting their invoices to run thirty to sixty days past the due date. With retailers, however, repossessions still are numerous, and collections are not so good as they are in other major appliance lines, such as electrical refrigerators and laundry equipment. Collections on accounts sold during the past few months have been fairly satisfactory, but both retailers and wholesalers have on their books many old accounts, which they are liquidating slowly.

The survey made by R. G. Dun & Co., of bad debt losses among manufacturers of pianos, radios and musical instruments for the first six months of 1931 showed the average for the trade to be .881 per cent. In the high-price range group, the bad debt loss reached 1.076 per cent on 1,260 accounts that were sold merchandise valued at $547,000. On the medium-price range merchandise, the bad debt loss was only .765 per cent on 11,957 accounts that bought goods with a total value of $9,138,000. On merchandise sold to retailers the bad debt loss was .622 per cent, while on goods shipped to wholesalers it reached 1.143 per cent.

The best-paying accounts were in Washington, Oregon, California, and Nevada, the total loss for those States reaching a low of .465 per cent. In the geographical subdivision which included Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut, the large number of delinquent accounts brought the bad debt loss to .996 per cent.

▲

THE DESIGN OF PORTABLE SPEECH INPUT EQUIPMENT FOR REMOTE CONTROL BROADCASTING

(*Concluded from page* 24)

designed for compactness and light weight and are entirely satisfactory for the type of service in which they are used.

The 31A equipment was developed for use on last-minute assignments. Such occasions demand rapid transportation of a minimum amount of equipment to the point of broadcast and when the destination is reached a rapid setup, test through, and then—"on the air." Three and one-half minutes is the length of time required for complete assembly of stands and microphones and test through to studios with the 31A equipment.

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BROADCAST RECEPTION ON AIRPLANE

WHAT is believed to be the first airplane in the United States equipped with long-wave radio installation for the entertainment of passengers, left the Dallas shops of American Airways, Inc., some weeks ago.

Up until this time the rapid flight of the plane increasing or decreasing the volume of local stations, the interference of the 425 h.p. engines, and the two-way radio telephones from the ship to the ground stations have prevented satisfactory reception on long wave sets, although short wave sets have been employed with some success.

The development of an automatic control by which the volume remains stationary despite the high speed of the plane, and the shielding of the magneto and other electrical devices to prevent interference, as well as the solving of numerous other technical problems by American Airways' radio department has resulted in perfect reception. The set is a 9 tube automobile type and is located in the front cockpit, with the controls in the passenger cabin and plugs at each seat where head phones are connected. It has a day range of 500 miles and a night range of 1,500 miles and does not interfere with the radio telephones.

Airline officials declare that better reception is possible from the air than in the home because the absence of high tension wires eliminates static.

It is planned to install similar equipment in all ships of the system as they are put into the shops for regular overhaul.

▲

A NEW EXHAUST PUMP FOR HIGH VACUUM

(*Concluded from page* 25)

to the outlet tubes, the braking effect of air resistance is removed and a speed of from 10,000 to 12,000 r. p. m. is attained by the rotating member. At this speed the pump will exhaust at the rate of 1,600 cc. per second, as calculated by Gaede's equation. Its ultimatum vacuum is in the neighborhood of 0.0003 of a micron mercury pressure, or 3×10^{-7} mm. of mercury. With a combination of the Aristovac and Hypervac pump, a vacuum system of 22 liters can be exhausted from atmospheric pressure to a few units times 10^{-6} mm. in less than 10 minutes. The motor, being of the universal type of a fractional h.p., will operate off either an a-c. or a d-c. lighting circuit. It places a new tool within the reach of both research and production engineers engaged in the development and the production of highly exhausted products.

THE Group Subscription Plan for RADIO ENGINEERING enables a group of engineers or department heads to subscribe at one-half the usual yearly rate.

The regular individual rate is $2.00 a year. In groups of 4 or more, the subscription rate is $1.00 a year. (In Canada and foreign countries $2.00.)

The engineering departments of hundreds of manufacturers in the radio and allied industries have used this Group Plan for years, in renewing their subscriptions to RADIO ENGINEERING.

Each subscriber should print his name and address clearly and state his occupation—whether an executive, engineer, department head, plant superintendent, or foreman, etc.

Remember this Group Plan when *Your* Subscription Expires

(Radio Engineering)

Bryan Davis Publishing Co, Inc.
19 East 47th Street
New York, N. Y.

Los Angeles Chicago St. Louis

NEWS OF THE INDUSTRY

ADVERTISER DEVOTES SPACE TO EMPLOYMENT DRIVE

Readers of many national magazines and trade publications will, beginning this month, find the above sentence prominently displayed in heavy type in the body of advertisements signed by the Kester Solder Company. The appearance of this message in costly paid space signalizes the beginning of a constructive movement inaugurated by the Kester Solder Company, the largest manufacturers of flux-core solder in the United States.

"The idea of urging the purchase of U. S.-made products is not, in itself new," said F. C. Engelhart, president of the Kester Solder Company, in explaining the plan. 'But almost always, in the past, these efforts have been in connection with a particular product only, and, therefore, have lost much of their sincerity and effectiveness because the public sensed that the advertiser was merely taking a new means of endeavoring to sell his own product.

"In our own case, we have virtually no foreign competition. Practiically all the flux-core solder used in this country is made in America and by far the largest single percentage of it is sold by our own company. Therefore, we, ourselves, have little to gain directly. Our idea is simply to help unemployment generally throughout the United States by urging the purchase of products of any and every kind that are made in the United States by American labor. Naturally, we, together with every other organization, will benefit from the growth of such a movement.

"We believe that if a large number of American manufacturers and retailers adopt and use this slogan in their advertising, it will have an important effect on the unemployment situation. A number of prominent manufacturers have already complimented us on the idea, as well as numerous editors, Associations of Commerce and public spirited men.

"We devote approximately one-fourteenth of our total advertising space to this message. What this means in dollars and cents, we haven't stopped to figure out—though it comes to a respectable sum. We are glad that our extensive advertising schedule enables us to broadcast this constructive message to such a vast army of readers, and hope that other patriotic advertisers will do likewise. The effect on the public, we feel sure, will be beneficial."

▲

NEWARK'S NEW WIRE CLOTH HANDBOOK

It is encouraging to be able to announce the release by the Newark Wire Cloth Company, Newark, N. J., of its new general catalog No. 32.

Newark's new catalog has many novel and distinctive features. Actually, it is more of a "handbook" on wire cloth and wire cloth products than a mere catalog, departing radically from regulation wire cloth catalog style. Every effort has undoubtedly been made to produce a publication that will be truly useful and educational. It is not a gaudy, expensive, space consumer, but can be conveniently carried around in one's pocket. It is handy and complete, containing more than 100 pages of concise information of value for both inexperienced and experienced users of wire cloth. An outstanding novel feature of the book which is contained in no other publication is a "Glossary of Wire Cloth Terms." Thus if it is desired to know the exact meaning of "mesh," "gauge," "counts," etc., the glossary makes everything clear. The book is also up-to-date in every other respect. For instance, it is the only catalog in the world listing 400-mesh cloth—160,000 square openings per square inch. Stainless steel wire cloth, first announced by the Newark Wire Cloth Company, is included. Also "nichrome," monel metal, nickel, and all other malleable metals such as aluminum, brass, copper, bronze, phosphor bronze, plain steel, galvanized steel, manganese steel, silver, gold, platinum, etc. Full information on metallic filter cloth and gasketed metallic filter cloth is made available.

▲

INCA ISSUES NEW TECHNICAL BULLETINS

A series of new and complete data sheets on copper wire and coils has just been issued by the Inca Manufacturing Division of the Phelps-Dodge Copper Products Corporation. They are attractively printed and conveniently arranged in loose-leaf binders so that subsequent pages can be added as issued.

These bulletins are perhaps the most complete and authoritative published up

to this time on these subjects and will be welcomed by every designing engineer.

They were prepared originally as a service to customers of the Inca Company and while the edition is limited, any recognized engineer can secure a copy by addressing the company to the general offices of the Inca Division at Ft. Wayne, Ind.

The book is a proper size for standard vertical filing and is attractively and durably bound.

PHILCO NATIONAL SERVICE SCHOOL DAY

The greatest Philco Day for Philco servicemen—Tuesday, August 16—Philco National Service School Day. Ten thousand radio servicemen throughout the United States and many foreign countries will meet at their local Philco distributors' on this day to learn more about Philco radio.

The purpose of the school is to give servicemen as much practical information about the new Philco line as it is possible to convey in a one-day session. The many new features of Philco will be explained in detail. Philco circuit information, just received from the Philco Research Laboratories, and never before made public, will be an important subject of discussion.

▲

NEW JOBBERS FOR EVEREADY RAYTHEON

Among new jobbers appointed recently by the National Carbon Company, Inc., to handle its Eveready Raytheon 4-pillar tubes, are: E. A. Bowman, Inc., Detroit, Mich.; Sacks Electric Supply Co., Akron, Ohio; E. R. Poter Hardware Co., Dothan, Ala.; Falls City Auto Supply Co., Falls City, Neb.; Huey & Phil Hardware Co., Dallas, Texas; Midwestern District, Inc., Denver, Colo.; Thos. Goggan & Bros., Houston, Texas; Burns Radio Company, Dayton, Ohio; Wedemeyer Radio Co., Ann Arbor, Mich.; J. H. Simon, Washington, D. C.; Langdon & Hughes, Syracuse, N. Y.; Harley D. Carpenter, Meadville, Penna.; Chas. B. Scott Company, Scranton, Penna.

▲

FLECHTHEIM APPOINTMENT

A. M. Flechtheim & Co., Inc., 136 Liberty St., New York City, announce that Clifford E. Denton, well-known radio authority, has been added to the staff and will handle the technical problems of that condenser manufacturer.

▲

MICAMOLD TUBULAR TYPE DRY ELECTROLYTIC CONDENSERS

Micamold tubular type dry electrolytic condensers are available in a wide variety of capacity and voltage ratings to meet the requirements of practically all general filtering by-passing and coupling purposes, in pulsating power supply and audio circuits.

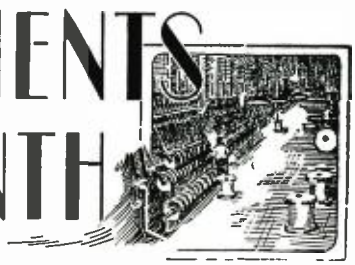
They are especially suited for use as by-pass condensers across grid bias and voltage divider circuits where compactness, high capacity and low impedance at low frequencies are required.

They can be mounted in place with suitable, inexpensive mounting straps or fuse clips, or they can be hung direct from the wiring.

The flexible leads consist of 2¾ inch lengths of No. 20 wire. Red wax at one end and black wax at the other end, through which the leads come out, indicate the positive and negative terminals respectively of the condenser.

The Micamold Radio Corporation is located at 1087-1095 Flushing Ave., Brooklyn, N. Y.

NEW DEVELOPMENTS OF THE MONTH



NEW B POWER FOR AUTO RADIOS

A new low-priced B power unit for auto, boat radios, etc., is offered by Premier Electric Co., of Chicago. This unit is offered to manufacturers and retailers at a price but little higher than the cost of 3 good B batteries. Features of the unit are small size—3 x 5½ x 5½ inches—and a universal mounting bracket which permits quick, easy installation. Weight is only 5 lb. Output is 35 mils at 130 volts or 30 mils at 180 volts.

▲

CONDENSER MICROPHONE

Remler Company, Ltd., long and favorably known for the quality of its radio parts, units and kits, re-enters the national field with the new Remler condenser microphone. In addition to the suspension type illustrated, this new line indicates floor, hand and desk types.

Specifications include two stages of preamplification with an essentially flat response from 40 to 10,000 c.p.s. The head is gold plated with non-resonant molded

grill in a white and red brown agate effect. It is moisture proof. The diaphragm is pressure equalized. The head amplifier and transmitter head is a complete plug-in assembly. The Remler has a combination 50 and 200 ohm output. Electrical interference is eliminated by reason of the fact that the transmitter head has an imbedded copper shield. Automatic bias and a special high permeability core are other features. The unit is built by Remler Company, Ltd., 2101 Bryant Street, San Francisco, California.

▲

TRIMMER CONDENSER

Oak Manufacturing Company of 308 W. Washington Street, Chicago, Illinois, announce a new trimmer condenser especially designed to meet the requirements of the new all-wave receivers. Several months of careful research by a group of radio's leading engineers, representing both the supplier and the set manufacturers, has resulted in a product exactly suited to its purpose.

The single hole mounting prevents stress being transferred from the chassis to the body of the trimmer. The Bakelite insulator is so placed that any change due to expansion does not affect the capacity. This is proved by exhaustive tests which show that there is no detectable change in capacity with extreme variations of temperature and humidity. Thus, the set manufacturer is assured that the capacity, once set, will remain so indefinitely. Triple X Bakelite, the highest grade obtainable, and the finest India mica are used as insulators. No insulating washers are required for mounting since both plates are insulated from the large eyelet.

The trimmer can be made in capacity ranges from 5 to 75 $\mu\mu$f up to 300 to 900 $\mu\mu$f.

▲

SOCKET WITH "FLOATING CONTACTS"

A new departure in radio socket designing has just been introduced by the Cinch Manufacturing Corporation. Scientifically designed, with floating contacts, all strain on the Bakelite is eliminated, preventing warping and loss of tension after the tube is inserted. The floating principle employed makes the contacts self-aligning, assuring a rigid contact on each tube prong at all times. This construction eliminates all holes generally used for riveting contacts to Bakelite. Thus a considerably stronger socket is provided. A special lip on the contact simplifies the soldering operation.

The new Cinch radio sockets are made for 4, 5, and 6-prong tubes with 1 27/32 inch, 1 11/16 inch and 1½ inch mounting centers.

Blueprint and samples will be sent without obligation to any one addressing the Cinch Manufacturing Corp., Chicago, Ill. The new 1932 illustrated catalog of the complete Cinch line of radio parts may also be obtained for the asking.

▲

WESTON MODEL 571 OUTPUT METER

The Model 571 output meter, manufactured by Weston Electrical Inst., Corpn., Newark, N. J., consists of a five range copper-oxide rectifier type voltmeter enclosed in a sturdy Bakelite case. The ranges, 150 60, 15, 6 and 1.5 volts, are brought out to two pin jacks through a dial range selector switch. A self-contained condenser for blocking any d-c. component is brought out to a separate pin jack for use when desired.

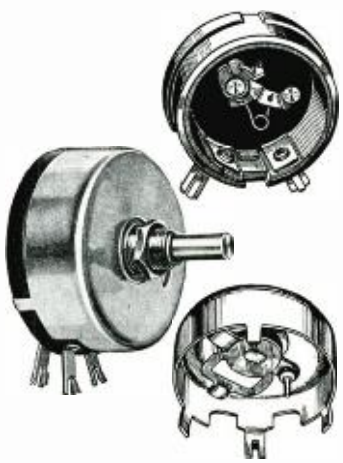
The Model 571 has a non-inductive impedance of 4,000 ohms for all ranges, and is particularly suited, therefore, as an output load.

Since the impedance is constant for all ranges and the output voltage is measured directly it is easy to compute the power output of the radio set and adjustments can be made on the set to give the highest operating efficiency. Dimensions: 5½ x 3⅝ x 2⅛ inches. Scale length: 2.3 inches. Approximate weight: 1 pound 10 ounces.

YAXLEY OFFERS NEW VOLUME CONTROL

The simplification and improvement of individual parts in radio is not so exciting as the design of a new circuit, but it still offers many opportunities.

Yaxley engineers have just designed this wire-wound volume control with inclosed



switch of the "click-on" type which is especially simple and efficient in most sensitive circuits. It is very compact and operates quietly both electrically and mechanically.

The Mallory-Elkon group of metallurgists now associated with Yaxley assisted greatly in achieving the high quality of this instrument. Two sizes are available, with or without switch, in any desired taper. Diameters are 1½ inch and 1⅞ inch. Depth, ¾ inch.

▲

SOCKETS FOR SEVEN-PRONG TUBES

Central Radio Corporation, Beloit, Wisconsin, now have available sockets for the new seven-prong tubes. The CRC seven-prong sockets are of the usual spring, reinforced contact type with maximum separation between contacts. This is the same type of construction found in CRC sockets for use with the newer rectifier tubes where good contact and conductivity are necessary to insure safe and efficient operation of the tubes and to prevent overheating. CRC seven-prong sockets may be had in both 1-27/32 inches and 1-11/16 inches mounting centers. Of the conventional elliptical shape, the overall dimensions are 2-7/32 inches long by 1-⅝ inches wide. This small size permits space economy in chassis design, and in the "800" series the overall depth of the socket is only 7/16 inches. Reports from several manufacturers who have used several thousands of these new sockets state that they are satisfactory in every respect. Samples may be had by manufacturers upon application, specifying mounting centers desired.

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THEY CAN

"TAKE IT"!

600 MODEL

800 MODEL

The proper performance of the new 82 and 83 type Power Tubes requires that the tube sockets be capable of carrying extremely high voltage.

Engineering logic dictates that sockets have the following features:

Maximum space between contacts . . .
(to prevent arcing through the air gap)

Highest grade insulation . . .
(to prevent arcing through the insulation)

Sufficient and permanent contact tension . . .
(to prevent heating and excessive voltage drop)

More and more manufacturers are coming to appreciate the necessity of using sockets of superior electrical and mechanical design with the new tubes. They specify CRC sockets for SAFETY.

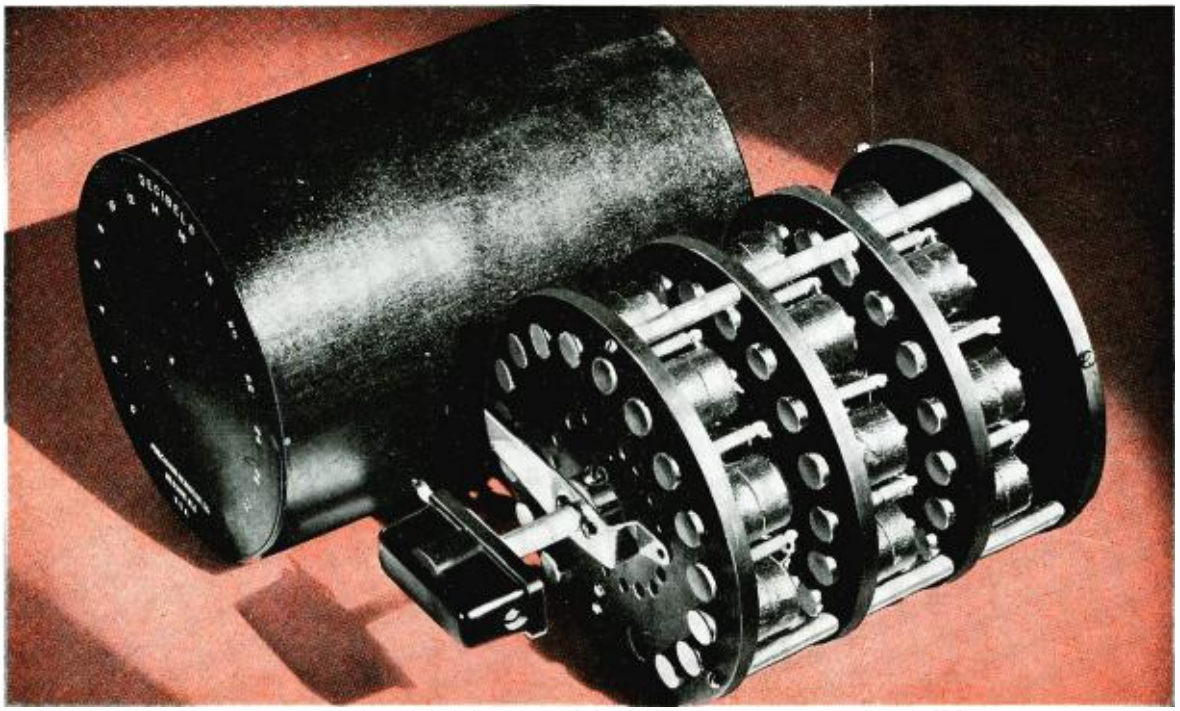
Samples are now available.

CENTRAL RADIO CORPORATION

BOX 357 BELOIT, WIS.

Production simplified, design improved

...through using standard Bakelite Materials



Attenuator made with Bakelite Materials by the Precision Resistor Co., Newark, N.J.

IN DESIGNING the attenuator pictured above, skilful use was made of standard forms of Bakelite Materials, to keep down production costs and at the same time take full advantage of the superior properties of these materials.

The T-L-H Pads are discs of Bakelite Laminated, which are easily drilled for assembling any desired combination. The knob is Bakelite Molded. The cylindrical shield is a 5½ inch length of 3¾ inch Bakelite Laminated tubing, sealed at the end with disc of Bakelite Laminated sheet. Circuit diagrams and calibrations are indelibly etched in the Bakelite Material, and any possibility of incorrect wiring or installation through indistinct marking is permanently avoided. Through the use of Bakelite Materials the Precision Resistor Co. was enabled to produce an improved attenuator at a very reasonable cost.

Write for illustrated booklets, 12M, "Bakelite Molded", 12L, "Bakelite Laminated" and 12V, "Bakelite Varnish". These booklets contain valuable information concerning the properties and uses of Bakelite Materials. There are also many special materials developed to solve particular insulating problems. Call upon us for information about any of them.

BAKELITE CORPORATION, 247 Park Avenue, New York, N. Y. . . 635 West Twenty-Second Street, Chicago, Ill.
BAKELITE CORPORATION OF CANADA, LIMITED, 163 Dufferin Street, Toronto, Ontario, Canada

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The registered trade marks shown above distinguish materials manufactured by Bakelite Corporation. Under the capital "B" in the monogram sign for infinity, or unlimited quantity, it symbolizes the infinite number of present and future uses of Bakelite Corporation's products.

THE MATERIAL OF A THOUSAND USES