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Accident Environment Assessment for the Development of a Flammability Risk Monitoring System

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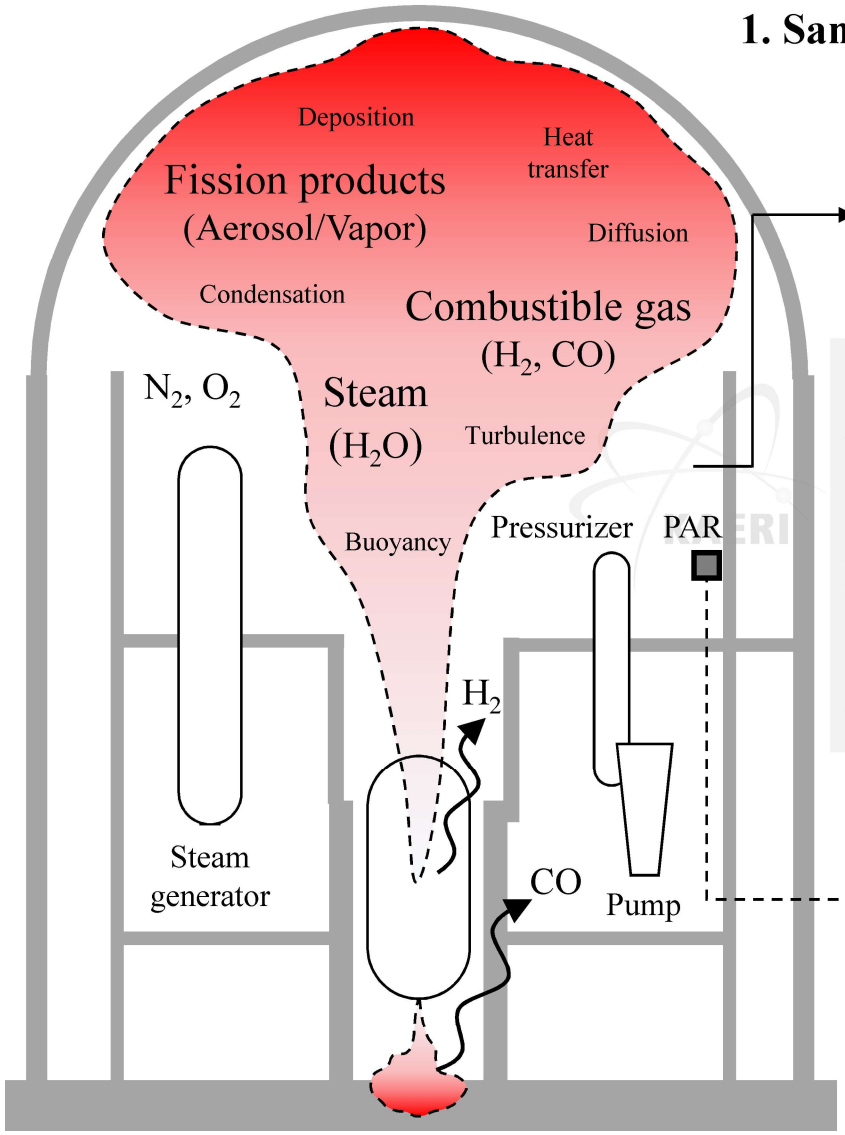
Development of flammability risk monitoring system



1. Sampling measurement system and performance assessment

Gas mixture (H_2, CO H_2O, Air, aerosol, ...) → Prepocessing module (T, P, H_2O, V, filter, ...) ↔ Sensing module ($H_{2,l}$, $H_{2,h}$, CO, O_2) → Data processing module (Transmitter, DAS, PC)

2. Severe accident analysis

H_2, CO, O_2

DB of event sequences
H_2, CO, $H_2O(t, x)$

DB of TH conditions
$T(t, x)$, $P(t)$

Data processing algorithm

Online monitoring of flammable gas risk

$LFL = f(T, H_2O, ...)$
Lower flammability limit

$$\sim \frac{H_2\&CO[vol.\%]}{LFL[vol.\%]} = 0\sim100$$

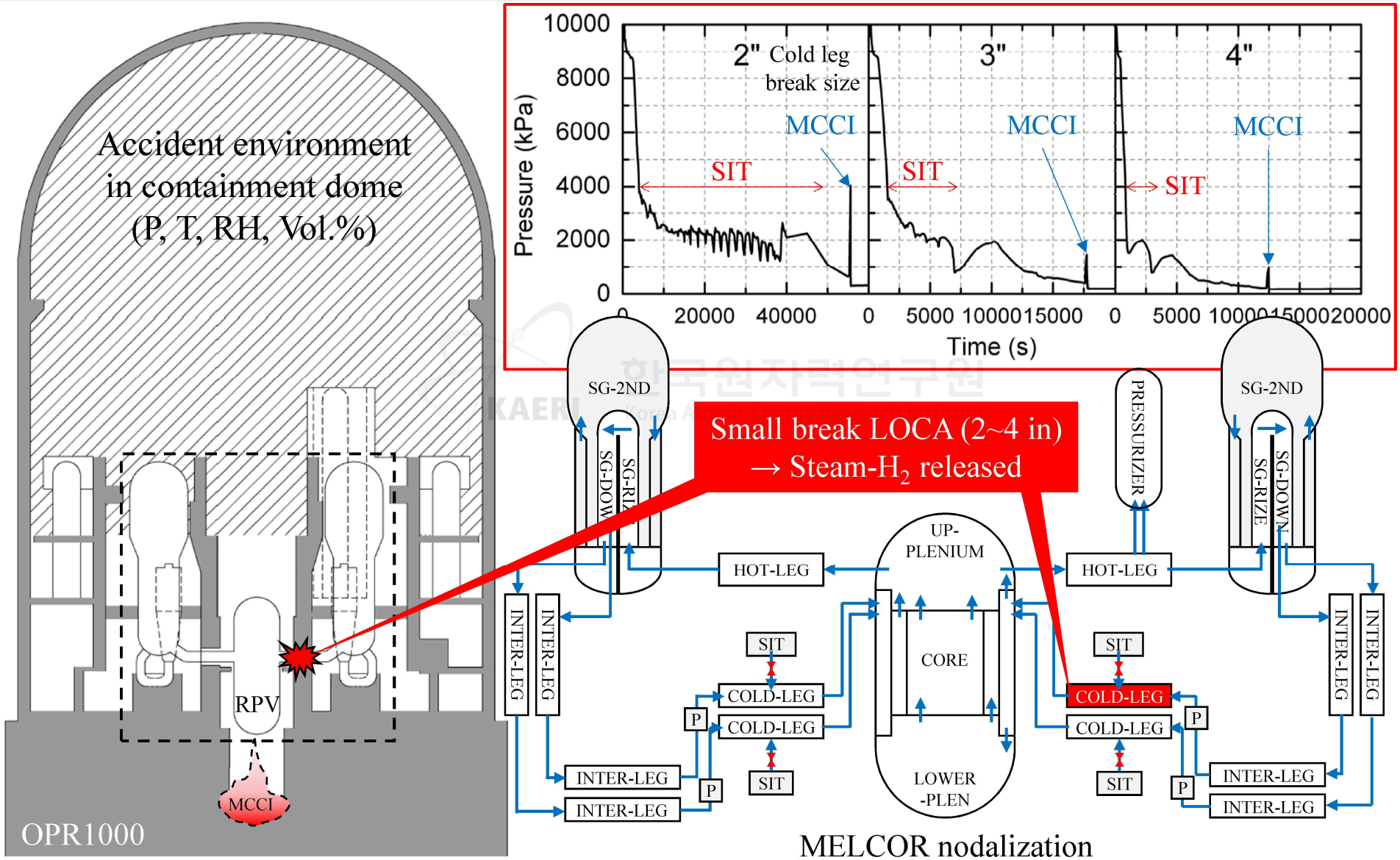
H_2

3. Non-sampling H_2 concentration evaluation method

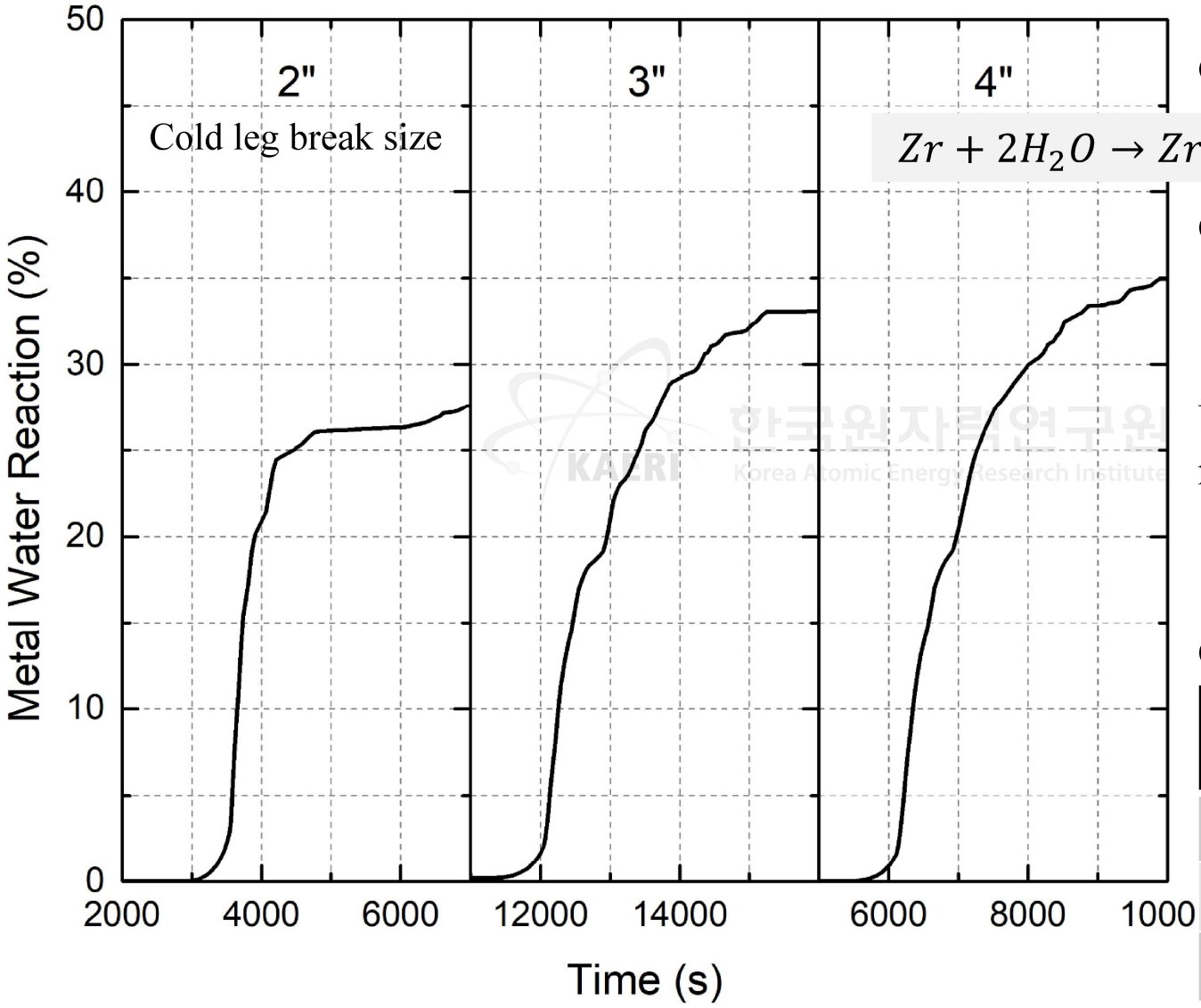
Evaluation model based on PAR operation

- Multi-physical analysis by CFD
- Heat and mass transfer models in PAR
- Lab/large scale PAR tests

TH conditions of the atmosphere being sampled



Key time ranges for H_2 production



Cladding oxidation

$$Zr + 2H_2O \rightarrow ZrO_2 + 2H_2 + 6.5\ MJ/kg$$

Oxidized Zr mass(kg/m^2)

$$\frac{d(W^2)}{dt} = K(T)$$

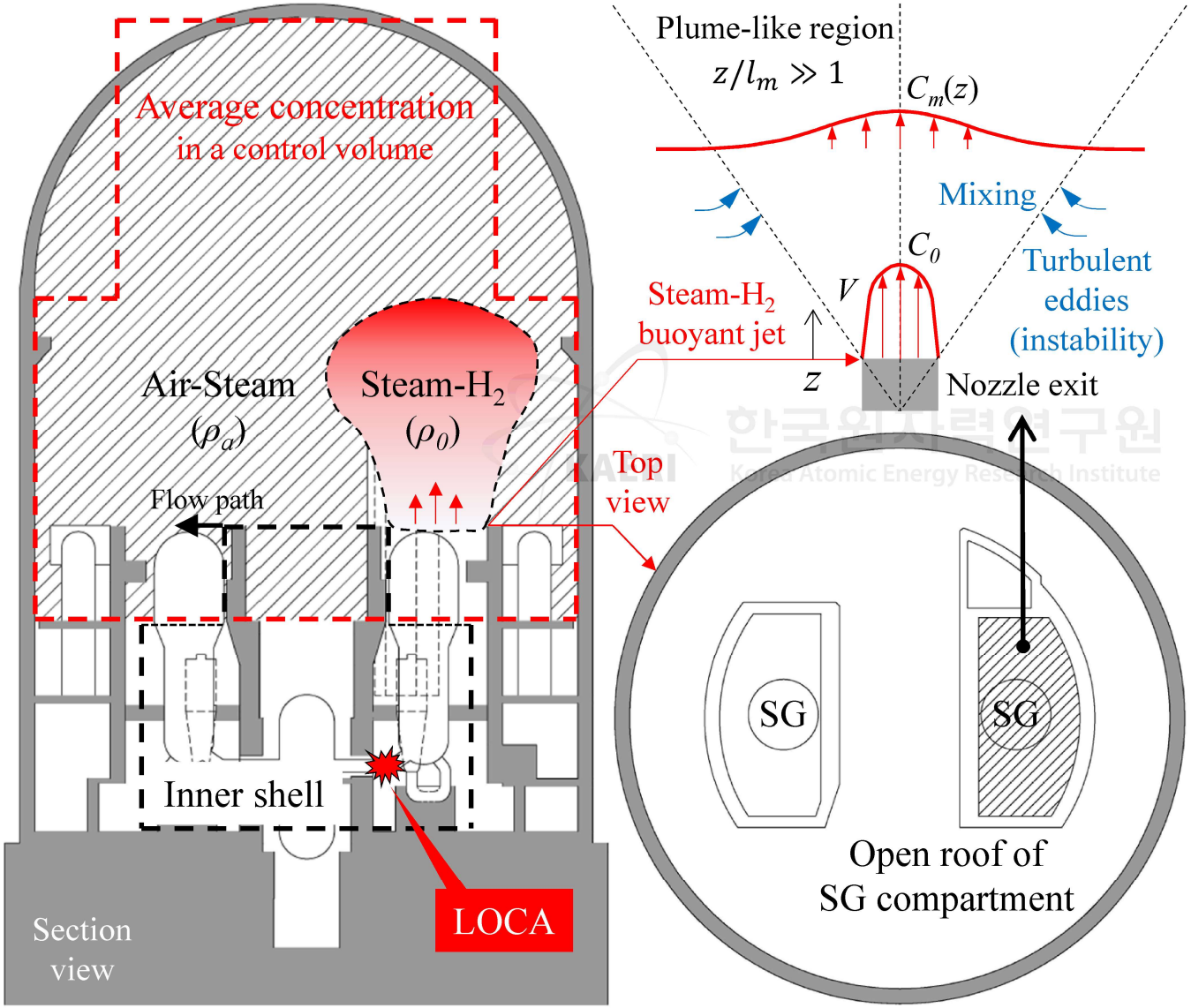
Urbanic-Heidrich reaction rate constant

$$K(T) = 29.6e^{\frac{-16820}{T}}$$

Oxidation time(s)

	Start at 1200 K	Rapid at 1853 K
2”	3,160 s	3,560 s
3”	11,550 s	12,100 s
4”	5,710 s	6,180 s

H_2 concentration in containment dome



Properties at nozzle exit	
Volume flux	$Q = V \cdot A$
Mass flux	$Y = Q \cdot C_0$
Momentum flux	$M = Q \cdot V$
Buoyancy flux	$B = Q \cdot g'$

$$g' = g \cdot \frac{\rho_a}{\rho_o} \qquad l_m = \frac{M^{0.75}}{B^{0.5}}$$

Centerline concentration of a plume

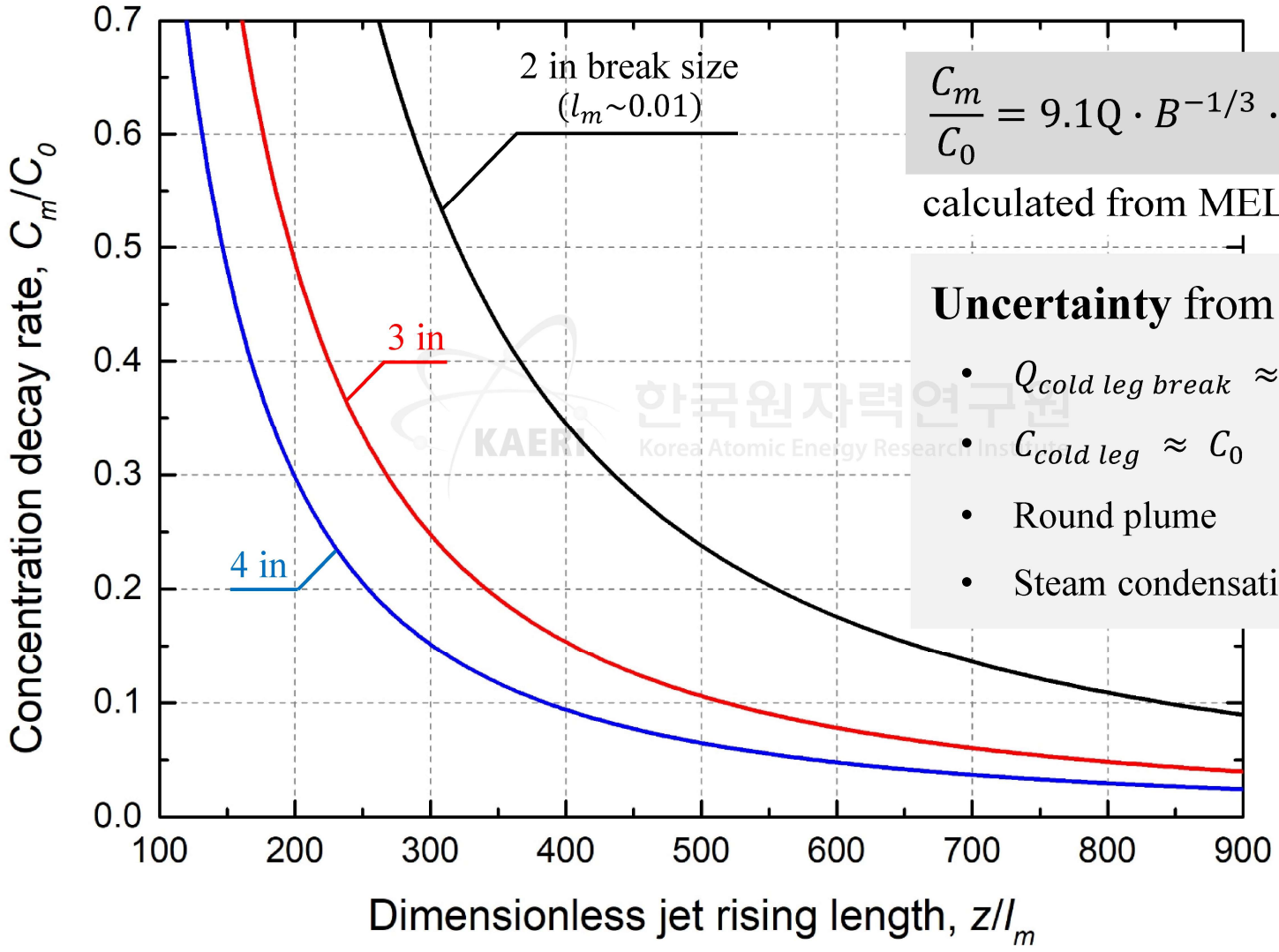
Dimensional analysis + Exp. DB

$$C_m \propto Y$$
$$C_m \propto B^{-1}$$
$$C_m \propto z^{-1}$$

Concentration decay rate

$$\frac{C_m}{C_0} = 9.1Q \cdot B^{-1/3} \cdot z^{-5/3}$$

Location and number of sampling points



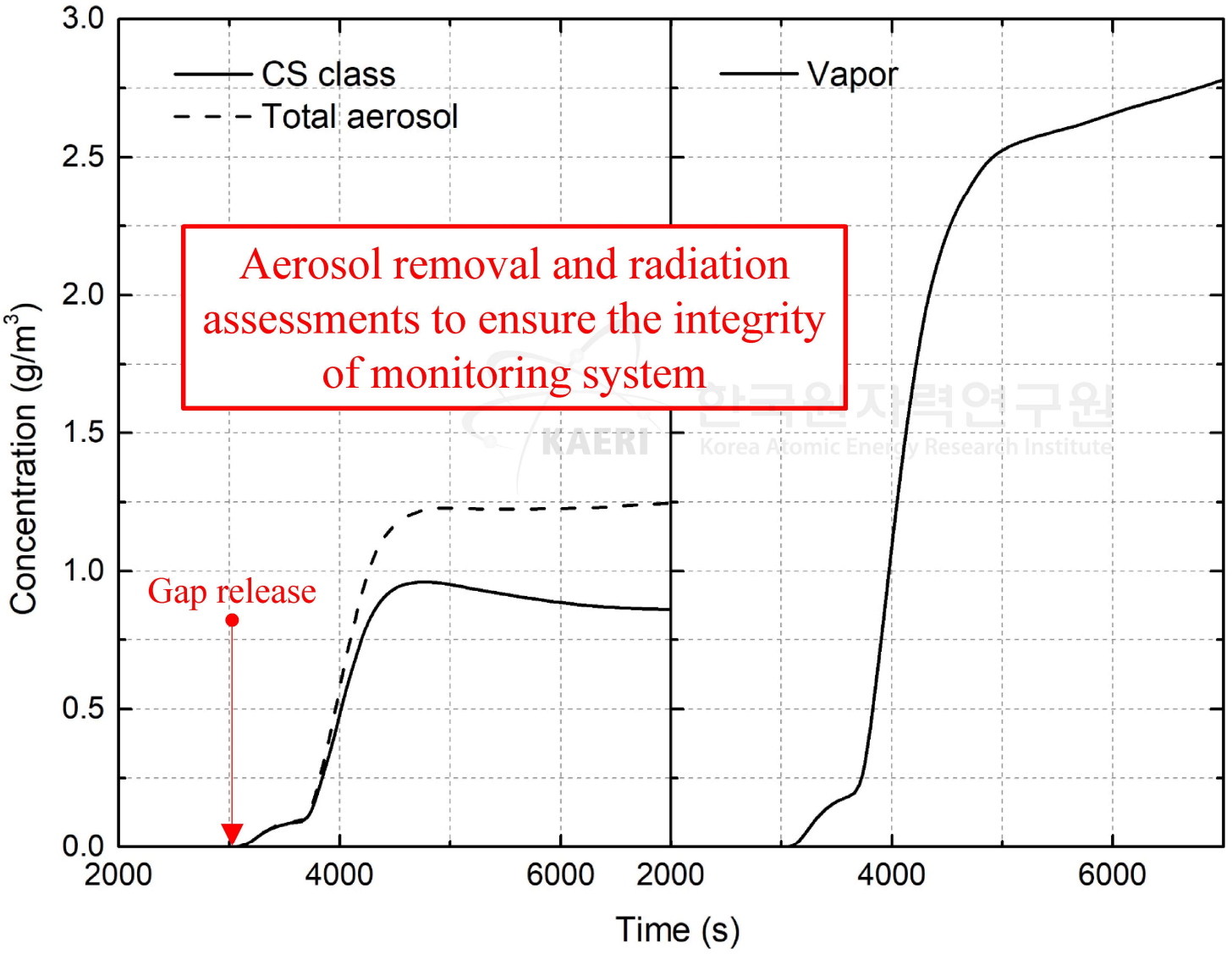
$$\frac{C_m}{C_0} = 9.1\mathrm{Q} \cdot B^{-1/3} \cdot z^{-5/3}$$

calculated from MELCOR output

Uncertainty from assumptions

- $Q_{cold\ leg\ break} \approx Q_{SG\ open\ roof}$
- $C_{cold\ leg} \approx C_0$
- Round plume
- Steam condensation

FPs behavior in the atmosphere being sampled



Size(mass) distribution(t) =

Source

generation

± Condensation /Evaporation

gas↔particle

± Agglomeration

combination

- Deposition

removal

Deposition velocity

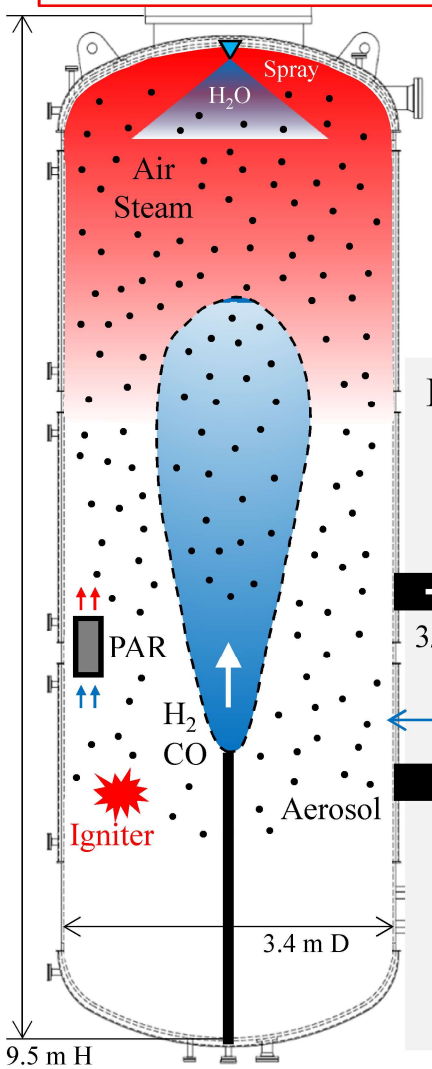
(1) Gravity = $f(d_p)$

(2) Diffusion(∇C, T)

(3) Turbulence = $f(d_p)$

Conclusions

Performance test of system in hypothetical accident environment

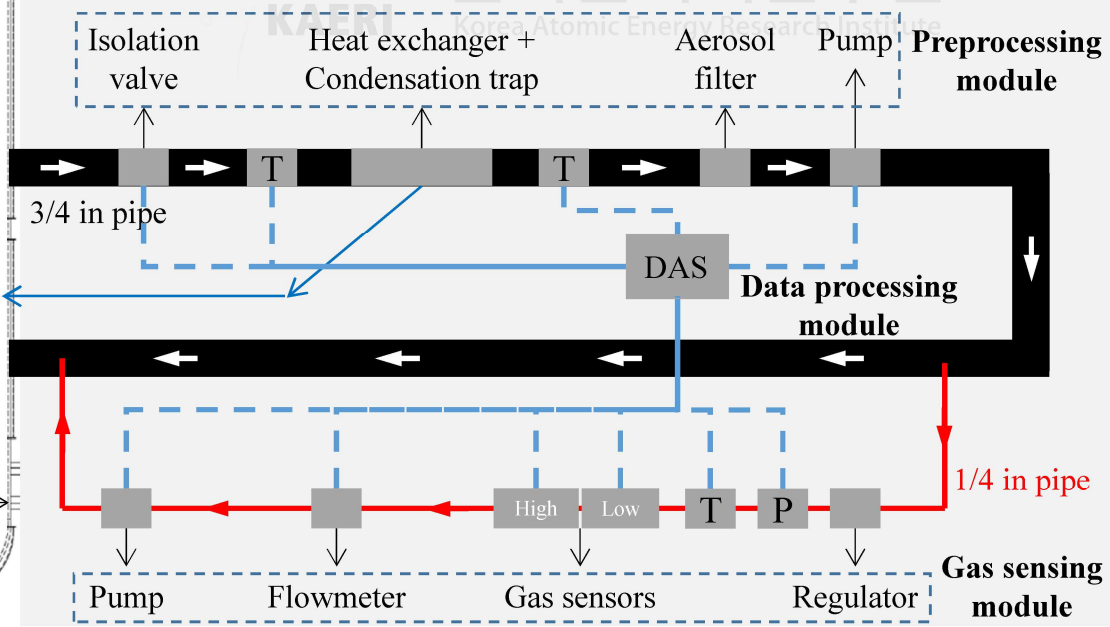


I. Accident environment assessment*

Variable	Range	Variable	Range
Pressure (kPa)	101~500	Temperature (K)	301~409
H_2 (vol.%)	0~4.0 / 15.0(sampling)	O_2 (vol.%)	21.0~5.5
CO (vol.%)	0~4.0 / 12.0(sampling)	H_2O (vol.%)	0~65.6
Aerosol (g/m^3)	0~5 / 1~5 μm	FPs vapor (g/m^3)	0~4

*LOCA in OPR1000 calculated by MELCOR code

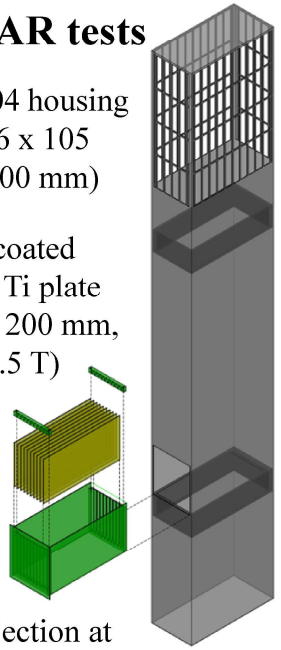
II. Technical specifications and conceptual design



III. PAR tests

SUS304 housing (216 x 105 x 1300 mm)

Pt coated on a Ti plate (100 x 200 mm, 1.5 T)



H_2 injection at 335 K, 134 kPa, 100%RH