TECHNOLOGY UPDATE FOR GREASE DUCT PROTECTION

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Commercial kitchen grease duct fires continue to pose a major safety and property loss threat in the U.S., causing well over $100 million in direct property damage every year. Grease duct fires commonly result from a flare-up at the stove, fryer or grill top. If a dry flame suppression system is not in place and operating effectively, fire can spread quickly into the vent system, resulting in an out-of control condition.

Hidden grease duct fires sometimes occur without the immediate knowledge of building occupants, and burn undetected until the combustion supply is depleted. Even though temperatures may spike dramatically under such circumstances, an effective fire resistive enclosure system will protect the structure throughout the episode. However, with sufficient grease duct fuel load and oxygen, a fire will not burn out quickly, but can grow to involve the entire duct with internal temperatures rising rapidly to as high as 1093°C (2000°F), depending on duct size, grease contaminant levels and available combustion air supply. Without an effective fire resistive enclosure, an internal grease duct fire can propagate rapidly to ignite adjacent flammables and structural elements.

CODE PROVISIONS

Grease duct fires are especially dynamic and demonstrate uniquely aggressive propagation characteristics. This poses special challenges in fire protection system standards and performance characteristics. The minimum code requirements necessary for a grease duct fire resistive enclosure system to be classified by a third-party laboratory and inspection agency include satisfaction of multiple code-driven performance tests. Table 1 lists the predominant performance-based minimum code-driven standards that must be met by commercialized grease duct wrap systems. Curiously, these rigorous standards apply to wrap systems but not to conventional gypsum chase systems.

GREASE DUCT CHASE INSULATION LIMITATIONS

The traditional means of fire protecting a grease ventilation system was to build a gypsum chase structure to create an encircling 6-inch air gap around the metal duct along its entire run from the vent hood to where the duct exits the roof. A double layer of gypsum on a metal stud assembly was generally specified to provide a 2-hour rating per ASTM E119 wall panel test, which evaluates a one-dimensional fire exposure under typical room fire temperature conditions.

The ASTM E119 Fire Resistance Wall Panel test calls for a four-hour sequence of gradual temperature increases, reaching 1700°F after one hour, 1850°F in two hours, 1925°F after three hours, and finally 2000°F after four hours. This time/temperature rating has little pertinence to a grease duct fire situation when fire conditions can reach 2000°F in less than ten minutes.

Industry standards for chase assembly call for approved screw fastener-s into all frame members, both inside and outside the chase, with seamless construction. But with only a six-inch spacing between the metal duct and the drywall chase, it is physically impossible in many cases to meet this construction requirement. However, this paradox is seldom addressed, since it is virtually impossible the upper temperature limit for continuous drywall exposure because the material gradually loses its moisture content and becomes desiccated and weakened under elevated temperature conditions. In fact, the average heat level inside a gypsum chase serving an operating grease duct can routinely exceed this level under normal cooking operations and during hidden grease duct fire episodes. Evidence of gypsum drywall deterioration can often be found by examining the inside of a gypsum grease duct chase that has been in use for a period of time. Drywall powder residue will commonly be found at the bottom of the shaft, and the drywall paper adjacent to the hot duct may be charred. The gypsum core may also be cracked and distorted as a result of extended exposure to temperatures above 125°F.

A third-party independent laboratory test was conducted using a typical 1-hour drywall enclosure with a 6" air gap in accordance with the more realistic time and temperature values of a grease duct fire specified in ICBO AC 101 acceptance criteria. In this large-scale grease duct test, normal cooking operations were simulated at 500°F for 4 hours followed by a quick ramp to 2000°F for 30 minutes to indicate a grease duct fire occurring within the duct. The drywall shaft enclosure failed less than 10 minutes after the temperature was spiked to 2000°F. In this case, a gypsum panel segment breached and fell away, leaving a large hole in the horizontal portion of the tested duct structure. Such failure would expose the force of the fire directly to surrounding combustibles and lead to very rapid propagation.

Grease Duct Insulation Test Standards			
Applicable standards/tests	BOCA	ICBO	SBCCI
ASTM E 84, Standard test method for surface burning characteristics of building materials	Surface burn		Surface burn
ASTM E 119, Standard test methods for fire tests of building construction and materials	Engulfment and wall tests	Wall test	Wall test
ASTM E 136, Standard test method for behavior of materials in a vertical tube furnace at 750°C	Combustion	Combustion	
ASTM E 814, Standard test method for fire tests of Through Penetration Fire Stops	Fire stop	Fire stop	Fire stop
ASTM C 411, Standard test method for hot surface performance of high temperature thermal insulation	Hot surface performance	Hot surface performance	
ASTM C 518, Standard test method for steady state thermal transmission properties by means of the heat flow meter apparatus		Temperature aging test	
UL 1978, Standard for grease ducts	Clearance to combustibles		Clearance to combustibles
ICBO AC 101, Grease duct enclosure assemblies		X	
External fire test		X	
Internal fire test		X	
Quality control program required	X	X	X

ANOTHER APPROACH

A more effective approach to grease duct insulation was certified and UL approved in 1992, after extensive review and the successful completion of several industry standard tests required by SBCCI ES acceptance criteria. This method consists of wrapping metal ducts directly with foil-encapsulated FireMaster® ceramic fiber insulation. This high-performance ceramic refractory blanket from Thermal Ceramics withstands a sustained temperature of 2300°F without affecting mechanical and insulation properties. It does not melt or otherwise lose physical properties below 3200°F.

Encapsulated or partially encapsulated ceramic fiber insulation duct wrap was deemed unsuitable for grease duct use because of the threat of physical or mechanical damage, potential problems related to surrounding pipe leakage, and the possibility of fiber saturation that could result from grease leakage through compromised grease duct seam welds over time. Full encapsulation also enhanced ceramic fiber insulation performance by making it easier to attach the insulation to ducts. Encapsulated ceramic fiber grease duct insulation directly applied to the metal duct also allows for zero clearance construction without an air gap or the metal stud construction that is required with gypsum chase systems.

There are several ceramic insulation formulations currently available in foil-encapsulated form for grease duct insulation. One is a low bio-persistent body soluble calcium magnesium silicate blanket material based on alkaline earth silicate wool, which is rated to withstand fire condition temperatures up to 2000°F, and the 2300°F material mentioned earlier, an alumina/silica based composition.

OTHER FIBER OPTIONS

More recently, foil encapsulated mineral wool grease duct insulation materials with reduced temperature capabilities have been introduced. These products have a sustained temperature rating of 1200-1500°F. While this lower temperature wrap material generally meets governing standards, it may not provide an equivalent level of long-term fire protection to ceramic or Alkaline-Earth Silicate insulation under full grease duct fire conditions.

Mineral wool duct wrap insulation is somewhat heavier than ceramic fiber material per unit volume -nominally 7.5 Ib/ft.2 for ceramic or Alkaline-Earth Silicate and 101b/ft.2 or more for mineral wool. Its lack of rigidity or form can also make it more difficult to feed mineral wool-based insulation through blind spaces around ducts.

Some mineral wool duct wrap is stitched to stabilize the fibers and reduce slipping inside the foil liner. The characteristic suppleness of mineral wool results in compression when the insulation is drawn around duct corners and sharp edges, thus potentially increasing thermal conductivity and reducing insulation value beyond that of the laboratory tested values.

The greater weight per volume and reduced rigidity of mineral wool' duct wrap may also affect the amount of supporting and fastening hardware required for installation, particularly on vertical grease duct runs . Wrap insulation manufacturers generally specify that mounting bands be applied with sufficient tension to maintain zero clearance between the duct and insulation, but not unduly compress and thus reduce wrap thickness. Duct wrap weight and handling properties are significant when calculating labor requirements and total applied cost of duct wrap insulation.

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THERMAL TESTS OF WRAPPED INSULATION

The ICBO ES AC-1 011 Internal Fire Test of gypsum chase construction referenced earlier also included a parallel test of foil-encapsulated ceramic insulation under equivalent conditions. Unlike the drywall chase assembly, foil encapsulated ceramic fiber insulation withstood these test conditions with no compromise to its fire protection effectiveness. It is paradoxical that while gypsum chase construction is still widely accepted for grease duct insulation, this construction method, is not capable of meeting the higher standards established by the model codes for zero clearance duct wrap systems for the same end use application.

In another procedure, an R&D laboratory conducted a test comparing the temperature performance of ceramic refractory blanket and a mineral wool based duct-wrap according to a modified ASTM C356 standard. In this test, temperatures ranged from 1200°F to 1700°F, with a dwell time of five hours at the upper limit. The mechanical properties of the ceramic insulation were not altered by these test conditions. In contrast, the same conditions caused mineral wool test samples to shrink considerably, become hardened, and exhibit significant reduction in flexural strength. This degradation in key properties could make mineral wool insulating wrap potentially vulnerable to fracturing under the thermal expansion that occurs in a grease duct under normal cooking conditions, thus compromising its ability to meet the required two-hour performance rating . Insulation that has hardened or shrunken in use over time will fail to meet "as tested" requirements for product performance when a real world fire occurs.

This laboratory test also revealed the tendency of mineral wool to shrink permanently with elevated temperature, beginning at about 1300°F, with a volume loss of 9.6% at 1500°F, and more than 11 % at 1700°F degrees. In contrast, the shrinkage of ceramic fiber insulation is essentially flat across this temperature spectrum and limited to a maximum of less than 1 % of volume at 1850°F (Figure 1).

As mentioned earlier, short, intermittent and undetected fires can occur in kitchen grease ducts when residual grease flashes and burns off. Such incidents are typically of short duration, but they can be intensely hot. Based on the demonstrated irreversible shrinkage properties of mineral wool at 1300°F and beyond, there is a possibility that high temperature spiking related to intermittent fire episodes could result in permanent degradation of a mineral wool wrap enclosure. This would reduce its potential to effectively insulate a duct in the event of a more serious fire of longer duration and higher temperatures.

GREASE DUCT FIRE EXPERIENCE

Mineral wool grease duct material insulation has been a relatively new alternative for just over a year, and information on its performance in the field under fire conditions is therefore limited. However, ceramic fiber duct wrap has been used extensively since FireMaster flexible wrap was introduced in 1992 by Thermal Ceramics, and while many fire incidents have been reported in these installations, there has been no reported circumstance to date when this material failed to confine fire to the grease duct.

For example, a serious kitchen grease duct fire at a new Branson, Missouri family restaurant in May of 1995 demonstrated the performance of ceramic duct wrap. This fire occurred during a busy evening just four months after the restaurant opened for business. The restaurant's steel grease duct was insulated from vent hood to roof vent with a double-layer of foil-encapsulated ceramic fiber insulation duct wrap, and installed with zero clearance to structural elements.

According to the restaurant manager, the Branson fire began with a sudden charcoal grill flare-up. The automatic suppression system did not activate, and flames quickly spread to involve the entire grease duct and caused flames to erupt more than 10 feet above the roof. Because of insulation effectiveness, fire was contained within the duct and damage was limited to the duct and metal roof vent structure. Inspectors later reported that the color distortion of the protected metal duct indicated that it had been subjected to internal temperatures well above 1000°F.

Unfortunately, there is a long record of costly and deadly fires in buildings where gypsum chase construction was used to insulate kitchen grease ducts. A hotel-based Italian restaurant in Sonoma, California, experienced a serious grease duct fire in 2000 that caused damage to the building above the kitchen. A long horizontal duct run in the kitchen ceiling insulated with foil-encapsulated ceramic insulation contained the fire as intended. Unfortunately the vertical portion of the grease duct run was inside a gypsum chase, which failed, allowing the fire to spread to 10 stories of the structure.

In 1999, an 8-alarm kitchen fire occurred in a New York City restaurant located in an apartment building. This restaurant's grease duct was enclosed in an 11-story gypsum chase enclosure. A stovetop fire spread into the duct and traveled up the metal duct to the roof within 20 minutes, aided by a ready supply of combustion air around the duct. The chase failed to restrict the fire, which eventually spread to the structure. Thirty-three people were injured in this blaze, and the apartment building suffered extensive damage.

RECENT CODE ACTIVITY

Two proposals related to grease duct fire resistive enclosures were reviewed by the ICC code council during final hearings during October 2002. In the first case, the council reinstated the six-inch duct-to-shaft wall air gap spacing specification (which parallels NFPA 96 -7.7.2.2.2) as opposed to a proposed three-inch air gap spacing. The second proposed code change called for added protection of flexible duct enclosures in areas where they might be subject to potential, physical damage. This proposal was adopted, with the specifics of protection left to the discretion of authorities having jurisdiction, which is also required (philosophically) by NFPA 96.

Based on available information, specifiers should consider the use of direct wrap high-temperature insulation for kitchen grease ducts for its demonstrated performance, safety advantages and space savings compared to traditional gypsum chase construction. Ceramic fiber refractory blanket insulation in particular offers a superior temperature rating, consistent weight and thickness, with reliable and favorable mechanical properties for kitchen grease duct fire protection.