The Origins of Fire Safety Engineering in the UK

by

Dougal Drysdale

BRE Centre for Fire Safety Engineering

University of Edinburgh

The Origins of Fire Safety Engineering in the UK

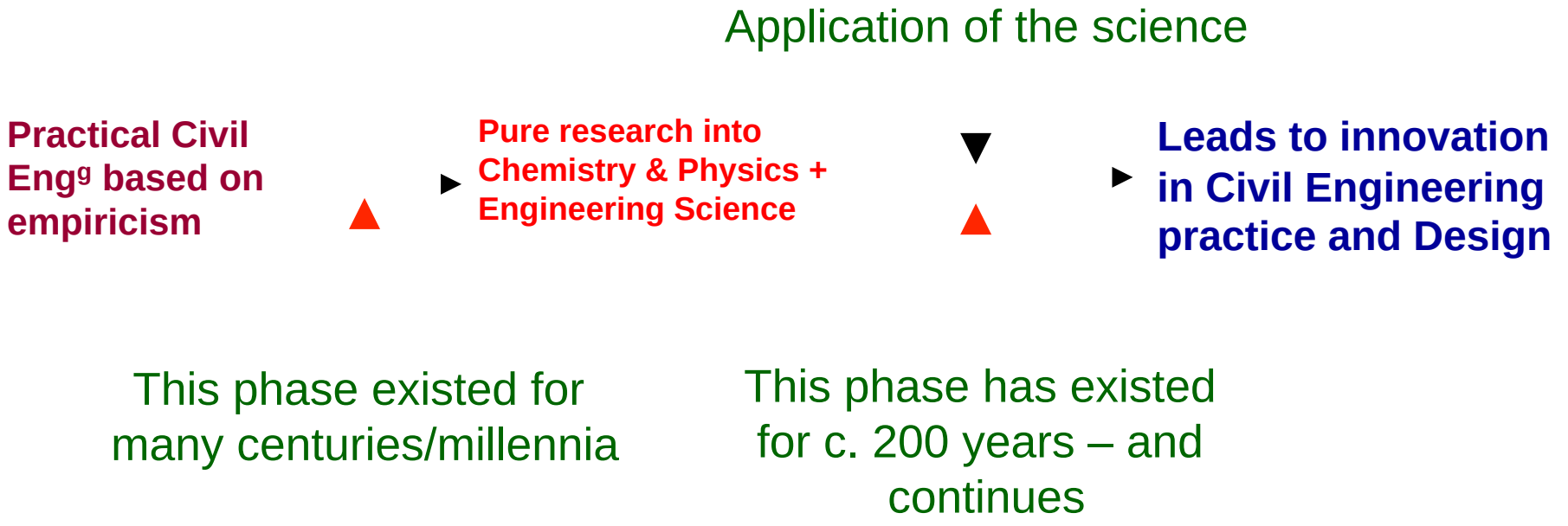
What is Fire Safety Engineering?

How did it evolve?

Who is to blame?

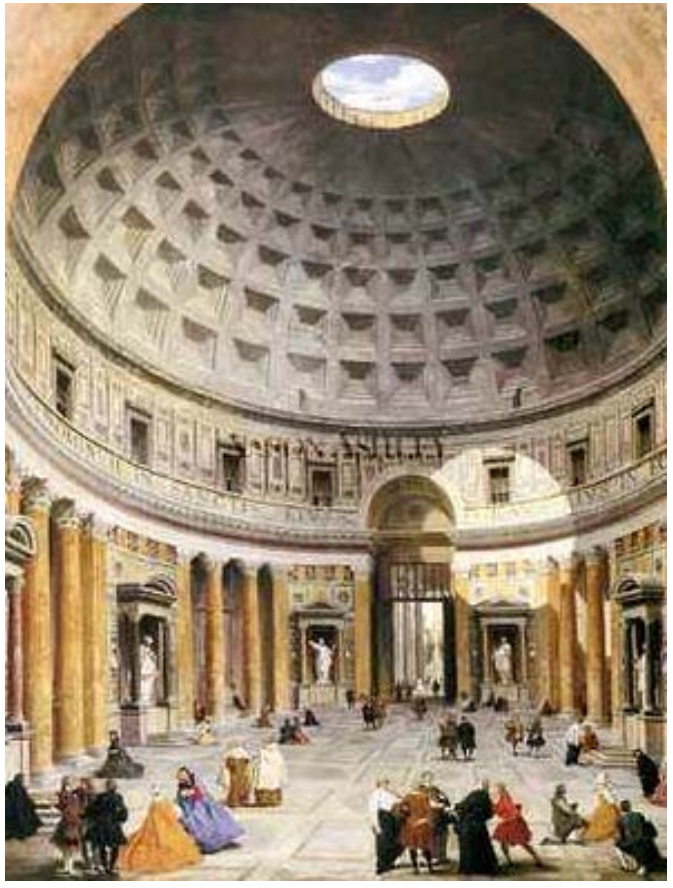
Start by comparing Fire Safety Engineering with other Engineering Disciplines

Applying new insights into Physics and Chemistry led to rapid development of Civil Engineering as a discipline



The Pyramids of Egypt (c. 2500BC)

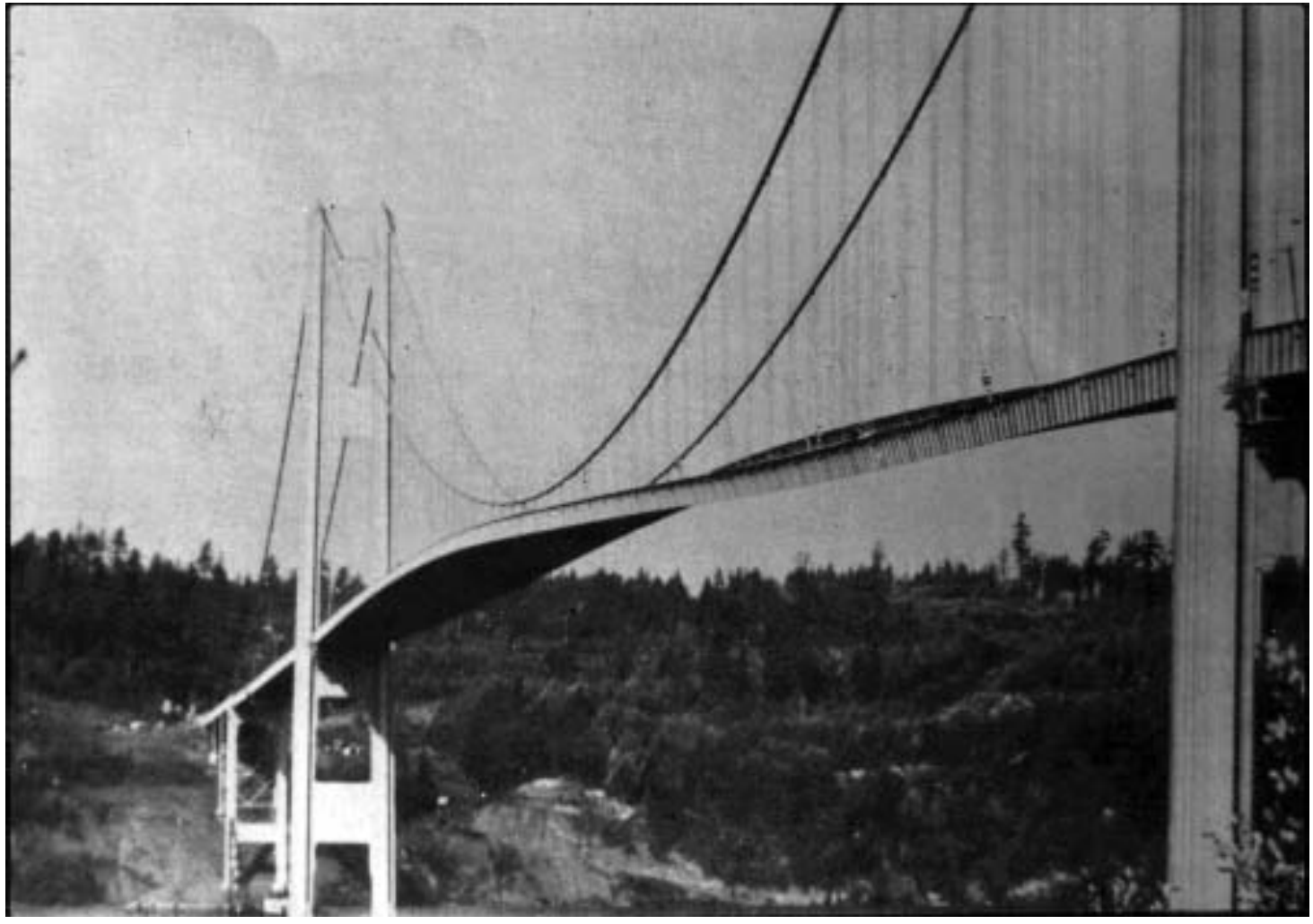
The Pantheon, Rome (118 – 126 AD)



But these were the successes!

We don't know much about the failures

Progress relied on lessons learned from failures



Tacoma Narrows Bridge (Galloping Gertie) on November 7th 1940. It was unstable in high winds and collapsed catastrophically as a result of violent oscillation

Is Fire Safety Engineering any different?

It shouldn't be, but consider this:

Practical FSE based on empiricism

This phase existed for many centuries/millennia

Is Fire Safety Engineering any different?

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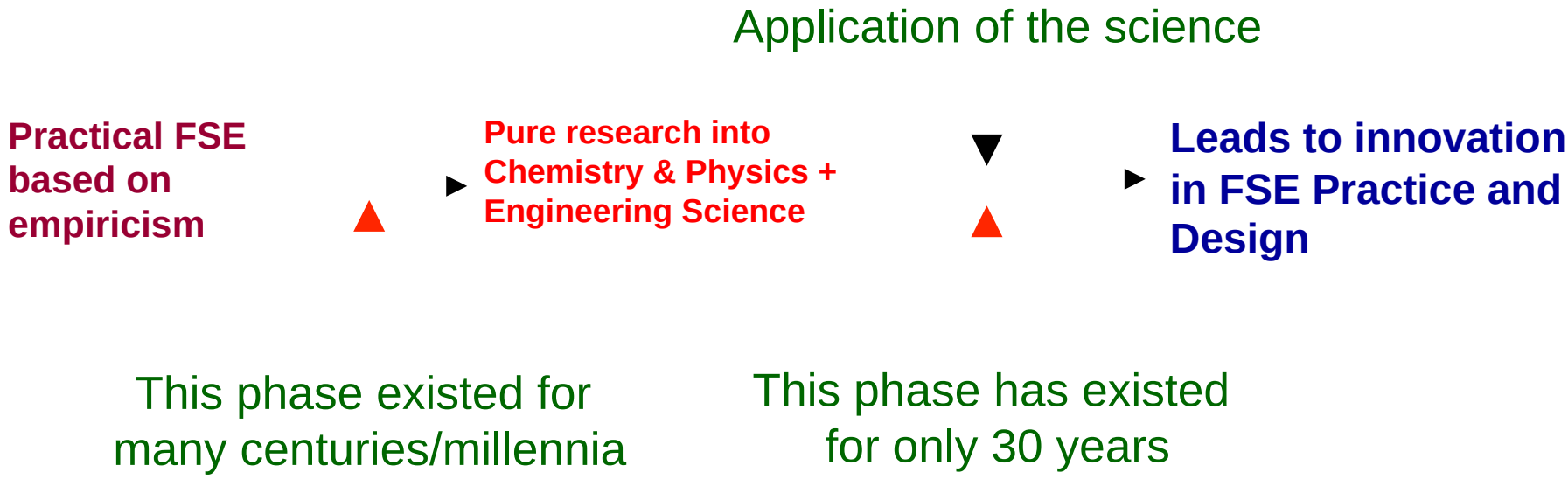


Led to the first proper Building Regulations, which prescribed wide streets acting as firebreaks, non-combustible cladding etc.

The Great Fire of London (1666)

The Great Theatre Royal Fire, Exeter 5th September 1887

A naked gas flame ignited some curtains – there were 186 fatalities, many from the upper gallery

Parliament legislated to bring in stringent safety precautions in all British theatres, including the fire proof safety curtain

The Empire Palace Theatre Fire, Edinburgh, 9th May 1911

pre-1911

c. -1970

The illusionist 'The Great Lafayette' accidentally set light to the stage with a lighted torch. The theatre burnt down.

Lafayette was one of ten performers and stage hands who died in the incident. No member of the audience was seriously affected, thanks to the safety curtain.

The audience cleared the theatre in 2½ minutes – *this was then adopted as the standard "evacuation time", particularly for places of public assembly*

Piper Alpha explosion and fire (1988)

This disaster led to the loss of 167 lives. The Public Inquiry (led by Lord Cullen) led to the biggest shake up of the regulation of Health and Safety in the offshore industry

Some buildings could not be made to comply with existing regulations

Structural Engineering was sufficiently advanced to allow the designer to prove that these structures were “safe” – at normal temperatures

Not so for Fire Safety Engineering – many of the fire regulations had to be “relaxed” to allow the WTC Towers to be built

Why were these things allowed to happen?

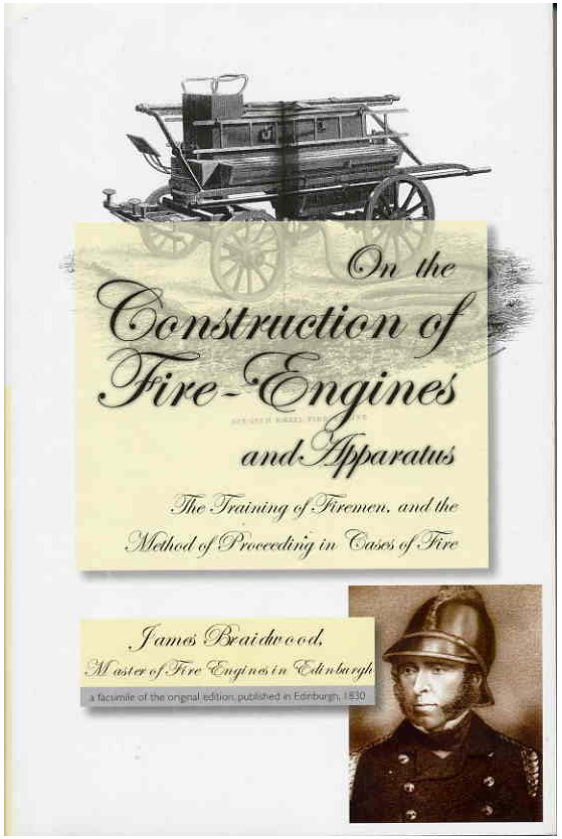
The underpinning “science” was absent until relatively recently

The underpinning “science” (Fire Dynamics) is only now becoming properly established

Qualitative understanding has been around for a long time …..

Firefighters developed their own qualitative understanding through observation

James Braidwood (1st Firemaster of Edinburgh) published a book in 1830 in which he describes compartment fire development from the point of view of the firefighter



The beginnings of the science

Establishment of government-funded Fire Research Labs in several countries after the second world war

UK – Fire Research Station (Borehamwood)

Japan – Fire Research Institute (Tokyo)

USA – Center for Fire Research at NBS (now NIST)

Finland – at VTT (Espoo)

The beginnings of the science

At the same time, key individuals took to the stage:

Philip Thomas, Margaret Law, David Rasbash (FRS)

Yokoi and Kawagoe (FRI/BRI, Japan)

Jim Quintiere, Howard Baum, etc. at NBS/NIST

Howard Emmons at Harvard University, USA

Ove Pettersson at Lund University, Sweden

Brady Williamson at UC Berkley

and many others

The beginnings of the science

Howard Emmons (Harvard University).

Ove Pettersson (Lund University).

The beginnings of the science

Philip Thomas (Fire Research Station)

Bud Nelson (NIST)

The beginnings of the science

Kunio Kawagoe (Science University of Tokyo/Fire Research Institute).

$$R = 5.5 A_w \sqrt{H}$$

David Rasbash (Fire Research Station and Edinburgh University).

Responsible for the development of FSE Curriculum.

The beginnings of the science

Margaret Law (Fire Research Station and Ove Arup and Partners).

Ed Zukoski (California Institute of Technology).

The beginnings of the science

John Bryan (University of Maryland).

Brady Williamson (University of California, Berkley).

The beginnings of the science

John Rockett (NBS/NIST)

Ray Friedman (Factory Mutual Research Corporation)

The beginnings of the science

Where was this work published?

Mainly in Government Research Reports

- **Fire Research Notes**
- **NBS/NIST Reports**
- **FMRC Reports**

Occasionally in the open literature

- **Combustion and Flame**
- **Combustion Science and Technology**
- **Symposia of the Combustion Institute**

Note – the first Fire Symposium was held in Edinburgh in 1975

The beginnings of the science

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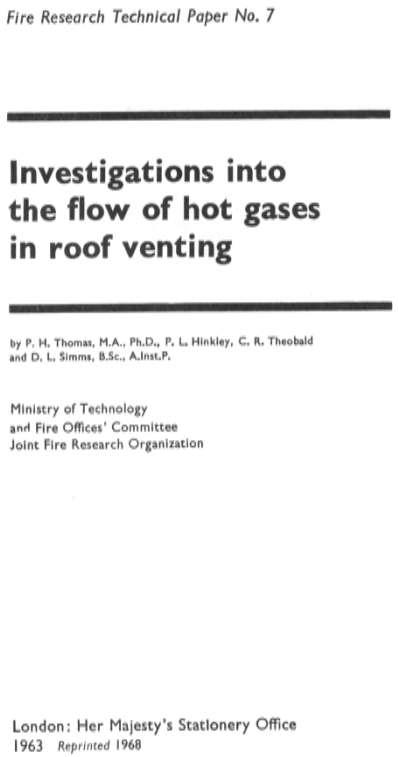


Fire Research Technical Paper No. 7

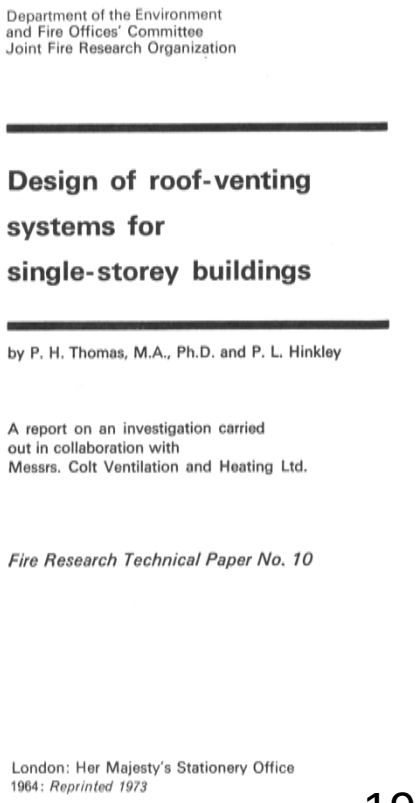
Investigations into the flow of hot gases in roof venting

by P. H. Thomas, M.A., Ph.D., P. L. Hinkley, C. R. Theobald and D. L. Simms, B.Sc., A.Inst.P.

Ministry of Technology
and Fire Offices' Committee
Joint Fire Research Organization

London: Her Majesty's Stationery Office
1963 *Reprinted* 1968

1963



Department of the Environment
and Fire Offices' Committee
Joint Fire Research Organization

Design of roof-venting systems for single-storey buildings

by P. H. Thomas, M.A., Ph.D. and P. L. Hinkley

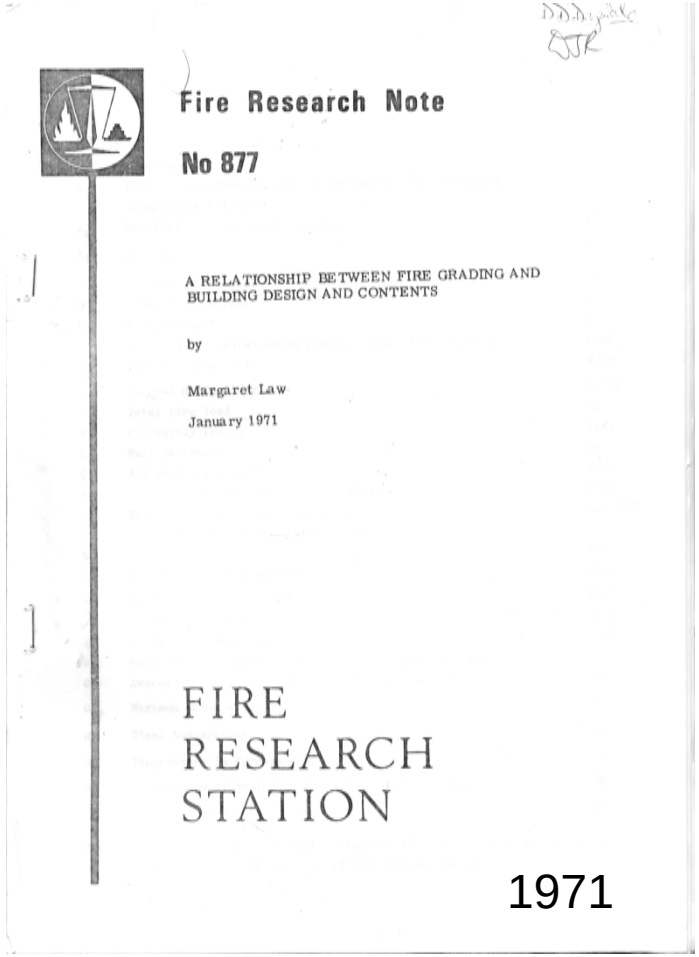
A report on an investigation carried out in collaboration with Messrs. Colt Ventilation and Heating Ltd.

Fire Research Technical Paper No. 10

London: Her Majesty's Stationery Office
1964: *Reprinted 1973*

1964

The beginnings of the science



Fire Research Note

No 877

A RELATIONSHIP BETWEEN FIRE GRADING AND BUILDING DESIGN AND CONTENTS

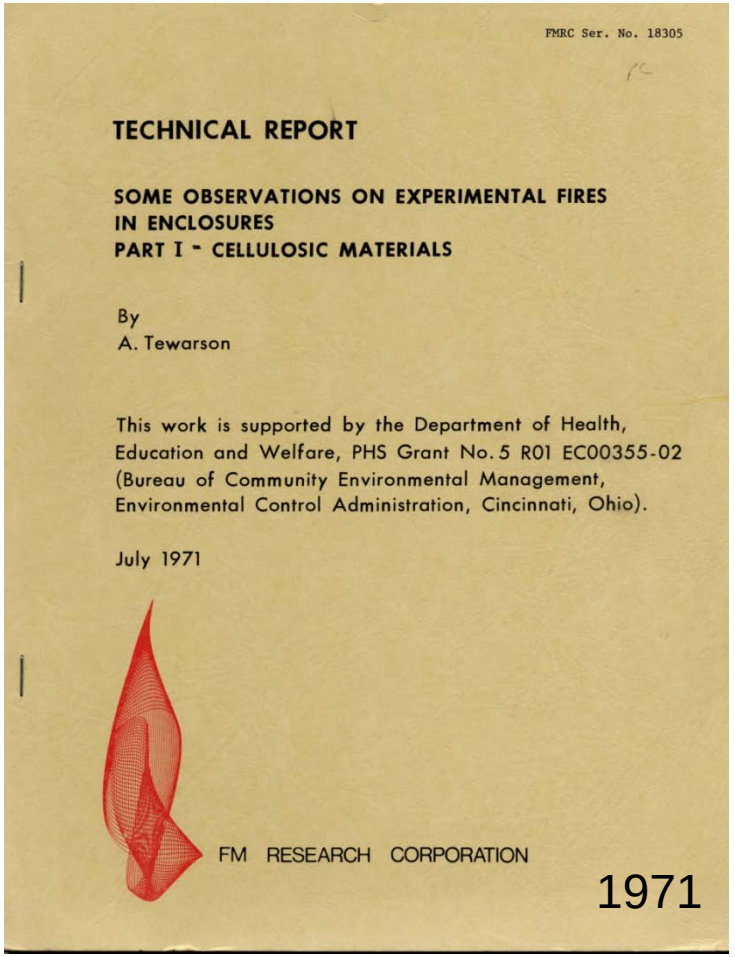
by

Margaret Law

January 1971

FIRE RESEARCH STATION

1971



FMRC Ser. No. 18305

TECHNICAL REPORT

SOME OBSERVATIONS ON EXPERIMENTAL FIRES IN ENCLOSURES
PART I - CELLULOSIC MATERIALS

By
A. Tewarson

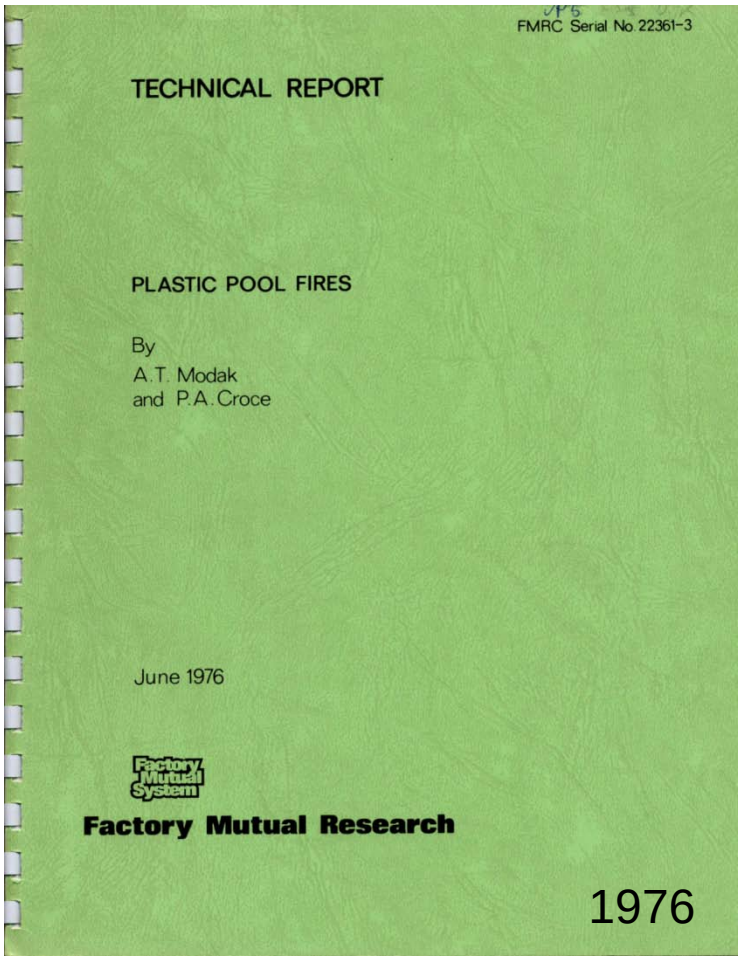
This work is supported by the Department of Health, Education and Welfare, PHS Grant No. 5 R01 EC00355-02 (Bureau of Community Environmental Management, Environmental Control Administration, Cincinnati, Ohio).

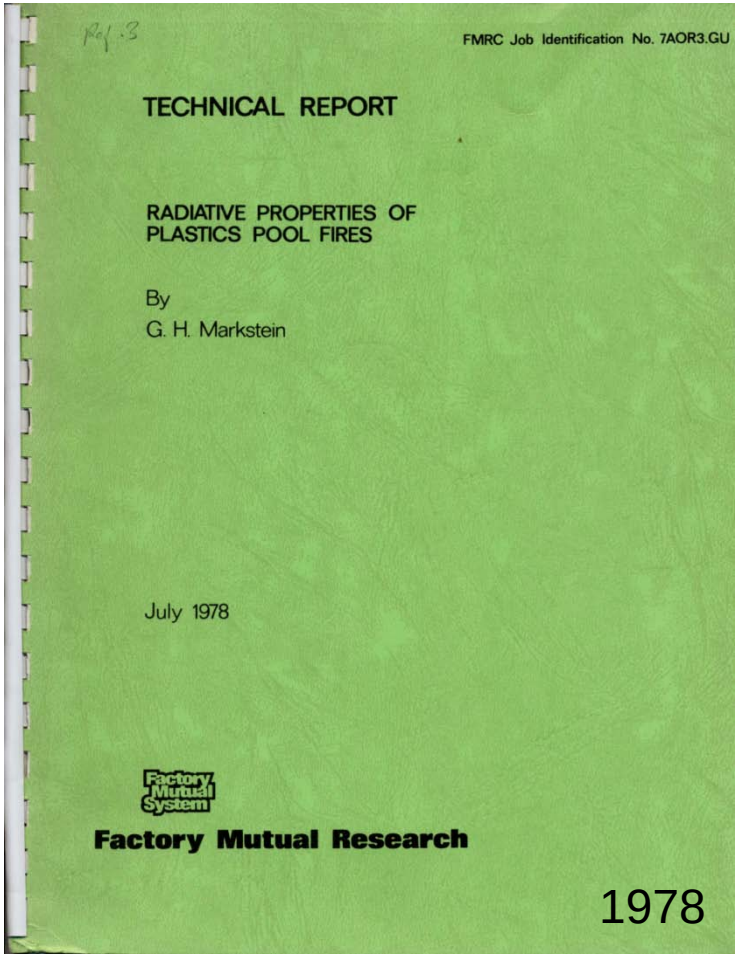
July 1971

FM RESEARCH CORPORATION

1971

The beginnings of the science





The beginnings of the science

Combustion and Flame **26** 85-103 (1976)

85

Flammability of Plastics—I. Burning Intensity

A. TEWARSON and R. F. PION
Factory Mutual Research Corporation, 1151 Boston-Providence Turnpike, Norwood, Massachusetts 02062

This paper presents the progress of an experimental study to develop a laboratory-scale test to define the burning intensity of various commercial samples of plastics. In the study, a steady state heat balance at the burning surface has been used to derive the burning intensities. An 'ideal' burning rate has been defined, which appears to correlate with full-scale fire test data. Conditions for the burning intensities in full-scale fires are postulated. Data for heat of gasification/pyrolysis/depolymerization, heat flux transferred from the flame to the surface, heat flux lost by the surface, and minimum mole fraction of oxygen required for flame extinction are presented for 16 commercial samples of plastics, a wood, and a plywood sample and six organic liquid samples.

Introduction

At the present time, flammability of plastics is one of the most pressing and difficult national and international problems. Due to lack of theoretical analyses and data on critical properties, flammability of plastics cannot be defined adequately for full-scale fires.

The flammability of plastics consists of five major components: ignition, fire growth, burning intensity, generation of smoke and toxic compounds and extinction/suppression. In this paper, however, we have made an attempt to define only the burning intensities of plastics in terms of their mass burning rates. Using a steady-state heat balance at the surface of a burning plastic, the mass burning rate can be expressed as follows

$$\dot{m}'' = (\dot{Q}''_T + \dot{Q}''_E - \dot{Q}''_L)/L_G, \quad (1)$$

where

$\dot{m}''$ = mass burning rate (gm/cm² sec)
$\dot{Q}''_T$ = heat flux transferred from the flame to the surface (cal/cm² sec) under experimental condition
$\dot{Q}''_E$ = additional heat flux received by the surface (cal/cm² sec) such as externally applied, flame radiative (if flames are much larger than the experimental flames) or, from hot walls and ceiling, nearby burning surfaces, etc.
$\dot{Q}''_L$ = heat flux lost by the surface (cal/cm² sec), under experimental condition
L_G = heat of gasification/pyrolysis/depolymerization (cal/gm)

If $\dot{m}'' \cdot L_G$ is plotted against $\dot{Q}''_T$ with $\dot{Q}''_L$ assumed constant, from Eq. (1), we should obtain a straight line with $\dot{Q}''_E - \dot{Q}''_L$ as the intercept. However, for plastics it is difficult to measure $\dot{Q}''_T$ directly. We have, therefore, used an indirect method.

For a limited range of mole fraction of oxygen, n_{O_2}, experimentally we find that $\dot{m}'' \cdot L_G$ is a linear function of n_{O_2} for all the combustibles examined in this study, as shown in Fig. 1. If we assume that $\dot{Q}''_E = \dot{Q}''_L$ values are the intercepts of the lines, then from the slope of the lines, ξ, which is constant,

$$\dot{Q}''_T = \xi \cdot n_{O_2}, \quad (2)$$

and Eq. (1) can be expressed as,

$$\dot{m}'' = (\xi/L_G) \cdot n_{O_2} + \dot{Q}''_E/L_G - \dot{Q}''_L/L_G. \quad (3)$$

If we define an 'ideal' condition where $\dot{Q}''_E = \dot{Q}''_L$, then

NISTIR 4449

ELEVENTH JOINT PANEL MEETING OF THE UJNR PANEL ON FIRE RESEARCH AND SAFETY

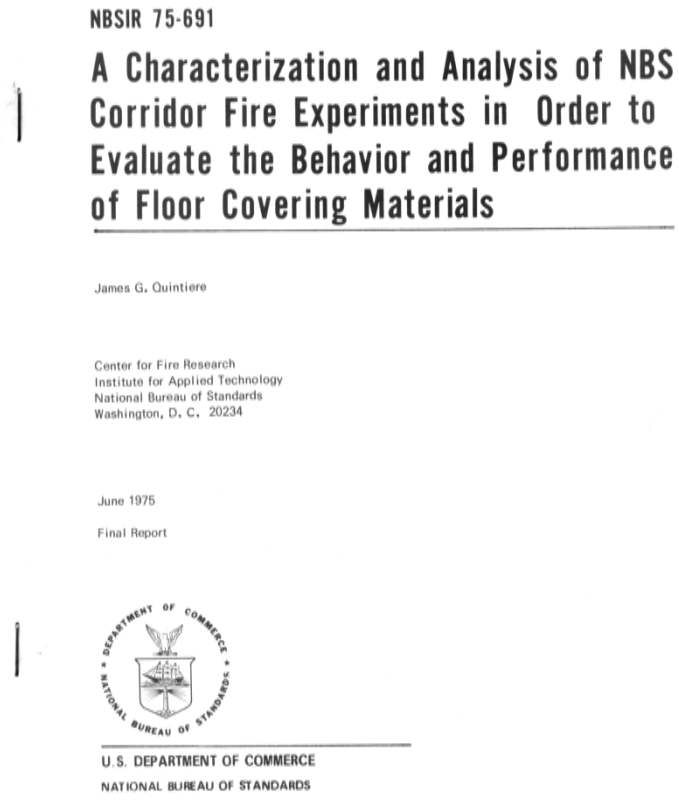
Nora H. Jason
Deborah M. Cramer
Editors

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
National Engineering Laboratory
Center for Fire Research
Gaithersburg, MD 20899

U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
John W. Lyons, Director

NIST

The beginnings of the science



NBSIR 75-691

A Characterization and Analysis of NBS Corridor Fire Experiments in Order to Evaluate the Behavior and Performance of Floor Covering Materials

James G. Quintiere

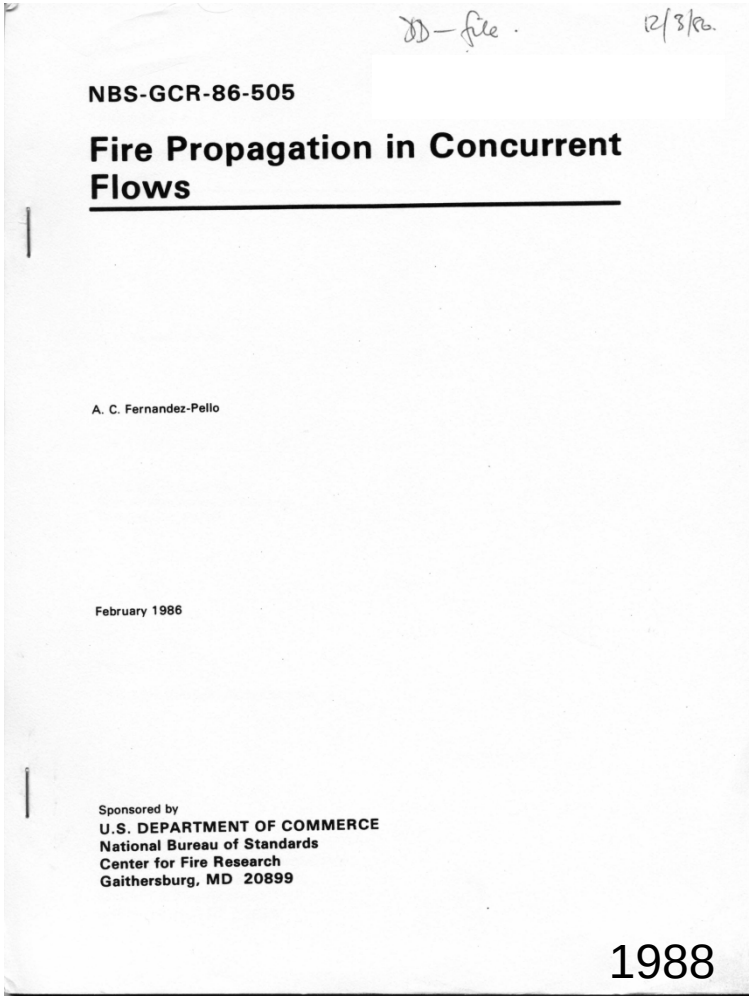
Center for Fire Research
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

June 1975

Final Report

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

1975



NBS-GCR-86-505

Fire Propagation in Concurrent Flows

A. C. Fernandez-Pello

February 1986

Sponsored by
U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Center for Fire Research
Gaithersburg, MD 20899

1988

The beginnings of the science

1970 – Frank Rushbrook, Firemaster of Edinburgh, persuaded Edinburgh University to create a Department of Fire Engineering

Background:

WHY? **Rushbrook appreciated that changes were coming and that there would be the need for graduates in the fire service to work alongside Architects and Civil, Structural and Mechanical Engineers**

ALSO – **recognised that there was a body of research which had to be disseminated and put into practise**

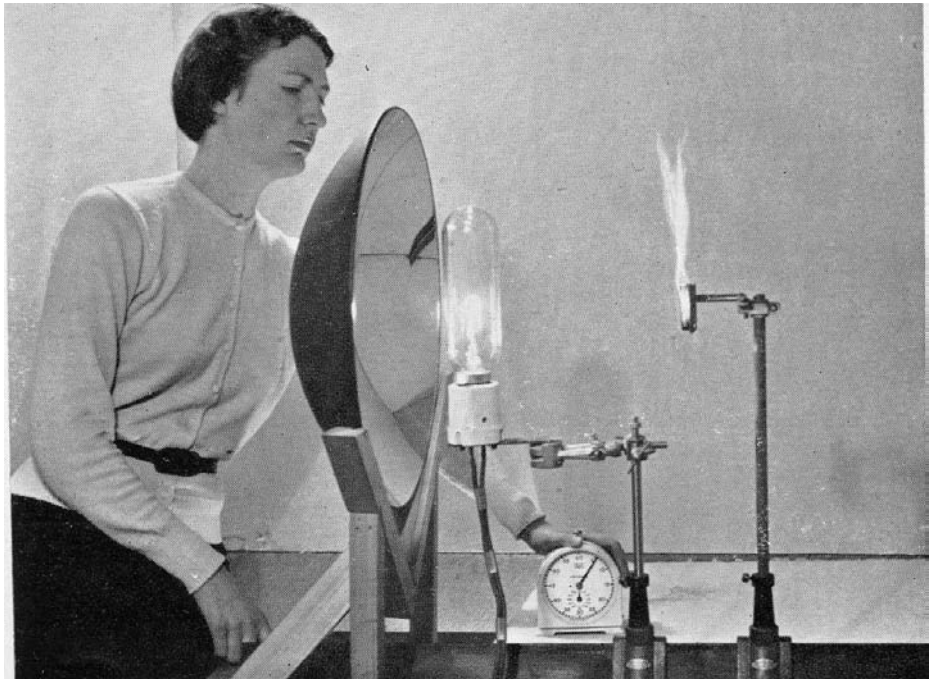
The beginnings of the Engineering

Development of industry, commerce and society demanded larger, more complex buildings that could not comply with the existing Building Regulations

"Relaxations" were sought, and permitted on the basis of "experience-based judgement" by Building Control Officers and Fire Prevention Officers

No quantitative methods were available

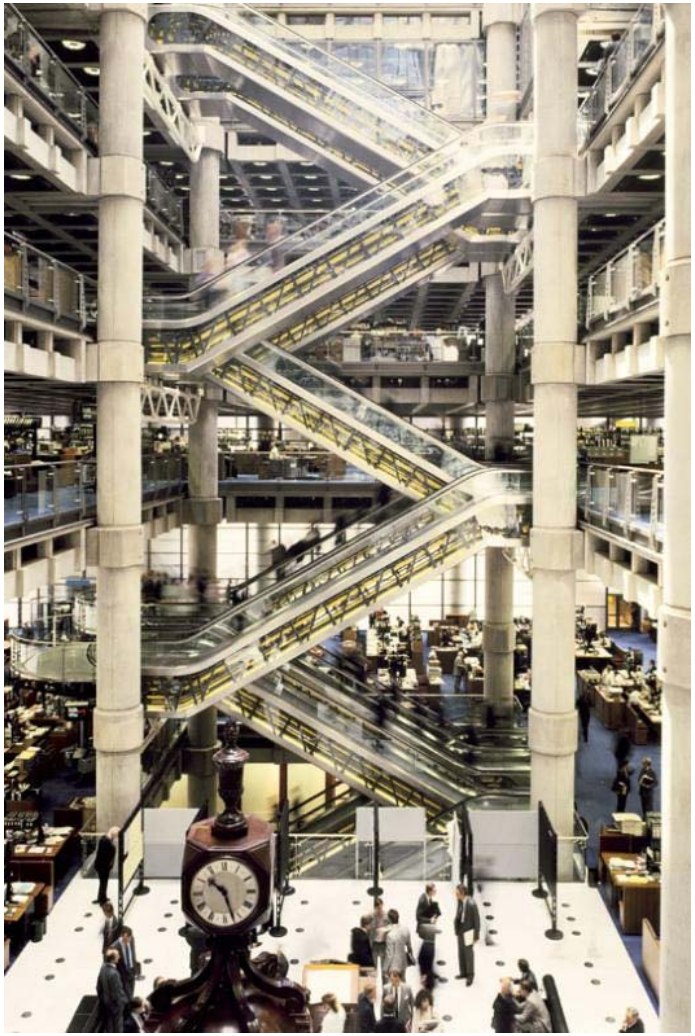
In 1973 – Margaret Law (Fire Research Station) joined Ove Arup and Partners to establish a Fire Safety Engineering Group within the company



(Research into ignition, compartment fire dynamics, thermal response of structural elements, external flaming, *etc.*)

Application of the science to engineering practice:

Application of the science to engineering practice:



Lloyd's Building, London

Application of the science to engineering practice:

HSBC Headquarters Building in Hong Kong.

Application of the science to engineering practice:

Hong Kong International Airport

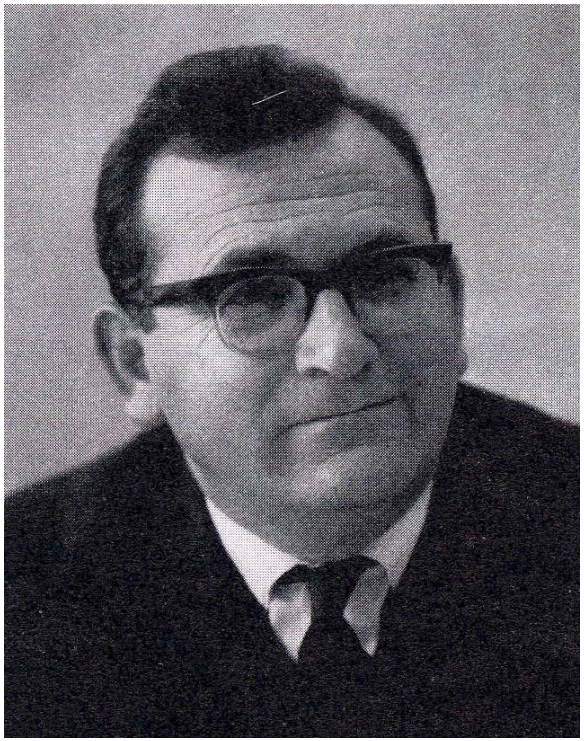
Application of the science to engineering practice:

Margaret Law and others with a background in fire research (Paula Beever, Bill Malhotra, Peter Jackman, Howard Morgan, *et al.*) formed the first cohort of Fire Safety Engineers

Where were their successors to come from?

In 1973 – a "Department of Fire Engineering" was established at Edinburgh University

David Rasbash appointed as the first Professor



(Previously Division Head at the Fire Research Station, Borehamwood)

In 1973 – a "Department of Fire Engineering" was established at Edinburgh University

Staff:

- David Rasbash (Chemical Engineer, originally)
- Eric Marchant (Architect and Civil Engineer)
- Dougal Drysdale (Physical Chemist, allegedly)
- David Colburn (Technical support)
- Jean Mills (Secretary)
- Ron Hirst (Process Engineer) (from 1978)

The way forward:

October 1974 – First Postgraduate Degree Programme (MSc) in Fire Engineering started

BIG PROBLEMS!

In 1974 the subject did not exist as an academic discipline

and

There were no textbooks!

David Rasbash outlined the courses that we had to teach and told us to get on with it!

BIG PANIC!

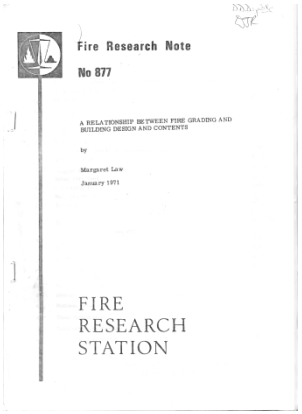
The key courses had to be created using information contained mainly in Research Reports


Fire Research Technical Paper No. 7

Investigations into the flow of hot gases in roof venting

Ministry of Technology and Fire Offices' Committee Joint Fire Research Organization

London: Her Majesty's Stationery Office 1963 Reprinted 1968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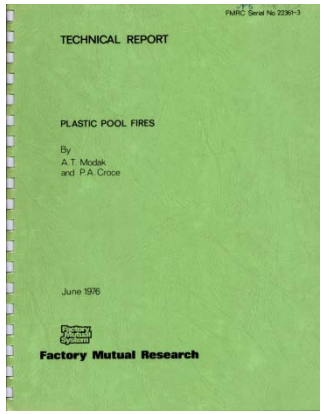

FMRC Serial No. 22361-3

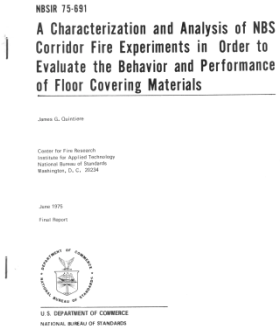
TECHNICAL REPORT

PLASTIC POOL FIRES

By
A.T. Modak
and P.A. Croce

June 1976

Factory Mutual Research


NBSIR 75-691

A Characterization and Analysis of NBS Corridor Fire Experiments in Order to Evaluate the Behavior and Performance of Floor Covering Materials

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

The following fire "courses" were taught:

Fire chemistry (DDD)
Fire behaviour of combustible materials (DDD)
Explosions and special hazards (DDD)
Fire statistics (DJR)
Fire legislation and regulation (DJR + EWM)
Fire risk assessment (DJR + EWM)
Firefighting and firemanship (DJR)
Fire safety and building design (EWM)
Fire protection systems (DRJ)
Laboratory work (8 experiments) (DDD)

\+ Heat and mass transfer
Fluid dynamics
Structures (an introductory course)

Service teaching by colleagues in other Departments

and more … (breathing apparatus, search and rescue (part of Merchant Navy Fire Course), field visits, visits to fire scenes, etc.)

The following fire “courses” were taught:

oustible materials (DDD)

l hazards (DDD)

tus, search and rescue (part of Merchant

visits to fire scenes, etc.)

A summary of the achievements

The MSc Course started in 1974 and ran until 1983 (when we ran out of staff and money)

During that period there were:-

53 MSc Graduates and 15 Diploma Graduates, of 17 nationalities

In addition -

Approximately 18 papers published (most based on MSc projects)

Three PhD projects successfully completed

Meanwhile in Worcester, Mass ….

In the 1970s, Bob Fitzgerald and Rex Wilson (FirePro Inc) were instrumental in persuading Worcester Polytechnic Institute to establish a Masters Programme in Fire Protection Engineering

Dave Lucht appointed as (initially, part-time) Director of CFS in 1978 and set about fund-raising

Immediately identified the lack of textbooks as a fundamental problem – particularly one on the "science of fire", i.e. FIRE DYNAMICS

Lucht raised $100,000 from CIGNA (CG/Aetna) to kick-start the process of creating a series of texts

Meanwhile in Worcester, Mass ….

Bob Fitzgerald approached several people (including Philip Thomas and David Rasbash) to help out – teach a course on Fire Dynamics and write a textbook

They both said “no”!

I paid a preliminary visit to WPI in August 1981 - then

Taught “Fire Dynamics” at WPI during the spring semester 1982 (late January – May)


FIRESEAT 10th November 2010
THE UNIVERSITY OF EDINBURGH
BRE Centre for Fire Safety Engineering

The Fire Dynamics course was built on three of the "Edinburgh" modules -

Fire chemistry
Fire behaviour of combustible materials
Explosions and special hazards

\+ Heat and mass transfer
Fluid dynamics

One (3 hour) lecture a week (Thursday evening)

Each set of lecture notes formed the first draft of a chapter (thanks to Carolyn Pike)

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Each lecture was followed by tutorial discussion in the Goats Head Pub

Tutorial in Progress


Tutorial in Progress

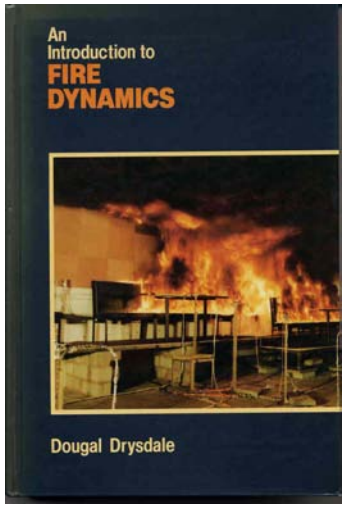

Tutorial in Progress

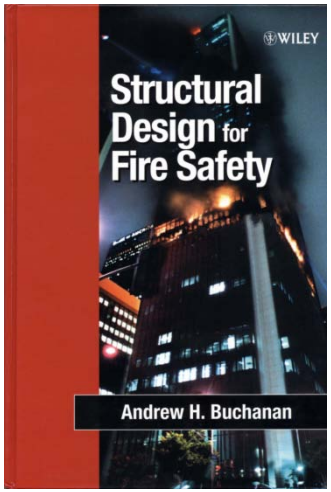
Final m/s passed to the publisher (John Wiley and Son) in May 1984

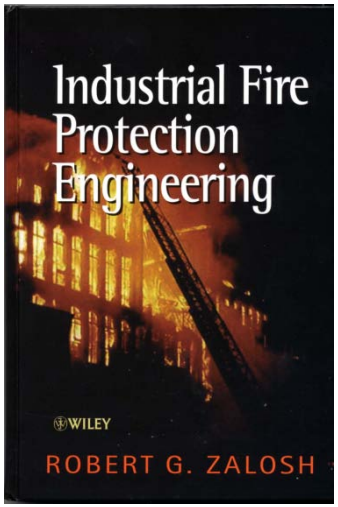
"Introduction to Fire Dynamics" published in June 1985

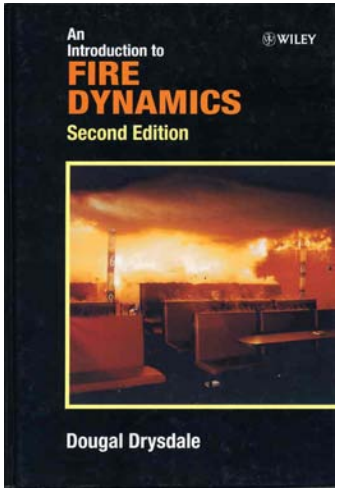
In 1985, began discussions with Wiley about the follow-up - a series of Textbooks for students of Fire Safety/Protection Engineering

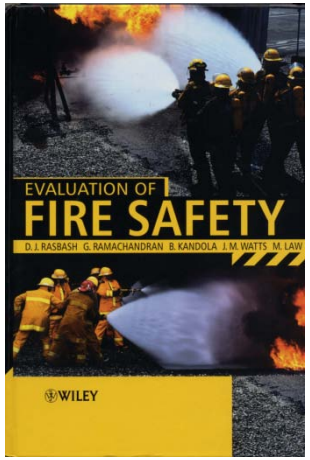
There are now six “Wiley” textbooks!

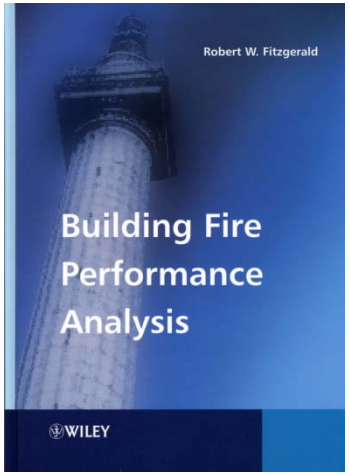


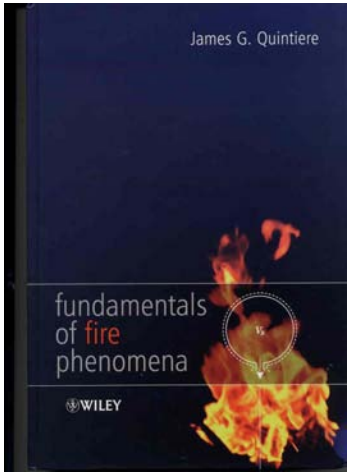












In addition:

The SFPE Handbook of Fire Protection Engineering (4th Edition published in 2008)

"Enclosure Fire Dynamics" (Karlsson & Quintiere)

"Combustion Fundamentals of Fire" (ed. Cox)

Journals: Fire Safety Journal
Fire and Materials
Fire Technology
Journal of Fire Protection Engineering

The International Association of Fire Safety Science

Regular conferences (IAFSS, Interflam, Fire and Materials, etc.)

Fire Safety Engineering is now well established at:

University of Edinburgh

David Rasbash

Jose Torero

Asif Usmani

Steve Welch

Martin Gillie

DDD

Guillermo Rein

Luke Bisby

Ricky Carvel

Fire Safety Engineering is now well established at:

University of Ulster (UK)

Jim Shields

Karen Boyce

Ali Nadjai

Faris Ali

Mike Delichatsios

and Gordon Silcock

Fire Safety Engineering is now well established at:

WPI (USA)


Bob Fitzgerald


Dave Lucht


Jonathan Barnett


Kathy Notarianni


Nick Dembsey


Brian Meacham


Ali Rangwala

<u>Not forgetting</u>: Bob Zalosh, John Woycheese, Milosh Puchovsky, Frank Noonan, Brian Savilonis, Jeff Tubbs, *et al.*

Fire Safety Engineering is now well established at:

University of Maryland (USA)


John Bryan


Jim Quintiere


Jim Milke


Fred Mowrer


Vince Brannigan

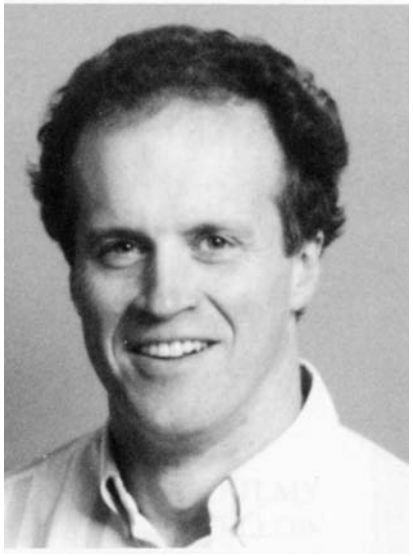

Arnaud Trouvé


André Marshall

Fire Safety Engineering is now well established at:

University of Canterbury (New Zealand)

Andy Buchanan



Charley Fleischman

Mike Spearpoint

Fire Safety Engineering is now well established at other Universities in the UK:

University of Central Lancashire

Glasgow Caledonian University

University of Leeds (?)

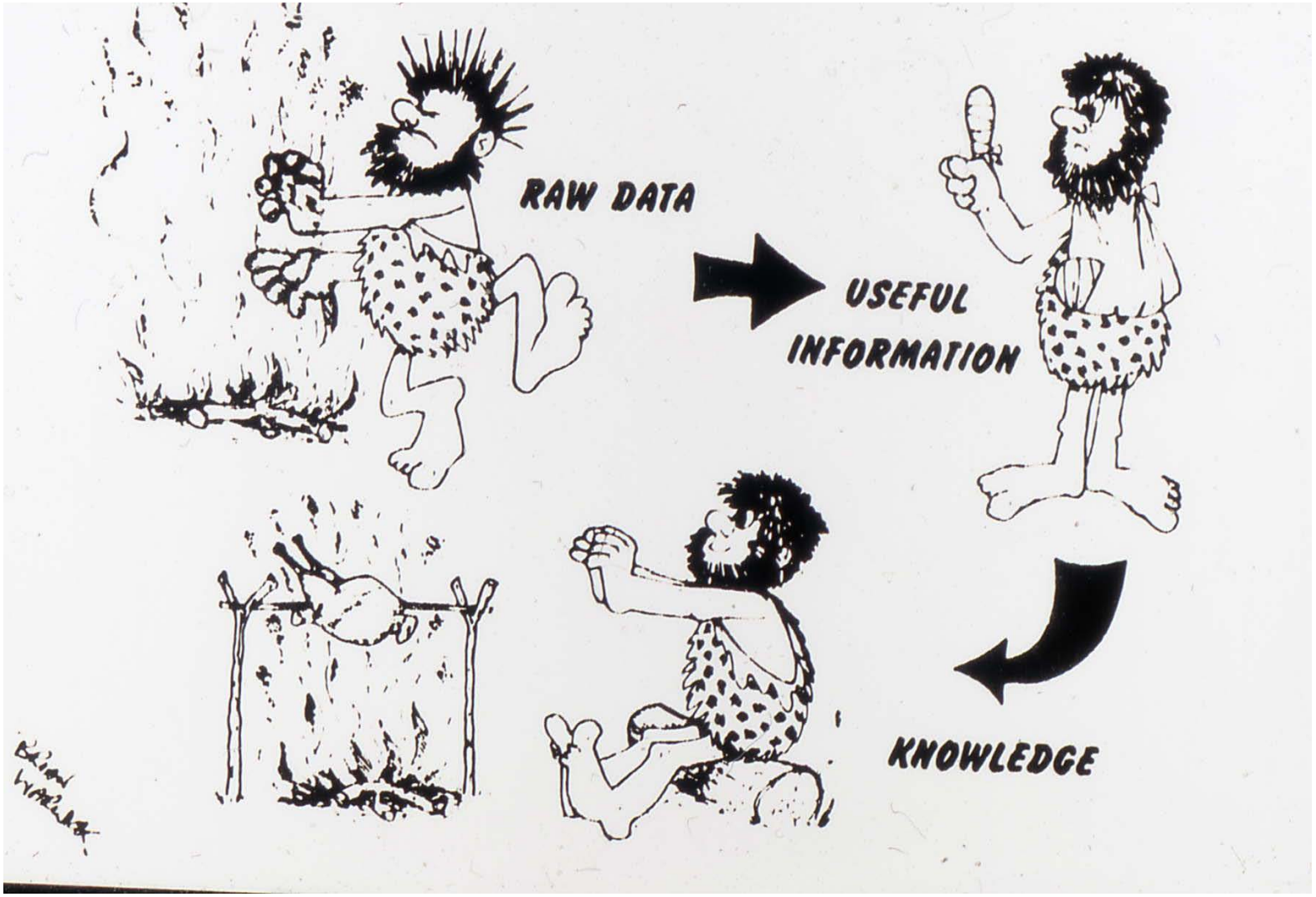
(South Bank University – until 1998)

- it all started with Frank Rushbrook and Margaret Law

Fire Safety Engineering is now well established worldwide!

Frank Rushbrook

David Rasbash


RAW DATA
USEFUL
INFORMATION
KNOWLEDGE


It’s an uphill task

Luke Bisby and Tim Stratford have been here!

Thank you for your attention

Any questions?