Simulation of Watermist System in ICUs

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Abstract

In case of fire, one of the biggest concerns is safe evacuation of people from the fired place or building. It will be more critical when fire happens in a hospital where displacing patients may cause irreparable injuries to them. Regarding this point, utilizing an appropriate firefighting system is of great importance as we discussed in our previous study (2014) on fire in road tunnels. Watermist system with its undeniable advantages as claimed by suppliers could be a reasonable choice as firefighting system of hospitals. Considering that watermist system eliminates two elements of fire triangle, heat and oxygen, in this study, an intensive care unit (ICU) has been modeled by FDS (fire dynamic simulator) software to find out percentage of oxygen reduction and temperature status during system application. The results of modeling help us predict the condition experienced by patients and develop guidelines to review hospital safety instructions and standards.

Keywords: water mist system, ICU, oxygen, hospital

I. Introduction

Trample and other disasters concerning mass crowd frequently happen in public places prone to fire, and the public evacuation safety draws the whole society's attention [1]. Hospital is such a public place; if safety infrastructures are not predicted, it would not be possible to prevent the catastrophe. In this case, utilizing an appropriate fire fighting system will be priceless. Watermist system, as claimed by suppliers, can play a key role to save patients who are critically ill or paralyzed. The key to its success lies in the capability of small water droplets to suppress or control a fire incredibly efficiently.

For a fire to survive, the presence of the three elements of the fire triangle, oxygen, heat and combustible material is needed. Removal of any of these elements can suppress or extinguish a fire. A traditional water-based system removes the heat element of the triangle whilst watermist removes both heat and oxygen. The smaller a water droplet size, the larger the surface area becomes and the more effective the system becomes in rapid reducing the temperature and oxygen at the flame front of a fire. This is because the heat absorption capacity of watermist is greater than any other water-based suppression systems. To put it another way, when water is converted to steam – which is what happens to the water droplets in watermist – then quite a lot of energy is used, energy which is taken from the fire which has occasioned the watermist discharge. This reduces the strength of the fire [3].

As studying on this case is rare and considering the safety of patients and the normal operation of hospital, it is not appropriate to carry out experimental fire test; thus in this study we conduct simulation of fire and the water mist system activation in one of the most critical places in hospital, ICU."

II. Introducing FDS Software

Fire Dynamics Simulator (FDS) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires [4].

III. Simulation Scenario and Input Data

a. Data Reference

A light hazard occupancy ICU space was selected for this analysis. The ICU space is based on a real one in Mehr Hospital of Tehran and the dimensions of it are 4 m x 4 m x 2.7 m height (See Figure 1).

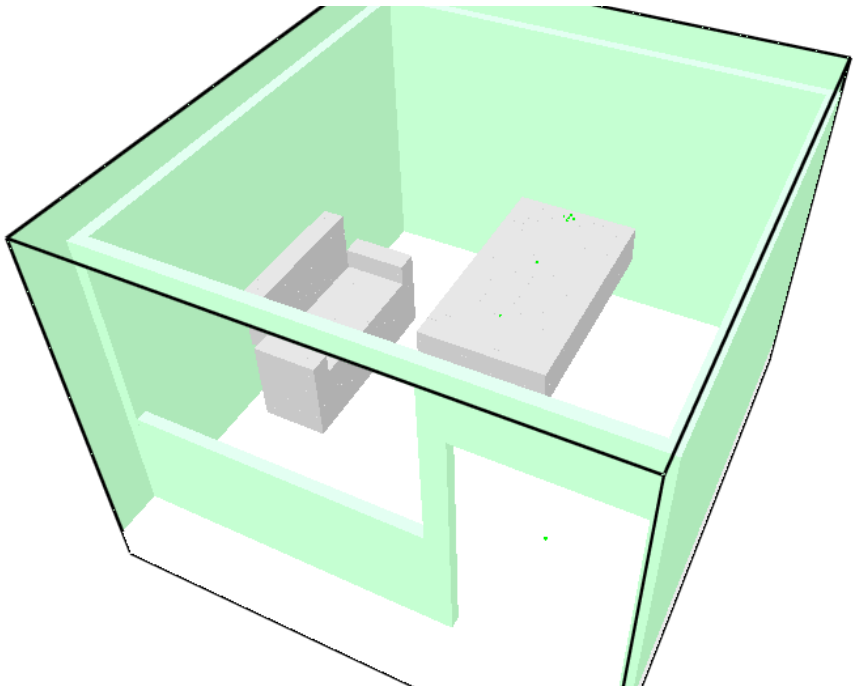


Figure 1: Sketch of the computational domain

b. Assumptions

The FDS models incorporated the following features:

1. The walls, floor and ceiling were constructed of brick (the ceiling is invisible on the above figure).
2. Walls were considered to be covered by gypsum plaster.
3. Thickness of walls was 10cm and floor and ceiling are 30cm.
4. Visiting window of ICU was made of glass according to ASTM C 1036.
5. Chair and bed were made of Fabric and Foam.
6. Initial temperature of ICU is considered to be 21°C.
7. Initial Oxygen percentage of ICU is 23%.
8. The couch was considered to be source of fire in simulation.
9. There was no forced ventilation during fire except the natural ventilation from open door.
10. Standard response nozzle has the following features: operating pressure: 80 bar, K-factor: 6.9 lpm/$bar^{0.5}$, flow rate: 100 lpm, particle velocity: 10 m/s

c. Limitations

This study has the following limitations:

1. The location of the watermist nozzle was held constant in all the FDS models.
2. No real fire testing was performed. Analysis was performed only with computer modeling.
3. Because of complexity, no electrical device has been modeled.

d. Measuring Devices

Considering the position of patient which should be constant, we assumed 5 nodes above his/her mouth to monitor the air mass faction. Another node has been considered on 1.7 m from floor on room inlet during the simulation. Also to measure the temperature being felt by the patient, 3 nodes above the bed and one more the same as air mass fraction measuring node on room inlet have been considered as shown in green bullets in Figure 2.

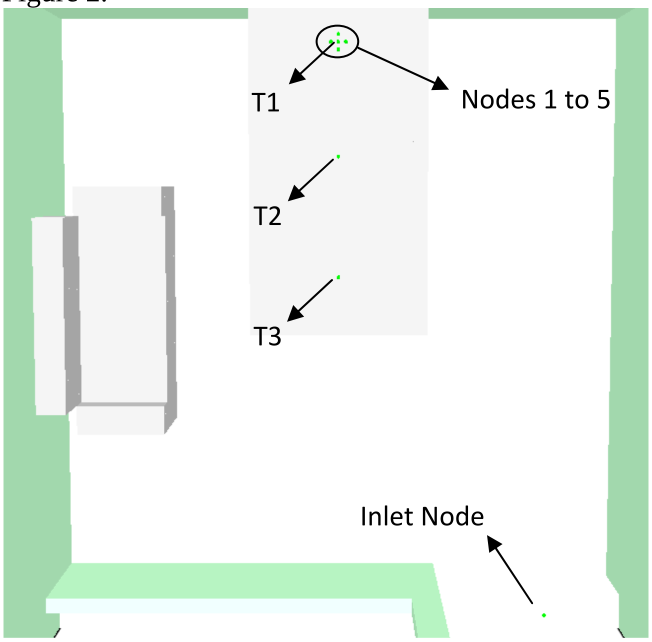


Figure 2: Green bullets show measuring nodes

Air mass fraction parameters which have been measured in simulation are Oxygen, Carbone Dioxide, Soot, Water Vapor and Nitrogen.

The first scenario is to find fire spread from its beginning up to 15 minutes and to monitor the measuring parameters to find the critical range. This study aims to see effect of watermist system on fire in its worst case.

Regarding obtained results, the critical fire duration last 200 seconds of simulation. So we activated watermist system on mentioned duration and let it continue up to 1000 seconds to monitor measuring parameters which has been completely described in results.

IV. Simulation Results

As mentioned above, fire and watermist system have been conducted in two consequent simulations. First, we let the fire begin and spread in 15 minutes. This simulation let us find the critical duration of fire which last 200 seconds. Then we modeled the fire again but with activation of watermist system in 700th second of simulation and let it extinguish the fire for 300 seconds. So our simulation time was 1000 seconds in 2nd scenario. Figures 3 and 4 show more snapshots of the simulations.

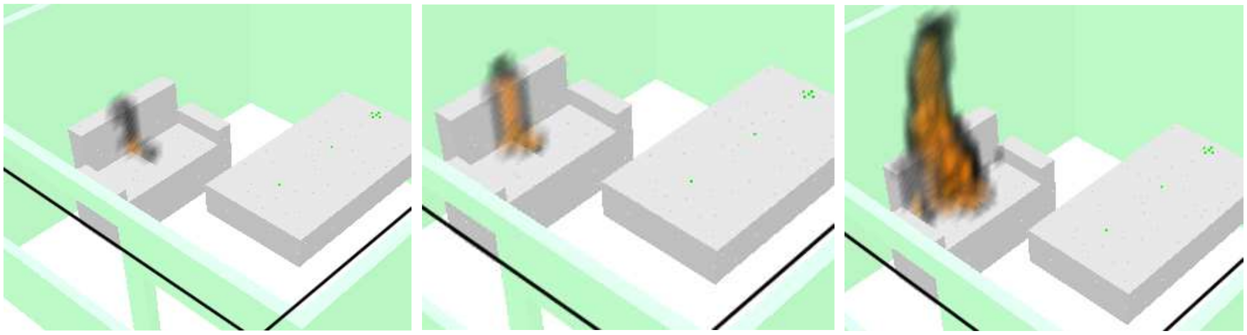


Figure 3: 1st simulation; fire spread in 400s (left), 700s (middle) and 900s (right)

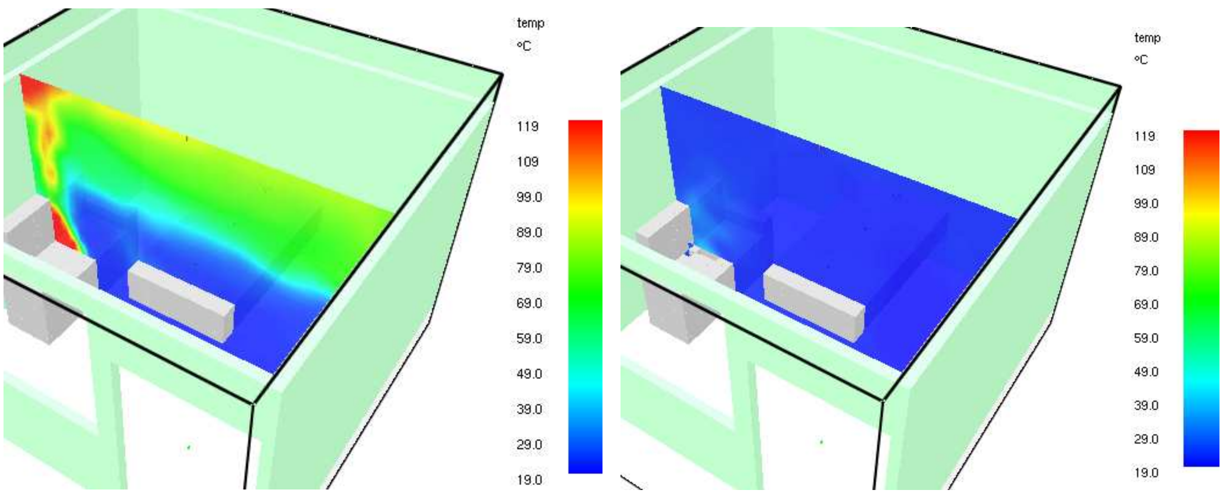
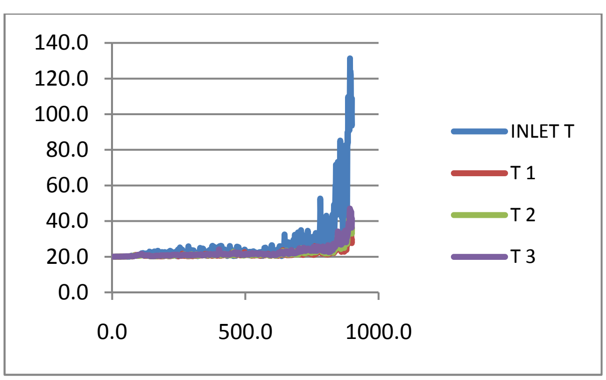


Figure 4: 2nd simulation; Temperature slice on Y=2.1m before (left) and after (right) activation of watermist system

Also diagrams 1 and 2 show the temperature and heat release rate of two simulations by time. As can be seen, there is a significant change from 700th second. The temperature has been controlled to around 20°C and heat release rate has been reduced to zero.



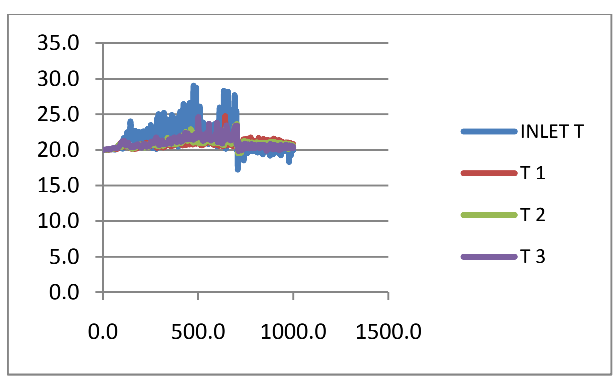


Diagram 1: Temperature (°C) change by time (s) for 1st simulation (no watermist system, left) and 2nd simulation (with watermist system, right)

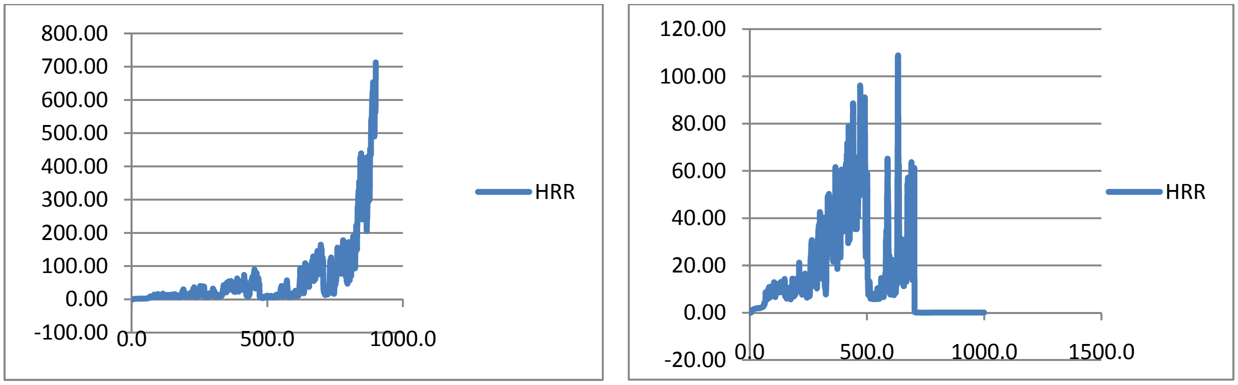


Diagram 2: Heat Release Rate (kW) change by time (s) for 1st simulation (no watermist system, left) and 2nd simulation (with watermist system, right)

Diagrams 3 to 7 show the air mass fraction changes by time. There is a sudden fluctuation in all parameters on 700th second when watermist system activates which lasts at least half a minute. The most critical parameters for patient are Oxygen, carbon monoxide and soot.

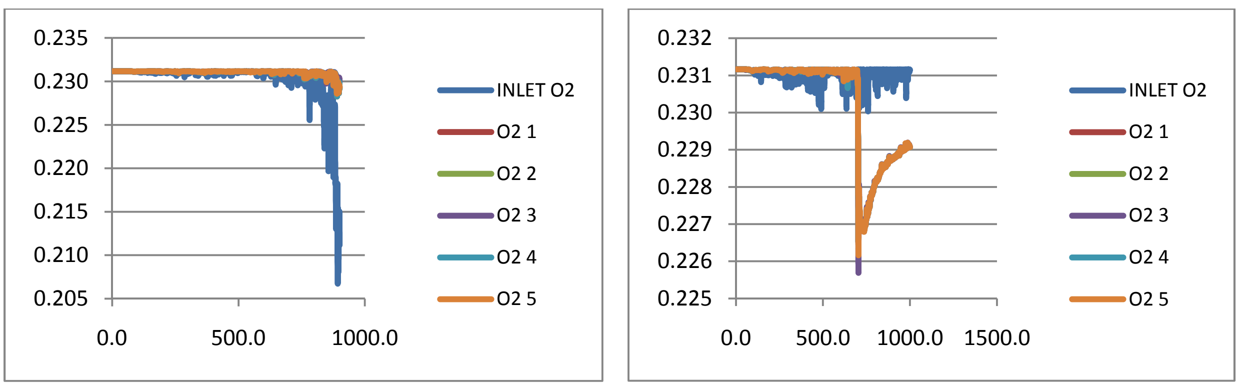


Diagram 3: Oxygen mass fraction change by time (s) for 1st simulation (no watermist system, left) and 2nd simulation (with watermist system, right)

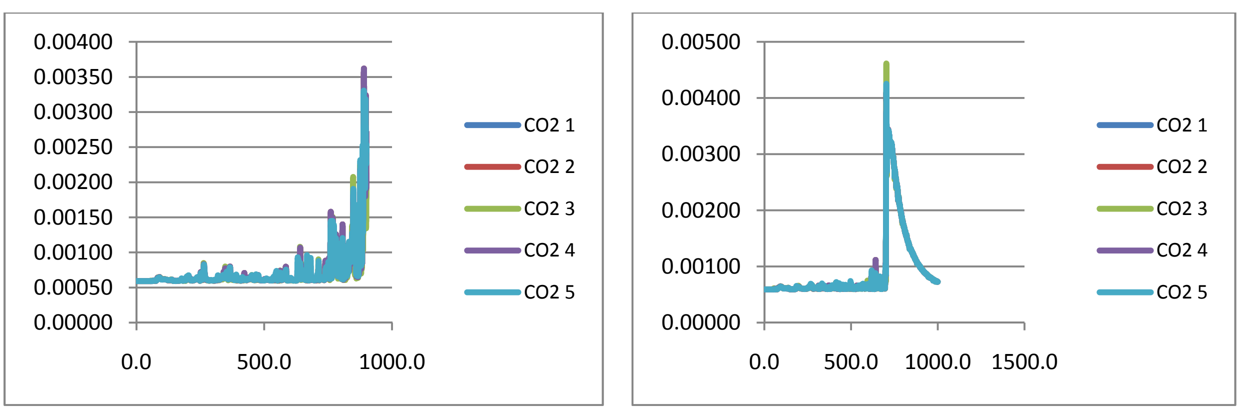


Diagram 4: Carbon dioxide mass fraction change by time (s) for 1st simulation (no watermist system, left) and 2nd simulation (with watermist system, right)

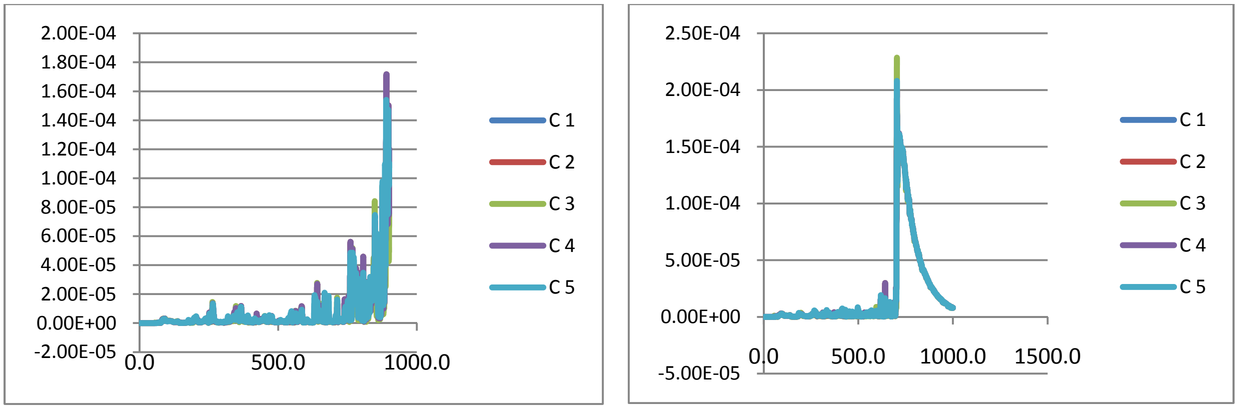


Diagram 5: Soot mass fraction change by time (s) for 1st simulation (no watermist system, left) and 2nd simulation (with watermist system, right)

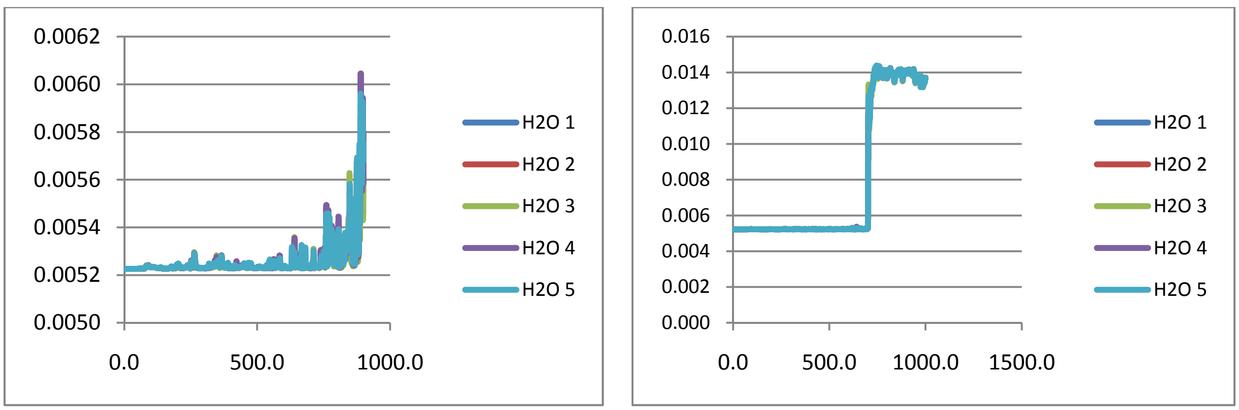


Diagram 6: Water vapor mass fraction change by time (s) for 1st simulation (no watermist system, left) and 2nd simulation (with watermist system, right)

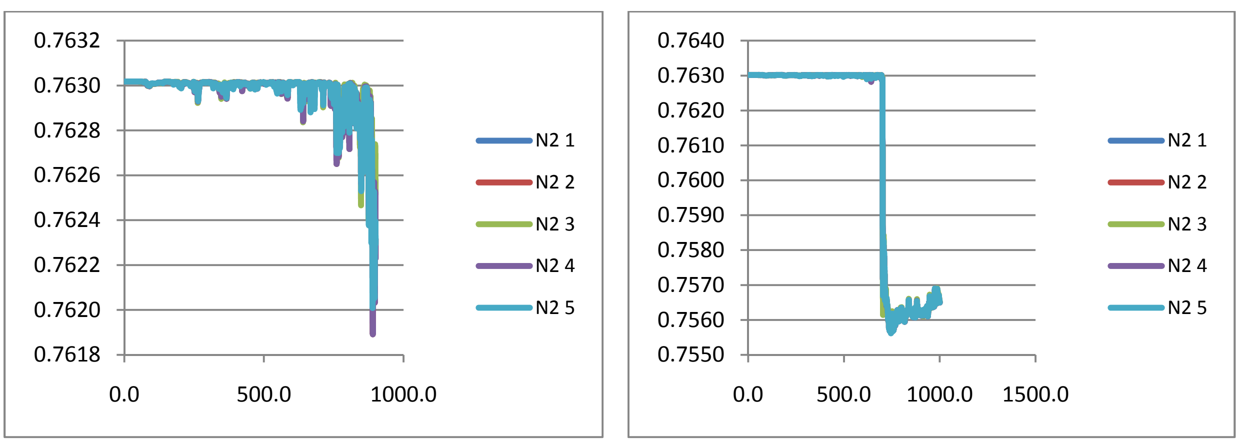


Diagram 7: Nitrogen mass fraction change by time (s) for 1st simulation (no watermist system, left) and 2nd simulation (with watermist system, right)

V. Conclusion

Intensive care unit, due to its special and unique equipment, is a unit which receives and takes care of the patients in very critical conditions. Codifying and using standards in ICUs will result in higher patient survival rates and lower costs through preventing mistakes in the management of the ICU affairs and reducing preventable deaths [5]. The results of this study showed that simulation of fire can be helpful in utilizing the best fire extinguishing system considering all dangers and effects of fire and extinguisher.

In this study, we modeled a real case of fire and watermist system in an ICU to monitor the results. The results showed that if watermist system is used for such an area, it should be noticed that from beginning of its activation up to 30 seconds, there will be a noticeable reduction in Oxygen level and sharp increase in carbon monoxide and soot mass fraction which patient feels. So if watermist system is chosen for such an area, the prediction of safe breathing apparatus is necessary. Also the staff of hospital should be well trained to be aware of safety instructions in dealing with such conditions to help patient continue his/her normal breathing with help of equipment.

VI. Acknowledgement

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VII. References

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