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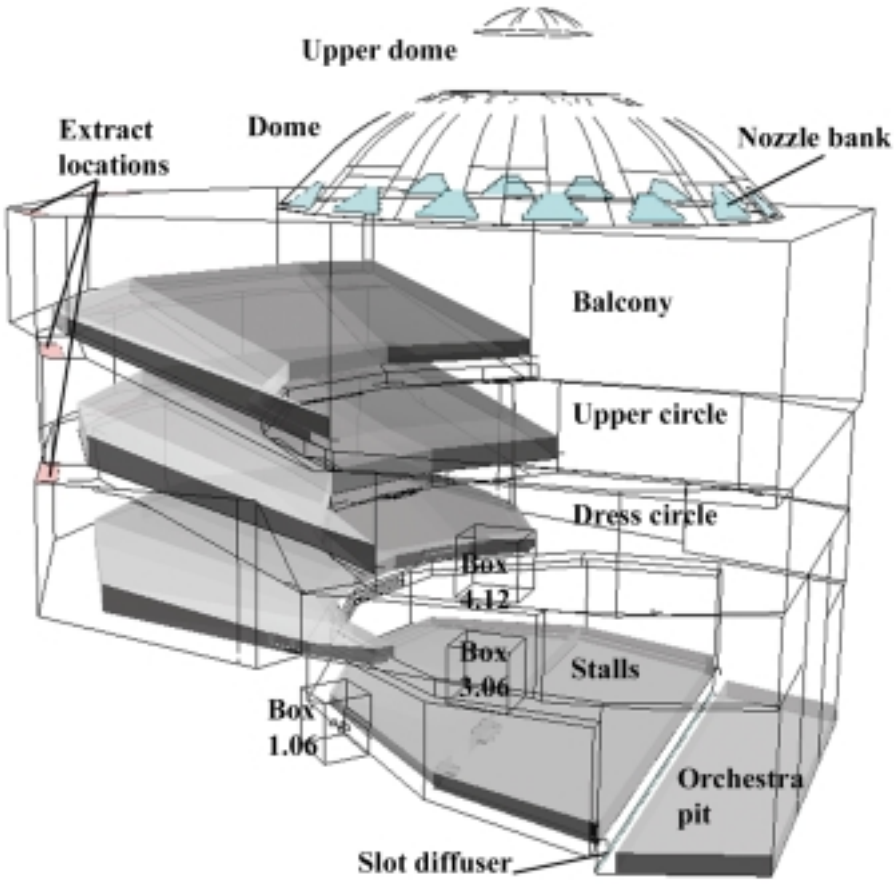
A breath of fresh air

for the London Coliseum

LONDON, March 29, 2001 – During its near 100-year history, the London Coliseum has played host to many forms of entertainment, including horse races, musicals, varieties, cinema and finally the English National Opera. But while the Coliseum continually reinvented itself as a venue, its infrastructure fell behind the times.



Coming to the rescue of the venerable institution is Arup, a London-based engineering firm. Arup is using STAR-CD and high-end visualization to help ensure that modern-day opera buffs no longer need to suffer for their art. The company's master plan for the Coliseum will improve the standards of support facilities, provide better disabled access and egress, and upgrade the appeal of the building.

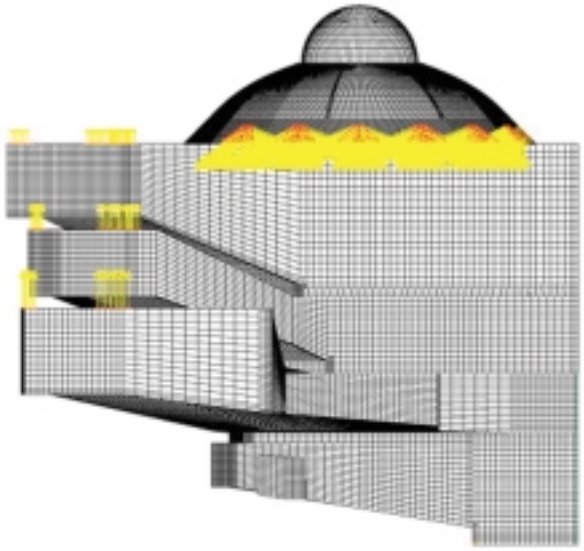
A major component of Arup's work is improving air circulation within the auditorium. Minor adjustments have already been made to improve the existing system, and entirely new ventilation will be installed during the English National Opera's off-season over the next three years.

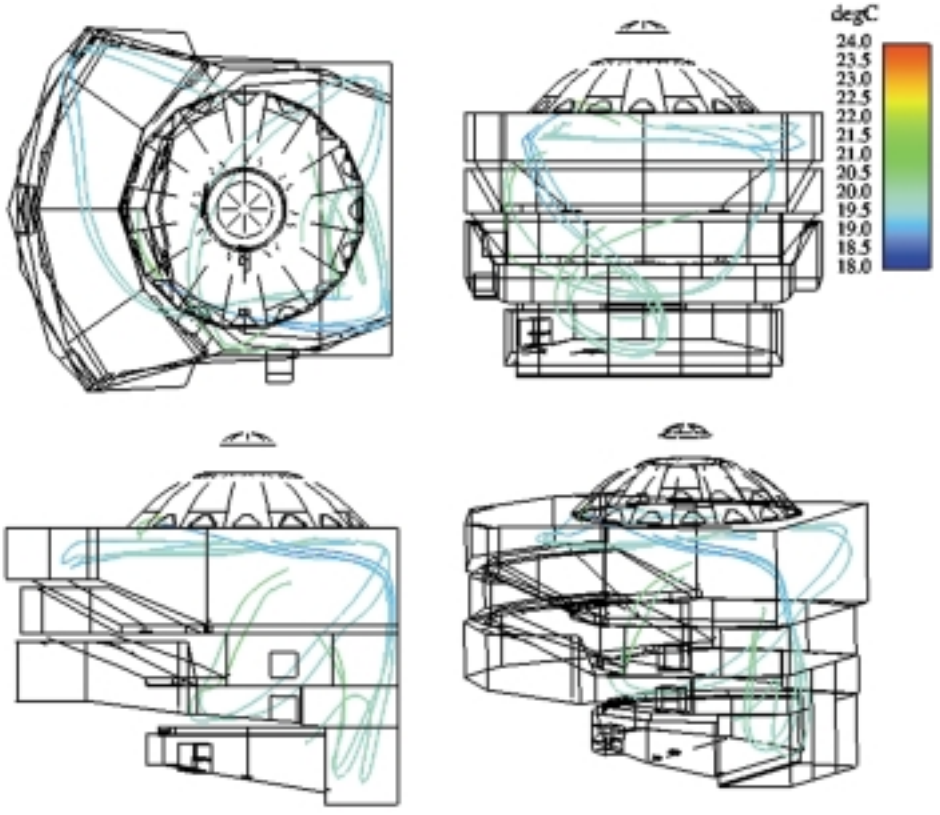
From Seats to Ceiling

The London Coliseum was completed in late 1904. The original plenum-style ventilation system was reversed in 1932, with air supplied at the seating levels and extracted at the ceiling. The current air handling units and horizontal ductwork distributing air to the risers were installed 50 years later in 1982. In 2000, the system was brought back to full working order at a lower air volume and the addition of cooling supply air.

Arup's new design is a direct inverse of the 1932 system. Air is supplied via nozzle banks in the domed ceiling. This creates a swirling airflow within the auditorium that doesn't affect the quality of acoustics. Air is extracted at the back of the seating regions, creating proper ventilation of the entire space.

Arup's CFD study took approximately five weeks to complete. STAR-CD was used for CFD testing and EnSight from CEI (Apex, N.C., USA) was used for 3D visualisation. STAR-CD solved the momentum, mass and energy equations needed to predict the detailed temperature distribution and air movement within the auditorium.





Making the Case for Better Air

Arup used three CFD case scenarios to simulate flow and temperature fields. Results from STAR-CD were loaded into EnSight, where animated particle trace paths were used to visualize air flow within the auditorium.

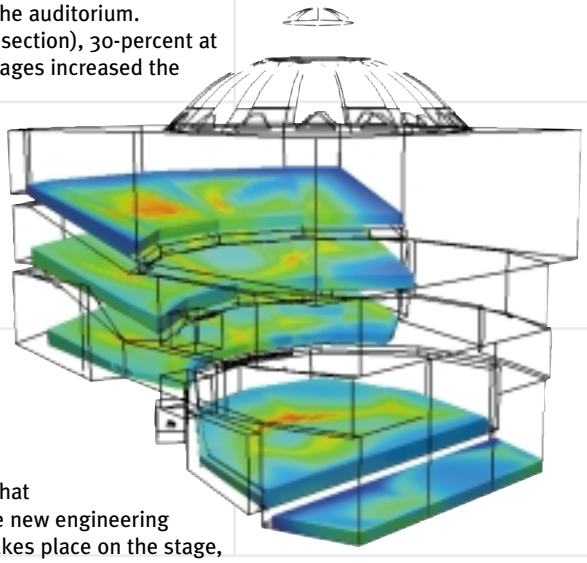
"The air movement is very complex," says Darren Woolf, fluid dynamicist at Arup. "It's driven by jet momentum, air temperature differentials (buoyancy), and wall-to-air temperature differentials that vary spatially and in magnitude. We needed to understand these factors and their various influences in order to improve the design of the system. We also needed to communicate our results. EnSight enabled us to create live demonstration materials and animations that convey the information in a way that's easy to understand."

In all three cases, air from the nozzles was set at 17ºC (63ºF). A convective heat load equivalent to 35W per person for the total 2,364 person occupancy was applied, giving engineers a feel for the atmosphere of the Coliseum under peak conditions. Lighting and other stage effects were not taken into consideration, as a neutral boundary was assumed between the stage and audience areas. Separate considerations were made for the orchestra pit as well.

Cooler Heads Prevail

In the first case, air was extracted in equal volumes, 33.3% from each of the three sections. CFD testing revealed that airflow in the balcony area was "short-circuited"; that is, the air produced by the nozzles was extracted before it had a chance to effectively cool the occupants. Likewise, air in the dress circle centre stalls and seating areas was not drawn off forcefully enough to cool occupants, resulting in stagnant airflow and higher temperatures.

Using these findings, engineers varied the amount of air being drawn from each section of the auditorium. The second case extracted 50-percent of the air volume at dress circle (the most-populated section), 30-percent at upper circle, and 20-percent in the balcony. Particle trace analysis showed the new percentages increased the scope of the swirling airflow, allowing it to reach the dress circle occupants. Unfortunately, the increased percentage over-compensated for the shallow reach of the air in the first case, and the flow was drawn too low. Temperatures were more evenly spread throughout the audience, however, eliminating the cold and hot zones seen in the first case.



Extraction volumes were further adjusted in case 3, with 40-percent going to the dress circle, 33-percent to the upper circle, and 27-percent to the balcony. Airflow paths were again traced within EnSight. Engineers saw that the swirling air penetrated lower in the seating area, resulting in cooler temperatures in the most densely populated areas. This scenario was determined to be the optimum choice for the ventilation system.

The Final Act

STAR-CD and EnSight have helped flow engineers at Arup design a new ventilation system that harmonizes with the London Coliseum's acoustics and historical character. Thanks to these new engineering technologies, opera enthusiasts can enjoy their favourite arias in comfort, as the anguish takes place on the stage, not in the seats.