CENF – Air purge with He

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Objectives

The project concerns a CFD simulation of purging air out from the CENF facility with helium flow of 0.7 m^3/s.

The objective of the project is to

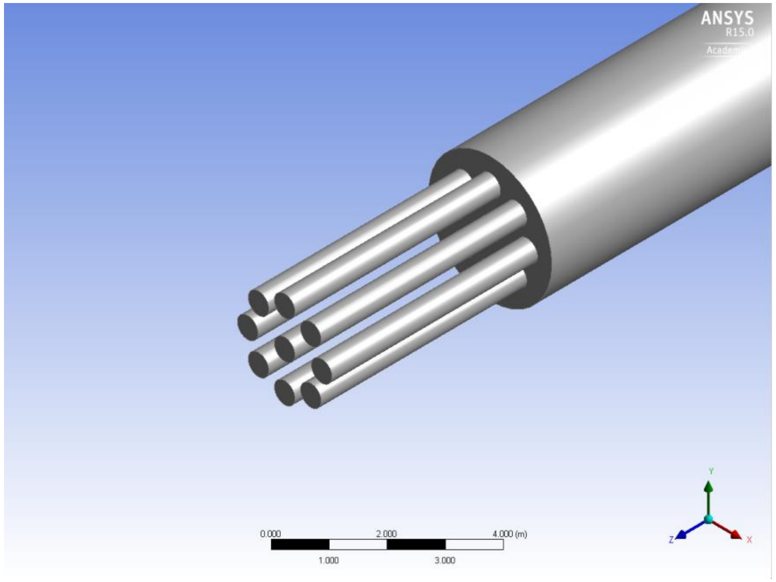
- investigate realizability of piston flow of helium in the CENF facility in the process of purging the air out of the system.
- reach desired air concentration for the system equal 0.1%.

Preliminary setups

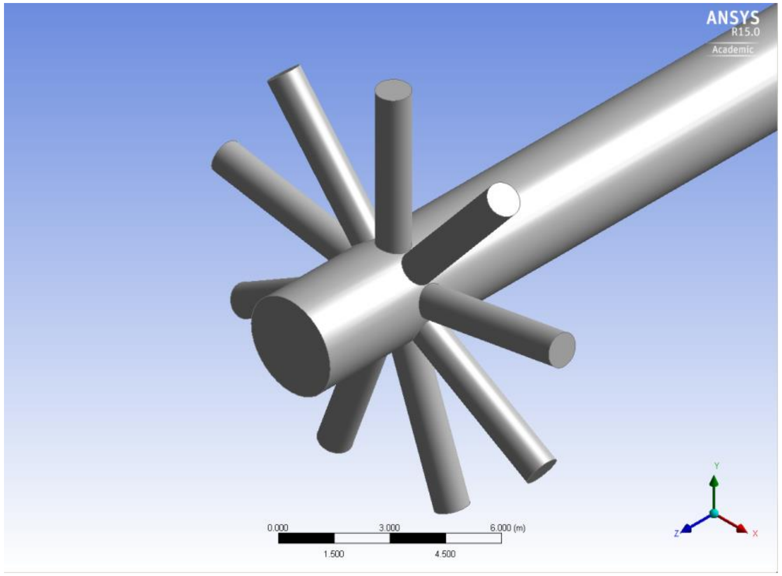
In the first simulations, the distribution of helium was studied **only for the cylinder.**

The following arrangements of inlets to the cylinder were investigated:

9 axially located inlets of D=0.5m

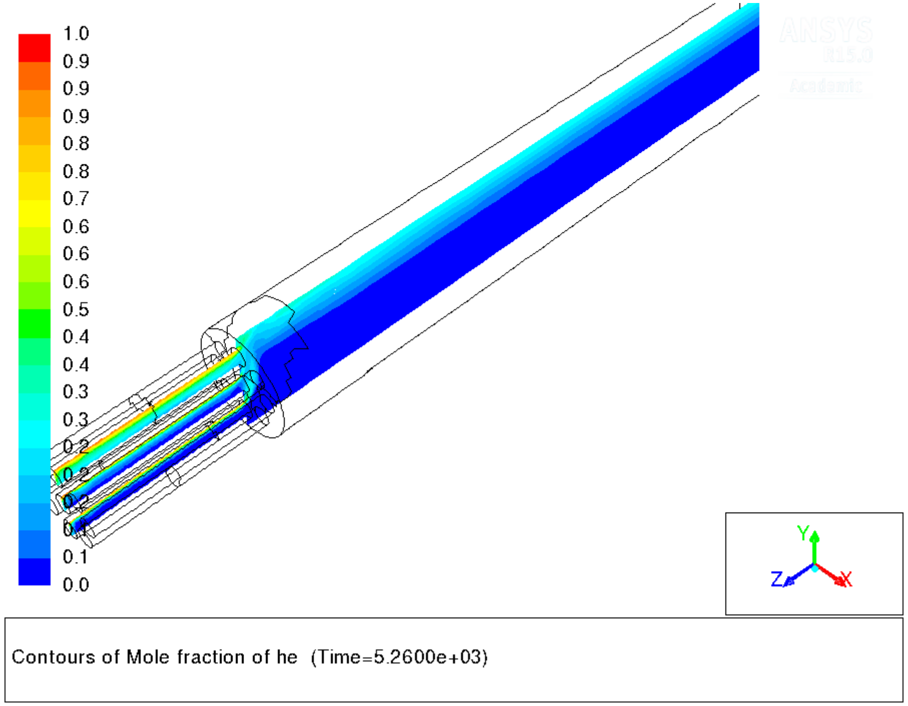


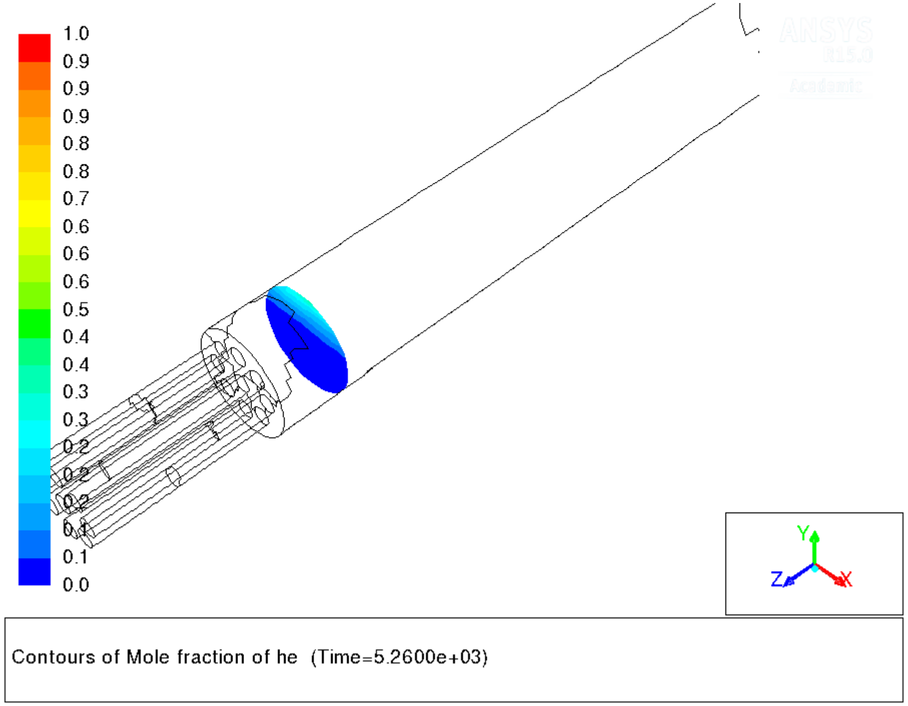
9 radially located inlets of D = 1m



Results – axial arrangement

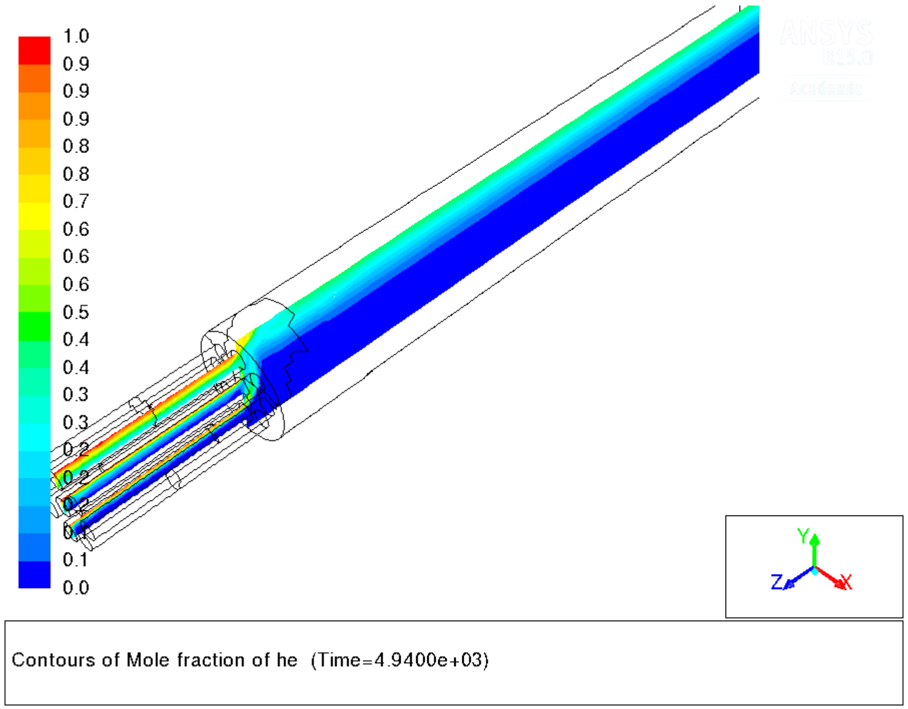
Mole fraction contours at 5260 s of simulation. Inlet flow rate of 0.35 m^3/s (½ of the original inlet flow). Key: 0 – pure air, 1 – pure helium.

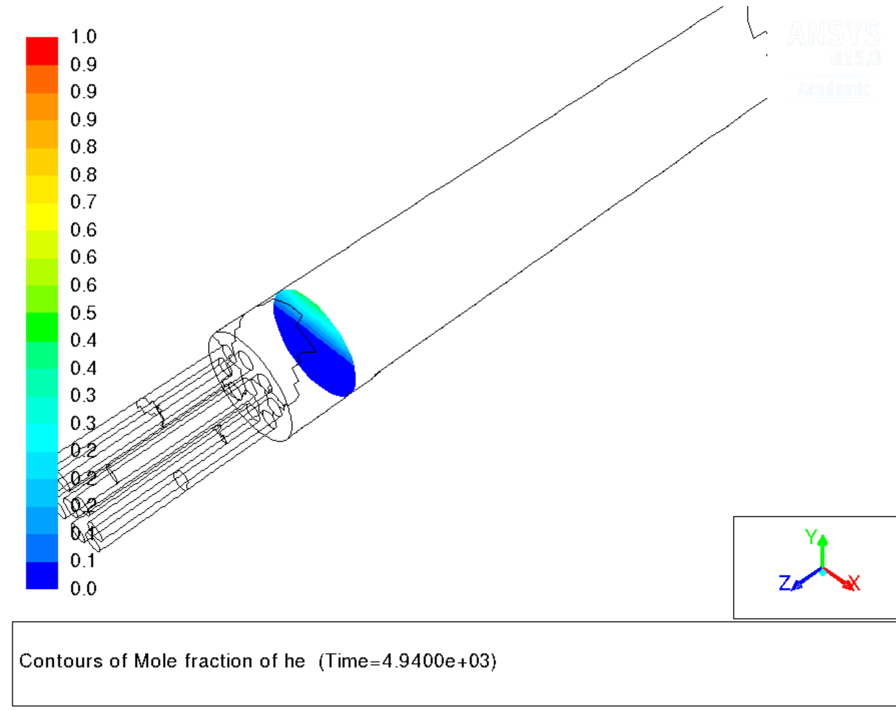




Results – axial arrangement

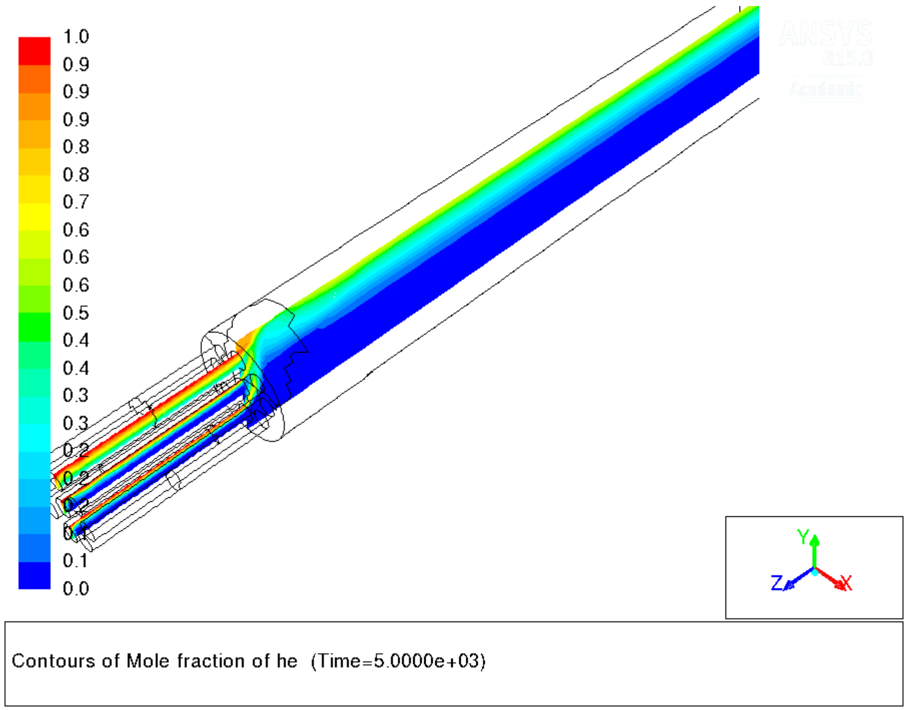
Mole fraction contours at 4940 s of simulation. Inlet flow rate of 0.7 m³/s.

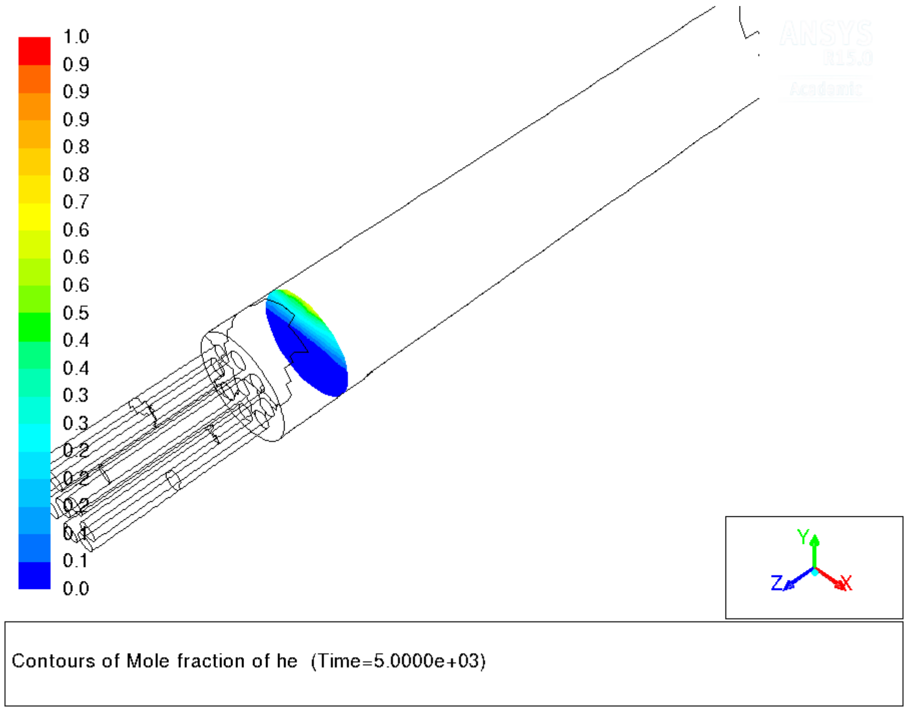




Results – axial arrangement

Mole fraction contours at 5000 s of simulation. Inlet flow rate of 1.4 m^3/s (two times the original flow rate).

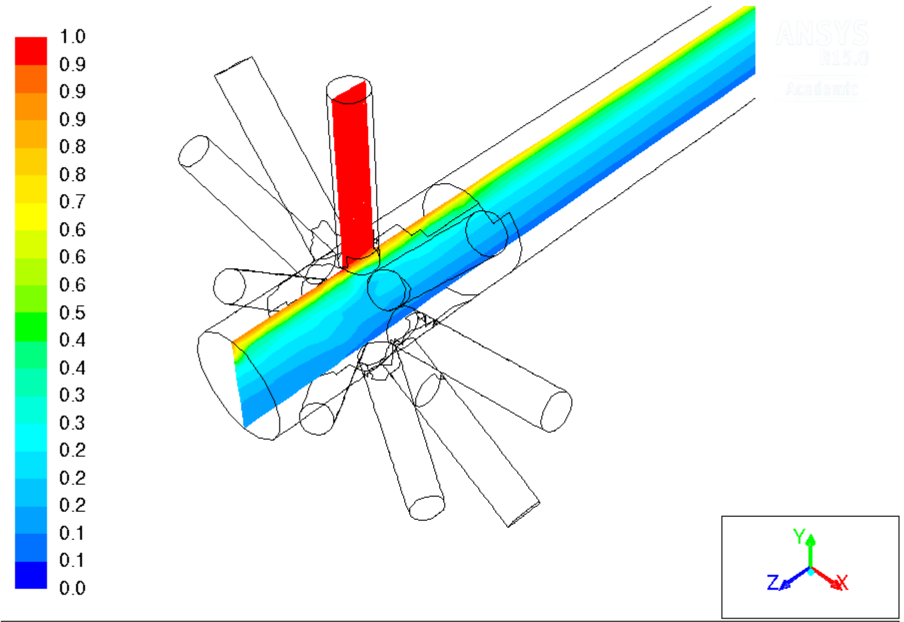




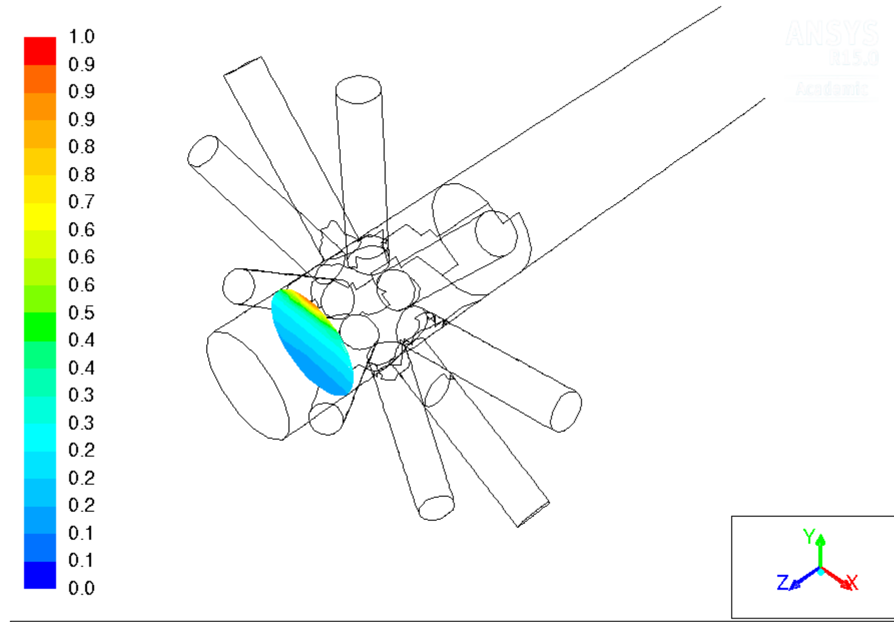
CFD team

Results – radial arrangement

Mole fraction contours at 2600 s of simulation. Inlet flow rate of 0.35 m^3/s (½ of the original inlet flow).



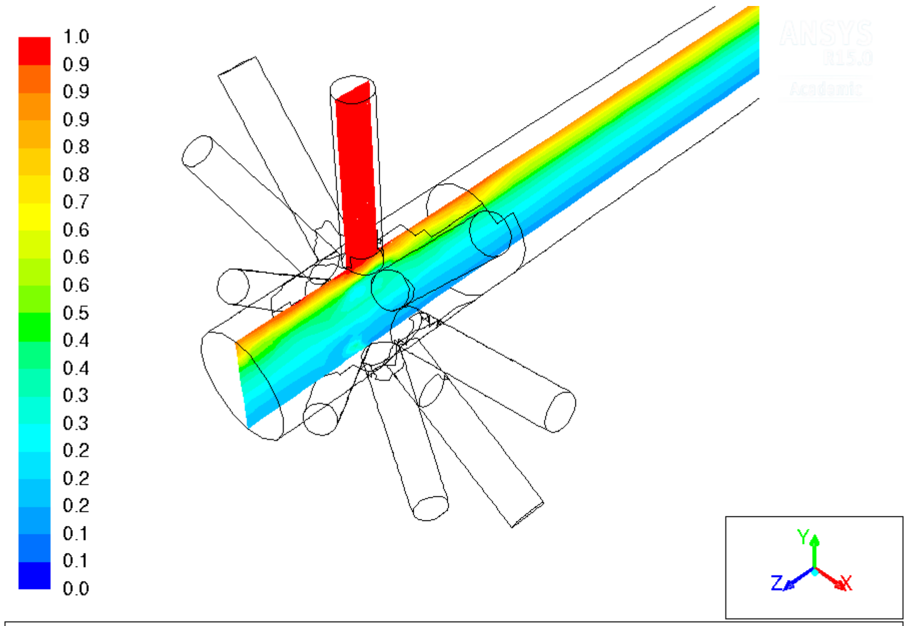
Contours of Mole fraction of he (Time=2.6000e+03)



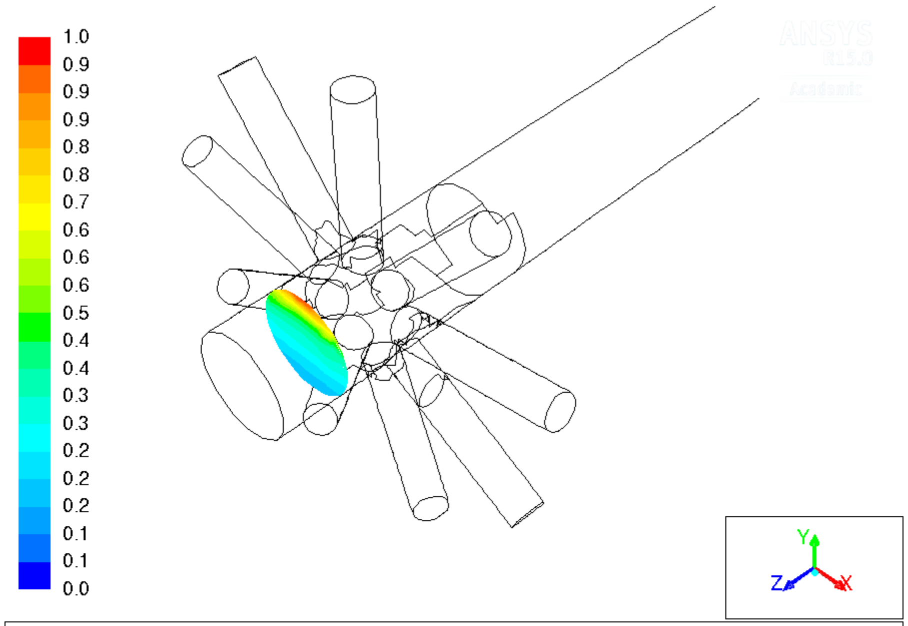
Contours of Mole fraction of he (Time=2.6000e+03)

Results – radial arrangement

Mole fraction contours at 2580 s of simulation. Inlet flow rate of 0.7 m^3/s.



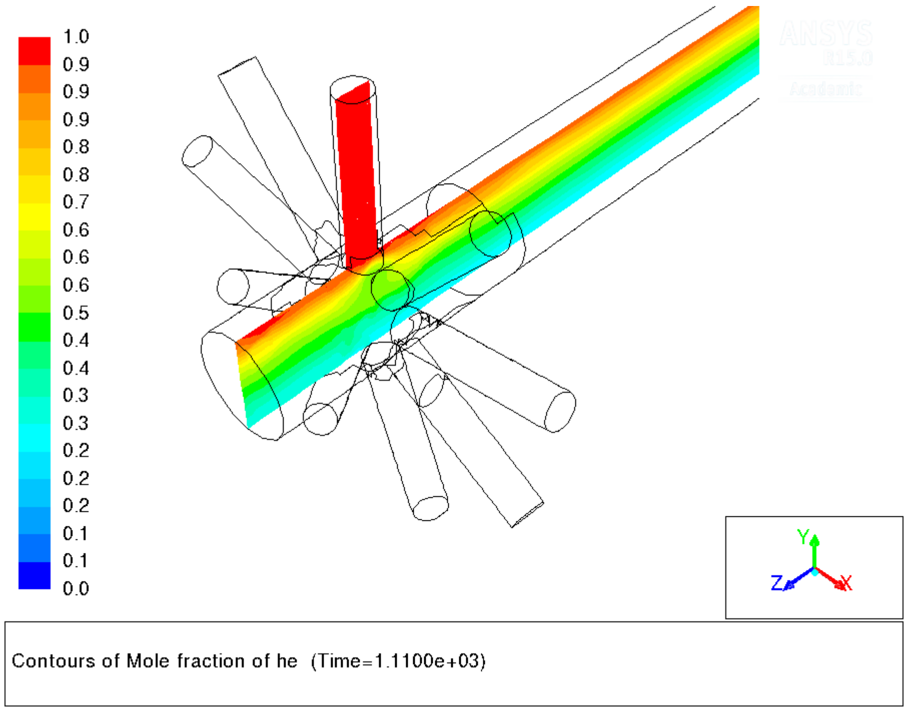
Contours of Mole fraction of he (Time=2.5800e+03)

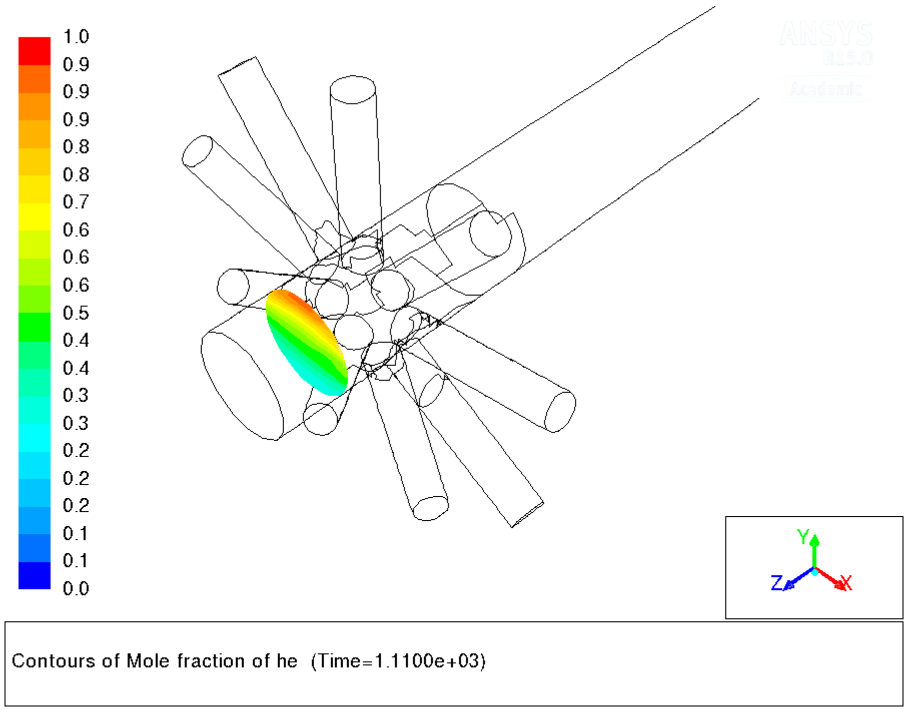


Contours of Mole fraction of he (Time=2.5800e+03)

Results – radial arrangement

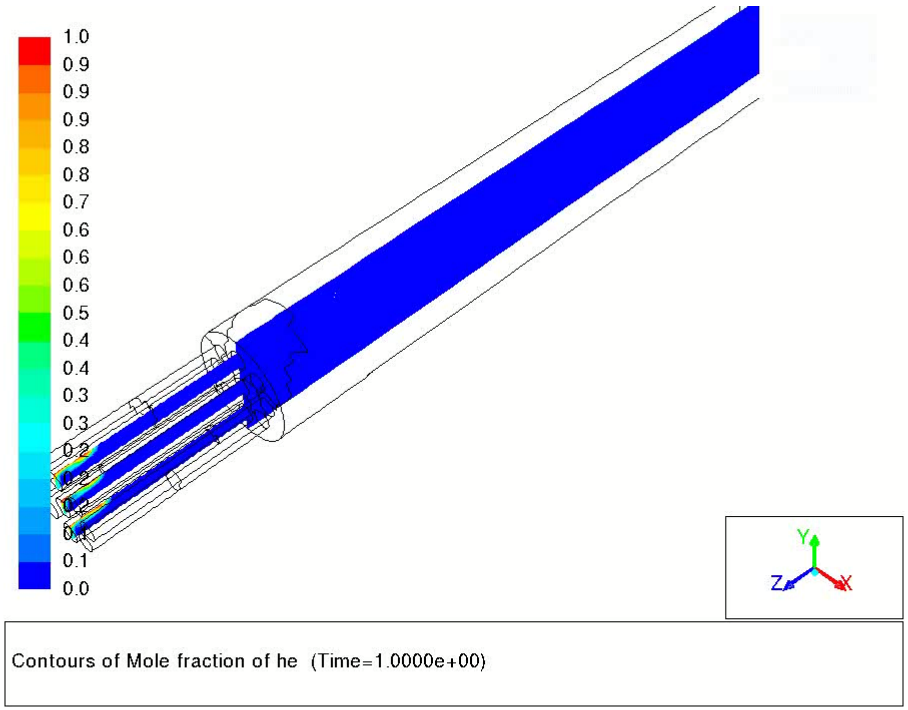
Mole fraction contours at 1110 s of simulation. Inlet flow rate of 1.4 m^3/s (twice the original inlet flow).



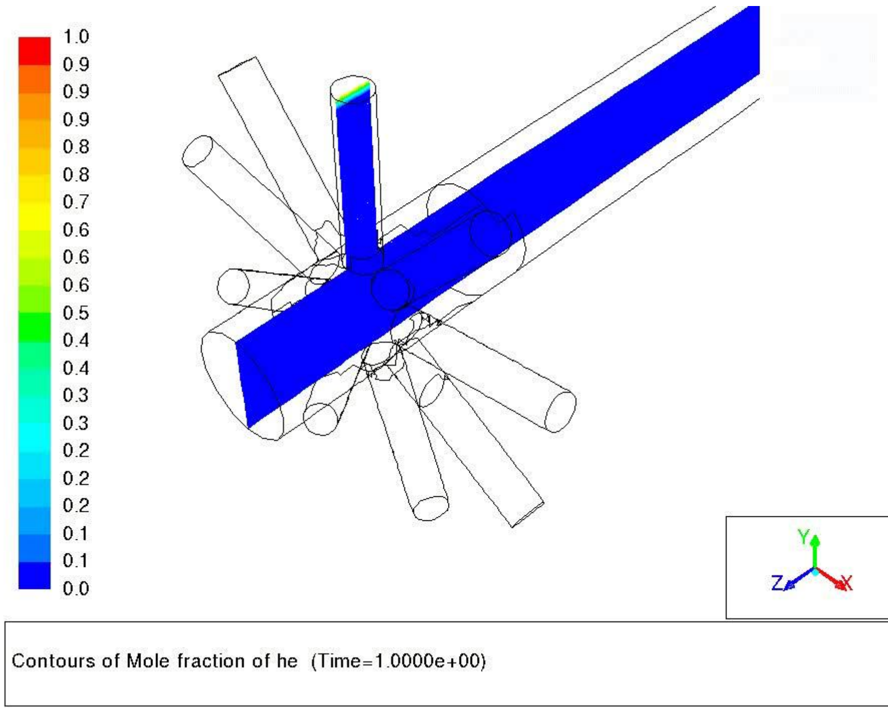


Videos – He mole fration

Axial arrangement – 0.7 m^3/s



Radial arrangement – 0.7 m^3/s

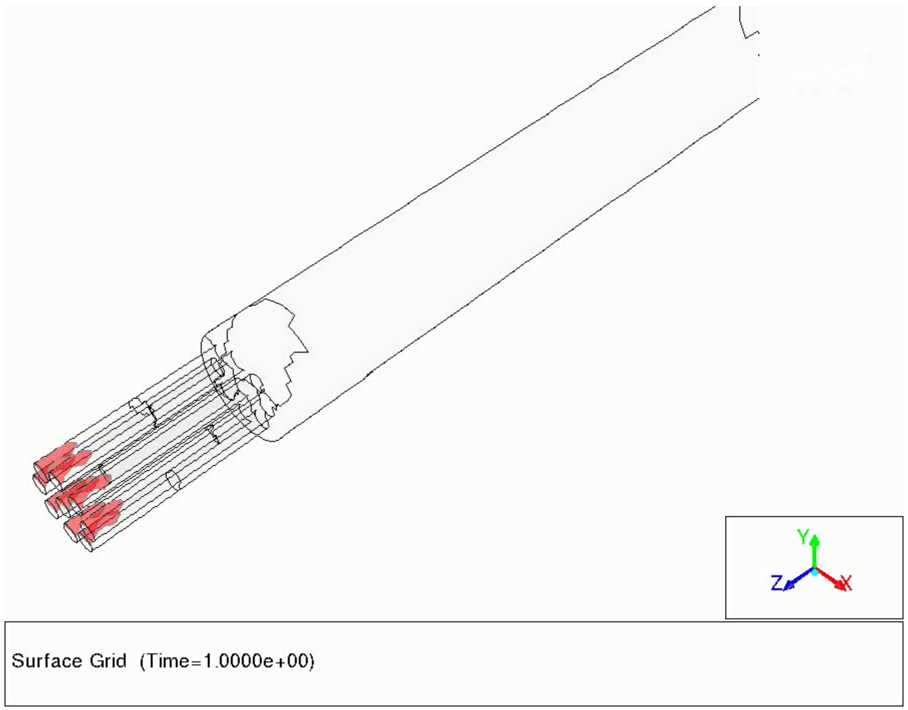


Note: video time is not real-time (1 sec of video equals 25 seconds of simulation)

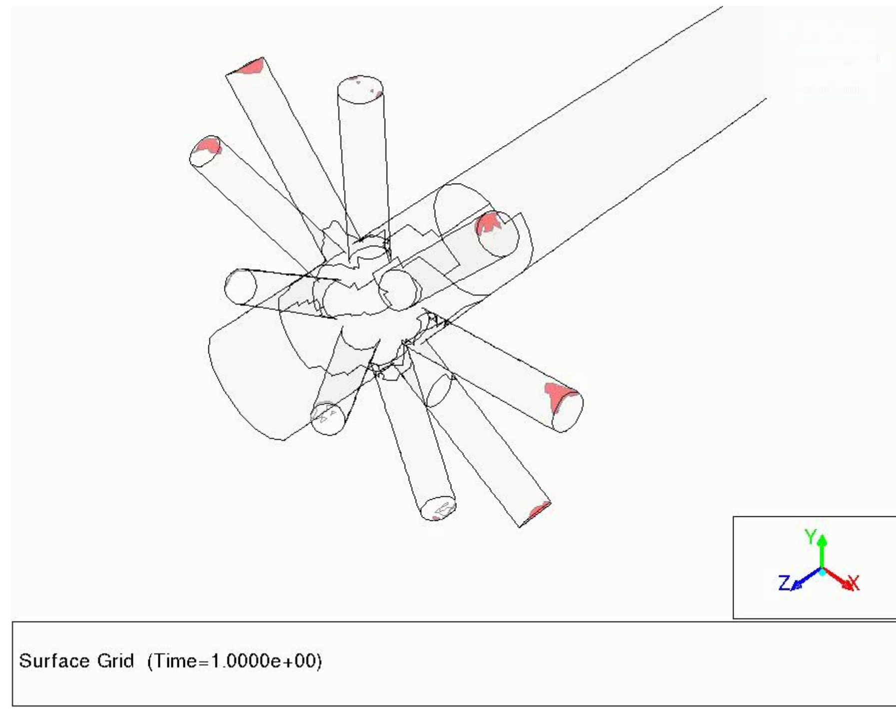
Videos – He cloud

Cloud defined as isosurface of 0.8 volume concentration of Helium

Axial arrangement – 0.7 m^3/s



Radial arrangement – 0.7 m^3/s



Note: video time is not real-time (1 sec of video equals 25 seconds of simulation)

Conclusions

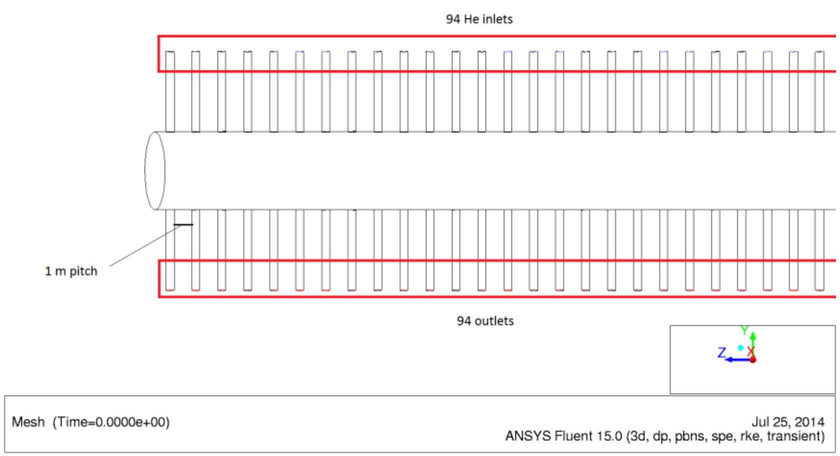
Based on the simulations the following conclusions can be drawn:

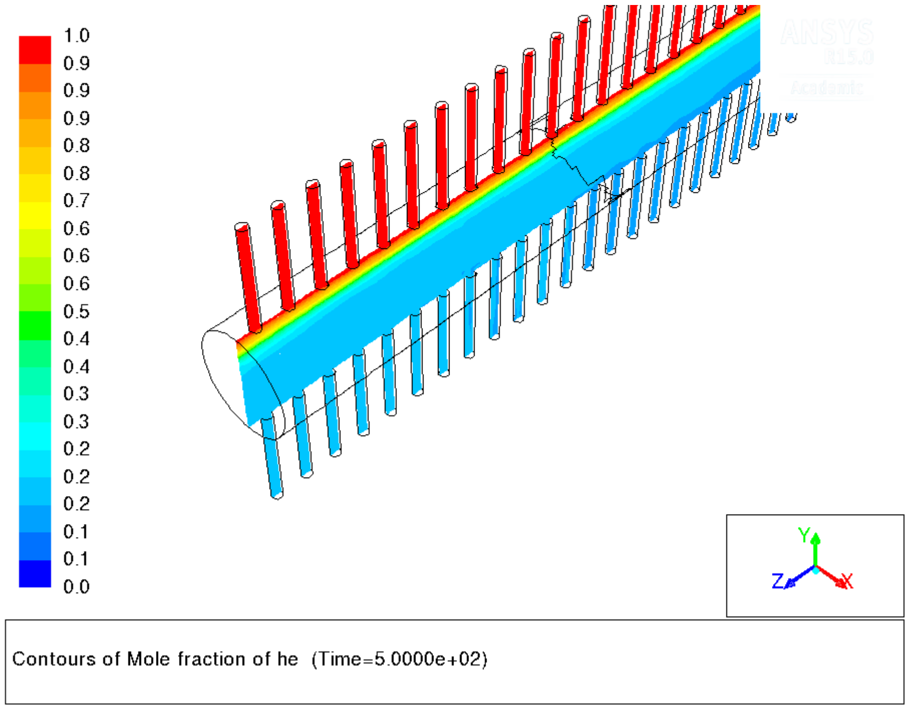
- in all cases significant stratification of helium occurred.
- regardless of the inlet flow rate, the axial inlet arrangement seems to be unable to reproduce a piston flow, as the buoyancy forces are prevailing over viscous and inerta forces.
- radial inlet arrangement provides better purging of air, but as in the axial arrangement, the piston effect is not reproduced.
- increased flow rates lead to faster stratification of helium but do not result in piston flow.

Backup slides

Proposed setup

Another setup was arranged to see if the piston effect is realizable from top to bottom. However, the helium stayed at the top as well and no top-down piston effect was observed.



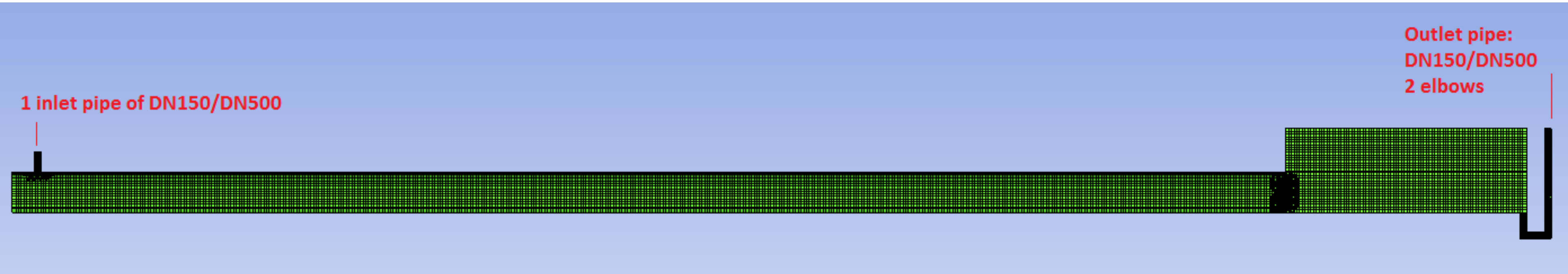


CENF Air purge

Results – simulation with CENF facility building

Overview of the simulations

Compared to the previous simulations, tn the simulations shown in this presentation the CENF facility building was added with a pipe located at the bottom of the building. The building in the simulation is empty - none of the components placed inside the building was taken into account.



Two cases were investigated:

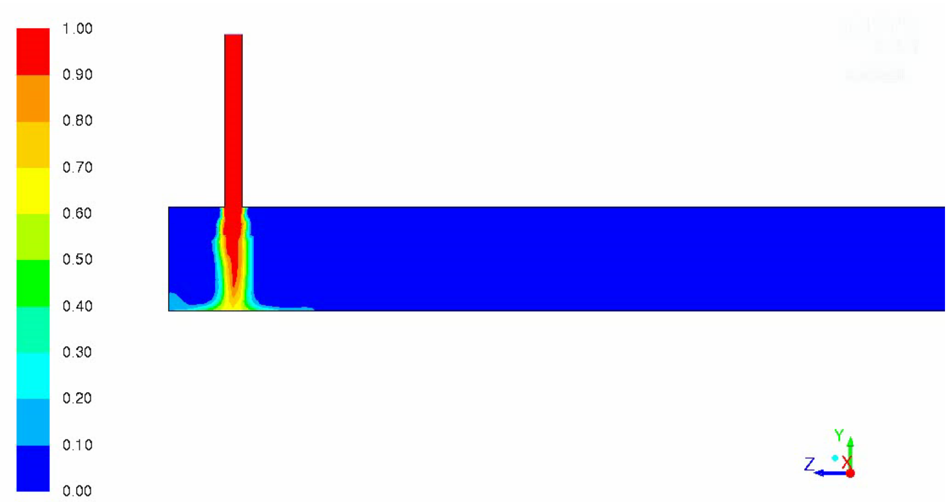
- DN150 inlet and outlet pipes with 15 m/s inlet velocity (corresponding to volumetric flow of 0.27 m^3/s)
- DN500 inlet and outlet pipes with 15 m/s inlet velocity (corresponding to volumetric flow of 2.95 m^3/s)

A steady state case with DN150 inlet pipe was investigated and the results indicated that it is possible to flush all the air from the cylinder with flow as little as 0.27 m^3/s, however a transient simulation is needed to determine the time required to achieve 99.9% Helium content in the facility.

An important thing to note here is that simulation of case with DN500 pipes is faster than with DN150 pipes – 2.9 vs 13.68 simulation minutes per day.

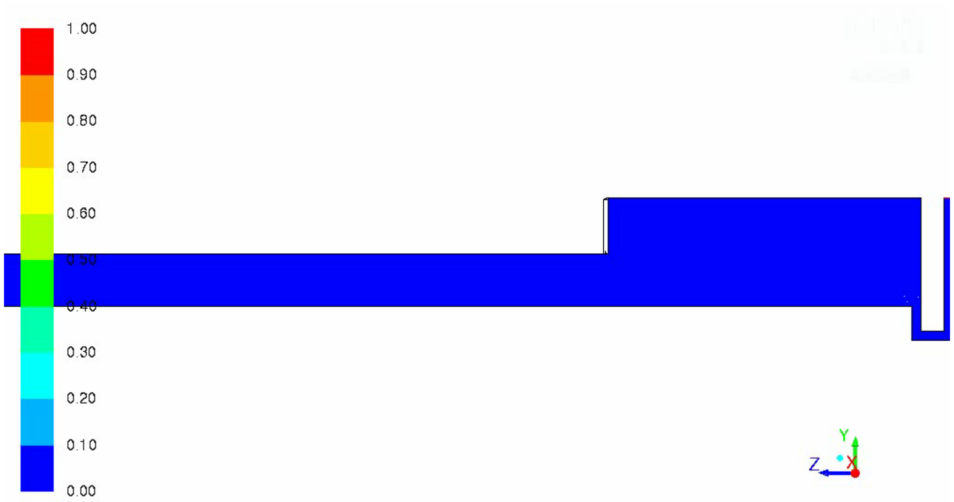
Mole fraction of helium – 2.9 m³/s, DN500 inlet

Mole fraction of helium at the cylinder inlet



Contours of Mole fraction of he (Time=1.0000e+00)

Mole fraction of helium at the cylinder outlet and the building

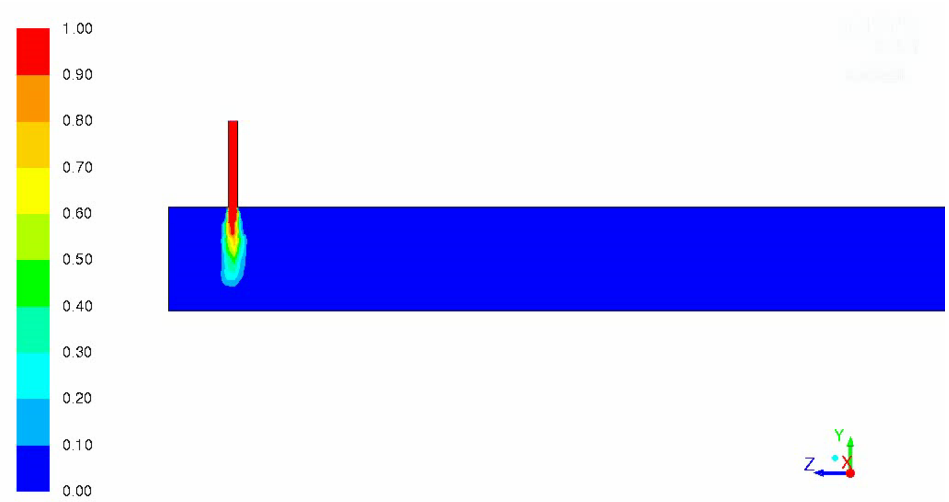


Contours of Mole fraction of he (Time=1.0000e+00)

The whole facility is flushed within ca. 20 minutes – after that time the is helium content is 100%

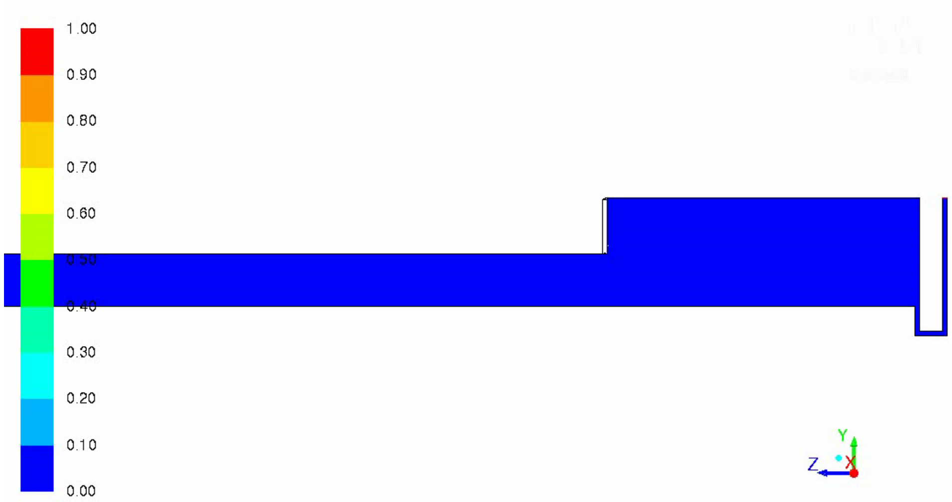
Mole fraction of helium – 0.27 m³/s, DN150 inlet

Mole fraction of helium at the cylinder inlet



Contours of Mole fraction of he (Time=5.0000e-01)

Mole fraction of helium at the cylinder outlet and the building



Contours of Mole fraction of he (Time=5.0000e-01)

CENF Air purge – further simulation results

P. Pacholek

Simulation results – time required to flush CENF entirely

The results showed that the real to ideal (i.e. if the fluids did not mix) flush time ratio does not change much with flows below 0.75 m^3/s, thus we believe it is reasonable to extrapolate the flush time beyond the simulated cases based on a conservative 2.51 flush time ratio. The influence of pipe diameter is yet to be investigated (cases with DN150 inlet are now running).

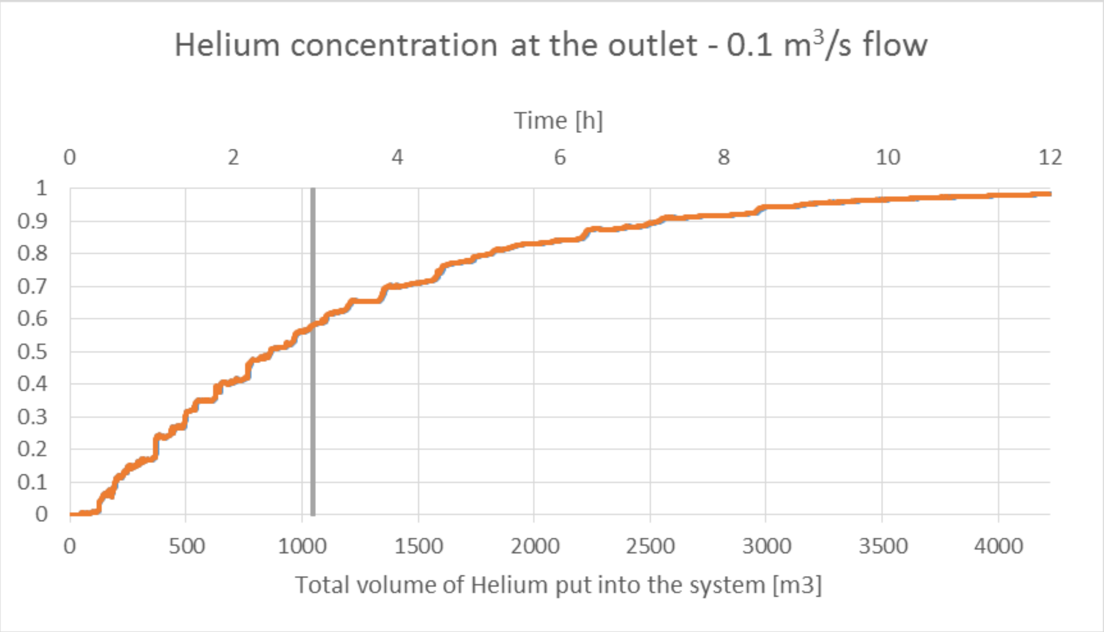
The CFD simulation results and expected (extrapolated) flush times are presented in the table below.

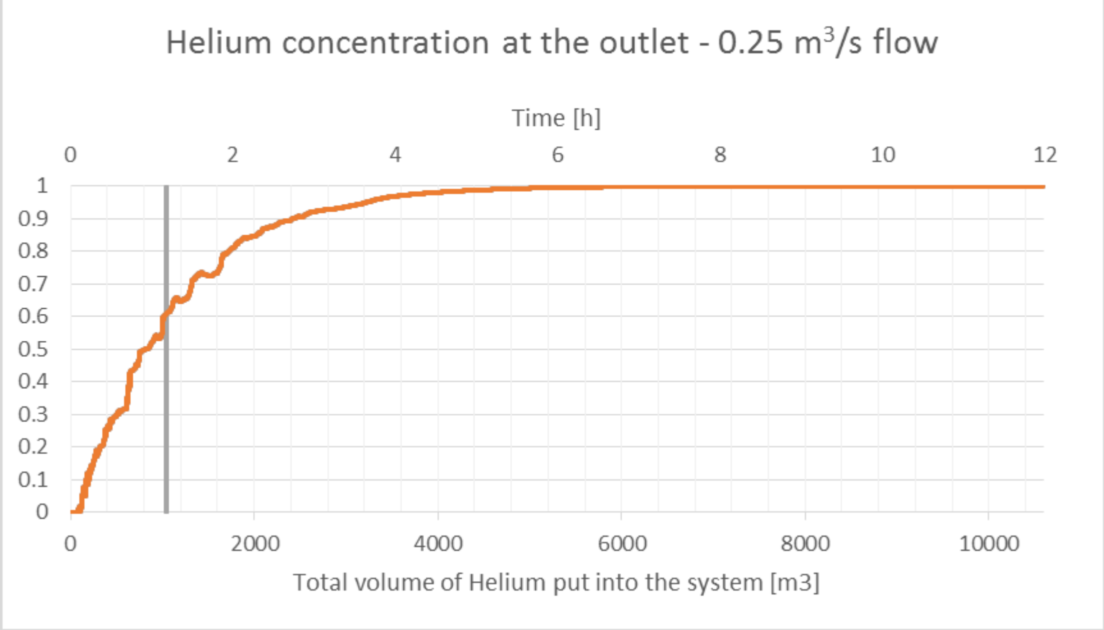
Case	Flush time - immiscible fluids [h]	CFD simulated/expected flush time [h]	Real to ideal flush time ratio	
DN500 VFR = 2.94 m^3/s v = 15 m/s	0.1	0.3	3.26	CFD simulated
DN250 VFR = 0.74 m^3/s v = 15 m/s	0.4	1.0	2.51	CFD simulated
DN250 VFR = 0.25 m^3/s v = 5 m/s	1.2	3.1	2.49	CFD simulated
DN250 VFR = 0.1 m^3/s v = 2 m/s	3.1	7.5	2.44	CFD simulated
DN250 VFR = 0.05 m^3/s v = 1 m/s	6.1	*15.4 (0.64 days)*	*assumed 2.51*	Expected
DN250 VFR = 0.025 m^3/s v = 0.5 m/s	12.3	*30.8 (1.28 days)*	*assumed 2.51*	Expected
DN250 VFR = 0.0125 m^3/s v = 0.25 m/s	24.5	*61.6 (2.57 days)*	*assumed 2.51*	Expected

Helium concentration at the outlet

The plots presented on the right show concentration of helium at the outlet from the system for two of the simulated cases, i.e. for flows of 0.1 m^3/s and 0.25 m^3/s. The vertical grey bar represents the simulated volume of CENF facility, as well as the inlet and outlet pipes, which is 1084.6 m^3.

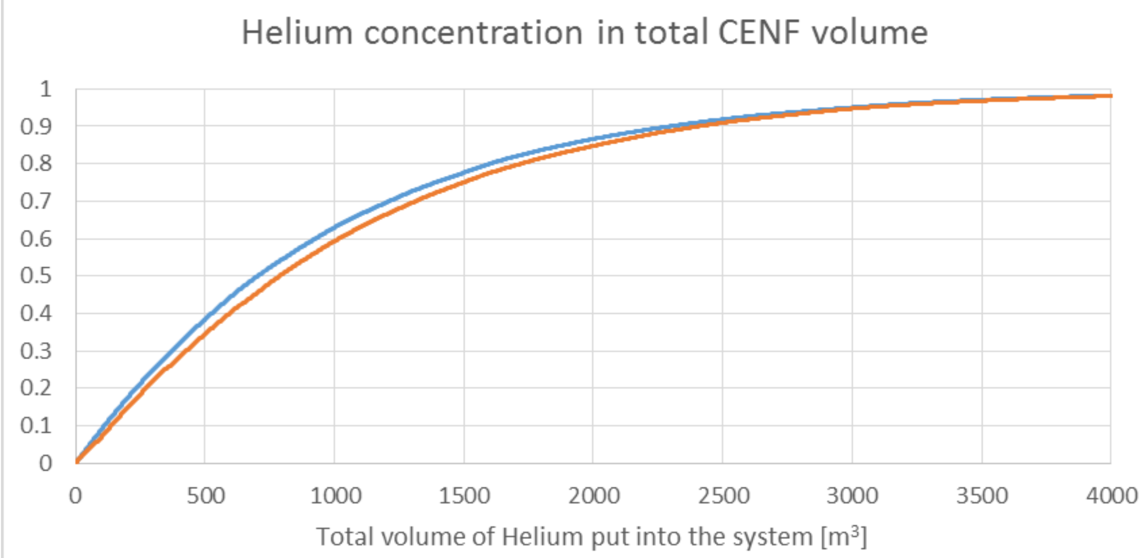
A similar trend can is observed for both flows– in order to arrive at an acceptable level of concentration of helium in the system it is necessary to use around 4000 m^3 of the gas.



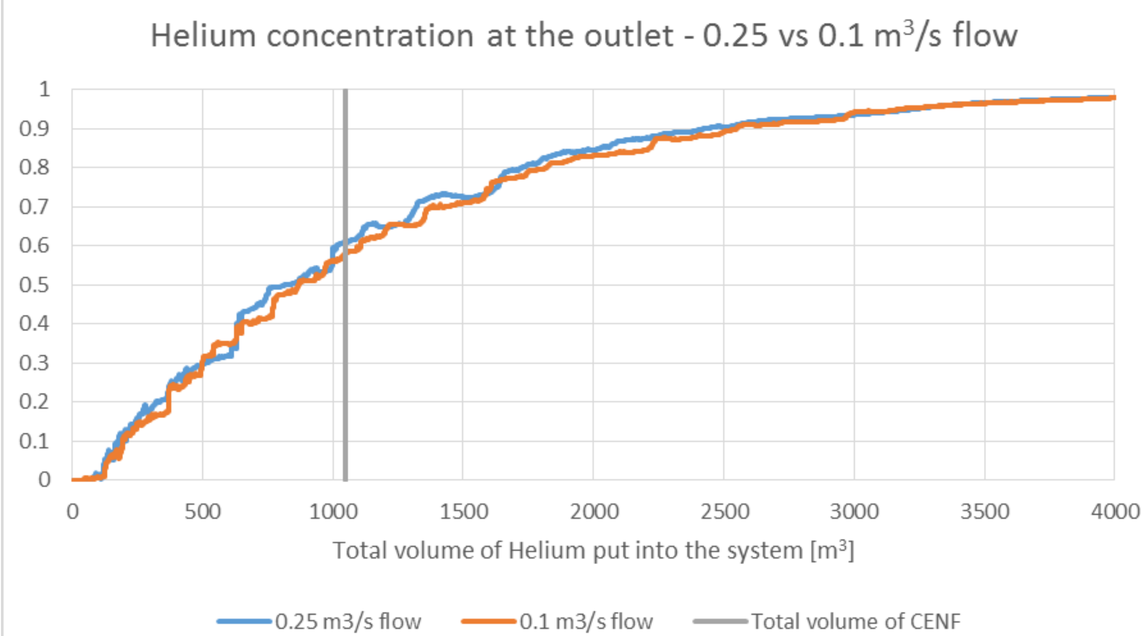


0.25 vs 0.1 m^3/s cases - comparison

The plot on the top shows that there is little difference between flushing the system with 0.25 or 0.1 m^3/s flows. However, a slight difference of about 4% of helium concentration in total volume is observed in favour of the higher flow.



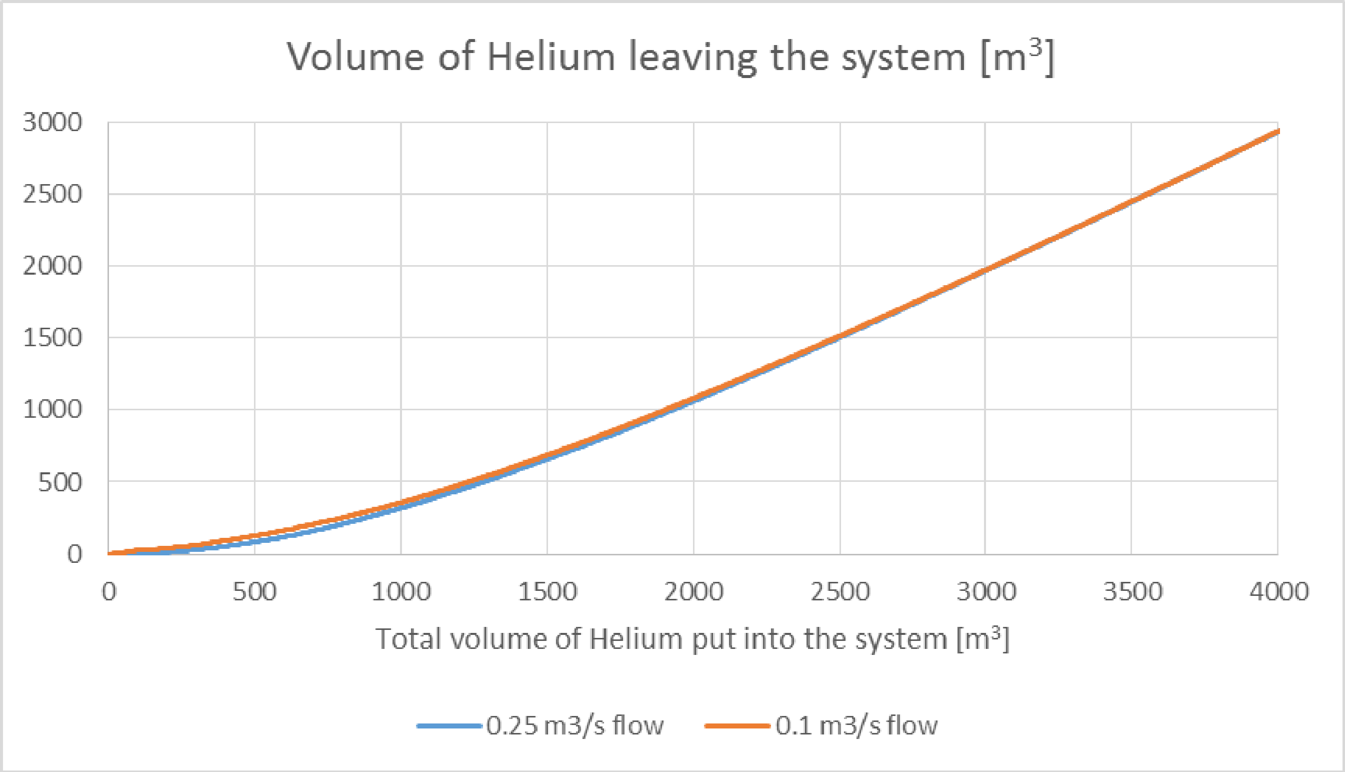
The trend from the upper plot is also reflected in the bottom plot – the concentration at outlet is on average higher for the higher inlet velocity flow.



Helium leaving the system

The plot below is a comparison of both flows in terms of helium that is not stored in the system and leaves through the outlet. There is very little difference between two presented flows, although the plot confirms that the bigger flow is slightly favourable.

The plots show that it would be best to consider starting the He purification plant after some 500 to 1000 m^3 has been flushed, as the slope of the function increases considerably after that point. Still, the actual costs should be calculated based on the time chosen for the flush-only mode to be carried out.



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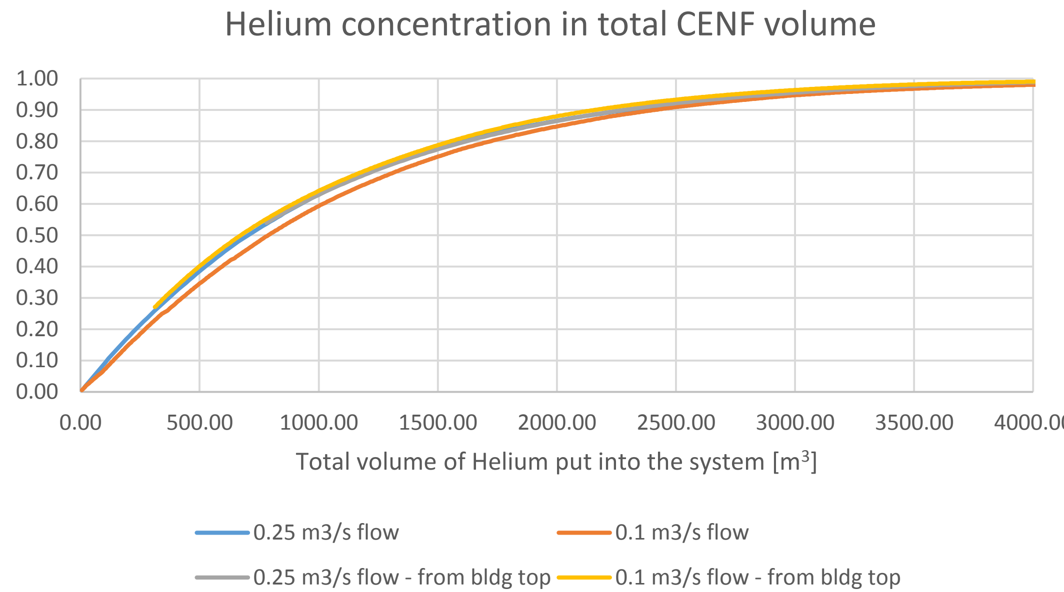

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