Demystifying fuses and circuit breakers

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It is a very common misconception that fuses and circuit breakers (and some variations of them) protect electrical devices.

Fuses are electrical devices in which a filament of metal melts (fuses) when too much electrical current passes through it. The metal filament has a small amount of resistance which causes it to heat up with the current in accordance with Ohm's law. Above a certain amount of electrical current or "overload," the temperature of the filament will rise, then it will melt, open the circuit and stop the current. Time is required to melt the filament, but the greater the overload current, the faster it will open. It will operate more slowly or at higher currents in low-temperature environments.

Once the fuse has opened or "blown," it is usually replaced with another one to re-activate the circuit.

Circuit breakers are similar to fuses in that they open (trip) the circuit when too much electrical current passes through it. But unlike fuses, they operate with a bimetal strip that heats with the current. When the bimetal strip bends with the heat, it opens a pair of contacts to interrupt the current. Often the opening of the contacts is assisted by a magnetic element which speeds the opening if there is a severe current overload. This type of operation means that the circuit breaker can be reset, saving money and the nuisance of replacement.

So why do fuses and circuit breakers not protect electrical devices? It is because usually the device fails first and then causes the fuse or circuit breaker to open. If there is an electrical fault in a device, the fuse or circuit breaker usually opens and removes the power from the circuit. It may protect the wiring to the device, but it's too late to protect the device itself.

If fuses and circuit breakers don't protect electrical devices, why use them at all? I have answered this question for lawyers several times. The answer has three parts: to prevent human injury; to prevent further damage to the failed device and other equipment such as the wiring to the failed equipment; and to limit the extent of the service interruption, usually by isolating only one circuit of the system.

If a device fails, and the fuse or circuit breaker opens, there is no injury or further damage. If any one of the three situations listed above has not occurred, the fuse or circuit breaker has not done its intended job.

There are many cases where the fuse or circuit breaker fails to operate as intended. An indication of this can be an injury, excessive electrical damage, damage to the wiring, or perhaps a fire.

Occasionally the damage occurs at the fuse or circuit breaker itself. There are a variety of possible fuse or circuit breaker failures: water gets into the area and starts forming an electrical path or arc across the insulation; the fuse or circuit breaker has an ampere trip rating that is either too low or too high; the voltage rating of the fuse or circuit breaker has been exceeded; the interrupting rating of the fuse or circuit breaker has been exceeded; or something else that I haven't thought of or experienced yet.

Most of these situations are self-explanatory. But the interrupting rating is often overlooked, even by engineers who design electrical systems. If the electrical capacity of

the supply exceeds the circuit breaker's ability to open, an arc will form that does not extinguish. Within seconds or less, the arc does considerable damage and is usually more serious than the original fault. Now the protection is lost just when it was needed, and one is dependent on the next protective device upstream in the electrical system which, hopefully, does not have the same problem. The primary indicator of this type of problem is a fuse or circuit breaker that exhibits massive damage.

If this happens, cross your fingers – and hope the designer is well insured.

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