

PSA

Identification of Initiating Events Using a Master Logic Diagram in Low-Power and Shutdown PSA for Nuclear Power Plant

150

/ (LPSD) 가(PSA)
 (Master Logic Diagram: MLD) LPSD PSA
 Top-Down MLD
 MLD PSA MLD LPSD PSA
 가
 MLD MLD
 MLD LPSD PSA 가

Abstract

It is necessary to apply a formal technique instead of an empirical technique in the identification of initiating events for low power and shutdown (LPSD) probabilistic safety assessment (PSA) of nuclear power plant (NPP). The present study focuses on the examination of master logic diagram (MLD) technique as a formal technique in the identification of initiating events. The MLD technique is a deductive tool using top-down approach for the formal and logical identification of initiating events. The present study modified the MLD used in the full power PSA considering the characteristics of LPSD operation. The modified MLD introduced a systematic formation in decomposition process of which the MLD for full power PSA lacked. The modified MLD was able to identify initiating events systematic and logical. However, the formal techniques including the MLD have a limitation for precisely identifying all of the initiating events. In order to overcome this limitation, it is necessary to combine it with an empirical technique. We expect that the modified MLD can be used in an upgrade of the current LPSD PSAs.

1.

/ (LPSD) 가(PSA) PSA
 LPSD (Risk) LPSD PSA
 [USNRC, 1999; Lois, 2002]. PSA (RIA) PSA
 LPSD PSA RIA 가 RIA
 LPSD PSA 가

LPSD PSA (Screening Out), Risk-Significate

LPSD PSA (Definition), 가 (Estimation of Event Frequency)

PSA (Identification), (Risk) (Grouping), 가

LPSD PSA 가

LPSD PSA (Master Logic Diagram: MLD)

2 가 MLD

LPSD PSA

3 LPSD MLD

4

2.

2.1

LPSD PSA 가 [Lois, 2002]. 1 LPSD PSA LPSD PSA (Level 1)

PSA . Level 1 LPSD PSA (, , ,)

가

LPSD PSA

Feedback 5

LPSD

2.2

2.2

LPSD PSA (Initiator)

PSA LPSD PSA

가

가

Risk-Significant

LPSD PSA 가 [Lois, 2002].

가 Risk-Significant (Formal Technique)-

LPSD PSA 가 PSA

PSA LPSD PSA 가 PSA

LPSD PSA 가 LPSD PSA 가

가 [USNRC, 1999].

LPSD PSA 2

PSA [Lois, 2002]:

- (Master Logic Diagram: MLD)
- (Systematic Deductive Identification of Events)
- / (Technical or Physical Considerations Disturbing the Heat or Reactivity Balance)
- (Fault Trees: FT)
- (Procedure Trees: PT)
- (Failure Mode and Effects Analysis: FMEA)
- (Human Reliability in Isolation/Mitigation)

Hazard Indices [Garrick, 1983; Papazoglou, 2003]

Bottom Up Top Down 가

HAZOP 가 가 가

가 [Papazoglou, 2003].

MLD (Decomposition) 가 [Garrick, 1983].

FMEA 가

/ 가 가 / 가

가

1 (Risk Metrics) 가

2 - LPSD PSA; NUREG, NSAC, and IAEA ; ; Licensee Event Reports (LER); Letter and Information Notices - ; 가 () ; USNRC Generic

가
 . Seabrook PSA (Deductive Tool)
 3 (Heat Balance Method) [Garrick, 1983]
 Risk Metrics
 가 MLD 가
 . MLD
 가 PSA
 MLD LPSD PSA

3. MLD

3.1 MLD

MLD (System) (Function) PSA
 PSA MLD Seabrook PSA [Garrick, 1983] USNRC 'PRA Procedures Guide'
 [USNRC, 1982] MLD PSA
 MLD (Risk Metrics)
 (Top Event) [Garrick, 1983; Papazoglou, 2003]. MLD

MLD PSA
 PSA LPSD PSA 1 (Risk Metrics) PSA /
 4 MLD (precede) -

MLD ,
 LPSD
 LPSD
 가 MLD

3 가
 4 1 PSA LPSD
 가 LPSD 1 PSA 가
 (heavy load drop) 가

MLD
MLD
MLD
PSA
MLD
가
5W1H

5W1H (What, Where, How, Why, When)

MLD
가
LPSD
가

MLD
PWR⁵
가
MLD
1, 2
가
5W1H
가
MLD
Q&A 2
MLD
PSA MLD

5W1H
How

⁵ PWR CANDU

CANDU, BWR,

Why 2 . who , when
가 what, where, how
Level ,

3.2 MLD

LPSD 1 PSA MLD MLD MLD
MLD , MLD , MLD PSA
3.1

2 MLD 3 / ,
1

PSA MLD , 2

Q&A . 2 Level 1 1.1 'What can threaten
environment?' 'Release of Radioactive Materials to environment' 가
Level 1 1.2 1.3
Level 2 2.2 'Where does it originate?' 'From
Inside RCS (Core Materials) or Outside RCS (Noncore Materials)'

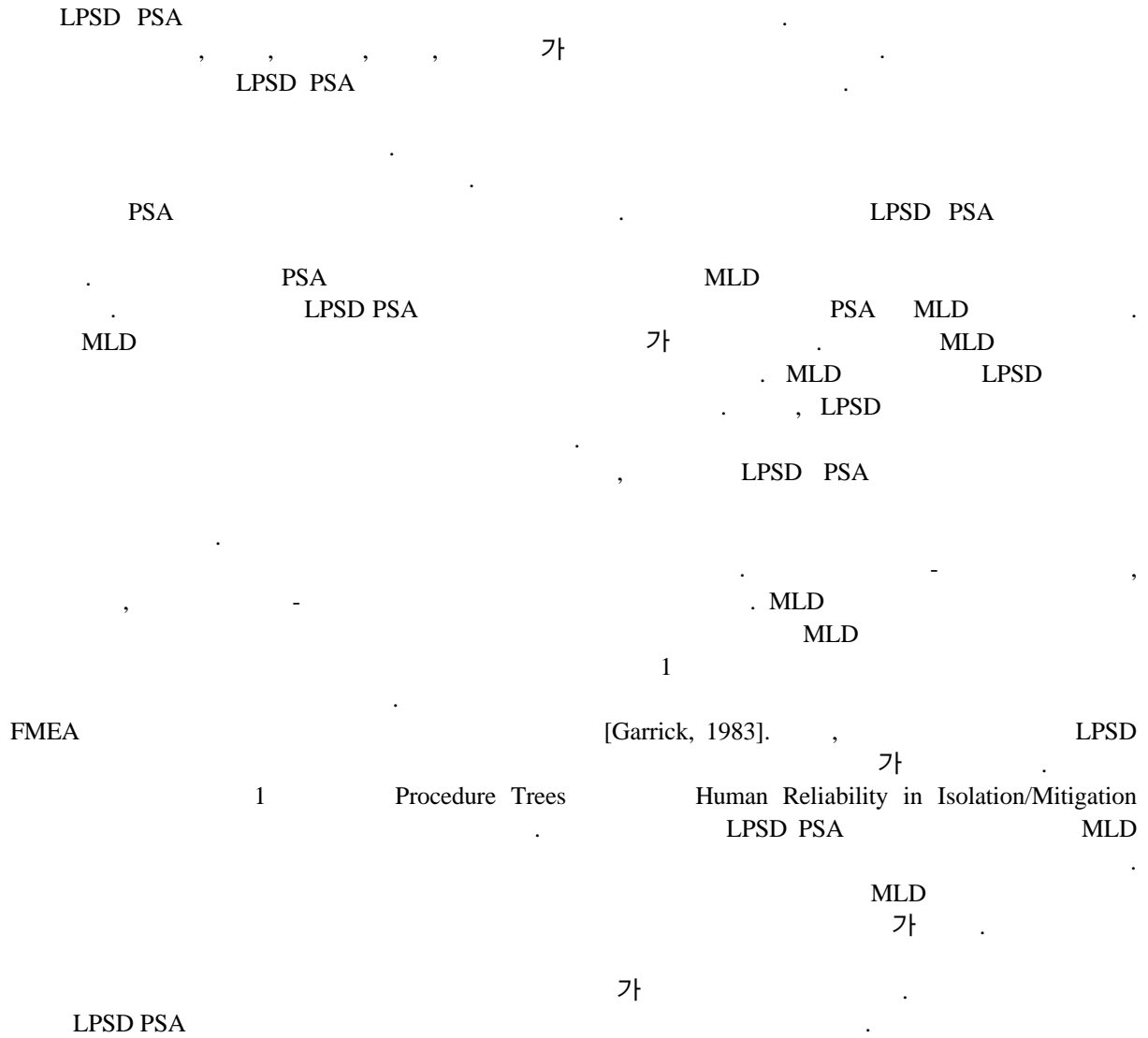
LPSD 가
MLD Level 3 . Level 3
Level 3.1, 3.2, 3.3
(Source), , Level 3.1 'What are main sources of
degradation of core materials?' 가 .

가
Level 3.2 'Where does it originate?' 가 . Level 3.3 'How can degradation
occur?' , 가 가 .

Level 3 가 .
(Level 3) 가 .
Level 4 Level 3 가 .
Level 4.1 'What are main sources of malfunction of it?'

가 originate? 가 가 Level 4.2 'Where does it originate?' 가 가 Level 4.3 'How can a fluctuation of sources occur?' 가 Level 4.2 RCS / 가 Level 5 Level 4 / 가 Level 4 Level 5 'What are main prevent functions of it?' 가 Level 5.1 'What are main prevent functions of it?' 1 2 가 RCS Coolant Makeup 가 Level 4.3 가 Level 5.2 Level 5.3 가 가 Level 5.2 5.3 MLD 가 가 Level 6 MLD Feedback 가 가 2 3 3 Q&A Level 5.2, 5.3 Level 6 LPSD PSA 2 MLD 8 Q&A MLD 5, 6, 7, MLD 가 LPSD Midloop

4.

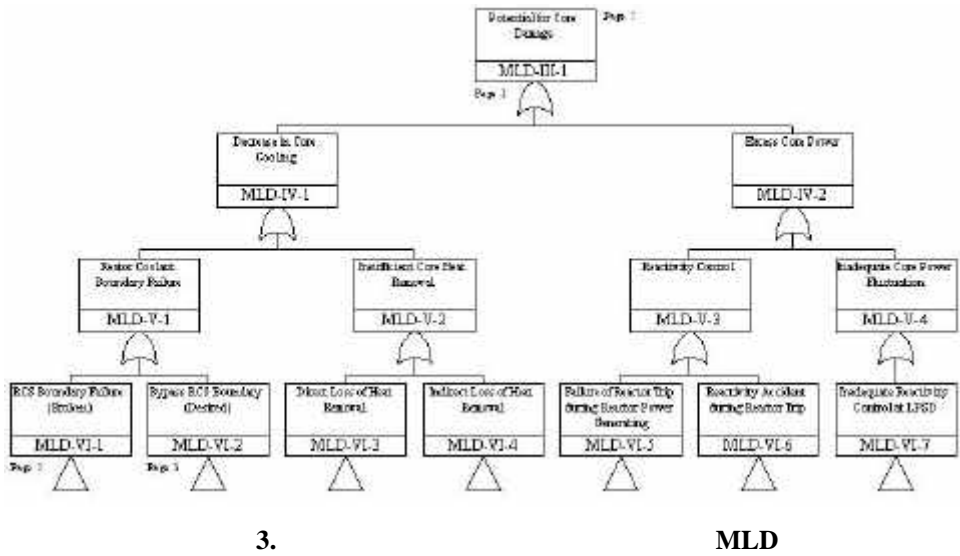
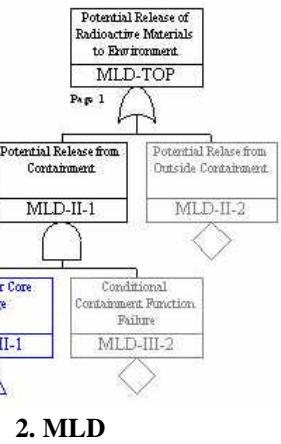
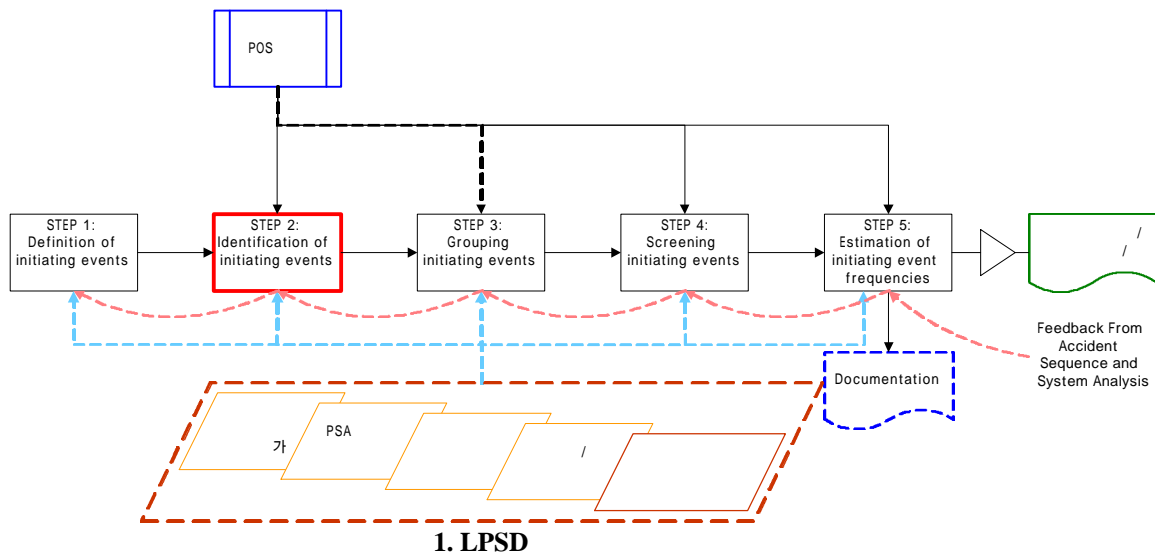


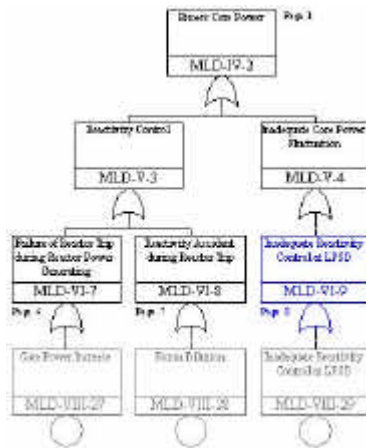
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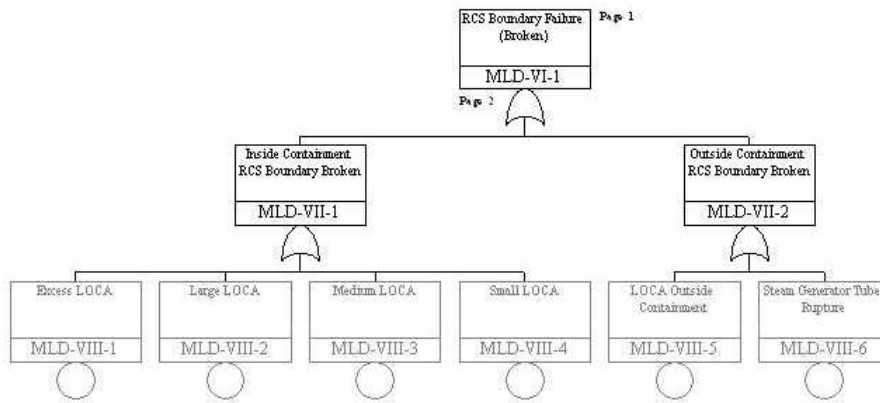
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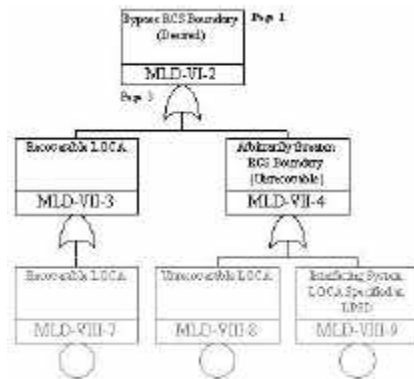
4.

MLD



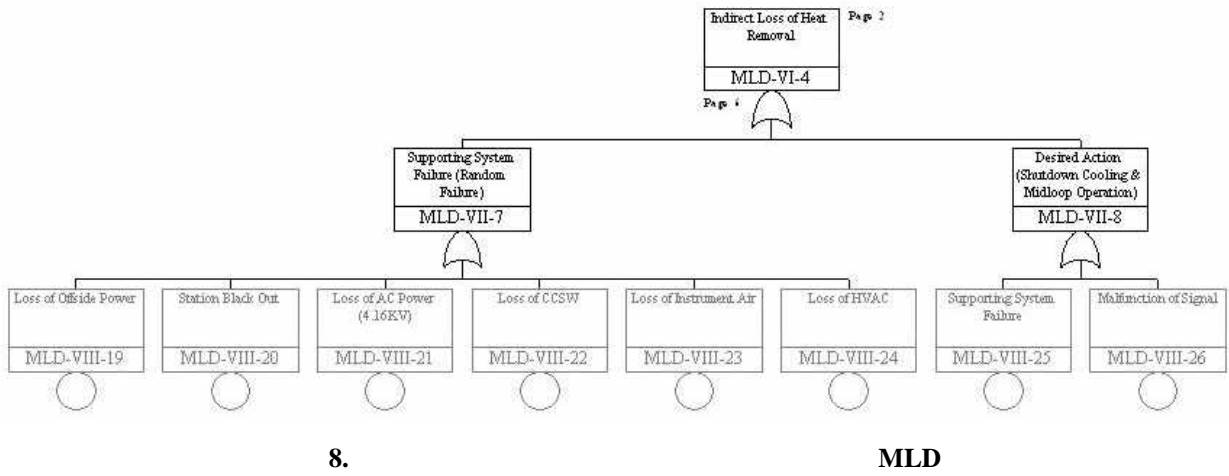
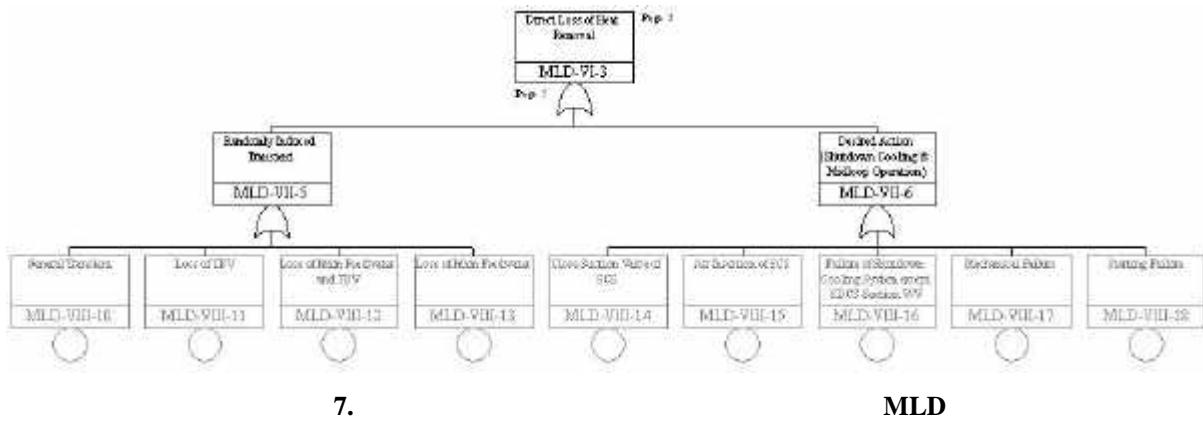
5. RCS

MLD



6. RCS

MLD



1.

(Formal Technique)

| | | | | | |
|-----------|--|---|---|---|-----|
| Top-Dwn | Systematic Deductive Identification of Events | ● | | ● | |
| | | | | ● | |
| | Master Logic Diagram (MLD) | ● | | ● | PSA |
| | Fault Trees (FT) | ● | | ● | 가 |
| | | | | ● | |
| | Technical or Physical Considerations Disturbing the Heat or Reactivity Balance | ● | 가 | ● | |
| | | ● | | ● | |
| Bottom-Up | HAZOP | ● | | ● | |
| | | | | ● | |
| | | | | ● | |
| | Failure Mode and Effects Analysis (FMEA) | ● | | ● | |
| | | | | ● | |
| | Procedure Trees (PT) | ● | | ● | |
| | Human Reliability in Isolation/Mitigation | ● | | ● | |

2. MLD

Q&A

| Decomposition Level | Main concept | sub decomposition | sub concept | Main Question | Answer |
|---------------------|--------------|-------------------|-------------|--|--|
| Level 1 | What | Level 1.1 | what | What can threaten environment? | <ul style="list-style-type: none"> ● Release Of Radioactive Materials To Environment ● From Inside Containment (Core Materials/Noncore Materials) Or ● Outside Containment ● Potential Pathway To Release Core Materials Or ● Non-Core Materials |
| | | Level 1.2 | where | Where does it originate? | |
| | | Level 1.3 | how | How can a significant release to environment occur? | |
| Level 2 | Where | Level 2.1 | what | What is a main pathway from containment to environment? | <ul style="list-style-type: none"> ● Containment Function Failure (Broken, Bypass-Undesired,Desired) With Release From RCS Boundary ● Containment Having A Indirect Effect On Release (Conditional Behavior Of Containment Housing Direct Source-Core Materials) ● From Inside RCS (Core Materials) Or ● Outside RCS (Noncore Materials) : i.e., Damage Core ● Potential Pathway To Release Core Materials |
| | | Level 2.2 | where | Where does it originate? | |
| | | Level 2.3 | how | How can a significant release to inside containment occur? | |
| Level 3 | How-1 | Level 3.1 | what | What are main sources of degradation of it? | <ul style="list-style-type: none"> ● Thermal Energy: <ul style="list-style-type: none"> ■ Decay Heat, ■ Reaction Power ● Mechanical Energy: (i.e., External Force) ● From Reactor Core ● Malfunction Of Heat Transfer By Normal Pathway Of Thermal Energy: <ul style="list-style-type: none"> ■ Decay Heat, ■ Reaction Power ● Malfunction of Reactivity Control: <ul style="list-style-type: none"> ■ Reaction Power |
| | | Level 3.2 | where | Where does it originate? | |
| | | Level 3.3 | how | How can degradation occur? | |
| Level 4 | Why-1 | Level 4.1 | what | What are main sources of malfunction of it? | <ul style="list-style-type: none"> ● Loss Of Heat Transfer: <ul style="list-style-type: none"> ■ Loss Of Heat Transfer Material (Coolant) ■ Loss Of Heat Balance ● Loss of Reactivity Control ● Loss Of Coolant: <ul style="list-style-type: none"> ■ Failure Of Reactor Coolant System Boundary ● Loss Of Heat Balance: <ul style="list-style-type: none"> ■ Direct Loss Of Heat Balance ■ Indirect Loss Of Heat Balance ● Loss of Reactivity Control <ul style="list-style-type: none"> ■ Failure of Reactor Trip ■ Reactivity Accident ● Failure Of RCS Boundary: <ul style="list-style-type: none"> ■ Random (Arbitrary) ■ Desired Action Failure ● Loss Of Heat Balance: <ul style="list-style-type: none"> ■ Direct Loss Of Heat Balance; ◆ Random |
| | | Level 4.2 | where | Where does it originate? | |
| | | Level 4.3 | how | How can a fluctuation of sources occur? | |

| Decomposition Level | Main concept | sub decomposition | sub concept | Main Question | Answer |
|---------------------|--------------|-------------------|-------------|--|---|
| Level 5 | How-2 | Level 5.1 | what | What are main prevent functions of it? | <ul style="list-style-type: none"> ◆ Desired Action Failure ■ Indirect Loss Of Heat Balance; <ul style="list-style-type: none"> ◆ Random ◆ Desired Action Failure ● Failure of Reactor Trip <ul style="list-style-type: none"> ■ Mechanical failure of Control Rod ■ Failure of Control Signal ● Reactivity Accident <ul style="list-style-type: none"> ■ Arbitrary Recriticality; ■ Inadequate Reactivity Control ● Failure Of RCS Boundary: <ul style="list-style-type: none"> ■ Random (Arbitrary): <ul style="list-style-type: none"> ◆ Makeup Coolant ◆ Plug Up A Leak ■ Desired Action Failure: <ul style="list-style-type: none"> ◆ Recovery Action ◆ Other Recovery Action ● Loss Of Heat Balance: <ul style="list-style-type: none"> ■ Direct Loss Of Heat Balance; <ul style="list-style-type: none"> ◆ Random : <ul style="list-style-type: none"> ● Recovery Action ● Other Recovery Action ◆ Desired Action Failure : <ul style="list-style-type: none"> ● Recovery Action ● Other Recovery Action ■ Indirect Loss Of Heat Balance; <ul style="list-style-type: none"> ◆ Random : <ul style="list-style-type: none"> ● Recovery Action ● Other Recovery Action ◆ Desired Action Failure : <ul style="list-style-type: none"> ● Recovery Action ● Other Recovery Action ● Failure of Reactor Trip <ul style="list-style-type: none"> ■ Mechanical failure of Control Rod <ul style="list-style-type: none"> ◆ Recovery Action ◆ Other Recovery Action ■ Failure of Control Signal <ul style="list-style-type: none"> ◆ Recovery Action ◆ Other Recovery Action ● Reactivity Accident <ul style="list-style-type: none"> ■ Arbitrary Recriticality; <ul style="list-style-type: none"> ◆ Recovery Action ◆ Other Recovery Action ■ Inadequate Reactivity Control |

| Decomposition Level | Main concept | sub decomposition | sub concept | Main Question | Answer |
|---------------------|--------------|-------------------|-------------|---|---|
| | | | | | <ul style="list-style-type: none"> ◆ Recovery Action ◆ Other Recovery Action |
| Level 6 | Why-2 | Level 5.2 | where | Where does a main prevent function fail? | <ul style="list-style-type: none"> ● List of related systems or components ● List of function failure causes ● Loss Of Coolant: Feedback From Experience Direct Loss Of Heat Balance: From Experience Indirect Loss Of Heat Balance: From Experience |
| | | Level 5.3 | how | How does a main prevent function fail? | |
| | | Level 6.1 | what | What are fluctuations of it? | |
| | | Level 6.2 | where | Where does a fluctuation occur? | <ul style="list-style-type: none"> ● Loss Of Coolant: From Experience Direct Loss Of Heat Balance: From Experience Indirect Loss Of Heat Balance: From Experience |
| | | Level 6.3 | how | How does a fluctuation occur? | |
| Level 7 | when | Level 7 | when | How much does a failure of each sub function occur? | <ul style="list-style-type: none"> ● Estimation Of Frequency |