STUDY REGARDING USING POSITIVE PRESSURE VENTILATION IN CASE OF FIRES

POPA CONSTANTIN*, PANAITESCU VALERIU **

* *Academia de Poliție "A. I. Cuza"- Facultatea de Pompieri, Str. Morarilor nr. 3, București*

** *Universitatea „Politehnica" București, Splaiul Independentei numărul 313, Sector 6, București*

Abstract: In high buildings fires, most of the casualties are situated at the top floors - asphyxiated because of the smoke and hot gases - although the fire occurred at a lower floor. The smoke and hot gases travel from one floor to another mainly using the stair shaft. If this stair shaft would be pressurized, then the people at the top floors will be able to use the stairs for evacuation, as smoke and hot gases will find other way to dissipate. The research below uses a fire modeling on a high building, to assess and approximate the influence of positive pressure ventilation.

Keywords: *ventilation in fires, FDS, firefighting, positive pressure ventilation*

1. INTRODUCTION

In the firefighting, the term "ventilation" is used to define the removal of heated air and smoke from a structure, and their replacement with fresher air. Positive Pressure Ventilation (PPV) is achieved by forcing air into a building using a fan or a blower, to increase the pressure inside, relative to outside atmospheric pressure.

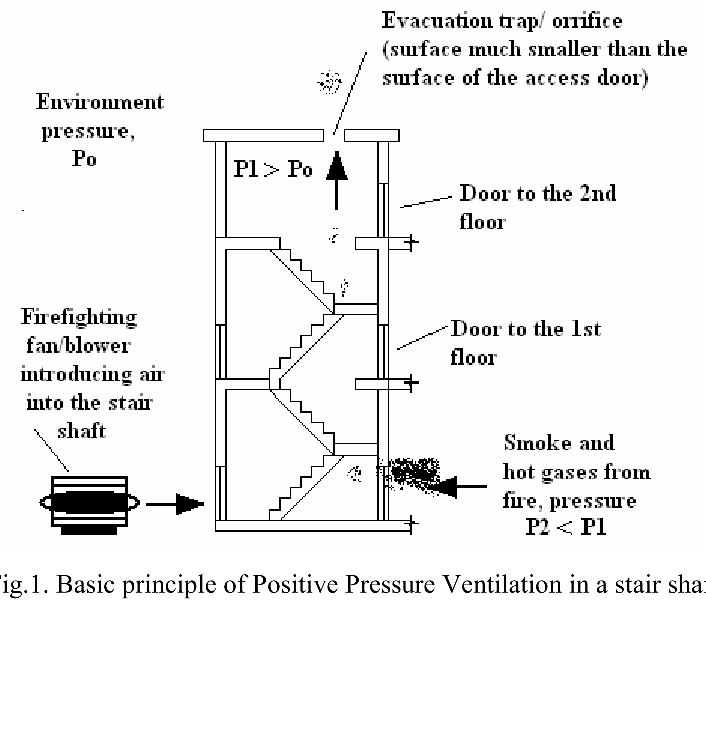

Fig.1. Basic principle of Positive Pressure Ventilation in a stair shaft

Extracting smoke from the fire compartment as a part of operational fire fighting would be most beneficial, but sometimes it involves certain risks when initiated during the fire. In some cases the smoke ventilation is advantageous: the hot gases are removed from the fire enclosure, the visibility improves and the enclosure cools down. In other cases the opposite happens: with the accelerated burning rate, more smoke is spread around, and the temperatures rise. The basic principles of PPV are relatively simple, as can be seen in figure 1.

2. PRACTICAL CONSIDERATIONS

As said, Positive Pressure Ventilation is accomplished by using high powered fans/ blowers outside the burning building – typically close to a door opening – to force heat and smoke out of the building, on another exit. An exhaust opening, e.g. a window or a trap, is required to direct the smoke out in a controlled way. At its best, the PPV technique rapidly reduces temperatures, and the removal of smoke and toxic gases improves visibility inside the structure, increasing in the same time, the survivability for potential victims.

2.1. EXPERIMENTALLY VERIFIED ADVANTAGES OF PPV [1]

The experimentally verified advantages of using PPV in a fire emergency situation are:
- reduced temperatures: at key fire fighting positions, for example, PPV contributed to temperature reductions from 450 °C to 50 °C within 1minute;
- improved air quality: PPV was shown to contribute to oxygen addition and carbon monoxide removal;
- faster smoke removal and faster restoration of visibility: when PPV was used, fire fighters had water on a residential fire 6 min after it began and were walking upright in a cool, high-visibility environment. By contrast, 8 min after the start of a second, identical fire in which PPV was not used, fire fighters were still crawling around a hot, smoke-filled environment;
- reversal of the direction of flames away from the fire fighting location: for example, flashover flames that entered a hallway were pushed back into the burning room soon after the start of PPV;
- no spread of heat damage.

If, when we talk about the reasons why PPV is not widely used in the developing countries, such as Romania, the answer is obvious. On one hand, the infrastructure of buildings and city housing are not so complex, and on the other hand, fire service is still caught in a developing stage, and do not find the reserves to properly invest at large scale in PPV; The mechanical basis respectively power fans, exist as firefighting equipments, but the “know how” to use them and create PPV in order to use it during a fire, and not only after it is suppressed, to exhaust the smoke, is not fully developed. Therefore, this research proves once again that the development of fire system in Romania and all developing countries should evolve, but, if finances are invested only in equipment, but not in tactical firefighter’s education also, the evolution is not a real and healthy one.

As well as for developing countries, but mainly for Western Europe and American fire services, we can find two more reasons why, although PPV has its benefits, still it is not commonly used by fire departments.
First, the fire service tradition is typically such that it is difficult to get new technologies or methods accepted; fire fighters are resistant to change. Second, the concept of introducing large amounts of fresh air into a burning building is not popular. [2]

2.2. STAIR SHAFT VENTING ANALYSIS

The authors chose to underline ventilation in a stair shaft, as it is a very important part of a building, in case a fire or other emergency situation occur, that’s because it is the most usual and rapid way to get out of the building (civilians), but also to get into it (firefighters).

In some pioneering fire brigades in the USA, PPV has become a standard operating procedure. The Los Angeles department is already routinely using PPV to pressurize stair shafts in high-rise buildings. Based on experience, probably the most amazing benefit of PPV to the fire fighter is the increase in visibility. [1]

2.3. FDS SIMULATIONS ON A STAIR SHAFT. RESULTS, DISCUSSIONS.

Fire Dynamics Simulator (FDS) is a computer program designed by the specialists at National Institute for Standards and Technology (NIST) in U.S.A., and is used by fire researchers all over the world, to simulate the development and all involved characteristics of fires, with given primary conditions (fire enclosure, fuel, wind current, etc.).[6,7]

Two simulations were made, both of them on the same building, in the same conditions. The difference is that in the first - which will be called *standard simulation* – no PPV was used; the second, *PPV simulation*, is the same as the first one, with PPV acting in the stair shaft, pressuring it. The stair shaft subject to this research, and the fire compartment as explained in the following, are highlighted in figure 2.

The fire origin office is situated close to the fire shaft, as it can be seen in the figure above. The room has 3mx3mx3m dimensions, an open door of 2m x 0,8m and o closed window of 1m x1, 6m x 0,004m. The fire load is considered to be 511 MJ/m^2, and the heat release rate (HRR) 250 KW/m^2, according to the destination of the enclosure (see Euro Code 1).[8]

Simulations are made in a computational domain of 14 m wide, 18 m long and 18 m height. The total number of cells inside whom are made hydrodynamic calculus is 656.100. The fire ignites on the locker in the office; the ambient temperature is 20 ^{O}C. The simulations were done on a computer with 2400 MHz Intel Core 2 Duo processor and 1024 MB DDRAM memory. In the table 1 can be seen few parallel information about the two simulations.

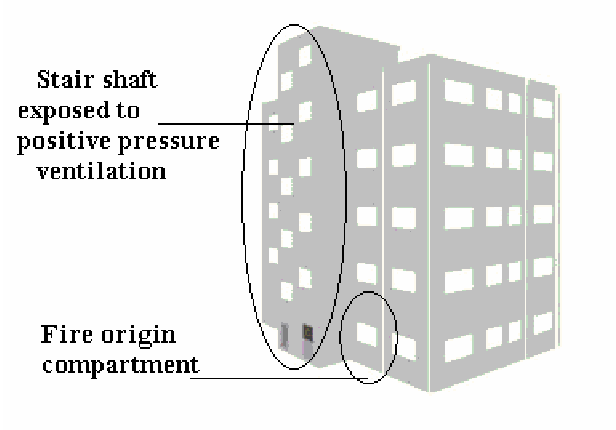

Fig.2. The building subject of the fire modeling. Emphasize on the fire origin office and on the stair shaft (in section) to be pressurized

As a real story of this hypothetically situation, we can have the following: during a normal work day, the office situated at the first floor burst on fire, because of an electric malfunction. With the door being open, the smoke soon fill up the hallway (see figure 3) situated at the first floor, beginning to evolve on the stair shaft, through the imperfections of the door situated between the hallway and the stair shaft. Smoke emerges also through the toilet window (0, 3 m^2) which was left open (see figure 3).

Firefighters soon arrive, (120 seconds after the initiation of the fire) and in order to allow people at upper floors to use the stairs to evacuate the building, pose at the entry into the stair shaft, a powerful fan which generates a great air flow current, pressuring the enclosure, stopping the smoke to dissipate outside the hallway, on the stair shaft, in large quantities. As previously said, standard simulation shows what could have happened if no PPV would have been used, and the PPV one shows what happen when firefighters use the fan to create a safer exit for the building users.

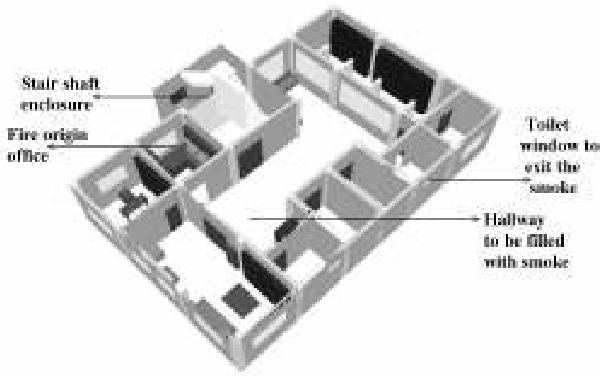

Fig.3. The building subject of the fire modeling. Plan of the first floor (in section)

The stair shaft is approximately 17, 5 m high with a footprint of 20 m^2. The total volume of the stair shaft is approximately 350 m^3. This does not take into consideration the volume filled by the stairs and landings.

Parallel information for the two simulations. Table 1

No.	Item to compare	Standard simulation	PPV simulation	Observations
1	Total time of simulation	600 s	600 s	The real time of computer working differs from one simulation to another, because in the second one, a new condition was introduced, the pressure produced by the fan
2	Real time of computer working	9,34 hours	10,49 hours	
3	Total number of iterations	8936	9521	

Assuming the airflow through the exterior doorway produced by the PPV fan was 1 m^3 /s, results an air change on the stair, once at 350 seconds. The venting rate for the stair shaft provided by the PPV system was approximately 10,2 air changes per hour (ACH). This is high compared with the 6 ACH required by the NBC for venting floor areas in high-rise buildings to aid firefighting. [3].

In these conditions, it can easy be seen in the parallel pictures (see figure 4) that smoke is allowed in a large quantity inside the stair shaft in the standard simulation, while the pressure in the stair shaft produced by the fan (firefighters fan or the fan which the construction is provided with, no matter) do not permit smoke to dissipate in large quantity. Also the same, in figure 5 can be observed the real differences between the air flow speed vectors, in the 6th figure the differences in levels of carbon monoxide. According to data received, also the levels of temperatures follow the same pattern. [12]

A comparison of the results in the two simulations can be viewed in table 2. Analyzing the table above, we can conclude:

- If a level of 100 ppm causes severe sickness [11], then for sure, the diminishing (starting at 120 s of PPV simulation) from 40 ppm to 15 ppm is more than welcome, when we think about usual people that need that exit, and are not wearing breathing apparatus;
- The level of smoke is quickly dissipated, finally is drawn out of the building through the small venting

outlet way on the top of the shaft (0,25 m^2);

- Pressure, by using the fan/ blower, rises from 0,45 Pa to 15 Pa;
- Temperatures are cooled down from approximate 35 °C in the standard simulation, to 20 °C in the PPV one.
- Visibility. An important item, it rises from minimum of 0, 5 meters to a minimum of 16 meters.

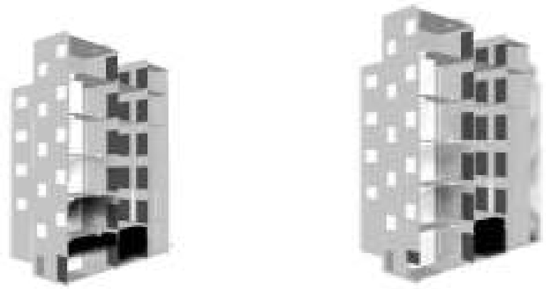

Fig.4. FDS Slice - Image of the two simulations at 140 s fire time.
Only smoke visible. Standard simulation (left), and PPV one (at the right side of the figure)

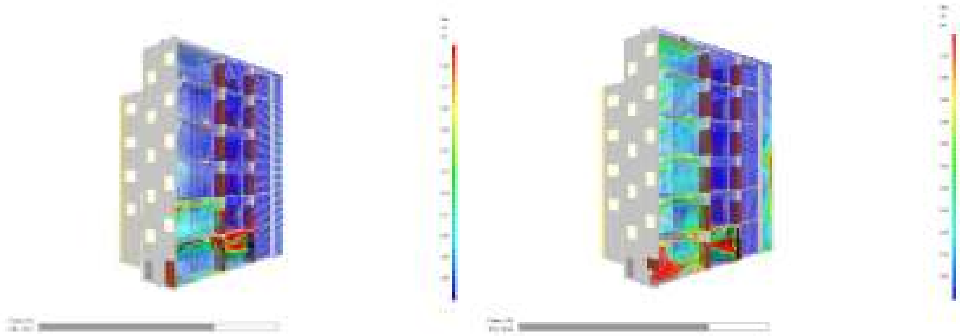

Fig.5. FDS Slice - Image of the two simulations at 144 s fire time.
Only air flow speed vectors visible. Standard simulation (left), and PPV one (at the right side of the figure)

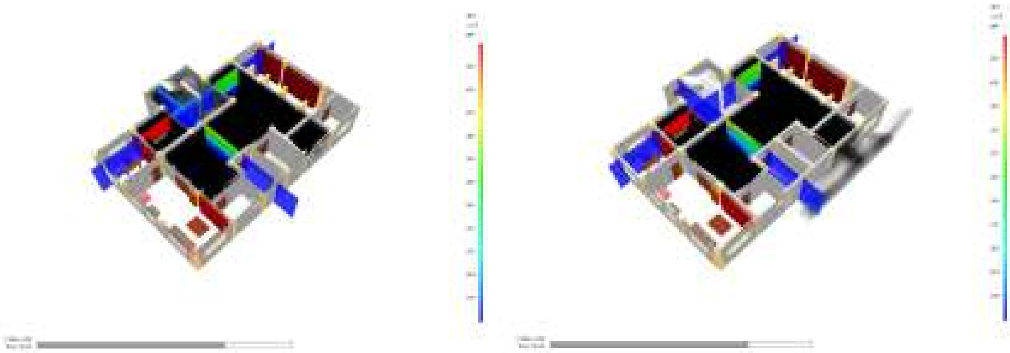

Fig.6. FDS Slice at the level of the first floor - Image of the two simulations at 144 s fire time.
Only levels of carbon monoxide visible. Standard simulation on the left, and PPV one
on at the right side of the figure

Comparison of the two simulations results, at chosen simulation time of 144 seconds, analyzed on the stair shaft. Table 2

	Items to compare	Standard simulation	PPV Simulation
1	Levels of Carbon Monoxide	Max 40 ppm	Max 15 ppm
2	Level of smoke	Approx. upper half of the 1st floor, evolving to the 2nd	dissipated to upper floors
3	Pressure into the shaft	15 Pa	0,45 Pa
4	Temperatures	35 °C	20 °C
5	Visibility	Min 0,5 m	Min 16 m

3. CONCLUSIONS

Using PPV in case of a fire in a high building, as proved in the research above, is more than welcome, as it helps users to evacuate, and firefighters to gain a clean access through the ventilated stair shaft. In Romania this kind of ventilation is rarely used, mainly because people are used to do things in the classic way, and in one's opinion, inserting fresh air in a building in fire, feed the fire, so it will grow larger. This is the reason why this kind of researches must be completed, published and applied in as many practical situations possible.

REFERENCES

[1]. Maarit T.- *Smoke ventilation in operational fire fighting,* VTT Building Technology Technical Research Centre of Finland, Espoo, 1997.

[2]. Martin T. - *The use of positive pressure ventilation in firefighting operation*, Home Office Research into Positive Pressure Ventilation, 2002.

[3]. Lougheed G.D., McBride P.J. and Carpenter D.W. - *Positive Pressure Ventilation for High-Rise Buildings NRC-CNRC Research*, Institute for Research in Construction National Research Council, Canada, 2002.

[4]. Rimen, J.G. - *An assessment of the use of positive pressure ventilation in an unpressurised Stairwell.* London, 1997.

[5]. Brian H. - *Firefighting in under-ventilated compartments*, Fire Statistics and Research Division Office of the Deputy Prime Minister, London, 2005.

[6]. McGrattan K. B. - *Fire Dynamics Simulator (Version 4) Technical Reference Guide*, NIST Special Publication 1018, Fire Research Division, Building and Fire Research Laboratory in cooperation with VTT Building and Transport - Finland, NIST, 2006.

[7]. Anghel I., Darie E. şi Flucuş I. - *Simularea numerică a unui incendiu într-o clădire cu structură uşoară* - A IX-a Sesiune de Comunicări Ştiinţifice cu participare Internaţională a Academiei de Poliţie "Al. I. Cuza" - Facultatea de Pompieri, p. 101-108, Bucureşti, 2006.

[8]. *** Eurocod 1: *Acţiuni asupra structurilor Partea 1-2: Acţiuni generale-Acţiuni asupra structurilor expuse la foc,* p. 43-44, 2004.

[9]. *** *Normativ de siguranţă la foc a construcţiilor*, P 118- Institutul de proiectare, cercetare şi tehnică de calcul în construcţii, Bucureşti, 1999.

[10]. *** NFPA 204 - *Standard for Smoke and Heat Venting*, National Fire Protection Association, U.S.A., 2002.

[11]. Flucuş I., Anghel I. and Popa C. - *Human incapacitation in fires* - a XI-a sesiune de comunicări ştiinţifice cu participare internaţională „Omul în organizaţia bazată pe cunoaştere" -Technical sciences section - a Academiei Forţelor Terestre „Nicolae Bălcescu", p. 232-239, Sibiu, 2006.

[12]. Popa C., Anghel I. and Panaitescu V. - *Ventilation in fire emergency situations, a life saver* - Conferinţa Naţională de Termotehnică cu participare Internaţională, Ediţia a XVI-a, 31 mai-1 iunie 2007, Ploieşti, ISSN: 1843-1992.