附錄一 2013 FORUM Meeting Agenda

The International FORUM of Fire Research Directors Annual Meeting

Tuesday, 17th September, 2013 through Friday, 20th September, 2013

Host: Centre Scientifique et Technique du Bâtiment (CSTB)

Venue: La Maison des Polytechniciens, 12, rue de Poitiers, 75007 Paris, France

Tuesday, 17th September

09:30 Welcome (CSTB)

10:00 Announcements and review of the agenda (Chaired by Marc Janssens)

10:30 Regional member presentations:
- BAM (D)-absence
- CSTB (F)
- BRE (UK)

noon Lunch

13:00 Regional member presentations (continued)
- LNE (F)
- VTT (SF)

15:40 Break

16:00 Liaison reports:
- ASTM E05 (Marc Janssens)
- EGOLF (absence)
- CIB W14 (Marc Janssens on behalf of George Hadjisophocleous)
- FPRF (Casey Grant)
- Brandforsk (Per-Erik Johansson)
- IAFSS (Anthony Hamins)
- *Fire Safety Journal* (José Torero)

18:05 Adjourn

Wednesday 18th September

09:00 Workshop on fire and wood products
- SwRI(Marc Janssens)
- VTT(Tuula Hakkarainen)
- NIST(Anthony Hamins)
- CSTB(Dhionis Dhima)
- SP (Björn Sundström)
- FPRF(Casey Grant)
- FM(Louis Gritzo)
- NRCC(Joseph Su)
- ABRI(Alec M.Y. Lei)

noon Lunch

14:30 Tour of CSTB facilities

18:30 Adjourn

Thursday 19th September

09:00 Regional member presentations (continued)
- SP (S)

09:30 Liaison reports (continued)
- ISO TC92 (Björn Sundström)

10:00 Members-only session[1]
- Approval of the minutes from 2012 meeting (Franco Tamanini)
- Status of action items from 2012 meeting (Franco Tamanini)
- Finances, Membership (Franco Tamanini)
- Sjölin Award Nomination Discussion

noon Lunch

13:30 Members-only session
- Review of process for developing position papers
- Review of FORUM purpose, goals and objectives (action item 15)

Collaborations
- Lithium battery fires - FPRF(Casey Grant)

[1] All sessions are open to visitors unless otherwise stated. No material presented can be distributed outside of the FORUM meeting without the express approval of the organization that is its source.

- Structural fire research – CIB & NIST(Anthony Hamins)
- Fire protection of nuclear power plants
- Other potential collaborations

17:50 Adjourn

Friday, 20th September

08:30 Departure for LNE

09:40 Members-only session
- Future meeting sites
  - 2014, North America (TBD)(UL or NRCC)
  - 2015, Asia/Oceania (TBD)
- FORUM website
- Review of action items (Franco Tamanini, members)
- Other new business

noon Lunch

14:00 Tour of LNE facilities

17:00 Adjourn

附錄二 歐洲區會員研究近況報告(英文)

- CSTB
- BRE
- VTTI
- SP
- LNE

CSTB
le futur en construction

CSTB « Risk mitigation » roadmap and Fire research

P Carlotti – 17th September 2013

CSTB scientific priorities

CSTB: French Public Agency in charge of the sustainable safety and quality of the built environment.

- **about 1000 people in 4 sites (Paris, Nantes, Grenoble and Sophia-Antipolis)**
- **activities: Research; Technical Agrément; Knowledge Diffusion**
- **6 scientific priorities**

	Du quartier à la ville durable	Bâtiments durables	Usages - Santé Confort	Maîtrise des risques
	Mutations de la filière construction			
	Simulation et outils numériques			

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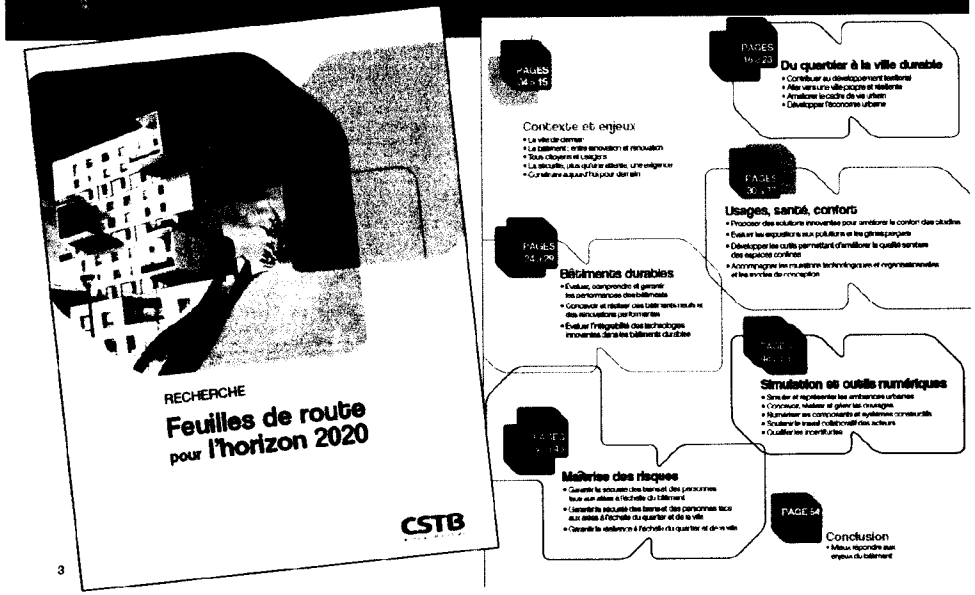
2020 Research roadmaps



Risk Mitigation Roadmap

Targets:
- Protect people
- Reduce economic losses
- Ease post-crisis reconstruction (resilient buildings and cities)

International comparisons → France is not doing bad.
However, some new issues may modify the balance:

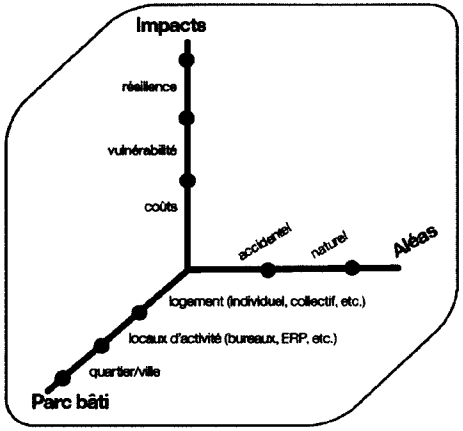
How do new ways of building (sustainable buidlings) modify the vulnerability of the built environment?

How to help the building industry to optimise its economic impact without jeopardizing safety?

How to adapt the way of building to the evolutions of our society (e.g. ageing of population)?

Can we anticipate climate evolution in order to built today for tomorrow climate?

How to act on several axes…



Three main directions of research:

1. Enforce safety of people and goods at buidling scale
2. Enforce safety of people and goods at district scale
3. Towards resilients districts and cities

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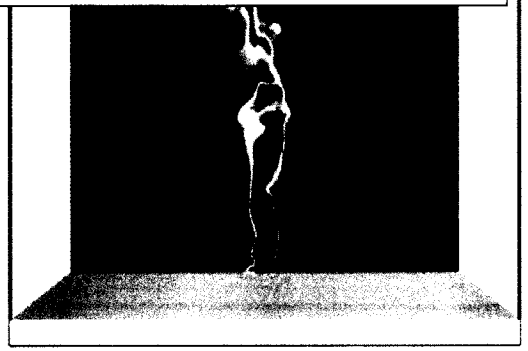
From the 2020 Roadmap to Operationnal Projects

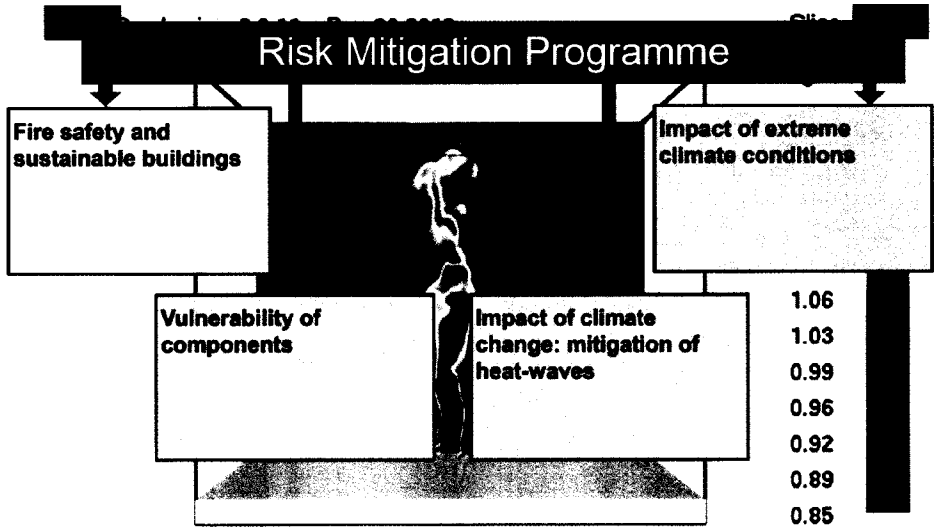
Selection of research projects
- Consistent with the 2020 Roadmap
- Based on 3 year cycles
- Of intermediate size (0.1 to 1 M€ per year)



Slice rho kg/m3

1.20
1.17
1.13
1.10
1.06
1.03
0.99
0.96
0.92
0.89
0.85

From the 2020 roadmap to research projects



2010-2013 research actions connected to fire: Fire safety and sustainable buildings (1)

Main issues

Ageing of the population
Increasing aversion to risk
New architectural techniques
Help innovation and competitiveness
Assure the safety level of sustainable building

Economic data

Direct losses due to fire in France in 2007: 3.4 Md€ (0.2 % of GDP)
Deaths per 100,000 persons (2007-2009): 0.96
Cost of fire protection for buildings: 0.18% of GDP

Performance based design

Global approach of fire safety level of a building
- Probabilities
- Scenarios

Performance-based design of smoke evacuation and reaction to fire
- Models
- Numerical tools
- Confidence level

Performance-based approach of fire resistance
- Structural system
- Finishings

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2010-2013 research actions connected to fire: Fire safety and sustainable buildings (2)

Global approach of fire safety level of a building

- Probabilities applied to evaluate fire safety level of a building (F. Fromy)
- Evacuation (F. Fromy)
- Reduce scale approach of heat and mass transfer in airflow plant of complex industrial building including fire accident (X. Faure)

role de l'occupant dans la propagation

Performance-based design of smoke evacuation and reaction to fire

Partie représentant la

- Level of confidence in CFD simulation (P. Carlotti)
- Improvement of FDS (E. Blanchard)
- Experimental campaign water mist / sprinklers (S. Lechêne)
- Durability of the reaction to fire performance (M. Bonhomme)

chambre

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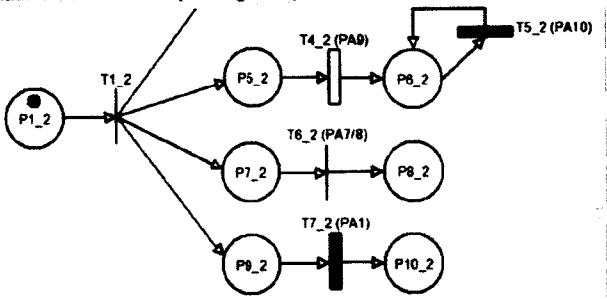
2010-2013 research actions connected to fire: Fire safety and sustainable buildings (3)

Performance-based approach of fire resistance

- Fire resistance of large size concrete compartment walls (C. Florence)
- Behaviour of structures under non-conventional temperature curve (H.H. Nguyen)
- Virtual furnace Vulcain (JP Daguerre)



Partie représentant le rôle de l'occupant dans la propagation de l'alerte

Partie représentant la vie et le décès de l'occupant

Partie représentant l'action de l'occupant sur la porte de la chambre

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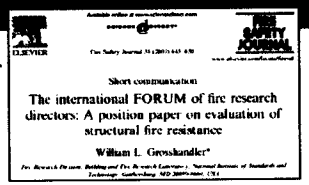
Our vision of Fire Resistance Challenges

2003 FORUM position paper

→ Still very helpful!



Short communication

The international FORUM of fire research directors: A position paper on evaluation of structural fire resistance

William L. Grosshandler*

CSTB position:

1. From a safety point of view, we should move from a component by component rating to a full building resistance assessment
2. We should be able to take into account new building methods (especially those pushed forward by sustainability)
3. In order to allow moderation in the use of ressources, we should also move from a descriptive approach to a performance-based approach (optimisation of strutures)
4. This would also be pertinent from an economic point of view

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Vulnerability of components

Main issues

New construction techniques→ global optimisation needed
Performance based design
Gain knowledge on innovative solution for effective evaluation

Target

Reduce the vulnerability of existing buildings
Develop tools for performance based design
Develop multirisk analysis tools

Multirisk approach

Component per component analysis	Multirisk analysis tools	Fiability analysis

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Vulnerability of components

Actions related to fire

Fire behaviour of new concrete
(RILEM WORKSHOP!)

Façade fire symposium

Fire behaviour of wood connectors

Fire behaviour of chemical anchors

Impact of climate change: mitigation of heat-waves

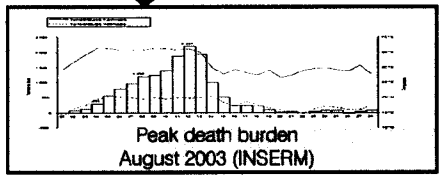
Main issues

Mitigation:
- **Reducing the mortality**
- **Lessen thermic stress**
- **Limit energy consumption**
- **Keep consistency with green house gases reduction policy**

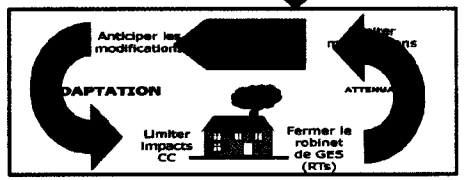
heat wave

- Same

All along the century



Peak death burden
August 2003 (INSERM)



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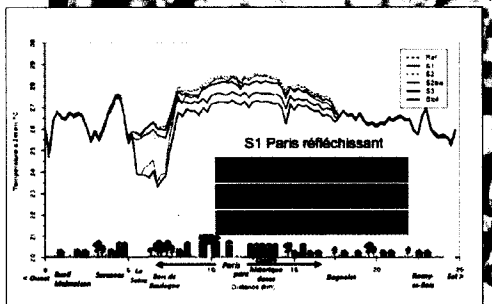
Impact of climate change: mitigation of heat-waves



Effets de mesures d'adaptation à l'échelle des bâtiments et des quartiers)
(projet EPICEA: Ville de Paris, CSTB, Météo France)

Act at all scales
- *Individual:* behaviour, clothing
- *Dwelling* : management of solar fluxes, internel energy fluxes, ventilation
- *building*: « reflecting surfaces », cool spaces
- *district*: green/blue , « reflecting surfaces »
- *City:* heat wave management plan, organisation of activuty

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Impact of extreme climate conditions

Main issues

New architectures
Help innovation and competitiveness
Warranty the safety of sustainable building
Increasing aversion to tisk
Taking into account European standards

Economic data from insurrance

Top 2 :
- Snow-wind-hail
- flood

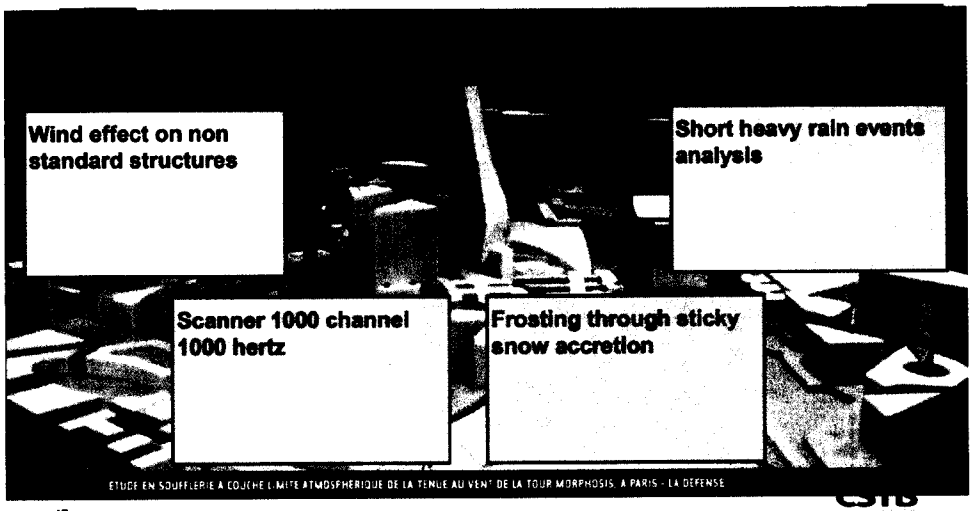
Performance based approach

Single risk approach- Indentification of vulnerabilities
Risk analysis for components and systems

Tools for reducing vulnerability
- experimental
- numerical

Regulatory framework
- Computations of the loads
- knowledge dissemination

Impact of extreme climate conditions



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Directions for 2014-2017

Risk Mitigation Programme

Fire Safety and sustainable buildings
- → Continuing the qualification of numerical codes (and users…)
- → Performance based approach of Fire Resistance

Impact of climate change : mitigation of heat waves
- → Integration in the "extreme climate"project

Vulnerability of components
- → Multirisk analysis
- → Fiability analysis
- → Fire effects (new structural glues for wooden products, green concrete)

Impact of extreme climate conditions
- → Network of institutes for flood vulnerability
- → Disctrict scale effects

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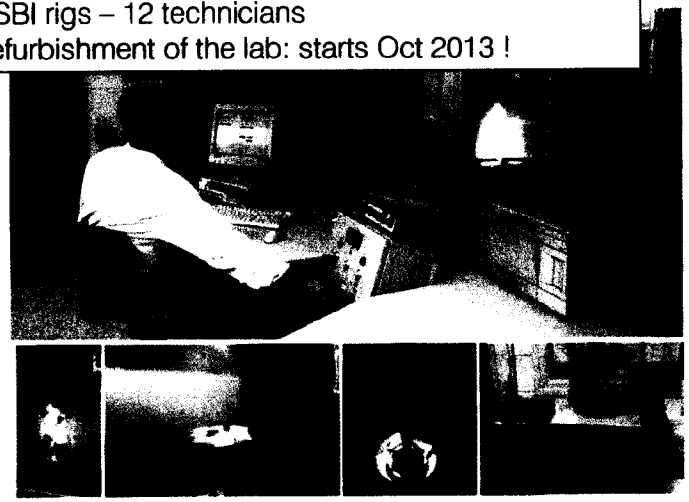
Fire labs in CSTB : reaction

Tests according to French and European standards
2 SBI rigs – 12 technicians
Refurbishment of the lab: starts Oct 2013 !



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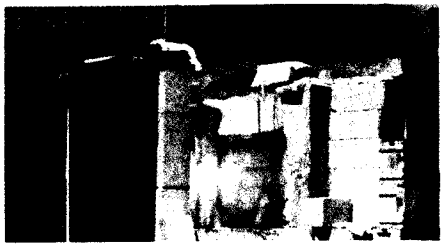
Fire labs in CSTB : resistance

2 « standard » furnaces (horizontal and vertical)
1 modular furnace (Vulcain)
1 mobile furnace



VULCAIN
Large research facility on the fire resistance of innovative structures

The aim of this new research and test platform led by **CSTB's DSSF (Safety, Structures and Fire Performance Department)** located on the Champs-sur-Marne site in Marne-la-Vallée is to create a combined test and simulation approach to improve the fire safety of existing buildings through innovation:

- Buildings
- Industrial sites
- Transport facilities
- etc.

The Vulcain research and tests platform is now operational and it forms an essential facility to satisfy new fire safety challenges:

- Change from assessing fire resistance of each component to assessing the entire structure;
- Take account of changes to the art of building;
- Move towards a performance-driven approach, based on optimisation of structures, to improve safety and optimise the performance/cost ratio.

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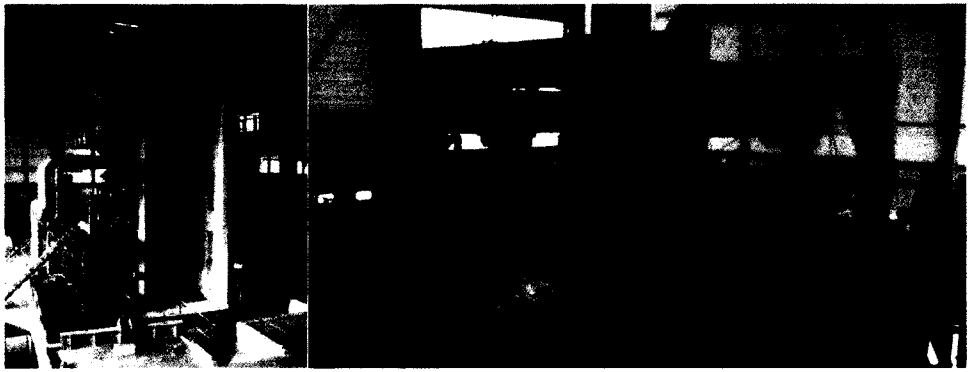
Vulcain (2)



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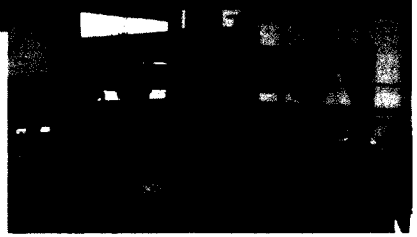
Vulcain (3)



Suitable metrology currently being set up:

- measurement of deformations by image analysis
- method of estimating damage by acoustic emission
- display in the furnace
- fast camera
- 200-channel acquisition unit (temperature and force measurements, etc.).

A hybrid test capacity

Mechanical and thermal loads can be modified in real time using simulation results that take account of measurements made on the test specimen, so that more realistic scenarios than ever before can be reproduced. Vulcain was designed for this purpose and it makes it possible to perform more precise studies on problems related to integration of fire safety into the general design of structures, particularly for high energy efficiency structures in new construction and in renovation. It thus makes it possible to improve optimisation of building structures, while improving their environmental and economic performances.

An approach combining tests and simulations

Thus associated, these two work typologies mutually enrich each other with general data and information, for example for the representation of fire physics, but also for thermomechanical calculations of structures:

- Digital simulations are enriched by validation data obtained from tests;
- Simulation data are helpful for making good measurement choices during the tests, the representativeness of thermal loads is optimised, a detailed analysis of special zones becomes possible, etc.

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Vulcain (4)

Vulcain is in an urban environment, without smoke treatment:

- We need to monitor air quality to prove we are not out of range
- We do not allow ourselves to test combustible materials

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Three proposed axes for Vulcain Research Programme

1. Study of size effect (C. Florence, S. Sakji)
2. Virtual testing and hybrid simulations (Ph. Rivillon)
3. Performance-based analysis of non-protected concrete structures (P. Pimienta)

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Thank you for your attention!

BRE Global Ltd

Dr Debbie Smith OBE
Director of Fire Sciences

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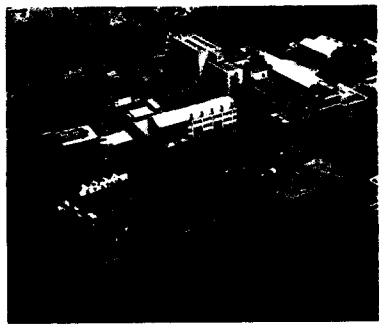
BRE Group

Owned by the BRE Trust, a charity:

"...to champion excellence and innovation in the built environment."

Approximately 680 staff:
- many international experts
- based in Watford
- BRE Associates
- University Centres of Excellence



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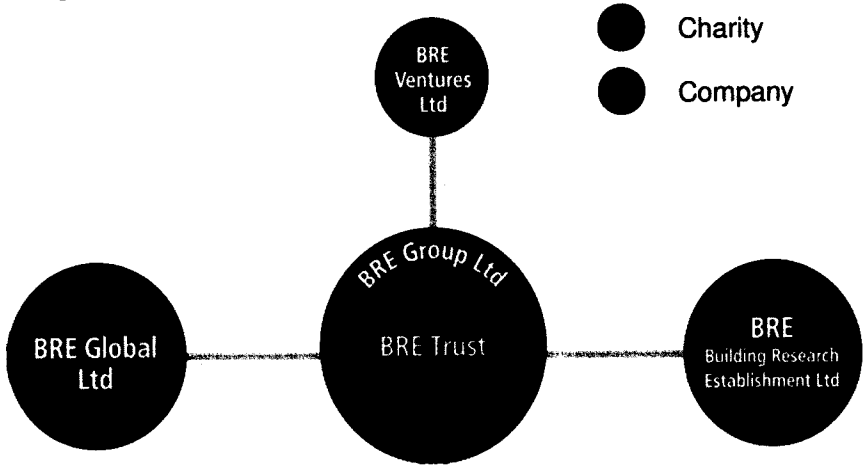
Corporate and Management Structure



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BRE Group

- Research, innovation, consultancy, testing, approvals, training
- Work mainly in the built environment, but also transport, manufacturing, electronics, agriculture...

Facilities

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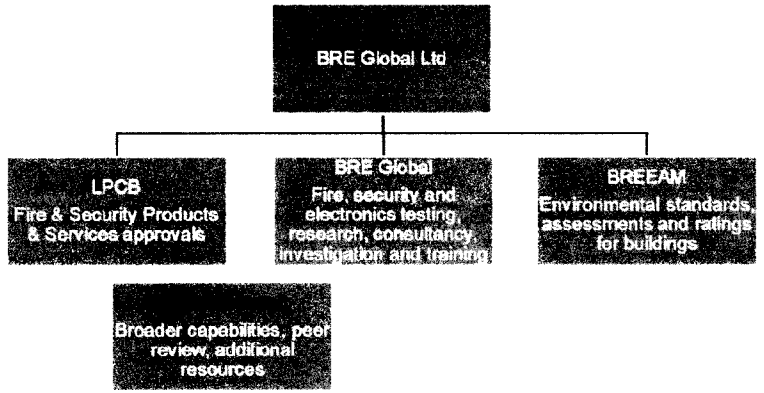
What we do



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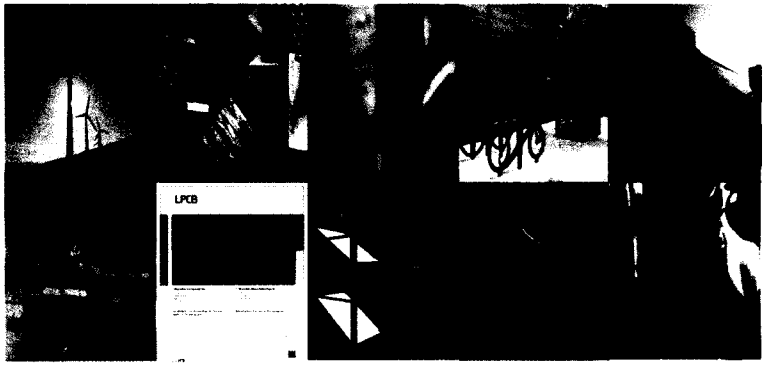
BRE Global

– Research, consultancy, training, standards, testing, approvals in fire, security and sustainability



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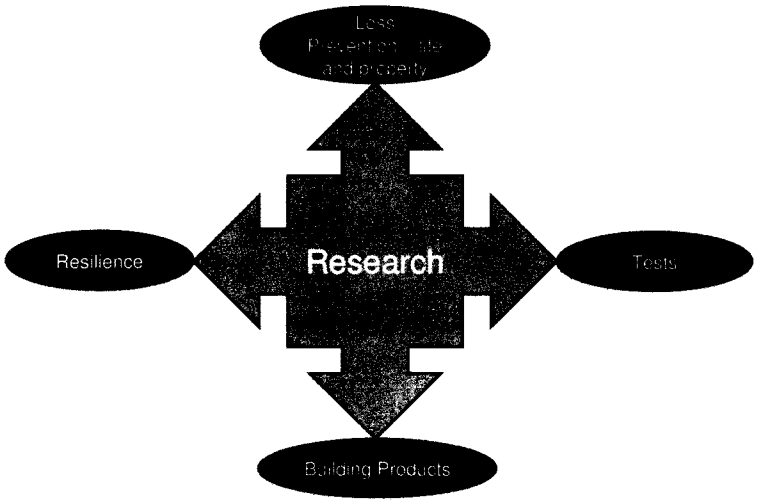
Products and services underpinned by research to ensure technical robustness



BRE Global

- BRE Global Ltd was formed in 1998
  - Incorporating the Fire Research Station (FRS)
  - Expertise in smoke movement, computational fluid dynamics modelling, evacuation modelling, fire dynamics, fire chemistry, structural fire engineering, fire safety engineering, fire investigation, material fire behaviour….
  - Technical approvals of construction materials and systems to enable CE marking against European Directives and certification of quality management systems
- LPCB was acquired by BRE Global in 2000
  - formerly owned by UK's Association of British Insurers (ABI) and Lloyd's of London
  - LPCB is a premier global Approvals Body specialising in fire and security systems and services

LPCB

Standards

Building Codes/Regulations

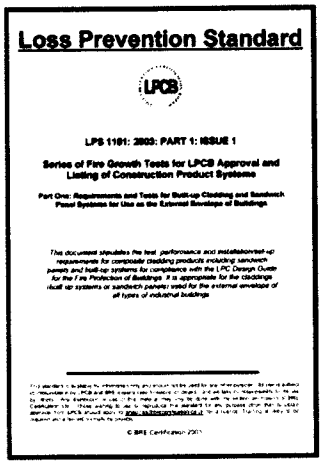
Installation/System Codes

Product Standards

LPCB

Loss Prevention Standards used for Approval

- Loss Prevention Standards (LPS) developed in collaboration with industry, clients, insurers, regulators and other stakeholders
  - LPCB documents
  - Consensus documents
- National, European or International standards
- European standards are new and therefore state of the art


Loss Prevention Standard

LPCB

LPS 1181: 2003: PART 1: ISSUE 1

Series of Fire Growth Tests for LPCB Approval and Listing of Construction Product Systems

Part One: Requirements and Tests for Built-up Cladding and Sandwich Panel Systems for Use as the External Envelope of Buildings

This document stipulates the test, performance and installation/set-up requirements for composite cladding products including sandwich panels and built-up systems for compliance with the LPC Design Guide for the Fire Protection of Buildings. It is appropriate for the cladding of built-up systems or sandwich panels used for the external envelope of all types of industrial buildings

© BRE Certification 2003

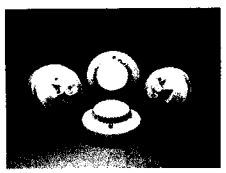
LOSS PREVENTION CERTIFICATION BOARD LPCB

LPCB

What do we approve?

- Passive fire protection products and services
- Fire detection and alarm systems and services
- Sprinkler, spray and deluge systems and services
- Fire extinguishers and hose reels
- Fixed fire fighting systems and services
- Security products
- Installers of fire protection products



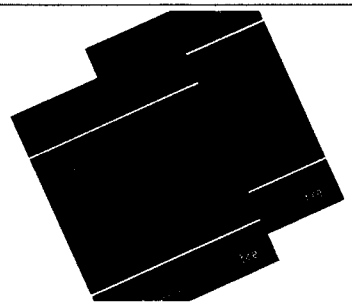


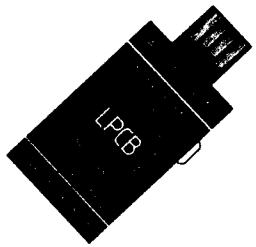

LPCB

Red Book

- All approved fire and security products and services are listed in our directory

  "The Red Book"
- Red Book available formats are;
  - web-based live database; www.redbooklive.com
  - APP
  - updateable memory stick





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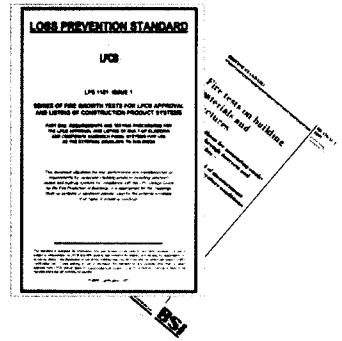
Research, policy development and guidance

Development of standards

- Major contributor to British, European and International standards: BS, EN, ISO, LPS



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Government funded research

- We carry out research projects to support the development of the building regulations in England and Wales and Scotland. Recent projects include;
- *Cavity barriers*
- *Smoke and burning droplets*
- *Ducts and dampers*
- *Timber frame buildings*
- *Modern methods of construction (Innovative construction product techniques)*
- *Fires in car parks*

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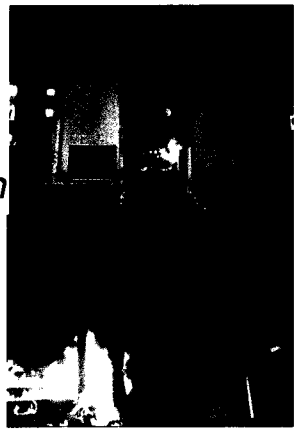
Government funded research contd.

- *Design fires*
- *Lifts for evacuation of buildings*
- *Timber stairs*
- *Environmental impact of fires*
- *Fire performance of SIP systems in construction*
- *Fire performance of wall coverings*



Consultancy and Specialist Investigations

- 3rd party review – designs, installation etc
- Fire safety engineering
- Fire risk assessments
- Advice on developing new regulations
- Experimental research
- Fire investigations :
  - Channel Tunnel
  - Mont Blanc Tunnel
  - Yarlswood Asylum centre UK
  - Rose Park care home Scotland
  - Harrow Court Stevenage residential UK
  - Lakanal House

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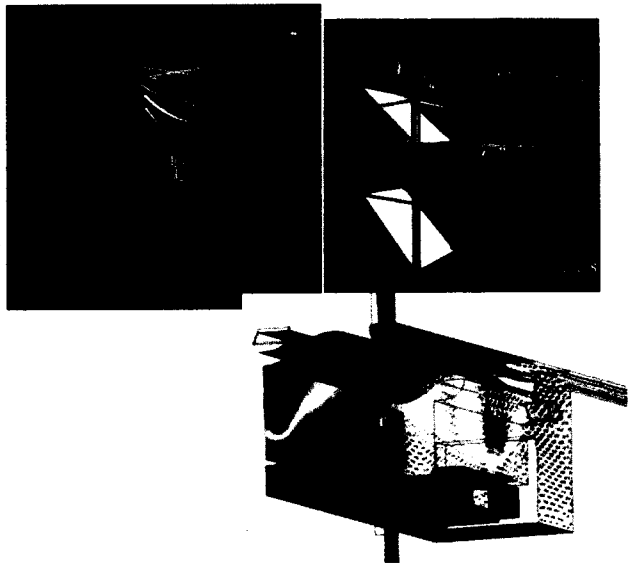
Research, policy development and guidance

Computer modelling

- Fire spread
- Smoke movement
- Evacuation



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We have to consider issues hollistically; Conflicts between sustainability, security and fire

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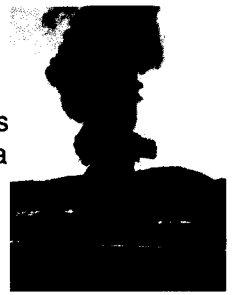
Our world is changing

- Construction site waste reduction leading to development of better/innovative construction methods/techniques – Modern Methods of Construction (MMC)
- The impact of fires on the environment
  - *Generation of carbon dioxide, toxic species*
  - *Pollution of water courses*
  - *Business interruption*
  - *Property damage*
  - *Societal - local community*
- New legislation – Construction Products Regulation
  - CE marking is mandatory for construction products placed on the UK market today for which there is a harmonised technical specification (hEN)



And our world is changing

- New construction products (e.g. Increased use of recycled materials such as tyres, pallets, bottles)
- Increasing thicknesses of insulation to improve energy efficiency
- Increasing air tightness of buildings
- Separation of buildings
- Fire and security during construction (largely unregulated)
- Performance of new laminated glazing products (impact and security resistance compared with fire performance)
- Technically robust data required to support the development of new generation "green schemes" such as BREEAM

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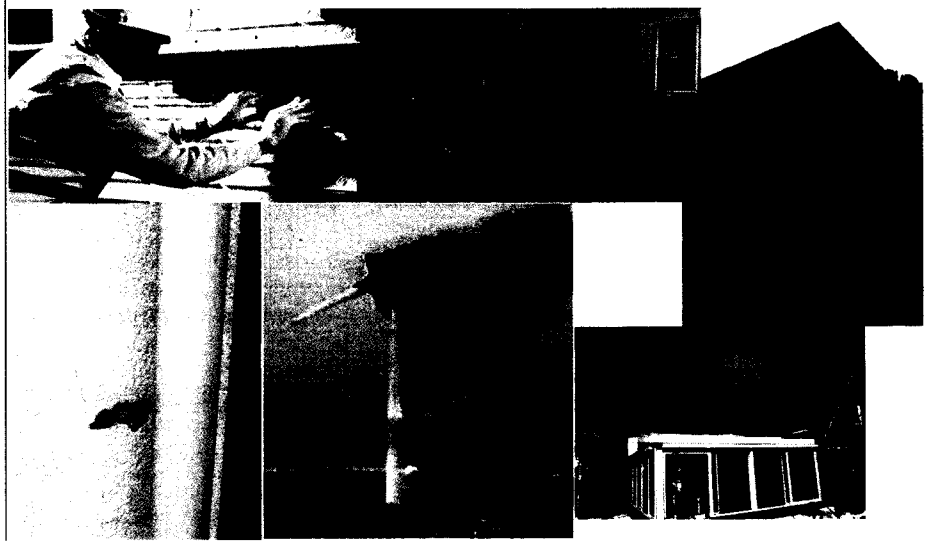
New construction technologies



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Issues we face

- No historical database available to assess performance
- Possibility of systematic faults
- Use of new materials (in particular increasing use of highly insulating combustible materials)
- Levels of safety and property protection unknown
- Possibility of disproportionate damage

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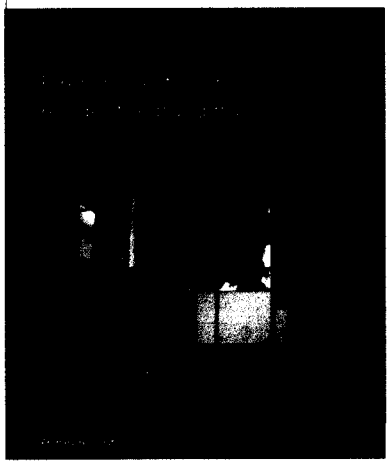
What do we need to do?

- Develop understanding of impact of innovations in the built environment through research
- Leading to development of
  - New published guidance
  - New test methods
  - New tools
  - New certification schemes for products and installers

Cavity barriers – jointly funded by BRE Trust and NHBC with Industry partnering for supply of materials



NHBC Foundation trust

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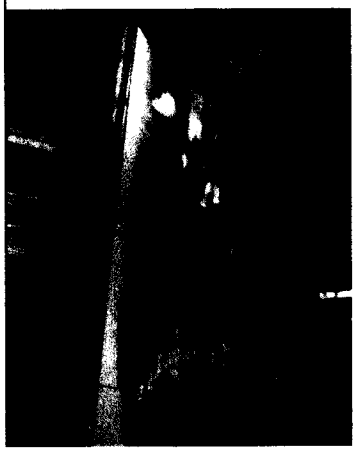
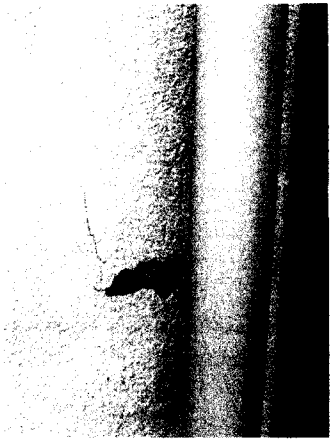
External cladding systems

BS 8414 parts 1 and 2 led to LPS 1581 and 1582 and now 12 products listed in Red book

BR 135 3rd edition revised and published 2013 (BRE Trust funded)





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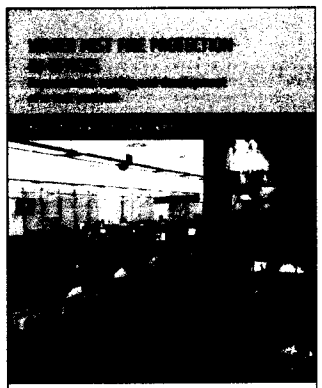
Water mist systems

- New technology
- Unregulated area
- BRE Trust funded research completed and report published in 2011
- Results input into BS and EN standardisation committees
- LPS 1283 published in 2012
- New LPS for installers to be developed later this year



press trust

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Research projects – funded by the BRE Trust

- *Smoke management in modern buildings*
- *Fire performance of phase change materials*
- *Sensor assisted evacuation from buildings*
- *Fire safety issues related to high rise and super rise buildings*
- *Real fires for the safe design of tall buildings*

Research projects

- *Performance and analysis of fire protection coatings for steelwork*
- *Water mist fire protection systems in different occupancies*
- *Smoke visualisation*
- *Evacuation of mobility impaired building occupants*
- *Cost benefit analysis of the effectiveness of sprinklers in residential premises (Welsh Government)*

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Drivers for change

- Unacceptable life safety risk?
- Unacceptable risk of losses (property, business continuity)?
- How to decide
  - Cost benefit analysis
  - Based on real data/statistics
  - Main tool used by UK governments
  - Now extended into the loss area by sprinkler industry
  - Incorporating environmental, societal and economic factors

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Example: Cost – benefit analysis – life safety

PROPERTY TYPE: House, multiple occupancy - traditional HMO

	average	uncertainty	net effect
Capital Cost of System (per unit)	? 85	? 67	0.46
Water connection charge (per unit)	? 03	? 4	0.05
Capital Recovery Factor	0.045	0.002	0.05
Annual Cost of Loan	? 5.07		
Annual Inspection Cost	? 8	?	0.04
Total Annual Cost	**? 2.67**		
Deaths per Million Units	28	5	0.17
Sprinkler Effectiveness Factor	1.00	0.00	0.00
Deaths saved per Million Units	28		
Monetary Value per Death Saved	? ,685,000	? 4,250	0.04
Monetary Benefit per Single Unit	? 4.14		
Injuries per Million Units	785	90	0.06
Sprinkler Effectiveness Factor	0.67	0.11	0.08
Injuries saved per Million Units	529		
Monetary Value per Injury Saved	? 0,446	? ,522	0.03
Monetary Benefit per Single Unit	? 6.71		
Fires per Million Units	3606	383	0.06
Sprinkler Effectiveness Factor	0.93	0.02	0.01
Unsprinklered property damage	? ,813	? 41	0.03
Reduced property damage per fire	? ,227		
Monetary Benefit per Single Unit	? 9.67		
Total Monetary Benefit per unit	**? 80.51**		
Benefit : Cost ratio	**1.91**	**+/-**	**0.82**
Confidence Level (ratio > 1)	**96%**		
Monte Carlo results			
Benefit : Cost ratio	1.96	+/-	0.49
Confidence Level (ratio > 1)	99%		

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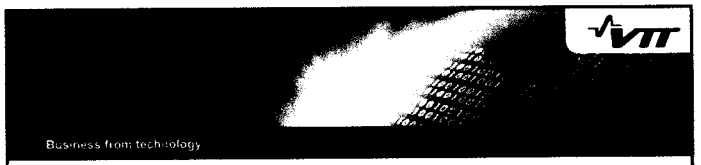
Thank you for listening

- Any questions?



Business from technology

Fire and evacuation safety research at VTT

The International FORUM of Fire Research Directors
Annual Meeting 2013

Tuula Hakkarainen
VTT Technical Research Centre of Finland

VTT Group in brief

Turnover 316 M€ (2012) • Personnel 3,206 (31.12.2012)

Customer sectors
- Biotechnology, pharmaceutical and food industries
- Chemical industry and environment
- Electronics
- Energy
- Forest industry
- ICT
- Machine, vehicle and metal industries
- Real estate and construction
- Services and logistics

Focus areas of research
- Applied materials
- Bio- and chemical processes
- Energy
- Information and communication technologies
- Industrial systems management
- Microtechnologies and electronics
- Services and the built environment
- Business research

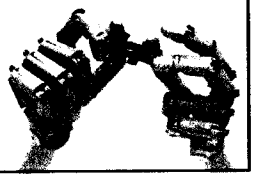
VTT's operations
- Research and Development
- Strategic Research
- Business Solutions
- Business Development
- Group Services
- VTT's companies
  - VTT Expert Services Ltd (incl. Lattilum Ltd and Enas Ltd)
  - VTT Ventures Ltd
  - VTT International Ltd (incl. VTT Brasil LTDA)
  - VTT Memsfab Ltd

VTT Technical Research Centre of Finland

VTT IS
- a globally networked multitechnological applied research organisation
- a not-for-profit and impartial research centre

VTT HAS
- extensive cross-disciplinary technological and business expertise
- unique research infrastructure
- comprehensive global partnership networks in business, industrial and research communities

VTT CREATES
- new technology and science-based innovations in co-operation with domestic and foreign partners



Fire and Evacuation Safety team

Competence

VTT's Fire and Evacuation Safety team conducts research on the methods of fire and evacuation safety assessment, material performance and risk analysis. We use both experimental and computational methods for the benefit of our customers. Fire tests using standardized methods are performed by VTT Expert Services Ltd.

Challenges

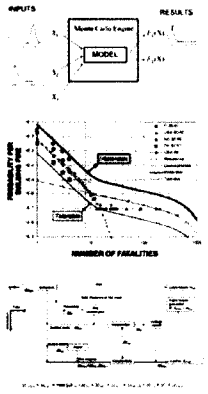
New materials, products and building methods can lead to unexpected risks for fire and evacuation safety. The consideration of both technological and human behaviour aspects of safety requires interdisciplinary research.

Methods for fire and evacuation safety assessment

- Fire simulation: Fire Dynamics Simulator (FDS)
- Evacuation simulation: FDS+Evac
- Efficiency of fire safety systems:
  - Experimental and simulation-based methods for assessment of water mist, sprinklers, smoke management etc.
- Simulation of fire and structures: FDS2FEM tool
- Pyrolysis experiments and modelling
  - Cone Calorimeter, TGA, DSC, Micro-scale Combustion Calorimeter
  - Evaluating material performance, FR effects, structural optimization etc.
  - Pyrolysis model parameter estimation: Pyroplot tool
- Atomistic simulation of materials: Reactive Molecular Dynamics
  - Thermal degradation of polymers

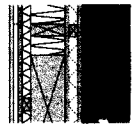
Risk analysis

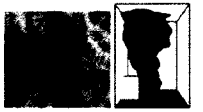
- Quantitative fire risk analysis
  - Combining probabilities of events to their consequences
  - Monte Carlo simulations: likelihood of critical consequences
  - Probabilistic Fire Simulator (PFS) tool: http://code.google.com/p/pfs-fire/
- Stochastic operation time modelling
  - Evaluation of efficiency of rescue and crisis management organizations
- Fire service impact and strategies



Applications

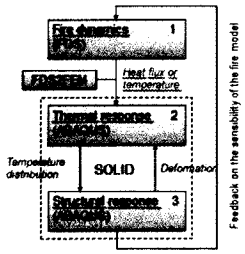
- People in urban environment
  - Computational methods in multi-objective evaluation of urban environment functionality
- Nuclear power plant fire safety
- Fire protection of structural elements
  - FSE in justifying protective methods for structures under building fire conditions
- Fire and evacuation safety of
  - Large buildings
  - Passenger ships and trains
- Aircraft impacts
  - Investigation of fires following an aircraft impact using CFD and FEM tools
  - Advanced experimental techniques

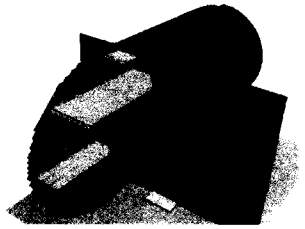




Simulation of fire and structures

FDS2FEM – A Tool for Coupling Fire and Structural Analyses





Further information: Antti.Paajanen@vtt.fi

1. Fire-structural modelling

- Various physical phenomena. Sub-models are required for

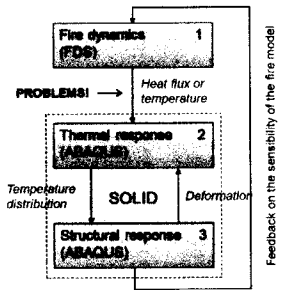
1. *the fire environment* ▪ convective and radiative heat transfer	fire-specific CFD software
2. *thermal response of materials* ▪ heating of of solids	BOTH
3. *fire-induced damage and weakening of materials* ▪ loss of load bearing capacity due to heating	
4. *the mechanical response of materials* ▪ *deformation and failure*	general purpose FEM software

- Problem: no single software can handle all of these!
- Solution: establish a coupling between existing software

FIRE-RESIST

2. One-directional sequential coupling

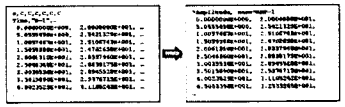
- The fire dynamics calculation is performed first
  - heat exposure from the gas phase to the structure is stored
- Two subsequent FEM-analyses predict the thermal and mechanical response
  - thermal boundary conditions are received from the fire simulation
- NB: structural changes have no effect on the fire environment
  - the analysis cannot be considered reliable after a structural failure



2. How to transfer thermal boundary conditions?

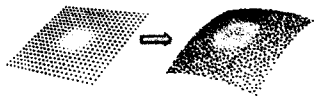
- FDS and ABAQUS are not able to communicate with each other
  - both are operated using configuration files
  - straightforward use of default functionalities and commands
    FDS output → ABAQUS input

straightforward



- FDS and ABAQUS models have different spatial and temporal discretizations
  - heat exposure data has to be transformed between the two representations

not so simple



FDS: rectilinear grid of nodes

ABAQUS: something more complicated

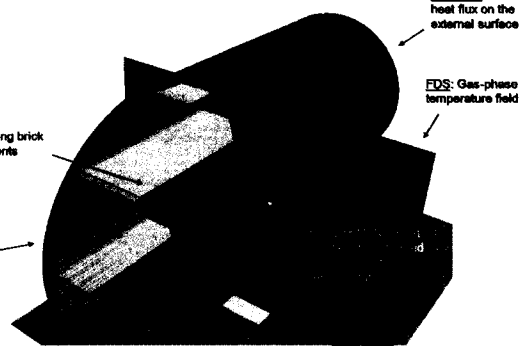
FIRE-RESIST

2. Problems solved

- "An interpreter" between the command languages of FDS and ABAQUS and a conversion algorithm between the boundary conditions of different discretizations are needed.
- FDS2FEM software tool
  1. reads model geometries from FDS and ABAQUS input files
  2. creates a mapping between the spatial discretizations
  3. transforms FDS heat exposure data to be used as a boundary condition in a subsequent ABAQUS analysis
  4. writes the boundary condition into the ABAQUS input file

FIRE-RESIST

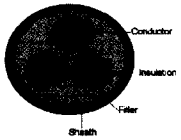
Kerosene pool fire near an airplane hull



Compound image of fire and structural simulations

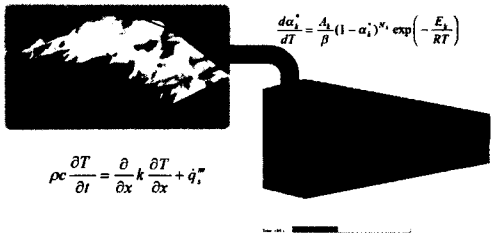
Modeller decisions

- Experimental methods
  - TGA, DSC, Cone calorimeter, FPA, MCC
  - Mass, heat release rate, temperature
  - N of samples, heating rates, heat fluxes, ambient gas
- Reaction path
  - N of reactions, parallel/consecutive, reaction order
  - Significant parameters
- Estimation method
  - Curve fitting vs. analytical methods
- Model
  - Geometry, layer structure, backing conditions
  - Mesh, grid size



Pyrolysis experiments and modelling

Pyrolysis model parameters for electrical cables



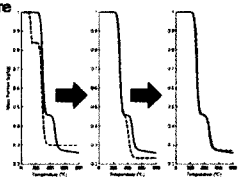
$$\frac{d\alpha_i^*}{dT} = \frac{A_i}{\beta}(1-\alpha_i^*)^{N_i} \exp\left(-\frac{E_i}{RT}\right)$$

$$\rho c \frac{\partial T}{\partial t} = \frac{\partial}{\partial x} k \frac{\partial T}{\partial x} + \dot{q}_s'''$$

Further information: Anna.Matala@vtt.fi

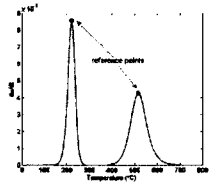
Curve fitting

- Evolutionary algorithms:
  - Genetic Algorithms (GA),
  - Shuffled Complex Evolution (SCE)
- Effective for multiple unknown parameters, nonlinear problems
- Do not limit the choice of reaction path or the parameter values
- Require significant amount of computational time and specific software

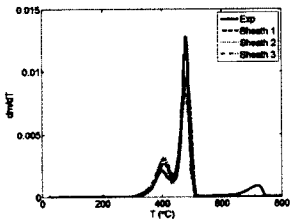


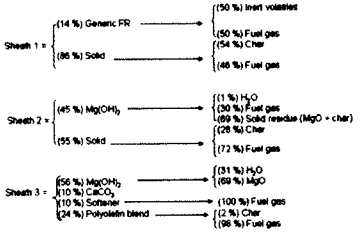
(Semi)analytical methods

- Based on reference points of the data
- Fast and easy to perform, no special software or computational time needed
- Often limited to certain reaction paths or reaction orders
- Challenging for real data with noise, several overlapping reactions



A case study: Modelling a cable tunnel
Small scale experiments





- All versions predicted TGA experiment equally accurate but with different values for kinetic parameters.
- ΔH and c_p from DSC results. The ΔH suggests that the FR filler is $Mg(OH)_2$

A case study: Modelling a cable tunnel
Bench scale experiments

Five alternative models:

Generic FR w/o additives:
Sheath 1 without fuel yield from the first reaction.

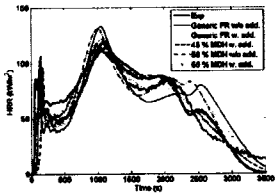
Generic FR w. additives:
Sheath 1 with fuel yield.

45 % MDH w. additives:
Sheath 2.

66 % MDH w/o additives:
Sheath 3 without fuel yield from the first reaction.

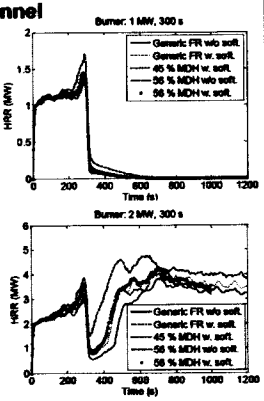
66 % MDH w. additives:
Sheath 3 with fuel yield.

Layer	Thickness (mm)	Materials
1	2.5	Sheath
2	5.0	Insulation (18 %) Filler (82 %)
3	2.5	Sheath
4	20	Substrate, used only in cone calorimeter.



A case study: Modelling a cable tunnel
Large scale simulations

- 40 m long cable tunnel
- 5 cable trays at 0.5 m vertical spacing
- Ignition source: 1 or 2 MW for 300 s.
- Well ventilated.
- Reaction path has no significant effect.
- If the duration or power of the initial fire were doubled, the fire continued spreading



Stochastic Operation Time Modelling

- Serial processes (AND) → SUM

$$\Delta t_{tot} = \sum_i \left(\Delta t_i + \sum_j \left(k_{ij} \cdot \delta t_{ij} \right) \right)$$

Where Δt_{tot} = total time delay
Δt_i = time delay of event i
δt_{ij} = time delay of additional event j related to event i
k_{ij} = 1 with probability p_{ij} and 0 with probability $(1 - p_{ij})$
p_{ij} = probability of additional event j

- Parallel processes (AND) → MAX
- Alternative processes (OR) → MIN

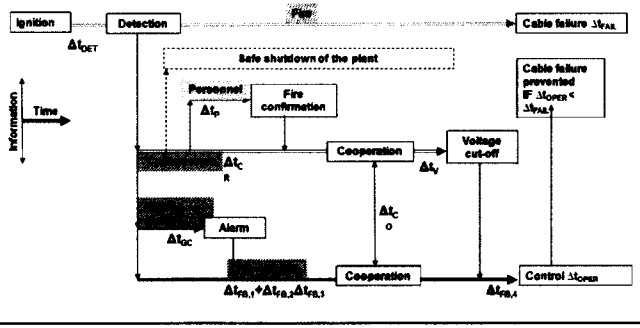
Further information: Terhi.Kling@vtt.fi

Stochastic operation time modelling

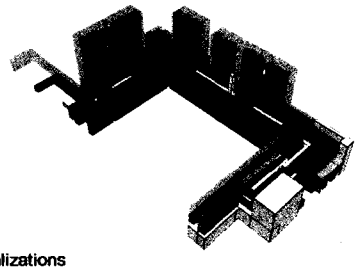
- A method for the estimation of time delays of rescue organizations in fires and other crisis situations
- Basic tools:
  - Event trees → Distributions of situations
  - Timelines of operational phases → Visualization of processes
  - Probabilistic fire simulator (PFS) → Realizations
    - Excel based interface for probabilistic fire and operation time simulations
- Examples of applications:
  - A cable room fire in a nuclear power plant
  - A tank wagon fire at a railway station in a city centre
  - Evaluation of the effectiveness of the preparedness of regional rescue services in Finland

An example: A cable room fire in a nuclear power plant

- A cable was assumed to be damaged when its insulation material reaches a critical temperature.

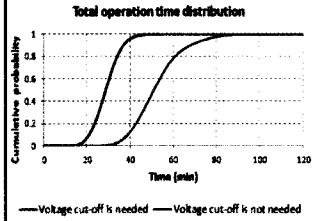


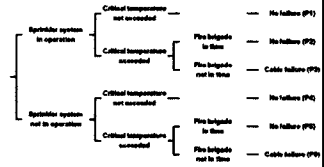
Monte Carlo –fire simulation using FDS



100 fire realizations
1,000 fire fighting realizations
100,000 situations in total

Results: Evaluation of Fire Suppression Success Probability for Fire-PRA



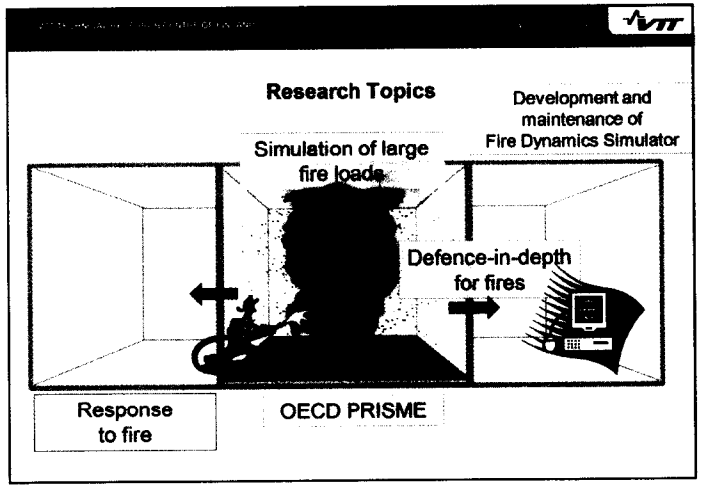


P("Failure in sub 2" | "Ignition in sub 1")
< 2.3…3.6 % with voltage cut-off
< 2.0…2.9 % without voltage cut-off

Nuclear power plant fire safety

Risk Assessment of Large Fire Loads

Further information: Simo.Hostikka@vtt.fi

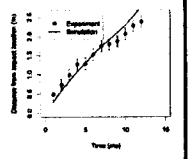


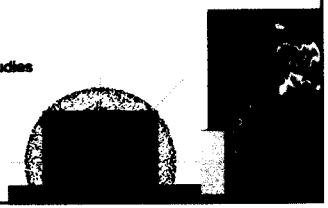
Aircraft impact fires

Further information: Simo.Hostikka@vtt.fi

Aircraft impact fires – three levels of research

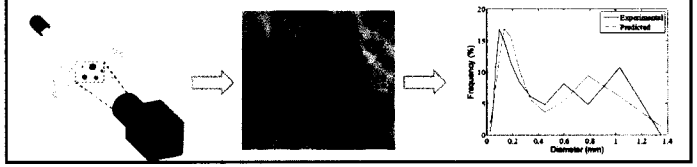
1. Experiments on liquid dispersal
   - Determination of CFD boundary conditions
   - Validation data for CFD
2. Spray CFD simulations
   - Learning how to simulate high-speed sprays
   - Verification and validation of Fire Dynamics Simulator CFD-code
3. Plant scale applications
   - Generic studies on impact fires
   - Capability for design-specific studies

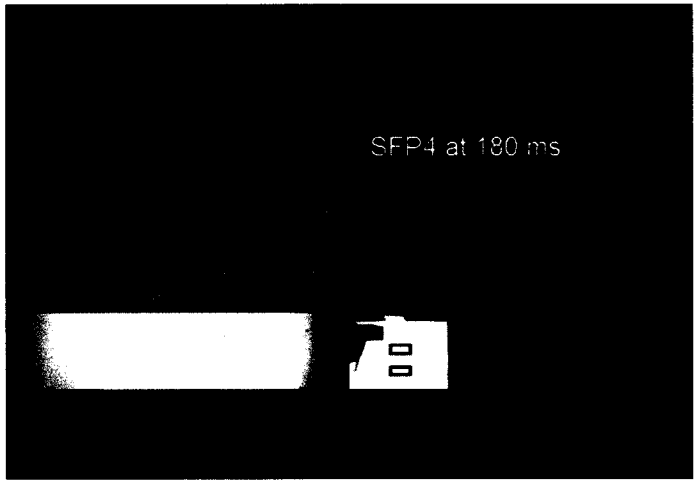




Experiments on liquid dispersal

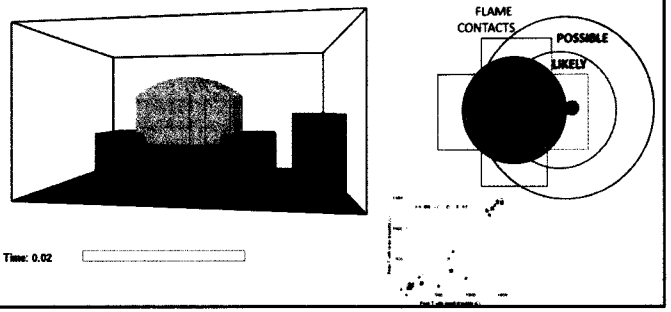
- IMPACT-tests with water-filled missiles
- High-speed video for spray speed and direction
- Ultra-high-speed video for drop size, velocity and massflux statistics.
  - Back-light illumination with pulsed high-speed diode lasers (810 nm, 300 ns pulse)
  - Frame rates up to 100,000 fps.
  - Resolutions down to 5 µm / pixel



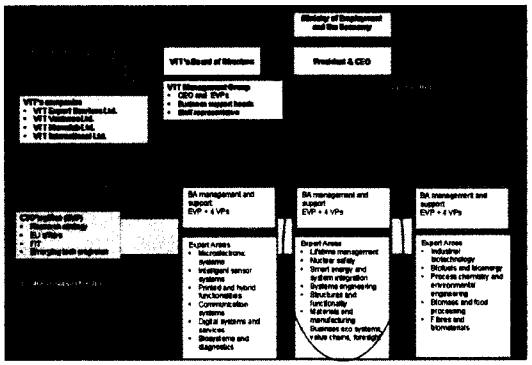


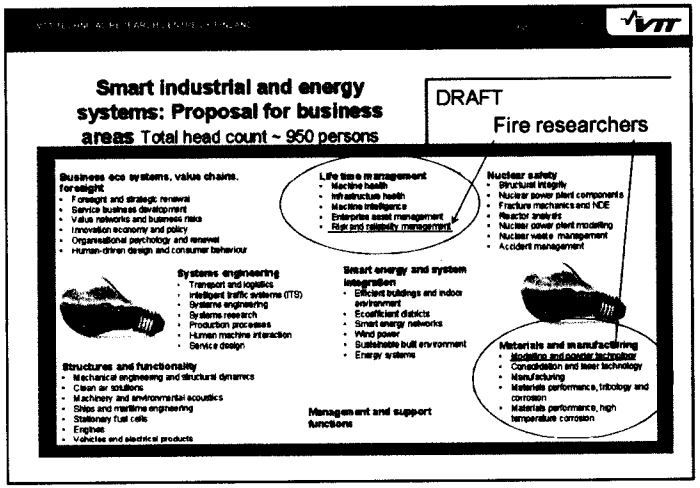
Plant-scale simulations using Fire Dynamics Simulator (FDS)

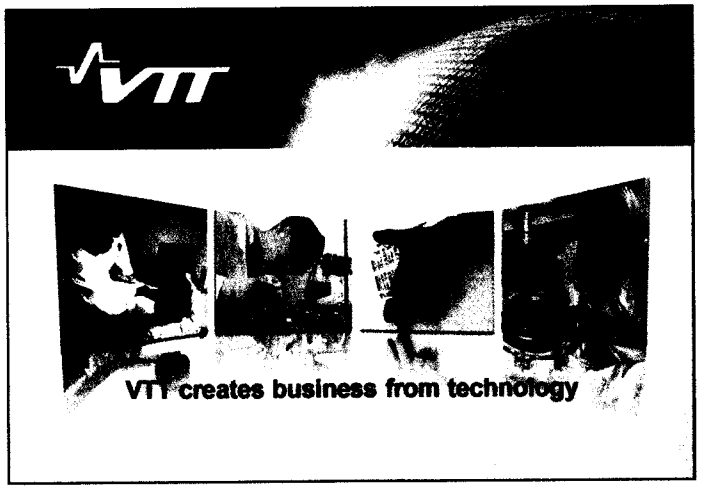
Assessment of flame and smoke spreading and thermal impact

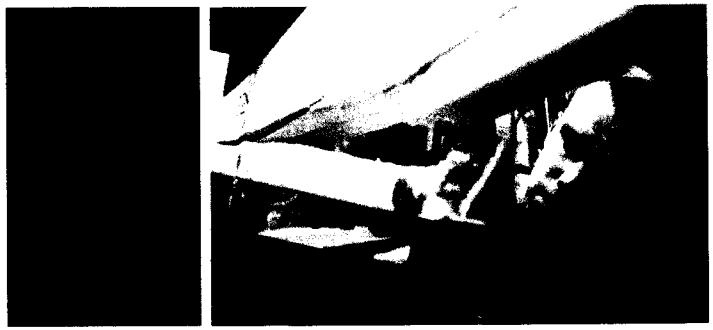


VTT in 2014



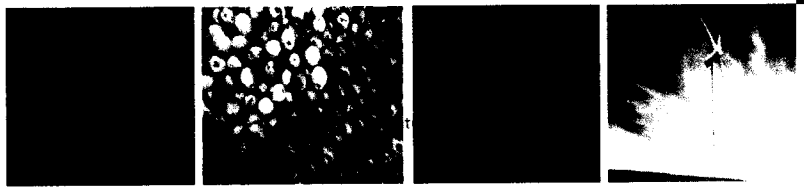

Smart industrial and energy systems: Proposal for business areas Total head count ~ 950 persons
DRAFT
Fire researchers
Business eco systems, value chains, foresight
Foresight and strategic renewal
Service business development
Value networks and business risks
Innovation economy and policy
Organisational psychology and renewal
Human-driven design and consumer behaviour
Life time management
Machine health
Infrastructure health
Machine intelligence
Enterprise asset management
Risk and reliability management
Nuclear safety
Structural integrity
Nuclear power plant components
Fracture mechanics and NDE
Reactor analysis
Nuclear power plant modelling
Nuclear waste management
Accident management
Systems engineering
Transport and logistics
Intelligent traffic systems (ITS)
Systems engineering
Systems research
Production processes
Human machine interaction
Service design
Smart energy and system integration
Efficient buildings and indoor environment
Ecoefficient districts
Smart energy networks
Wind power
Sustainable built environment
Energy systems
Materials and manufacturing
Modelling and powder technology
Consolidation and laser technology
Manufacturing
Materials performance, tribology and corrosion
Materials performance, high temperature corrosion
Structures and functionality
Mechanical engineering and structural dynamics
Clean air solutions
Machinery and environmental acoustics
Ships and maritime engineering
Stationary fuel cells
Engines
Vehicles and electrical products
Management and support functions


VTT creates business from technology



SP TECHNICAL RESEARCH INSTITUTE OF SWEDEN

2013

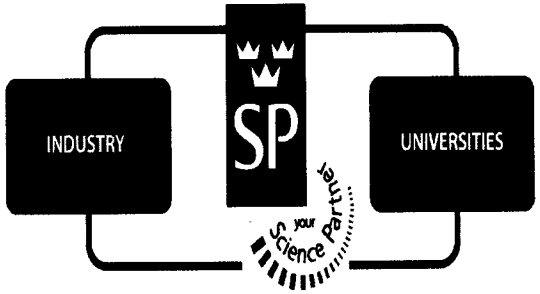


RI. SE INSTITUTES

ABOUT SP

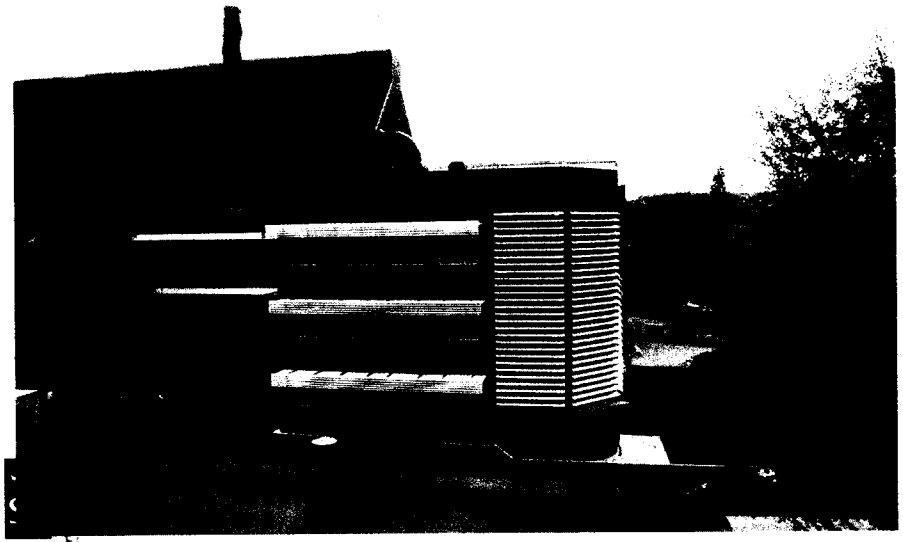
The SP Group	Wholly owned by the Swedish state
Subsidiaries	8
Employees	1 270
Revenues	Euro 130 million
Customers	> 10 000
Ph.D. and Lic. Eng.	approx. 300
Ph.D. students	approx. 80
Degree projects	approx. 70
Adjunct professors	27

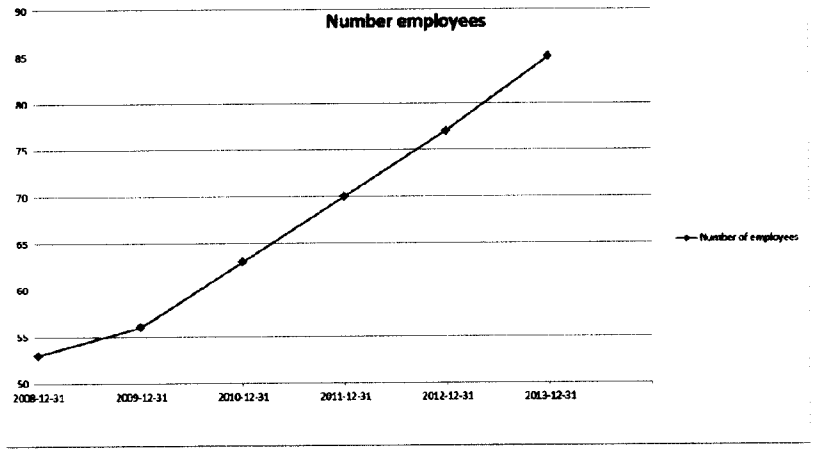
WE CREATE VALUE IN COLLABORATION



SP Sveriges Tekniska Forskningsinstitut

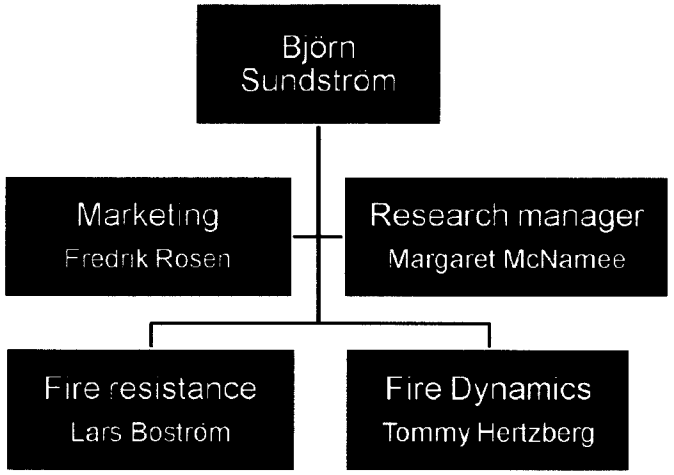
SP Fire Technology





82 employees Sep 2013: 4 professors, 12 PhD, 6 studying for PhD, 34 engineers (M.Sc. and others), 26 technicians and admin.

SP Sveriges Tekniska Forskningsinstitut

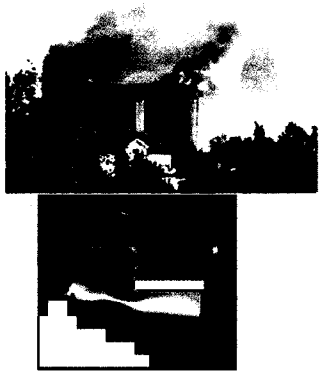


SP Sveriges Tekniska Forskningsinstitut

Research areas

- Building
- Industrial fire protection
- Fire safety in tunnels
- Fuel storage safety
- Lightweight constructions at sea
- Offshore
- Transport
- Shipping

Generic Fields
Sustainability
Toxicity
Measurement Technology
Computer Modelling



SP Sveriges Tekniska Forskningsinstitut

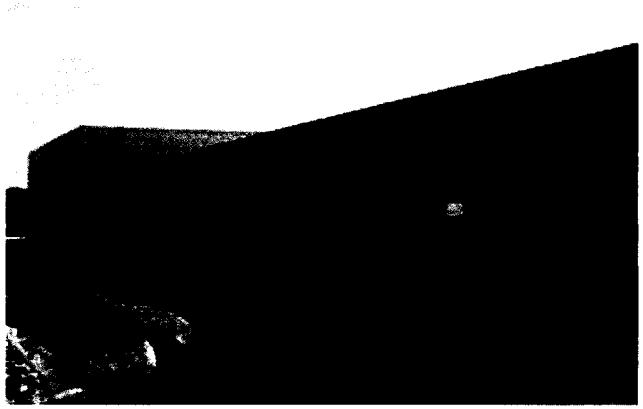
Building Research

- Product evaluation
- Material development, e.g. novel concrete formulations, fire retardants for use in building construction
- Development of test methods and classification systems
- Pre-normative research and standardisation (e.g. active in CEN, ISO, EOTA)

Hjällsnäs school fire 2008 (Sweden)

SP Sveriges Tekniska Forskningsinstitut

Steel buildings, e.g. super markets

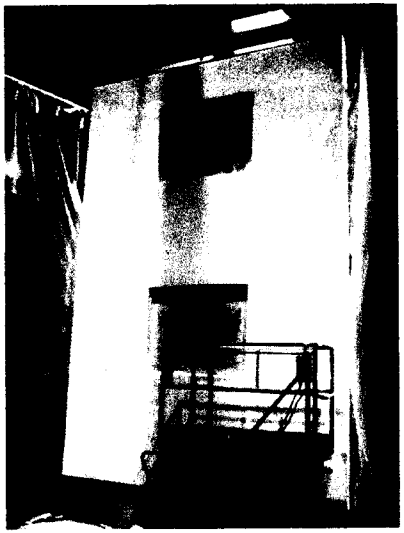


Tougher requirements in Sweden

30 min insulation (load bearing) of the roof construction

SP Sveriges Tekniska Forskningsinstitut

Facade testing



Workshop in France

Test required in Denmark

Large scale tests remains national there is no European harmonisation (yet)

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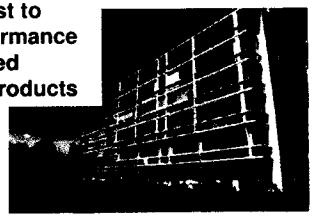
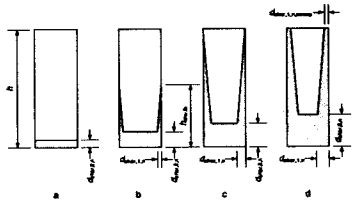
Wood Building Research

From forest to high performance wood based building products



Core Fields

- Reaction to fire
- Fire retardant wood based products
- Fire resistance of timber members, elements and construction
- Façades
- Detailing
- Design models and simple software tools for designers
- Fire risks on construction sites



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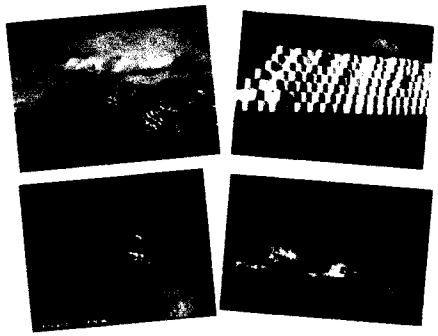
Fuel Storage Safety

- Bulk handling of fuels in focus
- Self-heating properties and risk for auto ignition
- Fire development and risk for escalation
- Detection techniques
- Extinguishment tactics
- Emissions to air and water
- Improved guidelines



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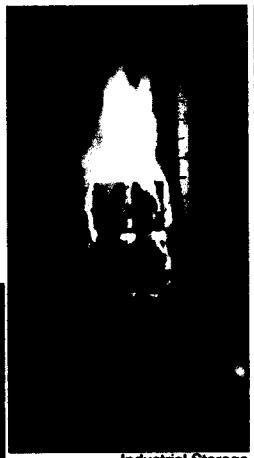
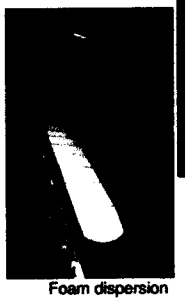
Industrial Fire Protection

- Suppression systems
- Goods classification
- Detection
- Risk Assessment



Industrial Storage

Fire Extinguisher test



Foam dispersion

Goods classification

SP Sveriges Tekniska Forskningsinstitut

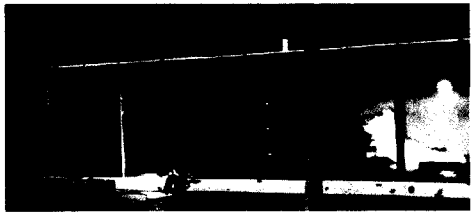
Tunnel and Underground Research Center

Kaprun tunnel fire 2000 (Austria)

- Design fires
- Active and Passive fire protection
- Suppression
- Egress
- Risk assessment
- Consulting
- Development of regulations and guidance documents

METRO

ISTSS Conference in New York (2012) and Marseille (2014)



Model scale tunnel fire tests

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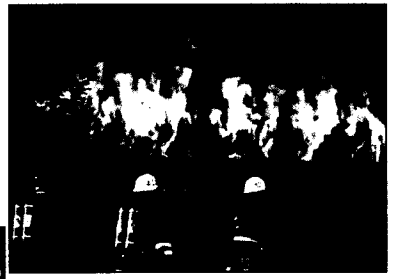
Transport

Full scale bus fire test



- Buses
- Trains
- Airplanes
- Heavy Goods Vehicles (HGVs)
- Cars

...all vehicles represent different risks and have different regulations associated with them

- We conduct research concerning:
  - Ignition
  - Fire load
  - Suppresssion
  - Regulations
  - Material performance

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Maritime Research

- Active suppression system characterisation
- Development of regulations
- Light weight constructions and material
- Modern test methods

Sprinkler test

Light weight superstructure

- Examples of research projects:
  - BESST
  - FIST
  - Fire-Resist

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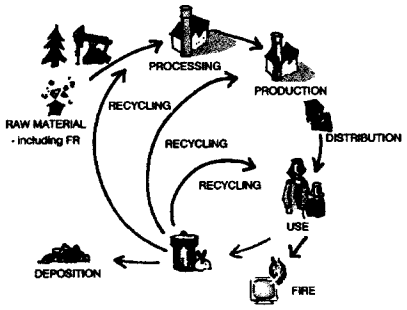
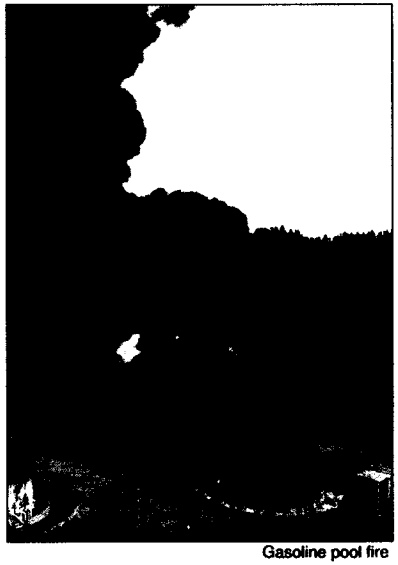
Sustainability and Toxicity



- Fire-LCA
- Fire-CBA
- Emissions: toxicity, characterisation, modelling



Gasoline pool fire

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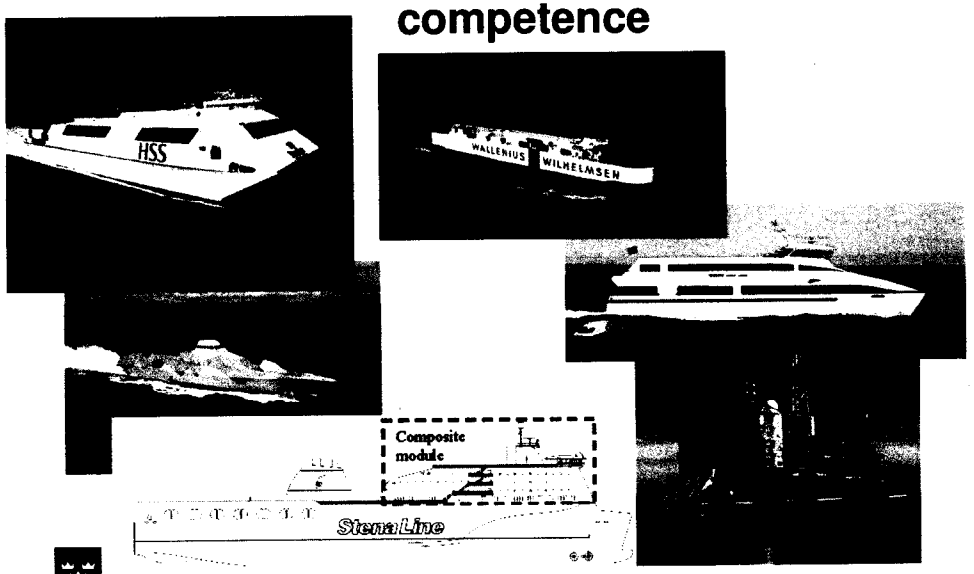
New Constructions at Sea – center of competence



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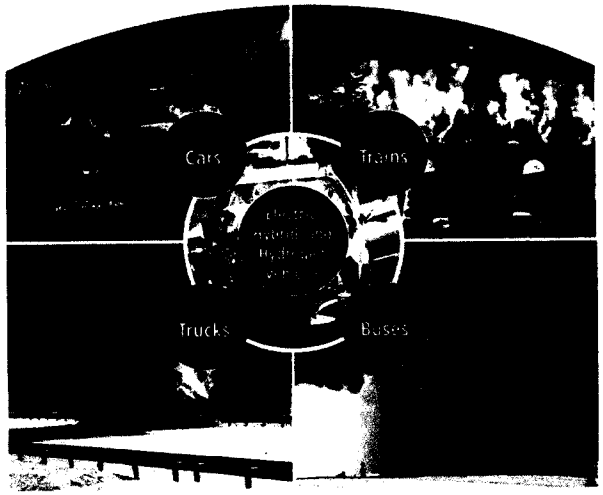
CONFERENCE

FIVE – Fires In Vehicles

Chicago 2012, Berlin 2014

More information at **www.firesinvehicles.com**



SP Sve

Fire investigations and expert interface

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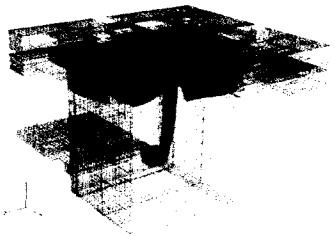
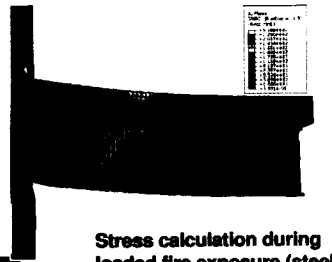
Calculation methods

Smoke movement





Stress calculation during loaded fire exposure (steel and concrete construction)

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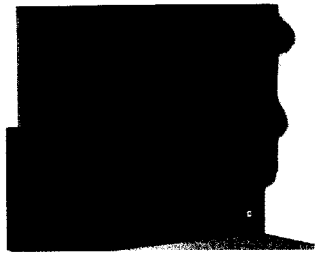
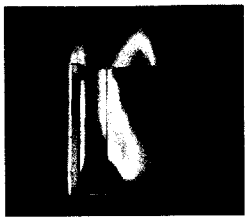


Simulation of large scale facade test



Simulation in the Room Corner Test, ISO 9705

Teaching, competence development

Courses in Fire dynamics: Luleå Technical University

Courses in heat transfer : Luleå Technical University and EGOLF

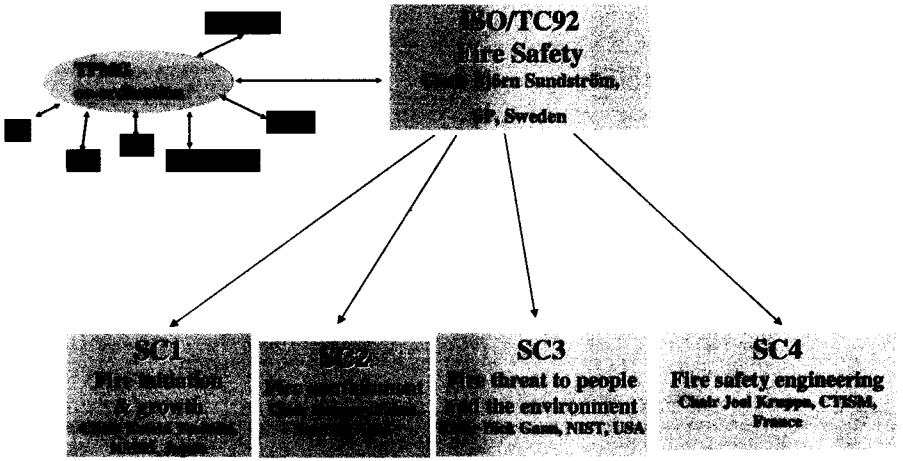
Courses in tunnel fire dynamics in LTH and Mälardalen

PhD students (6) in our own staff, linked to Lund University, Royal Institute of Technology and Luleå Technical University

Tutor for PhD students at Luleå and Mälardalens högskola (4)

Courses related to the CPR

International Standardisation Organisation



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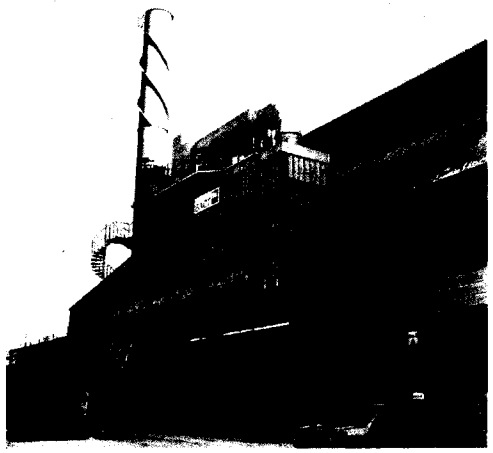
Modern Fire Testing



- Fire Characterisation
- Small scale testing to large scale performance

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Fire Protection Testing

- Extinguishing systems
  - Foam
  - Water mist
  - Sprinklers
  - Fire extinguishers
- Commodity classification
- Risk evaluation
- Scale modelling
- Detection
- Marine Applications
- Environmental Effects of Fires

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Fire Dynamics

Marine small scale testing
- Ignitability
- flame spread
- smoke production
- toxicity

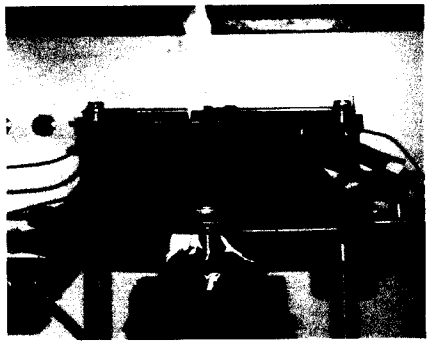
Marine large scale testing
- fire restricting materials (ISO 9705)

Furniture Calorimeter
- heat release rate
- smoke production rate

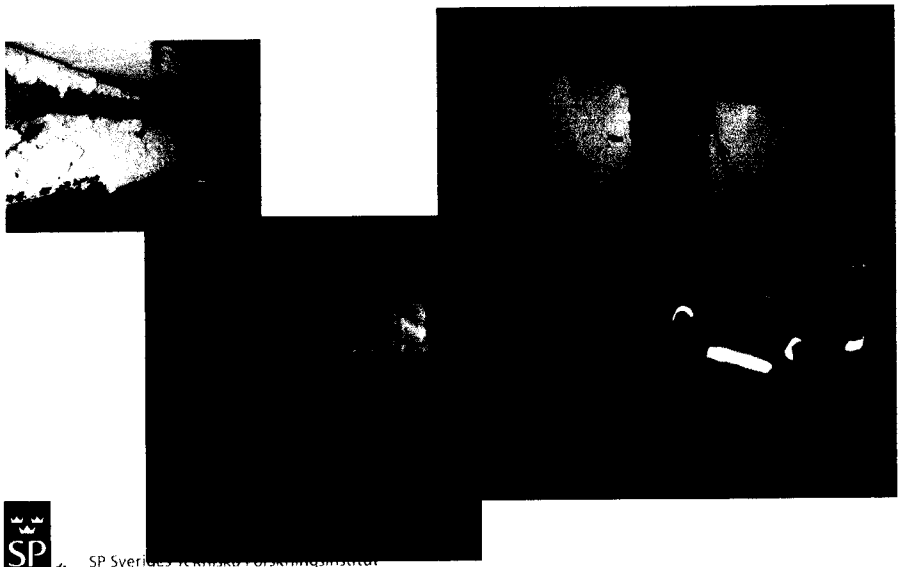
Fire Dynamics

Room test scenario
- Reference scenario for the Euroclass system

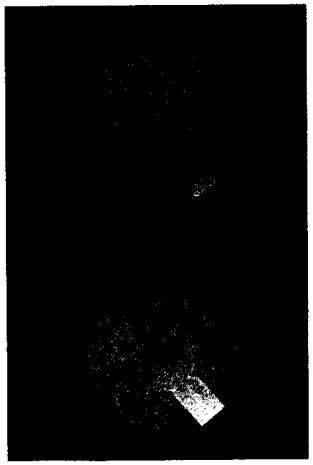
Cone Calorimeter
- Product development tool
- Input to fire safety engineering



Fire Resistance testing

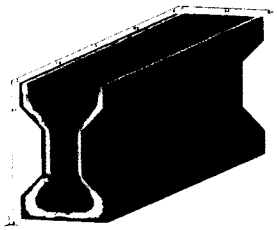


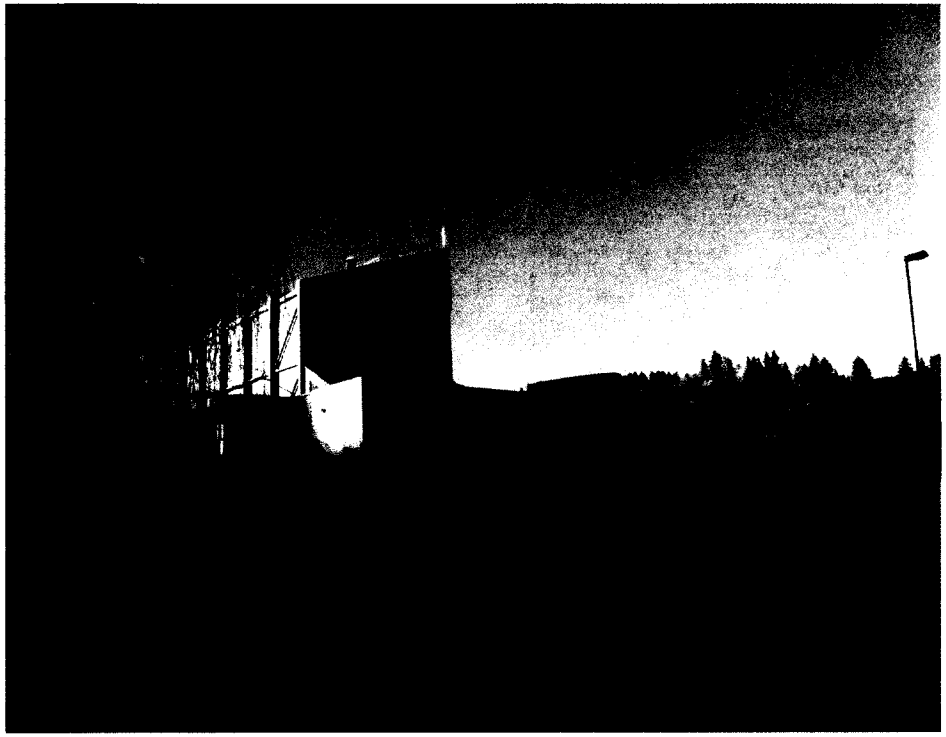
High Temperature Thermal Properties

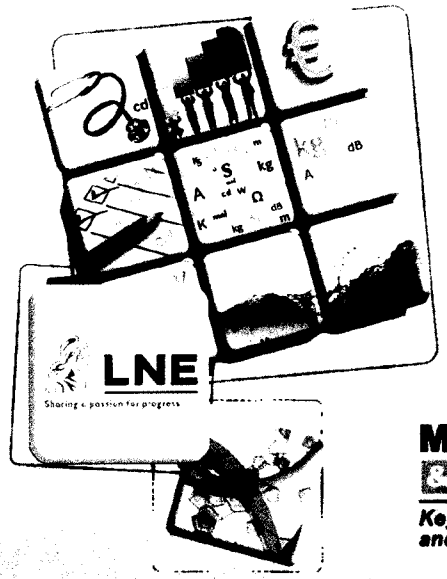


Transient Plane Source method (TPS)

A device for determination of the thermal conductivity, thermal diffusivity and the specific heat simultaneously







MEASUREMENT & STANDARDS

Keys to COMPETITIVENESS and A SAFER WORLD

Historical Background

Testing for industry until 1901

- **CNAM** : Conservatoire national des arts et métiers (1794)

Metrology until 1875

- **Observatoire de Paris** (1667)
- **CNAM** : Conservatoire national des arts et métiers (1794)

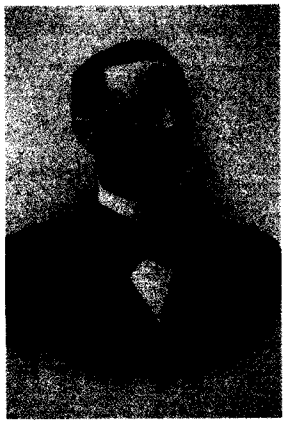
Metrology between 1875 and 1969

- **LCIE** : Laboratoire Central des Industries Electriques (1882)
- **LNE** : Laboratoire National d'Essais (1901)
- **CEA** : Commissariat à l'Energie Atomique (1945)

LNE funded 1901 from CNAM
Including all national metrology since 2005

LNE and Alfred PEROT

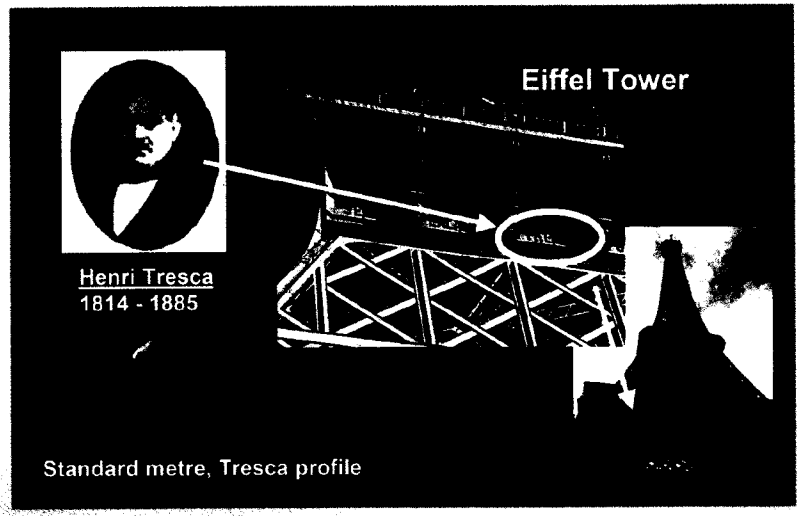
LNE headquarters, Paris since 1957



Alfred Perot 1901-1907 – Director Rumford medal

Previously, LNE at CNAM, Paris – (1794) 1901

LNE and Henri TRESCA

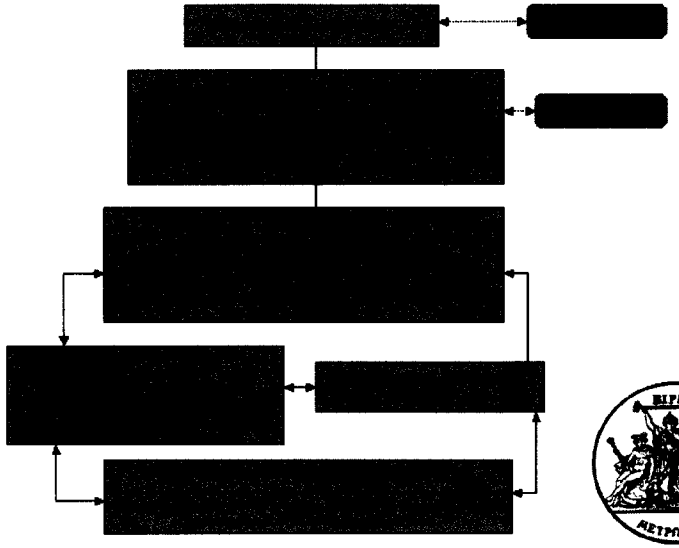


Science, metrology, measure, test, certify, form

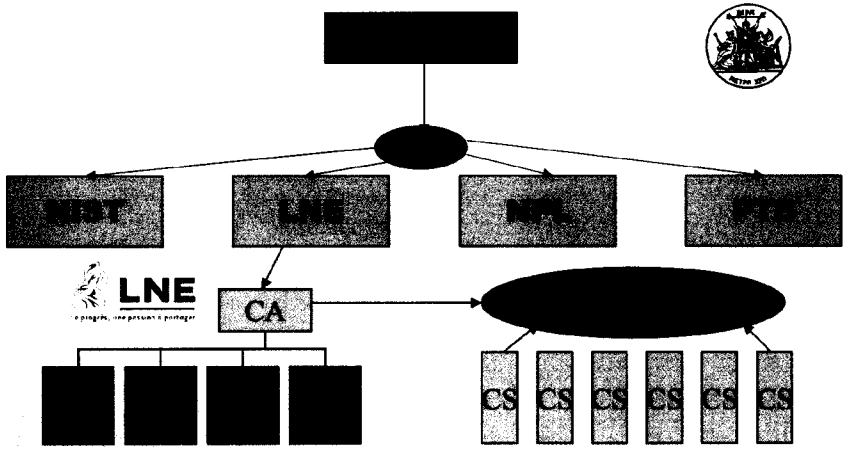
Recall of the missions of the LNE:

Generally, the LNE is charged by article 31 of law n° 78-23 of January 10, 1978, to carry out all work of study, research, consultation, expertise, test, control and all services of technical aid useful for the protection and the information of the consumers or the improvement of the quality of the products.

Metrology on a world level



French metrology in the world context



Missions: Industry, Society

XX century : 1901 - 1977
... LNE gradually widens its scope

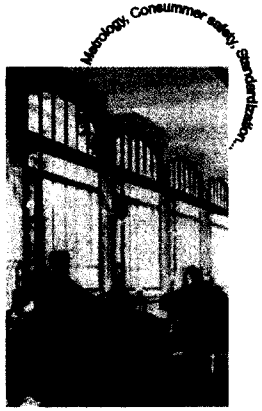
The LNE was established in 1901 as part of the Conservatoire National des Arts et Métiers (CNAM). It was set up to meet industrial testing and measurement requirements, especially in the fields of materials, machinery and physics. .

In 1930 LNE began focusing on consumer product safety, and in 1976 set up a consumer products department
1978 - 2000
... a state-owned enterprise

XXI century
... an international dimension

2004, LNE opened a centre for R&D in electrical metrology and nano-metrology at its Trappes site.

2009, le LNE strengthen its position in France in the field of Energy by creating subsidiaries devoted to Solar

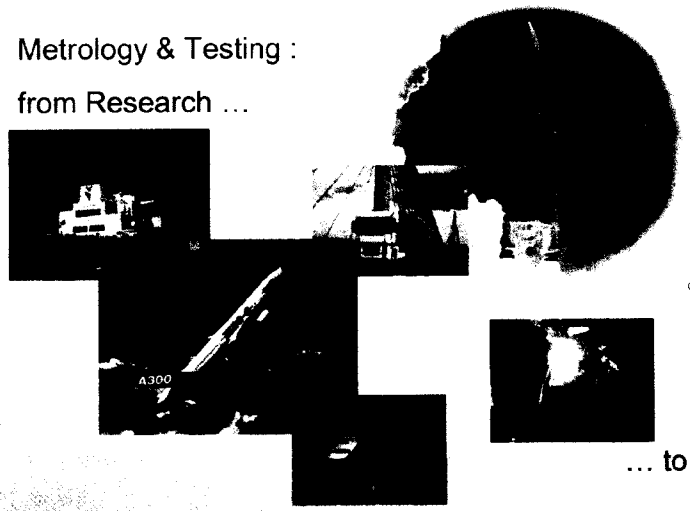


1910, mechanical tests
At the automotive
workshop (CNAM)

Support to industry

Metrology & Testing :

from Research …



… to Industry

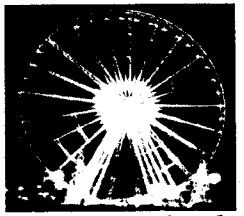
Laboratoire national de métrologie et d'essais

Main Activities : Protect & Inform Consumers

Food Sanitary Safety

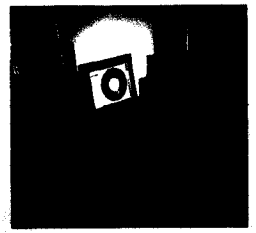
Fire Safety

Lighting safety



Chemical risks

Numerical storage



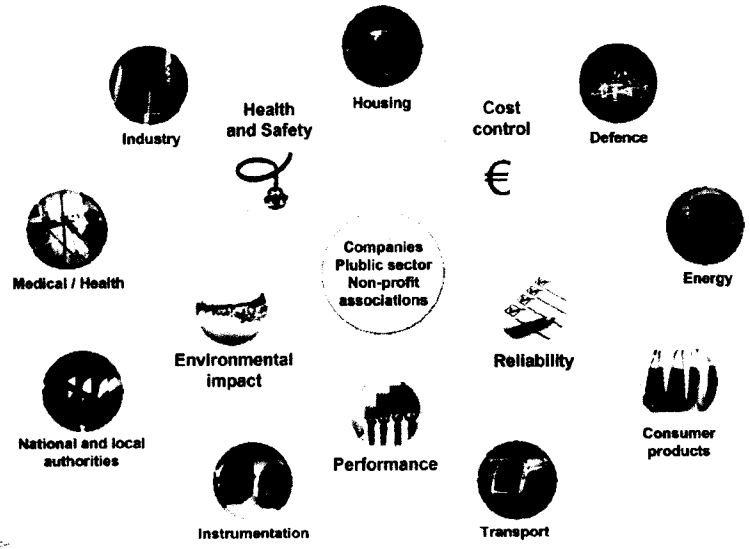
Swimming pool Safety

Childcare articles-Toys

Laboratoire national de métrologie et d'essais

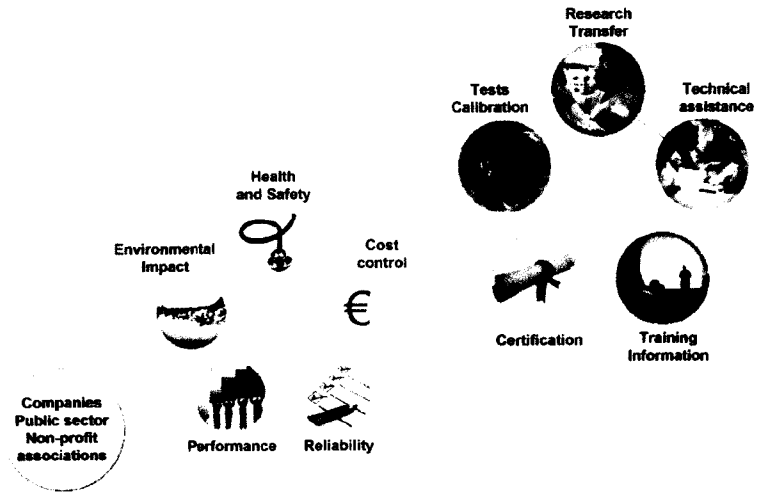
Measurements and standards – essential for all

LNE

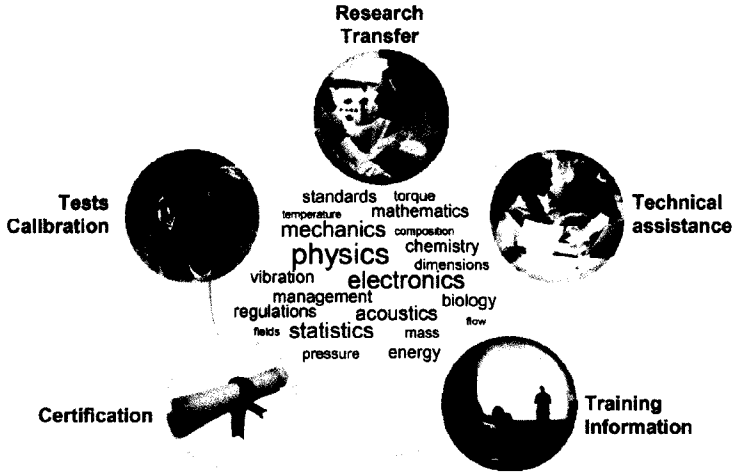


Measurements and standards: appropriate solutions

LNE



Extensive scientific and technological expertise



An essential player

An independant body

- A state-owned enterprise appointed by the French Ministry of Industry to perform a twofold mission: protection of public safety and consumers, and provision of services to companies

A recognized body

- Notified for over 20 European Directives
- Approved by competent ministries to perform tests and verifications on over 90 products covered by regulations
- Accredited by French accreditation body COFRAC for calibration, tests, certification of products and certification of management systems

Key figures

11 sites

- France (Paris, Trappes, Toulouse, Nîmes, Saint-Etienne, Poitiers, Chambéry)
- USA (Washington DC)
- China (Shanghai, Hong-Kong)
- Qatar

Outstanding resources

- 800/1200 staff including ¼ of technicians, engineers and researchers
- 55 000 m² of laboratory space
- Extensive network of partners
- 76 M€ turnover including 50 M€ sales
- 25 M€ investment over last five years
- 21% of budget allocated to R&D

LNE

Le progrès, une passion à partager

Fire behaviour and fire safety department

French National laboratory for testing and metrology

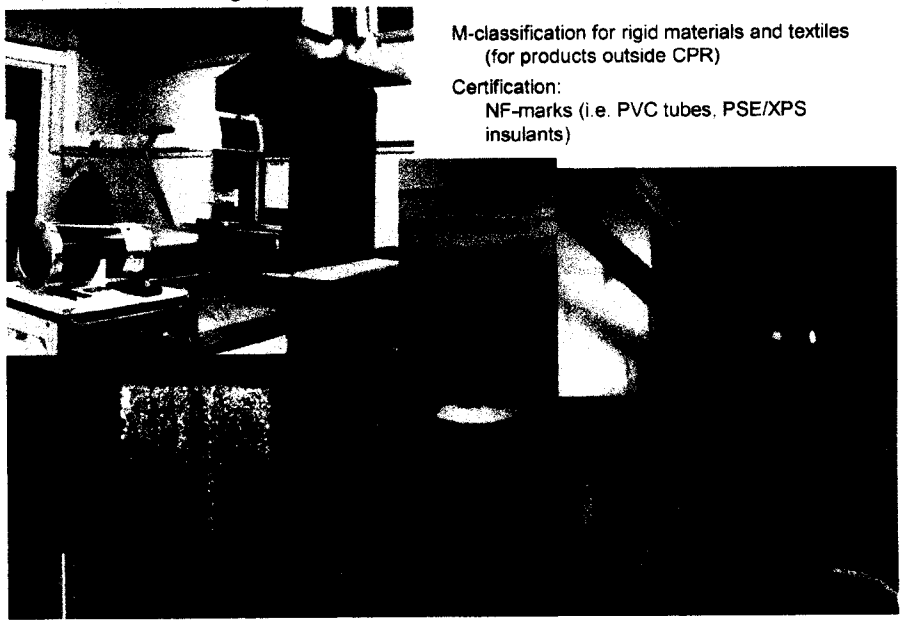
Tests, studies and research

LNE

- Regulatory tests
  - Building products and furbishing
  - Transportation
- Fire Safety Engineering, smoke control engineering
- Certification
- Standardization, assistance to regulators
- Training
- RTD on fire
  - Materials (composites, nanomaterials, etc)
  - Codes v&V

National Building Code tests

LNE

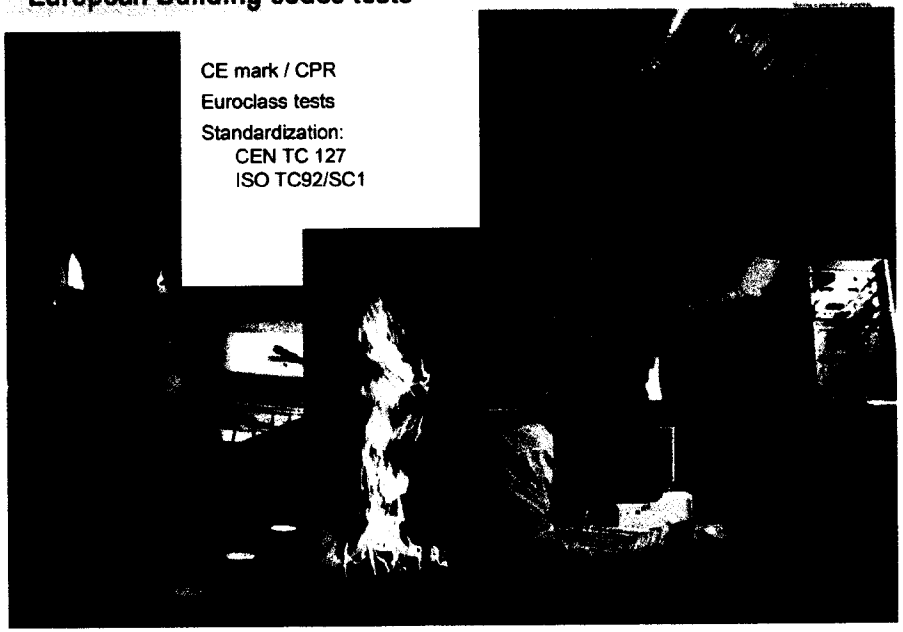


M-classification for rigid materials and textiles (for products outside CPR)

Certification:
NF-marks (i.e. PVC tubes, PSE/XPS insulants)

European Building codes tests

LNE



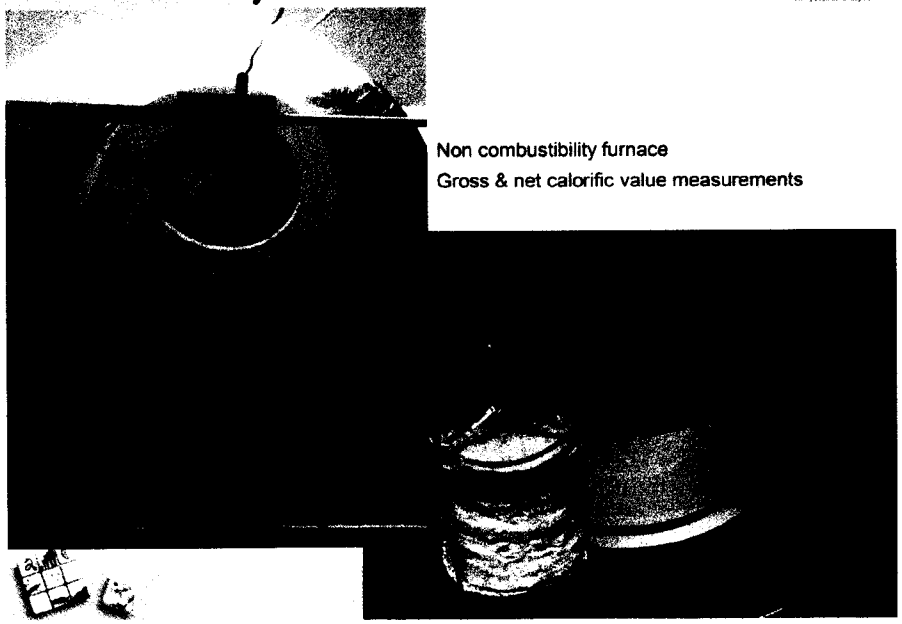
CE mark / CPR

Euroclass tests

Standardization:
CEN TC 127
ISO TC92/SC1

Non-combustibility

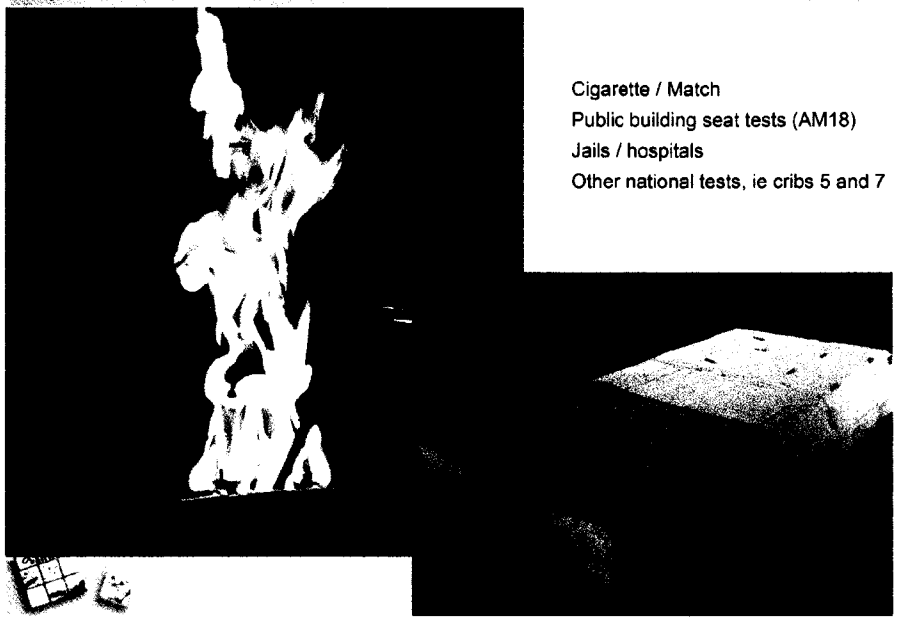
LNE



Non combustibility furnace

Gross & net calorific value measurements

Upholstered furniture - mattresses



Cigarette / Match
Public building seat tests (AM18)
Jails / hospitals
Other national tests, ie cribs 5 and 7

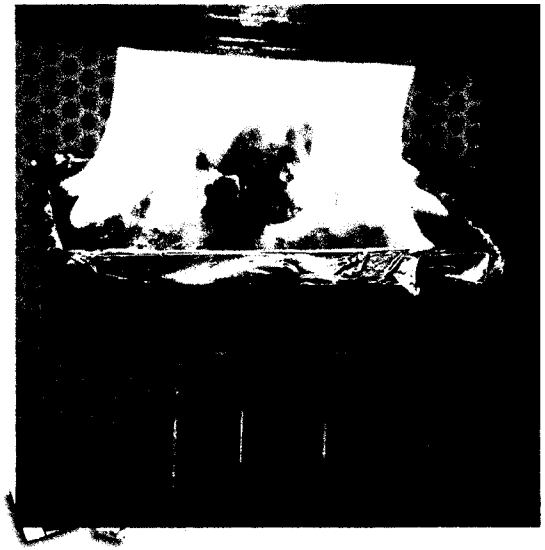
Railway domain

National tests (France, Italy, UK...)
European tests (EN 45545-2)
Standardization:
JWG CEN TC256/CLC TC9X

Maritime domain

Civil domain
IMO FTP code parts 1,2,5(6),7,8,9
Navy domain
AFAP tests (NATO), national codes
Smoke detectors
Standardization
IMO FP comitee,
NATO STANAG 4602

Calorimetry

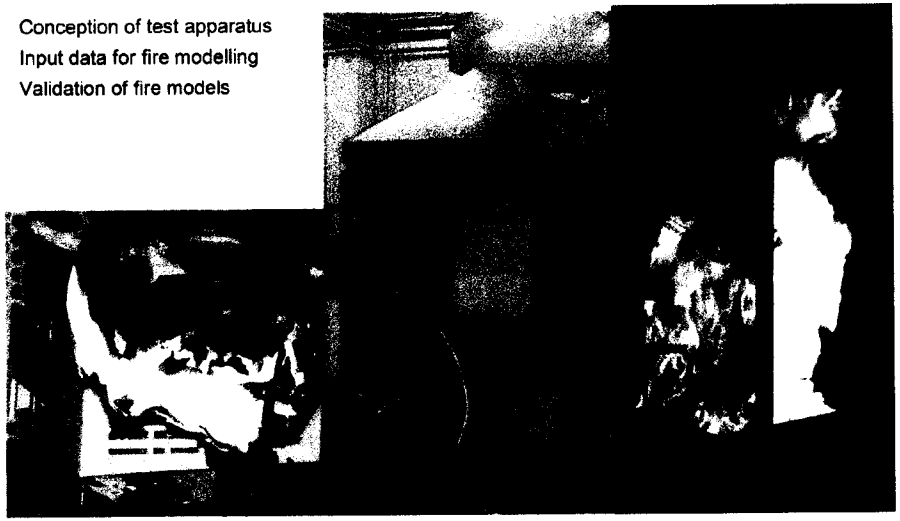


Cone calorimeters
Medium-scale calorimeter
Viciated atmosphere tests
Soot granulometry

Special tests

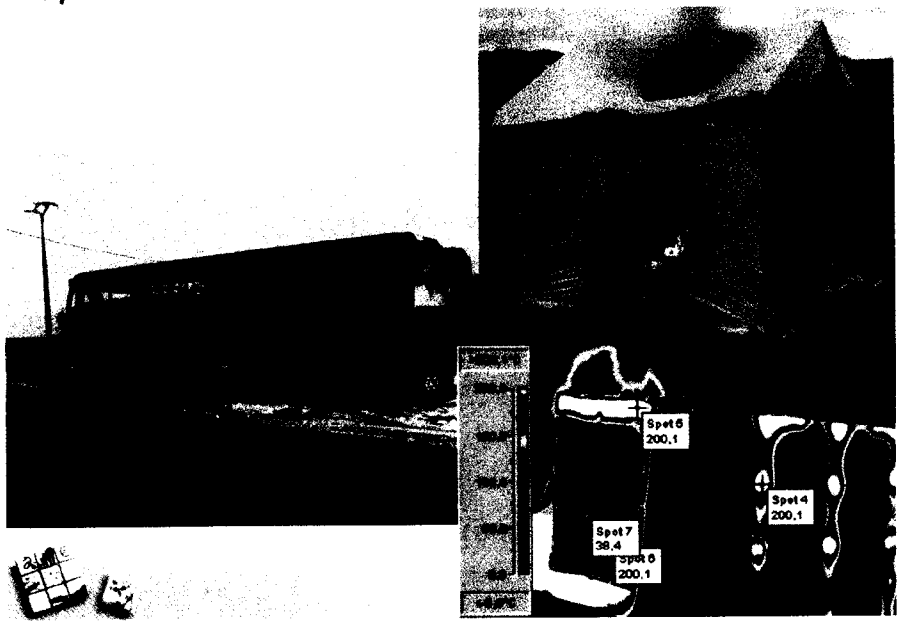
LNE

Conception of test apparatus
Input data for fire modelling
Validation of fire models



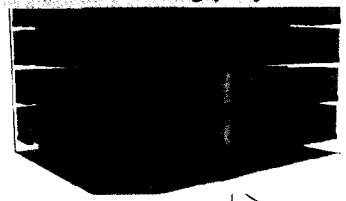
Expert assessment

LNE

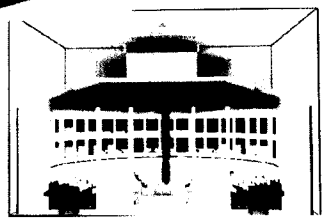


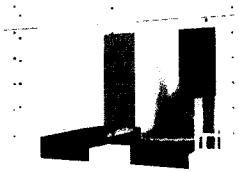
FSE on building projects

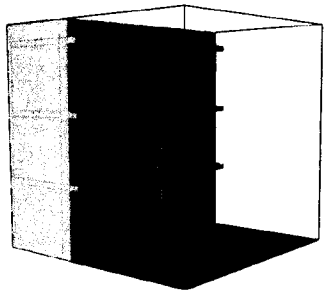
LNE

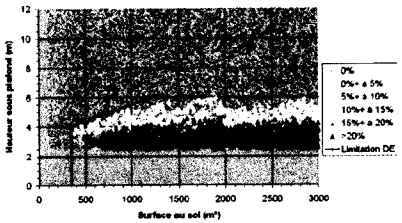


Smoke control design,
Use of combustible insulants,
Facades
Standardization: ISO TC92/SC4









Regulation and standardization survey

LNE

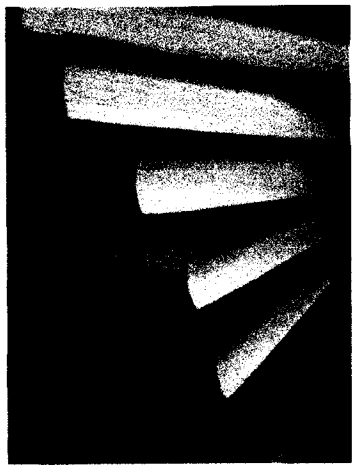
Assistance in understanding of EU structures & regulations, CE certification, national regulations and standards

ISO 14001, EN 16001/ISO 50001 (energy management) guidance and certification

Expert assessments

Comparison between national or regional regulations

Comparison between tests methods and levels of requirements



Standardization

LNE

ISO TC92 « Fire Safety »

- SC1: Reaction to fire
- (SC2: Fire resistance)
- SC3: Effects of fire on People and the Environment
- SC4: Fire Safety Engineering

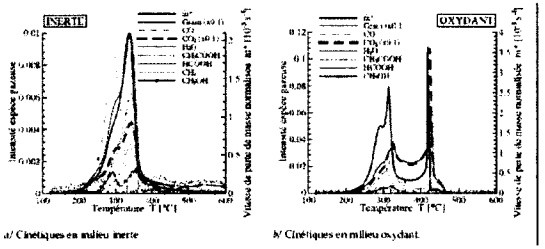
ISO TC61/SC4 « Plastics – Fire behaviour »

European TC's: CEN TC127, etc

National level : Chair of a lot of mirror comitees

Pyrolysis modelling (1)

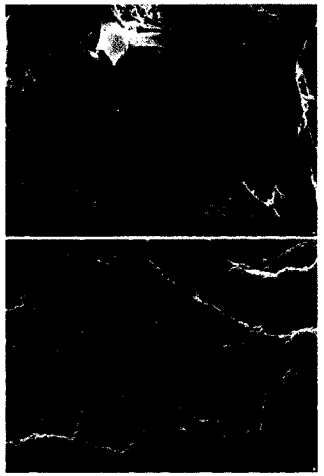
LNE



a/ Cinétiques en milieu inerte b/ Cinétiques en milieu oxydant

Plage [°C]	Type de réaction	Réactifs		Produits
[190-310]	Pyrolyse	balsa	→	$\upsilon_{p,\beta}$ βbalsa+$(1-\upsilon_{p,\beta})$ gaz
[310-380]	Pyrolyse	βbalsa	→	$\upsilon_{p,\beta\beta_1}$ gourdon+$\upsilon_{p,\beta\beta_2}$ charbon+$(1-\upsilon_{p,\beta\beta_1}-\upsilon_{p,\beta\beta_2})$ gaz
[190-320]	Oxydation	balsa + O_2	→	$\upsilon_{o,\beta}$ βbalsa+$(1-\upsilon_{o,\beta})$ gaz
[320-400]	Oxydation	βbalsa + O_2	→	$\upsilon_{o,\beta\beta_1}$ gourdon+$\upsilon_{o,\beta\beta_2}$ charbon+$(1-\upsilon_{p,\beta\beta_1}-\upsilon_{p,\beta\beta_2})$ gaz
[400-420]	Oxydation	gourdon + O_2	→	$\upsilon_{o,\beta\beta_1}$ résidu+$(1-\upsilon_{o,\beta\beta_1})$ gaz

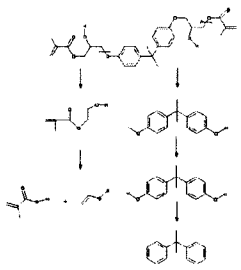
Development of a pyrolysis model for balsa wood

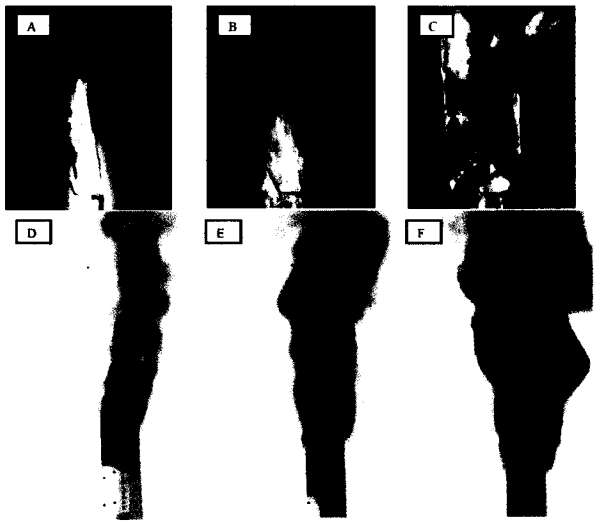


Oxydative and non-oxydative pyrolysis of polymers

Pyrolysis modelling (2)

LNE



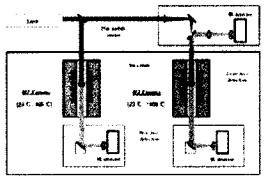


Mechanisms
Kinetic constants
Multi-scale assessment

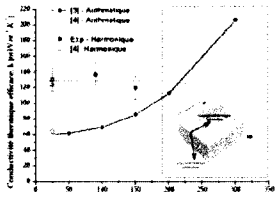
Intrinsic properties

LNE

Thermophysical properties – Equivalent thermal conductivity



LNE guarded hot plate conductimeter [23-1400°C], French national reference
[Hay B. et al., High Temp.-High Press.,2010,39 (3):181-208]



Marmuis et al., Congrès SFT, Perpignan 2011

LNE guarded hot plate [-25; +800°C], French national reference

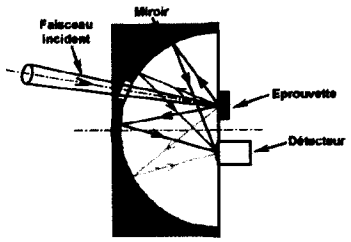
Reference Guarded Hot Plate [150°C; +250°C], French national reference

Actual difficulties :

- k_{eq} measurement during thermal decomposition
- k_{eq} measurement for transient species
- Uncertainty calculation at high temperature

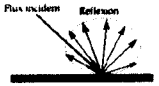
Intrinsic properties

Radiative properties – Material absorption coefficient



French national reference reflectometer build at LNE [Huy B. et al., *High Temps-High Press*,2010;39 (3):181-208]

Remit :



Directional hemispheric reflectivity

1. **Spectral directional hemispheric reflectivity measurement (reflectometer)**
2. **Transmission factor measurement (FTIR)**
3. **Effect of material thickness**

Semi-transparent material : transmission and reflexion meas.
Opaque material : only reflexion

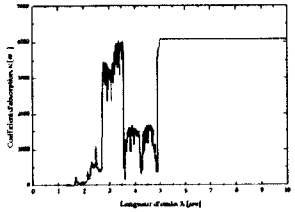
Notations

τ_λ : **Monochromatic transmittivity** $[m^{-1}]$ — e : **material thickness** $[m]$

κ_λ : **monochromatic absorption coefficient** $[m^{-1}]$

Intrinsic properties

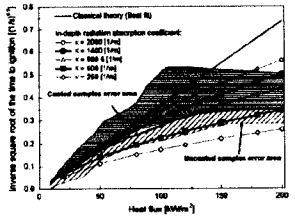
Radiative properties – Absprption coefficient of the material



Absorption coefficient of a GRP ; Maupin D. *Thèse de doctorat*, EMN, 2010].

Measurement depends of:

- Chemical nature of the material
- Spectral range
- Thickness
- Temperature and decomposition
- Surface topography (rugosity)
- Direction
- etc



Influence of κ on PMMA ignition
[Bal & Rein, *Combustion and Flame* 158 (2011) 1109–1116]

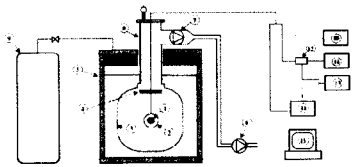
Are the values a characteristic of the material ?
Which wavelenght(s)?

Actual problems :

- Blackbody temperature
- Sample temperature
- Structural modifications
- Thickness
- Uncertainty at high temperature [2-5%]

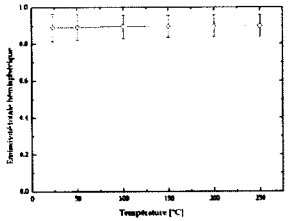
Intrinsic properties

Radiative properties – Total hemispheric emissivity



(1) specimen; (2) heating system; (3) chamber; (4) radiative screens; (5) dewar; (6) valve vacuum pump; (7) turbomolecular vacuum pump; (8) access well; (9) nitrogen tank; (10) manometer; (11) electrical supply; (12) calibrated shunt resistor; (13) voltmeter; (14) 0°C reference for the thermocouples; (15) computer

Spectral normal hemispheric emissivity reference apparatus at LNE [Huy B. et al., *High Temps-High Press*,2010;39 (3):181-208]



Total hemispheric emissivity of a polyester resin

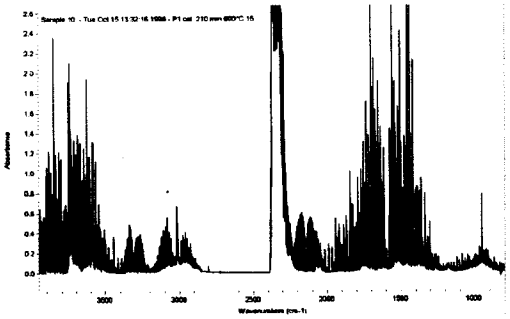
Measurement depends of:

- Chemical nature of the sample
- Decomposition of the sample
- Surface temperature measurement
- Sample temperature
- Blackbody reference temperature (Nitrogen, 77K)

Actual problems:

- Sampling
- Samples heating
- Samples temperature
- Structural changes
- Uncertainties with temperature

Smoke toxicity



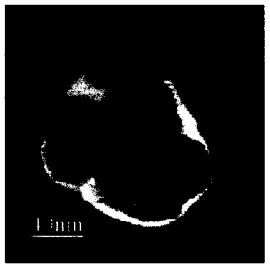
All gases

- Techniques: FTIR, GCMS, HPLC, etc
- Acute toxicants (CO, HCN, HXs, SOx, NOx, aldehydes, etc)
- Long-term, chronic toxicants (PAH, VOC's, dioxins, furanes, etc)

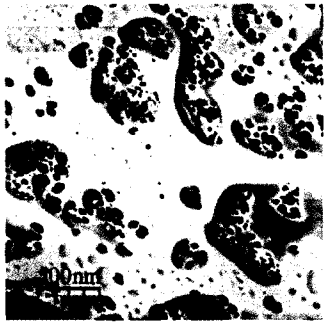
Standardization:

- ISO TC92/SC3

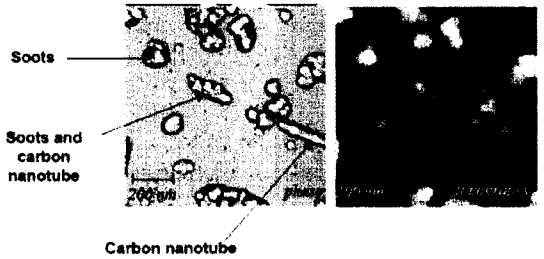
Aerosols and nanoaerosols



Phase image of a nanoaerosol resulting from the combustion of Nanosilica-filled PMMA

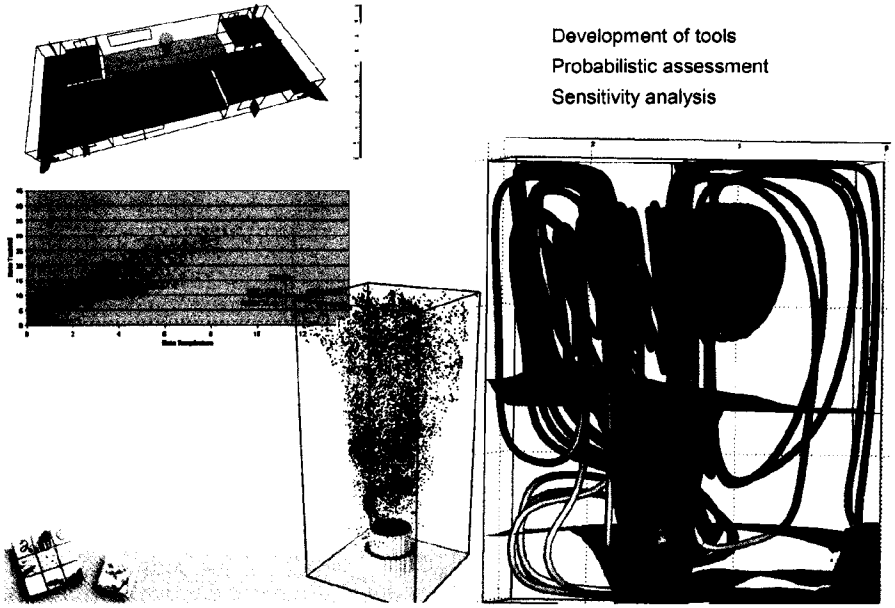


Impaction of tar and carbon aerosols



Impaction of PA6/MWCNT at 90 nm

Modelling tools



Development of tools
Probabilistic assessment
Sensitivity analysis

Main research topics – Fire, 2013-2016

- Modelling fire behaviour of materials and products
  - Pyrolysis modelling
  - Experimental/numerical multi-scale approach
  - Experimental development to provide input data
- Analysis of fire effluents
  - Smoke chemistry
  - Aerosols and nanoaerosols
- V&V of codes and tools
  - Sensitivity analysis
  - Probability of reaching a given threshold -> conformity assessment

Documents

Activity report (in english):
http://www.lne.eu/publications_en/annual-report-2012/lne-annual-report-2012.pdf

Research report (in french):
http://www.lne.fr/publications/rapport-activite-2012/LNE-rapport-activite-recherche-2012.pdf

French metrology: http://www.french-metrology.com/

LNE website: www.lne.fr

Many thanks for your attention