Fire Engineering Research and Education at LTH

My interest in fire engineering design aroused during the period between 1959 and 1964, when I was Professor of Building Technology and Structural Design at the KTH (Royal University of Technology). During this period, the foundations of that fire engineering research were laid, which was later transferred to the LTH (Institute of Technology) at Lund University, where it was further developed. The development then continued at the Department of Structural Mechanics up to 1981, and thereafter in a newly-established division (from 1985 Department of Fire Safety Engineering). As a result of the extensive and rapid expansion in fire research, my previous professorship in Structural Mechanics was converted to a professorship of Building Fire Safety and Technology in 1981.

With a broad scientific base in the extended research, LTH initiated Europe's first technical university level education of fire protection engineers in the autumn term of 1986. Counterparts outside Europe were very few at that time.

Research during the period up to about 1975

About 1960, fire engineering design was to a large extent characterised by stereotypical solutions, based on results from standardised tests that very often bore little relation to actual fire conditions. Function-based design methods hardly did exist. Long-term research programmes, systematically planned and implemented projects, and analytical solutions were very rarely encountered in fire engineering research and development.

This initial situation was a natural challenge for me to initiate the build-up of a structural fire engineering research by working out a general research programme for the definition and long-term development of an analytical method for a fire-engineering approach to building design, based on real fire exposure and well specified function requirements and evaluation criteria. The programme received the support of the Liaison Group of Inter-Scandinavian Building Research Conferences, and had a double aim: first, to facilitate systematic and integrated choice of research projects, and thus to be able to create a new design method practically applicable in a reasonable time, and second to initiate and stimulate collaborative Scandinavian fire research projects. Unfortunately, it was not possible to obtain a response to the latter objective at that time. However, over the years the programme became a significant instrument for a choice of integrated and mutually

stimulated research projects for the fire-research group which was formed at LTH from about the mid-sixties.

The work of the group was successful and, in the period up to about 1975, resulted in a large number of publications with great international originality, including six doctoral dissertations. Altogether, these research efforts extended the whole design process by:

* statistical research into fire load (type and amount of combustible material) in various types of locations
* experimental studies and development of analytical models and computer programs for the description of fully-developed compartment fires
* development of analytical models and computer programs for the determination of transient temperature fields in structures exposed to fire, and
* experimental studies and development of analytical models and computer programs for the determination of structural materials and structures thermo-mechanical behaviour in simulated real fires – with application to structures in steel, reinforced concrete, and wood.

Studies of the components of the design method were complemented by risk analyses with regard to component uncertainties, safety index, partial coefficients, and failure probability.

The design method is radically different from methods which continue to dominate internationally and which are based on classification and results from standardised tests. Compared with these simpler methods, the one developed at LTH has a more logical structure and provides a more uniform degree of safety and better economy. The great practical significance of the method has also been emphasised by public authorities, industry, and consultants (see quotations in Annex 1).

The research contribution and their practical results in the form of manuals and design rules provided the conditions for Sweden to become that first country to approve a function-based, structural fire-engineering design method for general application. This happened as early as 1967, and, to stimulate increased practical application of the design procedure, in 1976 the National Swedish Board of Physical Planning and Building issued, with our assistance, a special complementary volume to Swedish Building Code (SBN):

Fire-Engineering Design: Notes to SBN 1976:1. Sweden's internationally leading role in the area of regulations and codes for fire protection in buildings has since continued to be consolidated and verified right up to the present through, for example, the function-adapted regulations and general recommendations given in the National Board of Housing, Building, and Planning Regulations BBR 94 for the total fire protection of buildings (see Annex 1, citations 4 and 5).

Research during the period from around 1975 to around 1990

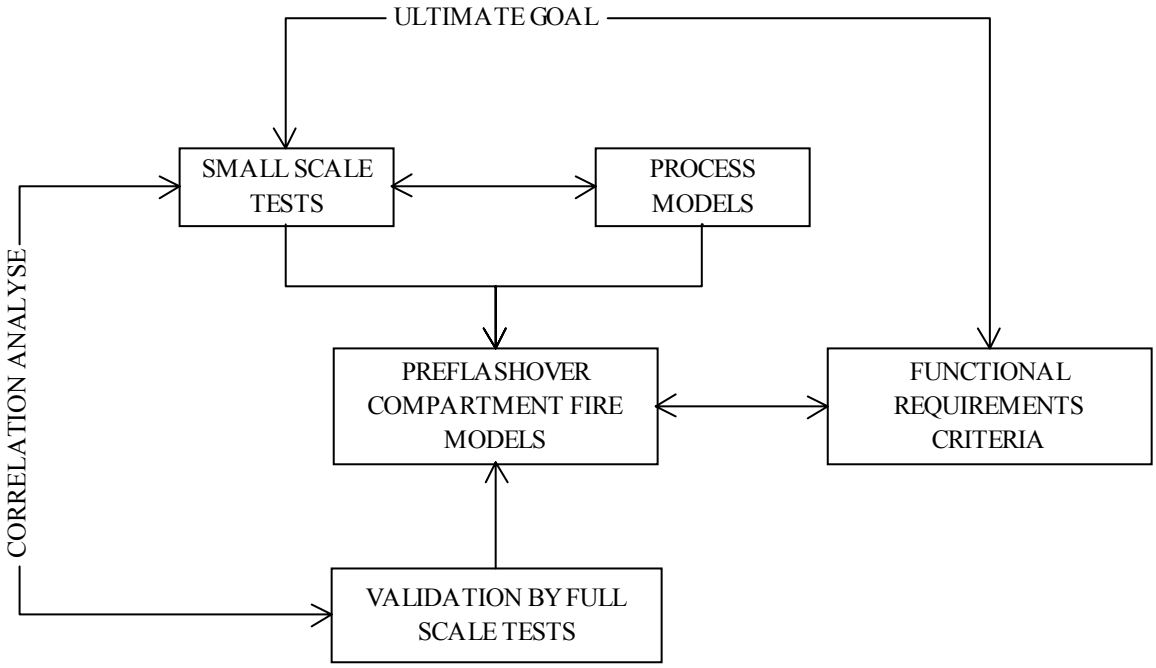
This period involved, on the one hand, further development and consolidation of the previous period's research on the behaviour and design of building structures at fire exposure, and, on the other, extension of the research area to include other aspects of total fire protection for buildings. On July 1, 1988, I retired from my professorship in Building Fire Safety and Technology, and was succeeded by Dr Sven Erik Magnusson.

The first major extension concerned a development of a fundamental new method for designing high-density, small house building areas with respect to the risk of fire spread from one house to another. The method incorporated partial models and computer programs for describing a fully-developed fire in an individual house, including external flames through window and door openings, radiation to neighbouring houses, and conditions for ignition and fire propagation to these houses. The method has been verified in full-scale tests. It is functionally adapted, based on simulation of real fires, is generally applicable, and is type approved by the National Swedish Board of Physical Planning and Building. For concrete or aerated concrete housing, diagrams and tables have been compiled to facilitate its practical application.

The largest research project during the period dealt with fire hazards and the compartment fire growth process. This stage of a fire, which extends from ignition to a fully-developed fire in, eg, a domestic or office flat, is critical for safety of people during evacuation. The effects and behaviour of building and fitting materials are crucial in this respect.

The project was carried out as a collaboration between the fire engineering laboratory and the chemical analysis laboratory at the National Testing and Research Institute (SP) and the Department of Fire Safety Engineering at LTH, with myself as project leader. It covered all basic components relevant to a description of the early stages of fire

development – ignition characteristics of exposed materials and time variation of energy released by combustion, flame propagation rate, gas temperature, gas flow rate, generation and opacity of smoke, as well as composition of products of combustion, especially toxic and corrosive gases. The aim of the project was to develop simplified full-scale or reduced-scale test methods for surface materials and furnishing products, the result of which can predict the effects and behaviour of the materials or products tested in a real room or apartment fire. A central, parallel, task was the evaluation and connection to a real fire growth process of small-scale fire-reaction tests for materials, which was then under development internationally.



For a qualified practical application of these new small-scale tests, it was necessary that support functional requirements were formulated, and that appropriate control and evaluation criteria were derived – see structure diagram above for details of the project. This in turn required the development of mathematical models, firstly to describe the test procedures, and secondly to describe the origin and development of a fire through to flashover under well-defined conditions. Verification via full-scale testing also formed part of the project.

The project, which began in 1980 and continued for almost ten years, incorporated eleven fully-integrated sub-projects. It generated around 100 reports and articles, and made a significant contribution to mathematical modelling, development of analytical methods, as

well as full-scale and reduced-scale test methods for combustible wall and roof coverings and furnishings.

Examples of other large research projects during the period with my participation are two experimental full-scale investigations carried out in a three-storey test-building. One test studied the contribution, behaviour, and hazards of external additional insulation of external walls for fires in a single fire-cell (apartment) in a multi-storey building. In the other investigation, corresponding studies of windows with frames and casements in plastic or aluminium alloy were carried out. These tests contributed to increased knowledge of thermal exposure to facades of multi-storey buildings for fires in apartments with modern fitting materials. In connection with the project, test criteria linked to function-based requirements differing with respect to the purpose and layout of the building, and to conditions for firefighting, were developed. Results from the tests were correlated with a test method previously used at laboratory scale by SP, which led to its further development. The overall practical findings from these investigations are that the constructional layout and combination of materials for an additional insulation system are more important from the fire viewpoint than the fire properties of the material used, and that windows with frames and casements of PVC, PUR, or aluminium alloy in the forms tested did not give a fire hazard greater than that of standard windows with frames and casements in wood.

The research projects described illustrate the marked extension and broadening which took place during the period from around 1975 until about 1990 at the Department of Fire Safety Engineering at LTH. During this period, also, research was initiated into flame spread, smoke development and spread, fire development in compartments of large areas, and detection environment and detector response. This research has since continued and been further developed, and more new research areas have been incorporated during the 1990s – see Annex 5. Responsibility for the overall research management has been with Professors Göran Holmstedt and Sven-Erik Magnusson, whereas my involvement in the Department's research during the 90s has been comparatively marginal.

On 1 July 1985, a Combustion Centre (FTC) was established at LTH, with the tasks of:

* carrying out and promoting research and development in fundamental combustion science
* co-ordinating these activities within LTH into a coherent programme
* promoting higher education in the area of combustion science
* promoting international and national experience exchange, and
* acting as a collaborative partner to external clients.

The object of the Centre is to work towards more effective and environmentally-friendly energy conversion in combustion. The FTC is governed by a Board including representatives from the universities and central industrial companies involved. A manager deals with the day-to-day administration of the Centre's activities.

The activities were successful from the very beginning, and have since developed impressively, both quantitatively and qualitatively. This success has been due in part to the co-ordinated efforts of collaborating departments and divisions, and also – to a very great extent – to its directors: Professor Thure Högberg between 1985 and 1989, and Professor Marcus Aldén, combustion physics, thereafter. My role in activities has been mainly as Board Chairman from 1985 to 1992. An information sheet on activities during my period of Chairmanship is attached as Annex 2.

Important stages in the Centre's development were the establishment of a Centre of Competence in Combustion Processes in 1994, financed by NUTEK, and a Centre of Excellence in Combustion Science and Technology, CECOST, in 1996, financed by the Foundation for Strategic Research, in which CTH and KTH are also involved.

The Department of Fire Safety Engineering has actively participated in FTC's activities from its beginnings in 1985, and this has been of great significance for fire research and researcher education at LTH through access to new areas of competence.

Participation in international organisations, committees, and working groups

The participation of the Department of Fire Safety Engineering in international organisations, committees and working groups has been vigorous for a long period of time.

My own participation began as long ago as 1963 and has continued up to the present, although to a much reduced extent.

My efforts have consisted of contributions to:

* development of fire testing methods and systems of classification (ISO, CEN)
* development of methods for fire engineering classification via calculation (ISO)
* manuals and guidance documents for fire engineering design of steel structures (European Convention of Constructional Steelwork, ECCS), and reinforced concrete structures (Fédération Internationale de la Précontraite, FIP, Comité Euro-International du Béton, CEB, Fédération Internationale de Béton, fib)
* state of arts reports as support for assessment of further model development (ISO, fib)
* development of model codes and calculation guides for probability-based fire-engineering design of load bearing structures (Conseil International du Bâtiment, CIB W 14), and
* manuals for fire engineering terminology (ISO, Technical Advisory Group, TAG 5).

Structural engineering fire research at LTH has had a major influence in these activities, see Annex 3.

Over the last few decades, international fire research has grown rapidly, but in volume and in terms of its level of knowledge. It was mainly against this background that the International Association for Fire Safety Science, IAFSS, was founded in 1985, with the aim of stimulating development of the international fire research, focusing on science. An important sub-task for the Association is to arrange international scientific symposia, and so far such has been held every three years. I had the privilege of being one of the founders of this Association, and was Vice-Chairman during the period 1985-1994.

Fire engineering education

Education in fire engineering has taken place at LTH in the form of courses in the Civil Engineering programme from the beginning of the autumn term in 1964. At the end of the sixties, education of fire engineering researchers was introduced.

After an extensive investigation during the seventies and the beginning of the eighties, the Swedish Parliament in July 1985 accepted the government proposition 1984.85: 'Management of Public Protection and Rescue Services'. A decision was also included that university education of fire protection engineers comprising 100 points (2.5 years) should be instituted at LTH from academic year 1986/87 with 25 new entry places per year. For competence as an officer in the rescue service, the decision also included a requirement for a one-year practical supplementary course in addition to the fire protection engineer examination, for which responsibility lay with Räddningsverket (the Swedish National Rescue Services Agency).

The decisive reason for the education of fire protection engineers – the first of its kind in Europe – being located at LTH was that it could be based directly on the wide and advanced competence which had been amassed over a long period through the internationally recognised fire research carried out at the Department of Fire Safety Engineering. This competence also created excellent conditions for knowledge from the rapid and extensive development of international fire research to be able to be applied in an optimal manner for the planning and scientific basis of education.

In order to prepare for the new university education, an interim study programme committee was formed from 1 July 1985, followed a year later by a regular study programme committee with responsibility for the continued build-up and organisation of the education. The interim committee was already well aware that the reduction in education, which for cost reasons had been made vis-à-vis the government proposal, would create difficulties in reaching the objectives of the education required by public rescue services. The requirement for an extension of the education was therefore put forward in the study programme committee's first appropriation presentation, and a result of following this up led nine years later to an extension of the higher education unit from 100 to 140 points, starting from academic year 1994-95.

Over the years, the entry number has gradually increased to 35 per year. Starting from the autumn term of 2000, the intake increased to 60 per year in order to enable transfer to the new graduate engineer programme in risk assessment, which starts in the autumn term of 2001. In this connection, transfer can be made after five terms' work in fire protection engineer education.

Further information on the structure and content of fire education programme, and on the complementary one-year rescue service training, which is carried out at the Rescue College at Revinge, is provided in the attached information sheets, Annexes 4 and 5. These also include general descriptions of the area covered by fire engineering as well as some current (1999) research projects at the Department of Fire Safety Engineering. National and international research collaboration is also covered.

The education programme of fire protection engineers is one of the country's most sought-after university education programmes. In autumn 1999, the number of applicants per place was as high as 16. The examination frequency has been high throughout – over 90%.

Fire protection engineer education has been very successful from the outset. It has also attracted considerable international attention. The study programme committee has played an important role in this, and for me as committee chairman during the period 1985-93 it was stimulating to be involved in the planning, extension, and implementation of the education. Good co-operation of many internal and external colleagues was also very significant. Also, the very extensive and superb efforts of senior lecturer Robert Jönsson, who as Director of Studies and Head of Department was responsible above all for the built-up process, were a major contribution to the programme's success.

For its efforts in the build-up and implementation of the fire protection engineer education, the Department of Fire Safety Engineering at LTH has been awarded:

* The Forum Cerberus 'Golden Hound' safety prize 1989 'for creating a significant competence centre in fire technology through successful fire research over many years, and for the renewal of Swedish fire engineer education', and
* The 1994 FORUM PRIZE 'for its (Lund University's) pioneering work in Fire Safety Science Education', awarded 14-6 1994 at the Fourth International Symposium on Fire Safety Science at Ottawa, Canada.

Lund, 16-3 - 2000

Ove Pettersson

Translation made by Lingo Translations Ltd, London