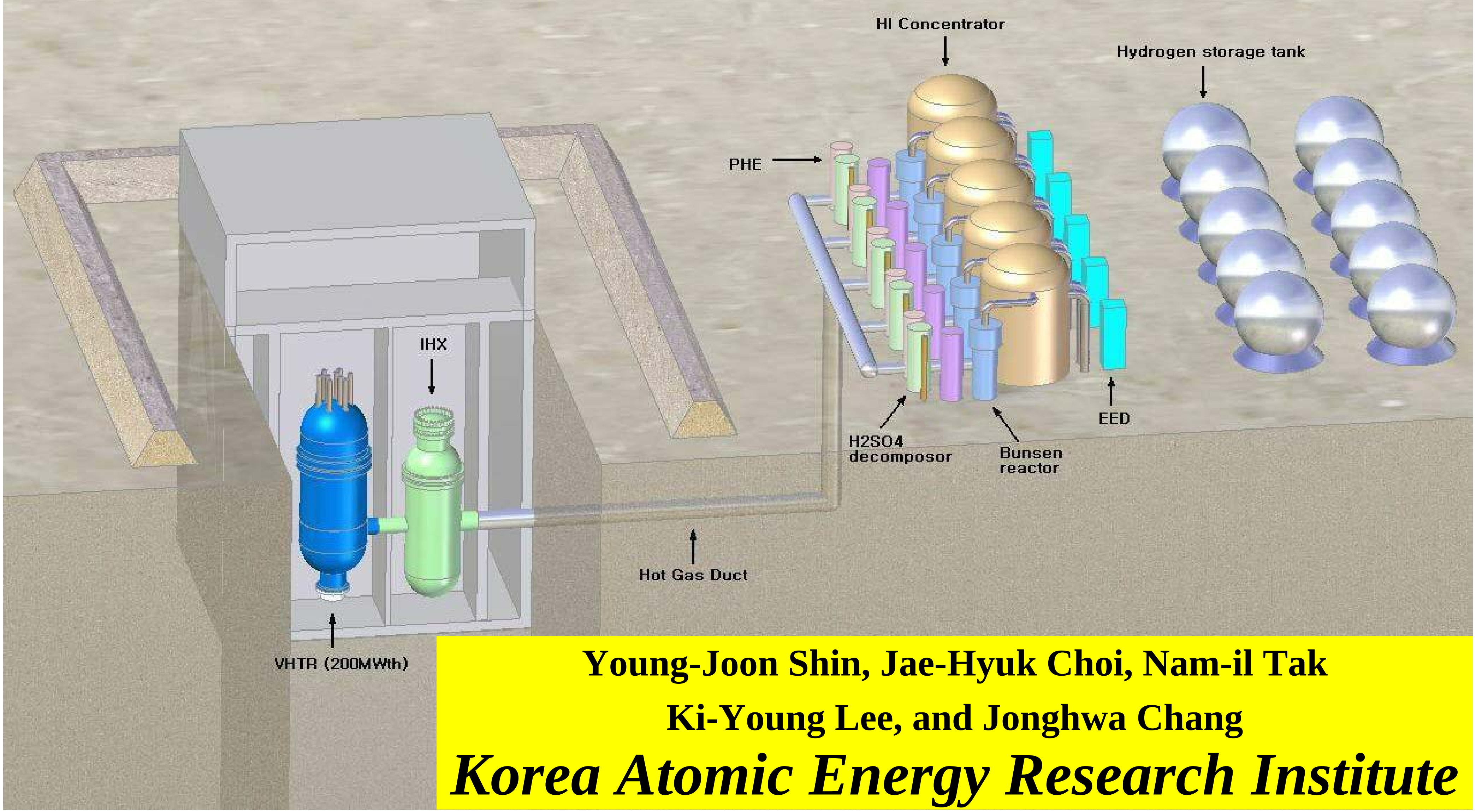
Computational Analysis of a Packed Column for SO_3 Decomposition in Sulfur-Iodine Process



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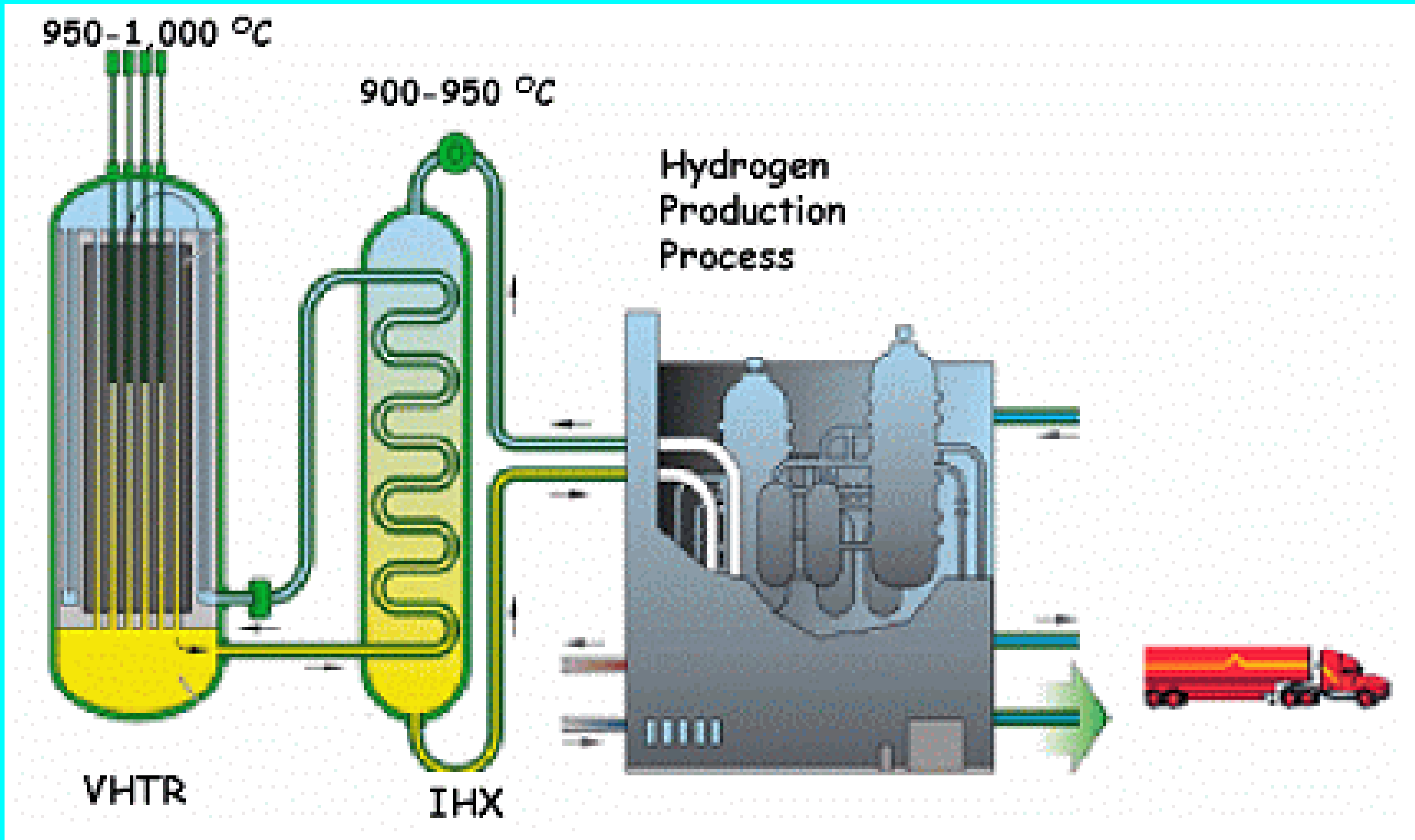
Research Background and Purpose

- The thermochemical and hybrid hydrogen production processes accompanied with the high temperature and strongly corrosive operating conditions basically have material problems.
- The development of a structural material and equipment design technologies is being carried out.

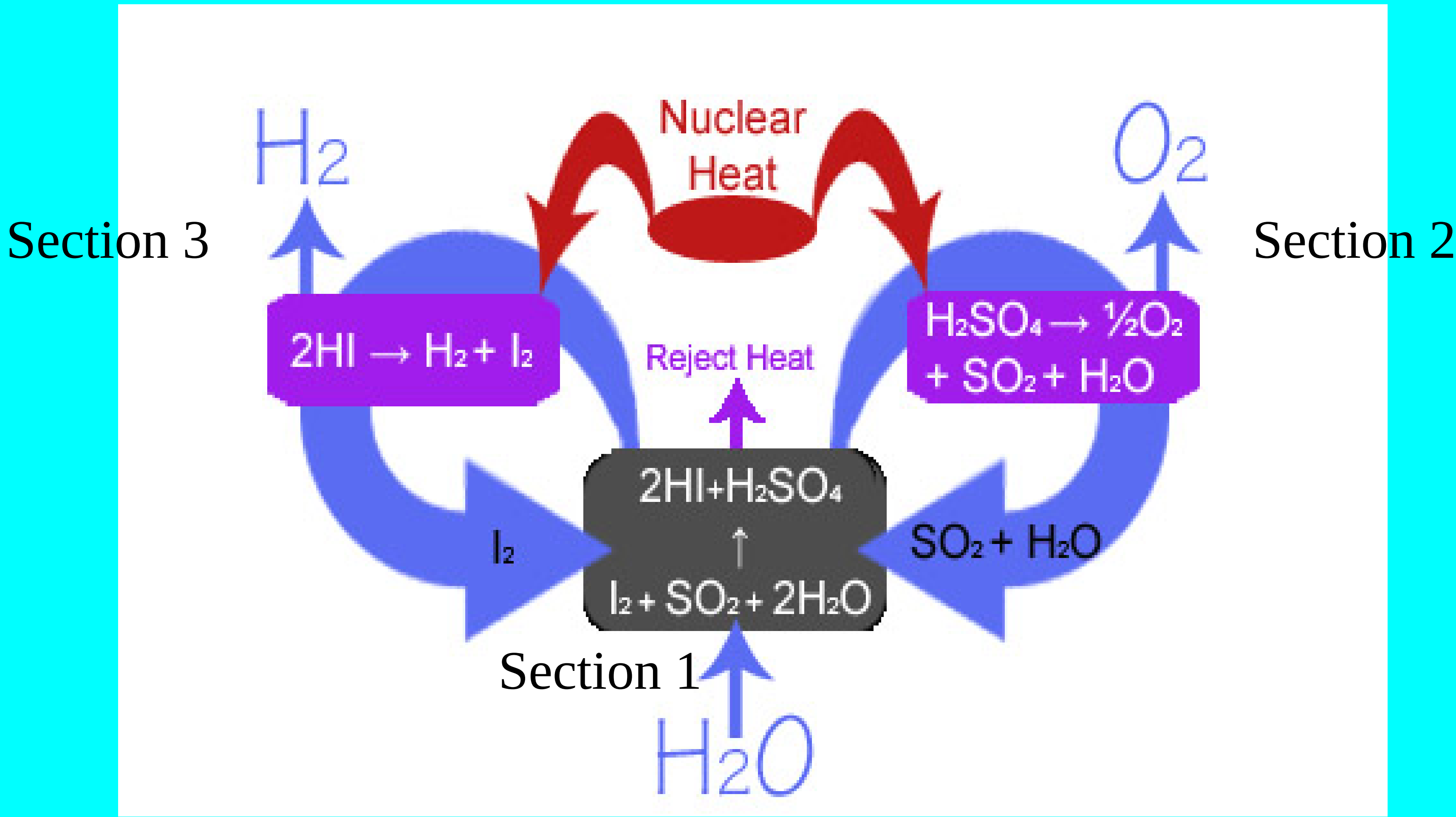
How to be free and easy from the material issue ?

☞In order to resolve these problems, the concept of a directly heated SO_3 decomposer for the SI and HyS processes has been introduced and analyzed by using a computational fluid dynamics code(CFD).

Nuclear Hydrogen Production System



Sulfur-Iodine Cycle



Preliminary Thermal Pathway for SI Cycle

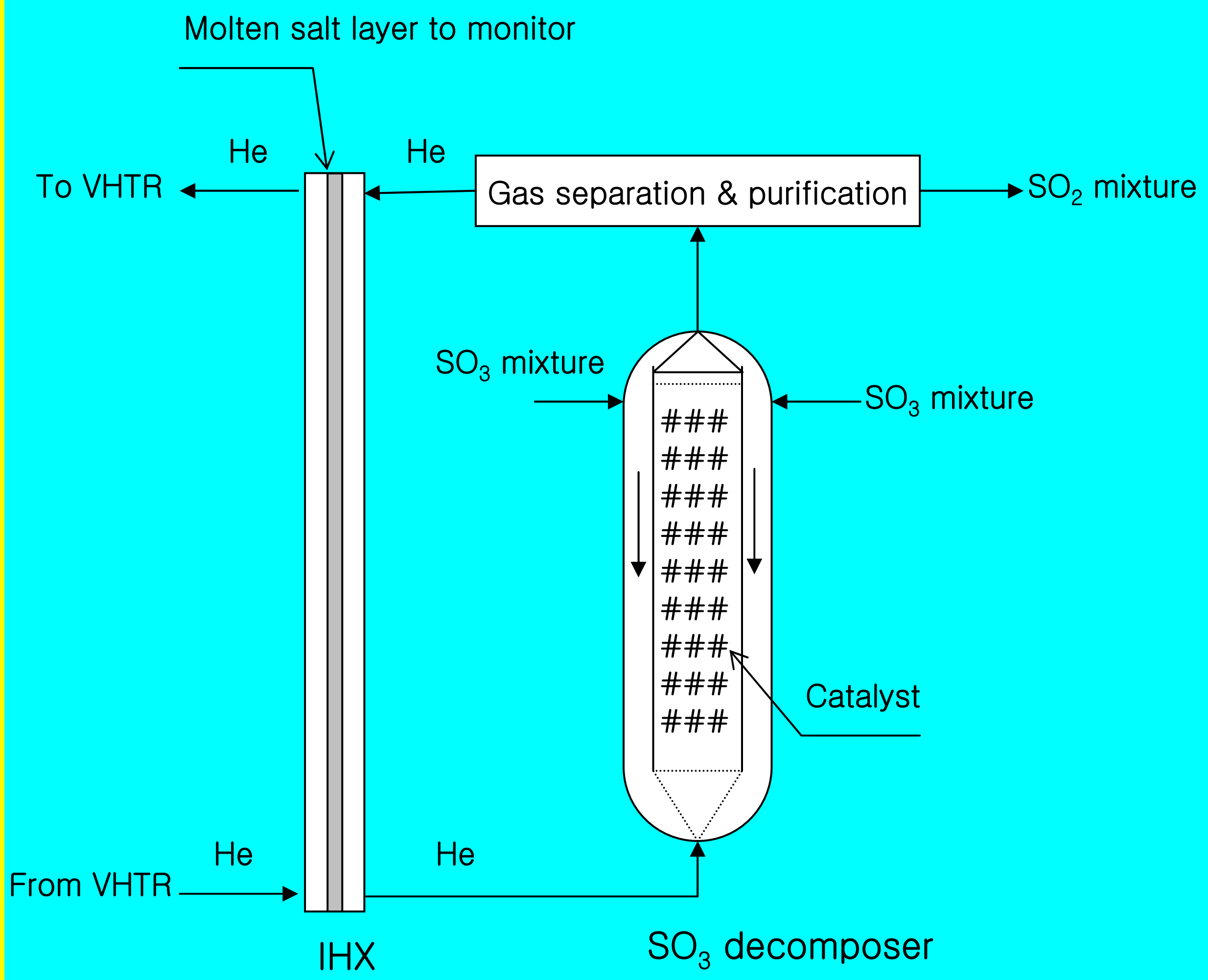
Concept of a Directly Heated SO_3 Decomposer

•In order to mitigate material problems and complex heat-exchanger configurations, the following conceptions are adopted.

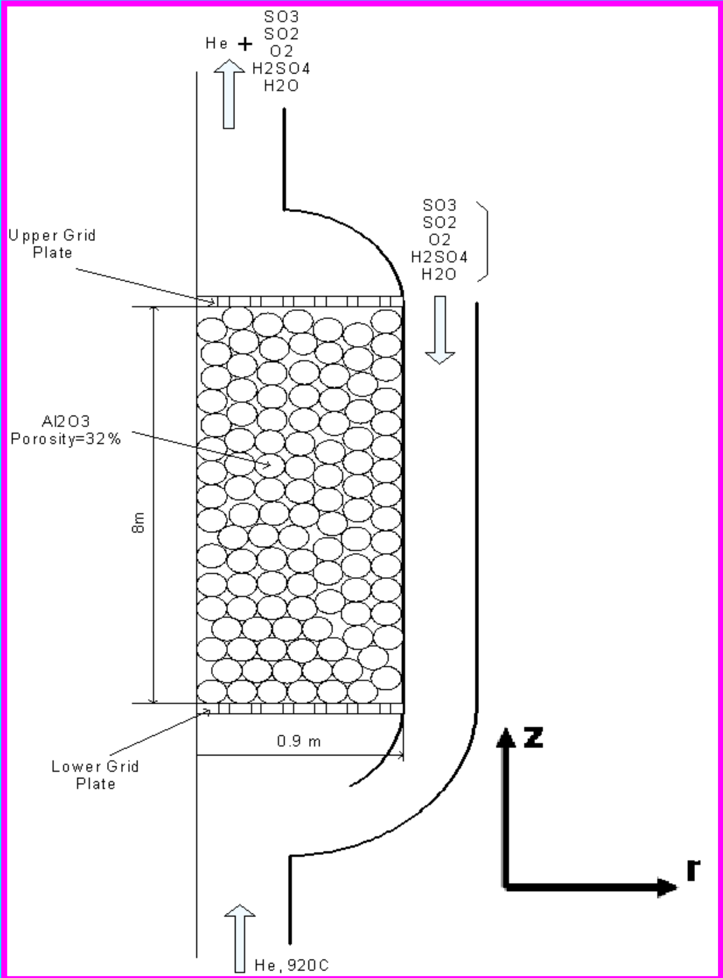
-A direct mixing of process and He gases to maintain an operation temperature.

-Insertion of molten salt layer to monitor the integrity of IHX.

-A gas separator to recycle He and process gases.



Design values for Chemical Decomposer(1/2)



Schematic of sulfur-iodine decomposer

Design values of thermo-chemical decomposer

	Values
Total decomposer length	16.06m
Decomposer height	8m
Inlet diameter for mixture gases	30cm
He inlet diameter	50cm
Upper & lower Grid plate thicknesses	3cm
Al_2O_3 catalyst diameter	2cm

□ RA330[6] as the material of the vessel and guide tube

Design values for Chemical Decomposer(2/2)

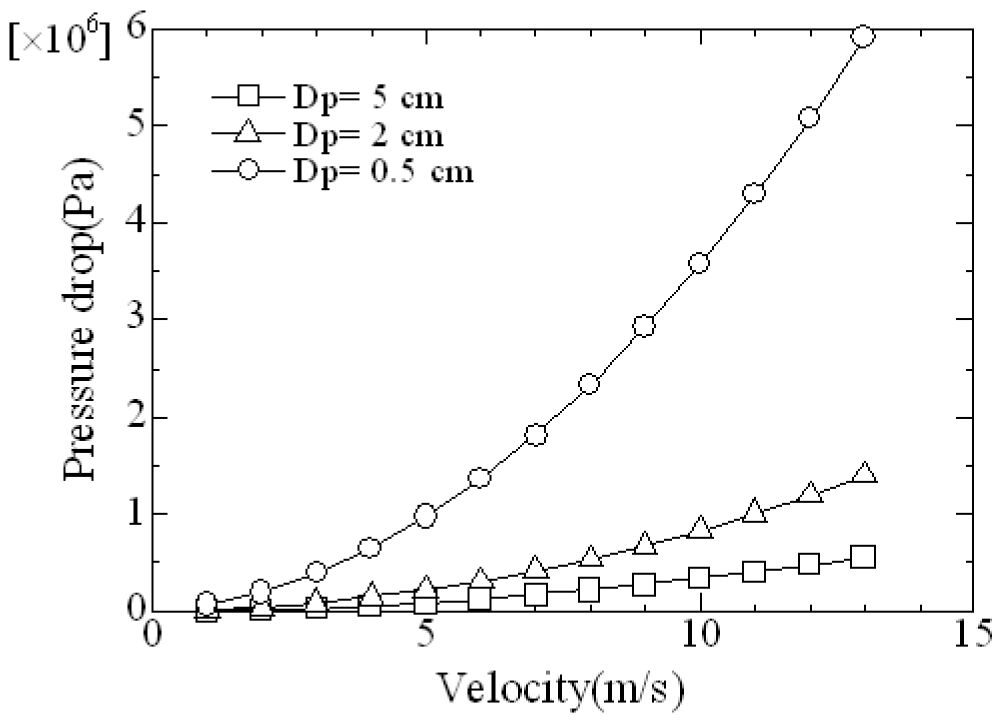
Mass fraction & mole fraction of mixture gases

	H_2O	O_2	SO_2	SO_3	H_2SO_4
Mass Fraction	22.12%	22.12%	22.15%	33.38%	0.22%
Mole Fraction	1.7777	0.5	1	0.6031	0.0033

Operating conditions of thermo-chemical decomposer

	Flow rate	Inlet temperature	Operating pressure
He	2.0628 kg/s	920 ^oC	7.09bar
Mixture gas	1.8046 kg/s	450 ^oC	7.09bar

Pressure drop as function of catalyst diameter and gas velocity



■ Ergun Model

$$\frac{dp}{L} = -\frac{150\mu(1-\varepsilon)^2}{\varepsilon^3 D_p^{\ 2}} - \frac{1.75\rho(1-\varepsilon)u^2}{\varepsilon^3 D_p}$$

$\mu = viscosity[kg/ms]$

$\rho = density[kg/m^3]$

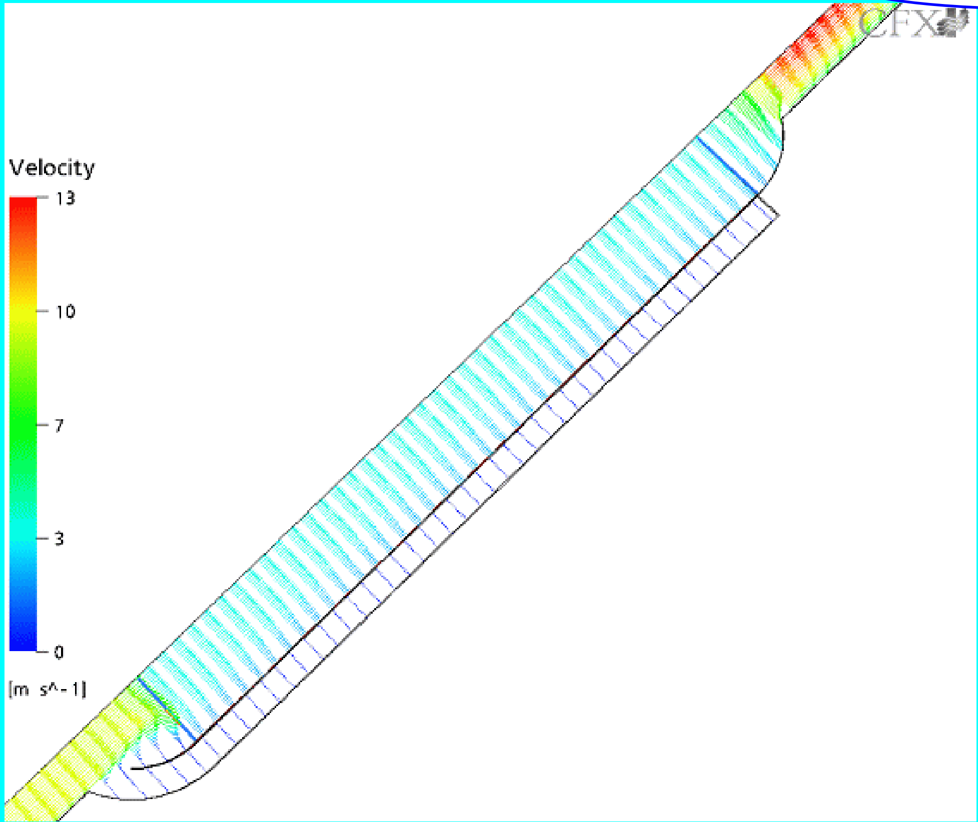
$D_p = Al_2O_3 diameter[m]$

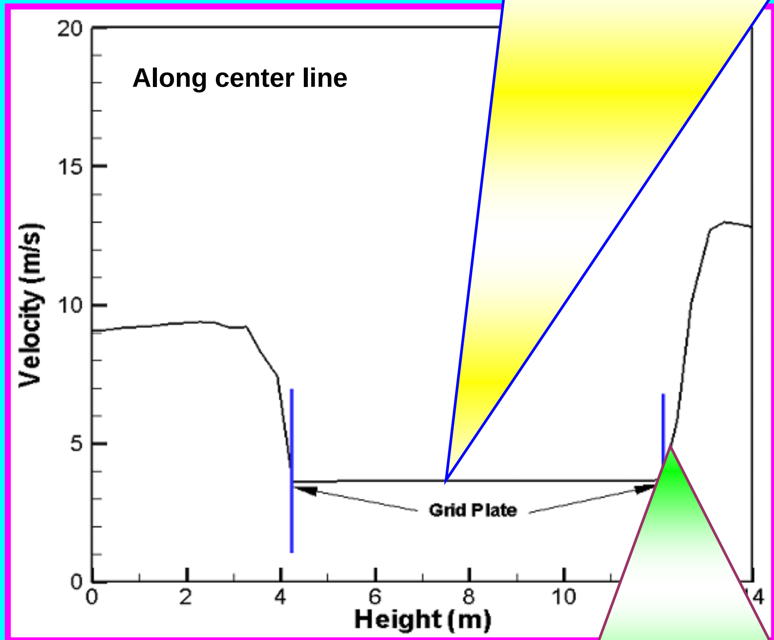
$\varepsilon = porosity[-]$

$u = su\,erficial velocity[m/s]$

Velocity profile

the velocity maintained about 9m/s is decreased drastically at a lower grid plate (z= around 4 m). The flow comes out of the upper grid plate (z=12 m) and the velocity maintained with 3.1m/s in the catalyst region

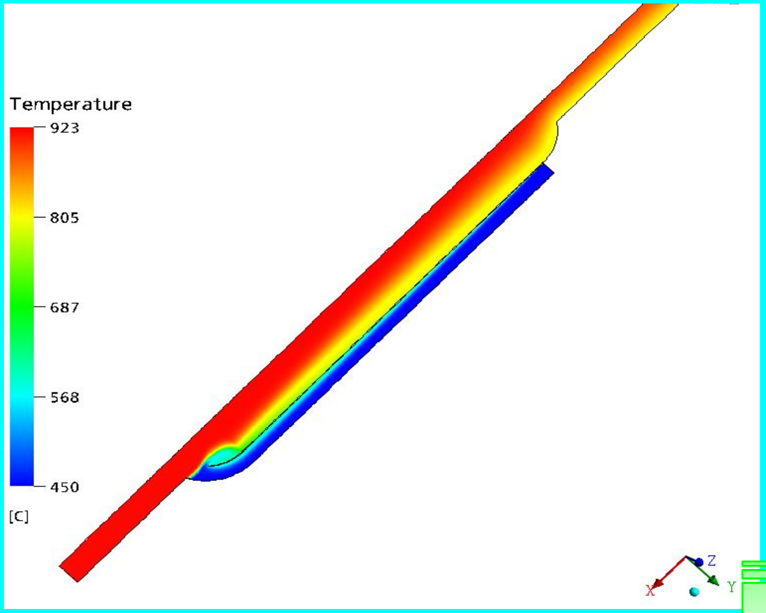




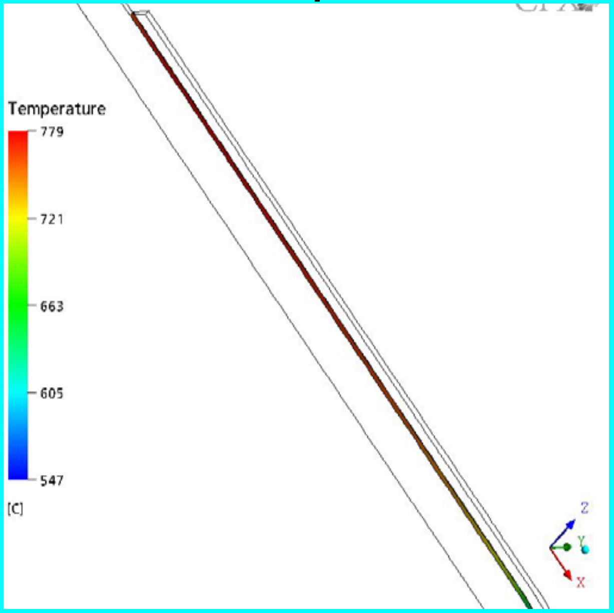
The rapid rise of the velocity at the outlet due to an augmentation by helium and process gas.

Temperature contour

Decomposer temperature contour



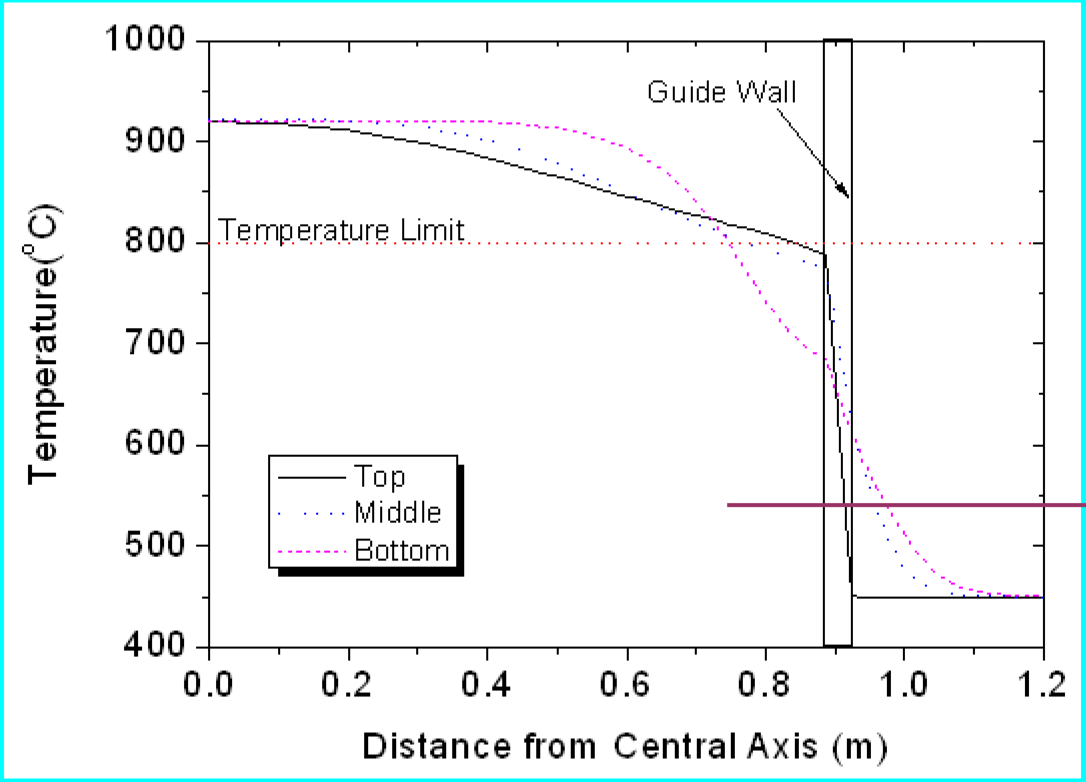
Guide tube temperature contour



the maximum temperature of RA330 is lower than 800 ℃ which is considered as a limiting temperature

RA330 has good conditions as a structure material of a high temperature decomposer

Temperature profile in the r-direction

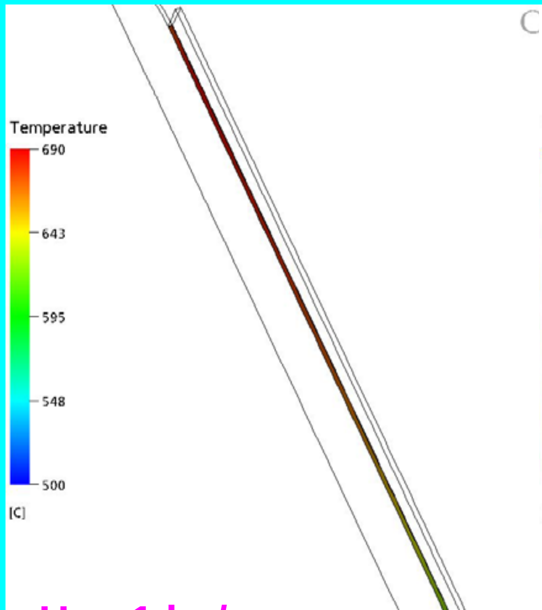


'Top' represents the bottom surface of the upper grid plate.
'Middle' indicates the middle position of the Al2O3 region .
'Bottom' represents the upside surface of the lower grid plate.

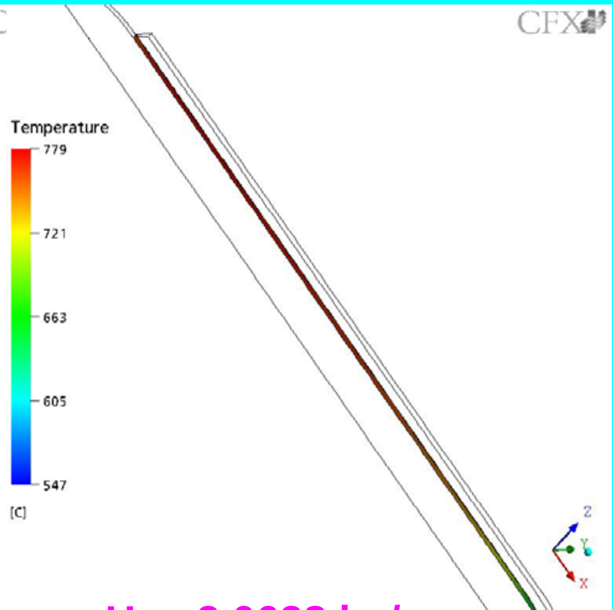
the guide wall maintains a temperature of around 850 ℃ in most of the Al2O3 region

The decomposer modeled in this study satisfies the temperature conditions for a chemical decomposition reaction

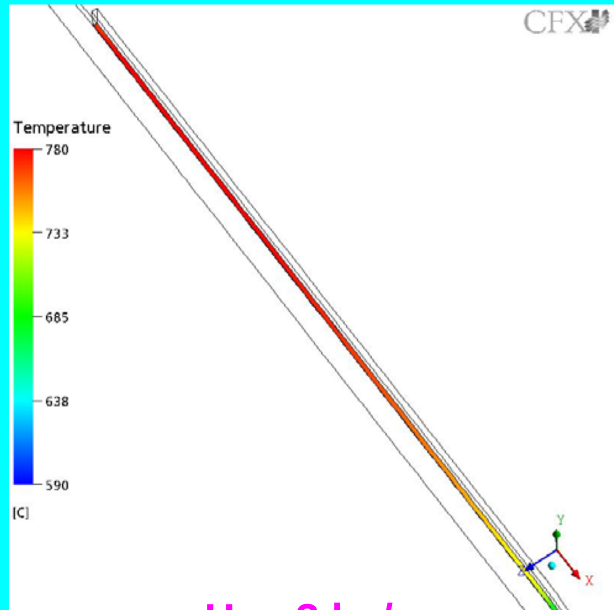
Guide tube Temperature contour with different He Flow Rate



He= 1 kg/s



He= 2.0628 kg/s



He= 3 kg/s

- ✓ The maximum temperature of RA 330 is 690℃ at He=1 kg/s. It is much lower than 800℃ which is considered as a limiting temperature. The mean temperature in the Al_2O_3 region is 783℃ which is a little low temperature to decompose a sulfur-iodine.
- ✓ The maximum temperature of guide tube is 780℃ at He=3 kg/s, and The mean temperature in the Al_2O_3 region is 890℃ which is good temperature to decompose a sulfur-iodine.

Conclusions

- A numerical analysis for a directly heated SO3 decomposer has been made.

- When the conceptual design conditions of the decomposer presented in this research were used, the maximum temperature of the structural material (RA330) could be maintained at 800℃ or less.

- It can be seen that the mean temperature of the reaction region packed with catalysts in the SO3 decomposition reactor could satisfy the temperature condition of around 850 ℃ which is the target temperature in this study.

- An improved heat transfer model for a catalyst layer including a chemical reaction is required.

Thank you.