

*Sigitas Rimkevicius - Mindaugas Vaisnoras - Eugenijus Uspuras -
Egidijus Babilas*

Lithuanian Energy Institute, Breslaujos str. 3, LT-44403 Kaunas, Lithuania

HAZOP application for the NPP Decommissioning and Dismantling projects

Outline

- Introduction. Hazards Identification Methodology
- HAZOP Procedure
- HAZOP Application for the Ignalina NPP buildings D & D
- HAZOP Application at Feasibility Study for the Management of Bohunice V1 NPP Primary Circuit Components
- Conclusions

Introduction. Hazards Identification Methodology

- The decommissioning of nuclear facilities requires adequate planning and demonstration that D & D activities can be conducted safely.
- The main purpose of the safety assessment is to demonstrate that residual risks have been reduced to As Low As Reasonably Achievable (ALARA) and to nationally prescribed safety criteria.
- The main steps of the harmonized safety assessment methodology for decommissioning:
 - Safety assessment framework;
 - Description of facility and decommissioning activities;
 - Hazard analysis: identification and screening;
 - Hazard analysis: evaluation;
 - Evaluation of results and identification of safety control measures.

Introduction. Hazards Identification Methodology (2)

- One of the first steps in developing a safety assessment for decommissioning activities is the identification of existing and future hazards that can affect workers, members of the public and the environment during decommissioning activities.
- All relevant hazards (e.g. sources of harm) to workers, the public and the environment should be considered in the decommissioning safety assessment, including:
 - Radiation exposures, for example, external exposure from direct radiation and other radiation sources (including criticality), internal exposure due to inhalation, ingestion or cuts and abrasions, and loss of containment leading to the uncontrolled release of radionuclides;
 - Toxic and other dangerous materials, for example, asbestos, flammable materials, carcinogens, chemicals used for decontamination purposes;
 - Industrial hazards, for example, dropped loads, work at heights, fires, high temperatures, high pressures, noise, dust and asbestos.

Introduction. Hazards Identification Methodology (3)

- According [IAEA Safety Guide WS-G-5.2](#) a systematic approach should be taken to the identification of hazards on the basis of the description of the facility and of the decommissioning activities.
- The identification of hazards (initiating events) and the analysis of their evolution should be carried out using an appropriate technique:
 - [Hazards and Operability Study \(HAZOP\)](#);
 - [Failure Mode and Effect Analysis \(FMEA\)](#);
 - [Fault Tree Analysis](#).
- In the nuclear industry HAZOP method is used rather often – it is a formal, systematic, and critical approach to identifying the qualitative potential of hazards and operating problems associated with an existing or new system or piece of equipment caused by deviations from the design intent and their resulting consequential effects.

HAZOP Procedure

- HAZOP can be used at varying times during the life cycle of the process, from process development through to the closure of the plant, including hazard assessment of any modifications proposed during its operational life span.
- The procedure identifies:
 - Possible initiating events;
 - Nature of accident consequences;
 - Existing Engineered Safety Systems;
 - Existing Operational Safety Systems;
 - Requirement for additional safety systems: engineered or managerial;
 - Operability or functionality issues.

HAZOP Procedure (2)

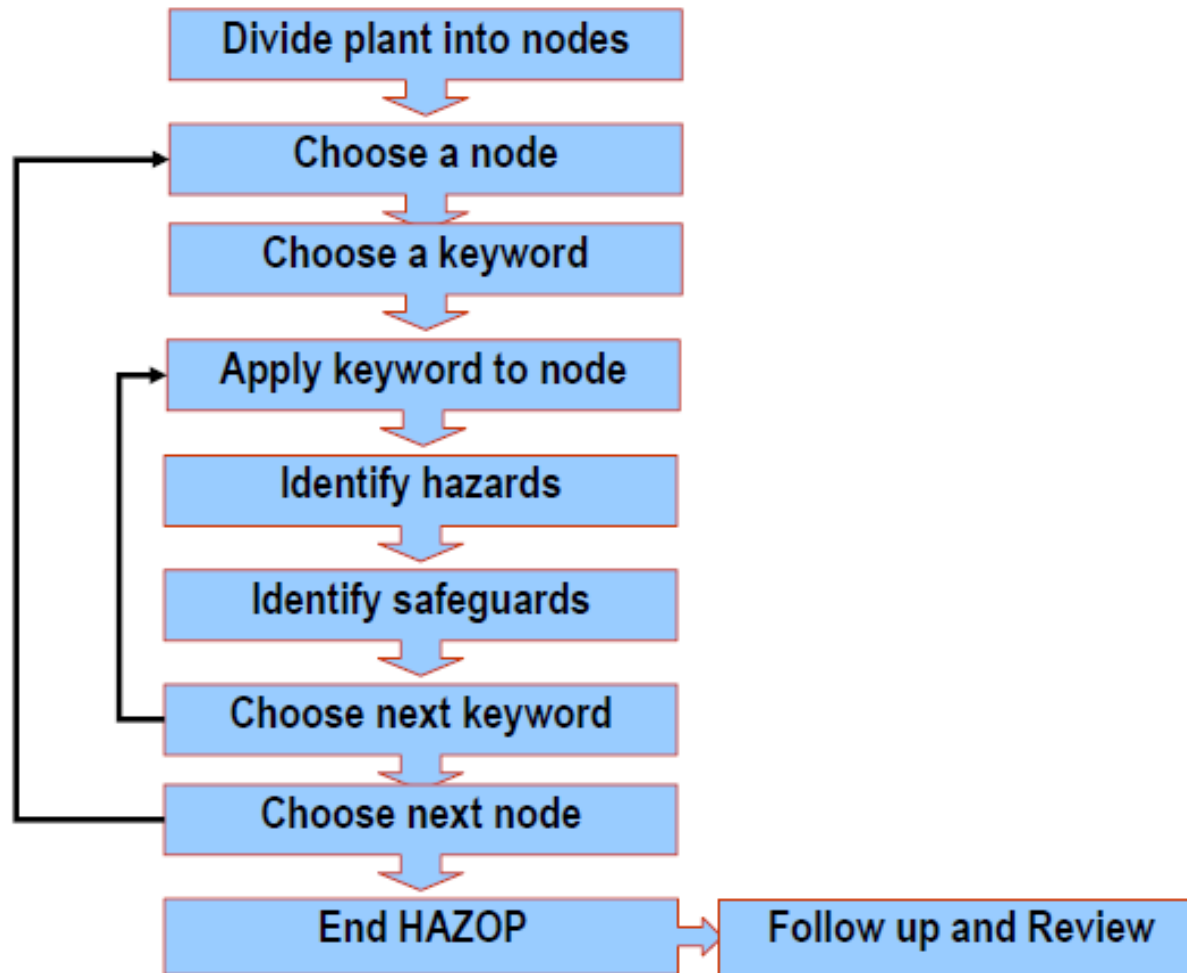
- The HAZOP technique is normally a team based structured method of identifying hazards, contributory causes and operability problems in plant and procedures.

HAZOP has been described as Structured Brainstorming!

- It has to be carried out by a multi-disciplinary team;
- A series of meetings involving interested parties and relevant technical specialists to give different view points working as a group to stimulate creativity and generate ideas.



HAZOP Procedure (3)



The procedure for performing the HAZOP study

HAZOP Procedure (4)

- **The Nodes:**

- In order to carry out a systematic study it is necessary to divide the plant, modification design or procedure into individual items, operational steps;
- These may be plant items or steps in procedures and are referred to as nodes;
- Each node is given a unique identifying number during the course of the study.

- **Keywords:**

- Keywords are words which are hazard based or fault initiating events which should stimulate identification of hazards when applied to nodes;
- Examples of Hazard based standard keywords in the nuclear industry:
 - o Fire / Explosion
 - o Radiation / Loss of Shielding
 - o Airborne / Surface Contamination
 - o Loss of Containment
 - o Wounding
 - o Impact / Dropped Loads
 - o Loss of Services – power, air, ventilation

HAZOP Procedure (5)

- **Safeguards:**

- HAZOP team identifies and records those safeguards which are currently built into the design or form normal practice on the NPP;
 - The safeguards will be separated into *engineered* (e.g. structural, containment, shielding, cladding, control and instrumentation etc.) *and operational/managerial* safeguards (e.g. procedures, training, supervision etc).
 - HAZOP team identifies engineered safety features, safety-related equipment and safety management provisions for the plant or modification;
 - Evaluation of results and identification of safety control measures.
- After completion of the HAZOP study, a list of the identified potential initiating events will be generated and their outcome will be summarized in the Fault Schedule.
 - The Fault Schedule will be an input for accident analysis of selected design option during preparation of Safety Assessment Report.

HAZOP Application for The Ignalina NPP buildings D & D

- Hazards identification approach (HAZOP) was used for D&D of the equipment located in buildings 117/1 and V1 at Ignalina NPP.

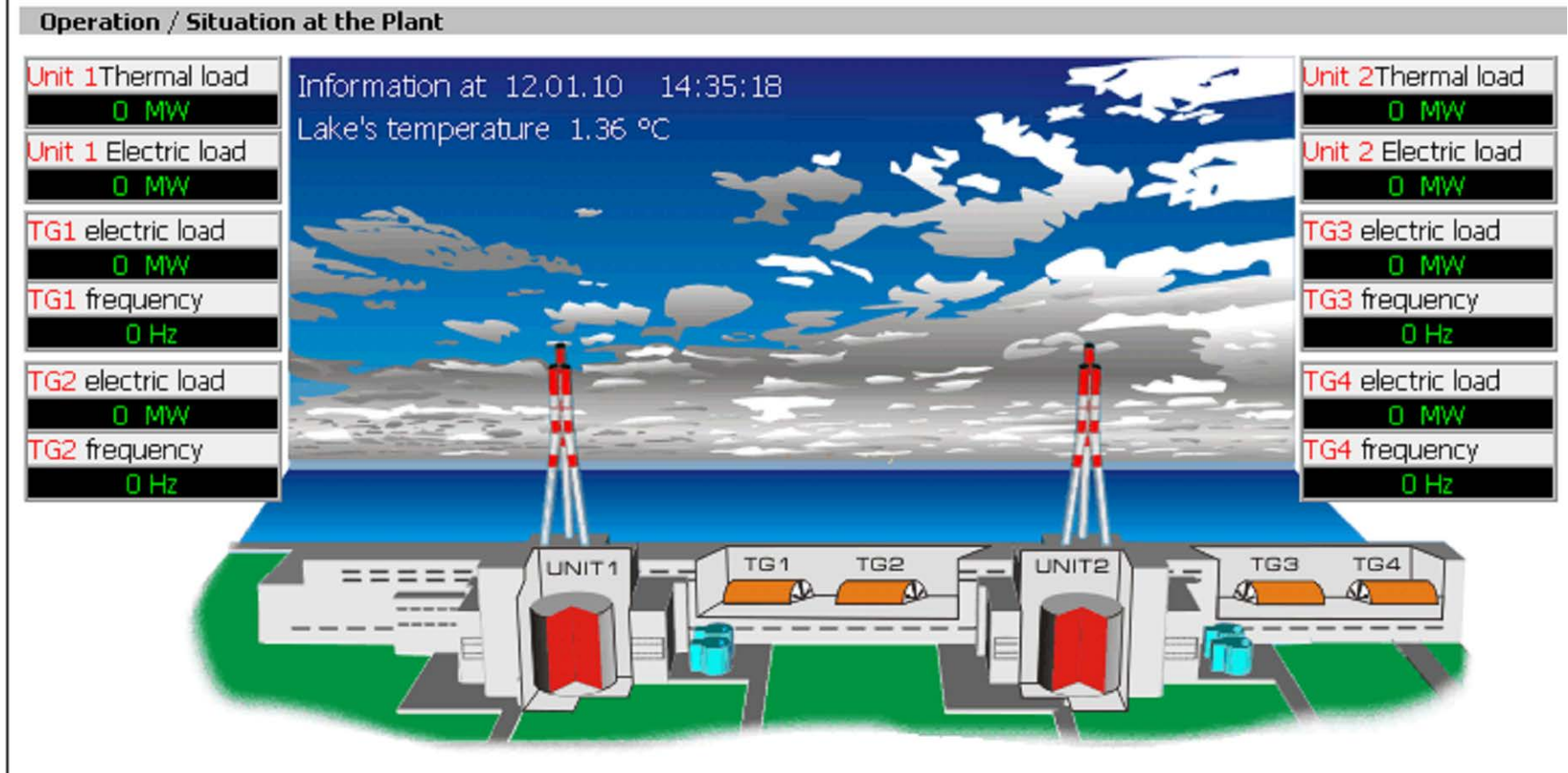


Building 117/1 of Ignalina NPP



Building V1 of Ignalina NPP

Ignalina NPP



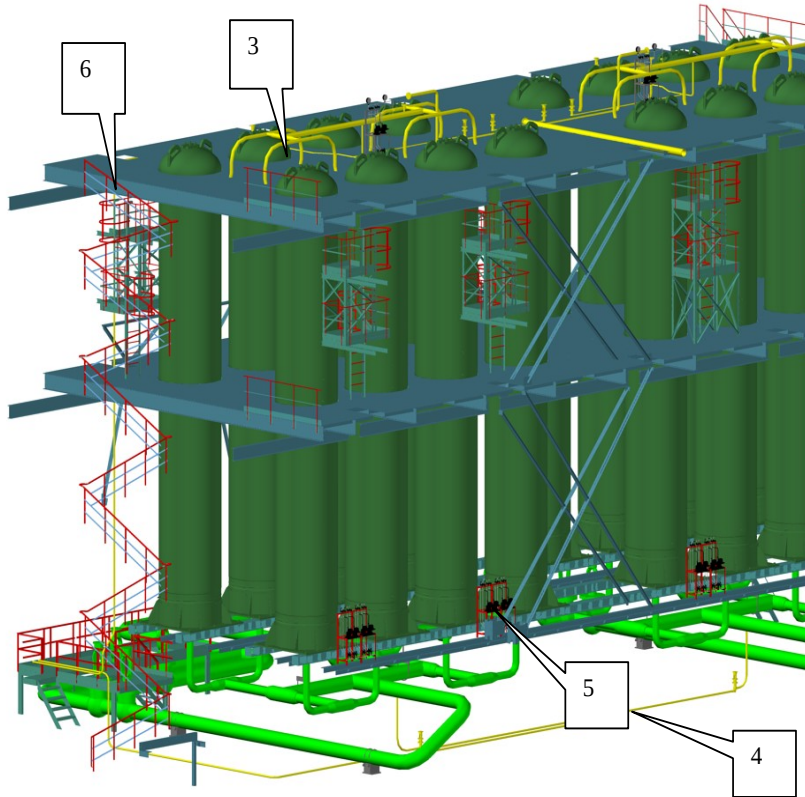
- Ignalina NPP – two units of RBMK-1500, commissioned in 1983 and 1987
- Both units are shutdown for decommissioning, at the end of 2004 and 2009

The Ignalina NPP buildings D & D

- According to the INPP Final Decommissioning Plan the INPP decommissioning process is split into several dismantling and decontamination (D&D) projects.
- Each of these D&D projects covers a particular field of activity for example initial primary circuit decontamination or dismantling of equipment using “room by room” or “system by system” approach.
- The objective of Ignalina NPP D&D Engineering Projects was the development of an optimal dismantling and decontamination strategy of the equipment and preparation of all documentation required for implementation of this strategy.

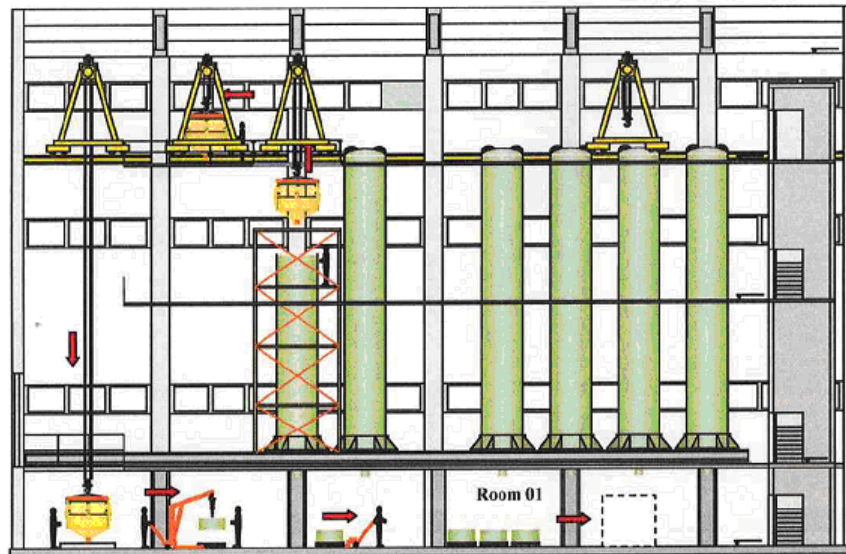
The Ignalina NPP building 117/1 D & D

- The main systems in building 117/1:
 - The Emergency Core Cooling System (ECCS) components (e.g. sixteen ECCS Pressure vessels, 14 m height and 47650 kg mass each),
 - Helium Facility (part of Reactor Gas Circuit)



The Ignalina NPP building 117/1 D & D (2)

- The D & D of the equipment within building 117/1 was based heavily on the experience on similar projects throughout Europe.
- The main characteristics of the preferred D&D Strategy were identified for implementing of building 117/1 D & D process:
 - In-situ size reduction followed by decontamination;
 - ECCS vessel cutting by oxy-acetylene;
 - Large pipe / valve and small pipes / fabrications cutting by 'tool kit' of techniques;
 - Decontamination by manually deployed vacuum abrasive blasting.



Cutting process of ECCS vessels

The Ignalina NPP building V1 D & D

- The main systems in INPP building V1:
 - Reactor gas circuit,
 - Exhaust gas cleaning system,
 - System of maintenance cooling tanks (part of Main Circulation Circuit),
 - Components of ventilation systems,
 - Part of ECCS.



The Ignalina NPP building V1 D & D (2)

- For building V1 D&D, the preference was for manual cutting techniques that minimize secondary waste.
- The cold-cutting techniques were favoured where appropriate to reduce the need for Mobile Filtration Units and ventilation modifications as required by hot cutting techniques.
- Combination of plasma arc and cold cutting techniques were used to cut the large items (tanks, vessels, etc).
- For dismantling and subsequent size reduction of large plant items (including vessels), a number of techniques have been considered in the development of options, namely plasma cutting, flame cutting, shears, diamond wire saws, circular saws and band saws.
- Hot cutting was generally preferred for thick-walled materials, such as vessels, tanks and filters.

Hazards for D & D tasks of Ignalina NPP buildings 117/1 and V1

- Decommissioning of INPP buildings involved different types of activities, tools, equipment and systems.
- There was a potential for a wide range of radiological and industrial accidents during various stages of INPP buildings decommissioning projects creating risk for workers and environment.
- The occurrence of hazards was possible due to many different operations involving movement and handling of large pieces of equipment and contaminated items.
- HAZOP method for the identification and evaluation of potential hazards, raised due to proposed D&D activities in INPP buildings, was used.
- HAZOP for Ignalina NPP buildings D&D was organized in a series of meetings involving different experts related to the planned activities and responsible for the radiation and industrial protection, operational activities, etc.
- The HAZOP study considered and reviewed the potential hazard management strategies available to satisfy the ALARA principle.

HAZOP Application for the INPP buildings D&D - Nodes

- The buildings V1 and 117/1 were assessed by separating the plant and equipment into functional nodes, each of which cover a subset of common issues and D&D strategy.
- These nodes were then analyzed in turn by the application of a set of keywords to each node.

The nodes considered at the INPP buildings D & D HAZOP studies

Node	Title
1	Plant and building preparatory work (e. g. install barriers and transfer systems, remove cladding and insulation)
2	Remove small items and small bore pipe-work from accessible areas, drives/ motors
3	Remove large items (vessels) and pipe-work, remove valves from pipe-work
4	Remove filter medium
5	Size reduce large pipe-work and vessels
6	Decontamination and monitoring of cut segments and pipe-work
7	Place all waste in containers/trolleys for removal
8	Remove steel platforms, redundant electrical cabinets and cables
9	Transfer waste from building
10	Clean / decontaminate room
11	Monitor room

HAZOP Application for the INPP buildings D&D - Keywords

- HAZOP studies for Ignalina NPP buildings D&D projects involved the application of defined keywords to the design in order to prompt a discussion that identified principal hazards and operability issues.
- The standard HAZOP keywords for decommissioning operating tasks were used

1. External dose	14. Wastes
2. Internal dose	15. Corrosion and erosion
3. Shielding	16. Associated facilities
4. Containment	17. Extreme weather, wind, temperature, flooding
5. Ventilation	18. Seismic
6. Fire	19. Toxicity
7. Explosion and overpressure	20. Dropped loads, impacts
8. Chemical reaction	21. Conventional hazards
9. Maintainability	22. Access
10. Remote handling	23. Environmental impact
11. Loss of services: power, steam, water, compressed air	24. Control and instrumentation
12. Operator error	25. Communications
13. Effluents: gaseous, liquid	26. Domino effects

HAZOP Application for the INPP buildings D&D - Hazards identified

- The following main hazards with potentially significant consequences associated with the Ignalina NPP buildings 117/1 and V1 D&D activities were identified by means of HAZOP studies:
 - o Dropped heavy loads creating a risk of structural damage, airborne activity releases, worker injury or fatality, damage to live essential services;
 - o Dropped highly contaminated items i.e. filters, waste drums resulting in release of airborne contamination;
 - o Loss of ventilation. Loss of ventilation can lead to operator asphyxiation, exceeding safe concentration limits for airborne toxic material, increased radiological internal dose and potential for spread of contamination.
 - o Loss of containment, damage to local containment tenting, failure to deploy temporary covers on pipe-work and vessels during cutting.
 - o Failure/malfunction of building ventilation system can lead to overpressure of building and potential uncontrolled release of airborne activity through building structural leakages into adjoining facilities and to the environment.
 - o Fire/explosion. Use of hot cutting technique potentially introduces fire/explosion hazards.

HAZOP Application for the INPP buildings D&D - Safety Measures

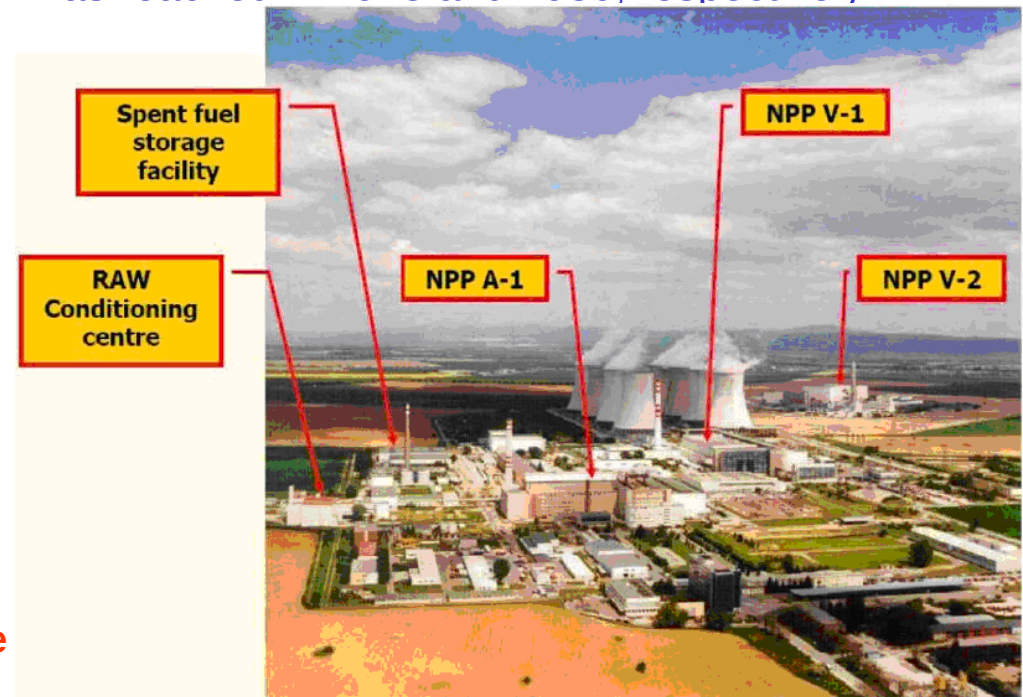
- A number of safety measures have been identified in order to satisfy the ALARA principle throughout the D&D operations in buildings 117/1 and V1:
 - The caps were welded on the open pipelines to avoid any possibly contaminated water leaking from the pipe-work;
 - Improved sealing of existing bulkhead in the pipe tunnel in order to minimize the concentration of airborne activity and control spread of contamination;
 - Polyethylene sheet and adhesive tape was used to seal openings into components to avoid contamination spread;
 - Ventilation systems were provided the necessary air changes to reduce the risk of high concentrations of toxic gases, metallic fume and airborne activity;
 - Localized mobile ventilation systems with HEPA filtration were used to supplement the existing buildings 117/1 and V1 ventilation system;
 - Catch pot at the bottom of the vessel to catch the hot cutting slag and particulate falling inside the vessel and thus avoiding blockage of the ventilation flow route from the vessel were used;

HAZOP Application for the INPP buildings D&D - Safety Measures (2)

- o Personal dosimeters, portable area gamma alarms and portable air monitoring units for continuous gas and airborne activity monitoring of occupied work areas with alarm function were used;
 - o Appropriate use of personal protection equipment (respiratory protection and safety measures to protect the face and hands);
 - o Emergency access and egress routes (including revised signage, emergency lighting, crash bar fire exit door to external area);
 - o Protection of live cables and operational systems in cutting areas to prevent damage;
 - o Control of equipment, tools and waste containers to ensure that they are certified, tested and adequately identified;
 - o All activities were done according to approved procedures, under direct management of works supervisor.
- It was assumed that the managerial protection and mitigation will include, but not be confined to the following generic requirements:
 - **Operator training;**
 - **Use of suitably qualified and experienced personnel;**
 - **Use of approved procedures and site instructions;**
 - **Compliance with Lithuanian regulations.**

HAZOP Application at Feasibility Study for the Management of Bohunice V1 NPP PCC

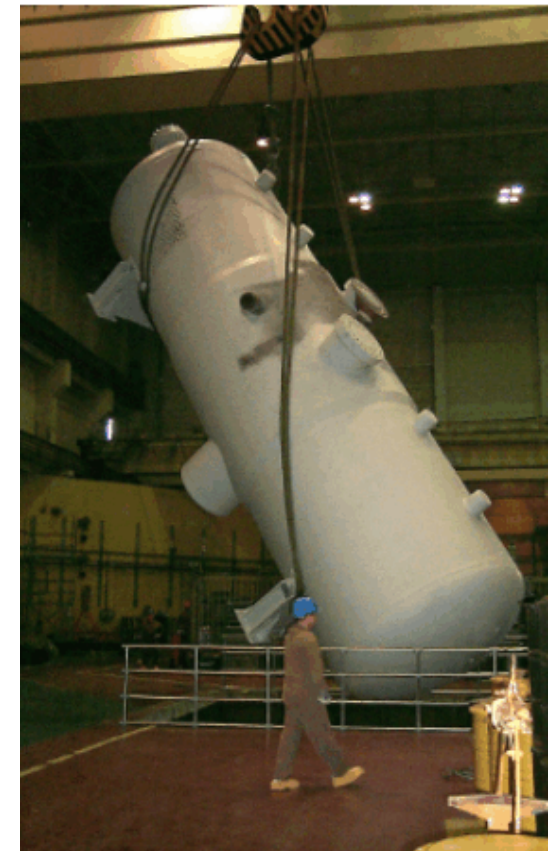
- The obtained experience of LEI experts in conduction of HAZOP studies for the assessment of the proposed D&D methods for Ignalina NPP buildings decommissioning was successfully adopted for the development of Feasibility Study for the Management of Bohunice V1 NPP Primary Circuit Components.
- Bohunice V1 NPP - two reactor units (type VVER 440/V 230)
 - constructed according to a Russian design in the period from 1973 to 1977
 - Initial criticality at Units 1 and 2 was reached in 1978 and 1980, respectively
 - In relation to Slovakia's access to the EU, the government of the Slovak Republic decided on the premature shutdown of the V1 NPP and approved the dates for Units 1 and 2 shutdown (2006 and 2008, respectively);



The view on objects at Bohunice site

HAZOP Application at Feasibility Study for the Management of Bohunice V1 NPP PCC (2)

- The objective of Feasibility Study for the Management of V1 NPP PCC was to identify, analyze, justify and rank alternative solutions towards the dismantling and management of the large components of the two units of Bohunice V1 NPP Primary Circuit:
 - o Reactor Pressure Vessel (RPV)
 - o Reactor Internal Structures (RIS)
 - o Main Circulation Pipelines and Main Circulation Pumps
 - o Steam Generators
 - o Main Gate Valves
 - o Pressurizer and Pressurized Tank
 - o Annular Water Tank (AWT)
 - o Mogilnik; etc.



Steam generator dismantling as a whole

HAZOP Application at Feasibility Study for the Management of Bohunice V1 NPP PCC (3)

- Feasibility Study included the development and screening of Alternatives, and detailed evaluation of alternative actions towards the dismantling and waste management of V1 large components.
- Application of HAZOP study to the management of Bohunice V1 NPP primary circuit components was used in assessment of each Alternative with respect to overall protection of human health and the environment criterion.
- Methods of Alternatives assessment and results of HAZOP Study formed the framework for Alternatives analysis.

HAZOP Application at Feasibility Study for the Management of Bohunice V1 NPP PCC (4)

- Three alternatives for **activated equipment** management (Alternatives A) and four alternatives for **contaminated waste** management (Alternatives C) were analyzed:
 - Alternative A1: Dismantling of activated equipment whole, placement of the RIS into the RPV, decay storage;
 - Alternative A2: Dismantling of activated equipment whole, placement of the RIS partly into the RPV, partly into shielding containers, decay storage;
 - Alternative A3: Fragmentation of activated equipment, separation and decay storage of Medium Level Waste;
 - Alternative C1: Dismantling of contaminated equipment whole and disposal whole;
 - Alternative C2: Dismantling of contaminated equipment whole with subsequent fragmentation and decontamination in a separate facility;
 - Alternative C3: Dismantling of contaminated equipment in large fragments with subsequent fragmentation and decontamination in a separate facility;
 - Alternative C4: Complete in-situ fragmentation of contaminated equipment and decontamination using other facilities.

HAZOP Application at Feasibility Study for the Management of Bohunice V1 NPP PCC (5)

- HAZOP study to Feasibility Study for the Management of V1 NPP PCC was applied in the assessment and ranking of individual Alternatives with respect to **overall protection of human health and the environment criterion**.
- This threshold criterion must be satisfied in order for an alternative to be eligible for selection.
- HAZOP workshop with a team consisting of consortium experts, plant operators, engineers, managers and others, was prepared and conducted in the initial assessment phase of the Feasibility Study.
- The main hazards, their causes and appropriate safety measures were identified.

HAZOP Application at Feasibility Study for the Management of Bohunice V1 NPP PCC – Nodes (6)

- HAZOP study considered each element or sequence (“Node”) of the Alternative and involved the application of Keywords in order to identify and evaluate problems that may represent risks to personnel or equipment.

Node	Node description
RPV-1	Disconnection of the RPV from all process communications
RPV-2	The RPV is slung and transferred into the transport corridor and anchored in the vertical position on platform
RPV-2*	The RPV is slung and transferred into the Steam Generator – Main Circulation Pump bay
RPV-3	Cutting of Protective Tube Unit upper part.
RPV-4	The Reactor Internal Structures (RIS) are emplaced inside the RPV
RPV-5	The RPV is lowered onto a platform with the aid of additional hoisting mechanisms
RPV-6	RPV and RIS fragmentation into fragments
AWT-1	Fixation of AWT
AWT-2	In-situ fragmentation of AWT
SG-1	Disconnection of SG from process communications
SG-2	SG is dragged under the aperture
SG-3	SG is removed through an aperture and transferred into the transport corridor and anchored on platform
SG-4	Cutting of SG at their regular position into large fragments
SG-5	Cutting of SG at their regular position into small fragments
MG-1	Demolishing of concrete
MG-2	Dismantling of pipes

HAZOP Application at Feasibility Study for the Management of Bohunice V1 NPP PCC – Keywords (7)

- For each Node under consideration, the appropriate keyword was applied to prompt discussion of the Alternative intent.

Direct radiation	Contamination
Dispersion	Fire
Explosion	Gas generation
Flooding	Handling
Missiles	Chemical/toxic
Utilities	Degradation/ageing
Maintenance faults	Operational faults
Interfacing (Domino effect)	Extreme weather
External fire	Seismic
Communication	-

- A summary of Individual Analysis results was developed based on the performed assessments and the results of HAZOP study.

HAZOP Application at Feasibility Study for the Management of Bohunice V1 NPP PCC - Hazards identified and Safety Measures

- The main risk of external and internal exposures for the operation personnel when handling the radioactive materials therefore it is required non presence of personnel on the reactor hall during activated equipment (e. g. RPV, RIS) handling and transfer.
- Spread of contamination, asphyxiation, drop of loads, pipe whip, heat and sparks, both of which are potential fire or burn hazards during acetylene cutting, structural failures are additional potential hazards.
- Barriers in preventing human exposure and/or spread of radioactive materials to the environment under management of V1 NPP PCC are employing of protective shields with varying wall thickness (depends on the dose rate), portable screens, heavy protective containers, weld-on metal stoppers (plugs), double protective lids.
- Other precautions for mitigating the hazards associated with a PCC dismantling operations:
 - Remotely controlled mechanical cutting to be used to avoid high dose rate;
 - Use of high resolution cameras for remote monitoring of dismantling operations to be required;

HAZOP Application at Feasibility Study for the Management of Bohunice V1 NPP PCC - Hazards identified and Safety Measures (2)

- o Building ventilation system with additional MFU to create suitable conditions for the work of operational personnel
- o Personal dosimeters, portable area gamma alarms and portable air monitoring units for continuous gas and airborne activity monitoring of occupied work areas with alarm function were used;
- o Appropriate use of personal protection equipment (eye protection; long-sleeved clothing; sturdy, full length pants; steel-toed boots or shoes; hearing protection; and safety gloves) to avoid exposure to workers during the handling of impacted materials;
- o Temporary coverings (tents) for building door opening were employed to reduce spread of airborne contamination);
- o Protective tent connected to the ventilation system was arranged to prevent concrete dust from spreading;
- o Fume extraction unit with spark arrester to be employed for extraction and filtration of welding fume;
- o Remote control for crane for exact positioning; additional crane load capacity check to decrease the risk of working environment hazards.

o etc.

Summary

- Application of HAZOP technique in two different decommissioning stages:
 - for identification of the hazards raised due to dismantling and decontamination activities in Ignalina NPP buildings after justification of the preferred D&D Strategy and
 - at feasibility study for the management of Bohunice V1 NPP PC components;was presented.
- All relevant hazards to workers, the public and the environment were considered and potential hazard management strategies have been identified.
- A number of safety measures have been identified in order to prevent undue routine radiation exposures to the facility staff, public and the environment according to the ALARA principle throughout the NPPs decommissioning operations.
- The adherence to the ALARA principles of time, distance and shielding underpins NPPs D&D operations and protects workers.
- Experience of Lithuanian Energy Institute experts in preparation of safety analysis for operating NPPs was successfully adopted at the development of D&D works safety assessment for NPPs decommissioning.

Acknowledgement

- In the presentation referred Dismantling and Decontamination projects B9-0 and B9-2 at the Ignalina NPP was grant funded by the EBRD-managed Ignalina International Decommissioning Support Fund (IIDSF)

Thank you for your attention

Questions?