19.8 Full-wave mercury-arc rectifier

A glass bulb B, shaped as in fig. 19.17, has a mercury pool C and two electrodes A_1 and A_2, made of graphite in small rectifiers and iron in large rectifiers. The bulb is thoroughly evacuated before being sealed. These electrodes are connected to the two ends of the secondary winding of transformer T and a mid-point tapping M is connected through an inductor L to one side of the load, the other side of which is connected to pool C.

The essential features of one method of starting the arc between

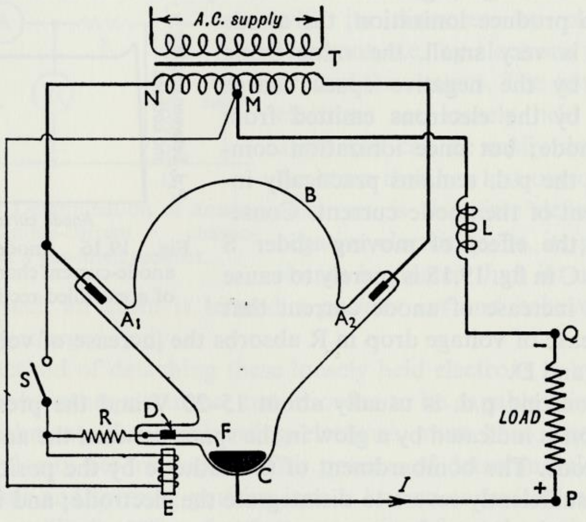

Fig. 19.17 Full-wave mercury-arc rectifier.

the anodes A_1A_2 and the cathode C is shown in fig. 19.17. A flexible metal electrode F carries an iron armature D, and an electromagnet E is situated directly under D. When switch S is closed, D is attracted downwards each time the flux in E grows from zero to a maximum. Consequently, strip F vibrates at twice the supply frequency, and the tip of F makes and breaks contact with the mercury pool C, the current being limited by resistor R to a relatively small value. Each time the circuit is broken, the arc between F and C vaporizes some of the mercury and also forms an incandescent spot on the surface of C, sufficiently to emit electrons. The latter are attracted towards the main electrode that happens to be positive with respect to cathode C and thus produce ionization. The positive ions produced by this ionization bombard the surface of the mercury sufficiently to maintain the incandescent spot and enable the supply of electrons to be continued from the cathode. Switch S is then opened. If the load current is less than a certain critical value, the ionization is insufficient to maintain the incandescent spot; consequently, the arc is extinguished.

If inductor L were not in circuit, the current through the load would vary between zero and a maximum every half-cycle, as shown in fig. 19.18. With L in circuit, the effect of the e.m.f. induced in L is to delay the decrease of the current at one anode until the potential

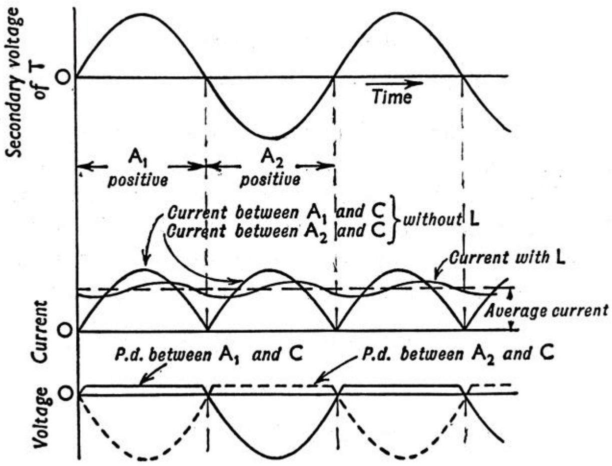

Fig. 19.18 Waveforms of voltages and currents for a full-wave mercury-arc rectifier.

of the other anode is sufficiently high to take over the arc from the first anode, thereby reducing the fluctuation of the current, as indicated in fig. 19.18.

The function of the large glass dome B is to provide the cooling surface necessary to prevent excessive temperature rise of the rectifier. In practice, the arms containing the anodes A_1 and A_2 are made with an elbow to reduce the risk of an arc directly between these electrodes.

The p.d. across the arc remains practically constant at about 20 V over a wide variation of current, as represented by the positive portions of the bottom curves in fig. 19.18 (see also section 19.7 and fig. 19.16); hence:

if $V =$ output voltage, namely the p.d. between Q and C,

$$\text{p.d. between Q and the conducting anode} \simeq V + 20.$$

But this voltage is the average value of the e.m.f. induced in one-half of the secondary winding of T, the impedance drop in the latter being assumed negligible,

i.e.
$$V + 20 \simeq \left(\frac{\text{r.m.s. value of e.m.f. induced in MN}}{1{\cdot}11}\right)$$

so that
$$V \simeq \left(\frac{\text{r.m.s. value of e.m.f. in MN}}{1{\cdot}11} - 20\right)$$

If
$$\text{output current} = I \text{ amperes,}$$
$$\text{output power} = IV \text{ watts.}$$

With the ripple in the output current reduced to a negligible value, the arc current between A_1 and C remains practically constant during alternate half-cycles, the p.d. between these electrodes being then about 20 V. Similarly, during the other half-cycles the current between A_2 and C remains practically constant. Hence, if the losses in the transformer and the smoothing coil L be neglected,

$$\text{loss in rectifier} = I \times \text{voltage drop in arc}$$
$$\simeq 20I \text{ watts,}$$

and
$$\text{input power to rectifier} \simeq IV + 20I$$

$\therefore$
$$\text{efficiency of rectifier} \simeq \frac{IV}{I(V+20)} \simeq \frac{V}{V+20} \qquad (19.1)$$

Hence the efficiency is practically independent of the load.

If $V = 100$ volts,

$$\text{efficiency} \simeq \frac{100}{100+20} \simeq 0{\cdot}83 \text{ p.u.}$$

but if $V = 1000$ volts,

$$\text{efficiency} \simeq \frac{1000}{1000+20} \simeq 0{\cdot}98 \text{ p.u.}$$

It follows that the greater the output voltage, the higher is the efficiency of the mercury-arc rectifier.