

$$\frac{\partial}{\partial t}(\rho\phi) + \text{div}(\rho\vec{V}\phi - I_{\phi}) = S_{\phi}$$

## The Louvre Museum uses FLOVENT to improve ventilation of underground service areas

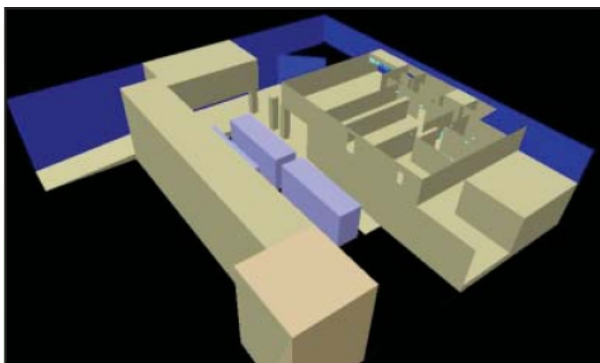
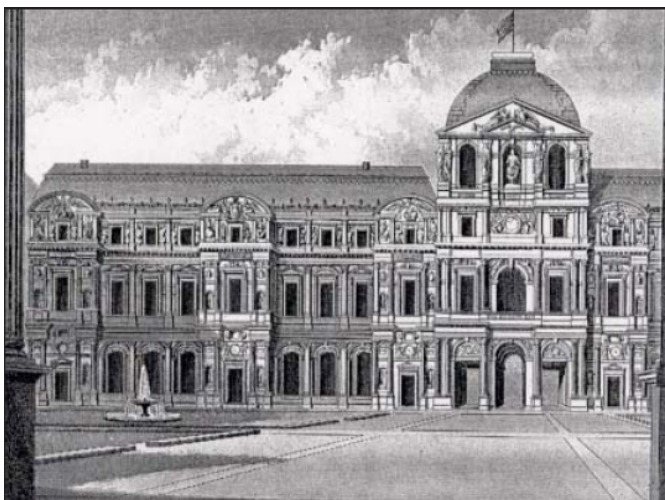


Fig 1. Artwork delivery areas with administrative offices at the top

The Louvre museum, situated in the historic heart of Paris, has a unique art collection. The Museum's storage and service areas are partially underground, beneath the Tuileries Garden. The artwork delivery area is the scene of a constant flow of heavy goods vehicles arriving to deliver paintings and sculptures for future exhibitions or inter-museum exchanges. The tight constraints of heavy goods traffic in enclosed areas, and the risks of staff being poisoned by engine pollutants (CO, NOx, COV, etc) led the Louvre museum to turn to computer airflow simulation using the FLOVENT software from Flomerics. The work was carried out jointly by experts from the University of Paris VII and engineers from Flomerics France.

The simulation work had three main aims:

- To assess the current risk of staff poisoning
- To propose modifications to the existing installations to ensure a good level of safety
- To identify the best positions for the gaseous pollutant detectors

### Assessing the risk of staff poisoning

A series of simulations made it possible to reproduce past incident and likely incident scenarios in order to gain an understanding of the airflow in the zone. It became apparent that there was a substantial build-up of exhaust gases at the top of the delivery area. In addition, substantial transfers of pollutants were identified, from the area occupied by the lorries to the adjacent administrative offices.

Continued on other side

Since 1988, Flomerics has pioneered a different approach to numerical analysis and simulation. Flomerics' software tools and services help bridge the gap between science and industry by embedding complex analysis and optimization software deeply into the design process, in a way which enhances productivity in engineering design. This approach is called "Design-Class Analysis".

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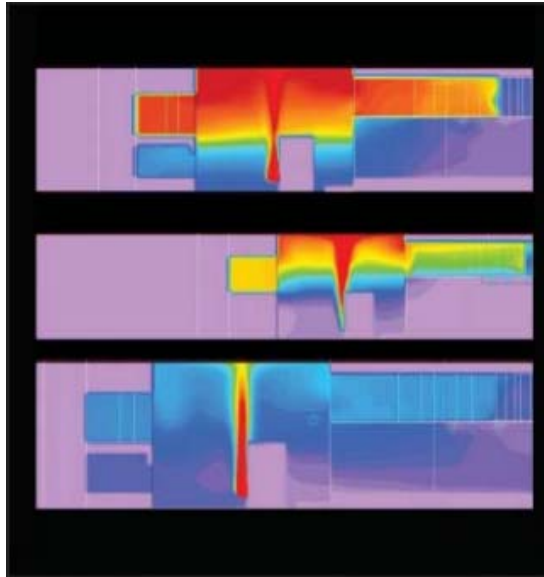


Figure 2. Impact of the extraction flow on the risk of contamination

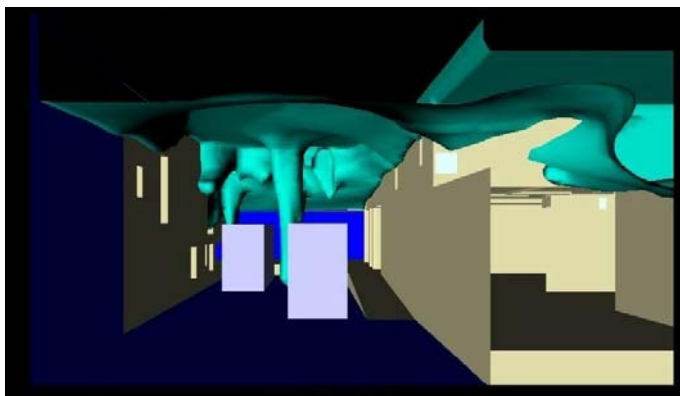


Figure 3. Forecasted carbon monoxide plume

These phenomena were caused by rising airflow due to having extractors at the top, and the high-temperature gases from the vehicle exhausts.

**Proposing modifications to the installations to achieve a good level of safety**

Following the initial study, further airflow simulations showed that simply increasing the volume of blown air through the zone would reduce the concentration and transfers of gaseous vehicle pollutant. However, using exhaust extractors to extract the pollutant gases at source was preferable to simply increasing the overall airflow, because it offered better performance and lower energy consumption.

**Identifying the best positions for gaseous pollutant detectors**

The simulations showed a strong build-up of toxic gaseous pollutants at the top of the space. However, the CO detectors were placed at the bottom in order to detect pollution near human occupants. These CO detectors control the ventilation airflow rate directly, with high extraction flows available in order to protect the staff. Independent from the simulation work, the knowledge of those involved in the study also suggested that the carbon monoxide detectors should be taken off the walls. Carbon Monoxide (CO), being very light, is absorbed into the silica of the concrete walls, where it oxidizes into CO<sub>2</sub> because of the oxygen in the air. Therefore, detectors placed very close to the walls may show a substantially underestimated carbon monoxide concentration.

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