Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

2/- FEB., 1942

The stars look down . . .

. . . upon the sleeping villages and towns of England. Over the peaceful scene the moon mounts guard with watchful eye. Yet, at any given moment, should the necessity arise, the quietest country village can be in instant communication with the greatest city; can command its resources and enlist its help. Our products for many years have served in spreading human happiness and in forging links between men, and to-day we still proudly play our part in maintaining human fellowship.

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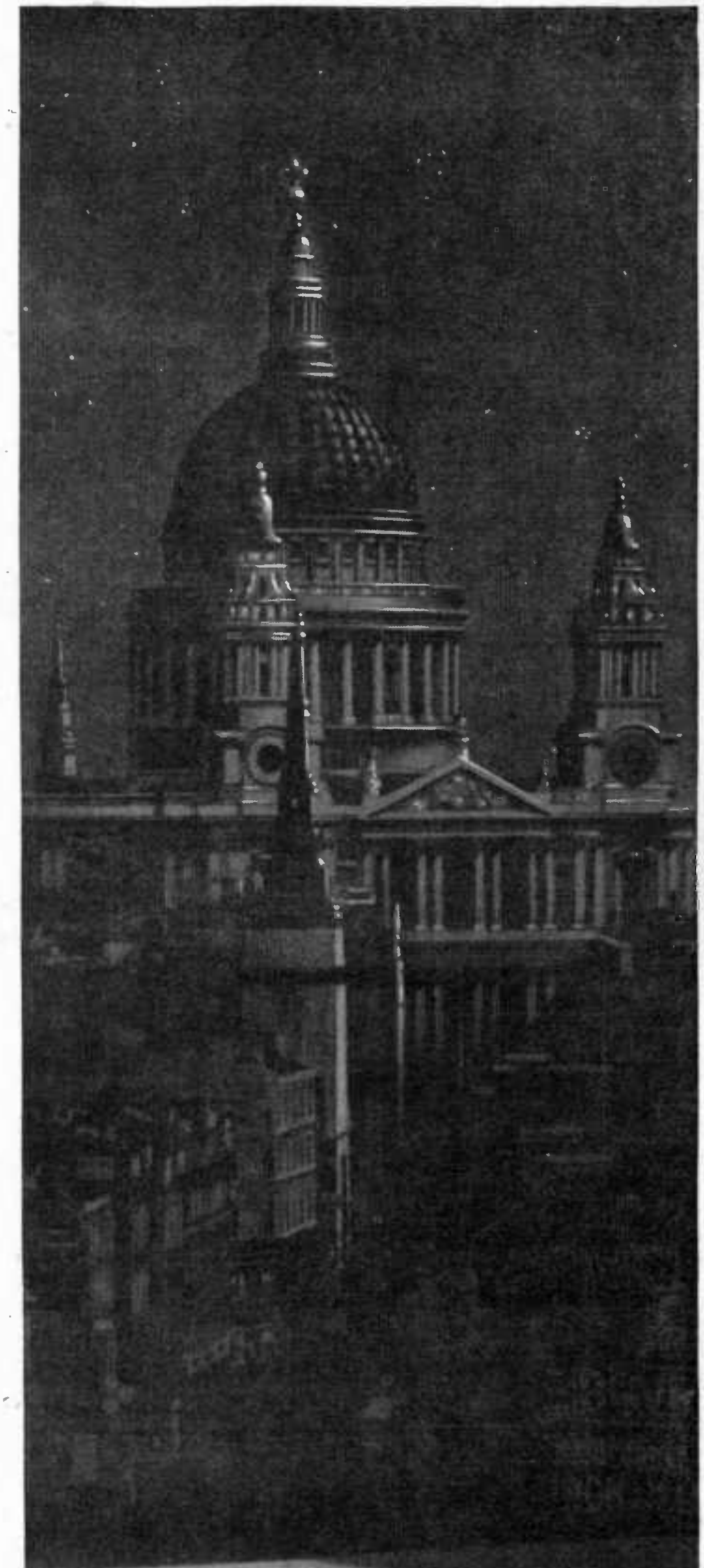

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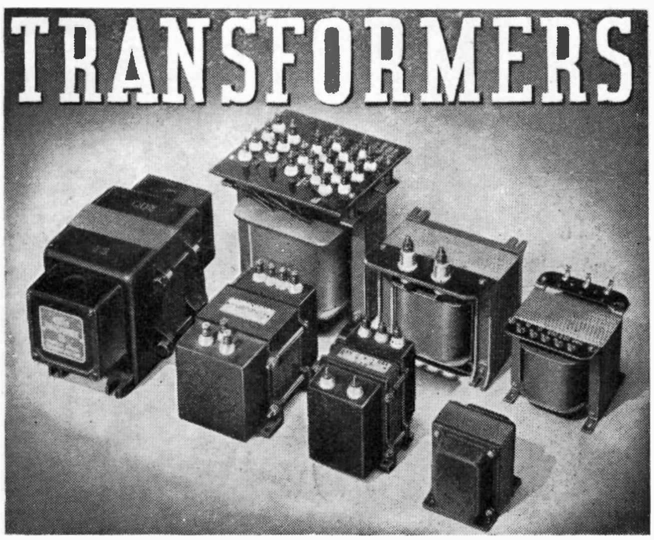

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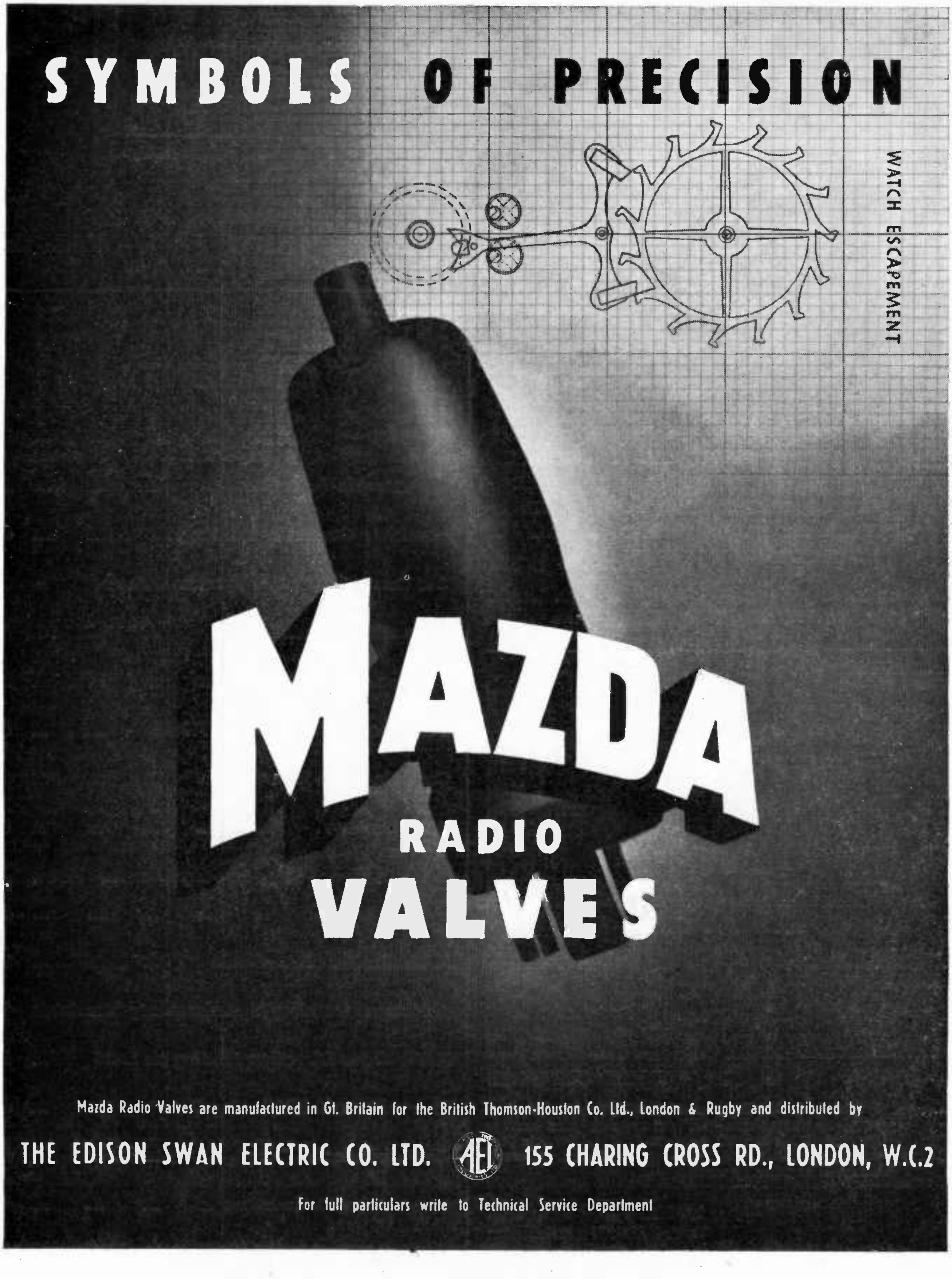
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Pioneering

On Thursday, December 18th, 1941, at his house at Sydenham, Mr. J. L. Baird gave a demonstration to the Press of stereoscopic television in colour: the first time, so far as we are aware, that such a picture has been shown.

A full account of the system, which Mr. Baird will agree, is still in its experimental stage, is given on another page in this issue. It seems opportune, however, to set down some facts about the science which gave so much pleasure to tens of thousands a short time ago and will, we hope, give more pleasure in years to come.

It was in January, 1926, that Mr. Baird demonstrated television to the British Association and a statement appeared in *Nature*[1]: "This is the first time that we have seen real television and so far as is known, Mr. Baird is the first to have accomplished this feat."

Three years later, the B.B.C. arranged for regular transmissions by the Baird apparatus from their studios, and in 1932, the apparatus was moved to Broadcasting House.

Meanwhile, the work of Zworykin Farnsworth and others in America, and McGee, Blumlein and others in Britain, had led to the development of high definition television using the electron camera and short wave-lengths for transmission. The advisory committee on Television first met in May, 1934, and their report issued in January, 1935, recommended that the Baird Company and the Marconi E.M.I. Co. should provide alternative services for public programme transmission. The first vision transmission from the Alexandra Palace was made (experimentally) on Wednesday, August 12th, 1936, and on Monday, November 2nd, 1936, the Television Station was officially opened.

In the congratulatory speeches which accompanied the opening ceremony, Mr. Baird's name was unaccountably not mentioned. Surely, it would have been a generous gesture to give a little credit to the man who started the television ball rolling.

Continuing: In 1939, a note appeared[2] to the effect that Mr. Baird had demonstrated a 102-line triple interlaced picture in colours. This, by the way, was not the first experimental demonstration that he had made of colour television.

In 1940 (Sept. 4th), Dr. Goldmark, of the Columbia Broadcasting System,[3] demonstrated quadruple interlaced colour television using a three-colour filter, the effective number of lines being 343.

Early in 1941, Mr. Baird demonstrated his colour television system again, with improved definition (600-lines), using two-colour filters. A photograph of the picture appeared in *Electronics and Television*, for April, 1941, and the erroneous claim was made that it was the first reproduction of a colour television picture.

Actually, the *St. Louis Post*, of September 22nd, 1940, carried colour reproductions of Dr. Goldmark's pictures. There is, however, a marked difference between the two definitions. Now, Mr. Baird has demonstrated the first stereoscopic colour pictures. The most remarkable fact about these pictures is not their colour nor their life-likeness. It is that they have been produced in a private laboratory at Mr. Baird's own expense.

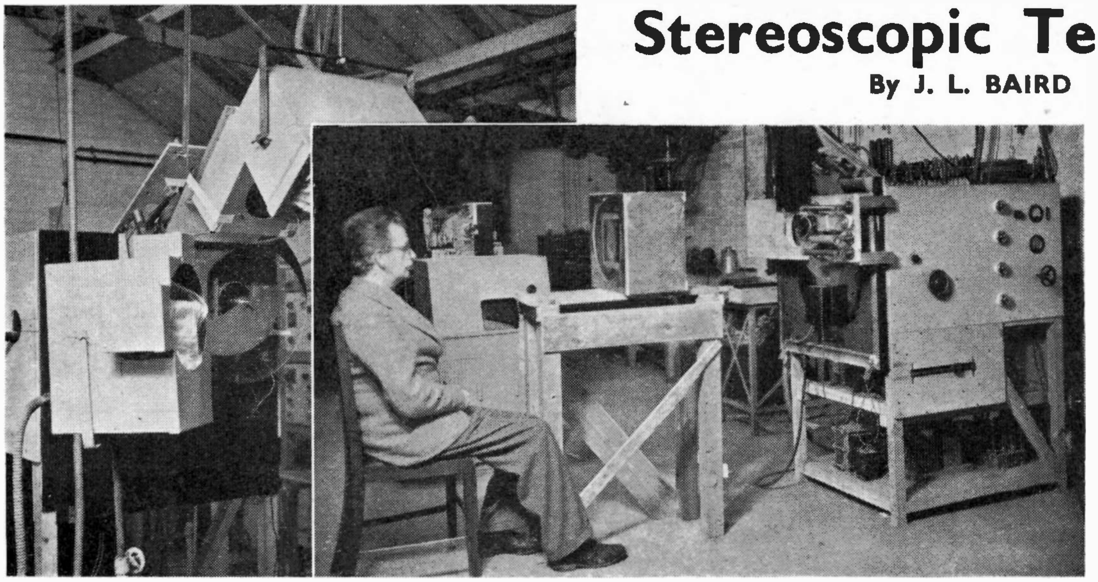
If Mr. Baird wishes to obtain more recognition of his pioneer work in television, work which has occupied his life for nearly 20 years, he might try growing a beard and calling himself Professor Bairdsky. He doesn't seem to be getting much encouragement in this country as he is.

There have been from time to time people who decry Mr. Baird's work, but they cannot gainsay the fact that he is our television pioneer, and as such deserves our admiration and better official recognition.

[1] July, 1926.
[2] *Wireless World*, Aug. 3, 1940.
[3] *Electronics*, Oct., 1940.

Stereoscopic Television

By J. L. BAIRD



A photograph of Mr. Baird in front of his experimental receiver and (left) a view of the transmitter showing shutter and photocells.

" The latest advance in television is the production of images in stereoscopic relief, which was demonstrated to the Press by Mr. Baird, on August 9th, a demonstration at which I had the privilege of being present."

The August 9th referred to by the writer of the above was not August 9th, 1941, but August 9th, 1928, when the first stereoscopic television picture was shown. After a lapse of over twelve years, Mr. Baird has resumed his experimental work on this form of television and gave a demonstration of high-definition colour stereoscopic television to the Press on December 18th, 1941.

THE phenomenon of stereoscopic vision is well known, but may be briefly recapitulated here to serve as an introduction to the description of the author's experiments on stereoscopy applied to television images.

When a single eye is focused on a scene it sees only a flat picture and can only estimate depth by comparison between objects of known size, or by change in the viewpoint. There is also the change in the accommodation of the eye necessary to see objects at different distances. In binocular vision the distance separating the observer from the various objects in the scene viewed is given by combining the visual images seen by the right and left eyes respectively.

The effect of relief in a scene can also be produced by observing simultaneously two plane views taken from points corresponding to the separation between the eyes (approximately 2½ in.), and this is the principle of the well-known stereoscope. The effect is shown in Fig. 1, where L and R represent two views corresponding to the " left eye view " and " right eye view " respectively. Points a,a¹ b,b¹ on the photographs are viewed simultaneously by the eyes EE and the intersection of the visual axes through corresponding points produces an image A,B,C,D having the appearance of depth.

Instead of presenting two separate views, as in the stereoscope, it is possible to combine them into one picture provided that they are capable of separation, the left and right eyes seeing only the left and right eye views respectively.

This is done in the so-called " anaglyphs " by colouring one picture green and the other red. The combined red and green pictures are then projected on a screen and viewed through glasses fitted with a red filter for the right eye and a green filter for the left. Each eye can thus only see the picture corresponding to its particular viewpoint and the scene is given the appearance of relief as before. In a similar way polarised light can be used and discrimination obtained by viewing through glasses fitted with polarising screens.

Early Experiments

In the apparatus with which the author performed his first experiments in 1928, the principle of stereoscopic viewing was followed, and the observer viewed the reproduced image through a hand stereoscope of the conventional type. The apparatus is shown diagrammatically in Fig. 2 and consisted of two spotlight scanners focused on the subject by the lenses L and R, the scanning disk S being furnished with two sets of spirally arranged holes to give a double 30-line scan. The subject was thus scanned alternately from two positions, one to the right and one to the left of normal. The light was reflected on to a bank of photo-cells PC and the variations in cell current amplified and transmitted in the usual way. At the receiver a similar scanning disk was employed with a light source behind the scanning areas and the images formed on the disk were viewed through a prismatic stereoscope, St, shown.

This arrangement gave satisfactory results within the limitations of the definition and the only disadvantage was the necessity of using a stereoscope to view the received picture.

Having demonstrated the possibility of such pictures, no further development was undertaken at the time owing to pressure of work in other directions and the subject was left until a more convenient time occurred.

At the beginning of 1941 experiments were resumed with a view to eliminating the stereoscope, and with the added advantage of high-definition technique. Cathode-ray tube scanning and projection was employed and the principle of the anaglyph was first tried. The received stereoscopic pair were passed through red and blue filters alternately, providing colour discrimination between right and left eye pictures instead of spatial discrimination, the received image being viewed through red and blue glass spectacles as in the cinema anaglyphs.

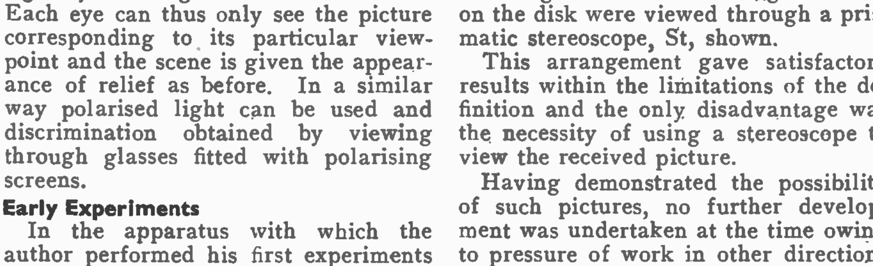


Fig. 1. Diagram illustrating principle of stereoscopic vision.

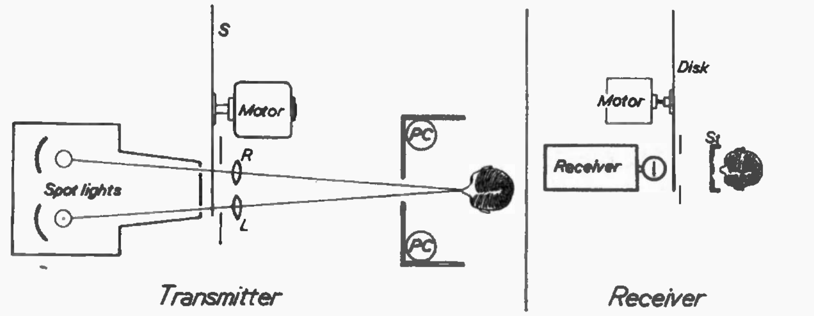


Fig. 2. Diagram of the author's early experimental apparatus (1928).

With a 600-line picture the results were very successful in monochrome and less so in colour. The explanation of this lay in the confusion between the colour of the scene and the colour used for discrimination. For example, if the right eye view were red and the left eye blue, a portion of the scene having a natural red colour disappeared when viewed through the blue (left) filter and thus lost relief. Colour rendering could thus only be achieved by this method at the expense of stereoscopy and *vice versa*.

Experiments were also conducted with polarised light and glasses using polarising screens to discriminate the left eye view from the right eye view in place of colour discrimination. This provided an alternative but more expensive and complicated method.

One aim of these experiments had been to produce a stereoscopic picture which could be used with the existing B.B.C. transmission system with little alteration, and this method achieved its purpose, giving good stereoscopic pictures. Owing to the war, however, any application to broadcasting was impossible and this scheme was of necessity postponed. In the meantime experiments were resumed in an endeavour to produce as perfect a picture as possible without regard to practical limitations, and to eliminate the use of glasses.

The frame frequency was first increased to 150 per second instead of 50 per second, and the scanning was altered to give a 500-line picture consisting of 100 lines 5 times interlaced. The discriminating eyeglass method was abandoned as the necessity of wearing glasses detracted considerably from the effect. Stereoscopy was obtained by the use of rotating shutters in combination with optical separating devices.

This enabled full colour reproduction to be attained and permitted direct viewing without glasses or eyepieces.

A three-colour filter disk was included in the apparatus giving successive frames of red, green and blue. The layout of the apparatus is shown in Fig. 3.

In front of the projecting lens a mirror device consisting of four mirrors at right angles splits the emerging light beam into two paths separated by a space equal to the separation of the eye. By means of a revolving shutter the scene is scanned by each beam alternately, so that images corresponding to the right and left eye are transmitted in rapid sequence. Before passing through the shutter disk the light passes through a rotating disk with blue, red and green filters. Thus superimposed red, blue and green pictures blending to give a picture with full natural colours are transmitted for left and right eye alternately. At the receiver the coloured stereoscopic pairs of images are reproduced in sequence and projected upon a field lens, alternate halves of the projecting lens being exposed by means of a rotating shutter, the image of the shutter being projected upon the eye of the viewer so that his left and right eyes are presented alternately with the left and right images, the combined effect being a stereoscopic image in full natural colours.

The shutters used differ at the transmitting and receiving ends as shown. At the transmitter it is desirable to maintain the total illumination of the subjects constant in order to avoid flicker and the shutter is accordingly provided with a spiral mask, shaped so that the area obscured in one light beam at any moment is equal to the area uncovered on the other.

At the receiving end this is unnecessary and it is only required to provide a plain alternate mask as shown.

It is, of course, essential to view the image with the eyes in the correct position for receiving the respective views and if the head is moved so that the right eye sees the left eye view the effect of relief disappears. This fact at present restricts the viewing to one or, at the most, two people, but further experiments are now in hand with a view to enabling the true stereoscopic picture to be seen by a large audience simultaneously without the use of glasses.

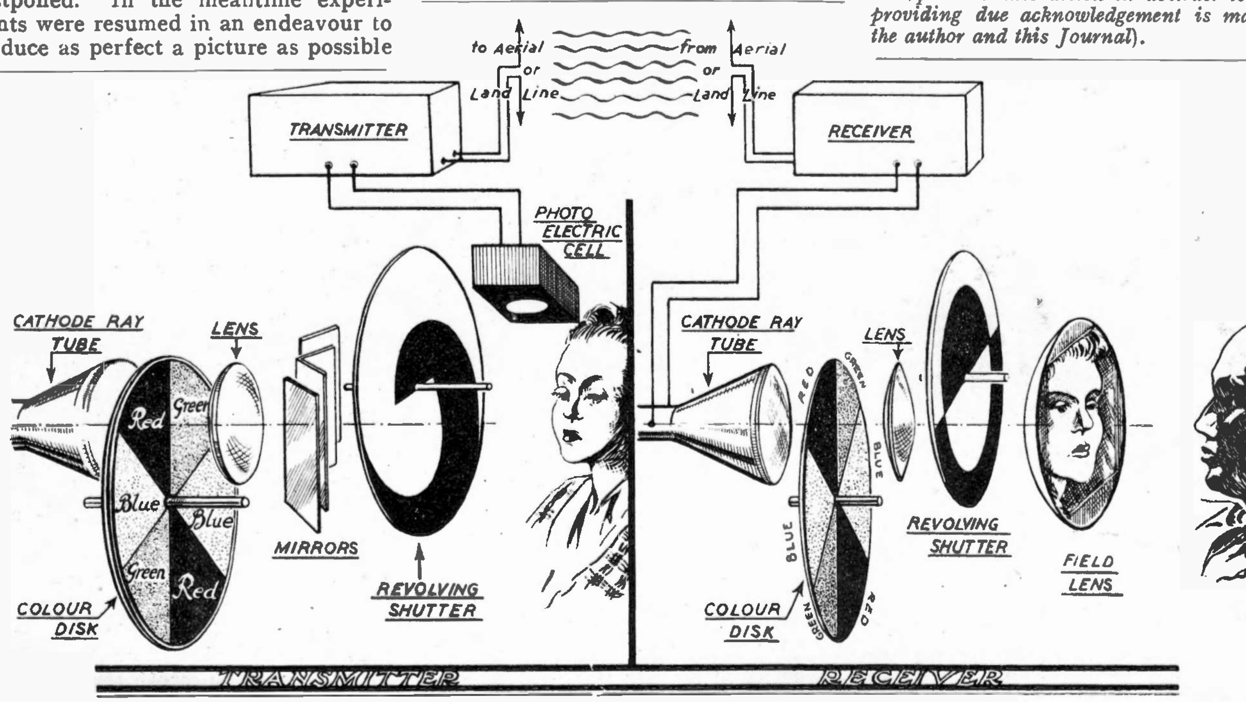


Fig. 3. Experimental apparatus for colour stereoscopic television.

Plastics in the Radio Industry

IV.—Manufacture (Continued)

By
E. G. COUZENS, A.R.C.S., B.Sc.,
(Messrs. B. X. Plastics, Ltd.)
and W. G. WEARMOUTH, Ph.D., F.I.P.
(Messrs. Halex, Ltd.)

Other Cellulose Plastics

THE description of the method of manufacturing nitrocellulose plastic also applies to other compounds of cellulose, except for the initial chemical processes. In the case of cellulose acetate the nitrating mixture is replaced by acetic acid, acetic anhydride and a small amount of sulphuric acid, the resulting cellulose acetate being obtained in the form of a syrupy solution in an excess of acetic acid. If immediately precipitated by the addition of water the product is insoluble in all common solvents and a "ripening" process, in the course of which the cellulose compound loses some of its combined acetic acid, has to be carried out by diluting the solution, neutralising the sulphuric acid and keeping the solution warm. Subsequent precipitation then gives a fibrous white material which is soluble in acetone and which can be worked into sheet, rod and tube by the "celluloid technique," i.e., in exactly the same way as Xylonite, but using acetone or certain other solvents instead of alcohol and replacing the camphor used in celluloid by high-boiling esters such as triphenyl-phosphate and methyl phthalate.

Since ethyl cellulose has a different chemical structure, cellulose requires a different type of treatment for its preparation. A sodium compound is first formed by treating the cellulose with caustic soda and reacting this compound with ethyl chloride. A double decomposition takes place, the ethyl group entering the cellulose molecule, the chlorine combining with the sodium. The resulting ethyl cellulose is a white powdery material which, like cellulose acetate, can also be worked by the celluloid technique, using such solvent mixtures as alcohol-benzene and various phthalates as plasticisers. From the fact that the celluloid technique can be applied to cellulose acetate and ethyl cellulose, it follows that all the special effects obtainable by this process, the beautiful patterns and the colours and the various forms, are also available with these other cellulose materials. Articles are also produced in the same way as in the case of Xylonite, from the basic forms of sheet, rod and tube, but the great heat stability of these plastics, more particularly in the case of cellulose acetate, permits of the application of moulding from powder. These powders are made by cutting up soft plastic into chips and seasoning them or grinding sheets made on hot rolls. The resulting powder can be moulded into sheets or articles in hydraulic presses, but, unlike the phenol formaldehyde resins, the moulds must be cooled before removing the finished products, which is a substantial drawback. This limitation is overcome in the remarkable injection-moulding process, derived from the die-casting of metals. In this process the moulding powder is forced by a ram through an electrically-heated chamber and injected by means of a nozzle into a split die which is water-cooled. The operation of the machine (Fig. 1) is automatically controlled, each part of the process only taking a few seconds, including the cooling in the mould, which on opening drops out the finished moulding in a sufficiently rigid state to be handled. All that is required to finish the moulding is the removal of the "sprue," which comes from the feed-port in the die, and articles varying in size from thimbles to motor-car steering wheels can be continuously produced at enormous rates.

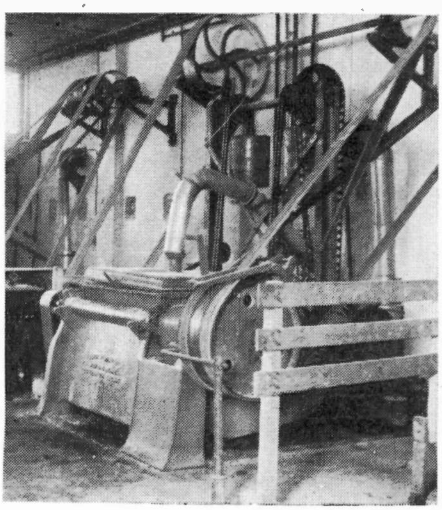


Fig. 2. Urea-plastic mixers.
(Courtesy of British Industrial Plastics, Ltd.)

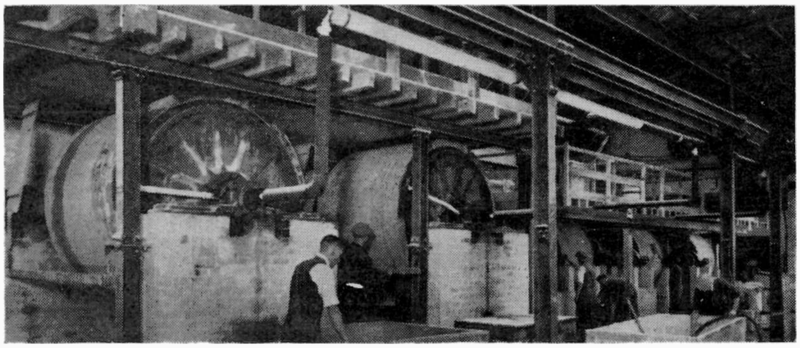


Fig. 3. Urea-plastic Ball-mills.
(Courtesy of British Industrial Plastics, Ltd.)

Amino-Plastics

Just as celluloid has been followed by other cellulose derivatives, so has the reaction of phenol with formaldehyde been followed by other formaldehyde reactions producing resins, of which the most important are the urea compounds, generally known as "amino-plastics." The first stage, the chemical reaction between the urea, or mixtures of urea and thiourea, and formaldehyde is carried out by heating in a kettle at temperatures below those required for the corresponding phenol reaction. The water in the formaldehyde solution and that formed in the reaction keep the product in solution, and the resulting syrup is transferred to mixers (Fig. 2) where it is worked into a paste with filler, and colour is added if necessary. The product is then dried, ground, and finally ball-milled to reduce it to a uniform fineness. A battery of ball-mills is shown in Fig. 3. The outstanding characteristic of aminoplastics is their basic water-whiteness and fillers such as paper-pulp are used to preserve this effect.

The moulding process resembles that of the phenol resins, and it is only necessary to refer to the well-known "Beetle" table and picnic-ware to characterise the product.

A recent development of the aminoplasts is melamine resin. Melamine, a polymer of cyanamide, is reacted with formaldehyde at low temperatures and gives a water-white resin with great resistance to heat and moisture

Fig. 1. Automatic machine for mass production of injection mouldings. The operator is holding a set of mouldings which have just been expressed from the machine.

(Courtesy of Alfred Herbert, Coventry.)

and with excellent electrical properties. It is very resistant to staining and can be used to produce a satisfactory glass-clear resin.

Subsidiary Thermo-setting Processees

The second phase in the manufacture of thermo-setting plastics, the production of stock-forms is capable of two interesting variations, the casting process and thermo-setting extrusion.

In the casting process, primarily developed for phenol-formaldehyde resins, by a modification of the polymerisation process the resin is obtained in a molten mass which can be poured into lead moulds previously formed on steel arbors. The final hardening process characteristic of the production of thermo-setting resins is carried out by stoving for some days and then knocking the hard resin forms out of the lead moulds. These forms are then sawn into sections. (Fig. 4).

The thermo-setting extrusion process can be applied both to phenol and urea-resins, and differs from the method used for thermoplastics in that pressure is applied by means of a ram with a reciprocating action, and there is a carefully stepped-up heating system for the extrusion die which effects a final cure of the resin as the tube emerges from the die, without holding up the flow of the resin by premature hardening (Fig. 5).

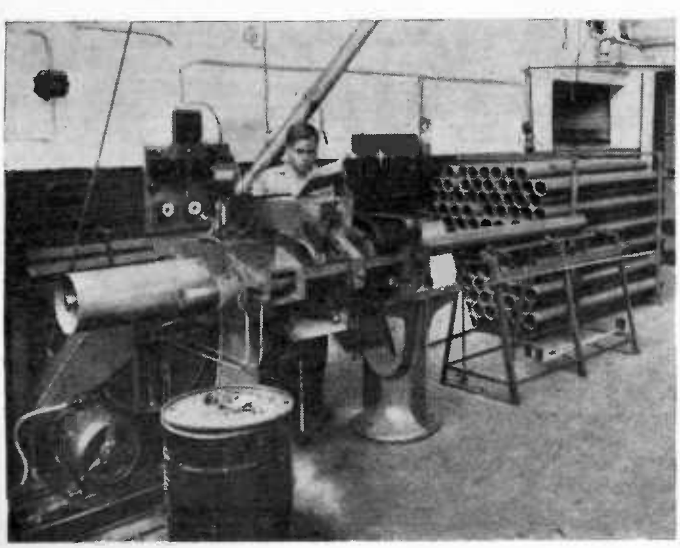


Fig. 5. Extrusion of tubes from thermo-setting resin.

(Courtesy of F. A. Hughes, Ltd.

Other Formaldehyde Resins

Formaldehyde condenses with a number of substances, but the only other resin suitable for the production of plastics is that obtained from aniline which is tough, has good electrical properties and, unlike the phenol and urea resins, is permanently thermoplastic.

Synthetic Thermoplastic Resins

These resins, known sometimes as organic glasses and as "ethenoid" plastics, may all be regarded as derivatives of the hypothetical "vinyl"—$CH = CH_2$, in which the spare bond on the left may be used to unite the complex to other complexes such as the benzene ring, or to a single element such as chlorine. In addition, the hydrogen attached to the carbon atom may be substituted by a hydrocarbon group.

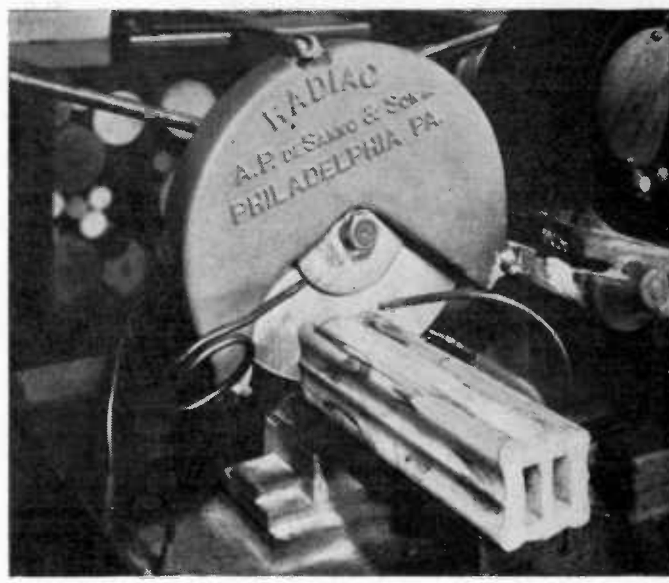


Fig. 4. Cutting sections of cast phenol-formaldehyde resin.

(Courtesy of Catalin, Ltd.)

The initial step is the production of the "monomer," followed by its polymerisation to form the resin, and while this process is common to all these resins, there is great variety in the chemical methods required to make and to polymerise the monomer. In general, the second phase, the production of sheets, rods and tubes, is carried out by moulding, extruding or casting. The third phase, the manufacture of articles, is achieved by the usual thermo-plastic shaping or by machining, as in the case of the cellulose plastics, or else is accomplished by direct moulding or injection-moulding from moulding powder. In certain cases plasticiser may have to be incorporated by a milling or mixing pro-

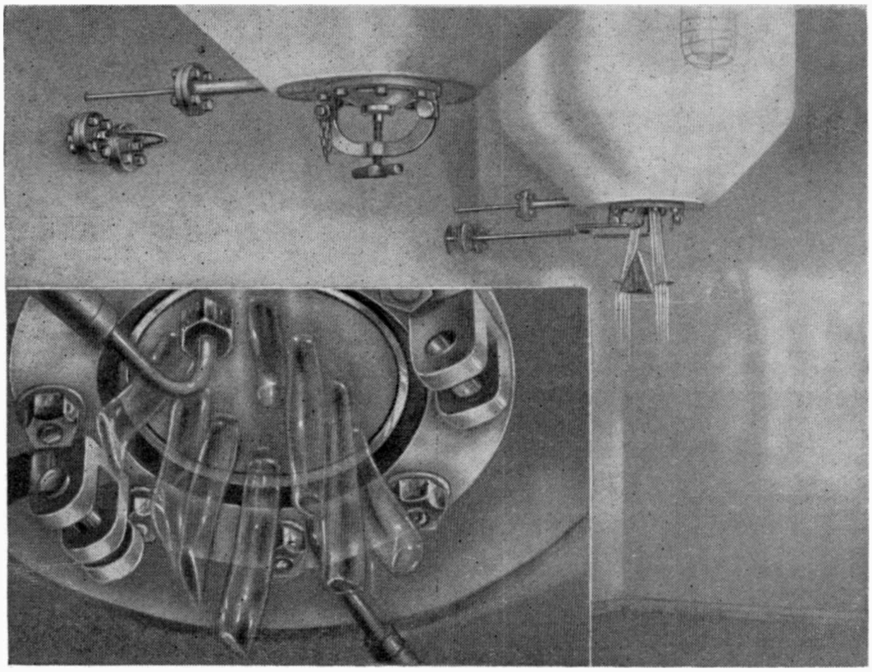


Fig. 6. Extrusion of "distrene" rods from the polymerisation pot. The inset shows the rods just emerging.
(Courtesy of British Resin Products, Ltd.)

cess, but this is almost invariably done without the use of a solvent, though in some cases the "celluloid technique" can be applied, with some difficulty, for the production of sliced sheets.

Alkathene and Polythene

This is the simplest of the vinyl derivatives and is formed by the polymerisation of ethylene $CH_2 = CH_2$ under pressure, the gas being converted to a wax-like solid, which can be extruded or moulded into blocks, and can be "sliced," owing to the softness of the material, in the same way as celluloid.

Polystyrene

The monomer in this case is styrene or vinyl benzene $C_6H_5 - CH = CH_2$, which can be formed in various ways, the simplest of which is by the preparation of ethyl-benzene from benzene and ethyl chloride, and the subsequent removal of hydrogen by a catalytic process. The monomer can then be polymerised, either in a pure state or in solution. In the latter case the solvent is distilled off and the plastic polystyrene mass extruded in the form of rods from the bottom of the polymerisation vessel (Fig. 6). These rods are ground when cool into powder which can be moulded into blocks or sheets, extruded in the form of rods and tubes, directly injection-moulded to give crystal mouldings, or worked up on the rolls with colours and fillers to give coloured injection powders of the most delicate shades.

Polyvinyl Acetals

These products are derived from vinyl acetate $CH_2 = CH - COOCH_3$ which is formed by passing acetylene into acetic acid, which can be readily polymerised into a long chain resin, the Shawinigan product being known as "Gelva." It is a soft resin not suitable for plastics, but if it is treated in such a way as to split off some of the combined acetic acid, leaving an $-OH$ group instead, this $-OH$ group can be made to react with aldehydes to produce acetals, of which the best known are Alvar and Formvar.

Alvar, with or without plasticiser, makes an excellent injection moulding powder, characterised by great strength and rigidity, while Formvar can be moulded into sheets having similar properties. It can also be worked up on rolls with large amounts of plasticiser to give permanently flexible tubes.

Polyvinyl Chloride and Copolymer

Polyvinyl chloride or P.V.C. is derived from vinyl chloride, a gas at ordinary temperatures, which is made by the interaction of acetylene and hydrochloric acid gas or by the interaction of ethylene and chlorine. Under suitable conditions, such as solution under pressure in a solvent, this gas can be polymerised into a white powder.

This powder has a very high softening point, is somewhat unstable to heat, and cannot be worked without the incorporation of a stabiliser and a lubricant and a varying proportion of plasticiser for practically all purposes, though extremely rigid tubes without any plasticiser can be extruded under special conditions.

The outstanding characteristic of this material is its capacity for yielding a very soft rubber-like plastic by the incorporation of plasticisers such as phthalates or organic phosphates, which are mixed into the polymer and then thoroughly incorporated on hot rolls. The plastic can then be sheeted out on multi-bowl calenders into endless rubber-like sheet of considerable strength or may be cut into strips for feeding screw extrusion machines for the production of sleevings or the direct covering of cables.

If to the vinyl chloride monomer is added a varying proportion of vinyl acetate, subsequent polymerisation gives what is known as a copolymer.

The properties of the copolymers depend upon the proportion of vinyl acetate in their structure, its general effect being to lower the softening point of the plastic and to increase its toughness within certain limits, the vinyl acetate acting rather like a plasticiser. The powder is worked in the same way as the P.V.C., producing sheets from hot multi-bowl rolls, which can be polished in polishing presses in the same way as the seasoned sliced sheets of Xylonite are finished. The product is an exceedingly tough plastic which is also hard and rigid, non-inflammable and water-resistant.

The copolymer can also be highly plasticised, producing rubber-like material in the same way as Polyvinyl Chloride, and if the proportion of vinyl acetate is greatly increased, the softening point is lowered sufficiently to give a material which will readily injection-mould and which rather resembles polystyrene.

Methylmethacrylate Polymer

This resin, which is so well-known as Perspex, is made by the polymerisation of the monomer methylmethacrylate, which is a water-white liquid. It can be made from acetone by a somewhat complicated process involving treatment with hydrocyanic acid. The final product has the formula $CH_2=C\ (CH_3)\ COOCH_3$, which, though somewhat complex, still conforms to the vinyl type $CH_2 = CH -$ and very readily polymerises into a hard clear water-white resin of high softening point. Sheets, rods and blocks can all be made by pouring the liquid monomer into suitable containers and polymerising *in situ*, with or without the addition of some plasticiser such as a phthalate.

The sheets, which can be made in very large sizes, are of extreme clarity and water-whiteness, and can be very readily shaped when hot by simple moulding processes. In massive form the plastic machines readily and takes a beautiful polish, while in the powder form known as Diakon it can be readily compression moulded and, in certain circumstances, injection moulded.

The Sunvic Hotwire Vacuum Switch

By G. L. WOOLNOUGH, B.E., A.M.I.E.E., A.M.I.E. Aust.

THE advantages to be gained by enclosing switching contacts *in vacuo* have been appreciated for many years, though it is only in recent years that the difficulties involved have been overcome satisfactorily and reliable vacuum switches have become available. A British Patent of 1895 describes an electromagnetically operated vacuum switch to be used in a novel scheme of street lighting by discharge lamps, but there is no evidence of any practical development of this device. There does not seem to have been any real progress until 1920 when the Birka Regulator Company in Sweden developed various types of vacuum switches on a commercial basis. This was followed within a few years by the development of vacuum switches in Germany by Siemens, Scherbius and Ritter, and others; and in the U.S.A. by the General Electric Company. The Sunvic Hotwire Vacuum Switch was first made in this country in 1934 and was rapidly developed to a valuable and reliable general purpose relay.

Attempts have been made to develop vacuum switches for heavier currents and higher voltages for power distribution networks, and there are records of a single-phase circuit-breaker successfully clearing a current of 926 amperes at 41,000 volts and a current of 15,000 amperes at 7,000 volts. However, the practical difficulties appear to have prevented such types being developed to the stage of commercial manufacture.

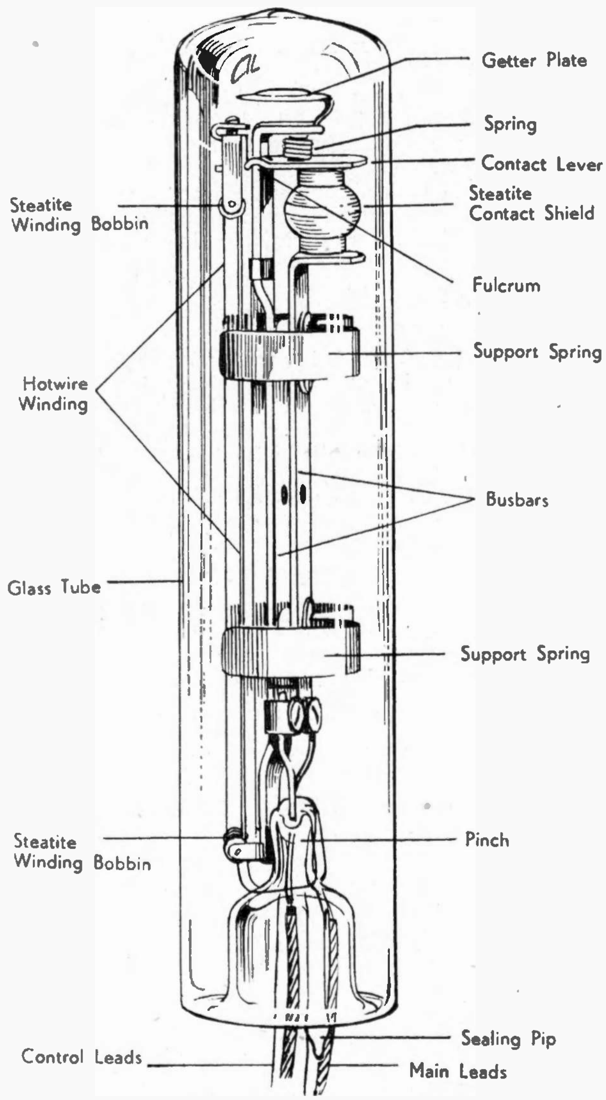


Fig. 4. Drawing of Sunvic switch showing assembly.

Methods of Operation

Vacuum switches may be of the relay type in which the contacts are operated by electrical means; or they may be of the mechanical type in which the contacts are operated by a cam mechanism, or as a limit switch, or by change of mounting angle.

Of the relay type, the magnetic operation is the most obvious though it has many disadvantages. Since the coil cannot be mounted inside the evacuated enclosure it is difficult to get an efficient iron circuit and large coil inputs are needed to get adequate contact pressures. The same coils cannot be used in both A.C. and D.C. circuits and the coil inductance is an undesirable feature since it leads to burning and welding of the controlling contacts.

Vibration and mounting angle are liable to cause difficulties, and in order to overcome possible contact welding it is almost essential to introduce some lost motion mechanism which gives the contacts a hammer blow and initiates the contact movement.

In the original Swedish Birka vacuum switches the contacts were operated by the deflection of a heated bimetal strip, the contacts and the heated operating bimetal both being enclosed in the evacuated container. This construction overcame many of the objections to the magnetic operation, but the time lag in operation was excessive for many purposes.

In the Hotwire Vacuum Switch (the HVS) the contacts are operated by the linear expansion of a fine wire winding which is directly heated by the control current passing through it, and due to the small mass which has to be heated the time lag is reduced to a few seconds which is acceptable or even desirable in a large number of practical applications.

Of the mechanically operated types the best known are those in which the contacts are operated by a rod passing through a semi-flexible wall of the evacuated container. In another type the contacts are associated with a soft iron armature which is caused to move under the influence of an external permanent magnet. Switches operated by tilting have been made, usually consisting of a ball which rolls to bridge two fixed contacts.

Rupturing the Load Circuit

In considering the conditions arising during the period when the load circuit is broken at the contacts there are several physical phenomena involved. The degree of vacuum in a sealed-off vacuum switch which has been gettered is rather difficult to determine, but it is generally considered to be between 10^{-3} and 10^{-4} mm. of mercury, though the pressure may rise temporarily during switching periods due to liberation of gases occluded in the contacts. At such low pressures and for small contact gaps the spark potential is greater than the potential required to initiate appreciable auto-electronic emission, the mean free path of the residual gas is of the order of 10 mils. and the limiting current below which it is impossible to maintain a metallic arc is of the order of 100 amperes.

As the contacts start to move apart there will first be a stage when the contact pressure and contact area decrease progressively and local overheating is likely to occur at the final point of contact. This may lead to some thermionic emission, but this is not regarded as significant. As soon as the contacts have parted, a voltage will build up between them at a rate governed by the circuit constants and tending towards a peak which may be very high, particularly in inductive circuits. If the rate of separation of the contacts could be made fast enough in relation to the rate of rise of voltage across the contacts, then no further electrical phenomena would

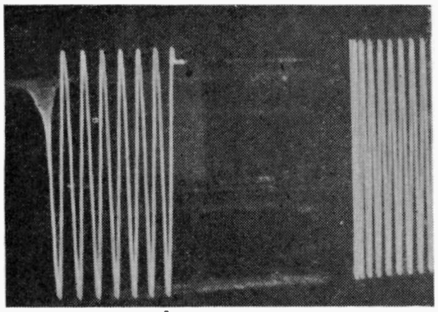


Fig. 1a. Oscillogram of break in three amp. circuit. For explanation *see* text.

occur at the contacts and the circuit would be cleared.

In practice restriking is likely to occur due to autoelectronic emission (the so-called "cold discharge") when the field strength reaches a value of the order of 10^6 volts per centimetre. At this stage a metallic bridge may form so that the contacts are in effect welded and the circuit is remade temporarily, the circuit being broken again as the contact movement progresses and breaks this weld; or in the absence of a bridge formation the emission may continue until it is extinguished by decrease of potential gradient. Alternatively if the impedance of the load circuit is sufficiently low a stable metallic arc may form and continue until the contacts are separated by a considerable distance.

No mention has been made of any glow discharge phenomena, since, at the pressures considered, the distance between the contacts is smaller than the length of the mean free path of the residual gas and a discharge dependent on ionisation by collision cannot be stable. Should the pressure rise sufficiently due to liberation of adsorbed gas then the electrons originating by thermionic or auto-electronic emission will collide with the gas molecules with consequent ionisation and development of a glow discharge which can continue as a stable process if the voltage between the contacts is high enough.

It is evident that in D.C. circuits development of the metallic arc or the glow discharge will destroy the vacuum switch, since the contact separations are never sufficient to extinguish these phenomena at the higher pressures. In A.C. circuits both discharges would cease automatically as the current passes through zero every half-cycle, and restriking will depend on the contact temperatures and the circuit constants.

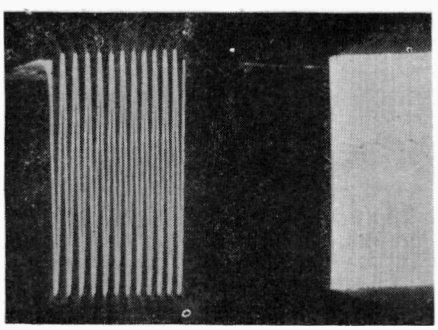


Fig. 2a. Break in 1 ampere inductive load with surge suppressor.

As far as normal switching in vacuo is concerned it should be understood that the distances and times involved are extremely small. The circuit is cleared with a contact separation well under one mil and, even allowing for restriking a few times, the time taken to clear the circuit is only a few microseconds. In the case of the single clean break it might be agreed that there is no switching time since the circuit changes from being made to being broken without any significant intermediate stage. Hence it follows that in the normal case it is immaterial whether the circuit is supplied with A.C. or D.C. since the circuit is cleared in a few microseconds at whatever time the contacts start to move apart.

Voltage conditions after the Break

In an entirely non-inductive circuit there is no stored energy associated with the current flowing and after the break the voltage across the contacts will build up to the supply voltage at a rate determined by the resistance and capacity of the circuit.

In practice, however, any circuit has some inductance so that there is stored energy of $\frac{1}{2}LI^2$ to be converted into alternative forms. Some of this energy may be dissipated as heat and light at the contacts on breaking and restriking, but most will appear in the form of voltage rise across the distributed capacity of the circuit as stored energy of $\frac{1}{2}CV^2$. This last energy will then be discharged back through the supply circuit, usually an oscillatory phenomenon, until all the energy has been dissipated as heat in the circuit resistance. In highly inductive circuits, peak voltages over ten thousand volts have been measured and, in order to protect the circuit wiring and associated apparatus, steps must be taken to limit this rise to say two thousand volts peak. A large condenser across the contacts will decrease the voltage rise, but such a condenser would have to be insulated for two thousand volts working, and constructed to be practically non-inductive to surges with microsecond wave fronts. A much simpler solution is the use of "Metrosil" across the contacts, this material having a non-linear relation of current to voltage. A standard unit commonly used follows the law $I = (V/800)^{4.5}$ and such a surge suppressor will pass a leakage current of

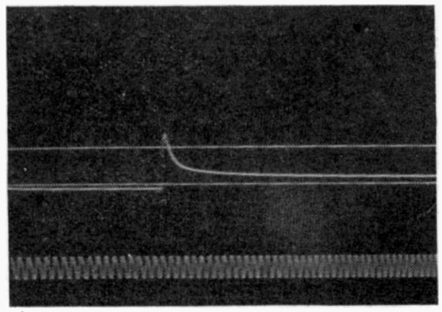


Fig. 1b. Break in three ampere circuit with non-inductive load. Similar to Fig. 1a.

5 mA at 250 volts D.C., but with a load current of 20 amperes the limiting voltage rise for a circuit of infinite inductance would be 1,550 volts, which is not serious as a surge.

It is usual to connect a small condenser of the order of 3,000 $\mu\mu$F across the contacts as standard in all circuits. This has the effect of reducing the rate of rise of voltage after the break, and in D.C. circuits it reduces contact material transfer to a great extent.

Oscillograph Records of Switching

Many oscillograms have been taken in the attempt to record the conditions at the moment of break, using a continuously evacuated high speed cathode ray oscillograph and typical examples of these are published by the courtesy of Metropolitan-Vickers Electrical Company, Ltd., in whose Research Laboratories they were recorded.

In obtaining these records the greatest difficulty is experienced in synchronising the tripping of the time-sweep circuit with the commencement of the switching phenomena. The commonly used method of the delay cable cannot be used since it introduces an undesirable capacitance in parallel with the contacts. Accordingly it is neces-

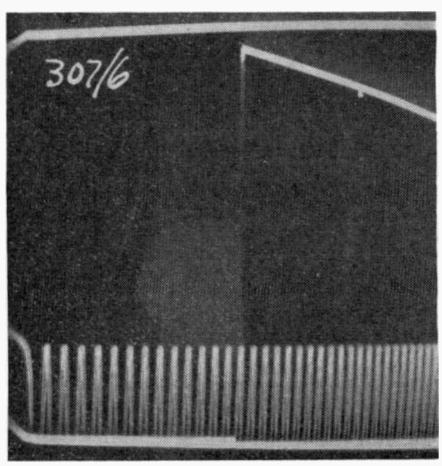


Fig. 2b. Similar to Fig. 2a with 14 microseconds timing wave. Calibration line 800 volts.

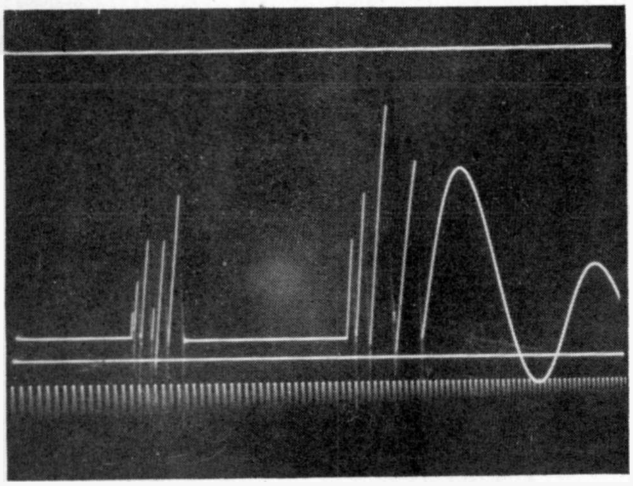


Fig. 3. Typical break on 1 ampere load, with 3,000 $\mu\mu$F across contacts.

sary to rely both on tripping the time-sweep circuit at some fixed time after switching the control circuit of the vacuum switch, and on the time of operation of the vacuum switch remaining constant. Due to uncontrollable variations in these operating times it is necessary to use time bases of the order of 1,000 microseconds which means that with the usual exponential time base about 7 cms long, phenomena occurring in a few microseconds cannot be studied properly. The difficulty can be overcome by using an oscillatory time base of the Dufour type, by which means the 1,000 microseconds time base may be retained, and the developed length may be say 150 cms against 7 cms for the exponential time base.

Figs. 1(a) and 1(b) show a typical break on a three-ampere commercially non-inductive load with no protective "Metrosil" or condenser. Fig. 1(a) is of the Dufour type, 14 microseconds period of oscillation, while Fig. 1(b) is of the exponential type with an 8 microseconds timing wave and 1,000 volts calibration line. In this case the rate of rise of voltage across the contacts is extremely rapid and repeated restriking occurs for a few microseconds before the circuit is cleared.

Figs. 2(a) and 2(b) show a typical break on a one ampere highly inductive load with a "Metrosil" surge suppressor, but no condenser. Fig. 2(a) is of the Dufour type, 14 microseconds period of oscillation, while 2(b) is of the exponential type with a 14 microseconds timing wave and 800 volts calibration line. Again the rate of rise of voltage across the contacts is rapid, but in this case the "Metrosil" limits the peak voltage, no restriking is apparent and the circuit appears to be cleared instantly.

Fig. 3 shows a typical break on a one ampere load with a 3,000 $\mu\mu$F. condenser across the contacts but no "Metrosil." The period of the timing wave is 8 microseconds and the calibration is 8,000 volts. In this case the rate of rise of voltage is much slower than in Figs. 1 and 2, but due to the much greater voltage rise there is repeated restriking and apparently a stage of contact welding. The circuit is oscillatory when finally cleared.

Construction and Operation of the HVS

Having considered the more general questions of switching in vacuo, it should be of interest to examine a construction which has proved satisfactory in commercial service.

Fig. 4 shows a typical Sunvic HVS, the complete assembly being enclosed in a glass tube which is evacuated and gettered. The tungsten contacts are enclosed in a protective shield and are carried one on the right hand busbar and the other on the moving contact lever which pivots on the left hand busbar. The contact spring provides a force tending to close the contacts, but they are normally held open by the operating winding which is under tension. The control current beats the operating winding and the linear expansion is sufficient to allow the contacts to be closed by the contact spring. Breaking the control circuit allows the operating winding to cool, whereupon it contracts and pulls the contacts open.

The operating winding consists of 15 turns of a special steel alloy wire, the turns being electrically in series, but mechanically in parallel. The winding wire is of high tensile strength at the working temperature (which is in the range of 300° C. to 400° C.), and under the working conditions the creep rate is negligible so that the HVS can be energised continuously without change of setting.

Such a switch, approximately 6 in. long and 1¼ in. in diameter, is rated for a load of 12 amperes at 440 volts or 18 amperes at 110 volts, A.C. or D.C., and will operate with a control current of 40 mA. in about three seconds.

The life of the HVS is usually determined by material transfer at the contacts. In A.C. circuits material is transferred symmetrically from both contacts, both of which tend to flatten from their original hemispherical shape. After several million operations at the rated load the extra contact gap caused by the contacts flattening may mean that the switch will not close. In D.C. circuits the usual pip and crater effect is found and failure when it occurs, is usually due to the pip jamming on the sides of the crater. On the rated loads failure may occur after several hundred thousand operations.

Advantages and Uses of the HVS

Having the whole of the mechanism enclosed in vacuo ensures freedom from dirt and corrosion troubles in addition to the advantages of being able to switch considerable loads in a small space without arcing or rapid contact wear. Further, the hot wire winding can be run at a high working temperature without oxidation and its power consumption is greatly reduced. The compact arrangement enables the weight of the parts to be kept small in relation to the working forces so that operation of the HVS is substantially unaffected by mounting angle or reasonable vibration.

The great virtue of the hot wire winding lies in the fact that it is of negligible inductance; it can therefore be used in A.C. or D.C. circuits without modification, and the duty on the controlling contacts is extremely light. It is possible to use controlling contacts of very simple design requiring low operating forces and having slow movements, without trouble from burning and welding.

The time delay inherent in the hot wire winding is of great value for many purposes since it prevents false operation due to any momentary vibration of the controlling contacts; and in the event of the controlling contacts being in a state of continuous vibration, an integrating effect is obtained so that the load circuit is switched at more reasonable intervals.

The principal use for the HVS is as a general purpose relay interposed between some sensitive thermostat, or other controlling device, and a load circuit, under which conditions its many advantages amply justify its use in place of the previously used magnetic contactor. It is also used extensively as a time delay relay in the range of two to twenty seconds for countless applications where a simple and reliable delay device is required. The inherent time delay and close ratio of closing to opening voltage make the HVS particularly suitable for use in voltage measuring circuits such as are used for battery charging relays. Amongst many other applications may be mentioned its use as a relay in the anode circuit of Thyratrons, where the non-inductive hot wire winding is of particular value in avoiding phase displacement between anode and grid circuits.

Frequency Modulation

Part IV.—The Frequency Modulation Receiver

By K. R. STURLEY, Ph.D., A.M.I.E.E.

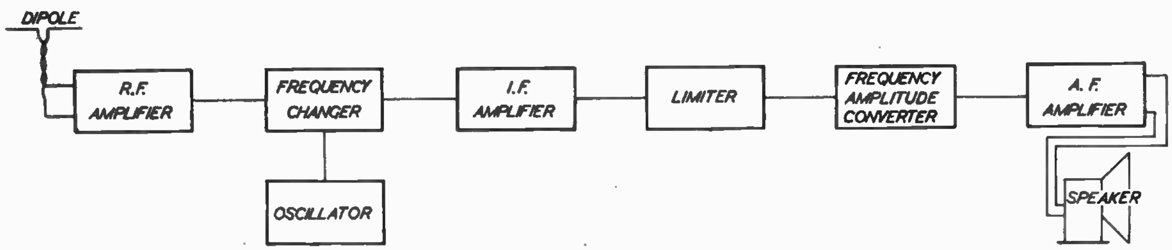


Fig. 1. Diagrammatic layout of Frequency Modulation Receiver.

IN the second of this series of articles it was stated that frequency modulation could not be satisfactorily employed for short wave operation because selective fading due to multipath transmission resulted in an almost unintelligible signal at the receiver; its sphere of usefulness is limited to the ultra short wave band where communication is mainly by the direct ray. In Europe no official decisions have been made with regard to allocation of wave bands for frequency modulation, but it is probable that they will be similar to those allocated in America, *i.e.*, over the range 40-50 Mc/s. Radio frequency amplification is very limited at these ultra high frequencies and the superheterodyne method of reception is essential to achieve sufficient overall amplification.

A schematic diagram of the probable form of receiver is shown in Fig. 1 and we see that it only differs from that of an amplitude modulation receiver in the inclusion of the limiter and frequency-amplitude converter stages. The dipole aerial is connected to a radio frequency stage followed by a frequency changer with a local oscillator. After the frequency changer is a series of intermediate frequency stages, the output of which supplies the limiter. A converter changing the frequency into amplitude modulation follows the limiter, and the amplitude modulated wave after detection forms the input to a high fidelity audio frequency amplifier covering a range from 30 to 15,000 c.p.s. The radio frequency, frequency changer and local oscillator stages will be practically identical with those for amplitude modulation at the same carrier frequency, but owing to the comparatively wide pass band (± 100 kc/s) required to accept the carrier deviation, a higher intermediate frequency is required. The limiter stage is necessary to suppress amplitude changes (due to transmission variations and noise) of the carrier because the detector following the frequency-amplitude converter is sensitive to amplitude variations. There is no need to comment on the frequency-amplitude converter; it is obviously required because the character of the original audio frequency voltage modulating the carrier is that of amplitude variation. The audio frequency stages will be identical in design to those used for high fidelity amplitude modulated transmission.

Starting from the aerial we will now turn to a more detailed examination of the various stages.

The Aerial

This consists of a dipole so dimensioned as to act as a half wave resonant aerial at the centre of the band of frequency modulated transmissions (its overall length is about 5 per cent. less than the wavelength of the resonant frequency, because owing to end effects its electrical length is always greater than its actual length). If a reflector is used it is usually spaced about one-quarter of the wavelength away from the aerial and it may be a half wavelength long or greater; a length greater than a half wavelength helps to give a more constant response[14] over the wave band. The centre of the dipole is taken to a centre tapped coil at the receiver by a twin wire feeder. Motor car ignition interference, a serious problem on ultra short waves, is mainly vertically polarised so that best signal-to-noise ratio is usually obtained by placing the dipole aerial horizontal. Ultra high frequency aerial design is a specialised subject which cannot be treated in detail in the present series of articles, but the bibliography (Nos. 6, 8, 11, 14, 16) contains a selected set of references to the subject.

The R.F. Amplifier Stage

The advantage of including a radio frequency stage before the frequency changer is increased sensitivity, signal-to-noise ratio and selectivity (against image signal and spurious intermediate frequency responses due to interaction between undesired signals and harmonics of the oscillator frequency). The first two factors, which are inter-related are the more important; owing to the use of a limiter stage, a high degree of overall amplification is required and as most of this must be obtained in the intermediate frequency amplifier, instability is a real danger. Additional amplification at the signal frequency, however small (it will probably not greatly exceed 3 times the general purpose receiving valves or 12 for acorn[1] valves) is desirable because it allows I.F. gain to be reduced for the same overall sensitivity.

Feedback of voltage developed in the inductance of the cathode-earth lead[9] through the grid cathode capacitance of the valve and, to a less extent, electron transit time contribute to a low grid input resistance component, the formula for which is

$$R_g = \frac{1}{g_m \omega^2 C_{gk} L_k} \quad \dots \quad (1)$$

where g_m = mutual conductance of the valve.

C_{gk} = grid cathode capacitance.

L_k = inductance of the cathode-earth lead.

Taking g_m = 3mA/volt, C_{gk} = 3.5 $\mu\mu$F and L_k = 0.2 μH, the input resistance due to cathode inductance is 6,000Ω; an average for the general purpose type of R.F. valve (incuding electron transit time damping) is 4,000Ω. Acorn valves having smaller transit times and shorter cathode-earth leads usually have an input resistance of the order of 20,000 ohms.

The heavy damping from the valve prevents the realisation of a high degree of selectivity in the signal stages. This fact, together with the restricted range of ultra high frequency transmission, makes it possible to consider preset tuning of the R.F. stage to the centre of the desired range, discrimination against adjacent transmission being achieved in the intermediate frequency and variable tuning by oscillator frequency adjustment. Under these conditions optimum coupling may be used between aerial and first tuned circuit; the aerial coupling then gives maximum voltage transfer, but at the same time reflects a resistance component into the first tuned circuit equal to that already existing before the aerial is coupled to it. If we take 4,000Ω as an average valve grid input resistance the total parallel resistance of the first tuned circuit cannot exceed 2,000Ω when aerial coupling is optimum. A value of first circuit tuning capacitance of 20 $\mu\mu$F (valve and stray capacitances make it impossible to consider much less) gives an inductance value of 0.626 μH and a magnification Q* of 2,000/176.5 = 11.3. The off-tune frequency at which the response of the circuit is 0.707 of its maximum value is given by

$$\Delta f = \pm\frac{fr}{2Q} = \pm\frac{45}{22.6} \approx \pm 2\ \text{Mc/s} \quad \ldots \quad (2)$$

where fr = the resonant frequency.

Hence such a circuit could easily accommodate transmissions covering a range from 43 to 47 Mc/s when the circuit is tuned to 45 Mc/s and it is clear that signal tuning would confer little advantage over this range, in which twenty frequency modulated transmissions having frequency deviations not exceeding ± 100 kc/s could be located. When signal circuit tuning is employed, selectivity can be improved by using Acorn valves or by tapping the grid of the R.F. valve down the coil; the reflected parallel resistance across the coil is thus reduced and its Q increased. The increase in Q may more than offset the decrease in grid voltage due to tapping down and a net increase in sensitivity may be registered. It may be noted that for a pass band of 200 kc/s (normal maximum frequency deviation at 45 Mc/s, = ± 100 kc/s) formula 2 calls for a Q of $fr/2\Delta f$ = 45/0.2 = 90 and signal tuning therefore requires a considerable reduction in damping if full advantage is to be derived from it. The input resistance of the valve may be increased by including a resistance[7] in the cathode-earth lead to reduce the phase angle between the cathode voltage and current. This causes the phase of the feedback voltage in the grid circuit with respect to the input voltage to change from approximately 180° for the inductive cathode-earth lead to 90°; *i.e.*, the feed back is mainly reactive and only slightly resistive. The inclusion of a resistance reduces the overall gain of the stage by reason of negative feedback in the cathode circuit, but this is usually more than offset by the reduction in damping on the tuned circuit and the net result is a slight increase in overall amplification. Adjustment of tuning may be by variable air condensers, but variation of inductance is preferable since fixed condensers are less susceptible to ageing and temperature effects than variable condensers, which are themselves much less stable than variable inductances. The latter consist of few turns of copper wire with a metal plunger capable of being screwed into the former. The plunger, which acts as a short circuited turn to reduce inductance must be of high conductivity material (copper, brass, aluminium) if it is not to alter appreciably the Q of the coil. The usual precautions appropriate to ultra high frequency operation must be taken; leads must be as short as possible, all earth connexions taken to the same point on the chassis, adequate decoupling by small mica condensers of electrodes normally carrying only D.C. or A.C. supply voltages (screens and heaters). A probable form of variable tuned R.F. amplifier is shown in Fig. 2, which is drawn to emphasise the points enumerated above.

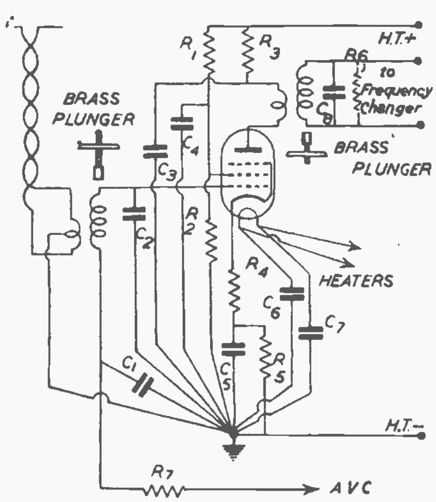


Fig. 2. Circuit of variable tuned R.F. amplifier using tuning plungers in the aerial and anode coils.

The second tuned circuit may require a damping resistance R_6 (shown dotted) if the frequency changer is a heptode with the signal grid further from the cathode than the oscillator grid. The input resistance component of this valve is often negative[3] at high frequencies. The resistance will not be required for a hexode frequency changer which has a low positive input resistance component comparable with that of the R.F. valve. Condensers C_1, C_2, C_4, C_5, C_6, and C_7 (mica 0.01 μF) are for bypassing radio frequencies to earth. The A.V.C. decoupling condenser C_1 need not be as large as for an amplitude modulated system, since feedback of any amplitude change (which should in any case be small) along the A.V.C. line is in such a direction as to help suppress it. C_3 and C_8 are fixed tuning condensers; R_1 and R_2 have values appropriate to the screen voltage required, generally 30,000 and 20,000Ω respectively. R_3 is a 1,000Ω decoupling resistance and R_5 a self bias resistance of about 300Ω. R_4 (20 to 40Ω) would not actually be included in a preset tuned amplifier operating over a range of frequencies and is the anti-damping resistance which increases the input resistance component of the valve. R_7 is an A.V.C. filter resistance of about 1MΩ.

The Frequency Changer

The frequency changer follows normal practice, a triode-hexode, a separate triode with hexode or heptode comprising the local oscillator and frequency changer; small mica decoupling condensers and a common earth point are necessary as for the R.F. amplifier. The I.F. transformer in the anode circuit is damped to secure the necessary pass band width. A typical frequency changer oscillator circuit is shown in Fig. 3. Condensers C_2, C_3, C_4 C_6 and C_7 (0.01 μF mica) are for bypassing radio frequencies to earth. C_1 and C_{10} are fixed tuning condensers for signal and oscillator respectively, and C_5 and C_8 tune the primary and secondary of the I.F. transformer. Resistances R_1 and R_2 form the screen potentiometer, R_3 is a damping resistance to give the required band width at the intermediate frequency, and R_4 (1,000Ω) and R_5 (300Ω) are decoupling and self bias resistances. Details of the oscillator components and I.F. transformer are given in their appropriate sections. If a pentode acorn valve (there is not a hexode or heptode type available in this series) is employed as a frequency changer, the oscillator voltage is usually applied to the suppressor grid. Cathode[15] application has been used, but is normally less satisfactory because of the higher interelectrode capacitance coupling between oscillator and signal circuits.

The Oscillator

The great difficulty in ultra high frequency oscillators is to obtain sufficient oscillation amplitude without squeggering or dead spots in the tuning range. A modified Colpitts circuit[1, 3] (the interelectrode anode-cathode and grid-cathode capacitances act as the splitting capacitance to cathode) is often favoured as it uses no separate reaction coil. The grid coupling condenser C_9 in Fig. 3 is used to control oscillation amplitude, a value of about 20 $\mu\mu$F being suitable. R_6, the self biasing grid leak, has a value of about 50,0000Ω. R_7 prevents the centre tap of the coil being earthed as far as radio

*Q = $\omega L/R_s$ = $R_p/\omega L$, where R_s and R_p are respectively the equivalent series or parallel resistance components of the tuned circuit.

frequencies are concerned. If it is short circuited we have a Hartley oscillator. R_8 and C_{11} are decoupling components to reduce feedback from the audio frequency stages and to smooth out variations of H.T. voltage. An alternative circuit is the electron coupled oscillator of Fig. 4,[13] it is satisfactory in operation and is very suitable for use in capacitance tuned circuits when one side of the condenser must be earthed. C_3 and C_4 are R.F. bypassing condensers, C_2, the grid coupling condenser, has a value of 50 $\mu\mu$F and R_1, the self bias grid leak, 50,000Ω and C_1 is the tuning condenser.

The oscillator is a key point in the ultra high frequency receiver and satisfactory overall performance demands a high degree of frequency stability. Frequency error of the oscillator has a different effect on frequency modulation from that on amplitude modulation. In the latter case unless the error is large detuning results mainly in frequency distortion of the audio frequency output with accentuated high frequency components producing high pitched shrill reproduction. Frequency modulation of the oscillator by hum or interfering voltages has no effect since the detector is responsive only to amplitude variation. In frequency modulation oscillator error limits the remissible frequency deviation of the carrier since it off centres the latter with respect to the frequency-amplitude converter and

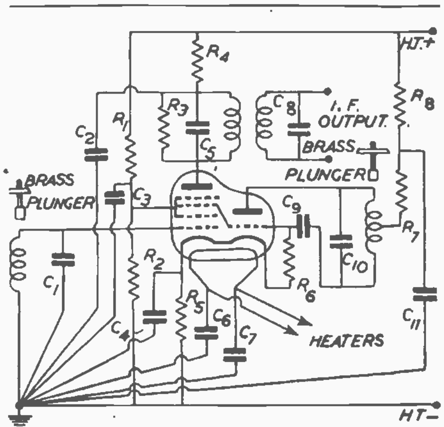


Fig. 3. Typical frequency changer oscillator circuit using a triode hexode.

amplitude distortion of the audio output—flattening of the top or bottom half of the wave shape—results at high level modulation. The action of the limiter largely prevents the frequency distortion effect present with amplitude modulation. Frequency modulation of the oscillator by hum, noise, etc., is a serious matter since the converter changes this to amplitude variation and produces an audio signal. We see, therefore, that oscillator long or short period frequency stability is of much greater importance in a frequency modulated system.

Causes of Frequency Instability

Let us now consider the causes of frequency instability, separating the long from the short period effects. Slow drift of oscillator frequency is due to heat and humidity, the former generally predominating, whilst rapid changes are chiefly caused by H.T. supply voltage fluctuation due to hum, mains interference or feedback from the audio frequency stages. The tuning inductance and capacitance increase[15] with increase of temperature is mainly responsible for long period changes, though heating of the valve also contributes its quota, and the chief problem is to reduce these variations to a minimum. It is generally more difficult to produce a variable condenser with low temperature coefficient than a variable inductance so that inductance tuning with fixed condensers of the silvered mica-type is preferable. Inductance variations with temperature result from an increase of radius and length the former increasing and the latter decreasing L. Reduced variation is therefore possible by suitably proportioning the coefficient of radial and axial expansion (radial expansion coefficient should be about half that of axial). This can be achieved by winding the coil turns loosely on a former and fixing the ends firmly to the former so that radial expansion is determined by the conductor and axial by the former. An alternative is to reduce both axial and radial expansion by shrinking the coil on to a former having low coefficients of expansion, *e.g.*, ceramic material has a coefficient of about 7×10^{-6} as compared with copper at 17×10^{-6} and the dimensional change of a coil shrunk on to a ceramic former will be largely determined by the coefficients of the ceramic material.

Capacity Compensation

Capacitance temperature changes are due to expansion and dielectric insulation variation. Careful mechanical design, such as accurate centring of the rotor plates of a variable condenser or the use of silvered mica plates to reduce capacitance variation due to pressure change in fixed condensers, can assist in controlling expansion effects, whilst the use of ceramic material reduces dielectric changes. Connecting leads should be short, securely fixed and not in tension. Preliminary cyclical heating is often an aid to frequency stability. Certain types of condensers can be constructed to give a negative temperature coefficient, *i.e.*, capacitance falls as temperature rises, and they may be used to compensate for the positive temperature coefficient of tuning inductance or capacitance. Compensation is only complete, however, at one particular frequency and the temperature of the corrector condenser must follow that of the component it is intended to compensate. Hence, it is still essential to aim at the highest possible stability before applying correction.

Oscillator Stability

Valve temperature effects due to interelectrode dimensional changes (the capacitance variation is of the order of 0.02 and 0.04 $\mu\mu$F.) can be reduced by loose coupling between active electrodes and the tuned circuit. The use of a harmonic of the oscillator for combining with the signal to produce the I.F., helps to reduce capacitance variations in inverse ratio to the harmonic employed, *i.e.*, using the second harmonic of the oscillator as the active frequency reduces the frequency drift for the same tuning inductance to one half. There are disadvantages to oscillator harmonic operation since signals spaced the I.F. away from the fundamental and other harmonics will produce spurious responses. Greater frequency stability may be realised by operating the oscillator at a frequency lower than the signal by an amount equal to the intermediate frequency and this confers no disadvantages when the signal circuits have preset tuning.

Humidity effects demand the use of non-hygroscopic insulation material such as ceramic.

Supply voltage changes may cause slow or rapid changes of frequency. L.T. heater change is generally comparatively slow in action affecting valve temperature, cathode emission and cathode-heater resistance and capacitance (this is important in the electron coupled oscillator of Fig. 4).

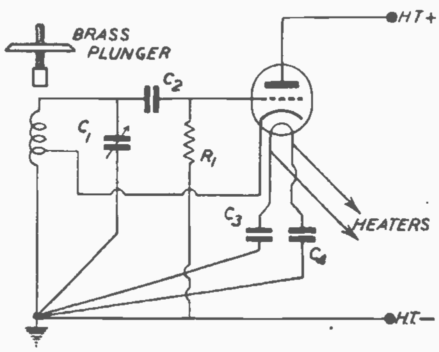


Fig. 4. Alternative form of oscillator circuit suitable for use with one side of the condenser earthed.

A palliative is again loose coupling to the tuned circuit. Variation of H.T. supply controls frequency by reason of its effects on the mutual conductance and internal resistance of the valve, and it is largely responsible for frequency modulation troubles. Adequate decoupling and smoothing is an essential to stability, and feedback from the A.F. amplifier is lessened by using a push-pull output stage to the loudspeaker or even a separate H.T. supply.

(*For Bibliography see page* 643.)

The Sun and the Ionosphere

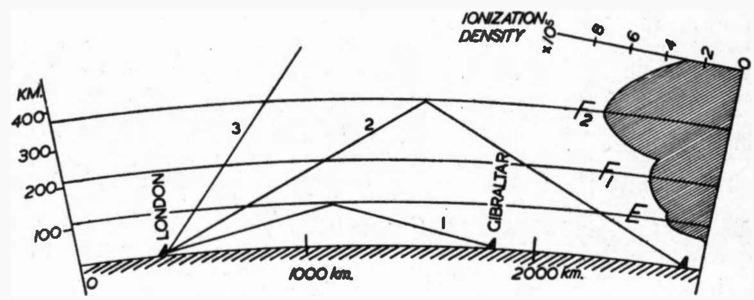
The Thirty-second Kelvin Lecture

By Prof. S. CHAPMAN, M.A. D.Sc., F.R.S.

This abstract of the Kelvin Lecture delivered before the Institution of Electrical Engineers in May last year has been printed in view of the interest of the subject to Service trainees at the present time. The full report appears in the *Journal I.E.E.* for November, 1941, Part I.

IT is convenient first to take a large-scale view of the height-distribution of our atmosphere. The pressure at any level corresponds to the weight of the column of air, of unit cross-section, above that level, and this diminishes with increasing height. In the lowest part of the atmosphere the height of the mercury barometer decreases by about 1 in. per 1,000 ft. rise. This means that a 1,000-ft. column of air has the same weight as a mercury column 1 in. high. But this rule cannot remain true at all heights, because the density of the air decreases as we go upwards. In an atmosphere of uniform composition and temperature, equal intervals of height correspond to equal ratios of reductions of pressure or density. The height-difference corresponding to a given ratio of reduction in that case determines the distribution of the whole atmosphere. The height interval corresponding to a reduction of the pressure in the ratio $1/e$ ($e=2.718$=the base of Napierian logarithms) is called the scale height of the atmosphere; 2.303 times this height gives the decimal scale height H, corresponding to a reduction in the ratio 1/10. If the atmospheric temperature and composition were everywhere the same as at the ground, the decimal scale height would be 19.4 km. or 12.1 miles.

The structure of the atmosphere up to a height of about 80 miles is illustrated by Fig. 1, which shows the positions of the levels at which the density is reduced by successive factors of 10, and the number of molecules per cubic centi-metre at each such level. The thickness of the second layer, in the cold lower stratosphere, is less than that of the lowest layer; then come four layers of greater thickness (especially the fourth and fifth), corresponding to the hot layer; the sixth and seventh layers are again of smaller thickness. The positions of the levels above 20 miles' height are somewhat uncertain, especially at the greater heights.



The E, F and F_2 layers of the ionosphere. On the right is a curve of height distribution of electron density (after Nat. Bureau of Stds., U.S.A.).

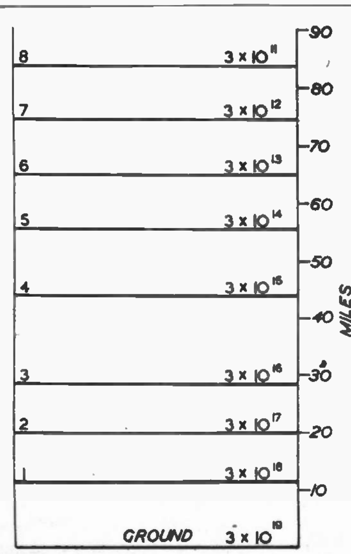


Diagram showing the rate of upward increase in density in the atmosphere: at successive horizontal lines the density is reduced in the ratio 10:1. The number above each line is the number of molecules per c.c. of the air at that level.

These variations of layer-thickness, however, are not so great as to preclude us, in a general qualitative discussion, from treating the scale height of the atmosphere as constant up to 80 miles or so.

Dissociation and Ionisation by Absorption of Light

When radiation of any wavelength passes through a gas, the fluctuating electric field of the waves causes the electrical structure of the molecules to oscillate. They become Hertzian oscillators, and radiate energy which they draw from the incident radiation. The gas is said to "scatter" some of the incident radiation.

Generally this is a feeble process, but the molecules may resonate to radiation of certain wavelengths or frequencies, and be set into strong vibration. The absorption of the radiation then becomes considerable, and the oscillation within the molecule may lose one or more of its atoms, or it may become ionised by losing an electron.

Such consequences follow from the ultra-violet absorption by ozone, oxygen and nitrogen. The ozone is not ionised; its molecules lose one of their atoms and become oxygen molecules:

$$O_3 + \text{radiation} = O_2 + O$$

Oxygen may be either dissociated into two oxygen atoms:

$$O_2 + \text{radiation} = O + O$$

or, for light of wavelength not much above 1,000Å, it may be ionised:

$$O_2 + \text{radiation} = O_2^+ + e-$$

Nitrogen is not appreciably dissociated into atoms by ultraviolet absorption, but may be ionised:

$$N_2 + \text{radiation} = N_2^+ + e-$$

Thus the absorption of radiation in the extreme ultraviolet end of the spectrum, wound about 1,000Å can ionise molecular oxygen and molecular nitrogen, producing negative electrons and positive molecular ions. If the two gases, nitrogen, and oxygen, absorb at different levels, they provide an ionosphere consisting of two ionised layers, such as is observed by radio methods.

The Ozone Layer

The light that dissociates oxygen seems to be absorbed in a layer of great thickness extending from 60 or 70 miles' height down to perhaps 10 miles from the ground. In the lower half of this layer the free oxygen atoms produced by the dissociation are likely to combine quickly with surrounding oxygen molecules to form ozone; but with increasing height the chance of such combination decreases, because collisions become less numerous, and also because the proportion of undissociated oxygen decreases upwards. Thus the ozone is formed mainly within a layer extending from about 10 miles to 30 or 40 miles in height; the winds in the lower atmosphere spread the ozone downwards, but mixing, the ground level.

The ozone is an extremely rare constituent at all levels. If all of it were collected together at the bottom of the atmosphere, at the pressure prevailing there, it would form a layer less than ⅛ in. thick; since it is actually spread throughout a layer 30 or 40 miles thick, it is highly diluted. Yet this very small amount is able completely to absorb all the radiation in the ultra-violet band from about 2,000 Å to 3,000 Å, and also some of the visible and heat radiation: in all it absorbs about 5 per cent. of the whole incident energy. The absorption tends to raise the temperature of the ozone layer, especially in its upper part, where the heat absorbed is large compared with the density of the air to be heated. This absorption by ozone, aided by oxygen absorption, is the cause of the hot layer that expands the third and fourth intervals of decimal scale height in Fig. 1.

Atomic Oxygen in the Ionosphere

With increasing height in the ozone layer, ozone is present in ever smaller proportion, and the molecular oxygen becomes increasingly dissociated into oxygen atoms. At first the increase is slow, but finally the molecular oxygen thins out rapidly, and at last becomes rare relative to the atomic oxygen. Above this level, whose height may with some uncertainty be placed at 60 or 70 miles, the oxygen exists mainly in the atomic form.

Thus the ultra-violet radiation that dissociates the oxygen sets the stage for the ionosphere: in all but the lowermost few miles the air of the ionosphere is probably composed mainly of molecular nitrogen and atomic oxygen. To the weather scientist this region, comprising only about one-millionth of the whole atmosphere, may seem the last insignificant shred of the earth's airy mantle. To the solar physicist the ultra-violet radiation from about 1,250 Å onwards, including only about 4 parts in a million of the whole energy of solar radiation, may seem a trifling and uncertain remnant of the solar spectrum. But together they give us the ionosphere, the scene of a series of phenomena of great importance to the radio engineer, and of great interest to the atmospheric physicist.

The E and F Layers of the Ionosphere

The location of ionised layers in the upper atmosphere was first definitely determined in 1925, by Appleton and Barnett in this country, and also, independently in the following year, by Breit and Tuve and also by Taylor and Hulburt. In 1927 Appleton recognised that there are two distinct main ionised layers; the lower one, at about 60 miles' height, is called the E layer, and the upper one is called the F layer. The F layer, in the daytime in middle and low latitudes, especially in summer, is composed of two parts; the lower part, at about 130 miles' height, is called F_1, and the upper, at about 200 miles, F_2, we may regard the F_2 layer as corresponding, in a diagram of electron density as a function of height, to a large bulge at the top of the F layer, or the F_1 layer as a slighter bulge in the lower part of the F layer (*see* Fig. 2).

The ionising solar radiation is much more likely to be absorbed by molecules than by atoms. Molecular nitrogen extends upwards for hundreds of miles above the ground, as is shown by the auroral spectrum, whereas molecular oxygen is probably scarce above 70 or 80 miles, hence the ionised nitrogen layer is likely to be situated above the ionised layer, and we may probably identify the nitrogen layer with F, and the oxygen layer with E.

The cause of the division of the F layer into two parts, F_1 and F_2, is still obscure.

Daily Variations in the Ionosphere

The electron density in the ionosphere varies throughout the day and night; on the whole it falls throughout the night, and increases rapidly at sunrise, which in the ionosphere occurs before dawn at ground level. In the E and F_1 layers, where the solar control of the daily variation is simple and direct, the maximum electron density occurs soon after noon; the daily variation changes with the season, in a way that is related very simply to the zenith, angle of the sun, or the obliquity of its rays.

In the F_2 layer the changes are less simple. In summer in our latitudes (and all the year round in low latitudes) the electron density attains a maximum before noon; then, while the altitude of the sun is still increasing, the electron density begins to decrease; it reaches a minimum at about noon, and then increases again to an afternoon maximum before declining towards sunset and throughout the night. Owing to this summer day minimum, the noon value of the electron density may be less in summer than in winter.

A promising explanation of this strange fact has been given by Appleton and by Hulburt. They ascribe it to a marked rise of temperature in the F_2 layer, owing to the conversion into heat of some of the radiant energy absorbed in the layer. This causes an upward expansion and rarefaction of the layer; the electron density already present is thereby reduced, and so also is the absorption of ultra-violet radiation and the consequent formation of new electrons; the normal forenoon trend of increase of the electron density is consequently reversed. In the late afternoon the layer cools again and sinks, producing the abnormal second maximum of electronisation.

The F_2 layer has a lower mass-density and a smaller heat-capacity than the E layer, whereas it absorbs more energy from the solar beam; also it may have less capacity to radiate heat energy. Probably this explains why the E layer appears to remain nearly constant in height and temperature, whereas the F_2 layer varies so greatly.

This variation shows itself also in the (decimal) scale height of the F_2 layer, which according to Appleton is about 60 miles in winter and about 100 miles in summer. Both these values far exceed those (less than 15 or possibly 20 miles) appropriate to the atmosphere in and below the E layer; they imply that in the upper part of the ionosphere the air density decreases upwards far more slowly than at lower levels.

This explanation demands remarkably high temperatures in the F_2 layer; even allowing for some reduction in the mean molecular weight of the air by the dissociation of the oxygen, temperatures imply large random molecular velocities in the F_2 layer; this weakens the hold of the earth's gravitational attraction on the air there, especially for the lighest gases, hydrogen and helium; it must enable these gases to leak slowly away into space. Helium is constantly being produced from radioactive materials in the earth's crust, and the process has been going on for over a thousand million years, but the atmosphere does not contain the corresponding amount of helium. This fact receives a natural explanation in the daytime heating of the F_2 layer.

Solar Outbursts and Radio Fade-Outs

So far I have been discussing the regular variations of the ionosphere. The solar control is indicated no less clearly by the irregular changes that occur from time to time. Among the most striking, and as suggesting that something had suddenly gone wrong with the plant. But it is now known, largely through the efforts of Jouaust and Dellinger, that the cause lies in the ionosphere, where at such times a new temporary layer of intense ionisation is suddenly produced at a level somewhat below the E layer. Upgoing radio waves that are short enough to enter this layer are absorbed in it, and therefore do not return to the ground, this is because the air density is greater, and collisions more frequent, at that level, and by their collisions the electrons quickly lose the energy imparted to them by the waves.

Solar physicists have observed that such radio fade-outs usually coincide with the occurrence of eruptions of intense light or certain wavelengths at some disturbed point on the sun. It seems likely that this light, which shows a line spectrum, includes ultra-violet components that are invisible to us, but which are able to penetrate our atmosphere to below the E layer, and there produce intense, but fleeting ionisation at a height of 40 or 50 miles. The E and F layers apparently remain almost unaffected.

At these times the daily magnetic variations undergo a simultaneous change; McNish has shown that it corresponds to a temporary increase in the electric current system normally present. Like the radio fade-out, the effect is confined to the sunlit hemisphere of the earth, facing the sun.

(*Continued on p.* 638)

DATA SHEET XX. Calculation of Shot Noise

Electronic Engineering

DUE to the random variation of the rate of arrival of electrons at the collector electrode of all thermionic devices, the current in the circuit of the collector electrode has superimposed on the mean current I a component I_n which is known as the noise or "shot noise" current, after Schottky.

The mean square value of the noise current is given by

$$\overline{I_n^2} = 2eI\Delta f.F^2 \quad \ldots (1)$$

where I = the mean current collected by the electrode in amperes

e = charge of an electron = 1.59×10^{-19} coulombs.

Δf = effective frequency pass-band in c.p.s. (*See* Data Sheet No. 19).

F^2 = noise reduction factor due to space charge.

Now it has been shown that for noise computation purposes it is possible to represent the thermionic device as a generator supplying a constant noise current I_n to a resistance R_a, where R_a is the A.C. slope resistance of the device.

To calculate the noise voltage output of, say, a triode with an A.C. anode resistance R_a and an anode load resistance R^L we have

$$\overline{E_n^2} = 2eI\Delta fF^2 \left(\frac{R_aR_L}{R_a+R_L}\right)^2 \quad \ldots (2)$$

where E_n is the mean square noise output voltage for a mean anode current I.

In the case of a pentode $R_a \gg R_L$ and (2) reduces to

$$\overline{E_n^2} = 2eI\Delta fF^2R_L^2 \quad \ldots (3)$$

If we insert the value of "e" and express R_a and R_L in ohms, equations (1) (2) and (3) can be written in R.M.S. values as

$$I_n = 5.63\ (I\Delta f)^{\frac{1}{2}}F \times 10^{-4}\ \mu\text{A} \ldots (1a)$$

$$E_n = 5.63\ (I\Delta f)^{\frac{1}{2}}\frac{R_aR_L}{R_a+R_L}F \times 10^{-4}\mu\text{V} \quad (2a)$$

and when $R_a \gg R_L$

$$E_n = 5.63\ (I\Delta f)^{\frac{1}{2}}R_LF \times 10^{-4}\ \mu\text{V} \quad (3a)$$

To obtain the equivalent shot noise voltage E_g at the grid we divide the noise at the anode by the stage gain, *i.e.*,

$$\text{Stage gain} = g\left(\frac{R_aR_L}{R_a+R_L}\right) \quad \ldots (4)$$

so that for (2a) and (3a)

$$E_s = 5.63\left(\frac{I^{\frac{1}{2}}}{g}.F\right)\Delta f^{\frac{1}{2}} \times 10^{-4}\ \mu\text{V} \quad \text{(R.M.S.)}$$

where g = mutual conductance in amps./volt.

To find the total noise in the grid circuit it is necessary, due to the random phases of the circuit thermal agitation and shot noise voltages, to add the two components in quadrature, *i.e.*

Total R.M.S. Noise in grid circuit = $\sqrt{E_T^2 + E_s^2}$. It was shown in Data Sheet No. 19 that E_T^2 is proportional to the resistive component of the impedance between grid and cathode, and $\overline{E_s^2}$ can also be expressed as an Equivalent Noise Resistance "R_{eg}."

The value of F^2 in all the above expressions depends firstly on the extent of space charge reduction present ($F^2 = 1$ when the space charge is wholly destroyed) and on whether the space current is collected by more than one electrode. A detail discussion is outside the scope of this Data Sheet the attached table will, however, be useful for estimating purposes.

TYPE OF VALVE	F^2
Triodes	0.05 – 0.1
Pentodes Is $\simeq$ 1/40 Ia (E.F.8)	0.065
Straight Pentodes Is $\simeq \frac{1}{4}$Ia	0.25
Var. – mu Pentodes Is $\simeq$ Ia	0.25 – 0.3

Equation (1a) is plotted on Data Sheet No. 20 for values of I between 0.1 to 100 mA and Δf between 10^3 and 10^7 c.p.s. The scale on the left gives the R.M.S. Shot noise current I_n in μA. The scale on the right gives the R.M.S. noise voltage per thousand ohms of load resistance for equation (3a) or the R.M.S. grid noise voltage per mA/V for equation (5) all for a value of $F = 1$. The equivalent noise resistance can be obtained by transferring the figures found for E on to Data Sheet No. 19.

DATA SHEETS XXI & XXII. Calculation of the Space-Current in Diodes and Triodes

Diodes

The variation of space current with anode voltage for a planar diode, under space-charge limited conditions is given by the well-known Child's Law:

$$I_a = 2.336 \times 10^{-3}\frac{(E_a+\varepsilon)^{3/2}}{x_1^2}\ \text{mA/cm}^2 \quad (1)$$

where

I_a = Anode current per square centimetre of emitting surface in mA.

E_a = Anode voltage.

ε = a small voltage which is an approximate correction to allow for emission velocities and contact potential.

x_1 = anode to cathode spacing in cm.

For the similar case with cylindrical electrodes, Langmuir has given the expression

$$I_a = 14.68 \times 10^{-3}\frac{(E_a+\varepsilon)^{3/2}}{r_a\beta^2}\ \text{mA/cm. length} \quad (2)$$

where I_a = anode current per centimetre length of the emitting surface.

r_a = radius of the anode in cms.

β^2 = a factor given in the table on the Data Sheet which is a function of the ratio (r_a/r_c).

r_c = radius of cathode in cms.

Triodes

It is possible for calculation purposes to visualise the triode as an equivalent diode with its anode in the plane of the grid.

For a triode with a plane electrode structure (1) becomes*

$$I = 2.336 \times 10^{-3}\frac{\left(\dfrac{V_a}{\mu}+V_g+\varepsilon\right)^{3/2}K_1}{x_1^2} \quad (3)$$

mA/cm², where

$$K_1 = \left\{1+\frac{1}{\mu}\left(1+\frac{4}{3}.\frac{x_2}{x_1}\right)\right\}^{-3/2} \quad (4)$$

V_a = anode voltage.

V_g = grid voltage.

x_1 = grid to cathode spacing in cms.

x_2 = grid to anode spacing in cms.

μ = amplification factor.

In the case of cylindrical electrodes expression (2) becomes*

$$I = 14.68 \times 10^{-3}\frac{\left(\dfrac{V_a}{\mu}+V_g+\varepsilon\right)^{3/2}K_2}{r_g\beta^2}\ \text{mA/cm. length} \quad (5)$$

where

$$K_2 = \left\{1+\frac{1}{\mu}\left(1+\frac{2}{3}\log_e\frac{r_a}{r_g}\right)\right\}^{-3/2} \quad (6)$$

and

r_a = radius of anode in cms.

r_g = radius of grid in cms.

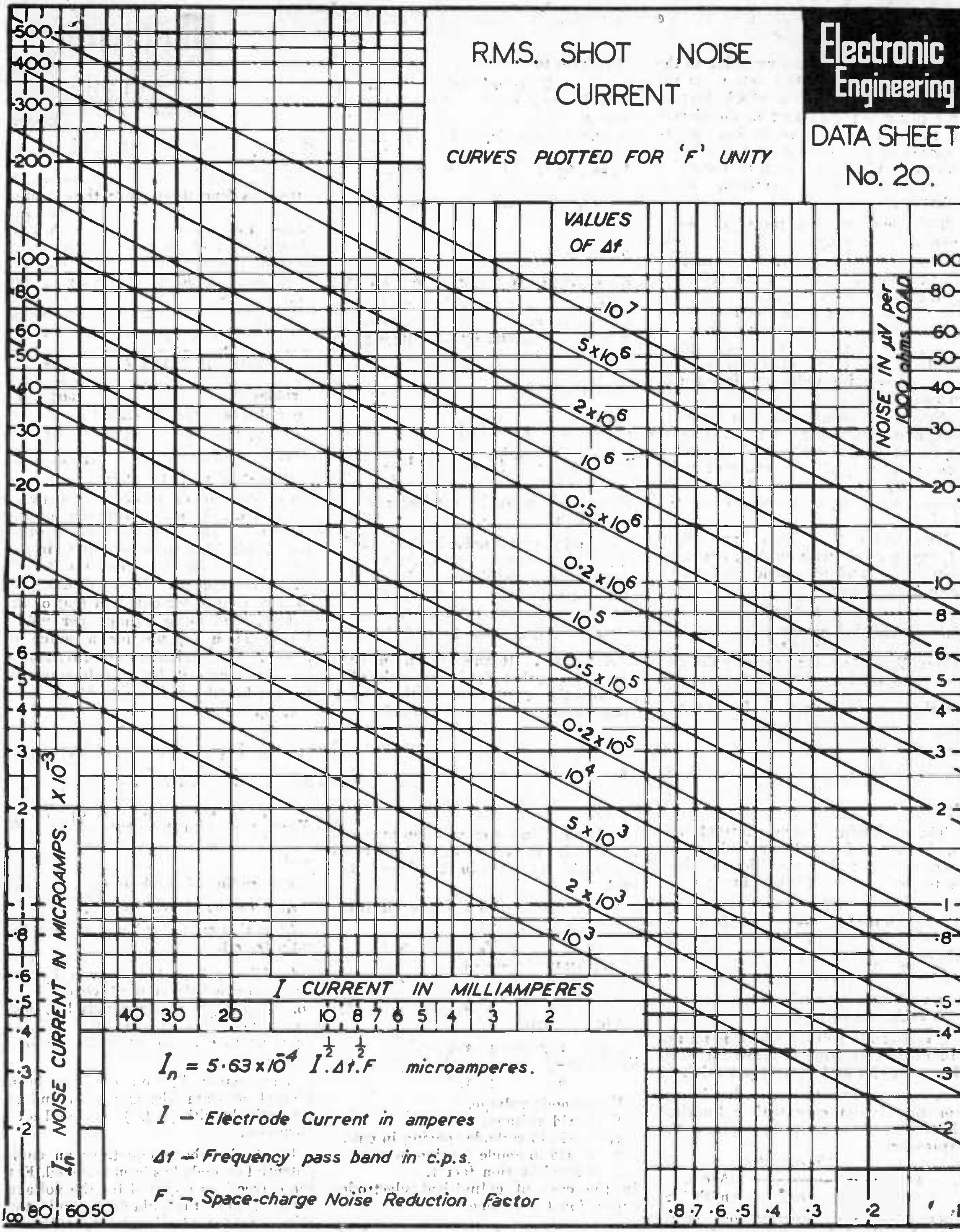
β^2 in this case is calculated from the ratio (r_g/r_c).

(b) The value of K_2 given by the equation can only be used when $r_g/r_c > 10$. When r_g/r_c is appreciably less than 10 K_1 should be substituted for K_2 in equation to give an adequate approximation.

The factors K_1 and K_2 have been plotted on Data Sheets No. 21 and 22 respectively with (x_2/x_1) (r_a/r_g) and μ as variables.

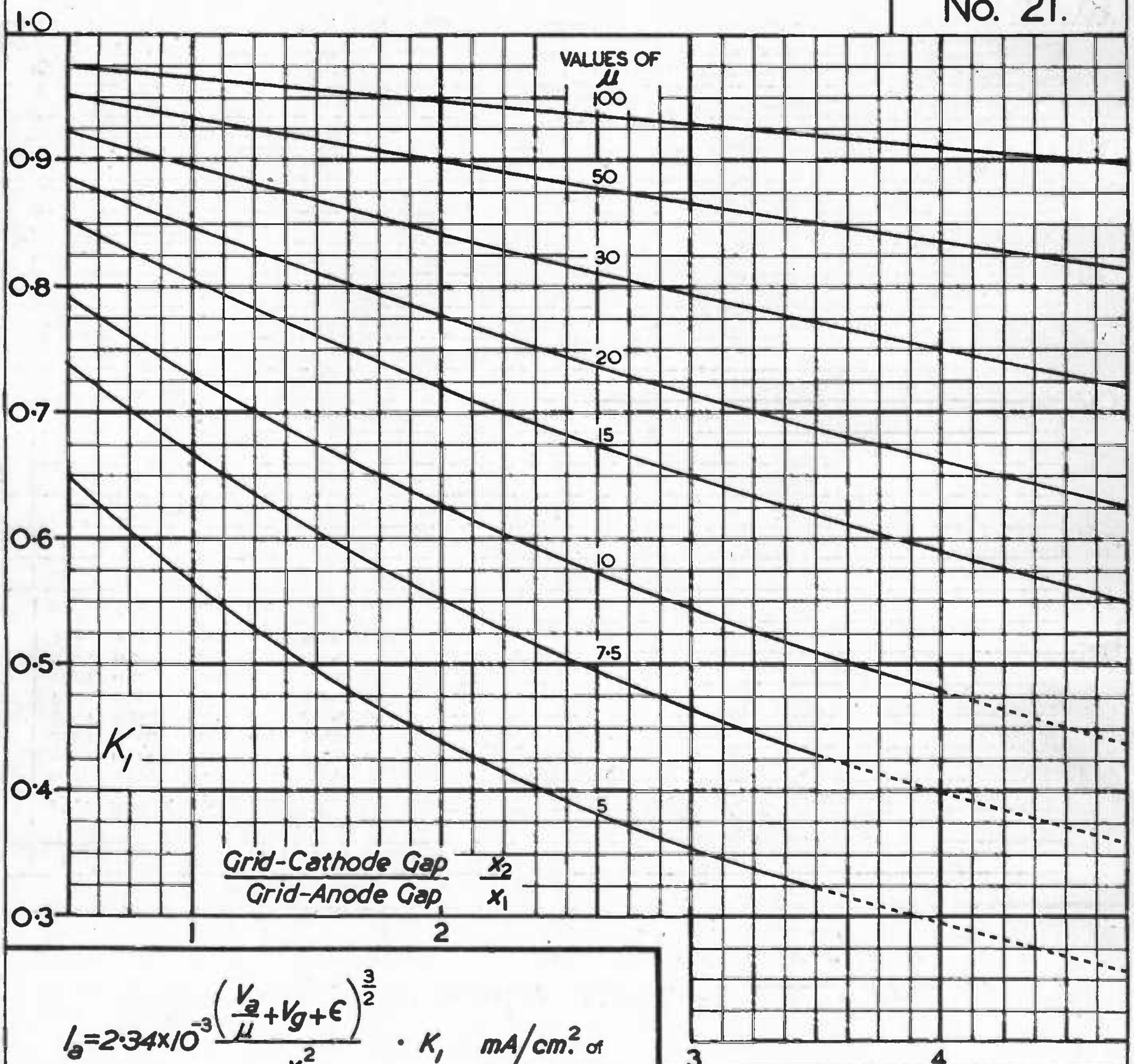
In all the above equations an equipotential cathode has been assumed. For the corrections required for the voltage drop along the filament and the effective area of filamentary cathodes the reader is referred to "Calculation of Characteristics and the Design of Triodes." Y. Kusunose, *Proc. I.R.E.*, October, 1929.

*B. D. H. Tellegen, *Physica*, 1925.


R.M.S. SHOT NOISE CURRENT
CURVES PLOTTED FOR 'F' UNITY
Electronic Engineering
DATA SHEET No. 20.
VALUES OF Δf
10^7
5x10^6
2x10^6
10^6
0·5x10^6
0·2x10^6
10^5
0·5x10^5
0·2x10^5
10^4
5x10^3
2x10^3
10^3
NOISE IN μV per 1000 ohms LOAD
In NOISE CURRENT IN MICROAMPS. X 10^-3
I CURRENT IN MILLIAMPERES
In = 5·63 x 10^-4 I^½.Δf^½.F microamperes.
I – Electrode Current in amperes
Δf – Frequency pass band in c.p.s.
F – Space-charge Noise Reduction Factor

Electronic Engineering
DATA SHEET No. 21.

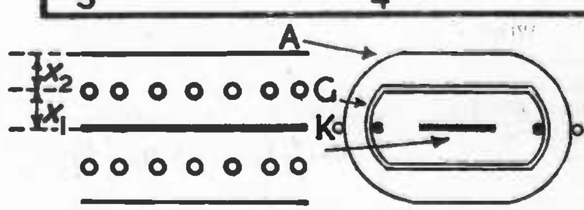
TELLEGEN'S ANODE CURRENT RELATION FOR TRIODE WITH PLANE ELECTRODES.



$$I_a = 2{\cdot}34 \times 10^{-3} \frac{\left(\frac{V_a}{\mu} + V_g + \epsilon\right)^{\frac{3}{2}}}{x_1^2} \cdot K_1 \quad mA/cm^2 \text{ of emitting surface}$$

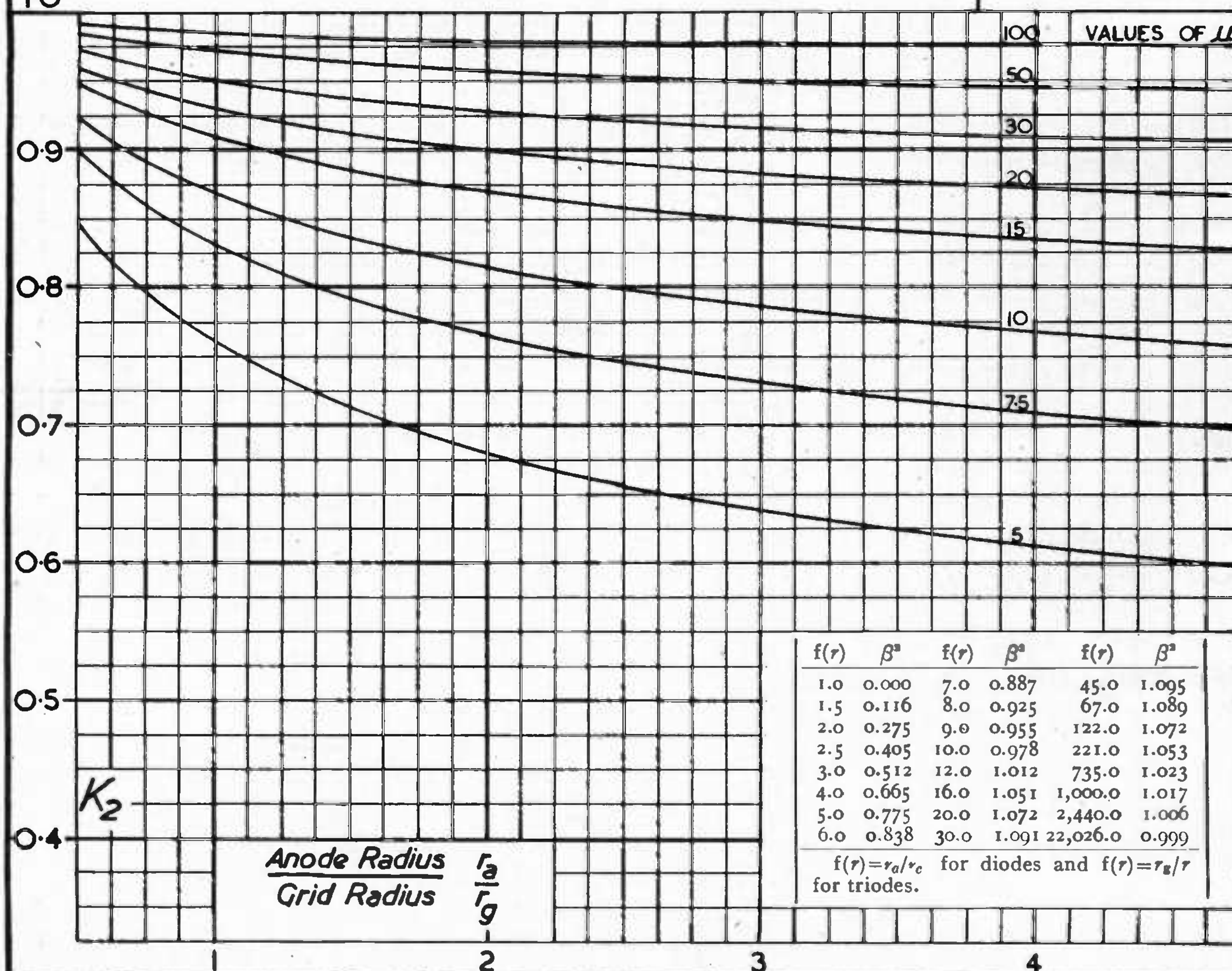
where

$$K_1 = \left[\frac{1}{1 + \frac{1}{\mu}\left(1 + \frac{4}{3} \cdot \frac{x_2}{x_1}\right)}\right]^{\frac{3}{2}}$$



Electronic Engineering DATA SHEET No. 22.

TELLEGEN'S ANODE CURRENT RELATION FOR TRIODE WITH CYLINDRICAL ELECTRODES



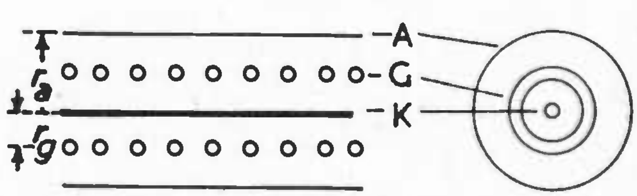
f(r)	β^2	f(r)	β^2	f(r)	β^2
1.0	0.000	7.0	0.887	45.0	1.095
1.5	0.116	8.0	0.925	67.0	1.089
2.0	0.275	9.0	0.955	122.0	1.072
2.5	0.405	10.0	0.978	221.0	1.053
3.0	0.512	12.0	1.012	735.0	1.023
4.0	0.665	16.0	1.051	1,000.0	1.017
5.0	0.775	20.0	1.072	2,440.0	1.006
6.0	0.838	30.0	1.091	22,026.0	0.999

$f(r) = r_a/r_c$ for diodes and $f(r) = r_g/r$ for triodes.

$$I_a = 14{\cdot}68 \times 10^{-3} \frac{\left(\frac{V_a}{\mu} + V_g + \epsilon\right)^{\frac{3}{2}}}{r_g \beta^2} \cdot K_2 \quad \text{ma./cm. length of emitting surface}$$

where

$$K_2 = \frac{1}{\left[1 + \frac{1}{\mu}\left(1 + \frac{2}{3}\log_e \frac{r_a}{r_g}\right)\right]^{\frac{3}{2}}}$$



(*Continued from p.* 632)

Magnetic Storms and the Ionosphere

The most remarkable irregular changes in the ionosphere, however, are those associated with magnetic storms. Magnetic storms are disturbances altogether different from the relatively feeble changes observed during radio blackouts; they last several hours or even days, and indeed the earth's magnetic field remains abnormal after the storm is over, and slowly tends towards the normal over a period of many days. Magnetic storms have a wide range of intensity, but in the greater storms the field at particular places and times may be altered by a few per cent.

During magnetic storms the part of the ionosphere most affected is usually the F_2 layer, except that in high latitudes the E region may be intensified and extended downwards, so that it causes absorption of radio waves and prevents our exploration of the upper layers there; this was observed by Appleton and Naismith at Tromso in 1932-33, in an expedition partly financed by the Institution. The radio effect resembles a blackout due to a solar eruption, but it may occur at night and last much longer.

The ionosphere is not entirely regular during the night at ordinary times; sometimes the electron density in one or other layer increases, and at nighttime the cause evidently cannot be solar ultra-violet radiation. Meteors and thunderstorms are among the causes suggested for such irregularities. But magnetic storms affect the whole world simultaneously, and are accompanied by pronounced changes in the ionosphere over both the daytime hemisphere and the night hemisphere.

In the equatorial belt the F_2 layer is intensified during all but the greatest magnetic storms. Elsewhere the intensity is reduced and the height increased; qualitatively this resembles the change in the F_2 layer during the middle hours of a summer day, and the same explanation has been given for it, namely, abnormal heating of the air by an increased supply of energy from without. Over the night hemisphere this cannot be due to ultra-violet radiation, and many other facts point to solar gas as the cause. In order that this may get round the earth to the dark hemisphere, where it produces the aurora polaris and magnetic disturbance as well as the ionospheric changes, the gas must be ionised, and therefore subject to the deflecting action of the earth's magnetic field. It is natural to suppose that solar gas is the cause also of the ionospheric changes over the sunlit hemisphere during a magnetic storm.

The Electric Currents of Magnetic Storms

The magnetic changes observed during magnetic storms of average intensity considerably exceed those due to the electric currents regularly present in the ionosphere. Much mystery still surrounds the mechanism of a magnetic storm, and at the end of a lecture on so extensive a subject as the ionosphere I can touch only lightly on this large associated topic; something, however, should be said about it.

In a quite moderate storm the magnetic evidence indicates the presence of an intense current system in the ionosphere over each polar cap, along and within the auroral zones. Each of these two relatively small regions, covering about 5 per cent. of the earth's surface, carries a storm current system of more than half a million amperes. The magnetic effects over the remaining 90 per cent. of the earth betoken a current system of about the same total intensity, half a million amperes.

The pioneer radio observations at Tromso, in Northern Norway, by Appleton and Naismith, showed that the ionisation in the lower part of the ionosphere in high latitudes is greatly intensified, and extended downwards, at times of auroræ and magnetic disturbance. It is the lower levels of the ionosphere that are the most conducting, when ionised to any specified degree, because there the collisions are sufficiently numerous to inhibit the reducing action of the magnetic field upon current flow transverse to the lines of force. It seems not unlikely that the polar cap is the seat of a permanent system of electromotive forces, due to dynamo action by regular air movements. If so, any notable increase of ionisation and conductivity will intensify the electric current system over the polar regions, just as occurs during a radio fadeout, where the ionisation in and below the E layer over the sunlit hemisphere is temporarily increased by a brief solar eruption. In both cases, however, the absorbing effect of the downward-extended ionised layer prevents the radio observer from determining those facts that at ordinary times are well within his scope and that we should so much like to know, namely, the location and the exact amount of the increased ionisation.

Over the non-polar part of the earth, however, he is not subject to this difficulty, because a magnetic storm is not commonly accompanied by abnormal absorption below the E layer in middle and low latitudes. The ionosphere remains open to his inspection, and we have seen something of the treasury of remarkable facts that he brings to us thence. But alas! if I judge aright, his treasury is almost empty of information concerning the cause of the magnetic storm itself over the region. The conducting E layer is not greatly increased in conductivity, and though the F layer suffers great changes, this layer has but little capacity to conduct electric currents. I think we must look farther afield for the cause of the main magnetic-storm variations over the middle belt of the earth.

Cathode Phase Inversion

By O. H. SCHMITT

Prior to his return to America a few years ago, Dr. Schmitt was engaged on electro-physiological research at the University College, London, and published the first account of this circuit in *J. Sci. Inst.*, Vol. 15, 1938.
He is now in the Dept. of Physics of Minnesota University and the following extract is taken from a paper published in the *Review of Scientific Instruments*, Nov., 1941, to which acknowledgment is made.

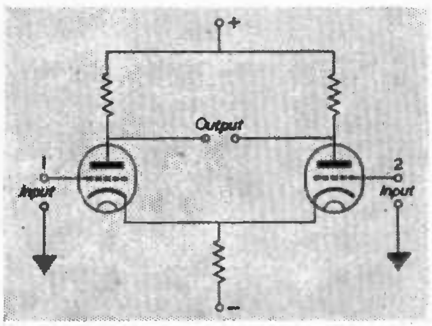


Fig. 1.

ESSENTIALLY, the cathode phase inversion stage is a conventional push-pull amplifier stage in which the cathode resistor R_k (Fig. 1) common to both valves, has been increased until the product of its resistance with the mutual conductance of either amplifier valve is large with respect to unity, and in which the cathode return (—) is biased to a suitably high *negative* potential with respect to the control grid. Under these circumstances, a signal applied to *either* control grid appears almost symmetrically amplified, but in opposite phase, in the two anode circuits.

Because this phase inversion is accomplished without loss of amplification in the stage, the circuit is economically adapted to ordinary audio-amplifier use. Here it can be employed in the final power stage, as well as in one or more of the preceding stages. In any case it eliminates the push-pull input transformer, and, when used in the low level stages, permits operation from poorly filtered power supplies because of the degenerative self-filtering action of the circuit.

The modification of the circuit shown in Fig. 2 is peculiarly adapted for oscillographic use, directly coupled to either magnetic or electrostatic (*D.P.*) deflection cathode-ray tubes, since here the circuit serves not only as a phase inverter and final amplifier, but also provides a means of shifting the axis of the beam to either limit of the tube screen without requiring increased linear output characteristic of the final amplifier for complete tube face coverage.

Additional advantages of this type of amplifier are that it responds equally well to a push-pull input, a single sided input with one input terminal earthed, or to the difference between two independent inputs each applied to a separate grid. It will be noted, further, that so long as heater-cathode type valves are used, any number of stages can be supplied from one filament source and one H.T. source.

In this circuit, as in most push-pull systems, attenuation presents a serious problem since exactly equal loss must be inserted into each side of the circuit to keep potential differences symmetrical, and because two variable elements must usually be inserted into each stage which is to be controlled. Since the total attenuation usually cannot be accomplished in one stage, this means a multiplicity of ganged resistance elements. In the case of d.c. amplifiers, further difficulty arises because attenuation must not occasion baseline shift. These troubles can be avoided by the slight change in the fundamental circuit illustrated in Fig. 3. Here the common cathode resistor R_k has been replaced by separate ones (each having twice the original resistance) joined by a single variable element.

The approximate amplification may be calculated for any value of the attenuating resistor R with the aid of the formula

$$A = \frac{R_p R_x G_m}{R_p + R_x + G_m R_l R_p + R_l}$$

where

$$R_l = \frac{2RR_k}{R + 4R_k}$$

Here A the useful amplification is given in terms of R_p the dynamic anode resistance of one valve, R_x the resistance of one load resistor, and G_m the transconductance of one valve. This formula applies primarily to triodes and gives less accurate results for pentodes and tetrodes unless the transconductance to the screen is taken into account.

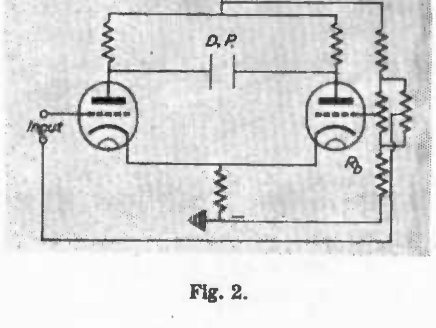


Fig. 2.

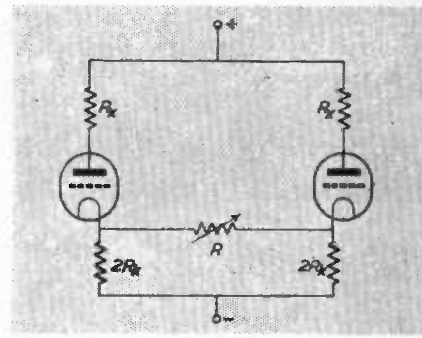


Fig. 3.

As usual, where attenuation is achieved through use of negative feedback, the linearity of the amplifier improves as greater attenuation is introduced, and consequently a long linear voltage output characteristic accompanies even moderate attenuation. 6J7G pentodes, ordinarily bad offenders in respect of linearity, will give 260 volts of linear output at a stage gain of 50, while they produce 300 volts of output at 14 gain. It should be remembered, however, that this linearity is achieved as the result of cathode feedback, and consequently is *current linearity*.

In those cases where the amplifier is not required to respond below, perhaps, 10-20 cycles per second, the cathode resistor may be replaced by a choke, or, if the attenuation method is to be employed, by a pair of chokes. In this case the grids may be maintained at a convenient zero potential and yet have no large loss of anode supply potential in the common cathode resistors. Often a choke can be found having the correct d.c. resistance to bias the valves; if not, it can be supplemented with small additive resistors.

Calculation of the necessary cathode resistance in any case is extremely simple. If no attenuator is to be employed, the value of R_k will be

$$R_k = R_c + V/I,$$

where R_c is the published value of cathode resistor for ordinary push-pull operation, V is the voltage between control grids and the cathode return and I is the desired value of total anode current for the two valves. For use with the attenuator circuit, twice this resistance is inserted in each branch of the circuit.

BOOK REVIEWS

" Practical Sound Conversion for Amateurs."

By F. G. Benson, 88 Greenfield Avenue, Carpenders Park, Watford, Herts. 5s.

Had this booklet appeared in more leisured times, it would have had the effect of converting innumerable sub-standard cine enthusiasts to sound. While it avoids the fault of so many books of its class, of making light of difficulties (or worse, of ignoring them) it does make it clear that the conversion of a sub-standard projector to sound is a task within the capabilities of any amateur with a certain mechanical ability.

The principal snag of sub-standard projectors, that of speed variations, is well cared for in so far as relates to low-frequency variations, which are known as " wow " and not, as stated, warble. However, the author rather tends to ignore (notably in his suggestion of a chain-driven sound sprocket) those speed fluctuations of higher frequency, known as flutter, which have the effect of producing harsh sound and unintelligible speech; it is flutter that is the biggest difficulty of sub-standard sound.

There are a number of small errors in the text which will not, however, mislead the intelligent reader.

R.H.C.

Modern Assembly Processes

J. L. Miller with foreword by E. A. Watson. 168 pp. 147 figs. (Chapman & Hall, 13/6 net).

This book deals with the assembly of small parts such as compose the greater part of electronic instruments and apparatus, and for this reason has a special appeal to the production engineer in the radio and instrument industry.

The greater part of the book is devoted to welding in its various forms, but there are earlier chapters on hard and soft soldering, brazing and riveting which will give several useful suggestions even to those who know all there is to be known about these simple (?) operations.

Mr. Miller has been associated with the development of copper brazing in a reducing atmosphere in this country and the results of his experience are set out in an interesting chapter on hydrogen furnace brazing. No flux is needed in copper brazing of mild steel since the parts are chemically clean in the gas, and the copper flows freely over the surface of the joint. Many engineers will want the book for this reference chapter alone, and radio valve engineers will be interested in the subsequent chapters on spot and resistance welding. Altogether a book that can be thoroughly recommended for the works library.

The Radio Amateur's Handbook,

19th (1942) Edition, by the Headquarters staff of the ARRL. 552 pp. 680 figs. (American Radio Relay League, Inc., West Hartford, Conn. $1.00 in U.S.A. $1.50 elsewhere).

In planning the 1942 edition of the HANDBOOK, the editors were governed by defence needs, and the general plan of the book has been revised to meet the growing need for a simple and non-mathematical text on the theory, design and operation of radio communication equipment in addition to providing the constructional information on tested amateur equipment which has always been an outstanding feature of this book.

The chapter on transmitter construction has undergone complete revision. Twenty transmitter units and eleven power-supply units are described, representing an increase of 50 per cent. in constructional material; the majority of these units are described in the HANDBOOK for the first time.

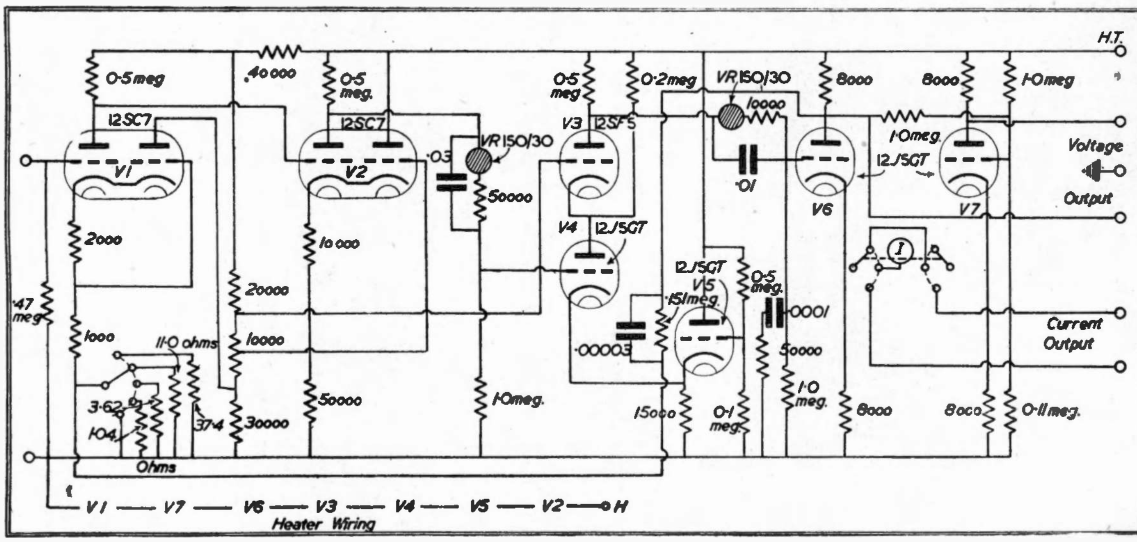
The u.h.f. section has also been enlarged. The chapter on u.h.f. receiving equipment includes converters for use in conjunction with communications receivers or with a special f.m. amplifier which is also described.

Copies are available in this country from Webb's Radio, Soho Street, W.1.

A New Direct-Coupled Amplifier for Mains Operation

This amplifier, which is described by S. E. Miller in our American contemporary *Electronics*, makes use of a new form of stabilisation, termed by the author "cathode control."

It is suitable for C.R. tube work, with a flat characteristic from 0 to 20,000 c.p.s.



AMONG the more important features which have been incorporated in this amplifier, and which contribute to its stability may be listed the following: (1) cathode control circuit for overcoming the difficulties of slow drift in the operation of the amplifier, most of which are caused by ambient temperature changes, (2) the development of voltage-regulated power supply in which the a.c. component in the output is 0.5 millivolt for a 250 volt supply, and in which variations of input voltage from 95 to 125 volts produce changes in the output of less than 0.4 millivolt, (3) interstage coupling device enabling several cascaded stages having a gain, without feed-back, of about one million, to be operated from a single 250-volt supply.

The characteristics of the completed amplifier (*see* Fig.) may be summarised as follows:

Input Circuit.—Both terminals are normally at low potential, one terminal earthed. Input resistance may be any value from zero to several megohms.

Output Circuit.—Both voltage and current output terminals are available simultaneously. Current output is ± 5 milliamperes, and voltage output is ± 80 volts peak from a balanced output circuit.

Sensitivity.—Full-rated output is obtained for input of 0.35 to 10 millivolts.

Amplifier Gain.—Voltage gain is variable from 72 db to 102 db. The overall voltage feed-back is varied from 15 to 45 db.

Noise Level.—Noise level is 4 microvolts peak or roughly 1 microvolt rms (referred to the input) with the input shorted, or 16 microvolts peak (11 microvolts rms) with input resistance equal to 0.5 megohm.

As a remedy for cathode drift a number of designers have attempted to maintain constant heater current in the low-level amplifier valves.

A common error in connexion with this problem is the assumption that feedback will aid in reducing cathode drift. Suffice it to say that cathode drift is a form of valve noise, and is not reduced by means of negative feedback.

As a partial solution to the problem the writer has developed what he calls the cathode-control amplifier. Assume that the heater voltage E_h is made variable, and the other voltages are held constant. Then it will be found that the anode current is a function of the heater voltage, and if the changes in anode current are referred to the input, a plot may be made showing the equivalent input to the amplifier as a function of the change in heater voltage. The problem is to determine that point in the cathode-grid circuit for which the equivalent input voltage represents the effect of the change in heater voltage. This equivalent input voltage which represents the effect of a change in heater voltage may be placed in series with the cathode lead, and by choosing a valve having two sections arranged around a common cathode and by connecting these sections in the proper manner, the cathode drift may be eliminated from one section.

As a further means of overcoming cathode drift it was decided to regulate the heater voltage. Since it was also necessary to regulate the anode voltage supply, it was considered good economy to use the same regulator for anode and heater currents. The 12-volt 150-milliampere series of valves was used, the heaters being placed in series.

The first and second stages of the amplifier are of the cathode-control type. The selector switch in the cathode of V_1 is the gain control. The third stage, which employs V_3 V_4 and V_5 is a form of direct-coupled voltage amplifier. V_5 is used to obtain a low-impedance 40-volt drop in the cathode of V_4.

The output stage employing V_6 and V_7 is balanced in a forward-acting manner and errors are reduced through the degeneration caused by the cathode bias resistors.

Due care in construction is absolutely essential in an amplifier of this type. In particular, it was found necessary to use wire resistances for the cathode and anode resistors of V_1, the bleeder chain for V_1 and V_2 and the gain control resistors.

Power Supply

The voltage regulated power supply for the amplifier uses three 2A3 valves in parallel as the series impedance, the control being by means of two 12SC7 s in cascade. The heater supply for the amplifier is taken direct from the H.T. output terminals through a resistance giving 150 mA at the rated heater voltage. The input transformer is 430-0-430 and the rectifier is a 5T4.

A Limitation of the Diode

Improving the Circuit for Higher Modulation Levels

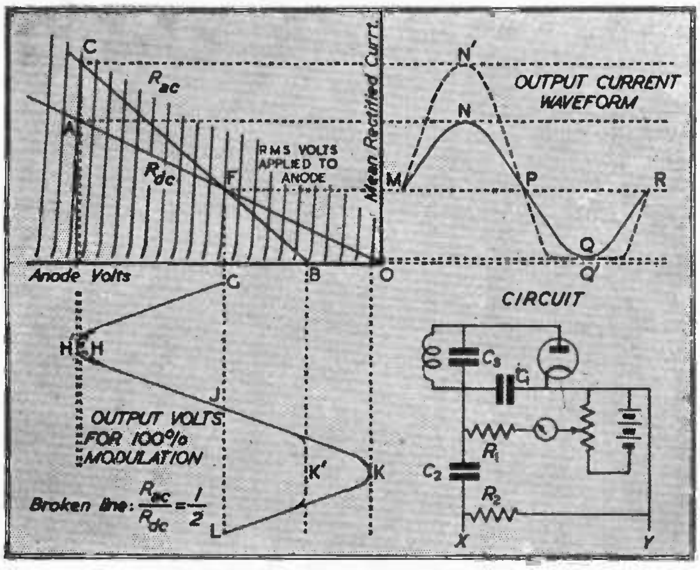
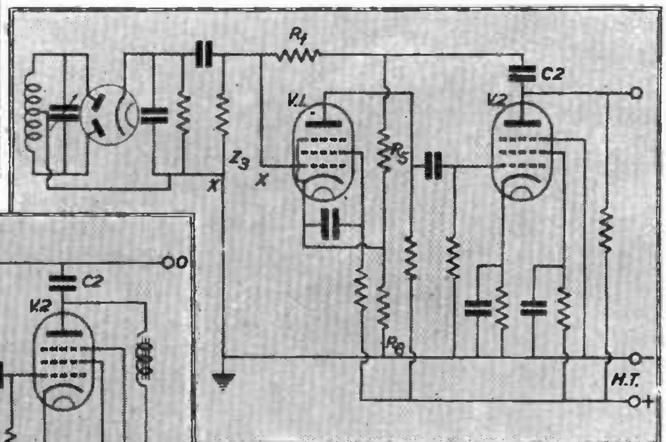


Fig. 1 (above). Signal rectification characteristics of diode.



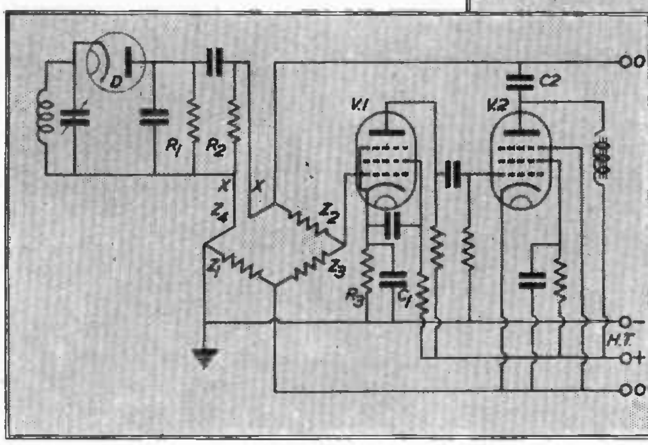


Fig. 2 (right). Circuit giving negative admittance load, and Fig. 3 (left) a form of bridge network for the same purpose.

As is well known, a properly designed diode rectifier can rectify modulated carriers of reasonably large amplitude with negligible distortion. However, this low distortion can only be obtained by making the diode load impedance to modulation frequencies as nearly equal to the D.C load resistance as possible. The distortion introduced by a low A.C. to D.C. load ratio is illustrated in Fig. 1.

In Fig. 1 are drawn the signal rectification characteristics of a diode. These are obtained by applying a known voltage say, 3 volts R.M.S. across the condenser C_3 and then plotting the mean rectified anode current I_a, with the resistance R_1 shorted for different values of bias on the anode. The procedure is repeated for a range of voltages from zero upwards. To obtain the output waveform at low modulation frequencies with R_2 infinite and C_2 large, we draw the load line of the D.C. resistance R_1 as shown by O.F.A. and as in this case the A.C./D.C. load ratio is unity ($R_2 = \infty$) we can plot the load current for a 100 per cent. sinusoidal modulation as shown by the curve M N P Q R. Similarly, the voltage across the load can be plotted as G H J K L. If, however, R_2 is finite the A.C. impedance of the load for medium modulation frequencies will be $(R_1R_2)/(R_1-R_2)$ and a load line of this value has to be drawn (B.F.C.) through F, the intersection of the D.C. load line and carrier voltage rectified current curve. The resultant load current and output voltage waveforms (across XY) are shown by M N^1P Q^1R and G H^1J K^1L respectively.

From the above diagram it will be seen that the effect of a low A.C./D.C. load ratio (in this case ½) is to introduce considerable distortion at the higher modulation percentages. At the higher modulation frequencies C_1 may have an appreciable shunting effect and this will alter the A.C. load line into an ellipse which will still further increase the distortion. The normal way of increasing the A.C./D.C. load ratio is to use the highest ratio of R_2/R_1 and tap the condenser C_2 across only a portion of R_1 the resulting loss of amplification is usually easily made up in the amplifier. The shunting effect of C_1 can, however, only be eliminated by keeping R_1 low, which will load the I.F. tuned circuit unless the diode is tapped down on the coil.

Prof. F. E. Terman in a recent patent* discloses a circuit arrangement which, in addition to enabling a unity A.C./D.C. load ratio to be obtained by providing a negative admittance for the amplifier connected between X and Y (Fig. 1), can also correct for the shunting effect of C_1 by giving this admittance a suitable phase angle.

The simplest arrangement of the invention is shown in Fig. 2, where the valves V_1 and V_2 are, with the exception of the components R_5R_6,R_f and C_2, arranged as a normal two stage amplifier.

If we designate by $|A|$ the voltage amplification of the amplifier under operating conditions between the grid of V_1 and the anode of V_2, then it will be seen that for any given applied voltage e_s across X X a voltage $|A|e_s$ is developed between the anode and cathode of valve V_2. This voltage is of such a phase as to drive a current through R_f X X which is in phase opposition to the current that would exist if the amplifier gain were zero. This phase opposition current is equivalent to connecting a negative resistance or admittance across the terminals X X instead of the amplifier. The magnitude of this admittance may be controlled by suitably proportioning R_f.

With the network R_5 R_6 not incorporated, the effect of R_f C_2 would be to provide positive feed-back to the amplifier and this could lead to instability. The network R_5 R_6 provides sufficient negative feed-back to compensate or over-compensate the positive feed-back of R_f C_2 without preventing a negative admittance being obtained. The magnitude of R_f C_2 would normally be ad-

* No. 539,596, assigned to S.T. & C. Ltd.

justed to provide a negative admittance equal to $1/R_2$ (Fig. 3) or, if the shunting effect of the diode condenser must be compensated, $R_f C_2$ can be given a suitable phase angle. If the output load resistance is low in magnitude compared with R_f and $(R_5 + R_6)$ then, for a given value of $|A|$, R_f will control the magnitude of the negative admittance; if, however, the load resistance is high then the admittance will be also a function of the other components.

Fig. 3 illustrates an alternative arrangement where stability in the amplifier is not obtained by compensating the positive feed-back by negative feed-back. In this circuit the output of the valve V_2 is developed across the corners of the bridge $Z_4Z_1Z_2Z_3$, while the input to the first value V_1 is taken from the opposite corners. If $Z_4/Z_1 = Z_2/Z_3$ then the bridge is balanced and none of the output from V_2 is transferred to the valve V_1; however, a negative admittance can still be obtained as a high current, can still be made to flow in phase opposition through Z_4. A certain amount of negative feed-back is bound to be present due to Z_1 being in the cathode circuit of valve V_2.

Bibliography of Frequency Modulation

(*Continued from page* 630)

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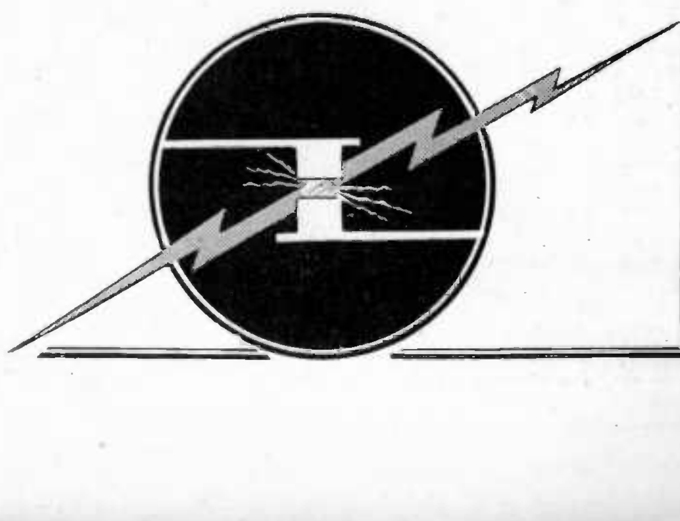
The fact that goods made of raw materials in short supply owing to war conditions are advertised in this magazine should not be taken as an indication that they are necessarily available for export.



A NOTE ON

Building Up Laboratory Sub-standards

By T. H. TURNEY, Ph.D.

TECHNICAL colleges are at the moment expanding and developing their electrical laboratory equipment. This note indicates how this can be done when the sole accurate equipment is enough resistances to make a good D.C. Wheatstone Bridge.

The apparatus which it is desirable to construct for light current work comprises radio and audio frequency oscillators, attenuators, filters, valve voltmeters and miscellaneous demonstration apparatus.

The primary need is a good audio frequency bridge for all measurements, either inductive or capacitative. The best bridge is a fourfold one using a variable condenser in the form of a three-dial box totalling 1 μF., but if no such box is available there will probably be two fixed condensers of good power factor having mica insulation to be found in the laboratory which can be "standardised." This is done in the following way :—

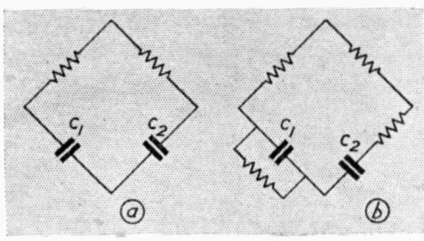


Fig. 1. Simple frequency bridges.

Exact Measurement of a Pair of Condensers :

Make up an 800 c.p.s. or even a 400 c.p.s. oscillator. By comparison with the 50 c.p.s. A.C. mains, this oscillator may be made exact in its frequency.

Connect say 40 volts from the secondary of a mains transformer on to the X plates of an oscillograph. Connect the oscillator output to the Y plates and add small condensers to the oscillator tuning condenser until the Lissajous figure on the screen is stationary. If it has 16 peaks the frequency of the oscillator is 16 × 50 = 800 c.p.s. If it rotates, the oscillator frequency is "out" and a small condenser added may bring it right or else make it rotate faster still which is worse; in this case a smaller condenser is wanted in the oscillator tuning circuit.

The 50 c.p.s. mains frequency is easily checked by reference between an electric clock and a good watch, and is usually accurate to a far greater degree than any other piece of apparatus, even during war-time. The Robinson frequency bridge (Fig. 1a) now gives a method of finding the product $C_1 C_2$ of two condensers where neither value is known accurately. The bridge for comparing two condensers (Fig. 1b) gives $C_1 \div C_2$ and from these both C_1 and C_2 are accurately found, since $C_1^2 = (C_1/C_2) \times (C_1C_2)$. A standard condenser, C_1 and also a reserve C_2, both known, are now available.

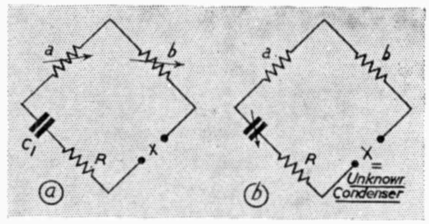


Fig. 2. Checking unknown capacity.

Quality of Resistance Boxes on A.C.

It is necessary to find out whether the resistance boxes used in these bridges are good at speech frequencies. The thousands dial of a decade box is usually bad even if non-inductively wound, but the hundreds dial is usually good. Either of the condensers C_1 and C_2 may now be used to set up inductance capacity bridges if three decade boxes are available. In Fig. 2a the condenser C_1, although fixed may be used to measure an unknown condenser by varying "a" and "b."

If, however, C_1 is used to check a dozen bought condensers of values, say .5, .2, .2, .1, .05, .02, .02, .01, .005, .002 .002, .001 μF., these will make up a box of total capacity 1.11 μF. variable in steps of .001 μF. The ratios "a" and "b" in Fig. 2b need not then be decade boxes; fixed values will do instead. There should be four choices of 10, 100, 1,000 and 10,000 ohms in each ratio box.

For the condensers, mica transmitting condensers may be ordered or selected to be "under" rather than "over" capacity. They may then be compared with the laboratory standard C_1 or C_2 and made up by addition of small condensers in parallel. R in Fig. 2 should be variable.

Inductance Bridges using a Condenser as Standard.

There are two bridges for inductance measurements: Maxwell's (shown in Fig. 3a), and the one shown in Fig. 3b. If the coil to be measured is not of good quality, Fig. 3a is very easy to balance. If, however, the coil is of high quality, *e.g.*, a telephone loading coil, the bridge 3a requires R to be of such a high value that it may exceed what is to be found in the box. Then the circuit of Fig. 3b will be easy to use because the R will be small. The one bridge is suitable for those measurements which are hard to make on the other one.

These three bridges and another, which is useful for unloaded telephone

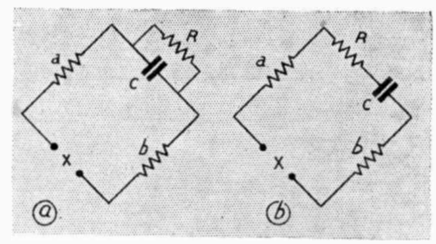


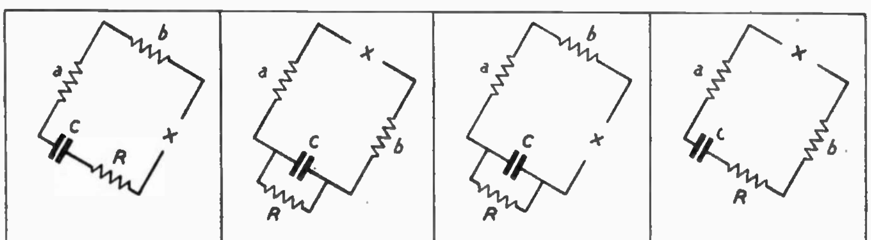
Fig. 3. Two Inductance bridges.

lines, may all be made in one by using two double pole change-over switches as shown in Fig. 4.

The formulæ for all these are shown in the table below.

Often $\sqrt{1 + R^2C^2\omega^2}$ is nearly unity, which simplifies the formulæ further.

Radio coils may now be measured at an audio frequency with a powerful oscillator and the 10 ohm ratios. A



CAPACITY $\frac{a}{b}C$	INDUCTANCE = Cab	REACTANCE: (Negative) $\dfrac{\frac{b}{a}R^2CW}{1+R^2C^2W^2}$	REACTANCE: (Positive) $\dfrac{abCW}{1+R^2C^2W^2}$
RESISTANCE. $\frac{b}{a}R$	RESISTANCE = $\frac{ab}{R}$	RESISTANCE $\dfrac{\frac{b}{a}R}{1+R^2C^2W^2}$	RESISTANCE $\dfrac{abR^2C^2W^2}{1+R^2C^2W^2}$

good Ferranti push-pull transformer works well as a step-up telephone transformer.

Checking decade boxes.

Checking the boxes on A.C. is done by seeing if three boxes balance on A.C. as on D.C. with a carbon resistance to make the fourth arm of the bridge. It will soon be seen if they are "out" or correct to within 1 per cent., which they should be to be useful.

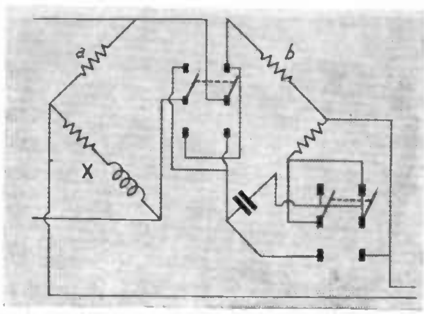


Fig. 4. Combined bridge with switching.

With Maxwell's bridge, 1,000 ohm ratios make the bridge read in henrys for C in microfarads, but a 10 and 100 ratio or two 31.6 ohm ratios would give millihenrys for C in microfarads; thus one can get accurate readings of radio coils.

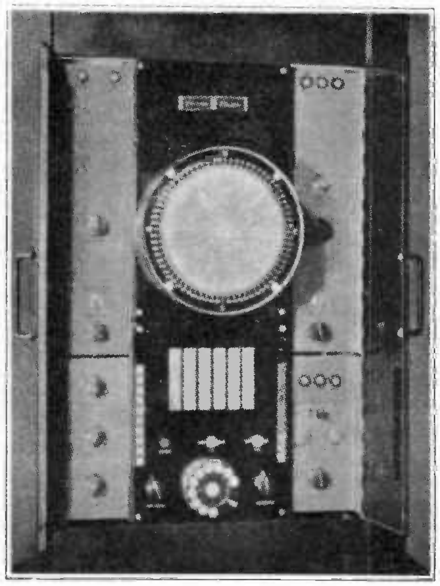
By making up a radio oscillator or using the B.B.C. stations one can tune in condensers with coils and so find the capacity of the small variable condensers used for tuning radio circuits.

These condensers (say .0005 or .0003 μF.) may be compared directly with larger ones on the bridge, and these in turn compared with the three dial condenser, providing a check on everything.

Deaf, Dumb and Blind American Amateur

21-year-old Leo Sadowsky, of Ashford Street, Brooklyn, U.S.A., who is deaf, dumb and blind, has qualified for an amateur radio operator's licence, and has the call sign of W2OFU assigned to him. He was taught by R. T. Gunderson (W2JIO) who is himself blind and is an instructor in radio at the New York Institute for the Education of the Blind. Sadowsky became totally blind at 16, having been born deaf, and learnt the code by the use of a low frequency buzzer which produced vibrations at his finger tips. A similar buzzer actuated by a relay converts the high pitch signals from a communications receiver into a frequency that he can feel. For the purpose of the Federal Commission examination, the code signals were translated into 60-cycle A.C. fed to a pair of headphones to conform to the requirements that the candidate should take the code test "aurally." Sadowsky is now operating on 80 metre CW. and is said to tune his transmitter by touching the tank circuit and adjusting for maximum r.f. burn!

Short-Wave Direction Finding on Land



An advanced type of "azimuth indicating receiver," developed by the Western Electric Co., is now available for operation in the 2.8-6.6 megacycle range, and it is expected that with completion of final tests and refinements now in progress, equipment of this type will find wide application.

This azimuth indicator consists essentially of an aerial collector system, a remote controlled ten-frequency fixed tuned receiver, and a unit combining an azimuth indicating oscilloscope, operating controls, and the necessary voice frequency equipment.

The aerial collector system, which is fundamentally of the elevated-H fixed Adcock type, and the radio receiver are mounted on an outdoor supporting structure at the actual receiving site. The remote control and indicating unit is shown in the illustration with the side panels opened to shown auxiliary adjustments.

The system employed is entirely carrier-operated. The collector system extracts the necessary directional information from the incoming carrier wave; this Adcock type of collector, as is well known, provides defence against polarisation effects (so-called "night effect" or "airplane effect").* In the radio receiver the directional information collected from the aerials is translated into forms suitable for transmission on a two-wire line over a considerable distance to the remote indicator.

* "Mountain Effects and the Use of Radio Compasses and Radio Beacons for Piloting Aircraft," H. Busignies, *Electrical Communication,* Vol. 19, No. 3.

An outstanding feature of the system is that this two-wire line also is utilised for all remote control operations involved in frequency and volume selection of the radio receiver and control of a test oscillator at the receiving site.

The indicating device is a cathode ray oscillograph having a 360 degree azimuth scale around the periphery of the screen. In the absence of both signal and noise the light spot is centred with respect to the azimuth scale. As soon as a carrier wave reaches the collector system the spot is radially deflected toward the azimuth indication corresponding to the arrival azimuth of the wave itself with respect to any desired reference, such as true north. The indication is instantly and automatically unilateral, thus eliminating any 180 degree uncertainty. The position of the spot can easily be read to within two degrees, which is approximately the accuracy of the system when receiving from planes up to a few hundred miles under favourable conditions. Errors of over four degrees are ordinarily rare.

The equipment is considered a medium range, medium accuracy device, but in operation its sensitivity is such that satisfactory indications may be obtained from planes carrying 50 watt transmitters in flight over land at distances up to a few hundred miles in the daytime and evening when transmitting in the 4-6 megacycle band. A few checks have been made on planes using 5 Mc/s. when well over 1,000 miles at sea.

The obvious application of a single radio receiver, equipped as described above with an azimuth indicator, located on an airway or at an airway terminal, is to verify that the plane is on course or to obtain an indication of its angular deviation from the course. Alternatively, a single receiver placed in an off-course position may be used to take bearings on a plane and thus indicate its advance along the course. However, there are other possible applications for a single terminally located receiver. It can be used to great advantage in case the pilot, under bad weather or visibility conditions, either becomes confused in the immediate neighbourhood of the airport or overshoots the mark. Under such conditions the directional indication, especially in view of its rapidity, can be of great assistance to the ground crew in assisting the pilot to re-orient himself for a landing.

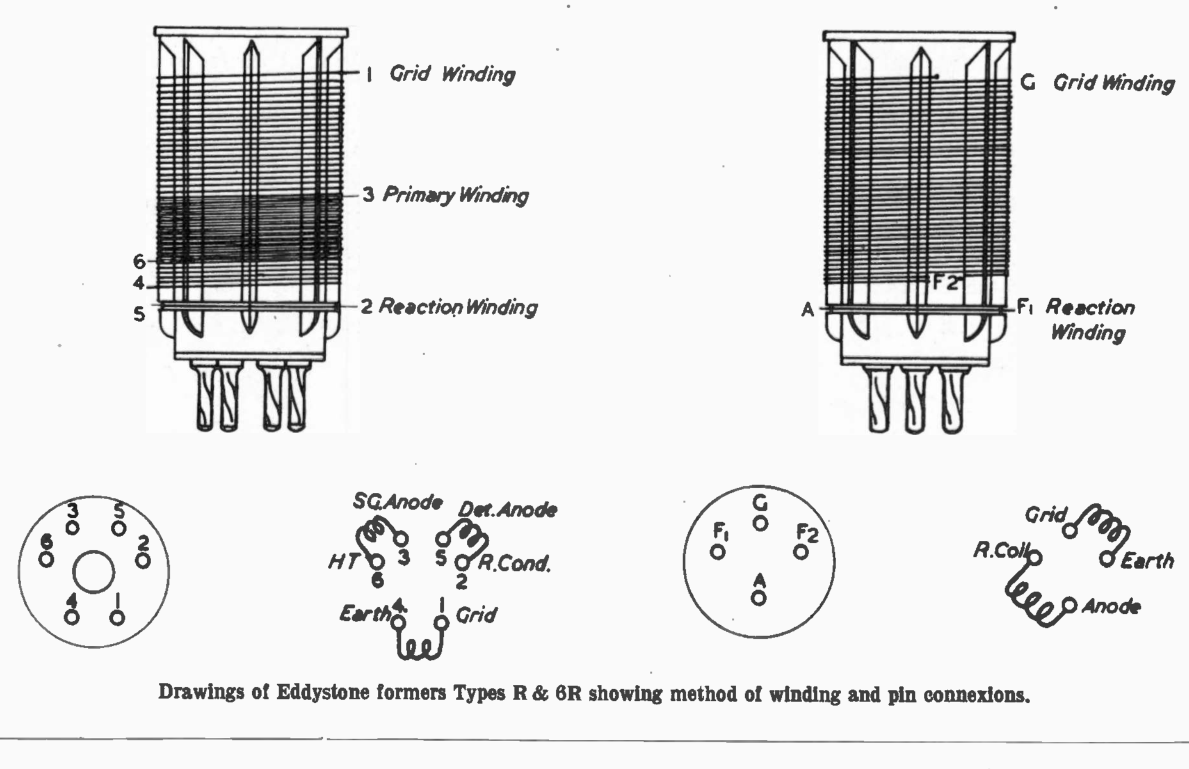
—*from "Electrical Communication," Vol. 20, No. 1, 1941.*

Short Wave Coil Winding Data

Requests are frequently received both by ourselves and the manufacturers for particulars of the windings of short-wave plug-in coils as used in the Eddystone receivers. The following table, which is given with the co-operation of Messrs. Stratton & Co., gives particulars of the coils wound on standard " Eddystone " formers to which the type letters refer.

The sketches show two typical formers and the connexions, which are the same throughout the range of formers. The approximate tuning range is with a .00015 tuning condenser.

Type of Former.	Grid Winding.	Reaction Winding.	Primary Winding.	Connexions.	Wavelength.
P	92 turns 26 SWG. commencing 9/32" from top and 1 27/32" long. Lacquered.	25 turns 38 SWG. D.S.C. in slot 1/16" wide by 3/32" deep. Lacquered.	—	As Type R	150—325 m.
6P	As above.	As above.	On inner former : 42 turns 34 SWG. D.S.C. commencing 3/16" from top and 3/16" wide, wound honeycomb lattice.	As Type 6R.	150—325 m.
R	$23\frac{7}{8}$ turns 22 SWG. enamelled, wound 14 t.p.i. (See sketch) Inductance 14.13 μH.	$9\frac{3}{8}$ turns 30 SWG. DSC. wound in slot 1/16" wide by 3/32" deep. Winding anti-clockwise viewed from pin end.	—	See sketch	41—94m.
6R	As above	As above	$9\frac{1}{2}$ turns 30 SWG. enamelled DSC. wound in between grid turns. (See sketch)	See sketch	41—94 m.
W	35 turns 26 SWG. enamelled commencing 22/32" from top and 11/16" long. Lacquered.	15 turns 26 SWG. enamelled commencing 3/32" from grid winding and 5/16" long. Lacquered.	—	As Type R	76—100 m.
6W	3/16" below primary winding. 35 turns 26 SWG. enamelled 11/16" long. Lacquered. Inductance 45 μH	3/32" below grid winding. 14 turns 26 SWG. enamelled $\frac{1}{4}$" long. Lacquered.	$\frac{1}{8}$" from top of former and 3/16" long. 10 turns 26 SWG. enamelled. Lacquered.	As Type 6R	76—100 m.



Drawings of Eddystone formers Types R & 6R showing method of winding and pin connexions.

CORRESPONDENCE

Measurement of the Electron

SIR,—I was surprised to find that the article by G. Windred in a recent number of your journal was principally devoted to a description of the Millikan experiment for the measurement of electronic charge, and was even more surprised that he quoted Millikan's result complete with his over-optimistic estimate of his errors.

The various experiments on which a value of the electronic charge have been based have been reviewed in detail by F. G. Dunnington in the *Reviews of Modern Physics*, Vol. 11, page 65, 1939. There are still certain points which are not certain, and the values admittedly tend to separate into two groups leading to different results. Dunnington goes into the various possibilities of error, and investigated the effect of assuming slightly different values for other constants.

The work principally responsible for our present value is that of J. A. Bearden in *Phys. Rev.* Vol. 48, p. 395 1935. Together with other modern work, it approaches the problem indirectly. A crystal of a suitable salt is obtained in a very perfect condition, and the distance apart of the atoms is obtained by X-ray diffraction methods. These X-rays are then very accurately measured in terms of ruled grating, at grazing incidence. The density of the crystal is measured. Then, knowing the weight per c.c. and the number of atoms per c.c. the number of atoms per gram molecular weight can be calculated. By use of the very accurately known figure for the electric charge required to transport a gram molecule of ion in the solution (The Faraday) it is possible to deduce the charge on the electron. This is the inverse of the process whereby Mr. Windred deduces the weight of the electron, ultimately from its charge.

While I would hesitate to claim the accuracy that Dunnington gives for his deductions from a wide mass of data, I feel it would be safe to adopt the value:

$$e = 4.800 \pm 0.0035 \times 10^{-10} \text{ e.s.u.}$$

with an emphasis on the higher limit.

G.L.R., Cambridge.

SIR,—Your correspondent G.L.R. has evidently found a distinct element of surprise in my article on "Measurement of the Electron," but I am not sure that I appreciate his reasons. In any case I cannot agree to the use of the term "over-optimistic" in referring to Millikan's estimate of his errors.

Your correspondent is undoubtedly aware that practically every outstanding physical theory or set of measurements is followed by criticism, not always constructive, and often less instructive than the original work. To have entered into a discussion of this kind would have taken me far outside the sphere within which I have endeavoured to keep in the present series of articles, and certainly out of sight of applied electronics.

However, I am quite sure that any readers wishing to study the interesting evidence for values of the electronic constants differing slightly from those given in my article will be grateful to your correspondent for drawing attention to the papers by Dunnington and Bearden.

G. WINDRED.

Plastics

SIR,—The compilation of tables attributing the various plastics to their manufacturers seems to be full of pitfalls. You have been good enough to insert some errata already, but we should be glad if you could find space for a summary of corrections which will do justice to our various friends in the plastic industry.

First, in the table on p. 484, "Cellomold," a well-known cellulose acetate moulding powder made by F. A. Hughes & Co., Ltd., was omitted as was "Erinofort," a similar material made by Erinoid, Ltd. In the same table, but already acknowledged, was the omission of Bakelite laminated sheet and we have since realised that we also left out the "Bakelaque" resins and laminated sheet of Attwater & Sons, Ltd. The "Chlorovene" of F. A. Hughes & Co., Ltd., should have had a dot in the appropriate column of the same table to indicate that the name includes the vinyl chloride copolymer and "Rockite" made by the same firm should not have included U.F. resin. Finally, we neglected to state that Panilax, the Aniline-formaldehyde resin of the Micanite & Insulators Co., Ltd., is thermoplastic. There are probably still some further errors for which we express regrets in advance.

W. G. WEARMOUTH.
E. G. COUZENS.

Television Receiver Conversion

SIR,—I am contemplating the purchase of a "pre-war" television receiver, such as were advertised in your columns, but before doing so would be glad of your readers' experience.

I thought that the cathode-ray tube and scanning circuit could be adapted for measurement work by making the time base variable in speed, and using the receiver (short-wave only) as a local station high quality receiver.

Has anyone carried out such alterations successfully and what are the snags? Any suggestions will be gratefully received.

G.W.L.
London.

Editorial Note: This letter raises an interesting point which will be covered in a future article. In the meantime, readers' suggestions are invited, and will be paid for at the usual rates on publication.

NOTES FROM THE INDUSTRY

Radio Industries Club

At the last luncheon of the year held by the Radio Industries Club the guest of honour was Chief Inspector Fallon of Scotland Yard, who was invited to address the members on Radiocommunications in the Police Force. His discretion in avoiding giving away vital information was more than compensated for by the humour of his speech, which drew frequent laughter from the large audience.

Sir Philip Game, the Chief Commissioner, was also present. The chairman reported that the membership had increased by over twenty during the past few months.

Full particulars of membership, which is open to those actively engaged in the radio industry, can be obtained from W. E. Miller, Esq., *The Wireless Trader*, Dorset House, Stamford Street, S.E.

The Institution of Electrical Engineers

London Students' Section

The following programme of lectures and visits has been arranged for the session 1942:

Saturday, February 7. (Afternoon).—Visit to Switchgear Department of British Thomson-Houston Company, Ltd., Willesden. Party limited to 30. Applications giving full name and National Identity Card Number to reach the Secretary, I.E.E., Savoy Place, Victoria Embankment, W.C.2, between January 14 and 21.

Monday, February 9.—Meeting. Problems night.

Friday, February 20.—Stag Supper. (Tentative date).

Wednesday, February 25.—Meeting. Details later.

The informal meeting on February 9 is of particular interest in view of the variety of topics listed for short discussions. Among these are: "How does current density affect electron velocity in conductors?" and "Is there sufficient justification for the increasing complexity of equipment in long-distance telephony?"

Further particulars of the Section's activities can be obtained from the Hon. Secretary, Mr. J. D. MacNeill, 51 Gloucester Drive, N.4.

Time Bases

A paper of interest to all users of cathode-ray tubes in research will be read by Mr. O. S. Puckle at the Institution of Electrical Engineers on February 4.

Tickets of admission for non-members are available on application to the I.E.E.

The British Institution of Radio Engineers

The secretary informs us that the following programme of meeting has been arranged for the 1942 session:—

7th February, 1942.—"Transmitting Valves," by L. Grinstead, M.I.E.E., M.Brit. I.R.E.

7th March, 1942.—"Harmonic Distortion in Audio Frequency Transformers," by N. Partridge, B.Sc.(Eng.), A.M.I.E.E.

9th April, 1942.—"Wired Broadcasting," by Capt. P. P. Eckersley, M.I.E.E.

Full particulars and tickets of admission for non members, can be obtained from the Secretary, Mr. G. D. Clifford, at Duke Street House, Duke Street, London, W.1.

Marconi-Ekco Instruments

At the annual general meeting of Messrs. E. K. Cole, Ltd., the chairman announced that the company had sold the whole of its share interest in Marconi-Ekco Instruments, Ltd.

Technical Catalogues Received

A well-illustrated catalogue of porcelain products from Messrs. **Geo. Bray & Co.** (Leeds, 2) gives full details of their wide range of tubing, screwed or flanged, bushes and washers, disks and beads.

The plain tubes have a high Sillimanite content and are used for winding resistance heaters, the diameters ranging from 4.75 in. to .018 in. They can also be supplied threated or with twin holes.

The photographs give an excellent illustration of the enormous variety of special shapes which can be moulded in porcelain to individual requirements. Full data can be obtained from the Head Office of the Company at Trafalgar Square, W.C.2, or from Leeds.

Messrs. Hammans Industries, Ltd., have supplied samples and technical data on Delaron laminated material, which has already been mentioned in the series of articles on Plastics in this Journal. Various types of insulating sleeving are also available, all to Air Ministry requirements and approved specification. The prices of these have been revised (December, 1941) and inquirers should ask for the new list, which is available from the company at Brighton Road, Sutton, Surrey.

Londex, Ltd., the well-known remote control engineers, have introduced a floatless liquid level control system which is termed "Lectralevel." Two electrodes are immersed in the liquid at pre-determined levels, energised from a low voltage transformer.

For emptying a storage tank, the circuit is arranged so that a relay is energised as soon as the liquid level reaches the top electrode and starts a pump. As the level drops below the top electrode the relay still holds in until the liquid reaches the lower electrode, when the pump is switched off. Particulars of the system are given in Leaflet 94 from the makers at Anerley Works, Anerley Road, S.E.20.

American Developments in Experimental Physics

The publication by the Institute of Physics of a survey of recent American Developments in Experimental Physics is a particularly apt one with which to commence the new volume of its *Journal of Scientific Instruments.* This valuable illustrated summary has again been contributed by Dr. C. J. Overbeck of the Northwestern University, Illinois; it will interest all concerned with the application of the several branches of science, and particularly engineers.

Copies of the issue containing this article are available from the Institute of Physics, at The University, Reading, Berkshire, price 3s., post free.

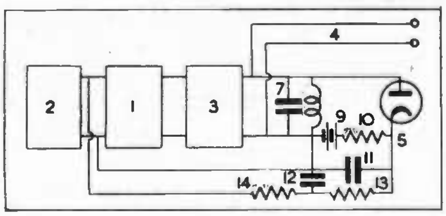
PATENTS RECORD

The information and illustrations on this page are given with the permission of the Controller of H.M. Stationery Office. Complete copies of the Specifications can be obtained from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

Improvements Relating to Systems for Transmitting Frequency - Modulated Carrier-wave Signals

The invention has been developed in connexion with the transmission of television signals comprising picture signals and interspersed synchronising signals. One object is to provide a convenient method of stabilising the frequency of an unmodulated carrier oscillator in a television signal transmission system where signals are transmitted by frequency-modulated carrier.

Part of the amplifier limiter 3 is fed to the demodulation device indicated generally at 5, the output of which is applied to the input of the oscillator 1 to effect the required adjustment of the frequency. The device 5 comprises a band-pass filter 7. Signal potentials



developed across the filter 7 are applied to the rectifier which serves as a detector. The biasing battery 9 and the loading resistance 10 are bypassed by a condenser 11 which partially smooths the rectifier output before it is fed into the line and additional smoothing is provided by shunt condenser 12 and resistance 13. A resistance 14 is inserted between shunt condenser 12 and oscillator 1 so that condenser 12 does not by-pass the output.

The invention is not only applicable to a modulating arrangement in the manner illustrated, but it could, if desired, be applied to a frequency changer stage. In this case the initial modulated carrier or the intermediate frequency carrier could be used to actuate a demodulator device and the output applied to vary the frequency of the locally-developed oscillations in the required manner.

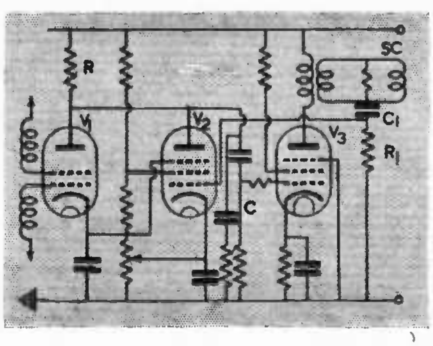
The invention can thus be applied to any part of a system operating with a frequency-modulated carrier in which it is desired to stabilise the operation of the system, so that in the carrier transmitted a predetermined carrier frequency is made to correspond to a pre-determined signal amplitude at all times.—*W. S. Percival. Patent No.* 538,198.

Electron Discharge Valve Circuits for the Generation of Electric Currents of a Desired Waveform

An arrangement for producing a scanning wave in which the generation of the deflection current is controlled so as to tend to correct the waveform without feeding back the actual waveform produced. Also to provide a generator for the generation of sawtooth waveforms where non-linearity appearing in the flank of the sawtooth is effective to set up a strong reaction in the input of the generator tending to impart to the long flank the desired linearity.

While the valve V1 is non-conducting, the charging condenser C tends to charge up through the resistance R, thereby increasing the potential of the control grid of valve 3 so that the valve passes an increasing current. The impedance of the valve V2 is controlled by the potentials applied to its control grid through the feedback connexion. The condenser and resistance have the same time constant as the coil S_C. With this arrangement, during the forward stroke of the sawtooth current flows through resistance R1, so charging condenser C1 that the rise of potential across the scanning coils due to their resistance is neutralised and only the potential due to the charge of current through the inductance of the coils will be applied to the control grid of valve V2. Thus, the potentials will be proportional to the potential difference developed due to the passage of the scanning current through the inductive component of the impedance presented by the scanning coils. The potential fedback to the control grid of valve V2 during the forward stroke of the sawtooth should be constant.

When the valve V1 is rendered conducting, condenser C is discharged rapidly and the potential of the control grid of valve 3 falls, thereby reducing the current through the valve. The consequent rapid decrease of current in the coils Sc develops a large negative impulse which is thus rendered non-conducting. In this way the feedback through valve V2 to the control grid of valve 3 is rendered inoperative during the return stroke of the sawtooth.—*E. L. C. White and E. W. Bull. Patent No.* 538,369.



Improvements in Piezo-Electric Crystals

Means whereby crystal plates may be adapted to give a considerably increased power output without any substantial interference with the temperature coefficient on the frequency of vibration.

A piezo-electric crystal plate is formed with two major surfaces of the same size and parallel to each other by cutting at a selected angle from the mother crystal. Subsequently both the major surfaces are shaped by grinding so as to substantially reduce without eliminating the thickness of the crystal at its periphery so that part of the side walls of the crystal is unaffected by the grinding process.

—*Automatic Telephone Electric Co., Ltd. Patent No.* 538,002.

Control by Variable Inductance

The invention relates to circuit arrangements comprising a variable inductance such as are used for synchronisation purposes for remote tuning of oscillatory circuits, such as local oscillator circuits in radio receivers, for maintaining constancy of voltages.

The circuit arrangement is provided with an iron core, the required variation in the self induction is brought about by a variation of the amplitude of the alternating magnetic field produced in the iron core by an alternating control current. The variable inductance consists of two coils each provided to cause the control current to set up an alternating magnetic field in each of these cores, the control-frequency voltages induced in the two coils being in anti-phase.

—*Philips Lamps, Ltd. Patent No.* 537,801.

Negative Feedback

A negative feedback amplifier in which the gain control is effected outside the feedback path by means of a potentiometer across the input transformer characterised in that means are provided for counteracting the variation of input impedance with adjustment of the potentiometer due to capacity to earth of the transformer winding.—*Standard Telephones and Cables Ltd., A. H. Roche, and A. J. Buxton. Patent No.* 529,360.

ABSTRACTS OF ELECTRONIC LITERATURE

C. R. TUBES

Photography of Cathode-Ray Tube Traces

(*H. F. Folkerts and P. A. Richards*)

A permanent record of the trace on the screen of a cathode-ray tube is often desirable. For patterns which may be caused to stand still or follow the same path each cycle, the time of exposure is dependent upon the characteristics of the lens, the cathode-ray tube, and the type of film. These same factors affect the velocity of spot which may be photographed as it traverses the screen only once. Some photographs of the latter are taken with moving film cameras. In this case the persistence of the fluorescent screen may be a factor. Constants relating these factors are given for several films and cathode-ray tubes.

—*R.C.A. Review,* Vol. 6, No. 2, page 234 (1941).

Voltage Dividers and Delay Cables for Cathode Ray Oscillographs

(*A. M. Angelini*)

The author considers the conditions to be fulfilled by different voltage dividers and delay devices for cathode-ray oscillographs for recording high-speed phenomena, as well as their influence on the factors affecting the accuracy of these recordings. The influence of the characteristics of the delay cable is investigated, and practical consequences are deduced from the results obtained. He shows that delay cables of sufficient accuracy can be made by simple means. He does not take into account the capacitive currents passing through the resistances during rapid variations in voltage.

—*A. S. E. Bull,* 18/7/41, page 305.*

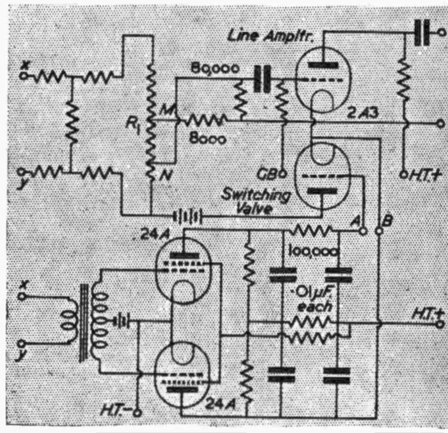
Cathode-Ray Demonstration Panel

(*R. K. Patrick*)

A C.R. demonstration panel designed by Burlec Limited and the R.C.A.F. for instructional use in wireless schools consists of a 14-valve superheterodyne radio receiver, a two-stage transmitter with modulator, amplifier and power supply mounted on a panel approximately 8 ft. × 4 ft. The components of the receiver are spread out across the face of the panel so as to correspond as closely as possible with a schematic diagram which is drawn on the face of the panel. Two 9 in. oscillographs are embodied at the top of the panel and are used for visual demonstration.

By the use of interchangeable components, which are readily plugged into the face of the panel, and by interswitching, practically any radio phenomenon can be demonstrated.

—*Communications,* Vol. 21, No. 9 (1941), page 5.



An Electronic Oscilloscope Marker

(*E. Moen*)

A generator is described which can inject sharp breaks in any sinusoidal wave of frequency from 60 to slightly under 1,000 cycles per second.

The circuit utilises coupling between the anodes of two amplifiers to generate the marking pulses. When the first anode tends to draw current, the current in the second anode which is in opposite phase is suddenly reduced by the reduction in anode voltage. The result is a sharp differential pulse at each change in input voltage.

—*Electronics,* Vol. 14, No. 9, 1941, page 68.

Characteristics of Fluorescent Materials

(*L. H. Stauffer*)

Recent improvements in luminous efficiency and colour range have placed fluorescent materials among the most important light sources now in use. Luminescent crystalline materials have been developed with efficiencies exceeding 70 per cent. for ultra-violet excitation, and almost any desired hue, including white, is obtainable.

In this article a useful table is given of approximate characteristics of typical phosphors, together with the following characteristic curves:—

- Emission curves of several zinc sulphide phosphors. (Pure zinc used as a standard.)
- Effect of varying concentration of manganese, used as an activator, on alpha willemite.
- Emission curves of several tungstate phosphors.
- Relative visibility and emission curves of several mixtures of zinc sulphide and cadmium sulphide phosphors
- Relative light output of willemite screens as a function of acceleration voltage.
- Light output curves for phosphor screens uniformly scanned by an electron beam.

—*Electronics,* Vol. 14, No. 10 (1941), page 32.

CIRCUITS

Automatic Phase Reversal Amplifier

(*R. P. Crosby*)

This type of operation as compared with manual phase reversal is claimed to be approximately equivalent to an effective gain of 6db. without causing any additional distortion. The circuit (see col. 2) consists of a normal line amplifier, a switching valve, and a push-pull amplifier whose function is to operate the switching valve, in accordance with the polarity of the voltage at its output terminal. Assuming that the 2A3 switching valve is connected, the flow of anode current will set up a steady voltage across the resistor R_1, which will give a somewhat more positive bias to the line amplifier, but the signal voltage will remain unchanged. Thus, the effect is the same as if the bias control were at the point M instead of at N, so far as the instantaneous voltage on the input of the line amplifier is concerned.

For zero signal on the input of the push-pull valves, the terminals A and B are at the same potential, and consequently the 2A3 valve has zero negative bias. When a signal voltage is applied, one of the terminals becomes negative with respect to the other. If the terminal A is relatively negative, the 2A3 valve is biased to cut off since only a low voltage is used on the anode of the 2A3. By means of this mechanism we can automatically reverse the circuit so that the higher peaks will always modulate the transmitter upward, although for proper operation the position of the terminals A and B may have to be reversed.

—*Electronics,* Vol. 14, No. 10, page 65 (1941).

A Pentode Lock-in Amplifier of High Frequency Selectivity

(*W. C. Michels and N. L. Curtis*)

An amplifier which is based on the scheme of heterodyning the signal to be measured with a locking-in voltage of the same frequency, as proposed originally by Cousens, is described and its characteristics are discussed. The particular design used with the locking-in voltage applied to the screens of two pentodes, possesses a distinct advantage over earlier instruments because the valves operate on a linear portion of their transfer characteristics, reducing harmonic response, and also because the main power supply is direct current, so that there is little drain on the control supply. It is found that the response band can be given a width of the order of one cycle per second without undue inconvenience or expense.

—*Rev. Sci. Inst.,* Vol. 12, No. 9, 1941, page 444.

ABSTRACTS (*contd.*)

CIRCUITS

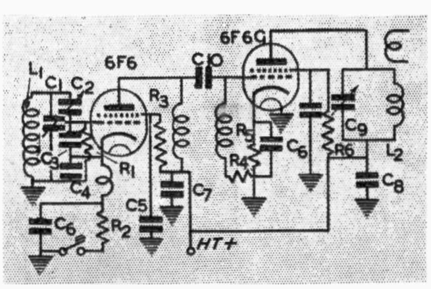
A Low-C Electron-Coupled Oscillator

(*E. O. Seiler*)

This circuit is essentially that of a Colpitts oscillator, with the valve loosely coupled to the tank circuit by means of the capacitive voltage divider C_2, C_3, C_4. The high capacities across the valve elements are retained, thus giving the capacity "swamping" effect of the ordinary high-C circuit.

At no time is the total capacity across L_1 greater than 250 $\mu\mu$F., which is low-C, considering that the oscillator operates in the 1.75 Mc band. The 100 $\mu\mu$Fd variable, C_2, controls the coupling between the valve and tank. It may also be used for band setting, but the circuit will stop oscillating if the capacity is reduced too much. The coil L_1 should be pruned so that nearly all the capacity of C_2 is in use. The main tuning condenser, C_1, is a 150 $\mu\mu$Fd variable with a micrometer dial. Tuning is fairly sharp without additional provision for bandspread, so that a form of vernier dial is useful. In this case the band from 1,750 to 2,000 kc/s. is spread over 155 divisions on the dial.

Apart from the tank circuit, the remainder of the e.c.o. unit is conventional and needs little special comment. The oscillator is choke-coupled to the buffer, and the buffer anode tank is tuned either to the fundamental or the second harmonic of the oscillator frequency, using a 350 $\mu\mu$Fd tank condenser to cover both bands without changing the coil.



C1	150 $\mu\mu$Fd variable
C2	100 $\mu\mu$Fd variable
C3	525 $\mu\mu$Fd silvered mica
C4	200 $\mu\mu$Fd (525 $\mu\mu$Fd and 460 $\mu\mu$Fd silvered mica and 215 $\mu\mu$Fd all in parallel)
C5	0.05 μFd paper 400 volts
C6)	0.01 μFd paper 400 volts
C7	0.003 μFd paper 400 volts
C8	0.02 μFd paper 400 volts
C9	350 $\mu\mu$Fd variable
C10	50 $\mu\mu$Fd mica
C11	8 μFd electrolytic 450 volts
R1	50,000 ohms.
R2	1,000 ohms.
R3	18,000 ohms.
R4	25,000 ohms.
R5	450 ohms.
R6	15,000 ohms.
L1	44 turns No. 23 s.c.e. on 1½ inch dia.
L2	35 turns No. 23 s.c.e. on 1½ inch dia. output coil 5 turns
RFC	2.5 mh r.f. choke

—*QST*, November, 1941, page 26.

TELEVISION

Television Transmission

(*M. E. Strieby and C. L. Lewis*)

Experiments in the transmission of television signals over wire lines have been made from time to time as the television art has developed. This paper discusses experiments made during the summer of 1940 with 441 line, 30 frame interlaced signals transmitted over coaxial cable and other telephone facilities. Some of the general problems of wire transmission have been included. In particular the results of transmission studies on a system linking New York with Philadelphia is reported.

—*Proc. I.R.E.*, Vol. 29, No. 7, 1941, page 371.

Photographic Analysis of Television Images

(*D. G. Fink*)

In this article a miniature camera (Contax 1) was used. The basic lens is a Zeiss Sonnar 5 cm. f/1.5 fitted with auxiliary lenses (Proxar 1 and Proxar 2) for reducing the lens-to-object distance to a minimum of 8 inches.

A rigid copying stand was constructed to fit directly over the picture tube of the television receiver. The mirror was removed and the connexions to the vertical scanning coil reversed to simulate the reversing effect of the mirror.

The electrical equipment consisted of a 0 to 100 μA microammeter for measuring the beam current of the picture tube, and, with a calibrated resistance, for measuring the second anode voltage. A direct coupled cathode-ray oscilloscope was used to measure the peak-to-peak values of the signal voltage applied to the picture tube grid.

—*Electronics*, Vol. 14, No. 8, 1941, page 26.

A Simplified Television System for the Radio Amateur and Experimenter

(*L. C. Walker and P. A. Richards*)

A new iconoscope has made it practical for amateurs to participate in electronic television investigations. An experimental amateur television system, including camera unit, receiver, and 2½-metre transmitter, is briefly described. In this system the frame frequency and lines per picture are, respectively, 30 and 120.

—*R.C.A. Review*, Vol. 6, No. 2, page 245 (1941).

MEASUREMENT

A Photoelectric Fluorimeter

(*G. F. Lothian*)

A description is given of a photoelectric fluorimeter using two photocells in a null circuit. The method of use to give greatest accuracy in estimation of the concentration of a fluorescing solution is considered theoretically: it is shown that by working with dilute solutions the effect of impurities may be detected and sometimes be eliminated.

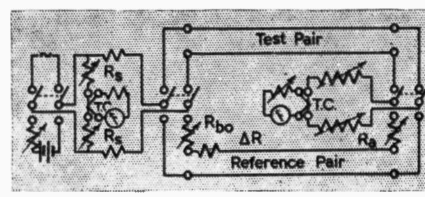
—*Jour. Sci. Inst.*, Vol. 18, No. 10, 1941, page 200.

D.C. Substitution Method of Measuring High-Frequency Attenuation

(*H. B. Noyes*)

Attenuation measurements are often made by passing currents of various frequencies over a section of the line and measuring the input and output with thermocouples.

The D.C. substitution method has been found to give more precise results on measurements of this type. The arrangement of the circuit is indicated below.



The pointer of the galvanometer at each end of the line is brought to a position on the scale where the sensitivity is greatest by adjusting the output of the oscillator and the resistances R_s, and then an indicating pointer, operated by hand, is brought immediately over the galvanometer pointer to indicate its position. The three switches are then immediately thrown down, and a resistance in the battery supply is adjusted until the pointer of the input galvanometer returns to the position of the indicator pointer. The resistance, R_A, in the D.C. reference circuit is then adjusted until the pointer of the galvanometer at the distant end is also brought in line with its indicator. When these two conditions are met, the loss in the reference circuit is the same as that in the test pair.

Since various pairs differ slightly in resistance, and as the resistance of any pair varies with temperature, an adjustable building-out resistance R_{BO} is added and so adjusted that its values plus the resistance ΔR of the pair itself is always the same for a series of measurements. Since $R_{BO} + \Delta R$ is held constant, the insertion load of the test pair when placed between two resistance terminations R may be determined directly from resistance R_A.

—*Bell Laboratories Record*, Vol. 20, No 2, 1941, page 38.

Power Factor Meter

(*A. B. Bereskin*)

Based on the phase control operation of gas thyratrons, direct reading power factor meter has been designed for either 150 or 250-volt circuits and for currents of from 0.1 to 10 amperes. All errors are less than those in reading the indicating meter.

—*Electronics*, Vol. 14, No. 10, page 38.

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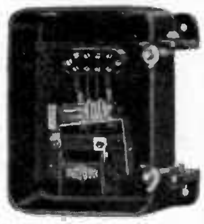

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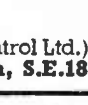

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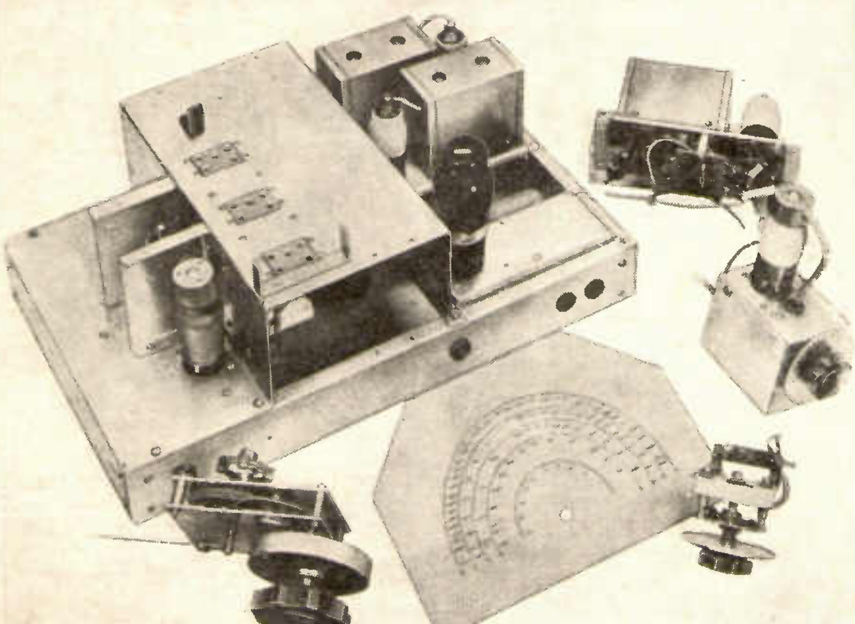

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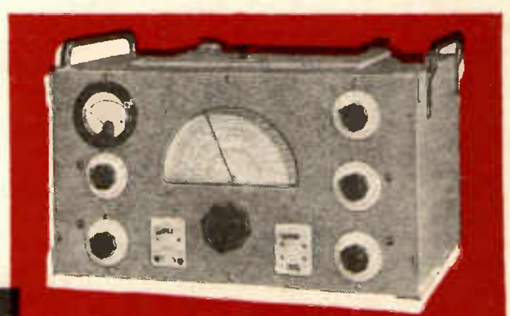

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