Development and deployment of FiRECAM<TM>
Yung, D. T.; Bénichou, N.

nrcc 44290

Development and Deployment of FiRECAM™*

David Yung and Noureddine Benichou
Fire Risk Management Program
National Research Council of Canada
Ottawa, Canada K1A 0R6

A version of this paper was published in the Proceedings of the Symposium of China's 8th Equipment, Technology Conference and Exhibition, October 2000

Extended Abstract Résumé

Many countries in the world, including Canada, are moving towards the more flexible performance-based building regulations and away from the present restrictive prescription-based regulations. Performance-based regulations allow the designers and building officials the freedom to come up with innovative designs that will provide a level of safety that satisfies the objectives established by the regulations. Such innovative designs often lead to lower fire protection costs. The implementation of performance-based building regulations can be facilitated by the development of engineering tools that can help assess the overall fire safety performance of a building.

Fire Models to Support the Introduction of Performance-Based Codes

To support the introduction of performance-based codes, many research organizations around the world are developing computer models that can help designers predict how fire and smoke develop in a compartment and spread to other compartments in a building [1]. These models include both field and zone models. The field models divide a compartment into many cells and compute, using computational fluid dynamics (CFD), the thermal and flow conditions in each cell. These models provide detailed information in a compartment but are computationally intensive and require a lot of computer time even with the fastest computers. An example of the field models is the JASMINE model that was developed by the Fire Research Station in the U.K. [2].

Different from the field models, the zone models divide a fire compartment into a number of characteristic zones, such as the upper hot layer, the lower cold layer, the fire plume and the compartment boundary. The conditions in each zone are modelled separately and then linked together through fluid dynamics and heat transfer equations. This approach simplifies the intensity of computation and allows previously developed models, such as plume models or ceiling jet models, to be applied. A notable model of this type is the CFAST model that was developed by the National Institute of Standards and Technology (NIST) in the U.S. [3].

Other more comprehensive models that predict not only the fire and smoke spread in a building, but also the expected risk to life of the occupants, are also being developed. These risk assessment models combine the interaction of fire growth, smoke spread, occupant response and evacuation, and fire department response to assess the expected risk to life of the occupants. Two such models that are being developed are the CESARE-RISK [4] that is being developed at the Victoria University of

* Submitted for presentation at China Fire 2000, Beijing, China, October 17-20, 2000.

Technology in Australia and FiRECAM™ [5] at the National Research Council of Canada (NRC).

Development of FiRECAM™ and other Risk Assessment Models at NRC

To provide a tool that can assess the overall fire safety performance of a building, NRC is developing a computer fire risk-cost assessment model called FiRECAM™ (Fire Risk Evaluation and Cost Assessment Model). The model can assess both the expected risks to life of the occupants in a building, as well as the expected costs of fire protection and fire losses in the building. Therefore, the model can be used to identify cost-effective fire safety designs that provide a level of safety that is required by the code (performance-based code), or alternative designs that provide a level of safety that is equivalent to that of a code-compliant design (prescription-based code). The model is being developed in partnership with the Public Works and Government Services Canada (PWGSC) and the Department of National Defence Canada (DND).

To undertake the evaluation of fire risks and losses, FiRECAM™ simulates the ignition of a fire in various locations in a building, the development of the fire, smoke and fire spread, occupant response and evacuation, and fire department response. These calculations are performed by a number of submodels interacting with each other. There are nine submodels that are run repeatedly in a loop to obtain the expected risk to life values and the expected fire losses from a set of probable fire scenarios that may occur in a building. The computer model also includes three optional submodels that can be run if the building fire characteristics and fire department response are not considered typical or if fire costs are required. One submodel is run only once to obtain the failure probability values of boundary elements. FiRECAM™ is the only comprehensive model in the world that includes the probability of fire spread in a building, the response of the fire department and the estimate of fire costs, in addition to the typical modelling of fire growth, smoke spread and human response and evacuation.

FiRECAM™ uses statistical data to predict the probability of occurrence of fire scenarios, such as the type of fire that may occur or the reliability of fire detectors. Mathematical models are used to predict the time-dependent development of fire scenarios, such as the development and spread of a fire and the evacuation of occupants in a building. The life hazard posed to the occupants by a fire scenario is calculated based on how quickly the fire develops and how quickly the occupants evacuate the building for that scenario. The life hazard calculated for a scenario multiplied by the probability of that scenario gives the risk to life from that scenario. The overall expected risk to life to the occupants is the cumulative sum of all risks from all probable fire scenarios that may occur in a building. Similarly, the overall expected fire cost is the sum of fire protection costs (both capital and maintenance) and the cumulative sum of all fire losses from all probable fire scenarios in a building.

Another research group at NRC, in partnership with the DND, is developing a new computer model to evaluate fire protection systems for light industrial buildings, with the primary focus on warehouses and aircraft hangers. FIERAsystem (FIre Evaluation and Risk Assessment system), is based on a framework that allows designers to establish objectives, select possible fire scenarios, and evaluate the impact of each scenario on life safety and property protection. The framework leads the user through a series of steps in setting up the problem, including defining building and occupant characteristics, and specifying fire safety objectives and appropriate performance criteria for fire and smoke spread, occupant safety, property protection, continuity of operations, and environmental protection. Potential fire scenarios are then selected from a list, along with active and passive fire protection options to be evaluated.

Deployment of FiRECAM™

Over the past decade, NRC, in partnership with PWGSC, has been developing a version of FiRECAM™ for PWGSC's use. The model, FiRECAM™ – Office Model, allows designers and regulators to evaluate the impact of various design options on life safety and property protection for office buildings. PWGSC owns most of the Canadian federal government buildings. The model will help PWGSC to identify cost-effective fire-safety designs for these buildings.

To help evaluate the performance of FiRECAM™ before its actual use, PWGSC has formed a number of task groups across Canada during the past three years. Groups were formed in Halifax, Montreal, Ottawa, Toronto, Winnipeg, Edmonton and Vancouver. Each task group consisted of PWGSC regional staff, fire consultants, building and fire department officials. Task group members were provided with the computer program as well as the necessary training, education and guidance. They learned how to apply the model as a fire safety assessment tool, interpret its results and understand its capabilities and limitations. The objectives of the evaluations were: a) to assess FiRECAM™ in order to determine whether its predictions were reasonable and realistic for applications to office buildings; and b) to provide constructive comments and recommendations for improving FiRECAM™ if there were any areas requiring improvement.

Real and fictitious case buildings were used in the exercise and numerous runs were conducted. For each building, a base fire safety design case was established and then one fire safety design parameter was changed at a time to determine the impact. In later runs, multiple parameters were changed to determine the impact of tradeoffs and additions. After each run, the members presented and discussed their results. At the end, they concluded that the predictions by the model in general were reasonable. In a few situations when the results differed from users' expectations, these differences were discussed and resolved. This is an important step in gaining the confidence of users and, ultimately, their acceptance and adoption of this program. Feedback gained from this comprehensive evaluation process also led to improvements in the computer program.

Following the evaluation of FiRECAM™ through PWGSC's task groups, NRC plans to release the FiRECAM™ - General Model by November 2001. The target date of November 2001 is set to allow sufficient time to fix bugs that may be identified through the current evaluation by PWGSC through March 2001. The executable module, the user's manual and the system model document will be available. Other reference material can be obtained from NRC Publications. NRC will not provide any technical support. However, training workshops may be provided at the request of the users and at full cost recovery. Users take full responsibility when they use FiRECAM™.

For those parties interested in developing the model further for their specific use, NRC could enter into a collaboration agreement that will allow the model to be further developed. For example, if Tianjin Fire Research Institute (TFRI) wants to develop FiRECAM™ further for use in China, a research collaboration could be setup between

TFRI and NRC. The collaboration will allow TFRI to carry out the required research and development work, with the support by NRC researchers, to make FiRECAM™ applicable in China. Such collaboration will benefit both organizations: allowing China to have the use of FiRECAM™ and allowing NRC's FiRECAM™ to have a wider application.

References

1. Friedman, R., "An International Survey of Computer Models for Fire and Smoke", J. of Fire Protection Engineering, Vol.4, No.3, 1992, pp.81-92.

2. Kumar, S., Cox, G., and Gupta, A. K., "Effects of Thermal Radiation on the Fluid Dynamics of Compartment Fires", Proceedings of the 3rd International Symposium on Fire Safety Science, Edinburgh, Scotland, July 8-12, 1991, pp.345-354.

3. Peacock, R. D., et al, "CFAST, the Consolidated Model of Fire Growth and Smoke Transport", Technical Note 1299, National Institute of Standards and Technology, Gaithersburg, Maryland, February 1993.

4. Beck, V. R., "CESARE-RISK: A Tool for Performance-Based Fire Engineering Design", Proceedings of 2nd International Conference on Performance-Based Codes and Fire Safety Design Methods", Maui, Hawaii, May 3-9, 1998, pp.319-330.

5. Yung, D., Hadjisophocleous, G. V., and Proulx, G., "A Description of the Probabilistic and Deterministic Modelling Used in FiRECAM™", International J. on Engineering Performance-Based Fire Codes, Vol.1, No.1, 1999, pp.18-26