APPENDIX

In Fig. 2, with voltage control as shown in (*b*), let V_3 have mutual conductance S and amplification factor μ. Let the overall amplification of V_4 circuit be n times, i.e.

$$\left|\frac{V_g}{E_g}\right| = n$$

Then the stabilisation ratio of the regulator is defined as :

$$a = \frac{\Delta E_0}{\Delta E_i}$$

and the internal resistance as :

$$R_i = -\frac{\Delta E_o}{\Delta i}$$

where the Δ's represent corresponding small changes in the variables.

From elementary valve circuit theory we can see that

$$\Delta i = S\Delta V_g + \frac{S}{\mu}(\Delta E_i - \Delta E_o) \quad \ldots \quad \ldots (1)$$

Now let k be the reduction factor of the potentiometer formed by R_5 and R_6

Then $k = \dfrac{R_5}{R_5 + R_6}$

and $\Delta V_g = -nk\Delta E_0$

whence

$$\Delta i = \frac{S}{\mu}\Delta E_i - S\Delta E_0\left(nk + \frac{1}{\mu}\right) \quad \ldots \quad \ldots (2)$$

If the load resistance is R

$$\Delta i = \frac{\Delta E_0}{R} \quad \ldots \quad \ldots (3)$$

$$\text{Whence } a = \frac{\Delta E_0}{\Delta E_i} = \frac{1}{\frac{\mu}{SR} + \mu nk + 1} \quad \ldots \quad \ldots (4)$$

Similarly, if the effective resistance of the power supply is R_r, we can see that

$$\Delta E_i = -R_r\Delta i \quad \ldots \quad \ldots (5)$$

and from (5) and (2) we can then derive

$$R_i = -\frac{\Delta E_0}{\Delta i} = \frac{\frac{\mu}{S} + R_r}{\mu nk + 1} \quad \ldots (6)$$

This shows that, as a rule, the power supply resistance has not much effect on the performance of a regulator, as far as its regulating properties go. It is, however, of great importance when a wide range of voltage control is desired, because the extra variations of E_i caused by the power supply resistance with varying load, all have to be dissipated in V_3. Unless the current is low, this is a serious limiting factor in wide range designs.

Voltage Compensation

In Fig. 5, let R_{10} be zero. As the resistance seen across the terminals of the regulator is very low, when we calculate the ratio $\frac{AC}{DC}$, R_5 and R_6 are effectively in parallel. Calling this factor q we get :—

$$q = \frac{\frac{R_5 R_6}{R_5+R_6}}{R_8 + \frac{R_5 R_6}{R_5+R_6}} = \frac{kR_6}{R_8 + kR_6}$$

We can write the stabilisation ratio thus :

$$a = \frac{\Delta E_g}{k\Delta Ei} \quad \ldots \quad \ldots (8)$$

Now if compensation is to be perfect, E_0 is zero. There must therefore be a voltage change at point A equal and opposite to that implied by (8). If we obtain this change via R_8 from the changes in E_i, this voltage is obviously $q\Delta E_i$. Equating we get

$$q = \frac{k}{\frac{\mu}{SR} + \mu nk + 1} \quad \ldots (9)$$

from which we can at once evaluate R_8. Remembering that

$$q = \frac{kR_6}{R_8 + kR_6},$$

$$R_8 = R_6\left(\frac{\mu}{SR} + \mu nk + 1 - k\right)$$

Current Compensation

If Fig. 5 assume that R_8 is sufficiently high that it may be ignored when connected in parallel with R_5 and R_6. Let the potentiometer factor $\frac{AC}{FC}$ be t. Then

$$t = \frac{R_6}{R_5 + R_6}$$

As with (8) we may write

$$R_i = -\frac{\Delta E_g}{k\Delta i} \quad \ldots \quad \ldots (10)$$

The grid voltage change implied by this must be correspondingly balanced at point A.

$$\text{Now } \Delta E_g = q\Delta E_i - tR_{10}\Delta i \quad \ldots \quad \ldots (11)$$

Whence from (5)

$$\Delta E_g = -(qR_r + tR_{10})\Delta i \quad (12)$$

$$\text{Therefore } R_{10} = \frac{kR_i - qR_r}{t} \quad \ldots (13)$$

or expressed otherwise,

$$R_{10} = \frac{k}{t}\left(\frac{\frac{\mu}{S} + R_r}{\mu nk + 1}\right) - \frac{qR_r}{t} \quad \ldots (14)$$

If voltage compensation is not used at the same time, then R_8 is infinitely large, and

$$R_{10} = \frac{kR_i}{t} = \frac{k}{t}\left(\frac{\frac{\mu}{S} + R_r}{\mu nk + 1}\right)$$

These compensating resistance values are calculated for one set of controlling values only. Therefore any circuit or voltage output changes would require different values. The residual stabilisation ratio and internal resistance may be given thus :

$$a_{(c)} = \frac{1}{\frac{\mu}{SR} + \mu nk + 1} - \frac{q}{k} \quad \ldots (15)$$

$$\text{and } R_{(c)} = \frac{\frac{\mu}{S} + R_r}{\mu nk + 1} - \frac{qR_r + tR_{10}}{k} \quad \ldots \quad \ldots (16)$$

These resultants may obviously be positive or negative, corresponding to under- or over-compensation.

The method of computing the above results is based on that given by Lindenhovius and Rinia in the article mentioned in the last issue. The method is open to criticism when thus extended, on several grounds, and calculated compensation values should always be used as a guide only. The results are quite good approximations, and are much more convenient in practice than some others which have been published.