Laboratory Tests and extended Applications of Test Results

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Laboratory Tests and extended Applications of Test Results

Ragnar Wighus, SP Fire Research Norway

- The approval of water mist systems is based on real-scale experiments with relevant scenarios.
- In some cases, there are scaling rules that can be applied, (IMO Machinery spaces)
- In most cases, the installations at certain applications are limited to the tested volume and ceiling heigth.
- Application of systems into larger volumes and /or higher ceiling heights is not formalized. The only formalized scaling rule is in the IMO machinery Space test protocol IMO MSC.1/Circ. 1165, presented in IMO MSC.1/Circ.1385 SCIENTIFIC METHODS ON SCALING OF TEST VOLUME FOR FIRE TEST ON WATER-MIST FIRE-EXTINGUISHING SYSTEMS.

ANNEX

SCIENTIFIC METHODS ON SCALING OF TEST VOLUME FOR FIRE TEST ON WATER-MIST FIRE-EXTINGUISHING SYSTEMS

1 Scaling from the maximum tested volume to larger volumes may be accepted based on the approval fire test scenarios in appendix B, paragraph 4.3.1, table 1 of the Revised Guidelines for the approval of equivalent water-based fire-extinguishing systems for machinery spaces and cargo pump-rooms (MSC/Circ.1165), provided that:

.1 none of the test fires 1 to 4 has an extinguishment time exceeding 10 min; and

.2 provisions of the table below are met.

Average time to extinguishment for the three fires with the longest extinguishing times (tests 1 to 8)	Scaling factor
≤ 10 min	2
12.5 min	1.5
15 min	1

2 Linear interpolation may be used for average extinguishing times between the values above. The ceiling height should not be increased over that tested. All the volumes referred to should be the net volume.

Laboratory Tests and extended Applications of Test Results

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- SPFR have the possibility to carry out all standardized water mist tests, IMO, FM, VdS, BRE, NORDTEST, UL…….
- SPFR can carry out tests of gas extinguishing systems
- SPFR can carry out sprinkler system tests and deluge system tests
- SPFR can carry out foam firefighting systems tests
- SPFR can carry out tailored tests (for special purposes)

- The test hall in Trondheim has the dimensions of 17 x 34 m floor area, ceiling heigth from 21-25 m.
- Suspended ceiling at 10,5 m now, to be extended to approximately 15 m.
- Test hall in Borås has dimensions 18 x 22 with ceiling heigth 19 m.

- SPFR can carry out tests with water based systems in a road tunnel 1650 m long, with cross section approx. 50 m^2. (Runehamar test tunnel)

SPFR can evaluate applications

- In cases where SPFR has carried out the tests with the system
- Based on test reports from approved laboratories

- Since SPFR has first-hand knowledge to the test, we can evaluate if there are reasons to consider an extended application of the tested systems from case to case.
- In cases where SPFR has carried out the tests. We have even better knowledge of the water mist systems performance, and can do more precise evaluations of proposed extended applications

SPFR can carry out simple simulations

- SPFR has developed a one-zone room model with water application inside, WATMIST
- In general cases, one can carry out senstivity studies with WATMIST. A paper presenting this one-zone model was presented at HOTWC conference in 2001, and is copied in the following slides of this presentation.

- In cases where SPFR has carried out the tests with the system, we can evaluated different applications, since we can define a system efficiency factor. This makes the simulations better fit for the purpose.

WATMIST-

a one-zone model for water mist fire suppression

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Discipline manager

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Scientist

Fire Development and Extinguishing

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The input values to the model

- Enclosure data:
- Dimensions:
- Length, widht and ceiling height [m]
- Wall thickness [m]
- Specific heat capacity of wall material [kJ/kg K]
- Convective heat transfer coefficient to walls [kW/m^2 K]

The input values to the model (cont)

- Fire data:
- Dimensions:
- Pool side [m]
- Specific fuel burning rate [kg/m^2 s]
- Theoretical net heat of combustion [kJ/kg]
- Theoretical net heat of combustion per unit of Oxygen [kJ/kg]
- Constant combustion efficiency [-]

The input values to the model (cont)

- Initial atmospheric conditions:
  - Air temperature [°C]
  - Initial Oxygen concentration [vol%]

The input values to the model (cont)

- Water mist characteristics:

• Water supply temperature	[°C]
• Water supply rate per nozzle	[litres/min]
• Number of nozzles	[-]
• Preburn time without water supply	[s]
• Median droplet diameter	[m]
• System efficiency factor	[-]
• Heat transfer coefficient water droplets/atmosphere	[kW/m^2 K]

  - Optional: Intermittent spray sequence.

Model description

- Mass conservation of gases inside the compartment
- Complete mixing momentarily
- Constant pressure (atmospheric)
- Water that evaporates is added to the gas phase

Model description (cont)

- Conservation of energy of the gases inside the compartment
- Heat produced by variable fire size (with time and with oxygen concentration)
- Heat loss to the walls, which operates as a heat sink and a transfer mechanism to the ambient

Model description (cont)

- Oxygen conservation
- Consumed by the fire
- Lost/gained by exchange with the ambient
- Depleted by water evaporation

Model description (cont)

- Fire development
- Time dependent growth phase
- Reduction by limited oxygen concentration
- Extinction by a temperature dependent oxygen concentration

Model description (cont)

- Water mist/atmosphere interaction
- Calculates a Surface area flux (dependent of droplet size) [m^2/s]
- Convective heat transfer between droplets and gases
- Below 100 °C: Saturation pressure of water vapour limits the evaporation
- Above 100 °C: A system efficiency factor limits the evaporation
- Heat supply always limits the total heat-up and evaporation of water

Fuel burning rate

$$\dot{m}_{fuel} = \dot{m}_{fuel\max} \cdot (1 - \frac{f_t}{t})$$

Increases with time

Heat release rate of fire

$$\dot{Q} = \dot{m}_{\max} \cdot \varepsilon_c \cdot \Delta H_c$$

Heat release rate dependent on Oxygen concentration

$$\dot{Q}_{redstoich} = \dot{Q} \cdot (1 - 1/\exp(2{,}5 \cdot \phi^{-2{,}8}))$$

Based on stoichiometry in compartment

Heat release rate dependent on Oxygen concentration

$$\dot{Q}_{ext\,limit} = \dot{Q}_{redstoich} \cdot \left(\frac{C_{O_2} - C_{O_{2\,limit}}}{C_{O_{2\,init}} - C_{O_{2\,limit}}} \right)$$

Based on vicinity to extinction limit

Extinction limit of Oxygen

$$C_{O_{2\,ext\,\lim\,it}} = 20{,}9 - 0{,}000045 \cdot T^{2}$$

Dependent of temperature of the gases entrained into the combustion zone

(T is the temperature in Kelvin)

Heat balance of the walls

$$T_{wall(t+1)} = T_{wall(t)} + (T_{gas} - T_{wall})_{(t)} \cdot h_{cwall} \cdot A_{wall} / c_{pwall} \cdot m_{wall}$$

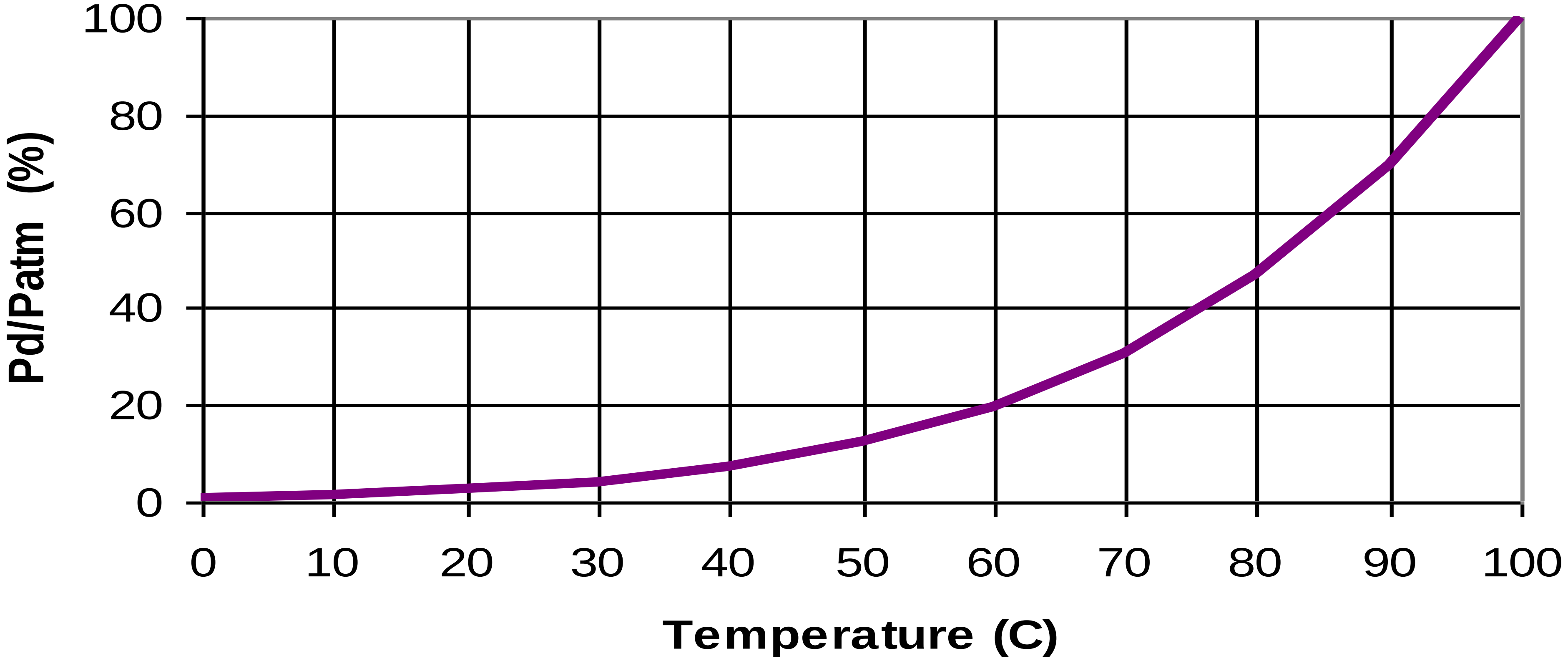
$$\dot{Q}_{wall} = \Delta T_{wall} \cdot c_{pwall} \cdot m_{wall} / \Delta t$$

$$\dot{Q}_{wall/ambient} = (T_{wall} - T_{ambient}) \cdot h_{cwall} \cdot A_{wall}$$

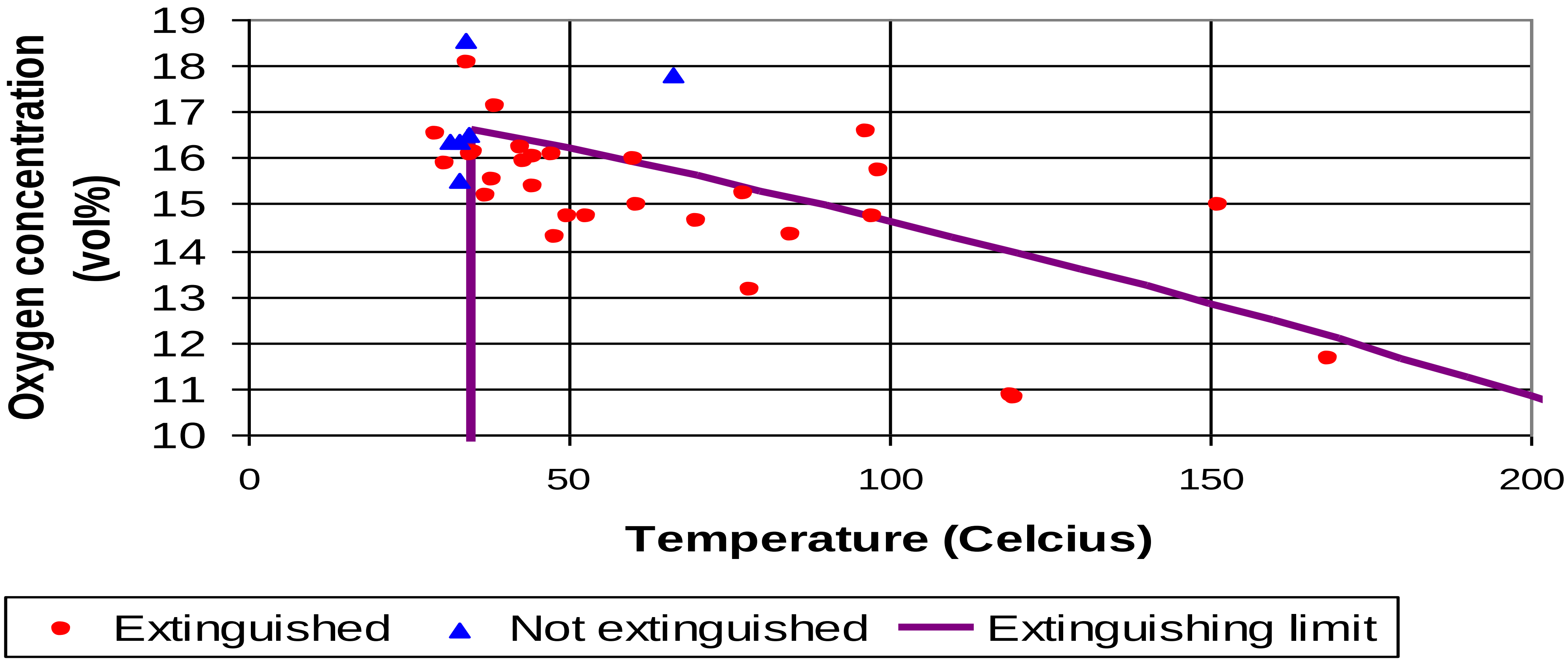
Heat transferred to the water mist

$$\dot{Q}_{water} = \dot{m}_{water} \cdot (6 / D_m \cdot \rho_{water}) \cdot h_{cdroplet} \cdot (T_{gas} - T_{water}) \cdot \varepsilon_{water}$$

Saturation pressure of water in air at atmospheric pressure



Critical oxygen concentration for extinguishment with water mist



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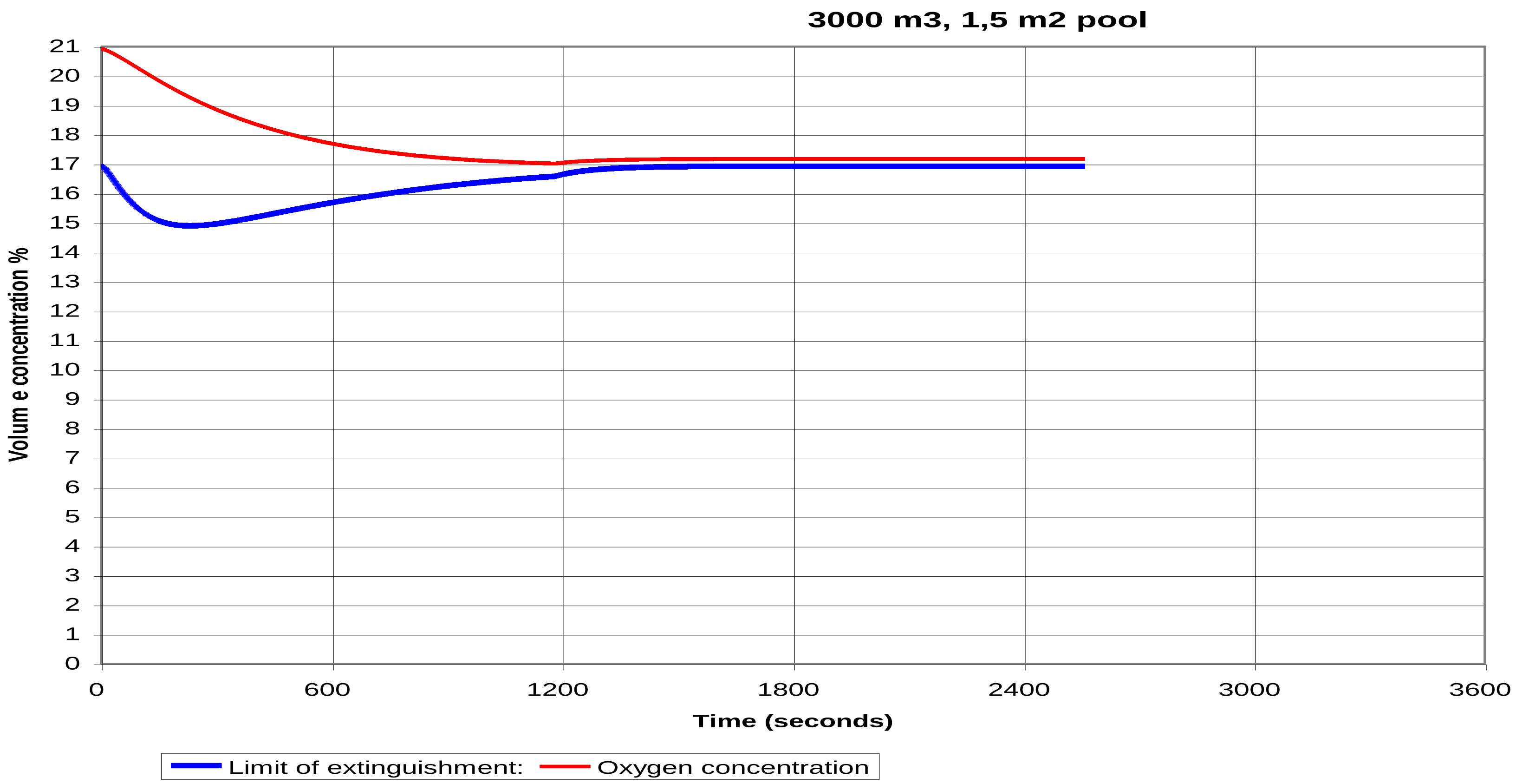
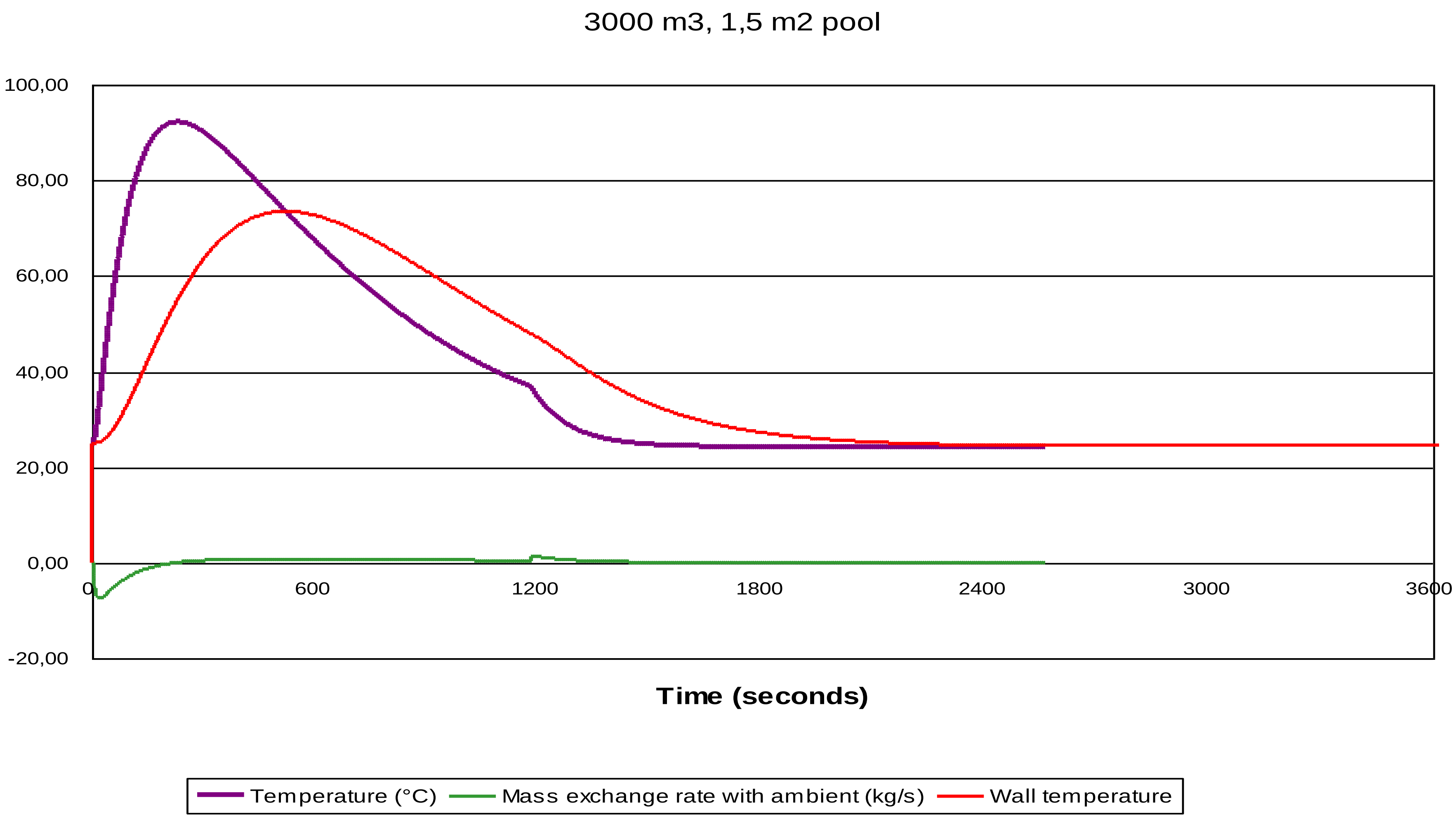
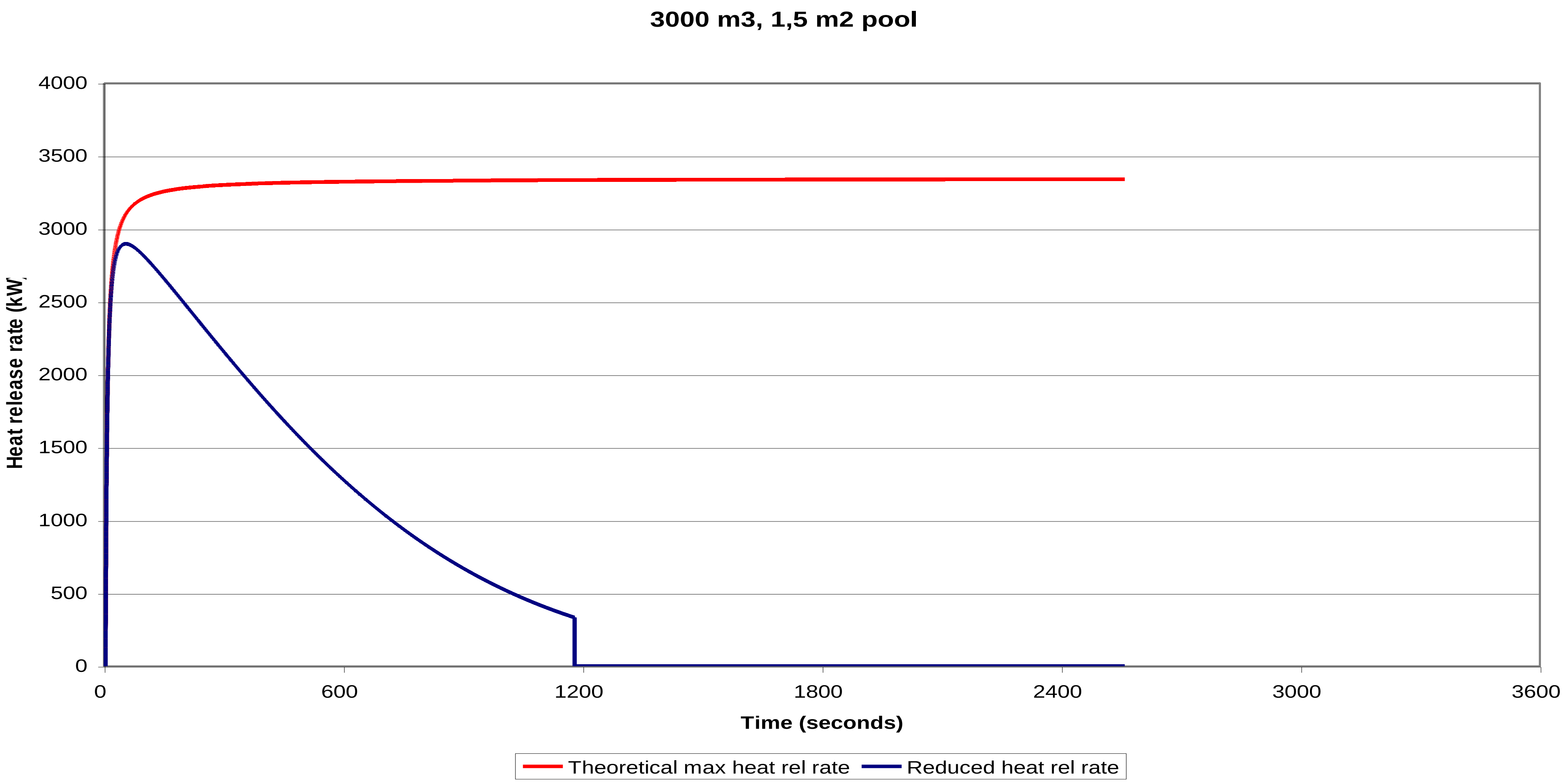
Oxygen concentration



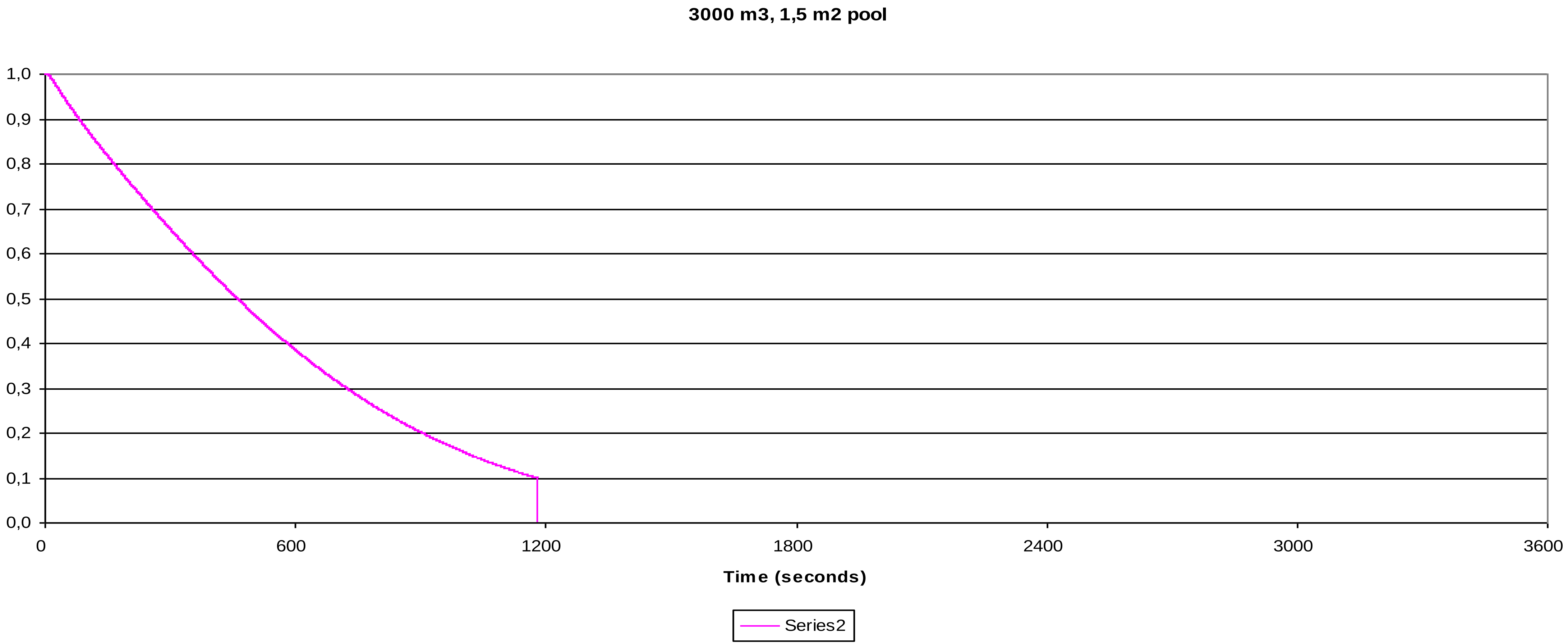
Temperatures



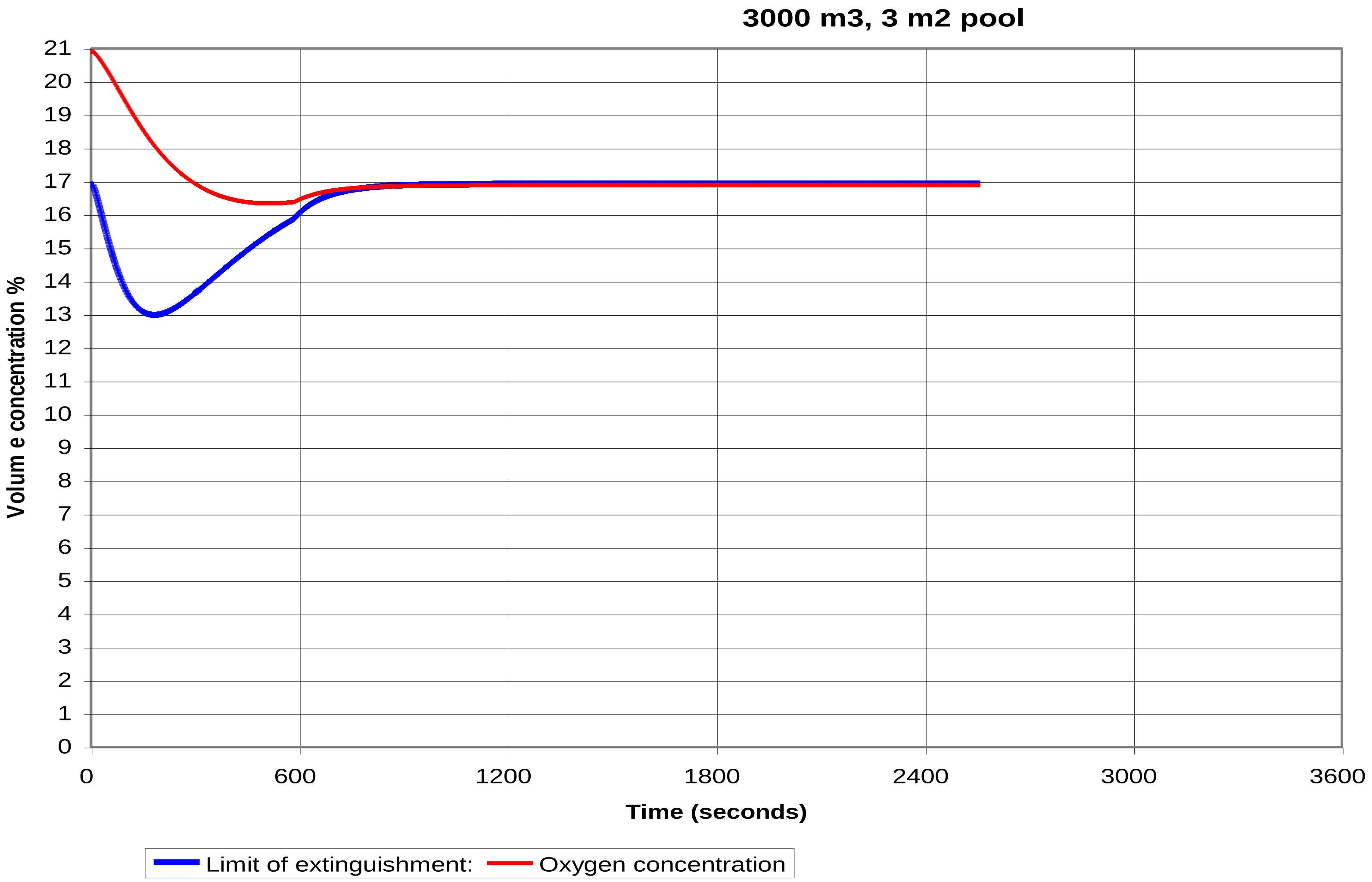
Heat release rate



Extinction criterion



Oxygen concentration



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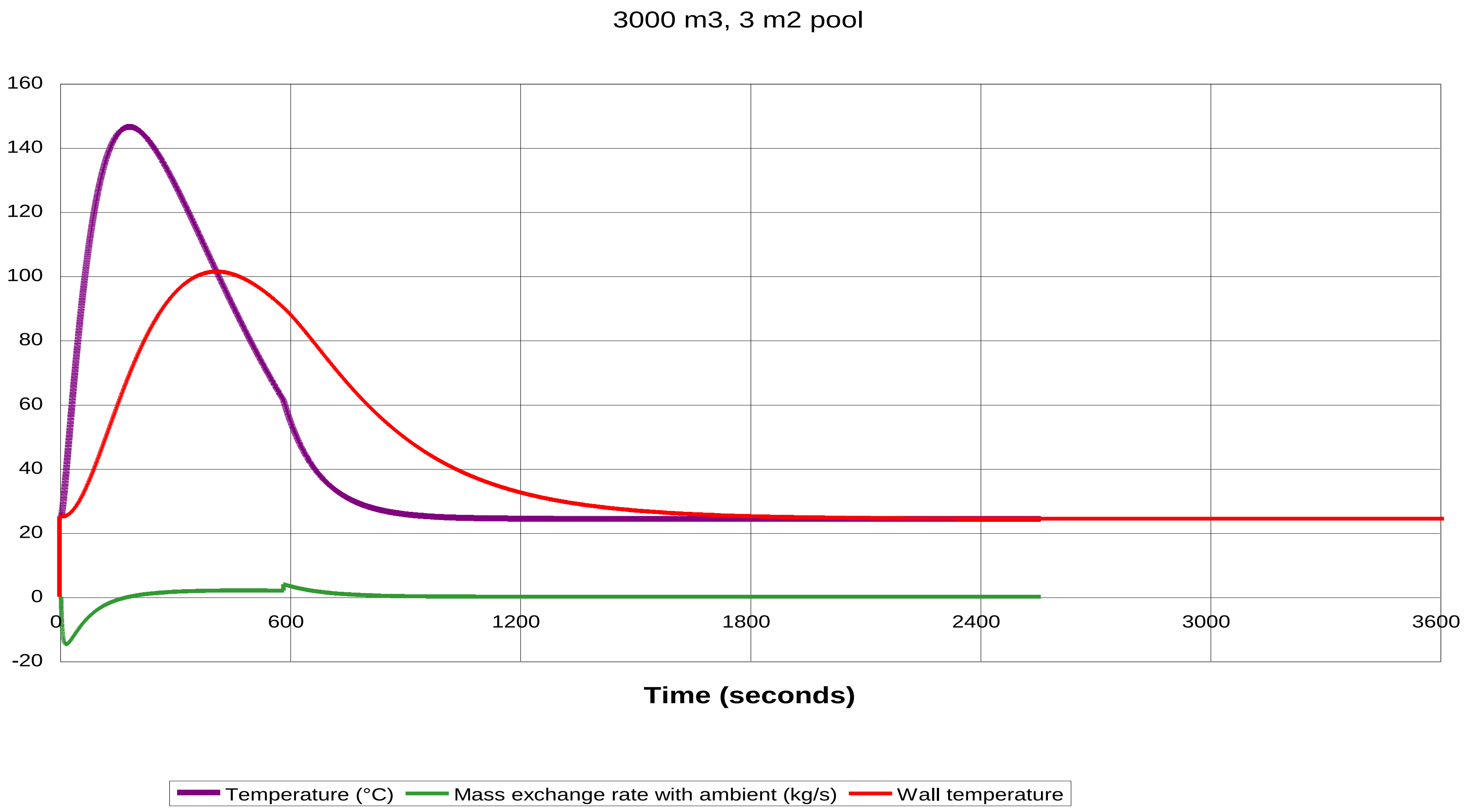
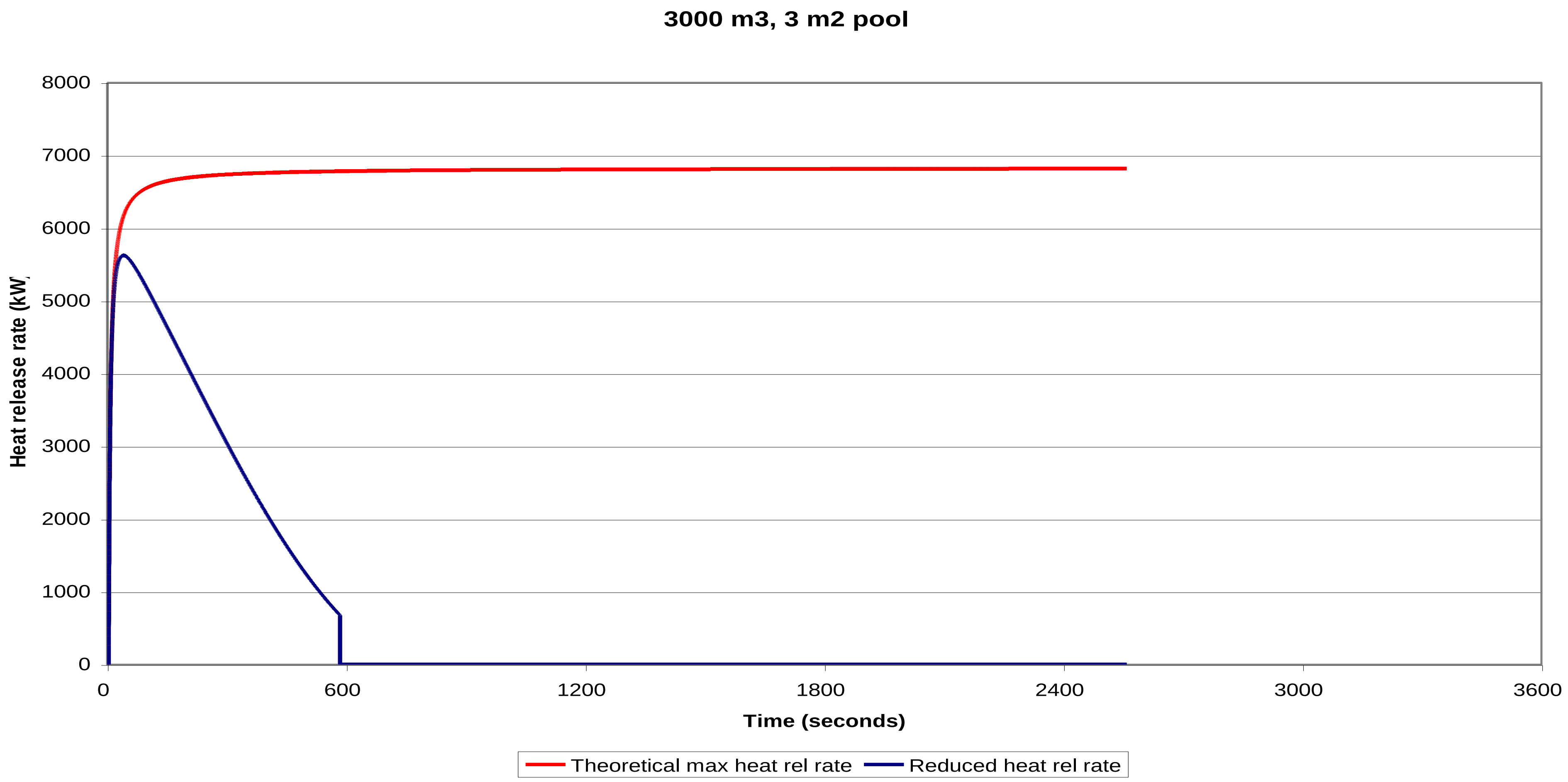
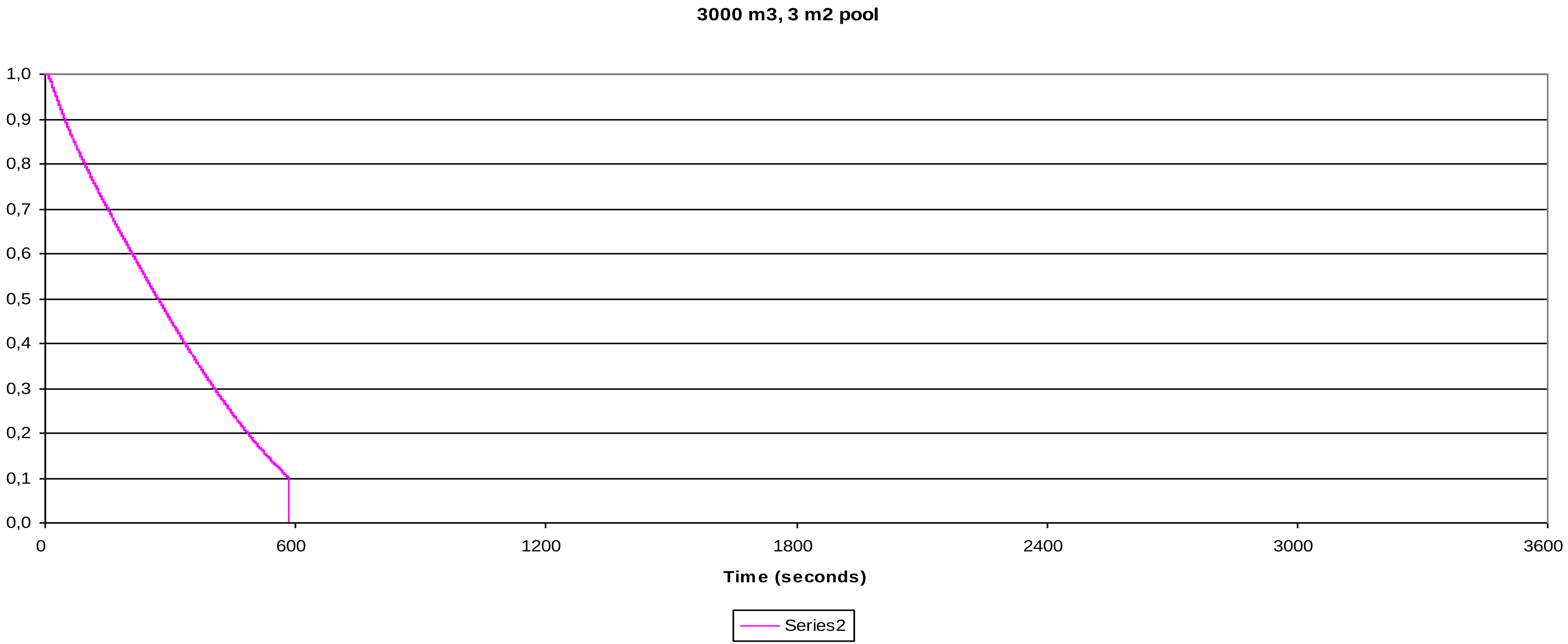
Temperatures



Heat release rate



Extinction criterion



Paradox of Water Mist

- COMPARTMENT FIRES:
- Small fires are more difficult to extinguish than larger
- Too much water makes it difficult to extinguish small fires

Paradox of Water Mist

- Possible explanation:
- When the temperature of the gases of the compartment is lowered (below about 70 °C), the maximum concentration of water vapour that can exist is limited (to less than 30%). This makes the added effect of water vapour as an inert gas less pronounced. Larger fires heat up the compartment to higher temperatures, and hence more water can exist as vapour (inert gas)

Status of WATMIST

- WATMIST has been tested against results from large scale water mist tests (up to 3000 m^3). Results regarding predicted Oxygen concentration and compartment temperatures are within reasonable limits. Prediction of times to extinguishment is very dependent on extinction criteria, but can be adjusted to system characteristics.

Status of WATMIST

- WATMIST is compared to two other models (Beck’s model and Optimist by Vaari). Results in the same order of magnitude, but some deviation on time-variations. (Presented at the International Water Mist Association Conference, Vienna, April 2001)

Verification of Models

- Verification of models requires well defined and well instrumented experiments
- Measured gas temperatures should be treated carefully, radiation from flames and water droplets on thermocouples will influence the measurements significantly
- Water vapour concentration should be measured.
- Water mist droplet size distribution should be available
- Remember that Oxygen concentration is often given as dry gas concentration

Performance data

- WATMIST can be run on a PC
- Excel 97
- Typical calculation time is 2-3 minutes per case, fire duration 30 minutes, on a 600 MHz - 126 MB Ram computer.

Availability

- WATMIST will be made public available for research and in-house use within this year

SP Fire Research

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