A Pilot Study on The Best-Estimate Thermal-Hydraulic Analysis Methodology Applied For a Probabilistic Safety Assessment

PSAM9

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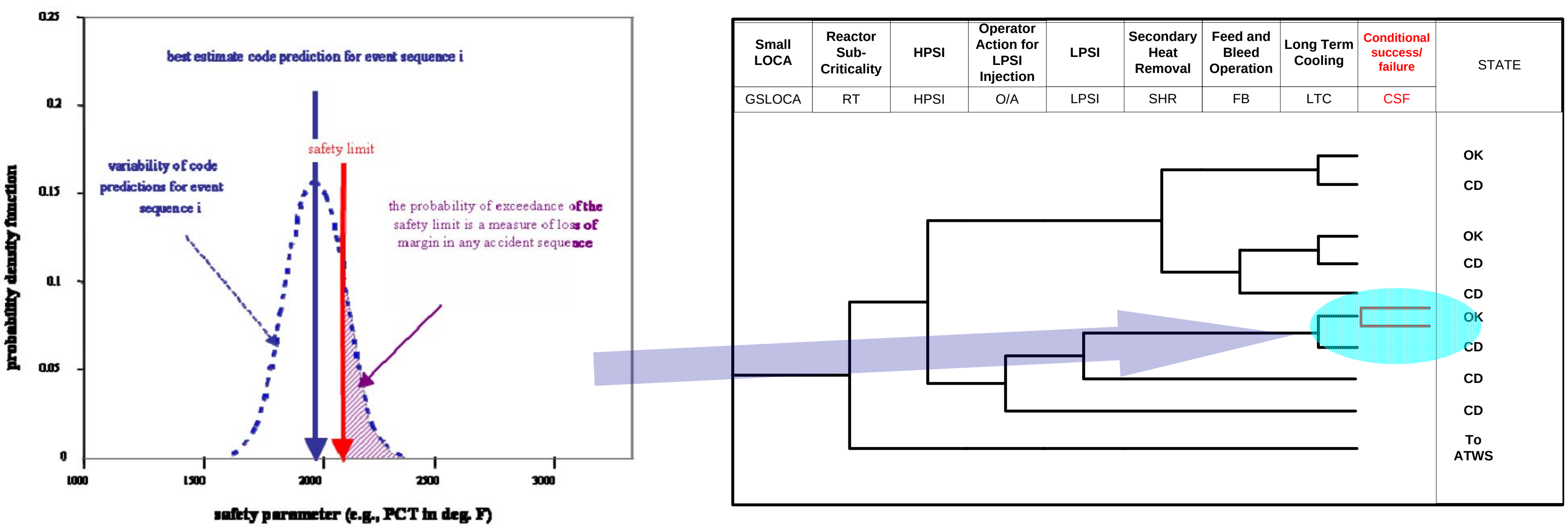
Contents

Introduction

- A thermal/hydraulic (T/H) calculation and an expert judgement are used to develop event trees (ET).
- Conservative approach was implemented to compensate the uncertainty.
  - The conservative approach can distort the results of PSA (shadow effect).
- Recently, the use of best-estimate T/H code is emphasized
  - ASME PRA Standard
- There is a concern about hot to deal with the uncertainty caused by to the best-estimate analysis
  - We proposed a procedure to quantify the uncertainty due to the best-estimate analysis

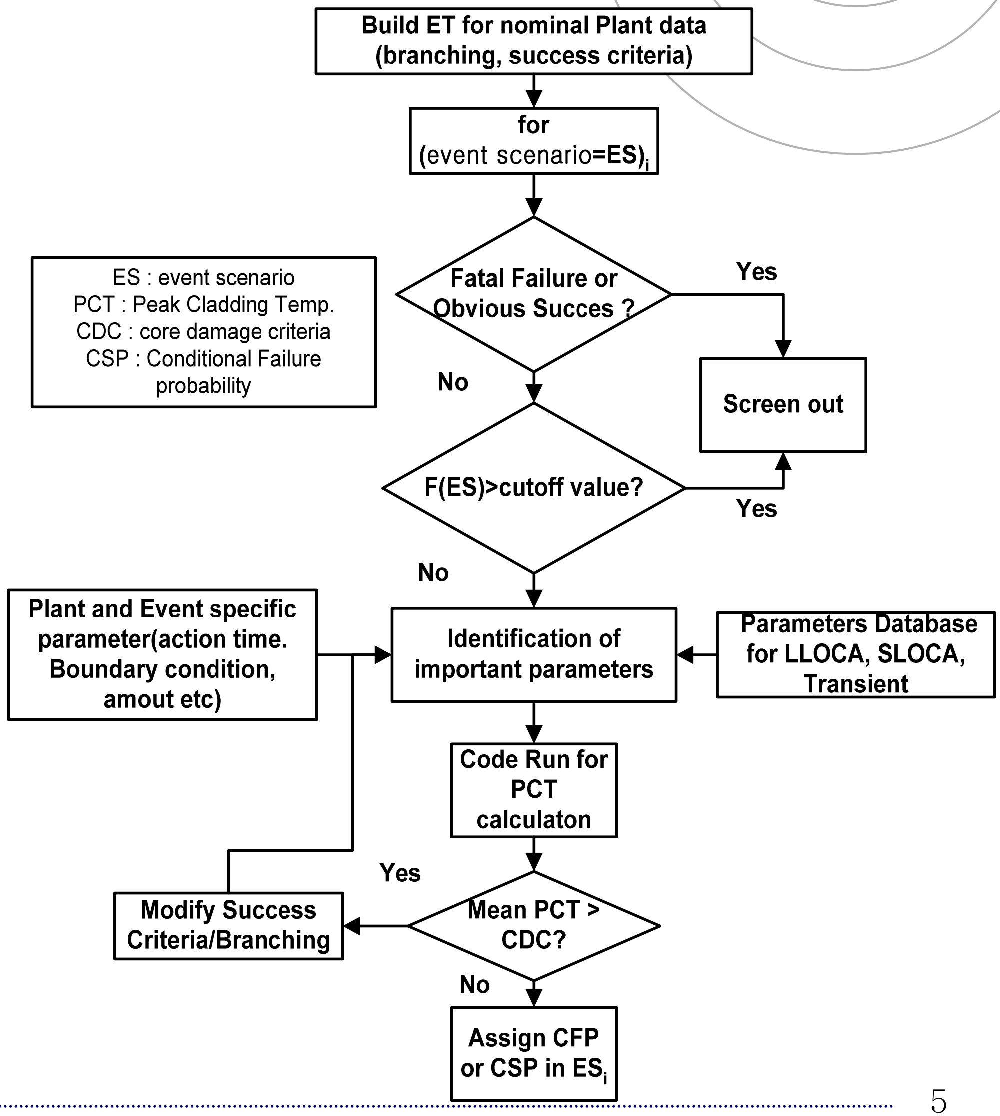
OECD/NEA Safety Margin Action Plan

- Calculate the distribution of safety criteria (PCT, RCS pressure)
- Compare to Safety Limit (ex. 2200 °F) and calculate exceeding probability
- Assign success/failure probability of a event scenario using new event tree heading



Procedure for Uncertainty Quantification

- Construct the ET based on the Nominal Plant Data
  - Eliminate conservative bias
- Screening
  - Fatal failure or obvious success
    - Failure of RHR
    - Normal shutdown procedure in ET
  - Insignificant accident scenario
    - $F(ET_i) < \varepsilon$
- Identification of Parameters
  - Important parameters affecting accident progression
    - Code and plant specific parameters
- Calculation based on Random Sampling
  - 10CFR50.46 alternative
    - Response surface construction
  - 100 random sampling in the present study
    - Sampling method is not fixed yet.
- Feedback to existing ETs or conditional failure probability quantification

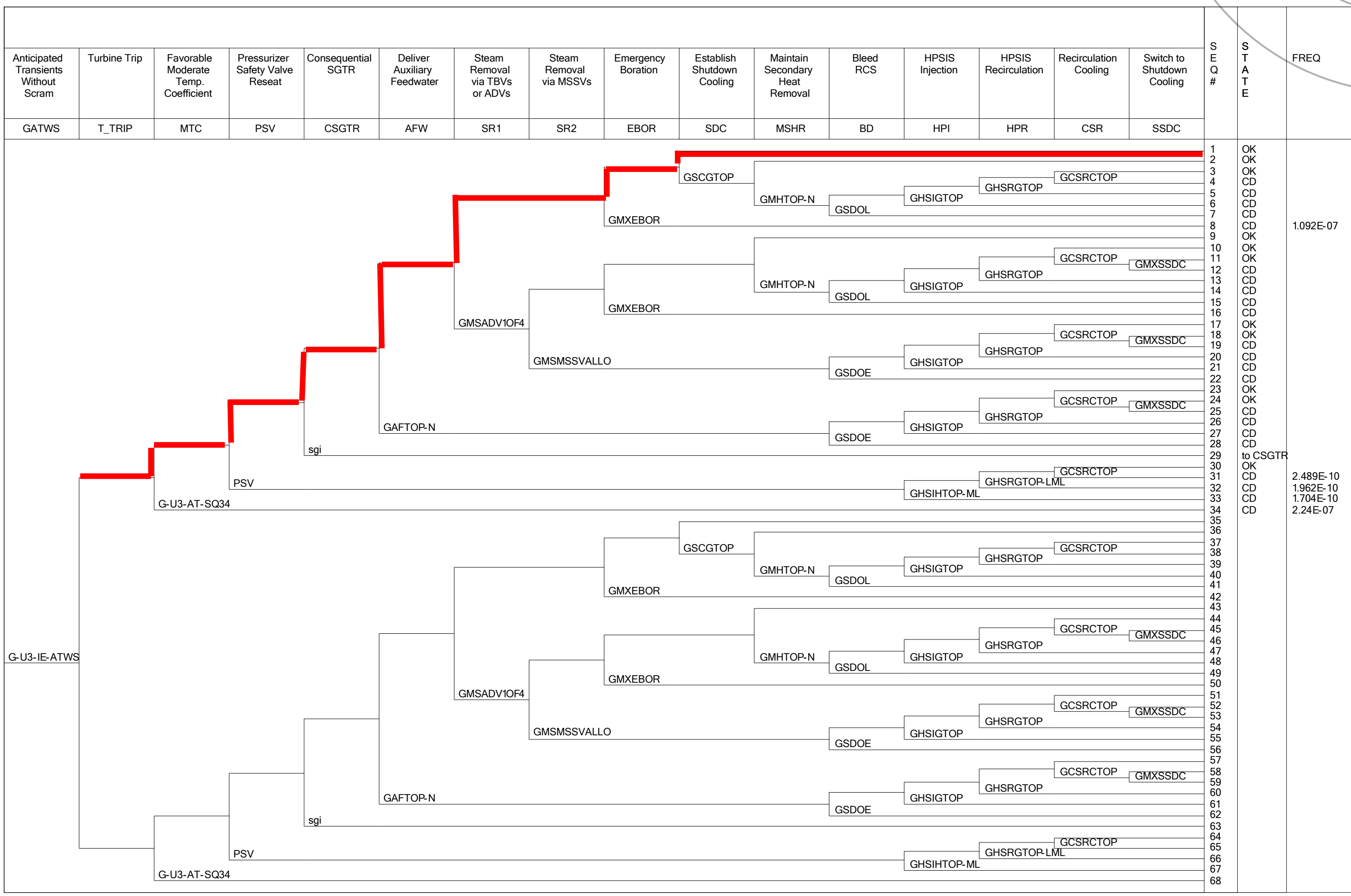


Accident sequence Selection(1/2)

- Anticipated Transient Without Scram (ATWS)
- Characteristics of a selected scenario
  - Composed of successful turbine trip, favourable exposure time, PSV reseat, and so on
  - An event sequence with the largest frequency
  - Large uncertainty exist due to reactivity feedback and the pressure relieving characteristics
  - The unfavourable exposure time (UET) is determined based on the nominal plant data

Accident sequence Selection(2)

- ATWS first scenario #1 in Ulchin 3&4 in Korea



IDENTIFICATION OF THE IMPORTANT PARAMETERS (1/2)

- It is necessary to know the parent distribution effectively under the given calculation resources

- General Procedure for Parameter Selection
  - Identification of important phenomena in the accident scenario
  - Identification of parameters in code describing the important phenomena
  - Ranking their importance in terms of ΔPCT or Δp_{op}

- In the Present analysis
  - Simplified phenomena identification and parameter selection procedures
  - No ranking process

IDENTIFICATION OF THE IMPORTANT PARAMETERS (2/2)

phenomena	parameter	variable distribution					Selection
		Dist.	2σ	min	max	Nominal (mean)	
RCS pressure relieving valve capacity	opening set pressure(bar)	Normal	2.76	171.03	175.17	172.41	O
	PSV discharge rate(kg/s)	Normal	10.79	57.96	79.55	68.75	O
Reactivity feedback	Fuel-Clad conductivity						X
	Clad-coolant conductivity						X
	initial coolant temperature						X
Pressurizer solid state	pressurizer water level (meter)		0.67	-0.381	0.9652	0(50%)	O
Heat transfer to secondary side	Aux. capacity					500 gpm bound	X
	delay time					45 second bound	X
	Aux. temp.(K)		22.22	277.44	321.89	293	O
	Convective heat transfer coeff.						X
	turbine trip time						X
	MSSV flow rate		134.61	722.75	991.97	857.34	X
	MSSV set pressure		1.03	85.52	87.59	86.21	O
	MSIV closing Time					5	x

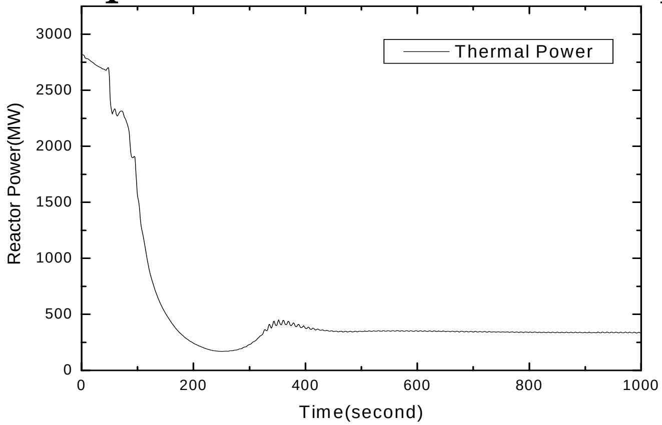
Nominal Event Calculation (1/3)

- Event history for nominal plant state

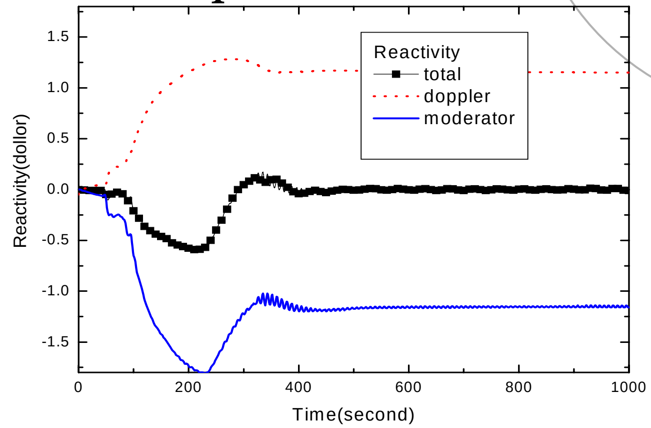
Time (sec)	Event
0.0	Loss of main feedwater (representative ATWS IE)
42.8	RCS trip set point by PZR high pressure(164 bar)
53.5	Auxiliary Feed water actuation set point by S/G low level
63.8	S/G dryout
72.01	PZR Safety valve opening set pressure
81.9	First PZR blowdown pressure
83.72	Main steam line isolation valve (MSIV) closing set point by low pressure
86.0	Second opening of PZR safety valve
88.72	Complete closing of MSIV
95.1	PZR solid state
98.5	AFW start
~100	Hot leg saturation pressure
115.1	RCS peak pressure
159.	MSSV set point by S/G high pressure
1000.0	Calculation terminated

Nominal Event Calculation (2/3)

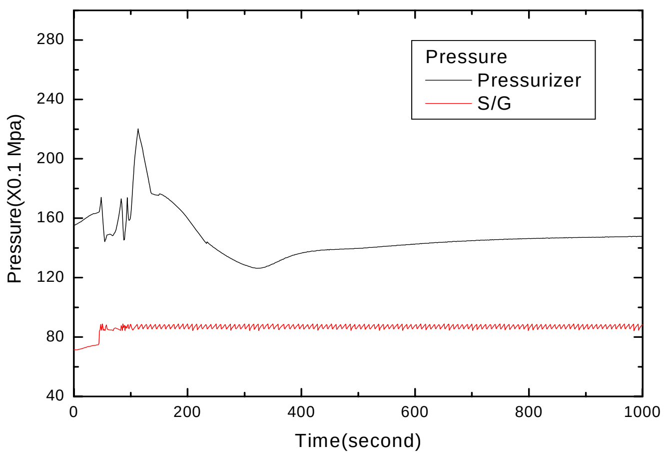
- Temporal Behavior of plant main parameter



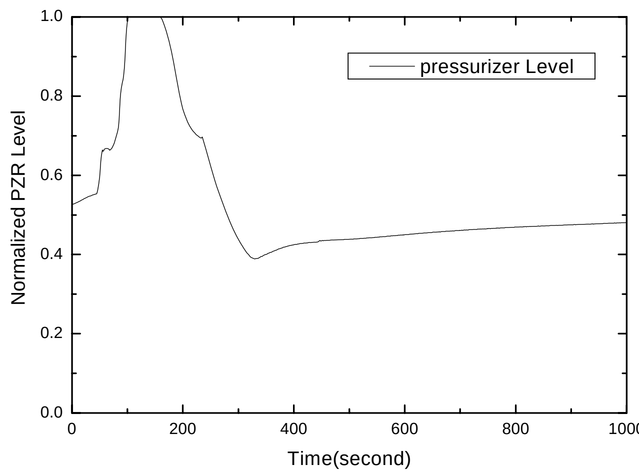
- Reactor Power



- Reactivity



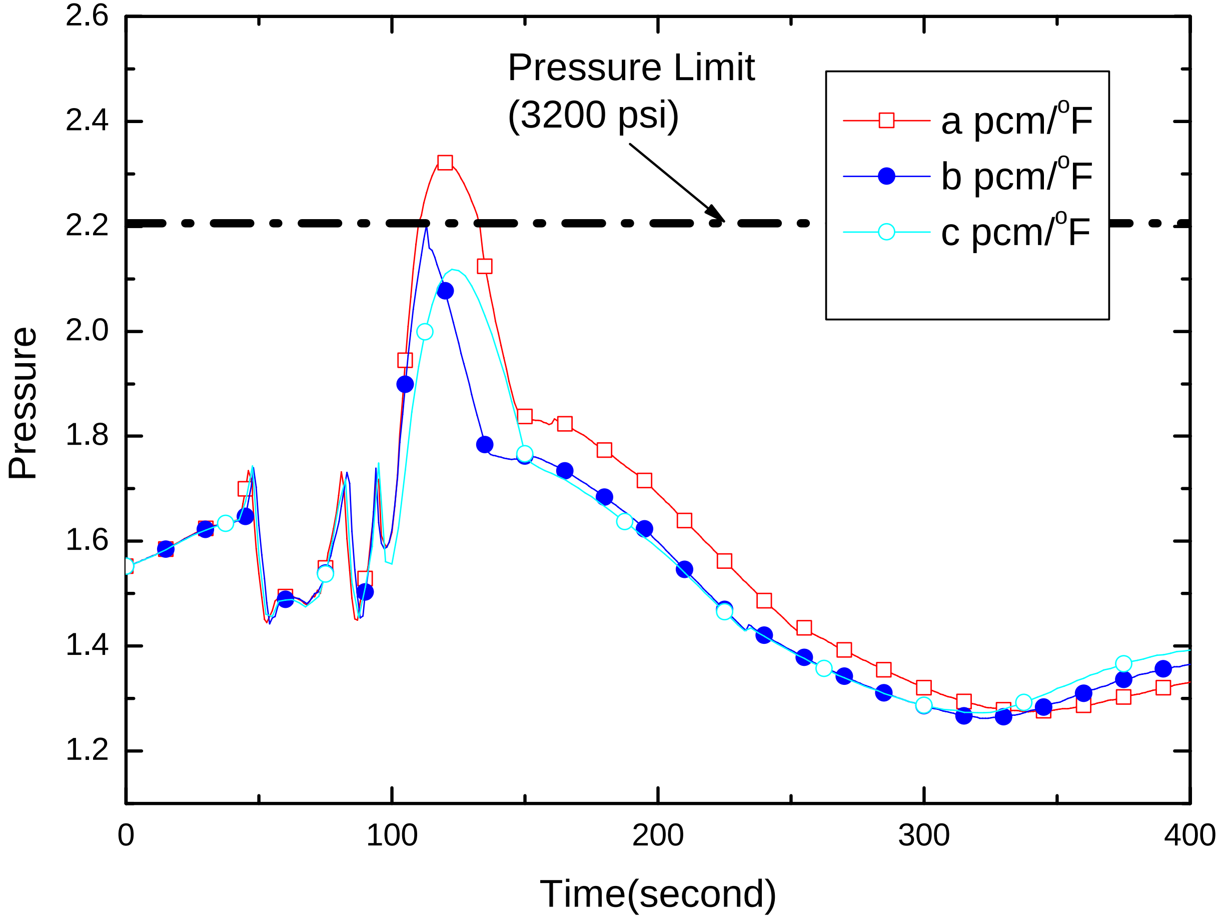
- RCS & S/G pressure



- PZR level

Nominal Event Calculation (3/3)

- Determination of UET (Unfavorable Exposure Time) according to the fuel burn-up



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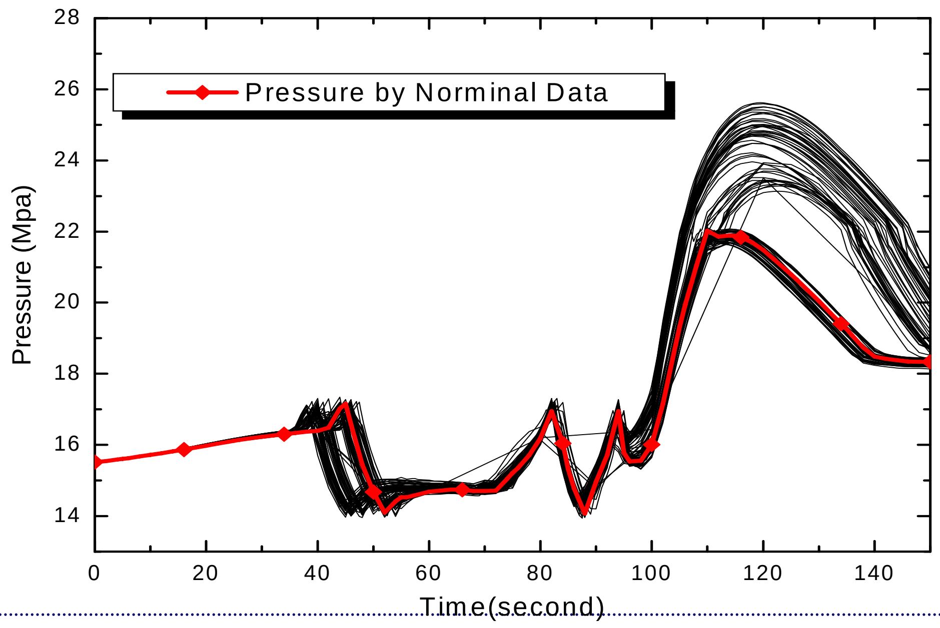
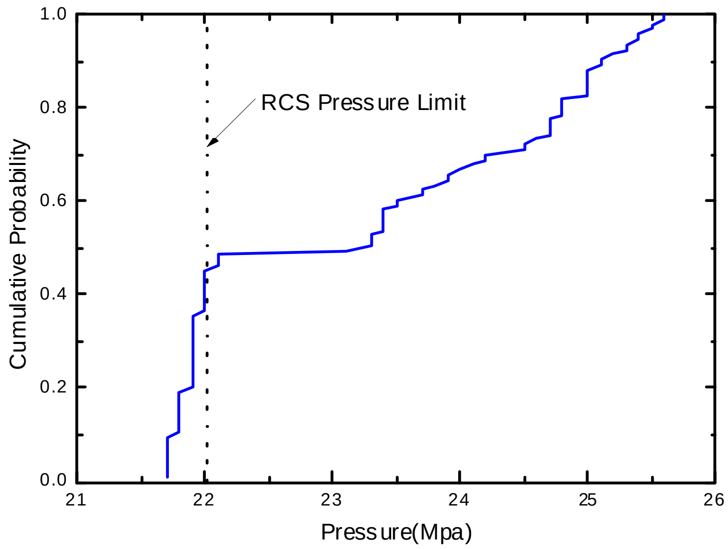
Calculation to Get the Distribution of The Event Sequence (1/2)

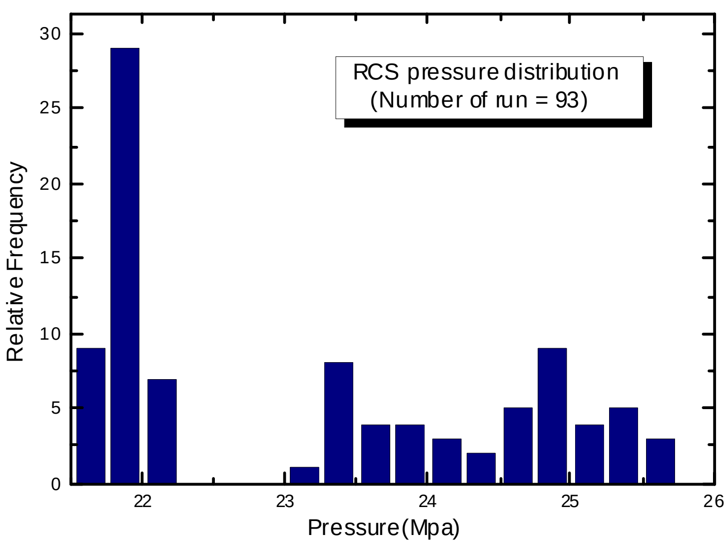
- 100 sampling calculation for the selected parameters based on their probability density function)
- 95/95 approach based on Wilk's formula is not applied
- The calculation by the nominal data is covered well by the sampling calculation results
- There is a bifurcation in the calculation, which has frequently appeared in a BE T/H calculation



Calculation to Get the Distribution of The Event Sequence (1/2)

- The distribution has a camelback shape due to a bifurcation of the calculation
- The failure probability of the event sequence is given as 0.55 approximately





Quantification of the Event Sequence Failure Probability

- In a PSA, the frequency of success scenario is not quantified
  - Conservativeness of success scenario

- Event Scenario frequency

$$f_{ES_i} = f_{ES} \cdot p\left(\prod_{j=1}^{n-m} S_j \cdot \prod_{k-n-m}^{n} \overline{S}_k \right)$$

f_{ES_i} : Frequency of the event sequence, i

S_j : The failure event of system, j

f_{ES} : Initiating event frequency

- The frequency of success sequence is 6.183E-6
  - The failure frequency is 3.4E-6

Conclusion & future work

- Conclusion
  - Best-estimate thermal-hydraulic approach to calculate the uncertainty of an event sequence is implemented
  - ATWS was selected as a pilot study
  - The RCS pressure was used for the core damage criterion
  - Although all the important parameters was not identified and used in the calculation, we demonstrated the possibility that the conditional failure probability can be calculated through the best-estimate T/H calculation
- Future Work
  - Determination of sampling method and number of sampling
  - Application for whole event trees considered in a PSA model