forced into or out of conducting states, or when a transient is applied during a particular portion of the power frequency supply cycle (see ***timing of surges*** in Appendix B22).

Shorter rise times are found in many transients, but as they propagate into the wiring or are reflected from discontinuities in the wiring, the rise times become longer (Martzloff and Leedy, 1990 [B46]; Martzloff, 1990 [B48]).

The peak voltage can produce insulation breakdown in connected components and equipment, even if the energy involved in the 100 kHz Ring Wave is small. Surges with higher energy deposition capability will be represented by other waveforms.

7.4.3 High-Energy Surges. Although the data base on energy is limited, there is a need to acknowledge the occurrence of high-energy surges capable of depositing more energy than that associated with the 100 kHz Ring Wave.

Anecdotal field experience shows that surge-protective devices with limited current handling capability installed at the service entrance have a significant failure history, while applications of the same device further inside a building are generally successful. From the energy and source impedance factors discussed under 7.5, it becomes apparent that the 100 kHz Ring Wave will not deposit enough energy in surge-protective devices to produce the observed failures.

Several types of events can be the origin of high-energy surges capable of delivering significantly more damaging energy:

(1) Lightning surges on overhead distribution systems (A)
(2) Lightning surges originating on overhead lines and traveling in cables (B)
(3) Surges generated by fuse operation involving trapped energy in the power system inductance (C)
(4) Surges generated by power-factor correction capacitor switching (D)

(A) Lightning surges on overhead lines have long been represented by a voltage surge of 1.2/50 μs and a current surge of 8/20 μs (IEEE C62.1-1984, [7]), which is described as "impulse" in IEC Document 99 [B97], and as the Combination Wave in the present document. These two waveforms have long been used, are readily generated in many laboratories, and are an appropriate simplification of the environment near the service entrance of a building connected to an overhead distribution system. They also have substantial energy deposition capability, when applied from a generator with inherent capability to supply a voltage as well as a current waveform (IEEE C62.45-1987, [8]), to provide representative stress to connected equipment.

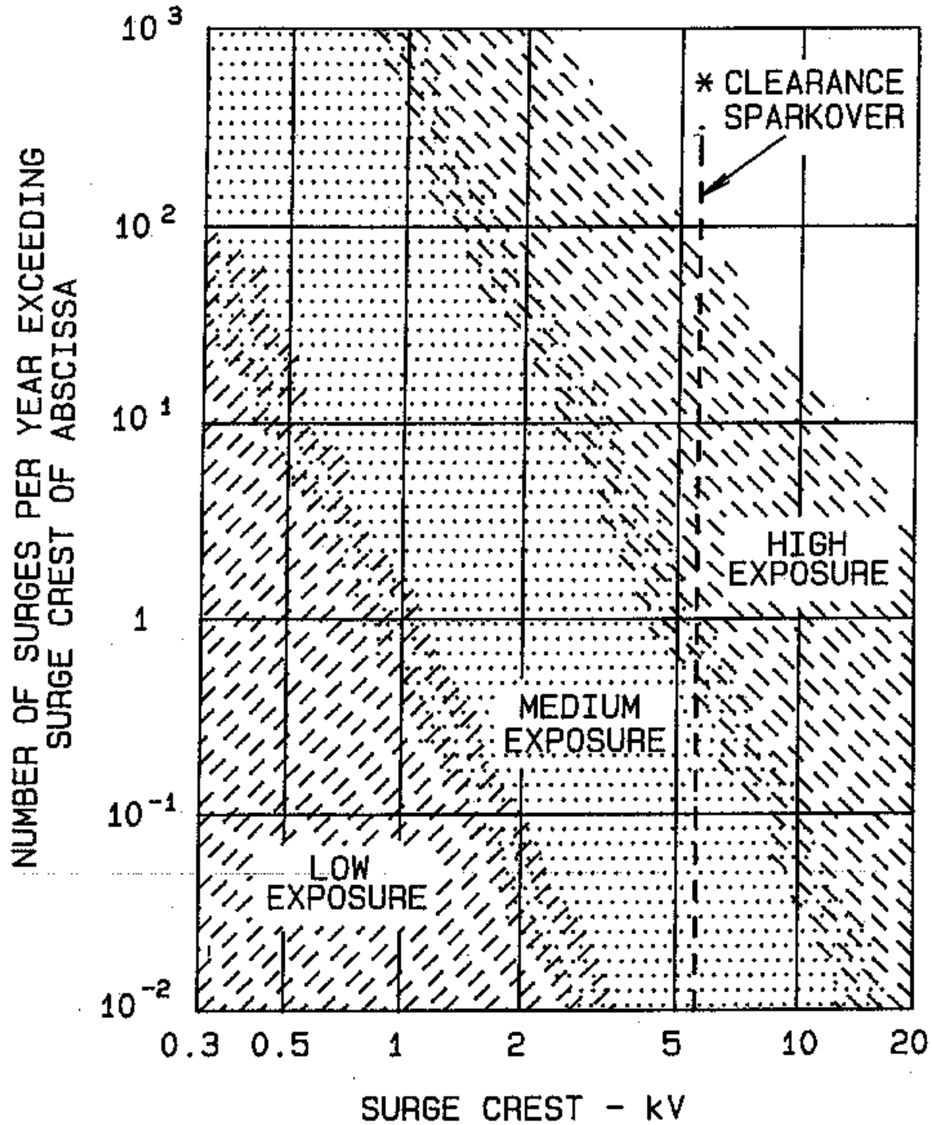
Because of the relatively short front time of 8 μs, such a postulated current surge would not propagate very far into a building. The voltage drop associated with the propagation of a high-amplitude current surge front (thus high di/dt) in the inductive impedance of the wiring would require a driving voltage at the service entrance high enough to cause sparkover of the clearances (Martzloff, 1983 [B43]). This limitation sets the basis of the selection of waveforms associated with the location categories discussed in 7.7 and makes their maximum amplitude less dependent on the system voltage than on the actual clearances.

(B) Lightning surges traveling in underground systems involve longer durations. Lightning surges that have traveled along a long cable have wave fronts with a slope less steep than that of the initiating wave, as a result of the propagation characteristics of the cable. The peak of the initiating surge is likely to reflect the operation of a surge arrester at the interface of the overhead system and the cable.

(C) Surges generated by fuse operation involving long cables are unidirectional surges lasting several hundred microseconds, depending on the inductance of the cable and the transformer feeding the fault being cleared by the fuse (Meissen, 1983 [B25]).

(D) Capacitor switching surges and some other switching surges involve damped oscillations at low frequency (a few hundred hertz to a few kilohertz) lasting for a few milliseconds at most (Boehne and Low, 1969 [B5]; Wiitanen et al., 1971 [B35]; Martzloff, 1986 [B22]). From the point of view of energy exchange, such a long oscillation could be simplified as the envelope of the oscillation. Such an envelope would have a duration in the same order of magnitude as the surges generated by fuse operation.

These last three types of surges, (B), (C), and (D), have maximum amplitudes reflecting the system voltage rather than clearances, in



NOTES: (1) In some locations, sparkover of clearances may limit the overvoltages.

(2) This figure shows one measure of surge severity. Other possible measures include peak current, rise time, and energy transfer.

Fig 6
Rate of Surge Occurrences Versus Voltage Level at Unprotected Locations