A Case Study of LBE Selection Based on the New Concept of TI-RIPB Methodology for MSRE

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1 Evolution of Licensing Laws in Nuclear Reactors in USA

10CFR50 = Two Step Licensing (PSAR for CP and FSAR for OL)

10CFR52 = One Step Licensing (SDA, DC, ESP)

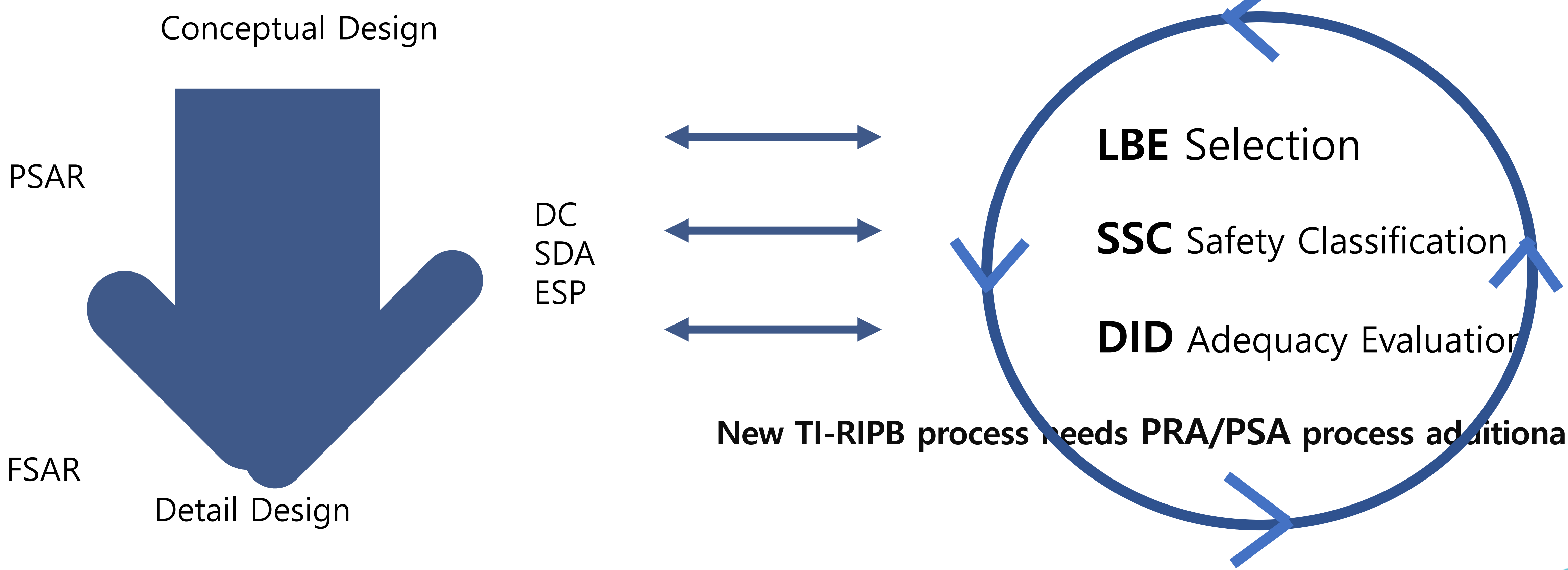
10CFR53 = Licensing with TI-RIPB Process on Advanced Non-LWRs (for instance, SFR, VHTR, PBMR, MSR, FHR, micro-reactors, space reactors, …)

PSAR = Preliminary Safety Analysis Report
FSAR = Final Safety Analysis Report
DC = Design Certificate
SDA = Standard Design Approval
ESP = Early Site Permit
LWR = Light Water Reactor

1 Relationship between Design process and TI-RIPB regulatory framework

Conventional Design Progress

New Regulation (Licensing) Process with TI-RIPB concept



New TI-RIPB process needs PRA/PSA process additionally

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1 TI-RIPB process needs PRA/PSA on new reactor types

TI-RIPB = Technology-Inclusive, Risk-Informed, Performance-Based

LBE = Licensing Basis Event selection

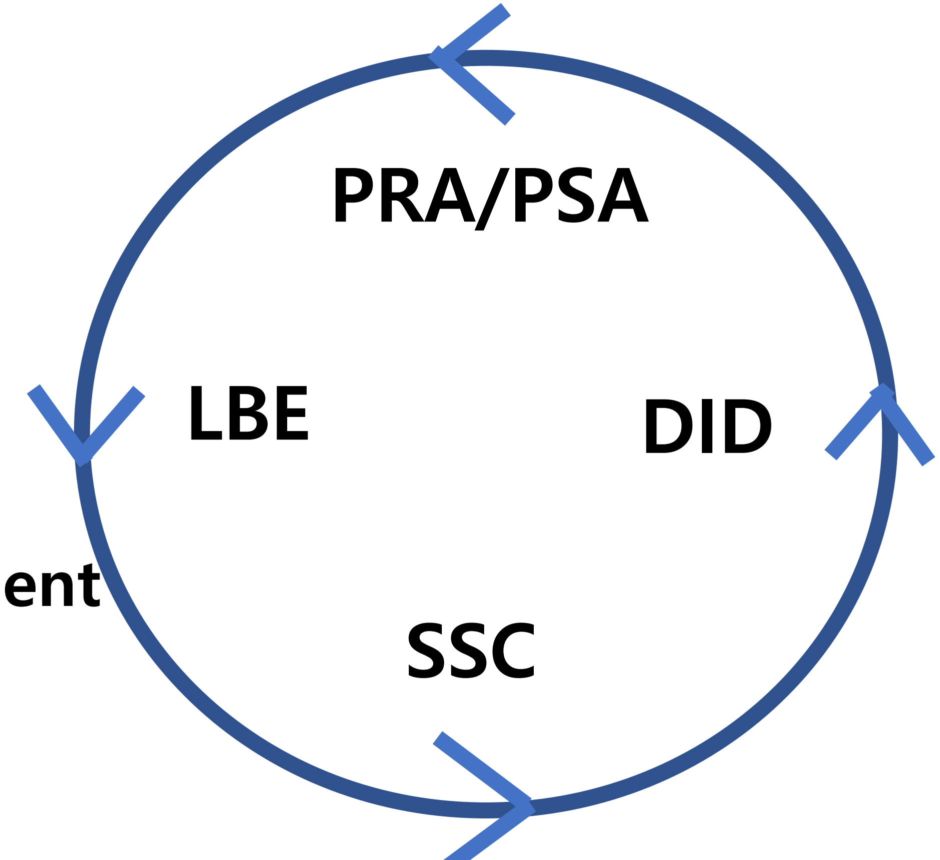
SSC = Structure, System, and Component

DID = Defense in Depth

PRA/PSA = Probabilistic Risk/Safety Assessment

AOO = Anticipated Operational Occurences

DBE = Design Basis Event, BDBE = Beyond DBE, RR = Residual Risk

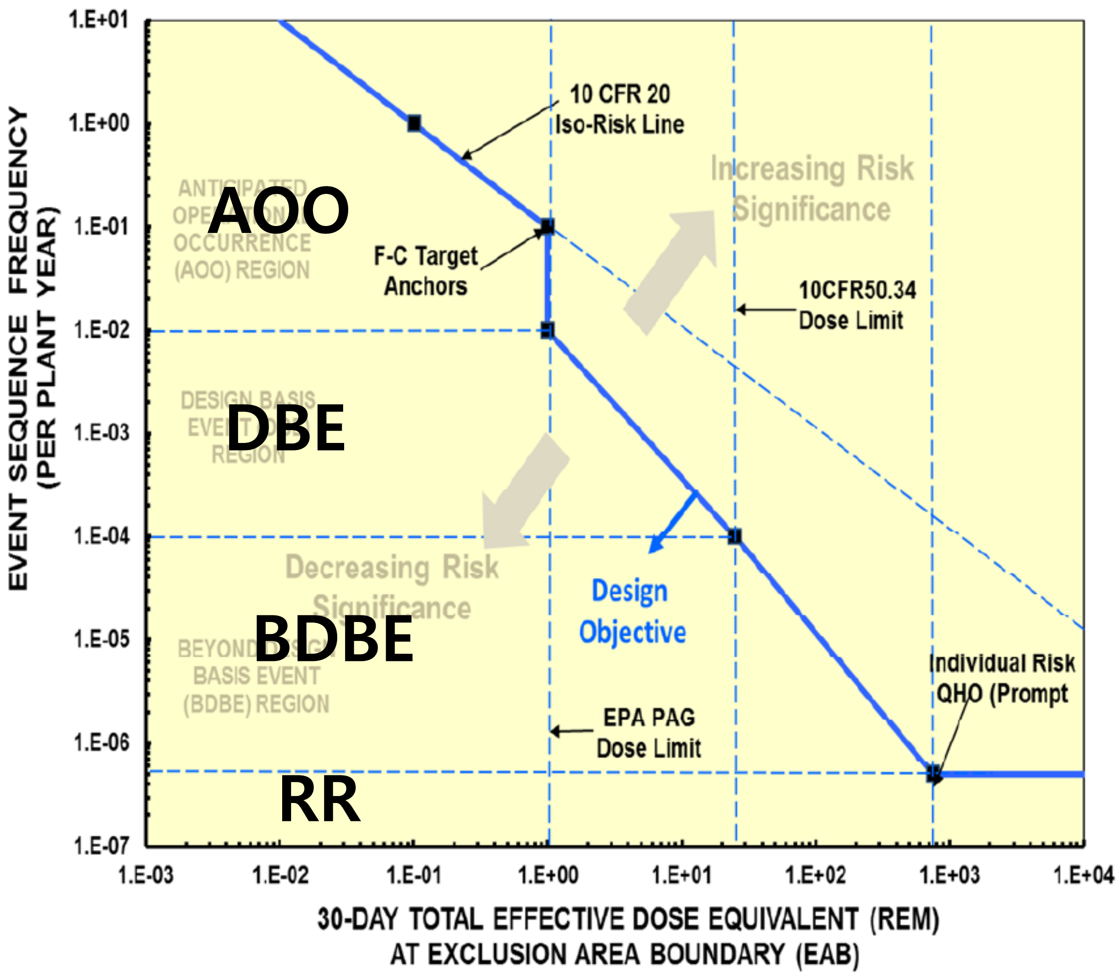


1 F-C (Frequency-Consequence) target is required in TI-RIPB

- For the licensing of different types of reactors except LWRs we need one consistent measure such as F-C curve

- Previous licensing (10CFR Part 50, 52) concept is performed deterministic and prescriptive way

- New licensing concept (10 CFR Part 53) is performed with probabilistic and performance-based way



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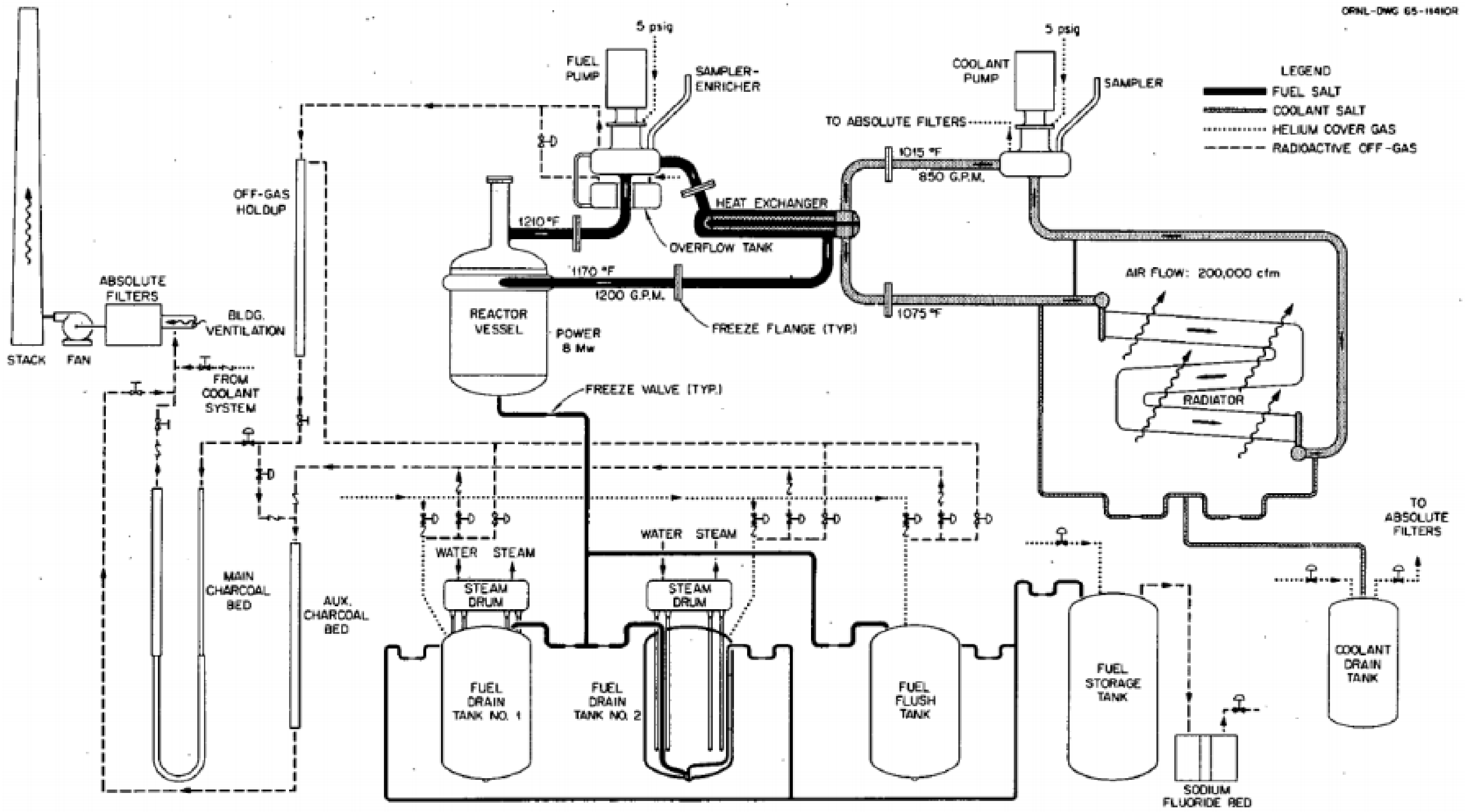
LMP (Licensing Modernization Project) demonstration was performed in USA for the following reactor types with addition of prototype PRA works

PRISM (SFR, G.E Hitachi),
XE-100 (X-Energy)
KP-FHR (Kairos Power)
MSRE (ORNL)
Westinghouse eVinci micro reactor
With help of NGNP, PBMR, MHTGR PRA Experience and Results

We will illustrate a simple example case of TI-RIPB process in MSRE

2 We will illustrate the TI-RIPB concept with MSRE reactor as an example case of Advanced Non-LWR



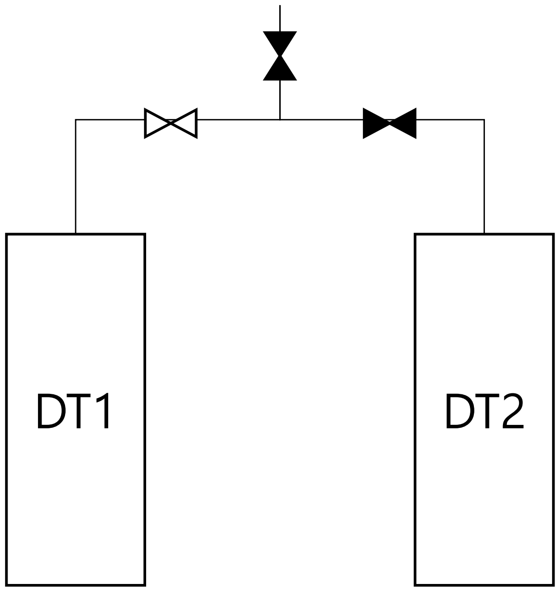
- MSRE = Molten Salt Reactor Experiment
- MSRE was designed and operated successfully in ORNL in 1960

2 MSRE LMP Demo – System Design Options

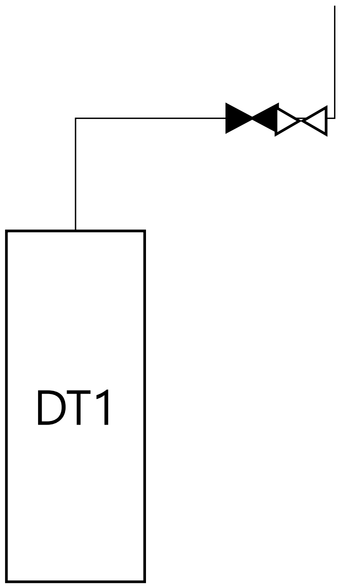
o Optimization of System Configuration

- Sample : ORNL MSRE Drain Tank Configuration

Design Option 2
(Dual Drain Tank)



Design Option 1
(Single Drain Tank)



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2 MSRE LMP Demo - Frequency

- Frequency estimate
  - Design Option 1 (single train of drain tank)

FUEL PUMP FAILURE	FUEL SALT DRAIN	DT1 AHRS	Seq#	State	Frequency
IE4	NO-FS-DRAIN	DT1-AHRS-FAIL			
%IE4			1	AOO	9.986e-2
		DT1-AHRS-FAIL	2	DBE	1.382e-4
	NO-FS-DRAIN		3	R	3.576e-7

  - Design Option 2 (dual trains of drain tanks)

FUEL PUMP FAILURE	FUEL SALT DRAIN	DT1 AHRS	SALT TRANSFER TO DT2	DT2 AHRS	Seq#	State	Frequency
IE4	NO-FS-DRAIN	DT1-AHRS-FAIL	NO-TX-DT1-DT2	DT2-AHRS-FAIL			
%IE4					1	AOO	9.986e-2
		DT1-AHRS-FAIL			2	DBE	1.351e-4
				DT2-AHRS-FAIL	3	R	1.87e-7
			NO-TX-DT1-DT2		4	BDBE	2.991e-6
	NO-FS-DRAIN				5	R	3.576e-7

2 MSRE LMP Demo – Consequence Analysis

- Consequences estimate : TID following Maximum Credible Accident in MSRE Safety Analysis Report
- Depending on the EAB distance (Case A : 3,000 m, Case B : 100 m)

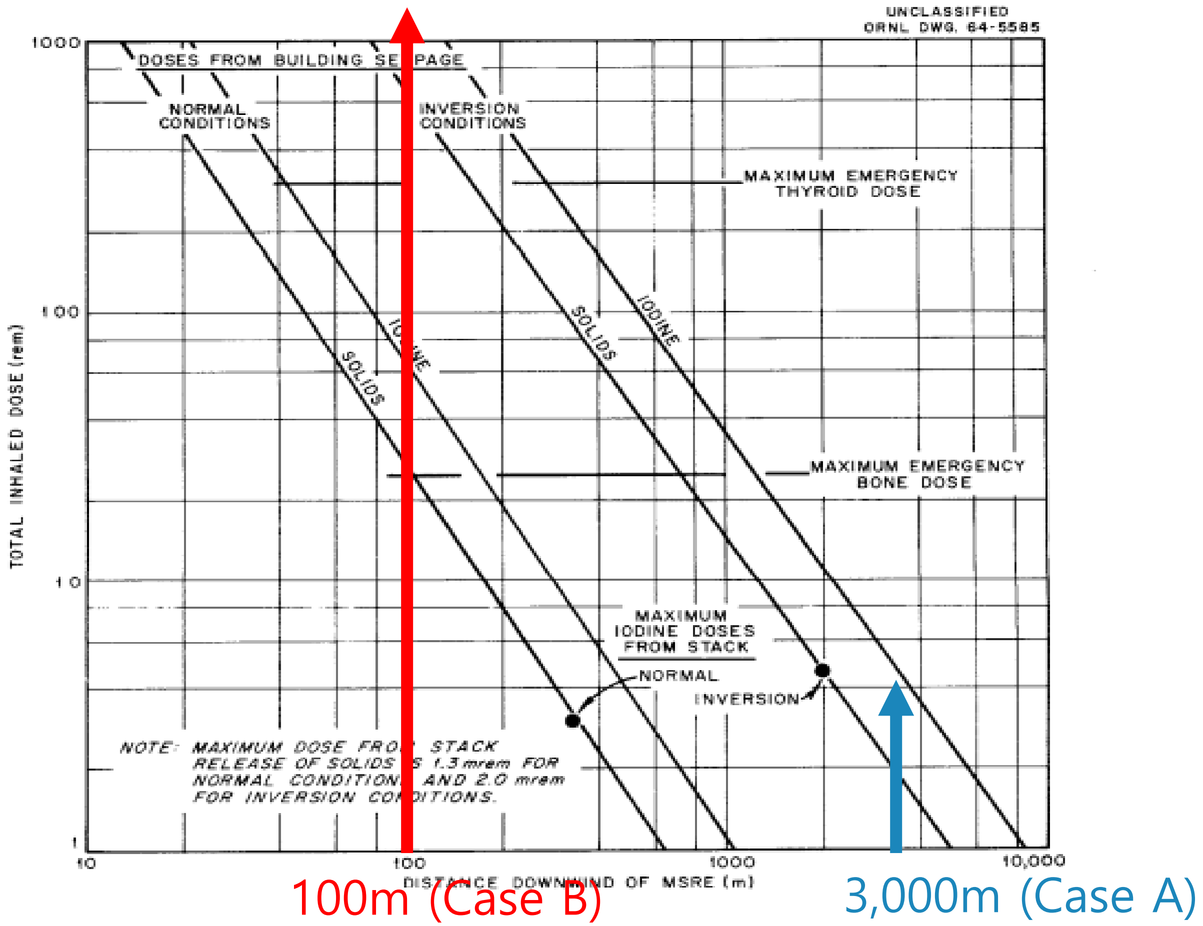


Fig. 8.7. Total Integrated Doses Following Maximum Credible Accident.

2 MSRE LMP Demo – Option 1 Result

- Summary of Frequency and Consequence for Option 1 (Case A)

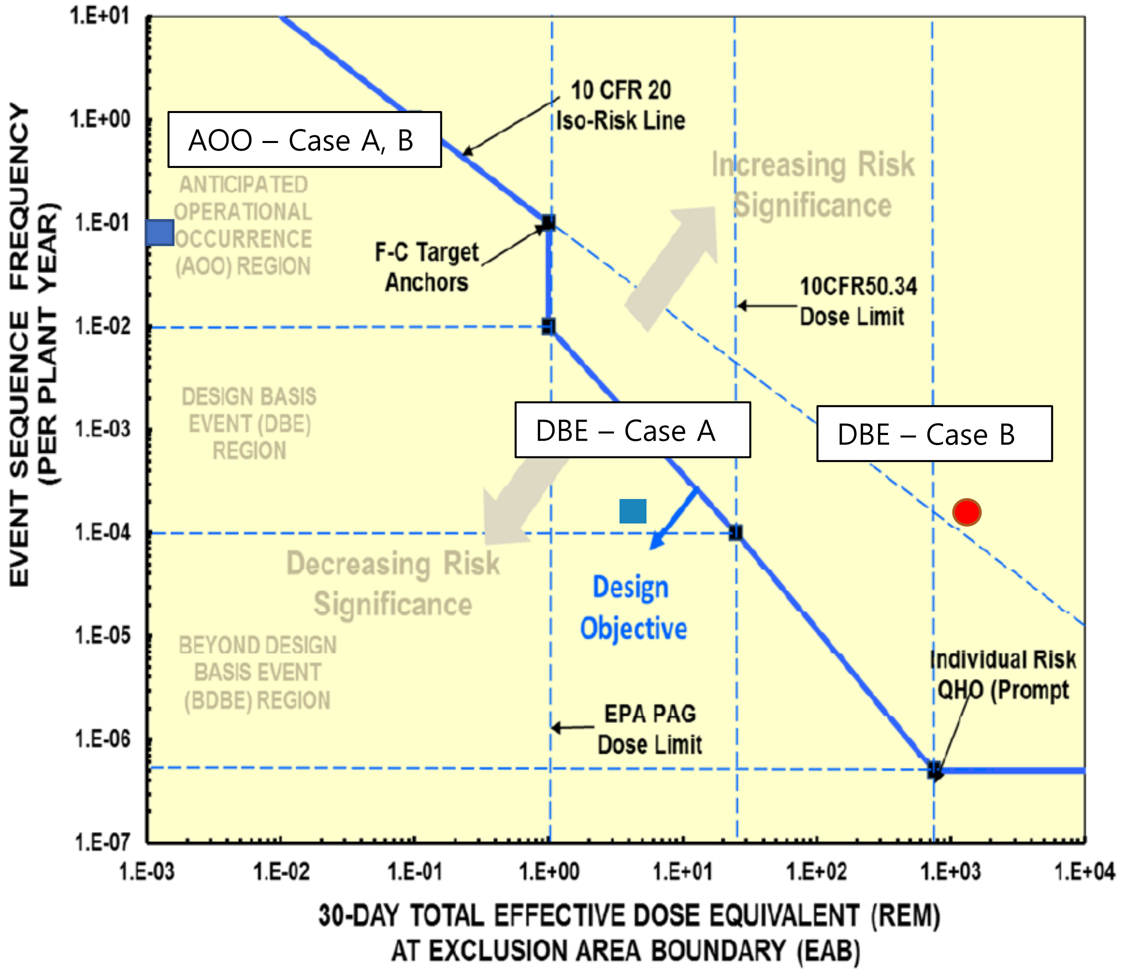
	Sequence		Frequency (/yr)		Consequence	
	AOO		9.99E-02		Negligible	
	DBE		1.38E-04		~ 5 rem at EAB(3,000m)	

- Summary of Frequency and Consequence for Option 1 (Case B)

	Sequence		Frequency (/yr)		Consequence	
	AOO		9.99E-02		Negligible	
	DBE		1.38E-04		>1,000rem at EAB(100 m)	

2 MSRE LMP Demo – Option 1 Result

- Frequency and Consequence results of Option 1 on F-C target



2 MSRE LMP Demo – Option 2 Result

- Summary of Frequency and Consequence for Option 2 (Case A)

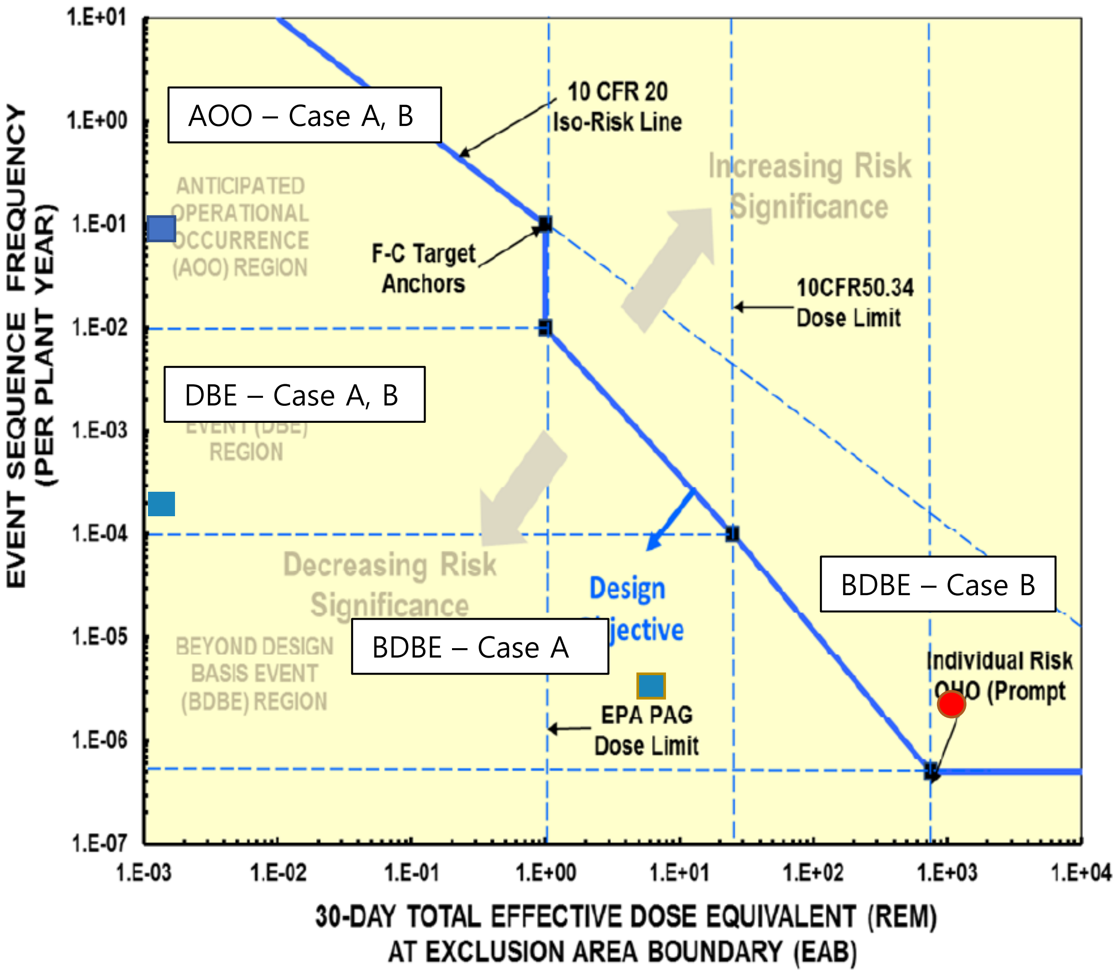
Sequence	Frequency (/yr)	Consequence
AOO	9.99E-02	Negligible
DBE	1.35E-04	Negligible
BDBE	2.99E-06	~ 5 rem at EAB(3,000m)

- Summary of Frequency and Consequence for Option 2 (Case B)

Sequence	Frequency (/yr)	Consequence
AOO	9.99E-02	Negligible
DBE	1.35E-04	Negligible
BDBE	2.99E-06	>1,000rem at EAB(100m)

2 MSRE LMP Demo – Option 2 Result

- Frequency and Consequence results of Option 2 on F-C target



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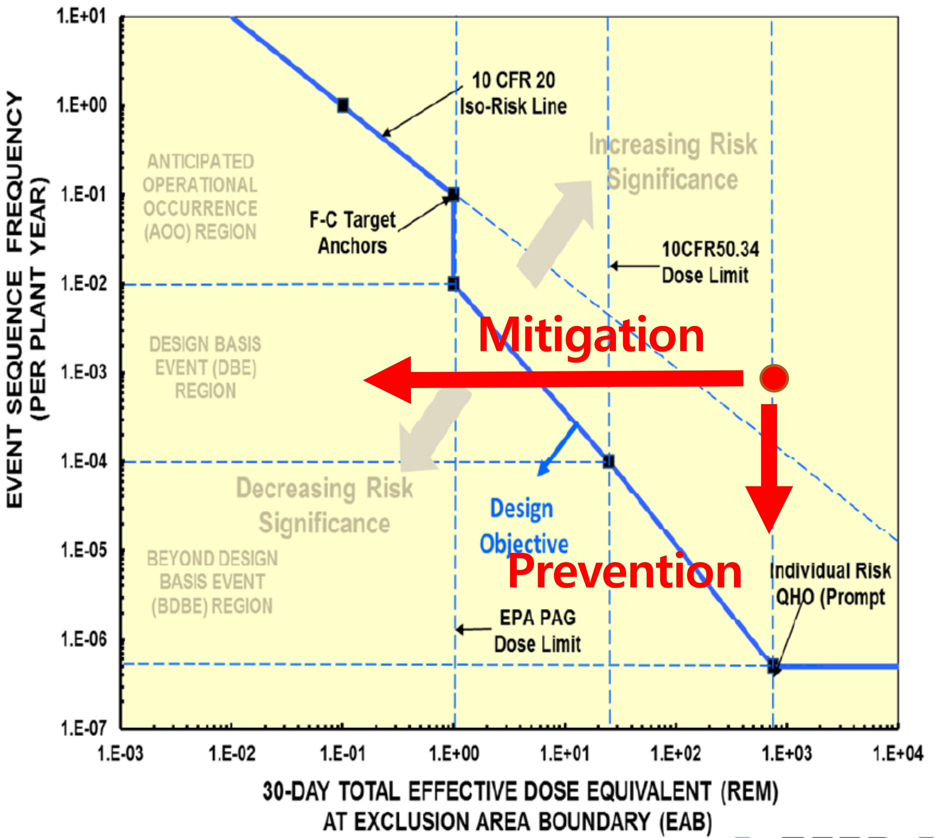
3 Insight from **MSRE LMP Demo study (Technical Issues raised during this study)**

- TI-RIPB Approach can show the risk level which will be the key metrics of reactor safety in new regulatory framework (i. e. 10CFR53)
  - Single failure criterion will not be the mandatory requirement.
  - Redundant design will be determined by the risk level.
  - MSR Developers do not know the level of risk in their systems and the relationship between system design process and TI-RIPB.
  - According to the results of the demo study, design option 1 of a single drain tank results in high consequence under DBE condition, so it is essential to provide redundant design or/and mitigation feature.



- LMP Demo exposed many problems.
  - ET/FT model is too simplified to estimate the actual frequency.
  - Radiological source term for consequence estimate is very uncertain and needs to be developed mechanistically.

- Reduction of EAB, EPZ is a crucial issue for SMR/MSR.
  - NuScale tried to reduce the EPZ within the site boundary(EAB).

3 Conclusions

- With this new TI-RIPB concept the licensing of new non-LWR type reactors will be realized in Korea
- It can work among different types of reactors only addition of PRA/PSA works
- A Danish company Seeborg now develops a floating reactor CMSR and try to get a licensing in Korea
- Korea should start to develop a new regulation/licensing framework with the same steps of new reactor type development and safety assessment processes, etc.

감사합니다