The Locomotive

Renewable Fuses:
Protection or Self-Deception?

By Brian Yarbrough and Jim Nelson, The Hartford Steam Boiler Inspection and Insurance Company

Introduction
Renewable fuses are those in which the element, typically a zinc link, may be replaced after the fuse has opened, and then reused. Renewable fuses are made to Class H standards. Class H fuses are rated at 250V and 600V; limited to 10,000 amperes of short circuit interrupting current; and are designed to be installed as branch circuit fuses. These fuses are available in current ratings from 1 amp through 600 amps.

When selected for the proper application and installed, inspected and maintained according to the manufacturer’s recommendations, these fuses generally function well for their intended use. When these fuses are not properly selected, installed and maintained, they can cause significant damage, including insulation damage, melting of conductors, vaporization of metal, ionization of gases, arcing, fires, explosions and even loss of life. Exhibit 1 shows a typical installation of this type of fuse.

Exhibit 1:

There is little difference in the visual appearance of the renewable and the non-renewable fuses shown below as Exhibit 2 and Exhibit 3 respectively.
Nor is there a significant difference in the respective thermal images (Exhibit 2a and Exhibit 3a). However, the cause of the problems associated with these fuses is actually very different.

Exhibit 2a reveals heating due to internal faults in both the left and middle phase fuses. The problem is most likely due to high electrical resistance at one of the mechanical...
connections on the renewable fuse link. Exhibit 3a reveals heating that is due to an external fault on the left phase fuse. This problem is most likely due to high electrical resistance at the connection between the fuse end and the fuse clip.

Construction
The construction of these fuses gives insight into the root cause of these problems. As with any electrical apparatus, the cause of a hot connection is high electrical resistance. Each of the mechanical connection points is a potential source for high resistance and eventually a hot spot.

Exhibit 4 shows a renewable fuse in which the element is inserted into slots on the top and bottom of the fuse. The threaded caps screw on and apply pressure to the element.

Exhibit 4:

Exhibit 5:

Also note that this fuse had two 300-amp links installed, which effectively made this a 600-amp fuse. The wiring in this leg of the motor circuit had no protection against an overload condition.

Exhibit 6 shows an installation of renewable fuses where the personnel thought that heat was developing on the fuse clips. These clamps are typically used to apply pressure to hold the fuses tighter than the fuse clips can. These clamps are commonly known as "depth charge clips." They are used on submarines to prevent dislodging the fuse when under attack by depth charges. Here they are being used, unsuccessfully, in an attempt to eliminate the heating that was actually being caused by high resistance connections inside the fuses.

In Exhibit 5, the connections become more complicated. The element is bolted onto the top and bottom ferrules. The retaining cap is placed over the top of the ferrules. A non-conducting material is used to maintain stiffness for inserting the element into the barrel. Note the heat damage on the non-conducting stiffener.
Exhibit 6:

Failure
In general, a fuse is a reliable overcurrent protective device. A "fusible" link or links encapsulated in a tube and connected to contact terminals comprise the fundamental elements of the basic fuse. Electrical resistance of the link is typically so low that it simply acts as a conductor. Renewable fuses; however, introduce another factor — the mechanical connection between the link and the ferrule or fuse cap. If this mechanical connection becomes loose, dirty, corroded or otherwise faulty, the result is a high resistance connection. The heat generated by the high resistance connection can be in the hundreds of degrees.

Exhibit 7 shows what is probably the most common form of failure. The heat generated by the high resistance connection causes the insulation on the conductor to deteriorate. Once the conductor makes contact with the metal of the panel or the conduit, a short circuit occurs. A short circuit may generate fault currents from 40,000 to more than 200,000 amperes. This level of short circuit fault current can result in vaporization of metal, ionization of gases, arcing, fires and explosions. This does not take into account collateral damage due to ignition of flammable or explosive materials in the area.

Exhibit 7:

When a fuse opens due to an overload condition that melts the link, a gap is formed and an electric arc is established. 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.

Suppression or quenching of the arc is accelerated in modern fuses by a filler material. Renewable fuses do not have a filler material to assist in the suppression or quenching of the arc. Usually the arc is contained within the confines of the fuse barrel or cartridge. In some cases the fuse barrel may be severely damaged due to having been burned or charred by the intense heat. If there is an explosive atmosphere, such as fine particle sawdust, then an ignition source could easily be the opening of the fuse link.
If all electrical enclosures were maintained according to applicable standards, then the chance of a fire would be greatly reduced. Consider the situation shown in Exhibit 8, where the cable penetrations are not properly maintained. Not only is the conductor insulation susceptible to damage, but the components inside the enclosure are now exposed to the atmosphere outside the enclosure. Additionally, it is now possible for charred/burning material from the fuse barrel or conductor insulation to fall through this hole and possibly ignite combustibles beneath the enclosure.

**Exhibit 8:**

![Exhibit 8: Electrical Enclosure with Cable Penetration](image)

**Low-Temperature Ignition**

While the failure of electrical equipment is of concern to most commercial and industrial facilities, it can be especially problematic for facilities in the lumber and wood processing industry. The inevitable presence of large amounts of wood and sawdust adds another dimension to the typical electrical failure that is commonly found via infrared thermography.

The common ignition temperature of wood is approximately 608°F to 660°F. However, temperatures do not need to get this high to present a fire hazard. When heat as low as 250°F (121°C) is applied to cellulose materials (wood) for a long period of time, pyrophoric carbon is formed. In this process the character of the material is changed. The exposed material becomes almost pure carbon and is subject to spontaneous heating.

Although the minimum temperature of 250°F is the generally accepted limit, there is some indication that lower temperatures could actually initiate low-temperature ignition. Temperatures of 212°F, 200°F and 180°F have been known to initiate low-temperature ignition. Note that all of these temperatures are well below the melting points of aluminum (1,220°F) and copper (1,980°F).

**Fuse Inspection and Maintenance**

Insulators should be clean to avoid flashover as a result of accumulation of foreign substances on insulator surfaces where abnormal conditions exist.

- If applicable, clean the insulators and inspect them for breaks, cracks, or burns. Loose or missing fasteners can cause high resistance connections.
- Check the lock or latch, and check for missing or damaged bolts, nuts, washers, pins, and terminal connectors. Poor contact surfaces result in reduced area for current flow and subsequently cause a corresponding increase in resistance.
- Inspect contact surfaces for burning, pressure, pitting, and alignment. Badly pitted or burned contacts should be replaced. When a renewable fuse opens, a small amount of carbon and metal is deposited inside the tube.
- Refinish fuse tubes made of organic (class "A") material as required and specified by the manufacturer.
- Examine the fuse tube, renewable element, and fuse unit for corrosion of the fuse element or connecting conductors, excessive erosion of the inside of fuse tubes, discharge (tracking) and dirt on the outside of the fuse tube, and improper assembly that may prevent proper operation.
- Replace fuse units or tubes showing signs of deterioration.
Summary
Unlike most fuses, renewable fuses do require some maintenance. Due to the design factors discussed above, and a corresponding lack of maintenance, renewable fuses present a higher than normal risk for equipment damage and fires. If the maintenance items listed above were completed routinely, then many of the failures due to renewable fuses would be less likely to occur.

Recommendation
As replacement becomes necessary, renewable fuses should be replaced with non-renewable, current-limiting type fuses.

About the Author
Brian Yarbrough is certified Level II Thermographer with HSB Thermography Services, which provides infrared thermography at facilities around the world. He joined The Hartford Steam Boiler Inspection and Insurance Company in 1995 and holds a National Board Commission with 'A' endorsement. Brian resides in Washington State and services customers located throughout the Northwestern United States and Western Canada.

Jim Nelson is a Level II Thermographer with HSB Thermography Services. He is a Nuclear Trained Senior Chief Electrician and is a member of the International Society of Optical Engineering. Jim joined The Hartford Steam Boiler Inspection and Insurance Company in 1987.