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Scoping Analysis of Spent Fuel Storage Cask for Monitoring Application

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NSE TECHNOLOGY

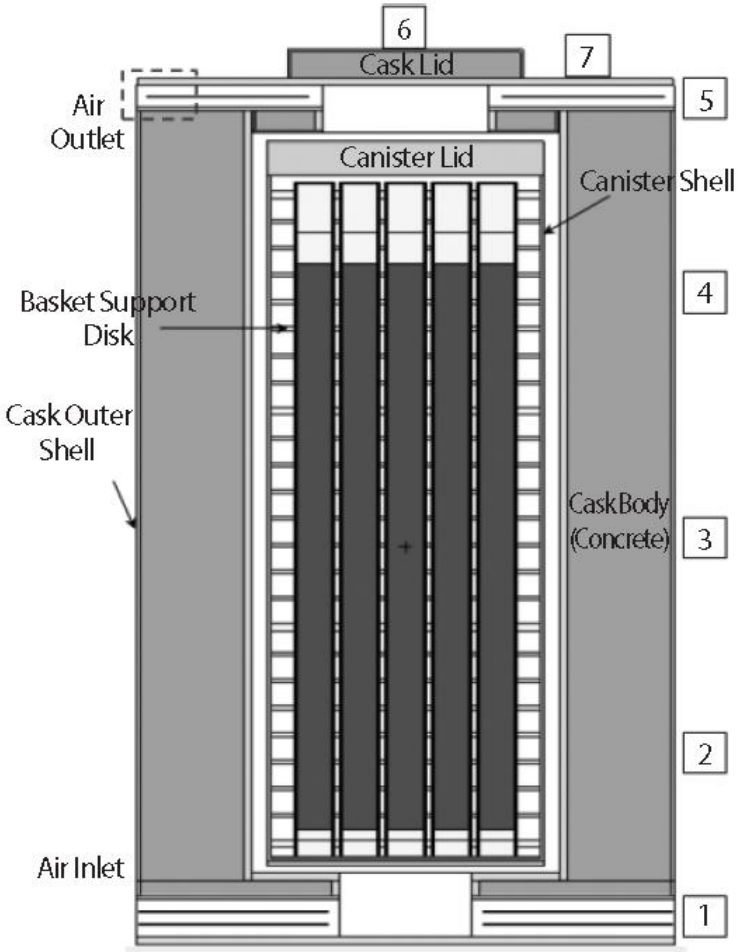
Introduction

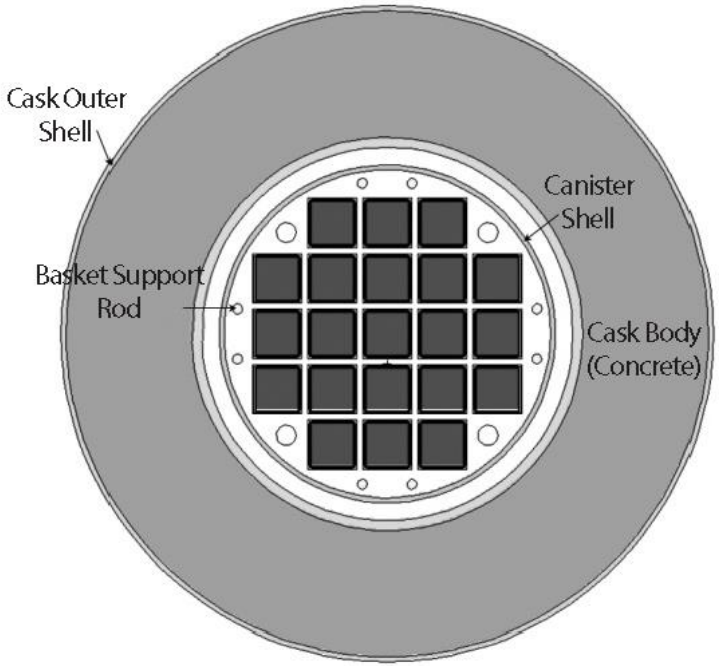
- **SNF Dry Storage Casks**
  - Over 1500 casks in US
  - Initial license of 20 years
  - Delay of permanent disposal facilities
  - Extension of storage terms up to 40 years renewal
  - Issues of aging management and monitoring
  - Confinement monitoring (10CFR 72.122(h)(4))

- **Focus of the Present Study**
  - Monitoring without sensor line penetration through the canister wall
  - Canister surface temperature (CST) measurements for detecting helium gas leak from canister
  - Analyzing the dependence of CST on the canister internal pressure

■ Analysis Methods

● Modeling Reference

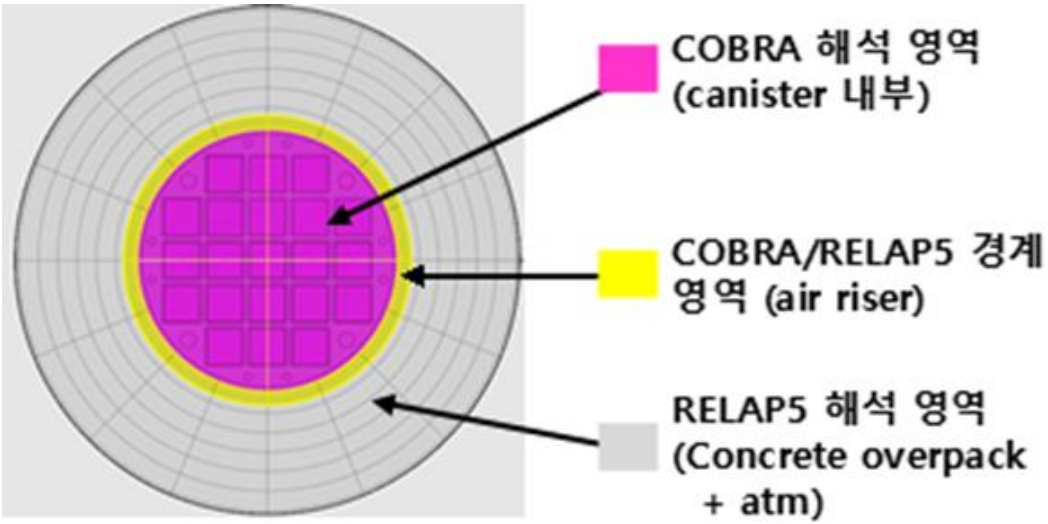




※ Tae-Man Kim, et. al, Preliminary Shielding Analysis of the Concrete Cask for Spent Nuclear Fuel Under Dry Storage Conditions, JNFCWT, Vol.15, No.4, pp.391-402, 2017.

■ Analysis Methods

- **Analysis Tool**
  - **COBRA-SFS**
    - **RADGEN**
  - **RELAP5**
  - **Coupled using the air gap temperature distribution as b.c.**



■ Analysis Methods

- **COBRA-SFS Input**
  - **22 assemblies (21 fuels and one downcommer)**
  - **308 slabs with 36 axial nodes**
  - **Uniform pressure drop for zero net inlet mass flow for assemblies**

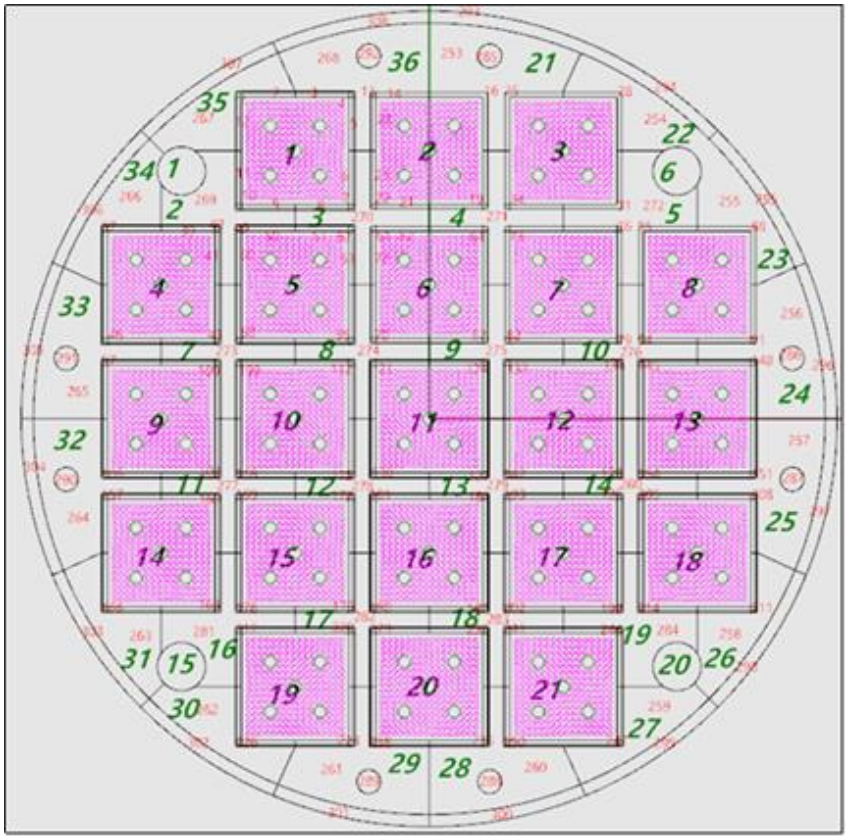


Fig. 2. COBRA-SFS input nodalization

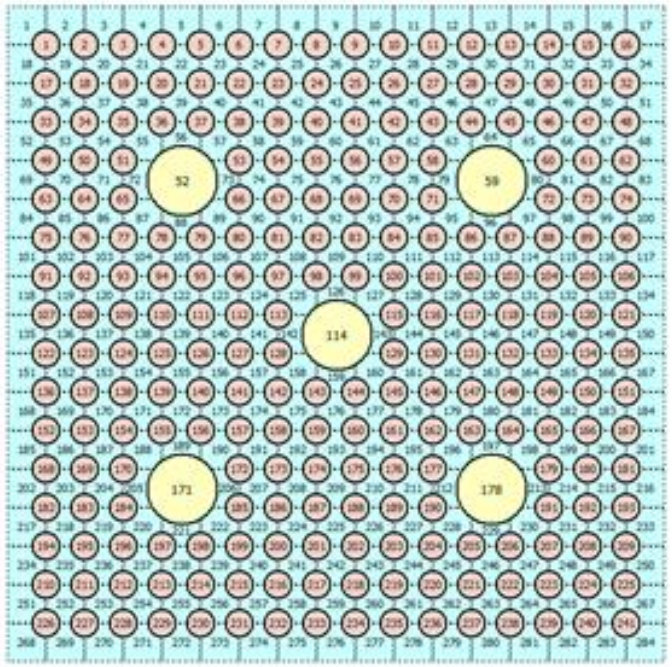
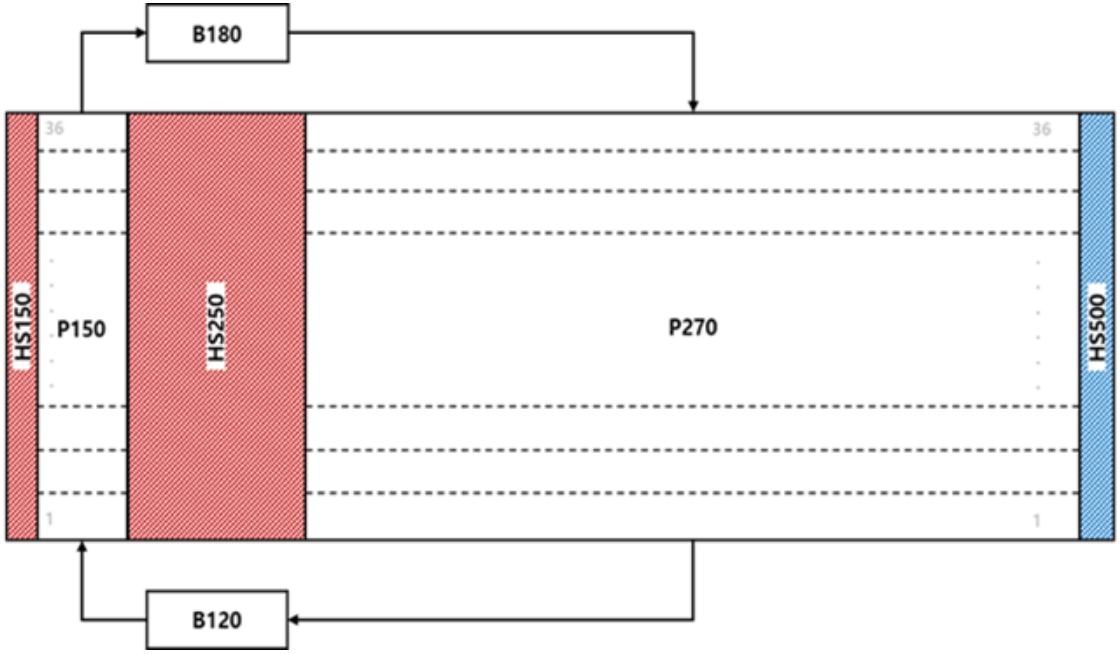


Fig. 3. COBRA-SFS fuel assembly nodes

■ Analysis Methods

- **RELAP5 Input**
  - **2 pipe components**
  - **2 branch components**
  - **3 heat structures**

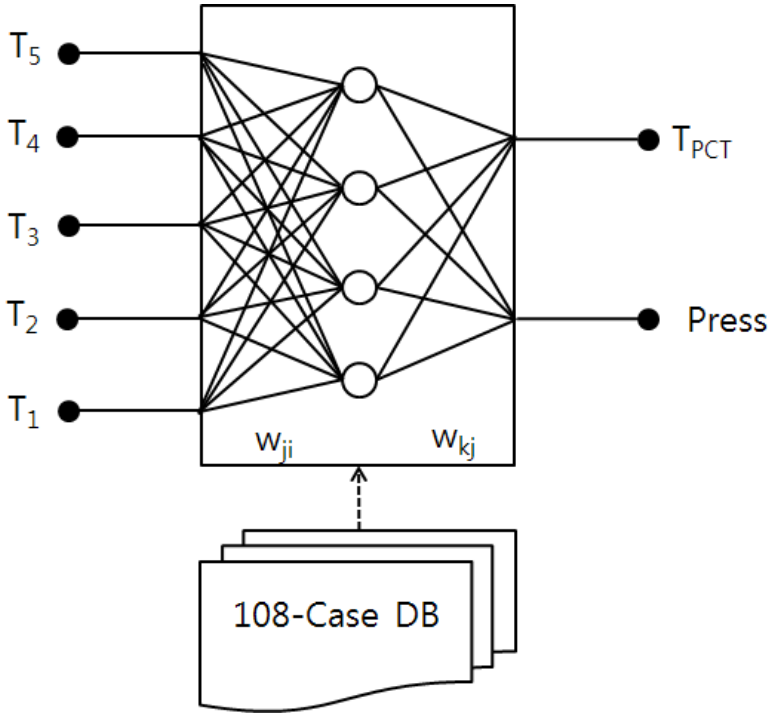


HS150 : canister shell
HS250 : concrete overpack
HS500 : virtual heat sink.
P150 : air gap
P270 : ambient air
B120 : the air inlet
B180 : outlet paths

Fig. 4. RELAP5 Nodalization

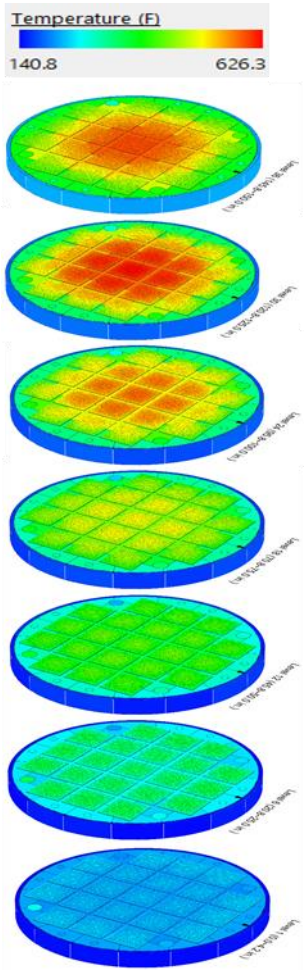
■ Analysis Methods

- **Correlation Development**
  - **Neural network model using the generalized delta rule for feedforward net with backpropagation of error**
    - **Input variables : canister surface temperature and ambient air temperature**
    - **output variables : canister internal pressure**

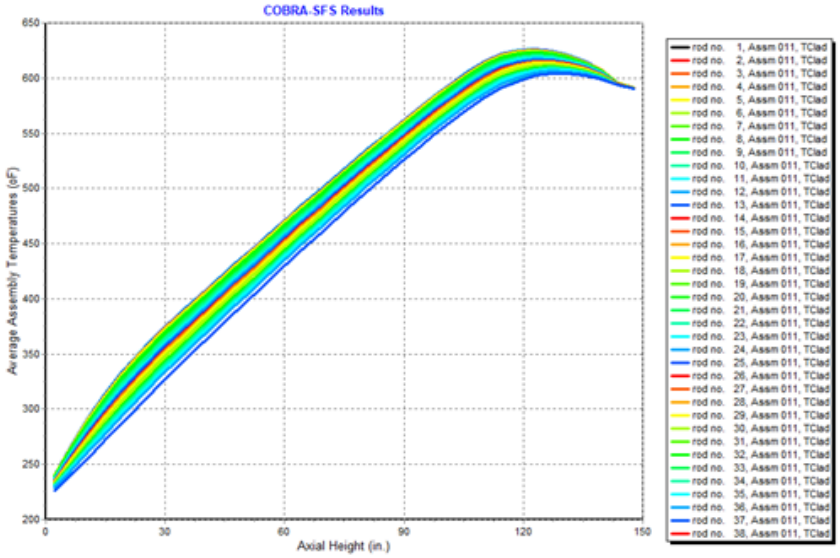


■ Analysis Results

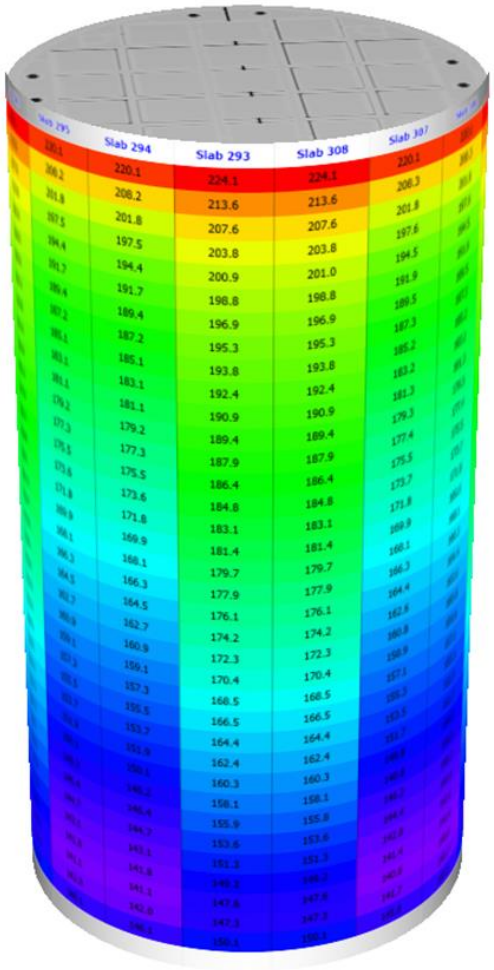
- **COBRA-SFS 해석 결과 예시**



<내부 온도 분포>



<Hottest Assembly Rod Surface T (ºF)>



<캐니스터 표면 온도 (ºF)>

■ Analysis Results

- **COBRA-SFS Calculation Results**
  - **800 W assembly power and 20 ℃ ambient air**

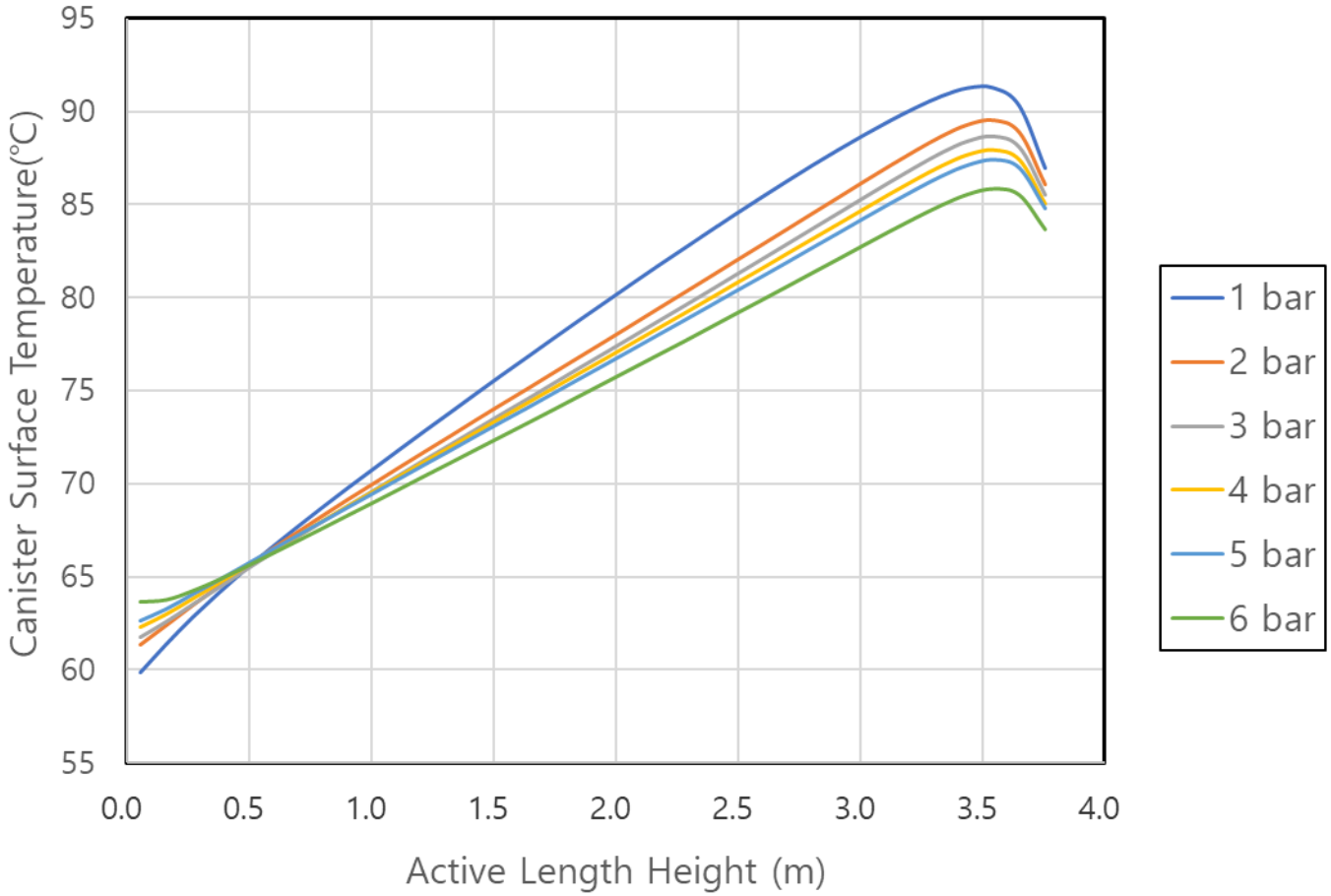
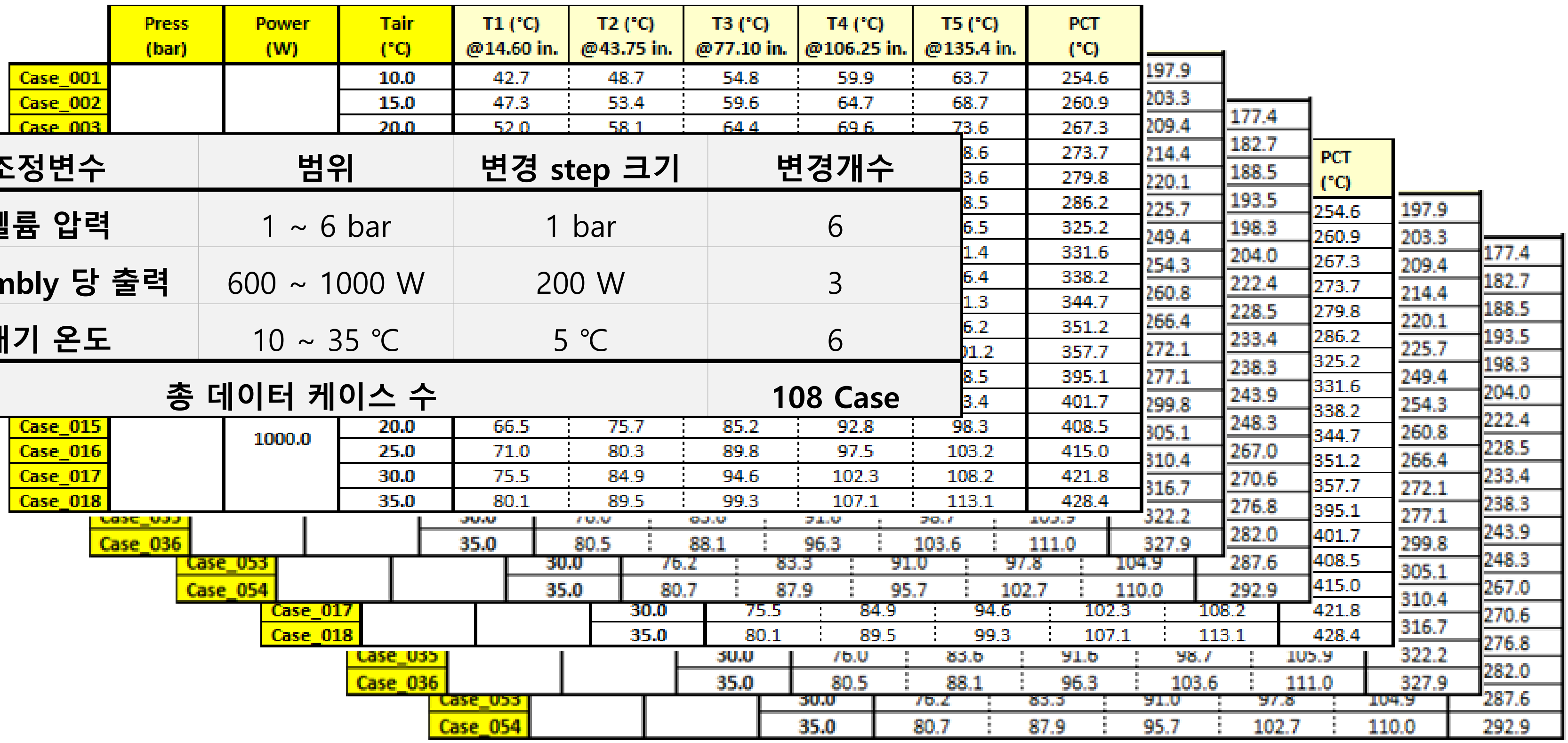


Fig. 5. Canister surface temperature distribution

■ Analysis Results

- **COBRA-SFS DB 구축**
  - 예측 알고리즘 구축을 위한 예비 분석 DB (108-Cases)



	Press (bar)	Power (W)	Tair (°C)	T1 (°C) @14.60 in.	T2 (°C) @43.75 in.	T3 (°C) @77.10 in.	T4 (°C) @106.25 in.	T5 (°C) @135.4 in.	PCT (°C)
Case_001			10.0	42.7	48.7	54.8	59.9	63.7	254.6
Case_002			15.0	47.3	53.4	59.6	64.7	68.7	260.9
Case_003			20.0	52.0	58.1	64.4	69.6	73.6	267.3
Case_015		1000.0	20.0	66.5	75.7	85.2	92.8	98.3	408.5
Case_016			25.0	71.0	80.3	89.8	97.5	103.2	415.0
Case_017			30.0	75.5	84.9	94.6	102.3	108.2	421.8
Case_018			35.0	80.1	89.5	99.3	107.1	113.1	428.4

조정변수	범위	변경 step 크기	변경개수
헬륨 압력	1 ~ 6 bar	1 bar	6
Assembly 당 출력	600 ~ 1000 W	200 W	3
대기 온도	10 ~ 35 ℃	5 ℃	6
총 데이터 케이스 수			108 Case

<압력 변화에 따른 축방향 캐니스터 표면온도 변화>

■ Analysis Results

- **Prediction results of canister helium pressure**
  - **Standard deviation of pressure prediction ratio : 4.6%**

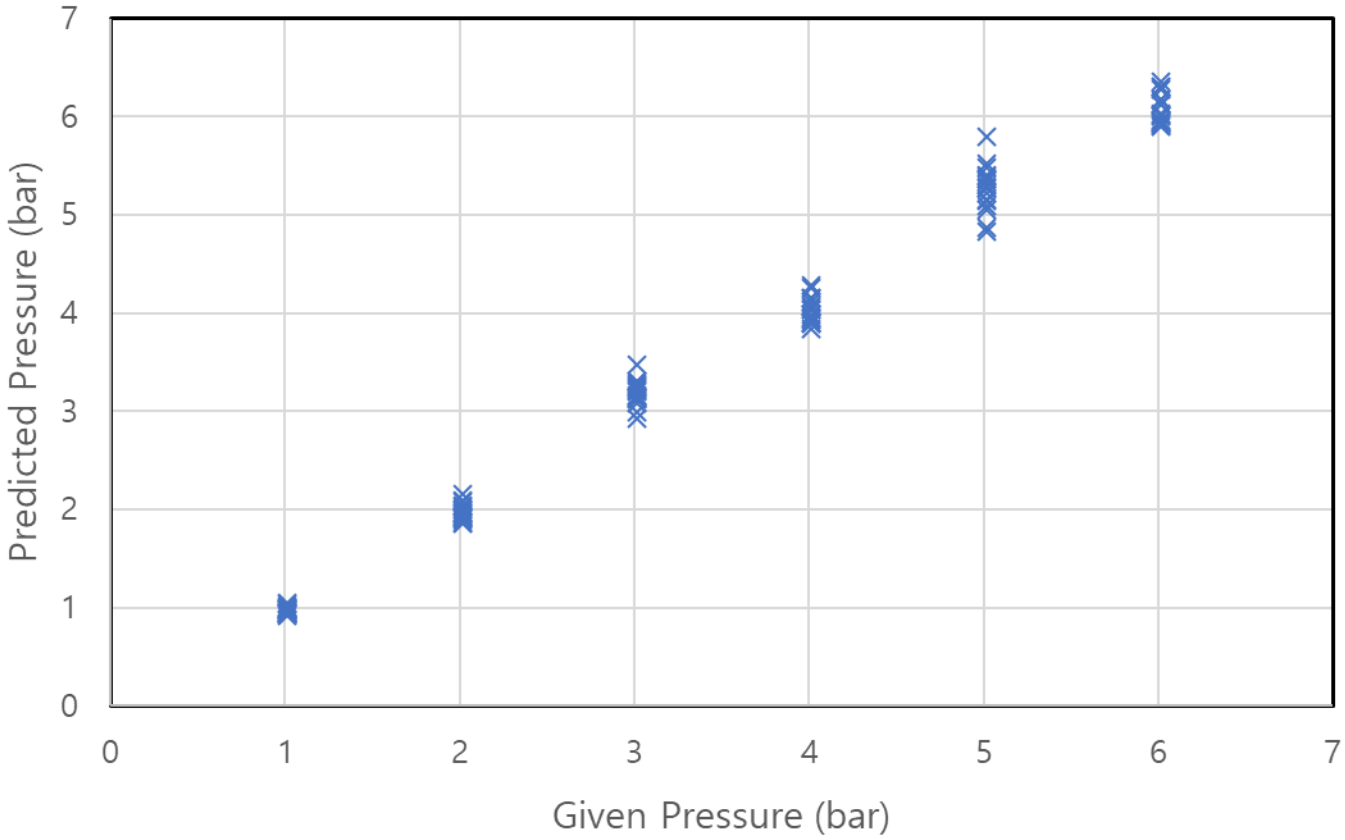


Fig. 6. Prediction results of helium pressure

■ Analysis Results

- **Prediction results of peak cladding temperature**
  - **Standard deviation of PCT prediction ratio : 1.1%**

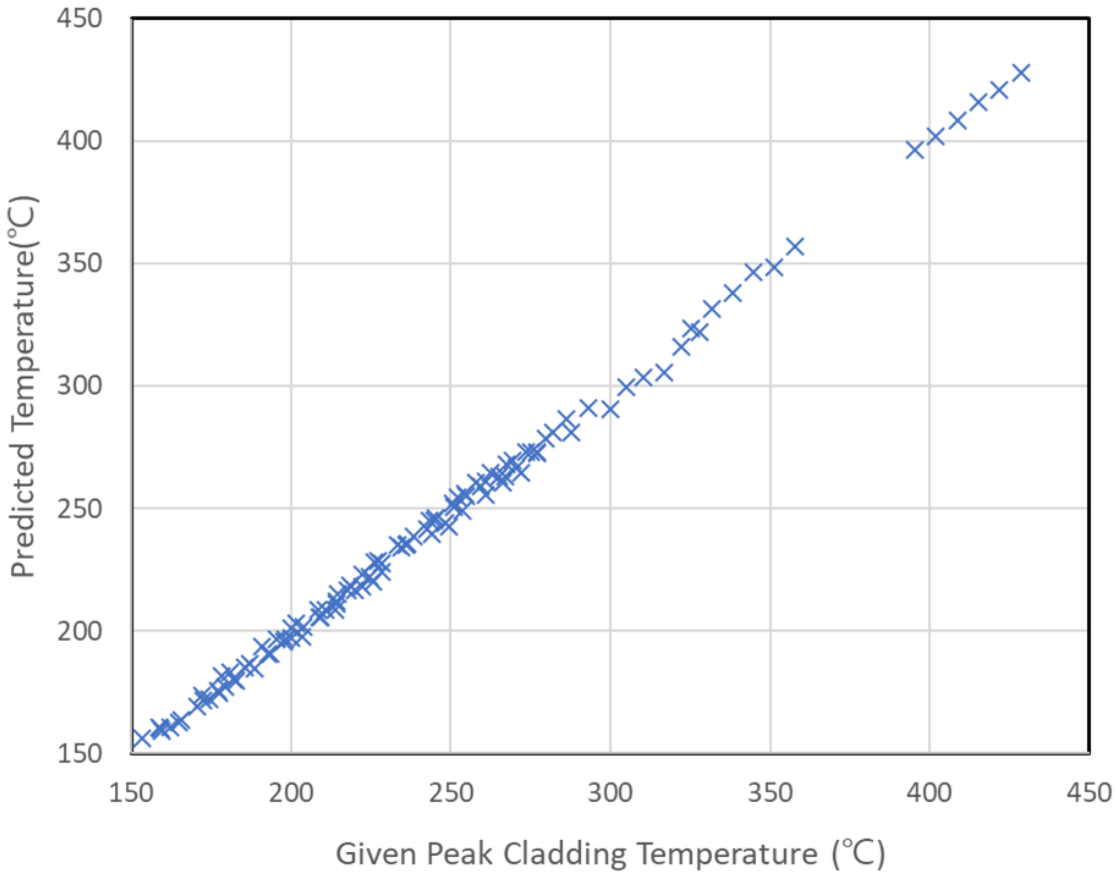
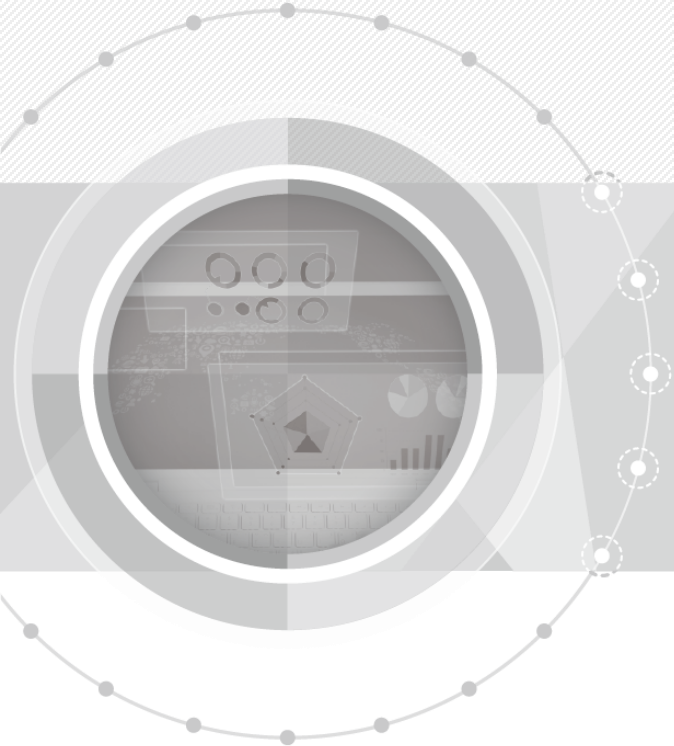


Fig. 7. Prediction results of peak cladding temperature

■ Conclusions

- A COBRA-SFS/RELAP5 code system has been established for the thermo-dynamic analysis of SNF dry storage casks.
- Analyses were carried out to investigate the canister surface temperature distribution dependence on the canister internal pressure.
- A neural network model was employed to predict the canister internal pressure based on the canister surface temperatures.
- Canister integrity can be monitored by helium leak detection based on the canister surface temperature measurement eliminating the need for pressure probe into the canister.
- Similar prediction model may be applicable for predicting peak cladding temperature using the surface temperature measurements.
- Detailed computational fluid dynamics analyses and supporting experiments are needed for more extensive verification.

감사합니다



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