Commercial Kitchen Fire Suppression Solutions

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Some restaurant cooking fires are not being reliably extinguished by conventional fire suppression systems with fusible link detectors, limited suppression agent, and other unmonitored failure points. This is especially true with fires from solid fuel cooking.

The authors draw this conclusion from reviews of fire reports, investigations, and analyses of restaurant kitchen fires over the past few years. A similar conclusion is drawn from a 2012 NFPA report in which 13 restaurant fires are described.[1] Close reading indicates that fire suppression systems did not operate reliably in five of the 13 cases. Most kitchen fires involve grease, and fires from solid fuel cooking add highly combustible creosote to the fire risk.

This article discusses significant reliability issues with conventional fire suppression systems and presents several sample fire case studies that highlight these issues. It describes hybrid systems developed in the past few years, and it describes fully electronic systems that provide electronic detection, self-monitoring, and other functions for providing more reliable operation and suppression.

Recent Sample Fires

A well-known comedy club, theater, and performance school in Chicago experienced significant damage from a fire that began in a restaurant in the multistory building. Estimated damage and lost business was $9 million. According to the fire department spokesman, "the blaze made it past a fire suppression system and spread through vents (sic) to the roof."[2] The conventional fire suppression system actuated, but the fire was already burning in the exhaust duct and spread to two floors of offices and the roof structure before being extinguished hours later.

Coincident fires occurred on the same day in Houston and Kansas City locations of a restaurant chain with solid fuel charbroiling. Both fires ignited in exhaust ducts above fusible link detectors and were not suppressed by conventional systems. One of the fires spread to a pollution control unit, where it was extinguished by a fire suppression system with electronic detection and suppression by water and surfactant.

In 2016, fires in several restaurants have not been

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reliably suppressed by conventional systems, with or without solid fuel cooking, with significant damages and lost business. One restaurant was offered for sale after its third solid fuel fire.

Issues and Solutions

Fire Detection. As discussed in the authors' article on the history of commercial kitchen fire suppression systems,[3] conventional systems in current use were developed in the 1950s. A patent titled "Fusible Link" was filed in 1920,[4] and that was for improvements to fusible links, so this detection method is nearly a century old.

Fusible links are typically two small metal plates that are held together by solder that fuses (melts) at a rated temperature, such as 360°F (182°C), allowing the links to separate when under tension. A typical fusible link detector assembly is shown in *Figure 1*.

Separation of fusible links takes time, and the time varies with heat applied, tension on the cable lines, and other factors. A negative factor cited by a prominent conventional suppression system manufacturer is: "Fusible links loaded with grease and other extraneous material can result in excessive delays in actuation."[5]

Case Study: Total building loss occurred when a quick service restaurant caught fire and partially collapsed in California. The fire suppression system did not detect the fire, and fusible links were found encrusted with solidified grease, as shown in *Figure 2*.

A newer-design fire suppression system uses unlimited building water with added surfactant to suppress fires, and it includes daily automatic cleaning with hot water and surfactant of the hood plenum, electronic fire detectors, and lower duct surfaces.

Detector Response. Another issue for fusible links is the speed with which fires can travel before the links can separate. For example, with a duct 15 ft (4.6 m) long and common exhaust speed of 1,500 fpm (7.6 m/s), fire travels in the exhaust stream and through the duct in only 0.6 seconds.

In contrast, electronic fire detectors, as shown in *Figure 3*, are available that can sense the rate of temperature rise in addition to sensing rated temperature. These detectors are proactive, with "rate compensation" to account for thermal lag. In UL 300 testing witnessed by the authors, electronic detectors more often detected test fires by rate of temperature rise than by temperature setpoint.

Detector Locations. Some cooking fires start directly in exhaust ducts, especially from solid fuel cooking and auto-ignition of unburned vapors that condense and deposit creosote in upper, cooler portions of ducts. With conventional systems, fusible link detection in upper ducts is limited by maximum cable allowed length, and interference of the cable, tees, and pulley elbows with duct cleaning.

Case Study: A fire occurred in an Italian restaurant on the California coast. With solid fuel cooking, the fire ignited in the main hood duct, beyond fusible links detection, and the conventional fire suppression system was not automatically actuated.

With new electronically operated systems, electronic fire detectors are placed in duct openings, and optionally over appliances and in upper ducts, especially for solid fuel cooking applications. With temperature and rate of rise sensing, these detectors initiate suppression of fires that start in or move quickly into ducts. New electronic systems also include electrically operated pull stations for manual actuation.

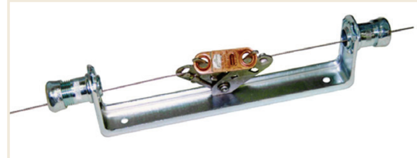

FIGURE 1 Typical brass fusible links and bracket assembly with tensioned cable.

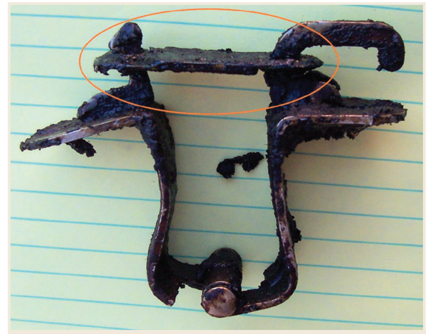

FIGURE 2 Grease-encrusted fusible links that did not separate in fire.

FIGURE 3 Electronic fire detector that senses temperature and rate of temperature rise.

System Power and Operation. With conventional systems, power is provided by a heavy-duty spring that holds small diameter cable sections and fusible links in tension when the system is armed. When heat causes fusible links to separate, the cable is released and triggers the release mechanism to pierce the seal on a compressed gas cartridge. This action pressurizes the suppressant tank(s) to disperse suppressant through pipes and nozzles. However, about 30 sequential mechanical actions must be accomplished to set up, actuate, and operate conventional systems reliably.

Case Study: At a full service restaurant in a major airport terminal in central Arizona, fire ignited in the hood and duct over a solid fuel charbroiler and solid fuel rotisserie. The fire system actuated, but suppressant tanks were found full, suggesting faulty system setup and maintenance.

FIGURE 4 Valves, gages, and controls for electronic fire suppression and hood cleaning system in hood end cabinet.

New electrically powered systems are protected with battery backup power supplies. Power is supplied to detectors and system controls to activate the system, open water valves, and run a small pump that adds surfactant to the water. The battery backup is designed to power the system for 30 minutes after being on standby power for 24 hours. System components are preferably mounted in a hood end cabinet, as shown in *Figure 4*.

Fire Suppressant Composition. Conventional fire suppression systems use a low pH liquid chemical solution, which replaced powder suppression in the early 1980s in response to fryer fires reigniting after suppression. The liquid suppressant aids saponification of the cooking oil, providing soapy foam to withhold oxygen from the fire, if the system works reliably.

New systems suppress fires with unlimited water, with surfactant added for better wetting of hood and duct surfaces. An overlapping mist of water droplets forms a thermal blanket on surfaces coated with grease or creosote to limit fuel temperature, rapidly extinguish fires, and eliminate fire spread. Mist suppression also reduces temperatures because energy is absorbed to vaporize water. These actions are especially important for suppressing solid fuel fires.

Additionally, as water droplets vaporize, the vapor volume increases to more than 1,000 times the water volume, which displaces oxygen to further suppress combustion. The thermal blanketing effect, surface cooling, and oxygen displacement occur as the water and surfactant solution is sprayed on appliances, exhaust hoods, exhaust filters, hood plenums, and exhaust ducts.

Fire Suppressant Amount and Discharge Time. Conventional systems typically include one or more tanks of suppressant liquid, which sprays the protected area, surprisingly, for only about one minute. Additional tanks of liquid suppressant are sometimes added to protect more appliances under longer hoods, but spray time is still limited to about one minute.

Case Study: A total loss fire occurred in Ohio in a quick service restaurant. Igniting in a group of fryers, the fire spread to residual grease in the exhaust hood and grease filters over the fryers. The conventional suppression system actuated, but it did not suppress the fire, likely

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because of limited suppressant and spray time, and the fire spread quickly throughout the historic building.

Case Study: An Italian-themed restaurant in northern New Jersey was totally destroyed by a fire that ignited in a deep fat fryer under a long hood. The conventional fire system actuated but the fire was not suppressed, in part because one of two suppressant tanks did not discharge.

Though water is unlimited for suppressing fires and eliminating reignition with new systems, timers are typically provided to avoid flooding the protected area. Example settings are 30 minutes for hood plenum and duct suppression, and 15 minutes for appliance surface suppression; however, if fire is still detected after the set time, new systems will continue suppression until detectors indicate the fire is extinguished.

Hood Cleaning. So-called water-wash hoods are designed to clean exhaust systems with detergent solutions, and some of these systems include fire suppression. In the authors' opinion, these systems are often unreliable, because they're unmonitored and depend on fusible links for detection.

Case Study: In western Maryland, a solid fuel cooking fire was not suppressed by a water-wash hood. Water to the hood's fire system had been turned off to stop constant water leakage from the system piping.

One new electronically operated suppression system provides automated daily cleaning of the hood plenum, backs of filters, and lower ducts with hot water and surfactant, using some of the pipes and nozzles that are also used for fire suppression. The system initiates cleaning when the hood exhaust fan is turned off at closing, operating for three minutes with periodic surfactant additions.

System Monitoring. Typically, with conventional systems a small metal flag, visible through a small window in the sealed fire suppression system cabinet, indicates if the system is armed for operation. Otherwise, monitoring of conventional system components occurs only when required checks and tests are performed every six months by a certified fire system technician, and once every 12 years for tank testing.

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Case Study: A quick service restaurant in Maryland was totally destroyed after a grease fire ignited in a deep fat fryer. The fire suppression system was actuated, but no suppressant was discharged, because the gas cylinder was not installed in the release mechanism, as shown in *Figure 5*.

FIGURE 5 Fire marshal photo showing gas cylinder not installed in release mechanism.

Case Study: Total loss of a new quick service restaurant occurred in Minnesota when a kitchen fire was not suppressed by a conventional system. The system actuated but did not discharge suppressant because a gasket provided for sealing the gas cylinder to the release mechanism was not installed.

With new fire suppression systems, all components and functions are continuously monitored, including water pressure, valve positions, surfactant level, etc. Faults are annunciated on the system display and can be remotely monitored by building management and other electronic systems, including Internet connection. As with conventional systems, new systems require semiannual maintenance by certified technicians, and the backup power supply battery must be replaced every two years.

Reliability Analysis

Conventional Systems. There's a simple mathematical means of analyzing the reliability of systems that include a series of required actions, such as conventional fire suppression systems. Reference 5 describes up to 30 sequential actions and component functions necessary for setup, actuation, and suppression with a typical conventional system. If each of 30 sequential actions and components is assumed to operate correctly 99% of the time, the overall reliability would be 0.99 × 0.99 × 0.99, etc. (multiplied 29 times), which equals 0.74 or 74%, suggesting the system would fail about one of every four times.

Significantly, many of the required actions and components in conventional fire suppression systems are "go" or "no go." Examples are fusible links separating or not, gas cartridge properly installed or not, detection cable free to move or not, and more. If any of the "go" or "no go" actions fail, the entire process fails. In reality, each of the required actions would have its own reliability factor, which could be life-cycle tested and improved as needed.

Efforts are under way to improve conventional fire suppression systems. One manufacturer offers an optional feature to determine if a gas cartridge is installed in the release mechanism, but it doesn't verify that the cartridge is pressurized, and this is only one of the actions required to operate a conventional system.

New Systems. There are fewer components in new electronic systems, and as explained above key actions and components are continuously monitored. If faults are found, alarm conditions are indicated locally by coded flashing lights and can be relayed to building management systems, data networks, and other communication devices.

TABLE 1 Comparison of features for conventional and electronic fire suppression systems.

FEATURE	CONVENTIONAL SYSTEM	ELECTRONIC SYSTEM
DETECTOR TYPE	Fusible Links and Cable Release	Electronic Fire Detectors
DETECTION MODE(S)	Rated Temperature	Rated Temperature and Rate of Temperature Rise
COMPENSATION	None	Rate Compensated to Offset Temperature Lag
DETECTOR LOCATIONS (PER LISTINGS)	Over Appliances and in Duct Openings	Duct Openings and Optionally in Ducts and Over Appliances
SOLID FUEL FIRE PROTECTION	Limited Distance in Ducts	Electronic Detectors in Ducts as Needed
COVERAGE METHOD	Appliance-Specific or Overlapping	Overlapping Standard
REQUIRED DETECTOR REPLACEMENT	Every Six Months, by Certified Service Technician	Only if Monitoring Reveals Problem
SUPPRESSION AGENT	Low pH Liquid and Foaming Agent	Water and Surfactant
SUPPRESSION QUANTITY	Fixed by Size and Number of Tanks	Unlimited Water with Added Fixed Quantity of Surfactant*
SUPPRESSANT DISCHARGE TIME	About One Minute	Unlimited, But Timers Available for Setting Appliance and Hood Plenum Discharge Times
POWER	Mechanical; Spring Tension	Electric, with Battery Backup
MONITORING	Service Technician Every Six Months	Continuous 24/7 Monitoring and Technician Every Six Months
FAULT ANNUNCIATION	None	Local, Building Management System, and Network Devices
AUTOMATIC HOOD PLENUM AND LOWER DUCT CLEANING	None, Except for Water-Wash Hoods	Daily at Closing, Including Detectors
AUTOMATIC HOOD CLEANING AGENT	Water and Detergent, as Specified	Hot Water with Periodic Surfactant Injection

*Surfactant available for about 40 min. with full tank, or about 20 min. at 50% alarm level.

Solid Fuel Fires

Solid fuel cooking fires present additional challenges to conventional fire suppression systems, as fully discussed in Reference 6:

- Buildup of combustible creosote in ducts, often beyond the detection points of fusible link detectors;
- Relatively low flash point and auto-ignition temperatures of creosote;
- Robustness of creosote fires that spread past fusible links quickly or ignite directly in ducts;
- Limited amount of suppressant and discharge time to suppress fires; and
- No means to automatically shut off burning solid fuel.

Case Study: At a Missouri restaurant with a wood-fueled barbecue pit, a grease and creosote fire ignited in the duct. The fire system actuated but did not suppress the fire, which was extinguished by the fire department.

Case Study: Extensive damage was caused to an Italian restaurant and other building spaces in Maryland by a fire originating in a combined gas- and wood-fueled pizza and baking oven. The oven was under a hood with a conventional fire suppression system, but the fusible links did not actuate the system, nor was the system manually actuated. The fire exited the oven, spread through the hood and filters to the duct, and damaged second-floor office spaces and the roof.

Table 1 compares key features of typical conventional and new systems.

Hybrid Systems. To enhance conventional system effectiveness, several manufacturers have developed hybrid fire suppression systems. One system provides water suppression following actuation and wet chemical discharge, but it retains fusible links for detection. Two other systems provide electronic detection in place of fusible links, but they retain a fixed amount of suppressant and limited discharge time.

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Summary

The reliability of conventional fire suppression systems is diminished by several factors, including unreliable fusible links detection; limited suppressant quantity; short discharge time; inability of fusible links to detect quickly moving fires; and the serial reliability issue of many sequential actions required for setup, actuation, and suppression.

Fortunately, new electronic fire suppression systems are available to counter the limitations of conventional systems. The authors recommend specifying electronic fire suppression systems, especially for kitchens with solid fuel cooking, where fire risk is greater, and for commercial kitchens in multistory buildings where the risk of damage is greater.

Regardless of the effectiveness of fire suppression systems, housekeeping and maintenance are important to fire prevention. Evarts[1] found that "One in five fires (21%) in eating and drinking establishments had a failure to clean as a factor contributing to its ignition."

Acknowledgments

Thanks to consultant Doug Horton for background research and sharing details of several fire investigations in which he has participated; public officials for information contained in their fire reports; and several of the authors' coworkers who have visited restaurant fire sites in conjunction with restoration and learned about fire system issues from officials and owners.

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