Preliminary Failure Mode and Effect Analysis for CH HCSB TBM

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Outline

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- FMEA Main Analysis Purposes
- FMEA Methodology
- FMEA Analysis Condition for HCSB TBM
- Main FMEA Analysis Outcomes for HCSB TBM
- Summary

Introduction

- The complexity of the ITER TBM (International Thermonuclear Experimental Reactor Test Blanket Module) and the inventories of radioactive materials involved in its operation require a systematic approach to perform detailed safety analyses during the various stages of the project in order to demonstrate compliance with the safety requirements.
- A Bottom-Up methodology based on component level failure mode and effect analysis (FMEA) has been applied to perform the safety analyses for Chinese TBM design with helium-cooled solid breeder (HCSB) concept.
- Some FMEA analyses for Chinese TBM have been performed and further works are ongoing.
- FMEA analyses for ITER TBM can accumulate many experiences for the coming fusion power plants safety analysis.

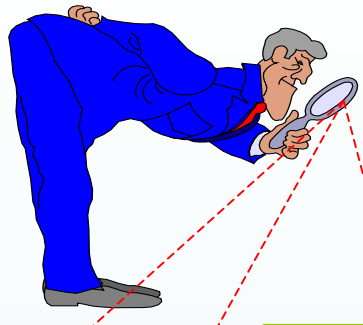
FMEA Main Analysis Purposes

The main purposes of the work are to:

- Identify important accident initiators;
- Find out the possible consequences for the TBM deriving from component failures;
- Identify individual possible causes;
- Identify mitigating features and systems;
- Classify accident initiators in postulated initiating events (PIEs);
- Define the deterministic analyses which allow the possible accident sequences to be quantified;
- Summarize and then come into being a paper report.

FMEA Methodology (1/3)

Steps to Practice FMEA:



1、Confirm tasks and objects for FMEA

2、Determine analysis levels

3、Build function pane chart

4、Build reliability degree pane chart

5、List all potential failure mode

6、List all possible failure causes / mechanism

7、List ponderance classes arising from failures

8、Complete FMEA table

9、 Preventive and mitigating and improving actions

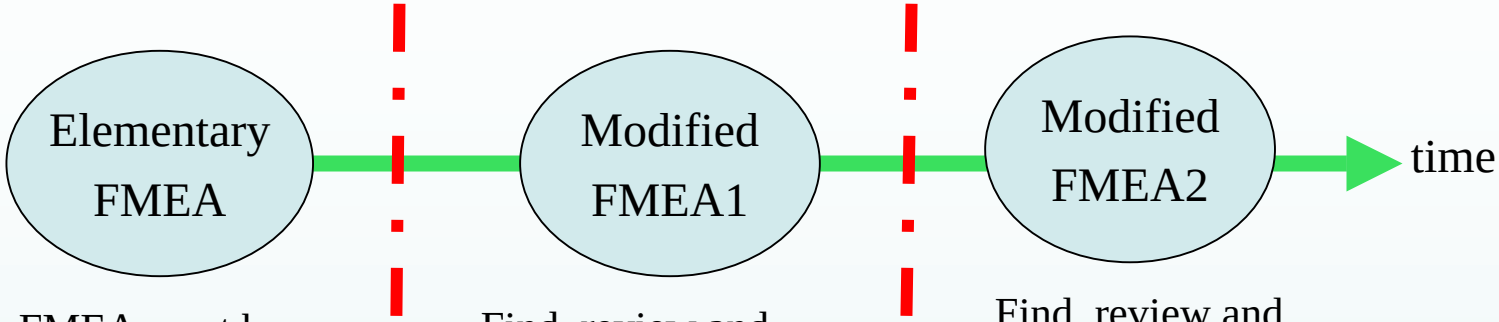
FMEA Methodology (2/3)

To assess the possible failure modes by the FMEA at component level, FMEA analysis should contain:

- Component
- Operating States
- Failure Modes
- Causes
- Preventive Action on Causes
- Consequences
- Corrective/Preventive Action on Consequences
- PIEs (Postulated Initiating Events)
- Frequency Category
- Comments

FMEA Methodology (3/3)

FMEA is dynamic document：



FMEA must be completed before last design for manufacturing will be released.

Find, review and update every failure mode without Being considered in former design.

Find, review and update every failure mode without Being considered in former design.

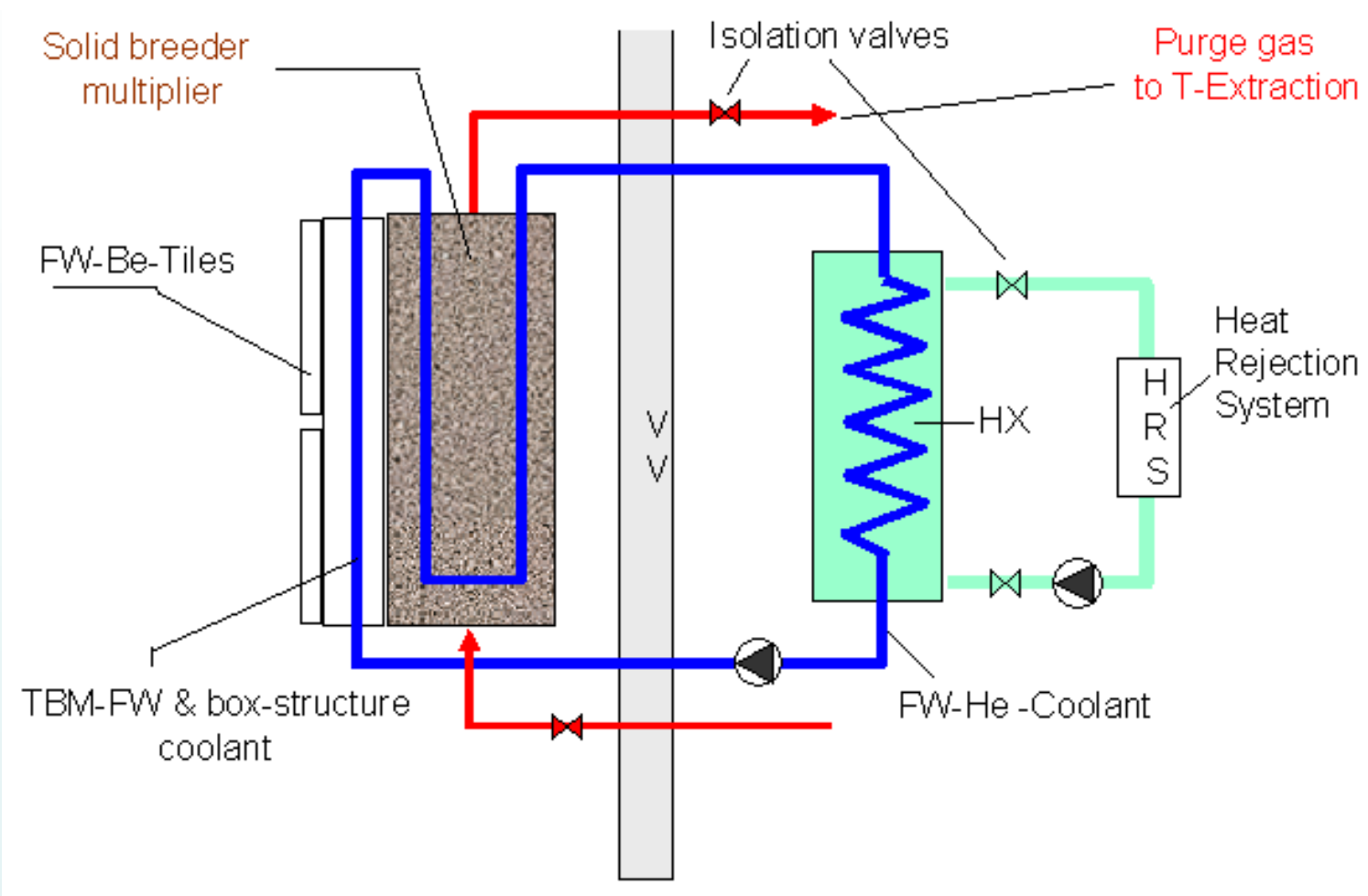
WORKTEAM !

Require all related engineers of different fields cooperation.

FMEA Analysis Condition for HCSB TBM

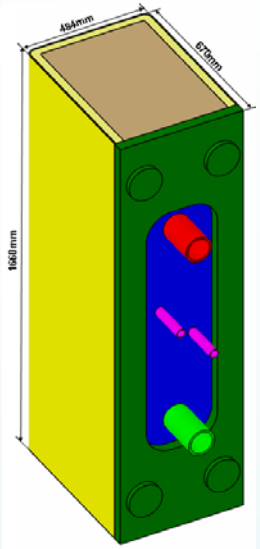
- The PI-TBM (Plant Integration module), which will operate in the last period of the high duty cycle D-T phase of ITER-FEAT life, has been considered in the assessment because it is the most representative from a safety point of view.
- The analysis has been performed for the burning and dwell operating phases, the so called “Normal Operation”.
- This FMEA analysis is based on the HCSB TBM design information updated in April 2007.

Schematic Concept of the TBM Systems

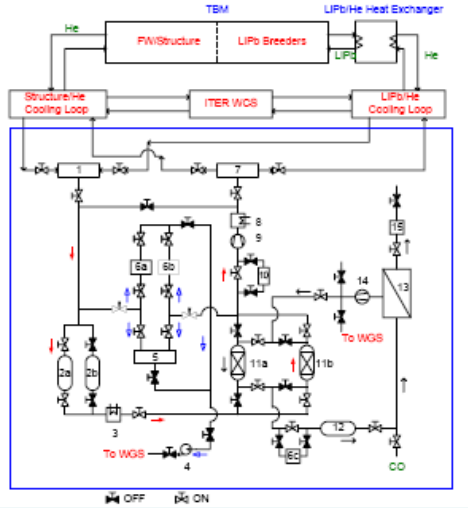


Reference: presented by M. Iseli in TBWG Safety workshop meeting, July 18, 2006, Garching

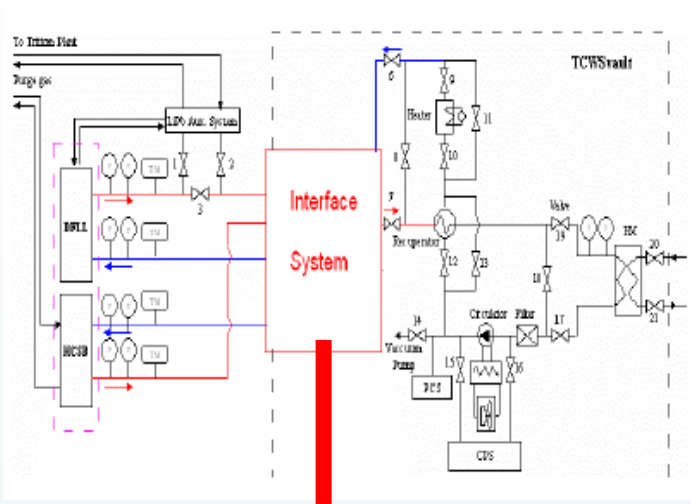
Design Updated of HCSB TBM and Related Systems



TBM



CPS

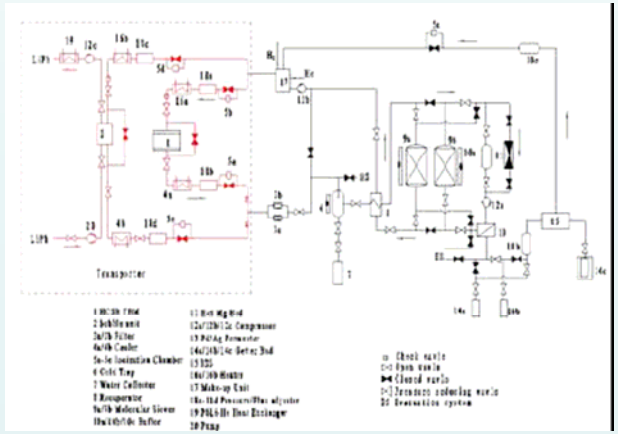


HCS

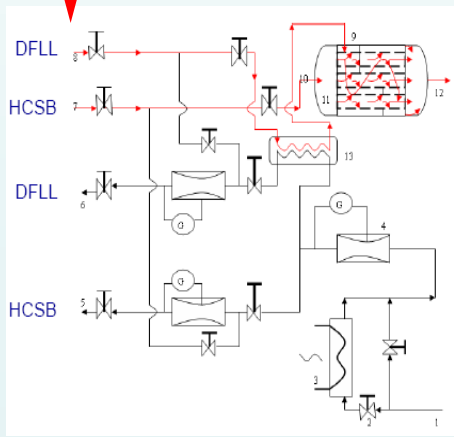
The following sub-systems have been analyzed by this study:

- TBM
- Helium Coolant System (HCS)
- Coolant Purification System (CPS)
- Tritium Extraction System (TES)

The present study is focused on the PI-TBM module, which will operate in the last period of the high duty cycle D-T phase in ITER.



TES



Interface System in HCS

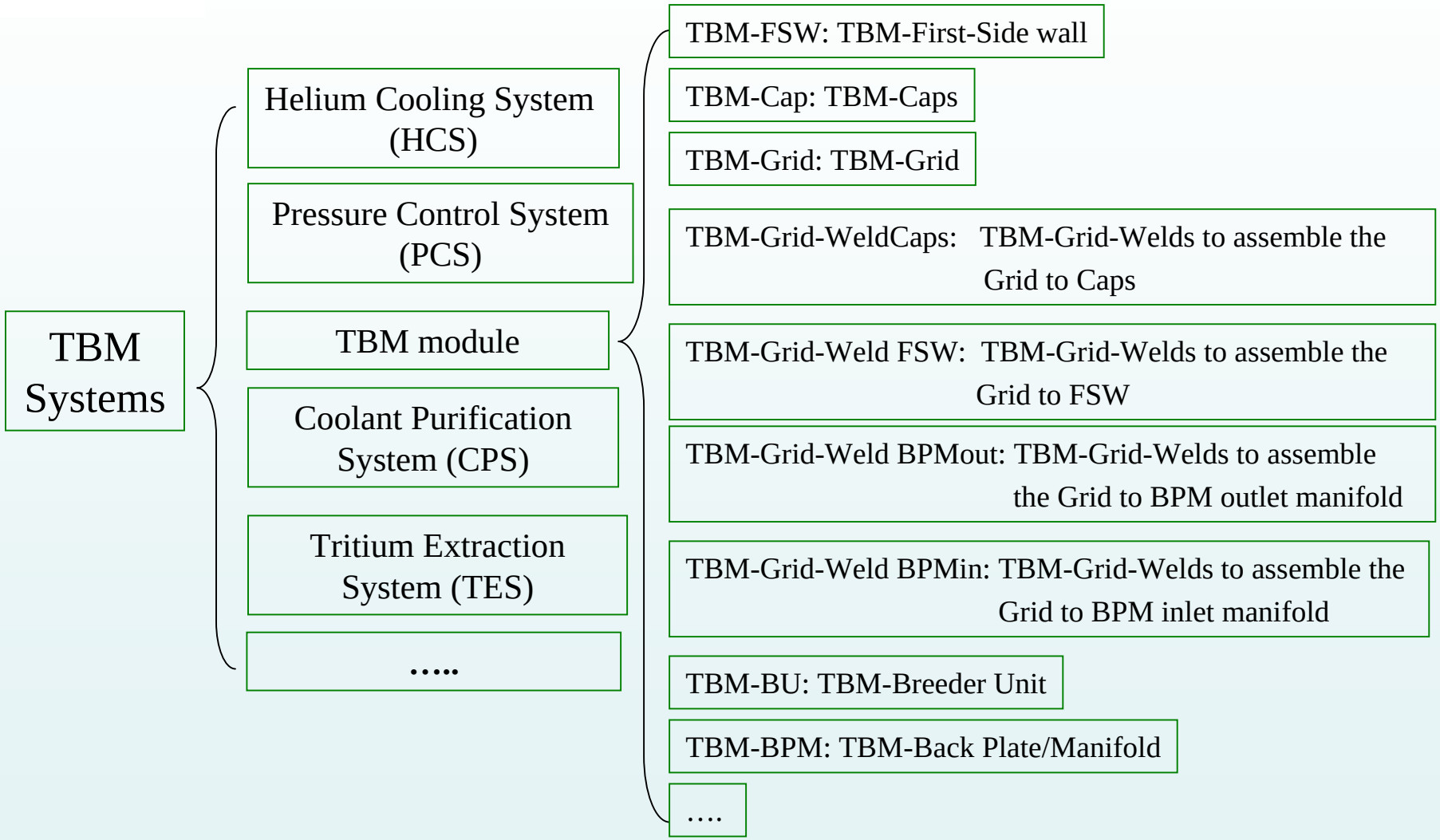
Main Components of HCSB TBM

Assessment of possible failure modes by FMEA is at component level, so the component need to be identified first. For HCSB-TBM, the identification of components is based on the following sub-systems:

- TBM Module
- Helium Cooling System (HCS)
- Pressure Control System (PCS)
- Coolant Purification System (CPS)
- Tritium Extraction System (TES)

Detailed components for each sub-systems is shown in Excel Table.

Main Components of HCSB TBM (Cont.)



FMEA Analysis for HCSB TBM: Main Outcomes (1/3)

FMEA has been done for HCSB-TBM system, Detailed FMEA process is shown in Excel Table.

Microsoft Excel - FMEA FOR CH HCSB TBM (DRAFT)

	Component	Op. St.	Failure Mode	Causes	Prev.Action on Causes	Consequences	Corr./Prev. Act. on Consequence	PIEs	Comm
2	TBM-FSW	NO	Rupture	Material defects; Impact of heavy loads (missile inside VV); Abnormal operating conditions (e.g.: vibrations); Fatigue; Arcs due to halo currents	Test during manufacturing & assembly; In-vessel viewing; Optimize maintenance procedures	Loss of He coolant into VV; Plasma disruption; VV pressurisation; Pressure relief towards VVPSS; Release of RadP_VV to VVPSS		LBV1	Missile should nc because magnetic fi vessel should acce objects towards inb not towards outbc any case, such rem to be excluded by analysis
3						Possible local VV pressurization over design limits in case of particular dynamic effects or fault in VVPSS devices opening; Possible loss of leak tightness in FTs or windows of VV; Release of RadP_VV to Port Cell	Periodic testing & maintenance of VVPSS devices; Design VVPSS to treat over pressurization generated by He gas		
4						Loss of purge gas into VV; Possible pressurization of purge gas system (TES); Possible loss of leak tightness in purge gas system; Release of RadP_VV and RadP_TES to Port Cell and/or to GB according the leak location in the TES circuit	Provide TES with dedicated devices to avoid pressurization of the circuit by gases coming from TBM box side (He coolant and/or steam)		
5						Loss of Be pebbles into VV due to dynamic effects (e.g. VV suction, He flowing) caused by the FW rupture			This event n complicated reco inside the VV to chamber before rest
6						Possible rupture in other water cooled PFCs due to disruption; VV over pressurization due to the combined effects of He and steam; Reaction between steam lost from PFCs and Be [Be pebbles inside the vessel (low T) & Be pebbles remained in the TBM box (high T) & Be armour of PFCs (low T)]; H2 production; Risk of H2 explosion in case air gets in touch with H2	Isolation of broken circuits to reduce the coolant released in VV; Design VVPSS to treat over pressurization generated by mixture of He gas and steam; Increase cooling capability of effective circuits in order to quickly reduce temperature of PFCs and VV structures		Pebbles of Be re should be cooled water entering Consequently, rela reaction should effects; But, on the othe leave more space steam that could e box and could reac remained in the box
						Increase of ORE for recovery actions	Apply detailed procedures		

List of PIEs identified by FMEA for HCSB TBM (2/3)

- PIEs -	Description
LFC-1	Loss of flow in a TBM cooling circuit
LFC-2	Partial flow blockage in a TBM cooling circuit
LHS-1	Loss of heat sink in TBM coolant-He
IBC-1	In breeder region loss of TBM coolant-He: Rupture of a sealing weld
IBC-2	In breeder region loss of TBM coolant-He: Leak of a sealing weld
LVV-1	LOCA out-VV: large rupture of TBM coolant pipe in TWCS room
LVV-2	LOCA out-VV: small rupture of TBM coolant pipe in TWCS room
LVV-3	LOCA out-VV: rupture of tubes in a primary TBM-HCS HX
LVP-1	LOCA out-VV: rupture of TBM coolant pipe in Port Cell
LVP-2	LOCA out-VV: small rupture of TBM coolant pipe in Port Cell
IVC-1	In-VV loss of TBM coolant-He: Rupture of TBM-FSW
IVC-2	In-VV loss of TBM coolant-He: leak from TBM-FSW
LVC-1	LOCA out-VV: small rupture of PFW/BLK coolant pipe in Port Cell
LIV-1	LOCA in-VV small PFW/BLK: equivalent break size-a few cm^2
RVP-1	Small rupture of VV coolant pipe in Port Cell
RVV-1	Small rupture in the internal VV shell-equivalent break size: a few cm^2
LTG-1	Leak of TBM-TES process line in Glove Box containment
LTP-1	Leak of TBM-TES process line in Port Cell
VBG-1	Loss of vacuum in VV: break inside the VV of TBM purge gas system
VBG-2	Loss of vacuum in VV: leak inside VV from TBM purge gas system
AVV-1	Ingress of air in the VV-small leakage

FMEA Analysis for HCSB TBM: Main Outcomes (3/3)

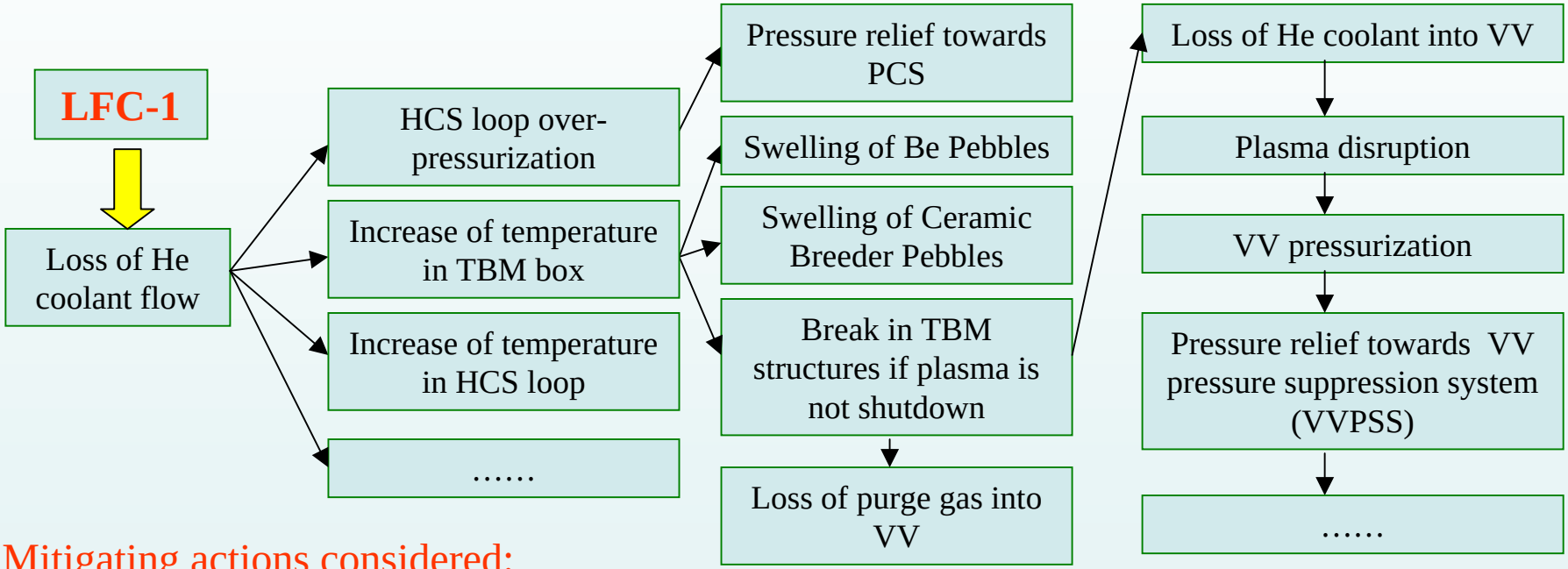
From a safety point of view, the PIEs are the most representative accident initiators, in terms of radiological consequences, between a set of elementary events challenging the plant in similar way and producing equivalent fault palnt conditions.

- PIEs were pointed out by assessing elementary failures related to the different components of HCSB TBM systems. Accident sequences arising from each PIE have been qualitatively defined.
- Four of these PIEs were already identified by the FMEA on other ITER systems and already documented in [GSSR]. Six of the other PIEs are taken into account and judged to cover all the most demanding accidents, Such as LFC-1, IBB-1, LVV-3, LVP-1, IVC-1 and LTP-1.
- The PIEs definition is useful to limit the set of accident initiators to be taken into account in the deterministic transient analyses.

PIE1: LFC-1

(Loss of flow in a TBM cooling circuit because of circulator /pump seizure)

The severe loss of flow in the TBM cooling circuit could be determined by a seizure of the circulator or malfunctions in some valves located in the HCS circuit. The following chain of consequences could follow the initiator:



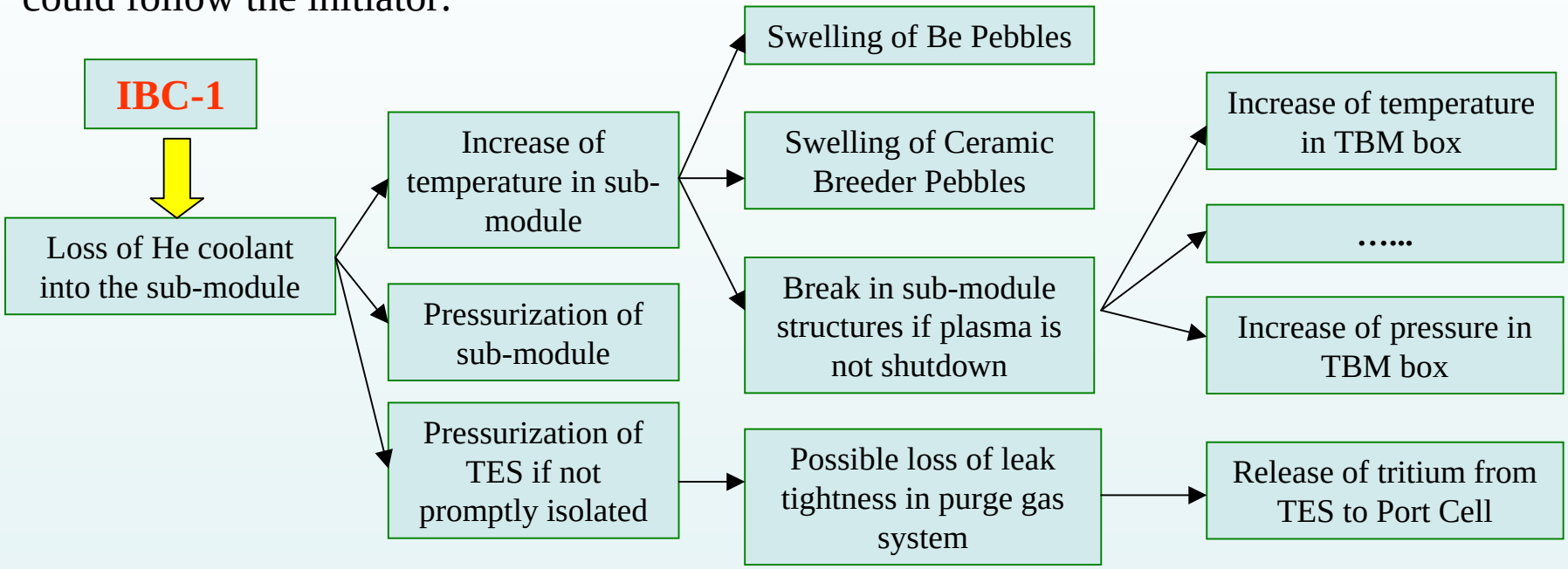
Mitigating actions considered:

- Monitoring of TBM coolant inlet flow-rate and temperature;
- Plasma shutdown;
- Periodic testing&maintenance of VVPSS devices
- Design VVPSS to treat over pressurization generated by He gas;
- Isolation of broken circuits to reduce the coolant released in VV.
- …..

PIE2: IBC-1

(In breeder region loss of TBM coolant-He: Rupture of a sealing weld)

Several rupture of welds sealing clapboard plates and plate manifolds could determine ingress of helium coolant at 8MPa into TBM box. The following chain of consequences could follow the initiator:



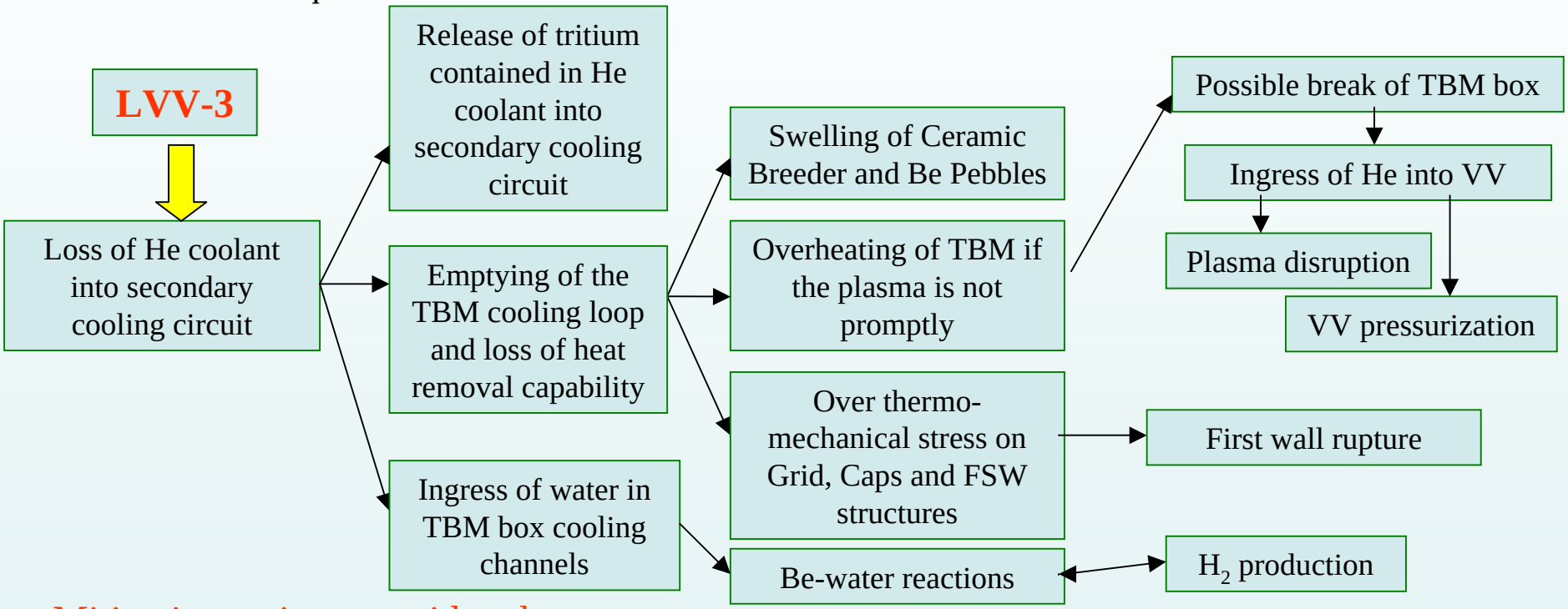
Mitigating actions considered:

- Monitoring of TBM sub-module and TBM box pressure;
- Isolation of TES to prevent over-pressurization;
- Stop ITER operations;
- Perform TBM maintenance.

PIE3: LVV-3

(LOCA out-VV: rupture of tubes in a primary TBM-HCS HX)

Inner pipe breaks in heat exchanger of HCS or cooler of CPS are grouped in this PIE. A multiple pipe rupture in the HCS-HX has been selected as representative event. The following chain of consequences could follow the initiator:



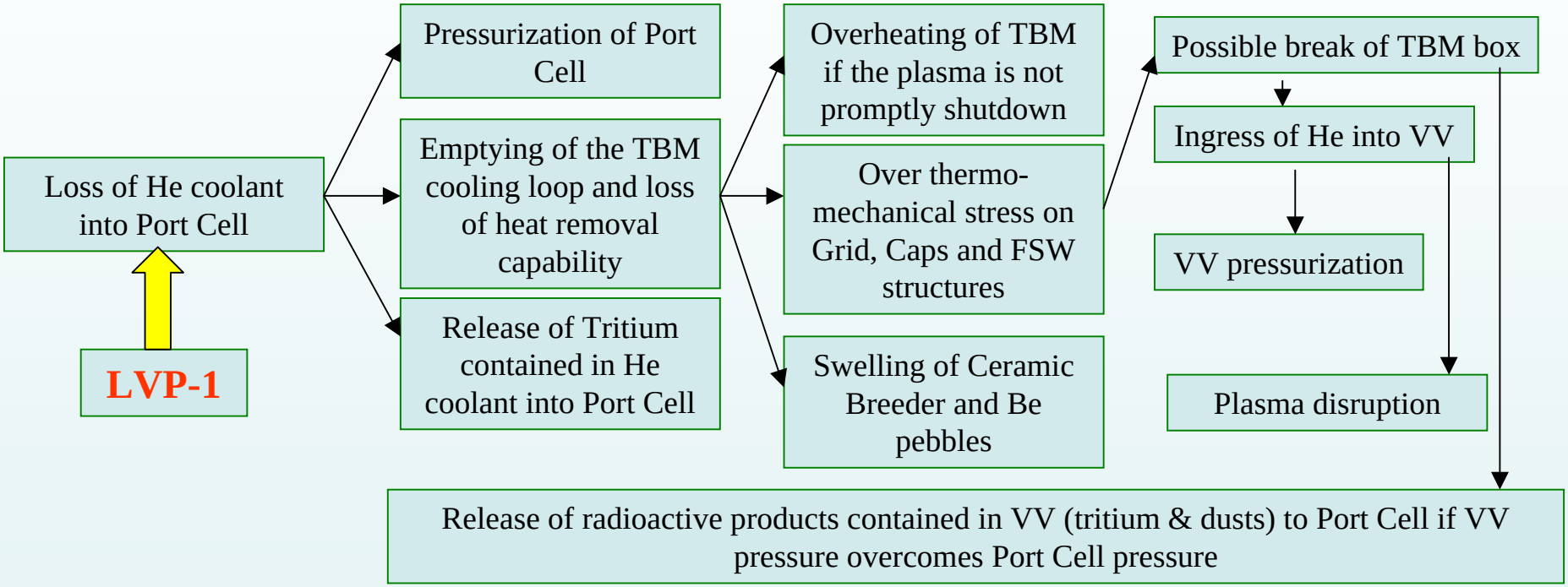
Mitigating actions considered:

- Monitoring of secondary loop parameters (flow rate, temperature and pressure);
- Monitoring of HCS parameters (flow rate, temperature and pressure);
- Isolation of secondary loop, and so on.

PIE4: LVP-1

(LOCA out-VV: rupture of TBM coolant pipe in Port Cell)

The representative event selected for the PIE is the break of a cooling pipe inside the Port Cell. The following chain of consequences could follow the initiator:



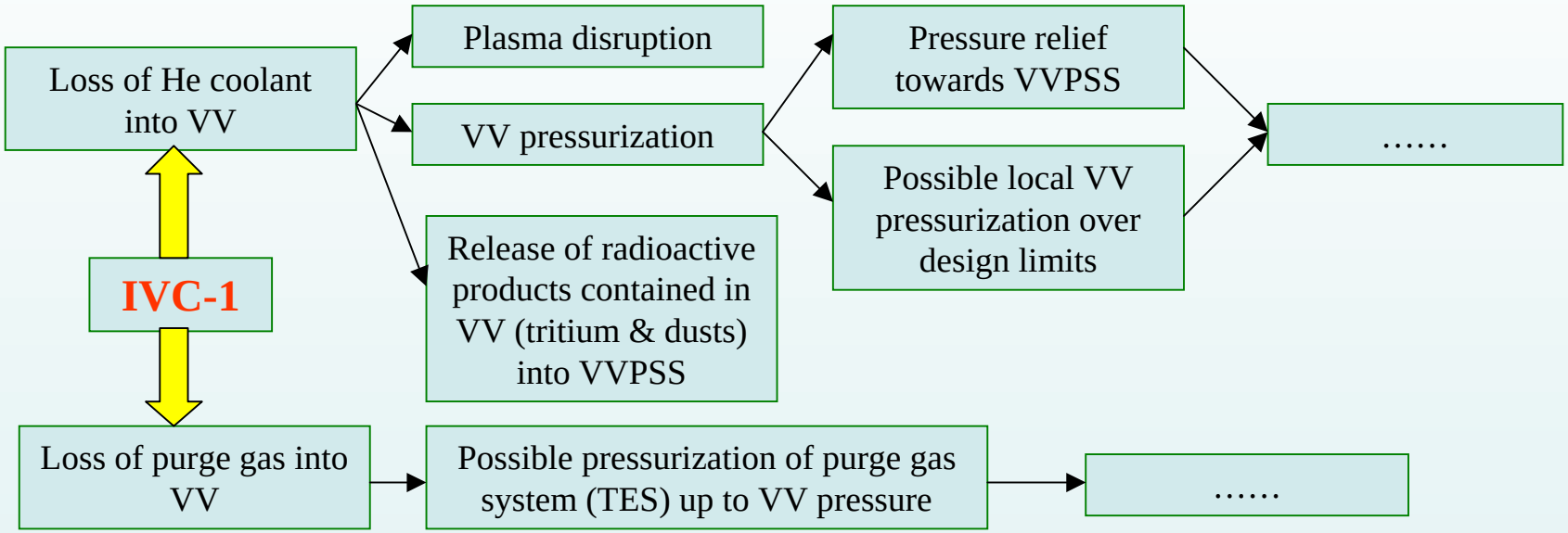
Mitigating actions considered:

- Prompt shutdown of the plasma to avoid aggravating in-vessel failure;
- Isolation of broken circuits to reduce the coolant released into the Port Cell;
- Activation of Vent detritiation system, and so on.

PIE5: IVC-1

(In-VV loss of TBM coolant-He: Rupture of TBM-FSW)

Several ruptures in the TBM structure (e.g.: First Wall, Caps, Plate Manifolds) could determine a large in-vessel LOCA from TBM. A catastrophic rupture in the FSW that cause the loss of integrity in both the containments of He coolant and He purge gas has been selected as representative event. The following chain of consequences could follow the initiator:



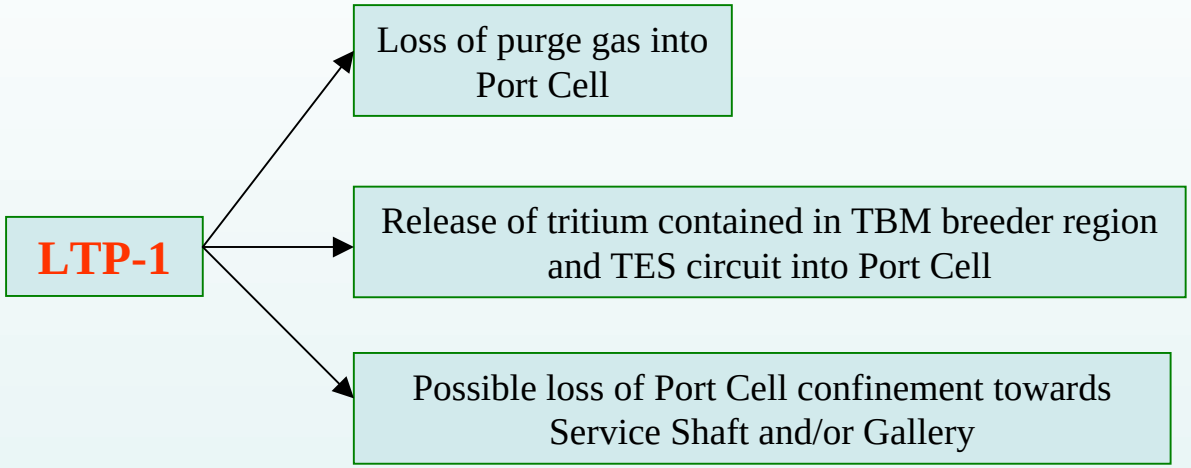
Mitigating actions considered:

- Periodic testing & maintenance of VVPSS devices;
- Design VVPSS to treat over pressurization generated by He;
- Isolation of broken circuits to reduce the coolant released in VV, and so on.

PIE6: LTP-1

(Leak of TBM-TES process line in Port Cell)

This PIE groups leaks from the TES circuit into the Port Cell. A small rupture in the TES piping located in the Port Cell is selected as representative event for the PIE. The following chain of consequences could follow the initiator:



Mitigating actions considered:

- Use double containment around TES process line;
- Port Cell atmosphere detritiation;
- Isolation of TES and TBM box to reduce the amount of gas released in Port Cell, and so on.

Summary

- The systematic approach to the identification of potential hazards arising from CH HCSB TBM systems has provided a preliminary assessment of accident initiators;
- Six of PIEs have been identified by the discussion on possible consequences as the ones more relevant to be studied with deterministic assessments;
- Each PIE of six PIEs has been discussed in order to identify accident sequences arising from each PIE itself;
- This work is just underway, more work will be developed.

Acknowledgement

- The authors are grateful to Prof. T. Pinna for his advices and beneficial helps about FMEA technology.

- The authors also thank Dr. L.Q. Hu and Dr. H.L. Chen in ASIPP, Hefei, China for their beneficial discussions.

That's All !

Thank you very much for your attention and the patience to follow all my presented issues.