Thermal & CO$_2$ Leakage Analysis of ATLAS USA15 CV Room

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USA15 CV Room.

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Introduction

• In this presentation, CFD simulation process and results for the USA15 CV Room are presented.

• The objective was to study the temperature and the CO$_2$ concentration distributions for different scenarios.

• This will demonstrate how CFD supports in the optimization of the CV room ventilation system and the risk assessment of CO$_2$ cooling systems.

• Insight in to required information, expected output and limitations/simplifications/assumptions.
Location: ATLAS Point 1
Geometry

• Complex geometry takes a lot of computational effort.
• The solution is to simplify some elements of the geometry.
Meshing

- Meshing is a process of creating CFD model from CAD model.
- In the CFD model, the fluid volume is discretized into many small cells, which cumulatively form mesh for CFD analysis.
Thermal loads are applied as heat flux on the surfaces of racks (W/m²).

The main thermal loads of this problem are:

- Pumps.
- Electric racks.
- Frequency variators.
Boundary Conditions: Inlets & Outlets

Case 1: AHU1 OFF, AHU2 OFF
Case 2: AHU1 ON, AHU2 OFF
Case 3: AHU1 ON, AHU2, ON

Air inlets: 1700 m³/h
AHU1: 14000 m³/h
AHU2: 14000 m³/h

Outlets
CO₂ leakage
Ventilation Optimization
Results: Temperature Distribution

AHU1: OFF  AHU2: OFF
- $T_{\text{ave.}} = 30.3$ °C
- $T_{\text{max.}} = 60$ °C

AHU1: ON  AHU2: OFF
- $T_{\text{ave.}} = 22.7$ °C
- $T_{\text{max.}} = 52.4$ °C

AHU1: ON  AHU2: ON
- $T_{\text{ave.}} = 19.5$ °C
- $T_{\text{max.}} = 40.1$ °C

$X = 8.3$ m

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AHU1: ON  AHU2: ON
- $T_{\text{ave.}} = 19.5$ °C
- $T_{\text{max.}} = 40.1$ °C

$X = 8.3$ m
Results: Temperature Distribution

AHU1: OFF
AHU2: OFF

- $T_{p1} = 45.7 \, ^\circ C$
- $T_{p2} = 20.3 \, ^\circ C$

AHU1: ON
AHU2: OFF

- $T_{p1} = 30.3 \, ^\circ C$
- $T_{p2} = 19.1 \, ^\circ C$

AHU1: ON
AHU2: ON

- $T_{p1} = 24.2 \, ^\circ C$
- $T_{p2} = 17.7 \, ^\circ C$

$Z = 6.1 \, m$
Results: Temperature Distribution

AHU1: OFF  
AHU2: OFF

AHU1: ON  
AHU2: OFF

AHU1: ON  
AHU2: ON

Y = 5 m

[°C]
Results: Ventilation Optimization

Consequences of installing the CO$_2$ – 2PACL system:

- In the worst case scenario, AHU1 OFF & AHU2 OFF, the temperatures the workers will be exposed to are too high (>30 °C) for normal working conditions.

- In the current scenario, AHU1 ON & AHU2 OFF, the ground level temperatures are acceptable, but the mezzanine 2$^{nd}$ level will reach high local temperatures.

- If an additional AHU is installed, AHU1 ON & AHU2 ON, temperatures everywhere are in the safety limit of long – term working in underground caverns (< 26 °C).
CO$_2$ Leakage
Results: Steady State

Leak enters at high speed (150 m/s).

Steady state
AHU1: OFF
AHU2: OFF
CO₂: 100 g/s

X = 8.3 m

Z = 16.8 m
Results: Steady State

Steady state
AHU 1: OFF
AHU 2: OFF
CO₂: 100 g/s

Y = 1.6 m

Y = 4.1 m

CO₂ conc.
Results: Scenarios

Final concentration (assuming perfect mixing):
\[ C = \frac{q_{CO_2}}{N} \left(1 - e^{-Nt}\right) \]

The \( CO_2 \) leakage can bear 2 scenarios, considering a 1 ton reservoir.

- **Small leakage**: A steady state is achieved.
  - Example: With 100 g/s, \( CO_2 \) runs out after 20 hours.

- **Large leakage**: A steady state is NOT achieved.
  - Example: With 750 g/s, \( CO_2 \) runs out after 20 minutes.

- Simulation of 20 minutes consumes too many resources (>20 days).
- Simulation of 2 minutes is enough: evacuation time for the room.
Results: Transient

Transient: 2 min.
AHU1: OFF
AHU2: OFF
CO₂: 750 g/s

Z = 16.8 m

T = 10 s
T = 1 min
T = 2 min

X = 8.3 m

Z = 16.8 m

T = 10 s
T = 1 min
T = 2 min

0% 1% 2% 3% 4%

CO₂ conc.

IDTL
Results: Transient

T = 10 s

T = 1 min

T = 2 min

Y = 2 m

IDTL

CO₂ conc.

0% 1% 2% 3% 4%
Results: Transient

Transient: 2 min.  
AHU1: OFF  
AHU2: OFF  
CO$_2$: 750 g/s
Results: CO₂ Leakage

Consequences of installing the CO₂ – 2PACL system:

• The CO₂ quickly extends in the room, causing concentrations higher than the safety limits (IDTL, 4%).

• The areas immediately close to the leak reach the 4% IDTL in 40 seconds.

• The mezzanine area takes longer to increase the CO₂ concentration, due to the air renewal of the inlets and the distance with the leak.
Conclusion

CFD served as a powerful tool to solve the ventilation optimization and CO₂ leakage analysis of the CV Room at ATLAS:

• Accurate results concerning the air stratification in the CV room.

• Study of the ventilation system behavior in different scenarios (failure of AHUs, additional AHU, etc.).

• Examination of the CO₂ concentrations if a leak occurs in the 2PACL system.
Thank you for your attention!...
Any questions?

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