New insights into ventilation

The International Fire Instructors Workshop (IFIW) gathered in March 2011 in Indianapolis. Numerous firefighters and scientists were there to give lectures. Several of these lectures were about changed fire behavior and the influence of ventilation. Ventilation is hereby defined as the planned, systematical and coordinated removal of heat, smoke and other fire gases by replacing them with fresh air.

1. The fire formula

There's a growing awareness that fire behavior is rapidly changing. In the US the concept of the "Fire Formula" is used to clarify this changing fire behavior. This formula is made up of five components: bigger houses, open spaces, greater fuel loads, hidden spaces and new building materials. It is stated that these five components are equal to quicker fire spread, less time till flashover, more rapid changes in fire behavior, shorter time periods in which to evacuate and faster collapse of structures.

1.1 Bigger housing

In the US an evolution can clearly be seen when it comes to housing size. For the past 30 years, surface space of houses has increased by 40%. In Belgium things haven't progressed at that pace in the area of housing size. However, a phenomenon that has been occurring the past decades is the increase in building levels. A rising number of towns and cities are being developed with low and middle rise apartment buildings. Because of a shortage of land slabs designated for housing construction, apartments are now being built larger than before.

1.2 Open spaces

In past housing, the kitchen was often separated from the dining area. The living room was yet another space. These rooms were separated by a wall and usually there was a door closing off the areas. Nowadays the dining area and the living room form a single space. The concept of an open kitchen is more frequently applied. This leads to the creation of a single large area. Such an open area contains substantially more fuel and a larger volume of air (oxygen). This will lead to an increased peak power generated by the fire.

1.3 Greater fuel load

The nature of furnishings has also changed drastically over the last 50 years. A seat is nowadays constructed with a polyurethane sitting. Polyurethane is a product that's derived from oil. Therefore a modern seat contains a lot more energy than the seats of past days. Because of this, such seats are often described as "solid gasoline". A modern seat can release 3 to 4 megawatts (MW) worth of power providing there's sufficient oxygen in the room. A power of 2 to 3 MW is sufficient to progress a compartment fire to flashover. A three person couch will produce a power three times as high as the power of a single seat. Aside from a seat and a couch, a living room will contain many other objects adding to the fuel load. These days those objects are primarily synthetic products. More often than not, the maximum power will not be achieved due to lack of oxygen. Because of this an important quantity of pyrolyzates will not burn up, but will remain inside the room in gaseous form. When at some point after that extra oxygen is made available, the power of the fire will rise swiftly.

1.4 Hidden spaces and new building materials

Fig 1.1 Wooden frames. *(Photo: NIST).*

In the US a lot of housing is constructed using wood. In the past this was done by using solid wooden beams. Lately more and more calculated rafters are being used. Engineers have developed wooden I shaped beams and frames in which wood and metal are combined. In North America this is referred to as "replacing mass with math".

When these kinds of constructions are finished at the bottom with board material a large hidden space is formed where smoke gases can amass. Likewise when lining walls with plasterboard, hidden spaces are being created in which smoke gases can move around and even start a fire where a wooden structure is being used. Should a (partial) collapse occur, a hidden fire could find itself on the floor below and spread there. Recent studies have shown that the fire resistance of such a construction is limited to only 10 minutes. Therefore in the US, firefighters often experience the problem of falling through floors. In Belgium the use of such floor constructions is rather rare. Wood is however becoming more frequently used as a building material, so what's happening right now in the US could be perceived as a warning for things to come.

2. Research by UL

Underwriters Laboratories (UL) is a well-known institute in the US. They perform all sorts of research pertaining fire, fire resistance tests, inspections, … Their research is primarily focused towards industries but as of late, studies are also being done into the domain of firefighting. Researchers were curious about the effect of ventilation on fire behavior in new housing. UL has access to a large research hangar (1.338 m²). Inside the hangar two houses were constructed: a single story house and a two story house. A total of 15 fires were started inside these houses. Fire behavior was observed and afterwards the houses were vented. The five different scenarios were studied:

1. Opening the front door
2. Opening the front door and venting horizontally close to the fire
3. Opening the front door and venting horizontally far from the fire
4. Venting horizontally before opening the door
5. Opening the front door and venting horizontally through 5 windows

The results of the research were published under the form of an online training course. Every firefighter with an interest for the subject should look into this course. The training course is called "Impact of ventilation on Fire Behavior in contemporary and legacy residential construction". It can be found at www.ul.com/fireservice.

Fig 2.1 Single story house (112 m²) *(Photo: UL)*

Fig 2.2 Two story house (297 m²) *(Photo: UL)*

3. Opening the front door = venting

3.1 Experiment

Out of all the different tests performed by UL, one in particular really was an eye opener. The fire was initiated for a scenario in which only the front door was to be opened. Next the fire was given time to grow. As expected, the fire developed into an under ventilated state. The arrival of the fire department was enacted. The front door was then opened up just as it would have been done by fire crews to enter and attack the fire. It is very interesting to observe how the heat release rate (the power) of the fire evolves after the front door was opened. Up until this point the fire had been under ventilated and it's power was limited by a lack of oxygen. By opening the front door, air is again allowed to rush in. The fire happily accepts this supply of air to crank up its power. The time elapsed from the opening of the front door and the rapid increase in power is about 80 seconds. In reality this is the time used by firefighters to enter the residence. Advancement into the building will be conducted under rather "cool" conditions until suddenly ventilation induced flashover occurs. Firefighters caught unawares in such a situation are sitting ducks.

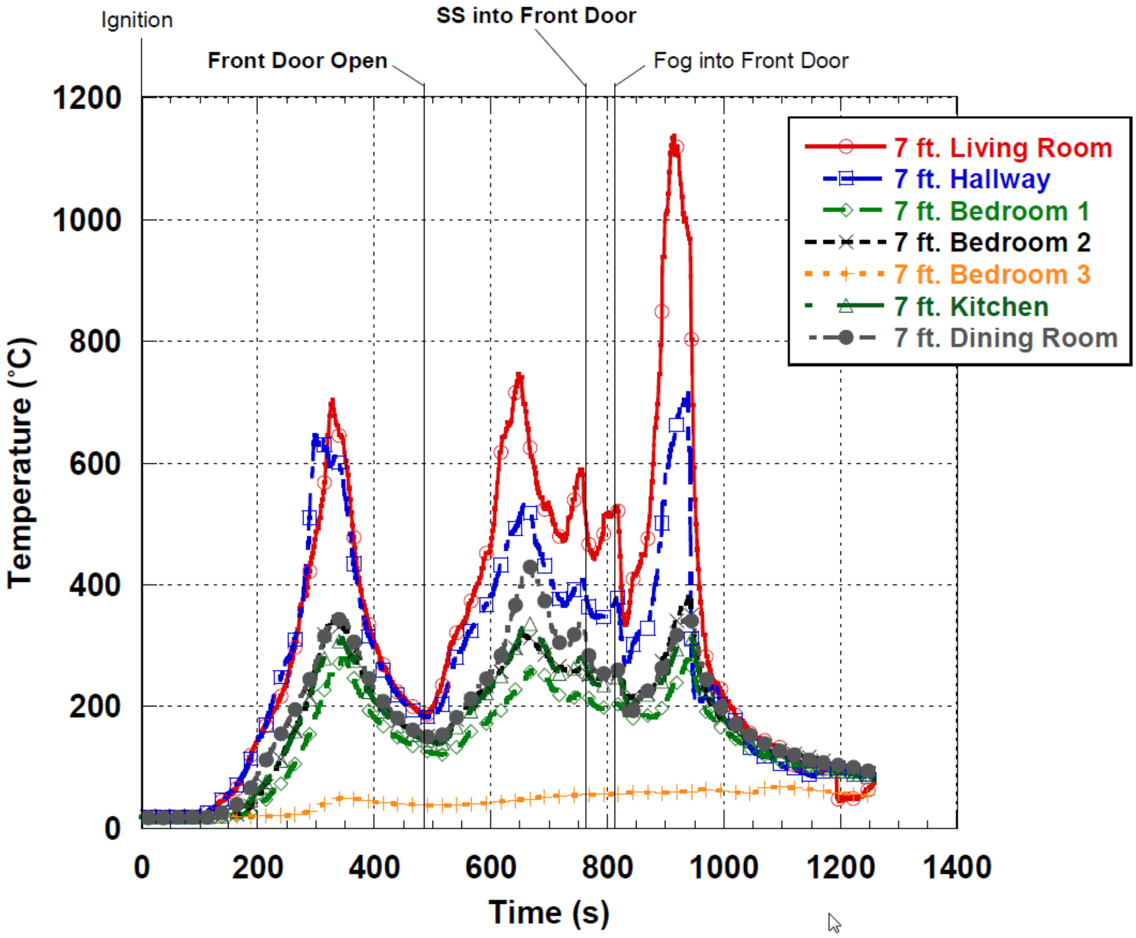

Fig 3.1 The temperature-time line of the experiment shows the start of the increase in power shortly after opening the door.*(Graph: Underwriters Laboratories)*

3.2 Conclusions

The results of this experiment clearly show that it's inadvisable to open up a door without a manned and charged hose line being ready to tackle the fire. From the moment the door is opened up, the clock starts ticking. Very shortly after opening the door, the power of the fire will progress violently. By closing the door, the clock can be stopped.

4. Research by NIST in a building containing student flats.

4.1 The building

The American NIST was given a building by the university of Arkansas. The building contained student flats and was scheduled for demolition. Built in the 50s, the load bearing structure was made up of concrete. The walls separating the different flats were built using masonry.

The ground floor was used for the experiments. Here, five separate student flats were located connected by a large hallway of 19 meters long, 2,5 meters wide and 2,4 meters high. Each flat measured 3,44 by 4,48 meters.

Fig 4.1 View on the hallway *(Picture: NIST)*

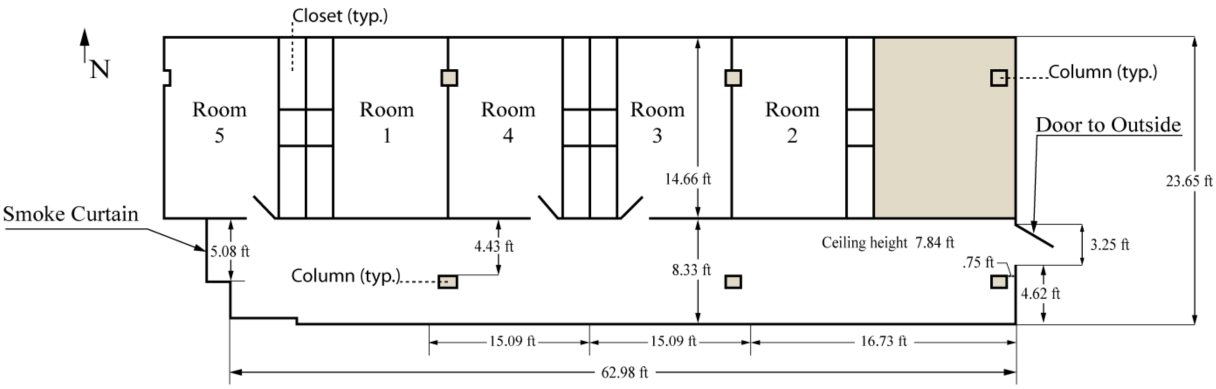

Fig 4.2 Floor plan for the ground floor. *(Image: NIST)*

4.2 The experiments

4.2.1 The fuel load

Every flat was furnished with fuel load similar to that of a standard student room. A carpet was placed on the ground. There were also a bed with some pillows, a desk with a computer, study books, posters on the wall, a wardrobe, …

4.2.2 The tests

In the first test a fire was started in room 1. The door was closed. The fire reached a limited peak after 210 seconds after which it entered the decay stage. The maximum temperature was registered 30 cm below the ceiling and reached 200 °C (see Fig. 4.3)

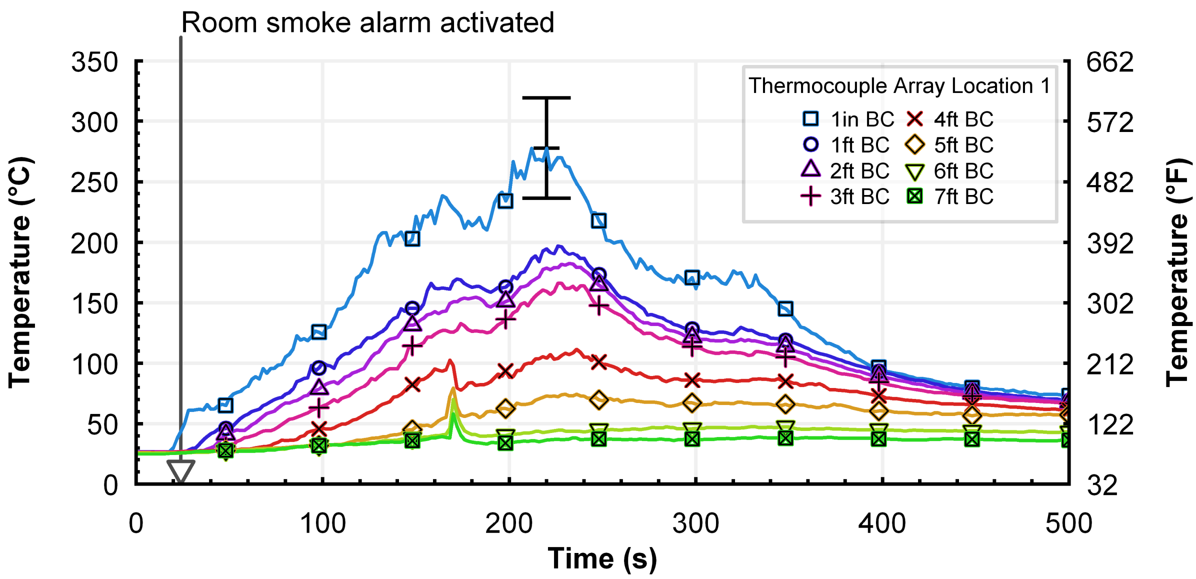

Fig 4.3 Development of the temperature inside the room with the door closed. *(Graph: NIST)*

For the live fire test in room 5 the door was left open. Therefore a similar room produced completely different results. At first a smoke layer was formed of which the temperature was significantly higher than during the first experiment. After 200 seconds the temperature below the ceiling started increasing rapidly and after 400 seconds flashover occurred. Contrary to the first test, the entire flat was lost to the flames. In addition it has to be noted that this fire, in reality, would endanger the entire building. Providing there are smoke detectors, the residents will be able to get themselves to safety. The fire will however force hot smoke gases into the hallway and into the neighboring rooms. This will cause a swift expansion of the fire if firefighters aren't quick to intervene.

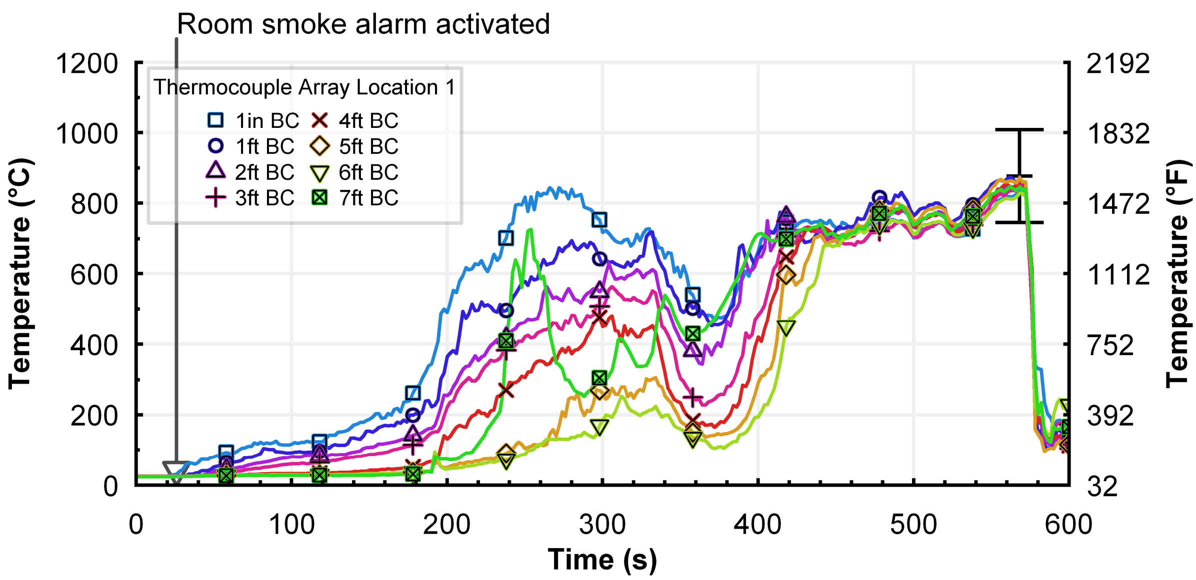

Fig 4.4 Temperature development inside the room with an open door. The temperature rises significantly after 200 seconds. Flashover occurs after about 400 seconds. *(Graph: NIST)*

4.3 Conclusion

Again this set of experiments clearly shows us that ventilation is of great importance in relation to fire behavior. In normal sized rooms a fire is unable to develop into flashover provided the door and windows are shut. Fire crews are able to use this information in several different ways. It's possible to slow down a developing fire by closing an open door. The flip side is that firefighters absolutely have to realize that opening a door allows air to rush into the room. This newfound air supply will allow the fire to increase its intensity. In extreme conditions this will lead to a ventilation induced flashover. Ventilation can therefore either be beneficial or adverse for firefighting operations. *He who controls the air, controls the fire…*

5. Bibliography

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