



CHAM

## Modelling of pressurization in HVAC systems

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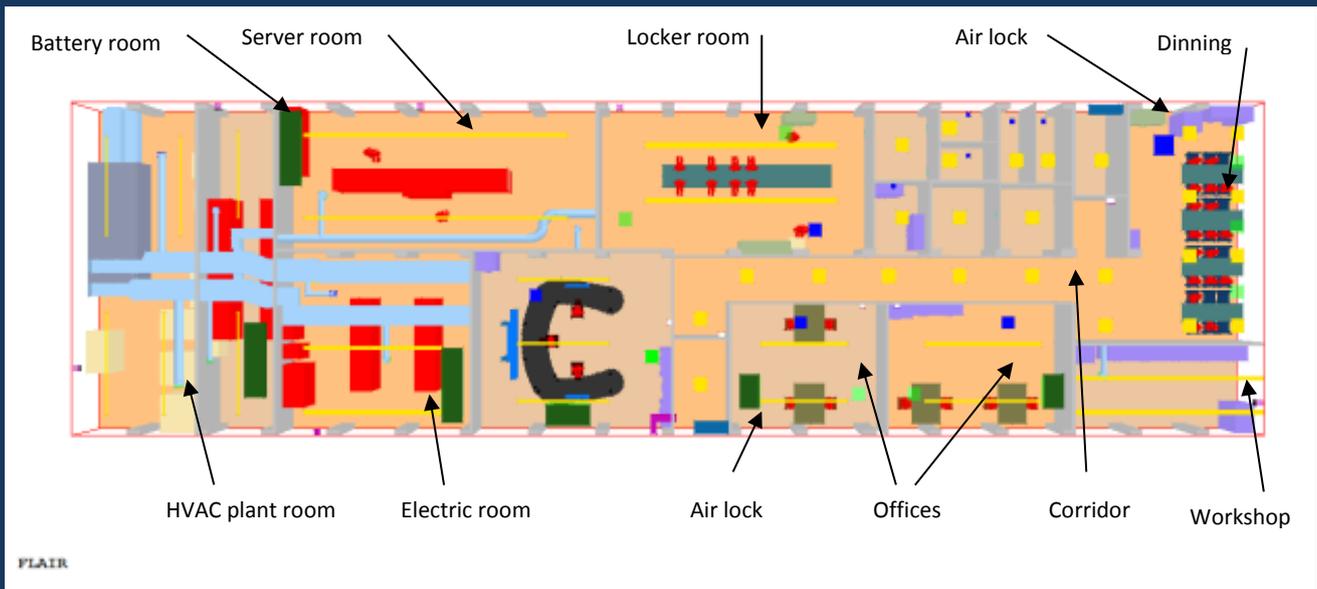
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There is often a need to pressurize buildings, or areas within buildings, in order to protect their occupants from process emissions from outside, or to retain a high level of air purity inside. Examples include refineries, the chemical processing industry, electronics production, hospital environments, and so forth. To ensure that HVAC systems carry out this function effectively, HVAC designers can now accurately test and verify their designs with the aid of CFD technology.

The function and construction of the building described below is unique and is located within a refinery. Its function is technical supervision offices and to house and protect people in the event of pollution release outside (mostly H<sub>2</sub>S). It was decided to check the technical assumptions and functional design of the HVAC system operating in various modes – operating scenarios – using CFD modelling.

The aim of the project, and the HVAC system, is to create and retain an overall overpressure in the interior spaces of the building (see 3D model shown in Figures 1 and 2) relative to the external pressure, wherein the pressurization system was adapted for different room functions. Additionally, it was required that the HVAC control system had to sustain four main operating conditions providing different overpressure values and ventilation air volumes, which were to be verified by four CFD analyses, as follows:-

1. Scenario no 1: HVAC and control system work under normal operation in the *summer time*, with no fire or pollution hazard outside the office block. During this scenario, the following were considered: heat gains (from humans, lights, equipment, external walls/floor/roof), air supplied with constant air temperature chilled and controlled by the AHU (Air Handling Unit), the individual DX-multi-split air conditioners (with heat pump option) dedicated for server room, electrical-power supply room, battery room and 3 office rooms.
2. Scenario no 2: HVAC and control system work with normal operation in *winter time*, with no fire or pollution hazard outside the office block. During this scenario, the following were considered: heat losses, air supplied with constant air temperature heated and controlled by the AHU, the individual DX-multi-split air conditioners with heat pump operation dedicated to individual rooms.
3. Scenario no 3: HVAC and control system work with emergency operation with *partial air recirculation* (in both winter & summer time), with pollutants having been detected in the fresh air ductwork of the AHU. The rate of air entrainment is reduced to a minimum, and the air is filtered.
4. Scenario no 4: HVAC and control system work with emergency operation with *full air recirculation* (in both winter & summer time), when the filtration system is not able to clean the air using fresh air from outside.



**Figure 1 - Top view of 3D model**



**Figure 2 - Side view of 3D model**

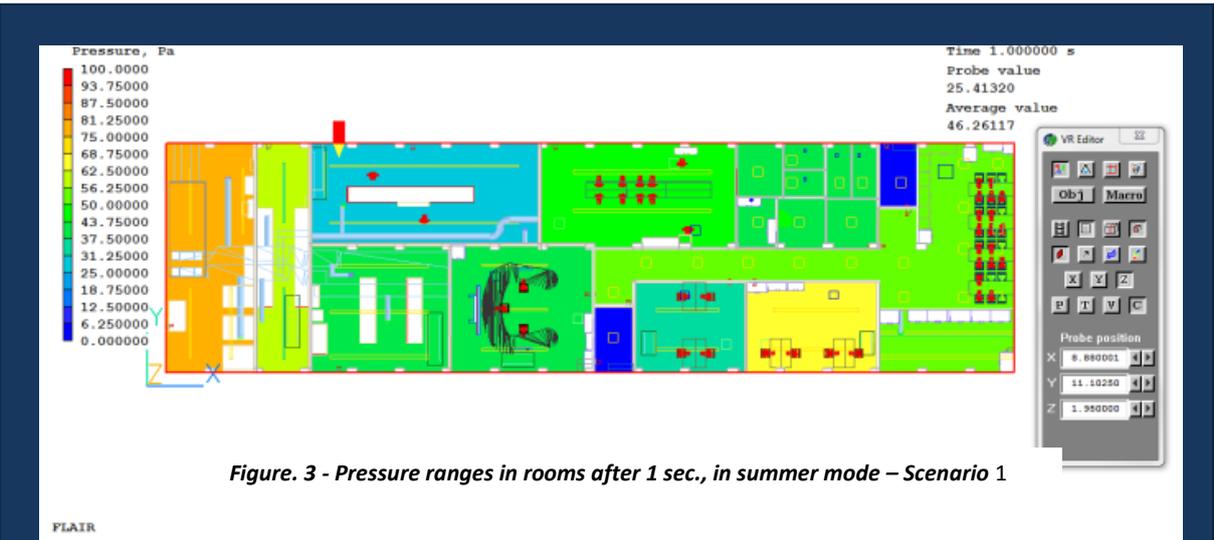
The design involves the use of automatic pressure transfer dampers below the suspended ceiling in the office rooms. The air is transferred towards the corridor if the pressure rises above a set value  $+100\text{Pa}$  and the pressure in the corridor has a lower value. The air is transferred from the corridor towards air locks through the pressure transfer dampers, if the pressure in the air lock has a lower value than in the corridor. Finally, the pressure in air locks is released outside of the building through pressure relief dampers, fitted on external walls and above the floor, set on a value  $+50\text{Pa}$  of overpressure.

In the technical rooms, pressurized air is transferred similarly towards the outside of the building through automatic pressure relief dampers. There are fire dampers and gas-shut-off dampers - located near the pressure transfer dampers - that control flows and adjust the system according to its operating mode (*normal mode* with partial air recirculation or *emergency mode* with full air recirculation).

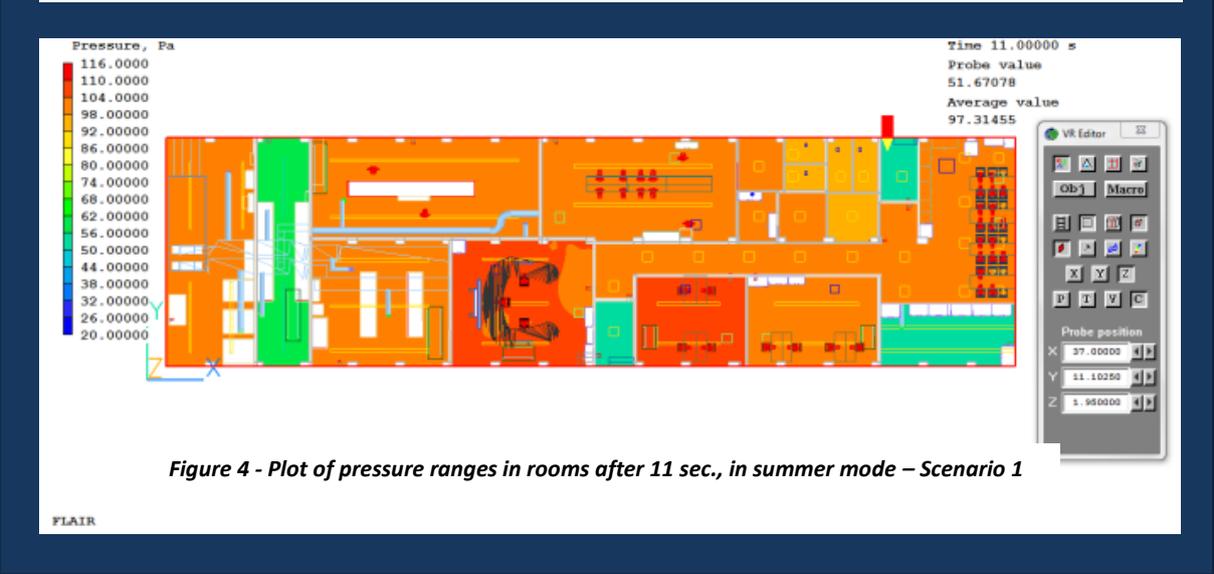
The HVAC system in Scenarios 1 & 2 operates using fresh air from outside and the objective of the ventilation scheme is to produce pressurization (overpressure) in the different areas shown in the CFD model (see Figures.1 and 2):

- HVAC plant room, server room, electrical (power supply) room, lockers rooms with toilets, corridor with dining room, 3 offices: +100Pa
- 2 air locks, battery room, workshop: +50Pa

In Figure 3 can be seen the result of the CFD simulation showing pressure distribution at a time of 1 second for Scenario 1; this assumes that the volume of air supplied and extracted start at the design value. Figure 4 shows pressure ranges after 11 sec.



**Figure 3 - Pressure ranges in rooms after 1 sec., in summer mode – Scenario 1**



**Figure 4 - Plot of pressure ranges in rooms after 11 sec., in summer mode – Scenario 1**

The CFD simulation also predicted the temperature and air flow distribution from diffusers and DX split conditioners during cooling mode in summer time – Scenario 1 (e.g. office room – Figures 5 & 6) and during heating mode in winter time –Scenario 2 (e.g. temperature distribution above the floor – Figure 7).

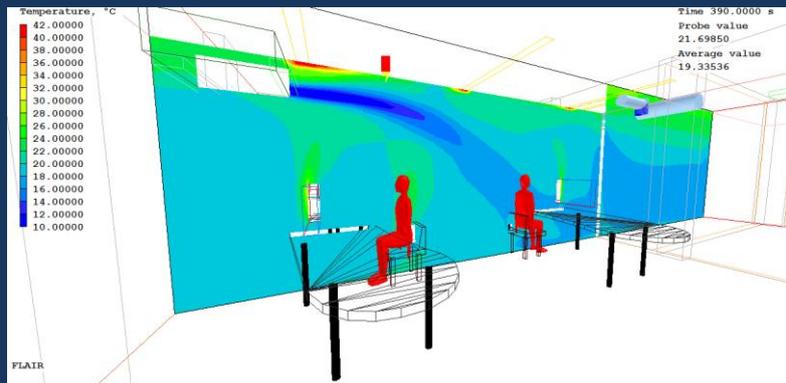


Fig. 5 - Plot of temperature ranges in office/monitoring room, in summer time – Scenario 1

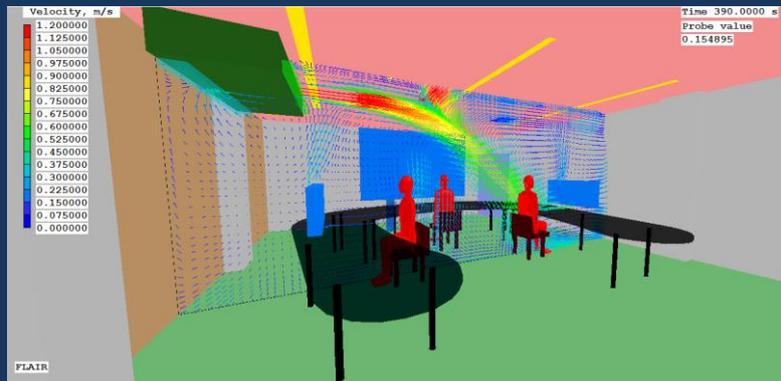


Fig. 6 - Plot of velocity vectors with DX-split air conditioner in office/monitoring room, in summer time – Scenario 1

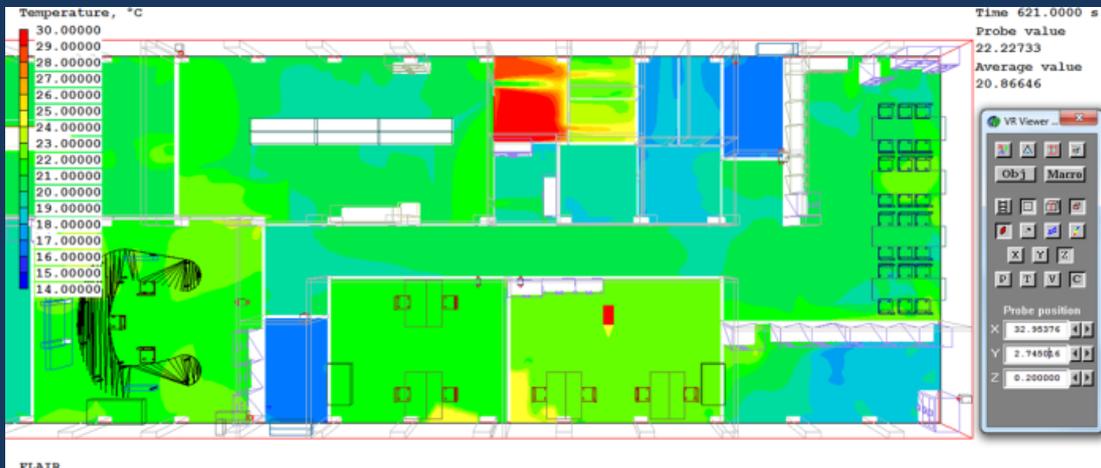


Fig. 7 - Plot of temperature ranges above the floor, in winter time – Scenario 2

The HVAC system in Scenario 3 acts with partial outside (fresh) air and the objective is to produce pressurization (overpressure) in various spaces:

- HVAC plant room, server room, electrical (power supply) room, lockers rooms with toilets, corridor with dining room, 3 offices: +100Pa
- 2 air locks, battery room: +50Pa
- workshop: not pressurized.

Figure 8 shows the result of the CFD simulation showing the pressure range at a time of 1 sec. for Scenario 3. As before, this assumes that the volume of air supplied and extracted commence at the design value. Figure 9 shows the pressure range after 11 sec.



The analysis of each scenario simulated showed that the pressure in the rooms attained the required level very quickly and no case exceeded 9 seconds. The rate of increase in pressure can also be calculated using mathematical formulas, not only via CFD modelling.

The HVAC system in Scenario 4 operates with the full recirculation of air (with the resulting lack of oxygen compensated for by a “life-support system”) and the objective of the ventilation system is to produce pressurization (overpressure) in various spaces:

- lockers rooms with toilets, corridor with dining room, 3 offices: +100Pa
- 2 air locks: +50Pa

- HVAC plant room, server room, electrical (power supply) room, battery room, workshop: not pressurized

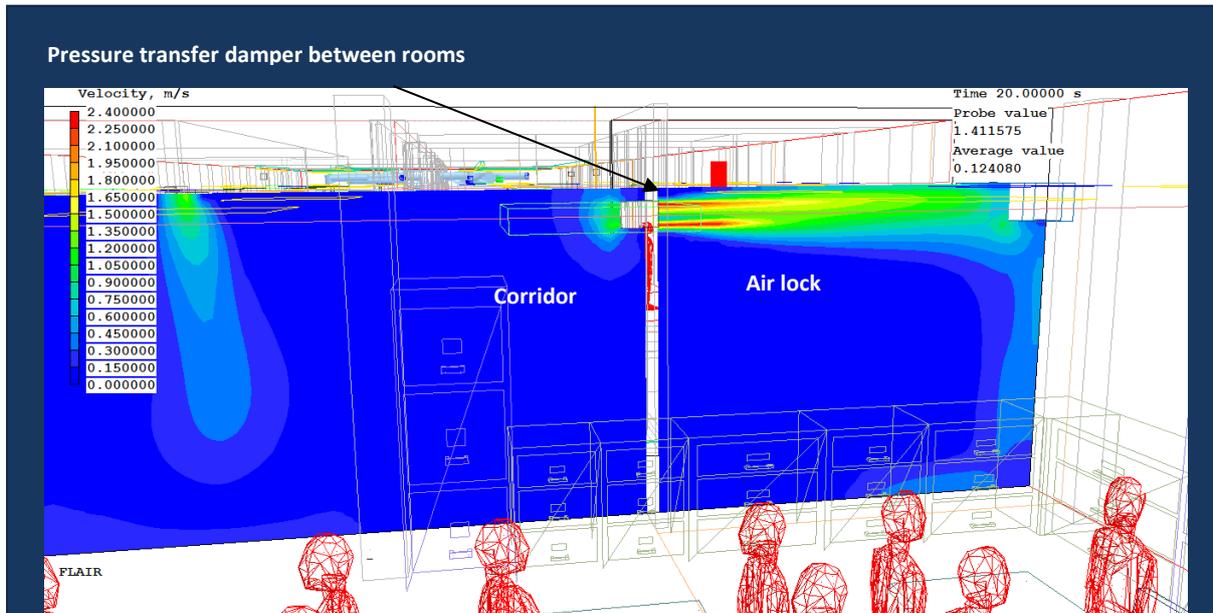


Figure 10 - Plot of velocity plans in cross-section through pressure transfer damper in wall between air lock and corridor – Scenario 4

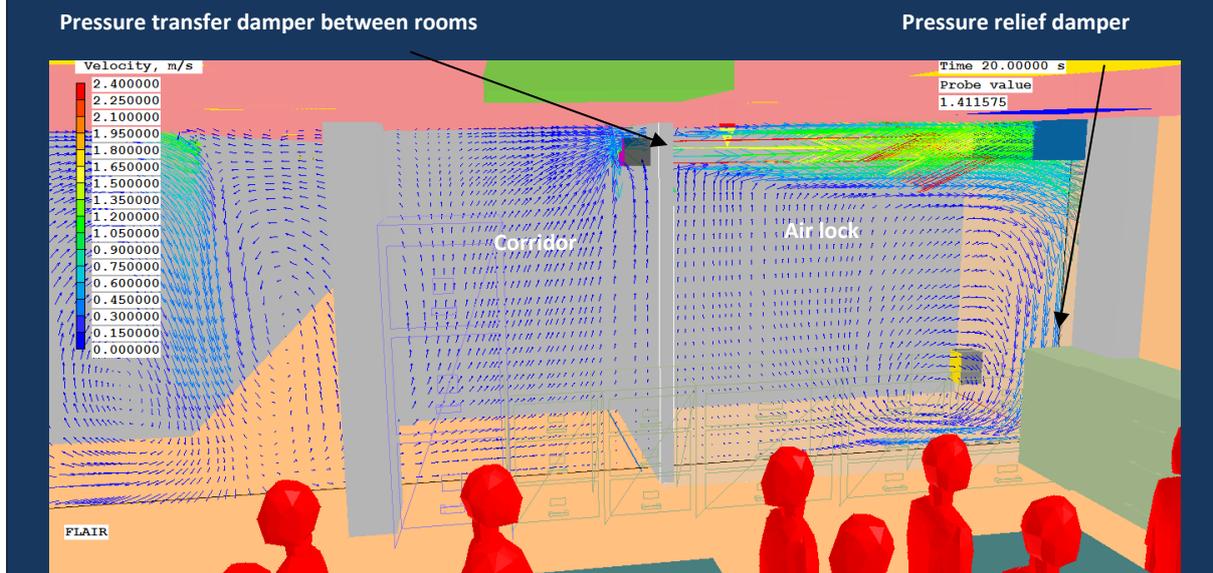


Fig. 11 - Plot of velocity vectors in cross-section through pressure transfer damper in wall between air lock and corridor – Scenario 4

The biggest challenge for any pressurized ventilation system is the correct design of controls and the system of automatic valves regulating the pressure, as well as checking the air-tightness of doors and windows, and the proper estimate of quantities, parameters and identifying the location of potential leaks within the facility.

In fact, it may sometimes be necessary to operate the facility as a completely-sealed entity, where the doors and windows and installation culverts are sealed carefully to the exclusion of any natural ventilation. In some cases,

there may be a necessity to design the exterior walls and ventilation ducts, fire dampers and valves to close in a gas-tight manner to protect the building against penetration of dirt or fumes during periods when the premises are not pressurized.

As it was a pioneering project using CFD discipline for this type of application, CHAM's Dr John Ludwig created especially dedicated models of pressure transfer and pressure relief dampers with mass, temperature and momentum transfers.

The performing of such calculations, estimating and verifying ventilation requirements is a difficult and responsible task, as made clear by the requirements of Polish Building regulations. These state that only people with appropriate education and professional experience can perform such calculations.

The same applies to the CFD calculations where the scope of the calculations have to satisfy the technical and physical goals. If such calculations are performed by people without suitable building expertise, the result may be the refusal of insurance companies to pay compensation in the case of technical problems with the installation.

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