CHAM Limited
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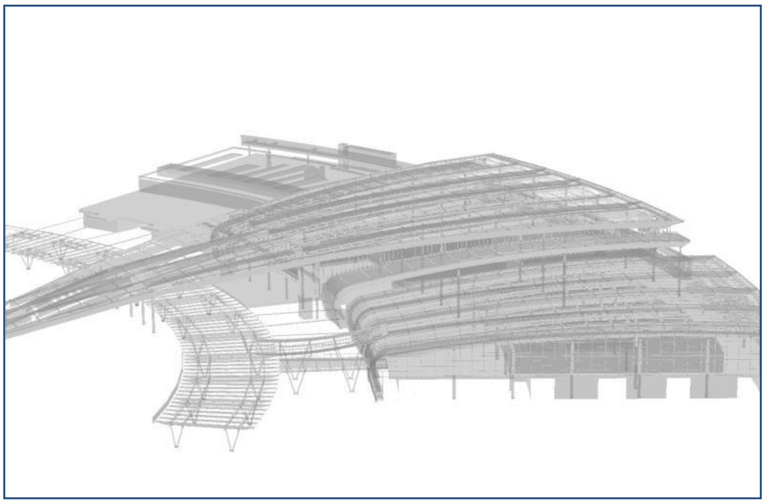
CHAM Case Study – Airport Fire Test Example

Fire & Smoke Study of Hypothetical Fire at New Airport Design

The Sir Seewoosagur Ramgoolam International Airport is the primary airport in Mauritius. It has been re-designed to cope with greatly increased traffic experienced over recent years and anticipated for the future. As part of the design processes, CHAM limited was contracted by Gustave Maurel & Fils to undertake a simulation of the fire control measures operating within its main and baggage halls.

The project involved importing a 3D model of the new terminal building for the SSR airport and incorporating its major structures, heat sources and ventilation system. The purpose was to investigate the heat and smoke dispersion from a hypothetical exhibition car fire located in the departure hall on its first floor; and, secondly, a luggage fire located in the passport control area on level 2.

Mauritius Airport – picture courtesy of Amitexo

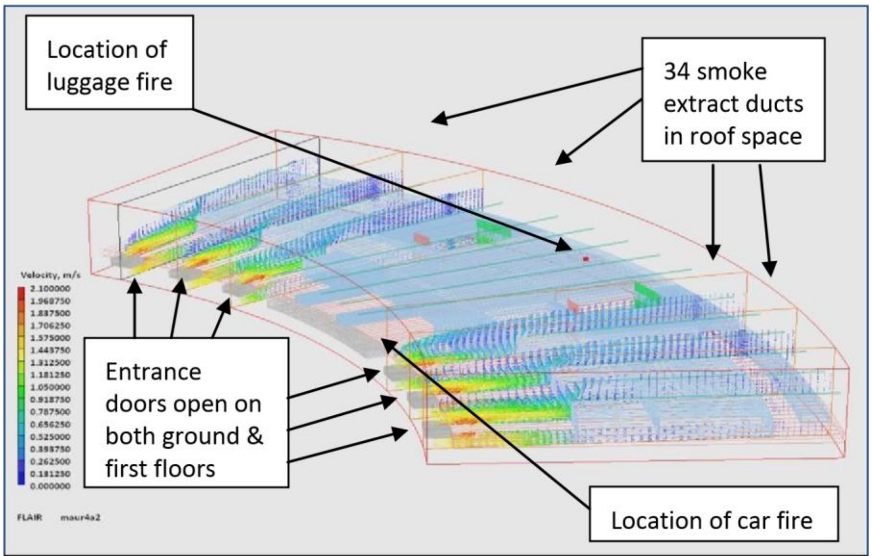


Once a fire starts, the normal ventilation system is de-activated automatically with the airport's twelve primary external access doors located on the ground floor being opened fully to permit public egress and provide a source of fresh air. Finally, the emergency smoke extraction systems located in the airport's roof structure are switched on.

CAD file imported into PHOENICS

Model construction

The CFD model was constructed using a polar coordinate meshing system suited to the particular layout of the airport's design. The work scope included construction of a CFD model (above), including provision of smoke extraction grilles from supplied drawings and extraction rates based upon operational specification.



Terminal Building in Polar Co-ordinate Mesh. [Roof structure not shown.]

Both steady -state and transient simulations were undertaken. Results of the steady - state cases showed the overall flow regimes including major heat and smoke product sources, a ir inlet and smoke extraction. However, steady-state results reflect a "worst-case" scenario of a continuous fire with constant heat and smoke release , and fail to reflect the effectiveness of the smoke-extraction units over a specified period of time.

Transient calculations were needed to show the accumulation and dissipation of smoke product, its layering and the expected visibility at head height, throughout the progression of each fire simulated. As before, the CFD model incorporated operation of the smoke extraction system whilst assuming that the normal ventilation system is inactive, but now with the addition of a representative fire curve over time.

Fire specification

The heat and product output of both luggage and car fires were in accordance with CIBSE guidelines. In transient mode, the luggage fire was set to grow and dissipate over 10 minutes, and the car fire over a 20-minute period, to simulate the development of the smoke plume and layer. In this example, the heat release increases linearly for 300s, remains constant to 600s, and then declines linearly after 1200s total.

For the car fire the smoke production was based on a heat of combustion of $2.5x10^7$ J/kg, and a particulate smoke yield of 0.157kg_smoke/kg fuel; for the luggage fire the corresponding figures were $5.7x10^6$ J/kg and 0.16kg_smoke/kg fuel. These values are typical for polystyrene and PVC respectively. It was also assumed that the stoichiometric ratio was 1.908kg_O2/kg fuel for the car fire and 0.435kg_O2/kg fuel for the luggage fire.

Sight Length

The variable "sight length" or "visibility" (SLEN) is been used in this report to display the variations of smoke concentration. This a measure of how far one can see through the smoke, being inversely proportional to the smoke particulate density (and proportional to the brightness of the object being looked at). Following CIBSE Guide E this quantity is defined as follows.

SLEN = min (D_{max}, $A/(K_m * C_{s,p})$) where Km is the mass-specific extinction coefficient in m2/kg-particulate-smoke, $C_{s,p}$ is the particulate smoke concentration in kg/m^3 of mixture, and A is an empirical coefficient with the value A=3 for light-reflecting objects. In the literature, it has been established empirically that the value of K_m can be considered as a constant of the order of 7000 to 8000 m^2/kg particulate smoke. The CIBSE Guide E and other authors suggest a value of 7600 m^2/kg for the flaming combustion of wood or plastics, and this value has been used in the model.

The visibility coefficient D_{max} is defaulted to 30m; this provides an effective maximum for SLEN, and simply ensures that the visibility has a finite rather than infinite value in smoke free regions.

The particulate smoke concentration $C_{s,p}$ is derived from the solved-for combustion products mass-fraction C_s via the expression: $C_{s,p} = r * Y_s * C_s /(1+R_{ox})$ where r is the mixture density (kg-product/kg-mixture), Y_s is the particulate smoke yield (kgparticulate-smoke/kg-fuel), and R_{ox} is the stoichiometric ratio (kg-oxygen/kg-fuel). The CIBSE Guide E suggests that for the purposes of escape, visibility should be at least 8m.

Mathematical Representation

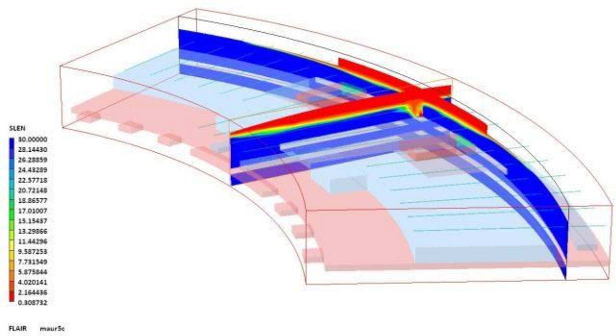
Partial differential equations for steady flow were solved, representing conservation of mass and three components of momentum, these being the familiar Navier-Stokes equations which govern fluid flow. Conservation equations of this form have been solved for the following variables: three components of momentum, thermal energy, two turbulence variables (k and epsilon - see below), and smoke concentration. The mass continuity equation is also solved. This is expressed in the form of a pressure-correction equation, from which the pressure field is determined.

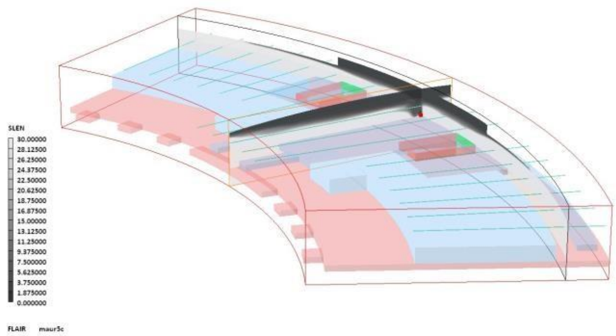
A "turbulence model" has been employed to represent the effects of turbulent mixing. The standard “k-epsilon” model was employed; this requires the solution of two additional equations, for turbulence kinetic energy (k) and dissipation rate (epsilon). It was not considered necessary to solve for radiative heat fluxes.

Numerical Solution

Numerical grids of between 1.2 million and 1.4 million cells were used for the solution, representing an appropriate balance between the competing demands of computer run time, accuracy and available budget.

Results - Luggage Fire Results – level 2

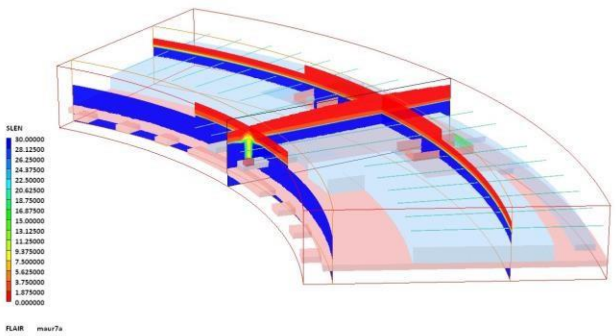


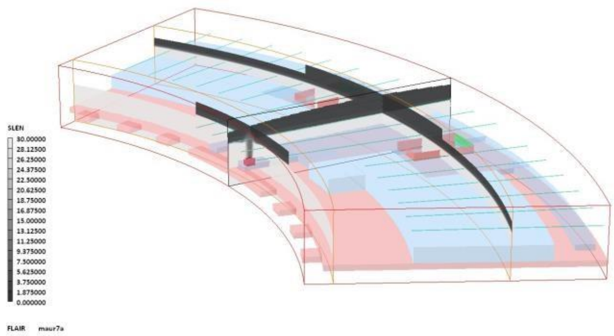


Sight Length after 20 minutes
Blue/Green/Yellow acceptable – Orange/Red unacceptable

Sight Length after 20 minutes – Grey Scale

Car Fire Results – level 1





Sight Length after 20 minutes Blue/Green/Yellow acceptable – Orange/Red unacceptable

Sight Length after 20 minutes – Grey Scale

The results show that the fire generates both heat and smoke product in the form of a plume that rises towards the smoke extraction grilles. Any smoke that passes the extract grilles accumulates in the roof structure but does not impede visibility at lower levels. With the exception of the immediate vicinity of the fires, the visibility (sight length) at 2m above floor level remains good throughout the airport and above the 8m minimum suggested by CIBSE.

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