One day symposium on

Fire & Rescue in the 21st Century

How Science & Engineering Support the Fire Service

Murrayfield stadium, Edinburgh

WEDNESDAY 4TH NOVEMBER 2009

THE UNIVERSITY OF EDINBURGH

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A Decade of Scandinavian Research Aimed at Benefiting the Fire Service

The Philip Thomas lecture
FIRESEAT conference
4th November 2009

Dr. Björn Karlsson
Director General, Iceland Fire Authority
Associate Professor, University of Iceland

Contents

- Background
- Flashover, backdraft, smoke gas explosion
- Ventilation, including PPV
- Suppression
- Tactics
- Conclusions

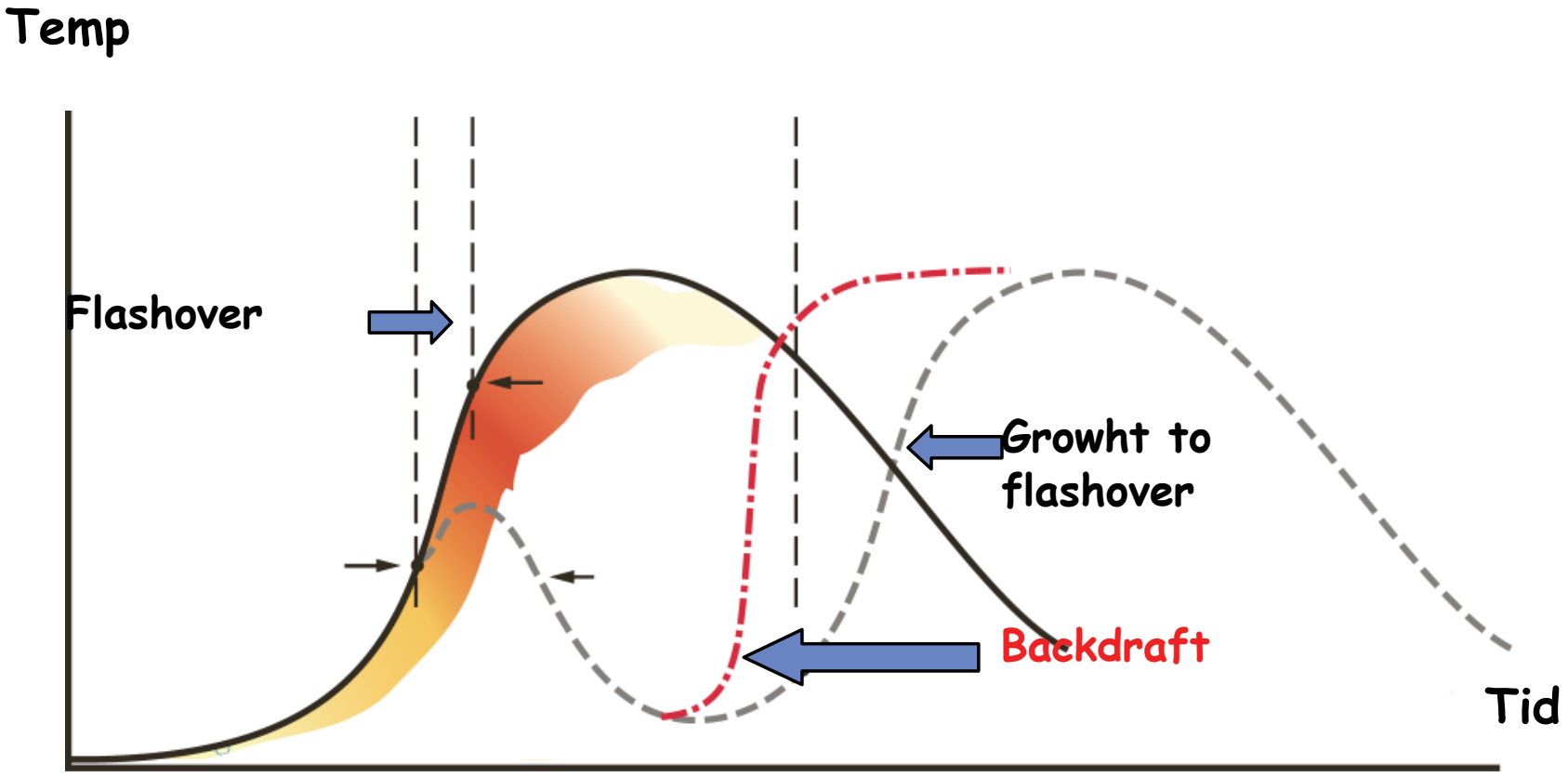
Background

- Fire fighter training and experience is important, but buildings are getting much more complex (atria, underground, etc)
- Rapid progress in understanding fire phenomena, computer programs, etc
- Important to use new technology in training
- Here: Give overview of research for fire service, researchers from Lund University who subsequently worked in fire service

Flashover, backdraft, smoke gas explosion

- Very hazardous phenomena
- Controversy over terms used
  - Flameover, rollover, lean and rich flashover, etc
- Research project with aims to
  - Clarify terminology
  - Increase understanding of the dominant thermal and chemical processes
  - Produce basis for teaching material

Flashover, backdraft, smoke gas explosion

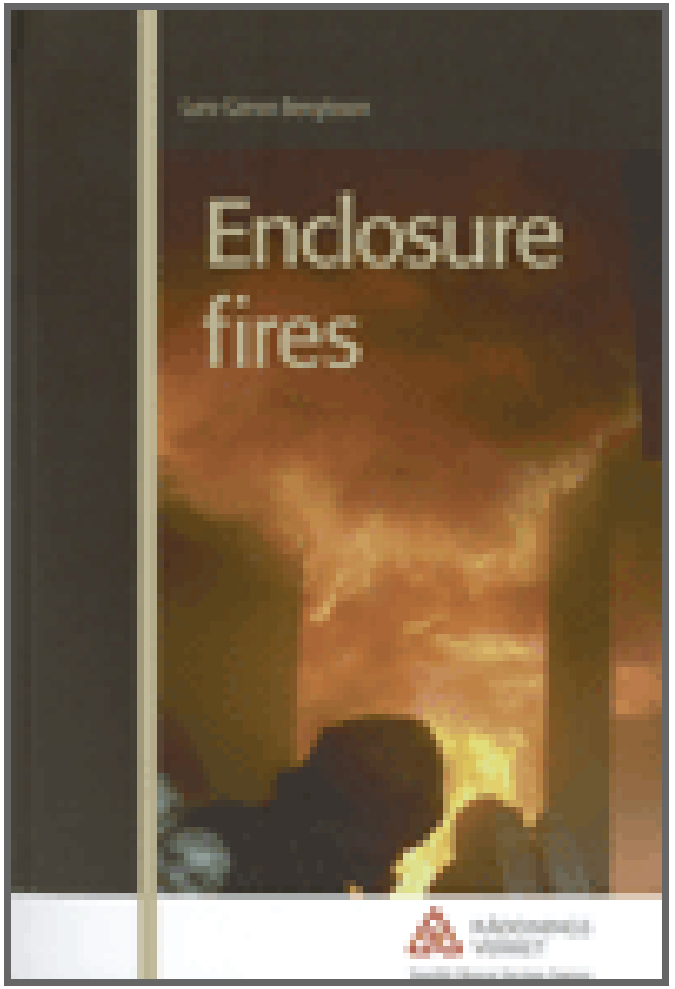


Results

- The phenomena Flashover, Backdraft and Smoke gas explosion occur relatively seldom but can involve great danger to fire fighters
- The work divides potentially hazardous situations into categories based on fundamental physical and chemical processes
- These categories are observed in practice and experiments have been performed for verification
- The phenomena are closely related and it can in some cases be difficult to distinguish one from the other

Result

A new textbook for Fire Fighters And Fire Officers used by the Swedish Fire and Rescue Training Facilities



Backdraft

- Backdraft arises from an under-ventilated fire
- A majority of fires are under-ventilated, or limited to first item ignited, when the fire service arrives on the scene
- Most fire research work over the last 40 years has concentrated on well-ventilated fires
- In under-ventilated fires one must deal with both thermal and chemical processes
- Our aim: Educational material for fire fighters

Backdraft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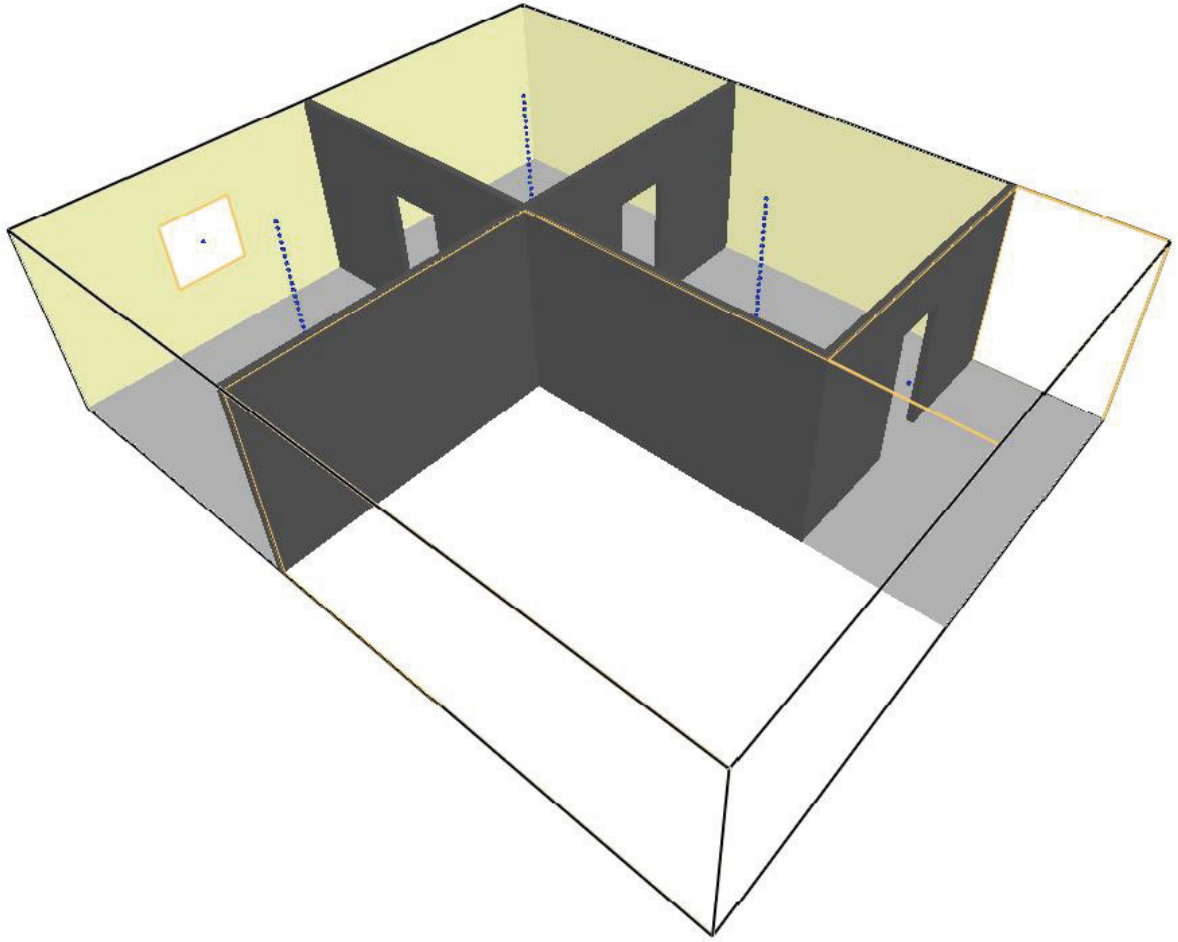
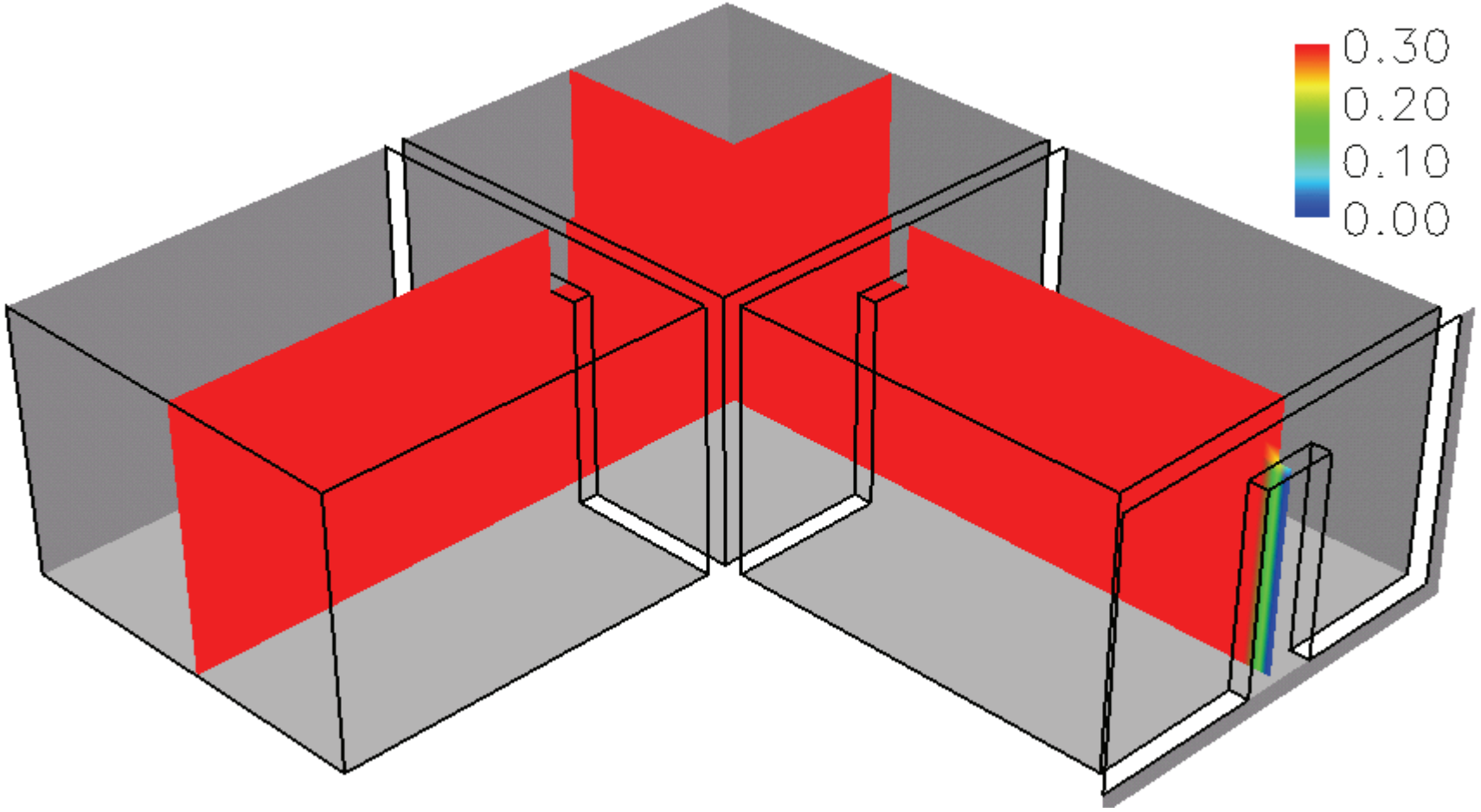
Risk of Backdraft vs Tactics



Risk of Backdraft vs Tactics

- Offensive attack, BA team enters front door
- Defensive attack, natural ventilation by opening a window at the back
- PPV at low flow rate 3.73 m^3/s.
- PPV at high flow rate 5.38 m^3/s.
- Incorrect use of PPV at 5.38 m^3/s.
- Dilution of unburned gases, by water spray before opening.

Risk of Backdraft vs Tactics



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Ventilation including PPV

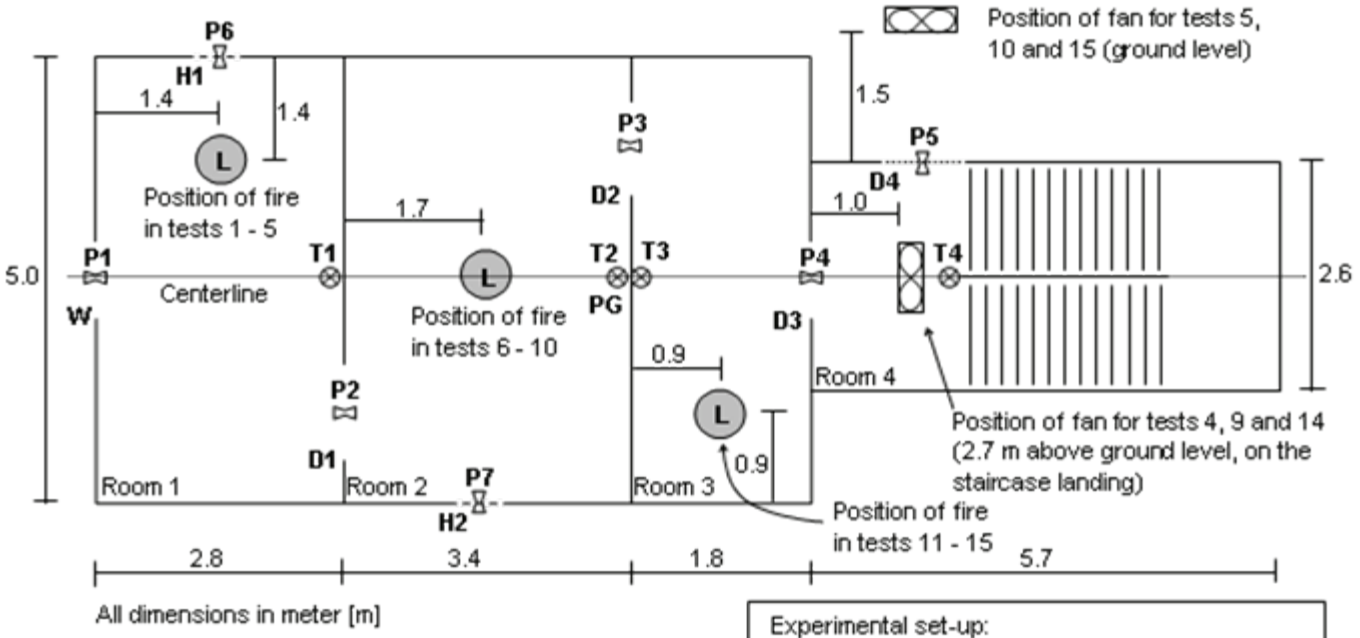
1. Experimental Study of Fire Ventilation Actions During Firefighting Operations
2. Experimental Study of Fire Ventilation Procedures in a Large Hall
3. Investigating positive pressure ventilation

1. Study of fire ventilation during fire fighting operations

- Purpose of the tests
  - investigate the effect of measures taken by fire & rescue services, including positive pressure ventilation
  - to provide fire & rescue services with qualitative data to be used as a basis for decision making on the fire ground
  - 15 experiments
- Experimental set-up
  - fire fighter training facility (concrete/lightweight concrete)
  - 0.50 m diameter heptane pool, burn time app. 700 seconds, RHR appr. 0.37 MW
  - PPV by a Typhoon 18T5 fan, nominal flow of 2.7 m3/s

The test facility

Experimental lay-out



Experimental set-up:	
T1 - T4	stacks of thermocouples
P1 - P7	Pitot tubes
L	load cell (moved between tests)
PG	pressure gauge
W	window, 0.88 × 1.18 m^2
D1 - D2	doors, 1.16 × 1.98 m^2
D3 - D4	doors, 0.92 × 2.00 m^2
H1 - H2	hatches, 0.6 × 0.2 m^2

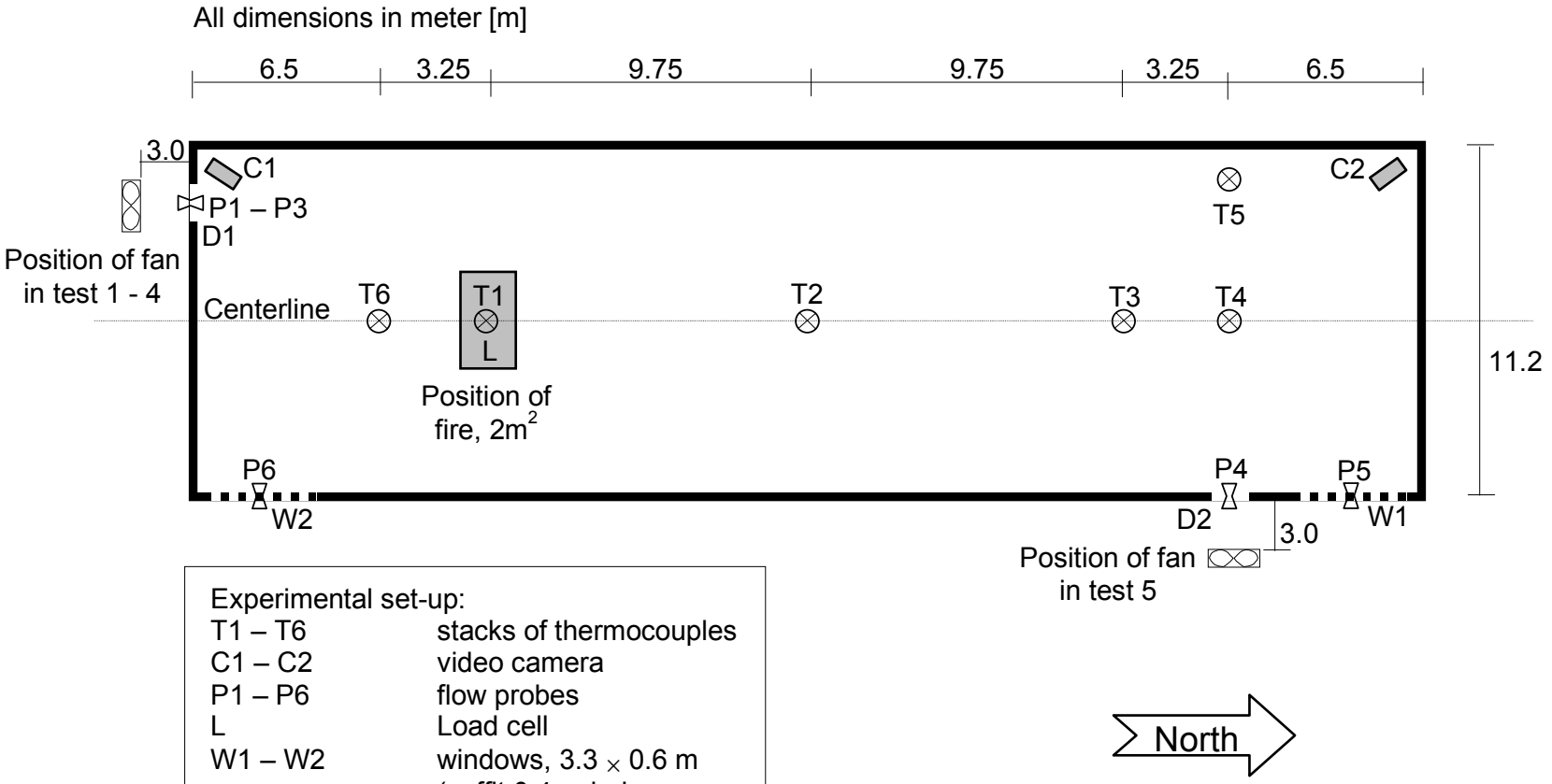
Fire fighting scenarios

A. via staircase (access route through D4, Room 4, D3), window (W) closed
B. via window (W), door between staircase (Room 4) and apartment closed (D3)
C. via staircase (access route through D4, Room 4, D3), window (W) open
D. via staircase (access route through D4, Room 4, D3), window (W) open, PPV, fan positioned in Room 4
E. via staircase (access route through D4, Room 4, D3), window (W) open, PPV, fan positioned outside door to staircase (D4)

2. Study of fire ventilation procedures in a large hall

- Purpose of the tests
  - Investigate fire ventilation actions taken by the fire services, including PPV, for fires in large halls
- Experimental set-up
  - Five tests were performed in a large hall measuring 39 m long, 11.2 m wide and 8.1 m in ceiling height
  - 1×2 m methanol pool, RHR appr. 1.0 MW
  - Smoke was produced using propylene glycol from smoke generators
  - PPV provided by a standard type fan, nominal flow of 4.5 m3/s.

Experimental lay-out



Experimental set-up:	
T1 – T6	stacks of thermocouples
C1 – C2	video camera
P1 – P6	flow probes
L	Load cell
W1 – W2	windows, 3.3 × 0.6 m (soffit 0.4 m below ceiling)
D1 - D2	doors, 1 × 2 m

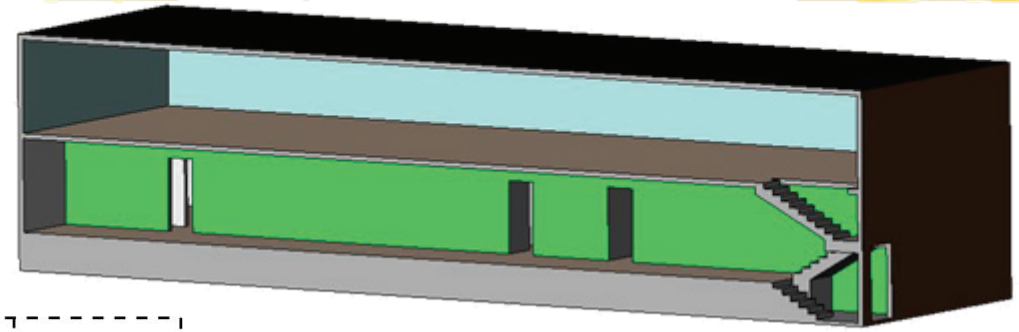
Investigated scenarios

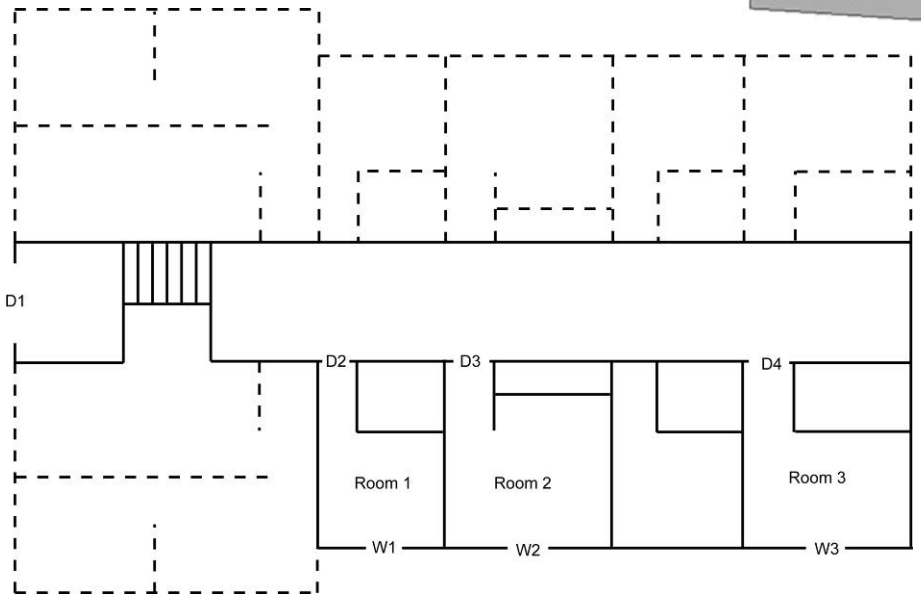
1. Door in the south wall, D1
2. Window at ceiling level in the northeast corner, W1
3. Door in the south wall, D1 in figure 1, and window at ceiling level in the northeast corner, W1
4. Door in the south wall, D1, and window at ceiling level in the northeast corner, W1, using positive pressure ventilation, fan located approximately 3 m outside D1, blowing into the hall
5. Door in the northeast corner, D2, and window at ceiling level in the southeast corner, W2, using positive pressure ventilation, fan located approximately 3 m outside D2, blowing into the hall

3. Investigating positive pressure ventilation

- Purpose of the tests
  - effects of distance between fan and inlet
  - size and numbers of outlets
  - volume of building
- Experimental set-up
  - Forty-three experiments on the first, second, and third floors of a three-storey brick building with wooden trusses
  - Cold-flow only (unfortunately…)

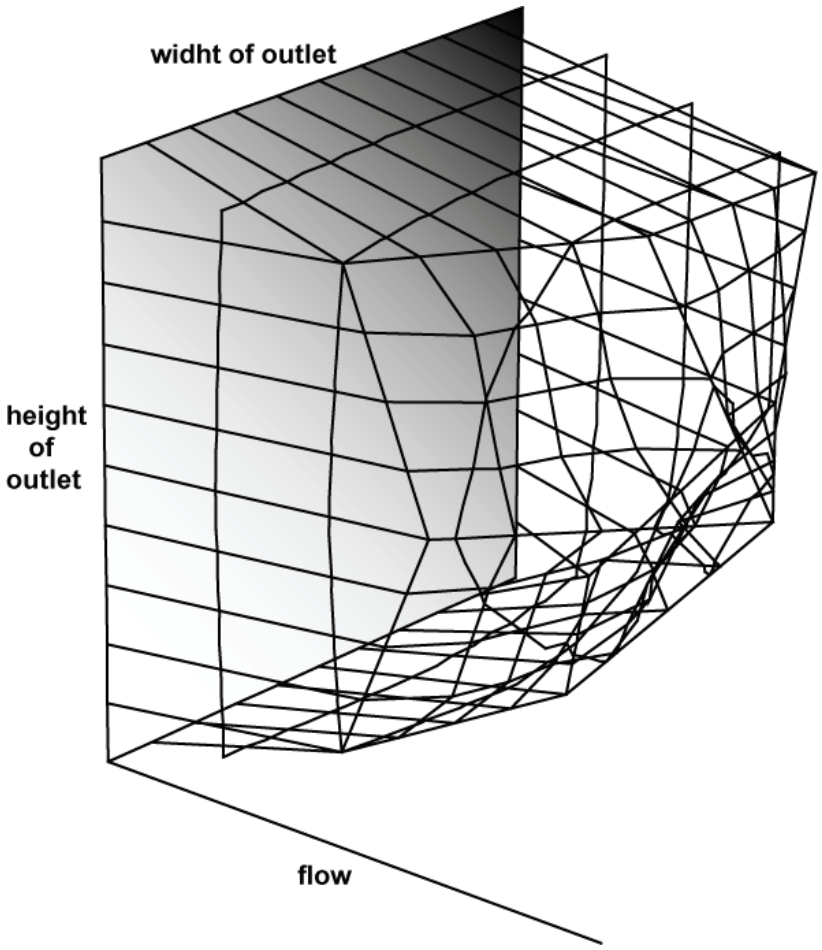
The test facility





Results

- Including comparison with CFD-calculations



Results

- Positive pressure ventilation increases the mass loss rate of fuel, consequently increasing burning rate of the fire, also, risk of fire spread to adjacent rooms will increase
- Working conditions for fire fighters are improved by positive pressure ventilation, but the lives of any victims trapped in an apartment on fire are jeopardised
- Co-ordination of different measures at a fire scene is crucial and the importance of command and control is prominent.
- Exhaust flow rate increases with increasing distance between fan and inlet
- Exhaust flow rate decreases as volume of the structure increases

Result

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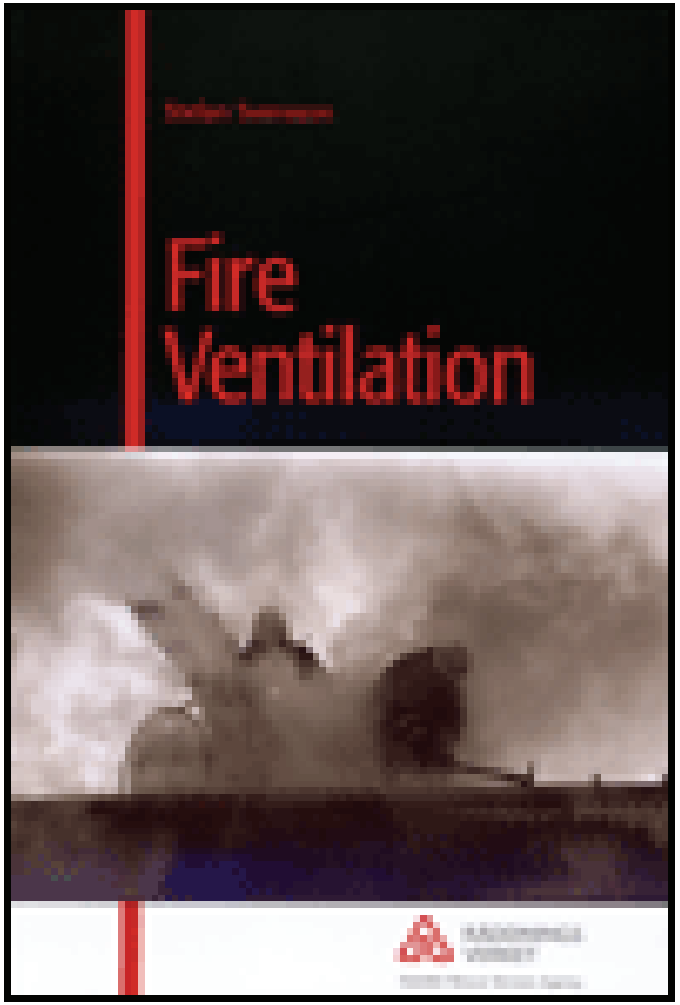

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SUPPRESSION

1. Live Fire Tests on Suppression of Post-flashover Fires using Manually Applied High and Low Pressure Water Sprays
2. Fire Tests in a Large Hall, using manually Applied high and Low Pressure Water Sprays

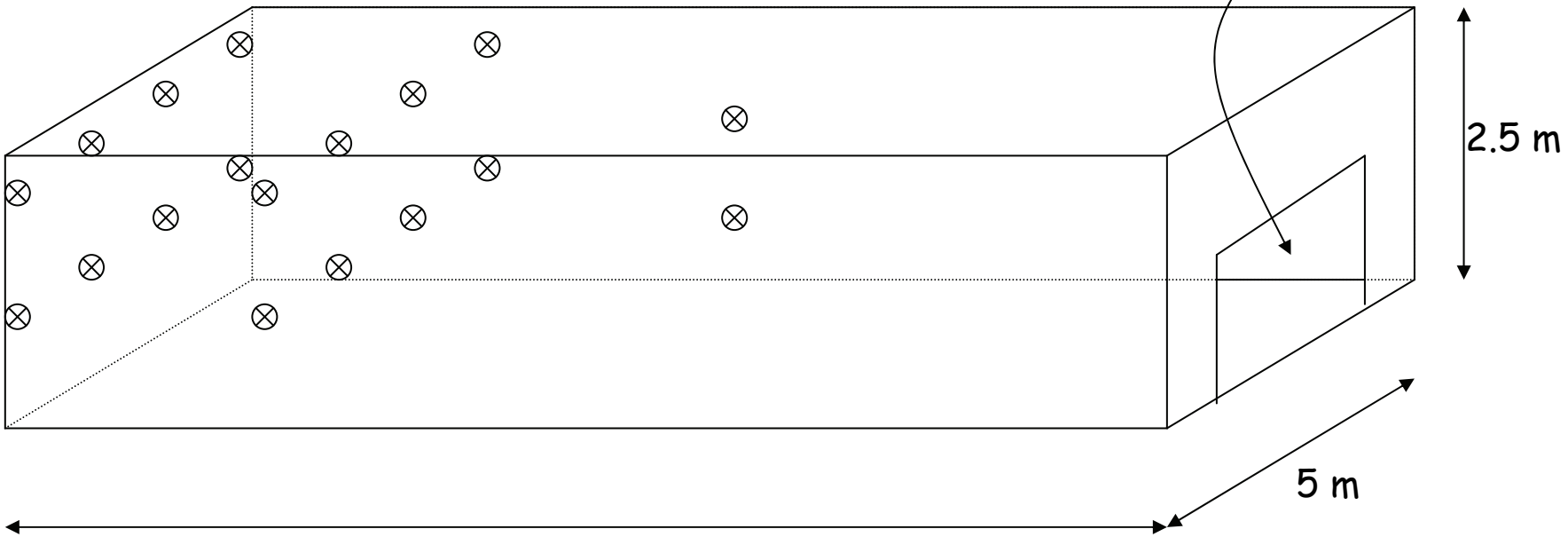
1. Suppression Tests Using High and Low Pressure Water Sprays

- Purpose of the tests
  - Compare a high-pressure (~40 bar) system with a normal pressure (~10 bar) system, systems mounted on a fire engine
- Experimental set-up
  - 15 tests in a fire fighter training facility
  - Water application using a manually oscillated nozzle
  - Actual fire-fighting techniques
  - The fuel was applied on the walls and in the ceiling of a fire fighting training facility, appr. 18 m2, 18-mm particleboard

The test facility

18 thermocouples at heights 1 m and 2 m above floor, located at 0.1 m, 2.5 m and 7.5 m from far end wall, respectively.

opening 2.5 × 1.1 m

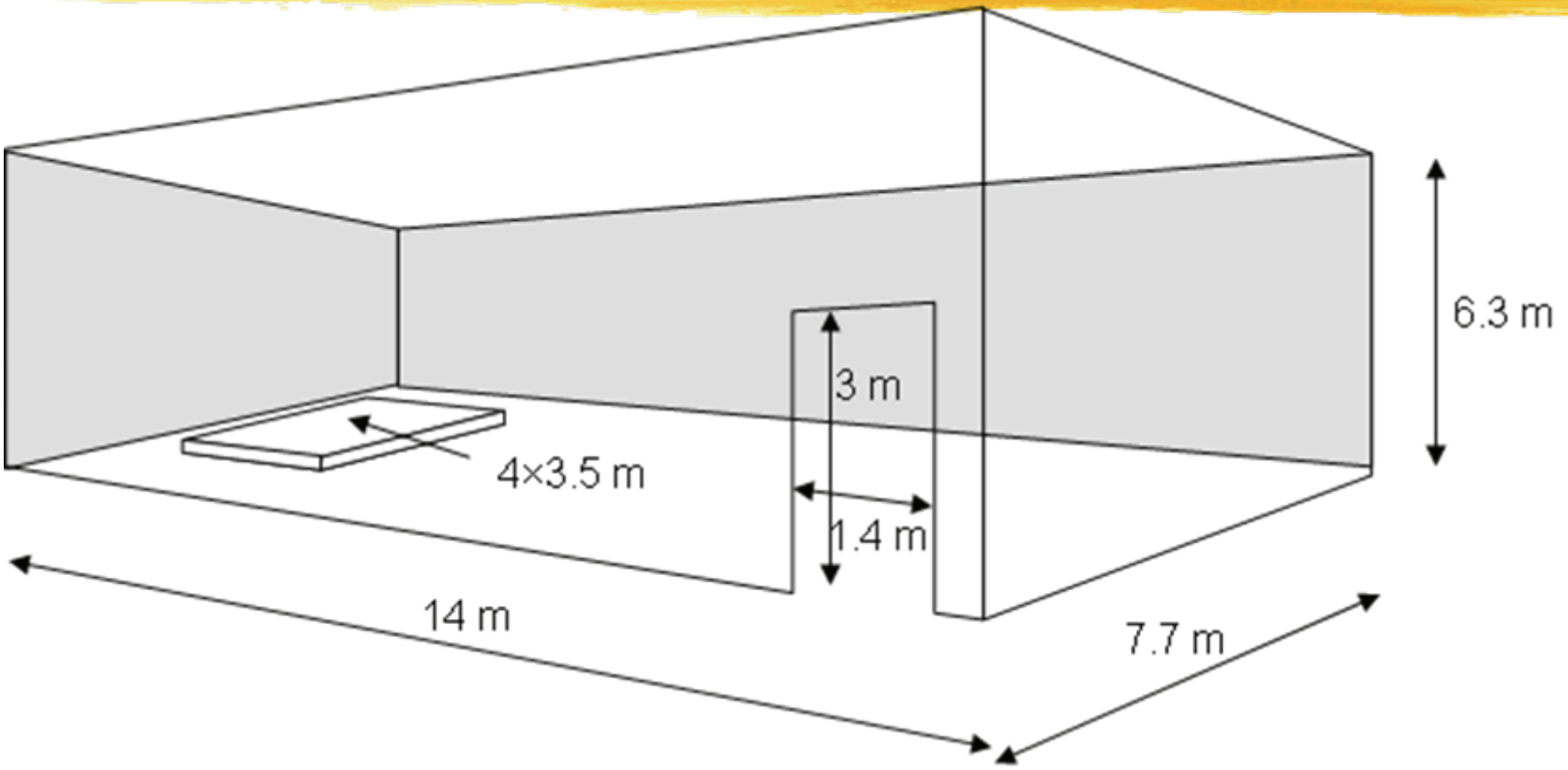


⊗ = thermocouple

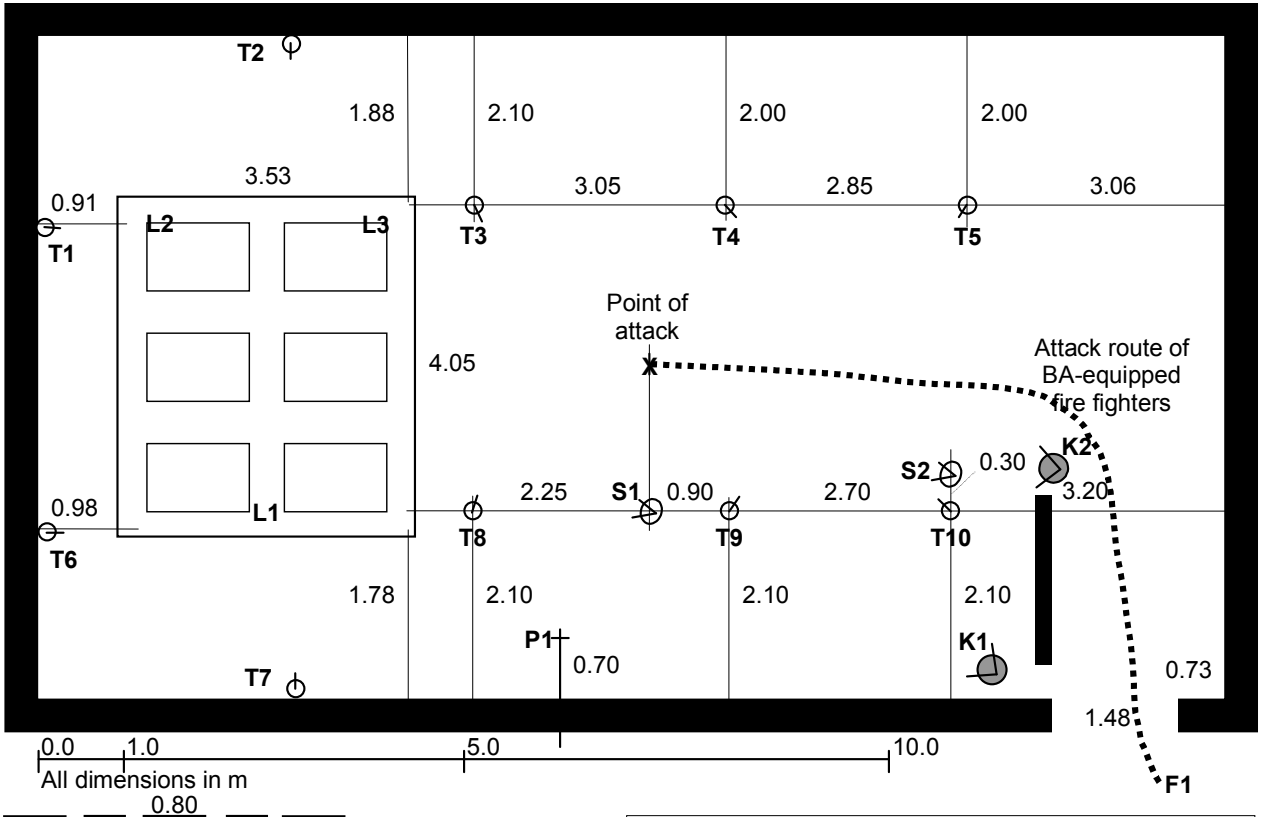
2. Tests In A Large Hall, High- And Low Pressure Water Sprays

- Purpose of the tests
  - investigate the capacity of the fire service to fight fires in large spaces and obtain quantitative data
  - compare a high-pressure with a low-pressure system
  - measure the heat stress on BA-equipped fire fighters
- Experimental set-up
  - Six tests in a room measuring 14.0 × 7.7 m², 6.3 m in height, with 0.4 m thick walls of concrete
  - The fuel consisted of standard wood pallets arranged in 6 stacks with 13 pallet in each stack

The test facility



The test facility



Experimental set-up:

F1	Flow meter	P1	Pressure gauge
K1-K2	Video cameras	S1-S2	Radiometers
L1-L3	Load cells	T1-T10	Stacks of thermocouples

Results

- A rigid hose used together with a high-pressure system generally decreases the attack time and reduces temperatures quicker
- High-pressure system has a better extinguishing effect regarding gas phase extinction
- When both surface cooling effects and gas phase effects are considered, the high-pressure system requires only two-thirds of the water required by the low-pressure system to achieve the same extinction capacity in this scenario
- The increase in pulse rate of the fire fighters appeared to be triggered by mental stress and increased due to increasing skin temperature

Results

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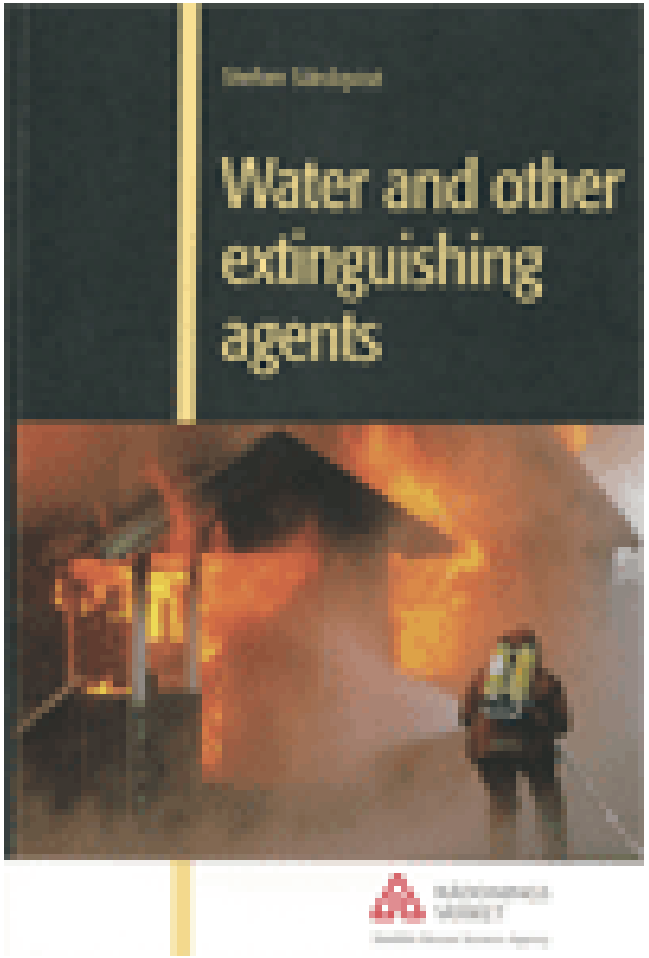

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TACTICS

1. A Study of Tactical Patterns During Firefighting Operations
2. Investigating Firefighting Tactics in a Mechanical Workshop
3. Investigating Tactical Patterns in a Residential Type Structure
4. Tactical Patterns and Their Implications for Fire Fighting Operations

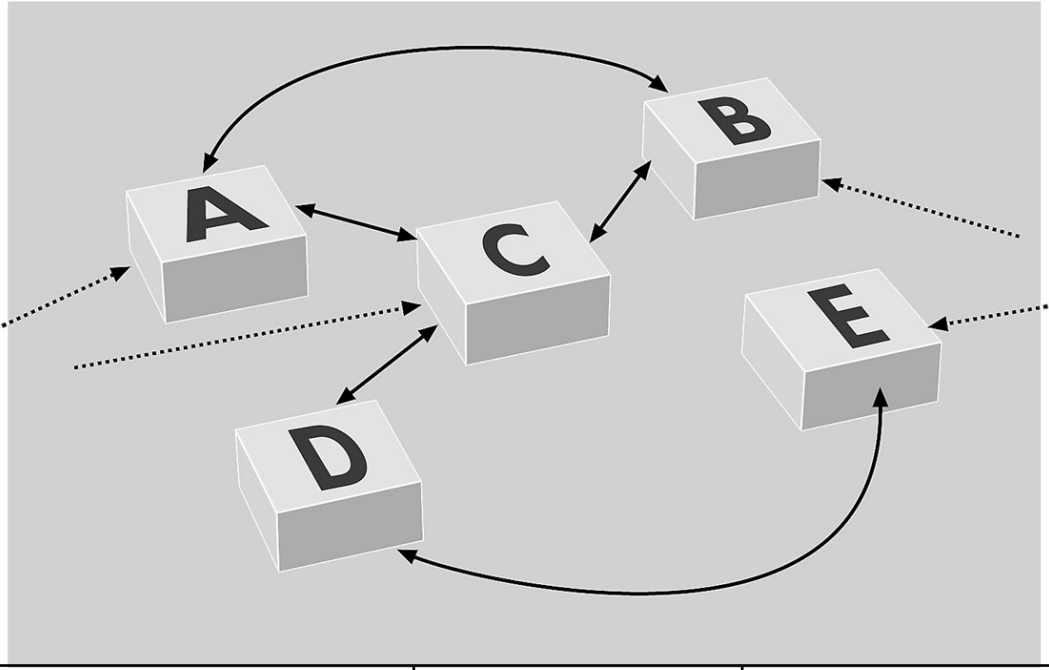
1. Tactical Patterns During Firefighting Operations

- Purpose of the tests
  - to investigate how tactical patterns interact with a fire in an apartment
  - examine and draw conclusions from the course of events during operations and on their outcomes
  - a basis for further treatment of command and control problems
- Experimental set-up
  - twenty tests performed in a fire fighter training facility
  - eight standard wooden pallets used as fuel in each test

Questions of interest

- Why is a specific task chosen during a fire fighting operation?
- What happens when this task is executed?
- What would have happened if some other task were to be executed?
- What would have happened if the task were to be executed at some other point in time or space?

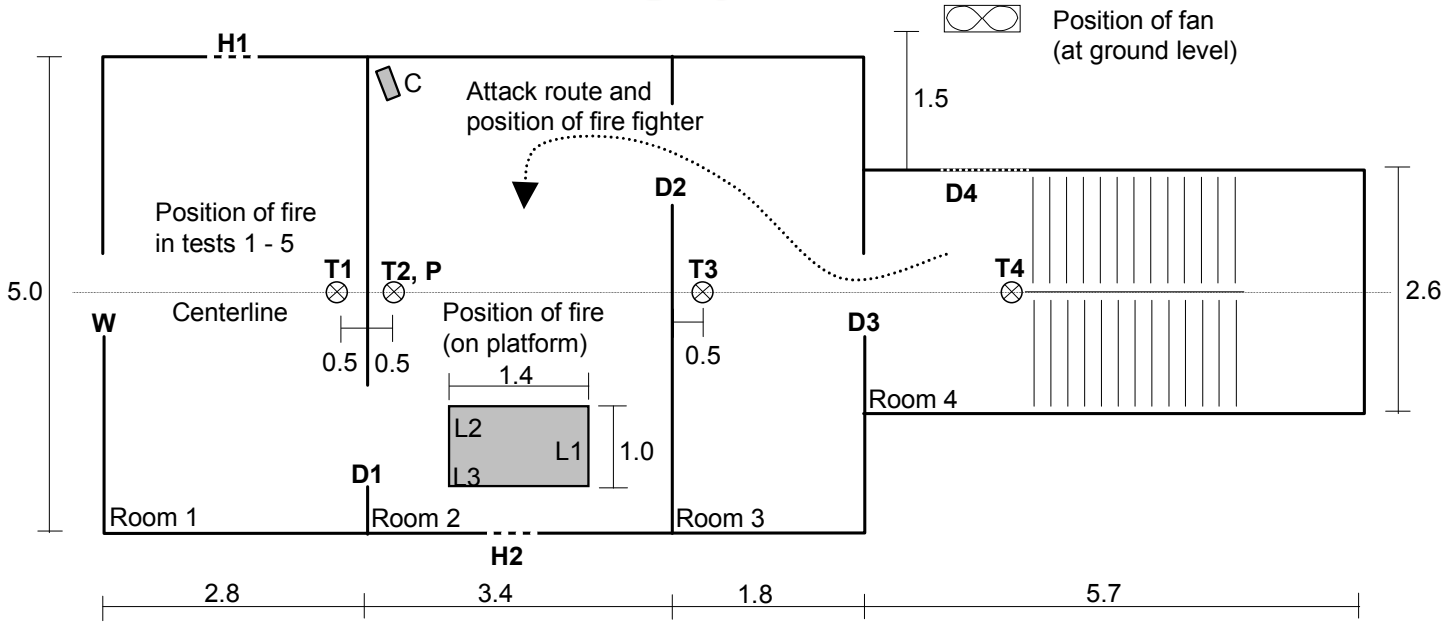
The basic idea



Available procedures	X		Y
Possible combinations	only X	first X then Y	X and Y
	only Y	first Y then X	

The test facility

Experimental lay-out



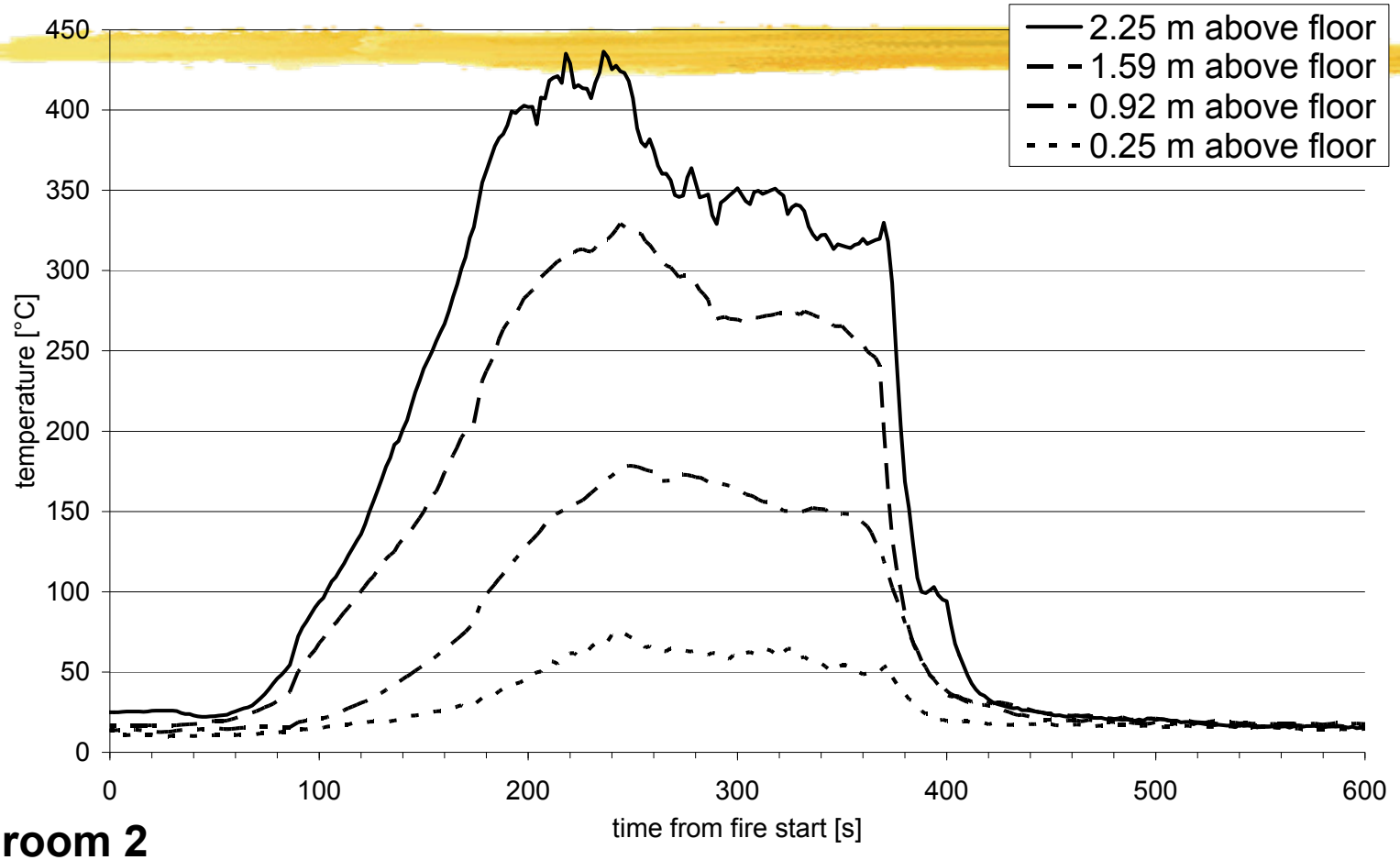
All dimensions in meter [m]

Experimental set-up:	
T1 - T4	stacks of thermocouples
P	pressure gauge
L1 – L3	load cells
C	camera ("Hubert")
W	window, 0.88 × 1.18 m^2
D1 - D2	doors, 1.16 × 1.98 m^2
D3 - D4	doors, 0.92 × 2.00 m^2
H1 - H2	hatches, 0.6 × 0.2 m^2

Overview of tests

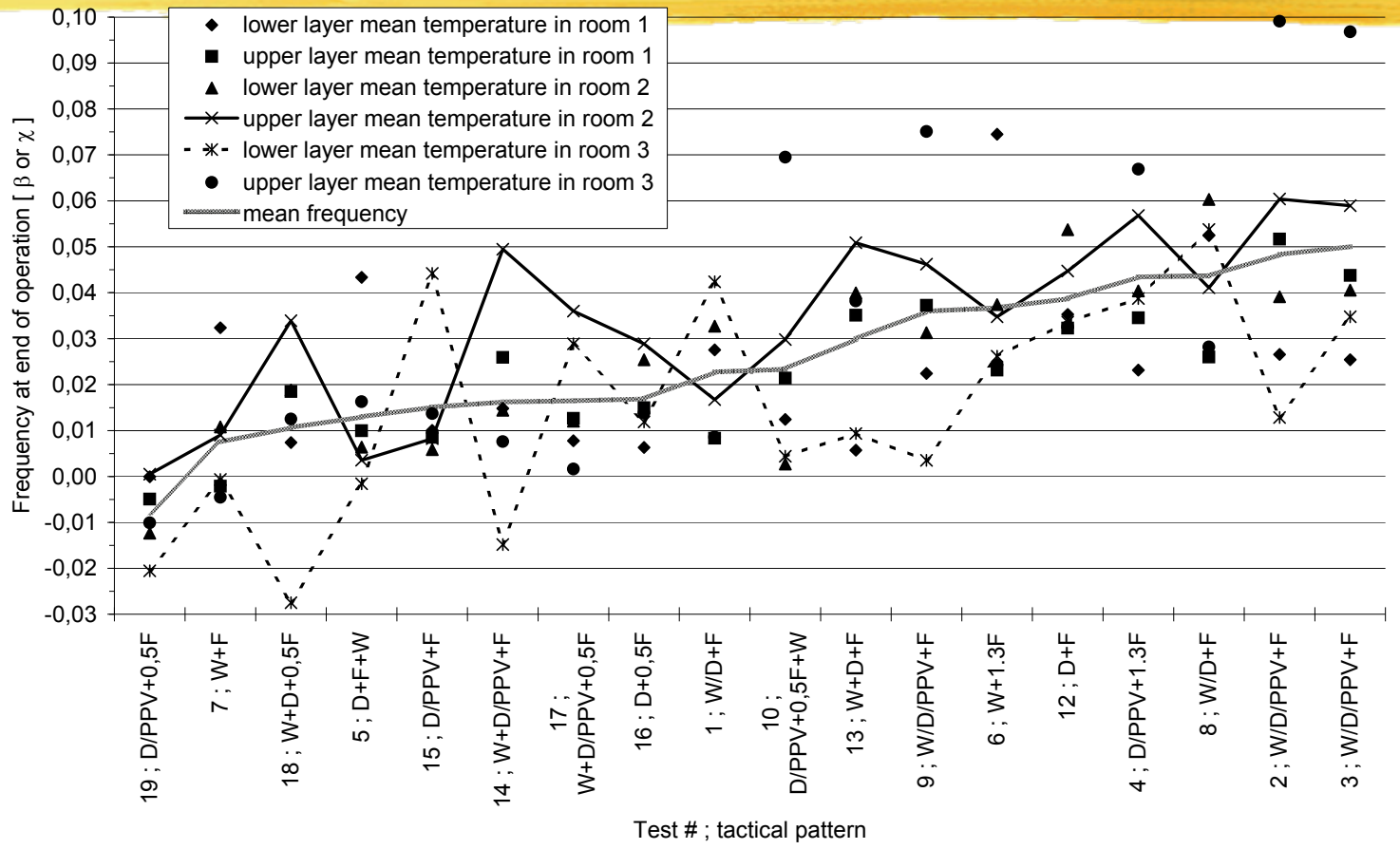
Test #	Tactical pattern
1	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened.
2	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened, using positive pressure ventilation.
3	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened, using positive pressure ventilation.
4	Attack through the door to the apartment (D3), using positive pressure ventilation.
5	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened.
6	Attack through the window (W).
7	Attack through the window (W).
8	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened.
9	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened, using positive pressure ventilation.
10	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened, using positive pressure ventilation.
11	No attack (full-burn), door (D3) and window (W) opened and fire extinguished for safety reasons.
12	Attack through the door to the apartment (D3).
13	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened.
14	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened, using positive pressure ventilation.
15	Attack through the door to the apartment (D3), using positive pressure ventilation.
16	Attack through the door to the apartment (D3).
17	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened, using positive pressure ventilation.
18	Attack through the door to the apartment (D3), door to the apartment (D3) and window (W) opened.
19	Attack through the door to the apartment (D3), using positive pressure ventilation.
20	No attack (full-burn), door (D3) and window (W) opened and fire extinguished for safety reasons.

Results



Test 9, room 2

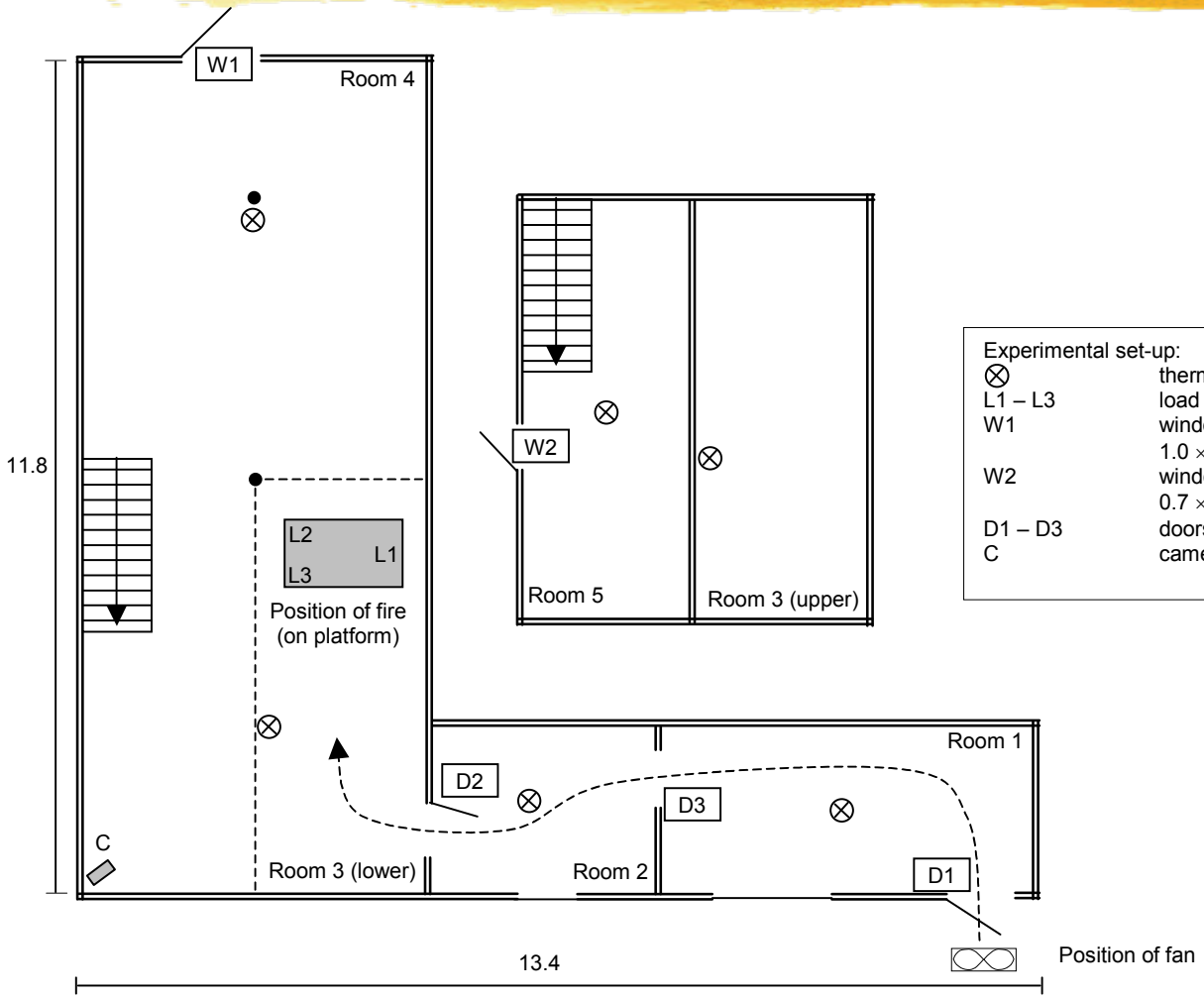
Results


lower layer mean temperature in room 1
upper layer mean temperature in room 1
lower layer mean temperature in room 2
upper layer mean temperature in room 2
lower layer mean temperature in room 3
upper layer mean temperature in room 3
mean frequency
Frequency at end of operation [β or χ]
0,10
0,09
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0,00
-0,01
-0,02
-0,03
19 ; D/PPV+0,5F
7 ; W+F
18 ; W+D+0,5F
5 ; D+F+W
15 ; D/PPV+F
14 ; W+D/PPV+F
17 ; W+D/PPV+0,5F
16 ; D+0,5F
1 ; W/D+F
10 ; D/PPV+0,5F+W
13 ; W+D+F
9 ; W/D/PPV+F
6 ; W+1.3F
12 ; D+F
4 ; D/PPV+1.3F
8 ; W/D+F
2 ; W/D/PPV+F
3 ; W/D/PPV+F
Test # ; tactical pattern

2. Fire Fighting Tactics in a Mechanical Workshop

- Purpose of the tests
  - verify basic tactical principles identified in earlier experiments
  - Verify the methodology for analysis
- Experimental set-up
  - nine tests were performed in a fire fighting training facility, representing a small mechanical workshop
  - thirteen standard wooden pallets were used as fuel in each test

Experimental lay-out



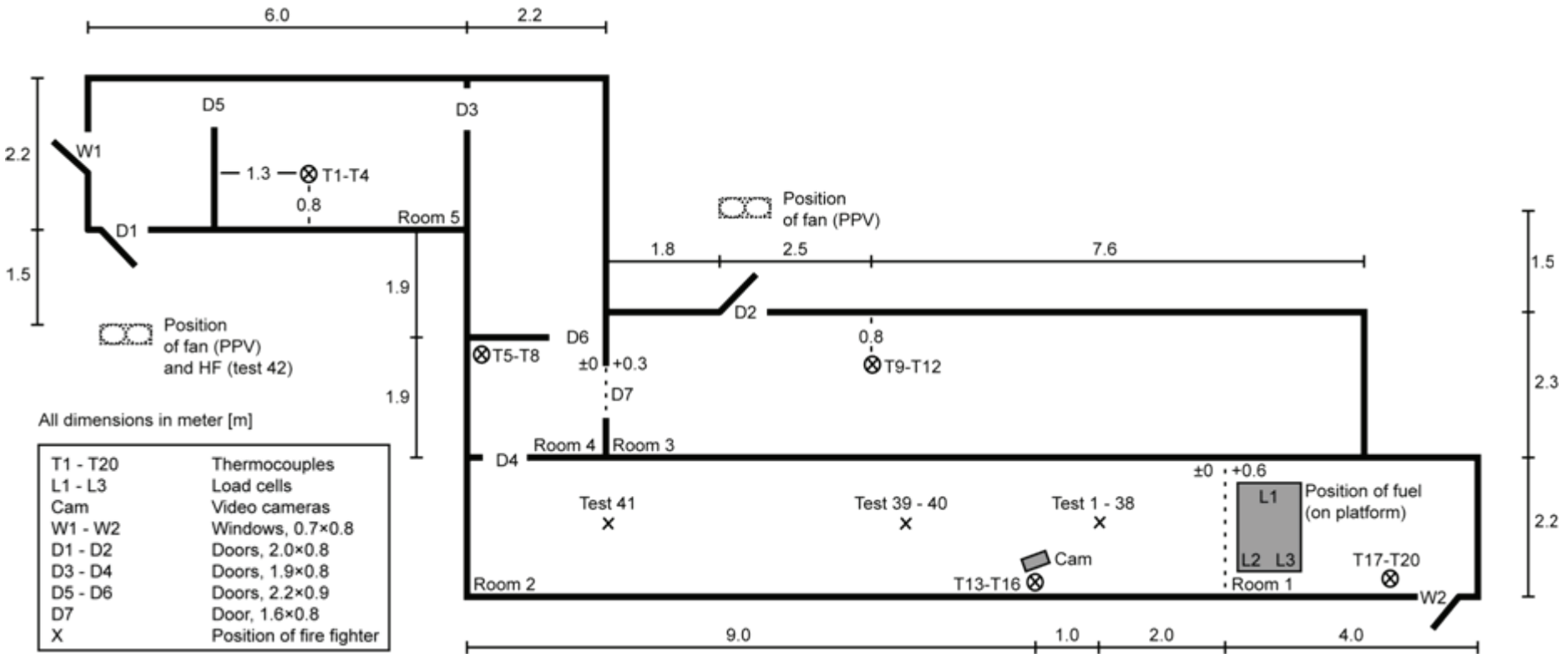
Experimental set-up:

⊗	thermocouples
L1 – L3	load cells
W1	window (at ceiling level), 1.0×0.5 m^2
W2	window (at floor level), 0.7×0.7 m^2
D1 – D3	doors, 0.8×2.0 m^2
C	camera ("Hubert")

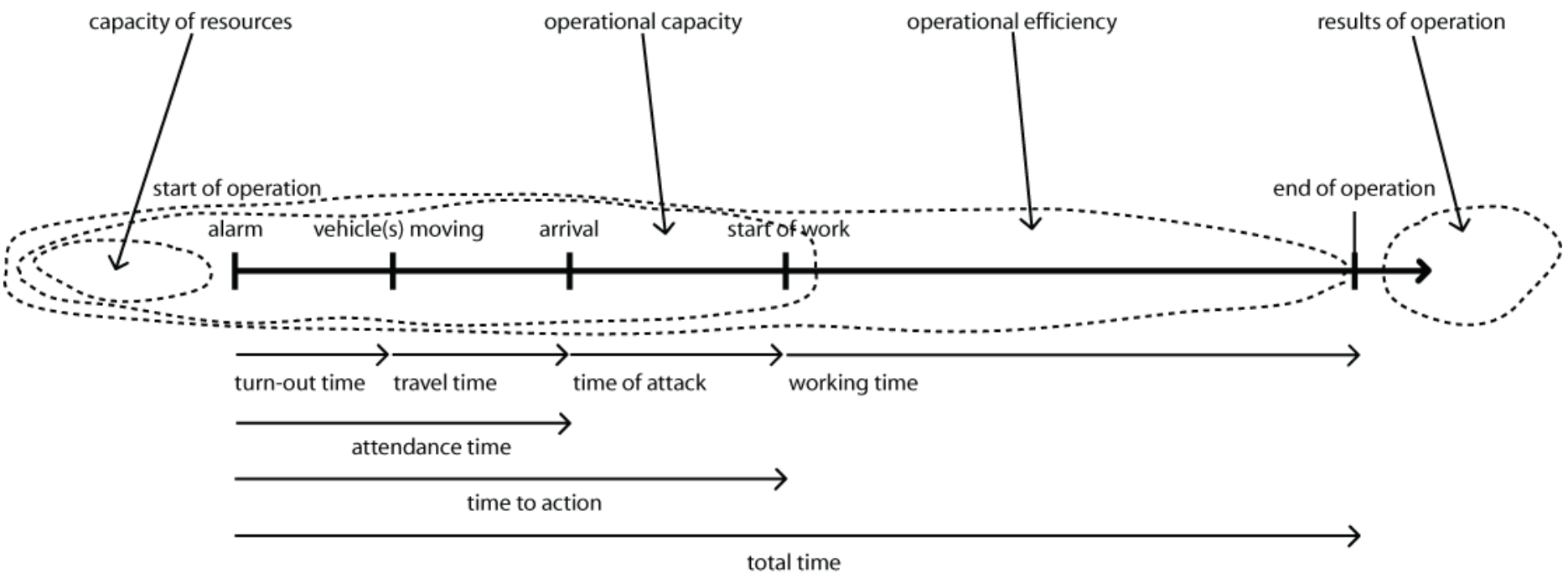
3. Tactical Patterns In A Residential Type Structure

- Purpose of the tests
  - verify basic tactical principles
  - verify the methodology of analysis
  - retrieve data for future work
- Experimental set-up
  - 44 tests were performed in a residential type, multi-room fire fighter training facility
  - included various suppression techniques, positive pressure ventilation and various openings for ventilation
  - 10 wooden pallets were used as fuel in each test

Experimental lay-out



4. Tactics and their Implications for Fire Fighting Operations



Results

- Fire fighting tactics can be experimentally investigated. Through such experiments basic tactical principals have been identified and verified.
- In a wider perspective, the experiments constitute a basis for further treatment of command and control problems.
- Based on this type of analysis, mathematical models for fire fighting operations can be developed.

Basic tactical principals

- the outcome of a fire fighting operation is dependent on the individual procedures as well as on their sequence of implementation
- the choice of tactical pattern is dependent on the situation as well as on the objectives of the fire fighting operation
- various procedures initiated on the fire ground must be coordinated, i.e. command and control of fire fighting operations is vital
- the choice of tactical patterns may be of a greater importance to the outcome of an operation than the outcome of a single procedure itself
- certain tactical patterns have an inherent indulgence towards defective or inappropriate procedures
- defective or inappropriate procedures or tactical patterns can be corrected during a fire fighting operation
- an objective may change during a fire fighting operation and different objectives during an operation may influence what tactical patterns are considered as "correct" and what are considered as "incorrect"

Result

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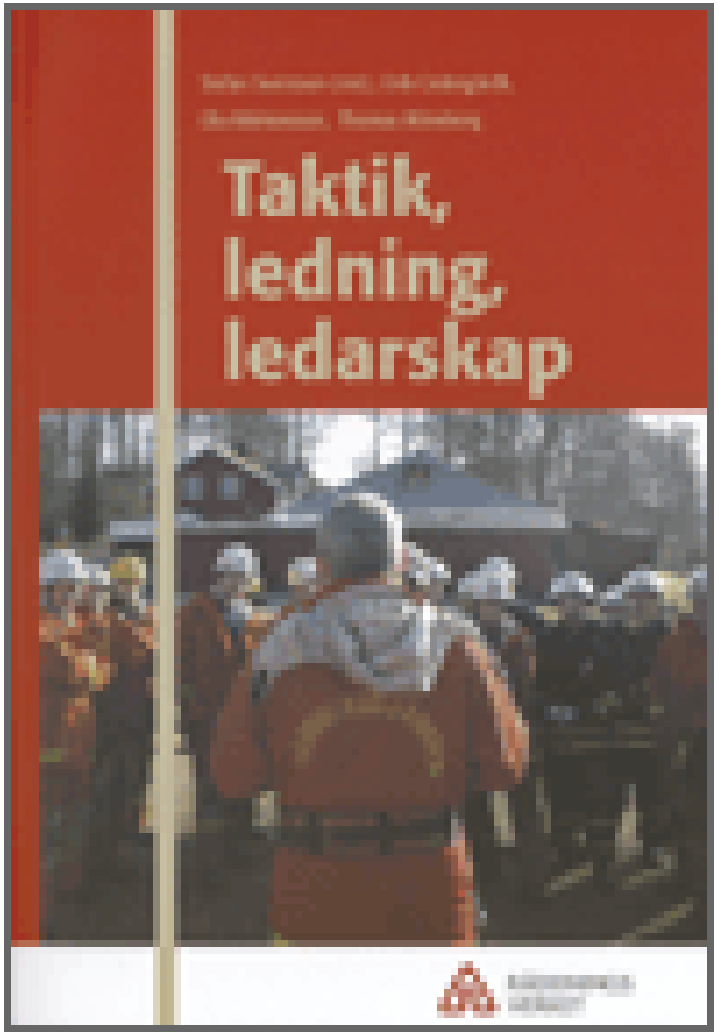

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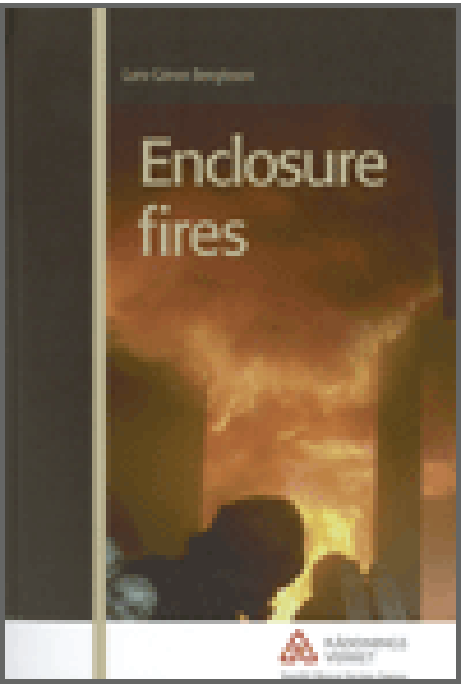
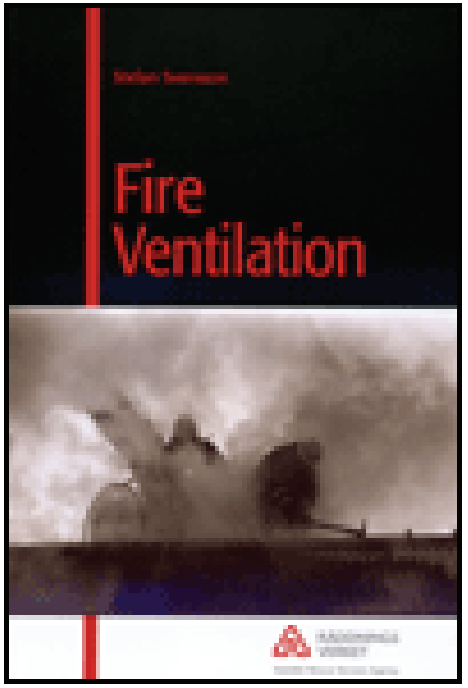
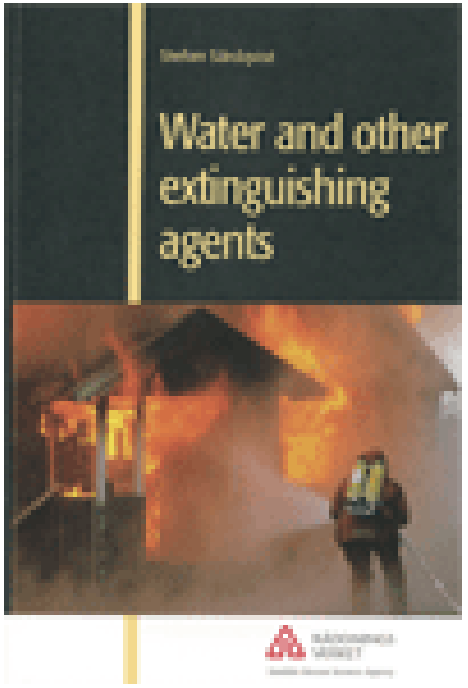
Conclusions

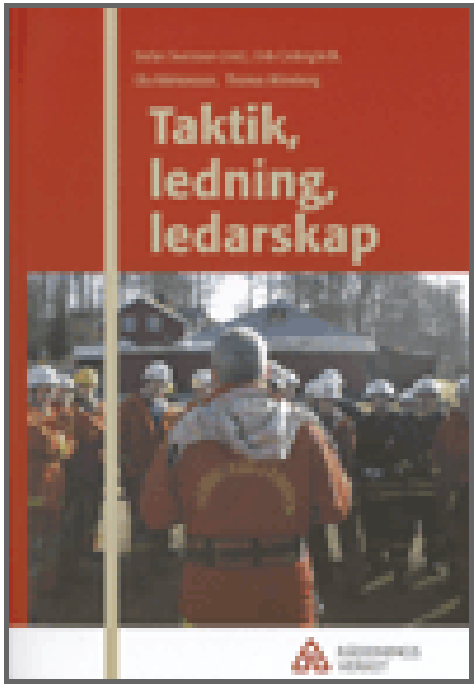
- Buildings getting much more complex (high atria, underground, etc)
- Rapid progress in understanding fire phenomena, computer programs, etc
- Important to facilitate rapid transfer of technology from fire science to the fire service
- We do this by cooperating with fire service and training establishments, conducting experiments, and providing relevant and appropriate teaching material, with a sound scientific basis, to fire fighters and fire officers

Educational material for fire fighters and fire officers









Thanks to

- Dr. Stefan Svensson, my co-author, Swedish Civil Contingency Agency (the fire and rescue training facility at Revinge)
- Prof. Dougal Drysdale, for instigating some of the work
- Dr. Philip Thomas, for his wisdom and generosity