RADIO SCIENCE

VOL. 2.—No. 9

Registered at the G.P.O. Sydney for transmission by post as a periodical.

SEPT.-OCT., 1949

LIGHTNING PREFERS TALL STRUCTURES

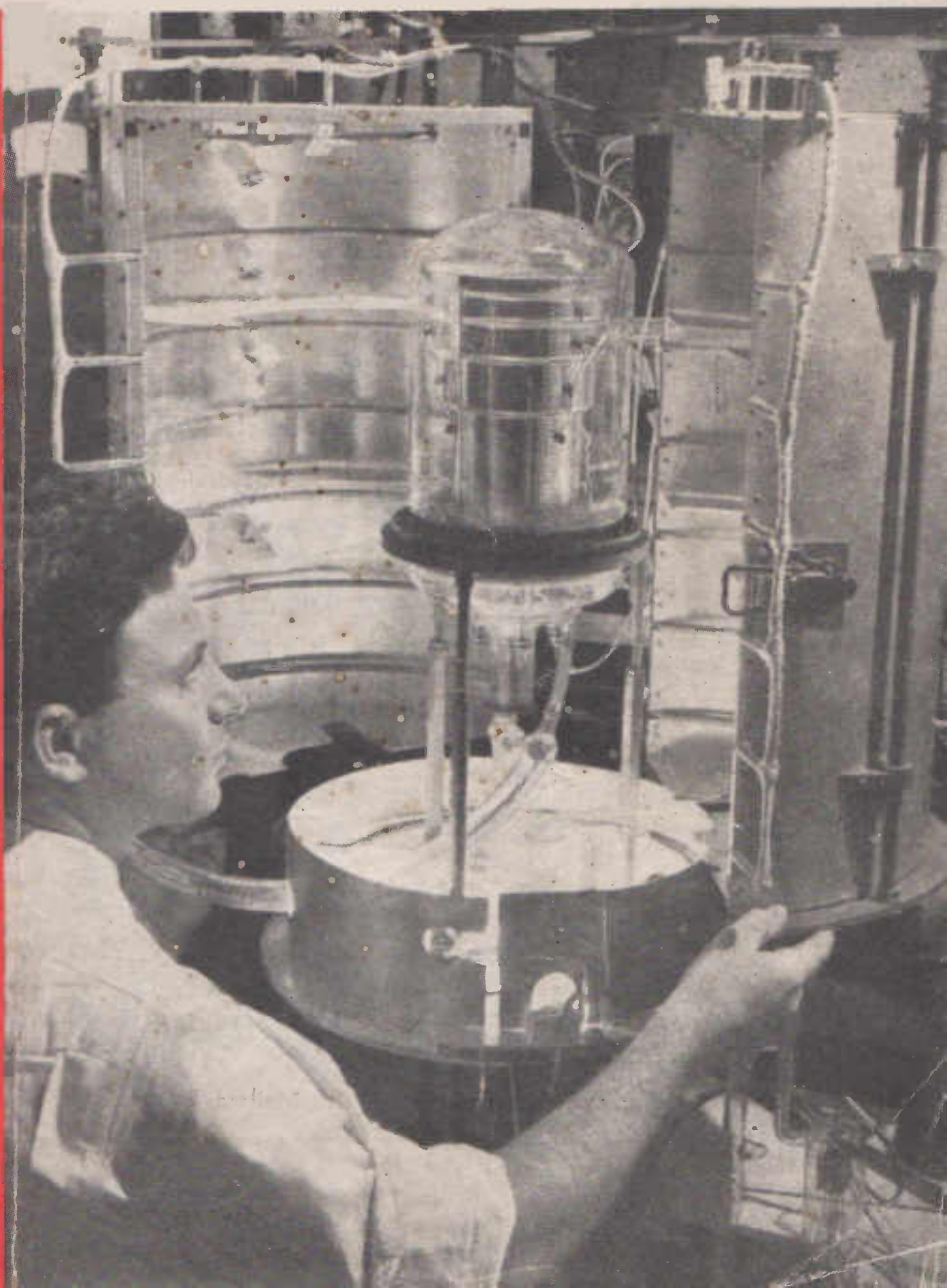
Volume Expansion For Your Amplifier

T-V MEASUREMENTS (Part 1)

Complete Broadcast & Short Wave Notes

PRINTED CIRCUIT TECHNIQUES

PRICE 1/-



editorial

Facsimile Transmission

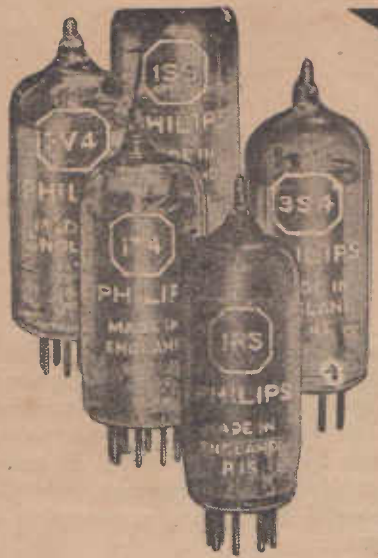
Long regarded as the Cinderella of the radio industry, facsimile transmission has at last come of age following successful demonstrations in the U.S.A. of *multiplexing*—that is, simultaneous transmission of FM and facsimile signals. The decision to permit a commercial service in the existing FM channels has already resulted in several leading newspaper organisations making rapid progress with their plans to provide regular facsimile news sheets, thus augmenting the scope of their ordinary newspapers.

Facsimile, which is now gaining public recognition, is a system of transmitting pages of printed matter via line or radio waves. The page of printed text and pictures to be transmitted is placed around a revolving drum in a scanner. As this drum revolves, a small, sharply focused lightspot scans the page, line by line, at the rate of 105 lines per inch, and the reflected light ray is picked up by a photocell. In this manner the varying intensity of the reflected light converts the graphic material into a fluctuating current. This current is amplified and then used to modulate an FM carrier.

At the receiving end in the home, this signal is picked up by a suitable FM receiver, and, after being changed back to an AM current, is taken to the facsimile recorder. In this unit, a drum mechanism pulls a roll of paper, sensitised and moistened to conduct current, between two metal blades. The facsimile current is fed into one of the blades, and then passed through the coated paper to the second blade. This process causes the paper to become blackened in proportion to the amplitude of the current, being black where the current is maximum, shades of grey where it is weaker, and white where no current passes through. In this manner, a facsimile of the original transmitted signal is built up at the receiver unit.

Under the present transmission standards, the fidelity of both pictures and type reproduced is extremely high, resembling photo-offset printing, and consequently are much better in quality than usually seen in the average newspaper. The equipment produces copy on a continuous strip of paper at the rate of 3.5 inches per minute, and in a regular fifteen-minute news broadcast will deliver four $8\frac{1}{2}$ x 11 inch pages of news and photographs.

At this stage it is somewhat premature to predict the full commercial possibilities of this system, since one of the major factors for its success must necessarily be the ready acceptance of the service by the public. However, now that the initial services have been launched, there is no doubt their progress will be closely watched by all broadcasting interests. In view of the phenomenal public reaction to FM and television, it seems logical to assume this new medium—"publishing via the airwaves"—could easily be the forerunner of another revolution in radio broadcasting.



little fellows with a BIG FUTURE

These Philips miniatures are small in size but really **big** in performance. Miniaturisation is the modern trend in valve technique. It's the answer to compact design, circuit flexibility and generally streamlined amateur gear.

The range of Philips miniature 1.4 volt battery valves includes the 1R5 Pentagrid Converter, the 1T4 Radio Frequency Amplifier Pentode, the 1S5 Diode Audio Frequency Amplifier Pentode and a choice of two Output Pentodes, types 3S4 and 3V4; the 3S4 for either 67.5 or 90 volt operation and the 3V4 for 90 volt operation.

PHILIPS ELECTRICAL INDUSTRIES
OF AUSTRALIA PTY. LTD.

Sydney ○ Melbourne • Brisbane • Adelaide • Perth

V16B-48.

PHILIPS

MINIATURE VALVES

RADIO SCIENCE

For the Advancement of Radio and Electronic Knowledge

Vol. 2, No. 9 SEPTEMBER-OCTOBER, 1949

EDITORIAL CONTENTS

OUR COVER: One of the greatest needs in radiology has been a bright-image fluoroscope. The pilot model electronic fluoroscope amplifier shown has been developed by research engineers as a basic step in solving the fluoroscope's greatest handicap—weak images. This new unit will permit the amplification of the fluoroscopic pattern by several hundred times, thus enabling more accurate and informative medical diagnosis. (Courtesy Westinghouse Electric Coy.)

Published Monthly by RADIO AND SCIENCE PUBLICATIONS, and printed by Alanson's Pty. Ltd., Marrickville Road, Marrickville.

Address all Correspondence to Box 5047, G.P.O., SYDNEY.

EDITOR AND PUBLISHER: C. E. Birchmeier (A.M.I.R.E., U.S.A.).

SUBSCRIPTION RATES: Australia, 1/- per copy, 12/- per year, 21/- for two years; British Empire (except Canada), 12/- (stg.) per year, 21/- (stg.) for two years; Canada and U.S.A., 2.50 dollars for 1 year, 4.00 dollars for two years. Post free to any address. Foreign remittances should be made by International Money Order or Bank Draft negotiable in Australia.

CONTRIBUTIONS: Articles of a suitable technical nature will be considered by the Editor, and if accepted paid for at current rates. Accepted material is subject to any revision or changes deemed necessary. Contributions will be handled with reasonable care, but this magazine cannot be held responsible for any loss or damage. A stamped addressed envelope should be included for the return of manuscript if unsuitable for publication.

WHOLESALE DISTRIBUTORS: "Truth" and "Sportsman" Ltd.

Lightning Strokes Prefer Tall Structures

by E. BECK, (Westinghouse Electric Co.)

The lightning rod, oldest of electrical devices was in use almost a couple of centuries before its principles were understood. Now not only its action but also the mechanism of lightning—the birth, growth and decline of a lightning stroke—can be set for the in the simplest terms. The requirements of a good lightning shield and the extent of protection it provides can be rather exactly predicted.

The lightning rod, oldest of electric devices was in use almost a couple of centuries before its principles were understood. Now not only its action but also the mechanism of lightning—the birth, growth, and decline of a lightning stroke—can be set forth in the simplest terms. The requirements of a good lightning shield and the extent of protection it provides can be rather exactly predicted.

The attraction for lightning possessed by tall structures that extend above their surroundings is well known. In fact it was observed more than two thousand years ago. That smaller objects within a certain volume adjacent to such a structure are unlikely to be struck is also well known. The protection of one object by another has become known as shielding. What is the explanation of this phenomenon and over what region will a shielding structure protect?

General Explanation

The explanation is made manifest by th eaccepted theory of the formation of a lightning stroke between cloud and earth[1]. As a result of certain processes that occur during thunderstorms, electric charges are accumulated in clouds or parts of clouds. These charges have their counterparts in equal and opposite charges in the earth beneath.

As the charges grow, the potential between cloud and earth increases. This potential is not distributed uniformly. In the formation of strokes to open country or to moderately high objects of, say, 600 feet or less, the potential gradient is most intense in the vicinity of the charged volume in the cloud. When the gradient, which is expressed in volts per centimeter or inch exceeds the dielectric strength of the short length of air across which it appears, the intervening air breaks down and a streamer starts from the cloud toward the earth.

This streamer, or pilot leader as it is sometimes called, carries a charge with it. Thus the potential gradient ahead of its tip is high and further breakdown of the air ahead of it occurs. The leader proceeds towards the earth in jerks, at the same time charging the embryo stroke channel.

Streamer Current

The current in the streamer is not high, probably below a hundred amperes. It's average velocity of propagation is relatively slow, about one half a foot per microsecond, i.e., a hundred miles per second. (The velocity of propagation of electricity in a wire is almost one thousand feet per microsecond). From a cloud

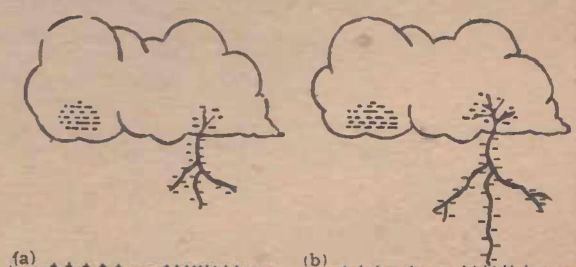


Figure 1. A lightning discharge in "slow motion." In (a) the charge centres in the cloud are shown. The pilot streamer and stepped leader start earthward. The outward branching of streamers lowers the charge into the space beneath the cloud. In (b) the process begun in (a) is almost completed and the pilot streamer is about to strike the earth. The heavy return streamer is indicated in (c), the negatively charged space beneath the cloud now being discharged to earth. One charged cloud centre is fully discharged in (d) and streamers between charged centres within the cloud start to develop. As the cloud charge centres neutralise in (e) a dart leader is propagated to ground along the original channel. Finally in (f) a return streamer is created, discharging to earth the negatively charged space under the cloud, completing the stroke.

two thousand feet above the earth the streamer reaches the earth in 400 microseconds or four thousandths of a second, the equivalent of one-quarter cycle of 60-cycle current.

When the tip of the leader comes close to the earth the electric field becomes intense and eventually a short upward streamer rises from the earth to meet the descending pilot leader. As they meet, contact is finally made with the earth, or some object connected with the earth.

Establishment of this contact is like closing a switch between the two opposite charges, one charge residing partly in the stroke channel and partly still in the cloud, and the other charge in the earth. It is now that the high currents associated with lightning flow. A high impulse current first flows to neutralise the charge in the stroke channel. This may then turn into a moderate current of longer duration than the first peak to exhaust whatever charge remains in the cloud. The process of stroke formation is illustrated stepwise in Fig. 1 and a generalised curve of stroke current in Fig. 3.

As the potential in the charge centre, from which the stroke started, falls, other adjacent charge centres in the same cloud may discharge into it and down the same channel, thereby producing successivve current peaks. Such strokes are called multiple or repetitive strokes. They occur frequently, and sometimes the rapidly repeating flashes can be seen with the unaided eye.

Safe Region

Consideration of the formation of lightning strokes makes it apparent why tall projections from the earth's surface are struck more often and why there is, around such a projection, a region seldom struck. In Fig. 2 (a) is shown a pilot leader approaching the earth at some distance from a high conducting projection, such as a tower. The leader is not cognisant of the tower, and contacts the ground. Fig. 2 (b), the leader's path is close enough to the top of the tower that the electric field between the tower and the leader's tip becomes sufficiently intense to draw a streamer from the tower toward the leader. Contact is made as in Fig. 2 (c) and the stroke current passes through the tower. In this wise the tall tower draws to itself leaders that without the tower would have gone to earth in its vicinity.

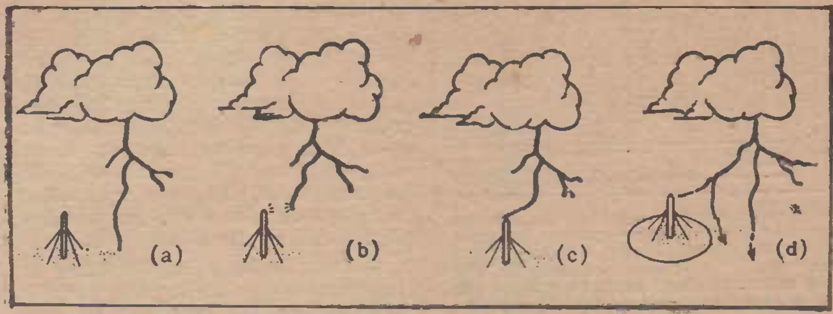


Figure 2. The effect of a mast on a lightning stroke. In (a) the stroke leader is sufficient distance from the mast to be unaffected by it, whereas in (b) the leader approaches the top of the mast. A strong field appears between the mast and leader, causing the top of the leader to be drawn to the mast, in (c). In (d) appears the shielded area. Strokes always terminate either in the mast or outside this area.

It is now also apparent that because of the attraction of the tower for leaders that pass within its reach, there is a region, Fig 2 (d) surrounding the tower where strokes are highly improbable. Either a leader contacts the ground at some distance from the tower or approaches sufficiently close to the tower to contact it.

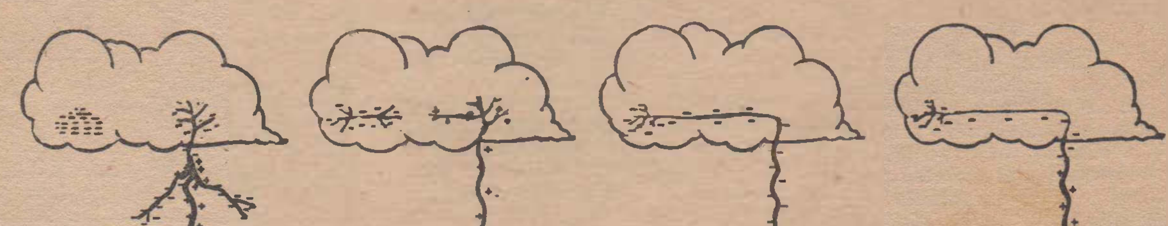
Strictly speaking, an object is not protected absolutely from all strokes unless it is surrounded by a conducting and grounded shield. However, the probability of an object being struck can be reduced to a small figure by proper arrangement of masts, rods, or wires. A shield configuration is considered good if it will allow only one stroke in a thousand to reach the protected object.

This is called 0.1 per cent exposure. Roughly speaking, for a single mast or rod, the exposure is 0.1 per cent within a cone whose apex is at the top of the mast and whose surface makes an angle of 30 degress with the vertical. As a rule of thumb the cone of protection has a base whose diameter is equal to the height of the mast.

The exact exposure for a given configuration depends on several factors, such as the height of the cloud above the earth, the height of the shielding mast or rod, and probably on the charge at the tip of the leader. The parameters of various degrees of protection have been established by theory, observation, and laboratory tests on models.[2]

Isokeraunic Maps

As a result of measurements and observations of lightning strokes, it is possible to make estimates of the probabilities of objects being struck, the figures given later being averages over several years. Actually they will vary from year to year. They may be affected considerably by local conditions. They are based on a storm frequency or isokeraunic level of 30 thunderstorm days per year. The isokeraunic level varies throughout the country.



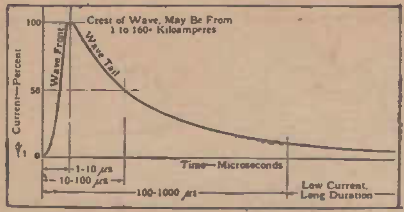


Figure 3. In general lightning-stroke current rises to a maximum in from 1 to 10 microseconds, declines to a half value in times between 10 and 700 microseconds, and has a total life of a few thousand micro-seconds.

Isokeraunic maps have been published by the U.S. Weather Bureau. [1, 5] These maps average, over a considerable period of years, the observed number of days on which thunder was noted. Although they do not give direct information on the number of severity of strokes that occur, they are useful in estimating the probabilities of objects being struck, because it may be assumed that these probabilities vary with the isokeraunic level.

The frequency with which isolated masts or towers are struck varies directly with their height above ground or surrounding objects, up to heights of about 600 feet[3], Above that height the probabilities increase faster, because, in the case of a very high structure, the field at its tip becomes so intense as the charge in the cloud and the earth are built up that the pilot streamer starts upward from the structure instead of downward from the cloud. This promotes strokes to such high structures even more actively.

Masts up to about 600 feet in height, in an isokeraunic level of 30, are likely to be struck once a year for every 275 feet of height. Thus, an isolated mast or chimney 150 feet high, located in level terrain in the region where the level is 30, is likely to be struck about once in two years. If located where the isokeraunic level is about 80, it would probably be struck about one and a half times per year or three times in two years.

Some estimate, also, can be made of the probable frequency with which buildings of known roof area and elevation may be struck, assuming they are located in level terrain and isolated from structures of comparable or greater height, although the data available is not as definite as for masts. By weighing the data for masts, the statistical data on strokes to transmission systems or overhead ground wires, and the probabilities of strokes to open country, it seems reasonable to conclude that a building 100 feet square and 30 feet high will be struck on the average of about once in 10 or 15 years. With in certain limits, the chances of being struck vary with its height but not in the same ratio as its area.

For example, a tall building is considered as a mast. Thus a building 200 by 100 feet and 60 feet high may be struck four times as often or once in two and a half to four years. It should be remembered that nearby structures or adjacent hills may reduce the exposure. On the other hand, a building on a hill top or a hillside may have an increased exposure.

Protection Requirements

As the familiar lightning rod amply demonstrates, buildings can be shielded from lightning. To protect a building effectively, three requirements must be met. The shield must be so placed as to intercept strokes; the shield must be a good conductor connected to earth and adequately insulated from conducting bodies that are to be protected; and the termination of the conductor in the earth must make good contact with the earth.

Considering these requirements, not all buildings need additional protection. Whether or not they do depends on the construction. An all-metal building or one with a well-grounded, substantial metal roof is not damaged if struck, because the lightning current has a good conducting path to ground.

Tall, steel-reinforced buildings are struck frequently without the occupants being aware of it, except perhaps for the crash of the thunder. Such a building or any substantial metal enclosure, for example, an automobile, is a safe refuge during a thunderstorm when it is separated from ground by only the distance between the tire rim and earth.

A wood or masonry building, however, may be damaged if struck by lightning, and protection is necessary if damage is to be prevented. In the case of a wood or masonry building with a metal roof, the owner should avoid the mistake made by the farmer who equipped his barn with a copper roof but failed to ground it. The outcome of this was unpleasant.

A demonstration with man-made lightning shows that an automobile is a safe refuge in a storm. Note the arc from metal tyre rim to ground.

Power-station or substation structures, although often of steel, are frequently provided with direct-stroke protection. This is not done to protect the structure, but to avoid risk of severe direct strokes into the line conductors adjacent to the apparatus in the station.

For any particular building, the probabilities of being struck may be low, but considering a number of buildings, such as several substations on a power system or a group of farm buildings, the chances that some building may be struck is appreciable. Whether to shield or not is usually a question of economics and sometimes of sentiment. It may be considered more economical to run the risk to human or animal life may make protection mandatory, or the sentimental attachment to such things as old trees or buildings may make it desirable.

Methods of Shielding

Buildings can be shielded in various ways. Suppose, for example, a building 100 feet square and 30 feet high, with a probability

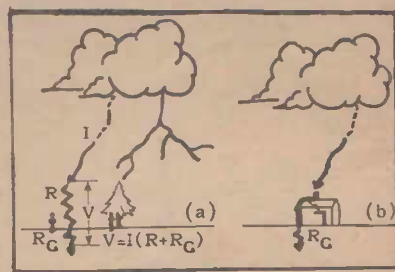


Figure 5. Lightning stroke to a tree (a) and the equivalent circuit, and a stroke to a house (b).

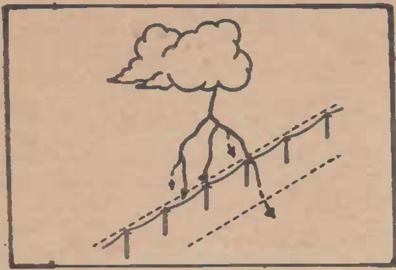


Figure 6. A horizontal conductor, supported above earth on poles, gives a zone of protection against lightning.

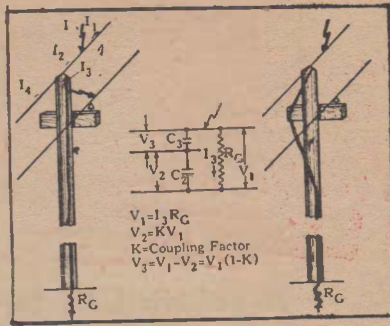


Figure 7. The overhead ground wire and its equivalent circuit. It indicates the effect of ground resistance, voltage in line wire produced by coupling, potential between line and ground wires, possibilities of flashovers, and means of increasing clearance to avoid flashovers.

of receiving a direct stroke once every 10 years. Based on the data given in reference No. 2, exposure of 0.1 per cent for the building can be obtained with a single mast in the centre of the roof, projecting 55 feet above the roof. The mast rising 85 feet above ground, may be struck 0.31 times a year or once every three years, but the building itself would be struck only once in 3200 years. Other configurations can be used to obtain the same exposure, such as a greater number of short masts or rods properly disposed around the building, or one or more horizontal overhead grounded wires.

There is evidence that the shielded area between two masts or rods is greater than the sum of the shielded area of each.[4] Walter concludes that two masts of equal height may be separated by a distance equal to five times the height of one of the masts and still provide effective shielding in the band between them. The Wagner, McCann, and Lear data indicates that even wider spacings give effective protection under certain conditions of heights of shield and shielded objects. The increase in shielding afforded by several masts, or rods, is considerable and possibly has not been realised generally.

The conducting connection of the shield to the earth must be good, to prevent secondary flashes from the struck shield because of voltage drops produced by impedance to the lighting current. Suppose the tall structure in question is a poorly conducting masonry chimney or a tree, as in Fig 5 (a). The tree attacks the pilot leader; it is a good lightning interceptor but an unreliable shield.

When the tree is struck, lightning current flows in a high resistance, as indicated in the equivalent circuit. If the lightning current is large, high voltages occur. Hence a man standing under the tree may be the recipient of a side flash. For this reason, trees, particularly isolated ones, are dangerous things under which to take shelter during a thunderstorm.

The same applies to masonry chimneys not provided with well-grounded lightning rods. Under a chimney, one not only runs the risk of being a spark terminal but also of being struck by falling bricks knocked loose by the effects of the energy produced in accordance with Ohm's Law. Like most tall chimneys, valuable trees are protected by wires run up the trunks to provide a good conducting path should the tree be struck.

(Continued on page 37

A TECHNICAL SURVEY OF LATEST OVERSEAS DEVELOPMENTS

ELECTRONIC CONVERTER FOR PIANO

Novel musical arrangements are now made possible by an electronic converter that attaches to a piano so that it becomes three instruments; a piano, an organ, or a piano-organ combination.

The conversion of the piano is accomplished by clamping a key switch frame across the keyboard so that the plungers make contact to the keys. Operation of the keys in the normal piano technique then actuate the switches to close the appropriate circuits of organ tone generators connected to an audio amplifier and loudspeaker system in an adjacent cabinet.

Cascade Generators

The sources of all tones are twelve cascade generators. The circuit of one of these is shown in the accompanying diagram. Each cascade has five stages of 12AX7 twin triodes, and supplies the tones for the octavely related notes over the range of the instrument (for example the C cascade supplies all the C tones and the C♯ cascade all the C♯ tones. There is one output from each stage of cascades, thus providing a tone coverage of 60 notes extending through C1, 65 cycles, through B5, 1976 cycles.

On each cascade the 12AX7 twin triode nearest the tuning coil is both the master oscillator and a reactance tube. The master oscillator triode is an inductively tuned electron-coupled oscillator having a sawtooth output waveform.

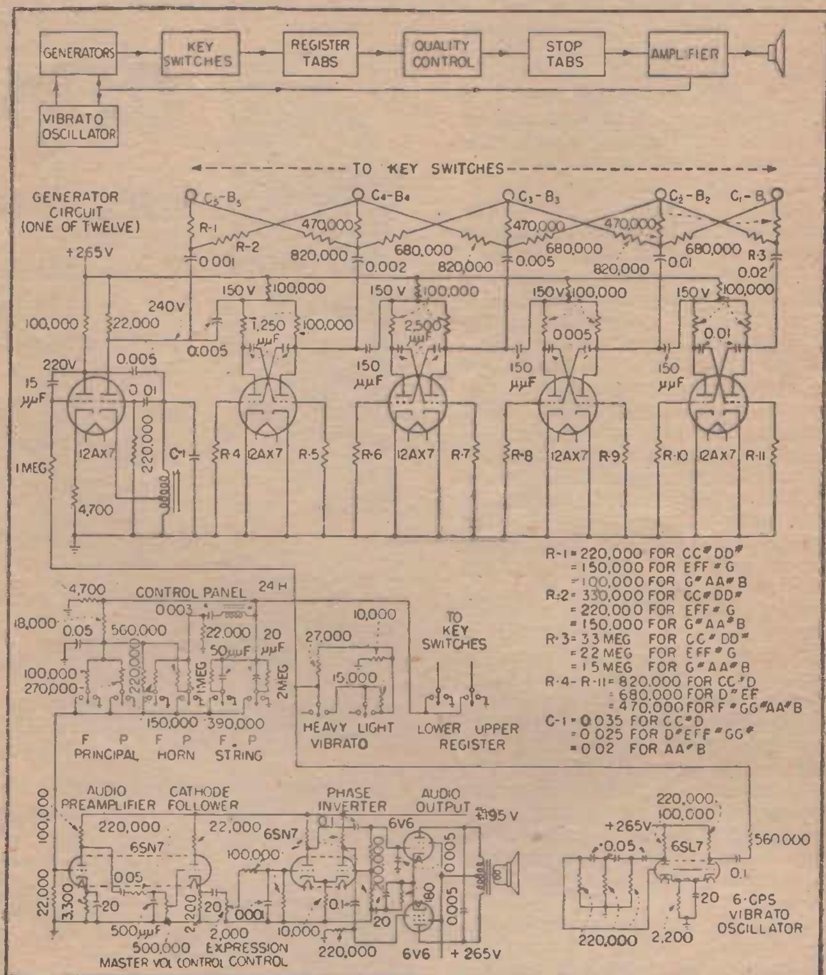
The other triode is a reactance tube across the master oscillator tank circuit. Each master oscillator is the highest frequency generator on its cascade, and its output is used for the top octave of the range, C5 to B5.

Frequency Dividers

The four remaining tubes on each cascade are simple slave multi-vibrators, each locking in and oscillating at one half the frequency of the one driving it. The master oscillator drives the first multivibrator, which in turn drives the second, and so on, down the line, to produce the five tones, each an octave apart.

If a tube or one of its associated parts should fail, the indication is a drop in pitch of the note concerned, All the lower octavely related notes will also be out of tune.

As the slave multi-vibrators are capacitively coupled and driven, any change in the tuning of the master oscillator, by movivng the



Circuit of multvibrator tone ge cerators, audio amplifier, control panel and vibrato oscillator of the electronic piano-to organ converter. The block diagram shows the sequences of functions.

tuning coil core, will also tune the multivibrators directly. The reactance triode grid is driven by the output of the vibrato oscillator to frequency modulate the master oscillator, to produce vibrato.

Except for slight differences in the values of some of the components, all twelve cascades are similar.

Control Panel

The control panel that clamps to the front of the piano contains the register, vibrato, and tone quality selector switches. It also contains the tone-control components and the expression control.

The register selector switches select either the bottom register, C1 through C, or the upper register C3 through B5, by connecting collector bars on the key switches to the tone-quality selector switches.

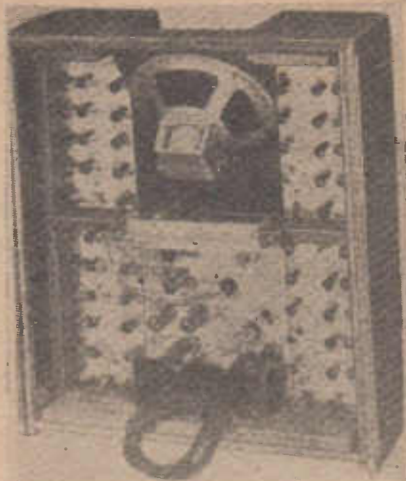
Following the register selector switches, the notes played pass through the tone selectors, namely principal, horn, and string. From the tone selectors the notes played go to the amplifier input.

The principal tone is obtained by means of an RC filter comprised of an 18,000 ohm resistor and a .05 mfd capacitor, which attenuate the higher-frequency components of the generated sawtooth waveform.

The horn tone is obtained by passing the generated signal through an LC filter. The filter consists of a 24 henry coil and a .003 mfd capacitor and is peaked at approximately 600 cycles. The horn is augmented by borrowing from some of the principal tone through a 560,000 and 220,000 ohm resistor.

The string tone is obtained by passing the signal through a very small capacitor shunted by a high resistance. The f string is produced by using a 50-mmfd capacitor and 1 megohm resistor. the p string uses a 20-mmfd capacitor and a 2 megohm resistor.

The key switch frame fits across the piano keyboard and is held in place by expanding clamps. It contains a bank of 60 contact switches operated by plungers that contact the white and the black keys. (1) Mounted in front of the keyboard is the control panel (2) containing selector stops and knee-operated expression control.



Tone generators and audio amplifier of the Organ are connected to the control elements of the piano by a multiwire cable.

8-watt Amplifier

The 8 watt audio amplifier is conventional, using a master volume control after the preamplifier stage and an expression control after the cathode follower.

The vibrato switches select either heavy or light vibrato. The vibrato oscillator is a 6SL7 twin triode, one triode of which is a phase shift oscillator. Its frequency is determined by the three 220,000 ohm resistors and the three 0.05mfd capacitors in the grid circuit. The second triode is a buffer amplifier between the vibrato oscillator triode and the reactance tubes on the cascade generators.

—Courtesy Electronics.

Scientists "Tag" Atoms

Radioactivity is now being used to trace the movement of atoms in metals, according to a recent G-E report. The atoms do a lot of travelling between the grains that make up a piece of metal, and scientists have been "tagging" certain atoms with radioactivity to find out how far and fast they move.

In an experiment just completed it was found that silver atoms within a block of silver may move between the grains as fast as 1/10 of an inch per week at 500 degrees centigrade. However, atoms passing through rather than around the grains take about 10,000 years to move an inch, according to the scientists.

Tube Weight Reduced

By adapting an idea used for lightening warplane engines, radio engineers have been able to cut the weight of giant radio broadcasting tubes by at least 50%.

The success of aluminium cooling fins for aircraft engine cylinders suggested their tryout in the radiators of transmitting tubes. As a result 25kw tubes using the laboratory built aluminium radiators only weigh 98 lbs as compared to the conventional 225 lbs with the copper radiators.

Aluminium tube radiators were made feasible by an aluminium-to-steel molecular bonding process, developed after previous designs had failed because the fast oxidising rate of aluminium rendered its soldering directly to the copper anode impractical.

Report on Projection TV.

Projection Television offers pronounced advantages to the viewer from the standpoint of visual health, it is reported in the Journal of the New York State Optometric Association.

The Journal's statement followed a critical study of the Protelgram projection system, manufactured by North American Philips Company, by a group of the Association's officers.

"After studying images of varying sizes from several different receivers tuned to different degrees of brightness, the optometrists found the projection system particularly noteworthy from the standpoints of ease and comfort of viewing," the Journal reported.

"Advantages noted for the larger, more photographic images yielded by projection were: Less eye-strain because there is less need to strain to see detail in the larger picture; less need for accommodation for close viewing, since the larger picture is naturally viewed and best seen from a greater distance; and the visual advantage of watching a softer, reflected image of photographic quality upon an optically correct screen, rather than looking directly into the light source, as is required with the direct view system."

No attempt was made to evaluate Protelgram in comparison with other projection systems, the Journal emphasised. Sole purpose of the optometrists' study of the system was to ascertain its effects on the eyes of the viewers, in comparison with direct-view systems.

LOW DISTORTION—

VOLUME EXPANSION

The dynamic range of recorded or broadcast music can be materially increased by the correct use of a well-designed volume expander. In this article, experimental data and circuit values are detailed for two effective expander units and which will introduce very little distortion.

During recent years an ever-increasing interest has been shown in the high-quality reproduction of recorded music, as well as of radio broadcasts, and this has led to the design of a number of high-fidelity amplifiers. Many and varied circuits have been used to achieve the desired tonal response, as well as decrease the total harmonic distortion, and now to restore the full dynamic range of the recording, interest is being shown once again in volume expander circuits.

Although many audio enthusiasts look askance at the use of volume expanders, usually going to great lengths to state their objections, in practice it will be found that a considerable improvement in the loudness range can be made by the correct use of a well-designed volume expander.

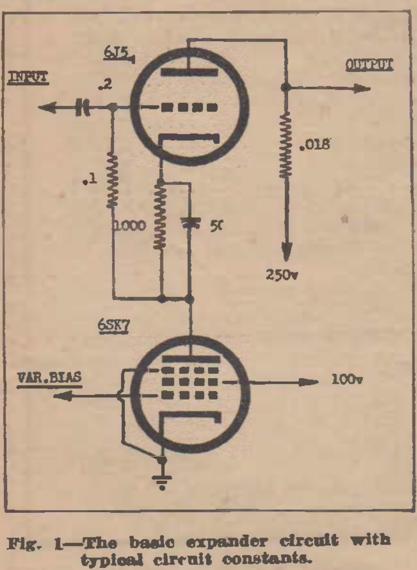


Fig. 1—The basic expander circuit with typical circuit constants.

In fact, it is now coming to be recognised as a valuable addition to any audio system for the reproduction of recorded and broadcast music.

Increases Dynamic Range

The reason for its usefulness is due to the compression that takes place in broadcasting or recording, introduced to hold the dynamic range within the limits determined by various factors. This compression, naturally, detracts from the vitality of music, but the full dynamic range can be restored by the use of an expander. However, it should be borne in mind that this does not necessarily mean that the reproduction will be exactly the same as the original, for the compression is manual and consequently does not follow any mathematical law. Furthermore, due to the nature of all expansion systems, sharp transients, like isolated drum beats, are not expanded. In spite of these disadvantages, comparison of the expanded and unexpanded reproductions of a phonograph record will convince almost anyone that expansion is indispensable in the modern audio system.

In the past numerous circuits have been devised to accomplish the desired effect, but in most cases these have all had the disadvantage that considerable distortion is introduced into the amplified signal. In particular, a very well-known circuit, using 6L7, causes severe distortion with an input level of any reasonable magnitude. Many other arrangements make use of variable-mu pentodes connected in various ways and similarly cause appreciable distortion under some circumstances. Furthermore, there is practically no published data regarding the gain, performance or circuit-constant calculations of such expanders, and the designer is forced to locate little-known tube characteristics charts to estimate these factors for himself.

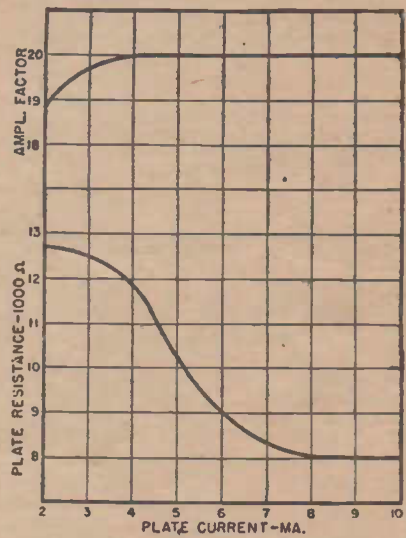


Fig. 2—Variation of amplification factor and plate resistance of the 6J5 with plate current for the circuit of Fig. 1.

In the first section of this article, the experimental data and circuit values for an effective volume expander which introduces very little distortion is detailed, and this is followed by the description of a simple three-valve circuit which was described recently in an overseas journal. Both of these units are quite effective in operation and should present little difficulty to the home constructor.

They can be built up on a small separate chassis, or, if there is sufficient room, simply added to the amplifier chassis where convenient.

Basic Design Data

In the circuit shown in Figure 1, expansion is accomplished with a triode by varying the amount of feed-

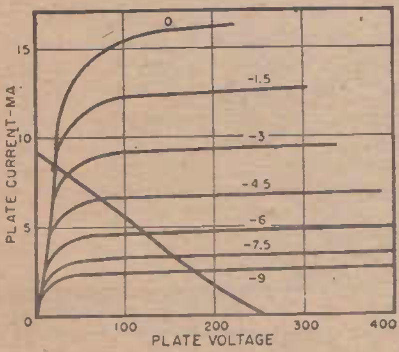


Fig. 3—Characteristic curves of the 6SK7 with load line drawn as explained in the text. Numbers on the curves are values of control grid bias. Screen grid is at 100 volts.

SUBSCRIBERS NOTE!

Owing to the late arrival of recent issues of this magazine, due to circumstances beyond our control, it has been necessary to date this issue September-October in order to regain our normal publishing date. All subscriptions, therefore, have been automatically increased by one month, thus assuring all subscribers will receive the full number of copies paid for in advance.

back. The only consequential disadvantage to the arrangement is that it attenuates rather than amplifies, and hence requires an extra stage of amplification. The performance of the circuit is easily calculable, however. and this is of great assistance to the experimenter.

The 6J5 triode has a load consisting of the .018 meg resistor and the 6SK7 tube in series; the latter portion is also in the input circuit and, as is well known, acts degeneratively. In principle, the resistance of the 6SK7 is made to vary with the signal so that the gain of the stage varies in the desired manner.

The first step in the design is to determine the value of the grid bias resistor for the 6J5 so that there is no danger of positive grid swing. This is done more or less by hit or miss; a value of 1,000 ohms, specified in Figure 1, is quite conservative and should serve most purposes. This resistor is bypassed with a suitable condenser; the size shown provides for a cut-off at 30 cycles per second.

Plate Current Assumed

We now assume a series of plate currents which, obviously, flow through both the 6J5 and the 6SK7 in series. The actual 6J5 grid biases may be calculated from the value of the bias resistor and these assumed plate currents. With these grid biases. and the plate currents, a series of operating points can be located on the 6J5 plate characteristics chart. The plate resistance and the amplification of the tube must then be found at each operating point.

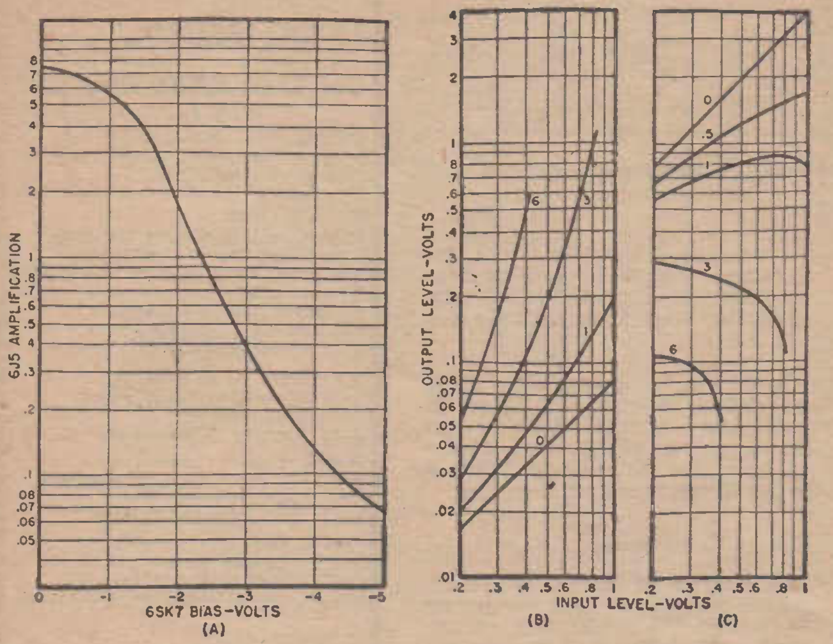


Fig. 4.—(A) Relationship between the voltage amplification of the expander and the bias on the 6SK7 control grid. (B) and (C) performance curves for the circuit connected as an expander and compressor respectively. The numbers on the curves denote the amplification of the signal fed to the 6SK7 grid.

Figure 2 shows the results of these calculations for the circuit shown in Figure 1. The plate resistances were found by arithmetical differentiation of the plate characteristics curves and were rounded to correspond to the expected accuracy of the curves. The load resistor was chosen so that its resistance plus the minimum resistance of the 6SK7 tube, found below, is approximately as small as possible. This requires a little more trial-and-error calculation, but the value shown in Figure 1 is approximately correct. The resistance is actually not extremely critical.

The next step is to calculate the performance of the 6SK7 tube. Once the resistance of the 6J5 is known, this presents no special difficulties.

Again, a series of plate currents—the same as those above—is assumed, and the corresponding 6SK7 load resistances are found by adding the plate resistance of the 6J5 to its load resistance. Each load resistance represents a load line on the 6SK7 plate characteristics chart that is, however, valid only for the assumed plate current. This means that we have a series of points lying on the actual load line of the 6SK7, which is itself curved, as shown in Figure 3.

We may now assume a series of control grid biases on the 6SK7 and compute the plate resistance of this tube in the same manner as we did for the 6J5. The results of these calculations are shown in Table 1. The performance of the stage can now be found. The voltage amplification is given by the equation

$$\text{V.A.} = \frac{uR_L}{(u+1)R_P + r_P + R_L}$$

where R_L is the triode load resistor, u is the triode amplification factor, R_P is the pentode plate resistance, and r_P the triode plate resistance, all taken at some fixed plate current.

For the circuit of Figure 1, the results are plotted in Figure 1A as a function of the bias on the 6SK7. If it is found desirable to operate between —4.5 and —1.5 volts bias, there would be about 34 decibels of expansion available, far more than enough for almost any purpose. The practical limitation to the negative grid bias is the allowable heater-cathode voltage for the 6J5 which, if the heater supply is grounded, is equal to the plate voltage on the 6SK7. This voltage is 75 when the grid bias is —4.5 volts, which leaves a 15 volt margin of safety.

Practical Circuit

A practical circuit using this expander is shown in Figure 5. The signal from the phonograph pickup, assumed to average about 0.4 volt, is fed through a 6C4 with a gain of 12, and into the grid of the expander 6J5. The signal is also sent through another 6C4, rectified with a 1N34 rectifier, and passed through a time-delay net-

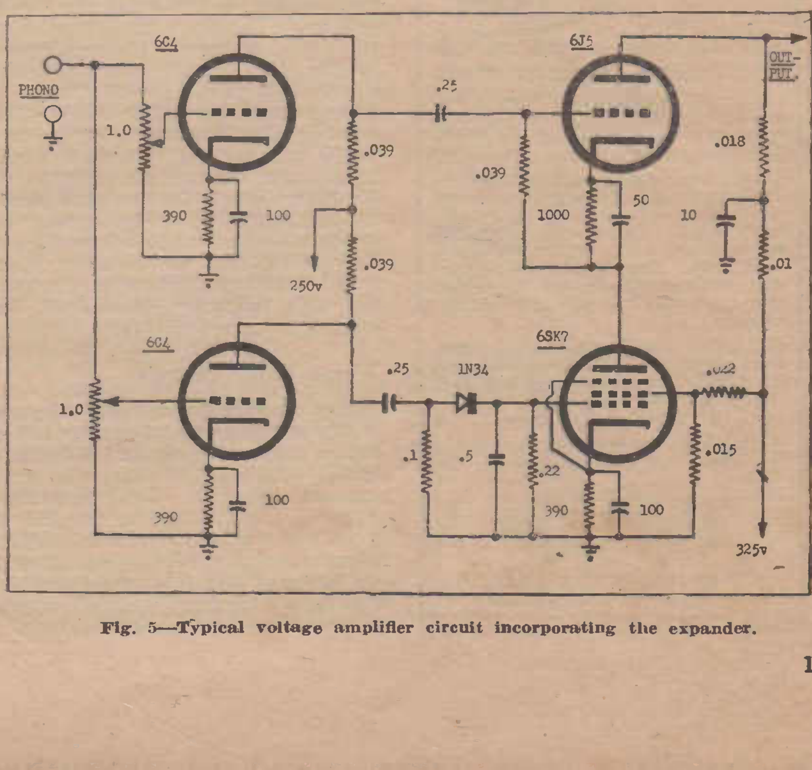


Fig. 5—Typical voltage amplifier circuit incorporating the expander.

Grid Bias	0	−1.5	−3.0	−4.5	−6.0	−7.5
Plate Current (MA.)	8.80	8.50	8.10	6.50	4.60	3.25
Plate Voltage, V.	22	22.5	38.0	75	115	155
Plate Resistance (Ohms)	1,000	3,000	44,000	200,000	400,000	3,000,000

Table 1—Plate Resistance of 6SK7 for various values of control grid bias.

work into the grid of the 6SK7. The rectifier is so connected that positive bias is delivered to the 6SK7, which counteracts the 4.5 volts negative bias already provided.

With the curve of Figure 4A, an idea of the performance of the circuit of Figure 5 may be gained readily. This is done by assuming the expansion control set so that the bias fed to the 6SK7 is, say, 0, 1, 3 and 6 times the average signal level from the pickup.

For the sake of simplicity it can also be assumed that the signal is fed from the pickup directly into the 6J5 grid, or that the amplification of the upper 6C4 is 1.

If the results of such calculations are plotted, the curves of Figure 4B result. In an ideal expander the curves would be straight lines. Figure 4B shows that the expander described in this article is not far from ideal.

Use as Compressor

As a matter of interest, the circuit can be reconnected as a compressor by making the initial bias of the 6SK7 —1.5 volts and reversing the connections to the 1N34 so that it supplies negative bias to the 6SK7 grid. The curves in Figure 2C show, however, that the performance of such a compressor is likely to be temperamental, and at its maximum setting the loud passages would come through a great deal softer than the soft ones! While it might be curious to hear such reproduction, it certainly would serve no useful purpose.

In designing an amplifier incorporating the expander stage shown in Figure 1, its gain can be assumed as 0.085, which is the value with zero expansion. A slight disadvantage of the circuit is that the plate resistance of the 6J5, viewed from the next stage, is increased, as it always is with constant-current feedback. The expander should consequently be followed by a pentode or low-mu triode to minimise the harmful influence of the Miller effect. On the other hand, the input capacitance of the expander triode is reduced, so that it would not be expected that the expander itself would have any detrimental effect on the high frequency demand of the amplifier.

Three-Valve Circuit

The compressor-expander circuits shown in Figure 6, and described in a recent issue of "Radio and Television News" (U.S.A.), differ from the conventional types in that the control signal is applied to the screen grid of a variable-mu pentode This has the advantage that relatively low filtering of the signal voltage is needed and the fact that the expander circuit cannot be overdriven by the contol voltage.

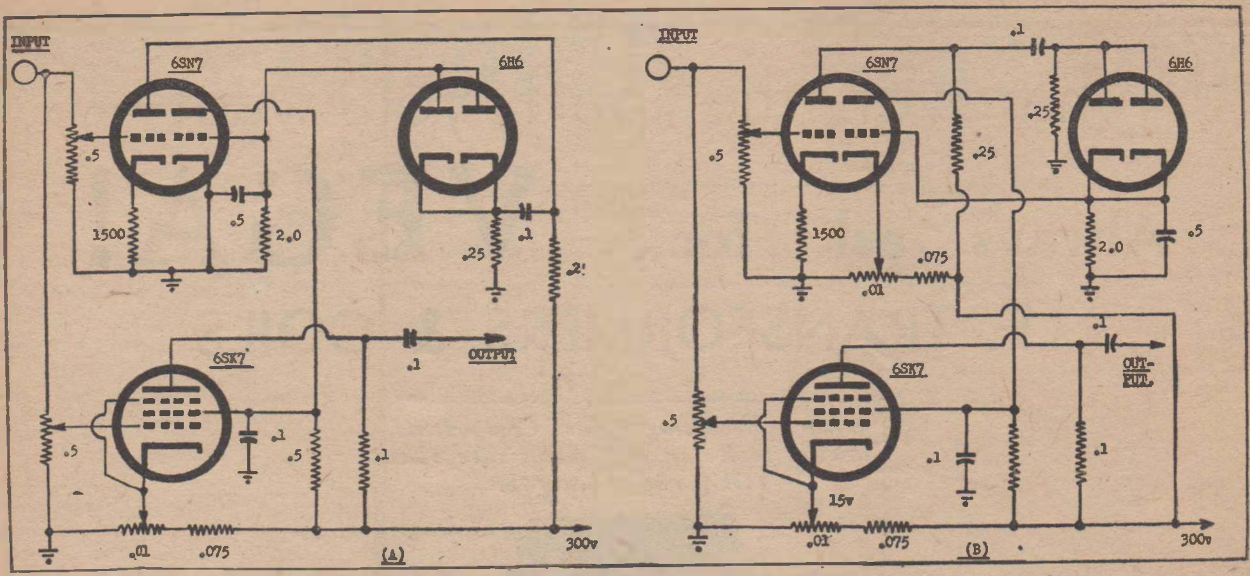


Fig. 6—Diagram of three-tube volume expander (A) and a wide-range compressor (B).

The operation of either circuit is effected by varying the plate resistance of a low-mu triode, the plate of which is connected to the screen grid of the variable-mu pentode. An appropriate d-c voltage is applied to the grid of the triode, changing its effective plate resistance which, through a voltage divider action, changes the screen voltage of the pentode, consequently changing the transconductance.

Distortion introduced by this circuit is desirably low and consists almost entirely of second harmonic distortion that can be eliminated through using two pentodes in push-pull if desired. For single-ended operation, distortion is greatest at maximum compression, and measurements showed that eight per cent. second harmonic distortion could be expected at a compression ratio of 20:1, with a one-half volt input to the grid of the 6SK7. Halving either the compression or the input voltage will halve the destortion. In practice, the circuit functions smoothly from inaudibility to full power output.

Time Constants Important

The time constants of the compressor expander circuits will generally represent a compromise of several factors. If the time constants are small, the switching action may be unpleasantly jerky. If the time constants are large, a smooth switching results, but sharp dynamic effects may suffer

In this system, a time delay of about one-half second is used. On percussive passages this gives the effect of two sets of instruments, with one set taking the first beat and the other set finishing the passage. The principal elements determining the time constants of the circuit are the load resistor and bypass condensor of the 6H6. Increasing the size of these components will increase the delay and decreasing the values will decrease the delay.

A two-megohm potentiometer might be substituted for the fixed load resistor to make a convenient means of adjusting the time delay to various types of music. It will be noticed that the cathodes of the 6SK7 and the 6SN7 are fed from "B+" through a voltage divider. This is necessary to provide good grid bias regulation. The optimum grid bias for the 6SK7 appears to be about 15 volts, while the screen grid voltage will vary from twenty to two hundred volts depending on the degree of expansion or compression.

Method of Operation

In operation of the expander, the expander voltage control is turned down and the bias of the 6SK7 adjusted until no signal is heard. The expander voltage control is then advanced until only the loud passages come through the amplifier.

The compressor operation is quite similar. With the compression control off, adjust the bias on the 6SN7 until the volume decreases slightly, then advance the compression control until the loud passages are reduced to inaudibility. A certain amount of delay in either system may be introduced by increasing the bias voltage. In both the compressor and expander, care should be taken that the input signal to the grid of the 6SK7 does not exceed one volt, or disagreeable distortion may result.

ANSWERS TO PROBLEMS ON PAGE 38

1. (a) 2.000 volts.
   (b) 900 ergs Approx.
2. 168 inches.
3. (a) 5 milli-coulombs.
   (b) 625 volts.
   (c) 3120 × 10^{13}.

Basic Electricity & Magnetism

After discussing practical capacitors and their method of construction, the author introduces the electric current concept.

PRACTICAL capacitors consist of two conductors separated by either a single dielectric or two or more dielectrics in combination. It is the material and dimensions of the dielectric (or dielectrics) used which determines the capacitance and suitability of a capacitor for any given service. Capacitors are chosen or compared solely in terms of the dielectric used in their construction; the material used for the conducting surfaces is relatively unimportant.

It is well to recall the basic capacitance equation,

$$C = K' \frac{A}{t} \quad \text{(where } K' = K/4\pi) \quad \ldots\ldots 11.1$$

This equation actually yields the capacitance of a given volume of dielectric material; capacitance is the intrinsic property of a dielectric which permits it to store electro-static energy. Conducting surfacos have no effect on capacitance which are only used to establish an electric field in the dielectric. The conducting surfaces may cause losses but losses are not capacitance.

Capacitors are classified as either fixed or variable. So called "fixed" capacitors have a "fixed" volume of dielectric which cannot be readily altered by mechanical means. Since most dielectrics are affected by age, by temperature and by operational conditions it is extremely difficult to obtain an unvarying capacitance although this is what the word "fixed" seems to imply. In the case of capacitors the word, "fixed" simply means that we cannot or do not alter the capacitance deliberately.

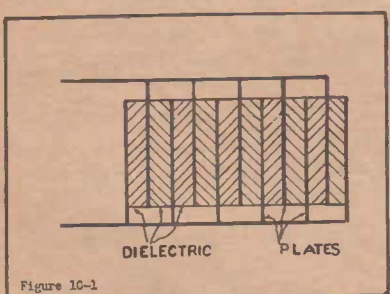


Fig. 1. This diagram illustrates the "sandwich" form of construction, such as is found in small mica type capacitors.

Construction of Fixed Capacitors

Fixed capacitors are either of the "sandwich" form shown in Fig. 11 - 1, or the "rolled" form depicted in Fig. 11-2. In both cases the aim is to cram as much dielectric area into a small a space as possible. Although reducing the thickness of the dielectric will increase the capacitance there is a practical limit to the degree to which the thickness can be reduced; further, if the dielectric is made too thin the potential gradient is too high and there is a risk of breakdown.

By
A. L. THORRINGTON, A.S.T.C.

The "rolled" type is cheaper to make than the "sandwich" type. On the other hand, losses in the "sandwich" type are lower and they are less likely to fail in service. In addition, the capacitance of the "sandwich" type is higher per unit volume, and it can be electrically stressed to a greater degree than its rolled prototype.

Wax or oil impregnated paper, mica, or air are generally used as the dielectric in fixed capacitors, although oil dielectrics are used for high voltage service. Chlorinated diphenyl is used extensively; it is non-inflammable and has other desirable properties.

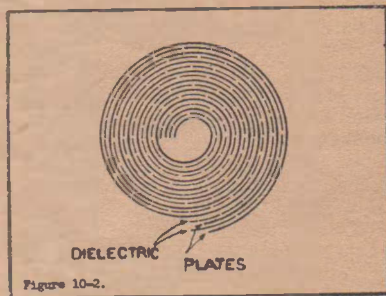


Fig. 2. The "rolled" construction as found in the familiar "Tubular" type capacitor.

Paper is relatively inexpensive and, when impregnated, has a relatively high dielectric constant and moderate dielectric strength. Against this, it is a source of loss, especially at radio frequencies, and it undergoes an aging process in service which lowers its dielectric strength, and breakdown of paper dielectrics is a factor that must always be considered. Paper dielectrics should never be used in networks wherein a failure is liable to cause extensive damage; neither should paper dielectrics be subjected to high and/or transient potential differences.

Mica dielectrics are characterized by low loss, long life, and high dielectric strength. They are relatively expensive because all mica has to be examined for flaws and because assembly costs are high.

Air dielectric has negligible loss, never ages, but has a low dielectric constant and dielectric strength. Capacitors using an air dielectric are bulky and are not suitable for high voltage service.

Electrolytic Capacitors

If two aluminium plates are immersed in a solution of ammonium borate or sodium phosphate and a continuous current is established between them a thin film of aluminium oxide forms on the positive plate or anode and which gradually insulates this plate from the solution. The thickness of the film depends on the potential difference between the plates; high potentials produce thick films. The small thickness of the film ensures a relatively high capacitance between the anode and the solution, so that very high values of capacitance are obtainable in a fraction of the volume required by paper dielectric capacitors.

Losses are high in electrolytic capacitors and they cannot be used across alternating current circuits because a reversal of current in the solution breaks down the insulating film. Their use is limited to d.c. networks wherein high losses are of little consequence.

So called "dry" electrolytic capacitors contain a paste instead of a liquid. Such capacitors have been developed to such a degree that a capacitance as high as 6000 mfd. is contained in a volume of only 100 cu. in. Life of either the liquid or "dry" electrolytic types is limited because both types "dry out" in time and must be replaced.

IN THE NEXT ISSUE . . .

CAN the wave and particle characteristics of an electron be correlated? Can the approximate velocity of electric charges in motion be calculated? Do Newton's laws of Motion invalidate modern theories of the electrical transmission of energy?

These questions are answered in the next article of this series which analyses the Physical Significance of an Electric Current.

Reserve Your Copy of Radio Science Today!

Variable Capacitors

Since the introduction of variable capacitors many ingenious methods have been used to alter the amount of dielectric between the conducting surfaces but the only ones in common use today are the rotary type shown in Figure 11 - 3, and the book or compression type shown in Figure 11-4. In the rotary type one set of moving vanes are arranged so that they inter-leave a set of stator vanes. Air is the principal dielectric. Suitable shaping of the rotor plates allows the capacitance to be varied at different rates as the rotor is turned and this is an advantage in cases where the capacitor is used for "tuning" purposes.

Losses in the rotary type are low but some loss must occur in the solid dielectric used to insulate the rotary and fixed vanes. The better grade capacitors reduce these losses to a minimum by using a dielectric with an inherent low loss and by placing it at zones where the electric field has a low potential gradient.

The capacitance of a book type capacitor is varied by turning a screw. This compression changes the amount of air dielectric in

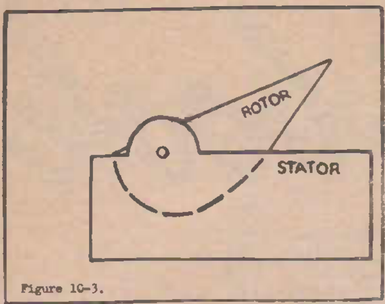


Fig. 3. The rotor type capacitor which is used for tuning a receiver, comprises a set of fixed and moveable plates with air as the dielectric.

series with the mica dielectric thus changing the capacitance. Losses in the book type are higher than those in the air type, unless the former uses air solely as a dielectric. When air is used solely, the unit is more bulky for a given capacitance than one using air and mica.

Our discussion about practical capacitors has necessarily been brief because we have not as yet considered those phases of electrical phenomena encountered in practice. We will often refer to this fundamental data as we learn more about dynamic electricity. Meantime it is both futile and illogical to discuss losses and efficiencies until such times as we have information about the agent producing the losses.

The list following gives the dielectric constant, the dielectric strength and the resistivity of the common non-conductors used in practice.

Dynamic Electricity

Electro-static phenomena is produced by electric charges at rest; electro-dynamic phenomena is produced by charges in motion. In the same way as a body in motion produces effects entirely different to those which it produces when at rest, so moving electric charges reveal inherent properties that are not apparent when they are still.

For instance, we know that all matter has inertia, but we wouldn't know this if it were not possible to start it moving. Matter in motion gives us different problems to those which exist when it is at rest. Mathematical treatment of matter in motion differs from the way we treat it when it is stationary and involves new concepts as to the nature of matter. Our overall concept of substance must be broad enough to include matter in all states.

Similarly, electric charges in motion create phenomena which we can only explain and treat mathematically by endowing electric charges with additional properties. Some of these properties are real in the sense that the inertial property of matter is real; other properties are either not real because they have not been experimentally proven to exist or they are pure mathematical abstractions used only for the purpose of expressing the phenomena of dynamic electricity mathematically.

The Electric Current Concept

When two bodies at differing potentials are electrically connected there is a general movement of charge from the body at the higher potential to the one at the lower potential. We refer, rather loosely we confess, to the flow of charge between the bodies.

The word, flow, inspired by the original notion that electricity was some sort of fluid, has persisted until this day and is never likely to be discarded. Its use promotes much error and confusion because "flow" in the electrical sense differs entirely from the meaning it has when used to describe physical phenomena. The electrical meaning of flow will be apparent as we analyse the electric current concept. At this juncture it would be unwise to use some other term so we will use it with the intention of making its electrical meaning clear as we progress.

Material	Dielectric Strength k.v./m.m.	Resistivity Megohms/ cm. cu.	Dielectric Constant
Asbestos	3-4.5	1.6×10^5	—
Bakelite	20-25		5-6
Cotton	3-4	10^3 upwards	—
Ebonite	10-40	$2 - 100 \times 10^5$	2-3
Glass	5-12	5×10^5 to inf.	3-8
India Rubber	10-25	$2 - 10 \times 10^8$	2-3
Mica	40-150	$5 - 100 \times 10^6$	3-8
Paper	4-10	As cotton	2
Porcelain	9-20	100×10^6	4-7
Shellac	5-20	9×10^6	3-4

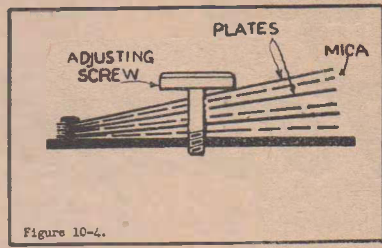


Fig. 4. The construction of the compression type capacitor is shown in this drawing.

Electric charges in motion inspire the idea that, whatever they are or however they move, they must be moving at a definite rate with respect to time; or, simply, they have a definite velocity. The time rate of displacement of the charges, or "flow" of electricity constitutes what we call an electric current.

This concept, then, leads to the definition of an electric current which can be defined as the rate of flow of electric charge, the word "flow" having its electrical meaning. To a degree we can regard the idea of an electric current as analogous to velocity, but is using this analogy we must not confuse the idea of a high current with a high velocity.

Strictly, the word, current, measures the time rate displacement of a substance. For water this is usually expressed in gallons per minute of flow. The gallons per minute due to a large sluggish flowing river is higher than the gallons per minute of a swiftly flowing brook. The current in the case of the river is higher than that of the brook, although the velocity of the water in the brook is greater than the river velocity. High current does not necessarily imply a high velocity.

Does Current Flow?

Since electric current is defined as the rate of flow of electric charge, it is clear that by using the expression, current flow, we are talking about the flow of a rate of flow, and the phrase, flow of a rate of flow, simply doesn't

(Continued on Page 38)

For your note book

A page of radio servicing hints and notes of practical value to the radio serviceman and technician.

HEATER-CATHODE HUM

Electrical leakage between an a-c operated heater and cathode of a vacuum tube can introduce low frequency voltage into audio amplifier circuits and cause objectionable hum when it occurs in a stage in which there is considerable gain. High frequency circuits are also subject to hum, if they allow the low-frequency voltage to modulate the signal.

The principal source of this hum is a minute leakage current which flows between the heater and cathode. The flow of this current through the self-biassing resistor or the parallel combination of the resistor and by-pass condenser applies a hum voltage between the grid and cathode of the tube. It is the voltage across the heater, especially between the high voltage end and ground, that causes this current to flow.

Thermionic Phenomena

The heater-cathode leakage current is essentially a thermionic emission phenomenon, and consequently the flow of current is due to the emission of negative charges (electrons) and positive charges (positive ions) from the insulation on the heater to the cathode sleeve. The capacitance between the heater and cathode being of the order of 10 uuf. is too small to constitute a leakage path.

If the heater varies in potential with respect to the other electrodes, the same phenomenon can cause hum by emission of charges to these electrodes. Hum from this effect occurs most frequently in a-f amplifiers having a grid bias that is less than the highest voltage between heater and ground.

To overcome hum troubles, heaters should not be operated above rated voltage, as hum doubles with only six per cent. increase in heater voltage. If self-biassing circuits are used, the 50 cycle impedance should be as low as possible. This is attained by the use of low cathode resistance and high capacity by-pass condensers, and is particularly important in the early stages of a high gain a-f amplifier. Use of fixed bias avoids this type of hum.

Valves having a comparatively small leakage, used as biassed detectors, frequently hum as the cathode resistor is necessarily high and practical conditions require a small by-pass condenser. The most satisfactory method of avoiding this difficulty is to arrange the circuit so as to ground the cathode of the detector.

The hum can also be reduced to a negligible value through the use of sufficient bias between heater and cathode to prevent the net voltage from reversing. This condition occurs in infinite impedance detectors and certain cathode loaded circuits. Grounding the centre of the heater winding is also effective.

Hum resulting from emission of charges from the heater to other electrodes is reduced by decreasing heater temperature, by keeping the impedance of the electrode circuits low and by keeping the electrodes constantly biassed with respect to the heater.

Removing Wire Insulation

Here is an easy method of removing hard or tough insulation. Pinch the wire with a pair of pilers at the point up to which it is desired to clean off the insulation, and then set it on fire. The flame will then burn up to the pliers and go out, after which the burnt insulation can be easily pulled off and the wires cleaned with a knife or sandpaper.

Cleaning Contact Points

Frequently when cleaning contact points or terminals, it is difficult to reach many points with the liquid cleaner if the ordinary methods of application are used.

This difficulty can be overcome by using a piece of bare copper wire to guide the cleaner to the desired position. The cleaner is simply placed on the wire with an eye-dropper or any hollow glass tube, open at both ends, so that the quantity of liquid can be readily regulated. The cleaning liquid will then run down the wire guide to the desired contact point or terminal to be cleaned.

Soldering Iron Stand

A useful soldering iron stand be made from a worn-out piston from a car. The piston should be placed on a heavy piece of asbestos to prevent any damage through heat to the bench, and then filled to a depth of approx. ½ to ¾ inch with solder. In operation, the tip of the iron during periods of non-use will rest in this solder, which quickly becomes molten, thus preventing the "tinning" on the iron from burning off.

PRINTED CIRCUIT Techniques —

The methods of applying the resistor paints, together with the means of controlling their values is detailed in this third article of the series. In addition, information is given on the practical construction of capacitors and inductances.

E.—DRYING

After applying silver wiring to ceramic plates, they are heated to remove the binder and solvents and to bond the silver to the plate. Properly fired silver has the typical dull metallic silver appearance and will adhere to the ceramic surface with a tensile strength of approximately 3,000 lb./in.² when the paint is made of finely divided metallic silver or silver oxide uniformly dispersed in a suitable binder.

The degree of bonding or adherance of the fired silver depends on the surface condition of the ceramic before the paint is applied. To obtain the strength quoted, the surface must be absolutely free of dust, dirt, grease or other contaminants.

As with most techniques, the successful painting of electronic circuits depends upon the careful observation of small points. The manner in which the coating is dried is important and may be determined experimentally for the type of paint used. Instructions may be obtained from the paint manufacturer. For example, one manufacturer specifies a 3-hour drying at 50° C. for silver paint which it manufactures for use on thermoplastics applied by means of a screen. Other paint and spray preparations dry satisfactorily in one hour at 40° C. or overnight at room temperature[2]. Longer drying is to be preferred if time allows. If the basic material is thermosetting instead of thermoplastic, the temperature may be raised 10° or 20° C. and the time reduced. Infra-red lamps are often used for drying printed circuits.

Dielectric Heating

Dielectric heating may be employed to heat the paint after application to the surface. By designing a suitable set of electrodes under which the work is slowly passed on a conveyor belt, it is possible to drive the binder and solvents out of the paint by treating them as the dielectric in a high frequency dielectric heating system. It is suggested that binder and solvent materials be selected which, if possible, have high loss factors, i.e., a high product of dielectric constant and power factor. Thus, acetone is preferred over alcohol.

This method may be useful in working with base materials such as thermoplastics, which will not stand high baking temperatures. In dielectric heating, the heat can be centred in the materials it is desired to evaporate from the paint.

TABLE 4. Variation in Pilot Production of Printed Resistors.

No. of Resistors Tested	Minimum Resistance	Average Resistance	Maximum Resistance	Mean Deviation from Average	Outside ±10% Tolerance	Outside ±20% Tolerance
38	4.5	5.9	10.6	±3.1	9.8	0
61	1,500	1,600	1,800	±3.0	1.6	0
61	48,000	54,000	59,000	±5.0	8.2	0
61	81,000	93,000	110,000	±4.5	9.5	1.6
376	800,000	1,800,000	2,100,000	±2.8	2.2	0
91	3,200,000	3,600,000	4,200,000	±11.7	21.0	13.0
35	7,200,000	8,400,000	9,500,000	4.5	11.5	0

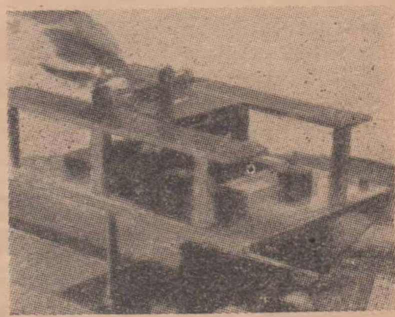


Fig. 1. Pressure-controlled painted resistor applicator.

4. APPLICATION OF RESISTOR PAINTS

A.—Carbon-Film Resistors

Resistors may be painted by brushing or stencilling the resistance material onto the wiring surface. In brushing, the same technique is followed as for the conductors. In the stencilling method, stencils are employed with openings at positions corresponding to blanks in the conductor wiring stencil. The position of the openings in one example may be seen by referring to figure in which are shown plates before and after resistors have been applied.

Excellent results have been obtained using a simple squeegee as is done in painting conductors. Resistors of better quality are produced with two applications of paint though an 80 mesh silk or 120 mesh copper screen, using a pressure-controlled squeegee.

As might be expected, the pressure and speed of the squeegee bar moving across the screen play an important part in the uniformity of the resistance produced. Using similar paints, stencils and base plates, the pressure-controlled squeegee yields a considerably larger percentage of resistors within fixed tolerance ranges than the hand wiping method. Uniformity suffers in the hand wiping method because of the difficulty of exerting the same pressure each time the bar is moved across the screen. Any paint remaining in the screen after one operation will affect the value of the resistors painted in the subsequent operation.

As powdered carbon has more of a tendency to adhere to the screen than silver, clogging may occur. This difficulty is relieved by proper selection of the other paint ingredients. A screen with larger mesh openings may also be used. Typical silk screen mesh sizes vary from 74 to 200 mesh. The latter is useful only for painting high values of resistance for which carbon of very small particle size is used.

Varying Resistance

Not only the point formulation but the width, length, and number of coats of resistor material may be varied to increase the range of resistor values possible. Practice has shown that closer uniformity may be had using several coats to build up the resistor. The paint should be allowed to dry between coats. The drying cycle between coats is determined by practice and may vary from exposure to air for 5 minutes at room temperature to a 10-minute exposure at 75°.

Filing or grinding may be employed to increase the resistance after the resistor has dried. To decrease the resistance, additional paint is brushed on. In this manner individual resistors may be adjusted to very close tolerances.

The type of stencil and the accuracy with which it is made are important features influencing the reproductibility of painted resistors. The stencil must adhere closely to the base plate. Paper masks have been used to position the resistors and determine their size but although they adhere closely to the surface, they tend to leave ridges at the sides of the resistor.

Adoption of the silk or metal screen has eliminated the ridges and given remarkable improvement in uniformity. It should be possible to obtain better than 80 per cent. yield of resistors within 15 per cent. tolerance with production line methods. Those few that ordinarily require closer tolerances may be adjusted as described above.

The distribution of a limited number of resistors of values ranging from 5.9 ohms to 8.4 megohms produced by the silk-screen method on a small pilot line is shown in table 4. From 79 to 98 per cent. were within 10 per cent. of their average value. Greatest spread was observed with the smallest (5.9 ohms) resistors. Those of 1500 ohms and above were held within limits much closer than is required in usual electronic sets manufacture.

Curing Paint

After the resistors have been air dried, the paint is finally cured in an oven. Curing is affected at the proper temperature to convert the heat polymerizable resin into an infusible state. For carbon paint in a bakelite resin binder, the curing temperature is approximately 150 deg. C. One practice is to oven dry the first side of the plate for 20 minutes at 150 deg. C. then paint the second side and oven dry the assembly for 2 hours at the same temperature.

It would be highly desirable to be able to print the complete useful resistor range with a single paint formulation. Although this is theoretically possible, it may require printing some resistors in unreasonable sizes or placing unattainable tolerances on the physical dimensions of other resistors.

A practical compromise is to cover the range from 3 ohms to 200 megohms with from three to six resistor mixes using one or more applications of the paint. Figure 3 shows a coverage of the range 1,000 ohms to 10 megohms using four mixes and two applications of paint.

If the design permits, some advantage may be gained by placing the low values of resistance on one side of the plate and the higher values on the other. This reduces the number of repetitions per face required to produce the requisite number and range of resistors. High values of resistance may be painted in a small space by zig-zagging the lines in any of the several variations used to denote resistors in conventional wiring diagrams.

If resistors of large power capacity are needed, they may be painted on the inside of the cabinet housing the set. The resistance may also be divided in two or more parts, each placed on a separate wall to dissiplate the heat better and further increase the power rating.

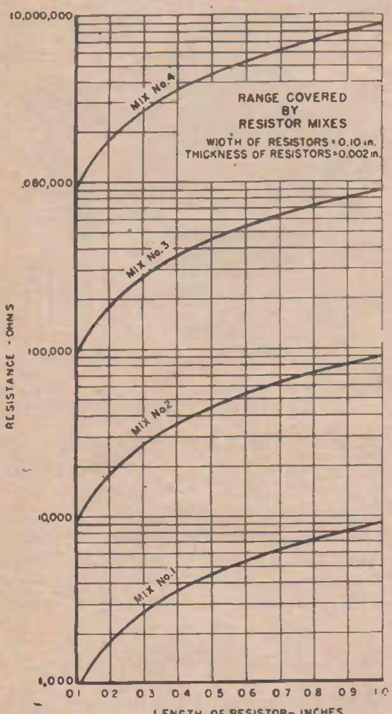


Fig. 3. Tyical range covered by carbon resistor mixes.

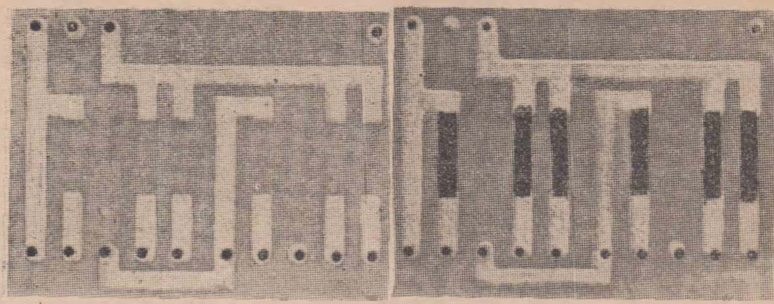


Fig. 2. A steatite plate before and after the application of the resistors.

Reports show that during the past war, German plants produced carbon film resistors in fairly large quantities. At one point (13), a colloidal suspension of carbon in lacquer was used, followed by firing in an oven at 240 deg. C. Only single resistors or cylindrical ceramic sticks were manufactured (15). The 0.25 watt size was 0.16 in. in diameter and 0.6 in. long. Tolerances of 10 per cent. were met by production methods. The carbon film type of resistors were claimed to yield superior performance over the moulded type and particularly to have a lower noise level.

B. METAL-FILM RESISTORS

Metal-film resistors are produced by depositing a thin film of metal on a suitable base. In one method (14) this is done by painting a dilute solution (as low as 1 per cent.) of palladium resinate in ketone on a ceramic base material, drying in air for 30 minutes and heating to 750 deg. C. for an hour to an hour-and-a-half. Under the high temperature, an extremely thin layer of palladium is deposited on the ceramic surface and the residue burned off.

The noble metals are used in this process because they remain substantially stable and nonoxidizable at the high temperature. The palladium is deposited chemically as the temperature passes the range 200 deg. to 400 deg. C. The temperature is kept in this range for 15 to 30 minutes, after which it is raised to 750 deg. C. for an hour to completely oxidise the ash or residue and insure thorough precipitation of palladium.

Resistors up to 1 megohms may be produced in this way. Higher values are difficult to produce by the painting method principally because of the problem of depositing a uniformly thin or narrow strip. However, the resistors have better characteristics than wire-wound resistors, i.e., low positive temperature coefficient, good stability, low-noise level, very good frequency charasteristics and good heat dissipation. The adherence to the ceramic base is particularly strong.

5. CAPACITORS

It was stated that capacitor components of printed circuits may be printed by using a base material of high dielectric constant and painting silver disks of the correct area on opposite sides of the plates. The capacitance is effectively that formed by the two silvered areas and the dielectric between them. This practice is now used in applications where the high dielectric constant base material does not affected the electrical performance adversely or where it may be advantageously used in designing the circuit.

The principal problem has been the control of dielectric losses and performance with temperature. The capacitance for printed circuit use is controlled not only by the chemical formula of the dielectric but the thickness of the disk and the area of silvering on the faces. Dielectric constants ranging from 40 to 10,000 have been used for capacitors from 6.5 to 10,000 uuf. They are from 0.020 to 0.040 in. thick and 0.125 to 0.5 in. in diameter. Higher dielectric constant materials are available, but their electrical losses and extreme variation with temperature in certain temperature ranges limit their use.

The capacitors are soldered to the plate with a low temperature solder, such as 20 per cent. tin, 40 per cent. bismuth, and 40 per cent. lead. This solder has a melting point of 110 deg. C. Soldering is accomplished by laying the capacitors over a silvered area of the plate, after tinnning the surface, and simply pressing down on top with a soldering idon. Preheating and the low temperature solder prevent the dielectric from fracturing during the soldering operation.

Any type of capacitor may be soldered to a printed circuit assembly but those described above have the greatest economy of space and adapt themselves very well to the printed circuit technique.

Capacitor Formation

Capacitors may be built on the base plate by spraying alternate layer of a conductor, such as silver paint, and a high dielectric constant lacquer. The base plate may have a high dielectric contant material moulded into it as a filler so that silvered areas on opposite sides of the base material will form a capacitor. By moulding the space for the dielectric thinner than the rest of the plate, it is possible to obtain large capacitors without weakening the base plate.

Another capacitor particularly adaptable to printed circuit techniques is the vitreous enamel dielectric type (17). It consists of alternate layers of dielectric and conductive materials built up by spraying and fired together, producing a capacitor which appears to be a solid plate of vitreous material. This capacitor may itself be used as a base for printed circuits and may be built up to any reasonable number of capacitors. Thus the circuit can be printed over the capacitors, making a very compact assembly.

These units may be made with any capacitance value if enough volume is provided. The usual volume allowance is 0.02 uuf/in. (3) for working voltage of 500 v. direct current. The power factor is low enough so that Q's of 3,500 may be had above 250 uuf. and 1,000 for 10 puf. Temperature coefficient is approximately 100 ppm. deg. C. up to 125 deg. C.

They are stable and in general are equivalent to mica capacitors. They can be produced to tolerance of 1 per cent. if desired. Average production batches show over 50 per cent. under 5 per cent. tolerance.

One of the important features of this type of construction is that it is entirely mechanised so that it should be possible to turn out printed circuit assemblies including capacitors, wiring and resistors in an entirely automatic process. This should make possible inexpensive mass produced electronic sets.

6. INDUCTORS

The printed circuit technique may be used at high as well as low frequencies. The lowest frequency for which inductors may be printed is limited by the printing area available. For a given area, however, the inductance may be increased by printing the inductor in multiple layers. Circular or rectangular spiral inductor (18) may be printed flat on the base plate in the same manner as the wiring leads using silver paint. To increase the inductance, a layer of insulation is painted over the inductor after which a second inductor is printed.

The material in this article is compiled with acknowledgement from the National Bureau of Standards Circular, C468—Printed Circuit Techniques. Readers desirous of obtaining this complete report should write direct to the Superintendent of Documents, Washington 25, U.S.A. The price of the booklet is 35 cents, post free.

Any number of layers may thus be built up to form inductors of high inductance. The usefulness of this method is limited principally by the distributed capacity and the Q. required of the inductor. Multiple layer inductors may also be printed on cylindrical tubing.

The multiple layer idea need not be restricted to inductors. Several circuits may be printed on the same plate, one above the other, by interposing a layer of insulation between them either by painting, spraying, etc. The proximity of the circuits to each other must be taken into account in laying out the design so that undesirable couplings are avoided.

It is possible to print reasonably high Q. inductors by first applying silver paint and then silver plating. Spiral inductors in the two meter band have been printed on a circle 0.625 in. in diameter. A Q. of 125 is obtained by silver plating to a thickness of approximately 0.002 in. Inductors painted on glass and steatite tubes have performed very satisfactorily in oscillator circuits.

Inductors of silver fired on to cylindrical ceramic forms have been manufactured for some time (19). Better adhesion of the silver to the ceramic is had when the metal is fired on to the surface using a suitable flux than when some other method such as chemical reduction of the metal is used.

Increasing Inductance

The inductance of printed inductors on an insulating surface is low not only because of the limited space employed for them but because they operate in a medium of low permeability. One side is principally exposed to air while the other side has the insulating base material, also of low permeability, in its field.

A method of increasing the inductance is to eliminate some of the centre turns and fill the area with a magnetic paint made as a colloidal suspension of powdered magnetic material. A modification is to print intertwined spirals of silver and magnetic material or, if the magnetic paint is made nonconducting, the whole inductor may be sprayed or painted with it.

(Continued on Page 39)

T-V MEASUREMENTS

The first of three articles dealing with the problems of voltage measurement in television receivers. Whilst specific reference is made to TV equipment the principles outlined are equally applicable to measurements made on any electronic equipment.

In the servicing of television receivers, observation of the picture and sound will very often yield sufficient information so that the defect can be isolated to a certain part of the receiver. However, in order to determine the stage or circuit in which the defect exists and then the defective part itself, it is usually necessary to make various measurements in the television receiver.

Many of these measurements are the same as those used in servicing radio receivers. These include d-c and a-c voltage and resistance measurements. Other measurements such as high-voltage and waveforms, are peculiar to television receivers. By high-voltage is meant the voltage used on the anode of the picture tube, which may be anywhere between 5,000 and 30,000 volts.

The measurement of low d-c voltages in television receivers includes that of B-plus supply voltages, bias voltages, plate, screen, and cathode voltages, and the control voltages used in the afc or agc systems. These voltages vary from a small fraction of a volt to perhaps as high as 400 volts. These will all be referred to as low d-c voltages to distinguish them from the high voltages mentioned above.

Wide Measurement Range

The measurement of a-c voltages in a television receiver may involve power line voltages which are usually 60 cycles, audio voltages which may range from 40 to 10,000 cycles, and video voltages which may be as high as 4 mc. In addition there are the sync and sweep voltages, which only go up to 15,750 cycles in frequency, but due to their irregular waveform require some special care in measuring. In some cases it may be necessary to measure i-f or r-f voltages. In this case the frequencies range from 4.5 mc to as high as 216 mc.

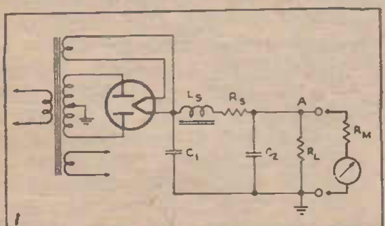


Fig. 1. A conventional low-voltage power supply circuit. The meter resistance is in shunt with the load resistance.

From this brief description, it can be seen that the voltages encountered in a modern television receiver have a tremendous variety with regard to frequency, amplitude, and waveform. Because of this, it is necessary to know which instrument should be used to make any necessary measurement. It is important for the serviceman to know how to take full advantage of the instruments he has at hand, at the same time realising the limitations of each. In many cases the serviceman can improvise in order to obtain measurements that he ordinarily could not make with his existing test equipment.

Instrument Accuracy

In general, the accuracy of a measurement will depend on two factors:

1. The accuracy of the calibration of the instrument.
2. The effect of connecting the instrument in the circuit where the measurement is made.

The calibration accuracy of the meter is specified by the manufacturer as plus or minus a definite percentage. A fairly good meter has an accuracy of ±2 or 3 per cent. on d.c. and from ±3 to ±5 per cent. on a.c. For service work a meter with an accuracy of ±5 per cent. on either a.c or d.c is sufficient as far as calibration accuracy is concerned.

It should be remembered that the voltage and resistance measurements given in the service data for a television receiver are REPRESENTATIVE of that particular model and are not the exact values for every receiver of that type manufactured. In most of the circuits in a receiver, the resistor and capacitors used have a tolerance of ±10%. In addition, each tube of a particular type has somewhat different characteristics due to manufacturing tolerances.

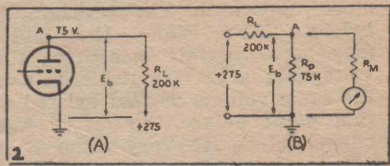


Fig. 2. (A) The plate circuit of a triode amplifier. The meter reduces the voltage at the plate of the tube, the amount of reduction depending on the resistance of the meter. (B) Equivalent d-c circuit.

In the design of a television receiver, the maximum allowable tolerance for any part in the receiver receives careful consideration. For the purpose of economy, it is impractical to use parts with a lower tolerance than necessary. For example, if a circuit design required a 1,000-ohm resistor and the circuit worked equally well with a resistance as high as 1,100 ohms or assister would be used. On the other hand, if the circuit did not operate properly when the resistance was increased above 1,050 ohms or below 950 ohms, then a 5% resistor would have to be used.

These manufacturing tolerances must be remembered when comparing the voltage or resistance measurements given for that set by the manufacturer. A 20% tolerance should be allowed in almost all voltage or resistance measurements. In other words, unless a voltage or resistance measurement is more than 20% off the value given by the manufacturer, it will usually not be significant in isolating a defective circuit.

TABLE 1			
Scale	1,000 ohms/v	20,000 ohms/v	VTVM
3 v	3 K	60 K	11 meg
10 v	10 K	200 K	11 meg
30 v	30 K	600 K	11 meg
100 v	100 K	2 meg	11 meg
300 v	300 K	6 meg	11 meg

Second Consideration

This far in our discussion of the accuracy of a measurement, we have neglected the second determining factor, which is by far the more important. The problem is briefly this: While the meter may be accurately measuring the voltage at a certain point, is this the same voltage as that existed at this point before the meter was connected to it? Very often it is not.

When using an oscilloscope to observe the waveform of a signal, the question arises as to whether the waveform seen on the 'scope is the same waveform that existed before the scope was connected. This problem is a basic one in taking any type of measurement and must always be considered.

There are two solutions to this problem. The ideal solution, of course, would be to build test equipment that has no effect on the circuit at all or if this is not possible, only a negligible effect. The other solution is not really a solution at all, but rather a way of getting around this problem. That is to simulate the conditions under which the original measurements on the receiver were made and to compare these readings with the reading obtained on the receiver under test.

For example, if a voltage reading was originally taken with a 1,000 ohms-per-volt meter, it should be possible to obtain the same reading on another receiver with another 1,000 ohms-per-volt meter. Even if this reading is not the actual voltage present before the meter was inserted in the circuit, it provides a means of comparison. This method, however, is not infallible and may still introduce errors under certain conditions, as will be discussed in more detail.

Measurements Low D-C Voltage

As previously mentioned, low d-c voltages include all the d-c voltages encountered in the television receiver with the exception of the high d-c voltages used in the picture tube. Three types of meters are commonly used to-day to measure d-c voltages.

These are the 1,000 ohms-per-volt meter, the 20,000 ohms-per-volt and some with sensitivities even greater than 20,000 ohms-per-volts, but these meters are not as common as the three groups mentionend previously. For simplicity we will limit the discussion to these three types, although most of it will also apply to any other type of meter.

Input Resistance

The input resistance of 1,000 and 20,000 ohms-per-volt meters is equal to the product of the maximum scale reading and the sensitivity. Let us consider a 1,000 ohms-per-volt meter and a 20,000 ohms-per-volt meter, each with scales of 3, 10, 100 and 300 volts. For comparison, we will consider a vacuum tube voltmeter which has an input resistance of 11 megohms. The VTVM has a constant input resistance for all scales on the meter. The input resistance of these three meters on their various scales are shown in Table 1.

From this table we can see the limitations of the three instruments as far as input resistance is concerned. Theoretically, each meter will always have some effect on the circuit across which the meter is applied. Practically, it is possible to make this effect negligible by making the meter resistance high enough. To determine how much the meter will effect the circuit, it is necessary to consider the resistance of the voltage supply at the point being measured, the load already across this point, and the additional load supplied by the resistance of the meter.

In the ideal case where the voltage supply has no internal or series resistance at all, there would be no difference in the meter readings. While this ideal condition never actually exists since all generators and power supplies have some resistance, it is possible to approach it in some cases. For instance the internal resistance of a large d-c generator, such as those used by the power companies, is only a small fraction of an ohm.

TABLE II		
Meter	Point A	Point B
VTVM	—5.2 v	—5 v
20,000/v	—0.2 v	—0.8 v
1,000/v	0 v	—0.1 v

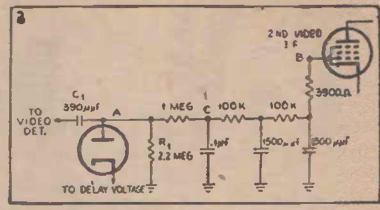


Fig. 3. A typical automatic gain control (agc) system used in television receivers. Only one controlled stage is shown, usually there are more than one.

Therefore, any meter could be used to measure the line voltage of a d-c power line since the resistance of the meter is so great compared to the resistance of the generator that the effect of the meter would be negligible. For all practical purposes the voltage at the line terminals after the meter is connected would be the same as before.

Power Supply Measurement

Fig. 1 illustrates a conventional power supply such as may be used in a television receiver to supply B-plus voltages. The resistance Rs is equal to the sum of the resistance of the choke, the rectifier tube, and the transformer winding. Since these resistances are all in series they can be replaced by one resistance, Rs. Let us assume that Rs is 500 ohms. The load on the power supply has been replaced in Fig. 1 by the shunt resistor RL. The value of this resistance is equal to the voltage at point A divided by the load current. For example, if the voltage at A equals 275 volts and the load current equals 100 ma, RL would be equal to 2750 ohms.

If we connect a voltmeter from point A to the ground, the resistance of the meter would be in parallel with the load resistance RL. The load RL causes a voltage drop in resistor Rs. In this case the voltage drop is equal to 500 times 0.1 or 50 volts. When the meter is connected the total load resistance decreases and the current through Rs increases, causing a greater voltage drop across it.

However the resistance of even the least sensitive meter, the 1,000 ohms-per-volt meter, is equal to 300,000 ohms on the 300-volt scale, which is the scale that would be used to measure the voltage at point A. This 300,000 ohms resistance, represented by Rm, in parallel with the 2,750 ohms of RL would give a parallel resistance equal to approximately 27,30 ohms.

The change in load resistance from 2,750 ohms to 2,730 is very small, and will have a negligible effect on the voltage at point A.

The 20,000 ohms-per-volt meter and the vacuum tube voltmeter will have even less effect on the voltage being measured, For a measurement of this type, therefore, any one of the three meters would do equally well.

Amplifier Plate Circuit

The plate circuit of a triode amplifier is shown in part (A) of Fig. 2. The 275-volt B-plus voltage is obtained from a power supply as shown in Fig. 1. Assuming that the tube draws 1 ma plate current, the drop in the plate resistor will be 200 volts and the d-c voltage on the plate of the tube will be 75 volts.

The equivalent d-c circuit is shown in part (B) of Fig. 2. The plate circuit of the tube is replaced by the resistance which is equal to the voltage on the plate divided by the current, or 75,000 ohms. To measure the plate voltage, the meter is connected from point A to ground. As before, the input resistance of the meter is represented by Rm.

Effect of Meter

First, let us consider the effect of using the 1,000 ohm-per-volt meter, whose resistance on the 100 volt range is equal to 100,000 ohms. This resistance Rm is in parallel with Rp. The resistance of the parallel combination is equal to approximately 42,80 ohms. The voltage at point A is now

$$E_b = 275 \times \frac{42{,}800}{42{,}800 + 200{,}000}$$

= 48.5 volts. The 1,000 ohms-per-volt meter, therefore, changes the voltage at the plate from 75 to 48.5 volts.

Similarly, we can determine the effect of connecting the other two meters. The 20,000 ohms-per-volt meter has a resistance of 2 megohms on the 100-volt scale and will cause the voltage at the plate to drop to 73 volts. The VTVM has an input resistance of 11 megohms, and when connected to the plate will cause the voltage to drop to 74.6 volts.

In this particular circuit then, it can be seen that the 1,000 ohms-per-volt meter would introduce a large error, the 20,000 ohms-per-volt meter a small error, and the VTVM no error at all.

Bias voltage measurements are another type of voltage measurement often made in television receivers. These measurements include those of grid-leak bias, fixed bias, cathode bias, and automatic gain control (agc) voltages. Fig. 3 is an example of an agc system used in a typical television receiver. The agc usually controls more than one stage in the receiver, but for the purpose of illustration we have chosen the second video i-f stage.

A.G.C. Circuit Voltages

First, let us briefly consider the operation of this circuit. The i-f signal from the video detector is applied through capacitor C1 to the diode. If the i-f signal exceeds the delay voltage, this signal will be rectified and charge capacitor C1 so that a negative voltage appears at point A to ground.

Resistor R1 enables capacitor C1 to discharge so that the voltage at A can change in accordance with the strength of the i-f signal. Following R1 there are three stages of R-C filters which filter out the a-f and r-f components and allow only the d-c control voltage to be applied to the grid of the second video i-f stage.

When a voltmeter is connected from point A to ground, the resistance of the meter is in parallel with that of R1 which is 2.2 megohms. The total parallel resistance from point A to ground will then be smaller than it was. The time constant of R1C1 will then be smaller and the charge on capacitor C1 will leak off faster than it normally should, resulting in a smaller d-c voltage at point A. It is possible to calculate the effect of the meter being inserted at this point, but this is rather laborious due to the rectifier circuit, so instead we will consider the results of actual measurements made in this circuit.

To make these measurements, all three meters were set on the 10 volt scale. From Table I, the 1,000 ohms-per-volt meter, the 20,000 ohms-per-volt meter, and the VTVM have input resistances on this scale of 10,000 ohms, 200,000 ohms, and 11 megohms respectively. Table II shows the results of measurements made on points A and B in the circuit of Fig. 3 with three different voltmeters.

An examination of this table shows that the 1,000 ohms-per-volt meter is worthless for this type of measurement and that the 20,000 ohms-per-volt meter is not much better. The VTVM, therefore, is the only meter of the three types investigated which will give a reliable reading in this type of circuit.

(Courtesy "Successful Servicing")

AROUND THE INDUSTRY

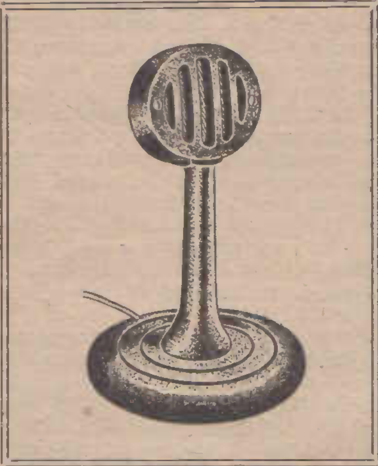
NEW CRYSTAL SPEECH MICROPHONE

Latest release by Amplion (A/sia) Pty. Ltd. is a new lightweight crystal microphone designed specifically for the reproduction of speech frequencies.

Incorporated in a cast aluminium case and stand, this microphone, designated as type "A," will be found ideal for use in public address equipment, office and factory call systems, amateur transmitters and mobile radio transmitters. The complete unit weighs only 1 lb., is 7 inches high and mounted on a base 4½ inches in diameter. It is obtainable in either black or brown crackle finish.

Because of its high inherent sensitivity, the mass of the moving parts, including the crystal, has been kept as small as practicable. The result is a highly efficient microphone which electrically appears as a constant voltage generator in series with a capacity, nominally .0005mfd at a temperature of 20 degress C. As is common with all piezo-electric devices, this capacity varies somewhat with temperature, but its effect can be made negligible by using a high impedance load, preferably in the order of 10/30 megohms.

The price of this microphone is £6/17/6, and supplies are now readily available from all distributors.



Further particulars, including a descriptive leaflet, can be obtained by calling or writing direct to Amplion (A/sia) Pty. Ltd., 36-40 Parramatta Road, Camperdown.

VALVES FOR TELEVISION

To assist television receiver designers in their choice of valve types, the Amalgamated Wireless Valve Co. has prepared a tentative list of suitable valves, all of which should become generally available in the near future.

In view of the interest shown in the proposed television services, the following guide to valves suitable for use in experimental television receivers should be of interest to every technician, designer or experimenter.

In some cases it will be noticed that alternative types are given for some applications and consequently the actual choice will depend on the designer's circuit arrangement.

The types and their circuit application recommended are as follows: R.F. Amplifier—6J6 or 6AU6; R.F. Oscillator—6J6 or L77 (= 6C4); Converter—6J6; Video I.F. Stages—Z77 (= 6AM6) Video 2nd Det.—6AL5 = D77; 1st Video Amplifier—6AU6*; 2nd Video Amplifier—6V6GT or 6AQ5*; Sound I/F Stages—6BA6*; Sound 2nd Det. & Audio—6AV6*; Sound Output—6V6GT or 6AQ5*; Sync. Separator—6AU6*; 1st Sync. Ampl.—6BA6*; 2nd Sync. Ampl. & Hor. Dis.—6SN7-GT*; Vert. Sweep Osc. & Dis.—6AU6*; Vert. Sweep Output—6V6GT or 6AQ5*; Hor. Sync. Dis.—6AL5 - D77; Hor. Sweep Osc. 6V6GT*; Hor. Sweep Osc. Cont.—Z77 (=6AM6); Hor Sweep Output—6BG6G or 6P28; Hor. Reaction Scan.—5V4G*; High Volt. Rect.—1B3GT or U24; Power Supply. Rect.—U52/5U4G; Low Volt. Rect.—5Y3GT*; DC Restorer — 6AL5 (=D77).

Types marked with an asterisk are Australian Made Types.

NEW "AEGIS" PRODUCTS

Advice has been received from the Aegis Manufacturing Co. of two new releases—the KC5 Tuning Unit and a Communications Cabinet for the KC4 Tuning Assembly.

The KC5 is an all-wave tuning unit specially developed for use in high-grade custom-built console receivers. The unit is, in effect, the entire "front end" of a radio receiver, completely assembled, wired and pre-aligned, thus enabling its use in a variety of circuits and designs with a minimum of connections.

The unit covers both the Broadcast and popular Short Wave bands, the frequency coverage being: 550-1630 kc., 3.4 to 4.05 mc., 5.8 to 7.5 mc., 9.4 to 12.3 mc. and 13.9 to 18.2 mc. A multi-coloured, full vision, illuminated dial is fitted and this is calibrated for the broadcast, 16, 19, 20, 25, 31, 40, 49 and 80 metre bands. The wave change switch operates an automatic band indicator on the dial face to show the band in use. The inclusion of a 29:1 ratio dial drive, flywheel spin tuning shaft and electrical band-spreading simplifies the tuning on the short wave bands.

Providing an r-f stage on all bands to ensure maximum performance, this unit should be of interest to all home set builders, since it requires only five connections to feed it into any 455 kc. i-f channel.

For those who may have purchased or are contemplating the purchase of the KC4 kit, this firm now advises that a special communication cabinet, front panel and chassis to suit are available for immediate delivery. The retail price of this cabinet, etc., is £6/10/- plus tax.

Further details can be obtained from any Aegis distributor or by writing direct to the Aegis Manufacturing Co., 208 Little Lonsdale Street, Melbourne, C.1.

Modern Amateur Transmission Techniques

Class C operation is generally used to achieve high efficiency in a transmitter circuit. This article discusses the basic oepration of the Class C amplifier, and the methods of obtaining maximum results from it.

By
ALAN WALLACE

Since it is neither practicable nor desirable to extract any large amounts of power from a controlling oscillator, such as have been described in the last two issues, it is necessary to employ a power amplifying stage to provide the necessary amplification. Furthermore, since it is often desired to operate on some harmonic of the fundamental oscillator frequency, one or more frequency multiplier stages are required, depending upon the degree of multiplication.

Although at audio frequencies it is usually necessary to employ a linear amplifier, operating under Class A conditions, to ensure a distortionless output, the situation at the highest frequencies is quite different, and it becomes possible to use the highly efficient Class C amplifier to achieve the desired result. In order to understand the operation of this class of amplifier, and employ it to the best advantage, it is necessary to grasp the difference between its operation, and that of the conventional stage. Since the same fundamental principles govern the operation of buffer, doubler and final power amplifiers, the general case of the Class C amplifier may now be considered.

Class "C" Operation

As is well known, a normal Class C amplifier has a bias applied

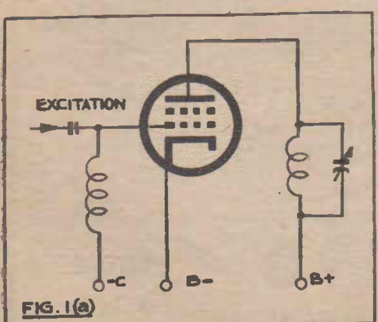


Fig. 1(a): The fundamental Class C Amplifier.

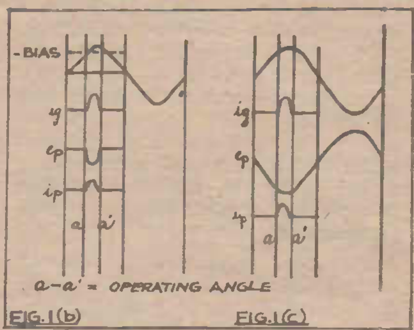


Fig. 1(b): This graph illustrates the operation of a Class C Amplifier. The operating angle is between points a-a'.

which is greater than the cut-off value for the tube employed, and thus, in the absence of a driving signal, sufficient to overcome this cut-off bias, no plate current will flow. However, if a sufficiently large RF voltage is applied to the grid of the tube this bias will be overcome on the positive peaks, plate current will then flow for the time during which the applied signal is greater than the bias, obviously over only a small portion of the cycle,

This will be seen in Figure 1a between points a and a1. It will be observed that both plate and grid current flow for only a small fraction of the cycle, and this fraction, expressed in degrees, is known as the "operating angle" of the stage.

Now the curve for ep shown in Figure 1a would only be correct of the amplifier were working into a non-resonant resistive load. The usual relationship is shown in shown in Figure 1b, where the anode load is a purely resistive impedance, as presented by a tuned circuit at resonance. Under these conditions, the amplifier tube may be considered as a form of "switch" which supplies the tuned circuit with a pulse of energy at exactly the correct instant to maintain a circulating current of the resonant frequency in the tank circuit.

If the wave forms relating the instantaneous plate voltages and currents are now examined, it will be obesrved that the plate current through the tube only flows when the plate voltage is at a minimum, and herein lies the "secret" of the high efficiency of this form of amplifier. It would seem, at first sight, that the smaller the operating angle, i.e., the shorter the period of time for which plate current flows, then the higher the efficiency which will be obtained. This is in fact so, but we must remember that, in order to obtain the same mean power input to the stage, then the peak anode current would need to be increased.

High Efficiency

This becomes a limiting factor, being limited for any particular type of tube by the cathode surface and its temperature, and it is necessary to strike a compromise between maximum efficiency and maximum power output. It is normally quite possible to achieve an efficiency of between 70 and 80 per cent. in a well designed stage, and these efficiencies will be obtained with an operating

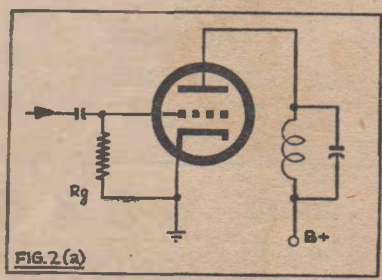


Fig. 2(a): The use of a grid leak as a bias source.

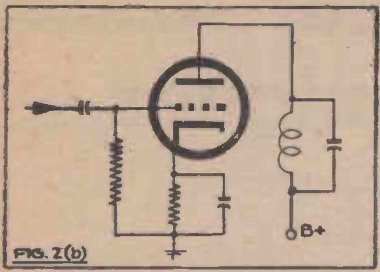


Fig. 2(b): To safeguard the valve a more common arrangement is to use partial cathode bias.

angle which is between 120 deg. and 140 deg.

It will be appreciated that, with any given tube, as the applied anode voltage is increased, then the plate efficiency will increase since, with the minimum plate voltage at the original level, the voltage excursions during the cycle will be much larger, for the same plate dissipation, resulting in a larger proportion of the power being delivered to the tank circuit. Care must be taken however, to ensure that ratings of a particular tube are not exceeded, as, since the peak RF voltages developed have twice the amplitude of the amplified DC voltage, internal breakdawns in the tube can easily occur.

Circuit "Q" Important

The Q. of the tank circuit employed will have a large influence in determining the correct operation of the amplifier. It may be shown that the tank circuit efficiency is given by the expression

$$eff = \frac{Qa - Qb}{Qa} \times 100\%$$

where Qa is the Q of the circuit when loaded, and Qb is the efficiency of the tank circuit in the unloaded condition.

From this equation, it can be seen that it is desirable for a high Q in the tank circuit when not loaded, in other words, its inherent Q, to be as high as possible, whilst it would appear that a low Q in the loaded condition is desirable, if high efficiency is to be attained.

However, since an excessively low Q. results in poor harmonic discrimination, it is usual to employ a tank circuit having a Q. of about 12 when loaded, this having been found to present the best compromise for amplifiers of the 100 watt and smaller classes.

The grid bias applied to the amplifier must have such a value as to permit the desired operating angle (between 120 deg. and 150 deg.) when the peak voltage applied to the grid equals the minimum plate voltage, this relationship giving the optimum ratio between grid driving power and plate circuit efficiency. The exact bias required will vary with different tubes, but for the typical modern tetrode, approximately two or three times cut-off will be found satisfactory. However, precise

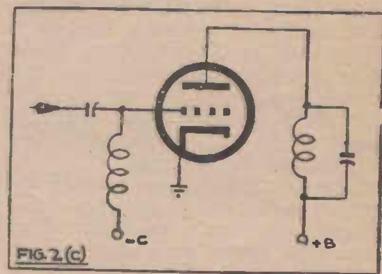


Fig. 2(c): Connections for a fixed bias source.

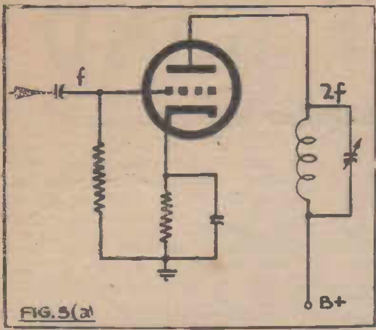


Fig. 3(a): A typical frequency multiplier stage.

information for any particular type of tube is usually contained in the valve manuals, and it is to be recommended that the valve manufacturer's recommendations for stated values should be followed as closely as possible ,unless special design considerations warrant any alterations.

It is particularly necessary to ensure the correct operating conditions when the stage is being used as a plate modulated amplifier. In this condition, the excursions of plate voltage are doubled, for a given applied potential, and care must be taken on modulation peaks, that the minimum plate potential does not fall below the peak grid voltage, thus causing a non-linear modulation characteristic as well a reduction in tube life.

It is important also that the impedance presented to the tube by the tuned circuit when loaded, should equal the plate impedance, at the condition of operation. For practical purposes this may be taken as being proportional to the applied voltage and current. A convenient table, showing the minimum required value of tuning condenser, in picrofarads, for a circuit Q of 12, is shown in Table 1, for the respective bands of operation.

It can be borne in mind that in applications using a split-stator tuning condenser, the total capacity used need only be one quarter of that shown; that is, each section of the condenser will be one half of the normal value. However, since these are minimum values, the use of a larger value of condenser than that stated will result in a higher Q being obtained providing a better harmonic filtering.

Grid Bias Source

The grid bias may be supplied from one of several different sources. The most commonly used in ham transmitters today, is what is commonly known as grid leak bias, as shown in Figure 2a.

The flow of grid current, on the peak of each positive half cycle, develops the required voltage across the grid leak, which is of sufficient size to dissipate the heat generated by the flow of grid current. The power dissipated in this resistor is given by the expression $P = i^2.R$ watts, where i is the grid current in ma, and R is the grid leak resistance in megohms.

Although this system is very convenient, obviating as it does the need for a separate bias power supply, it suffers from the disadvantage in that, should the RF drive to the tube fail for any reason then the tube is deprived of its bias, the ensuing excessive plate and screen dissipation may result in permanent damage to the tube. This disadvantage may be overcome, however, either by use of partial cathode bias, as in Figure 2b, or fixed bias, as in Figure 2c.

In the event of fixed bias being used, it is most essential to use a bias source having a low internal resistance, and good regulation characteristics, in order that its output voltage will not change too appreciably during the vast changes in grid impedance.

A commonly used source of bias voltage is the now standard Minimax 45 or 67½ volt "B" battery, which, as it is called upon to supply no power, will last its full shelf life. However, where the voltage range required is suitable, gaseous voltage regulators of the VR series may be used, as described last month, and will be found to be quite suitable.

(Continued on Page 39)

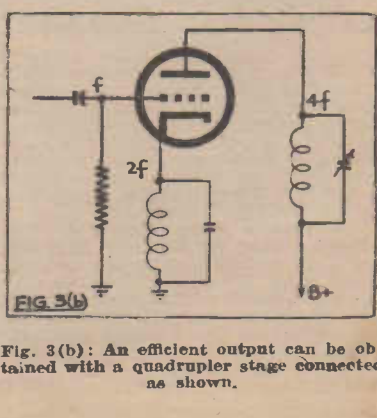


Fig. 3(b): An efficient output can be obtained with a quadrupler stage connected as shown.

ON THE BROADCAST BAND

ASIATIC STATIONS

Asiatic stations have provided particularly interesting DX this winter, several new ones being heard. Most of the old reliables have made their presence felt in no uncertain manner, thus providing excellent listening for many of our new readers.

Art Cushen has identified a station be heard as far back as last August, operating on 930 kc. This was believed to be Singapore, but is now known to be Colombo, Ceylon, operated by the British Broadcasting Corporation. This station is heard carrying All India Radio news service from Delhi at 1.30 a.m. while the B.B.C. news from London is taken at 2 a.m.

So far we have been unable to discover location of two Indian stations Arthur Cushen refers to hearing with English news at 1.30 a.m. on 990 kc. and 1490 kc. He also mentions a station on 1360 kc. playing English recordings, and which he has not been able to identify. It closes at 1.30 a.m., and should not be confused with the AIR station, Cuttack, on 1355 kc.

This reader has now logged all AIR stations, his latest verifications coming from **Baroda, 1,200 kc.** 5kw. This uses a self-radiating mast, 180 ft. high, and has been assigned the call sign of **VUB7**. It remains on the air daily until 3 a.m. and carries the 1.30 a.m. news in English. At other times Gujarati is the principal language broadcast.

From Vijayawada our friend received an airmail letter verifying his reception of the 1 kw transmitter operating on 840 kc. signed by the station Assistant-Director. A copy of the station schedule enclosed shows sign off as 2.30 a.m. EST. This one also carries English news at 1.30 a.m. The call sign **VUV** is listed for this station, which call has previously been associated with the station controlled by the Government of Hyderabad, so possibly the latter have dropped their claim for this call sign.

An airmal letter verification has also been received from the "**Radio Pakistan**" station at **Karachi, 825 kc.** It will be noticed that stations in this network carry news in English now at 12.45 a.m. daily.

Also from Pakistan a verification card has arrived at George Francis' QTH, showing an emblem in green with black printing on white background. This came from the station at Dacca, heard at good strength in most locations on 1167 kc.

Radio Malaya "Verification"

From "**Radio Malaya**," **Singapore**, the attractive verification card now being issued by member stations of this network has arrived at our listening post in reply to our comments on the 620 kc outlet of the above studios. The card shows the geographical relationship of many of the well-known cities of South Asia to Singapore Island. The latter is shown in Red with location of other centres in blue on a white background. Apparently this card must have been prepared some time ago, as the frequencies 570 kc. and 1333 kc. are still shown on the printed station list included in the design.

The address of the Singapore studios is—"**Radio Malaya**," **Cathay Building, Singapore.**

Stations carrying "**Radio Malaya**" programmes operate at present on the following medium wave channels with additional outlets on shortwave operating from Kuala Lumpur and Singapore.

620 kc. Singapore, 10 kw. Leaves the air at 12.30 except Sunday mornings (Saturday nights, of course, in Singapore) when they run an extra half hour. The last several hours of transmission are in English, with a news bulletin at Midnight. Announces as the "**Blue Network.**"

740 kc. Singapore 7 kw. Signs off nightly after a two-hour Chinese programme at 12.30 a.m. This is known as the "**Red Network.**"

1203 kc. Kuala Lumpur, 1.2 kw.
1013 kc. Kuala Lumpur, 250 watts.
1280 kc. Penang, 2 kw.
1101 kc. Penang, 400 watts.
1023 kc. Seremban 50 watts.
1073 kc. Malacca, 50 watts.

It is of course most unlikely that the two latter transmitters would be heard over here running such low power, but under particularly favourable conditions some readers may catch them. No doubt too, Lahore 1022 kc. would interfere with Seremban, whilst it is not very likely that the 400 watt transmitter on 1110 kc. would be able to override the signal from 2UW, Sydney, which is on a 24-hour schedule. However, the others on the list should be tried for.

by
ROY HALLETT

S.A. "All Night" Schedules

During the strike period Adelaide stations have been taking turn about presenting programmes from normal close down time till 6 a.m. S.A. time next morning, providing local electricity supply authorities with a means of warning industry when to "ease up" on their consumption of power to avoid overloading generators at the city power station.

We were a little puzzled at first when listening for the new 1XH one morning recently to experience strong interference from a station on the same channel. However a word or two from the interfering station announcer left us with no doubt that it was 5AD taking its turn on Adelaide's emergency all night shift.

Philippine Islands News

Signals from the Philippine Islands have been quite fair to good over recent weeks. Art Cushen has reported **DZFM** heard till signing off at 2 a.m. on 710 kc. George Francis reports **DZRH, Manila**, 650 kc. as poor, although this one is generally fair level at our listening post. **DYRC, Cebu City**, 600 kc. is also reported as poor level.

DYBU, situated in **Cebu City**, operating on 1250, is another good one to tune for, remaining on the air till 2 a.m. when it closes after a short news bulletin. Listen, of course, also for the Manila stations **DZAB, 760 kc.** and **DZMB 860 kc.** from around midnight till around 2 a.m.

Although we have had little success logging this one at our listening post, ZBW, Hongkong, is apparently getting through at some locations on 845 kc. according to a "Radio Call" report. Listen around midnight; English language is used and European music is generally featured from this station.

HLKA, 970 kc. provides one of the best signals from Asia at present. Long station announcements are broadcast in English just prior to closing at 1.30 a.m.

The Manila, P.I., relay station for "**Voice of America**" shortwave service on 920 kc. is quite good most nights. It is easily identified and can be heard around midnight.

WVTR, the American Armed Forces Radio Service station in **Tokyo** is a good one for newcomers to listen for. Operating on 870 kc, this station is usually quite strong from around 11.15 p.m.

Are you interested in Broadcast DXing? If so, you are invited to send in reports of your latest logging, equipment being used, as well as any suggestions regarding the information you would like included in this page. All letters should be posted direct to Mr. Roy Hallett, 36 Baker St., Enfield, N.S.W.

READERS' REPORTS

Mr. R. Harding, Lakemba, is quite pleased with the performance of his receiver on both broadcast and short wave bands, particularly as he, with friend Bill Belford, built it up. The valve line up at present includes, ECH35, EBF35, 6H6, 6V6, 5Y3, and a magic eye tuning indicator.

An Indian station near 750 kc. (quite probably **Tiruchi, 758kc**) provides a surprisingly good signal on this reciever around 12.30 a.m., whilst on the 1500-1600 kc. band, **XERF, 1570kc** is quite fair with its hillbilly programme around 9 p.m. Operating from over the U.S. border in Mexico, this station may be addressed "**Del Rio, Texas, U.S.A.,**" and now appears to be the strongest signal on this section of the band at many locations. Announcements, when given, are in English, and consist largely of advertisements.

At our listening post, perhaps the next strongest signal on this band is **KOMA** in Oklahoma City, Oklahoma,

(Continued on page 39

SHORTWAVE LISTENER

SOME RECENT VERIFICATIONS

Mention was madè of Radio Hue in a recent issue. Now a verification has been received by your editor, and the text is given for the interest and help of readers,

Radio Hue,
Post Box 65,
H U E. ANNAM. 21st June 1949.
"The Director, R. Steenbrugge writes—

I have this day received your listening notes on Radio Hue, and we thank you for the information that you sent us on our broadcast. I hope to have the means of putting on an English broadcast, and will not fail to advise you of this. For the moment the general outline of our broadcasts is as follows (G.M.T.)

2300 to 2330 — Relay of Radio Saigon
0930 to 1030 — Voice of Vietnam (in Vietnamese)
1030 to 1050 — Broadcast to French troops in Central Annam.
1050 to 1200 — Variety Program.
1200 to 1215 — News.
1215 to 1230 — Records and closing theme.

AUSTRIA

A letter recently received from the Radio Service for the United States Forces in Australia, which operates under The Blue Danube Network, may be of interest to those who are hearing the transmissions. It reads as follows:—

"I wish to thank you for your fine letter of the 9th May, our Engineering department was greatly interested in your report of reception, and the broadcast which you heard came from our Salzburg Station KZCA, now operating on a shortwave frequency of 9533 megacycles."

A current schedule was enclosed and the writer said that the station appreciated the interest and thoughtfulnss in sending on a report.

Address is as follows:—Floyd H. Willey, U.S. Civ. Chief, SSO. Blue Danube Network, A.P.O. 777, U.S. Army.

PAKISTAN

A card of Verification together with a letter was received recently. The card is rather unique in its design, groundwork is white, with a green and black setting for the Official insigna of Pakistan. The wording on the foot of card confirms the reception report, and states Radio Pakistan is now located — Karachi, Peshawar, Lahore and Dacca, but only Dacca on Shortwave at present. (Ed.)

NICARAGUA

Yet another Sth. American station has news in English, and this service is dedicated and beamed to listeners in North America, YNVP, La Voz de Nicaragua, transmitting on a frequency of 6758 kcs., with a power of 0.8 kws. The service is from the capital, Managua, and the times are 12 a.m. till 2 a.m. and 9 a.m. till 4 p.m. Signal strength is good, according to an English correspondent. (Eric Good.).

NEW STATION LOGGINGS

Callsign	Kcs	Metres	Location	Time Head
YSR	6,272	47.83	San Salvador	10.00 p.m.
ZYF8	4,955	60.54	Manaos, Brazil	8.00 p.m.
YVMO	4,990	60.12	Venezuela	8.45 p.m.
YVKC	5,020	59.75	Venezuela	9.30 p.m.
CKLO	9,630	31.15	Canada	7.15 p.m.
ZL2	9,780	30.67	New Zealand	7.00 p.m.
HPC	7,005	42.83	Siam	9.00 p.m.
V. of America	17,770	16.88	Manila Philippines	7.00 p.m.

STATION ADDRESSES

REPUBLIC OF COSTA RICA

TIPGH — Alma Tica, Apartado 800. San Jose.
TIRH — Radio El Mundo, San Jose.
TILS — Radiodifusora Para Ti, Apartado.3. San Jose.
TIEP — La Voz del Tropico, Apartado 257, San Jose.
TIRCC — Radio Emisora Catolica, San Jose.
TINRH — La Voz del Costa Rica, Apartado 1064, Heredia.

EL SALVADOR

YSR — La Voz de el Salvador. San Salvador.
YSF — Radio Vanguardia, San Salvador.
YSA — Radio Cultura, Santa Ana, San Salvador.
YSW — Radio del Pueblo, Santa Ana, San Salvador.
YSHQ — La Voz del Progreso, San Salvador.
YSI — Radio Intercontinental, San Salvador.
HUB — Radiodifusora Nacional. San Salvador.
YSPD — Voz de la Cuscatlan, San Salvador.
YUSA — Radio Mil Cincuenta, San Salvador.
YSN — Voz de la Democracia, San Salvador.

CHINA

Communist transmitters are being heard on various short-wave channels since the Nanking stations have changed hands. In addition to the normal channels used in the various towns in North China they have been heard on Nanking channels 5985 and 9730 megacycles. Other channels reported are 14.950, 6.096, 9.040, 10.260 megacycles. Ken Desouza, of Singapore, reports these stations to be of very low power.

In Communist-controlled territory, call-signs are not used, and it will be noticed that in some instances station's are now in the Communist areas and will not use the call listed by the Nationalist Government. One example of this is the Peiping transmitters, who announce as the New China Station.

LISTEN FOR THESE

ANGOLA

From Radio and Television News, U.S.A. we have some interesting news of these stations. In sending on a verification card to Rex Gillett (Australia) the station advises that Radio Clube de Angola, CR6RL on 9470 kcs, and CR6RN 8090 kcs, operate from 11.30 p.m. to 2 a.m., while CR6RA, on 10.795 kcs is on the air from 11 a.m. until 1 p.m.

CR6RH on 8232 kcs Hilla, has extended its schedule by a half hour, and now runs to 1 a.m., Radio Diamang, CR6RG on 8242, at Dundo has been heard at 12 a.m. to 12.30 a.m., with Portuguese National Anthem.

Speech intelligibility low with bad QRM from stations using both CW and phone, some days orchestral music is heard at 11.45 p.m., both man and woman are announcers, but no English is noted. (Pearce).

Radio Clube de Angola, Luanda, sent a QSL card for the reception of CR6RN on 7142 kcs, and said that this replaced the 8090 kcs channel. Also asked for a check on CR6RL on 31.68 metres, approximately 9470 kcs.

BRAZIL

An American correspondent recently received a letter from Ceara Radio Club, Fortaleza, in Brazil, and its contents will be of interest to those hearing the transmissions on 15.165 kcs. The station is said to open at 1 a.m. and continue until 2 a.m., announcements are made in Spanish, French, Portuguese and English.

The letter says:—"Your most welcome report recently reached us and we surely were glad to hear from you, we would appreciate you telling your friends about our international program, for we don't receive many letters from your country, which we sincerely regret, so give us a hand, will you? Your co-operation will be greatly appreciated by us, let us hear from you again, won't you?

The international program is on the air, Mondays and Fridays from 11 p.m. until 1 a.m., with announcements in English, Epanish, French and Portuguese. (Boice.)

SIAM

Ken. DeSouza of Singapore, reports by way of Radio Australia an interesting item of news on The Overseas Station of Siam, giving times and frequencies, as follows:—

10 a.m. till 11 a.m. on 6010, 7105, and 11650 kcs.

7 p.m. until 9.30 p.m. on 600, and 11650 kcs.

10 p.m. till 1.30 o.m. on 6010, 7105 and 11650 kcs.

Another new transmitter has been logged on 7005 kcs, from 7 p.m. until sign off at 10 p.m. The entire program is in Thai, with Western, Thai and Chinese music. On Wednesdays an English/Thai language lesson is broadcast at 8.30 p.m .till 9 p.m. No identification in English is given, however subjects for the lessons are taken from Bangkok daily newspapers .

A time signal of six pips has been heard, and the callsign appears to be HPC. This station does not take programmes of other Bangkok stations, and is **not** on the air on Sundays.

PAKISTAN

Radio Pakistan, Dacca, has moved from 1527 kcs. to 15,335 kcs. the schedule is as follows: 11.30 a.m. till 1.30 p.m., 3.30 u.m. till 5.30 u.m., 9 p.m. until 2.30 a.m. News in English is given at 12 p.m., 4.10 p.m. 10 p.m. and 2.45 a.m. Talk in English on Pakistan will be given on Sundays at 4.30 p.m.

Radio Pakistan, Lahore, on approx. 11740 kcs. news in English at 12 p.m., 5.10 p.m., 9 p.m., 12.45 a.m.. and 2.30 a.m. (Illias.Cochin-India.)

GERMANY

We have details of some transmitters operating from Berlin, Stuttgart and Hamburg. RIAS on 6080 kcs is heard with a strong signal at 9 p.m., and again at 4 a.m. after "The Voice of America" program, and with RIAS programs until 5 a.m. Radio Stuttgart on 6030 kcs is heard with some difficulty through QRM after 9.30 p.m., it has News in German at 4.45 p.m. and 9. 45 a.m. and fades out around 12 p.m. This same transmitter has been heard at 3.20 a.m. till 4.30 a.m. at good level, and signed off at 5 a.m.

FRENCH MOROCCO

Radio Maroc, on a freq. of 6005 kcs, has been heard at 11.30 a.m. to 12.15 p.m., with French News, at 11.45 a.m, to 12 p.m., then Arabic to Sign off. Location is Rabat. (Alfred.)

Readers' Reports

Readers desirous of submitting Short Wave reports for inclusion in these notes should eusure that they reach our Short Wave Correspondent not later than the 1st of each month. Address all letters to: Miss D. Sanderson, 23 Elizabeth Street, Malvern, S.E.4., Victoria.

PORTUGAL

A station announcing as Emissora Nacional at 9 p.m. is heard with news in Portuguese and musical items, seems to sign off at 4 a.m., according to an American correspondent.

Radio Clube Portuguesa CS2W1 on 12,875 kcs has been heard with English vocal recordings at 3.40 a.m., man and woman are heard as announcers, plenty of chimes used as interval signals, but no English noted. Also has guitar music with vocal by man in the Portuguese language.

Lisbon on 11.027 kcs is heard at 11 a.m. until 12.45 p.m. when the station fades out. seems to be off on Sundays. ZPA1 Radio Del Sstado, Asuncion, transmits on 6275 kcs. with a power of 3 kilowatts, daily in Spanish from 8 p.m.. till 10 p.m., and 4 a.m. until 8 a.m.

PARAGUAY

ZPA5 Radio Encarnacion, now has a somewhat irregular schedule, seems to be on at 7.30 p.m. till 10 p.m., and 1 a.m. until 3 a.m. The early sign off is due to an electricity shortage. Frequency is 11.945 kcs. (Leven.)

LUXEMBOURG

Radio Luxembourg on a frequency of 15.350 kcs signs on at 5 p.m. It has news in French at that time. The 6090 channel is heard on Sundays with an English program from 9.30 p.m. until 11 p.m., then a French program. The station announced another English session at 3 a.m. (Pearce.)

MADASCAR

A correspondent in Hawaii reports that Radio Tananarive on a frequency of 12.127 kcs is heard from 5.45 p.m. until 6.10 p.m. on a fair level.

The 9695 outlet is heart at 8.30 a.m. signing on with "La Marseillaise" then has a musical program; news in French at 9 a.m., music again until 9.20 a.m. to 10 a.m. when the station fades out It is easily recognized by the call 'Ici Radio Tananarive."

LEBANON

Printed schedules received from Ted Norris of Beirut, give some details of transmissions being heard from that country, and they list Radio Leban on 8036 kcs at 10.45 a.m. till 11 a.m., (Sundays 11.45 a.m. until 12 p.m.,) 4.30 p.m. till 5.30 p.m., 12 a.m. until 1.15 a.m. News in French at 10.45 a.m., (Sundays at 11.45 a.m.) 4.30 p.m. and 12 a.m. I believe that English is used between 8 p.m. and 9 p.m.

BEIRA

From Mervyn Laubscher our correspondent in South Africa we have an interesting item of news on Aero Clube da Beira, which is back on the air again.

After some absence, it is listed as being on 7155 kcs but is being heard on approximately 7200 kcs with a good signal and signs off at 1 a.m. It is supposed to have increased its power, as it is listed as using 300 watts.

SUMATRA

According to a verification received recently from Radio Palembang this station is on the air daily on 4855 kcs from 2.30 p.m. until 8 p.m. with programs in Dutch, and Indonesian—QRA for reports is given as—

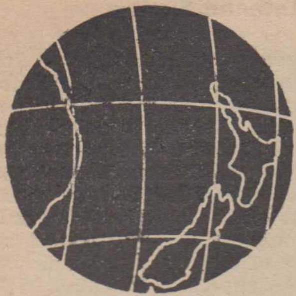
..Radio Palembang, Katoorin Studio, Talang Djawa 7, Palembang, Sumatra. (Gillett.)

ECUADOR

HCJB, QUITO, is now issuing schedules quarterly, free on request, and the address is HCJB, Casilla 691, QUITO, ECUADOR, Sth. America.

English periods are scheduled now Tuesday through Sunday:—4.30 p.m. till 5. 30p.m. on 12.455, and 9958 kcs, 3 am. till 4 a.m., 7 a.m. until 9 a.m. on 15.115, 12455, and 9958 kcs, 9 a.m. until 11.30 a.m. on 15.115, 12.455, 9958, and 5995 kcs, and to Europe on 17,890 and 15.115 kcs at 1 a.m. until 2 a.m.

Chief engineer Howard Clayton informs Ken Boord of Radio and Television News that he is getting a lot of good reports on the 16 metre transmission and feels very much encouraged with the new frequency. (R & T.N.USA.)



TRANS-TASMAN DIARY

By J. F. FOX
(Special N.Z. Correspondent)

MOBILE RADIO SERVICES EXTENDED

Since the introduction of the first mobile radio-telephone station in Auckland over two years ago, users have acclaimed the system and it is now being expanded to take in other areas.

It is less than two years since the first mobile radio-telephone station was opened by the Post Office at Auckland, but since then the service has expanded and users are acclaiming the system.

The Wellington Co-operative Taxis Ltd. can claim being the largest users of the service in the Dominon, the company has some 40 units in operation. The Wellington fixed stations are located at Tinakori Hills and Mount Crawford. In the Queen City, its units are working while an additional eight are to come into use shortly.

At Christchurch, four units are already working, though a fixed station is yet to be established on Cashmere Hills. When this station is opened 30 taxis will operate on a separate private utility channel.

Meanwhile, in Dunedin the two fixed locations at Roslyn and Highcliff are providing coverage for the city and Port Chalmers area for the Dunedin Metropolitan Fire Board who are the only users at present.

In the Hutt Valley district a station will be erected on the Western Hutt hills; however an interim service will commence with a few week's with a station located on the roof of the Hutt Post Office. One public and a private utility channel will be available.

At Napier and Wanganui surveys have been carried out by Post Office engineers, and a service will be established for business concerns in the near future. At Palmerston North, eight units were expected to be in operation by the end of June.

Large Order Placed

One of the largest peace time orders for specialized radio equipment ever to be placed in New Zealand has just been given by the Post Office to a Wellington manufacturer. The equipment provides for fifty mobile radio-telephone base station units which will be built to a prototype designed by Post Office engineers.

A few of the new units will replace modified war surplus equipment at present in use in the mobile telephone services at the four main centres. Some of the units now in use by the Police Department will be replaced, but most of the new equipment will provide service for new mobile subscribers, such as the fire, traffic and ambulance services, and for taxis, carrying firms and other private utility concerns.

Party-Line System

To provide the simplest and cheapest way of giving the advantages of this modern mobile service, the communications for public and private utilities will continue for a time to be on the party-line system which is already successfully operating in the four centres. Later, should users of the service wish it, the selective calling of mobile units will be possible. This will mean that they will be able to call the one they want without other units hearing the call.

A future development envisaged by the Post Office is the provision of public telephone service for mobile. By this service a mobile unit could be connected to any number in the telephone system. This is, of course, some way off yet, but the work now being done in establishing remotely-controlled radio stations will form a valuable basis for the eventual mobile-unit-to-public-telephone system.

The hilly nature, the general topography, of New Zealand presents some difficulties in obtaining adequate coverage for mobile

THE VOICE OF WAIKATO

Yet another radio station has come on the air in New Zealand. This time it is station 1XH, "The Voice of the Waikato," which opened on Saturday, July 2, at 8 p.m.

Like its sister station 3XS Timaru, station 1XH is designed to serve the Waikato district and operates along the same lines with commercial and non-commercial programmes for seven hours each day.

The station is in two parts of the City of Hamilton, the studios are in the basement of the City Council Chambers in Alma Street while the clerical advertising and copywriting section are in Clark's Buildings, Ward Street. The station manager, Mr. C. I. B. Watkins, is well known to listeners of 4ZB, 2ZB, 2ZA, and 2XN.

New Antenna Tower

Station 1XH is the first station to have the new 175 feet mast, and this was erected in six days at the transmitter site at Hillcrest near the junction of the Morrinsville and Rotorua highways. The unattended transmitter has a power of two kilowatts and operates on a frequency of 1310 kilocycles. Unlike Timaru, no temporary equipment is installed, for the audio frequency equipment at 3XC was of a temporary nature pending delivery from Australia of the proper equipment.

radio services. The most effective types of radio waves for this class of communication are those falling in the very high-frequency part of the radio spectrum using wavelengths a few feet in length. With these frequencies radiation is extremely effective where there is a line-of-sight path but falls away rapidly where there is a line-of-sight path but falls away rapidly where there are large obstacles, such as ranges of hills.

The Post Office carried out extensive investigations, including field surveys, in Wellington and Auckland to determine the best system and technical designs to be employed. The results of these tests, as well as guiding the Post Office's own work in providing base facilities, were incorporated in mobile apparatus of prospective subscribers. Local Manufacturers and importers were told of this some eighteen months ago, and so have been able to furnish suitable types of equipment for use in the service.

Diversity System Used

The particular radio system adopted by the Post Office is a recent development known as the multi-carrier or diversity transmission system, the only system available at present by which coverage of an area can be extended. This feature is of the utmost importance in countries like New Zealand, where the nature of the land effectively limits the usefulness of transmission by a single station.

For example, in the Wellingeon area the assured coverage obtainable from a single station would be limited to the area enclosed by the hills surrounding the harbour. By using multi-carrier transmission this coverage can be extended to bring in areas such as the Porirua basin and Hutt Valley. The cost of excessive lengths of control line usually make it uneconomical to extend the coverage any further.

The only visible sign of this Post Office service is, a small table cabinet which forms the control unit and sits on the table in the subscriber's office. It has a loudspeaker for the reception of incoming speech and a hand-microphone for speaking to the cars. This unit connects through underground telephone cables to the unattended radio station where the transmitters and receivers are located, together with a special type of aerial used both for sending and receiving.

Vehicles taking part in the mobile radio service can be recognised by the short vertical radio aerial which is usually mounted on top of the car. This is used both for transmission and reception, the controls being placed in a convenient position for use by the driver while travelling or stationery.

Rotorua Is On The Air

The well-known tourist resort of Rotorua made another step towards progress recently when the New Zealand Broadcasting Service commenced regular transmissions from Station 1YZ.

Rotorua's station came on the air on April 27, when the Minister of Broadcasting declared the station open at 8 p.m. Designed to serve the Bay of Plenty area, 1YZ completed the YZ network of stations and is the 23rd Government station on the air.

The studios are located opposite the Municipal Buildings in Arawa Street, and are constructed of surplus Air Force materials used during the war. This temporary establishment consists of a medium size studio, an announcers' studio and a control room. The remainder of the building contains the necessary offices for the administration of the station. When building restrictions are lifted, permanent buildings at both Rotorua and Tauranga will be erected with a further set of studios.

Since its inauguration, 1YZ has received hundreds of reports on its reception. Primarily intended for Rotorua and the Bay of Plenty districts, 1YZ has been reported with excellent signals throughout the whole of the dominion. From Kaitaia in the north to Invercargill in the south listeners are receiving the Rotorua station with perfect signals. In Dunedin, where 4YA is only 20 kilocycles away, 1YA is heard as good as 3YA.

However, this does not complete the area so far reported. From Noumea, in New Caledonia, a listener has written in saying he is hearing 1YZ at great strength. The Melbourne office of A.W.A. state that reception is good in the Victorian capital. It will not be surprising if in the near future 1YZ receives reports from the North American continent, where its signals should be heard well.

New Antenna System

Paengaroa, on the road to Tauranga and 25 miles from Rotorua, is the location of the transmitter and the now well-familiar 500 ft. radio mast. The aerial system is new to this country, for it consists of a 500 ft. steel mast radiator, which is sectionalised and loaded with an inductance coil at a height of 370 ft. The remaining 130 ft. is completely insulated from the lower portion of the tower, which gives maximum ground-wave and minimum sky-wave radiation, thereby giving maximum primary coverage.

Using a modern transmitter constructed by Amalgamated Wireless Australasia Ltd., 1YZ gives a radiated power of 10 kilowatts on a frequency of 800 kilocycles. The transmitter employs high-level class "B" modulator and uses air-cooled valves throughout.

Mr. K. G. Collins is the station manager, while Mr. H. J. Alexander is the senior technician, and Mr. A. E. Sanft is the chief announcer.

The inaugural programme took place at 8 p.m. on April 27, when the Minister of Broadcasting, Hon. F. Jones, declared the station open. Other speakers were the local members of Parliament, and the mayors of Rotorua and Tauranga, who were welcomed by the new Director of Broadcasting, Mr. William Yates. A programme by local artists, including Maori entertainers, concluded the opening programme.

Synchro-Cyclotron

A new atom-smasher which will provide for an energy output of over 400 million electron volts has been planned for the Carnegie Institute of Technology. It is hoped that this equipment will enable the bombardment of mesons, particles found in cosmic rays, and thus furnish a key to the nature of the forces that hold atomic nuclei together.

The coils will carry 20,000 amperes and will produce a magnetic field of 20,000 Gauss. The magnetic force between the pole faces will be 1250 tons. Under construction now ,this cyclotron is expected to be in operation by 1950.

Lightning Strokes Prefer Tall Buildings

Continued from page 7

Similar unhappy results may occur with poorly grounded lightning rods or masts. Lightning current flowing in a high contact resistance between the grounding electrode and earth creates a voltage drop, so that the shielding conductor may be raised many thousand volts above true earth potential. In Fig. 5 (b) is shown a house with a lightning rod. The resistance of the earth connection is high.

If the rod is struck, a spark may jump from the rod to some nearby grounded object in the house, such as a water or gas pipe or to the electric wiring. This occasionally happens, as manifested by flashes in rooms, the stripping of shingles from roofs, or plaster from walls, or similar occurrences. Poorly grounded lightning rods may be a hazard rather than a safeguard.

Correct Grounding Essential

One of the principal reasons why lightning rods were in disrepute for some years is that in many cases little attention was given to careful grounding. Lightning rods can be very effective if the teachings of Benjaman Franklin, augmented by the later experimental data that was denied him, are observed.

Methods and instruments for measuring the resistance of the ground termination are available, and it is wise to use them because the resistance of a ground cannot be termined by looking at it. How low should the resistance be? The lower the better; one ohm is better than many. In some soils it is easy to secure low ground resistance, in others it may be extremely difficult.[5]

In the case of long, circuitous conductors the rapid rate of rise of lightning current may produce voltage as a result of inductance. The inductance of a straight wire of usual cross section is about 0.4 microhenry per foot. A lightning current rising at the rate of 10,000 amperes per microsecond—a high but not improbable value—will produce 4000 volts per foot of wire as long as the current is rising at the aforementioned rate. In a 50-foot length of wire this amounts to 200,000 volts, sufficient to bridge a foot or so of air to an adjacent grounded conductor. Lightning conductors should therefore be as straight and direct as possible.

Side flashes and consequential damage as a result of bad grounds or long leads are not inevitable, because lightning currents vary in intensity. Many strokes contact trees or masonary or poorly grounded lightning rods without causing damage. However, the purpose of protection is to insure against the widest range of practical possibilities.

The opinion is sometimes advanced that lightning has a penchant for jumping from conductors at sharp bends, because of the "inertia". This is erroneous. If it jumps from a sharp bend to some other object it is probable that the path from the bend along the lightning conductor to ground is long, and therefore has appreciable inductance, or there is resistance somewhere in the path, so that a high voltage exists momentarily, sufficient to spark to something in the vicinity of the bend. The clearance to other objects is probably least at the bend, for that may well be the reason for making the bend.

Lightning current is an electric current, and doubtless many of the reported miraculous occurrences could be explained by the application of the laws of electro-physics if all evidence and facts could be ascertained. That is usually difficult to achieve because lightning damage has much in common with an automobile accident, as far as evidence and recollection are concerned.

Overhead Wires

The considerations pertaining to tall structures and their shielding influence apply also to overhead wires. Suppose a horizontal conductor be supported on piles, Fig. 6. The wire, like the mast, will attract leaders that approach within its sphere of influence. Since such a wire may extend for miles, the probabilities of its being struck become appreciable.

Statistical data indicates that transmission systems, meaning the line conductors or their overhead ground wires if present, are struck on the average of once per mile per pear, if located in isokeraunic levels of 30. If the wire has no direct metallic connection to the earth, the lightning current will produce very high voltage, and flashover to ground will probably occur. If the wire is grounded at intervals high voltage is prevented. The wire acts like a continuous lightning rod.

Such a grounded wire also provides a protected zone paralleling the conductor. Another wire within this "tent like" volume is not likely to be struck directly. This is the principle of the overhead ground wire widely used over transmission lines.[6] The shielding angle to assure 0.1 per cent exposure is 30 to 45 degrees, depending upon the height above ground. The matter of secondary fiflashes from a struck ground wire system to the line conductors is an important consideration.

A simple arrangement on a wood pole of one line conductor with an overhead ground wire is suggested in Fig. 7. In (a) the down lead that connects the ground wire to earth is attached to the pole. It is assumed that the ground resistance is high.

When the ground wire is struck, currents are as indicated. The current in the down lead and into the earth causes a voltage drop in the ground connection, thereby raising the potential of the ground-wire system above true ground. The line conductor is held at a potential, which is near ground, by its capacity to ground. It picks up voltage from the struck ground wire by coupling. The coupling factor may be 30 to 40 per cent. The difference in potential between the ground wire and the line conductor may thus become high, and if the clearance between the down conductor and the line is small, of if the pole is metal and the insulator is small, a flashover occurs from the ground-wire system to the line conductor.

This is just as bad as a direct hit on the line conductor with a flash to ground, because either may cause a short circuit. Furthermore, a backflash from the ground wire to the line injects current and high voltage into the line, which may unnecessarily endanger other insulation.

Ground resistance and clearances are important considerations in the design and construction of lines with overhead ground wires. Sometimes special measures are necessary to obtain reasonable ground resistances, and sometimes it may also be necessary to offset the down leads so that adequate clearances are secured, as in the right hand view of Fig. 7.

The foregoing is an elementary description of the factors that enter into the arrangement of a simple combination of line and overhead ground wires. The design of lightning-proof transmis-

(Continued on page 39

Basic Electricity & Magnetism

Continued from page 19

make sense. It only makes sense if we think of current as being a quantity of something, and since an electric current is NOT a quantity but a description of the dynamic state of electric charges, the term, **current flow,** promotes ideas that are entirely wrong and which often inhibit you in comprehending many of the complex phases of electrical phenomena.

Many of the latest text books, especially those of an advanced nature, recognise the danger inhering to the term, **current flow,** and use phrases like, **the current is established, the current exists, the current is directed.** Such phrases imply the true nature of current.

B. M. Strong in his Basic Analysis of Electrical Engineering says, "The use of the term current, even electrically, customarily takes liberties with the strict usage . . . It is quite usual to find expressions as "the current flows", "the flow of current" and the less objectionable, "current flow" when it would seem preferable to say, "the current is directed", the "direction of current," or merely, "the current." This seems to arise from a long period of indefiniteness about the substance of the current when the layman, at least, had little concept of electric current beyond its being "the juice." He naturally assigned to "current" a sense of substance beyond the mere rate of flow which it strictly connotes. Because the direction of electron flow has been found opposite to that assumed for conventional current, it is still embarrassing to explain just what actually flows in the direction of the convevntional current."

Since the current concept is the notion on which we build all our concepts about dynamic electricity it is clearly necessary to have the right idea about electric current, and we must discard any terms likely to promote wrong ideas.

Electrical Conduction

Electrical conduction is the transfer of electrical energy from one place to another. Electrical energy can be transmitted with varying degrees of efficiency through solids, gases, liquids and space, and its transmission is usually accompanied by one or more secondary effects which may be regarded as by-products of the actual transmission, which are often undesirable but are accepted as losses.

TRY THESE PROBLEMS

1. A variable air capacitor has a minimum capacitance of 50 pfd. and a maximum capicitance of 500 pfd. If the p.d. is 200 volts across the plates when the capacitance is at maximum—
   (a) What is the p.d. across the plates when the capacitance is a minimum?
   (b) Neglecting friction, what work is done in rotating the the plates from the maximum to their minimum positions.
2. Two strips of paper 0.003 in. thick and 1 in. wide are used to make a fixed capacitor of 0.1 mfd. What is the length of each piece of paper? Take the dielectric of paper as 4.
3. A current of 10 amperes exists in a circuit containing a capacitance of 8 mfd. for 500 microseconds. Assuming that the current remains uniform—
   (a) What is the total charge given the capacitor?
   (b) What is the final p.d. across the capacitor plates?
   (c) How many electrons are transferred from one plate to the other by the charging of the capacitor?

Our immediate interest is the transmission of electrical energy through solids which, according to the **Electron Theory,** is due to the presence of **free electrons** within the solid. Solid substances which permit the transfer of electrical energy with a minimum loss are classified as good conductors. Good conductors are characterized by the extremely loose bonds which exist between nuclei of its atoms and the electrons in the outermost orbits of these atoms. These electrons drift haphazardly from atom to atom and are called **free electrons.** Their degree of freedom is course insufficient to permit them to escape entirely from the confines of the body.

While we have no definite proof as to the exact number of free electrons there are per atom in a conducting solid, it has been found experimentally that little error is introduced by assuming that there is one free electron per atom, and we will use this assumption shortly in developing a mechanical picture of how charge is transferred along a solid.

Mathematical Significance of Current

Accepting the theory that the transfer of electrical energy is due to the movement of free electrons through a solid it becomes necessary to express the idea mathematcially. We have previously seen that an electron may be regarded as a particle or as a wave, but, visualising the electron in this case as a particle, then we can accept it as having mass as well as inertia.

It has been experimentally established that an electron has a charge equivalent to 1.602×10^{-19} of that endowed on a coulomb of electricity, which, you will remember, is the practical unit of electrical quantity. It follows that it requires 6.28×10^{18} electrons to promote a charge equal in intensity as that given by one coulomb. It is clear that the charge of the electron is so microscopic that it would make mathematics dealing with it unweildy so that, despite the acceptance of the electron theory we still use the coulomb as the practical unit of quantity.

The movement of charge through a solid is best visualised as thinking then of so many coulombs of electricity passing any selected point in the conductor every second. This picture gives us the idea of a **time rate displacement of quality;** a ratio of quantity to time. Mathematically,

$$\text{Current} = \frac{\text{Quantity}}{\text{Time}}$$

Introducing practical units of quantity and time we get,

$$\text{Unit Current} = \frac{\text{Coulombs}}{\text{Seconds}} \quad \ldots 11.2$$

Unit current is called the **ampere,** and one ampere exists in an electrical circuit when one coulomb of electricity passes a given point in that circuit in one second.

Finally, introducing symbols, we get

$$I = \frac{Q}{t} \quad \ldots . 11.3$$

where I is the current in amperes, Q is the total charge in coulombs, t is the time in seconds.

Equation 11.3 is true only when the current is uniform. Later we will derive an expression for cases when the current is not uniform.

Transposition of Equation 11.3 to

$$It = Q \quad \ldots . 11.4$$

allows us to express current and time in terms of quality, and substituting this value Q in the basic capacitance equation, we get

$$C = \frac{It}{E} \quad \ldots .. 11.5$$

We will later be using Equation 11.5 in deriving a number of very interesting relationships and its importance will be appreciated then.

On The Broadcast Band

Continued from page 32

U.S.A. Operating on 1520 kc., this one is quite fair with news highlights and weather notes at approximately 9.4. This news is generally preceded by a popular tune, after station announcements, while music is again featured after the news from about 9.11. Both KOMA and XERF generally verify DXers reports.

Mr. George Francis has written us for the first time from his home near Daily, Eastern Victoria, mainly to advise reception of what appears to be a new American station operating on 1520 kc. This reader heard the station conducting equipment tests around 7.15 p.m. late June and believed the call sign announced to be KPED. A request for information on this one had me puzzled at first, although there had been a reference in "DX Times" to reception by N.Z. DXers of a station testing on this channel using the call sign KTED.

Art Cushen however came to the rescue with advice to the effect that station KTED, Laguna Beach, California is now in this channel, running 1,000 watts during the daylight hours, and 250 watts at night. It is believed that 1,000 watts would have been the power used for equipment tests. We think our Victorian friend should feel proud of his logging and look forward to hearing of his receipt of a verification from the station.

While on this band, Art Cushen has received a verification from VIA operating from Adelaide, in contact with ships at sea. This was heard around 6,30 p.m. and advises 250 watts, having been assigned 1520 kc, although for the time being will use 1540 kc. We are not certain just when the move is to take place, but this is certainly one to watch for, with 1520 kc being the likeliest channel.

Evening DX

Mr. Francis is experiencing some interesting early evening DX, which is something we do not hear a great deal about from listeners in this country. Our own location does not appear to favour us in this regard, whilst our colleagues in New Zealand, of course, thrive on their opportunities of hearing American stations towards the end of their night transmission.

He believes a station heard on 1500 kc. around 5.15 a.m. to be WTOP way across the U.S.A. in Washington, D.C. This is quite good DX indeed, as this station is rarely reported over here. In most cases 2BS Bathurst causes interference to this one as it is not heard at very good volume.

From the American West Coast, KGA, Spokane, 1510 kc., in the State of Washington, is fair level around 6 p.m., while under this one around 5.30 p.m. station KUSN, in San Diego, California has been identified. Last heard, this one used only 1 kw.

On 1530 kc this readers hears KFBK, Sacramento, California around 6.30 p.m. This is eventually blotted out by 5AL, Alice Springs, around 7.30 p.m., which in turn suffers from interference from WCKY, Cincinatti, Ohio towards 9 p.m. KFBK is also heard about this time.

Transmission Techniques.

Continued from page 31

Frequency Multipliers

Since the pulse of plate current produced at the peak of each cycle is far from sinusoidal in character, many harmonics of the fundamental frequency will be produced. Selection of the desired harmonic frequency may easily be accomplished by tuning the anode circuit to that frequency. In order that maximum efficiency may be obtained, in this class of operation, it is desirable to use a smaller operating angle than normal for Class C operation, and this entails an increase in the applied grid bias, often up to five times cut-off.

Whereas the efficiency of the normal Class C amplifier can reasonably be expected to be about 75%, the maximum efficiency of a doubler stage is about 50%, and that of a trebler stage in the region of 35%.

As the effect of the normal push-pull connection of the amplifier tubes is to cancel out, or at least greatly attenuate all the even harmonic frequencies in the output circuit, it is not possible to use a push-pull stage as a doubler. However it is often used as a tripler, particularly on the Ultra High Frequencies, where the push-pull connection minimises the effect of distributed circuit capacitances, and allows the use of more efficient balanced tuned circuits.

The efficiency of the frequency multiplier stage falls off very rapidly above the third harmonic but a satisfactory output can be obtained as a quadrupler using the circuit of Figure 3b. Here the cathode circuit is tuned to the frequency of the second harmonic, as shown, and an efficiency of between 20% and 30% can usually be realised.

As stated above, the normal push-pull stage cannot be used as doubler, due to the cancelling action of the even harmonics, but the circuit shown in Figure 3c is often used and is that of the "push-push" doubler. This particular circuit has a somewhat higher efficiency than the normal doubler stage, due to the fact that the driving pulses are delivered to the tuned circuit at twice the fundamental frequency.

This may be seen in Figure 3 where the respective anode currents are 180° out of phase, occurring at such a time with respect to each other that they sustain the harmonic oscillations in the load circuit, and tend to suppress any fundamental signal which may be present.

It is not normally desirable to use a doubler as the final amplifier stage in a transmitter, since it is difficult to ensure that all traces of the fundamental signal are removed by the aerial and final tank circuits. This produces the familiar "overtone", as for instance, explaining the presence of a strong signal on 7Mcs, when one is actually working on 14Mcs, and is particularly likely to occur, if an aerial resonant at the overtone frequency is used.

(To be Continued.)

Lightning Strokes Prefer

Continued from page 37

sion lines is not as simple as discussed here,[7] but the basic principles upon which modern power-line design rests are those mentioned.

Whether or not a transmission system has overhead ground-wire protection, it is subjected to lightning voltages if located in regions where there is lightning. If it is without ground wires, it may be struck directly or it may experience voltages by induction from nearby strokes. If it has ground wires, it may still pick up voltage from the ground wire by coupling, or from a backflash from the ground wire. Such voltages will be impressed on apparatus connected to the system. To safeguard it against lightning damage it is necessary to provide some means of limiting the voltages that can appear at the apparatus to values that the apparatus insulation can withstand. This is the function of the arrester.

REFERENCES

1. "Lightning Phenomena," by Wagner and McCann, Electrical Engineering, August, September, and October, 1941.
2. "Shielding of Substations," by Wagner, McCann and Lear. Trans. AIEE, Vol. 61, 1942, p. 96.
3. "The Measurement of Lightning Currents in Direct Strokes," by McCann,, Trans. AIEE Vol. 63, 1944, p. 1157.
4. "Ueber Blitzchutz durch Fernblitzableiter (Concerning Lightning Protection by means of Remote Lightning Diverters) by R. Walter, Zeitschrift fuer technische Physik, Vol. 14, 1933, p. 118.
5. "Code for Protection Against Lightning," U.S. Bureau of Standards Handbook H-40.
6. "Shielding of Transmission Lines," by Wanger, McCann, and MacLane, Trans. AIEE, Vol. 60, 1941, p. 313.
7. "Transmission Line Design and Performance," by Harder and Clayton. AIEE paper 49-111, not yet published.

The Mail Bag

C.W.C. (Christchurch, N.Z.) writes: ". . . Having been a reader of RADIO SCIENCE for some time, I feel it is time I wrote to you and told you how much I have enjoyed reading it, and how it has helped me. I have just finished the 'Super-Portable Battery Receiver' that appeared in the June issue, and it is giving wonderful service. I wish you all the best in the future with RADIO SCIENCE and I will always be a keen follower."

A.—Thanks for the letter, C.W C., and we are pleased to hear of your success with the portable receiver. To date we have received many excellent reports on this circuit. Your remarks about the magazine are appreciated, and we trust you will find the future issues even more interesting than those copies already received.

F.T. (Sth. Yarra, Vict.) refers to the "Basic Electricity and Magnetism" article in the June, 1949, issue, and points out what he considers to be some misleading statements made in connection with the electron theory.

A.—Your remarks concerning the article were read with interest, and then forwarded to the author for comment. Here is Mr. Thorrington's reply, which we trust will elucidate some of the points you mention:

"Many thanks for your remarks regarding 'The Electron Theory' and the queries you raise regarding the validity of a number of statements made therein. A careful study of your letter seems to indicate that any disagreement is due chiefly to the condensed nature of the article. It is obviously impossible to qualify all statements made about the atomic theory in an article of some 3,000 words. Taking your points in the same order as you list them, I would like to reply to them as follows:

GALILEO'S ATOM:

"I pointed out that Galileo's atom was more philosophical than practical; **it was not the atoms we think of.** Galileo did use the idea of atom, but only as a means for distinguishing between material objects and abstract entities like weight and colour.

CATHODE RAYS:

"As far as I can determine, the discovery of 'cathode rays' was accidental. As to the force being 'terrific,' perhaps a small calculation will give us an idea of the magnitude of the forces involved. Let us assume that we have two coplanar electrodes, 1 centimetre apart. Let the anode be 10 volts positive with respect to the cathode, and let us assume that the current established between the electrodes is 1 ampere.

"The number of electrons reaching the anode per second will be 6.24 x 1018 electrons, and the total force acting on these electrons will be

$$f = \frac{EX}{d} \text{ dynes}$$

where E is the p.d. in e.s.u. between the electrodes, X is the charge due to one electron, or 4.8×10^{-10} e.s.u. of charge, and d is the distance between the electrodes in cms. Hence, the force, f, is

$$f = \frac{10 \times 4.8 \times 10^{-10} \times 6.24 \times 10^{18}}{300 \times 1}$$

9.984×10^7 dynes or 10^8 dynes close enough.

"Taking 445,000 dynes as equivalent to 1 lb. weight, the force in lbs. is

$$f = 10^8/445 \times 10^3$$
$$= 225 \text{ lbs. weight.}$$

"It all depends on whether we are thinking in terms of a single electron or huge quantities of them.

INCREASE OF MASS:

"During the evolution of the electron theory, it was, as you admit, once speculated that the whole of the mass of an electron was due to electricity. I did not imply that modern concepts embraced this speculation.

SOLAR SYSTEM ANALOGY:

"Here again it was speculated that the nucleus of an atom contained both negative and positive charges. Such a concept existed before Bohr advanced his theories.

QUANTAM THEORY:

"While certain parallelism does exist between certain phases of thermo-dynamic and electro-dynamic laws of radiation, I agree that I should have said **electro-dynamic** in preference to **thermo-dynamic.** It is rather pedantic, don't you think, to argue on the defference between **several years** and a **decade.**

EINSTEIN THEORY OF RELATIVITY:

"Einstein's equation, E = hf — p, is a **general** equation, in which p represents a general **work** function. We should, perhaps, express the idea more precisely by writing E = hf — (f) p, indicating that p has the dimensions of energy, and is a function (f) of E. Einstein's equation is modified in specific applications.

"When developing the idea of each electron having a space-time configuration of its own, I stressed that **'the idea was a mathematical device and not a description of physical reality.'** As you say, it is possible to endow the space occupied by an atom with metrical properties which will make the geometry of atomic space depend on the distribution of matter within that space. This, to my knowledge, is the only satisfactory explanation as to how the electron remains in motion without requiring energy.

ELECTRON THEORY APPLIED TO ELECTRICAL PHENOMENA:

"I cannot agree that the **electrical behaviour** of a capacitor is microscopic at all. Energy is stored in a capacitor by virtue of a state of electro-static strain existing between two charged bodies at different potentials, and this strain exists in the space between the bodies, whether the space is occupied by substance or not.

"Maxwell deals with electro-magnetic fields mathematically, and his mathematics can be applied to electro-static phenomena, but mathematics do not necessarily describe reality. I personally cannot conceive of tiny **marbles being hurled into space** in the physical sense."

C. M. McR. (Balgowlah, N.S.W.) recently commenced a radio course and finds RADIO SCIENCE of inestimable assistance. He is interested in building up the test equipment described in some earlier issues of the magazine.

A.—The issues containing the circuits requested have been forwarded, and no doubt received by you. The additional issues were included as the amount you forwarded was in excess of that required. We wish you every success with your radio studies, and would be pleased to hear from you again when you have the portable receiver in operation

J.M. (Herne Bay, N.S.W.) intends building up the TRF tuner described in the July, 1948, issue of RADIO SCIENCE, but queries the values shown for the resistors in the back bias network.

A.—You are quite right in your reasoning, J.M., and this is brought about by an error in the published circuit. To ensure the correct bias for the 6SN7GT stage. It is necessary to connect the 6V6GT cathode bias resistor direct to the HT centre tap and NOT to earth, as shown. If this change is made you should have no trouble in getting the unit to operate correctly. Many thanks for your remarks concerning the magazine.

H.F.C. (Pt. Augusta, S.A.), in forwarding a two-year subscription to RADIO SCIENCE, writes: ". . . Please accept my congratulations for your interesting publication and on the reasonable price which you have so far managed to maintain. I am at present in the fortunate position of being able to subscribe to a number of magazines, and the variety of subject matter covered by RADIO SCIENCE, particularly the fairly complete coverage of various aspects of radio not usually readily available, fully warrants its inclusion among them."

A.—Many thanks for your letter and subscription, H.F.C. We appreciate your remarks concerning the topics covered in the magazine, and have no hesitation in saying that this magazine will continue with its policy to print articles not usually seen by the radio enthusiast in this country. Your subscription has been attended to by the Subscription Department, and the issue requested has been forwarded and no doubt in your hands by now.

TECHNICAL QUERY SERVICE

Readers are invited to send in any technical problems, either dealing with our circuits or of a general nature, and an earnest endeavour will be made to assist you through the medium of these columns. For convenience keep all letters to the point with questions set out in a logical order, as space is rather limited.

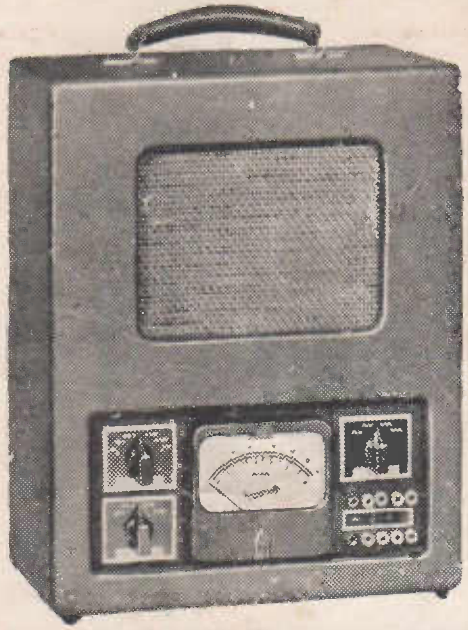
All technical enquiries will be dealt with in strict rotation and the replies will be published in the first available issue of the magazine. Address all letters to RADIO SCIENCE, Box 5047, G.P.O., SYDNEY, and mark the envelope "Mailbag."

VERSATILE!

HUNDREDS OF TESTS . . .
TWO INSTRUMENTS!

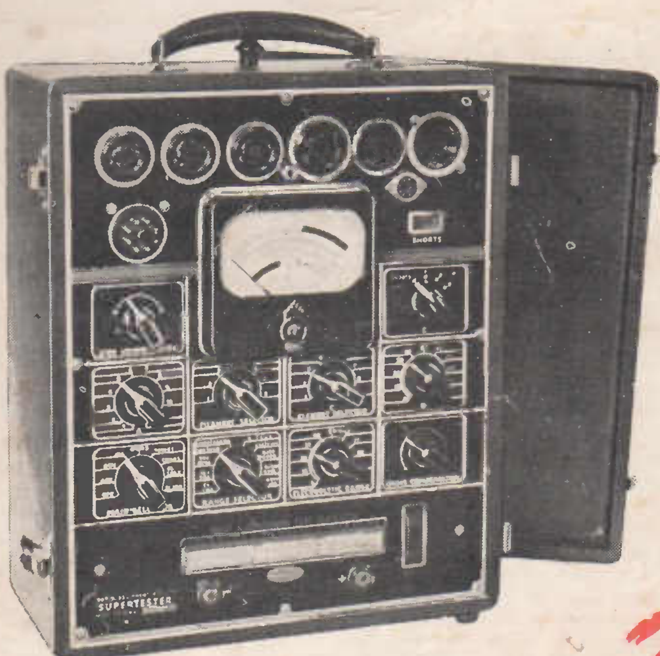
University

UNIVERSAL
SPEAKER AND OUTPUT METER—MODEL USO



A much-needed radio service instrument combining the functions of an accurate, calibrated output meter with a universal speaker designed to suit all types of radio receivers and apparatus—whether AC or DC.

Calibrated in Decibels and watts—ranges are 0/500 milliwatts, 0/5 watts and 0/50 watts. "University" square rectifier type meter. Outside measurements—15in. high x 12in. wide x 7in. deep.



SUPER TESTER—Model TST

Without a doubt the most efficient and up-to-date Valve and Circuit Tester in the Southern Hemisphere. The Model T.S.T. is a compact instrument combining the multifarious functions of a valve tester, multimeter, output meter, paper and mica condenser tester and electrolytic condenser tester (providing both leakage and impeddance tests). Feature is the time-saving roller chart.

University

RADIO KIT SETS • RADIO & ELECTRICAL TEST EQUIPMENT

Manufactured by RADIO EQUIPMENT PTY. LTD., 5 NTH. YORK ST., SYDNEY. BU3169 (2 lines)

RED LINE

TRANSFORMERS OF DISTINCTION

LINE TO VOICE MATCHING TRANSFORMERS.

The transformers described in this section are complementary to those listed in the previous month, and are intended to match 500 or 250 ohm output lines to any number of speakers from one to twenty inclusive.

They are high efficiency units with interleaved cores and low insertion loss. Although in many cases their nominal specifications appear suitable for direct coupling of valves to speaker voice coils, no provision has been made to prevent saturation due to superimposed direct current, and they should not be used for this application.

ITEM 65. **Type No. LV10**

Primary Z: 1000 ohm tapped 500 ohm-5W
Secondary Z: Speaker B-Coil .... 2 ohms
Base: 2 5-8 x 2¾ x 2¼" H .... Wgt. 1lb. 8 ozs.
Mntg.: MH1B .... "S" is ⅞"
Base plate fits standard 8" speakers.
No. Speakers matched: 500 ohm—1 or 2.
No. Speakers matched: 250 ohm—2 or 4.

ITEM 66. **Type No. LV20**

Primary Z: 2000 ohms tap 1500 ohm, 5W.
Secondary Z: Speaker V-Coil .... 2 ohms
Base: 2 3-8 x 2¾" x 2¼" H .... Wgt. 1lb. 8oz.
Mntg.: MH1B .... "S" is ⅞"
Base Plate fits standard "8" speakers.
No. Speakers matched: 500 ohm—3 or 4.
No. Speakers matched: 250 ohm—6 or 8.

ITEM 67. **Type No. LV30**

Primary Z: 3000 ohms tap 2500 ohm. 5W.
Secondary Z: Speaker V-Coil .... 2 ohms
Base: 2 5-8 x 2¾" x 2¼" H .... Wgt. 1lb. 8ozs.
Mntg.: MH1B .... "S" is ⅞"
Base Plate fits standard 8" speakers.
No. Speakers matched: 500 ohm—5 or 6.
No. Speakers matched: 250 ohm—10 or 12.

ITEM 68. **Type No. LV40**

Primary Z: 4000 ohms tap 3500 ohm. 5W.
Secondary Z: Speaker V-Coil .... 2 ohms
Base 2 5-8 x 2¾ - 2¼" H .... Wgt. 1lb. 8 ozs.
Mntg.: MH1B .... "S" is ⅞"
Base Plate fits standard 8" Speakers.
No. Speakers matched: 250 ohm—14 or 16.
No. Speakers matched: 500 ohm—7 or 8.

ITEM 69. **Type No. LV50.**

Primary Z: 5000 ohms tap 4500 ohm. 5W.
Secondary Z: Speaker V-Coil .... 2 ohms
Base 2 5-8 x 2¾ x 2¼" H .... Wgt. 1lb. 8 ozs.
Mntg.: MH1B .... "S" is ⅞"
Base Plate fits standard 8" Speakers.
No. Speakers matched: 500 ohm—9 or 10.
No. Speakers matched: 250 ohm—18 or 20.

The correct value of primary impedance for parallel arrangement for equal distribution of the output of an amplifier is found by multiplying the number of speakers by the line impedance. Take, for example, a 30 watts amplifier feeding six speakers from a 500 ohms line . . . The required primary impedance is equal to the number of speakers in parallel multiplied by the line impedance, i.e., 6 x 500, which equals 3000. Thus, Type LV30 would be selected, as this unit has a primary impedance of 3000 ohms, and the six speakers would be served from the 500 ohms tappings of the output transformer, as 3000 divided by 6 equals 500.

Type LV30, however, will also serve for 12 speakers, if required, but they would then be placed in parallel across the 250 ohms tappings on the transformer, as 3000 divided by 12 equals 250 ohms, and the reflected load would still be correct.

In many installations, however, owing to varying noise levels and other modifying factors, each speaker may be called upon to deliver different amount of power. In these circumstances the primary impedance may be determined by applying the following formula:—

$$Xx \text{ equals } Z\frac{W}{Ws}$$

where Zx equals the primary empedance to be determined.
Z equals the value of line impedance to be used.
W equals the power in watts from the amplifier.
Ws equals the required power for each speaker.

As an example, a 30 watts amplifier using 500 ohm line output is to have 5 speakers, and each speaker is to have the following power distribution:—

Speaker No.	Watts Each	Method of Calculation Z × W + Ws	Impedance Reqd.	Zx Type No.
1	10	500 × 30 + 10	1500	Use LV20
2	8	500 × 30 + 8	1875	Use LV20
3	3	500 × 30 + 3	5000	Use LV30
4	5	500 × 30 + 5	3000	Use LV40
5	4	500 × 30 + 4	3750	Use LV50

Substituting LV20 (2000 ohms) speaker No. 2 and LV40 (3500 ohms) for speaker No. 5 means that standard units may be used, with a slight decrease in power to speaker No. 2 and a slight increase in power to speaker No. 5.

These five transformers when wired in parallel would present a terminal impedance of 515 ohms approximately, which is a negligible degree of mismatching.

HIGH FIDELITY LINE TO VOICE COIL TRANSFORMERS

The following high level line to voice coil or recording head input transformers are complementary to the "AF" and "AW" series shown last month. These transformers are high fidelity units with an individual insertion loss of not greater than 0.5 db and a frequency range +/— 0.5 db 25 cps to 15 Kc/s.

References to their dimensions will indicate the large core structures adopted to keep iron distortion to negligible proportions by the use of low flux inductions at the maximum signal voltages incurred.

ITEM 70. **Type No. VW15**

Primary Z: 500 ohms .... 34 db. 15 watts
Secondary Z .... 15 ohms Voice Coil
Base: 2¾ x 2⅞ x 3$\frac{1}{16}$" H .... Wgt. 3lbs.
Mntg: V14 .... "S" is 1¼"

ITEM 71. **Type No. VW126**

Primary Z: 500 ohms .... 39 db. 45 watts
Secondary Z .... 12 ohms tapped 6 ohms
Base: 4¼ x 4 x 3¾" H .... Wgt. 8lbs.
Mntg: VS10 .... "S" is 2⅛"

ITEM 72. **Type No. VW84**

Primary Z: 500 ohms .... 39 db. 45 watts
Secondary Z .... 8 ohms tapped 4 ohms
Base: 4¼ x 4 x 3¾" H .... Wgt. 8lbs.
Mntg: VS10 .... "S" is 2⅛"

ITEM 73. **Type No. VW205**

Primary Z: 500 ohms .... 39 db. 45 watts
Secondary Z .... 2 ohms tapped 0.5 ohms
Base: 4¼ x 4 x 3¾" H .... Wgt. 8lbs.
Mntg: VS10 .... "S" is 2⅛"

RED LINE EQUIPMENT PTY. LTD.

TRANSFORMER ENGINEERS

2 Coates Lane, Melbourne. CITY OFFICE: MU 6895
WORKSHOP: Cent. 4773 (3 lines), 157 Elizabeth St., Melbourne

Cut out and file for reference

A guarantee of Dependability

DISTRIBUTORS:

VICTORIA:
Homecrafts Pty. Ltd.
Arthur J. Veall Pty. Ltd.
Radio Parts Pty. Ltd.
Howard Radio
A. G. Healing Ltd.
Healings Pty. Ltd.
Lawrence & Hanson Electrical (Vic.) Pty. Ltd.
Motor Spares Ltd.

NEW SOUTH WALES:
Warburton Franki (Melb.) Ltd.
United Radio Dist. Pty. Ltd.
Homecrafts Pty. Ltd.

QUEENSLAND:
A. E. Harrold, B. Martin
Denradio Industries (Maryborough).
J. Michaelmore & Co. (Mackay).

SOUTH AUSTRALIA:
Gerrard & Goodman.
Radio Wholesalers Pty.
Newton McLaren Ltd.

TASMANIA:
Noyes Bros. (Aust.) Pty. Ltd.
Lawrence & Hanson Electrical Pty. Ltd.