

Fuseology—Non-Time-Delay Fuse Operation

Operating Principles of BUSS® Fuses

The principles of operation of the modern, current-limiting BUSS® fuses are covered in the following paragraphs.

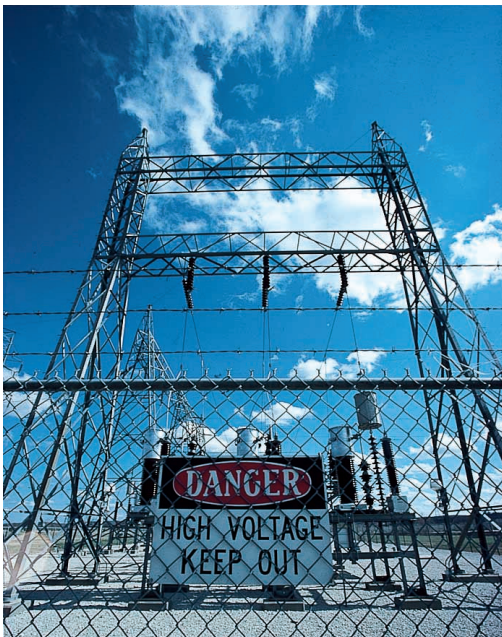
Non-Time-Delay Fuses

The basic component of a fuse is the link. Depending upon the ampere rating of the fuse, the single-element fuse may have one or more links. They are electrically connected to the end blades (or ferrules) (see Figure 1) and enclosed in a tube or cartridge surrounded by an arc quenching filler material. BUSS® LIMITRON® and T-TRON® fuses are both single-element fuses.

Under normal operation, when the fuse is operating at or near its ampere rating, it simply functions as a conductor. However, as illustrated in Figure 2, if an overload current occurs and persists for more than a short interval of time, the temperature of the link eventually reaches a level that causes a restricted segment of the link to melt. As a result, a gap is formed and an electric arc established. However, as the arc causes the link metal to burn back, the gap becomes progressively larger. Electrical resistance of the arc eventually reaches such a high level that the arc cannot be sustained and is extinguished. The fuse will have then completely cut off all current flow in the circuit. Suppression or quenching of the arc is accelerated by the filler material.

Single-element fuses of present day design have a very high speed of response to overcurrents. They provide excellent short-circuit component protection. However, temporary, harmless overloads or surge currents may cause nuisance openings unless these fuses are oversized. They are best used, therefore, in circuits not subject to heavy transient surge currents and the temporary overload of circuits with inductive loads such as motors, transformers, solenoids, etc. Because single-element, fast-acting fuses such as LIMITRON and T-TRON® fuses have a high speed of response to short-circuit currents, they are particularly suited for the protection of circuit breakers with low interrupting ratings.

Whereas an overload current normally falls between one and six times normal current, short-circuit currents are quite high. The fuse may be subjected to short-circuit currents of 30,000 or 40,000 amperes or higher. Response of current-limiting fuses to such currents is extremely fast. The restricted sections of the fuse link will simultaneously melt (within a matter of two or three-thousandths of a second in the event of a high-level fault current).



The high total resistance of the multiple arcs, together with the quenching effects of the filler particles, results in rapid arc suppression and clearing of the circuit. (Refer to Figures 4 & 5) Short-circuit current is cut off in less than a half-cycle, long before the short-circuit current can reach its full value (fuse operating in its current-limiting range).



Figure 1. Cutaway view of typical single-element fuse.



Figure 2. Under sustained overload, a section of the link melts and an arc is established.



Figure 3. The “open” single-element fuse after opening a circuit overload.



Figure 4. When subjected to a short-circuit current, several sections of the fuse link melt almost instantly.



Figure 5. The “open” single-element fuse after opening a shorted circuit.

With continued growth in electrical power generation, the higher levels of short-circuit currents made available at points of consumption by electrical utilities have greatly increased the need for protective devices with high short-circuit interrupting ratings. The trend is lower impedance transformers due to better efficiencies, lower costs, and utility deregulation. Utilities routinely replace transformers serving customers. These transformers can have larger KVA ratings and/or lower impedance, which results in higher available short-circuit currents. Devices that can interrupt only moderate levels of short-circuit currents are being replaced by modern fuses having the ability to cut-off short-circuit currents at levels up to 300,000 amperes.

Fuseology—Dual-Element Fuse Operation

Bussmann® Dual-Element Fuses

There are many advantages to using these fuses. Unlike single-element fuses, the Bussmann® dual-element, time-delay fuses can be sized closer to provide both high performance short-circuit protection and reliable overload protection in circuits subject to temporary overloads and surge currents. For ac motor loads, a single-element fuse may need to be sized at 300% of an a.c. motor current in order to hold the starting current. However, dual-element, time-delay fuses can be sized much closer to motor loads. For instance, it is generally possible to size FUSETRON® Dual-Element Fuses, FRS-R and FRN-R and LOW-PEAK® Dual-Element Fuses, LPS-RK_SP and LPN-RK_SP, at 125% and 130% of motor full load current, respectively. Generally, the LOW-PEAK® Dual-Element Fuses, LPJ_SP, and CUBEFuse™, TCF, can be sized at 150% of motor full load amperes. This closer fuse sizing may provide many advantages such as: (1) smaller fuse and block, holder or disconnect ampere rating and physical size, (2) lower cost due to lower ampere rated devices and possibly smaller required panel space, (3) better short-circuit protection – less short-circuit current let-through energy, and (4) potential reduction in the arc flash hazard.

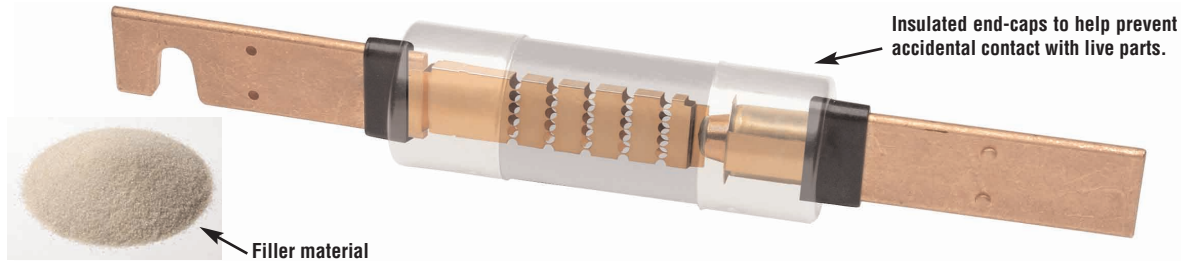


Figure 6. This is the LPS-RK100SP, a 100 ampere, 600V LOW-PEAK®, Class RK1, Dual-Element Fuse that has excellent time-delay, excellent current-limitation and a 300,000 ampere interrupting rating. Artistic liberty is taken to illustrate the internal portion of this fuse. The real fuse has a non-transparent tube and special small granular, arc-quenching material completely filling the internal space.

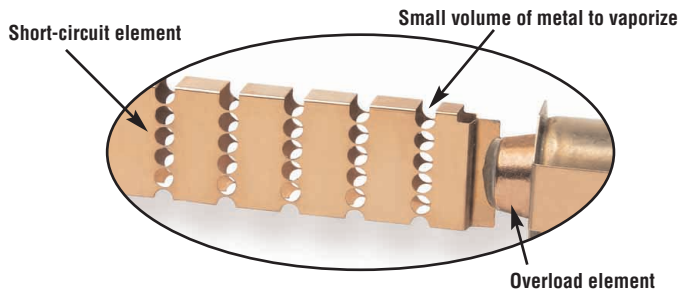


Figure 7. The true dual-element fuse has distinct and separate overload element and short-circuit element.

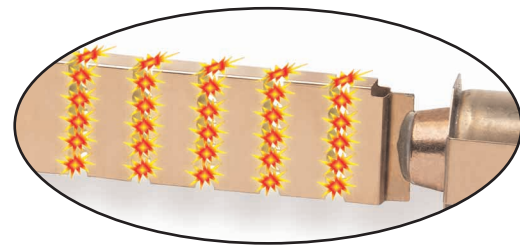


Figure 9. Short-circuit operation: Modern fuses are designed with minimum metal in the restricted portions which greatly enhance their ability to have excellent current-limiting characteristics – minimizing the short circuit let-through current. A short-circuit current causes the restricted portions of the short-circuit element to vaporize and arcing commences. The arcs burn back the element at the points of the arcing. Longer arcs result, which assist in reducing the current. Also, the special arc quenching filler material contributes to extinguishing the arcing current. Modern fuses have many restricted portions, which results in many small arclets – all working together to force the current to zero.

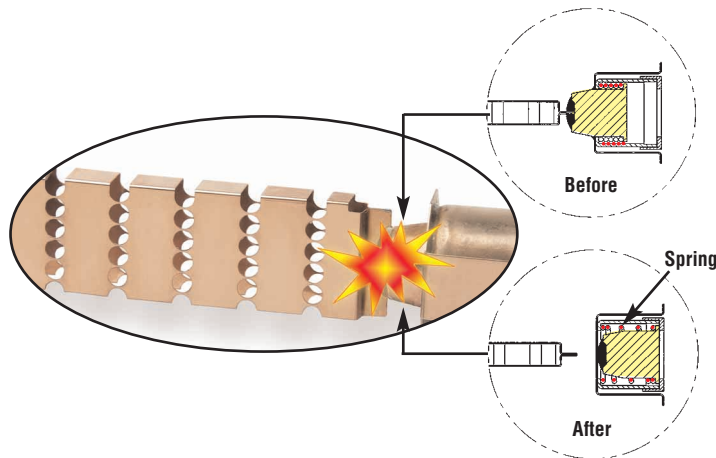


Figure 8. Overload operation: Under sustained overload conditions, the trigger spring fractures the calibrated fusing alloy and releases the “connector”. The insets represent a model of the overload element before and after. The calibrated fusing alloy connecting the short-circuit element to the overload element fractures at a specific temperature due to a persistent overload current. The coiled spring pushes the connector from the short-circuit element and the circuit is interrupted.

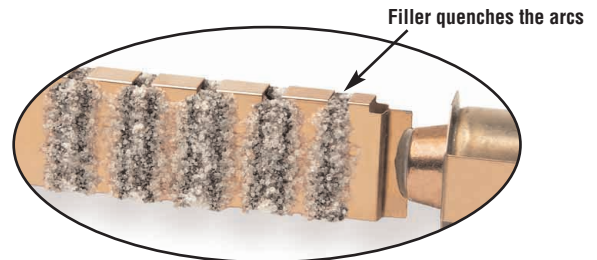


Figure 10. Short-circuit operation: The special small granular, arc-quenching material plays an important part in the interruption process. The filler assists in quenching the arcs; the filler material absorbs the thermal energy of the arcs, fuses together and creates an insulating barrier. This process helps in forcing the current to zero. Modern current-limiting fuses, under short-circuit conditions, can force the current to zero and complete the interruption within a few thousandths of a second.

When the short-circuit current is in the current-limiting range of a fuse, it is not possible for the full available short-circuit current to flow through the fuse – it’s a matter of physics. The small restricted portions of the short-circuit element quickly vaporize and the filler material assists in forcing the current to zero. The fuse is able to “limit” the short-circuit current.

Overcurrent protection must be reliable and sure. Whether it is the first day of the electrical system or thirty or more years later, it is important that overcurrent protective devices perform under overload or short-circuit conditions as intended. Modern current-limiting fuses operate by very simple, reliable principles.