IDENTIFICATION AND ASSESSMENT OF THREATS FOR A NUCLEAR FUEL FABRICATION FACILITY (NFFF)

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International Conference on Physical Protection of Nuclear Material and Nuclear Facilities 13-17 November 2017

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Background

- In uranium fuel fabrication facilities, large amounts of radioactive material are present in a dispersible form.

-In these facilities, the main hazards are potential criticality and releases of uranium hexafluoride (UF_6) and U_3O_8.

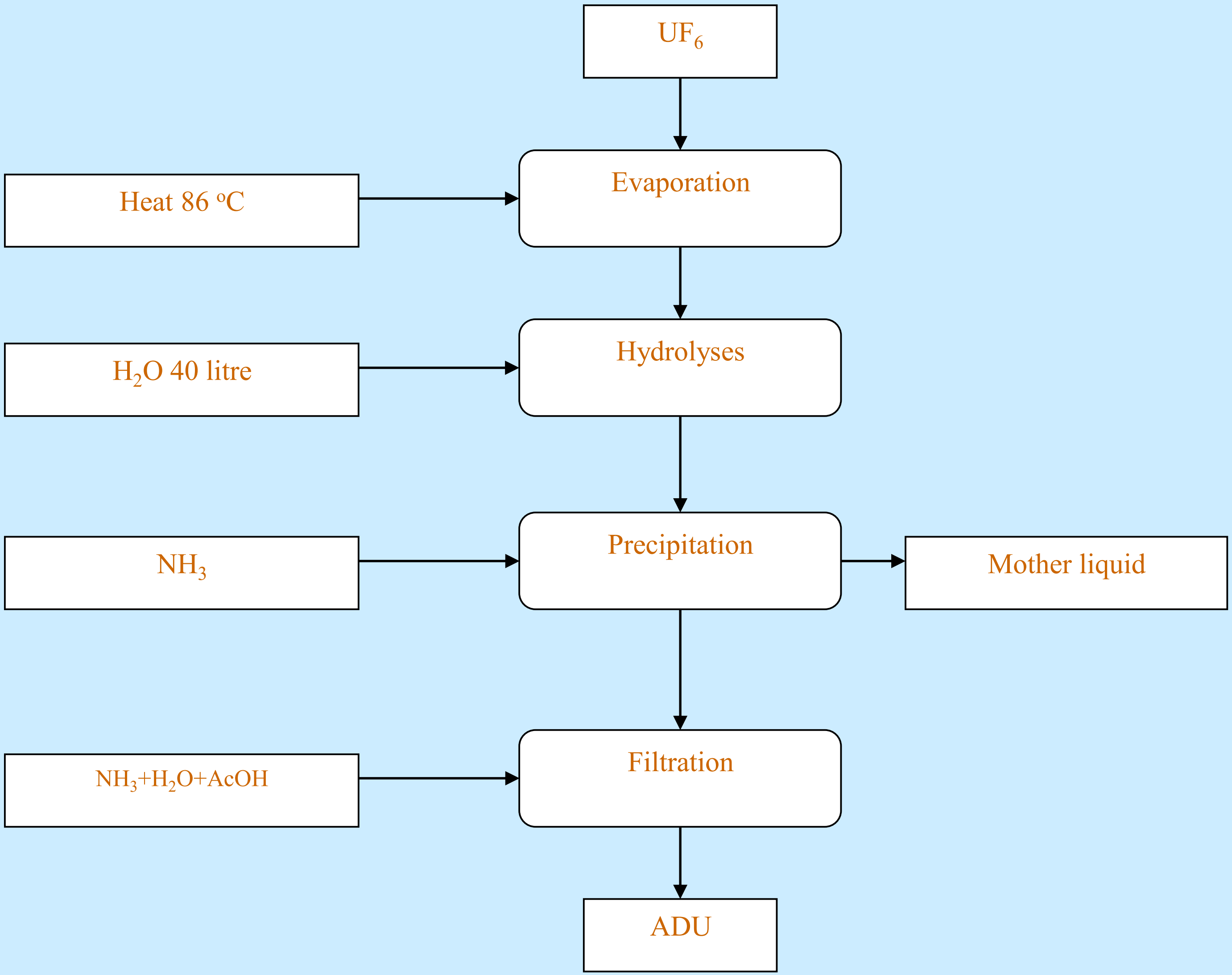
-workers, public and the environment should be protected from these hazards.

- The physical protection system (PPS) performed in the NFFF against the unauthorized removal of nuclear material and against sabotage of nuclear material and nuclear fuel fabrication plant.

General Description of Process in a Nuclear Fuel Fabrication Plant

Wet process (conversion process)

- **The obtainment of U_3O_8 starting from UF_6 comprises a wet stage consisting in the extraction of gaseous UF_6 by heating at 80 C, its hydrolysis to Uranyl fluoride (UO_2F_2) and precipitation to ammonium diuranate, and a dry stage where conversion to U_3O_8 powder takes place through calcination process at 800 C.**



Flow diagram of normal UF6 – ADU conversion process

Fuel Element Assembly

The type and quantity of the components required to produce one fuel element are as follows:

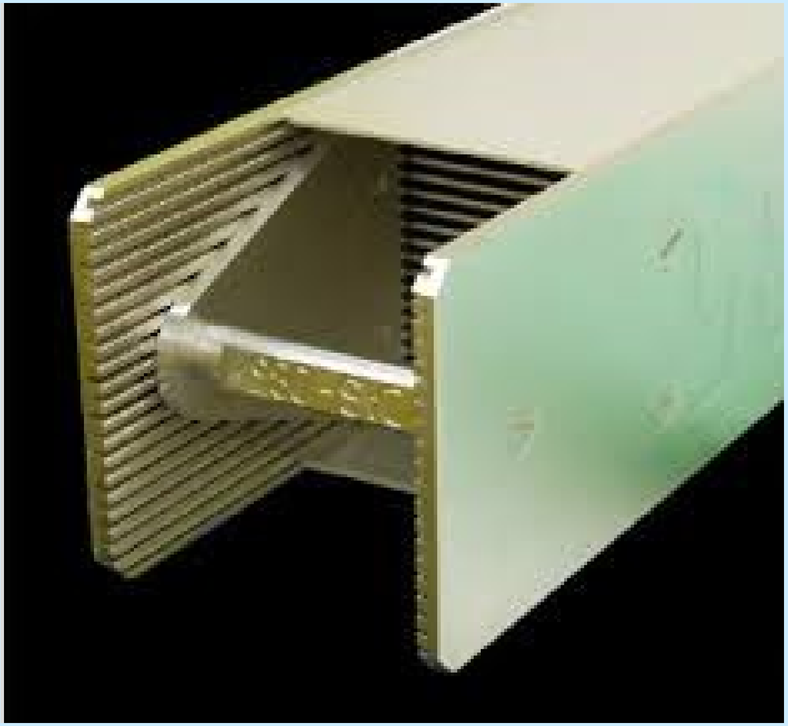
-External fuel plates 2

-Internal fuel plates 17

-Side plates 2

-End box 80 x 80 mm 1

-Handling pin 1



Design of Physical Protection Systems in NFFF

- **System functions that must all be present**
  - ✓ **Detection: Indicates the start of the adversary act**
  - ✓ **Delay: Only after detection is delay effective; delay retards the adversary to give the response force time to respond**
  - ✓ **Response: Can come from onsite guards or off-site police or military personnel**

Some terms and definitions

- ✓ **Physical protection** - measures for the protection of nuclear or other radioactive material or associated facilities designed to prevent unauthorized removal, theft or sabotage;

- ✓ **Physical Protection System (PPS)** - an integrated set of physical protection measures intended to prevent completion of a malicious act.

Some terms and definitions

- ✓ **Threat-** a person or group with motivation, intention and
  - capability to commit a malicious act;
- ✓ **Threat assessment** – an evaluation of the threats - based on available intelligence, law enforcement, and open sources information – that describes the motivations, intentions, and capabilities of these threats;
- ✓ **Design Basis Threat (DBT)** - attributes and characteristics of potential insider and/or external adversaries, who might attempt unauthorized removal or sabotage, against which the physical protection system is designed and evaluated

Some terms and definitions

- **Nuclear material accountancy and control (NMAC) -** an integrated set of measures designed to provide information on, control of, and assurance of the presence of nuclear and other radioactive material.
- It includes those systems necessary to establish and track nuclear and other radioactive material inventories, control access to and detect loss or diversion of nuclear and other radioactive material, and ensure the integrity of those systems and measures .

Categorization of NM and NMAC interface

Categorization is the basis for a graded approach for protection against unauthorized removal of nuclear material (NM) that could be used in a nuclear explosive device

IAEA categorizes the different types of NM in terms of element, isotope, quantity and irradiation

Nuclear operator should assess and manage the physical protection interface with safety and NM accountancy and control activities

Systems used for physical protection, nuclear safety, and nuclear material accountancy and control should be protected against compromise consistent with the *threat assessment* or *design basis threat.*

- At the NFFF could be used NMAC program to deter and detect unauthorized removal of nuclear material by maintaining an inventory of all nuclear material and implementing control measures to maintain continuity of knowledge of the nuclear material and its location. An effective NMAC system can detect malicious insider activity involving nuclear material or NMAC records, and support the correct assessment of an irregularity involving nuclear material. It is therefore important that the PPS and NMAC system function in a coordinated and complementary manner in order to detect any threats.

- Safety systems in NFFF could be used to assist the security, these systems are continuous air monitors, glove box negative pressure alarms, or criticality alarm system that provide protection for operator personnel, which may be used to provide alarms for potential sabotage or unauthorized removal. These systems could be integrated for safety and security protection by establishing procedural or automated alarm communications between safety and security disciplines for certain operational or event conditions.

IAEA Categorization of NM for PP

Material	Category I	Category II	Category III
Plutonium	2 kg or more	2… 0.5 kg	500… 15 g
HEU-235	5 kg or more	5… 1 kg	1000… 15 g
LEU 10-20%	-	10 kg or more	10… 1 kg
LEU less 10%	-	-	10 kg or more
Irradiated fuel	-	Depleted or natural or LEU	-

Categories of nuclear material The categorization of material ranges from category 1, the highest risk, to category 3, the lowest risk.

This depends on the type of material, quantity, proportion of fissile material and its physical and chemical form.

For example, 5 kg or more of uranium enriched to over 20% would be classed as Category 1,

while irradiated (spent) nuclear fuel, 10 kg or more of uranium enriched from (10-20%) would be Category 2,

and natural uranium Category 3.

Computer and Information Security ,Cont.

The IAEA Nuclear Security Computer and Information Security programme is focused on preventing computer acts that could directly or indirectly lead to:

a. unauthorized removal of nuclear/other radioactive material

b. sabotage against nuclear material or nuclear facilities

c. theft of nuclear sensitive information

Nuclear Security Threats

The IAEA defines radiological sabotage ***as "any deliberate act directed against a nuclear or radiological facility or nuclear or radioactive material in use, storage or transport that could directly or indirectly endanger the health and safety of personnel, the public and the environment by exposure to radiation or release of radioactive substances.***

Threats to nuclear security involve criminals or terrorists acquiring and using for malicious purposes :

- **Nuclear weapons**
- **Nuclear material to make improvised nuclear device (IND)**
- **Radioactive material for radiological dispersal device (RDD) or radiation exposure device (RED)**

Threats could also involve radioactive material dispersion through sabotage of facility or transport.

Insider threat **: is One or more individuals has:**

- knowledge and information about the facilities and the processes of production.

- with authorized access to associated facilities or associated activities or to sensitive information or sensitive information assets, or one or more individuals with nuclear security responsibilities who could commit a malicious act or who could aid an external threat to do so.

Insiders can be further divided into three sub-categories:

Passive **- the insiders does not actively participate in any operation by the adversary but provides information such as target locations and security procedures.**

Active nonviolent **- the insiders actively assists an operation through actions such as facilitating the adversary's entrance into the facility or disabling alarms along the adversary's path.**

Active violent **- the insiders participates in a violent attack.**

- ***Outsiders:*** (no authorized access): protestors (demonstrators, activists, extremists), terrorists, criminals

- ***Collusion***: cooperation between Outsiders and Insiders

Target Identification

- ***Determine the possible targets for the following actions:***
  - ✓ **Sabotage: identify vital areas to protect**
  - ✓ **Theft of material or information: identify location of materials to protect**

Design Basis Threat (DBT)

- The design basis threat DBT is a description of the attributes an characteristics of potential insider and outsider adversaries who might attempt a malicious act, such as unauthorized removal or sabotage against which a physical protection system for nuclear or other radioactive material or associated facilities is designed and evaluated.

IDENTIFICATION OF VITAL AREAS IN NFFF

- Identification of vital areas in NFFF is an important step in the process to protect the facility against sabotage. Vital area identification (VAI) is the process of identifying the areas in a nuclear facility around which protection will be provided in order to prevent or reduce the likelihood of sabotage.
- In the nuclear fuel fabrication facility NFFF, there are two vital areas identified, controlled area and supervised area (Production activities).

RISK ANALYSIS AND POTENTIAL SABOTAGE IN NFFF

- A major concern in nuclear fuel fabrication facility NFFF is the potential for accidental release of uranium hexafluoride. The UF6 is a reactive substance which reacts with water forming HF and UO2F2. The HF is a highly corrosive substance and the UO2F2 is very toxic.

- A sudden release of UF6 inside a building or to the atmosphere could cause undesirable health effects to workers and the public in general.

-

During the processes in nuclear fuel fabrication facility NFFF, the insider threat could be causes intended accidents during the operation of facility which be lead to hazard for workers and environment.

For this reasons, we should to be study the hazards during the operation of NFFF.

One example of an insider threat is an employee who has access to sensitive information about the operations in nuclear fuel fabrication facility and intends to use it maliciously.

Types of the Hazards in NFFF

- ***Hazard refers to the potential that a chemical or physical characteristic of a material, system, process, or plant will cause harm or produce adverse consequences.***

- **Hazards from nuclear fuel fabrication plant can be dominated by the toxic rather than by the direct radiological effects of the nuclear material.**
- **The health risks caused by chemical effects of Uranium exposure, that is effects not related to ionizing radiation.**

Types of Events During Process in NFFF

- Several events may be lead to internal contamination if combined with gloves or bags rupture and glove box ventilaion system failure:

1- the presence of HF or impurities in the UF6 cylinder may result in explosion while heating.

- \- To prevent this event must be determination UF6 vapour pressure at room temperature and before the heating.

Cont.

2- Heating at temperature higher than 120 C would lead to hydraulic rupture of a full UF6 cylinder.

- To prevent this event, the redundant, independent controls of temperature linked to automatic stopping of heating for above setting temperature.

3- Contact of UF6 with hydrocarbons generates explosive mixture.

- To prevent this forbidden use any hydrocarbons in the plant.

Cont.

- **4- Blocking in the piping or valves are events produce to pressure increase in the gas transfer system.**
- **To prevent the explosion transfer the UF6 gas to expansion tank system.**

5- Criticality accident may be take place during the process

- **The prevention of criticality is given operatively by the mass control of fissile material at the wet process.**
- **And the mass and moderator control at the dry process. Always units of less than 2.4 kg of uranium (20% U235) are handled.**
- **Absorber material used inside the hydrolysis tank to prevent the criticality accident.**

Another Hazards

- Industrial hazards like hydrogen fluoride HF is very extremely corrosive acid that is relatively volatile in its an hydrous form.
- Nitric compounds is widely used for nuclear fuel fabrication plant.
- Hydrogen gas may be can accumulate and explosion
- Fire

Case study: insider threat in NFFF

- Case study provide a very good source to illustrate that malicious acts by insiders have occurred.

- One example of an insider threat is a worker who has motivation **(political, financial, ideological, or personal)** access to controlled area, which the process of fabrication (20 % U235) carry out and intends to use his experience and knowledge to sabotage in the facility such as:

1- Increasing in UF_6 mass transferred into hydrolyser without control. It is assumed that the whole contents of UF_6 cylinder ~ 25 kg of UF_6 are transferred into the hydrolyser tank due to operators.

2- Heating at temperature higher than 120 C would lead to hydraulic rupture of a full UF6 cylinder.

To prevent this event, the redundant, independent controls of temperature linked to automatic

stopping of heating for above setting temperature.

3- Contact of UF6 with hydrocarbons generates explosive mixture.

To prevent this forbidden use any hydrocarbons in the plant.

4- Blocking in the piping or valves are events produce to pressure increase in the gas transfer system.

To prevent the explosion transfer the UF6 gas to expansion tank system.

5- Criticality accident may be take place during the process especially in the wet conversion area such as, Tokaimura nuclear accident in Japan 1999.

Criticality Accident Scenario

- **Insider threat (operator)** (has motivation) uses his experience and knowledge to do sabotage in NFFF during wet process **intend to do:**
- Transfer a large of amount of UF6 (greater than critical mass of 20% enriched U235) to hydrolyser tank.

- And then Transfer all UO2F2 with high concentration of Uranium (greater than critical concentration) from hydrolyser tank to precipitator tank.

The Parameters Affecting the Criticality

- Mass
- Absorber material
- Geometry
- Interaction
- Concentration
- Moderation
- Reflection
- Enrichment
- Volume

Tokai-mura Criticality Accident in Japan 1999.

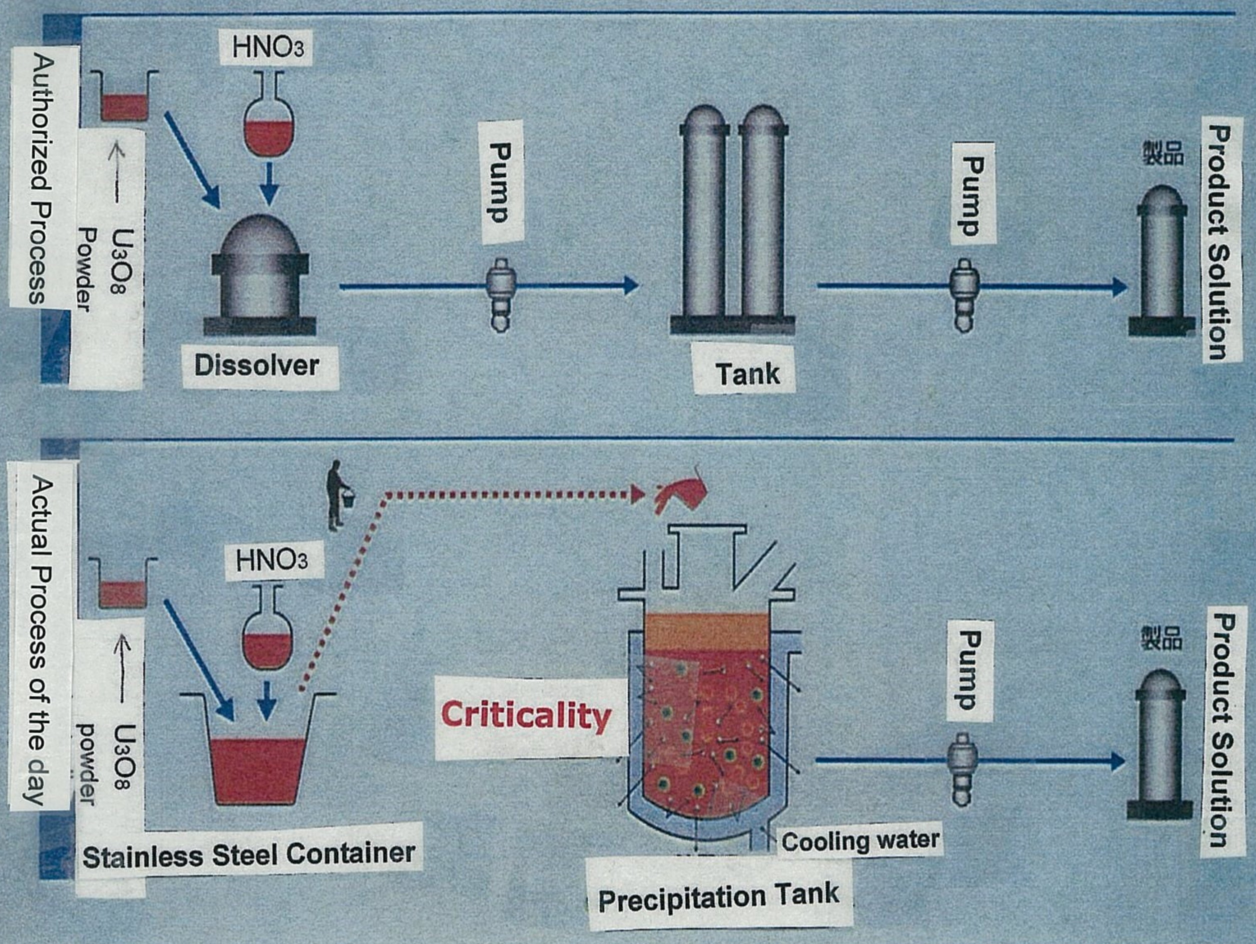
Criticality accident occurred on September 30, 1999, at 10:35 am, at the Japan Cooperation (JCO) conversion facility which was in the operation for the re-conversion of enriched uranium.

■ The three workers had used the powdered uranium (U_3O_8), which is 18.8% enriched-uranium, and dissolved them in the stainless steel container. Concentration of uranium nitrate solution is about 370 gU / l.

■ On September 30, 1999, at 10:35 am, the 7th solution in a stainless steel container was poured into the precipitation tank and the solution exceeded the critical mass limit lead to the criticality accident.

■ The precipitation tank was not geometrically safe for criticality. So criticality accidents would occur if much more than the criticality mass was poured.

Working Procedures



- The excursion continued for nearly twenty hours ,and the total number of fissions during the criticality accident was estimated to be 2 x 10^{18}.

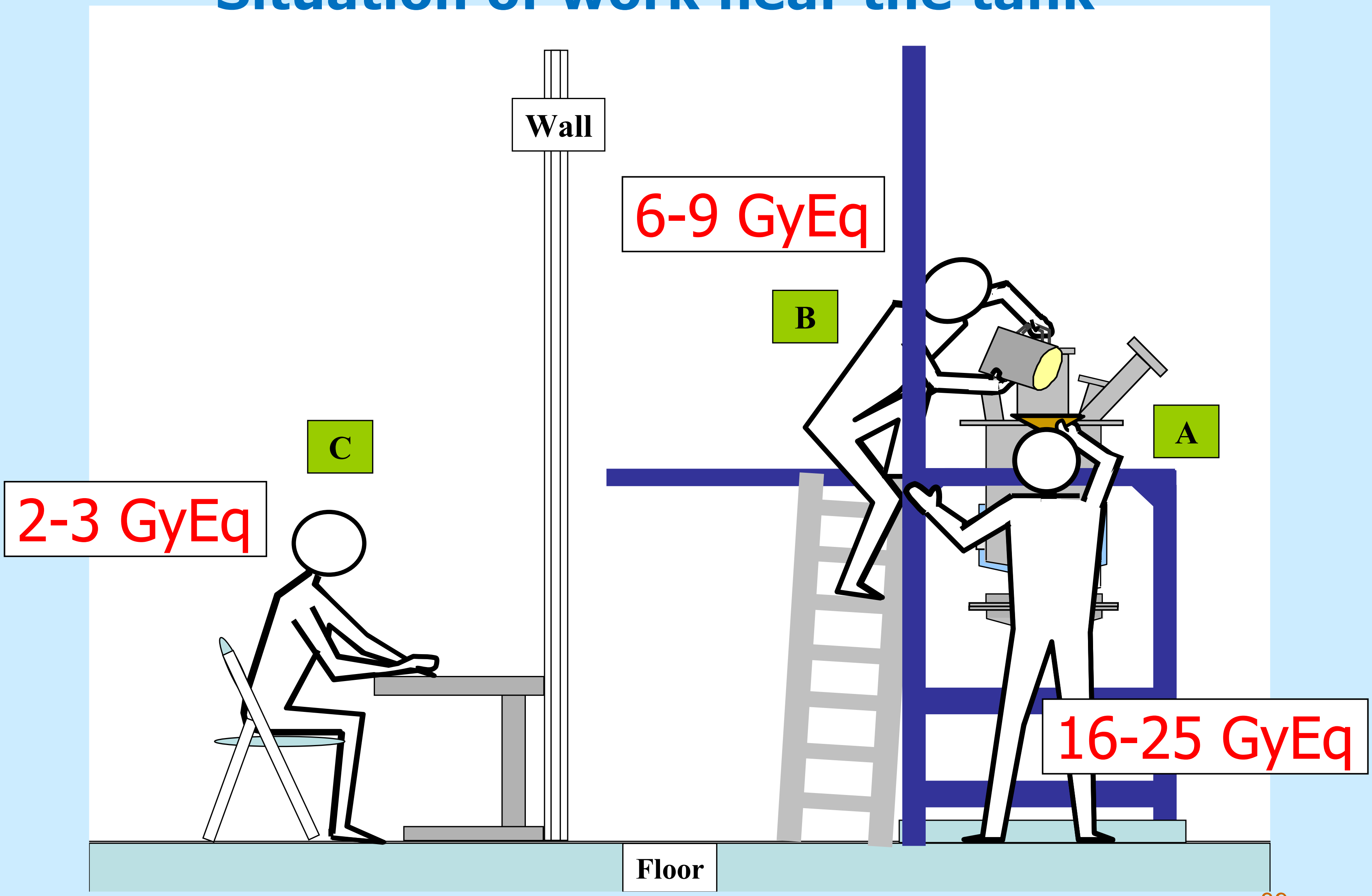
- Exposures were mainly from direct radiations, some rare gases and radioactive iodine were released into the environment, but the effect was small.

- The two workers who received doses of 16 ~ 25 GyEq (Gray Equivalent) and 6 ~ 9 GyEq died. Another worker whose dose was estimated to be between 2 ~ 3GyEq is still living.

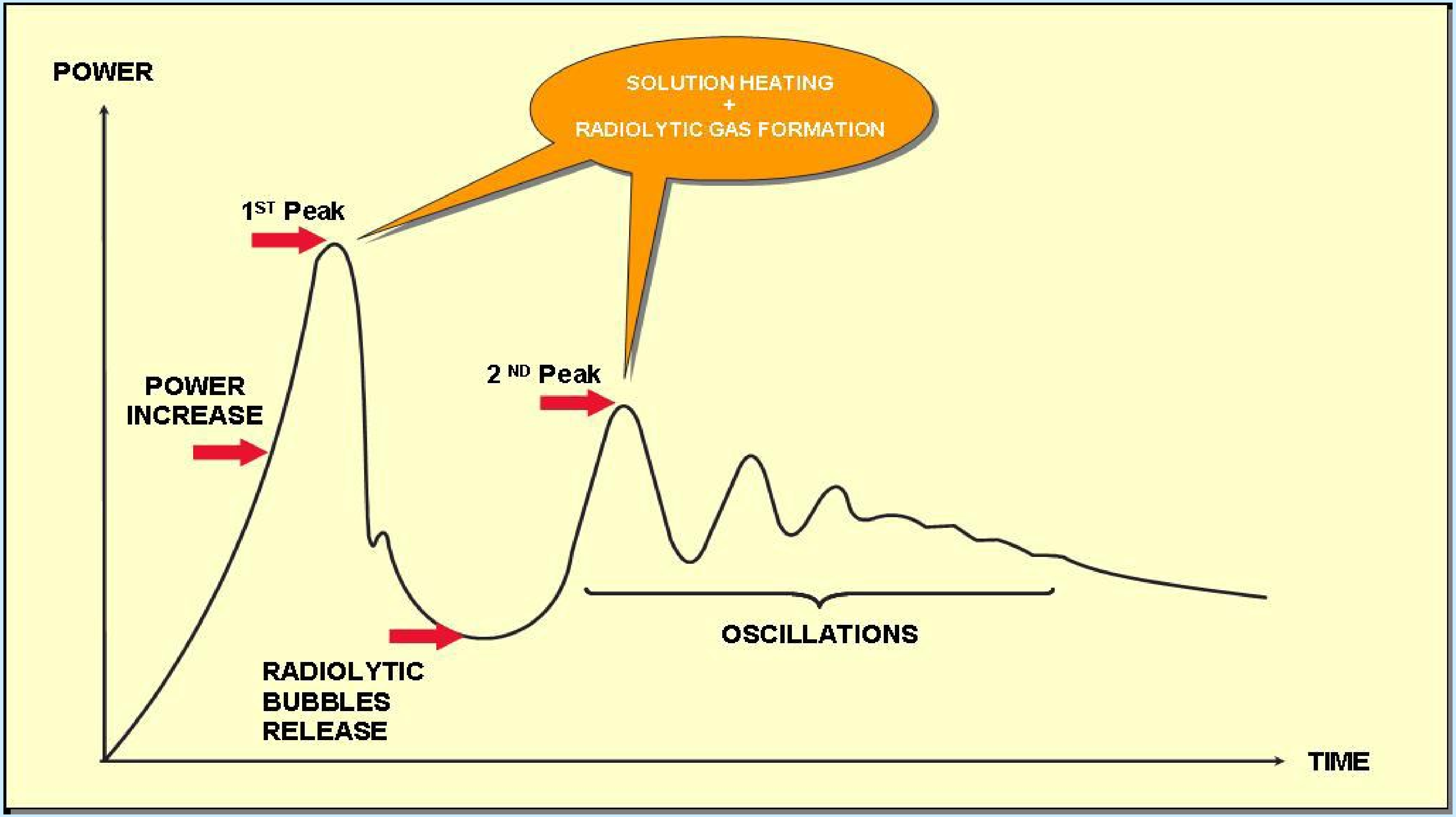
- Estimated 160 TBq (Tera Bq.) of noble gases, 2 TBq of Iodine gas.

- 167residents within a range of 350 meters from the criticality tank were evacuated.

Situation of work near the tank



Criticality accident in a fissile solution 1st phase of a power excursion in a solution



Criticality Prevention in NFFF

To prevent the criticality accident occurrence in the nuclear fuel fabrication plant, the following precautions must be achieved:

1. To follow the instruction written in the criticality card control in all devices/equipment’s.
2. Avoiding the flood, other material in water groups, oil, wood etc.
3. Avoiding the additional of reflector materials such as (graphite, beryllium etc.)
4. Avoiding the placement / the use of unit of equipment in the wrong place.
5. to check periodically the loss of neutron absorber (if any).

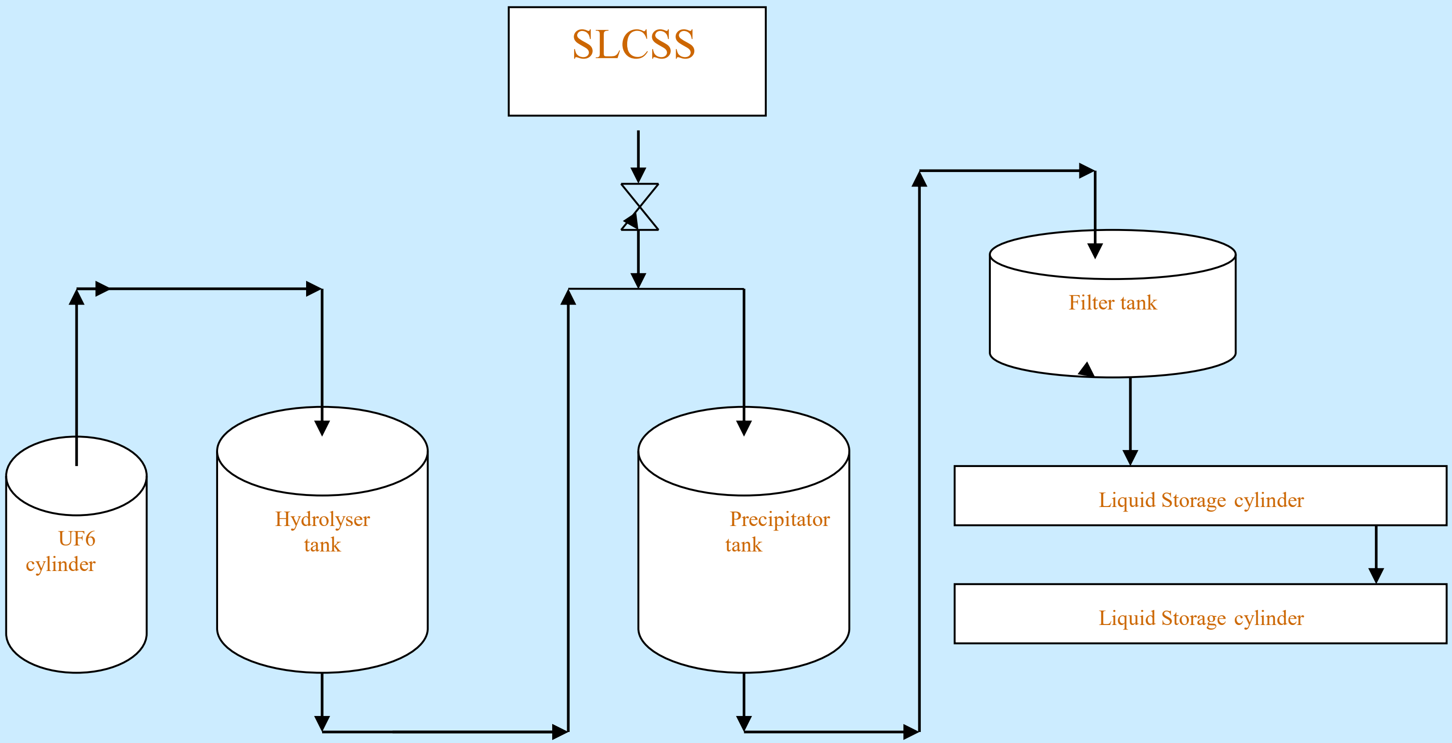
Criticality Prevention in NFFF

The plant is fully equipped with criticality detectors in strategic places to give an early warning to employees whenever the postulated mass criticality accident occurs. The signal alarm will active when the radiation exposure exits the limit 0.001 mSv/hr over background.

Criticality Prevention in NFFF

- Also, we proposed a safety control system SLCSS to stop the process and achieve the sub-criticality of the system in the precipitation process.
- Use of Soluble Neutron Absorbers tank connected with Precipitator tank.
- Use of Fixed Neutron Absorbers in the Hydrolyser Tank.
- The purpose of fixed neutron absorbers (poisons) in criticality control applications is to assure sub- criticality for normal and credible abnormal conditions over the operating life of the facility or equipment.

Process flow sheet UF6-ADU Conversion Process with proposed safety logic control safety system (SLCSS)



Process flow sheet UF6-ADU Conversion Process with proposed safety logic control safety system (SLCSS)

6- Proposed Safety Logic Control Safety System (SLCSS)

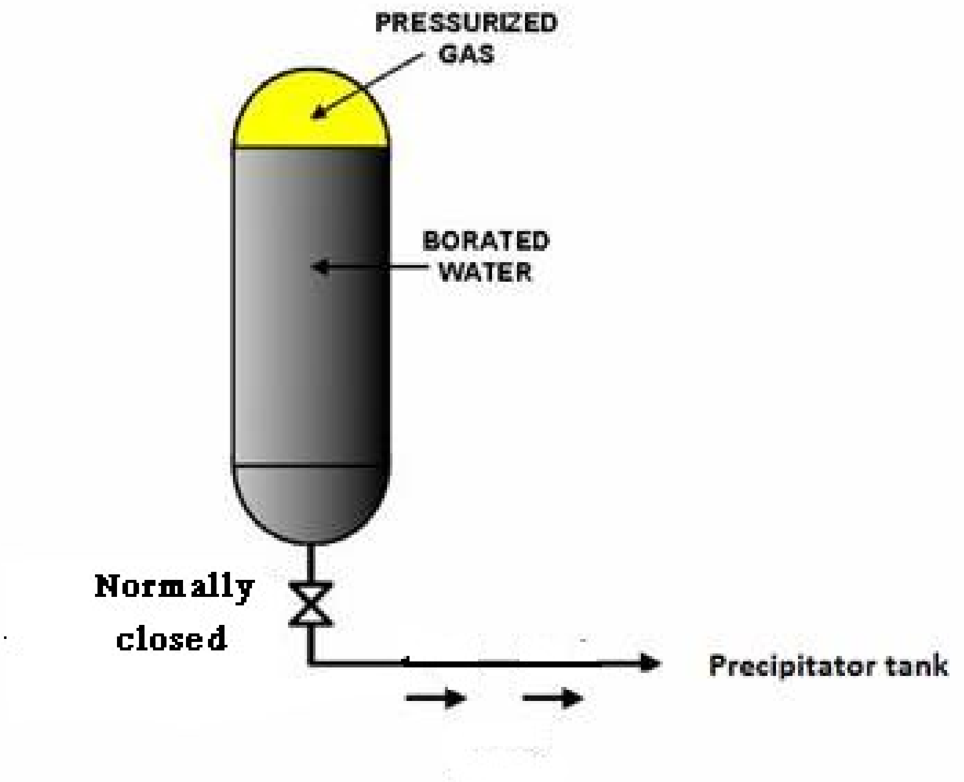
- This System is a safety related designed for abnormal conditions and automatic initiation of Boron solution injection into the precipitator tank.
- The purpose of SLCSS is protecting the system from reaching the set point initiating the critical conditions.
- This system consists of :

1- high pressure accumulator containing concentrated Boron solution

2- injection line with actuated valves

3-control system coupled to the process operating set points

4- cover gas pressure regulation system



Boron solution tank

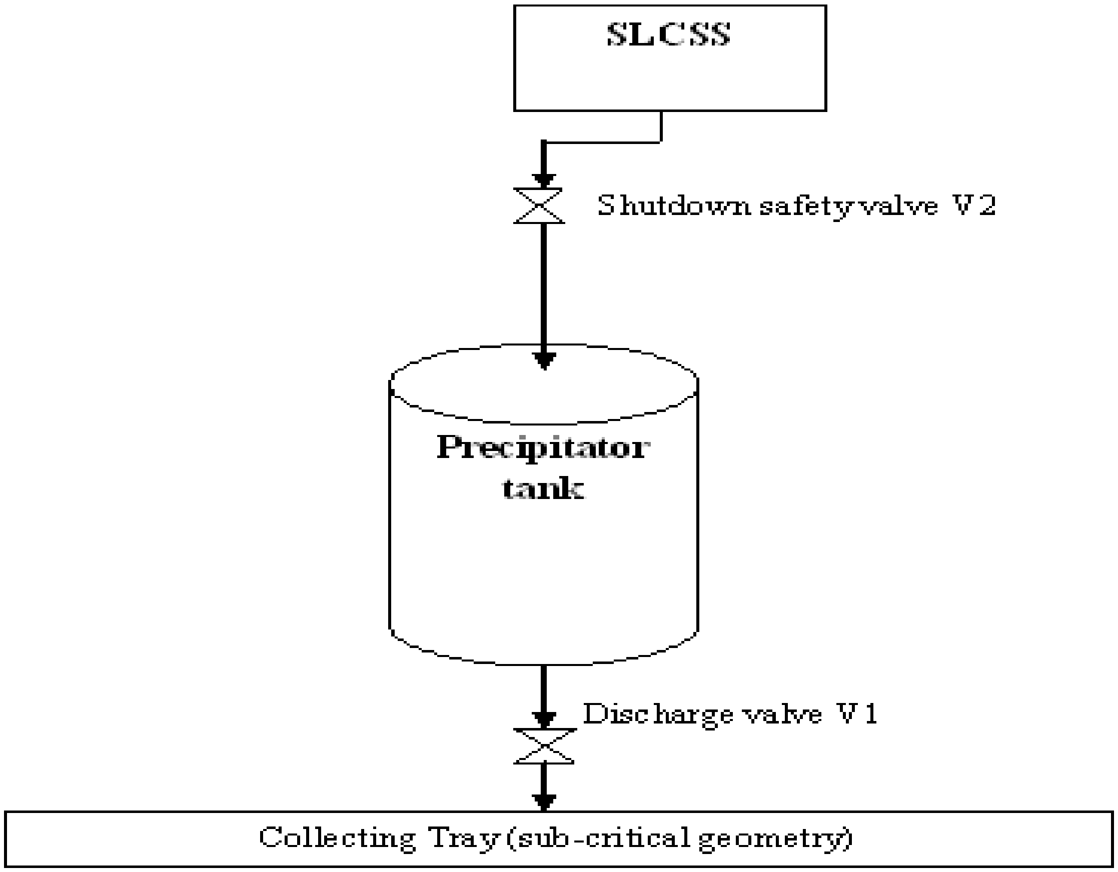


Fig 2.5 Block diagram for precipitator tank with SLCSS and collecting tray

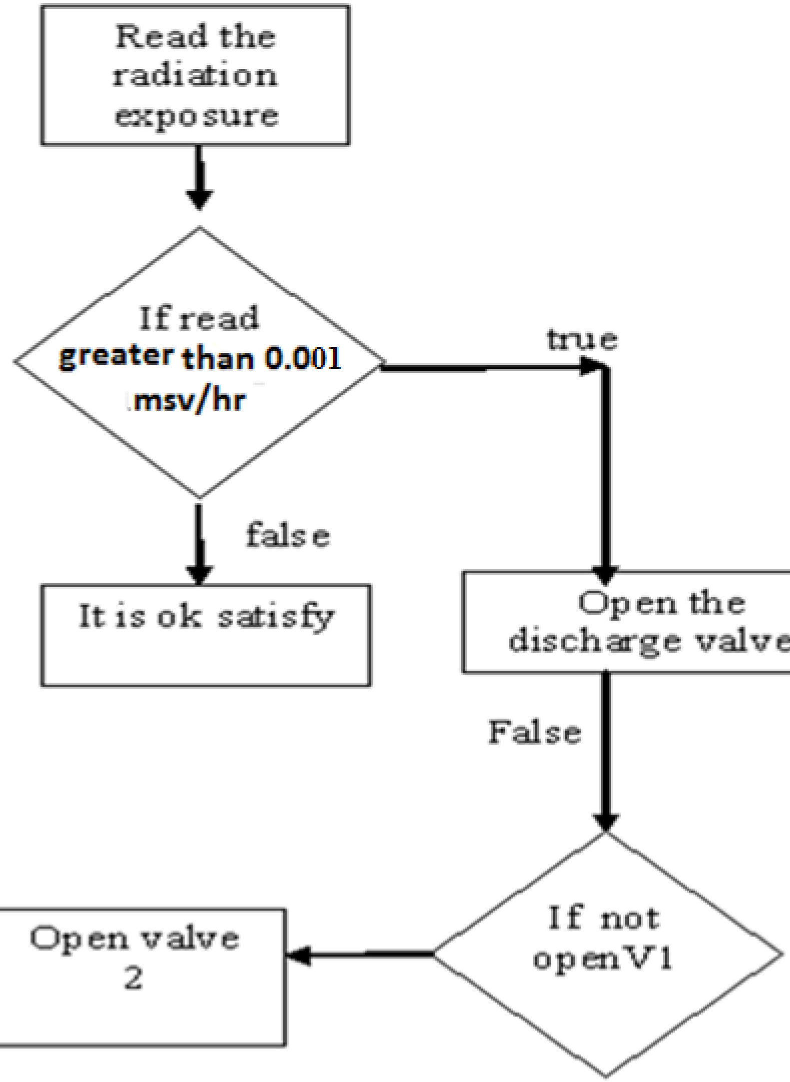
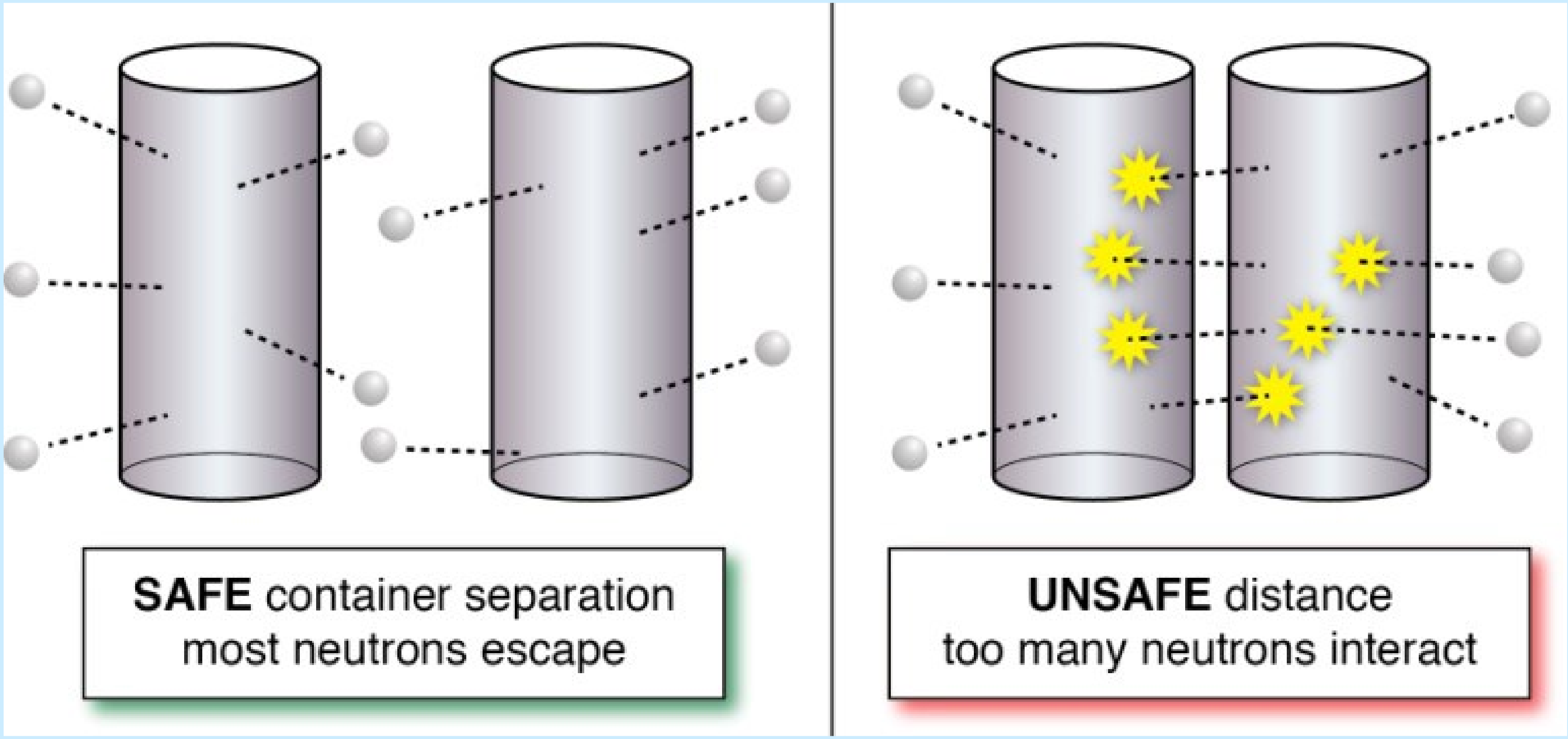
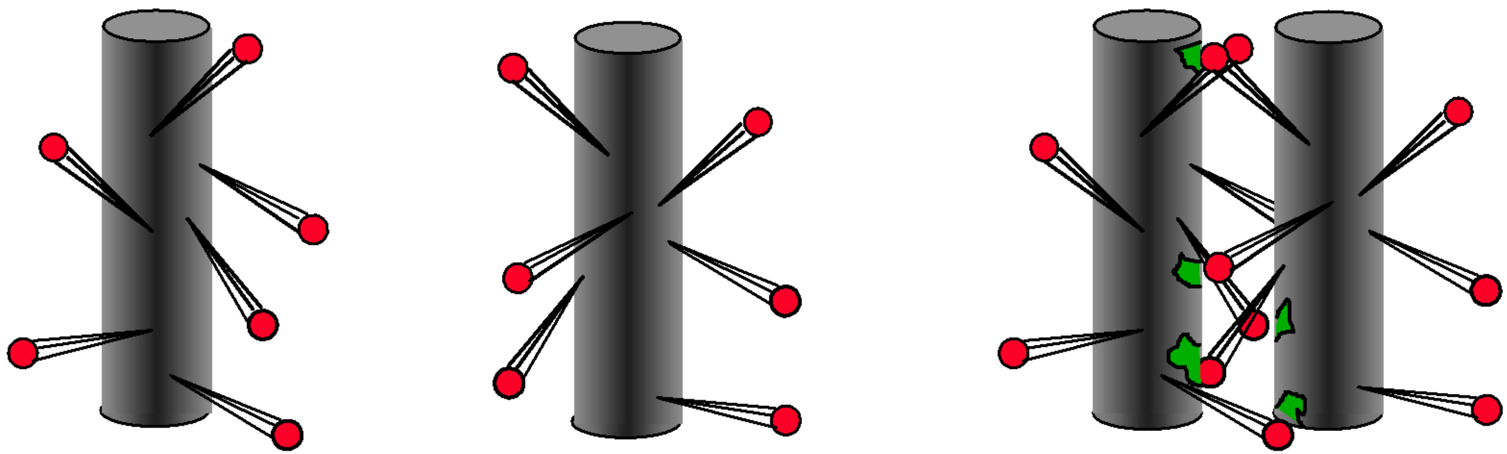


Fig 2.3 Flow chart of the criticality safety program for the precipitator tank.



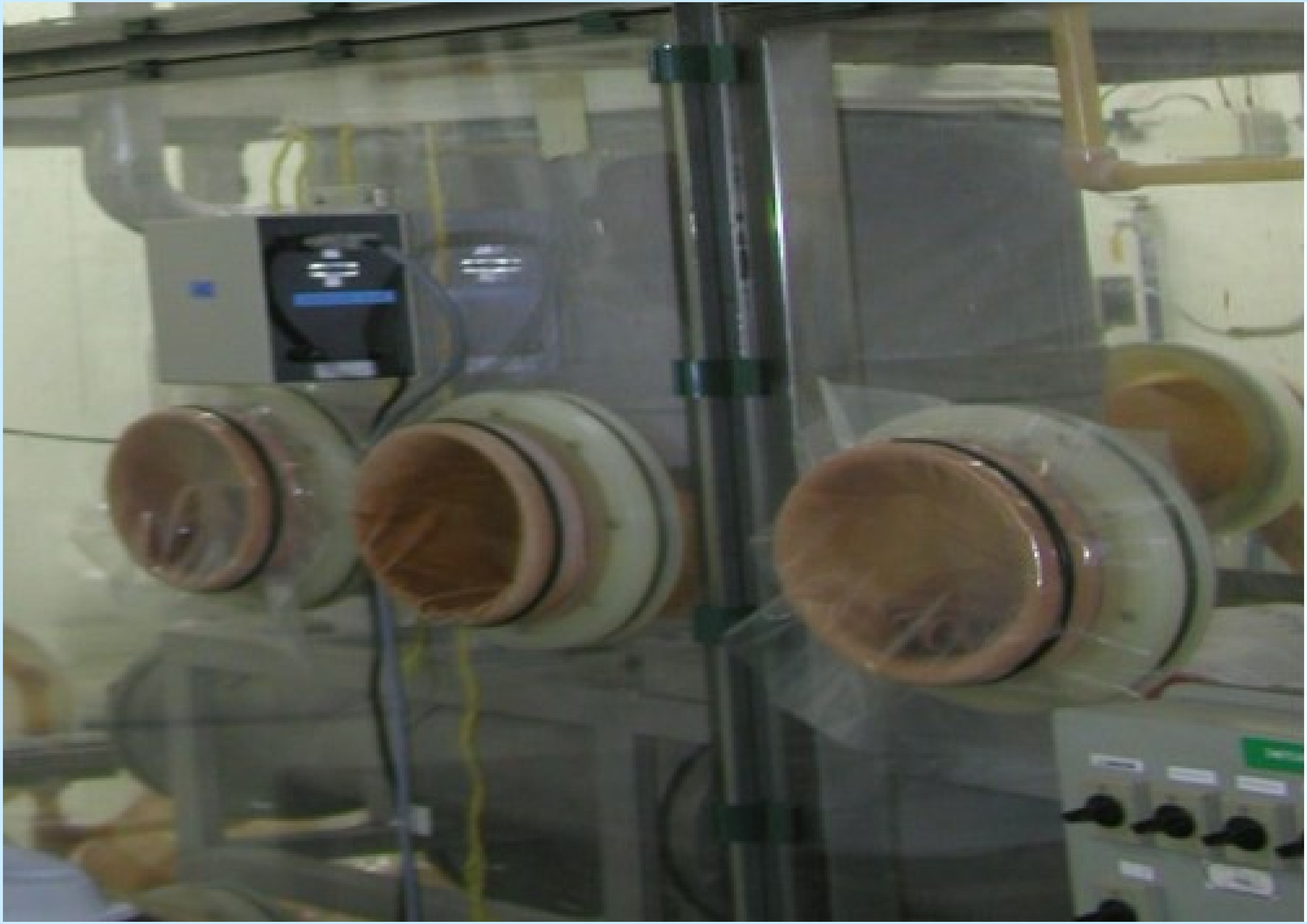
SAFE container separation
most neutrons escape
UNSAFE distance
too many neutrons interact

Neutron Interaction



Widely separated containers - no *interaction*

Nearby containers - *interaction*



Conclusion and Recommendation

- ✓ The physical protection program in NFFF must protect against the design basis threat of radiological sabotage.
- ✓ Physical protection is the essential part, but not cover all aspects of nuclear security.
- ✓ Detection, delay and response interface are the main functions of effective PP systems for nuclear facility
- ✓ PPS, NMAC and Computer security are the integral parts of Nuclear Security and need close cooperation.

- Training of workers:

Training At least once every year, all employees must be informed about how the alarm system works and any important aspects relating to the system. They must also receive training in what to do in the event of an incident occurring.

- In general to prevent and mitigate the hazards and insider threats in nuclear fuel fabrication facility must be implement all instructions and use the criticality alarms and safety system with physical protection system (all equipments and systems) to detect and prevent any threat or sabotage.

- Another recommendation to mitigate any threat or sabotage against the NFFF, the emergency plan must be implemented, and improvement the nuclear security culture for the workers.

Thank you for your attention