Use of the FDS Model to Analyze Two Competing Scenarios in an Alleged Arson Case

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BACKGROUND

A fire occurred in a residential structure in the early morning hours one day in September. At the time of the fire, three people were in the residence, two parents (age 81, male and age 57, female) and their son (age 31). The two-story house was composed of typical wood frame construction, and was built in approximately 1971. The downstairs included a living room and dining room in the front of the house and a family room, kitchen, and den/storage room with an adjacent bathroom in the rear of the house. The upstairs had four bedrooms and one bath. The master bedroom, where the two parents slept, was at the head of the stairs on the second floor. Figures 1 and 2 depict a computer generated picture of the geometry of the residence.

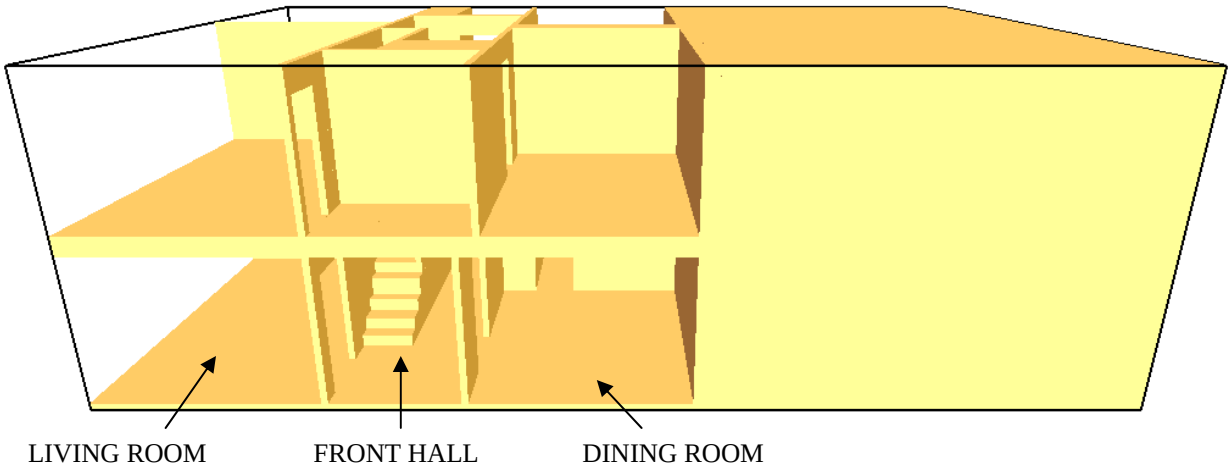

Figure 1. Geometry of Residence (view from the front of the house, north face).

The family room, which was situated in the back, left potion of the first floor (see lower right corner of Figure 2), was approximately 6 m (20 feet) long by 3.7 m (12 feet) wide with a large window and a door leading to the outside located in the west wall. The room had a brick fireplace along the south wall and plywood paneling along the other three walls. A substantial fuel load was present in the room at the time of the fire. The fuel load included a three-cushion

couch (with integral recliners at either end) along the east wall, a two-cushion love seat along the west wall, and a lift-type recliner chair near the north wall by the doorway to the kitchen. In addition, there were several small tables and a television. The family room also had wall-to-wall carpeting over the original hardwood floor.

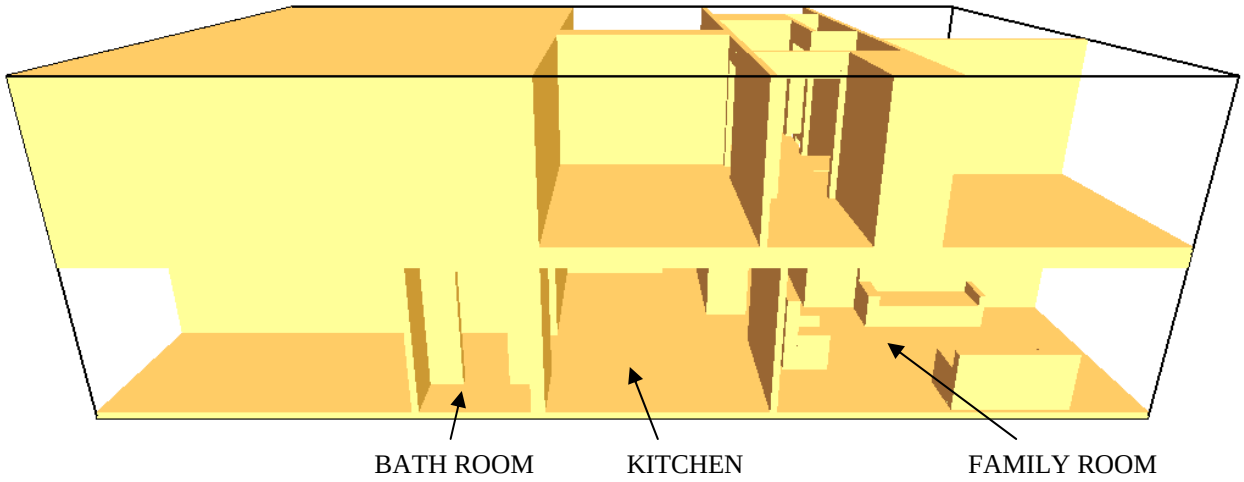

Figure 2. Geometry of Residence (view from the rear of the house, south face).

The fire was first reported by the son at 4:30 a.m. The first person to respond to the emergency call was a police officer who arrived at the scene at approximately 4:35 a.m. The son met the officer on the north side of the house and told the officer that not everyone was outside. They proceeded to the south side of the house. The officer reported that the large bay window on the southeast corner of the house had broken out and flames were venting through it. The officer found the mother on the back porch at the southwest corner of the house. The mother was found conscious and alert but suffering from burns to her upper body and head, including singed hair. The son had also obtained burns on his shoulders and head, although they were less severe than his mother's burns. The son told the officer that his father was still trapped in the house.

The first fire department units arrived at approximately 4:40 a.m. and the fire was declared under control at 5:03 a.m. A fire department search of the house found the father dead in the bathroom in the right rear of the first floor near the back door exit to the porch where the mother was found by the police officer. The mother was treated at the scene for burns and smoke inhalation and then transported to the hospital. After initial treatment in the emergency room, she was transferred to the Burn Unit of a second hospital. She ultimately died of complications from the fire in December. The son was also transported to the hospital and was treated for burns and smoke inhalation and was released.

An autopsy performed on the father revealed that he had non-lethal burns to his head and upper torso and had suffered smoke inhalation. He was declared dead by smoke inhalation as a result of carbon monoxide poisoning. His COHb was reported as 45%.

Police and fire officials conducted a cause and origin investigation. Their investigation determined that the fire originated in the family room in the left rear of the first floor. Examination of the scene revealed heavy burn damage to most of the furnishings in the family room. Heat and smoke damage was observed throughout the rest of the house with some fire extension into the kitchen and hallway adjacent to the family room.

Further investigation of the burn damage in the family room showed substantial damage to the couch, the love seat, and the lift chair. The greatest damage to the couch was at the north end (toward the kitchen) with damage decreasing toward the south end (toward the fire place). A similar damage pattern was noted on the love seat including greater damage high up on the back of the love seat. The lift chair showed greatest burn damage to the east (toward the couch). The wood paneling and studs behind the couch showed damage beginning behind the north end of the couch with a "V" pattern toward the south (fireplace). In addition, the carpet in the center of the room was heavily damaged including a substantial area where the carpet and padding had been consumed in the fire, revealing the hardwood floor underneath. The hardwood floor showed irregular discoloration in the center of the room where the carpet had been completely burned. Because of the irregular pattern on the hardwood floor, samples were taken of the carpet, padding, newspaper (used between the padding and the hardwood floor to stop squeaks), and floorboards by fire investigators and sent to a laboratory for analysis.

The son was interviewed by investigators and gave the following account of the fire. He stated that his mother had gone to bed at approximately 8:30 p.m. on Sunday night. His father subsequently went to bed at about 11:30 p.m. The son fell asleep watching the television, woke up about 2:30 a.m., and went to his bedroom. He was awakened at approximately 4:30 a.m. by his father's call for help from downstairs. He went downstairs to the family room in response to his father's call and discovered his father in the lift chair and his mother on the couch. Upon entering the family room, he observed his mother attempting to pat out a small fire on the couch with her left hand. He immediately went to the kitchen and got a pitcher of water. When he returned to the living room, he attempted to extinguish the fire with the pitcher of water but found that it had little effect on the fire. He advised his parents to get out and quickly retreated to the kitchen to call 911. While on the 911 call, he observed his parents transiting the kitchen toward the den/storage room (in the direction of the rear exit) as the fire continued to grow. Upon completion of the 911 call, he left the house through the front door. After retrieving some clothes from his car, he went to the rear of the house to meet up with his parents. When he arrived at the back of the house neither of his parents were visible. He opened the rear door and found his mother on the floor inside the door. He dragged his mother outside on to the porch but could not enter further to find his father because of the heat and smoke. He then went to the front of the house to await the arrival of emergency personnel. He met a police officer and accompanied the officer around back to his mother while advising the officer that his father was still in the house. Eventually, the son was taken to the hospital and treated for his smoke inhalation and burn injuries. The son suggested that the fire started as a result of his mother's mishandling of smoking materials.

Based on the burn damage to the residence and the son's statement, the investigation focused on the area near the north end of the couch. A lamp in this area was eliminated as a possible cause of the fire when an examination of the lamp and the adjacent outlet revealed no evidence of

damage consistent with initiation of a fire. Careless use of smoking materials could not be eliminated based on the burn damage, the statements of the son, and evidence of other smoking materials throughout the downstairs. Other possible accidental causes of the fire were eliminated as being outside the area of origin. Initial investigation reports concluded that the fire was accidental as the result of careless smoking or improper disposal of smoking materials.

In October, a report was received from the laboratory on the samples submitted by the investigators. The report showed that the samples of carpet, padding and newsprint were negative for common ignitable liquids but that the floorboards showed trace amounts of weathered gasoline. After receiving this report, one investigator changed his fire investigation report to conclude that the fire was intentionally set by the son through the use of gasoline as an accelerant. The motives given for the son's actions were that he wanted to collect the assets of his parents, and that he no longer wanted to provide care for them.

The fire investigator proposed the following account. While the parents were upstairs in bed, the son obtained 3.8 L (1 gallon) of gasoline and spread it on the carpet in the family room. He ignited the room on fire, grabbed the cordless phone, ran to the front door, went outside and shut the door, and waited for his parents to wake up. When they had been alerted to the fire, he called 911 from outside the house, held the door shut as his parents came down the stairs, and forced them to traverse the house to the rear of the building where they succumbed to smoke inhalation.

MODEL SETUP

After examining the available data, it was determined that a computer model should be employed in an attempt to determine which of the two competing scenarios was more likely to occur. The lead fire investigator insisted that the fire was a result of the son pouring gasoline in the family room, while the son maintained that the fire was the result of an accident. The Fire Dynamics Simulator (FDS) was chosen to perform the comparison.[1,2]

FDS is a Computational Fluid Dynamics (CFD) model, which is based upon Large-Eddy Simulation (LES) analysis. This methodology provides a computationally efficient method of calculating fluid flow and temperatures in a fire environment. This model allows the user to observe the calculated development of the fire through the use of a computer generated presentation of the model calculations.

The geometry was first constructed in FDS to form an accurate 3-D model of the structure of the house. In order to do this properly, measurements were taken from the residence in enough detail such that the model could be built. The model contained 900,000 cells and encompassed the entire house. The entire house was modeled in order to allow for as accurate a simulation as could be achieved. Each cell within the house measured approximate four inches on a side. After the geometry had been completed, the initiating fire scenarios had to be developed and placed into the model. The accidental scenario had two possible initiating events, while the incendiary scenario only had one.

For the accidental scenario (Case 1), two different accidental ignitions were possible: smoldering ignition from a dropped cigarette or flaming ignition from a dropped match. Previous research

conducted demonstrates that if smoldering ignition occurs it generally takes 30 minutes to two hours to transition to flaming.[3] Also, recent improvements in upholstered furniture fabrics make smoldering ignition by a cigarette much less likely. However, even these new fabrics are not resistant to ignition by an open flame. The long time frame for a smoldering ignition as well as the low probability of its occurrence led to the conclusion that the most likely ignition scenario was a dropped match that caused a flaming ignition of the couch. For the incendiary scenario (Case 2), there was only one ignition scenario proposed: the son spread gasoline across the family room floor and then ignited the floor using a flame producing element.

The FDS model allows a user to define a fire scenario in two different ways. A fire can be completely described using (1) a heat release rate curve or (2) the fire can be initiated using a small initial heat release and allowed to spread to other ignitable items. Both modeled cases utilized the second method of fire initiation. The difference between the two cases exists in the manner in which each scenario was initiated.

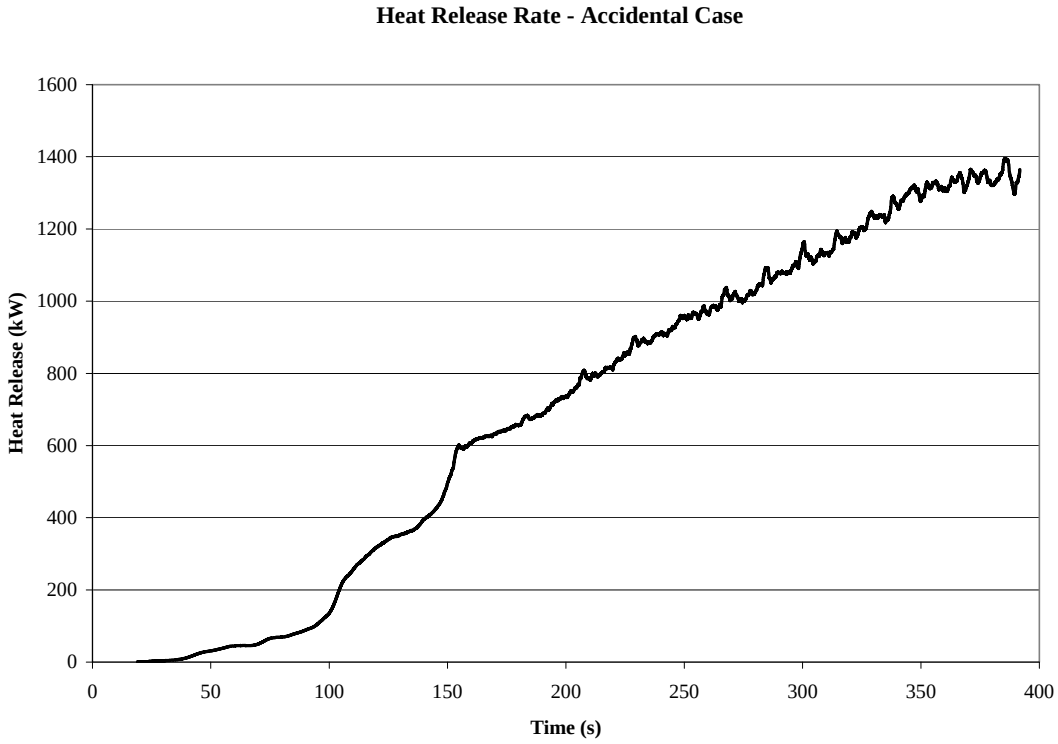

Figure 3. Convective heat release rate for the accidental fire scenario.

The fire scenario in Case 1 was initiated by a small heat release curve placed on the couch in the family room simulating a small flaming match dropped on the couch. The curve allowed a short fire exposure to ignite the surrounding couch structure and grow from that point. Flame spread rates along the couch were consistent with typical values obtained experimentally for surface flame spread along a surface.[4] Figure 3 depicts the resultant convective heat release rate modeled during this fire scenario.

The fire scenario in Case 2 was initiated by a large area of gasoline igniting, burning, and spreading quickly over a large surface area located on the floor in the middle of the family room. This surface area was approximately 6 m^2 (64 ft^2) and contained 3.8 L (1 gallon) of gasoline. Similar to Case 1, the initiating event allowed surrounding materials to ignite based on the fire conditions surrounding them. Initial flame spread rates for this scenario were consistent with gas phase flame spread.[5] Figure 4 shows the resultant convective heat release rate for the incendiary fire scenario.

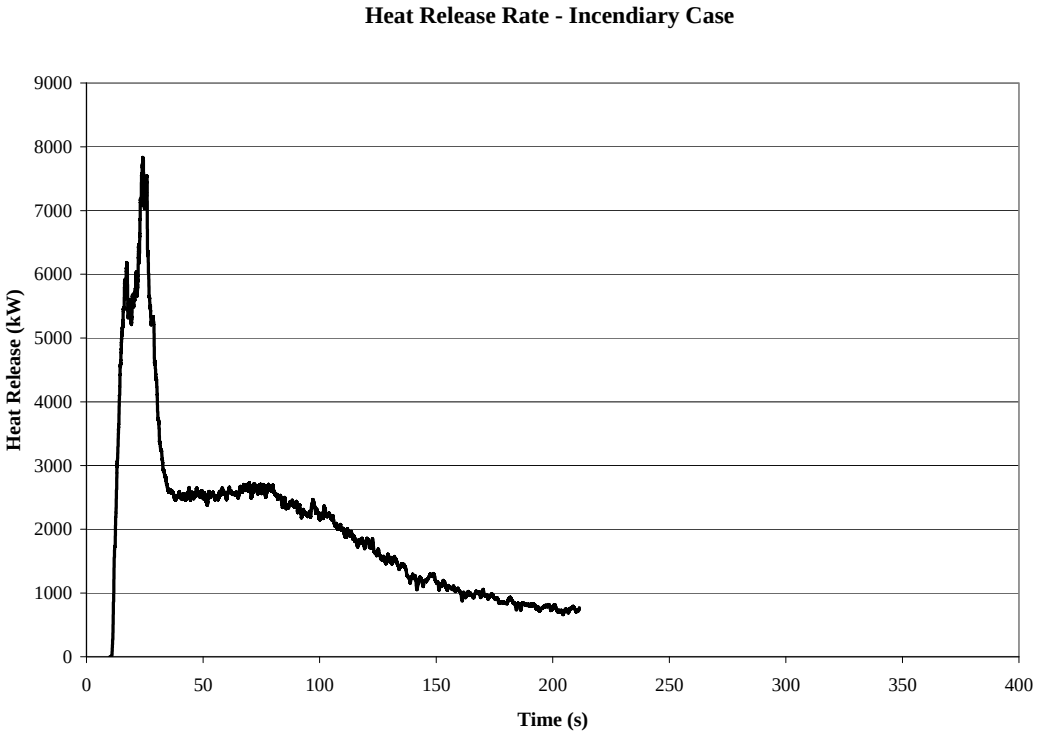

Figure 4. Convective heat release rate for the incendiary fire scenario.

RESULTS AND DISCUSSION

The model produces various resultant quantities that can be analyzed for each scenario to determine which scenario is consistent with the available data provided by witnesses and other sources. In Case 1, the greatest interest is how the tenability data fits with the story of the accidental fire provided by the son. In Case 2, again of greatest interest is how the tenability data fits with the story proposed by the fire investigator. To decide which scenario is most consistent with either of the two proposed theories, a quantity of data must be chosen to analyze such that a determination between to the two scenarios can be made. The temperature data recorded by the model was used as this quantity.

Figure 5 shows a temperature time curve for the conditions present within the family room during both the accidental fire scenario and the incendiary scenario. When the couch is burning due to the accidental scenario, the fire grows slowly and the temperatures within the room increase slowly over time becoming more and more dangerous. Conversely, the temperatures for

the incendiary fire spike early in the fire and slowly subside. This indicates a strong difference in the resultant fire conditions from each fire scenario.

Examining the accidental fire and the data presented in Figure 5, the question must be answered as to whether or not the temperature within the family room over a period of time is tenable enough for the son's story to make sense. The son claimed that he observed his mother trying to pat out the fire with her hands early on in the fire growth. This is consistent with resultant temperatures early in the fire cause by a small fire on the couch.

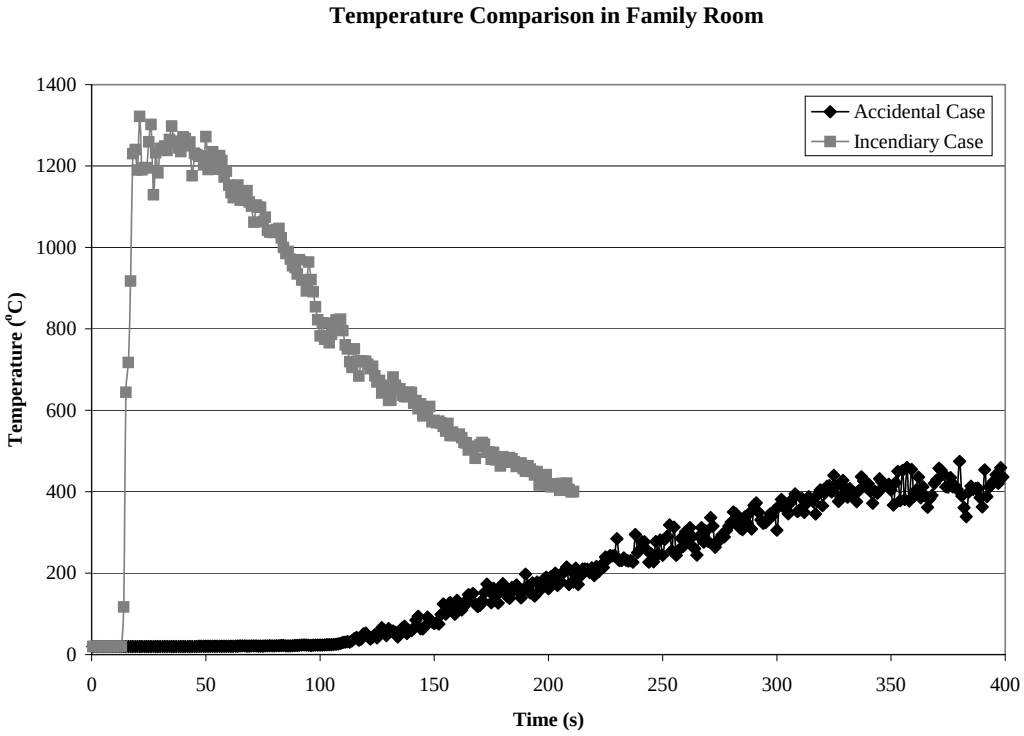

Figure 5. Temperature comparison between case 1 and case 2 in the family room.

Over the first 200 seconds of the accidental fire scenario, the temperature in the family room does not exceed 200 ^{o}C. It can be inferred then, for the accidental scenario, that for the first three minutes of the fire, the son would have had time to respond to his parent's call for help, attempt to put the fire out with a pitcher of water, call 911, urge his parents to leave the residence, and exit the house through the front door. The fire growth and tenability for this scenario is consistent with the story proposed by the son.

The incendiary scenario proposed by the fire investigator indicated that the son poured gasoline throughout the family room, lit the room on fire, and exited the building through the front door. Figure 5 clearly shows that the son would have to be moving very quickly to exit the residence without receiving significant burns. The fire investigator also indicated that the parents were upstairs asleep in their bed at the initiation of the fire. This was necessary to demonstrate that if the parents were located within the family room, the parents would have been very badly burned. In order to explain the parents being found where they were after the fire, the investigator states that the parents awakened at some point, moved downstairs, could not open the front door,

headed to the back door, and were found near the rear of the structure without severe burn injuries. In order for this to occur, the incendiary scenario must allow for temperatures cool enough to allow the parents to traverse the house over the course of a few minutes without being burned. Figure 5 indicates that conditions would have been severe enough to cause burns within the first 20 seconds from ignition. Figure 6 shows the temperature versus time in the front hallway near the stairs and the front door.

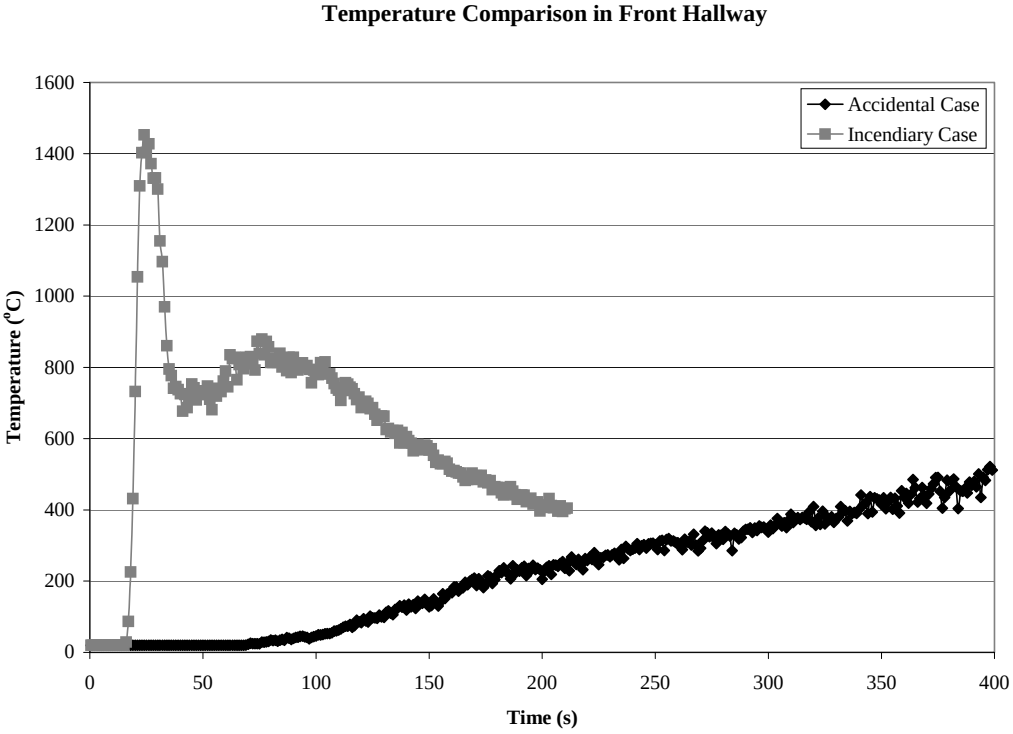

Figure 6. Temperature comparison between case 1 and case 2 in the front hallway.

It is apparent from Figures 5 and 6 that in the incendiary case the temperatures within the house become completely untenable very quickly. This result shows that if the parents were indeed in their bed asleep when the fire was lit, they would have most likely succumbed to the fire in their bedroom.

CONCLUSIONS

The FDS model was used to compare two competing scenarios in an alleged arson case. The analysis of each scenario using the FDS model demonstrated that the incendiary scenario was implausible based on the available evidence, possible time lines, and resultant fire conditions within the residence. The analysis of the temperature data within the residence indicated that the more probable scenario that was consistent with the available data was the accidental fire scenario.

REFERENCES

1. McGrattan, Kevin and Forney, Glenn, “Fire Dynamics Simulator – User’s Manual”, NISTIR 6469, January 2000.
2. McGrattan, Baum, Rehm, Hamins, and Forney, “Fire Dynamics Simulator – Technical Reference Guide”, NISTIR 6467, January 2000.
3. Ogle, R. A., and Schumacher, J. L., “Fire Patterns on Upholstered Furniture: Smoldering versus Flaming Combustion”, *Fire Technology*, Vol. 34, No. 3, 1998.
4. Drysdale, Dougal, “Spread of Flame”, *An Introduction to Fire Dynamics*, John Wiley & Sons, 1999.
5. Quintiere, James, “Surface Flame Spread”, *The SFPE Handbook of Fire Protection Engineering*, 2nd Edition, 1995.