Scaling of fire suppression characteristics in machinery spaces

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Background:

- IMO Sirc. 1165 states the following for water mist systems:

- *The installation specification provided by the manufacturer should include maximum horizontal and vertical nozzle spacing, maximum enclosure height, and distance of nozzles below the ceiling and maximum enclosure volume which, as a principle, should not exceed the values used in approval fire test. However, when based on the scientific methods developed by the Organization*, scaling from the maximum tested volume to a larger volume may be permitted. The scaling should not exceed twice the tested volume.*
- ** To be developed by the Organization*

IWMA project

- At the 2007 IWMA member meeting, a project was proposed with the aim to explore the possibility to develop a scheme to scale the conditions inside an enclosed space with ventilation through a doorway, as specified in IMO 1165.
- The project was agreed by the Board of IWMA, and is currently carried out by SINTEF NBL as.
- The project will include documentation of the scaling scheme by data from tests carried out by manufacturers (members of IWMA), who will let SINTEF publish the results of tests (manufacturers anonymous)
- Tests results of several water mist systems carried out at different linear scale, with similar fire size and ventilation conditions can be compared.
- The findings will be presented to IMO FP 53 (16-20 February 2009), with a suggestion of scaling procedure for water mist performance in volumes up to twice the tested volume.

Physical scaling

- Froude Number similarity
  - Linear scaling of enclosure dimensions
  - Scaling of fire size ($Q^{5/2)}$
  - Scaling of droplet sizes
  - ⟶ Similar scale for species concentration and temperature in space, with a time scale
- This scaling is not fully valid for radiative heat transfer
- Changing the scales of dimensions, heat release rate or droplet size will influence the time scale

Modelling of enclosure fires:

- Phenomenological models
  - Zone models with simulation of transients in temperature and species concentration based on phenomenological description of heat transfer (one or more zones)
- CFD models
  - Mathematical simulation of fluid mechanics, heat transfer and combustion of a grid of control volumes, transient or steady-state. The most complex models simulate the flow of droplets of different sizes and the interaction with the atmosphere of the fire compartment.
- Non of these models have been verified with a variety of test results, and can not at present be used as a design tool without fire testing.

Experience from tests:

- Several tests have been carried out with the scenarios defined by IMO Sirc.668 and IMO Sirc.1165.
- Tests results of several water mist systems carried out at different linear scale, with similar fire size and ventilation conditions can be compared.
- The present status is that the water mist systems produce a variety of spray patterns and droplet size distributions, and no generic method is available to define the performance by simple numbers as used in the sprinkler regulations.

Experience from tests:

- It is documented that for a certain enclosure volume, a minimum fire size is experienced, for which it is possible to extinguish the fire within the required 15 minutes. (The paradox of water mist)
- In these cases, the average temperature of the gases inside the compartment is typically less than 60° C.
- A possible explanation to the paradox is that the saturation pressure of water vapour in air do not allow inert concentration to occur with these low temperatures.
- Experience shows that larger fires are easily extinguished in the larger enclosures, only biased by fires directly fed by fresh air from the door of the test enclosure.
- Data from tests is not fully systemised and analyzed. This will be done in the near future.

Safety factors:

- The performance criteria of IMO Sirc. 1165 is based on extinguishment of all test fires within 15 minutes. The minimum fire size was changed from IMO Sirc.668, from 0,5 m^2 to 2 m^2. For the new thermal management test, a scaling rule for the fire size with respect to enclosure volume was introduced.
- The open door at floor level was kept from IMO Sirc.668, by some of the FP assembly participants defined as a safety factor. It is meant to compensate the feature that water mist may not act as a gas inside a compartment, but droplets will fall out and will not penetrate all hidden places.
- This requirement is not put forward for any other fire fighting medium, like for instance gas systems.
- This safety factor is in practice preventing the use of water mist in very large compartments.

Safety factors:

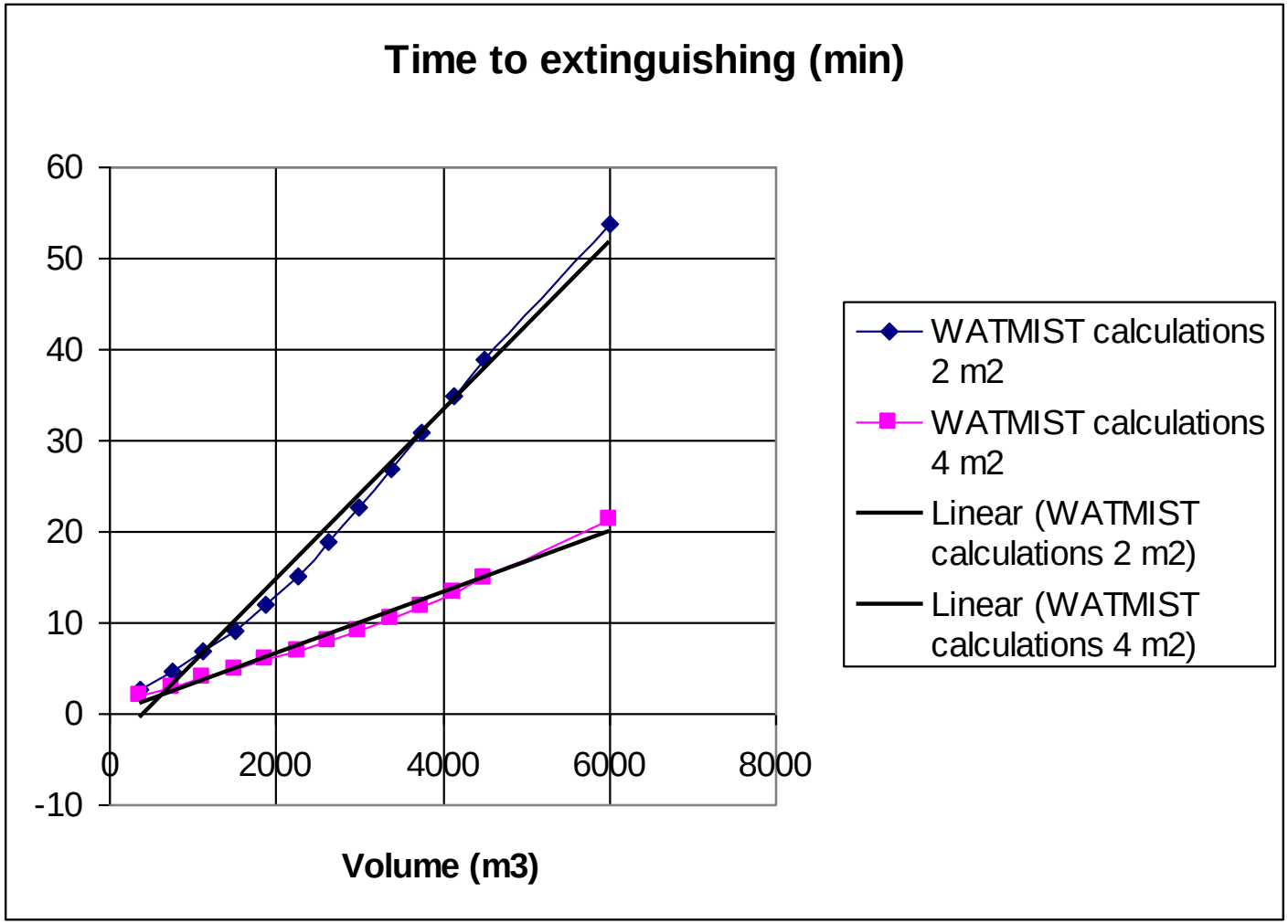
- Scaling with Froude Number similarity:
  - Doubling the enclosure volume,using the same water mist nozzles and spacing and doubling the water application density (Litres/m^2 min), keeping similar fire size, keeping the ceiling height constant and keeping the similar door opening:

  + The temperatur of similar positions outside the combustion zone will be lower at similar time

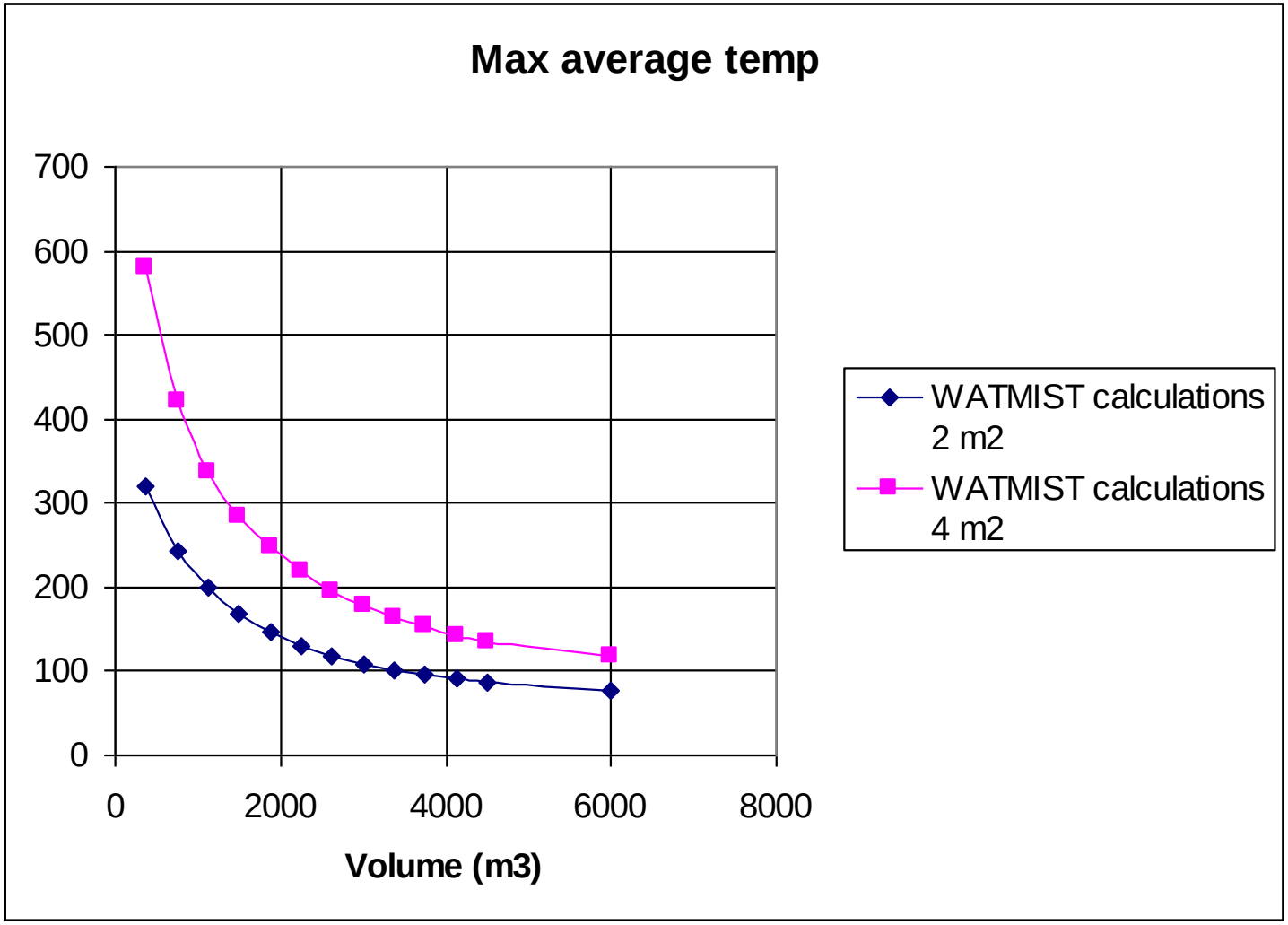
  +The concentration of species (CO, CO_2, particles) will be lower, Oxygen concentration will be higher at similar time

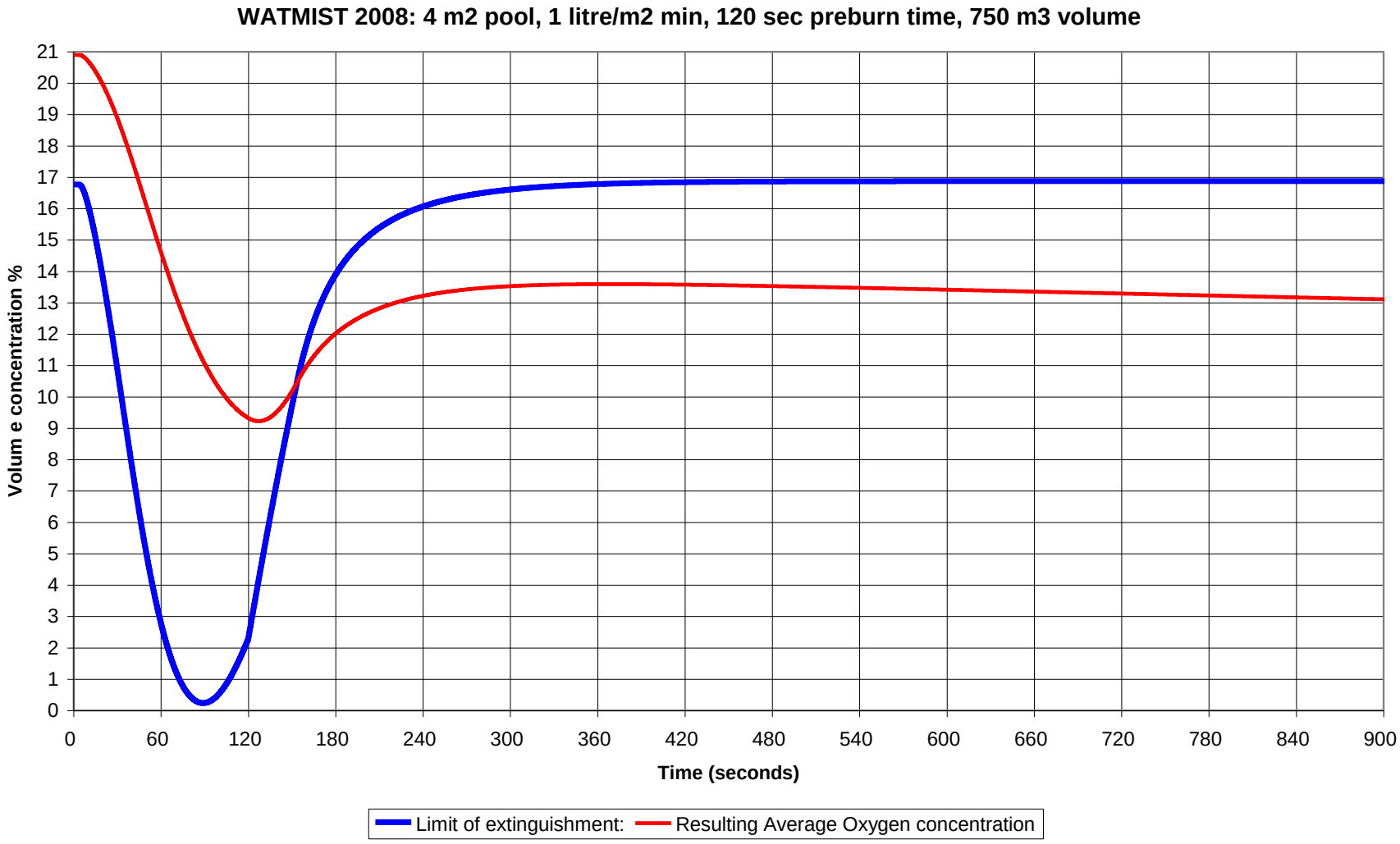
  - Time to extinguishment will be longer

Phenomenological model (one zone)



Phenomenological model (one zone)




WATMIST 2008: 4 m2 pool, 1 litre/m2 min, 120 sec preburn time, 750 m3 volume
Volum e concentration %
0
1
2
3
4
5
6
7
8
9
10
11
12
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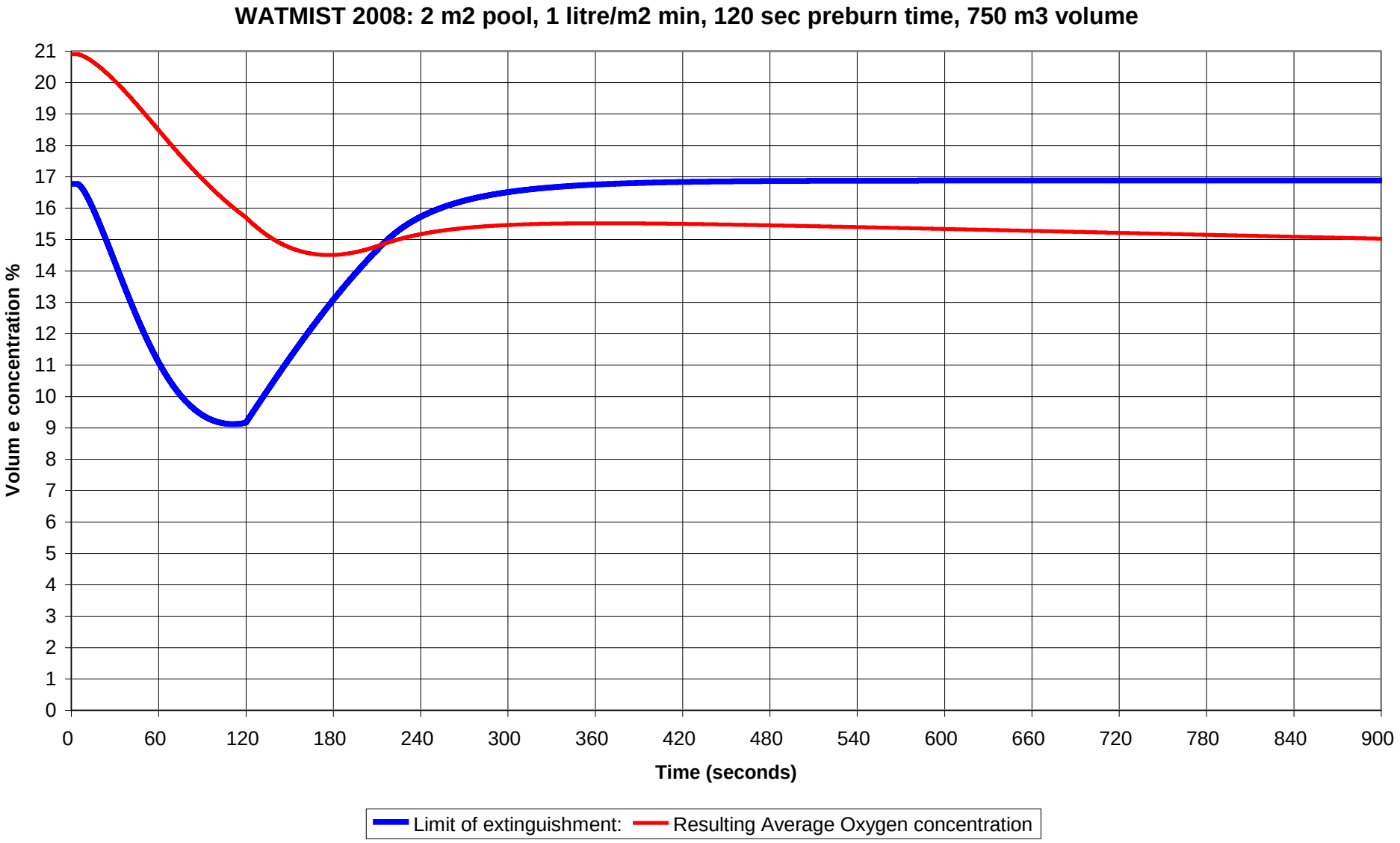
14
15
16
17
18
19
20
21
0
60
120
180
240
300
360
420
480
540
600
660
720
780
840
900
Time (seconds)
Limit of extinguishment:
Resulting Average Oxygen concentration


WATMIST 2008: 2 m2 pool, 1 litre/m2 min, 120 sec preburn time, 750 m3 volume
Volum e concentration %
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720
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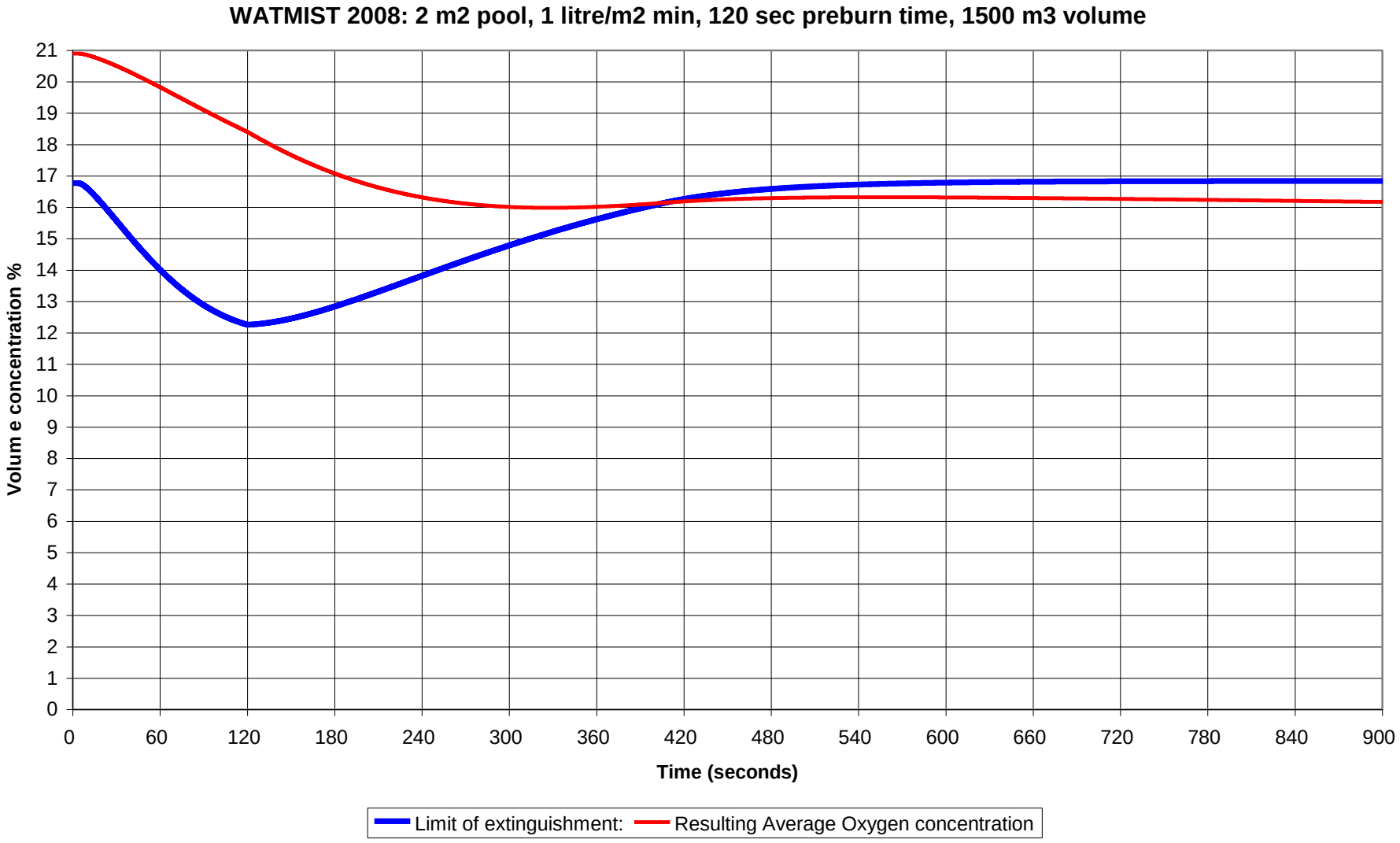
900
Time (seconds)
Limit of extinguishment:
Resulting Average Oxygen concentration


WATMIST 2008: 2 m2 pool, 1 litre/m2 min, 120 sec preburn time, 1500 m3 volume
Volum e concentration %
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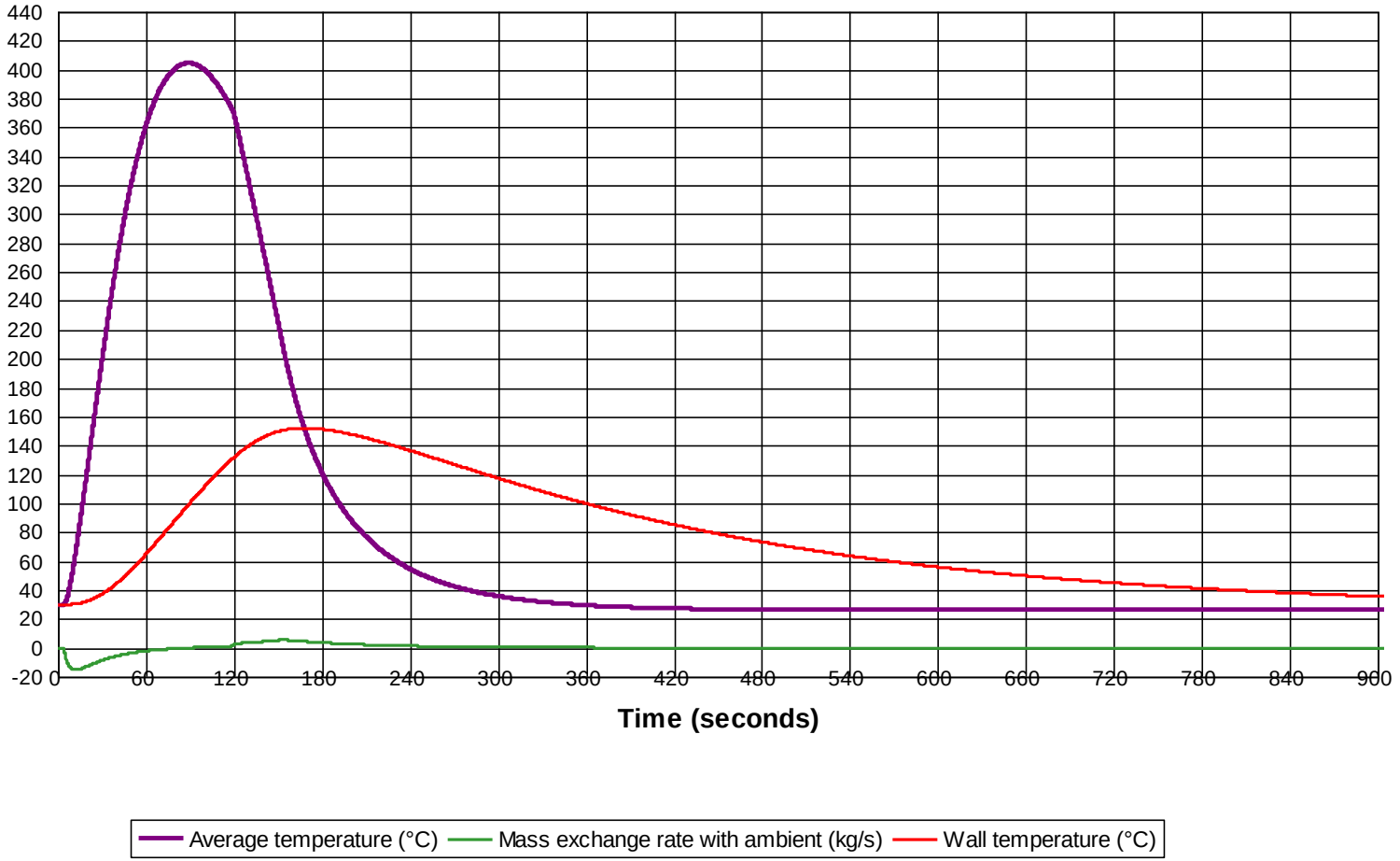
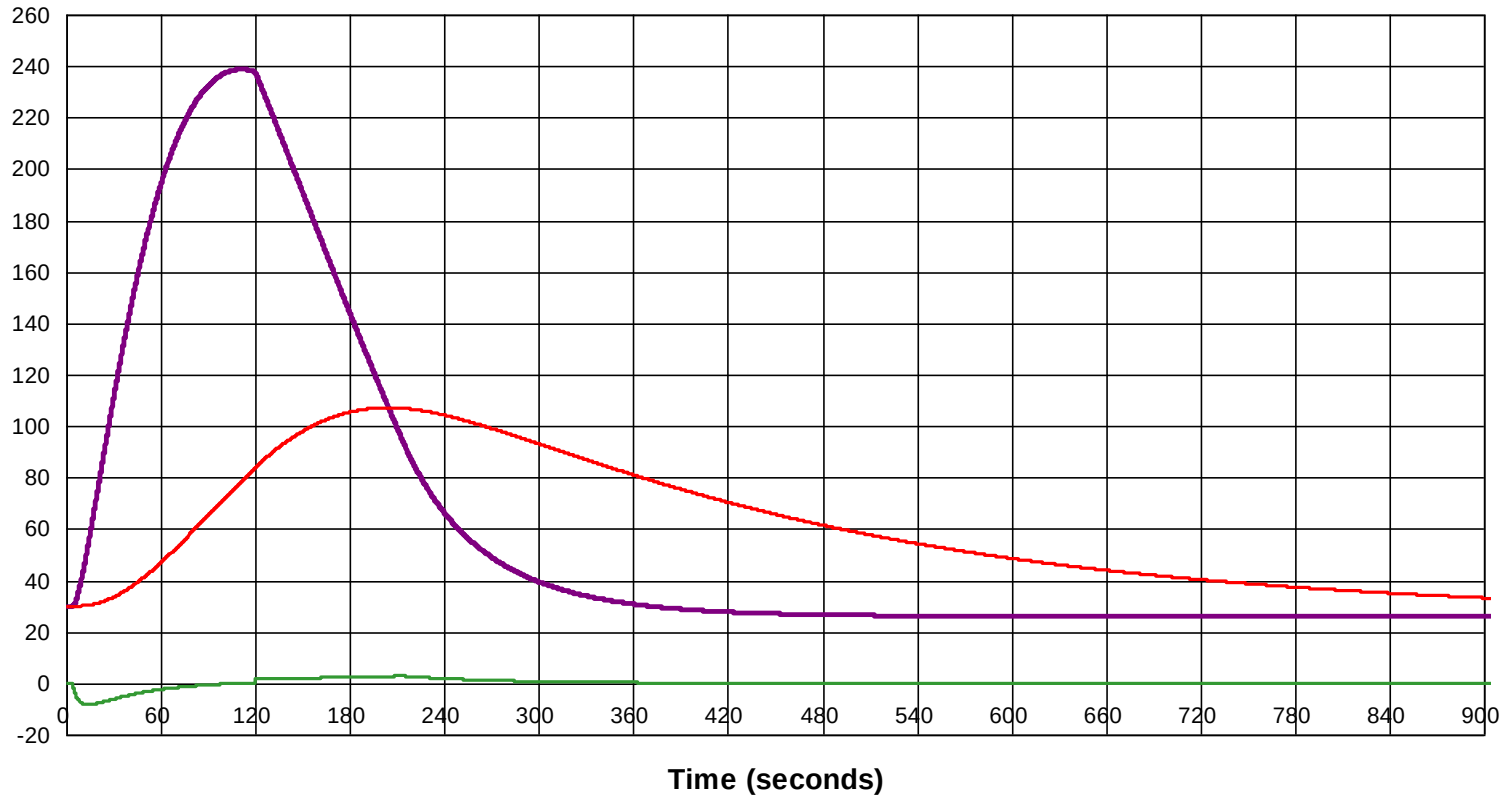
Time (seconds)
Limit of extinguishment:
Resulting Average Oxygen concentration

WATMIST 2008: 4 m2 pool, 1 litre/m2 min, 120 sec preburn time, 750 m3 volume



WATMIST 2008: 2 m2 pool, 1 litre/m2 min, 120 sec preburn time, 750 m3 volume



Preliminary conclusions:

- Scaling by Froude Number similarity can demonstrate that the conditions inside an enclosure with a certain fire will be less severe with double volume.
- However, time to extinguishment may be doubled, provided that all scaling is satisfying Froude Number similarity.
- The arguments for accepting scaling to twice the volume as tested should be based on safety measures, and the performance of the water mist should be compared to other accepted fire fighting methods.

Acknowledgements:

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