Large scale fire suppression tests with water mist systems in power transformer buildings

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Current state

- Sprinkler deluge systems are generally used ;
- Urban sites may have a limited space for water quantity needed by these systems;
- Some sites may involve a long intervention delay, e.g. urban sites where traffic jam can occur.

ERDF objectives

- Have at its disposal an alternative system able to solve these issues;
- The system performances should be validated through a series of representative yet critical fire tests (real scale enclosure, real transformer body, openings avoiding under-ventilated conditions, pre-heated body, flow of pre-heated oil);
- To be validated the system should achieve extinction in 3 repeated tests to ensure efective thermal management.

Contents

Test enclosure construction: many contraints involved

• **Resist multiple cycles of fire (high temperatures) and suppression (high humidity) ➡ strong limitation regarding usable materials;**

• **Resist bad weather conditions, in particular strong wind;**

• **Meet functional requirements (access door, smoke exhaust, recover effluent to allow subsequent treatment;**

• **Meet budget.**

Conception and construction of test enclosure

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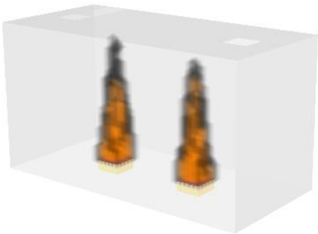
Defined fire scenario

Fire scenario consists in continuous flow (60 lpm) of preheated oil at a minimum of 150°C (oil fire point) on the top of the transformer body. The body itself has to be heated above 120°C to avoid oil cooling. Water mist is activated manually on a fully developed fire.

Three fundamental questions

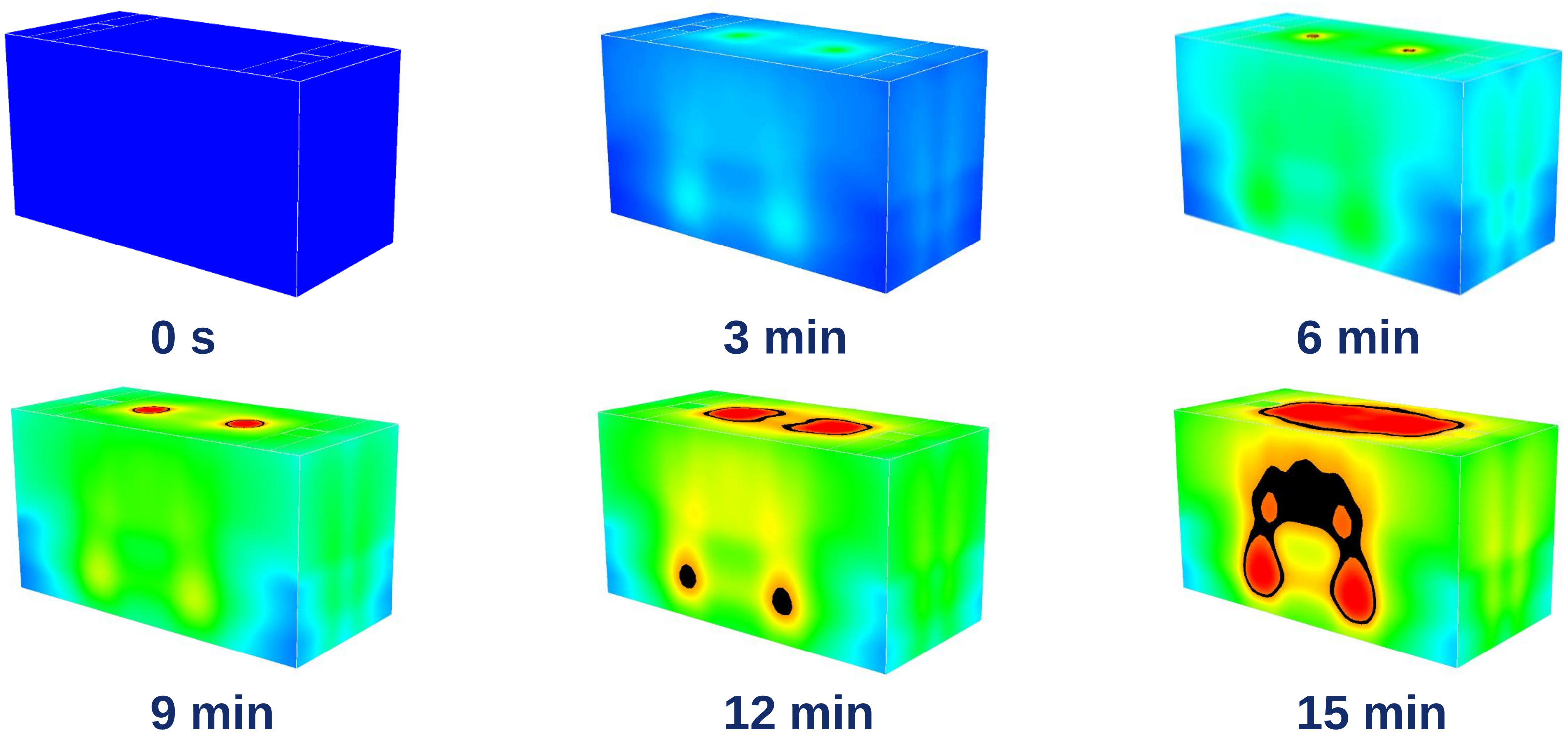
- **How can we heat the transformer body (9 t) to 120°C ?**
- **Will we meet under-ventilated conditions in the enclosure considering defined fire scenario and smoke exhaust surface ?**
- **How can we heat and transport the oil with a flow rate of 60 lpm ?**

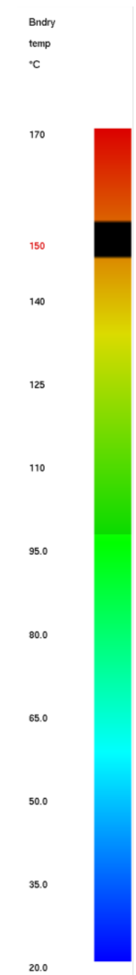
Conception and implementation of fire scenario



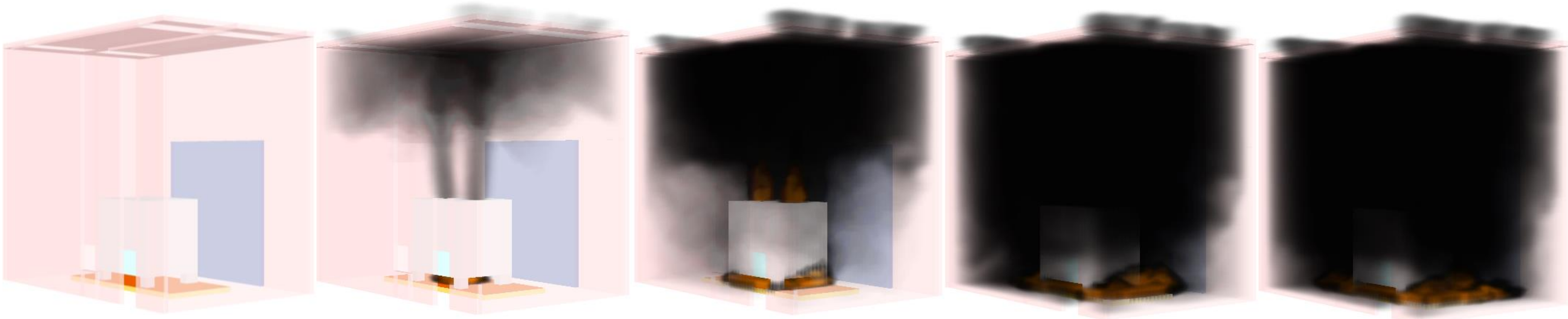
Can we heat the transformer body up to 150°C ?
If we can, how long will it take ?
Hypothesis : 2 burners 1 MW

Evolution of body surface temperature with time

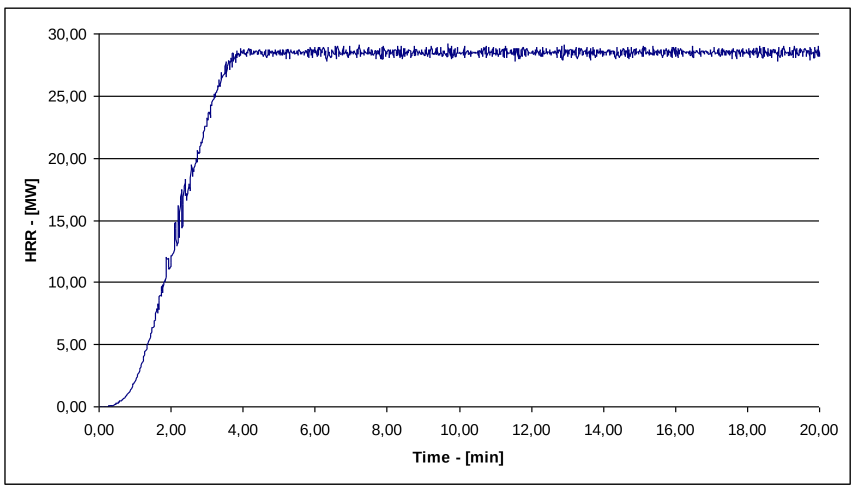




Conception and implementation of fire scenario



0 s | 1 min | 2 min | 3 min | 4 min

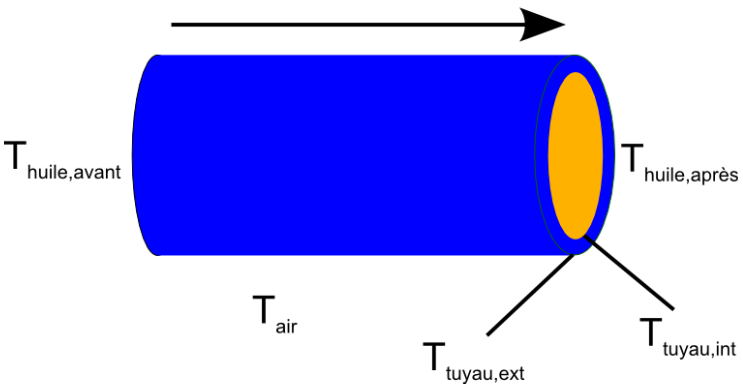


Will we meet under-ventilated conditions ?

➡ Numerical simulation of a similar fire in the enclosure.

No HRR evolution after 4 min ➡ fire is well ventilated.

Analytical calculation for oil temperature



How long should the pipes be so that we can heat oil up to 150°C with a flow rate of 1 l/s ?

Flux formula: $$\varphi = \frac{m.c_p}{A}\frac{dT}{dt}$$

So $$T_{huile,après} = T_{huile,avant} + \frac{\varphi.A.\Delta t}{m.c_p}$$

With $$\varphi = h_e(T_{air} - T_{tuyau,ext})$$

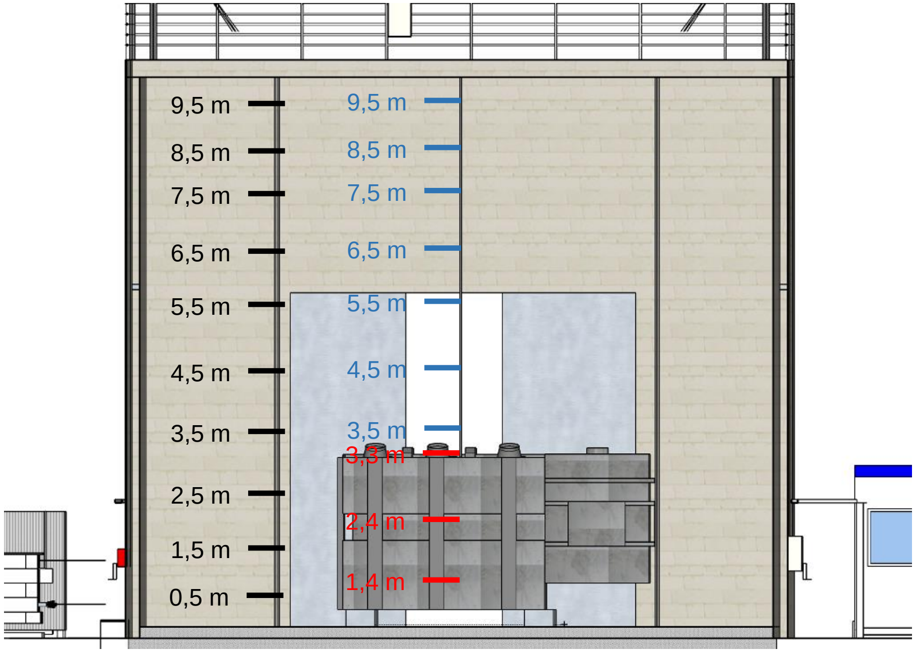
With $$T_{tuy,ext} = -\frac{h_i}{h_e}(T_i - T_{huile,avant}) + T_{air}$$

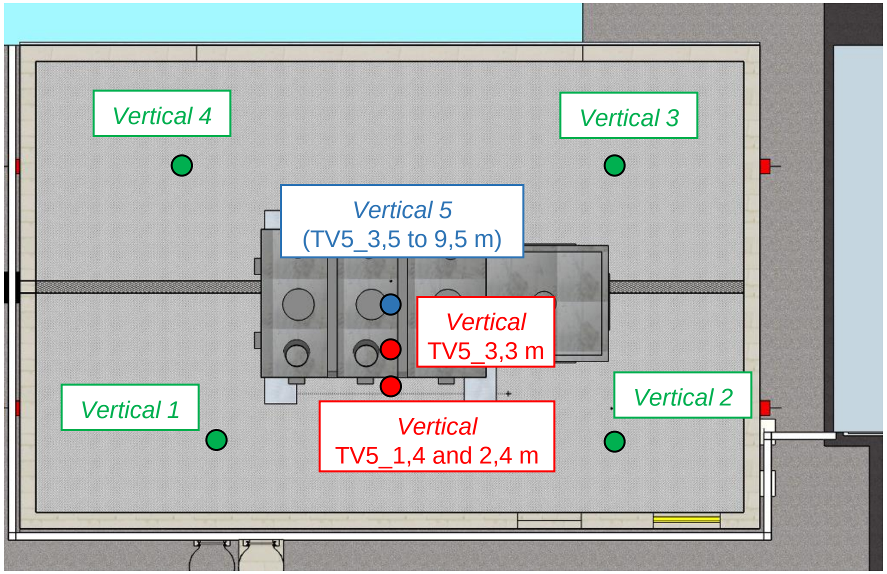
With $$T_{tuy,\mathrm{int}} = \frac{h_i.T_{huile,avant} + \frac{\lambda_{acier}.T_{air}}{\ln\left(\frac{R_e}{R_i}\right).e} + \frac{\lambda_{acier}.T_{huile,avant}.h_i}{h_e.\ln\left(\frac{R_e}{R_i}\right).e}}{h_i + \frac{\lambda_{acier}}{\ln\left(\frac{R_e}{R_i}\right).e} + \frac{\lambda_{acier}.h_i}{h_e.\ln\left(\frac{R_e}{R_i}\right).e}}$$

Measurements

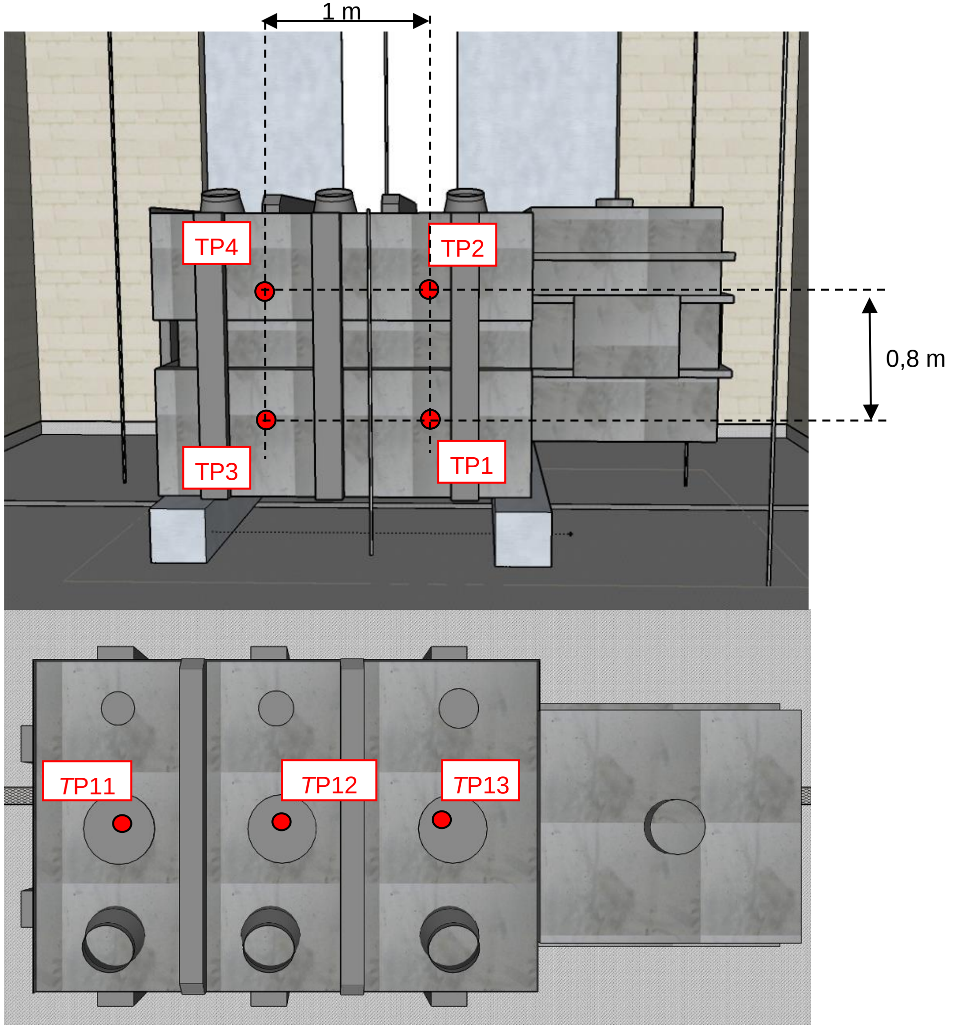
- 80 temperature devices in the test enclosure;
- 10 temperature devices for the process;
- 2 fluxmeters;
- Air velocity devices (in the door and smoke exhausts);
- gaz analyser to determine O_2,CO_2 and CO concentration;
- Devices for pressure and water flow in water spray systems;
- Video cameras.

Measurements



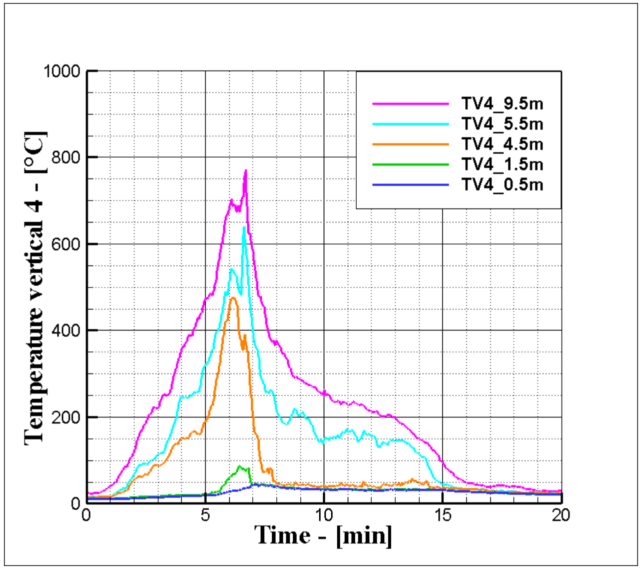


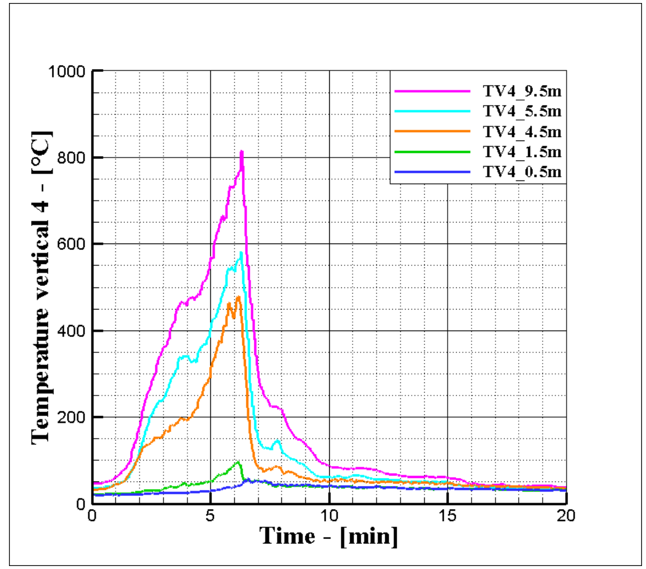
Measurements



Fire tests results

Typical results: ambient temperature

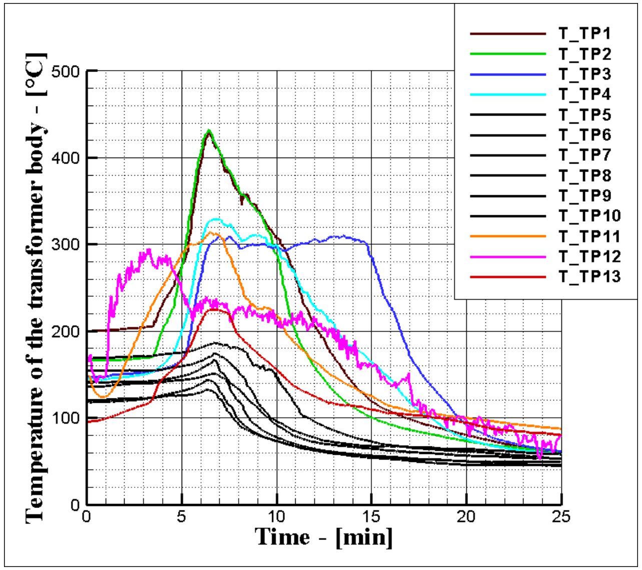


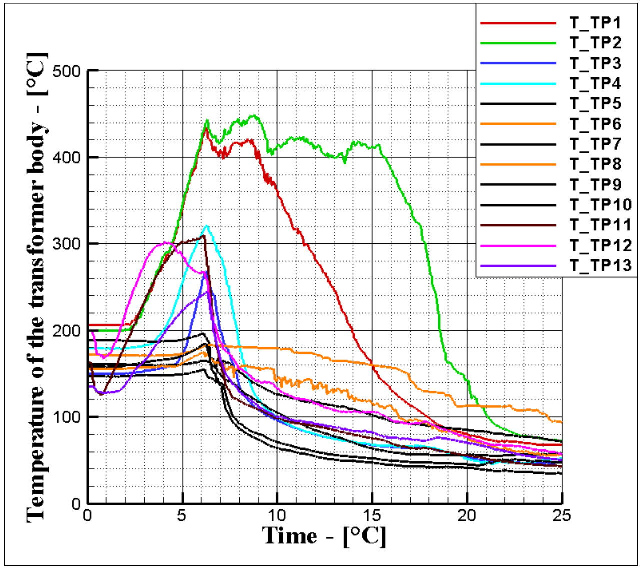


Extinction times are of the same order yet there is a significantly different evolution of ambient temperature due to a distinctive fire extinguishment dynamic:

- **Progressive decrease of HRR in first case ;**
- **Fast suppression but remaining flames for few minutes in second case.**

Typical results: body temperature





Extinction times are of the same order yet there is a significantly different evolution of body temperature due to a distinctive cover of the object by the water mist configuration.

There is a poor cooling near T_TP3 for the first cast while there is a lack of water near T_TP2 in the second case leading to a remaining flame.

Conclusions

- **Fire scenario induces many complex phenomena and thus there is no solution off the shelf. This application requires a specific design and each system (nozzle type, pressure, number of nozzles, location, etc.) has to be tested in a configuration matching the real case;**

- **Sufficient water quantity should cover the whole object homogeneously;**

- **The fire is likely to sustain or re-ignite at locations where there is a deficit of water mist;**

- **Additives will enhance performances (pool fire) and limit risk of re-ignition.**

Aknowledgements: François Robert, Christophe Breton, Augustin Mayunga.