CHAPTER 2: EFFECTS OF ALTERNATING CURRENT IN THE RANGE OF 15 Hz TO 100 Hz

1. General

This chapter is primarily based on the findings related to the effects of currents at frequencies of 50 Hz or 60 Hz which are the most common in electrical installations. The values given are, however, deemed applicable over the frequency range from 15 Hz to 100 Hz, threshold values at the limits of this range being higher than those at 50 Hz and 60 Hz.

This chapter considers principally the risk of ventricular fibrillation which is the main cause of fatal accidents in that range of frequencies.

2. Scope

This chapter describes the effects of alternating current passing through the human body within the frequency range 15 Hz to 100 Hz.

Note. — Unless otherwise specified, the current values defined hereinafter are r.m.s. values.

3. Definitions

3.1 *Threshold of perception*

The minimum value of current which causes any sensation for the person through which it is flowing.

3.2 *Threshold of let-go*

The maximum value of current at which a person holding electrodes can let go of the electrodes.

3.3 *Threshold of ventricular fibrillation*

The minimum value of current which causes ventricular fibrillation.

3.4 *Heart current factor*

The heart current factor relates the electric field strength in the heart for a given current path to the electric field strength in the heart for a current of equal magnitude flowing from left hand to feet.

Note. — In the heart, the current density is proportional to the electric field strength.

3.5 *Vulnerable period*

The vulnerable period covers a comparatively small part of the cardiac cycle during which the heart fibres are in an inhomogeneous state of excitability and ventricular fibrillation occurs if they are excited by an electric current of sufficient magnitude.

Note. — The vulnerable period corresponds to the first part of the "T-wave" in the electrocardiogram which is approximately 10% to 20% of the cardiac cycle (see Figures 6 and 7, page 29).

...s of current

Threshold of perception

The threshold of perception depends on several parameters, such as the area of the body in contact with an electrode (contact area), the conditions of contact (dry, wet, pressure, temperature), and also on physiological characteristics of the individual.

A general value of 0.5 mA, independent of time, is assumed in this report.

4.2 *Threshold of let-go*

The threshold of let-go depends on several parameters, such as the contact area, the shape and size of the electrodes and also on the physiological characteristics of the individual.

A value of about 10 mA is assumed in this report.

4.3 *Threshold of ventricular fibrillation*

The threshold of ventricular fibrillation depends on physiological parameters (anatomy of the body, state of cardiac function etc.) as well as on electrical parameters (duration and pathway of current flow, kind of current etc.).

With a.c. (50 Hz or 60 Hz) there is a considerable decrease of the threshold of fibrillation if the current flow is prolonged beyond one cardiac cycle. This effect results from the increase in inhomogeneity of the excitatory state of the heart due to current-induced extrasystoles.

For shock durations below 0.1 s, fibrillation may occur for current magnitudes above 500 mA, and is likely to occur for current magnitudes in the order of several amperes, only if the shock falls within the vulnerable period. For shocks of such intensities and durations longer than one cardiac cycle reversible cardiac arrest may be caused.

In adapting the results from animal experiments to human beings, a curve was constructed below which fibrillation is unlikely to occur. The high level for short durations of exposure between 10 ms and 100 ms was chosen as a descending line from 500 mA to 400 mA. On the basis of information on electrical accidents the lower level for durations longer than 1 s was chosen as a descending line from 50 mA at 1 s to 40 mA for durations longer than 3 s. Both levels were connected by a smooth curve derived from experimental results.

.4 *Other effects of current*

Ventricular fibrillation is considered to be the main cause of death by electrical shock. There is also some evidence of death due to asphyxia or cardiac arrest.

Patho-physiological effects such as muscular contractions, difficulty in breathing, rise in blood pressure, disturbances of formation and conduction of impulses in the heart including atrial fibrillation and transient cardiac arrest may occur without ventricular fibrillation. Such effects are non-lethal and usually reversible; current marks may occur.

With currents of several ampères, heavy burns resulting in serious injury and even death are likely to occur.

Threshold of perception

The threshold of perception depends on several parameters, such as the contact area, the conditions of contact (dryness, wetness, pressure, temperature), the duration of current flow and on the physiological characteristics of the individual. Unlike a.c., only making and breaking of current is felt and no other sensation is noticed during the current flow at the level of the threshold of perception. Under conditions comparable to those applied in studies with a.c., the threshold of perception was found to be about 2 mA.

4.2 *Threshold of let-go*

Unlike a.c. there is no definable threshold of let-go for d.c. for current magnitudes below approximately 300 mA. Only the making and breaking of current leads to painful and cramp-like contractions of the muscles.

Above approximately 300 mA, let-go may be impossible or only possible after several seconds or minutes of shock duration.

4.3 *Threshold of ventricular fibrillation*

As described for a.c. (see Chapter 2, Sub-clause 4.3), the threshold of ventricular fibrillation induced by d.c. depends on physiological as well as on electrical parameters.

Experiments on animals as well as information derived from electrical accidents show that the threshold of fibrillation for a falling current is about twice as high as for a rising current. For a current path hand to hand ventricular fibrillation is unlikely to occur.

For shock durations longer than the cardiac cycle the threshold of fibrillation for d.c. is several times higher than for a.c. For shock durations shorter than 200 ms the threshold of fibrillation is approximately the same as for a.c., measured in r.m.s. values.

In comparison with the time/current zones for a.c. (see Figure 5, page 27) a curve has been constructed separating the zone where fibrillation becomes likely from the zone where less harmful effects are to be expected (see Figure 8, page 35). This curve applies to a longitudinal rising current. With a longitudinal falling current the curve has to be shifted to a higher current magnitude by a factor of about two.

4.4 *Other effects*

Below approximately 300 mA a sensation of warmth is felt in the extremities during the flow of the current.

Transverse currents up to 300 mA flowing through the human body for several minutes might, increasing with time and current, cause reversible cardiac dysrhytmias, current marks, burns, dizziness and sometimes unconsciousness. Above 300 mA unconsciousness frequently occurs.