2021 KNS Spring Meeting

A SIRIUS Validation for an Aerosol Deposition by a Turbulent Flow in the LACE-3A Test

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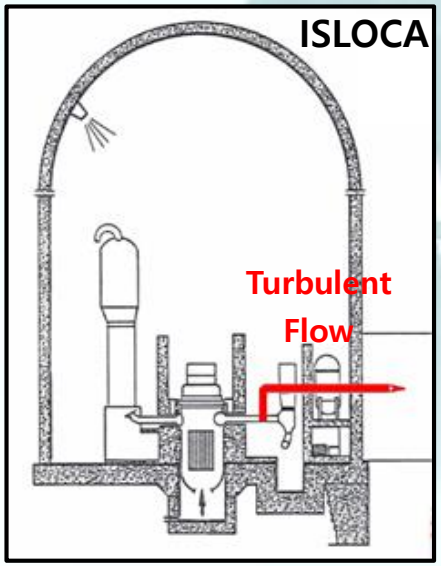
Table of Contents

Inter-System Loss Of Coolant Accident

❑ Amendment of Nuclear Safety Action(2015)

- ❍ Accident Management Program(AMP) – Effective date: 23 June 2016
- ❍ Safety Target
  - ⏩ Site boundary dose < 250 mSv
  - ⏩ Release to environment : Cs-137, 100 TBq < 10^{-6}/ry
- ❍ Accidents should be considered
  - ⏩ Containment bypass : TI-SGTR, ISLOCA

Fukushima accident (2011.3.)



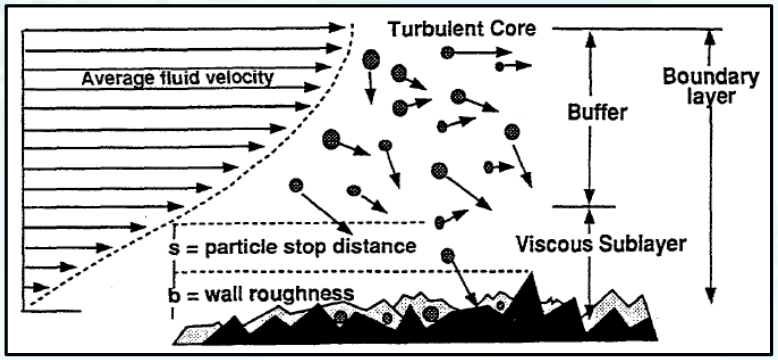
Aerosol Deposition
owing to Turbulent Flow

Aerosol Deposition in Turbulent Flow

❑ Aerosol Removal Model in the SIRIUS Code

- ❍ Sedimentation, Inertial Impaction, Diffusiophoresis, Thermophoresis
- ❍ Turbulent Flow $\lambda_t = \lambda_{sed} + \lambda_{imp} + \lambda_{diff} + \lambda_{th} + \lambda_{tub}$

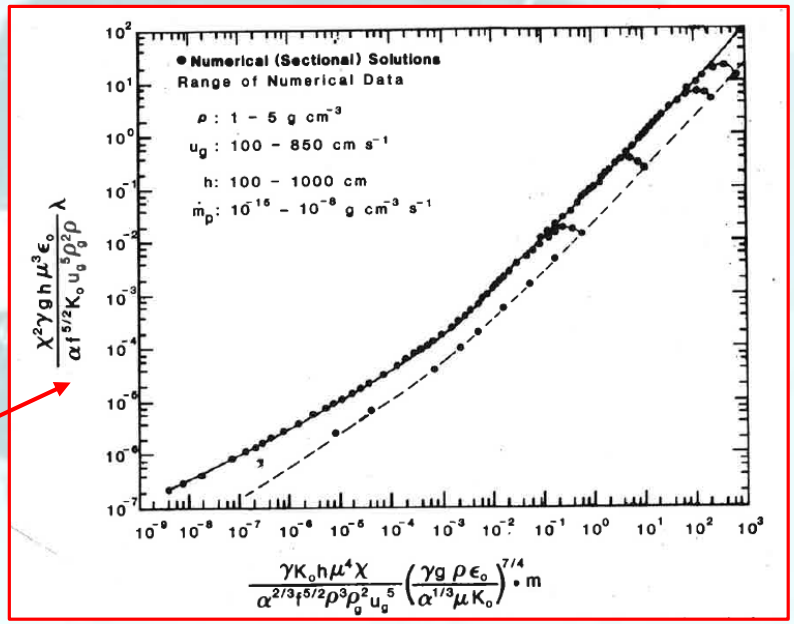
$$\frac{dm_{a,i}^n}{dt} = \dot{m}_{a,i,in}^n - \dot{m}_{a,i,out}^n - \lambda_{t,i}^n m_{a,i}^n + \dot{G}_{a,i}^n$$



$$\Lambda_{tub}^{SS} = 3.04\times10^{-3} M_{tub}^{0.606}\left(1+4.16\times10^{-3} M_{tub}^{1.36}\right)^{0.25}$$

$$M_{tub} = \left(\frac{\gamma K_o h_{eff}\mu^4\chi}{\alpha^{2/3} f^{5/2}\rho^3\rho_g^2 u_g^5}\right)\left(\frac{\gamma g\rho\varepsilon_o}{\alpha^{1/3}\mu K_o}\right)^{7/4}\cdot m_p \qquad \Lambda_{tub} = \left(\frac{\chi^2\gamma g h_{eff}\mu^3\varepsilon_o}{\alpha f^{5/2} K_o u_g^5\rho^3\rho_g^2}\right)\cdot\lambda_{tub}$$

Dimensionless aerosol removal rate constant for deposition in turbulent flow

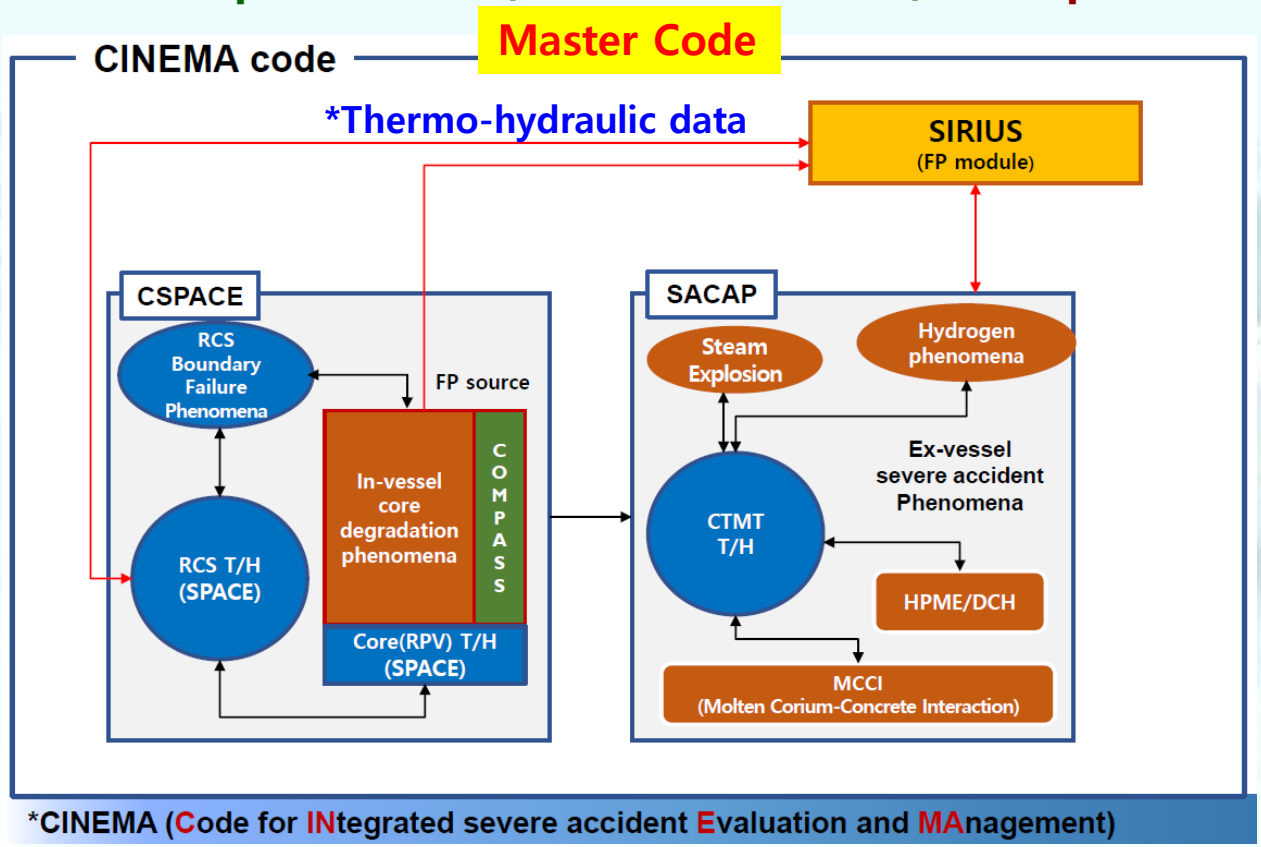


Ref. : M. Epstein, NED 107, pp 327-344 (1988)

Coupled Calculation between CSPACE and SIRIUS

❑ SIRIUS module for predicting an aerosol transport

- ❍ CINEMA code development (2011. 7 – 2017. 6) : Separated calculation
  - ⏩ 2017, KNS Autumn Meeting, H.S. Kang,et al.
- ❍ CINEMA code improvement (2019. 5 – 2023. 4) : Coupled calculation

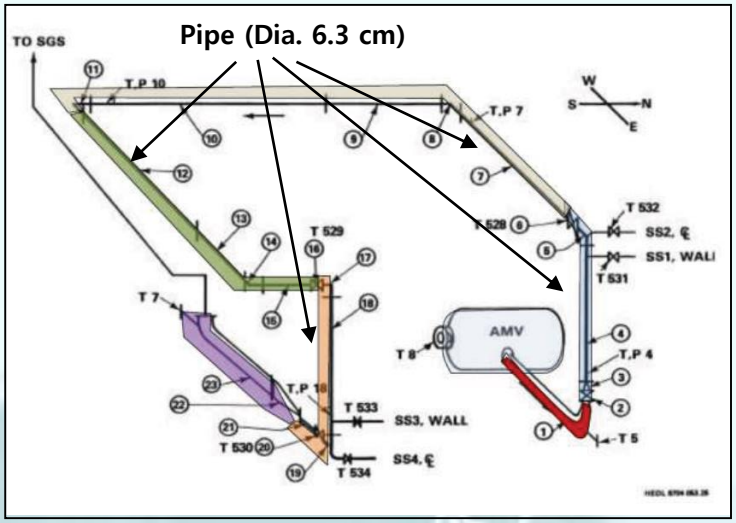


LACE-3A Test (1)

❑ Test Facility & Results

- ❍ Test duration : 0 - 3600 s
- ❍ N_2-Steam injection
  - ⏩ 75 m/s, 298 ℃
- ❍ Aerosol injection (CsOH/MnO)
  - ⏩ 0 – 3600 s
  - ⏩ 0.6 g/s, Mass Fraction 0.18

Test Facility



Test Condition & Result

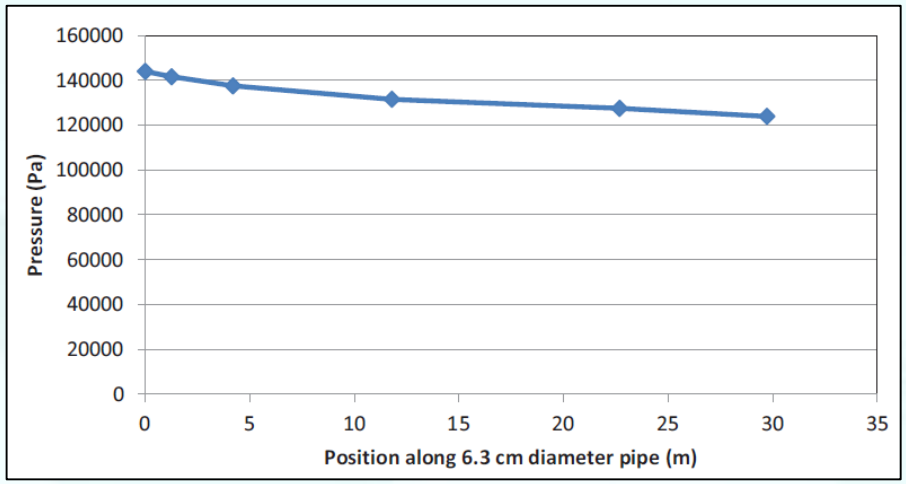
Test	Aerosol	CsOH Mass Fraction	Carrier Gas	Gas Velocity (m/s)	Temp. (°C)	Aerosol Source Rate (g/s)	Aerosol Size AMMD (μm)	Mass Retention Fraction
LA1	CsOH/ MnO	0.42	Air-steam	96	247	1.1	1.6	> 0.98
LA3 A	CsOH/ MnO	0.18	N_2-steam	75	298	0.6	1.4	> 0.7
LA3B	CsOH/ MnO	0.12	N2-steam	24	303	0.9	2.4	> 0.4
LA3C	CsOH/ MnO	0.38	N2-steam	23	300	0.9	1.9	> 0.7

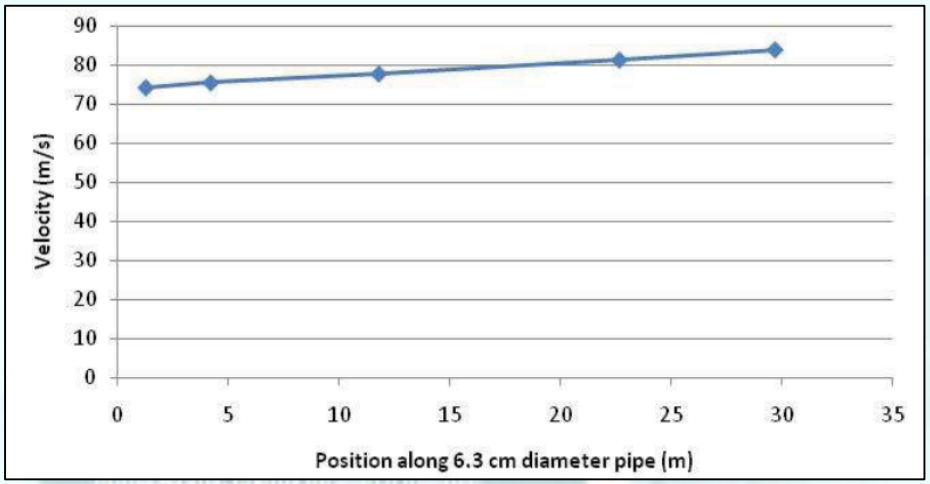
Ref. : NUREG-7110, Vol. 2

LACE-3A Test (2)

❑ Thermal Hydraulic Results by MELCOR

❍ No measurement data

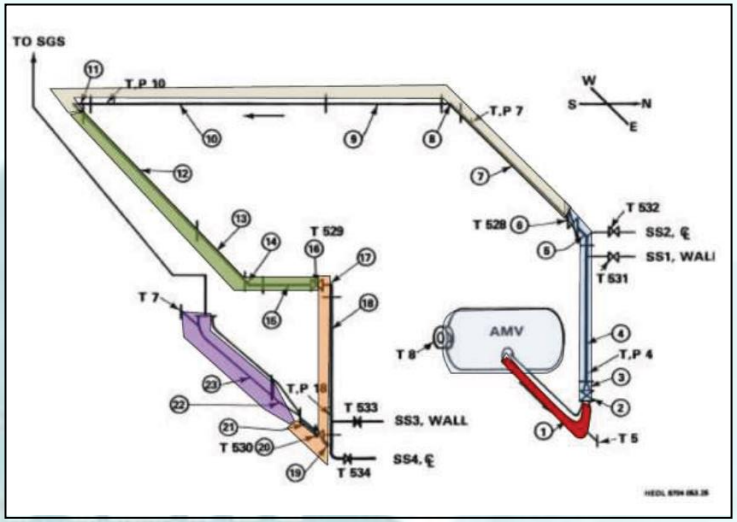




CSPACE Nodalization for LACE-3A

CSPACE Node Dimension and Type

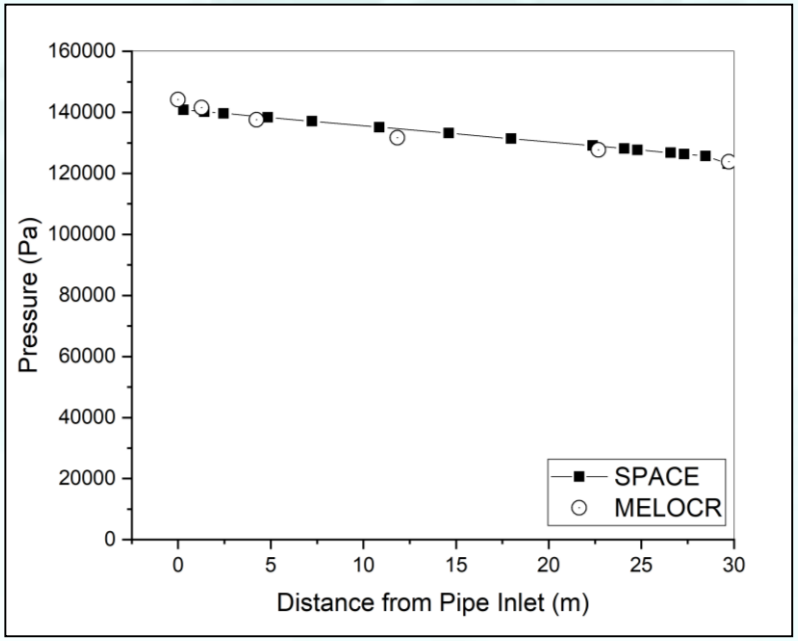
Section No.	Geometry Description	Flow Direction	Diameter (mm)	Length (m)	SPACE Node No.	SPACE Node Type
1	Mixing Chamber	East	63	-	C010	TFBC (Inlet)
4	Straight	Up	63	2.26	C015	Pipe (4 cells)
5	90° Bend	-	63	0.38	C016	Pipe (1 cell)
6	Ball Valve	West	63	0.19	C017	Pipe (5 cells)
7	Straight	West	63	4.20		
8	90° Bend	-	63	0.38	C018	Pipe (1 cell)
9	Straight	South	63	2.58	C019	Pipe (7 cells)
10	Straight	South	63	4.32		
11	90° Bend	-	63	0.38	C020	Pipe (1 cell)
12	Straight	East	63	4.32	C021	Pipe (8 cells)
13	Straight	East	63	3.17		
14	90° Bend	-	63	0.38	C022	Pipe (1 cell)
15	Straight	North	63	1.84	C023	Pipe (2 cells)
16	Straight	North	63	0.19		
17	90° Bend	-	63	0.38	C024	Pipe (1 cell)
18	Straight	Down	63	2.15	C025	Pipe (4 cells)
19	90° Bend	-	63	0.38	C026	Pipe (1 cell)
20	Ball Valve	West	63	0.19	C027	Pipe (2 cells)
21	Straight	West	63	0.71		
22	Transition	West	63 to 300	1.17	C028	Pipe (2 cells)
23	Transition	West	300	-	C029	TFBC (Outlet)

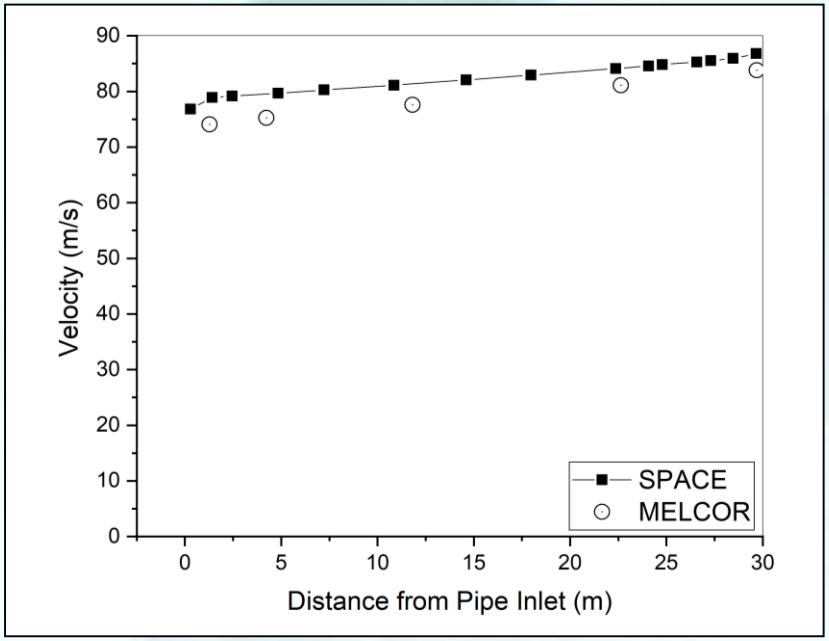


CSPACE Results for LACE-3A

❑ Thermal Hydraulic Calculation Results by CSPACE

- ❍ Transient Calculation with 0.0001 s – 0.01 s
- ❍ Pressure : almost same to MELCOR results
- ❍ Velocity : approximately 10% faster flow than MELCOR results



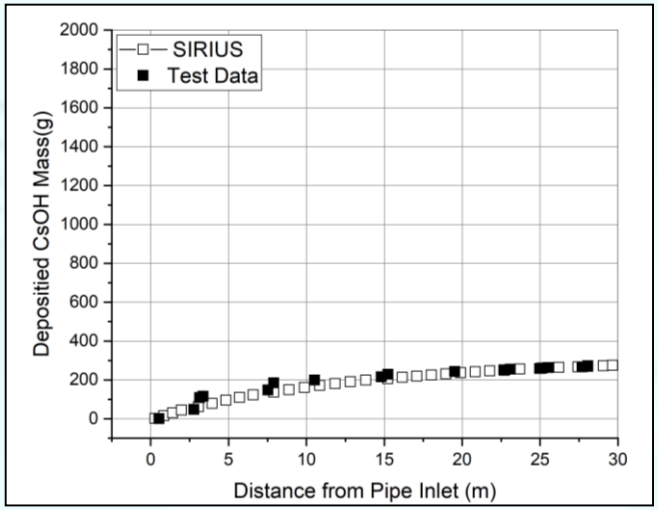


SIRIUS Results for LACE-3A

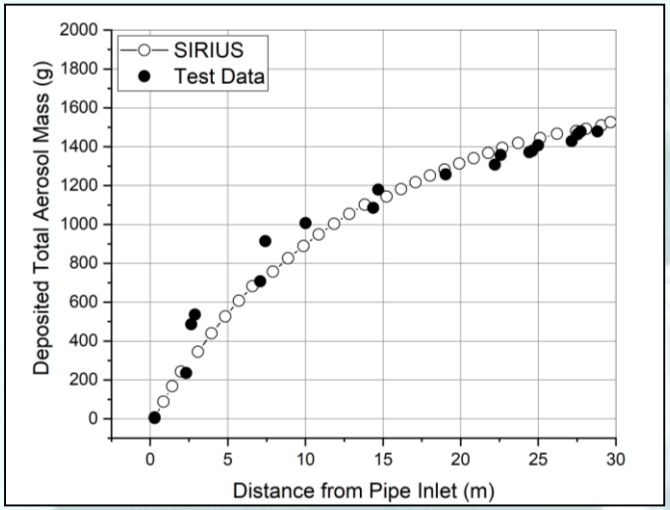
❑ SIRIUS Input and Results

- ❍ Aerosol Removal Model : Inertia Impaction & Turbulent Flow
- ❍ Shows good agreement with the test data

CsOH



CsOH + MnO



	Aerosol	Test	SIRIUS
Mass retention fraction on the pip wall (dia. 6.3 cm)	CsOH	> 0.7	0.706
	MnO	> 0.7	0.706

Conclusion and Further Work

❑ Conclusion

- ❍ We performed the coupled calculation between the CSPACE and SIRIUS codes against the LACE-3A test to validate the aerosol deposition in turbulent flow in the SIRIUS code.
- ❍ The predicted error range is below approximately 10%.

❑ Further Work

- ❍ Coupled calculation between the CSPACE and SIRIUS codes should be applied to other test data to increase an applicability of the CINEMA code.