National Synchrotron Radiation Research Center

實驗驗證之低溫氦氣洩漏模擬分析與耗能估算

報告人：張瑞麒

時間：2016年11月17日

地點：園區公會

大綱

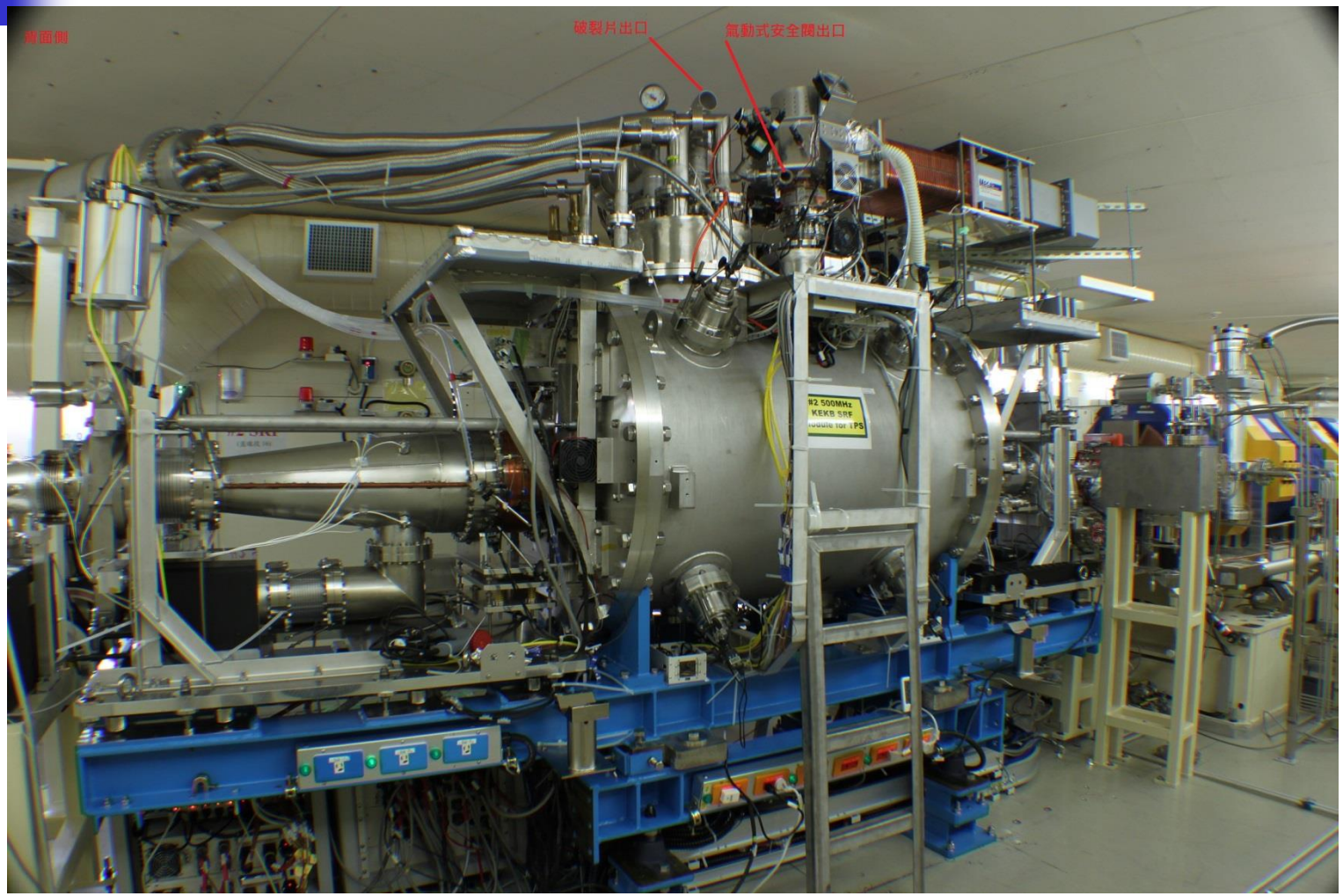
- 研究背景
- 建立模型
- 統御方程式
- 小型實驗驗證
- 邊界條件
- 分析結果
- 未來工作

研究背景

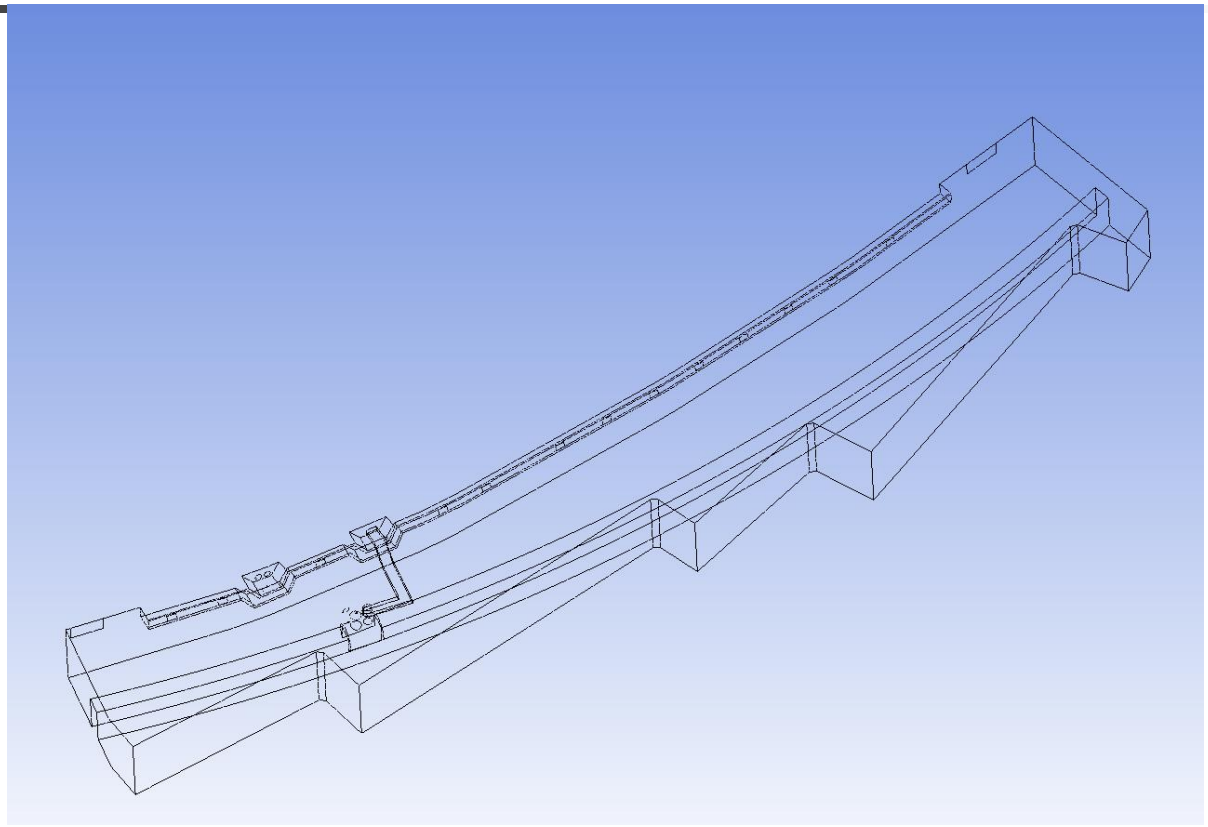
- 模擬液態氦洩漏之缺氧情形
- 小型實驗驗證
- 模擬Tunnel內空調對液態氦洩漏之影響

- **European Spallation Source：Numerical simulation of cold helium safety discharges into a long relief line (2014)**
- **CERN：EXPERIMENTAL SIMULATION OF HELIUM DISCHARGE INTO THE LHC TUNNEL**

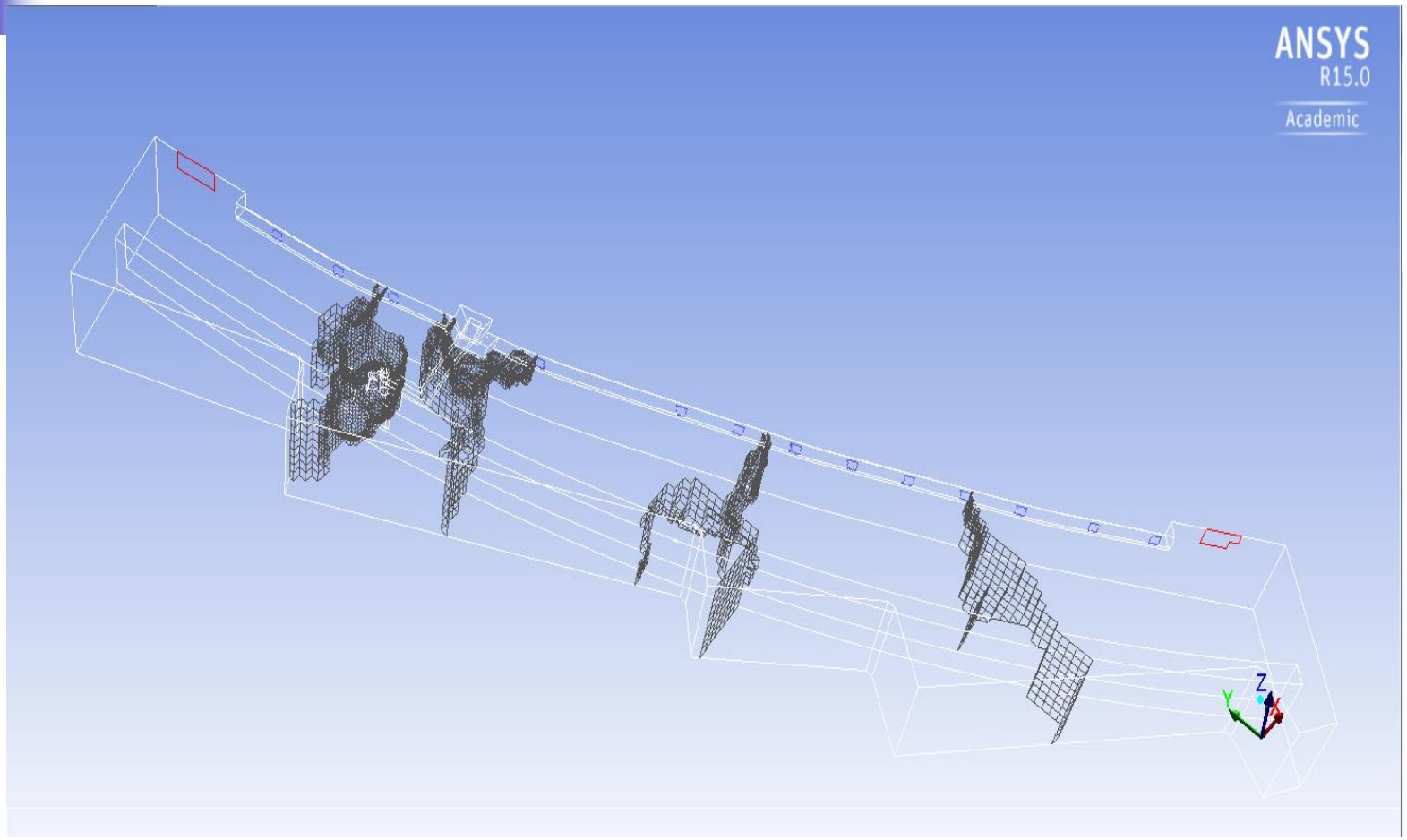
建立模型



建立模型

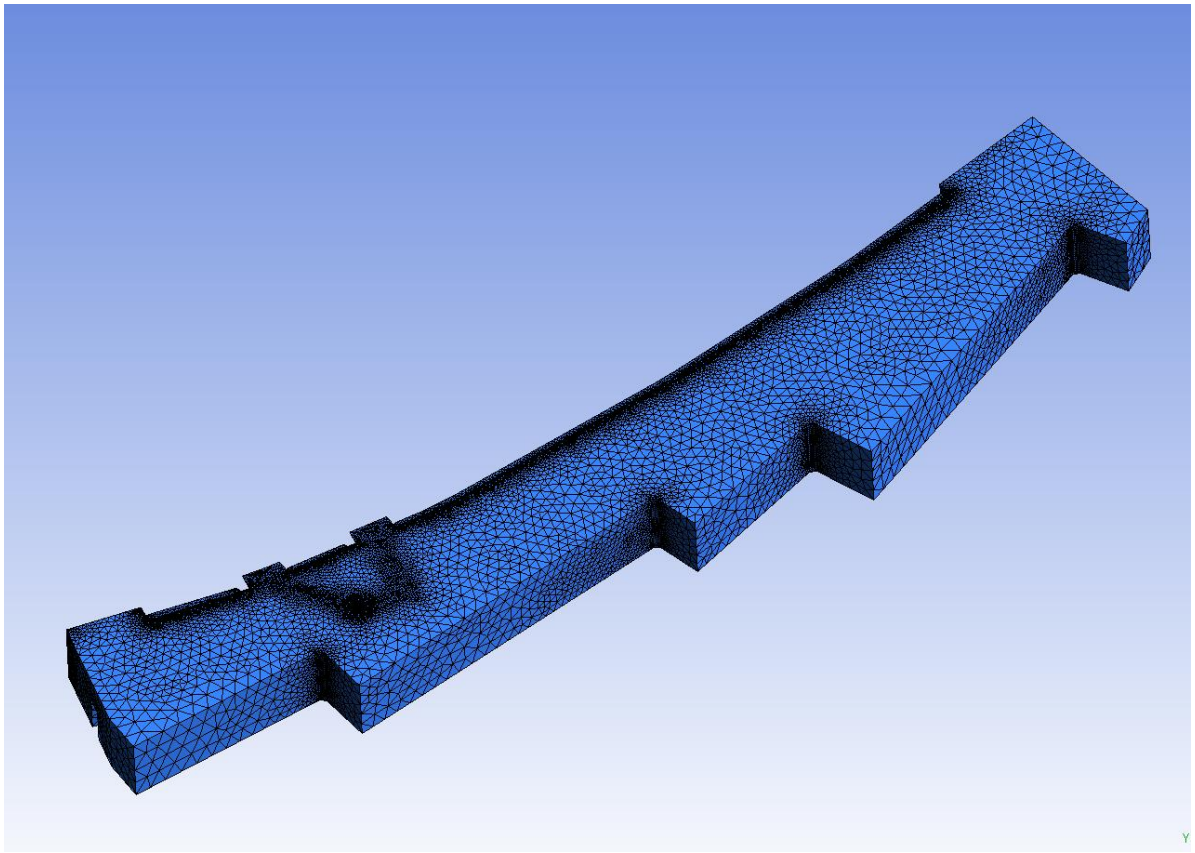


建立模型



網格

網格數：334萬
最大尺寸：1.55m
最小尺寸：0.007768m



統御方程式

Mass conservation

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$$

Momentum conservation equation

$$\frac{\partial (\rho \mathbf{u})}{\partial t} + \nabla \cdot (\rho \mathbf{u}\mathbf{u}) = -\nabla p + \rho \mathbf{g} + \nabla \cdot (\mu \nabla \mathbf{u}) - \nabla \cdot \tau_t$$

Energy conservation equation

$$\frac{\partial (\rho e)}{\partial t} + \nabla \cdot ((\rho e + p)\mathbf{u}) = \nabla \cdot \left(k \nabla T - \sum_j h_j \mathbf{j}_j \right)$$

統御方程式

Turbulence kinetic energy equation

$$\frac{\partial(\rho\kappa)}{\partial t}+\nabla\cdot(\rho\kappa\mathbf{u})=\nabla\cdot\left(\alpha_\kappa\mu_{eff}\nabla\kappa\right)+G_\kappa+G_b-\rho\varepsilon$$

Turbulent kinetic energy dissipation rate

$$\frac{\partial(\rho\varepsilon)}{\partial t}+\nabla\cdot(\rho\varepsilon\mathbf{u})=\nabla\cdot\left(\alpha_\varepsilon\mu_{eff}\nabla\varepsilon\right)+C_{1\varepsilon}\frac{\varepsilon}{\kappa}(G_\kappa+C_{3\varepsilon}G_b)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{\kappa}$$

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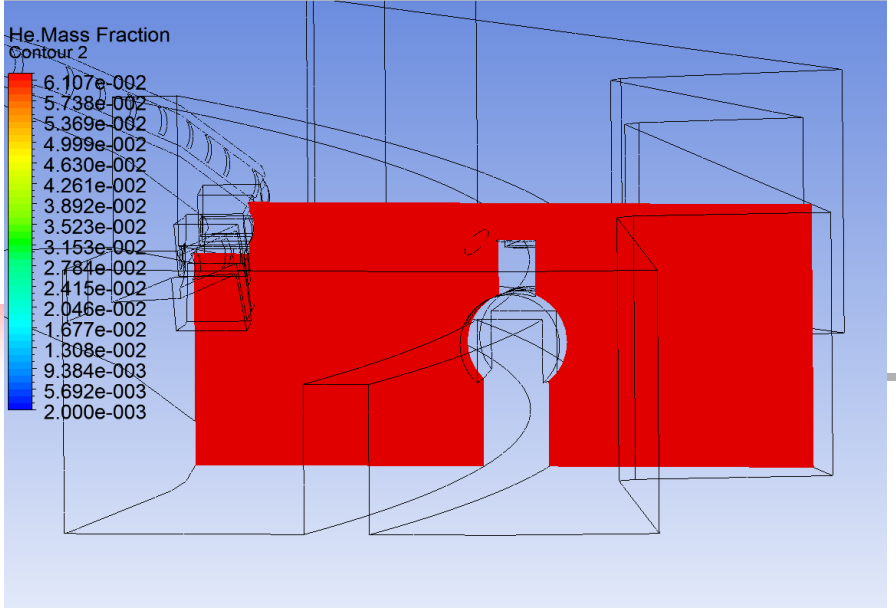
邊界條件 I

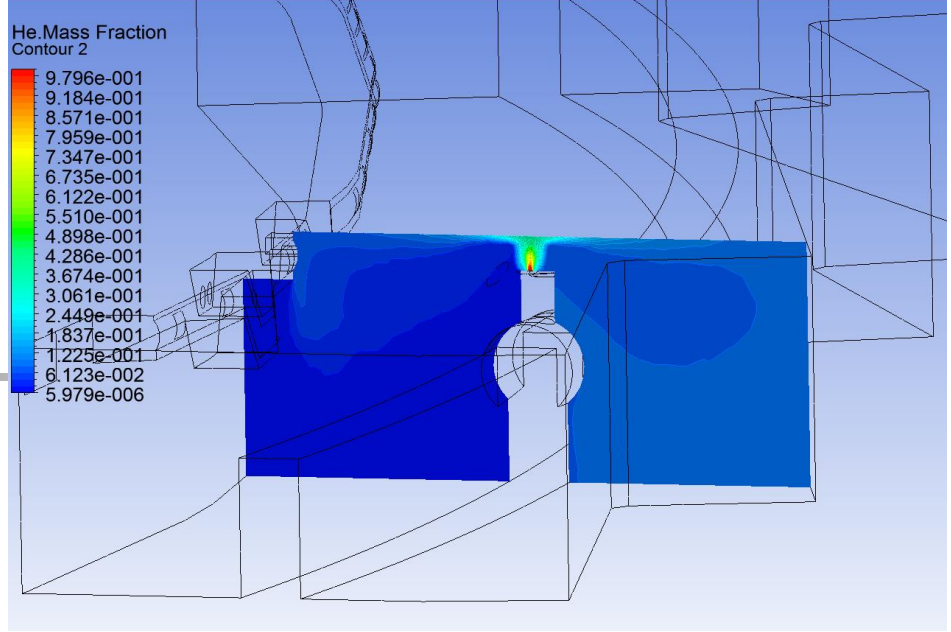
Case1

氦氣洩漏溫度(K)	4.5
送風口風速(m/s)	2
兩側牆壁封閉	
洩漏口方向	向上
洩漏時間	10秒
洩漏量	4.2kg/s
排氣壓力	1000pa

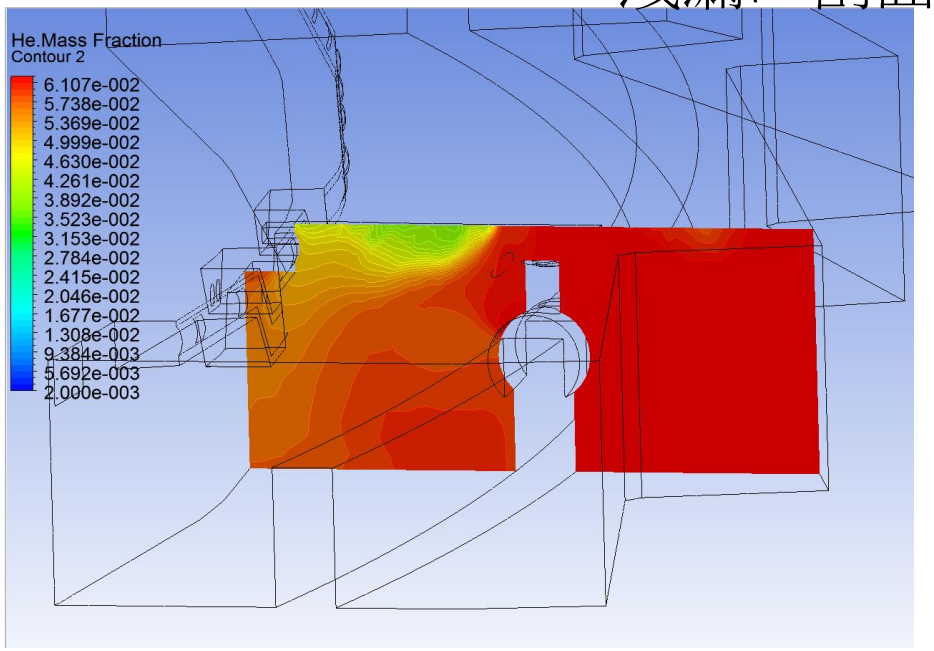
Case2

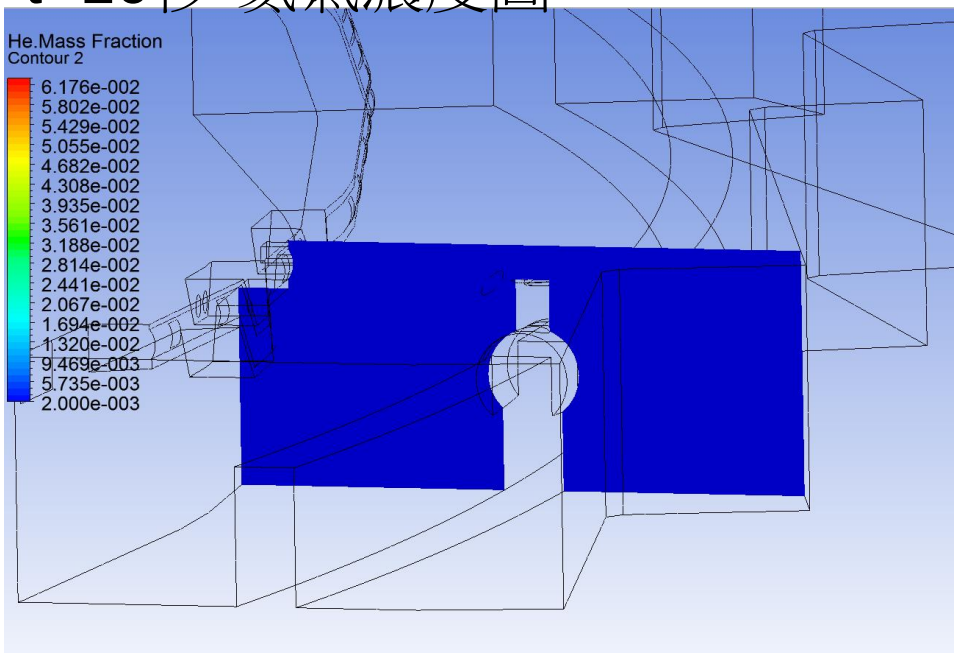
氦氣洩漏溫度(K)	4.5
送風口風速(m/s)	2
兩側牆壁打開	
洩漏口方向	向上
洩漏時間	10秒
洩漏量	4.2kg/s
排氣壓力	1000pa





洩漏口剖面 t=10秒 氦氣濃度圖

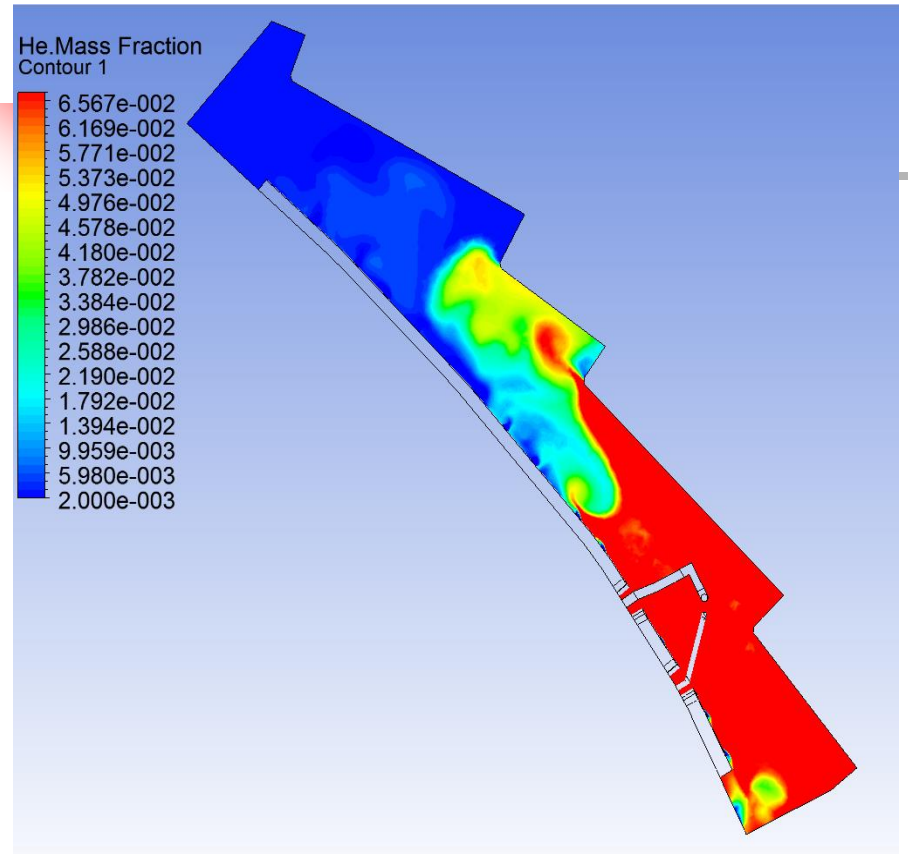


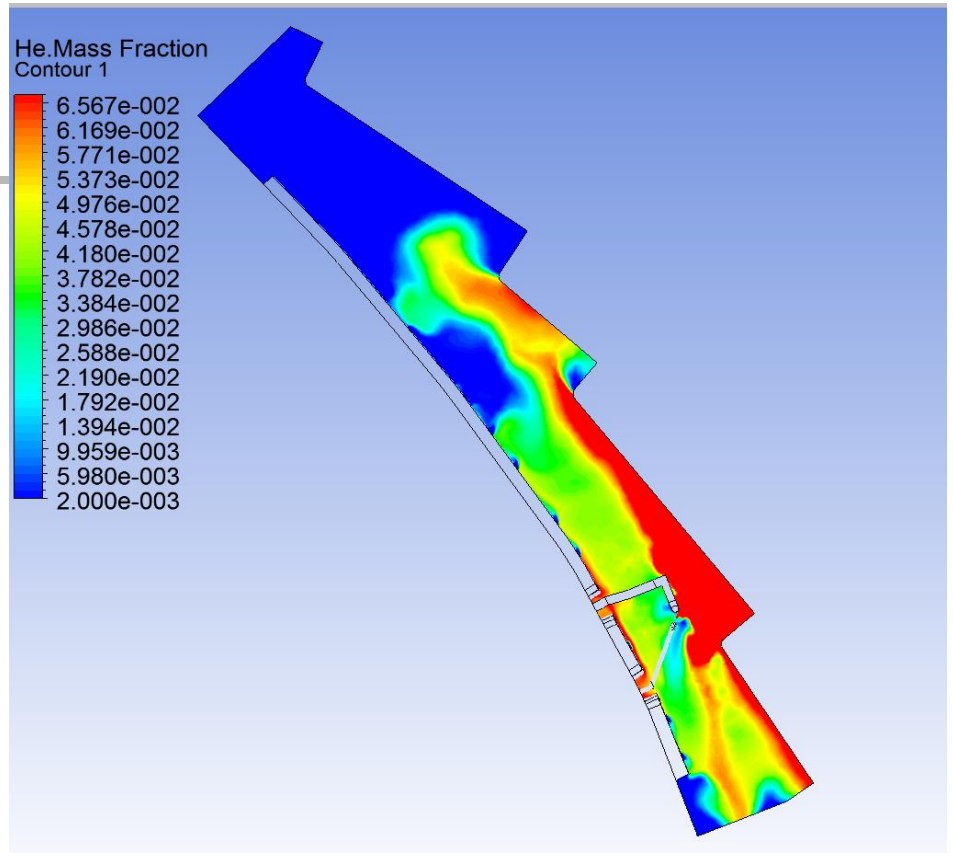


洩漏口剖面 t=30秒 氦氣濃度圖

Case1

Case2

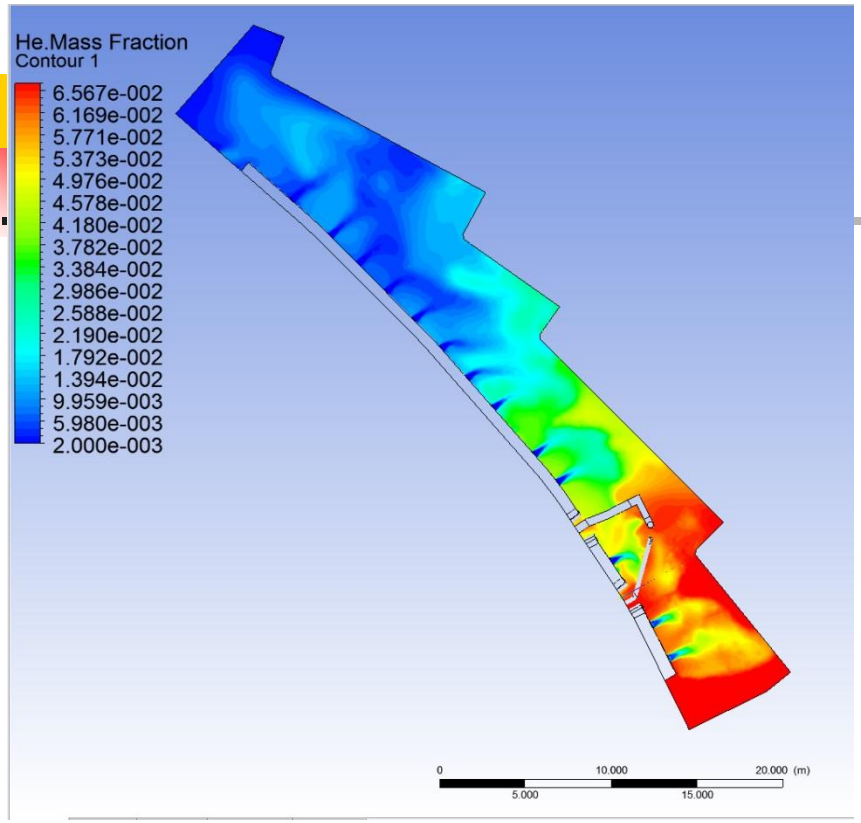


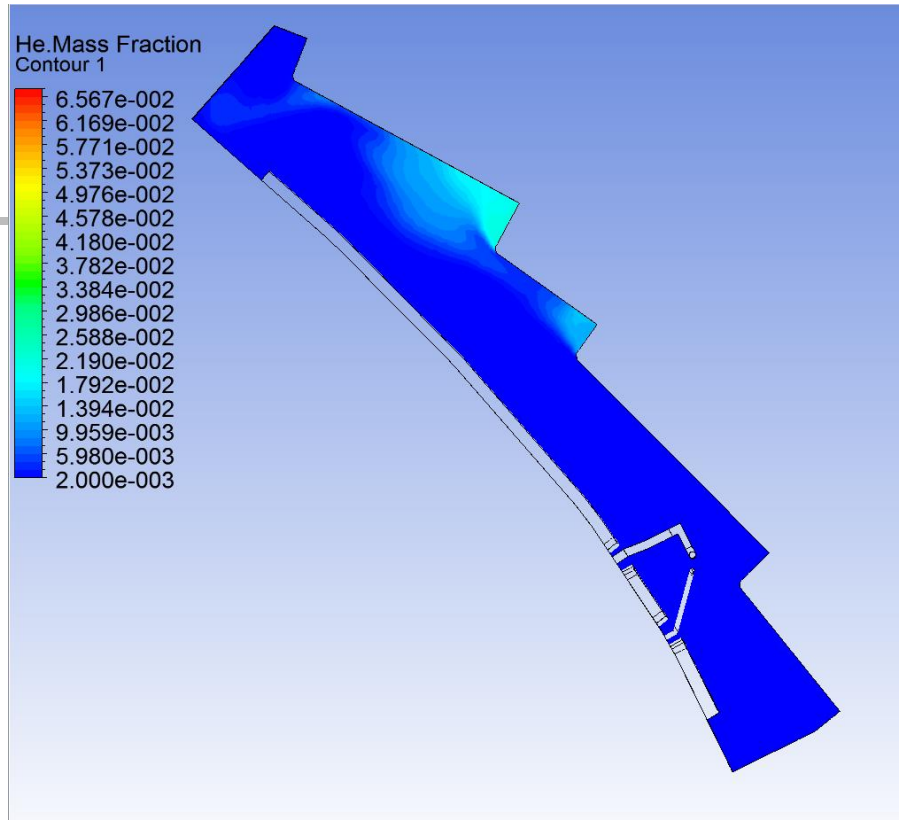


排氣口剖面 t=10秒 氦氣濃度圖

Case1

Case2

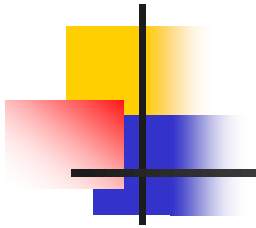




kg s1000pa_OPEN_close_timestep0 02(0-36.4sec).wmv

kg s1000pa_OPEN_close_timestep0 02(VOLUME0-36.4sec).wmv

排氣口剖面 t=30秒 氨氣濃度圖



Case1

Area-Weighted Average
Mass fraction of he

fan	0.052659565
he	0.99996817
in	0
ra	0.035524678
Net	0.022670641

Case2

Area-Weighted Average Mass fraction of he	
fan	0
he	0.99996817
in	0
ra	0.0011784028

邊界條件 II

Case1

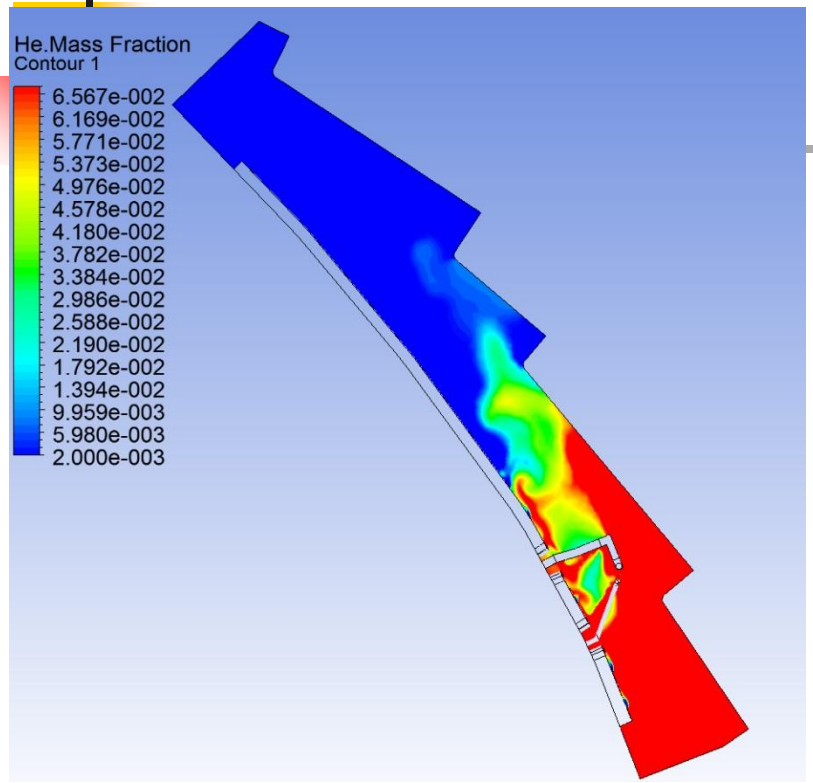
氨氣洩漏溫度(K)	4.5
送風口風速(m/s)	2
兩側牆壁封閉	
洩漏口方向	向右
洩漏時間	10秒
洩漏量	4.2kg/s
排氣壓力	1000pa

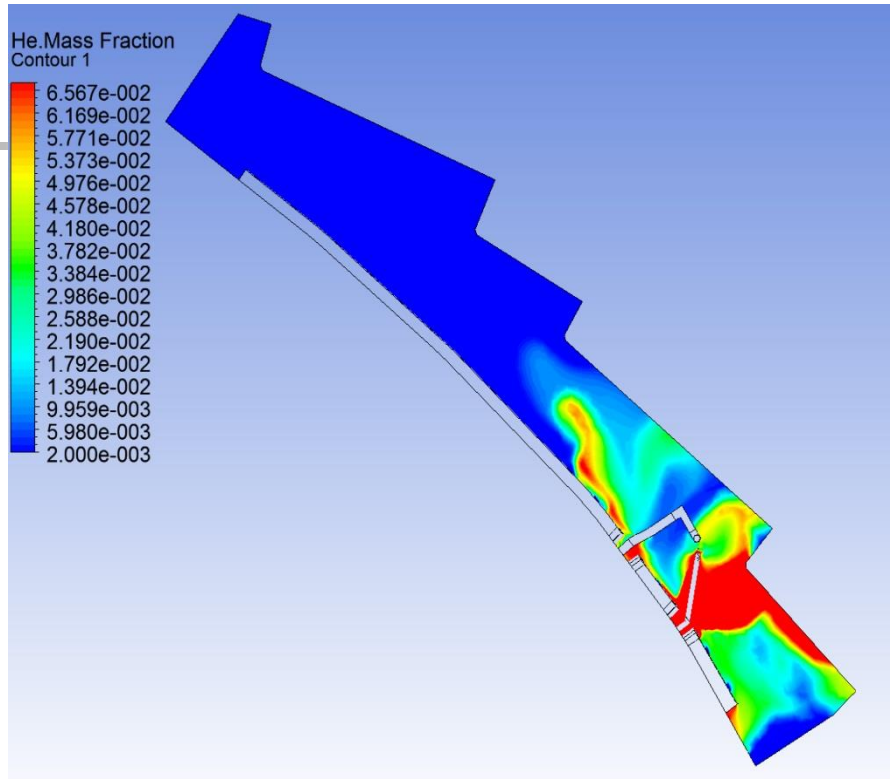
Case2

氨氣洩漏溫度(K)	4.5
送風口風速(m/s)	2
兩側牆壁開啟	
洩漏口方向	向右
洩漏時間	10秒
洩漏量	4.2kg/s
排氣壓力	1000pa

Case1

Case2

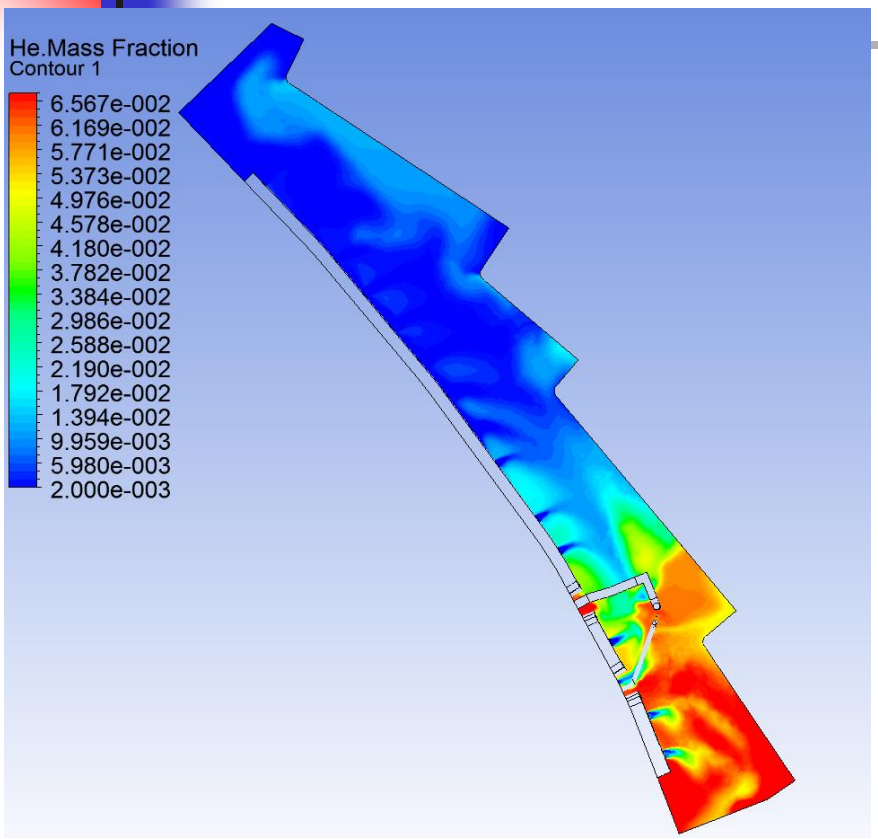


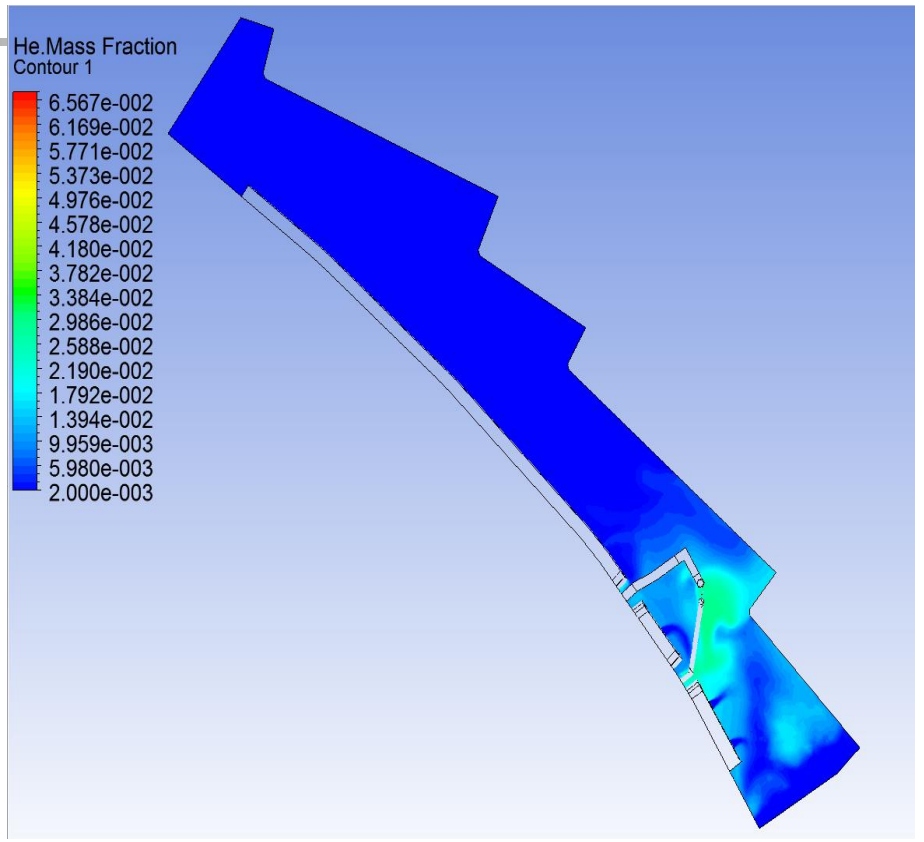


排氣口剖面 t=10秒 氨氣濃度圖

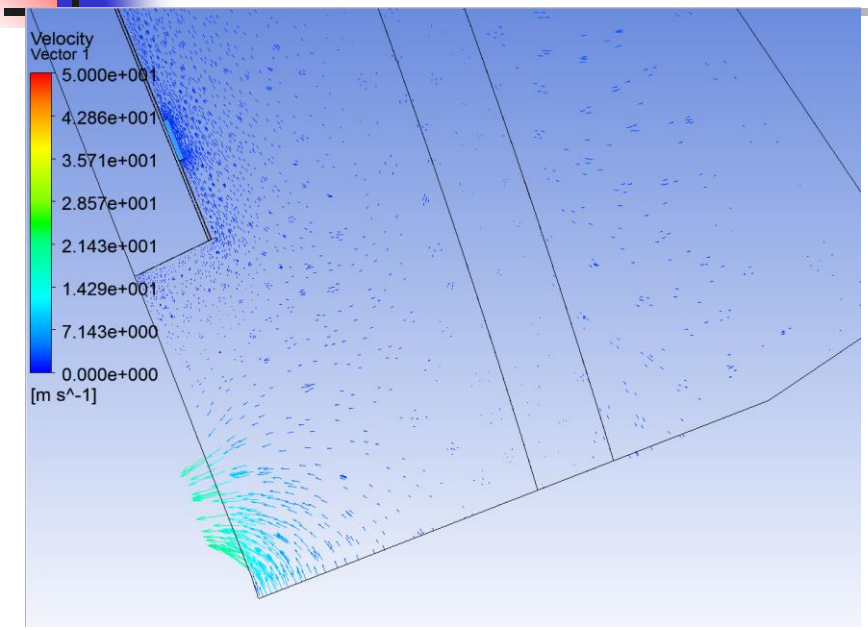
Case1

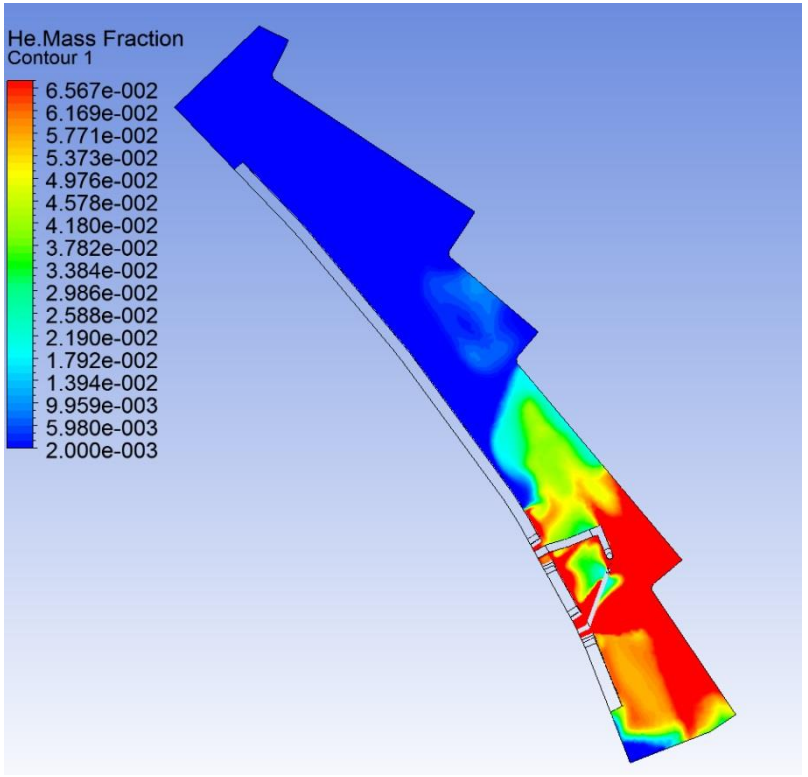
Case2





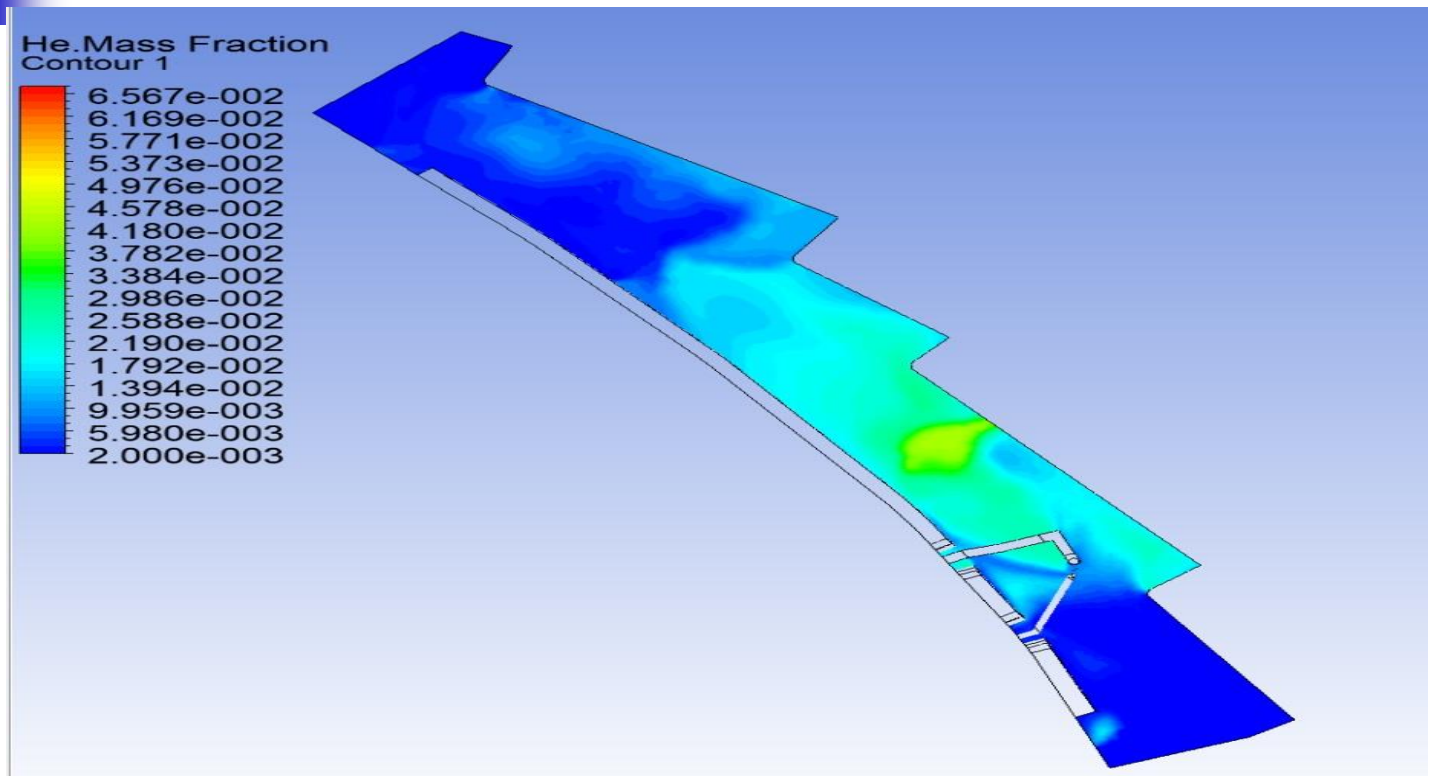
排氣口剖面 t=30秒 氨氣濃度圖





排氣口剖面 t=10秒 氨氣濃度圖

無空調送風

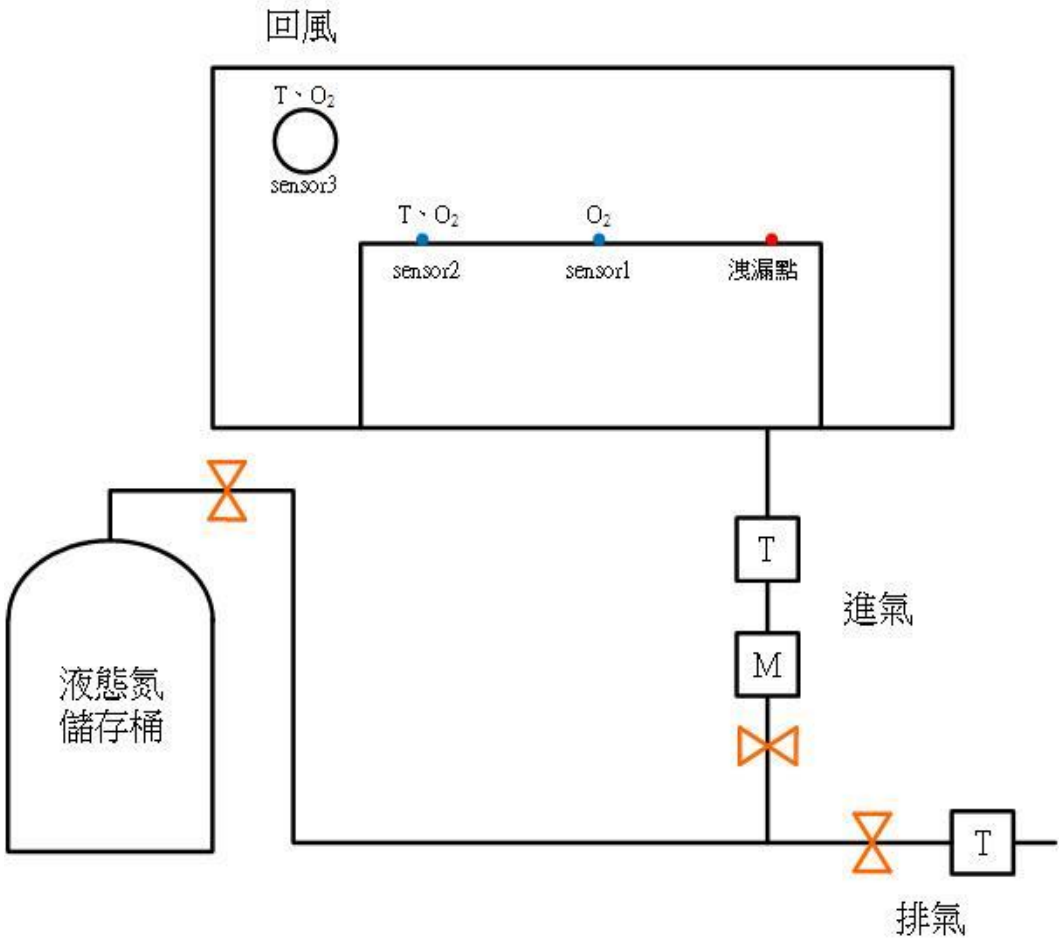


排氣口剖面 t=30秒 氨氣濃度圖

小型實驗驗證

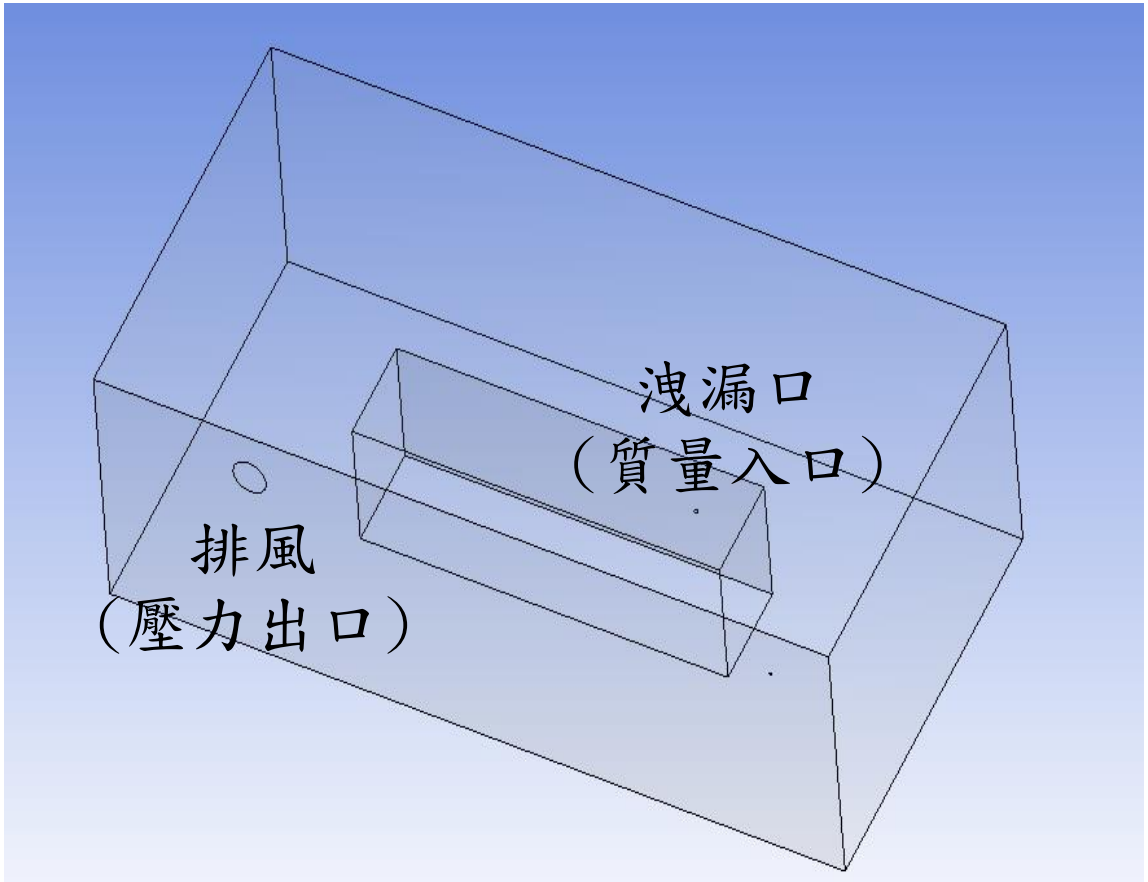
1. 進氣閥關閉、排氣閥開啟將管路冷卻
觀察排氣溫度sensor與出口狀態，待溫度穩定後(-150度C)，且確保出口為氣態時
，開啟進氣閥、關閉排氣閥。

2. 當氮氣進入腔體後sensor開始紀錄，持續時間10min。



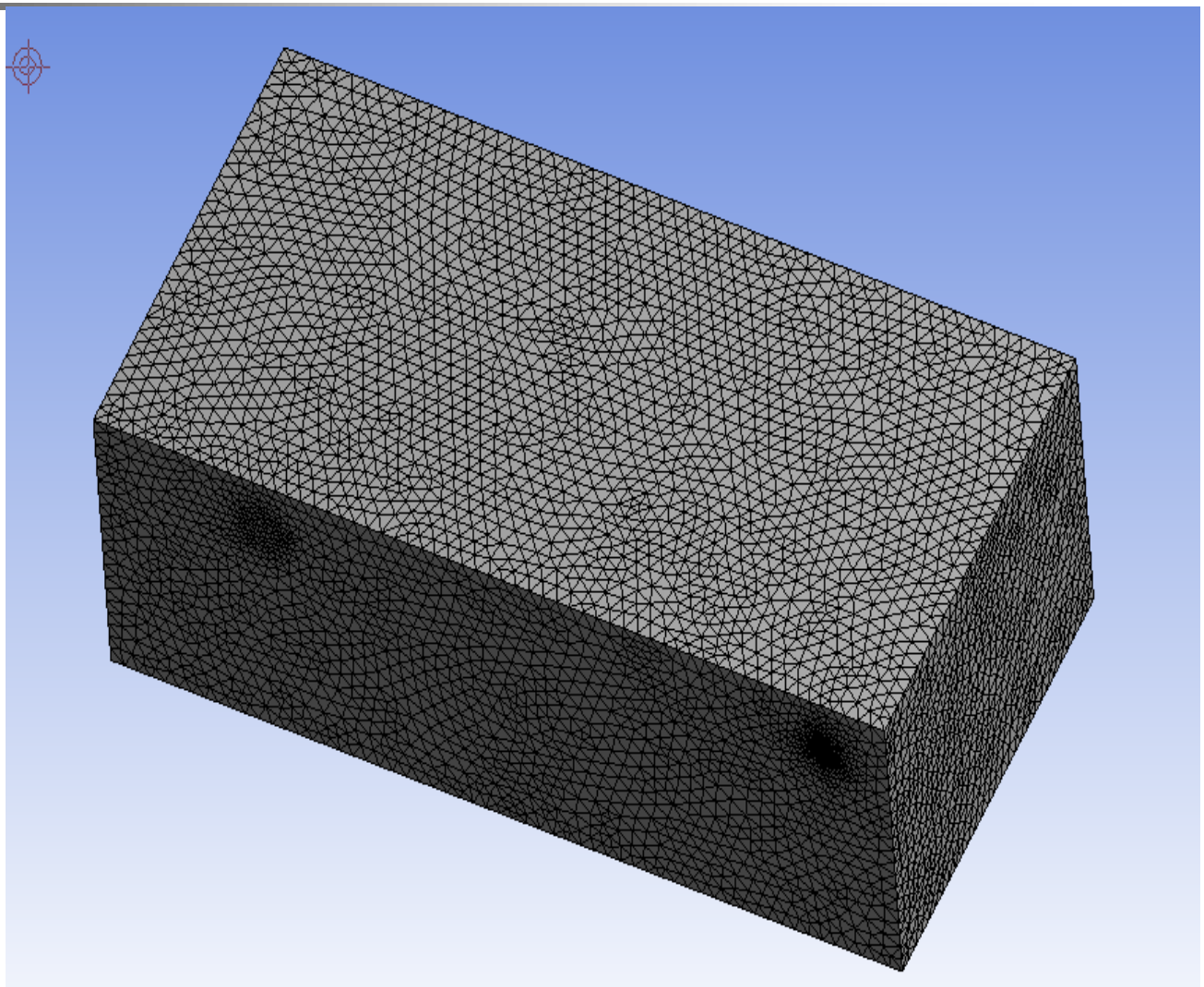
小型實驗驗證

模擬氣體：氮
洩漏溫度：
洩漏量：10LPM
模擬時間：600s

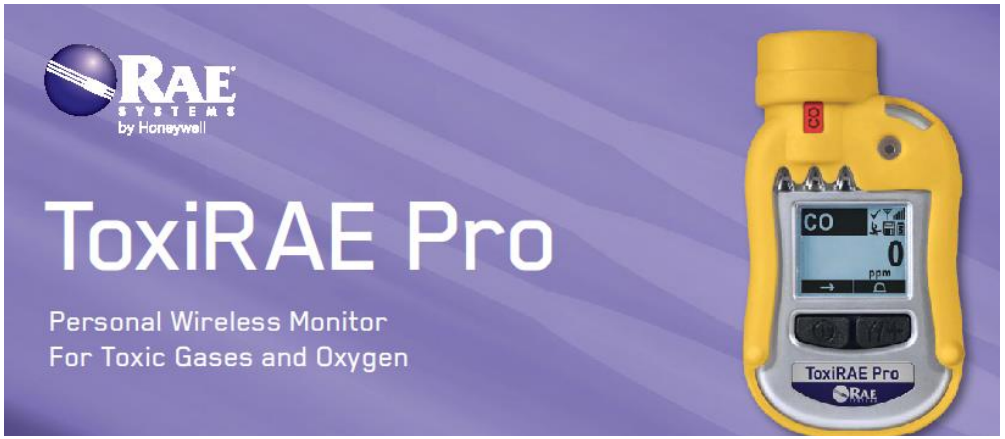


小型實驗驗證

網格數：18萬
最大尺寸：0.08m
最小尺寸：0.0004m



小型實驗驗證

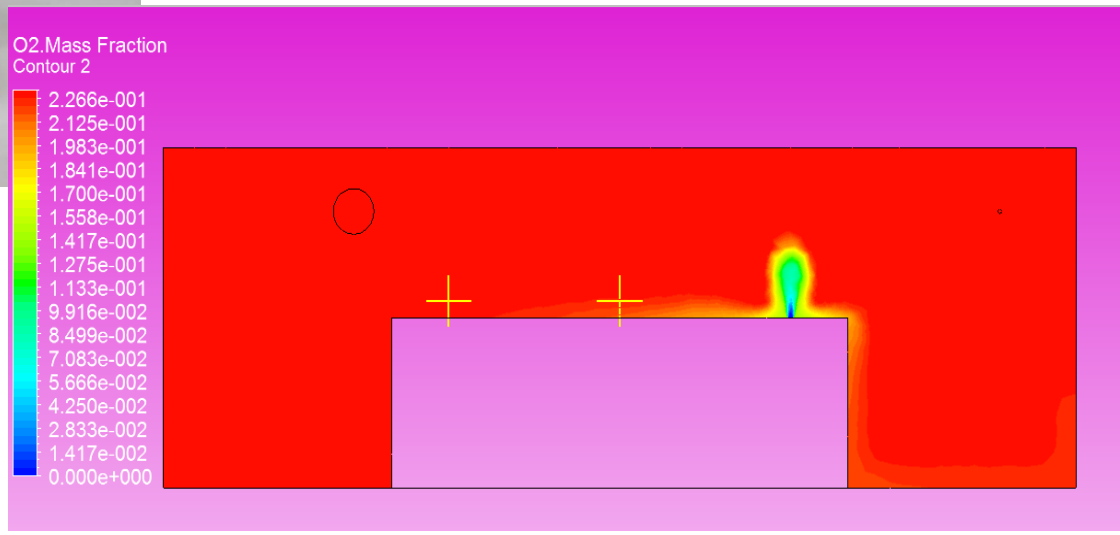


T type thermocouple (range:−200 to 350 ˚C)

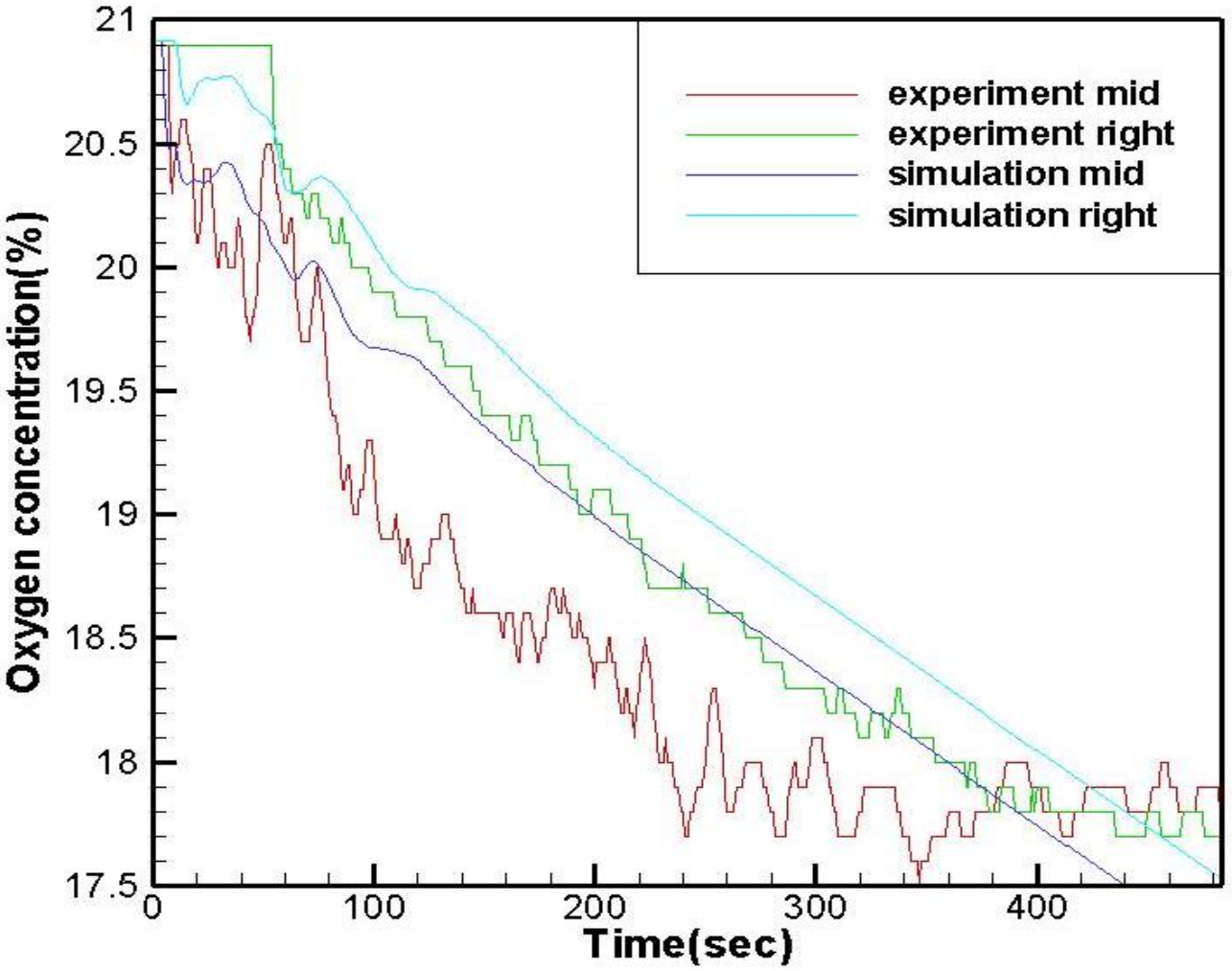
Sensor Specifications[4]

Sensor	Range	Resolution
Nitric Oxide (NO)	0 to 250 ppm	0.5 ppm
Nitrogen Dioxide (NO_2)	0 to 20 ppm	0.1 ppm
Oxygen (O_2)	0 to 30% Vol.	0.1% Vol.
Phosphine (PH_3) Phosphine (PH_3), Ext. Range	0 to 20 ppm 0 to 1,000 ppm	0.1 ppm 1 ppm

小型實驗驗證

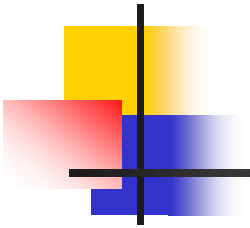

O2.Mass Fraction
Contour 2
2.266e-001
2.125e-001
1.983e-001
1.841e-001
1.700e-001
1.558e-001
1.417e-001
1.275e-001
1.133e-001
9.916e-002
8.499e-002
7.083e-002
5.666e-002
4.250e-002
2.833e-002
1.417e-002
0.000e+000

小型實驗驗證


experiment mid
experiment right
simulation mid
simulation right
Oxygen concentration(%)
Time(sec)
21
20.5
20
19.5
19
18.5
18
17.5
0
100
200
300
400

未來工作

- 修改小型實驗模擬邊界條件
- 繼續小型實驗與模擬驗證
- 修改Tunnel邊界條件與分析
- 模擬Hutch低溫氣體洩漏



謝謝聆聽，敬請指教