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Solid Fuel-Burning Appliance Fire Investigations

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Abstract

Solid fuel-burning fireplaces and wood stoves are popular because they provide heat and aesthetically pleasing environments. They also provide backup heat to gas, electric, and oil building heating systems. However, if they are not properly installed and maintained, they pose a risk of structure fires. This paper describes the basics of conducting a forensic engineering investigation of a building fire involving a suspected fireplace or wood stove. The paper examines the types of appliances available, the types of chimney systems, and related design standards and building codes. Case studies (highlighting common failure modes) are also presented.

Keywords

Solid fuel, fireplace, wood stove, chimney, cellulose insulation, creosote, forensic engineering

Introduction

Typical residential solid fuel-burning appliances include fireplaces and wood stoves, which this paper focuses on. There are other types of solid fuel-burning appliances, which may be the subject of a future paper. When in use, these appliances and their chimneys are sources of heat. Accordingly, they can cause ignition of nearby combustible building materials and structural components when they overheat. An important difference between solid fuel-burning appliances and other heat-producing appliances (electric, gas, or oil) is that solid fuel appliances cannot be simply turned off if a problem develops, since the fuel in the firebox will continue to burn until it burns itself out or is externally extinguished.

After a fire has occurred, and an origin and cause (fire) investigator suspects the area of origin to be near a solid fuel-burning appliance, a forensic engineer is often called upon to investigate whether the appliance caused the fire.

NFPA 921 *Guide for Fire and Explosion Investigations*[1] states:

In planning a fire investigation, specialized personnel may be needed to provide technical assistance including chemical, electrical, materials, mechanical, and fire protection engineers. (NFPA 921-2014, 15.5)

The use and operation of an appliance should be well understood before it is identified as the fire cause. More complicated appliances may require the help of specialized personnel to gain a full understanding of how they work and how they could generate sufficient energy for ignition. (NFPA 921-2014, 26.4.2)

The purpose of this paper is to provide information and general guidelines to the forensic engineer for inspecting residential solid-fuel burning appliances and chimneys involved in fires. Since each investigation is unique, the engineer may need to deviate from these guidelines. The paper also provides case studies that demonstrate the application of these guidelines.

Relevant Codes and Standards

Codes and standards are typically consensus-approved documents for technical issues related to human-made structures and systems, with a significant difference being that codes may be adopted into law.

Standards

Standards exist that provide guidelines for technical forensic investigations of solid fuel-burning appliance fire investigations. The following listing is intended to assure the engineer is aware of these standards. Investigators should use whichever ones are relevant to their particular investigation, and should have complete copies of the relevant standards available during their investigation.

NFPA 921 *Guide for Fire and Explosion Investigations,* a generally accepted overall guide to fire

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investigation, is the central standard an investigator should be aware of. The other standards are for particular appliances or components that may be the subject of an investigation. Accordingly, these standards would be relevant when the products they address are at issue. Some commonly used standards are (in alphabetical order):

ASTM C1015 *Standard Practice for the Installation of Cellulosic and Mineral Fiber Loose-Fill Thermal Insulation*[2] provides procedures for the installation of loose-fill thermal insulation in ceiling, attics, walls, and floors of new and existing buildings. It requires installers to block around heat-producing devices, including flues and chimneys, to prevent the insulation from contacting those devices. It requires clearances specified in NFPA 211.

NFPA 211 *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances*[3] applies to the design, installation, maintenance, and inspection of chimneys, fireplaces, vents, and solid fuel-burning appliances. It provides construction and installation requirements for those systems. It also includes the inspection of existing chimneys, including specifying particular requirements of Level I, II, and III inspections.

- Level I inspection verifies suitability of the chimney for continued service under the same conditions with the same or similar appliance, including examination of readily accessible portions of the appliance and chimney.
- Level II inspection verifies suitability of the chimney for changed conditions of service, including examination of accessible portions of the chimney interior and exterior, as well as attics, basements, and crawl spaces.
- Level III inspection includes examination of concealed areas of the chimney (suspected of damage or malfunction) that can be access only by removal of portions of the chimney or building structure.

NFPA 921 (previously mentioned) provides guidelines and recommendations to assist individuals responsible for investigating fire and explosion incidents and rendering opinions as to the cause and origin. The document is intended to provide a systematic framework for fire and explosion investigation.

UL 103 *Standard for Factory-Built Chimneys for Residential Type and Building Heating Appliances*[4] provides design, construction, and performance requirements for factory-built chimneys intended for venting gas, liquid and solid-fuel fired residential type appliances in which the maximum continuous flue gas temperature does not exceed 1,000°F. The chimneys also are to comply with a limited duration 1,700°F or 2,100°F temperature test, with type HT (high temperature) chimneys required to comply with the latter test. The standard, which requires installation to be in accordance with NFPA 211 and national building codes, includes installation and maintenance requirements.

UL 127 *Standard for Factory-Built Fireplaces*[5] provides design, construction, and performance requirements for factory-built fireplaces, including the firebox, chimney, roof assembly, and other related parts. It is intended for fireplaces burning solid wood or coal. The chimneys comply with either the 1,700°F or 2,100°F (Type HT) temperature test. The standard, which requires installation to be in accordance with NFPA 211 and national building codes, includes installation and maintenance requirements.

UL 1482 *Standard for Solid-Fuel Type Room Heaters*[6] covers room heaters that are freestanding fire chamber assemblies for use with solid fuels, which are intended to be attached to residential type chimneys.

UL 1777 *Standard for Chimney Liners*[7] covers metallic and nonmetallic chimney liners for field-installation into new or existing masonry chimneys, for use with solid fuel fired residential-type appliances with maximum continuous flue gas temperatures not exceeding 1,000°F.

Building Codes

When investigating a fire of a structure, one of the first steps is to determine which building codes are applicable. Whether the product at issue was installed and maintained pursuant to the applicable building codes is an important part of most investigations. Building codes are periodically updated; therefore, the editions of those codes relevant to the particular issue must be determined. The codes adopted by (and being enforced by) the authority having jurisdiction at the time the product at issue was installed or modified must be utilized by the investigator when determining code compliance.

The International Residential Code[8] (IRC) is a typical building code adopted by governing bodies. The 2012 IRC specified masonry fireplaces and chimney construction details and materials, including required clearances to combustible material. The IRC requires factory-built fireplaces be listed and labeled, installed in accordance with the listing, and tested in accordance with UL 127. Chimneys provided with factory-built fireplaces must also comply with UL 127. The IRC requires factory-built chimneys to be listed and labeled, installed in accordance with the manufacturer's instructions, and compliant with the Type HT requirements of UL 103.

Solid Fuel Consumption

Since only gases or vapors burn, solid fuel (such as wood, coal, or similar organic material) needs to be heated before it can burn. Heating the material creates vapors that will burn in a region above the surface. The fuel vapors can burn only if properly mixed with air and exposed to a competent ignition source, or if they are heated to their auto-ignition temperature.

A solid fuel-burning appliance needs an adequate supply of air to operate properly. The fuel vapor and air are mixed together and then ignited within the firebox of the appliance. The products of combustion are exhausted from the appliance through a chimney.

Burning wood produces water vapor, tar, carbon monoxide, carbon dioxide, and other organic vapors. These products combine to form creosote, which condenses, deposits, and accumulates on the inner surfaces of the chimney and chimney connector. A slow-burning fire, a fuel rich fire, or a cool chimney can increase the rate of creosote buildup. Burning unseasoned wood with high moisture content can also increase the generation of creosote.

Creosote is combustible material and can be vaporized and ignited by heat from the appliance, causing a chimney fire. Research described by Peacock[9] indicates creosote chimney fires have been documented to burn at temperatures as high as 2,500°F. These fires can damage the chimney and extend to nearby combustible structures of the building. Burning creosote can also be ejected out of the top of the chimney and drop onto the roof or nearby areas. Accordingly, it is important to periodically inspect and clean a regularly used chimney to minimize the accumulation of creosote.

NFPA 211 requires that solid fuel-burning appliances be installed with sufficient ventilation and combustion air supply to allow for proper combustion of fuel, facilitate chimney draft, and maintain safe temperatures[10]. Accordingly, combustion air kits, which provide outdoor air directly to the appliance, are typically available for fireplaces and wood stoves.

Complete venting of the products of combustion from solid-fueled appliances is necessary to assure the proper operation of those appliances — and to prevent the accumulation of the combustion products within a building. A chimney system is based on the principle that hot air is buoyant and rises. A proper chimney system conveys the products of combustion to the outdoors, prevents damage from the condensation of water in the flue gases, prevents overheating of nearby combustible materials, and provides fast priming of natural draft venting to minimize flow of combustion products into the building. A chimney that condenses water is more likely to accumulate creosote. Conversely, a fast priming chimney heats up quicker and is less likely to accumulate creosote. Common chimney systems for residential solid fuel-burning appliances include masonry and factory-built chimneys.

Appliances and Chimneys

Masonry Fireplace and Chimney

A typical masonry fireplace is constructed of solid masonry units, reinforced Portland cement, or refractory cement concrete. It is comprised of a firebox with a hearth (floor) and right, left, and rear walls made of fire-rated masonry materials. The firebox is usually equipped with a grate to keep the logs up off the hearth. It may be equipped with an outdoor combustion air supply as well as a gas starter or gas log set. The front opening may be equipped with a screen or glass doors. A manually operated damper is located at the top of the firebox and leads to a smoke chamber above the damper. A non-combustible hearth extension extends from the lower front edge of the fireplace outward into the room.

The smoke chamber narrows at its top and connects to a chimney flue that extends upward above the roof of the building. A masonry chimney is normally lined, and the flue size is based on the fireplace opening size. The top of the chimney is typically equipped with a cap that keeps rain and animals out and may be equipped with a screen to reduce the chance of sparks and embers escaping. Codes and standards relevant to masonry fireplaces and chimneys include NFPA 211, UL 1777, and local building codes.

Factory-Built Fireplace

A factory-built fireplace is a mass-produced appliance constructed of sheet metal or steel. It may be equipped with a factory-built chimney system provided by the same manufacturer, or installed with a chimney obtained from a different manufacturer (see the section on factory-built chimneys below). Codes and standards relevant to these fireplaces and chimneys include UL 127, NFPA 211, and local building codes.

An identification plate is included which provides basic information such as the manufacturer, model, serial number, date of manufacture, and relevant standards. Installation and user instructions are provided by the manufacturer, which contains information on proper clearances to combustibles.

A factory-built fireplace has a firebox with features similar to a masonry fireplace. Unique to a factory–built fireplace is the common construction that includes inner and outer metal cabinets separated by an airspace, which may or may not contain insulation. Firebrick may be replaced with refractory panels that cover the hearth (bottom) and sides of the firebox. Some factory-built fireplaces contain an integral grate on the hearth, and others intend for the firewood to be placed directly on the hearth. A non-combustible hearth extension, which is separate from the fireplace unit, is required to be provided by the installer. An air circulation blower may be installed to circulate room air through the unit and supply that heated air to the room. Similar to a masonry fireplace, an outside air supply kit and/or a gas log lighter, or gas log set, may be installed in the fireplace.

A typical chimney system, provided by the fireplace manufacturer, includes a double-wall or triple-wall air insulated chimney, firestops, attic insulation shield, radiation shield, support provisions, roof flashing, a storm collar, and a termination cap. The chimney must terminate a minimum of 3 feet above the roof and 2 feet above any portion of the roof within 10 feet.

The chimney may be equipped with an offset/return if it has to be jogged to avoid an overhead obstruction as it extends upward through the building structure. It may also be equipped with a chimney outside air kit to supply outdoor cooling air directly to the chimney.

Wood Stove

A wood stove is essentially a mass-produced firebox constructed of steel plate mounted on a pedestal or legs. An identification plate is included, and installation and user instructions are provided by the manufacturer. Codes and standards relevant to wood stoves include UL 1482, NFPA 211, and local building codes.

A glass door is located at the front of the stove, and a flue extends out the top. The interior bottom hearth and sides are covered with firebrick. A baffle may be located in the upper area, just below the flue, to increase efficiency of the appliance.

The wood stove may be equipped with an outside air kit to provide combustion air directly to the appliance, and controls to adjust the amount of air entering the firebox. The stove may also be equipped with an electric blower to circulate and heat room air.

If the stove is intended to be installed on a combustible floor, it may be required to be set on top of a hearth pad floor protector so that it complies with its listing. If a pad is not utilized, the floor may be exposed to excessive temperatures that may cause a fire hazard. Wood stoves are utilized with chimneys manufactured by companies other than the stove manufacturer. The chimneys may be masonry or UL-listed factory-built. A chimney connector attaches the wood stove to the chimney. Chimney connectors may be single-wall or air-insulated double-wall. Typical clearance to combustibles for single-wall connectors are 18 inches, and double-wall connectors are to be pursuant to the manufacturer's instructions (normally 6 inches). A "thimble" is utilized where the chimney or connector passes through a wall to maintain proper clearances.

Factory-Built Chimney

Codes and standards relevant to prefabricated factory-built metal chimney systems include UL 103 HT, NFPA 211 and local building codes. Type HT factory-built chimneys are tested to withstand a 1,000°F continuous flue gas temperature and a 2,100°F flue temperature for 10-minute intervals. Typical factory-built chimneys include air cooled triple-wall and insulated double-wall types. Air-cooled chimneys may be equipped with outdoor air supplies to their bases to provide required air. The engineer should determine the expected flue gas temperatures being generated by the appliance and vented through the chimney.

A basic system includes a chimney connector, chimney, supports, an attic insulation shield, radiation shield, firestops, roof flashing, a storm collar, and a termination cap. The cap prevents entry of rain, snow, and animals, and may be equipped with a spark arrester. An adapter may be provided to transition between the stove flue and the chimney connector. The chimney system is provided with manufacturer installation instructions.

Common Fire Causes

Clearances to Combustibles

A major cause of solid-fuel appliance-caused structure fires is inadequate clearances to combustibles. For factory-built appliances, appliance manufacturers provide the proper clearances to combustibles for installation in their installation instructions. Clearances to combustibles typically refer to combustible construction of the structure (i.e., wood structural members, plywood, oriented strand board [OSB], roofing materials, etc). Combustibles can also include thermal insulation.

Only cellulose insulation is discussed in this paper because, in the author's experience, it is common for that insulation to be the first fuel ignited in a structure fire. Typically, fiberglass insulation will smoke and melt, but will not burn. Loose fill cellulose thermal insulation is basically shredded newsprint treated with boric acid as a fire retardant. It is mechanically blown into place to a desired density and thickness. An engineering resource well known to the fire investigation field is the *Ignition Handbook*[11]. This text indicates loose fill cellulose insulation is known to combust in smoldering mode, and the generally accepted minimum hot surface ignition temperatures for cellulose insulation is approximately 450°F (232°C). Therefore, the external surface of the chimney would need to reach that ignition temperature from internal heating by the hot flue gases being vented from the appliance, and remain at that temperature long enough to ignite a fire.

Overfiring of Appliance

Even if there are proper clearances, the operating appliance can produce temperatures great enough to ignite nearby combustibles. Overfiring of the appliance may occur from burning too much wood, trash, or flammable liquids — or allowing too much air into the appliance, causing too intense of a fire. Overfiring may cause the chimney connector to glow red hot and/or ignite creosote deposits in the connector or chimney and cause a chimney fire. Evidence of overfiring may be witness observations of the size and intensity of the fire in the appliance, observed glowing hot components, information on the rate of fuel (wood) consumed leading up the fire event, or observed localized overheating damage to the appliance or chimney.

Chimney Fire

A chimney fire can overheat and damage a masonry or factory-built chimney, which can ignite adjacent combustible building construction. Type HT factory-built chimneys (as mentioned) are tested to withstand 1,000°F continuous flue gas temperatures and 2,100°F flue temperatures for 10-minute intervals. However, actual chimney fires can reach higher temperatures and/or last for longer durations. Non-HT factory-built chimneys are tested to withstand 1,000°F continuous flue gas temperatures and 1,700°F flue gas temperatures for 10 minutes.

Maintenance

Improper maintenance of fireplaces, wood stoves, and/or chimneys can lead to deteriorated or damaged units remaining in use, which may not perform as intended and create a fire hazard.

Inspection of Appliances

The purpose of the initial portion of a scene investigation is to document the location and condition of wood-burning appliances within a building. The level of detail of an examination of an appliance at a fire scene is dependent on the conditions at the scene, including the accessibility and physical condition of the appliance and the suspected involvement of that appliance in the occurrence. If conducting a thorough examination of an appliance at the scene is not feasible, then a more thorough examination may be conducted at a later date in a laboratory. Normally, only nondestructive inspection and testing would be performed on an appliance at the fire scene. A typical examination of the appliances would include the following steps:

1. The location and condition of each appliance should be documented and photographed. Distant photographs should be taken that depict the location of the appliance with respect to easily recognizable reference points within the building. Photographs of all accessible sides of the appliance should be taken. Inaccessible sides of the appliance should be photographed if or when the appliance is moved. Inspect and document heat and burn patterns and any other fire and/or heat damage to the appliance and adjacent objects.

2. Document the area around the appliance for clearances to combustibles, including the walls and floor of the room and storage materials, including flammable liquids. Also, check for proper clearance between the chimney piping and combustibles (walls, ceiling, etc.) of the room.

3. Photograph and document the means of supplying combustion air to the room containing

the appliance(s). Determine whether adequate quantities of air were supplied to the appliance for proper combustion. Document the layout and dimensions of any combustion air kits.

4. Photograph and document the chimney system, including its configuration, components, and dimensions (including the portion on the exterior of the building). Determine the condition, including if the chimney is unobstructed and pulling a draft. Inspect for blockages such as leaves or animal nests. Determine the configuration of a factory-built chimney, including clearances where it passes through a wall, ceiling, or roof. Inspect for damage, corrosion, or separation at joints. Record any loose or detached joints. Inspect for evidence of creosote (gray ash after a chimney fire) inside the chimney or connector. Document the presence and condition of a chimney liner. Verify that the cap/termination is properly located relative to the roof and other obstructions. Confirm whether all components of the chimney system are from the same manufacturer, and if there are mismatched parts.

5. A solid fuel-burning appliance may be equipped with a gas starter or gas log set. This configuration does not eliminate the necessity for the appliance and/or chimney to comply with the relevant solid fuel codes or standards. Record the position of any electrical switches and controls. Examine the electrical wiring for damage or evidence of modifications, which could include cut or disconnected wires or the presence of jumper wires/wire nuts.

6. Inspect and record the configuration of the gas supply piping if the appliance is equipped with a gas starter or gas log set. Document the presence of a manual shutoff valve, sediment trap (drip leg), and/or a flexible gas connector. Record the position of the manual shutoff valve. Document if the opening in the firebox around the gas pipe is sealed as well as the clearance from the gas pipe to combustibles. When feasible, measure the incoming gas pressure to the building at flow and no-flow conditions.

7. When inspecting the exterior of the appliance, document whether any access doors or panels are present and properly installed. Open or remove the access doors or panels only if they can be easily removed without altering the condition of the appliance.

8. Record identification and information labels and plates on the appliances, including manufacturer, model, serial numbers, date of manufacture, installation and operation instructions, warnings, and references to standards. Movement of the appliance or removal of debris from the appliance to accomplish that task should be kept to a minimum.

9. Document evidence of abnormal firing or overfiring, flame rollout, or excessive shooting/creosote within the appliance or its chimney. Document evidence of damage to the appliance (including internal explosion damage) and presence of excessive corrosion.

10. If the integrity of a solid fuel-burning appliance and chimney system is an issue, a smoke test of that system may be warranted. A smoke test involves sealing all openings of the system (including the fireplace front opening and chimney termination), pressurizing the system with colored smoke from smoke generators, and observing for smoke discharging through any breaches or openings.

Notification of Other Interested Parties

Reasonable efforts should be made to notify all other interested parties of an occurrence, and invite them to participate in the investigation. The forensic engineer's client, attorney, or insurance company representative normally performs actual notification of other parties. The other interested parties should be given a reasonable opportunity to inspect the scene before it is significantly altered or disturbed and participate in the formulation of plans to remove, preserve, and test the artifacts.

Removal of Evidence from Scene

Effort should be made to collect loose parts of an appliance and preserve the entire unit together. Wrapping an appliance in plastic before it is removed from the scene is an effective way to retain the debris or objects on or within the appliance. Some or all of the chimney system may need to be removed, especially if it is suspected of causing the occurrence. Prepare and distribute a chain-of-custody list of artifacts that are removed from the scene and preserved.

Figure 1
Rear of house showing chimney and chase debris in yard.

Case Study No. 1: Improper Installation of a Factory-Built Fireplace Chimney System

Incident: A husband and wife were in their house with a fireplace operating during early November. The fireplace had been operating for approximately 3 hours

Figure 2
Family room showing fireplace and chase.

Figure 3
Chimney pipes in yard.

when a fire was discovered in the attic of the single-story ranch-type house. The attic and roof portion of the house sustained damage.

Investigation: The house had been recently completed, and the owners occupied the house in April of the same year **(Figure 1)**. At that time, a factory-built fireplace and chimney system was installed in a chase in the corner of a family room **(Figure 2)**. The chimney was a double-wall type. When the homeowners used the wood-burning fireplace for the first few times that spring, they smelled burning wood in an attached garage. They did not use the fireplace during the summer, and had a natural gas log set installed in September. Between the gas conversion and the date of the fire, they had used the gas fireplace several times. The use of a natural gas log set in the fireplace did not eliminate the necessity for the fireplace and chimney to comply with the original relevant codes and standards.

The sections of chimney pipe and remnants of the wooden chase were found to be lying in the backyard. No termination cap was found for the top of the chimney. Discoloration of the chimney pipes indicated that they had gotten very hot **(Figure 3)**. The chimney had extended through a vertical wooden chase. The configuration of the chase and chimney were documented in detail **(Figure 4)**. Those components had sustained substantial damage from the fire and extinguishing activities of the fire department. Modeling the configuration of the chimney and chase revealed that the top of the chimney pipe did not reach the top of the chase **(Figure 5)**. Further, heat patterns and nails at the top of the chase suggested that a plywood cover might have been located over the opening at the top of the chase.

An inspection of an exemplar house that had been constructed by the same builder revealed that the upper portion of the fireplace chimney and rain cap clearly extended above the top of the wooden chase **(Figures 6** and **7)**.

Figure 4
Top of chimney assembly in house attic.

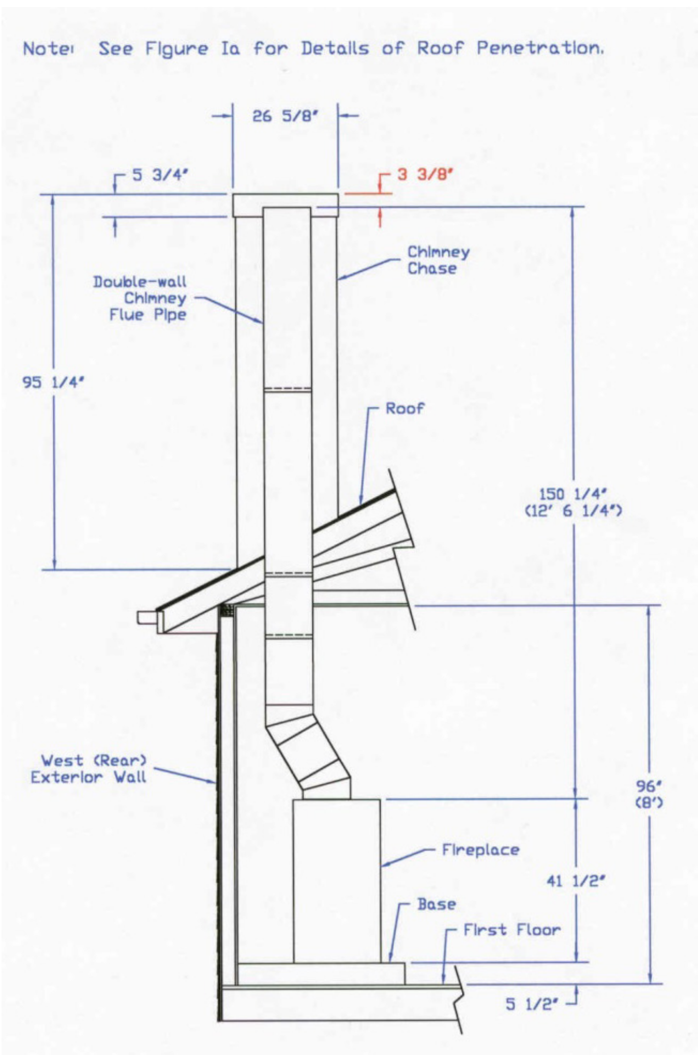

Figure 5
Elevation view of fireplace, chimney, and chase installation.

Figure 6
Exemplar house showing chimney chase.

During the investigation, a next door neighbor produced a photograph from a party that had occurred in their backyard that summer **(Figure 8)**. The photograph showed the subject chimney chase in the background, and clearly showed that nothing extended from the top of the chase. In other words, no fireplace chimney pipe and/or rain cap extended from the chase.

Since the fireplace unit was undamaged, it was later set up at the author's laboratory with a new and identical chimney system. The fireplace was then operated with the same gas log set installed, and the flue gases' temperatures were measured.

Figure 7
Exemplar chase showing chimney and termination cap extending above.

Figure 8
Subject chase before fire.

Figure 9
Family room showing fireplace and chase.

Conclusion: The fireplace chimney system had not been properly installed. The upper portion of the chimney and the rain cap were not present — and the chimney did not extend above the top of the chase. Further, it was likely that the top of the chimney chase had been enclosed. Consequently, the products of combustion from the fireplace flowed into the attic where they impinged on and heated the combustible construction and eventually started the incident fire.

Case Study No. 2: Loose-Fill Cellulose Insulation Contacting Chimney

Incident: The two-story house involved in the subject fire was constructed in 2009, and the owners moved in during the fall of that year. The house was equipped with a factory-built wood-burning fireplace and chimney within a wood framed chase (with a stone fascia) along a wall in a first floor family room, and the chase extended from the floor to the peak of the vaulted ceiling **(Figure 9)**. A second chimney was also present within the chase for a future wood-burning appliance in the basement. This second chimney had no part in the fire. The structure fire occurred in the house in February of 2010. The subject first floor fireplace had been used during the afternoon and evening of the fire, which was discovered at about 10:30 p.m. The fire was limited to the attic in the area of a wood fireplace chimney chase.

The upper portion of the fireplace chase was common to a second-floor bedroom wall. Drywall had been removed from that wall, exposing the chimney assembly **(Figure 10)**. Significant fire damage was present in the second-floor portion of the chase and the attic above, and fire damage to the house was limited to this area. Cellulose insulation was located on top of framing that surrounded the original location of two sheet metal firestop spacers located slightly below the second-floor ceiling level.

Several openings existed between the chase and the surrounding attic. Those openings were not blocked or covered with plywood, netting, or any other insulation barrier, and they permitted cellulose insulation to be blown into the chase and against the chimney at the upper firestop spacer shelf position.

Warning labels affixed to the chimney sections stated "*Fire Risk. Insulation and Combustibles must not touch pipe. Consult manual for clearance requirements.*" Information labels stated, *"Caution maintain 2 inches minimum air space clearance to combustibles and building insulation*."

Figure 10
Second-floor level showing subject chimney pipe (left).
Red line indicated original firestop spacer shelf position.
An undamaged "protected area" was present
on the unused (right) chimney pipe above the shelf.

Fire patterns on the exterior surface of the subject chimney pipe, directly above the firestop spacer shelf, indicated an area of relatively intense heat located within a larger triangular shape, which was an area originally covered with insulation that burned away during the fire **(Figure 11)**. A light coating of ash was located on the interior surface of the inner pipes of those sections. The termination cap contained black-colored deposits and loose material.

On the second (unused) parallel factory-built chimney, the portion located directly above the upper firestop spacer contained a "protected area" that was not heat/fire damaged. The maximum height of that protected area was approximately 18 inches above the firestop spacer. A pile of cellulose insulation had been located there during the fire, and protected that portion of the chimney section

Figure 11
Subject (left) and unused (right) chimney pipes.
Red line indicates original firestop spacer shelf position.

from the fire.

The fireplace and chimney installation manual instructed the installer to install an attic insulation shield around the chimney where there was a possibility of insulation coming into contact with the chimney. Also, the local building code required the fireplace and chimney to be installed pursuant to the manufacturer's instructions.

Chimney fires were a reasonably foreseeable use of the subject fireplace and chimney system, and the system was designed to safely contain a chimney fire and not permit it to spread to the building. Specifically, the fireplace and chimney system was designed and tested to comply with UL 127 *Standard for Factory Built Fireplaces*. This standard required the chimney system to successfully pass a 2,100°F flue gasses temperature test, where the adjacent combustible construction could not be heated to an unsafe temperature (the maximum permitted temperature was 175°F above room temperature). That test simulated the conditions of a chimney fire.

Factory-built chimney fire tests, involving the igniting and burning of creosote deposits on the interior surfaces of the chimneys, revealed peak chimney outside surface temperatures ranging between 278 and 811°F[8]. Those temperatures exceeded the generally accepted minimum hot surface ignition temperatures for cellulose insulation (approximately 450°F). None of the test chimneys were externally insulated during those tests. External insulation would have increased those temperatures. The only potential ignition sources in the area of origin were the heated fireplace chimney, the building electrical system, or a

Figure 12
Outdoor masonry fireplace and chimney in veranda.

lightning strike. The author's investigation eliminated the electrical system, and a lighting strike analysis eliminated that potential.

Conclusion: The point of origin of the structure fire was at and directly above the upper firestop spacer shelf location on the fireplace chimney. Fuel available at the point of origin was loose-fill cellulose insulation. The cause of the structure fire was the ignition and burning of loose-fill cellulose insulation in contact with the chimney, which ignited nearby combustible framing. The first fuel ignited was the loose-fill cellulose insulation. The ignition sequence was a likely chimney fire heating the chimney pipe, followed by the heated pipe igniting the insulation, which ignited combustible framing.

Figure 13
Wall of family room showing fire damage common to outdoor fireplace.

The subject fireplace and chimney system was improperly installed, which created a defective and unreasonably dangerous fire hazard condition. Specifically, the required attic insulation shield was not installed on the fireplace chimney. That shield was required to be installed on the top side of the firestop spacer, and its absence did not comply with the aforementioned fireplace owner's manual, codes and standards, and the standard of care.

The combustible loose-fill cellulose insulation was improperly installed in the area of the fireplace chimney in the attic. Specifically, blocking was not installed around the chimney to keep the insulation a safe distance away from the chimney.

Case Study No. 3: Improper Clearance of Masonry Fireplace

Incident: The subject house had been recently constructed. An outdoor veranda contained a masonry fireplace **(Figure 12)**. That fireplace had been built common to the east exterior wall of the house. The wall of the house was frame construction with a brick veneer. The fireplace had been used approximately 20 times previously. That fireplace had been used from approximately 5 p.m. to 10 p.m. the evening before the structure fire, burning cut hardwood logs. At approximately 2:30 a.m. the next day, smoke detectors in the house activated. The owner saw smoke and fire behind a cabinet in the family room along the exterior wall common to the outdoor fireplace.

Investigation: The east wall of the family room, common to the outdoor fireplace, had sustained fire damage (**Figures 13** and **14**). The frame wall was located directly adjacent to (and in contact with) the masonry rear wall of the fireplace. This frame wall was comprised of: house wrap fabric, ½-inch OSB sheathing, wood 2x6 studs on approximately 16-inch centers, cellulose blown-in insulation in the stud spaces, and ½-inch drywall (interior surface). The OSB sheathing was contacting the masonry at the rear side of the exterior fireplace. A burn pattern

Figure 14
Fire damaged wall common to outdoor fireplace.

through the OSB sheathing was aligned with the firebox of the outdoor fireplace.

A section of the interior frame wall, containing the fire damaged area, was removed, exposing the surfaces of the OSB plywood and masonry wall. Soot was found to be located on both surfaces. The integrity of the masonry fireplace and chimney was determined by conducting a smoke test. The front opening and chimney outlet of the outdoor fireplace were sealed, and smoke generators were placed in the firebox and ignited. No smoke was observed leaking through the rear wall.

A portion of the rear wall of the fireplace was removed, which provided access to the entire cross-section of the rear wall of the fireplace (**Figure 15**).

The overall thickness of the rear wall of the fireplace was measured and found to be about 7 inches. It was comprised of a 2½-inch-thick single row of firebrick, which was the back wall of the firebox, and a 3½-inch-thick single row of concrete masonry units (CMUs). A gap measuring between ¾ and 1 inch, between the CMUs

Figure 15
Rear wall of fireplace with portion removed, showing dimensions.

and firebrick, was partially filled with mortar. Electrical components within that wall were inspected by an electrical engineer and eliminated as a cause.

Conclusion: The subject fire was caused by heat energy from the firebox of the outdoor fireplace conducting through the rear wall of the masonry fireplace and igniting combustible building materials directly adjacent to, and in contact with, the masonry wall. The construction of the masonry fireplace and wall was improper, dangerous, and a fire hazard. The construction violated the standard NFPA 211 and the local building code. The 7-inch thickness of the masonry back wall of the fireplace was less than the minimum required 8 inches. The OSB sheathing of the interior wall was contacting the inner surface of the masonry wall for zero clearance to combustibles, which was less than the minimum required clearance of 4 inches. The thickness of the back wall and the absence of an air space clearance to combustibles provided much less thermal resistance between the firebox and the combustible wall than the building code required. This permitted an unsafe elevated temperature of the combustible wall, which resulted in its ignition.

Conclusions

When a forensic engineer is called upon to investigate whether a solid fuel-burning appliance caused a fire, the engineer should have a thorough understanding of the equipment and structures involved, the potential failure modes, and utilize a generally accepted methodology. The methodology should include application of the relevant codes and standards that provide reliable guidelines for fireplace and chimney design and installation. As the case studies showed, frequently the fire causes violated recognized codes and standards.

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