measurements give erroneous information, while breakers or fuses can be blowing although apparently sized correctly for the load power involved.

A further problem is the possibility of as much as 5 to 7% voltage peak clipping of the wave reaching the equipment in question, due to peak current loading as great as 5 to 15 times the value for which the lines are sized, in cases where loads are primarily electronic, i.e., rectifiers with capacitor input filters. The effect of this clipping is to drop the peak voltage available to charge the filter capacitor. Thus at 115 V rms, 5 to 7 volt peak clipping can use up a major portion of the low end of the ± 10 volt safety factor often built into the power supply design. When the capacitor is supplying input voltage to an electronic regulator, a decrease of a few volts in line voltage, not uncommon with brownouts and power saving measures, can then drop the supply out of its regulating band.

It is the purpose of this paper to investigate the high crest-factor loads implied by full-wave rectifiers with capacitor input filters. Theoretical evaluations are carried out as a function of capacitor ripple voltage. Experimental results check with calculated figures for all three types of measurement: peak, rms and average. Use of line chokes to reduce crest factor is indicated, and some idea given of the inductance values involved.

The notion of wave factor WF, a multiplying factor defined separately for peak, rms and average, is introduced as a means of characterizing high crest-factor loads more effectively than by simple use of crest factor itself.

ANALYSIS

Fig. 1 shows a typical full-wave bridge rectifier, and Fig. 2 the output voltage e_o across the load R_L and filter capacitor C in parallel. i_C and i_L are capacitor and load currents, respectively, while i_{IN} is shown as their sum. i_{IN}' is the unrectified ac input current, and if diode drops are ignored, it is equal in magnitude to the rectified i_{IN}.

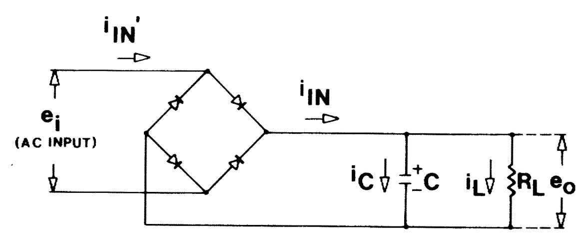

Fig. 1. Full-wave rectifier.

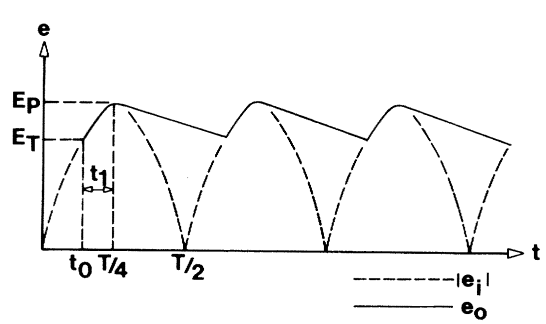

Fig. 2. Rectifier waveforms.

Fig. 2 shows waveforms for the circuit of Fig. 1, specifically input and output waves. The dotted lines denote the absolute or rectified form of input e_i, while the solid wave is the output e_o assuming perfect diodes, namely a dc plus ripple at twice input frequency. Peak output is equal to peak input, indicated as E_p. The lowest value attained by the output over the full ripple cycle is designated E_T. Period of the full wave is T, hence the first peak occurs at $T/4$. The capacitor starts to charge from the point E_T where the input wave equals the decayed, stored output, which occurs at time t_0 as shown. The time between t_0 and $T/4$ during which the capacitor charges, is termed t_1.

Capacitance for a Given Ripple

Since in most designs the most important single design decision is the amount of ripple voltage that can be allowed, the solution to the high crest-factor current problem will be formulated in terms of per cent ripple.

In the equations that follow, the various symbols have the following meanings:

e_o	output voltage;
E_P	peak of output voltage;
E_T	trough of output voltage;
R_L	load resistance;
I_L	load current;
t	time;
T	period of input sinusoidal voltage;
C	filter capacitor;
ρ	per cent ripple.

Load current I_L may be approximated as follows, for low ripple:

$$I_L \cong E_P/R_L \tag{1}$$

During the decay interval, the capacitor voltage e_o follows the exponential

$$e_o = E_P \exp(-t/R_LC) \tag{2}$$

where the zero reference for t in this case is taken at $T/4$, or the peak of the output wave.

Approximating for the exponential from (2)

$$e_o \cong E_P(1 - t/R_LC). \tag{2a}$$

For the purpose of this calculation, assume the ripple sufficiently small that t_1 in Fig. 1 is essentially zero with respect to $T/2$. Then the decay time, from the figure, is approximately $T/2$, and (2a) yields

$$E_T \cong E_P(1 - T/2R_LC). \tag{3}$$

Solving for $E_P - E_T$,

$$E_P - E_T \cong TE_P/2R_LC. \tag{4}$$

Equation 4 yields the peak-to-peak per cent ripple from

$$\rho = 100(E_P - E_T)/E_P \tag{5}$$

as:

$$\rho \cong 50T/R_LC \tag{6}$$