ANALYSIS AND MODEL TESTING OF A DUAL ORIGIN NATURAL GAS FIRE WITH REMOTE FUEL SOURCE AND REMOTE PILOTED IGNITION MECHANISM

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ABSTRACT

The fire investigator conducting investigations at facilities involving natural gas should consider the potential for the gas to be liberated at a location which is remote from where the fire ignited and began to burn and for there also to be a lack of burning near the location where the natural gas was first introduced. The investigator should be aware that more than one area may have fire patterns which individually appear to be a separate area of origin but which, in reality, are associated with the same first fuel and a single ignition mechanism which is remote from either area of origin. This paper presents information about a fire which occurred in a residence which was under construction but nearing completion. The frame structure included blown-in insulation within the 8-foot high 2 x 6 wall cavities, with 1/2-inch sheetrock on either side of the wall. A natural gas line that passed through one of the wall cavities contained an elbow fitting which had a threaded 21-inch long piece of pipe screwed into it. The opposite end of this piece of pipe was capped and extended a short distance through the sheetrock of the adjacent garage. A workman, on the day of the fire, failed to shut off the natural gas to the residence before unscrewing the piece of pipe and pulling it out of the wall. Once the pipe was removed, the natural gas filled the wall cavity and began to exit at two locations. One location was at the top of the cavity which led directly into an attic space. The attic extended throughout the house. The other exit was at the bottom of the cavity. This bottom exit led to a furnace air return duct. Natural gas from the lower exit was found to have passed through the duct to the connecting furnace and water heater closet, where it was subsequently ignited by the water heater pilot. The flame front in the closet then flashed back to the lower exit through the furnace air return duct to where a fire plume was created at that exit. At the same time, the flame front in the closet flashed up through the water heater stack ceiling opening to the attic, wherein it ignited the gas exiting at the top of the cavity and created a second fire plume at the upper exit location. The fire then spread throughout the attic space of the home. It also continued to burn for a time at the lower exit until the workman managed to shut off the natural gas at the meter outside the residence. The fire patterns in the building were of interest in that there appeared to be an area of origin of the fire at both exits from the insulation-filled cavity, but there had been essentially no burning inside the cavity. It was also noted that there was no evidence of direct burning inside the water heater/furnace closet. The fact that no burning occurred within the wall cavity

where the natural gas was liberated indicated that as it filled the cavity, at the same time it pushed the air out of the cavity. After the entire cavity was filled with natural gas, a low pressure leak could then occur at any opening of opportunity, such as at the top or bottom of the cavity, as it did in this fire. Burning within the cavity would have been precluded by the absence of oxygen, as long as the exterior structure surrounding the cavity remained intact. Fortunately, the fire was extinguished prior to the structure around the wall cavity burning in the subject case, leaving behind evidence sufficient to determine what had occurred in the fire sequence. In order to further illustrate the characteristics found in the fire patterns associated with the evidence, test models of insulation-filled structures were created and tested. The test models included a one-quarter scale and a full scale model. Representative photographs from the fire scene investigation and from the fire model testing are included in this paper.

FIRE INCIDENT BACKGROUND

The approximately 6,000 square-foot residence where the fire occurred was a single story, concrete slab floor, wood frame structure with flat roof areas and stucco exterior parapet walls (Figure 1). The structure had an attic that extended over the entire living space, including the garage. The residence was still under construction, but was nearly completed. The construction was complete, up to the point that all plumbing, electrical and natural gas lines were installed, with the exception of the gas connection of the boiler for the floor heating system. The boiler for that system was in the garage.

Figure 1 – The incident residence after the fire.

The walls of the residence were framed using 2 x 6 lumber, with 1/2-inch sheetrock on the walls and ceilings. The sheetrock was in place during the fire, but most of it had been removed prior to the investigation (Figure 2).

Figure 2 –The residence interior after the fire and after the sheetrock had been removed.

It was of particular interest that the ceiling height in the living areas of the home was approximately 18 inches higher than the ceiling height in the garage. This meant that the natural gas lines, which were routed just above the ceiling in the garage, entered into the end of a wall which was perpendicular to the garage wall, then progressed into the blown insulation wall cavity of the perpendicular wall, prior to turning downward for connections to the water heater, furnace and the boiler for floor heating. The gas line branch for the floor heating boiler turned downward at a T-fitting and proceeded to a location near the bottom of the blown insulation-filled cavity, where there was an elbow for connecting a short length of pipe that went horizontally back out of the cavity and into the garage. A 21-inch long length of pipe was screwed into this elbow and extended out through the garage wall where it was capped just outside the sheetrock at a location which was behind the boiler for the floor heating system (Figure 3).

Figure 3 – The floor heating system boiler in the garage of the residence. The capped gas line protruding from the wall and the nearby water heater and furnace closet can be seen behind the boiler.

Approximately two feet to the right of the boiler in the garage was an elevated closet which housed the natural gas water heater and central heating furnace. Below the closet was a furnace air return duct having dimensions of approximately 2 feet high by 4 feet wide by 6 feet long. The air return duct was constructed from wood framing, and it had a plastic vent cover over the open end in the room adjacent to the garage, which was behind the boiler (Figure 4).

Fire Investigation

Investigation indicated that fire patterns around the plastic vent cover and the structural members behind the vent cover of the air return duct had characteristics of a potential fire origin at that location (Figure 5). Additional fire patterns at the location where the natural gas line entered at the top of the end of the perpendicular wall were also of the type characteristic of a fire origin (Figure 6). Part of the evidence associated with these burn patterns was a lack of contiguous fire damage or burning between these two locations. It was of interest that except for the air return grille and its backing structural members, the fire was confined essentially to the attic of the residence and above the ceiling. The fire in the attic extended nearly throughout the entire attic and caused substantial damage to the residence. The greatest burn damage and char was located around and above the apparent second origin location where the natural gas line entered the top of the perpendicular wall.

Figure 4 –The water heater and furnace closet. Note the lack of fire damage in the closet.

Figure 5 – The burn pattern at the air return duct.

Figure 6 – The area where the gas line entered the end of the insulation-filled wall cavity.

Analysis of the Fire Evidence

Analysis of the evidence and witness interviews in the case indicated that when a workman was attempting to hook up the natural gas to the boiler in the garage, he mistakenly decided to do so without turning off the natural gas to the residence. He then failed to properly hold onto the pipe when he attempted to take the cap off the end of the pipe that was protruding from the garage wall. This led to the unscrewing of the 21-inch section of pipe from the elbow connection in the wall and removing it from the wall. At that point, natural gas began flowing into the blown insulation-filled structural cavity. The nominal dimensions of the cavity were 6 inches wide, 18 inches long and 8 feet high. In a short time, the leak filled the cavity with natural gas (Figures 7 and 8).

Figure 7 – The 21-inch pipe installed as it would have been prior to removal by the workman.

After it was filled with natural gas, gas began to exit through the enlarged hole around the natural gas inlet pipe at the top of the cavity. At the same time, natural gas found a small exit at the bottom of the cavity at the top of the plastic-grilled air return duct for the furnace. This exit was probably between the bottom edge of the sheetrock and the 2 x 6 wood framing at that location.

Figure 8 – The 21-inch long section of gas pipe which was removed from the wall cavity by the workman on the day of the fire.

The natural gas exiting at the bottom of the insulation-filled cavity was then able to proceed along the upper surface of the air return duct and back toward the water heater and furnace closet. At the near edge of the closet, it found a 3/8-inch gap above the closet floor board through which it could enter the closet (Figure 9). Once in the closet, the gas was able to rise up in the closet and pass through a hole in the ceiling around the water heater vent stack to the attic and to move into the closet until it encountered the pilot light of the water heater, where the pilot ignited the gas (Figure 10).

Figure 9 – The 3/8-inch gap above the floor board of the water heater and furnace closet where the natural gas entered the closet on the day of the fire.

Figure 10 – A similar water heater vent stack that was located in another part of the residence.

Once the gas was ignited, the flame front proceeded upward and into the attic, as well as back through the air return duct. After the initial flash fire, which left essentially no burn damage in the closet, flames began to stand at the two points where the gas was exiting the blown insulation-filled structural cavity which contained the open gas line. One of those points was at a small opening at the bottom of the sheetrock and the top of the air return duct. The other point was at the top of the blown-insulation filled structural cavity at the place where the natural gas pipe entered through the enlarged drilled hole into the insulation cavity. This second exit was at a location that was within the attic space of the residence.

Fire Cause Determination

Analysis of the evidence in the case led to the determination that the incident fire was an accidental fire which resulted from inappropriate workman conduct that led to the release and ignition of natural gas. The fire evidence in support of this determination was observed to include two areas of origin, connected by the same first fuel and an ignition source at a location which was remote from both of the areas of origin.

MODEL TESTING

Since the fire evidence of this incident fire was somewhat unusual, it was decided that fire model testing would be undertaken in order to demonstrate the sequence underlying the evidence. One objective for the testing was to demonstrate that fire plumes could be maintained at two different locations at exits from the insulation-filled cavity, without there being combustion inside the cavity.

Two models were constructed using materials of the type that had been used in the structure where the fire occurred. One of the models was built to one-quarter scale, while the other was full scale. The only difference between the actual insulation-filled cavity and the fire models was that one side of the cavity in the test models was covered with transparent 1/4-inch plexiglass instead of the 1/2-inch sheetrock. This was done in order to observe what was happening inside the cavity during the burn tests.

The one-quarter scale model is shown in Figure 11 prior to filling the model with the insulation. The copper tubing in the quarter scale model was proportionately sized to provide equivalent gas flow for the volume for the reduced size of the model. The insulation used in the tests was loose-fill fiberglass insulation, with the brand name *Attic Guard Premium*, which was the type that had been used in the residence where the fire occurred. Figures 12 and 13 show the quarter-scale model during testing. Note the near side of the model is covered with clear plexiglass. Also note that no burning occurred inside the insulation-filled cavity, even though the cavity was filled with natural gas.

Figure 11 – The one-quarter scale fire model prior to adding insulation.

Figures 14, 15 and 16 show views of the full-scale model under construction. Note the enlarged drill hole around the inlet pipe shown in Figure 15. Also note the elbow fitting shown in Figure 16. This elbow represents the location where the 21-inch pipe had been unscrewed by the workman, which allowed the natural gas to escape inside the wall cavity.

Figures 17 and 18 show the full-size model prior to testing. Note the enlarged hole seen in Figure 15 can also be seen in Figure 18.

Figures 19 and 20 show the full-scale model during testing. Note the absence of burning inside the model in Figure 19, even though the insulation cavity is full of natural gas.

Figure 21 shows the area of the enlarged hole in the full-scale model after the fire test; note the similarity to the burn pattern shown in Figure 6.

SUMMARY AND CONCLUSIONS

The investigation conducted on the incident fire resulted in a determination that the fire sequence involved the creation of two locations which had fire origin type burn patterns. The evidence was also found to be consistent with both of the areas of origin being associated with the same first fuel and a single ignition mechanism which was remote from either area of origin. The unusual fire patterns were subsequently reproduced using scale fire models. The testing of the fire models confirmed the determinations made as to the fire sequence in the incident fire.

Figure 12 – The one-quarter scale fire model during testing.

Figure 13 – The one-quarter scale fire model during testing.

Figure 14 – The full-scale fire model during construction.

Figure 15 – The enlarged hole where the gas line entered the full-scale fire model wall cavity.

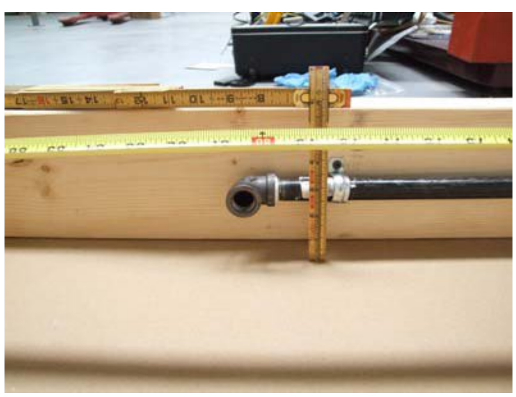

Figure 16 – The elbow near the bottom of the full-scale fire model where the gas escaped when the 21-inch pipe was unscrewed.

Figure 17 – View showing the plexiglass-covered side of the full-scale fire model prior to testing.

Figure 18 – The location near the top of the full-scale wall cavity where the gas line entered the cavity.

Figure 19 – The full-scale fire model during testing.

Figure 20 – The full-scale fire model during testing.

Figure 21 – The fire pattern created at the top of the full-scale fire model after the burn testing.

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