Comfort and safety in the Millennium Dome

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ANALYSIS OF SUBWAY FIRE VENTILATION

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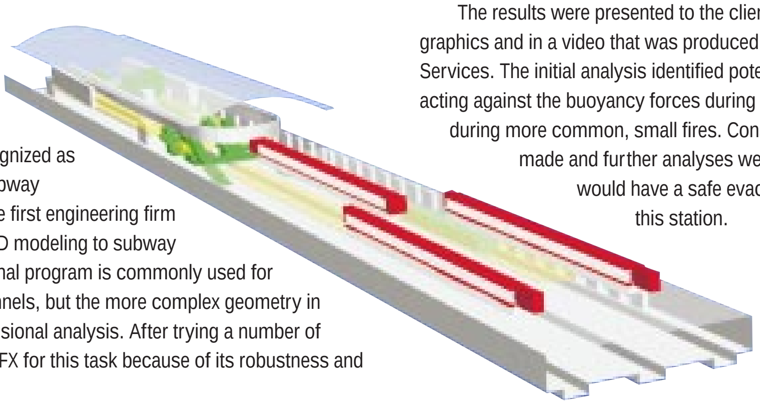
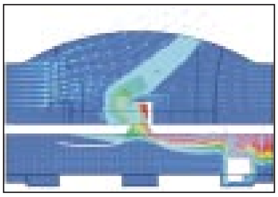
ICF Kaiser Engineers, Inc. is an engineering firm with a long history in the transportation industry. Recognized as an innovator in the field of subway ventilation, ICF Kaiser was the first engineering firm in North America to apply CFD modeling to subway station fires. A one-dimensional program is commonly used for modeling fire scenarios in tunnels, but the more complex geometry in stations requires three-dimensional analysis. After trying a number of products, ICF Kaiser chose CFX for this task because of its robustness and flexibility.

Recently, ICF Kaiser used CFX to perform a transient simulation of a rapid-transit train fire in the new station at the San Francisco International Airport. This is an elevated, but almost fully enclosed, facility. Buoyancy-driven natural ventilation was designed as the primary means of smoke removal for one half of the station area. Since this is a non-standard approach for transit stations, careful analysis was required. The CFX model simulated the multiple levels of the station and included details such as columns, stairs, escalators, ventilators and dividing walls. An initial steady-state run established the starting conditions, particularly the wind, for the transient study. A fire was then simulated by adding sources of heat and smoke. The fire was developed gradually over the simulation period and the distribution of heat and smoke at different intensities was used to evaluate the effectiveness of the smoke removal.

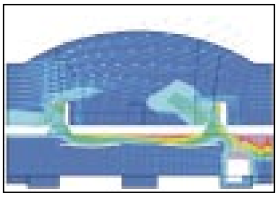
The results were presented to the client both in a report with extensive graphics and in a video that was produced by AEA Technology Visualization Services. The initial analysis identified potential problems caused by wind acting against the buoyancy forces during the early stages of fire growth or during more common, small fires. Consequently, design changes were made and further analyses were conducted to ensure patrons would have a safe evacuation route in case of a fire in this station.



Model of the station showing the trainways and column wall in the lower level, the monitors (ventilators) on the roof at one end (red) and the stairs to a separate airport light rail station on the other end. The canopy and walls of the light rail station on the upper level are also shown.



A section through the fire zone showing smoke distribution and velocity vectors from a large train fire. The smoke collects in the upper levels and flows out of the vents after enough heat reaches the vent to overcome the wind resistance. The outdoor wind was modeled as blowing into the vents as a worst case.



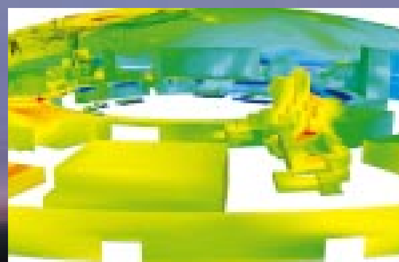
A section showing smoke distribution and velocity vectors through a different region of the fire. Smoke stays above the suspended ceilings, but spreads completely across the station.

Buro Happold is a multi-disciplinary international engineering consultancy providing design advice to the construction industry. Current projects include the Greenwich Millennium Dome, the British Museum Great Court project and the Lowry Centre in Manchester. The company's commitment to leading-edge CFD is emphasized through its continued investment in both staff and technology.

For the Millennium Dome, Buro Happold undertook, in collaboration with AEA Technology, CFD analyses to optimize the design of the ventilation systems. The dual objectives were to provide a comfortable environment throughout the year and, in the unlikely event of a fire, to ensure that the smoke extraction enables safe escape.

In line with current trends, natural extraction is used wherever possible. However, numerically the resulting flows are notoriously unstable and Buro Happold chose CFX because of its rapid convergence in these situations.

Using CFX, the optimum ventilation configurations for the Dome were designed and demonstrated. Comfort was assessed using the Relative Warmth Index, which takes account of an individual's metabolic rate and clothing, incident radiation and the local air temperature, humidity and velocity.



Simulation of ventilation in the Dome, showing flows induced by lighting.

In fire conditions, dilution of the smoke as it rises reduces its buoyancy, making it more susceptible to influence by environmental flows. To ensure that it would not then be transported downwards onto the escape routes, engineers modelled its movement over a 30-minute period with the ventilation system switched to emergency (maximum smoke-clearance) mode. The results confirmed that the public areas remained clear of smoke and that safe evacuation was possible.

"CFD analysis is becoming an essential part of engineering design," commented Buro Happold managing partner, Padraic Kelly, "and CFX will play a leading role in ensuring that Buro Happold continues to provide the best service to our customers."

Simulation of a postulated fire in the Dome, showing smoke spread along the roof.

Energy efficient office design

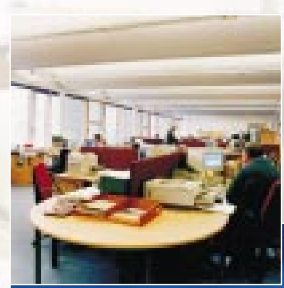
by Stewart Miles, The Building Research Establishment Ltd (BRE), Watford, UK

The BRE Environmental Building.

As part of the drive to reduce global emissions of CO_2, attention has turned to the design of more energy efficient buildings. Commercial buildings in particular consume significant amounts of energy, with 25% typically accounted for by air conditioning. Natural ventilation is one solution, where the thermal properties of the building and unforced flow of fresh air could potentially provide the cooling requirement during summer.

To ensure the successful cooling of such buildings, the design must account for factors including the air flow, the building's thermal response and any heat sources present (people, lighting and equipment). These complexities have drawn designers to physical and computational modelling to predict the internal environment and the occupants' thermal comfort satisfaction.

BRE has more than 20 years experience in CFD modelling and is now using CFX-5, where unstructured meshing provides the power and flexibility needed to analyze innovative building designs. It is currently being used to study the new Environmental Building at BRE, constructed as an exemplar naturally-ventilated office. Summer ventilation is driven by wind effects and buoyancy generated by the internal heat loads and by thermal stacks. The CFX-5 model considers the first floor office and the stacks, with surface heat fluxes prescribed for the people, computers and the glass panels on the front of the stacks. External air is drawn in through high level windows on one side of the office and discharged into the stacks on the opposite side. The results show that the internal temperature is nearly everywhere at or below ambient, which is the desired condition.



Inside the BRE Environmental Building.

Surface temperatures in the office.