

ODH SIMULATIONS BENCHMARK AND ACCESS CONDITIONS TO RF SECTOR

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Content

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- Risk Assessment & Scenarios
- Conditions
- ODH Results & Comparison
- Emergency Extraction
- Conclusion
- Benchmark Study
- Next Simulations



Oxygen Deficiency Hazard (ODH)

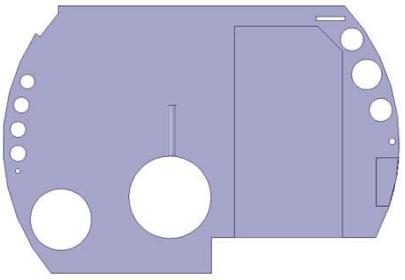
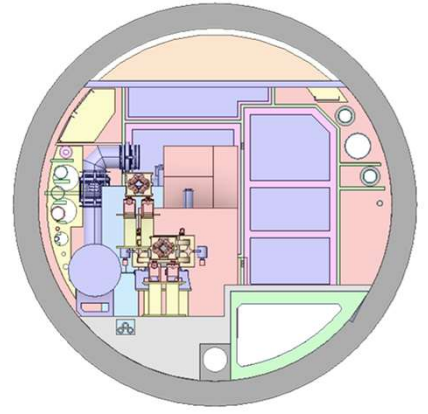
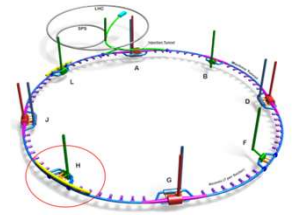


Minimum safe oxygen level in the tunnel is assumed as %18.

Oxygen (%vol)	Effects & Symptoms
23.5	Maximum "Safe Level" (23% is often the High level alarm of most O ₂ detectors)
21	Typical O ₂ concentration in air
19.5	Minimum "Safe Level" (19% is often the Low level alarm of most O ₂ detectors)
15-19	First sign of hypoxia. Decreased ability to work strenuously. May induce early symptoms in persons with coronary, pulmonary or circulatory problems
12-14	Respiration increases with exertion, pulse up, impaired muscular coordination, perception and judgment
10-12	Respiration further increases in rate and depth, poor judgment, lips blue
8-10	Mental failure, fainting, unconsciousness, ashen face, blueness of lips, nausea, vomiting, inability to move freely
6-8	6 minutes - 50% probability of death 8 minutes - 100% probability of death
4-6	Coma in 40 seconds, convulsions, respiration ceases, death

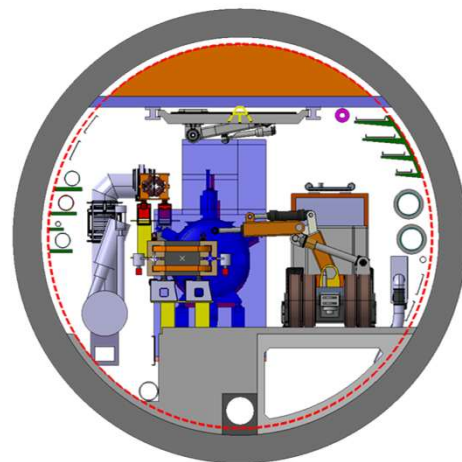
Ref: <https://emfsurvey.com/indoor-air-oxygen-levels-and-oxygen-deprivation-effects/>

Reference Version



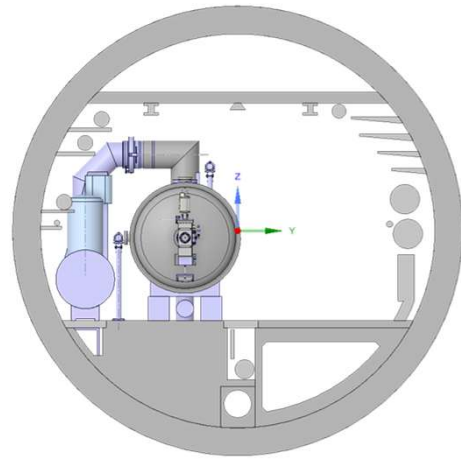
Version: 06.2023
 FCC Tunnel Point H – RF Section
*Previous version
 used for simulations*

Integration



<https://indico.cern.ch/event/1359335/#2-coupe-type-fcc>

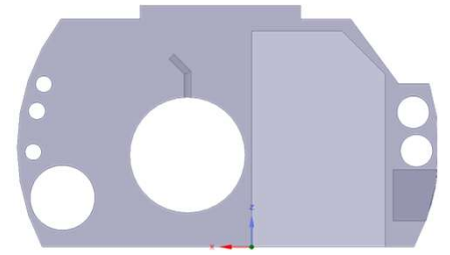
SY-RF



<https://indico.cern.ch/event/1359337/#4-fcc-ee-rf-study>

Version: 04.2024
 FCC Tunnel Point H – RF Section
*The latest version
 used for simulations*

Fluid Domain



Preliminary Risk Assessment & Scenarios

For 400 MHz Cavity

Class/Case	Risk Situation	Mass Flow	Pressure Reached [bara]	Discharge Diameter
1	Static losses on cryomodule insulated from cryogenic plant	10.36 g/s	~ 1.6	$\varnothing_{\min} = 3.48\text{mm}$ 1 SV of DN <5mm
2	Insulation vacuum break	4.55 Kg/s	~ 1.95	$\varnothing_{\min} = 62\text{mm}$ 1 x BD DN80
3	Beam vacuum break (100 mm aperture)	19.57 Kg/s	~ 1.95	$\varnothing_{\min} = 130.5\text{mm}$ 1 x BD DN150 or 2 x BD DN100 (each one taking half of the flow rate)

Assumption: Same discharge area from the LHC risk assessment

Scenario	Number of Discharge Points	Discharge Diameter (each point) [mm]	Discharge Rate (each point) [Kg/s]
SRF01	1	100	20
SRF02	2	100	10 (20 / 2)
SRF03	1	150	20

Ref: "FCC-ee CM Helium Safety Study", EDMS 3103096

Data from initial discussion, more up-to-date values have been provided by SY-RF

Risk Assessment & Scenarios

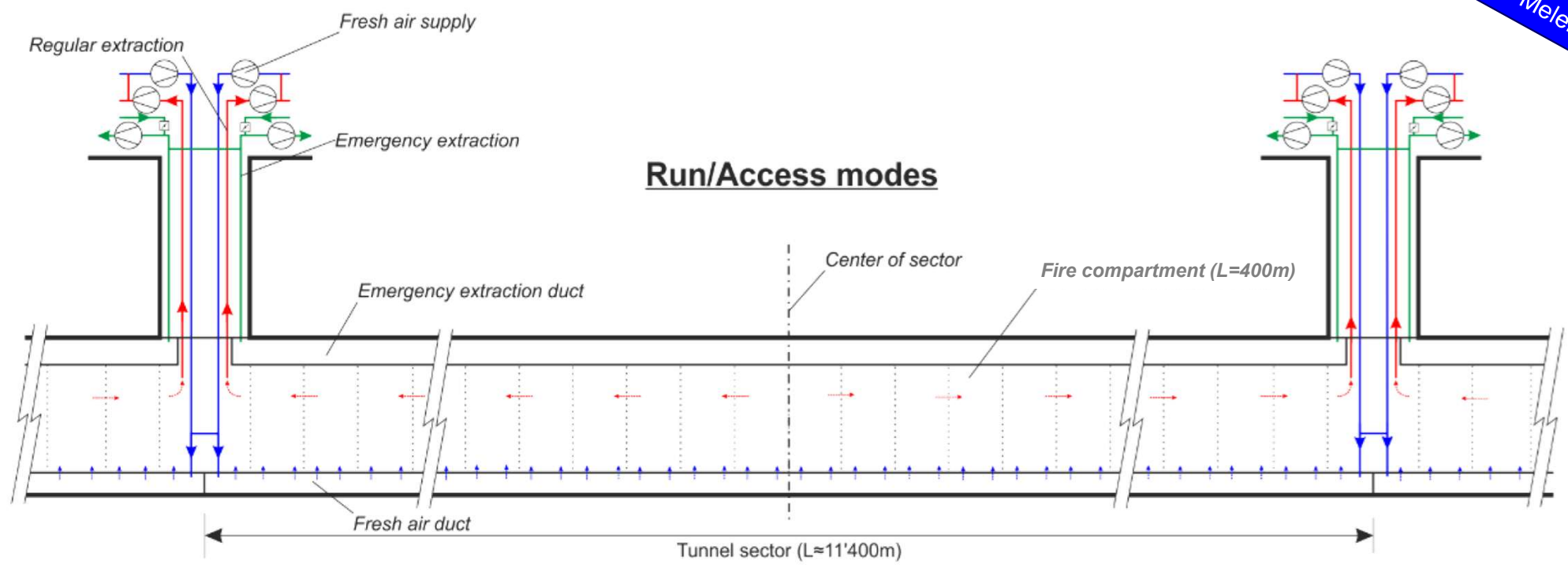
SC	Discharge Points	Diameter [mm]
SRF01	1	100
SRF02	2	100
SRF03	1	150

Helium Release:

- Max. Helium inventory 115.7 kg
- Total mass flow rate 20 kg/s Helium
- Discharge pressure 2 Bar (Total)
- @400 MHz Cryomodule;
 - Total release time = $115.7 / 20 = 5.8$ seconds | **6 seconds**
- Additional 60 s after helium release cut-off (66 s in total)

Semi-Transverse Ventilation Concept (27000 m³/h)

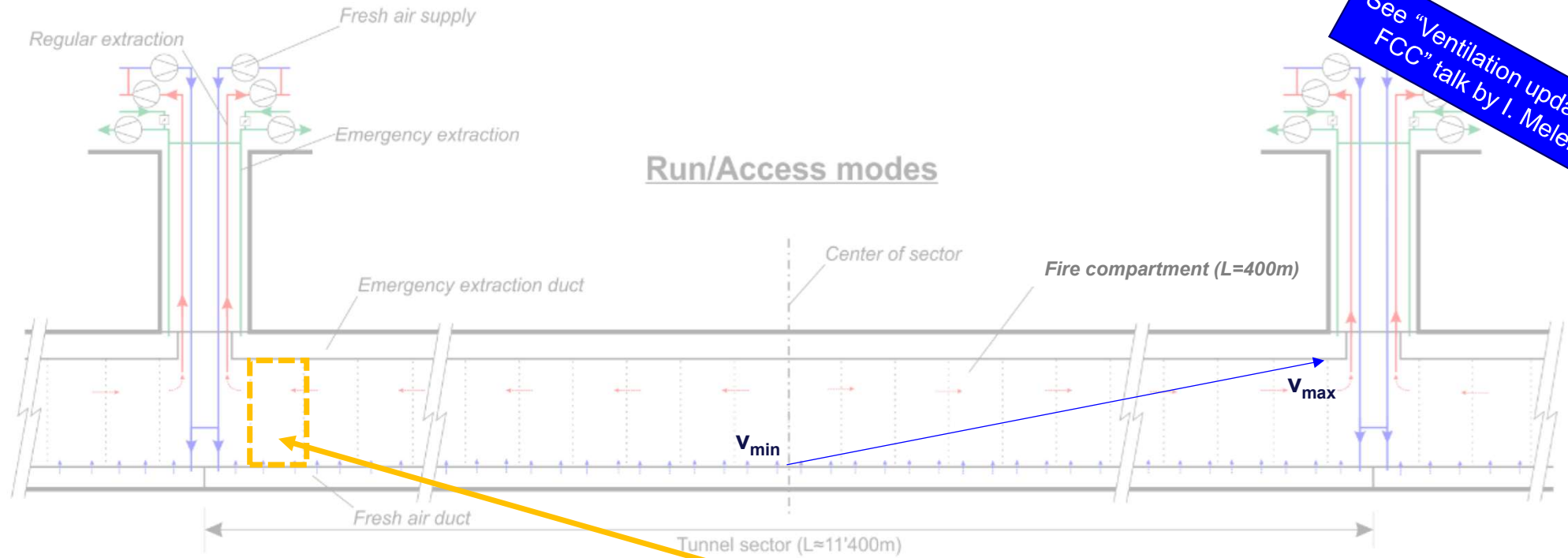
See "Ventilation update for FCC" talk by I. Melero



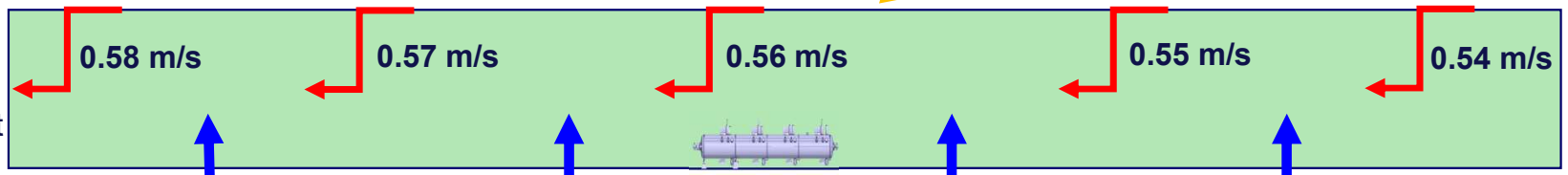
Run/Access modes

The Worst Case – The Last Compartment in the Semi-Transverse Ventilation Concept (27000 m³/h)

See "Ventilation update for FCC" talk by I. Melero



Average Air Velocity in the tunnel;



Pressure Outlet
 $D_h = 4.1 \text{ m}$
 $A_h = 13.05 \text{ m}^2$

Fresh Air Supply
465 m³/h (0.1525 kg/s)
@26-27°C

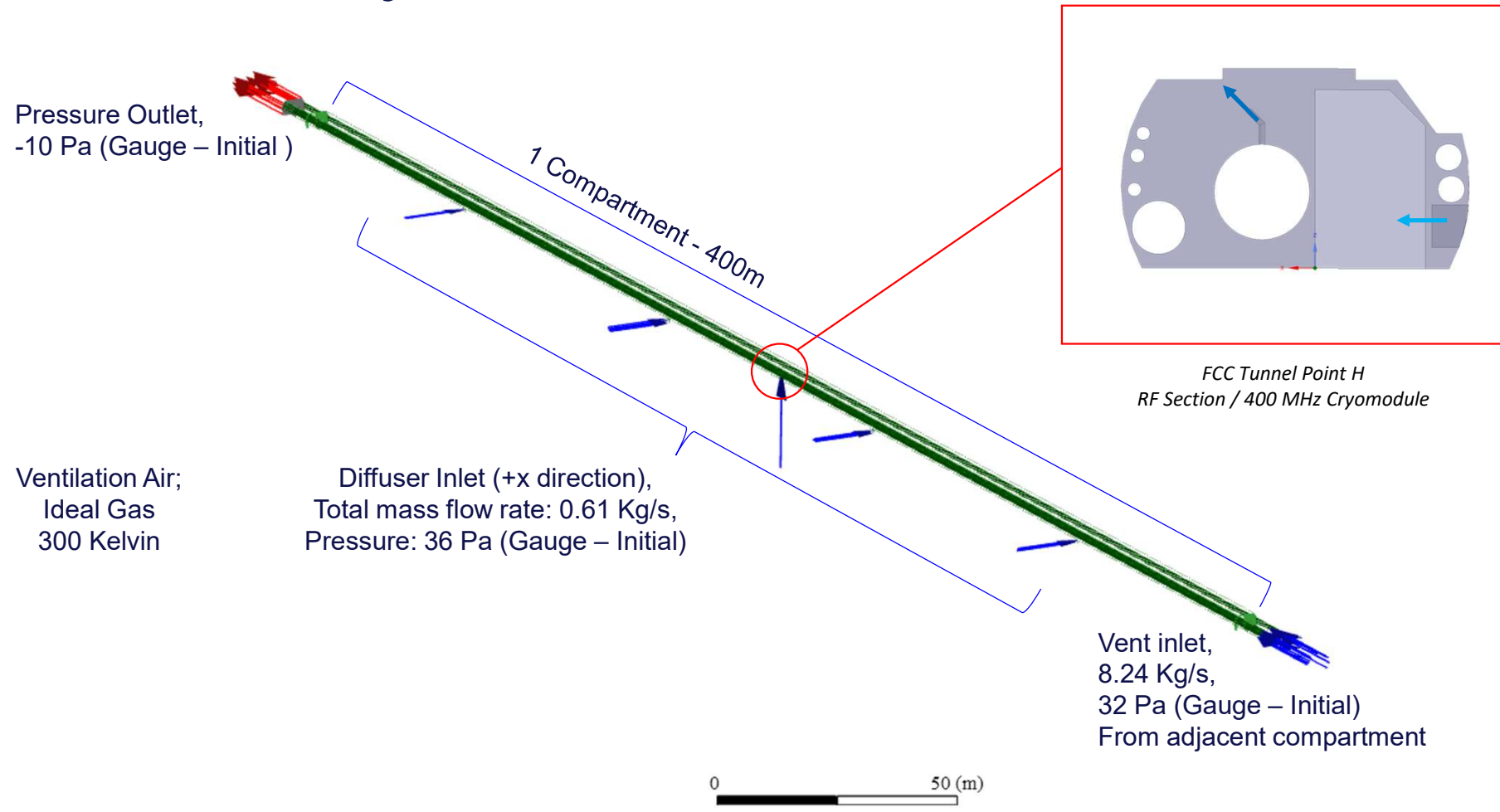
Fresh Air Supply
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@26-27°C

Fresh Air Supply
465 m³/h (0.1525 kg/s)
@26-27°C

Air Ventilation Supply
From Adjacent Comp.
25140 m³/h (8.24 kg/s)
{27000 – (465 x 4) m³/h}
@26-27°C

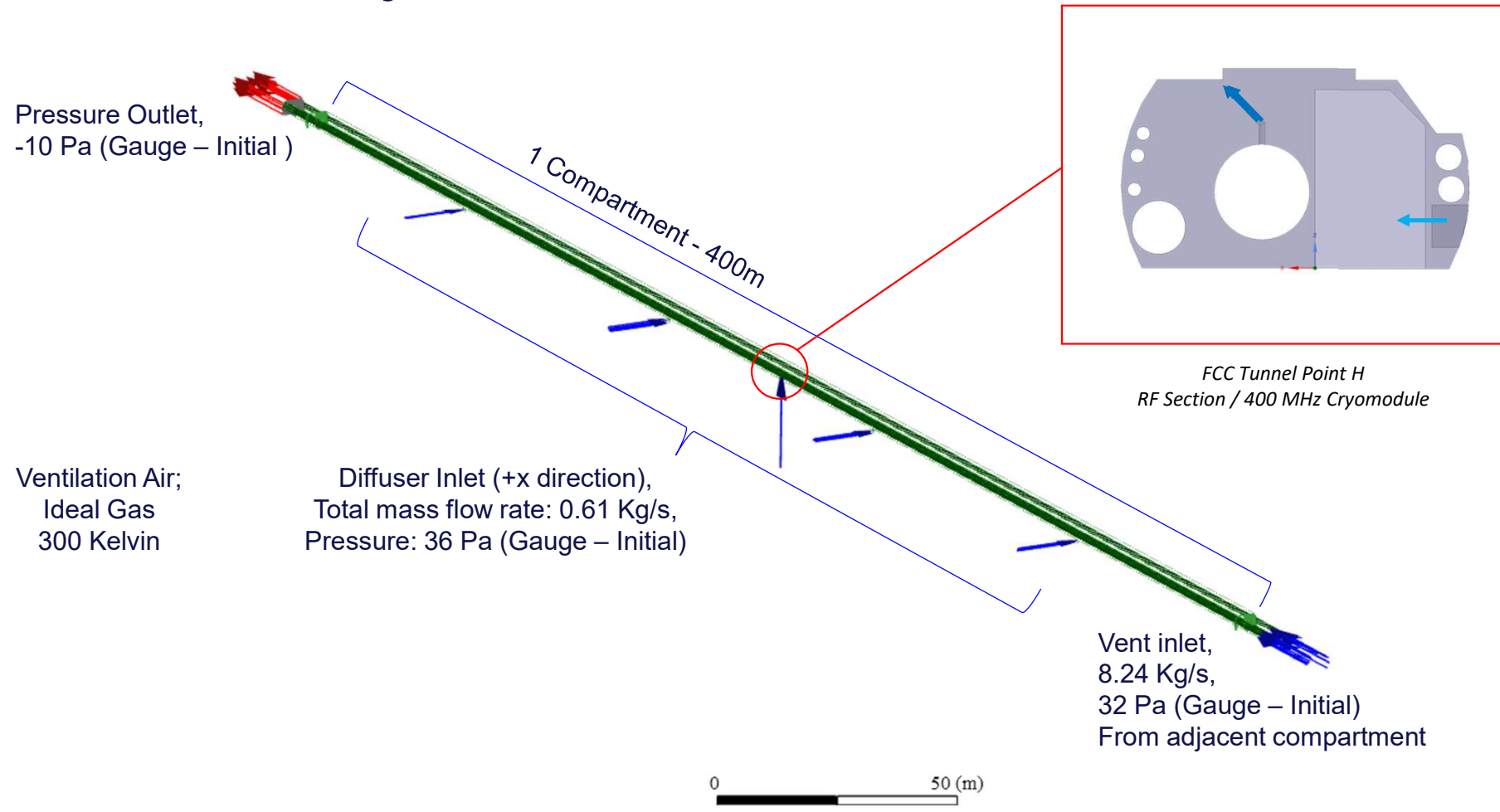
Boundary Conditions – SRF01 1xDN100



Helium Conditions

- 1 x DN100 Inlets
- Ideal Gas
- 5.32 K
- Total 20 kg/s
- 200000 Pa (2 Bar Absolute)
- Continuously
- Discharge Ø 100 mm
- 1 release point

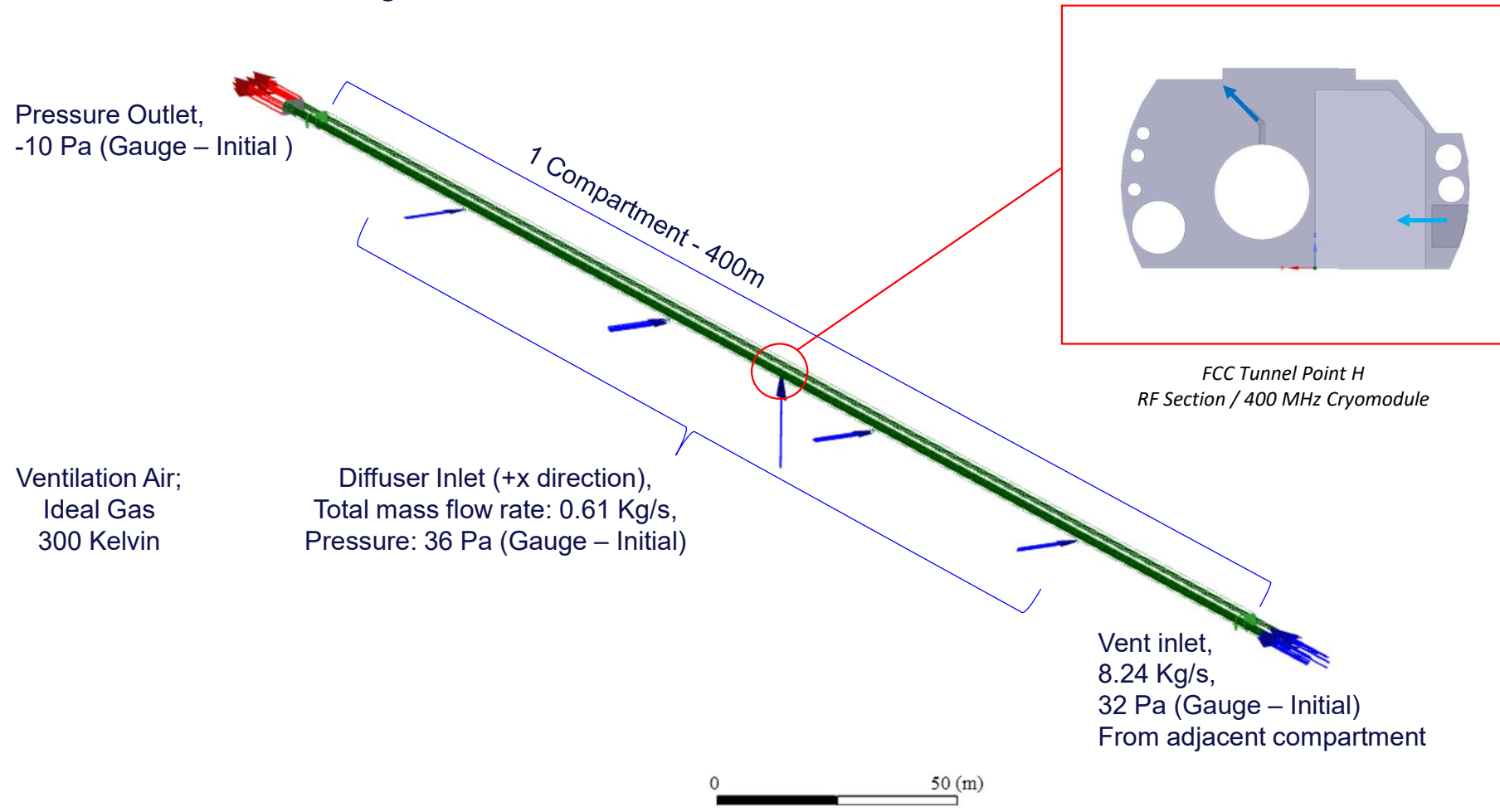
Boundary Conditions – SRF02 2xDN100



Helium Conditions

- 2 x DN100 Inlets
- Ideal Gas
- 5.32 K
- Total 20 kg/s (10 kg/s each)
- 200000 Pa (2 Bar Absolute)
- Continuously
- Discharge Ø 100 mm
- 2 release points

Boundary Conditions – SRF03 1xDN150

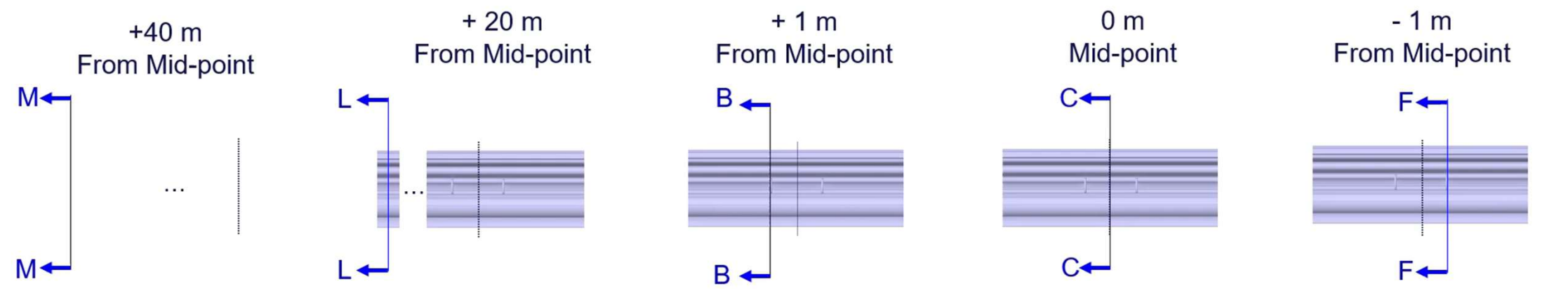
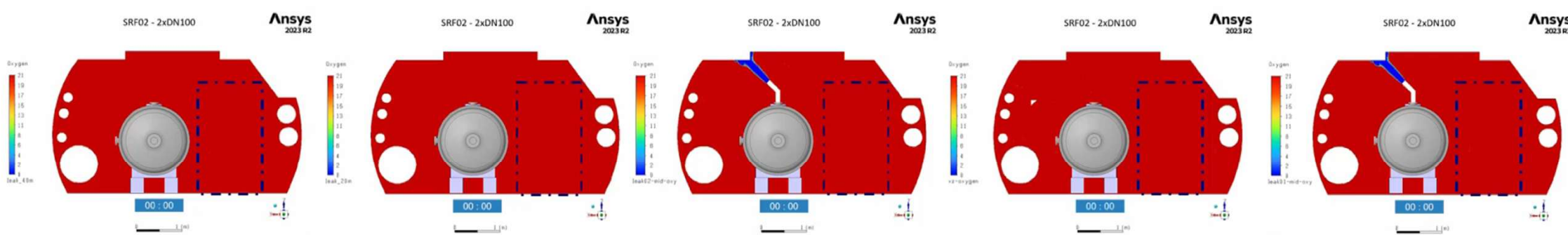


Helium Conditions

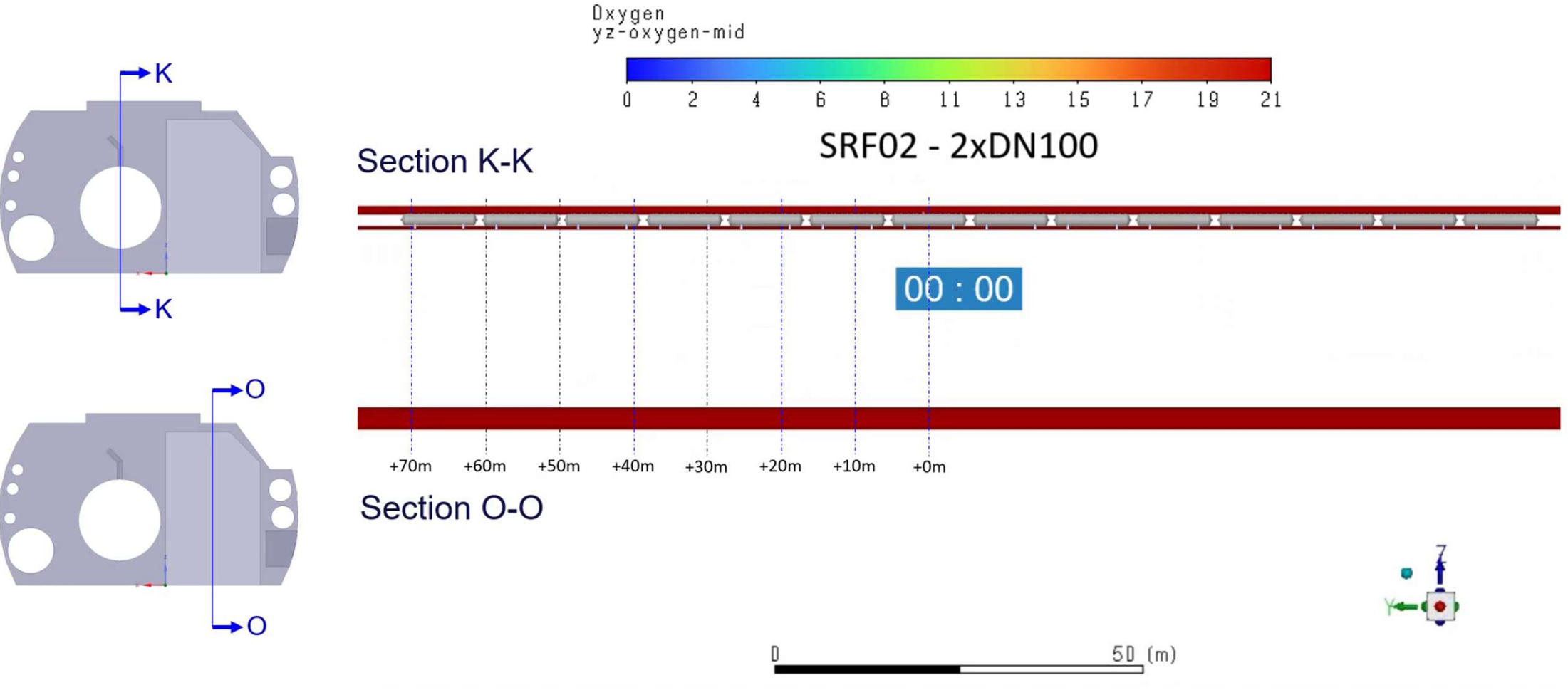
- 1 x DN150 Inlets
- Ideal Gas
- 5.32 K
- Total 20 kg/s
- 200000 Pa
- (2 Bar Absolute)
- Continuously
- Discharge Ø 150 mm
- 1 release point

Results – SRF02 (2xDN100) 66 Seconds

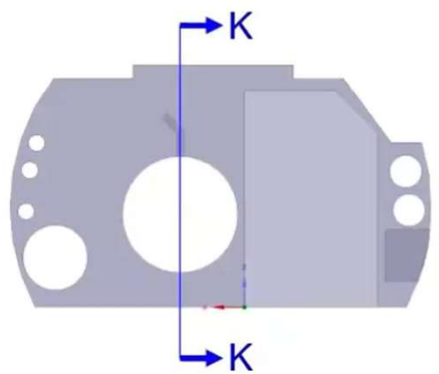
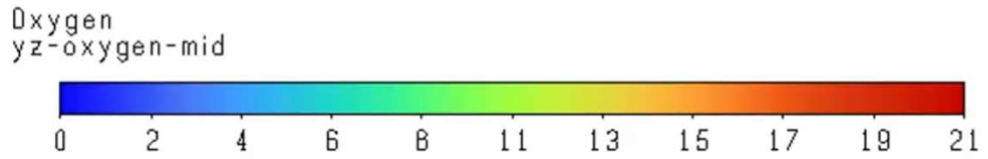
Results – SRF02 (2xDN100) 6 + 60 Seconds



Results – SRF02 (2xDN100) 6 + 60 Seconds

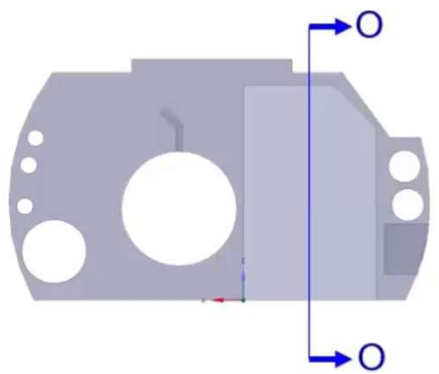
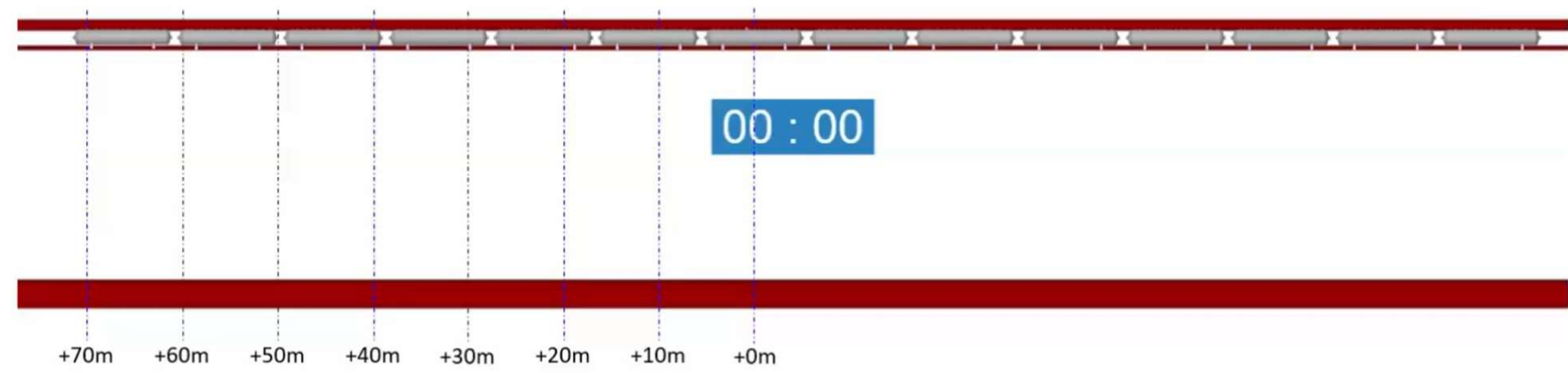


Results – SRF02 (2xDN100) 6 + 60 Seconds

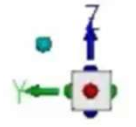


Section K-K

SRF02 - 2xDN100

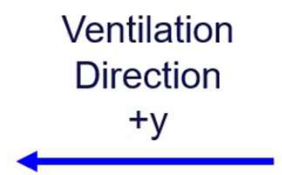
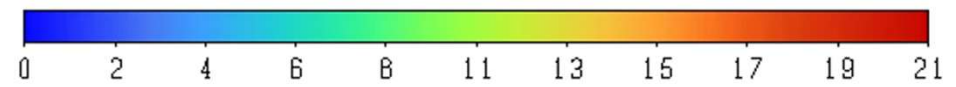


Section O-O



Comparison

Oxygen
yz-oxygen-mid



Section O-O

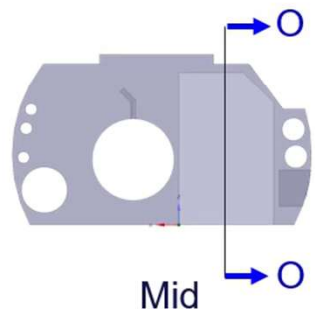
SRF01 - 1xDN100

SRF02 - 2xDN100

SRF03 - 1xDN150

+90m +80m +70m +60m +50m +40m +30m +20m +10m +0m

00 : 00



Evacuation Path

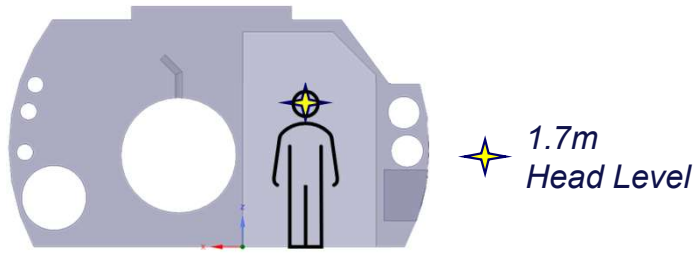
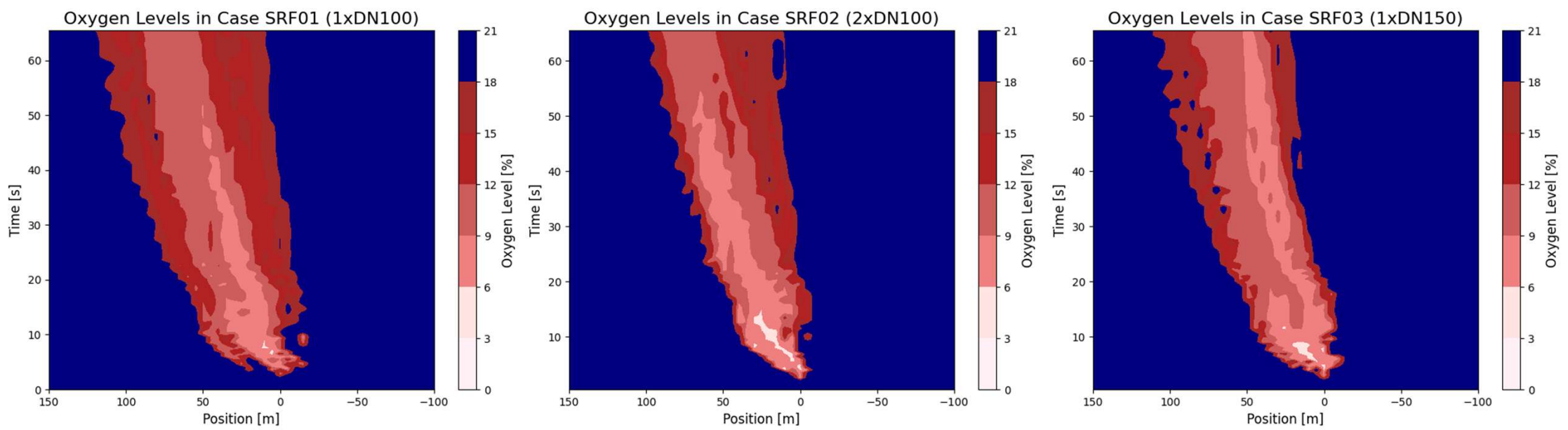
He Plug
size

SC	Cloud front [m/s]	He Plug (< 6s) [m/s]	He Plug (≥ 6s) [m/s]	He Plug (≥ 40s) [m/s]	Plug size [m]
SRF01	~2.7	~6	~1.5	~0.7	~73.2
SRF02	~2.5	~4.7	~1.5	~0.9	~53.3
SRF03	~2.6	~5.4	~1.5	~0.7	~56

!Mid-Cryo section values!

Propagation Speed

Oxygen Level at Occupant's Head Level

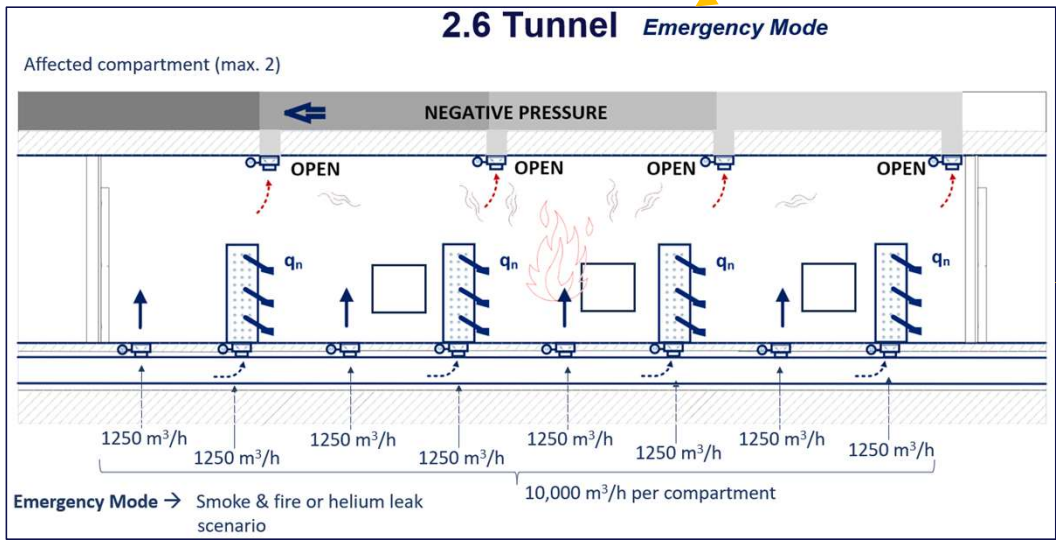
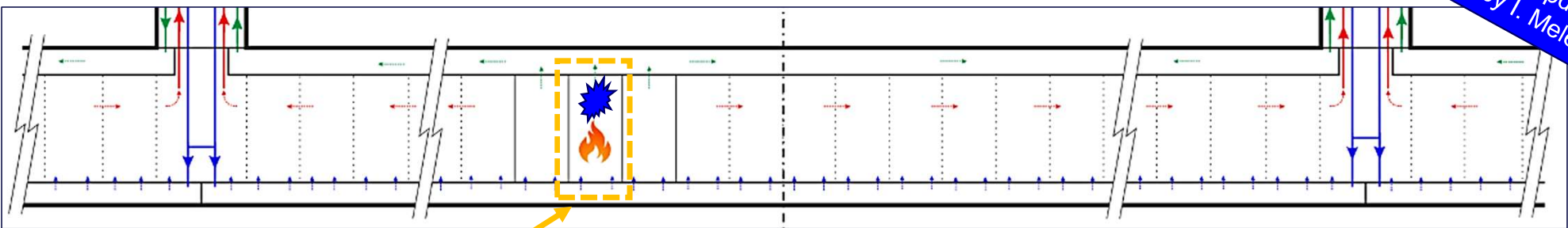


Helium Release Conclusions

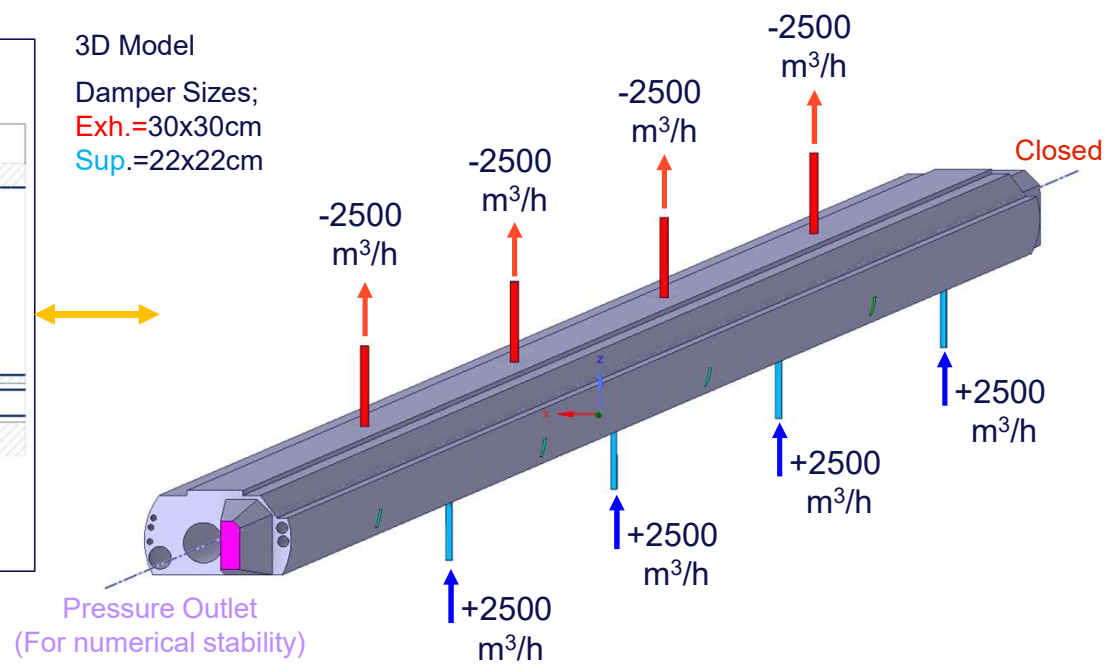
- Oxygen level has been **decreased** below %19 in **3 seconds** near release points,
- Helium (gas) released from **one single release point with DN100** possesses **greater momentum** compared to releasing simultaneously from **2 points** or **single point with bigger** pipe diameter.
- **Turbulence** and **pressure oscillations** occur in **all scenarios**, creating a **Helium plug** which **fills the cross-section** for several meters,
- SRF02 (2xDN100) and SRF03 (1xDN150) seem to have **similar impact** although SRF02 induces a slightly **lower cloud propagation**.
- **Active extraction** of Helium and safe **evacuation** of occupants should be assessed.

Emergency Extraction

See "Ventilation update for FCC" talk by I. Melero



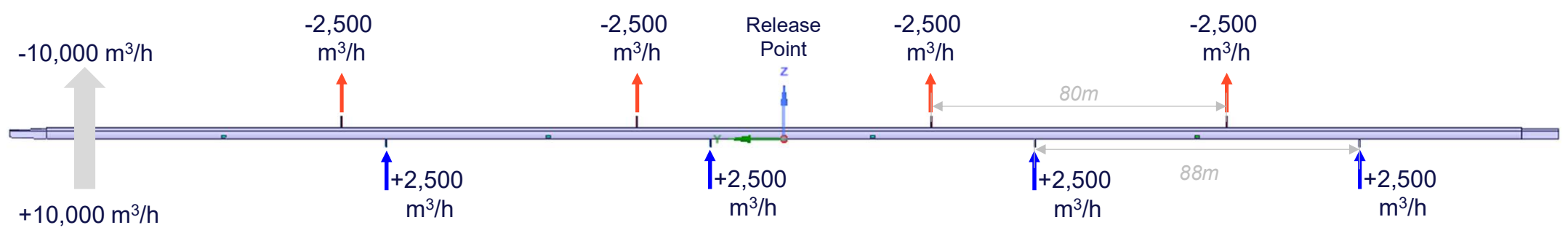
3D Model
 Damper Sizes;
 Exh.=30x30cm
 Sup.=22x22cm



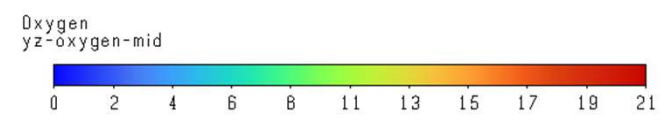
<https://indico.cern.ch/event/1298458/timetable/#38-ventilation-strategy-for-th>

Emergency Extraction

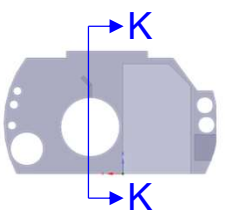
Extraction Supply: 10,000 m³/h Fresh Air @22°C



SRF03 - 1xDN150



K-K Section

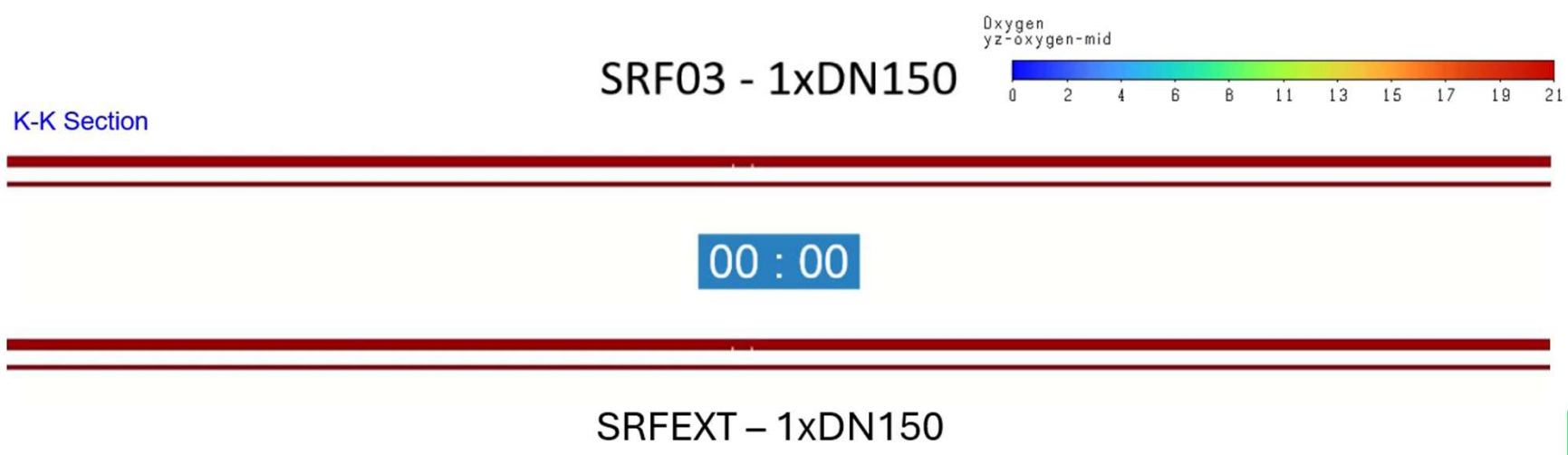
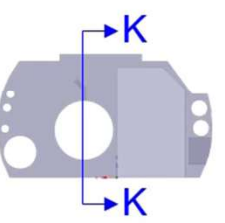
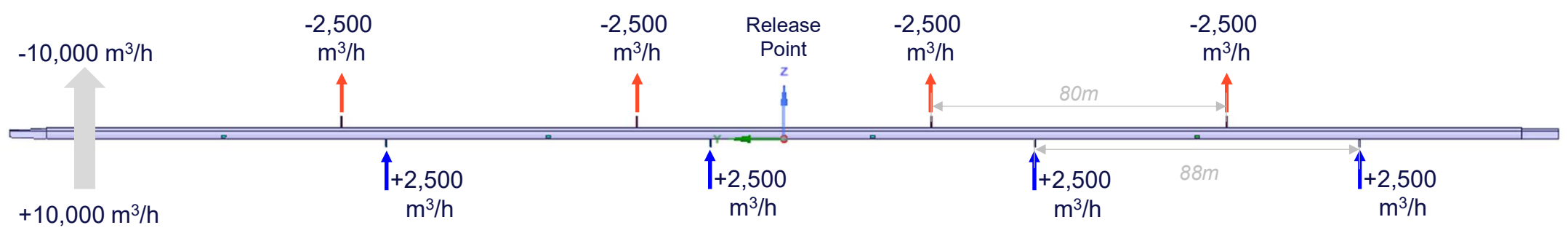


t=30 s
Max. Extraction Activated!

SRFEXT - 1xDN150

Emergency Extraction

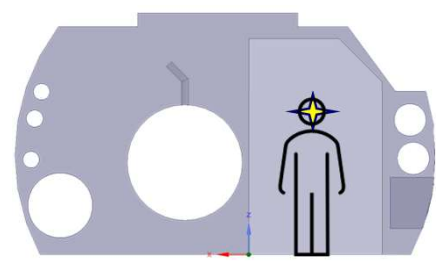
Extraction Supply: 10,000 m³/h Fresh Air @22°C



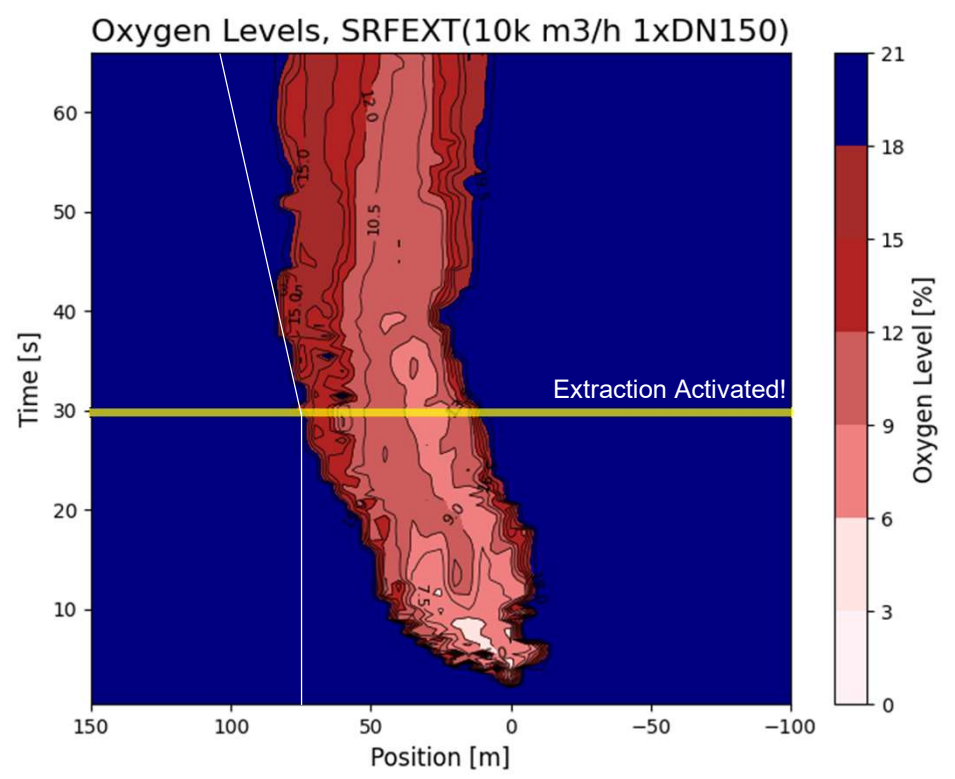
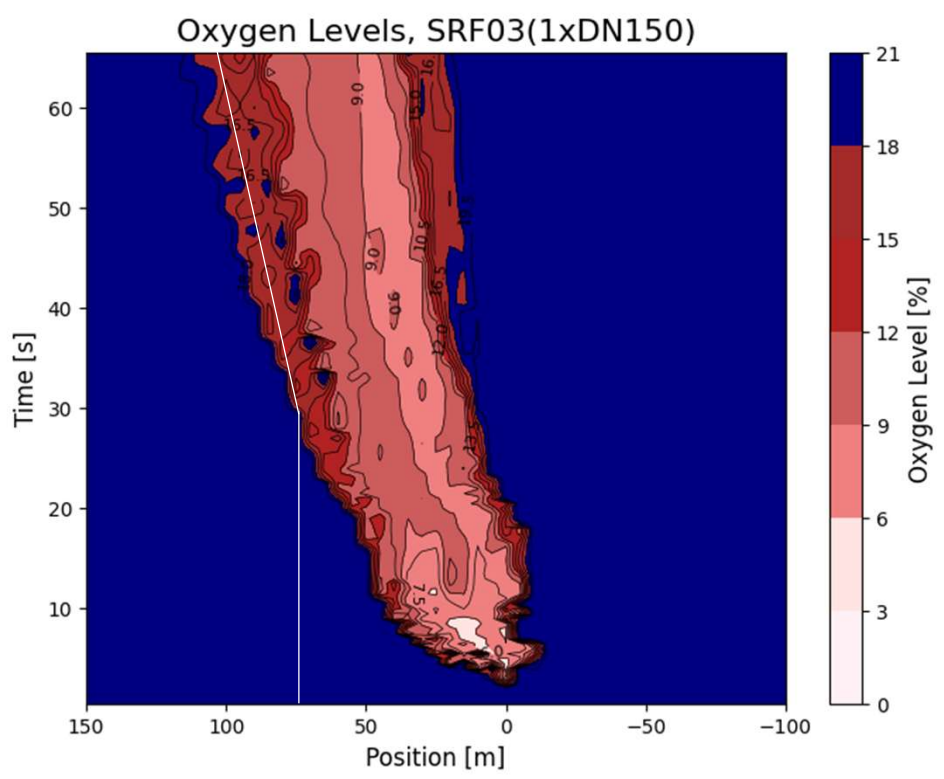
Emergency Extraction

– Occupant's Position

Position: +75 [m]
Reaction time*: 30 [s]
Walking speed*: 0.8 [m/s]



★ 1.7m
Head Level

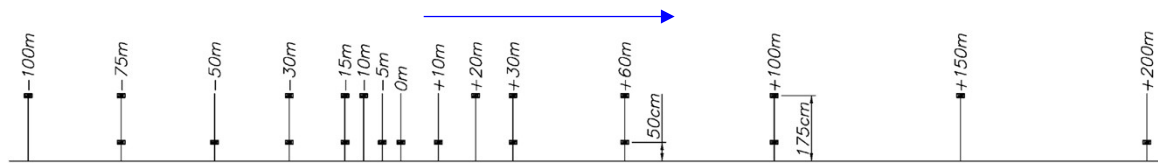


*Ref: BS PD 7974-6

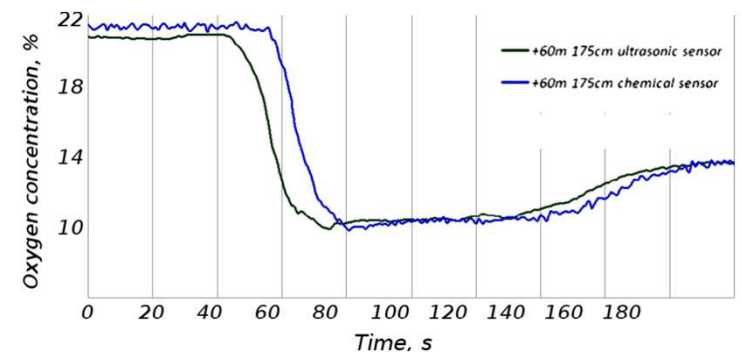
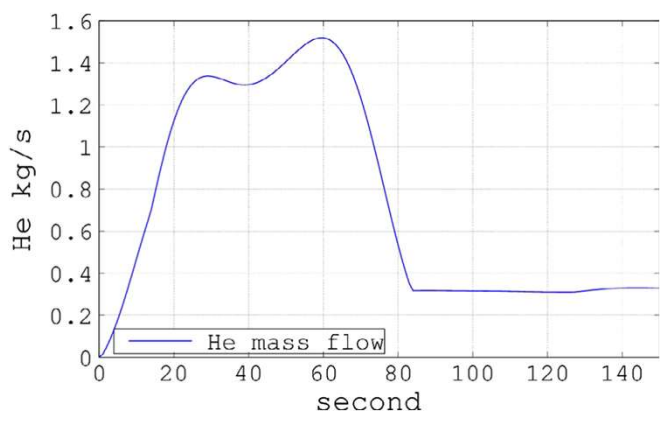
Final Conclusions

- The emergency extraction **stopped** the propagation of the helium cloud and provided a **safe margin** for occupants evacuating.
- Providing the Q_{\max} extraction **as fast as possible** is important,
- **Access** to RF section should be studied in further details,
- Potential access conditions should be discussed with SY-RF team (**please see talk by K.Canderan, May 21st**)
 - For interventions, **warming up the targeted cryomodules**: definition of 'safe zone',
 - Use of special **personal protective equipment (PPE)**, while transiting through the sector to the workplace.

Benchmark Study

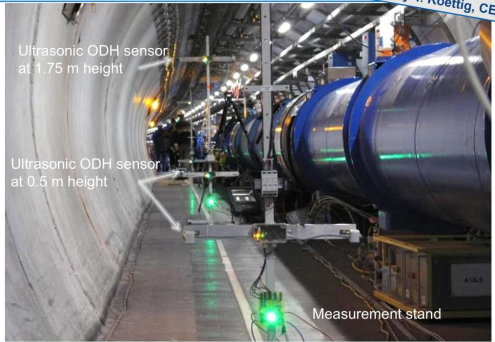


He spill test set-up - 2014



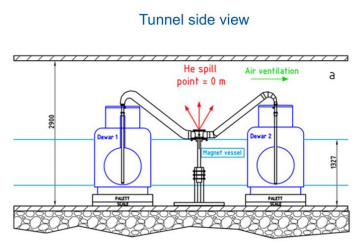
Helium Spill Test in LHC Tunnel – Instrumentation

Courtesy T. Koettig, CERN

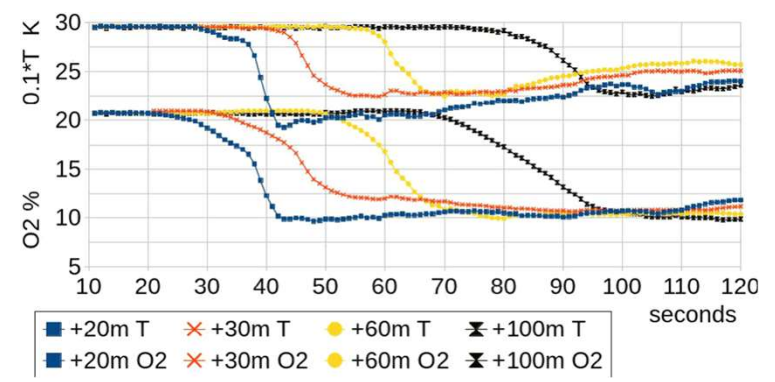


Helium Spill Test in LHC Tunnel – Experimental Set-up

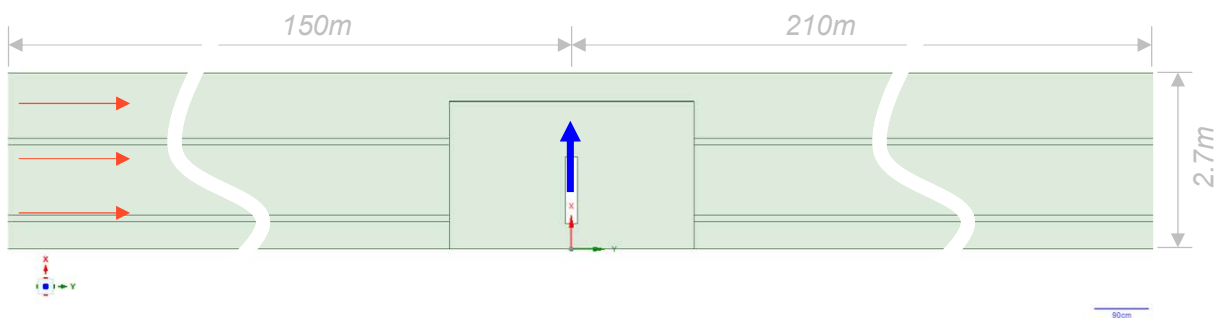
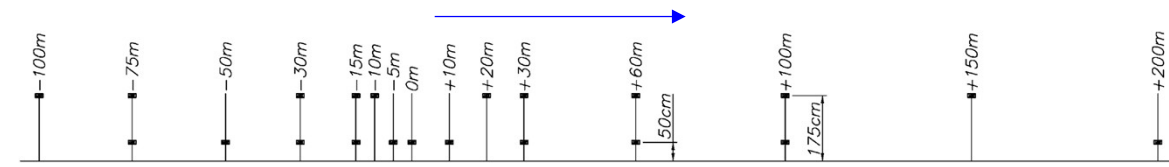
Courtesy T. Koettig, CERN



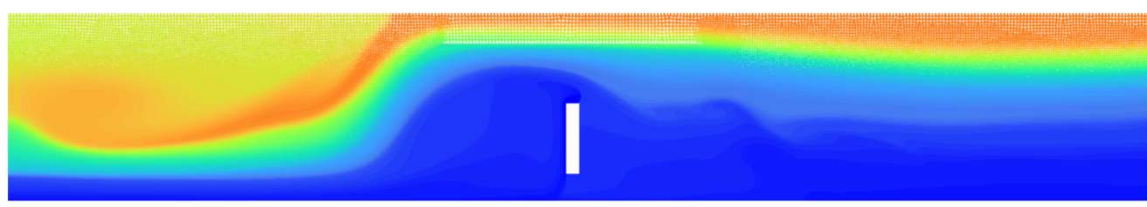
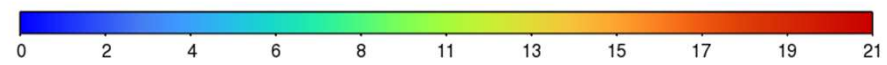
Two 500 l Dewars with liquid helium combined extraction system



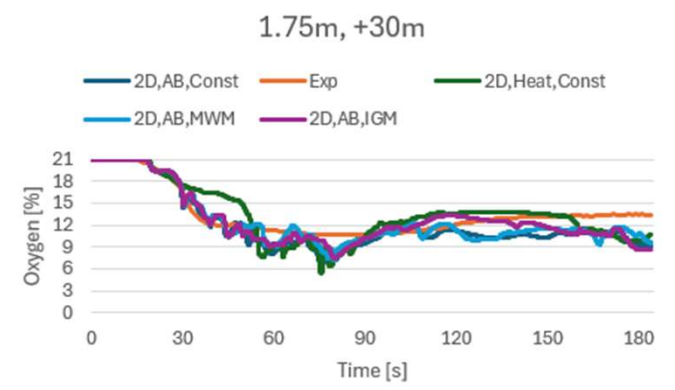
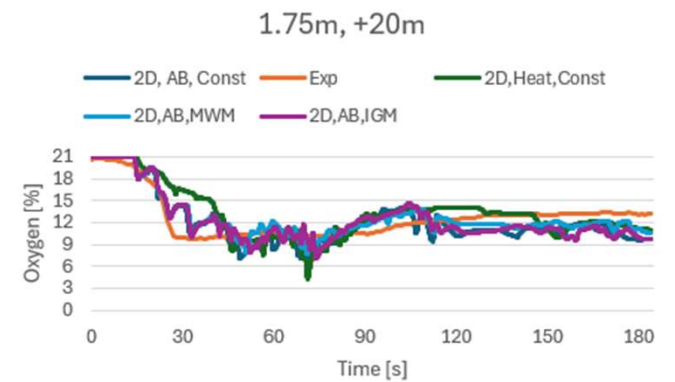
Benchmark Study



Oxygen

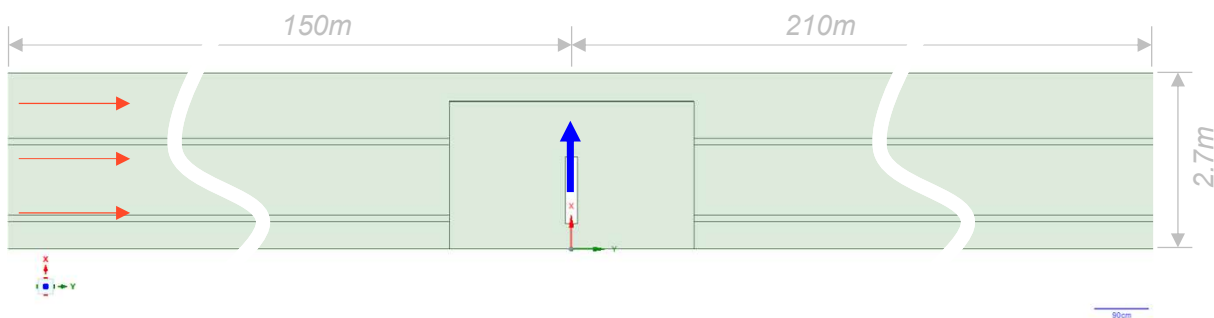
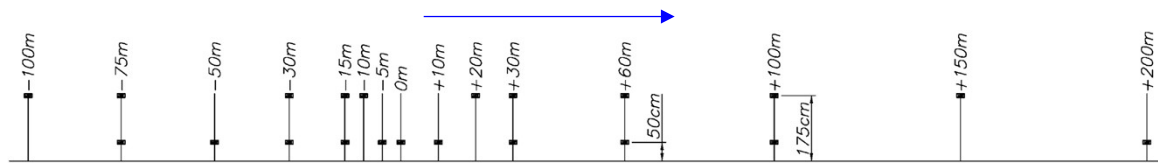


After 3 minutes

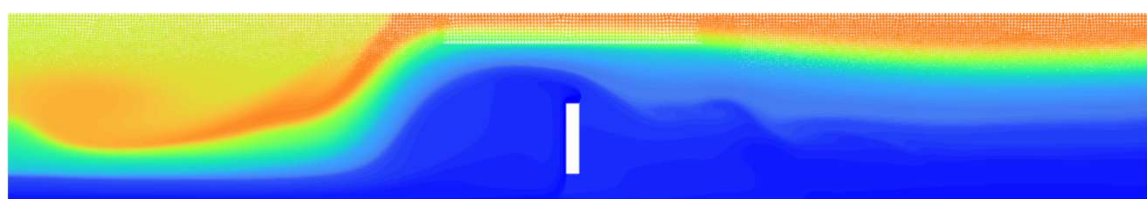
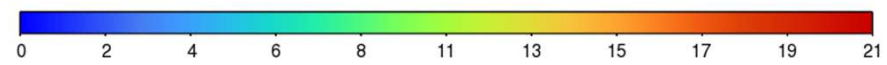


Exp: Experimental data, **AB:** Adiabatic, **Heat:** Heat transfer through walls, **Const:** Constant model for mixing properties (Cp, Thermal Cond., Viscosity, etc.) **MWM:** Mass Weighted Mixing, **IGM:** Ideal Gas Mixing

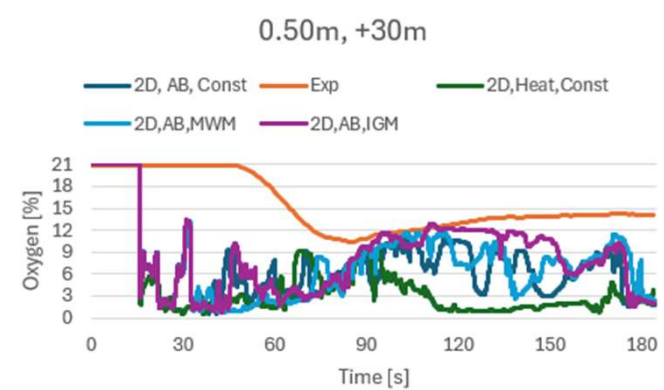
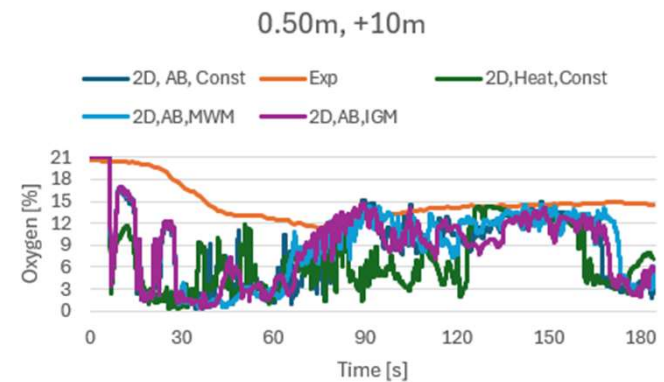
Benchmark Study



Oxygen



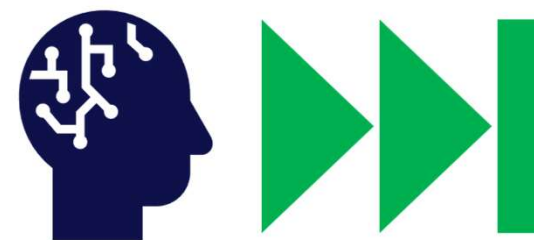
After 3 minutes



Exp: Experimental data, AB: Adiabatic, Heat: Heat transfer through walls, Const: Constant model for mixing properties (Cp, Thermal Cond., Viscosity, etc.) MWM: Mass Weighted Mixing, IGM: Ideal Gas Mixing

Next Simualtions

- Perform new simulations with:
 - ~~New data from SRF (updated risk assessment)~~
 - ~~New baseline cross section~~
 - An active extraction of Helium by considering the ceiling duct shape,
 - Definition of a 'safe zone',
 - 3D Validation of LHC helium spill test.



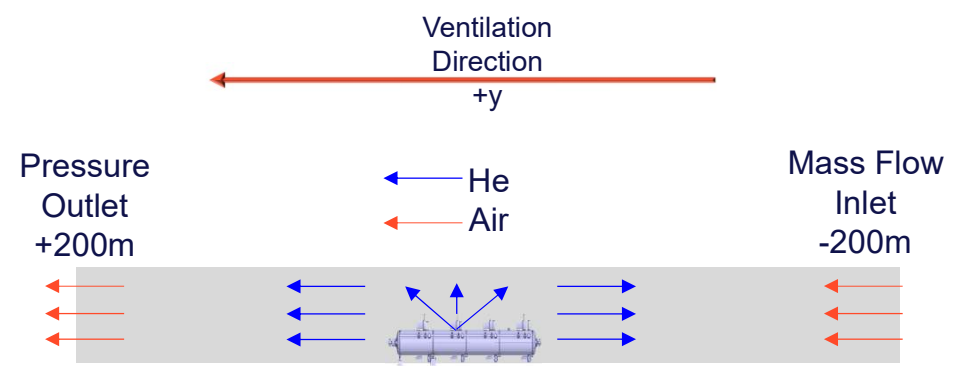
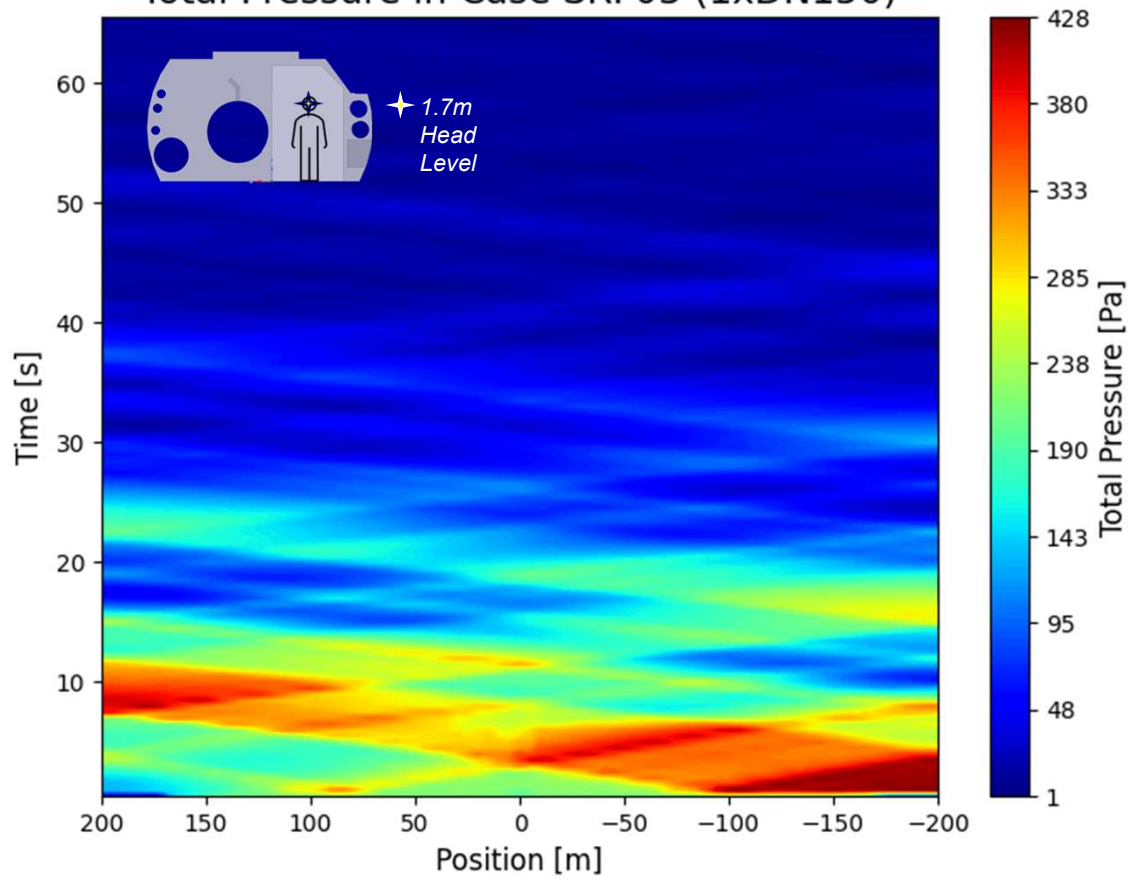


Thank you for your attention.

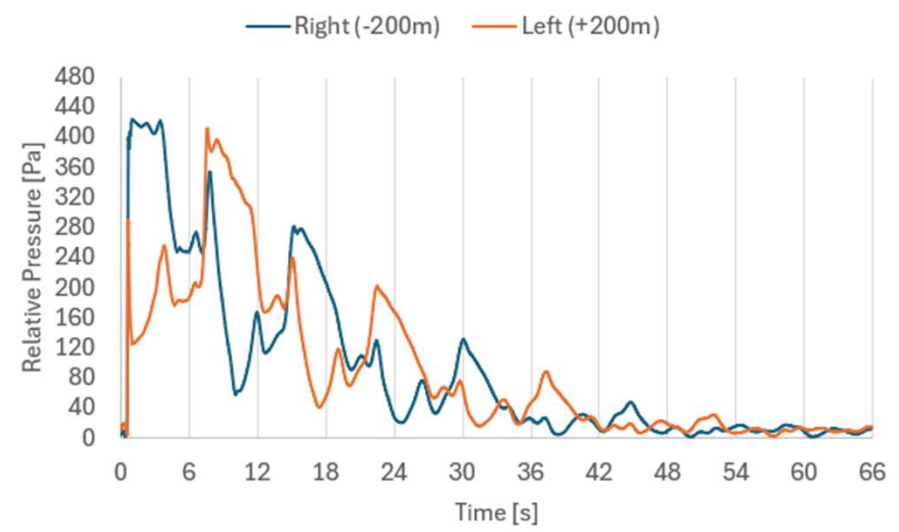
Spare Slides

Pressure Oscillations

Total Pressure in Case SRF03 (1xDN150)

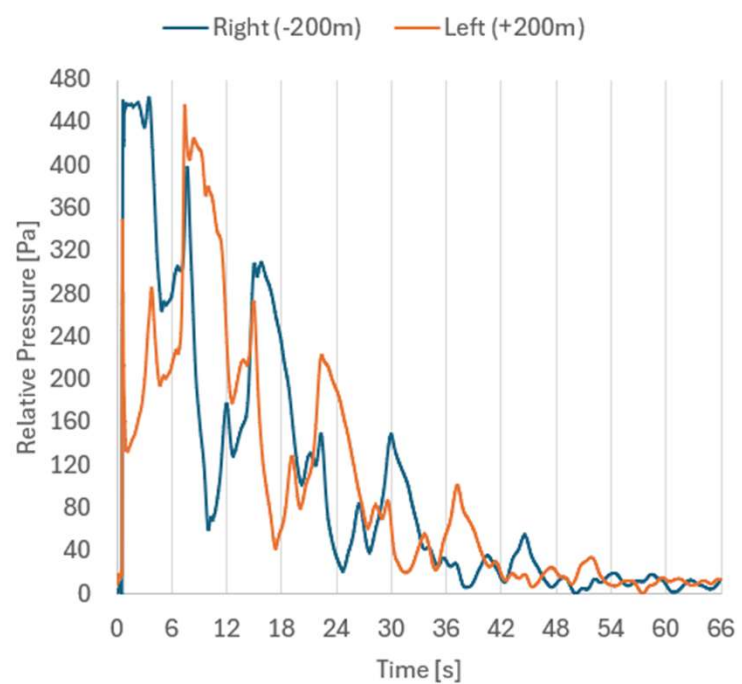


Relative Pressure on the Compartment Walls (SRF03)

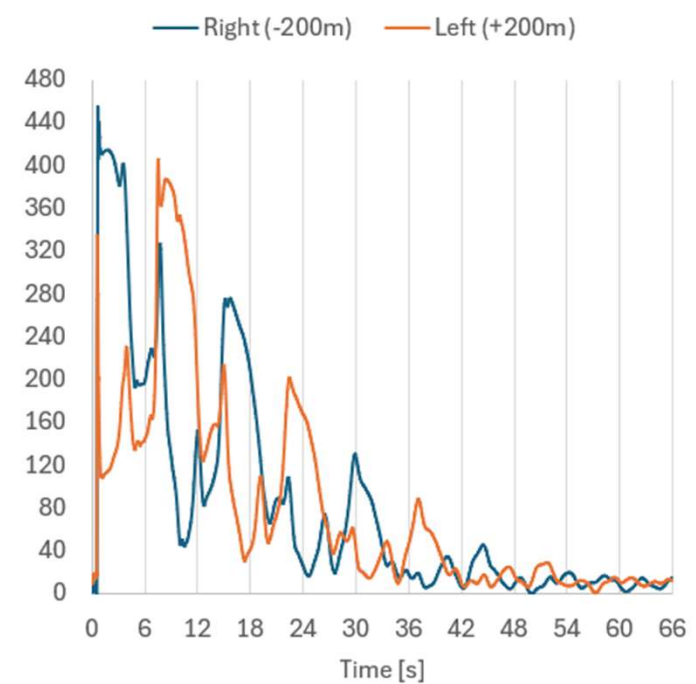


Pressure Oscillations

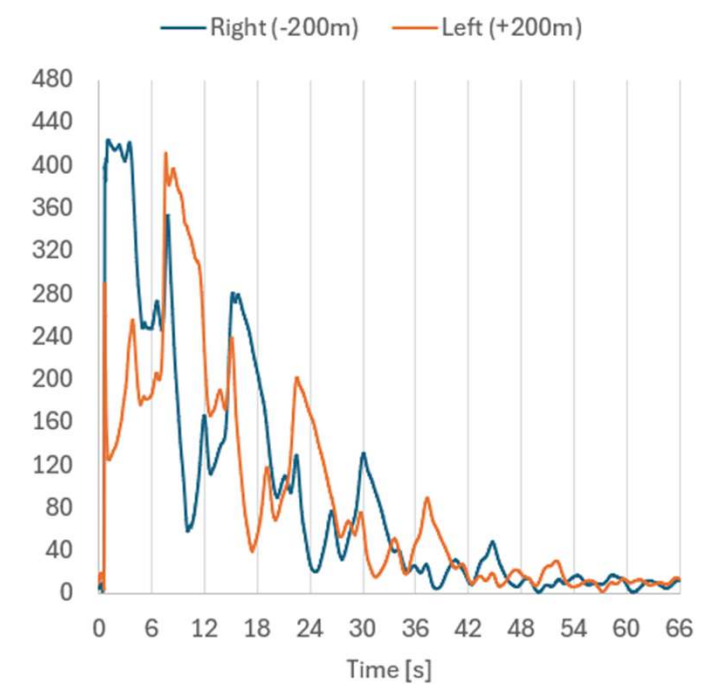
Relative Pressure on the Compartment Walls (SRF01)



Relative Pressure on the Compartment Walls (SRF02)



Relative Pressure on the Compartment Walls (SRF03)



Emergency Extraction

SRF03 - 1xDN150



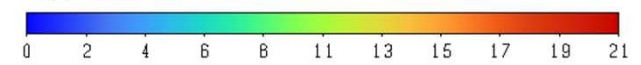
t=1 s
ODH Detected!

00 : 00

t=30 s
Max. Extraction Activated!

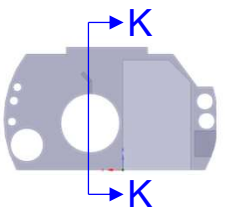
SRFEXT - 1xDN150

Oxygen
yz-oxygen-mid



SRF03 - 1xDN150

K-K Section



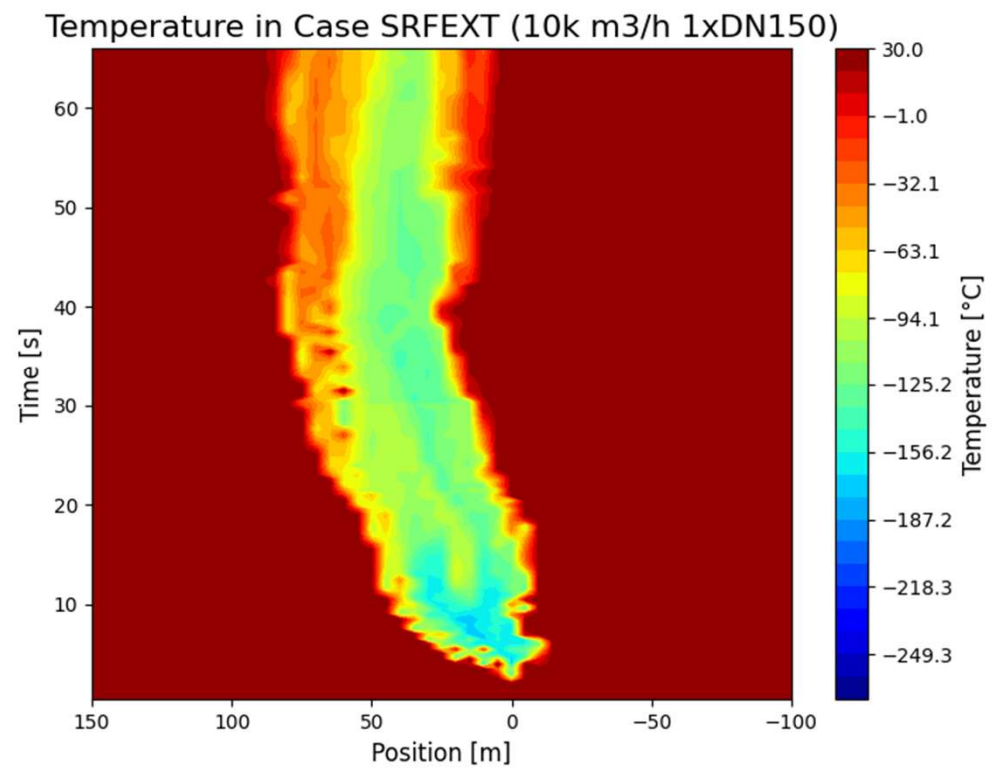
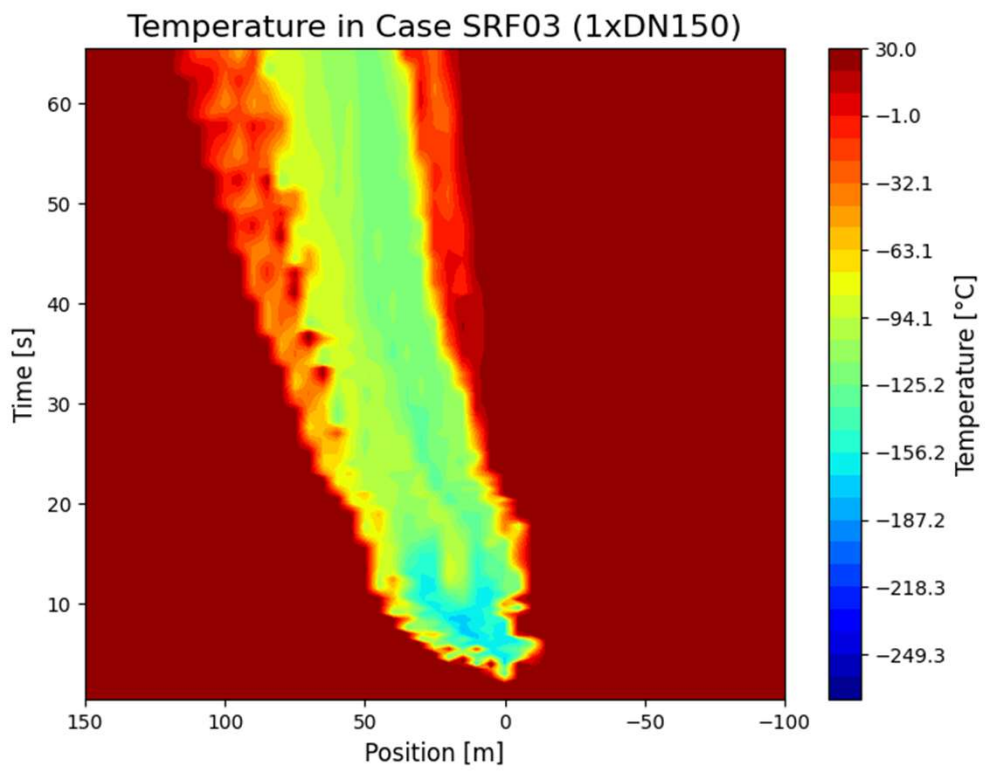
t=1 s
ODH Detected!

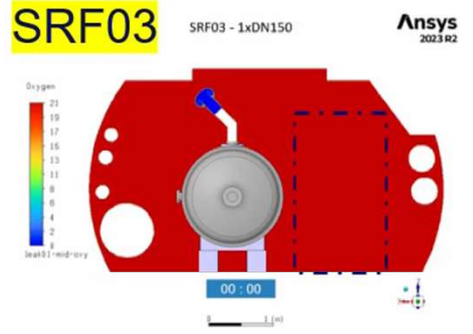
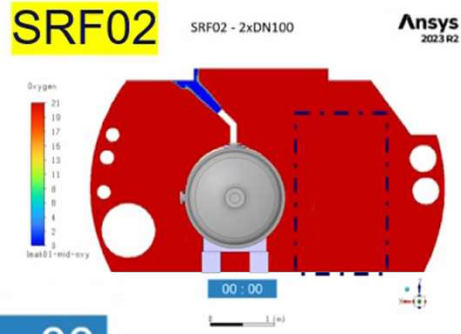
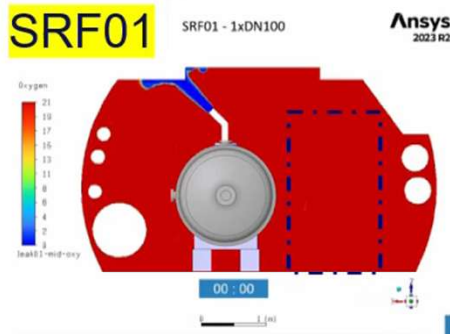
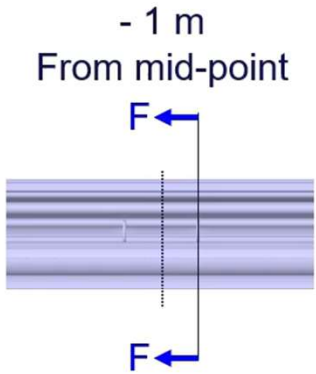
00 : 00

t=30 s
Max. Extraction Activated!

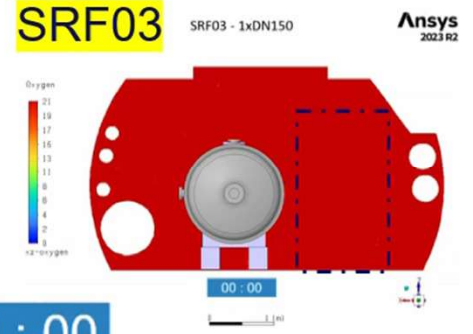
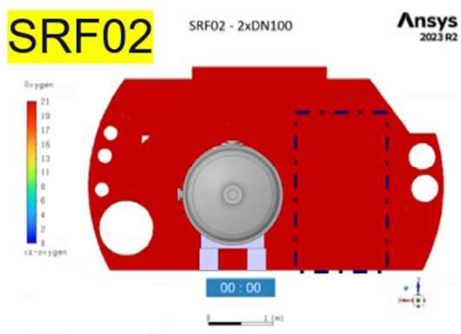
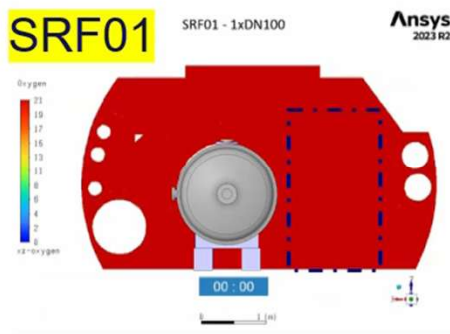
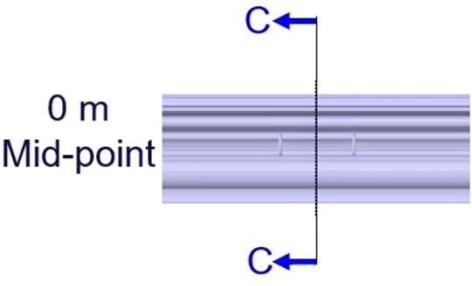
SRFEXT - 1xDN150

Temperature – SRF03 (1xDN150)





00 : 00



00 : 00

