OLYMPIC ARENA - CONCEPT AND DESIGN DEVELOPMENT

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ABSTRACT

This paper presents an original air conditioning concept and design development elaborated for a large arena, designed to accommodate the indoor sporting events during the 2000 Olympic Games in Sydney, Australia.

An air conditioning system, which provides a great level of flexibility and economical operation, has been developed and its performance studied in detail by the use of our computational fluid dynamics (CFD) software.

The CFD analysis has confirmed the advantages of the system by achieving a uniform temperature distribution and appropriate air velocities in the occupied areas, under all operational situations.

The proposed concept is also a key element of the smoke management strategy for the arena. Hence the study has been extended to incorporate evaluations of smoke concentrations for various fire scenarios.

KEYWORDS

Air Conditioning, CFD, Public Buildings.

INTRODUCTION

As part of the 2000 Olympic Games in Sydney, Australia, a large arena, designed to accommodate the indoor sporting events, was required.

The main arena hall was sized to accommodate, in a fully air conditioned environment, 15,000 patrons on fixed seats and 5,000 patrons on retractable seats.

The competition area was required to be suitable for a large range of sporting events, including ice competitions, and also entertainment venues and functions.

In addition, the arena building included a significant number of auxiliary areas designed to support the arena activities and provide amenities for patrons and competitors.

An open tender, with the participation of a number of consortia, was organised to select the best and most economical design.

Our company, a specialist in building services, was part of the winning consortium.

An important contribution to the winning process was the original concept of the air conditioning system developed for the main arena hall.

Hereunder we present the air conditioning concept, which differs considerably from classical concepts, and the results of the computational fluid dynamics (CFD) analysis, proving its viability.

The study has been extended to incorporate evaluation of smoke concentrations for various fire scenarios.

THE AIR CONDITIONING CONCEPT

The concept of the air conditioning system serving the main arena hall is shown schematically on Figure 1.

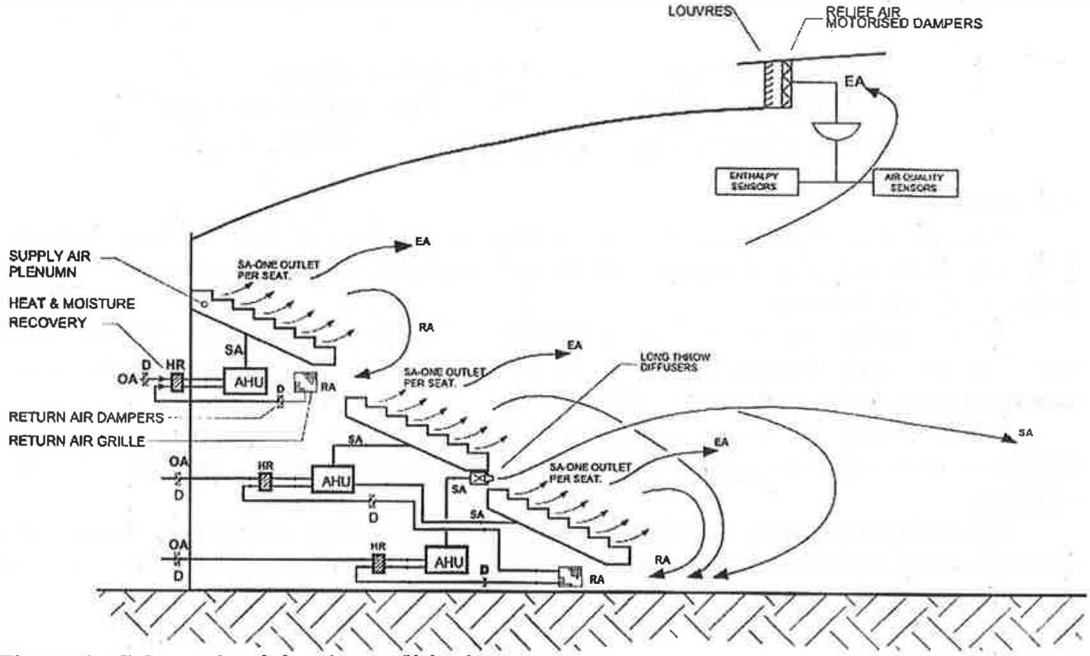

Figure 1 - Schematic of the air-conditioning concept

The system employs an under seat supply of conditioned air system for seating areas, and an overhead supply air system, via long air throw diffusers, for the playing ground area.

The return air has access back to the air conditioners via the hall entrances, located at different levels.

The original part of the concept is that the relief air dampers, associated with each conditioner and usually located on the return air duct, are located at the ceiling level.

Since a very important part of the heat load at Sydney design conditions consists of a significant amount of sensible and latent heat contained in the outside air, a demand controlled ventilation system has been employed.

The ceiling relief dampers, which operate in sequence with the outside air dampers, are controlled by either air quality sensors, located into the return air duct of each conditioner, or by enthalpy sensors, located at ceiling level.

The fundamental ideas on which the concept has been based are as follows.

- The use of natural ventilation, on partial occupancy when the outside conditions permit. This is possible by opening fully the conditioner outside air dampers, located at low level, and the conditioner relief air dampers, located at ceiling level.
- Reduce the energy consumption by releasing the cupola stratified hot air when its enthalpy is higher than the enthalpy of the outside air . This is also possible due to the fact that the relief air dampers are located on the top of the arena roof.
- Provide air conditioning to a limited area only, on low occupancy situations. This is possible due to the under seat supply system and due to the fact that eighteen conditioners were provided, twelve serving sections of the seating area and six serving the playing ground area.
- Provide protection of spectators against fire and smoke, but still allow for the use of smoke effects. As further shown, the concept can handle smoke situations without the use of exhaust fans.

CFD RESULTS

To verify the validity of the concept a significant number of CFD analysis for various operating conditions have been carried out, but only a few relevant ones will be presented.

We used a computational fluid dynamics model known as AIR, which was developed for air conditioning and smoke control modelling.

The model solves the transport equations of momentum, energy and species concentrations, together with global continuity for the given boundary and source conditions.

Turbulence is modelled by the widely used K-e model, involving transport equations for turbulence energy (K) and turbulence dissipation (e).

The equations are solved by finite differences. Grids are Cartesian with variable spacing. Embedded fine girds to any level were included to refine solutions in local regions and improve accuracy.

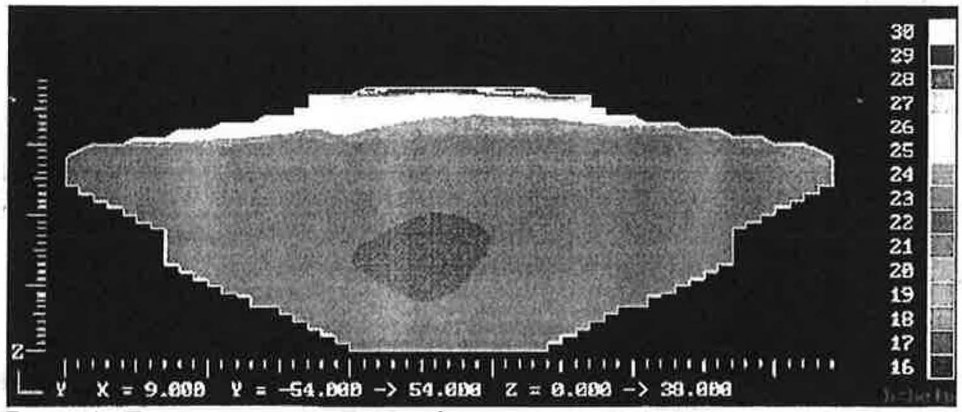

Figure 2 - Temperature distribution for our air-conditioning concept

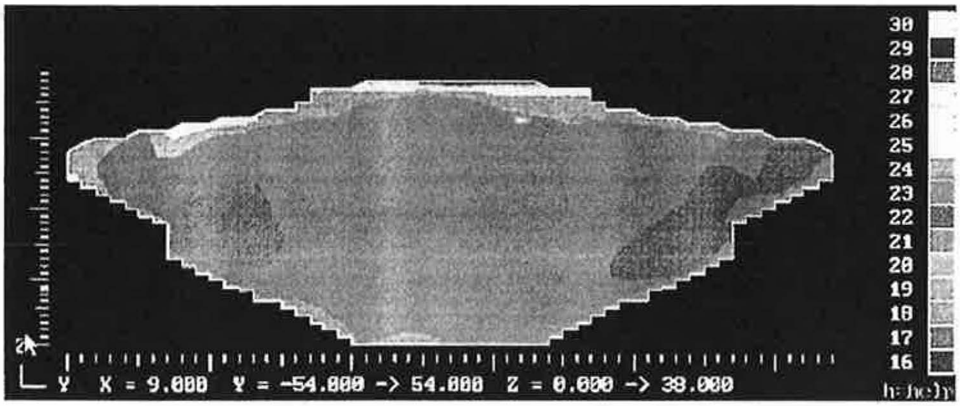

Figure 3 - Temperature distribution for a classical overhead supply air-conditioning system

Figure 2 shows the temperature distribution on a cross-section of the arena hall when 15L/s of conditioned air at 20^{0}C is supplied under each seat and conditioned air at 16°C is supplied to the playing ground, on full cooling demand situation.

Figure 3 shows the temperature distribution for the same cross-section for a classical overhead supply system.

As can be seen, our design provides not only a more uniform temperature distribution but also a higher degree of heat stratification, thus improving the overall efficiency of the air conditioning system by releasing the stratified heat.

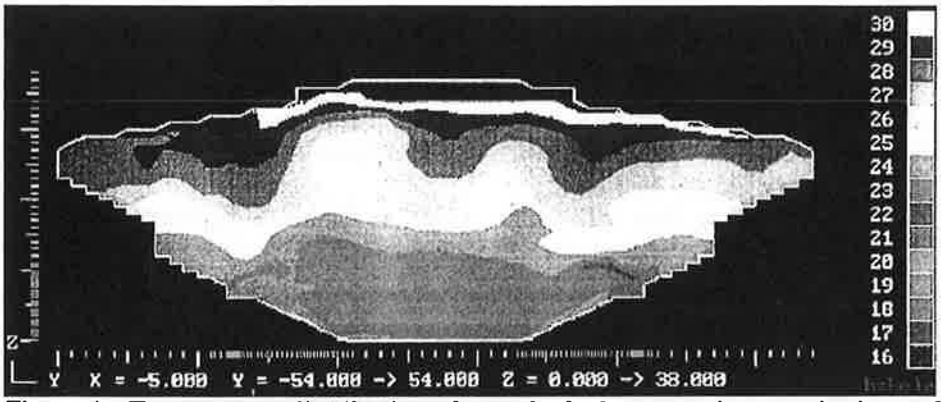

Figure 4 – Temperature distribution when only the lower seating area is air-conditioned

Figure 4 shows the temperature distribution when the lower seating area is occupied only, with conditioners serving the upper seats not operating.

At partial load, which would be a frequent occurrence after the Olympic Games, the energy savings provided by our design are even more evident.

We have encountered a special difficulty in providing a uniform air distribution and temperature to the playing ground area, which is supplied with conditioned air by dedicated conditioners, via long throw air diffusers.

Initially, we grouped a significant number of diffusers into compact batteries. The result was air dumping due to the gravitational effect of a large mass of cold air, as shown on Figure 5.

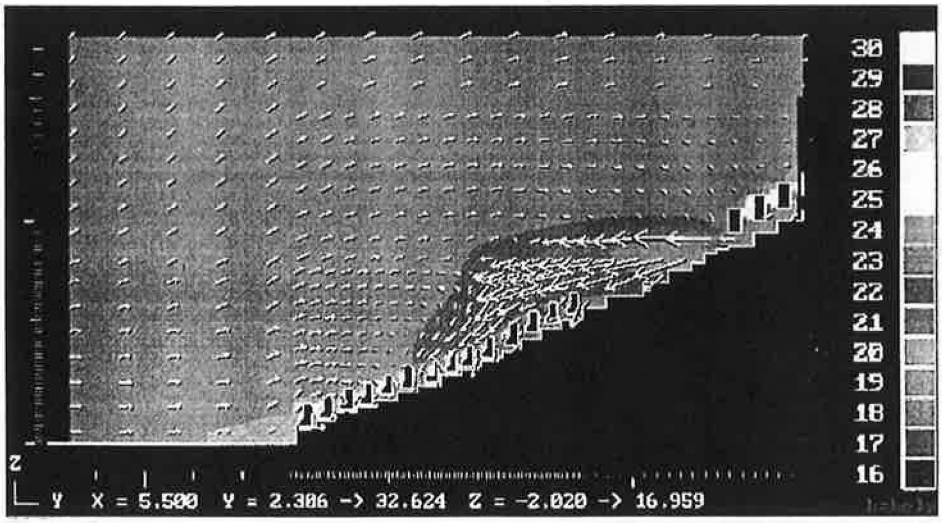

Figure 5 – Cold air dumping caused by incorrect positioning of the long throw diffusers

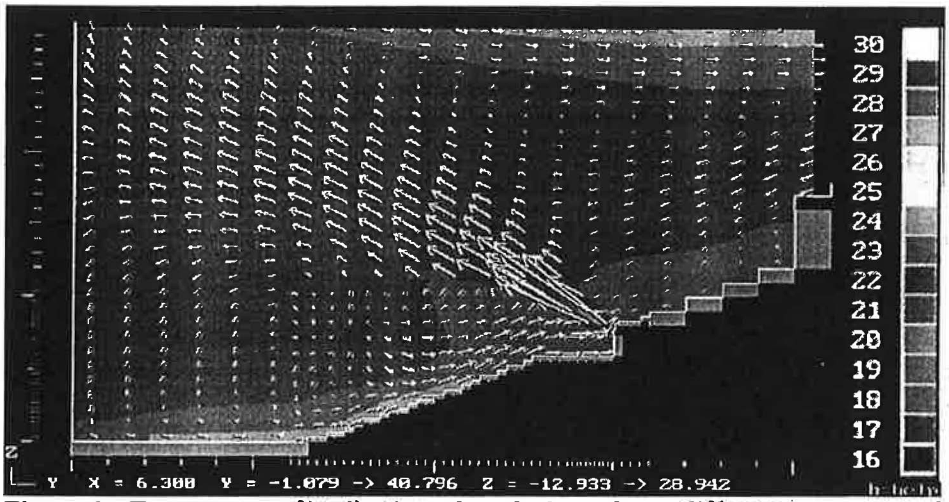

Figure 6 – Temperature distribution when the long throw diffusers were correctly positioned

By spacing the diffusers and providing the correct jet velocity and direction, we managed to avoid dumping and achieve a uniform temperature distribution at playing ground level, as shown on Figure 6.

The proposed concept is also a key element of smoke management strategy for the main arena hall.

By operating the seating areas on full outside air and stopping the air supply to the playing ground, smoke management could be achieved without the use of roof mounted exhaust fans.

To demonstrate the behaviour of the system on the fire mode operation, we have simulated different levels of fire intensity occurring on the playing ground of the arena hall.

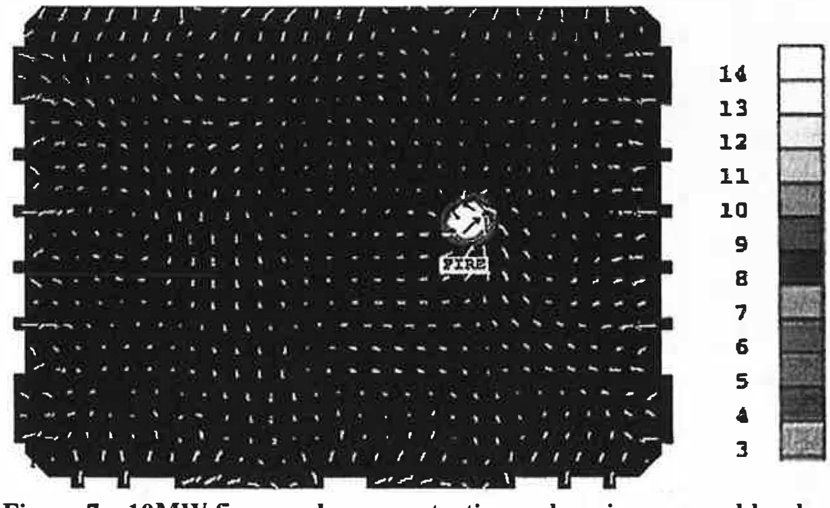

Figure 7 – 10MW fire, smoke concentrations, plan view, ground level

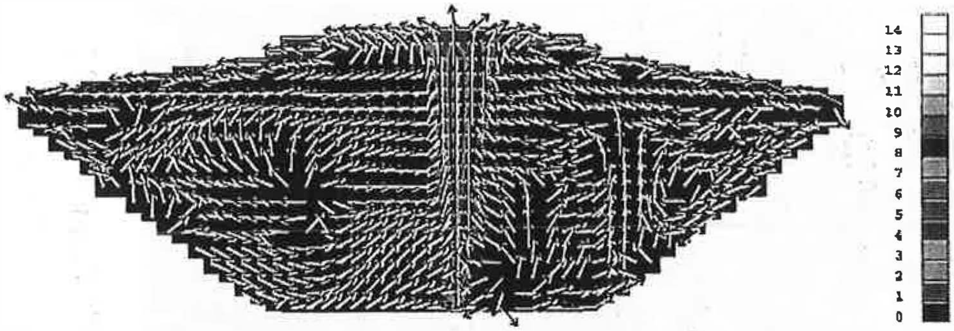

Figure 8 – 10MV fire, smoke concentrations, elevation

Figure 7 and Figure 8 show the smoke concentrations and velocities on fire mode operation for a 10MW fire occurring on the playing ground level. As can be seen, fresh air supplied under the seats prevents smoke reaching the seating area, with smoke being evacuated though the fully opened relief air dampers. This level of fire intensity could be practically caused only on shows involving cars, when two cars are colliding.

The colour code indicates that the smoke concentration at seating area is less than $1mg/m^3$ of air and the visibility is over 240m.

A similar behaviour has been found when a much less intensive fire, of 2MW, has been simulated. The results are shown on Figure 9 and Figure 10.

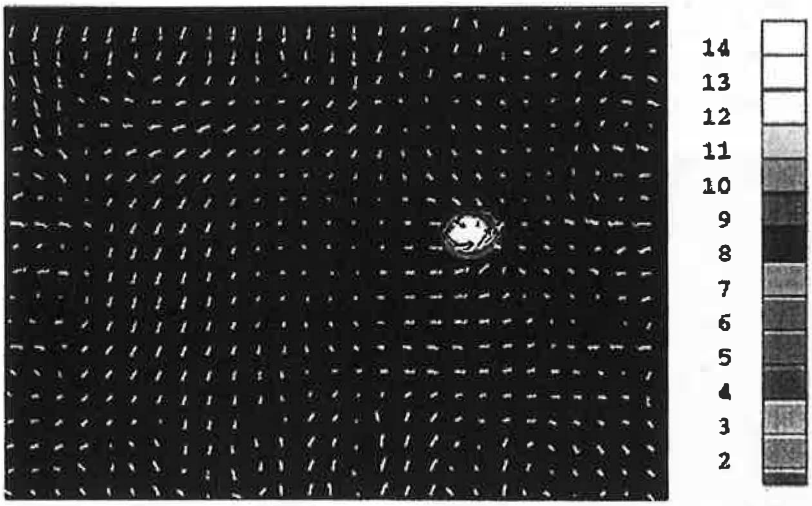

Figure 9 – 2MW fire, smoke concentrations, plan view, ground level

In order to find out the behaviour of the system when smoke effects are used, as part of a specific show, the simultaneous release of eight pyrotechnics generating "cool smoke" has been simulated.

The results are shown on Figure 11 and Figure 12.

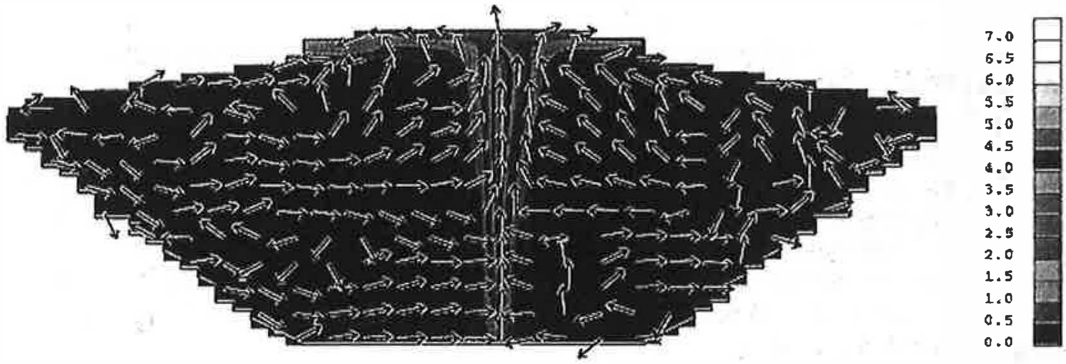

Figure 10 – 2MW fire, smoke concentrations, elevation

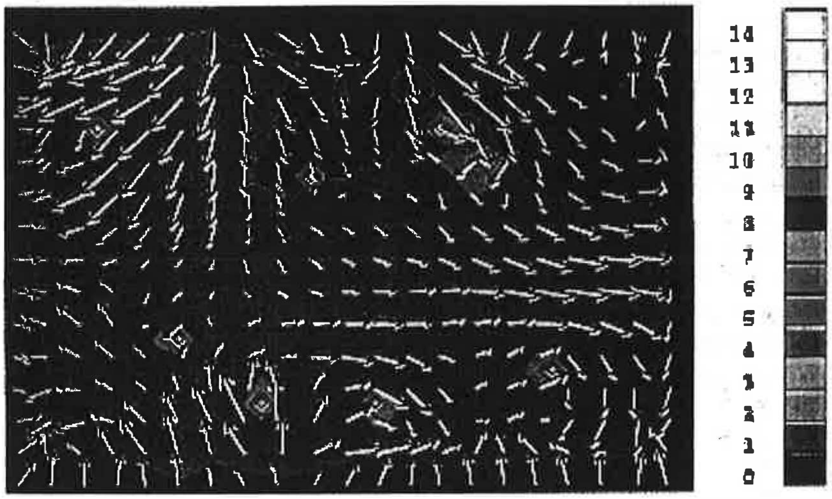

Figure 11 – 8 pyrotechnics, smoke concentrations, plan view, ground level

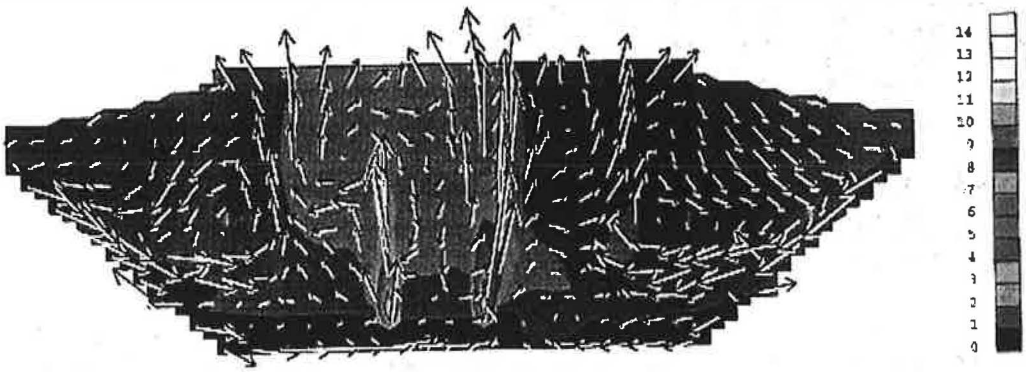

Figure 12 – 8 pyrotechnics, smoke concentrations, elevation

The colour code indicates that the smoke concentration at seating level did not exceed $2mg/m^3$ of air and the visibility was above 200m.

DISCUSSION

The proposed, and CFD analysed, air conditioning concept for the Olympic arena main hall fulfilled all expectations.

Results of the air conditioning modelling confirmed that the under seat supply air system achieves uniform temperature gradients over the seating area.

The long throw diffusers utilised for serving the central area, when correctly selected, located and orientated, also provide uniform temperature gradients and appropriate air velocities for the playing ground of the arena hall.

Supplying the seating area from a significant number of independently operated and controlled air conditioners, the system allows for conditioning limited number of zones, on partial occupancy situations.

By providing dedicated conditioners to the competition area, the system has the ability to vary the temperature and humidity requirements to cater for different usage, including ice competitions.

Whilst overall the basic concept has been adopted, the following refinements were carried out during the design development stage.

1. With respect to the seats located at the upper part of the Arena, a more conventional overhead air distribution system was selected as a result of a value management exercise. The key factor was the estimated occupancy rate of this upper seating area after the Olympics.
2. The smoke management system comprises fan assistance due to the following reasons:
   (a) Space limitations for the size of louvers required for relief.
   (b) Noise break-in potential.
   (c) The requirement for complete darkness within the Arena.
   (d) To achieve a more economical fire engineered solution.