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Wireless World

RADIO AND ELECTRONICS

JANUARY 1949

Comments of the Month

POPULARIZING TELEVISION

CONSIDERING that there is only one transmitter at present working in this country, the spread of television may be regarded as satisfactory. But the time will probably come when the potential output of receivers is greater than public willingness to absorb them; this state of affairs will certainly come about all too soon unless energetic steps are taken to dispel doubts, which still seem widespread in the lay mind, as to the adequacy of picture quality. The desirable end can best be achieved by well-organized public demonstrations, and we are glad to see that the Radio Industry Council has already made a start in this direction.

So far, most members of the public have gained their first impressions of television from demonstrations in retail shops. Without belittling the efforts of individual dealers, many of whom have shown great resource and enterprise, it is true to say that conditions in shops are inherently unfavourable, or even unfair, as they are worse than those obtaining in the average home. The interference level prevailing in a busy thoroughfare is higher than in most residential districts. Moreover, the average person naturally hesitates to visit a shop unless he has almost made up his mind to buy a television set.

Co-operation between industrial organizations and public bodies seems to be needed to ensure that in every large centre of population where a service is available the interested citizen can see demonstrations that fill all the requirements. We believe that in the whole of London the only place satisfying these requirements is the Science Museum at South Kensington, where the public can see the transmissions every afternoon. No doubt many comparable institutions within the service areas of the present and of future transmitters would be willing to grant facilities for regular demonstrations. Even if reception conditions are not ideal in conveniently central situations, most of the difficulties could be overcome at a cost that would not be excessive for a co-operative effort. We suggest that in this effort both the industrial organizations and the B.B.C. might co-operate with advantage.

"STATIC"

THIS synonym for "atmospherics," "interference," or even sometimes "jamming," is a word which *Wireless World* tries to avoid. We were glad to see that a contributor, writing in our December issue, refuses to accept "precipitation static" as a term to describe corona discharge interference. Though this may have a static origin, conditions are anything but static when the interference manifests itself.

A misleading—if not meaningless—statement due to a mis-translation ascribable to the currency of the deplorable term "static" has just come to our notice—and in an official publication at that. Below are given short extracts from the parallel French and English texts in the report in the *Journal des Télécommunications* * (Berne) on the Maritime Regional Radio Conference, Copenhagen. The italics are ours.

ARTICLE 12.

Les administrations prendront, en ce qui concerne leurs stations cotières, les mesures nécessaires: .....

.....

(b) pour éviter toute émission *parasite* susceptible de causer des brouillages nuisibles.

ARTICLE 12.

With regard to their coast stations, administrations shall take the measures necessary: ....

.....

(b) to avoid any *static* emission likely to cause harmful interference.

* September, 1948; p. 353.

Comment is hardly necessary, but we cannot help saying that the figurative French use of the word *parasite* for "interference" seems to be hardly less confusing than the Anglo-American "static," and to be even more to blame.

LOW-IMPEDANCE VARIABLE-

The Cathode Follower as a D.C. Potential Divider

By M. G. SCROGGIE, B.Sc., M.I.E.E.

IN previous issues[1] the series type of voltage stabilizer has been considered in some detail. It is, as we have seen, essentially a cathode follower with amplified feedback. The amplification enables a very high degree of stabilization and absence of internal resistance to be achieved, but introduces difficulties when the output voltage is required to be variable below about + 100 V. It is also rather elaborate if several independently - variable stabilized outputs are to be provided.

The internal resistance of a plain cathode follower, being approximately $1/g_m$, is relatively high—of the order of 150Ω—but is nevertheless far lower than that of a potential divider across the main stabilized output, even if the resistance of the potential divider were made so low as to waste most of that output. The various types of Marconi " Stabilivolt " provide from one to four tappings, with internal resistance in some types as low as 40Ω, but are limited to certain fixed voltages, generally multiples of 70 V. Cathode followers, on the other hand, can be controlled to provide continuously variable outputs from nearly zero up to that of the main supply, are simple and cheap, and in most cases their internal resistance is less than 1 per cent of the load resistance and therefore practically negligible. They can be added to any existing stable-voltage unit, or incorporated in the design; so the whole becomes a very flexible equipment for laboratory use. The same idea has been applied in power units forming parts of equipment such as amplifiers, to supply constant screen-grid potentials, and was devised for that purpose by the late Dr. Partridge.[2]

Fig. 1 shows the very simple essentials of the " electronic tapping." The symbols have been chosen to fit on to those used in the previous articles dealing with the main unit. V_0 can therefore be assumed to be a stabilized output, variable, say, from 200 to 400 V. $R_{10}R_{11}$ is a wire-wound potentiometer of about 0.1 MΩ, controlling the tapping voltage, V_t. R_{12} is a grid-current limiter to take care of the valve under conditions when R_{10} and the load resistance, R_L, are low.

The question is, what sort of valve should be chosen? The answer quickly becomes clear if one takes any valve characteristic curves and uses them to calculate the performance. Short-circuiting preliminary bad guesses, let us start with a type that will turn out to be particularly suitable in most respects—the Mullard EC52. (This happens to be intended primarily for very high frequencies, up to 400 Mc/s, so it is perhaps not the most obvious choice for a zero-frequency application).

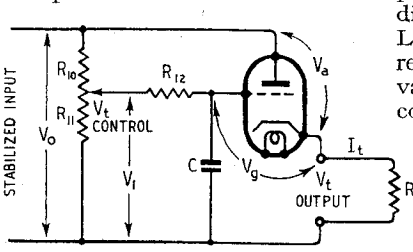

Fig. 1. Stable-voltage " electronic tapping," with output adjustable over nearly the whole range of V_o.

Fig. 2 consists of the ordinary I_a/V_a curves, which as regards Fig. 1 are I_t/V_a curves. Since $V_t = V_0 - V_a$, we can easily mark a scale of V_t for any given V_0. This is done in Fig. 2 for $V_0 = 400$. We can at once see the available range of I_t at any specified V_t. Suppose, for example, that with V_0 set at 400, V_t is 250. The curves show that anything up to 18 mA is available, at V_g from 0 to − 3.5. One has only to add this variable V_g to the specified V_t to get the relationship between I_t, the current drawn, and V_1, the setting of the V_t control (assuming no grid current to cause a drop in R_{12}).

What we want, of course, is not a curve of V_1 against I_t for a fixed V_t, but V_t against I_t (the so-called regulation curve) for any fixed V_1. Under these conditions, when V_g varies owing to a change in I_t drawn, V_a is altered by the same amount. But with a high-μ valve such as this ($\mu = 50$) the effect of the change in V_a is quite negligible. So far as the characteristic curves are concerned—in particular, the I_t/V_g relationship corresponding to any value of V_1—it is legitimate to disregard the difference between V_t and V_1, and to use the V_t scale as a scale of V_1.

Supposing for example that V_1 is set to 250 V, then; zero I_t is represented in Fig. 2 very nearly by point A, where V_g is −3.5, so the corresponding V_t must be 253.5, represented by point A′, set off to the left by a distance corresponding to V_g. Looking upwards from A, we can read off at intervals the decreasing values of $-V_g$ (and hence of V_t) corresponding to increasing load currents, and set them off to the left. The limiting point is where grid current starts to flow, causing a voltage drop in R_{10} and R_{12}. Voltage stabilization then fails. The start of the grid current varies from valve to valve of the same type, and in the EC52 lies between 0 and −1 V. The dotted curve at −0.5 represents an average, and in the assumed circumstances is met when I_t is 14.5 mA (point B).

From the way in which the regulation curve A′B has been derived it is obviously the familiar I_a/V_g curve (for $V_a = 150$ in this case), crowded on to the V_a

[1] Oct., Nov., Dec., 1948.

[2] *The Partridge Manual*, p. 16. (Partridge Transformers Ltd., Kingston By-Pass, Tolworth, Surrey).

VOLTAGE TAPPINGS

scale. That being so, it represents a resistance equal to $1/g_m$, confirming cathode-follower theory when $1/\mu$ is neglected. Thus, over the range 0 to 14.5 mA, the variation in output voltage is 3 V. If this variation were uniform, it would indicate a generator resistance of 3/0.0145 = 207 Ω. Actually, as the curves show, it is greater than this for small I_t, and decreases to about 140 Ω in the region of $V_g = -1$.

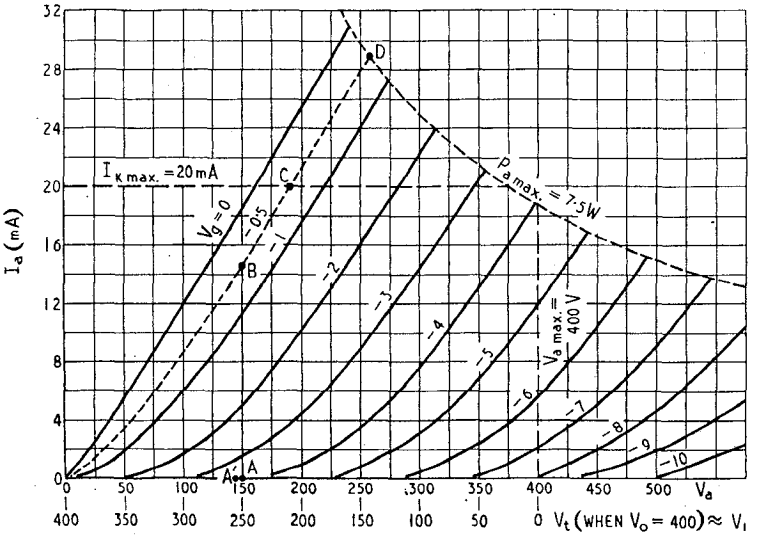

Fig. 2. I_a/V_a characteristics of EC52, illustrating properties and design of electronic tapping.

Assuming that R_{12} is large enough to keep V_g constant at −0.5 V as I_t is increased beyond point B, we must now follow the dotted line. In due course this would bring us into the zone fenced off by the maximum cathode current rating for the valve (20 mA). If it were not for this, one could proceed as far as point D, on the boundary set by the maximum anode dissipation (7·5 W). With other valves or conditions, especially with low V_t, it is possible to strike the anode dissipation limit first. A third limit, maximum rated V_a, is shown as a vertical dotted line. Exclusion of the area to the right of it conservatively assumes that V_t is liable to go right down to zero.

If we prefer a regulation curve in the more usual form, with a vertical voltage scale, we can draw it as in Fig. 3, constructed from data transferred from Fig. 2. For preliminary purposes it should be enough merely to inspect the valve makers' curves turned through −90°. This is because the regulation curve comprises two regimes; the first, A'B, in which stabilization is effective, consists of the I_a/V_g curve for the appropriate V_a ($\approx V_0 - V_1$), and with a high-g_m valve is nearly level. The second, BC, follows (unless the I_{kmax} or p_{amax} limits have intervened) when the tapping is overdrawn so that grid current flows. If R_{12} were so large that further reduction in $-V_g$ could be neglected, this part of the regulation curve would coincide with the I_a/V_a curve for V_g corresponding to the start of I_g (the dotted curve OBCD in Fig. 2). There are practical disadvantages in making R_{12} large enough to approximate very closely to this assumption, so that I_a/V_t characteristic should not be expected to represent this part of the curve accurately. So far as regulation is concerned, that matters little, seeing that it is a condition one avoids; but it does slightly affect the risk of overrunning the valve. Experimental results (with R_{10} R_{11} = 0.1 MΩ; R_{12} = 0.25 MΩ) have been plotted in Fig. 3 for comparison. Whereas the difference between them and the theoretical plots is imperceptible over most of the flat part, the experimental curve slopes less steeply in the unstabilized condition.

Regulation curves for other settings of V_1 can very quickly be added to Fig. 3 if the corresponding I_a/V_g are available; failing which, the data can be derived from the I_a/V_a curves of Fig. 2 as previously. This exercise makes it clear that on open circuit the output voltage is equal to the V_1

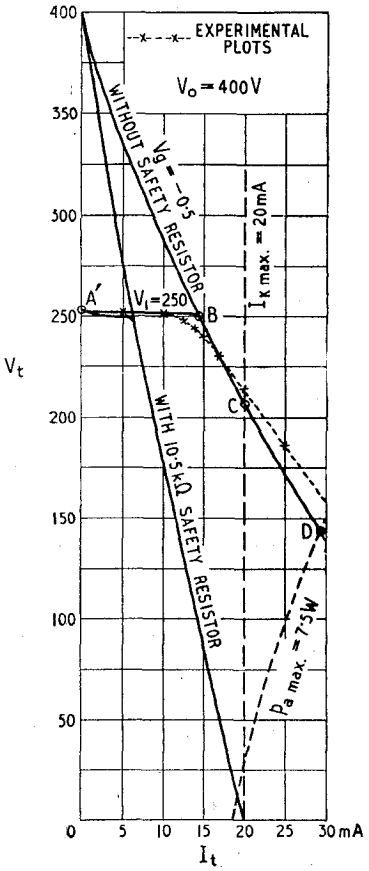

Fig. 3. Regulation curve, A'BC, derived from Fig. 2, with the voltage control set at V_1 = 250. An experimental curve is dotted in for comparison. The modification due to a fixed resistor in series with the anode, sufficient to prevent the rated limits from being exceeded under any conditions, is also shown.

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setting plus a voltage that ranges from practically zero when $V_1 = V_0$ to V/μ when $V_1 = 0$. The maximum stabilized output current increases from zero at $V_1 = V_0$ to approximately the zero-V_g anode current of the valve at $V_a = V_0$ when $V_1 = 0$, subject to I_{kmax} and p_{amax} ratings.

If V_0 is altered, V_1 obviously changes in proportion; and so (approximately) does V_t.

The relationship of output to load resistance can be examined by drawing the usual load line from the point $V_t = 0$, $I_t = 0$, to the working point, in either

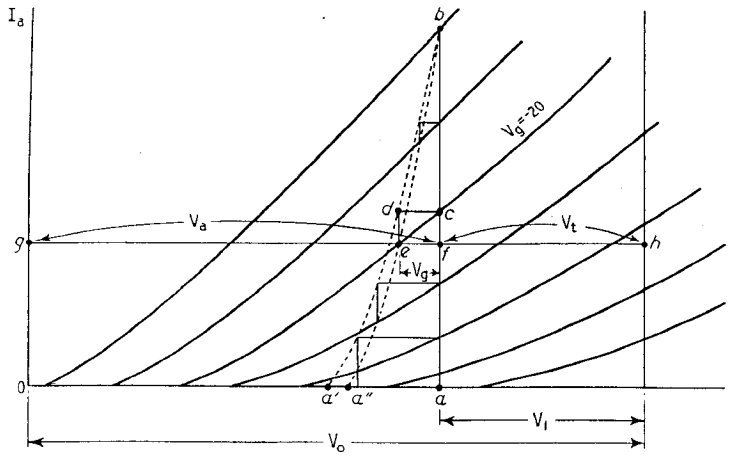

Fig. 4. Construction for drawing an accurate regulation curve, *a"b*, taking account of V_g being at the expense of V_a. *a'b* is the approximate curve of the type shown in Figs. 2 and 3.

Fig. 2 or Fig. 3. The output power is a maximum when the working point lies on the line $V_t = V_a$, at the highest permissible current.

The foregoing analysis has been based on the assumption that $\mu \gg 1$. This undoubtedly applies to the EC52, with a μ of 50; in fact μ has to be exceptionally small for the error to be significant. If it makes one happier to obtain the more exact result, it can be done quite easily, as shown in Fig. 4. Here *ab* is a vertical line representing the selected V_1. The approximate regulation curve, *a'b*, has been obtained as before, by setting off distances to the left of *ab* to represent V_g. Consider, for example, the curve marked $V_g = -20$, which crosses *ab* at *c*. Then if *cd*, drawn horizontally, represents -20 V on the voltage scale, *d* is a point on *a'b*. Dropping a vertical from *d* to meet the $V_g = -20$ curve gives a point on the accurate regulation curve, which, when completed, is *a"b*. The correctness of the construction can be seen by observing that *eg* represents V_a at the I_a and V_g considered, and $ef = dc = V_g$, so *fg* represents $V_a + V_g$, which is $V_0 - V_1$, and V_1 is thus represented by *fh*, *f* being on *ab*, which was drawn to mark V_1.

For most valves the difference between *a'b* and *a"b* is imperceptible on an ordinary curve sheet.

It should now be clear what sort of a valve one should look for to fulfil the requirements. If the most important need is good regulation, which can be reckoned in terms of low internal resistance, clearly high g_m is the most important feature. But of a number of valves having similar g_m, should preference be given to high μ or low r_a? We have already seen that high μ is convenient for design purposes, in that one can neglect the fact that V_g is obtained at the expense of V_a. And if one wants to be able to control the output voltage to practically zero, a high μ is again an advantage. Looking at Fig. 2, the output voltage when $V_0 = 400$ and $V_1 = 0$ is never higher than 8, even on open circuit; whereas with a low-μ valve of similar g_m (the Osram PX4, see Fig. 5) it is nearly 90 V. On the other hand, high μ means high r_a, which means that the current output at voltages not much below V_0 is very limited. Fig. 2 or 3 shows that with the EC52 the stabilized I_t from a tapping 100 V below V_0 is only about 8 mA, whereas the PX4 yields about 65 mA.

In estimating the current requirements, allowance must be made for any modulation of the mean current drawn. While the peak I_t can be allowed to overstep the p_{amax} and I_{kmax} limits (so long as the mean I_t or working point is within), it should not exceed the limits of stabilization, or unexpected effects may occur in the apparatus being fed.

When neither of these special requirements settles the μ question, the fact that high-g_m triodes are generally more easily obtained with low μ may be relevant. It must be remembered, however, that g_m is not constant, but decreases to zero as I_t is reduced. So if I_t is small relative to the maximum available, the nominally high-g_m valve may actually be inferior. For supplying, say, 5 mA, the EC52 would not only give a V_t much closer to the V_1 setting but would have a higher working g_m than the PX4, which would be under-loaded at that current. Alternatively one could keep clear of the bottom bend by using a shunt across the load.

Among other triodes which might be considered, there is the ECC32 with its two sections in parallel, totalling 10 W dissipation and 50 mA output but a lower g_m and V_{amax} than the EC52, and the ECC35 with $\mu = 68$ but maximum current only 16 mA.

A rather expensive but effective way of increasing the stabilized range of current, while retaining the high-μ advantages and reducing the internal resistance, is to connect valves in parallel. The performance is indicated by multiplying the I_t scale by the number of valves used.

One might ask, why not use a tetrode or pentode, seeing that there is a wider choice of these, and they offer high current, high g_m, and very high μ? The practical difficulty, which will be discussed later, is the need for keeping the screen grid at a constant voltage above the cathode. Such valves can be con-

nected as triodes, however. The clue to their triode μ, if it is not stated, is their μ_{g2-g1}, which is of the same order, and is beginning to be quoted more freely by valve manufacturers. It can be deduced from I_a/V_g curves, if they are shown for more than one V_{g2}, by noting the increment of V_{g2} needed to maintain constant I_a, per volt of V_g increment. The triode-connected Osram KT61 offers a useful combination of high g_m and high μ.

The valve's rated limits p_{max} V_{amax} and I_{kmax} must of course be taken into account. Unfortunately the published figures do not always include all three, and sometimes the voltage limit may seem lower than it need be on purely technical grounds. It is clear from the diagram that if V_0 is never greater than the V_a at which the zero-I_g bias line first meets a limit line (e.g. point C in Fig. 2) there is no need to worry about over-running the valve; the output terminals can be short-circuited at any setting of the V_1 control.

The valve can be made similarly foolproof for any higher value of V_0 by inserting in series with its anode sufficient resistance to drop the excess voltage. Suppose in Fig. 2 that the maximum V_0 is 400. Then the line representing the minimum fully safe resistance is the steepest that can be drawn from 400 on the V_a scale to meet the zero-I_g curve without crossing a limit boundary. In this case it joins point C; without the I_{kmax} limit it would have been D. The slope of the line shows that the resistor should be just over 10 kΩ and its maximum wattage 0.02 × 210 = 4.2.

Unfortunately such a resistor if fixed is in effect an increase in the valve's r_a so it degrades the performance correspondingly. The modified characteristics can easily be drawn by an obvious construction, in Fig. 3, shifting the points on the $V_g = -0.5$ curve downwards sufficiently to represent the voltage drop in the safety resistor. The "level" part of any regulation curve begins at the original point and meets the new curve at the same voltage, so obviously must slope more. It can be seen how seriously the current range is restricted at the lower settings of V_1.

As a compromise, to ensure safety when the widest possible range of adjustment is liable to be made in an experiment, but to retain maximum I_t and constancy of voltage in less severe conditions, the safety resistor can be made variable, from the safety value for maximum V_0, down to zero, and fitted with a scale marked in ohms and also in the value of V_0-V_t at which safety is assured. When the load resistance can be relied upon to be not less than the figure on the rheostat scale corresponding to V_0-V_1 equal to the maximum that will be used, the safety resistance can be turned to zero.

For $V_0max = 400$ in Fig. 2, the scale markings would be:

R(kΩ)	$V_o - V_t$ (= V_a)
0	0–190
0.5	200
1.75	225
3.0	250
4.25	275
5.5	300
6.75	325
8.0	350
9.25	375
10.5	400

A suitable value for the resistor R_{12} is 0.25 MΩ, rated to take maximum V_0 across it. Lower values cause the valve to reach its rated limits sooner, while higher values tend to encroach on the "level" part of the regulation curve. Both these effects are illustrated to some extent by the experimental curve in Fig. 3.

There are at least three possible causes of hum in the output. The most straighforward of these is hum in the input, V_0. Regarding the arrangement as a cathode follower, and assuming $\mu \gg 1$, load resistance high, and grid current nil, it is easy to see that the proportionate unsteadiness in V_t is approximately equal to that in V_1, which in turn is equal to that in V_0. The errors in this approximation, due to load resistance and μ not being infinite, tend to cancel out. Since the main stabilized supply presumably is extremely smooth (e.g., in a unit designed on the lines described in the preceding articles it was 1 mV or less) this cause is not likely to be troublesome in practice.

A relatively enormous amount can be introduced via the heater, if the heater winding is not screened, and especially if it is wound next the H.T. coil. Permissible maximum heater-to-cathode voltage forbids the heater from being tied to a constant-potential point, except for very limited ranges of V_t; and the maximum heater-to-cathode re-

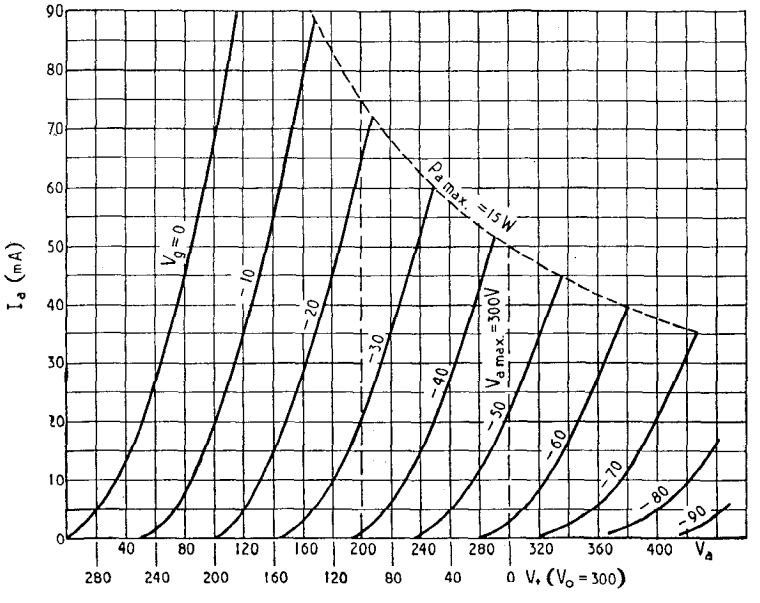

Fig. 5. Characteristic curves of low-μ valve (PX4), for tapping to provide relatively heavy current.

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sistance rating forbids one to leave it floating. So one is obliged to join the heater to cathode. Between the heater winding and any others there should therefore be a screen connected to the common negative point.

The grid circuit, owing to its high resistance, is sensitive to hum, and should be laid out so as to minimize pick-up. What is unavoidable can be reduced to a low level by about 1 or 2 μF connected to negative (C in Fig. 1). This confers the additional benefit of smoothing out contact irregularities as the voltage control is operated.

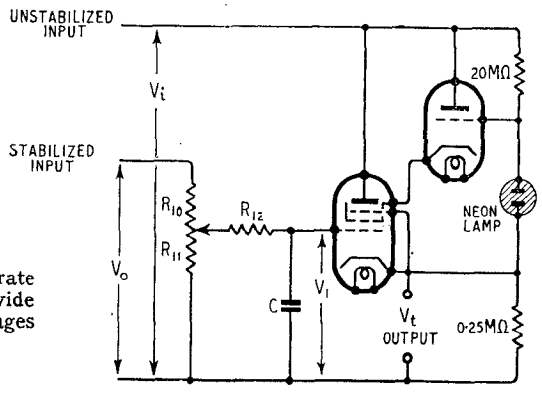


Fig. 6. A more elaborate type of tapping, to provide heavy current at voltages as high as V_o.

The overall hum is generally least at some middle setting of this control, depending on the load resistance. That is because, as already mentioned, the hum voltage increases in proportion to V_t towards the maximum V_t; and it also increases near minimum V_t because (with constant load resistance) the output current tends to be cut off, and with it the low cathode-follower output resistance which "holds down" hum.

In case it occurs to anyone to insert a voltage-calibrated milliammeter in series with the negative end of the voltage-control potentiometer for indicating the voltage of the main stabilized supply, it may be as well to point out that the reading is pulled down appreciably if the tapping valve runs into grid current.

The fact that the available current output falls off to zero as V_t is brought right up to V_0 may be a disadvantage. To get over it, the anode voltage must be supplied from a more positive point. The pentode (and tetrode) property of anode current being almost independent of anode voltage above a fairly low figure is an attractive one in this connection; especially such a valve as the Mazda 12E1, with rated limits at 35 W, 700 V, and 300 mA. The snag is constancy of V_{g2}. It is possible to provide it by means of an auxiliary cathode follower and neon tube, as in Fig. 6. An ordinary "beehive" lamp, without internal resistor, maintains about 160 V at currents of a few microamps, which are small enough not to cause serious trouble at the cathode end of the potential divider; and the resulting V_{g2} fits the 12E1 nicely.

This arrangement is rather tricky to design, however, and is subject to a number of limitations which make it not entirely suitable for general use. It is not easy to find a cathode follower valve rated to stand the anode voltage when V_t is low, nor to arrive at values of the potential-dividing resistors that are satisfactory over wide ranges of V_t and I_t. If low values of V_t are ruled out, one might as well revert to series stabilization, with its much better performance.

Nevertheless it is mentioned, because it might be quite useful in special circumstances.

ELECTRONIC MOISTURE CONTROL

Manual or Fully Automatic Operation

THE customary method of judging the degree of dryness of textiles during manufacture is by feel. Human judgment being far from infallible, electronics has now stepped in and apparatus is available for giving a more exact measure of the moisture content during the drying process.

The Fielden Drimeter can be used with any type of textile drying machine in which the material passes at a pre-determined speed between drying elements.

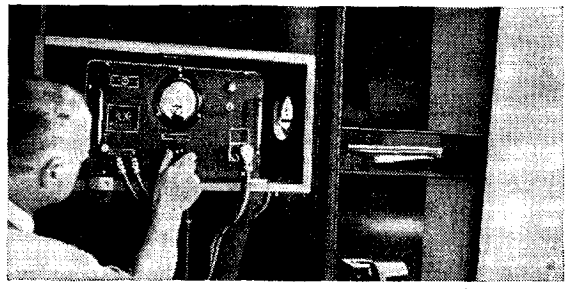
Operation of the Drimeter is based on the fact that the dielectric constant of the material passing between two flat electrodes varies with its moisture content. Thus by constantly monitoring the capacitance of these electrodes variations can easily be converted into changes in current and applied to a visual indicator.

The equipment is first set up by inserting a sample of material, dried to the desired degree, between the electrodes and setting the pointer of the indicating meter to a pre-determined zero. A knob is provided on the unit for this purpose. Alternatively, a moisture calibrating unit can be employed.

When the drying machine is in operation it is then only necessary to regulate its speed so that the needle of the indicator remains steady. The Drimeter can be supplied either with the indicating meter built-in or on a separate unit including the adjusting knob.

A more recent development is the production of a companion unit which gives full automatic control of the drying process. Control is electronic and the operating voltages are derived from the Drimeter and also from a small alternator driven off the main shaft of the machine.

It functions on the difference principle and produces a voltage that is applied to an electric motor which operates the speed control mechanism of the drying machine.



Fielden Drimeter with indicator and control embodied in a single unit.

The equipment is made by Fielden (Electronics), Ltd., Holt Town Works, Manchester, 10.

"Q" METERS

Function and Application

By H. G. M. SPRATT,
B.Sc., M.I.E.E.

AT his desk the radio engineer is, perforce, a purist. He precisely separates, and maintains separated, his inductances, capacitances and resistances. It is the most convenient basis for his calculations and, as frequencies rise, he clings to it until defeated by an invasion of lines, waveguides and resonant cavities.

At the bench, however, such an attitude is impossible. His Cs have some L, his finest R always contains L and C as trace elements, but, most annoying of all, his L always has some R. Furthermore he cannot separate these quantities physically. Yet, in most cases, he must determine their separate values if his design is to go forward.

On the average, of all components, inductors fall farthest short in their standard of purity and so, whenever a high-quality tuned circuit is required, the primary consideration is the goodness of the coil. Now it is not an easy task, and certainly not a speedy one, to measure directly and accurately the inductive and resistive components of any arbitrary coil at any arbitrary frequency with simple radio apparatus. As a result, the Q meter has been evolved, an instrument designed for the express purpose of effecting this by what is known as Q measurement.

Fundamental Considerations

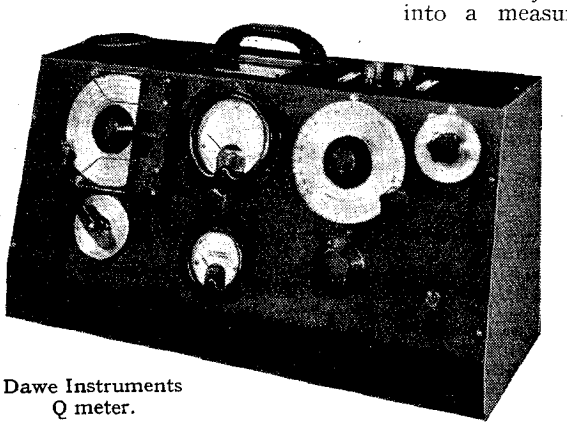
The fundamental definition of the Q-factor of any component is the ratio

$$\frac{\text{Energy stored}}{\text{Energy dissipated}}$$

and this is applicable to all components and conditions. In ultra-high-frequency circuits, where inductance, capacitance and resistance are distributed throughout each component, it is indeed the only definition, but at lower frequencies, where lumped components are involved, it is convenient to convert this ratio to the more practical form,

$$Q = \frac{\text{reactance}}{\text{resistance}}.$$

Furthermore, since, as suggested above, the limiting factor in the majority of tuned circuits is the goodness of the coil, it is usual to ignore the Q of the capacitor and consider that of the inductor alone, namely $\omega L/R$. Now $\omega L/R$ is the ratio of the voltage developed across the coil inductance in the tuned circuit to the voltage injected in series with the circuit and is what used to be termed the circuit magnification. It is essentially this circuit magnification which is measured by the Q meter, though such a term is hardly appropriate when applied outside the realm of coil measurement. Nevertheless, the fundamental nature of the measurement is such that it is applicable not only to coils and inductances, but to any electrical element which has both a reactive and a resistive component. It, therefore, applies to virtually all electrical elements.



Dawe Instruments Q meter.

The Q meter, intended primarily for coil measurements, naturally does not cover infinite ranges of frequency, reactance or resistance. Nevertheless, the ranges usually provided are so wide and the versatility of this instrument so great, that several other important uses have been found for it. It is perhaps obvious, from what has already been said, that if the Q measurement of coils is possible with it, the same should apply to capacitors. What is not so obvious is that the technique can be extended to the determination of the characteristics of transmission lines, the residuals of resistors and the dielectric constant and power factor of insulating materials and the like, the last named being an enormous field by itself.

There is a number of methods of measuring Q but one only has found favour in the majority of Q meters as manufactured and marketed today. Considering the case of a coil measurement, an oscillator injects a known voltage into a measuring circuit. This measuring circuit includes a calibrated low-loss variable capacitor, the resonant circuit being completed by the component under test. A calibrated valve voltmeter is connected across the variable capacitor and the circuit tuned to resonance; i.e., to maximum voltage reading. Then this maximum voltage reading is a measure of the Q of the component.

This method has for a start the great advantage of speed. In the case of a coil measurement, one reading only is needed, and that reading is the Q itself. Other components may demand more than one measurement and one reading but the method is still a quick one. Accuracy is, of course, dependent upon the absolute calibration of the meter but in the rare case where extreme accuracy is essential, the instrument can be used as it stands to measure the Q by another method, a lengthier one in which the resonance curve is plotted and in which the important factors are the accuracy of the capacitor

"Q" Meters—
calibration and the relative accuracy of the meter calibration.

Main Design Details

The modern Q meter is designed to cover a wide frequency range, generally from 50 kc/s up to at least 50 Mc/s, this coverage being, of course, effected by coil switching. In addition provision is often made for connection to an external oscillator, should operation at still lower frequencies be desired. Coupled to the oscillator coil is a second circuit consisting of a thermo-ammeter and a very small non-inductive resistor, this resistor forming part of the measuring circuit as well.

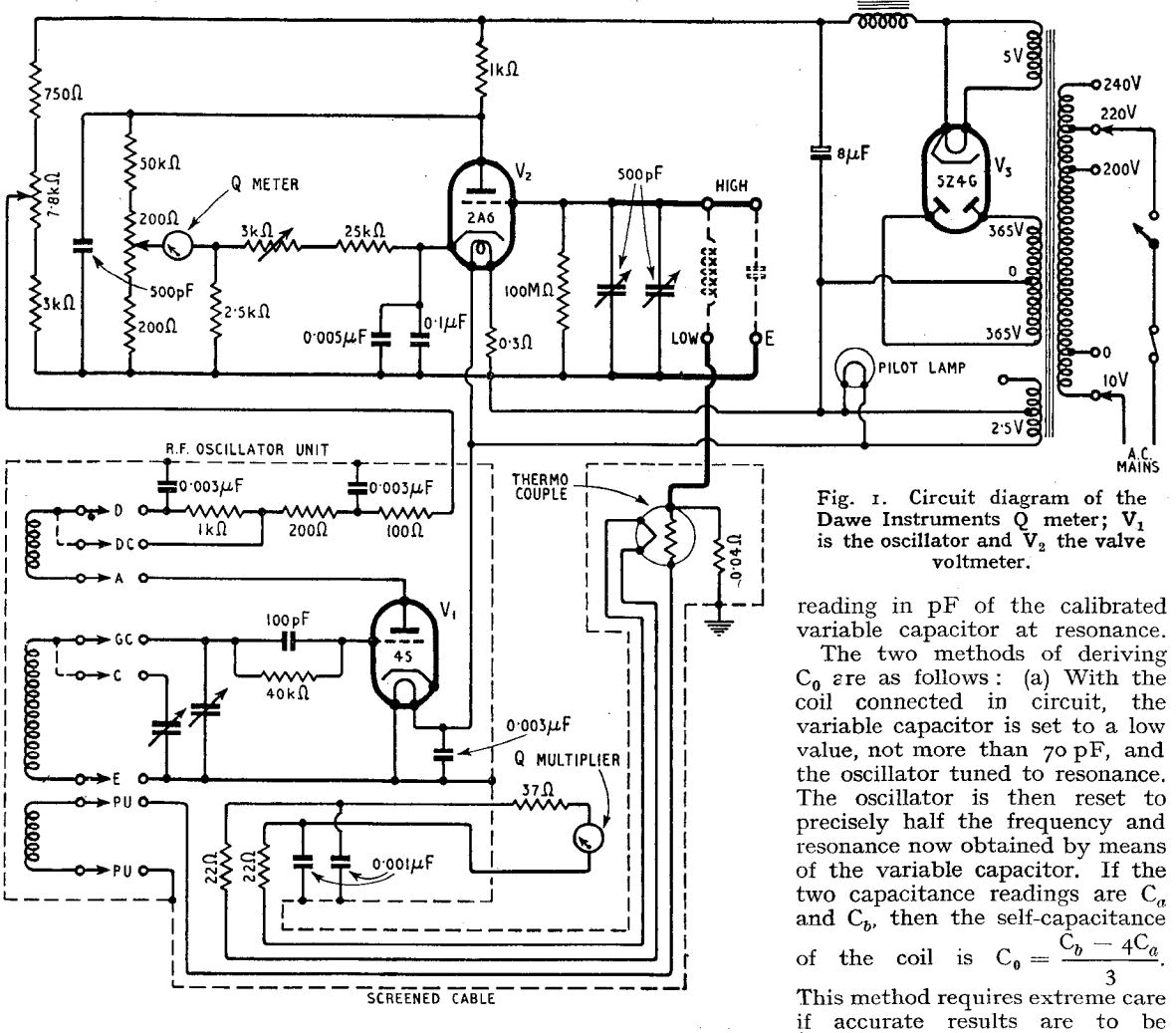


Fig. 1. Circuit diagram of the Dawe Instruments Q meter; V_1 is the oscillator and V_2 the valve voltmeter.

(See Fig. 1). Thus the measuring circuit has injected into it a small but definite voltage across an extremely small resistance of an amount which is negligible, except where high Q values, particularly at the higher frequencies, are involved. A correction for this small resistance in the circuit can easily be made where considered justifiable, as is shown later.

The measuring circuit also includes the calibrated variable capacitor, terminals for the connection of test components in series and parallel and the valve voltmeter. The latter must cover a wide voltage range, have a low input admittance and maintain a fixed calibration over the whole frequency range. The voltmeter circuit used depends upon the individual preference of the manufacturer.

The measurement of a normal coil is carried out by connecting it across the series terminals and adjusting the oscillator frequency and voltage level to the correct values. The variable capacitor is then tuned to resonance at this frequency and the Q value read directly off the meter. This is the effective Q, which is adequate for most purposes, but whose value differs slightly from that of the real Q owing to the fact that the self-capacitance C_0 of the coil has not been taken into account. There are two easy methods of determining C_0 on the Q meter itself and then the true Q can be determined from the equation—true Q = effective Q $(1 + C_0/C_1)$ where C_1 is the reading in pF of the calibrated variable capacitor at resonance.

The two methods of deriving C_0 are as follows: (a) With the coil connected in circuit, the variable capacitor is set to a low value, not more than 70 pF, and the oscillator tuned to resonance. The oscillator is then reset to precisely half the frequency and resonance now obtained by means of the variable capacitor. If the two capacitance readings are C_a and C_b, then the self-capacitance of the coil is $C_0 = \frac{C_b - 4C_a}{3}$. This method requires extreme care if accurate results are to be obtained.

In method (b) readings, with the coil connected, are taken of

resonant frequency, f_c and capacitance C_c with C_c at about 400 pF. The test coil is then removed and resonance obtained with a shielded coil of 1/20–1/30 the inductance of the test coil at a frequency f_d, about 10 times f_c. When resonance has been obtained, the test coil is connected in parallel and resonance again sought. If the tuning capacitance has to be changed, the oscillator frequency must be changed, (an increase in frequency for an increase in capacitance), the test coil removed, the shielded coil re-resonated and the effect on tuning again observed when the test coil is replaced in parallel. This process is continued until no change in tuning capacitance is required when the test coil is included in the circuit. At this frequency, f_d, the test coil is self-resonating and its self-capacitance C_0 is given by—

$$C_0 = \frac{C_c}{(f_d/f_c)^2 - 1}$$ which for most cases $\approx (f_c/f_d)^2 C_c$.

From the above data the true inductance L_t of the coil can be obtained from the formula

$$L_t = \frac{25{,}300}{f^2 C_1 (1 - C_0/C_1)} \quad [\mu H, \text{pF, Mc/s}]$$

This takes account of the self-capacitance of the coil. The effective inductance L_e at the frequency f_1 is given by the simpler formula

$$L_e = \frac{25{,}300}{f^2 C_1} \quad [\mu H, \text{ pF, Mc/s}]$$

Similarly the true series resistance of the coil R is given by

$$R_s = \frac{159{,}000}{f C_1 Q} \cdot \left(\frac{C_1}{C_1 - C_0}\right)^2 \quad [\Omega, \text{pF, Mc/s}]$$

and the effective resistance R at the frequency f by

$$R_e = \frac{159{,}000}{f C_1 Q} \quad [\Omega, \text{pF, Mc/s}]$$

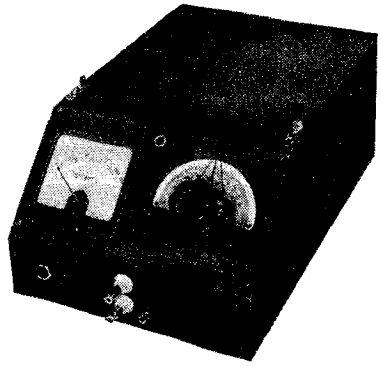
As suggested above, in the case of high Q values at high frequencies the additional accuracy obtained by correcting for the internal resistance of the measuring circuit may be desirable. This is effected as follows: If the value of the internal resistance is R_i, (generally 0.05 Ω or less), the net coil resistance is $R_s - R_i$. Then the absolute Q_a of the coil is

$$Q_a = \frac{6.28 f L_t}{R_s - R_i} \quad [\mu H, \Omega, \text{Mc/s}]$$

All these measurements can be carried out and the values determined in a similar manner in the case of low-inductance coils by introducing a larger coil and taking measurements on it with and without the small coil in series.

Capacitors

Measurements on small capacitors are carried out by introducing a suitable coil to complete the tuned circuit and then taking



Dawe Instruments production Q tester.

readings with and without the test capacitor connected across the internal calibrated capacitor, the setting of the latter being adjusted to resonance as required. If the readings taken are C_1, C_2 and Q_1, Q_2 then the capacitance of the test component is $C_1 - C_2$;

its Q value $= \frac{(C_1 - C_2) Q_1 Q_2}{C_1 (Q_1 - Q_2)}$

and its power factor

$$\approx \frac{100 C_1 (Q_1 - Q_2)}{(C_1 - C_2) Q_1 Q_2}$$

Other formulae will give the values of the effective series and parallel resistances.

For the highest accuracy when dealing with small capacitors of high Q, an external standard variable capacitor can be introduced into the measurement, the internal variable capacitor being left untouched throughout the measurement.

Limitations on measurement of capacitors are set by the high order of Q value associated with the components. Whereas the Q value of coils can be expected to range from 100—500 the corresponding values for capacitors will be 1000–6000 and even higher for high-quality air components. A value of 6000 will be about the highest that can be measured on most commercial Q meters. Most Q measurements on capacitors involve the determination of small differences between two comparatively large quantities and reasonable accuracy can only be obtained by taking careful measurements.

Another limitation is size, but capacitors above 400 pF up to about 0.1 μF can be measured by connecting them, in series with a small coil, across the coil terminals. Measurements are then made with and without the capacitor short circuited and appropriate formulae enable the Q, R and power factor figures to be determined.

Resistors

Two ranges of resistance values can be measured without difficulty on the Q meter, namely, the ranges corresponding to the normal effective series and parallel resistances of coils within the Q range of the instrument. Thus resistors of about 1–30 Ω and 0.1–2.0 MΩ are dealt with by connecting them in series with a suitable coil or in parallel with the internal capacitor of the Q-meter instrument. Measurements are taken with the resistor in and out of circuit and the resistive and reactive components derived from the results. Thus, suppose we are concerned with a resistor of about 20 Ω. A suitable coil is connected to the instrument and resonance obtained at the desired frequency f, giving readings of C_1 and Q_1. The resistor is then connected in series with the coil and readings again taken, giving values C_2 and Q_2.

Then the effective series resistance of the resistor is

$$159{,}000 \frac{Q_1 C_1/C_2 - Q_2}{f C_1 Q_1 Q_2} \quad [\text{pF, Mc/s}]$$

If C_2 is less than C_1 the effective reactance of the resistor is inductive, the inductance being equal to

$$25{,}300 \frac{C_1 - C_2}{f^2 C_1 C_2} \quad [\text{pF, Mc/s}]$$

If C_2 is greater than C_1, the reactance is capacitive, the series capacitance being $\frac{C_1 C_2}{C_2 - C_1}$.

The Q factor of the resistor can be determined but its value is seldom of interest.

A figure of much greater import-

"Q" Meters—

ance is the time constant, given by L/R or RC measured in henrys, ohms and farads, and obtainable direct from the above data. The higher range of resistance values is dealt with in a similar fashion only here measurements are made with the resistor first out of circuit and then connected in parallel with the capacitor.

The measurement of the dynamic resistance of a parallel-tuned circuit is merely a variant of the measurement of a high resistor. With a suitable coil connected to the Q meter, resonance is obtained at the desired frequency f, giving values C_1 and Q_1. The tuned circuit is then connected across the capacitor terminals and itself tuned to give resonance again. If the altered value of Q is Q_2, the dynamic resistance value is:

$$\frac{0.159Q_1Q_2}{fC_1(Q_1 - Q_2)} \quad [\text{pF, Mc/s, M}\Omega]$$

Insulating and Dielectric Materials

The essential qualities of these materials are revealed by the dielectric constant and the power factor, these parameters usually being determined by arranging for the material under test to form the dielectric of a capacitor. There are standard recognized procedures recommended for effecting this and it is not proposed to discuss them in detail. One method is to use mercury electrodes, while in another a sheet of the material is thinly coated with petroleum jelly and tinfoil of appreciably less area pressed down on both sides. In the case of a liquid a suitable vessel has to be constructed. Whatever method is followed, edge effects must be avoided by a generous margin of uncovered material around the edge of the sample. Suitable leads are fitted to the electrodes and taken to the capacitor terminals of the Q meter. The sample is then measured as a capacitor at the desired frequency. If the capacitance of the sample determined in the way described above is C pF the thickness d cm, the covered area A cm², then the dielectric constant $\epsilon = \frac{11.3Cd}{A}$.

The Q and, hence, the power factor are determined by taking measurements as described above for small capacitors. Then

$$Q = \frac{(C_1 - C_2)\,Q_1\,Q_2}{C_1(Q_1 - Q_2)}$$

and the power factor $\approx 100/Q$.

Transmission Lines

There are two methods by which transmission-line constants can be determined with the Q Meter. In the first, the frequency in c/s is fixed and a line length l metres, less than $\lambda/8$, is chosen. With the far end open circuited, the capacitance C_0 in farads and resistance R_0 in ohms are measured following the usual procedure for small capacitors. The resistance value is then transformed into the equivalent conductance G_0 mhos. With the far end short-circuited, the line is now measured as a coil and its inductance L_s henrys and series resistance R_s ohms measured. Then the characteristic impedance

$$Z_0 = \sqrt{\frac{R_s + j2\pi fL_s}{G_0 + j2\pi fC_0}} \quad [\Omega]$$

or for low values of R_s and G_0

$$Z_0 = \sqrt{L_s/C_0}$$

The attenuation A is given by

$$\frac{1}{8.69 \times 2l} \times \frac{G_0Z_0 + R_s/Z_0}{1 + (2\pi f)^2L_sC_0}$$ db per metre

and the velocity of propagation by

$$\frac{2\pi fCl}{\tan^{-1}\omega\sqrt{L_sC_0}}$$ metres/sec.

The second method avoids the measurement of very small or large reactances and enables any length of line above $\lambda/4$ to be used. With a line of length exactly $\lambda/8$ or an odd multiple of it, the numerical value of the reactance is equal to the characteristic impedance, being positive or negative depending upon the multiple and whether the far end is open or short circuited. The line is connected to the Q meter as a capacitor and the frequency adjusted until the capacitance on short and open circuit are equal and opposite in sign.

Then $Z_0 = \frac{1}{\omega\sqrt{C_sC_0}}$ [Ω, c/s, F]

At even multiples of $\lambda/8$ the input impedance becomes a very high or very low pure resistance, depending again upon the multiple and whether the far end is open or short circuited.

By adjustment of the Q-meter frequency a high-resistance condition is selected and this high resistance R_L measured.

The attenuation is then given by

$$A = \frac{Z_0}{8.69\,R_Ll}$$ db/metre

If in one of these measurements the frequency is f and the number of $\frac{1}{8}$ wavelengths n, then the velocity of propagation is

$$v = \frac{8lf}{n}$$ metres/sec.

Conclusion

The measurements which have been described are now recognized as well within the capabilities of the Q meter and are treated as standard practice. No doubt additional uses will be found from time to time. The outstanding advantages of the instrument throughout are its wide frequency ranges, direct reading features and ease and speed of operation. The last two features have led to the appearance of a modified form of Q meter, generally known as the Q Comparator. It is intended for repetitive and comparison testing and has in consequence been simplified by the removal of the thermoammeter, although the constancy of the injected voltages is still assured.

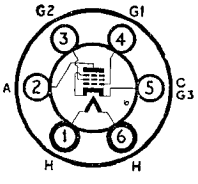
OUR COVER

A 27-in circular mirror and an 18-in diameter plastic correcting plate is incorporated in the television projector illustrated on the front cover. This equipment, which has been developed by Cinema-Television Ltd. for use in cinemas, operates on 405 lines with an anode voltage of 50,000. Experimental equipment has been in operation in a cinema in Bromley, Kent, for some time and it is hoped to give a description of the equipment and the proposed method of linking London cinemas in a future issue of *Wireless World*.

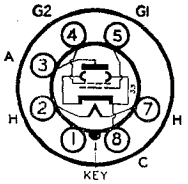
For a resounding Christmas BRIMARIZE

TYPE 89 is a low consumption output pentode used mainly in car radio receivers. It may be replaced most conveniently by type 41, or with change of socket, by type 6K6G. Type 6V6GT may also be employed together with change of socket and bias resistor.

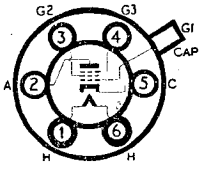
PUNCH HOLES HERE



Type 41



Types 6K6G, 6V6GT



Type 89

CHARACTERISTICS

	TYPE 89	TYPES 41, 6K6G	TYPE 6V6GT
Heater Voltage	6.3	6.3	6.3 volts
Heater Current	0.4	0.4	0.45 amp.
Anode Voltage	250	250	250 volts
Anode Current	32	32	32 mA
Grid Bias	−25	−18	−15 volts
Cathode Resistor	680	470	390 ohms
Optimum Load	7000	7500	7500 ohms
Power Output	3.4	3.4	3.3 watts

CHANGE VALVE		CHANGE SOCKET		CHANGE CONNECTIONS		OTHER WORK NECESSARY	PERFORMANCE CHANGE
FROM	TO	FROM	TO	FROM OLD SOCKET	TO NEW SOCKET		
Type 89	Type 41	U.X. 6 pin No Change		Pin 1 ,, 2 ,, 3 ,, 4 ,, 5 ,, 6 Top Cap	Pin 1 ,, 2 ,, 3 Disconnect Pin 5 ,, 6 ,, 4	Change bias resistor if necessary. The correct value for type 41 or 6K6G is 470 ohms 1 watt	NEGLIGIBLE
89	6K6G	U.X. 6 Pin Int. Octal.		Pin 1 ,, 2 ,, 3 ,, 4 ,, 5 ,, 6 Top Cap	Pin 2 ,, 3 ,, 4 Disconnect Pin 8 ,, 7 ,, 5		
89	6V6GT	U.X. 6 Pin Int. Octal.		As for Type 6K6GT		Change bias Resistor to 390 ohms 1 watt See NOTE.	HIGHER SENSITIVITY

NOTE.—In 12-volt receivers where the heater of the 89 is connected in series with one of the other valves a balancing resistor may be required in the heater circuit.

BRIMAR says BEST WISHES AND BETTER LISTENING

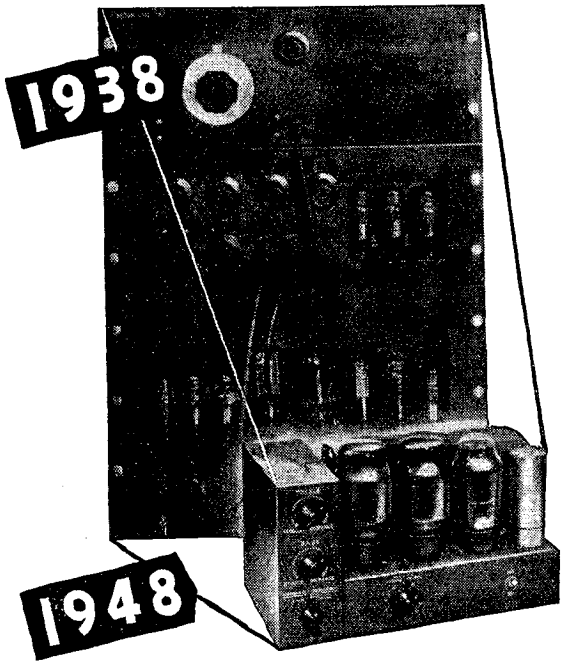
BRIMAR
RADIO VALVES

STANDARD TELEPHONES AND CABLES LIMITED, FOOTSCRAY, SIDCUP, KENT.

89

INSTRUCTIONS: Punch holes where indicated and cut away this portion. Cut out and file them in the order in which they appear. This column will then give you a quick reference index.

22



Evidence of PROGRESS

The illustration above shows an ACOUSTICAL product of ten years ago—an amplifier designed for high quality reproduction of records and radio programmes.
Using push-pull triodes throughout—RC coupled throughout—independent treble, middle and bass controls etc., it was considered about the best that could then be obtained. Indeed the circuit is often specified today for high quality reproduction.
A comparison of the performance with that of the QA12/P reveals the extent of recent developments.

	Pre-War	QA12/P	Improvement achieved
Output deviation within 20-20,000 c.p.s. range ...	3 db	0.3 db	7 times better (% power change).
Frequency range within ± 1 db ...	30–15,000 c.p.s.	15–30,000 c.p.s.	Increase of two octaves.
Total distortion at 10 watts (Both models rated 10–12 watts).	2%	0.1%	20 times less distortion.
Sensitivity (r.m.s. for full output) ...	0.2 v	0.0015 v	120 times more gain with no background increase.
Background noise (equivalent r.m.s. at input)	120 microvolts	1 microvolt	
Background for equal (low) gain	—65 db	—80 db	15 db lower background.
Load impedance Internal Impedance	2	12	Better damping.
Treble and bass controls	variable extent of boosts and cuts.	variable slope of boosts and cuts.	Wider range of control and slopes of controls more accurately designed for small room listening conditions.
PRICE ...	**£60**	**£30**	50% less cost.

ACOUSTICAL

Acoustical Manufacturing Co., Ltd.,
HUNTINGDON. *Tele.: Huntingdon* 361.

A poor life this
if full of care,
You end with voltage
through your hair,

No time to sing
and dance and play,
Because your volts
aren't under way.

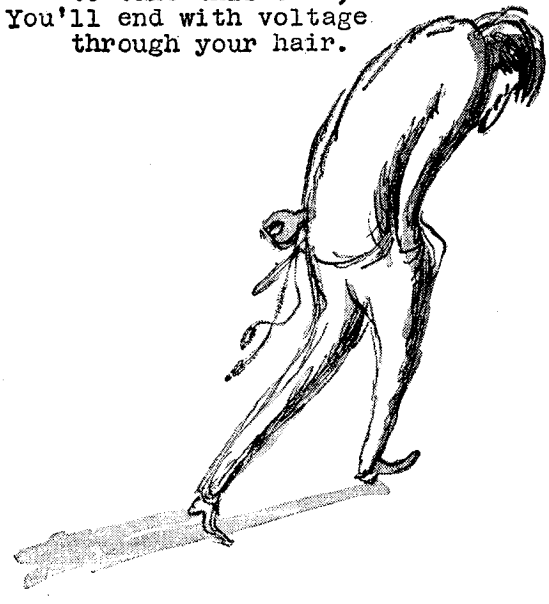
No time to step out
just because,
Your step-up system's
full of flaws.

No time because
tests have revealed,
That your Transformers
are not sealed.

'Gainst moisture - cold -
vibration - dust -
Heat - humidity and rust,
Fumes and fungus, sudden shocks,
Altitude and hearty knocks.

No time to seal
hermetically,
As Mercury
emphatically.

If you've no time
to take this care,
You'll end with voltage
through your hair.



PARMEKO of LEICESTER

Makers of Transformers for the Electronic and Electrical Industries

DISTORTION: DOES IT MATTER?

Further Discussion by the I.E.E. Radio Section

AT a meeting of the Radio Section of The Institution of Electrical Engineers on Tuesday, 9th November, 1948, P P. Eckersley re-opened a discussion on "To What Extent Does Distortion Really Matter in the Transmission of Speech and Music?"

He began by saying that the overall impression left by the first discussion[1] on the subject was that none of us knew a great deal about the subject, but many found it as engrossing as ever. Two questions still remained to be answered, namely, was it worth while to try to find out more and, if so, what line of attack against obscurities would be the best?

Although the final judgment of a transducer must be subjective, surely much could be learned by objective tests. For instance, the fact revealed, as we were told, by measurement, that the loudspeaker generated harmonics, should stimulate someone to produce an instrument that did not. Then the ear would judge whether the improvement in eliminating harmonics and combination tones were substantial. Further experiments with audiences listening to live performances, the sounds of which were modified artificially, ought to tell us a great deal more about what to aim for. Precise information could thus be obtained about the preferences of the ear.

Artificialities

This led to observations concerning a misunderstanding that was revealed during the previous discussion regarding certain suggestions made in the opener's previous remarks, namely, that in the presence of inevitable artificialities due to the circumstances of reproduction of broadcast programmes and gramophone records, other artificialities might, with advantage, be introduced. The object of these suggestions was that the impact of the reproduction upon the senses might be the more certain to "evoke emotion" in the hearer than if an exact copy of the original were reproduced. Some speakers seemed to imagine that he proposed a wholesale cutting away of parts of the spectrum. There was, in fact, no proposal, explicit or implicit, to perform any major operation upon the spectrum, but rather, as in beautifying by plastic surgery, to reduce exaggerated features and to encourage those that were weak. By such methods, the reproduction should gain in beauty, even though the means to that end were artificial.

[1] Reported in *Wireless World*, March, 1948.

Judges of Quality

Turning to detail, the dispute about the competence of musicians to judge loudspeakers was not resuscitated in the introduction, but it was raised apparently from the dead, during the discussion. It was revealed that B.B.C. engineers had discovered that certain of their musical colleagues could not form useful judgments on the qualities of loudspeakers. This was a limited discovery. Pursued a little further, it would be found that some musicians had sensibilities which transcended those of some technicians. Continued research would reveal that the co-operation of each person, according to competence rather than trade or calling, would be of greater benefit than the dismissal of one class of persons by ill-considered generalities.

This second introduction, bridging the two discussions, must once more stress the importance of providing better transmission facilities. As it was, the best of loudspeakers had no value since the conditions of radio transmission and often the background noise on gramophone records, made it impossible to use the upper parts of the audio spectrum. Thus, while there was no demand for a good loudspeaker because the lower and middle register sufficed to give pleasure to most ears, there would, in the face of the poor transmission facility, be not much use for it even if it existed.

The contention remained that, if transmission facilities were improved, an insistent demand would be created for a better reproducer. For nearly 30 years we had used the same type of radio transmitter and for 20 years the same type of receiver had cut off more and more of the spectrum broadcast at greater and greater levels. A solution of the problem of programme distribution, be it by frequency-modulated transmission or by the use of the much simpler wire networks to link microphone and transmitter, would put us on the way to find out which distortions did and which did not matter. We might also discover, in terms of a widespread high-fidelity service, how to shape an artificial spectrum for the greater benefit of the art of sound reproduction.

Heresy

The discussion which followed was by no means restricted to the technical and engineering aspects of transmission and reception. Valuable contributions came from representatives of the programmes department of the B.B.C., who put forward what to high-fidelity purists must have seemed paradoxical, not to say heretical views. In the broadcasting of eye-witness accounts the presence of considerable distortion, it was contended, would not only be tolerated by the listeners but would convey an atmosphere of actuality and excitement which could not be put over if the transmission had the impeccable quality of a studio broadcast. Even when distortion was so bad as to threaten intelligibility, there was still justification for re-broadcasting, for example, Mr. Churchill's speeches from the other side of the Atlantic.

In the broadcasting of symphonic music the best place for the microphone was not, according to one

Distortion: Does It Matter?—

speaker, just above the conductor's head, or, indeed, any position which faithfully reproduced the sound in the immediate vicinity of the instruments. The experienced concert-goer did not like his oboe "neat," but always chose, if he could, the 10th or 20th row back, where the higher-order harmonics were to some extent absorbed. Too much "top" was often associated with what musicians would dismiss as a bad hall. Often it was also a symptom of faulty tone production, which would incur the conductor's displeasure; yet engineers were always trying to preserve what the musician wished to get rid of.

Atmosphere

Support for this view was given by an authoritative statement that broadcasts of the Scottish Orchestra, which met with wide approval among the musically informed, were restricted to an upper frequency of little more than 6,000 c/s; but the acoustics of the studio were exceptional. This quality, which might be likened to the background scenery and lighting of a stage presentation was largely fortuitous; we could avoid the grosser errors in studio design and reduce the bad effects of existing halls by placing the microphone closer to the performers, but much remained to be learned before the creation of naturalness, perspective and "atmosphere" could be described as a known art.

One speaker thought that the comparatively simple task of reproducing the voice of a solo artiste with naturalness had not yet been solved, and suggested that the "invention" of the crooner was an engineer's subterfuge to circumvent this particular problem. Musicians often tried to persuade those responsible for "Balance and Control" to place the microphone farther away, "because it sounds better," but they did not always appreciate that an estimate of the optimum distance made by direct listening would not hold for the microphone, which was a monaural device and would make the reverberation components of the sound seem more pronounced. It was for this reason that the engineers insisted on bringing the microphone closer to the performer.

Few listeners took much trouble to improve the acoustic background of their rooms. It was true that the scope for such treatment was limited, and one speaker revived the suggestion that high-quality headphones might solve the problem when conditions proved intractable.

It was agreed that comparisons of quality, using as a reference standard the sound that one imagined would come from the mouth of the loudspeaker if it were, in fact, an aperture in the wall separating the living room from an adjacent concert hall—the "Pyramus and Thisbe" theory, as the opener put it—could be of value in judging the performance of equipment; but the opinion of those who had had actual experience of listening to "live" performances under these somewhat unusual conditions was that the quality was far from satisfying and not much to be desired.

The æsthetics of listening covered such a wide field, and tastes were so varied that in the opinion of some speakers the B.B.C.'s function should not extend beyond the transmission of a "facsimile" of the original. It should then be left to the listener to modify this by tone and volume controls "according to his perversity." The difficulties of sustaining a wide audio-frequency spectrum on programmes of varied origin was recognized and a plea was made for adequate top cut at the source when intermodulation distortion, which would be at once revealed by modern high-grade loudspeakers, could not be avoided. One speaker thought that binaural transmission would be a more welcome development than efforts to extend the higher frequency response.

Physiology of Hearing

All agreed that studies of listeners' preferences should be extended, but that the results should be analysed with due caution to avoid drawing false conclusions. Much remained to be learned about the physiology of hearing and the importance or otherwise of phase distortion. The difficulty was to measure the true phase relationships of the sound at the observer's ear, and experiments which were based on observations of the input waveform to the loudspeaker were of little value, without detailed knowledge of the transient response of the diaphragm and its effect on the acoustic output. Clear thinking was necessary before making generalizations, and comparisons of aural quality involving changes in the make-up of complex waveforms from similar spectral components were invalidated if there were redistribution of energy with time. An interesting case was cited of a series of pulses of random sign and amplitude, equally spaced in time, which on analysis showed a continuous spectrum like that of random noise. The aural effect, however, bore no resemblance to the characteristic hiss of random fluctuations.

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