INTERNATIONAL ATOMIC ENERGY AGENCY

REPORT

of the

EXPERT MISSION

'To Assess the Results of the Hungarian Atomic Energy Authorities Investigation of the 10 April 2003 Fuel Cleaning Incident at Paks NPP'

HUNGARIAN ATOMIC ENERGY AUTHORITY

And

PAKS NUCLEAR POWER PLANT

HUNGARY

16 to 25 June 2003

EXPERT MISSION
conducted under IAEA Technical Co-operation Project HUN/9/022
Support for Nuclear Safety Review Mission

DEPARTMENT OF TECHNICAL CO-OPERATION
Division for Europe, Latin America and
West Asia

DEPARTMENT OF NUCLEAR SAFETY
and SECURITY
Division of Nuclear Installation Safety

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INTRODUCTION / BACKGROUND

At the request of the Government of Hungary and within the framework of Technical Co-operation (TC) project HUN/9/022, the International Atomic Energy Agency (IAEA) conducted an independent expert mission at the Hungarian Atomic Energy Authority (HAEA) and Paks Nuclear Power Plant (NPP) to assess the results of HAEA's investigation of the 10 April 2003 fuel cleaning incident at the Paks NPP. A meeting was conducted on 20 May 2003 between the IAEA and HAEA where HAEA presented the background and preliminary results of their review of the fuel cleaning incident. At the meeting, Agency staff were given the opportunity to ask questions and obtain clarification about the incident. Dr. Jozsef Ronaky, Director General, HAEA presented DDG-Nuclear Safety and Security, Mr. Taniguchi, with the official letter of invitation from the President of the Hungarian Atomic Energy Commission to conduct this mission. Following the meeting Dr. Ronaky agreed to the date and scope of the mission. The mission was conducted from 16 to 25 June 2003.

The following report represents the results of the expert mission and is submitted to the Government of Hungary for its use in strengthening the safety of nuclear installations and regulatory programs. This report is not submitted to or intended to be used by other interested parties for the purpose of taking legal actions or obligations. Any use of or reference to this report that may be made by the competent Hungarian oranizations or by other interested organizations is solely their responsibility.

Objectives of the Mission

- To assist the Hungarian authorities with advice on the applicable international safety standards to this particular event and on the Agency's possibilities to provide for the applications of these standards at the request of the Hungarian Government;

- To present to the President of Hungarian Atomic Energy Commission, Mr. Istvan Csillag, an authoritative and factual overview of HAEA's review of the consequences and aftermath of the fuel cleaning incident at the Paks NPP as well as the available information on its originating causes, and

- To produce a comprehensive report, with appropriate recommendations, detailing the IAEA's independent and objective analysis of the actions taken by HAEA and Paks NPP prior to, during and after the incident.

Team Composition and Scope of Mission

The team composition consisted of a team leader, co-team leader and eight (8) experts who reviewed the following six areas: (1) Management Systems including QA/QC, (2) Regulatory Oversight/Interface, (3) Root Cause Analysis/Risk Analysis, (4) WWER Fuel Performance Characteristics, Thermo hydraulics and Chemistry (two experts), (5) Radiological Dose Assessment/Radiation Protection (two experts) and (6) Emergency Planning and Preparedness. The co-team leader assisted in reviewing the legislative aspects of the incident and assisted each expert in the evaluation of overall operational safety performance.

Conduct of the Mission

HAEA provided the IAEA with the final report, in English, of their investigation prior to the mission in order for team members to prepare for the review. The IAEA Safety Standards were used as the basis documents for the review, supplemented by appropriate Agency guidelines that were modified to support each review area (e.g. IRRT, OSART, and PROSPER guidelines).

The team arrived in Vienna on Sunday 15 June, 2003 and received team training and briefings regarding the incident at the IAEA headquarters on Monday 16 June. The team travelled by train to Budapest on Monday evening, 16 June to spend approximately three days conducting interviews and reviewing programmes and processes at HAEA offices before travelling to Paks NPP to continue the review. The team travelled back to HAEA headquarters in Budapest on Monday 23 June to complete the review. A formal exit meeting was held on Wednesday 25 June 2003 at HAEA headquarters in Budapest. HAEA and Paks NPP were provided a copy of the team's Technical Notes at the exit meeting.

The following were areas of emphasis for the review:

- Evaluation of the root cause of the incident including an analysis of Paks NPP and HAEA's root cause analysis.
- Evaluation of the effectiveness, by Paks NPP and HAEA, of the risk analysis performed to conduct the fuel cleaning operation.
- A review of the classification (category 3) criteria for the fuel cleaning activity as compared to IAEA safety standards.
- Evaluation of the assessment and approval process for modifications made to the fuel cleaning equipment and subsequent operations at both the Paks NPP plant level and at HAEA.
- Evaluation of operational safety performance during the fuel cleaning operation and subsequent identification of the problems leading to the incident.
- Adequacy of the procedures being used to conduct the fuel cleaning activity, including prerequisites and precautions.
- Adequacy of clearly defined roles and responsibilities for the conduct and supervision of the fuel cleaning activity.
- HAEA's effectiveness for licensing the fuel cleaning activity, with emphasis on HAEA's role for licensing NPP activities falling outside of the licensing basis of the plant.
- Adequacy of the training provided to Paks NPP operation, maintenance and radiation protection personnel on the fuel cleaning operation, precautions and possible indications of problems.
- Evaluation of emergency response capability and criteria for this incident.
- Evaluation of the radiological release and worker dose for this incident.
- Assessment of the adequacy and timeliness of the corrective actions proposed to prevent recurrence of a similar event.

EXECUTIVE SUMMARY

The Paks nuclear power plant (NPP), in Hungary has four WWER 440 MWE reactors that supply about 40 % of the electricity to the country. Units 1-4 went into commercial operation between 1983 and 1987.

On 10 April 2003, a fuel cleaning incident occurred during a scheduled maintenance shutdown for Unit 2. Thirty (30) fuel assemblies had been removed from the Unit 2 reactor and placed in a fuel cleaning tank approximately 10 meters under water in a shaft adjacent to the fuel pool. The fuel assemblies were being cleaned due to magnetite deposits on their cladding.

At 21:53 hours on 10 April activity was detected by the workers on the krypton measurements installed in the cleaning circuit, and at about the same time, the 'emergency' level was reached by the noble gas activity concentration monitors within the reactor hall. The plant shift supervisor ordered an evacuation of the area. Initially, Paks NPP and Framatome Advanced Nuclear Power (FANP) personnel suspected that a fuel assembly was leaking due to the cleaning operation. However, it was observed several days later, during a subsequent inspection performed with the use of a video camera that most of the fuel had suffered heavy damage.

At the request of the Hungarian Government, the IAEA conducted an independent expert mission to assess the results of HAEA's investigation of the 10 April 2003 fuel cleaning incident at the Paks NPP. The team was composed of nuclear and radiation experts from the IAEA, Austria, Canada, Finland, Czech Republic, the United Kingdom and the United States of America.

<u>The following is a summary of the review;</u>

Management of Safety: the team noted that the responsibility for operation of the fuel cleaning system was turned over to the contractor. The plant operations organization was more in the mode of a service provider to the contractor (FANP) than in having responsibility for the safe operation of this system. Neither HAEA nor Paks NPP used conservative decision making in the rigor of safety assessment given to this unproven fuel cleaning system.

The aggressive schedule for design, fabrication, installation, testing and operation of the fuel cleaning system contributed to a sense of urgency that influenced decisions regarding the rigor of nuclear safety assessment and design review. The team also noted that communications between organizational units at Paks NPP are not encouraged except through Department or Division managers. Thus, opportunities to share information among personnel in different organizational units are reduced.

The team concluded that the top management of HAEA and Paks NPP are committed to improving the safety of the plant. Both Director Generals said they would welcome further IAEA assistance as they continue to review and manage this incident and improve safety at the facility. An interview with the Paks NPP Director General has shown that he is a responsible, competent and knowledgeable professional, dedicated to improving the safety of the Paks NPP. He made the right steps to mitigate the incident.

The willingness to consider new ideas and implement necessary changes is a positive indicator of the potential for further improvement of the operational safety at the plant.

Regulatory Oversight: the team concluded that the Hungarian Atomic Energy Authority underestimated the safety significance of the proposed design for the fuel cleaning system, which resulted in a less than rigorous review and assessment than should have been necessary. The issuance of a "license in principle" lacked the requirement for an expanded and independent review and assessment.

Design deficiencies: the design of the cleaning system was deficient in several respects:

(1) The submersible pump provided for mode B was inadequately sized and had inadequate redundancy / back up

(2) The bypass flows around the fuel assemblies were not fully taken into account in the thermo-hydraulic analysis of the design

(3) Potential additional bypass flows around the fuel assemblies, because they may not be correctly seated, was recognized but ineffectively dealt with

(4) The simple thermo-hydraulic analysis of the design that was performed, even though over simplistic, did indicate unacceptable margins in fault conditions (time to boiling) but this was not effectively recognized

(5) The provision for lifting the cleaning vessel head in mode B or in fault scenarios was inadequate

(6) Changes in the configuration of the cleaning tank design (outlet pipe position and inlet plenum chamber) going from a seven assembly cleaning tank to a thirty assembly cleaning tank was not recognized to be significant

(7) Inadequate instrumentation, trend recording and alarm systems were provided to detect off normal conditions during cleaning

(8) Possible fuel assembly seating misalignment due to only one fuel guide plate utilized in the cleaning tank to align the bottom of the fuel assembly in its correct seating location. Slight misalignment will reduce cooling flow. Normally, two guide plates are used for fuel pool storage of fuel assemblies.

Fuel Cleaning Operation: the roots of 10 April 2003 fuel cleaning incident at Paks NPP are in 2000 and 2001 when the extensive steam generators decontamination process was performed at Units1-3. In the beginning of 2002 Paks NPP management determined that additional actions were needed to deal with the accumulation of magnetite deposits on the fuel. A contract was signed with FANP to perform out-of core fuel cleaning. The team found that the contractor worked without proper supervision of the Paks NPP plant. In general, personnel involved did not receive adequate training in the nuclear safety aspects of this specific operation. Additionally, operating and emergency procedures were not adequately developed nor was the plant operations department sufficiently engaged in the supervision of the operation.

Radiation Protection: the IAEA team found that the Paks NPP undertook appropriate monitoring and assessments of the radiation exposure to staff. Based upon the data and dose assessments provided by Paks NPP and other authorities, the team found no indication that the annual dose limits for occupational exposure as specified in IAEA Basic Safety Standards had been exceeded. The team also agreed with the Paks NPP and HAEA's assessment that the annual dose limits for the general public resulting from the release specified in IAEA Basic Safety Standards had not been exceeded.

Emergency Planning and Preparedness: the team noted that the emergency responses of the HAEA and Paks NPP were well coordinated and consistent with the information available to the emergency manager at the time. However, the lack of an emergency threat assessment for this activity affected the ability to recognize the potential severity of the situation, and some aspects of the emergency response procedures introduced delays and confusion in the implementation of the emergency response plan.

The team was given total access to all information and personnel at Paks NPP and at HAEA. The team was allowed to independently verify all information that it believed was relevant to its review. The team provided a number of recommendations for improvement in nuclear safety in the above and in other areas. The team noted the frankness and transparency provided by both HAEA and Paks NPP during the course of the mission. The Hungarian Government indicated that this expert mission report will be made available to the public.

1. MANAGEMENT SYSTEMS (INCLUDING QUALITY ASSURANCE, QUALITY CONTROL)

1.1. MANAGEMENT SYSTEMS FOR REVIEW AND ASSESSMENT OF THIS FUEL CLEANING METHOD

Both HAEA and the Paks NPP have implemented management systems for safety assessment that are based upon Hungarian law and decrees, and which are implemented through the Hungarian Nuclear Safety Code (NSC). The review team found the personnel responsible for safety assessment at both HAEA and the Paks NPP to be open and professional in discussing the characteristics of these systems with this review team.

Since 1996 the Paks NPP has been experiencing the accumulation of corrosion product deposits in the primary circuit of its units. The most fundamental cause of the deposits was the decontamination of the steam generators, however in some particular cases there might have been some other contributing factors, which so far have not been identified. The effect of these deposits on the fuel cladding has had the most impact on safety and reliability of operations, with the deposits reducing flow through the coolant channels and also reducing the heat transfer to the coolant. In 1998 the accumulation of these deposits necessitated a shutdown to change out the entire core of unit 2. The accumulation continued, resulting in a decision to investigate methods to clean the fuel and other parts of the primary circuit to remove the deposits. In 2000 and 2001 Paks NPP contracted with Siemens GmbH for cleaning of 170 “cold” fuel assemblies (i.e. partially used fuel assemblies that had been in the fuel pool for more than one year, and for which the decay heat was low). This cleaning was performed in a tank designed to hold seven fuel assemblies. The cleaning tank was installed in a shaft connected to the spent fuel pool.

In 2002 Paks NPP management determined that additional actions were needed to deal with the accumulation of deposits on the fuel, and initiated a set of actions they intended to implement during the 2003 planned re-fuelling outages. Based upon successful cleaning of cold Paks NPP fuel by FANP (the successor to Siemens GmbH), Paks NPP contracted with FANP to study two alternative approaches to fuel cleaning: 1) in-core cleaning of the fuel and other primary circuit components, and 2) ex-core cleaning. The second alternative was selected in October 2002 with a goal of having the ex-core cleaning system designed, installed and ready for use by March 2003. This resulted in a very aggressive schedule. The design work was initiated in October. This design considered lessons learned from the 2000/2001 cleaning of cold fuel assemblies. However, it was designed for 30 assemblies per load. A contract was signed in November. A license application, based upon a FANP preliminary design, was submitted by Paks NPP to HAEA on 18 December 2002 with a request for urgent action. On 24 January 2003, HAEA provided a license for the ex-core fuel cleaning, with only one comment on the safety analysis; a request to analyse a case with different fuel enrichment. The license in principle granted by HAEA meant that the Paks NPP had the authority for subsequent licensing/authorization of the details of the fuel cleaning including review of the design, fabrication, installation, testing and operations.

The safety analysis submitted with the license application for the fuel cleaning provided only a simple analysis of cooling of the fuel in the tank. This analysis identified that in the event of loss of cooling to the tank during cleaning, boiling in the tank could occur within 9.2 minutes. The approach proposed to respond to a loss of cooling to the tank was to immediately stop the cleaning operation and to open the cover of the tank and a valve at the bottom of the tank in order to establish natural circulation cooling. There was no analysis provided of the effects on fuel assembly cooling of not properly installing the fuel assemblies in the tank, or of blockage of a fuel channel during the cleaning process. The design provided no in tank measurement of temperatures or other parameters within the tank that would provide a means to monitor cooling of either individual fuel assemblies or of the batch. The safety analysis submitted with the license application also did not address the possibility of serious fuel cladding failure during the cleaning process; either the radiological releases expected from a single fuel element failure or a larger failure. (The lack of this information during the event contributed to an initial misdiagnosis of the incident.)

The licensing submittal for fuel cleaning indicated that the technology had been used at 300 other nuclear facilities. However, the Paks NPP 7 fuel assembly cleaning (in 2000-2001) was the first time that the technology was used to clean fuel assemblies, and the 30 fuel assembly cleaning tank (proposed in this application) was the first time that hot assemblies (fuel that had recently been removed from an operating reactor, which, as a result, had significant decay heat) had been cleaned. Thus, there were significant aspects of this cleaning project that were unique and unproven and for which conservative decision making should have been applied.

HAEA has established requirements in the NSC, Volume 1, Section 4 for the licensing of modifications, which include the fuel cleaning operations that resulted in this incident. However, the application of these requirements was not sufficiently rigorous to ensure that the analysis submitted for the license of the fuel cleaning operations addressed the risks associated with this activity. For example,

- The engineering design did not address the single fault criteria for safety systems required by the NSC and IAEA safety standards
- The operational aspects related to maintaining cooling of the fuel were not properly addressed in the license application.
- The fault conditions and indications related to inadequate cooling of the fuel being cleaned were not properly addressed in the license application.

This lack of rigor was, at least partially, the result of an interpretation of the NSC by HAEA that this was a modification of a safety class 3 system for which there was only a modification of a component, rather than being the installation of a new, unproven system. This non-conservative classification resulted in only a license in principle being required by HAEA, rather than a more comprehensive modification license. The safety assessments conducted by HAEA, Paks NPP and FANP did not identify the weaknesses in the safety analysis described above. The aggressive schedule for this project also had an impact on the decision making related to safety assessment, as the fuel cleaning system designer's calculation that boiling could occur in the tank only 9.2 minutes after loss of cooling did not trigger, by either the designer, operating organization or the nuclear safety regulator, further analysis or requirements for more rigorous design features or operational controls.

1.1(1) Recommendation: HAEA and the Paks NPP should establish mechanisms to ensure that the novelty and complexity of modifications are considered in determining the extent of safety assessments to be performed, and that the extent and quality of these assessments is not compromised due to operational priorities.

Basis: *The scope and depth of the review and assessment will depend on several* *factors such as novelty, complexity, previous history, the experience of the operator and the associated risk (Paragraph 3.7 of GS-G-1.2). In carrying out its review and assessment, the regulatory body should determine whether the operator has defined criteria which meet the safety objectives and requirements relating to:*

- *engineering design;*
- *operational and managerial aspects;*
- *normal operation and fault conditions.*

(Paragraph 3.41 of GS-G-1.2)

For 2 of the 3 hot fuel loads cleaned prior to the incident, the system was left in mode B (the post cleaning low flow mode during which the incident occurred) for approximately 100 minutes. Given that the mechanism for cooling of the fuel in mode B is not completely understood, it is possible that boiling also occurred for these batches. Subsequently, elevated fuel cladding temperatures may have been reached and some thermal shock to the fuel may have occurred when the cover was removed. There were no internal temperature measurements in the tank to confirm that no damage occurred.

1.1(2) Recommendation: The Paks NPP should conduct a safety assessment of the fuel cleaned prior to the incident to ensure that this fuel is suitable for reuse.

Basis: *The scope and depth of the review and assessment will depend on several factors such as novelty, complexity, previous history, the experience of the operator and the associated risk (Paragraph 3.7 of GS-G-1.2).*

In addition to this recommendation, there are a number of recommendations provided in Section 2 regarding improvements in the HAEA Nuclear Safety Code and Guidelines and implementation of these requirements and guidance related to the safety assessment weaknesses discussed above.

It is noted that since the incident, a new license application was made for a cooling system for the damaged fuel in the cleaning tank. HAEA has issued a modification license for this system. The system provides redundant cooling trains with two 100% capacity pumps in each train (a total of 4 pumps) and meets the HAEA requirements and IAEA safety standards to accommodate a single failure of an active component. This modification license is only valid for cooling the fuel in its current location. An additional license application has been approved for operation of a video camera in the fuel cleaning tank in order to better ascertain the extent of the damage to the fuel. This information will be used to prepare additional safety analysis and design alternatives for removal of the damage fuel from the cleaning tank, and subsequent safe storage and disposal. The cover of the cleaning tank is now open. Thus, even if forced cooling of the tank is lost, natural circulation should provide sufficient cooling of the damaged fuel. The principal nuclear safety issue with the damaged fuel in its present condition is uncontrolled criticality. Two independent organizations have made calculations that demonstrate sub-critical conditions will be maintained for the worst case geometry of the damage fuel as long as boric acid concentrations are maintained above established limits.

1.2. MANAGEMENT OF FUEL CLEANING OPERATIONS

The Paks NPP has a well structured shift team, led by a Plant Shift Supervisor that conducts the operational activities at the plant. The operation of the unit is supervised by the staff of control room personnel under the leadership of a Unit Shift Supervisor. However, the fuel cleaning operation was not integrated within this organization. The Paks NPP turned over operational responsibility for the fuel cleaning operation to its contractor, FANP. The only responsibilities of Paks NPP reactor operations personnel were to select the fuel assemblies to be cleaned, and transfer them to/from the fuel cleaning tank. This decision contributed to the incident in that the fuel cleaning procedures were not developed, reviewed and approved by reactor operations personnel. Operations personnel did not monitor the fuel cleaning equipment or process indications. Thus, opportunities were missed for the plant to identify deficiencies in procedures, and to identify indications of inadequate cooling of the fuel that were overlooked by FANP personnel. Additionally, operational limits (e.g. Technical Specification limits) for cooling, and fuel failure were not developed for fuel cleaning operations as they exist for other plant safety parameters. The turn-key approach used for this project was more suitable for an activity performed at a vendor's facility, than one performed using plant structures, systems and components important to safety.

The final aspects of the testing program included cleaning two loads of cold fuel that had been removed from the reactor more than one year earlier. The cleaning of this fuel was successfully completed on 3 April. On 4 April, testing of the fuel cleaning cooling system was conducted along with a trial use of the emergency operating procedure to be used in the event of the loss of cooling for the tank. On 5 April, cleaning of the first batch of hot fuel commenced. Prior to the incident that began on 10 April, three batches of hot fuel were cleaned.

While FANP developed normal and abnormal operating procedures for fuel cleaning, these procedures focused almost exclusively on chemical cleaning aspects, and there were no technical specifications for the evolution. Neither these procedures nor the process monitoring instrumentation had the rigor provided for the safety related equipment in the plant that is operated by the Paks NPP. For example, there were no temperature indications inside the cleaning tank. The FANP operators did not recognize that the decreasing delta T between the inlet and outlet temperatures of the cleaning tank cooling system were indicative of a cooling problem within the tank. Also, the FANP operators did not have any procedures as to radiation levels that would be indicative of fuel cladding failure of an individual fuel element or of more extensive fuel failure. This deficiency contributed to delays in recognizing the cooling incident, the extent of fuel damage and associated responses. There was also no consideration given to actions that should be taken in the event of cooling failure and associated elevated fuel temperatures in order to avoid the thermal shock that apparently did much of the damage to the fuel in the cleaning tank.

A tour of the FANP fuel cleaning control station and equipment indicated that these facilities did not meet plant standards for safety-related systems. Labelling of most valves and other controls/indications was either non-existent or of low quality. Some indications were taped over. Housekeeping in general in the U1/U2 reactor building was poor, not just in the areas for which FANP had been responsible.

1.2(1) Recommendation: Operational activities with safety significance should not be turned over to contractors without operating organization supervision. Operational activities with safety significance performed by contractors should be implemented using the operational controls and limits applicable for plant operations with safety significance.

<u>Basis</u>: *At all stages the operator should be able to demonstrate that it is in control of the facility and has adequate organization, management, procedures and resources to* *discharge its obligations and, as appropriate, its liabilities. (Paragraph 3.10 of GS-G-1.2)*

The fuel cleaning project was one of several initiatives related to solving the magnetite deposition problems that have affected the plant for several years. These initiatives were the responsibility of a dedicated Deposit Team. The team leader has no control or authority over team members and members are appointed by their departments and can be changed at any time. The Deposit Team Leader is a member of the Technical Department, but periodically reports to the senior plant managers and less often to the Board of Directors.

HAEA made a decision that an operating license was not needed for fuel cleaning operations as it was only a temporary, short-term activity. It failed to use conservative decision making in ensuring that this unique, first of a kind activity was properly analysed and tested prior to operation.

Since the incident, the cooling system for the fuel cleaning tank has been under the control of Paks NPP operations personnel. Controls and indications for the cooling pumps, and temperature and neutron flux indications have been installed in the Unit 2 control room. Operating procedures for this system have been developed and approved in accordance with Paks NPP operations division requirements.

1.3. QUALITY ASSURANCE PROGRAMME FOR THIS FUEL CLEANING ACTIVITY

At the end of 2002, HAEA completed quality management system certification per ISO-9001, 2001. This process-oriented certification required a comprehensive self-assessment.

Paks NPP has a mature and comprehensive quality management system in place. Paks NPP accepted the FANP QA program as acceptable to be used for the fuel cleaning operation. Paks NPP conducted QA supplier evaluations of FANP related to tank manufacture and had no documented findings. Two QA surveillances of fuel cleaning activities were conducted. One was monitoring of activities on 15 March 2003 during which time power was lost to both pumps used in Mode C. The individual performing the surveillance did not identify the safety significance of this situation, as both pumps were powered from the same circuit breaker, which violated the safety analysis commitment that the pumps would have different power supplies in order to satisfy single active failure criteria.

FANP operating procedures for fuel cleaning specified that, in order to ensure the fuel assemblies were properly installed in the tank, the assemblies should be at least 13 mm below the level of the seating surface of the tank (in order to ensure adequate cleaning of the fuel), and that this determination should be made through a visual examination using an installed video camera. In practice it was determined that this was not a workable solution, and an agreement was reached between a refuelling machine operator and FANP shift personnel that the limit should be 20 mm as that was the height of the lip on the seating surface where the fuel assemblies rested (and if the fuel assembly was less than 20 mm higher than expected then it must not be sitting on the lip). It was further agreed that this distance would be determined based upon indications related to fuel handling machine movement after the fuel reached the seating surface, rather than through the video camera. This agreement was not documented and related FANP procedure was not revised to reflect this agreement. Investigations subsequent to the incident indicated that the method used for measuring fuel assembly height was not reliable under all circumstances. These investigations also indicated that incorrect seating of fuel assemblies could also cause inadequate cooling of the assemblies in Mode B (due to the simple nature of the safety analysis performed in support of licensing this cleaning process, this information was not identified earlier).

1.3(1) Recommendation: The Paks NPP should ensure that temporary procedures, including those involving contractor activities, are developed, controlled, implemented and revised using the same controls as applied to permanent procedures.

Basis: *Temporary procedures/instructions may be used only when permanent procedures do not exist. The document control requirements for temporary procedures should be the same as the controls applied to permanent procedures The responsible organization may delegate and/or require suppliers or other organizational units to develop and implement all or part of the QA programme, but shall retain overall responsibility for the implementation and effectiveness of the programme. (Paragraph 324 of 50-C/SG-Q, Annex Q13)*

1.4. TRAINING AND QUALIFICATION OF PERSONNEL INVOLVED IN THIS FUEL CLEANING ACTIVITY

While HAEA has developed a comprehensive training plan for its personnel, attendance at scheduled training is not required, and much of the job specific training is provided through unstructured OJT.

The only special training provided on fuel cleaning operations for Paks NPP shift operations personnel was for the fuel handling operators who transferred the fuel to/from the fuel cleaning tank, and who were responsible to ensure that the fuel was properly placed in the tank. These were the only responsibilities for fuel cleaning assigned to Paks NPP shift operations personnel. Paks NPP shift operations personnel were not given any monitoring responsibilities of the FANP engineers who had total responsibility for the operation of the fuel cleaning process.

FANP provided on the job training for its personnel and pre-job briefings. However, due to serious mistakes in the Safety Analysis and also in the derived Operating Procedures FANP personnel seriously misdiagnosed the observed event, excluded the possibility of overheating of the fuel elements in the cleaning tank and seriously underestimated the extent of fuel damage.

1.4(1) Recommendation: The Paks NPP should establish controls to ensure that contractor personnel performing safety-related work have the competencies and qualifications needed for their assigned tasks. Additionally, Paks NPP should provide monitoring of the performance of contractor personnel in carrying out their assigned tasks.

Basis: *Before undertaking any safety related work, staff should demonstrate appropriate knowledge, skills and attitudes to ensure safety under a variety of conditions relating to their duties. (Paragraph 3.3 of NS-G-2.8). The contractors selected for specific safety related work should be required to provide documentary evidence that they and their staff have the appropriate training and qualification to perform the assigned work, and if necessary, the required certification. (Paragraph 3.41 of NS-G-2.8).*

1.5. MANAGEMENT OF SAFETY

The conclusions in this section of the report are based upon a summary of management issues identified in all review areas. As such, the issues and recommendations are directed primarily to senior managers.

The Paks NPP has had good operational performance for some time. In such a situation it can be difficult for both the plant and the regulator to recognize weaknesses in safety culture. After this incident, HAEA collected information over the past several years that it considered to be indicative of a decline in safety culture at the Paks NPP (this was a compilation of a number of communications from HAEA to Paks NPP over this time that HAEA felt were related to safety culture). The team did not draw an independent conclusion as to the validity of the HAEA conclusions. However, in reviewing information regarding this incident, the team identified the following that could also be indicative of safety management and safety culture weaknesses:

– **Commitment to safety.** The responsibility for operation of the fuel cleaning system was turned over to the contractor. The plant operations organization was more in the mode of a service provider to the contractor (FANP) than in having responsibility for the safe operation of this system that interfaced with and depended upon plant systems important to safety.

– **Conservative decision making.** Neither HAEA nor the Paks NPP used conservative decision making in the rigor of safety assessment given to this unproven fuel cleaning system. The aggressive schedule for design, fabrication, installation, testing and operation of the fuel cleaning system contributed to a sense of urgency that influenced decisions regarding the rigor of nuclear safety assessment and design review. The mindset was that the successful cleaning of cold fuel demonstrated the safety of the design and that the new system for cleaning hot fuel was only a larger version of this proven design.

– **Use of procedures.** The normal operation and emergency operating procedures used for fuel cleaning were not treated as operating procedures that were to be reviewed and approved by the plant operations organization. Key provisions in the safety analysis regarding availability of the crane to open the cleaning tank upon completion of cleaning or in the event of loss of cooling were not included in the fuel cleaning procedures. Modifications to procedural requirements for ensuring the fuel assemblies were properly positioned in the tank were made informally without modifying the associated procedure.

– **A reporting culture.** Problems in implementing the procedural requirement for ensuring the fuel assemblies were properly positioned in the fuel cleaning tank were not reported and addressed through established methods (they were noted in the FANP log). There were delays of 1 hour and 40 minutes in opening the fuel cleaning tank for earlier batches, but this issue was not elevated for resolution by FANP or Paks NPP. Neither FANP nor Paks NPP personnel responsible for the fuel cleaning were apparently aware of commitments made in the safety analysis for prompt opening of the tank upon completion of cleaning.

– **Challenging unsafe acts and conditions.** There are no indications that responsible personnel at HAEA, Paks NPP or FANP challenged the design or operation of the fuel cleaning system even though the analysis showed that boiling could occur only 9 minutes after loss of cooling to the tank.

– **A learning organization.** There are indications that communications between organizational units at Paks NPP are not encouraged except through Department or Division managers. Thus, opportunities to share information among personnel in different organizational units are reduced. Personnel in emergency preparedness and radiation protection organizations did not demonstrate knowledge of information in other organizational units that could be useful in improving their work. The information exchange among the different organisation units have some communications barriers.

1.5(1) Recommendation: The Paks NPP should use the assessment provided by HAEA concerning safety culture, supplemented by its own assessment information, in order to develop a program to continually monitor and improve safety management and safety culture at the plant. This improvement program should be transparent to both HAEA and the public in order that any doubts that the public or HAEA may have about the importance that the Paks NPP gives to safety can be addressed.

Basis: *In order to maintain high effectiveness of safety management at the plant, the operating organization should ensure a very high level of commitment to safety. The starting point for safety management is the involvement of top managers in all organizational structures. The lead in safety matters should come from the highest levels of management. Their safety policies and attitudes should be of the highest standards, and should permeate the operating organization at every level and extend to other organizations performing delegated tasks. (Safety Guide No. NS-G-2.4, Section 5.5) Organizations typically go through a number of phases in developing and strengthening safety culture. IAEA Safety Report Series No. 11 identifies three stages:*

(1) *Safety is compliance driven and is based mainly on rules and regulations. At this stage, safety is seen as a technical issue, whereby compliance with externally imposed rules and regulations is considered adequate for safety.*

(2) Good safety performance becomes an organizational goal and is dealt with primarily in terms of safety targets or goals.

(3) Safety is seen as a continuing process of improvement to which everyone can contribute.

Root cause analysis does not focus enough on management system weaknesses (see section 3 for details).

The Deposit Team was established to provide a coordinated response to resolving the problem of magnetite deposits on the fuel and other primary circuit components. This Team provided the interface with FANP including coordinating review of FANP procedures for the conduct of fuel cleaning. While the concept of a coordinated response to resolving this issue was appropriate, the implementation of this Team approach has some difficulties. These include:

- The leader does not have authority over members of the team
- Members of the team are nominated by their managers, but have no authority to act for their organization

- The team made decisions that have circumvented management systems designed to control plant operations (procedure approval and revision, operating limits for safety systems).

1.5(2) Recommendation: The Paks NPP should establish methods to ensure that there is greater management oversight of activities affecting safety, and a more visible top management level commitment to safety through actions as well as words.

Basis: *In order to maintain high effectiveness of safety management at the plant, the operating organization should ensure a very high level of commitment to safety. The starting point for safety management is the involvement of top managers in all organizational structures. The lead in safety matters should come from the highest levels of management. Their safety policies and attitudes should be of the highest standards, and should permeate the operating organization at every level and extend to other organizations performing delegated tasks. (Safety Guide No. NS-G-2.4, Section 5.5).*

2. REGULATORY OVERSIGHT / INTERFACE

2.1. REGULATORY REVIEW

Regulations for Nuclear Safety are prescribed in Nuclear Safety Codes 1 through 5 that are attached as Schedules to the Governmental Decree 108/1997. They set out HAEA-Nuclear Safety Department's (NSD) principles and criteria for regulatory licensing activities. For each Code, Guidelines are provided that interpret how the licensees and HAEA-NSD will work to satisfy its requirements. The Nuclear Safety Codes cover Regulatory Procedures, Operations, Design, Quality Assurance of Power Reactors and regulation of Research Reactors.

The Nuclear Safety Codes were last revised on June 25, 1997. Currently, they are under revision. Governmental Decree 108/1997, requires in Section 3(4), that, "The Regulations shall be reviewed, and updated as needed, once in every five years, with regard to scientific achievements and international experience." International experience regarding processing of modifications has changed with the updating of the IAEA safety standards in 2001. Those changes directly impact the IAEA safety standards for conducting Safety class evaluations and the categorization of modifications relevant to conducting safety analyses.

Built into the Nuclear Safety Codes are provisions for licensing. These provisions apply to the nuclear power plant as a facility, the safety systems, as well as the components of the plant. Contained within the Nuclear Safety Codes are requirements to issue licenses for modifications. There are five types of licenses, i.e., principal modification, fabrication and import, installation, modification (which includes fabrication, import and installation reviews) and operation licenses. Because the Final Safety Analysis Report (FSAR) does not meet current standards, it cannot be relied upon to form the safety basis of PAKS NPP. If the FSAR was updated and available for use, then many modifications could be performed without going through the formal licensing approval process by the HAEA.

Included in the licensing review for modifications is a review of the modification's safety significance and its Safety class in that order. If a modification has an impact on safety functions it then continues in the licensing process. The Safety class then determines the level of review. If the modification involves a Safety class 1 or 2 component, then a full safety review is conducted. However, for Safety class 3, some review requirements are eliminated. Additionally, by reviewing the Safety class after the safety significance review, the process does not categorize Safety classes 1-3 by safety significance. Most significantly, a review of the modification by an independent organization is eliminated as a requirement for Safety class 3 modifications. For some Safety class 3 components it is possible that the Safety class is the sole criteria for determining what type of review is to be to conducted. Reviewing the safety significance first then reviewing the Safety class essentially defeats the purpose of a safety review for Safety class 3 components.

There are four Safety classes as prescribed in NSD Policy No. 3.1. Components are placed in Safety classes based upon the consequences of their failure and the probability that the component may be required. This determination is conducted by the licensee according to a Guideline issued by HAEA and is used primarily as a design classification. The design classification determines what codes and standards apply to the modification. Safety Class 1 includes components that can cause serious events e.g., reactor coolant system. Safety Class 2 consists of components that are used to mitigate events and Safety class 3 consists of components that have some impact on safety but do not prevent releases of radioactivity or prevent mitigation of events. Components placed into Safety class 4 have no impact on safety.

This component level classification of equipment means that nearly every change to a component (that might impact safety) requires some type of license from the HAEA. This results in a significant burden for the licensee and the HAEA. In the past, around four thousand license submittals were forwarded to the HAEA in a year. These four thousand submittals might involve many separate licenses. Sometime ago, internal actions were taken to provide the licensee with the authority to issue approvals for some piping codes. This reduced the number of license submittals to HAEA to around 250 a year of which about 60-70% were modification requests. About 40 staff are available throughout the HAEA/NSD organization available to review licenses with 14 of them dedicated to license reviews. Paks NPP designates a significant number of license submittals as "urgent." Given that the Nuclear Safety Codes have the effect of law and must be issued prior to implementing changes, this places the HAEA under pressure to complete the reviews in a timely manner and may distract from their ability to focus on safety significant submittals.

Importantly, Government Decree 108/1997 (VI. 25.) Korm, stipulates that, "HAEA NSD shall proceed with priority, if so requested by the licensee, with regard to regulatory matters in connection with activities with substantial impact on nuclear safety, which are subject to licensing and are to be completed during the period between stoppage and restarting a nuclear facility." This Decree may compound the problem of the HAEA prioritizing their work. This situation results in three goals for the HAEA. Reviewing components based upon Safety class, safety significance and whether the work supports a unit stoppage (outage). These demands greatly complicate the HAEA's workload and may result in an incorrect sense of priority.

IAEA Standards suggest that modifications should not only be given a Safety class designator but be analyzed by "Safety Categorization." The Safety Categorization should be conducted by the Regulatory Body to determine the level of review for the modification based upon its impact on safety functions, regardless of its Safety class. This process assures that all modifications (of Safety class 1-3) are designed and reviewed by the licensee according to design requirements while focusing the Regulatory Body's review process on those modifications that have the highest safety implications. This protocol is essentially opposite of the protocol used by the HAEA, in that, the HAEA reviews safety significance first then they use Safety class to determine the level of review. The IAEA safety standards would have the regulatory body determine the Safety class first, then review all Safety classes for safety significance.

2.1(1) **Recommendation:** HAEA should review and revise its Nuclear Safety Codes as required by Government Decree 108 and experiences gained from this incident and other regulatory matters affecting nuclear safety.

Basis: IAEA Safety Standard GS R-1, 3.3(9), *"The regulatory body shall ensure that its regulatory principles and criteria are adequate and valid, and shall take into consideration internationally endorsed standards and recommendations."*

2.1(2) **Recommendation:** HAEA should pursue changes to its Nuclear Safety Code to reduce the number of various licenses required for plant modifications and ensure its focus is on those aspects with the greatest nuclear safety significances.

Basis: IAEA Safety Standard GS R-1, 3.2(3), *"The regulatory body shall provide for issuing, amending, suspending or revoking authorizations, subject to any necessary conditions, that are clear and unambiguous…"*

2.1(3) **Recommendation**: The HAEA should review Government Decree 108 and its nuclear safety policy to provide a priority system based upon IAEA safety standards of safety class and categorization.

Basis: IAEA Safety Standard GS.G-1.2, 2.5, *"The review and assessment of nuclear facilities necessitate considerable amounts of work and resources, and appropriate plans should be made for these. The regulatory body should develop a programme to review and assess information provided by the operator (see Ref. [4], paras 4.2–4.8) or collected during its own inspections [3]. The co-operation of the operator should be obtained to ensure that review and assessment can be carried out in an effective and informed manner."*

Basis: IAEA Safety Standard NS-G-2.3, 4.3, *"Following the completion of the initial process of safety assessment (see para.4.8), the proposed modification should be categorized in accordance with its safety significance. This categorization should follow an established procedure agreed with the regulatory body."*

2.1(4) **Recommendation:** HAEA and the Paks NPP should accelerate finalizing a Final Safety Analysis Report (FSAR).

Basis: IAEA Safety Standard NS-G-2.3, 2.1, *"Once a plant is completed and approved for operation, its operation needs to comply with all applicable regulations and standards and other relevant safety requirements. Throughout its lifetime, the plant should be regularly inspected, tested and maintained, in accordance with approved procedures, to ensure that it continues to meet the design requirements and remains consistent with the assumptions and results of the safety analysis."*

2.2. REGULATORY ASSESSMENT

2.2.1 Safety Analysis

It is important to review the licensing process for the seven-assembly cleaning tank before reviewing the processing of the thirty-assembly cleaning tank. The seven-assembly cleaning tank was a new fuel treatment process, however, during the licensing process it was treated as a modification. This approval is based on national regulation. It was given a Safety class 3 ranking because it was determined to be fuel-handling equipment only. Afterwards, when the thirty-assembly cleaning tank was licensed by the HAEA, that modification was treated as similar in function and impact as the seven-assembly cleaning tank even though the fuel conditions were to be much different. It was also classified as Safety class 3 and, therefore, not subject to the full range of review. The HAEA Code for Operations, Volume 4, Operations, Section 11, Handling of Spent Fuel specifically requires (11.002) "Special attention shall be paid of the requirements, regulations and procedures of the following activities: …by on-site movement of spent fuel, i.e., cooling of spent fuel."

During HAEA's review and assessment for the seven-assembly cleaning tank modification, HAEA determined that the cleaning system had no interaction with other plant safety systems or components and, therefore, would not impact any safety function. As a result, that modification was given a License in Principle. However, during the review the team observed that the electrical supply for the cooling pumps was directly tied to the plant emergency diesel generator (a plant safety system), therefore, it potentially did have an impact on safety systems. In accordance with the Nuclear Safety Code, a complete review of the modification was not conducted by HAEA, e.g., a license for fabrication, assembly and import, they were issued by Paks NPP. Also, HAEA's Nuclear Safety Code has provisions to issue a modification license if the modification affects a safety function, is complex, or might need a commissioning program. Even though this modification included an unproven technology, the HAEA did not enact the provisions to conduct a review and assessment for a modification license. Nor did the HAEA review or verify the claims by FANP that the cleaning process had been successfully used to clean fuel in another reactor in France to determine similarity with the proposed modification for Paks NPP. In fact, this process was used in France, however, it was used to clean one fuel pin at a time and not an entire fuel assembly or multiple fuel assemblies. This cleaning process is a modification of Framatome's ADMA cleaning process that is used throughout the industry to reduce the radioactive source term in plant systems. A vessel structure was designed and added to the system to clean nuclear fuel.

The safety analysis for the seven-assembly cleaning tank modification had a thermodynamic analysis regarding the amount of heat that the spent fuel could accept, but it did not include an analysis for the heat removal capacity of the cleaning system based upon the seven assemblies being in the cleaning tank. This becomes important because the thirty-assembly cleaning tank did have such a calculation due to the increased decay heat load. Furthermore, the tank was a different detailed design (see part 3). Thus, in the team's judgment, the two safety analyses were not the same and the two modifications in terms of risk to safety functions were not similar and in the licensing process, Nuclear Safety Code 1, paragraph 4.006a (… or the modification of components of the same type and accomplishing the same function), would require a "modification license" be issued not a "license in principle."

After successful operation of the seven-assembly cleaning tank and later when corrosion issues continued there was a special fuel deposit team established to resolve the issues with fuel deposits. Part of their solution was to conduct ex-core cleaning after some significant consideration was given to in-core cleaning. Nevertheless, ex-core cleaning was chosen and FANP developed a cleaning process for thirty assemblies. The fuel deposit team reviewed the safety analysis provided by FANP and forwarded it to the Technical Organization (MIG). Normally, the Technical Organization itself would develop the license package. It appears that this deviation did not impact on the content or processing of the package because the HAEA had only one question concerning the content of the package. After approval by MIG, modifications packages that involve nuclear fuel are forwarded to the Quality Inspection Department (MINFO). A decision was made that the Safety Department would review the modification package. This decision was made to provide for some independence in the review. Once the Safety Department processed the package they asked the Quality Inspection Department for an expert review of the package. The manager of the Quality Inspection Department and one other qualified colleague conducted the safety review. Apparently this review was not adequate enough to identify the flaws in the safety analysis.

After Paks NPP approved the modification then it was sent to the HAEA where it followed the normal licensing processes. The modification was assigned to a reviewer at HAEA. Nuclear Safety Code 1 and HAEA Guideline 1.5, "Licensing Documentation for Modification of Nuclear Power Plant Systems and Components" were used to process the modification. The team's review of the requirements contained within Nuclear Safety Code and Guideline 1.5, concluded that the modification package contents did not meet the requirements contained within Sections 3.1, 3.1.1, 3.2.1, 3.2.4, 4.3, 5.0 or Table 4.1. Specifically, the following items were required by those paragraphs and they were not provided within the modification package:

- "Reliability of the system component will or could be deviate from prescribed in the design, that is valid before the modification." The licensee was continually changing the power supplies for the system pumps and the size of at least one of those pumps.

- "Modifications that could change the course of events accounted for in the design, i.e. where the modification changes or could change the course of the events calculated in the safety analysis report, or a probability of new transients could be assumed." There was no probability analysis contained within the modification package.

- "…the ensuing alterations related to the content of the Safety Report and their evaluations." There was no Safety Report analysis contained in the modification package.

- "Documents ensuring the updating of the Safety Reports needed because of the modification are to be attached to the application, together with the draft of the updated Operational Conditions and limits prepared for licensing and/or validation, and the schedule of taking them into force." There were no documents updating the Safety Report or Operational Conditions.

- Table 4.1 specifies that for "licenses in Principle," that "documentation for human conditions of the modification (Education, training, post-graduation training, examinations)" and "Administrative and documentation pre-conditions of the Modifications (Modifications and new versions of Safety Report, Technical Operating Procedures, Manuals, Programs, etc.)" Documentation for human conditions was not provided nor were the Safety Report or Technical Operating Procedures (other than that emergency procedures that were inadequate) submitted.

- "For the purpose of proceeding to obtain the Modification License in Principle and the license for Construction (installation), the documentation establishing the Application shall be completed in depth and details that provide basis for Construction Design, and enables to implement the Modification, to get it commissioned and the Authority inspection performed". Clearly, the submittal did not contain the details of the modification in accordance with the intent of this requirement. Additionally, the submittal in many ways did not meet the requirements contained in Section 4.3 Establishing Safety, General Principles.

- Section 5. requires: "The submitted documents in general shall contain the unanimous declaration of the License that the implemented Modification and the "as built" state is consistent with the licensed documentation, or in case of deviation not affecting the safety, the itemized and identifiable list of the document(s) proving the reporting referring to the deviation, preceding the start of construction." Clearly the HAEA did not have all the required documentation concerning the as built configuration during the review of the cleaning system.

Despite the incomplete license application, the HAEA processed the application. According to that process the reviewer determined that the modification did have an impact on safety, so it was processed for a license review. At that point in the process the reviewer is required to determine the Safety classification.

Paks NPP had classified the equipment as Safety class 3 based upon their design guides. At HAEA, there was some consideration given to determining that the modification was Safety class 2 instead of Safety class 3 (which would result in a more thorough review and more stringent requirements for internal radiation and thermal monitoring and handling of the nuclear fuel). After reviewing the Finish guidelines for assigning Safety classes, HAEA identified that transport casks were rated as Safety class 3 by STUK. By a consensus decision, HAEA determined that the cleaning tank was similar to a transport cask and, therefore, Safety class 3 was appropriate. Further, HAEA considered this modification to be of the same type and function as the seven-assembly cleaning tank and, therefore, it was not a significant change to any safety function. However, because the modifications were not similar, a modification license should have been pursued, which would have required a more in-depth review of the design and operation of the system.

The safety analysis for the thirty-assembly cleaning tank includes a simple thermodynamic analysis both for the heat removal capacity of the spent fuel pool and the heat removal capacity of the cleaning system. In this calculation there is a statement that for a loss of cooling the time to boiling could be 9 minutes and 12 seconds. Initially there were measures taken by both the vendor and the licensee to have a crane available to open and lift the lid of the cleaning tank to allow for cooling of the fuel in the event of an emergency. During the regulatory review it was determined that this was an adequate mitigating strategy. During the team's review of the procedures, we observed that the vendor's procedures did not have an urgency built into the mitigating actions. The analysis written by the licensee did have a time frame, however, the time frame was that there was at least 42 minutes for operator action. There were no controls to keep the crane available for these mitigating procedures. Generally, the procedures were written to respond to a pump loss and did not contemplate prolonged operation in Mode B, which only uses a submersible pump for short term cooling while installing or removing the fuel and tank head.

The HAEA individual who reviewed the specific modifications was a Chemical Engineer with a background in operations at PAKS NPP. Because this evolution was seen primarily as a chemical process, this individual was assigned to review the submittal. HAEA's licensing process also has an option to consult an independent consultant for the license review even for Safety class 3 modifications. This option was not applied for this modification.

2.2.1(1) Recommendation: HAEA should review and revise their guidelines to ensure that all necessary actions are taken to verifying claims of vendors and the licensee.

Basis: IAEA Safety Standard, GS-G-1.2, 3.40, *"Much effort that the regulatory body will need to expend in the review and assessment process will be concentrated on the performance of a step by step review and assessment procedure to determine whether the applicable safety objectives and requirements for each aspect or topic have been met. This stage of the process consists in examining the submissions from the operator on its managerial arrangements, engineered systems and operational procedures and on the safety analysis for the facilities. This safety analysis should cover both normal and fault conditions in order to demonstrate that the safety of the facility meets the safety objectives and requirements of the regulatory body. It should be the responsibility of the regulatory body to determine whether these submissions have provided a sufficiently complete, detailed and accurate demonstration of this. In carrying out the review and assessment, the regulatory body may find it useful to perform its own analyses or research. Any input of this nature by the regulatory body should in no way compromise or diminish the* *operator's responsibility for the safety of the facility…."*

Basis: IAEA Safety Standard, GS-G-1.2, 3.1, *"The review and assessment process should include checks on the site and elsewhere to validate the claims made in the submissions."*

2.2.1(2) Recommendation: HAEA should evaluate its criteria for initiating independent review of modifications, particularly regarding novel, unproven or unusual techniques.

Basis: IAEA Safety Standard, GS-R-1, 5.9, *"A primary basis for review and assessment is the information submitted by the operator. A thorough review and assessment of the operator's technical submission shall be performed by the regulatory body in order to determine whether the facility or activity complies with the relevant safety objectives, principles and criteria. In doing this, the regulatory body shall acquire an understanding of the design of the facility or equipment, the safety concepts on which the design is based and the operating principles proposed by the operator, to satisfy itself that:*

… (3) the technical solutions, and in particular any novel ones, have been proven or qualified by experience or testing or both, and are capable of achieving the required level of safety."

2.2.1(3) Recommendation: HAEA should provide clearer guidance to the license reviewers regarding making determinations regarding the similarity of components being evaluated to determine their safety significance.

Basis: IAEA Safety Standard GS-G-1.2, 3.2, *"The regulatory body should provide internal guidance on the procedures to be followed in the review and assessment process and guidance on the safety objectives to be met. Detailed guidance on specific topics for review and assessment should also be provided, as necessary. Consideration should be given to the extent to which the regulatory body's internal guidance may be made available to operators and the public."*

2.2.2 Training

During the IAEA's IRRT review the HAEA presented a newly developed training and qualification program for their inspectors (this includes staff who review licenses). However, the team determined that this program had not been implemented. It was not implemented because it was too difficult to make time available for inspectors to attend mandatory training. Nevertheless, there is an annual training program for inspectors. Generally, inspectors who review license submittals are trained and qualified through on-the-job training and observation. They do participate, when available, in the annual training program. Supervisors make the decision on whether an inspector is qualified.

The annual training program for 2002 was very comprehensive. It consisted of 75 hours of training made available in areas such as enforcement, fundamentals of inspection, regulatory activities, Nuclear Safety Codes and safety improvements (much of the annual training is provided by universities, vendors and international experts). Importantly, there was training offered on safety analysis. The four courses consisted of 17 hours of instruction in the areas of probabilistic safety analysis and design basis events. Many of the inspectors who review licenses attended this training.

2.2.2(1) Recommendation: HAEA should re-assess the training needs for inspectors and develop the appropriate qualification requirements based on IAEA safety standards.

Basis: IAEA Safety Standard GS-G-1.1, 5.1, *"In order to ensure that the proper skills are acquired and that adequate levels of competence are achieved and maintained, the regulatory body shall ensure that its staff members participate in well defined training programmes. This training should ensure that staff are aware of technological developments and new safety principles and concepts."*

2.3. AUTHORIZATION

The content requirements for license submittals are provided in the Nuclear Safety Codes. The type of license required determines the depth and breadth of the review. Because so many of the submittals are designated as "urgent" often the reviewer must include notification or inspection points in the license. These license conditions specify that the licensee must notify the HAEA when certain conditions exist so that the HAEA can make a determination on whether or not to inspect the item. While this practice does work, with the extensive number of commitments HAEA has, it is highly reactive and difficult to track and verify them all.

The structure of the actual license is dictated by Governmental requirements. In that actual license, there is a decision section, a section of license conditions and a background section. There are no guidelines for stipulating the content of the license. The license itself may not provide the safety basis for the licensing decision. It is the responsibility of the individual reviewer to determine the content of the license, however, the Nuclear Safety Director signs all licenses.

2.3(1) Recommendation: Refer to recommendation 2.1(2). The HAEA and the licensee should work more efficiently to better plan the submittals so that fewer "urgent" licenses are requested.

2.3(2) Recommendation: HAEA should incorporate IAEA safety standards to ensure that the license includes the safety basis among other stipulations.

Basis: IAEA Safety Standard GS-G-1.4, 5.5, *"At several stages of the authorization process a decision will have to be made on whether a license should be granted. The regulatory body should record in the form of a report the basis for such a decision. This report should summarize the review and assessment performed by or for the regulatory body and should provide a clear conclusion about the safety of the authorized activity. Typically, the report should cover the following points:*

- *reference to the documentation submitted by the operator;*
- *the basis for the evaluation;*
- *the evaluations performed;*
- *conformance with regulatory requirements and guides;*
- *comparison with similar (reference) facilities;*
- *independent analysis performed by the staff of the regulatory body or by*
- *consultants on its behalf;*
- *conclusions with respect to nuclear safety;*

- *reasons for the decisions made;*
- *any additional conditions to be fulfilled by the operator."*

2.4. INSPECTION

Site inspectors were involved in the inspection of the cleaning systems. There were no license conditions for the inspectors to verify for the cleaning system. Nevertheless, based upon the information gained from attending routine licensee meetings, they conducted two inspections per week during the cleaning process. For instance, one day prior to the incident they conducted a radiation safety inspection. It appears that the site team was trained and qualified to conduct inspection of the cleaning process. Overall, it appears that the site inspection team conducted more inspections than what might normally be required for Safety class 3 components.

Given that the HAEA and PAKS NPP declared the cleaning process as Safety class 3, much like a C-30 spent fuel cask, this review team pursued the requirements for inspection of a C-30 spent fuel cask. Those requirements include inspections of the qualification of the people handling the spent fuel cask. They would require inspections of the handling procedures for the spent fuel cask. Also, they would require inspections confirming the safety analysis. For the cleaning system, these inspections were not conducted. HAEA representatives stated that because the cleaning tank was under water and there was continuous noble gas monitoring, they did not believe that those inspections were necessary. Thus, with regard to inspection activity, as discussed earlier, the inspection staff did conduct more inspections that might normally be required for Safety class 3 components, but overall HAEA did not treat the cleaning system modification similar to a spent fuel cask.

3. RISK ANALYSIS AND ROOT CAUSE ANALYSIS

3.1. EVALUATION OF THE RISK ANALYSIS RELATED TO FUEL DEPOSITION PROBLEMS

A review of the HAEA Report on the Official Investigation of the fuel cleaning incident that took place at Paks NPP Nuclear Power Plant on 10 April 2003 provides a good historical perspective. It underscores the shortcomings of the safety analysis processes that was used in part to form the basis of the decisions and actions that led to fuel damage at the Paks NPP. Management decisions to address the magnetite deposition on the fuel cladding surface was the subject of a lengthy series of attempts for resolutions and responses with HAEA beginning as far back as 1996.

A source of magnetite in the primary circuit was the high number Steam Generator (SG) de-contamination cycles performed during one outage. In the early 90s a corrosion/erosion problem was identified in the SGs' feed water collectors. One concern during the replacement of feed water collectors was radiological dose to maintenance staff. Several WWER plants managed collective doses to workers during replacement of feed water collectors by physical shielding. This experience was only recently used by the staff at Paks NPP and was not a major consideration when analyzing the risks associated with SG de-contamination. By 1998, SG de-contamination was suspected to be the source of the fuel deposition problem but was not firmly recognized as such until 2002.

The history of the plant shows that SG de-contamination was carried out 24 times between 1993 and the end of 2001. The reason for this high number of activities was the need to repair feed water collectors in the SG's. Maintenance programmes for the SG feed water collector repairs were however repeatedly postponed. The cumulative problems and risks associated with the postponement of needed feed water collector repairs were not anticipated.

As a consequence of these decisions, the SG repairs became more urgent as the years went by. A large amount of SG repair work had to be completed on a short time scale. This in turn was a contributor to the dose control regime applied to the SG work, i.e. de-contamination. In 2001 a total of fourteen SGs' were de-contaminated. The high incidence of this de-contamination work led to significant magnetite deposition problems on the surface of the fuel. The deposition problems then led to the need for an urgent programme for either the replacement or chemical cleaning of fuel.

The decisions by Paks NPP to de-contaminate the SG's were primarily made to meet "As Low As Reasonably Achievable"(ALARA) dose principles. The decision to use the SG de-contamination process was taken and applied to Units 1, 2 and 3. The strategy of physical shielding was applied for the feed water collector replacement work on Unit 4.

3.1(1) **Recommendation**: Paks NPP and HAEA should seek and actively share information and experiences with other WWER operating organizations that encourages a balance of risk approach to optimize NPP strategies for dealing with problems associated with WWER reactors.

Basis: *IAEA Safety Standards NS-R-2 Safety of NPP: Operation, 2 Operating Organisation, 2.22 ...the operating organization shall obtain and evaluate information on operating experience at other plants to derive lessons for its own operations. To this end the exchange of experience and the contribution of* *information to national and international organizations is of great importance.*

See also: INSAG-12 *'Basic Safety Principles for NPP', 4.5.10. Feedback of operating experience, 299...The plant management has access to operational experience relevant to plant safety from other nuclear power plants around the world. (Refer to IAEA Standard).*

3.2. EVALUATION OF THE RISK ANALYSIS RELATED TO FUEL CLEANING ACTIVITIES

In 2002 Paks NPP management determined that additional actions were needed to deal with the accumulation of magnetite deposits on the fuel (i.e. fuel cleaning) and initiated a set of actions they intended to implement during the 2003 planned refuelling outages (see section 1.1 of this report for additional historical details).

The increasing urgency of addressing the fuel deposition problem led to an extremely short programme for the specification, design, installation and testing of the ex-core fuel cleaning system. On 20 June 2002, Paks NPP submitted a proposal for in-core or ex-core fuel cleaning. The first cleaning operation was conducted on 20 March 2003. This extreme time pressure was a significant contributing factor to the shortcomings in the failure to design, analyze and approve the new fuel cleaning system with the rigour demanded by the level of risk involved. The team determined that the processes and procedures used to determine the entire spectrum of nuclear safety risks associated with the fuel cleaning design and operation activities were inadequate. The risks associated with placing almost 10% of the core inventory, with substantial decay heat, in a closed cleaning tank is significant.

IAEA safety standard NS-G-1.4, 'Design of Fuel Handling and Storage Systems for NPP', states in part that the most significant design features of fuel handling and storage systems in nuclear power plants are those which provide the necessary assurances that the fuel and core components can be received, handled, stored and retrieved without undue risk to health, safety or the environment. A review of the design features and operating instructions for the safe operation of this cleaning activity were clearly deficient.

As stated in IAEA Safety Standard NS-G-1.4, all design aspects of the fuel handling and storage systems are thus related to the objectives of: maintaining sub criticality of the fuel; ensuring the integrity of the fuel; cooling irradiated fuel; ensuring radiation protection and safety in accordance with the Basic Safety Standards; and preventing unacceptable releases of radioactive material to the environment. Also, the IAEA Safety Standard NS-R-1, Safety of NPP: Design states, in part, that the handling and storage systems for irradiated fuel shall be designed to prevent criticality by physical means or processes, preferably by the use of geometrically safe configurations, even under plant states of optimum moderation.

For the AMDA fuel cleaning system deployed at Paks NPP: Borated water, inside the cleaning tank, was displaced by a steam bubble created during the evaporation of coolant for the fuel. Independent assessments have confirmed that in the current situation sub-criticality will be assured by boron dosing of pond water. The geometry of the fuel was not maintained because of overheating and thermal shock, causing damage to most of the fuel pins.

The team concluded that the consideration and risks to nuclear safety were clearly not well analyzed by Paks NPP or HAEA for this fuel cleaning operation.

3.2(1) Recommendation: Paks NPP and HAEA should review and revise as necessary their policy, processes and procedures for determining the risks associated with activities affecting nuclear safety.

***Basis**: NS-G-1.4, 'Design of Fuel Handling and Storage Systems for NPP', states in part that the most significant design features of fuel handling and storage systems in nuclear power plants are those which provide the necessary assurances that the fuel and core components can be received, handled, stored and retrieved without undue risk to health, safety or the environment.*

3.3. EVALUATION OF THE ROOT CAUSES RELATED TO FUEL CLEANING ACTIVITIES

Definition: A root cause is a cause or condition which if corrected will prevent a reoccurrence of the problem.

3.3.1 Design Deficiencies

The designer responded to the request from Paks NPP for the provision of a 30 element, out of core cleaning system under urgent requests. The new system was a development of the earlier and successful 7 assembly out of core cleaning system. The request was made on 20 June 2002 and the response accepted by Paks NPP on 13 August 2002. There followed a busy period leading to performance proposal, contract placement, procurement, licensing installation and commissioning. The first fuel cleaning operation took place on 20 March 2003.

The design of the cleaning system was however deficient in several respects: (1) The submersible pump provided for mode B was inadequately sized and had inadequate redundancy / back up, (2) the bypass flows around the fuel assemblies were not fully taken into account in the thermo-hydraulic analysis of the design, (3) potential additional bypass flows around the fuel assemblies, because they may not be correctly seated, was recognized but ineffectively dealt with, (4) the simple thermo-hydraulic analysis of the design that was performed, even though over simplistic, did indicate unacceptable margins in fault conditions (time to boiling) but this was not effectively recognized, (5) the provision for lifting the cleaning vessel head in mode B or in fault scenarios was inadequate, (6) changes in the configuration of the cleaning tank design (outlet pipe position and inlet plenum chamber) going from a seven assembly cleaning tank to a thirty assembly cleaning tank was not recognized to be significant, (7) inadequate instrumentation, trend recording and alarm systems were provided to detect off normal conditions during cleaning, (8) Possible fuel assembly seating misalignment due to only one fuel guide plate utilized in the cleaning tank to align the bottom of the fuel assembly in its correct seating location. Slight misalignment will reduce cooling flow. Normally, two guide plates are used for fuel pool storage of fuel assemblies.

Other deficiencies included;

Operating instructions and event recovery procedures that were inadequately specified, especially in terms of time available for response; the assessment of the contractor's design by Paks NPP did not recognize, identify and correct the design failings listed above; the classification of the modification at Class 3 was not commensurate with the nuclear and radiological risk involved, should this modification be 'inadequately conceived or executed'. Class 1 or 2 would have introduced an independent assessment and further reviews; and the assessment and approval process applied by HAEA did not identify the deficiencies noted above.

The team concluded that the recommendations provided in sections 1 and 2 of this report address the team's concerns and corrective actions to be taken for the above noted deficiencies.

3.3.2 Report to HAEA by the Paks NPP

This report refers to the deficiencies in the risks and root causes associated with the 10 April 2003 fuel cleaning incident. The report to HAEA focuses on events between 10 and 13 April 2003. Only a brief reference is made to the historical context (the emerging magnetite deposition problems since 1998 and the 7 assembly cleaning tank). In the 'Event Assessment Section' (10) a good chronology and detailed supporting data are presented. Some sub-sections contain good technical evaluations, e.g. in 10.2, the potential reasons for the inadequate cooling of the fuel are examined and in 10.3 the positioning of fuelling assemblies within the cleaning tank are discussed. Although several deficiencies are exposed, the report does not consider the shortcomings in human factors or the adequacy of Paks NPP safety assessment, operating procedures and instructions, which significantly contributed to the incident.

The Paks NPP report to HAEA is not sufficiently self critical in that it does not examine in a comprehensive manner the licensee's organization to ensure that adequate arrangements are in place to ensure nuclear and radiological safety and to control and manage all activities at the NPP. The direct cause is identified as 'insufficient cooling' and the prime root cause as 'design failure'. Main contributors noted are: 'inadequate checks on the sufficiency of cooling'; 'inadequate checks on fuel loading (with deviations being dealt with via unapproved procedures)'; 'excessive self confidence' (relating to design assessment and licensing) and 'inadequate monitoring on the AMDA system for emergency situations'. While these contributors may be valid, the report does not address the underlying root causes that may have caused the deficiencies noted above to occur.

An analysis of the deeper issues concerning delays to the SG feed water collector repairs and the strategy for SG decontamination leading to magnetite disposition would improve the report.

3.3.3 Report on the HAEA Official Investigation of the 10 April 2003 Fuel Cleaning Incident

This report gives a comprehensive overview of the deposition situation and recognizes that the management of the SG feed water collector replacements and the strategy for decontamination of the SG's is important in the context of the urgent need for fuel cleaning. An examination of the reasons and causes for the delays to the SG feed water collector work should be included. The deficiencies revealed by the event are listed against relevant Nuclear Safety Code clauses and also lists non compliances during operations and the handling of malfunctions. The report makes a number of complaints about long standing concerns, e.g. on the number of urgent requests and on safety culture issues. However, the report does not identify improvements that can be made by HAEA to help resolve these issues.

The assessment and approval process applied by HAEA and Paks NPP was not effective in identifying the design or operational deficiencies discussed earlier in this report. In addition, the human factors and safety culture deficiencies (ref. section 1.5) are not adequately identified in the lessons learned from the Paks NPP and (to a lesser extent) in the HAEA investigations.

3.3(1) **Recommendation:** The Paks NPP and HAEA should review and revise as necessary their processes and procedures used to determine root causes of events. Consideration should be given to evaluate human and organizational factors associated with events, the basic assumptions used in making decisions leading to the events and the deterministic and probabilistic methods used to determine the risks associated with the activities surrounding the events.

Basis: NS-G-2.4 *'The Operating Organization for NPP', 6.64…. Abnormal events important to safety should be investigated in depth to establish their direct and root causes. Methods of human performance analysis should be used to investigate human performance related events.*

4. WWER FUEL CHARACTERISTICS, CHEMISTRY, THERMO-HYDRAULICS AND OPERATIONS

4.1. CHEMISTRY

4.1.1 Background

Steam generator decontaminations at Unit 2 during 1995 – 97

The fundamental reason for the chemical cleaning of fuel was due to the magnetite depositions on the fuel assemblies caused by corrosion products dissolved from decontaminated surfaces of steam generators. Thermal hydraulic anomaly in the reactor core, caused by corrosion product deposits on fuel assemblies, was discovered at Paks NPP Unit 2 in 1996. At the beginning of the 14^{th} fuel cycle in 1997, during power ascension, the temperature measurements at the outlet of fuel assemblies indicated an anomaly of temperature distribution in the reactor core near two loops. Reactor power was decreased to keep the outlet temperatures below the limits required by the Technical Specifications. As a result, Unit 2 was shut down for its annual refueling outage five months earlier than scheduled. The total amount of fuel in the core was replaced.

Detailed investigations were started at Paks NPP and at a technical institute (AEKI) to analyze the problem. The most probable cause of clogging and consequent asymmetry of the core has determined to be the deposits of corrosion products originating from the primary coolant. Corrosion products originated from the decontaminated surfaces of the steam generators, which were started at Paks NPP Unit 2 in 1995 and continued in 1996. During the Unit 2 refueling outage in 1996, large amounts of foreign material pieces were found in the primary circuit. The pieces were originated from a temporary maintenance lid that had been left in the header of one steam generators during the previous outage. The steam generator had to be decontaminated again during the 1997 outage.

Steam generator decontaminations at Paks NPP during 2000 to 2001

The extensive steam generator decontamination process was performed at Units 1 – 3 during 2000 and 2001 in order to reduce dose rates in the steam generators because of the change out of steam generator feed water collectors in all four Units. The work was done by the Paks NPP maintenance group following the instructions of the manufacturer of steam generators. Decontamination for ALARA considerations was regarded necessary by Paks NPP, especially by the maintenance and radiation protection sections.

The protective oxide layers on steam generator tubes had been partly destroyed. Corrosion inhibition and passivation was not optimal resulting in increased magnetite mobilization and further deposition on fuel assemblies. Cooling water flow-rate through the reactor core decreased. Consequently, the power of units 1 – 3 had to be decreased and in February 2003 full core fuel replacement became necessary in Unit 3. When Unit 3 was restarted, core asymmetry problems, due to an incorrect placement of a fuel assembly, was detected. Unit 3 has been operating at decreased power since then.

Assessment of the necessity of stem generator decontaminations

There were different opinions regarding the necessity of the decontamination of steam generators within separate groups at the plant, as well as between Paks NPP and HAEA/NSD. Finally, Paks NPP stopped the decontamination of steam generators, and to resolve the magnetite problem ordered fuel cleaning to start. The replacement of feed water collectors in the SG's at Unit 4 was performed without decontamination, using biological shielding and increased water level in the steam generator. This experience and knowledge was gained and applied from reviewing similar work done at the Loviisa NPP in Finland and through training and the use of consultants. It is also worth noting here that this method (shielding) of dose reduction during SG work had also been used by other WWER plants. Thus, Paks NPP determined that SG decontaminations were not needed.

The corrosion product deposition phenomenon and its causes at Paks NPP Unit 2, and later at Units 1 and 3, was carefully reviewed by HAEA/NSD. HAEA had requested clarifications regarding the situation, and in particular about the appearance, composition of depositions and certification of the fuel left in the reactor. These problems were discussed in annual senior management meetings between HAEA and Paks NPP.

4.1.2 Operational experience feedback (OEF)

HAEA/NSD conducted also its own investigation during 1997-98 concerning the anomaly in the core and the causes of fuel deposition. In connection of an ongoing problem the representatives of HAEA and Paks NPP visited Radiation and Nuclear Safety Authority of Finland (STUK) to get advice about requirements and methods to study and regulate the core asymmetry and fuel clogging problems. Hungary reported the results in an IAEA IRS-report prepared by Paks NPP and accepted and forwarded by HAEA in 1998. As a result, many corrective measures were presented for avoiding recurrence of such events in the future, e.g. by developing an inspection programme and if possible a cleaning method for affected fuel assemblies in order to make them available for further use in reactor. HAEA also recommended that a method should be developed, approved and applied to reduce the concentration of corrosion products in the primary coolant. The criteria for cleanliness of the primary circuit, and the technical and organisational measures prescribed to meet these criteria, were to be reviewed and corrected by Paks NPP. HAEA also recommended that the possibility to improve the effectiveness of protecting surface recovery following decontamination be considered. HAEA also recommended that the criteria for conducting decontamination should be specified and that other methods for the reduction of dose exposure be considered.

However, the implementation of the above recommendations was not effective at Paks NPP. A follow-up inspection performed by HAEA indicated that the corrective actions performed by Paks NPP did not achieve the desired results. Despite arguments against the necessity of steam generator decontaminations and recommendations of HAEA, decontaminations were continued by the same method and criteria with a modification to introduce a water flushing at the end of the cycle. The team further noted that there were numerous opportunities for HAEA to intervene on these issues as part of its normal inspection activities. The team concluded that improvements are needed in the area of licensee and regulatory interface (see section 2 of the report).

Through the use of an effective OEF program, identified problems should be followed-up and eliminated. Paks NPP and HAEA/NSD should have the tools and methods by which they systematically follow and assess the operating experience from other WWER and PWR

NPP's, as well as results of safety research especially as experience gained from the methods recommended by the Russian plant supplier are not always openly shared. Operating experience, the results of safety research and the advancement of science and technology should be applied for further safety enhancements.

4.1(1) **Recommendation:** Paks NPP and HAEA should develop a systematic approach for improving their OEF programmes. Strategy documents for the operating experience feedback process including goals, action plans and criteria should be created. HAEA should also set criteria for the licensee reporting on the utilization of operational experience and develop its own tools to follow-up of the implementation of corrective measures after operational events.

<u>Basis:</u> IAEA Safety Standard NS-R-2, 2.21*: "Operating experience at the plant shall be evaluated in a systematic way."NS-G-2.4, 3.2: "The operating organization management should have the following main responsibilities: …(8) Ensuring the collection, evaluation, implementation and dissemination of operational experience;… All these responsibilities should be documented."*

GS-R-1, 6.16: "Principles and criteria for intervention actions shall be established and the regulatory body shall provide any necessary advice in this regard."

NS-G-2.4, 6.62: "An effective programme for the review of operating experience should be established to provide methods to analyse both in-house events and events in the nuclear industry generally so to identify plant specific actions needed to prevent the occurrence of similar events." NS-G-2.4, 6.63: "…he involvement and support of senior management of the operating organization are key for an operating experience review programme to be effective. The line management of a plant should be responsible for assisting in the review of operating events and for specifying and taking corrective actions." NS-G-2.4, 6.64: "The operating experience at the plant should be evaluated in a systematic way, primarily to make certain that no safety relevant event goes undetected." NS-G-2.4, 6.66 "Operating experience should be carefully examined by designated competent persons to detect any precursor signs of possible tendencies adverse to safety, so that corrective actions can be taken before serious conditions arise." NS-G-2.4, 6.67 "The responsibilities, qualification criteria and training requirements of personnel performing activities to review operating experience should be clearly defined."

4.1(2) **Recommendation**: Paks NPP should improve communication with other WWER- and PWR-plants concerning the results of operational experience, safety research and assessment and the need for safety enhancement based on the advancement of science and technology.

<u>Basis:</u> IAEA Safety Standard NS-R-2, 2.22: *"Similarly, the operating organization shall obtain and evaluate information on operating experience at other plants to derive lessons for its own operations. To this end, the exchange of experience and the contribution of information to national and international organizations is of great importance."*

NS-R-1, 3.9: *"The design shall take due account of relevant operational experience that has been gained in operating plants and of the results of relevant research programmes."*

4.2. CLEANING OF FUEL

Magnetite production in the primary circuits of Paks NPP, Units 1, 2 and 3 increased due to decontamination of the steam generators, causing further problems with the deposits of magnetite into the reactor core. Magnetite deposits decreased the cooling water flow rate through the core and the outlet temperatures of fuel assemblies increased. To keep the temperatures within limits required by the plants technical specifications, the power output of the units had to be decreased: to 95 % at unit 2 in 1997 and during the latest fuel cycles at units 1, 2 and 3 to 80 - 98 %. In addition to the full core refuelling at Paks NPP unit 2 in 1997, the replacement of the total core load became necessary at unit 3 in the beginning of February 2003. The fuel deposition problems at unit 2 at the end of 1990's resulted in the early removal of 170 partially blocked fuel assemblies. A total of 270 partially blocked fuel assemblies had to be removed from units 1, 2 and 3 by the end of November 2002.

Magnetite deposits in the reactor core and in the primary cooling circuit has introduced other detrimental effects such as the speed of control rods: Visual inspections of reactor internals are difficult and sometimes impossible to perform. The original safety analysis for the fuel is not valid any more due to the assumptions made for calculations have moved from their original limits. New analyses and operating limits have been requested from the Russian fuel supplier. The probability of fuel leakages has increased because of deposits causing rod vibration and mechanical chafing against spacergrids. According to the interpretation, based on activity concentration of iodine-131 in the reactor water, there has not been any indication of fuel leakages at Paks NPP during their operational history. The applied activity limit is based on original limits set by the plant supplier and it is comparatively high (37 MBq/kg of coolant). However, an increased trend in ^{131}I activity concentration curves during the period from May 1996 to present indicate that since November 2000, Unit 3 had shown a small number of leaking fuel rods. The leaking fuel rods have been replaced according to the normal refuelling programme (i.e. not removed from the core until the end of their useful life).

The only possibility to continue operation in units 1, 2 and 3 at full power was to replace blocked fuel assemblies by used, but not yet spent fuel bundles, or to clean the blocked ones. The decision to clean the fuel was based in part on economical reasons because of the power production losses and the disposal of fuel elements before the end of their planned lifetime, and safety consideration also. Finally, when the core blockage problem occurred at all three units, there was not enough partly burnt fuel for accommodating all reactor loads.

In 2000 and 2001 Paks NPP performed the cleaning of 170 partly burned-out fuel assemblies, removed earlier from Unit 2, that had been stored in the spent fuel storage pool. Chemical cleaning and qualification measures for reuse of the fuel were performed by Siemens KWU, now FANP. Cleaning was done using Siemens HP/CORD UV process in connection with the Siemens Decontamination Equipment AMDA and a specially developed and fabricated cleaning tank with 7 positions for fuel assemblies. Evaluation of the cleaning process and the experience gained during power operation using the cleaned fuel assemblies demonstrated successful conformance of the cleaning process. No fuel assembly leakage was detected during the cleaning process or during reuse. The team concluded, however, that in the future Paks NPP needs to better analyse and correct problems associated with leaking fuel.

In June 2002, Paks NPP requested proposals for two separate studies (out-core and in-core), to perform fuel assembly cleaning. Invitations for bids were sent to Siemens KWU's successor in title Framatom ANP (FANP). A contract with FANP to perform out-of core cleaning was signed on 28 November 2002. The contract was based on the project performed earlier using the technology as the 7 fuel assembly cleaning process. Under the contract, FANP was to produce a cleaning tank capable of accommodating 30 fuel assemblies and to elaborate and perform on the cleaning process. Another difference that needed to be analysed in this project was that a major part of the fuel assemblies to be cleaned would be freshly removed from the reactor.

4.2(1) **Recommendation:** Paks NPP and HAEA should reassess the criteria and procedures used to assess the existence of fuel leakages in the reactor. Leaking fuel assemblies should be identified and removed from service in accordance with plant requirements.

Basis: IAEA Safety Standard NS-G-2.5, 2.29*: "To ensure that fuel cladding integrity is maintained under all core operating conditions, radiochemistry data that are indicative of fuel cladding integrity should be systematically monitored and analysed for trends."*

NS-G-2.5, 2.31*: "The normal level of fission product activity in the reactor coolant should be specified during initial period of reactor operation following startup in order to provide a reference ground level."*

NS-*G-2.5, 2.34: "To ensure that the core operates within radiological limits and that corrective actions for failed fuel are taken, a fuel failure contingency plan or policy should be established and implemented. It should contain the following key elements:*

-Action levels for investigation activities that focus on fuel failure;

-Action levels to restrict power operations in order to preclude additional fuel damage and to prevent exacerbation of any existing fuel damage;

-Measures to identify leaking fuel assemblies and to remove them from service;

-Measures to determine the cause of the loss of fuel integrity;

-Measures to remedy the cause of fuel damage;

-Fuel inspection activities;

-Fuel reconstitution activities;

-Review of lessons learned to prevent failures in the future stemming from the some root cause."

NS-G-2.5, 2.53: *"A core management and fuel handling surveillance programme should be established for the early detection of any deterioration that could result in an unsafe condition in the reactor core."*

4.2.1 Cleaning arrangements

Chemical cleaning

The patented HP/CORD UV process is a multi-cycle multi-step cleaning process, where permanganic acid is used for the pre-oxidation of oxide layers, oxalic acid for the dissolution of corrosion products and ultraviolet light for in situ decomposition of the cleaning chemicals to water and carbon dioxide.

The operating temperature is 90 - 95° C and initial pH 1.7 to 2.5. To achieve maximum effectiveness of removing fuel deposits, several hours of operation are required. The activity and corrosion products released during the process are continuously withdrawn by bypass purification through ion-exchangers.

In the fuel cleaning arrangements the pre-oxidation step was applied during the first cleaning load on a "small scale" (7 fuel assembly tank) and proved to be unnecessary because of characteristics of the deposit. Experience also showed that one cleaning cycle, using the CORD process, is sufficient to remove magnetite deposits from the fuel assemblies.

Mobile decontamination equipment, AMDA

Special cleaning equipment is usually used for the decontamination of dismantled components or entire systems. With the help of AMDA (Automated Mobile Decontamination Appliance), which is developed and constructed in modular form, the provision for the use of special NPP systems are not required.

AMDA equipment permits the standardized handling of operations for the heating up, injection of chemicals, cleaning, decomposition of chemicals and purification of solutions. In addition, a heater and a cooler are integrated into the system to reach the required decontamination temperature, or due to residual heat from fuel elements (latter, large scale decontamination). For removal of crud particles that are not completely soluble, a mechanical filter is provided. However, the team noted that the AMDA facility has limited instrumentation for the measurement of activity, temperature and coolant flow rate, all installed outside of the cleaning tank.

The cleaning system is controlled remotely and connected with flexible hoses equipped with quick couplings. According to the space available, the control panel and the make-up tank are located in an area with lower radiation levels.

The AMDA equipment at Paks NPP was positioned in the twin Unit reactor hall near pool number 1 of Unit 2. The cleaning tank was installed 10 meters under the water level. The cleaning tank was connected to AMDA with process lines to feed chemicals into the cleaning loop and consequently through the fuel assemblies.

Cleaning tank

The cleaning of fuel assemblies was performed in a specially designed tank. During 2000/01 the fuel cleaning took place in tank where the spacing of the fuel assemblies was the some as in the original Russian transport cask and which was constructed to handle seven fuel assemblies at a time. Each fuel assembly had separate feed and discharge pipes. The pressure drop through a fuel assembly, which was used to measure the cleaning results, was measured in each fuel assembly pipe.

For the fuel cleaning operation in 2003, FANP designed and fabricated a cleaning tank with capacity for 30 fuel assemblies. Certain additional boundary conditions had to be considered in terms of timeframes and the condition of fuel assemblies. This was due to the cleaning of fuel assemblies that had been removed from the reactor core only about one week earlier than the start of the cleaning operation. In this newly designed tank, the stainless steel inlet and outlet nozzles were fed from common plenum chambers, though there were four separate inlet pipelines to the inlet plenum to achieve more even distribution.

Two separate outlet pipelines were relocated (from the original design for the 7 assembly tank) from the top to the bottom of the tank. This was done so that un-dissolved particles existing in the fuel assembly channels and collecting at the bottom of the tank could be removed from the tank and immediately passed to the filter.

Thermo hydraulic conditions were better in the small cleaning tank than in the larger one. The pressure drop though each fuel assembly could not be measured in the larger cleaning tank. The decontamination results were measured on the basis of iron concentration in the cleaning solution. A linear correlation function between iron-release and pressure drop across the fuel assemblies was proven during licensing phase.

4.2.1(1) Recommendation: See recommendations 1.1(1) and 1.2(1).

4.2.2 Designed operational modes

Both the design of the AMDA facility and that of the cleaning tank were process oriented. This means that the basic and detailed designs were based on certain fixed parameters.

The fuel cleaning process was divided into the following different modes of operation by FANP.

- Mode A Pool cooling: tank is open, fuel assemblies are being loaded;
- Mode B Pool cooling: during closing of the tank cover;
- Mode C AMADA cooling: cleaning/decontamination
- Mode B Pool cooling: during opening of the tank cover
- Mode A Pool cooling: tank is open, fuel assemblies are being unloaded.

The purpose and restrictions of the different modes of operation were not fully understood by Paks NPP and FANP personnel.

4.2.2(1) Recommendation, See recommendations 1.2(1) and 1.4(1)

4.2.3 Operational procedures

Operating procedures for the 30-fuel-assembly cleaning process were prepared by FANP personnel. At Paks NPP these procedures were first assessed by the Deposit Team, which was appointed for preparation of the cleaning process. After an initial assessment, the operating procedures were submitted to the QA Inspection Section for review but were not reviewed by plant operations . The final approved procedures were then included in the Working Program SV-7/2003 (ESETI KISUM MUNKAPROGRAM). The individuals responsible for conducting the safety review of procedures from Safety Department were also members of the Deposit Team providing support for Framatom at the development stage of the cleaning process and therefore involved in the development of the procedures. This contributed to a lack of independence of the procedure review process.

The chemical section had managed the first fuel cleaning campaign from the planning and design phases to its implementation. During the second campaign, experience gained from the first campaign project was not effectively used. The chemical section did not participate in the planning and design phases for the second campaign and only provided logistical support during performance phase. The chemical section involvement during the second campaign was to supply water and pressurised air; arrange connections to other plant services as maintenance, provide radiation protection oversight and support for laboratory services. Chemists working on shifts did not supervise the technical activities of FANP. In addition to providing logistical support to FANP the chemists had their daily duties. The authorisation of individuals selected for the cleaning campaign was performed by the nominations of the Director General of the plant. A clear description of tasks in this project was not done or affirmed.

Paks NPP personnel were responsible for moving fuel into and out of the cleaning tank. FANP managed the cleaning process and equipment connected to AMDA. This review team concluded that the roles and responsibilities of Paks NPP personnel involved with the cleaning process were inadequately defined and that the overall supervision and co-ordination of activities was poor.

4.2.3(1) Recommendation: See recommendation 1.2(1).

4.2.4 Qualification measurements

To demonstrate the suitability of the decontamination process for fuel assemblies, and to ensure the integrity of the assemblies after the cleaning, FANP performed material compatibility tests, which contained visual examination, weight loss, metallographic examination and steam treatment tests. The results of these material compatibility tests with three cycles of CORD showed no evidence of detrimental effects on fuel assemblies. Siemens presented the results of these tests to the experts of the Russian fuel fabrication plant Mashinostroitelny Zavod, MSZ/Sosny, which gave its acceptance on the bases of the material compatibility tests performed only for the seven fuel assembly operation.

4.3 FUEL CLEANING OPERATION

4.3.1 Background

Chemical cleaning of partially irradiated fuel, unloaded from Unit 2 of Paks NPP, using the cleaning tank capable to accommodate 30 fuel assemblies, started in March 2003.

Prior to the incident, 2 batches of 30 fuel assemblies unloaded from Unit 2 earlier (approximately 2 fuel cycles ago) had been cleaned. By the time of the incident a further 4 batches of 30 assemblies were cleaned which had been irradiated during the immediately completed 19th fuel cycle. These assemblies had substantial decay heat potential. After the cleaning of the last batch, an operational incident with radiological impact occur on Unit (10-11 April, 2003) and the fuel assemblies in the cleaning tank were heavily damaged.

An analysis concluded that the fuel had experienced a maximum fuel cladding temperature in the range of 800 to 1300°C , hydrogen production was up to 5% of the total inventory of the Zr in the cleaning tank and melting of the fuel pins did not occur.

4.3.2 Responsibilities and functions of the HAEA and of the operating organization.

The overall responsibility of the operating organization for safe operation of the power plant as well as the responsibility of HAEA for establishment of safety requirements and for supervision of operational safety are well defined in Hungarian legal basis and are clear to both organizations. Licensing documents transmitted from Paks NPP to HAEA for approval of the cleaning facility, as well as reactions on supplementary regulatory requirements relevant to the respective incident, were assessed by this mission (see section 2 of the report).

4.3.3 Assessment of the fuel cleaning operation

The thermal hydraulic results were based only on a simple heat balancing methodology in the Safety Analysis to the "NPP Paks Application for approval of chemical out-core cleaning of fuel assemblies. The team concluded that a more sophisticated analysis was warranted, taking into account the different types (i.e. numbers of working fuel assemblies and fuel followers, and residual heat considerations) of fuel assemblies, coolant-flow bypasses (assembly bore-holes as well as miss-positioned assemblies in the lower plate penetrations of the cleaning tank), loss of cooling water flow and introduction of air (or gas) into the tank. Such analysis were not required for design verification. Also, a warning in the safety analysis on the potential of boiling in the volume with a fuel assembly pattern characterized with a decreased water density was not analysed during design verification to demonstrate the safe sub-criticality in all possible operating and accidental states.

A more systematic post incident thermal hydraulic analyses of the cleaning tank cooling conditions operated in operational mode "B" were accomplished at two Hungarian research institutes, (KFKI-AEKI, VEIKI), at Technical University Budapest, at HAEA, at Paks NPP and at the supplier organization FRAMATOME GmbH. The results obtained refer to the high possibility of non-stable cooling conditions in the cleaning tank, with boiling and overheating of the upper parts of the fuel assemblies. The assumptions used for these results were the following: (1) If coolant bypass through fuel assembly boreholes was modeled and additional coolant bypass flow was included due to estimated deviations of the assembly positions in the lower plate penetrations (in case of fuel batches with high residual power also without the last assumption), and (2) if the fuel assemblies residual power was taken into account in accordance with real irradiation and cooling-down conditions during and after 19^{th} fuel cycle.

The vulnerability of cleaning tank cooling in the "B" operational mode, resulting in non-stable conditions, had not been recognized by FANP during the design verification of the tank (due to the very simple thermal hydraulic model used for analysis). However, this vulnerability was also not discovered during the following reviews and assessment performed by Paks NPP or by HAEA. The team also noted that neither the Safety Analysis Section of Paks NPP's Engineering Division, (with their analytical codes) nor technical support organizations were involved in the review during the design stage.

Consequently, the operation of the fuel cleaning facility in the "B" operational mode was not prepared with due consideration of the nuclear safety aspects for keeping the fuel adequately cooled nor did it address the high potential to progress the cooling of the fuel to a non-stable mode. Key operational activities, influencing safety, were not clearly defined (e.g. residual heat removal from the cleaning tank to the pool, the important role of coolant outlet temperature, etc.). The team also noted that the training of the FANP personnel was not systematically oriented to the all most important tasks related to nuclear safety.

The emergency operating procedure for the chemical cleaning of fuel assemblies at Paks NPP was elaborated without clear identification of all the symptoms available to indicate the beginning of an accident condition. Some of the symptoms that were not given visible priority were (1) the coolant outlet temperature in "B" operational mode, (2) the increased coolant radioactivity and (3) the water level in the fuel pool, amongst others. Moreover, this emergency operating procedure was not consistent with the safety analysis that had been approved by HAEA during the licensing process. The non-conformance of the permissible duration of "B" operational mode in the safety analysis and in the emergency operating procedure, was not treated sufficiently during the review of the operating procedures for fuel cleaning, (managed by QA Department of the Safety Division). As a consequence, unlimited cooling of the cleaning tank in the "B" operational mode was approved in the Working Programme No SV 7 /2003 .

During the fuel cleaning, (in "B" operational mode) with the 6th fuel batch inside the closed tank, AMDA operators did not recognize the transition of the cleaning operation to the incident that resulted in fuel damage. The operators also did not recognize the safety consequence of relative long-term operation with the boiling in cleaning tank (approximately 7 hours) of this facility in the B operational mode. Mitigation measures to recover the cooling of the fuel in the cleaning tank (opening of the cleaning tank lid) was subsequently taken by the Extraordinary Maintenance Work Committee in discussion with FANP personnel.

4.3.3(1) Recommendation: Paks NPP and HAEA should review and revise as necessary their procedures and processes for handling and storage of irradiated nuclear fuel. Consideration should be given to analyzing all conditions out of the original design scope and should be managed at Paks NPP as modifications directly relating to plant configuration. Due to their high potential for radiological risk, the processing or handling of irradiated fuel should be categorized according to their safety importance.

Basis: IAEA Safety Standard NS-G-2.3 *para. 4.5, Category 1: "Modifications in Category 1 may have a significant effect on the radiological risk or may involve an alteration of the principles and conclusions on which the design and licensing of the plant were based. Such modifications may involve change in the set of design basis accidents, or they may alter the technical solutions adopted for meeting the safety goals or led to changes in operating rules. Modifications in Category 1 necessitate thorough analysis and may also necessitate prior approval, an amendment to the operating license or a new license".*

4.3.3(2) Recommendation: The initial safety assessment for a proposed modification should be carried out before implementing the modification, to determine the significance to nuclear safety and should lead to the conservative categorization of the modification. The tentative contents of a comprehensive safety assessment should be determined and reviewed by an independent expert in the field of the modification being proposed.

Basis: IAEA Safety Standard NS-G-2.3 *para 4.8, "An initial assessment should be carry out before starting modification to determine whether the proposed modification has any consequences for safety and whether it is within the regulatory constraints for the design and operation. This initial assessment should be carried out by trained and qualified personnel, taking a systematic approach, and reviewed by an independent expert".*

4.3.3(3) Recommendation: See recommendation 1.2(1).

4.3.3(4) Recommendation: NPP Paks should arrange for the availability of independent suitable personnel, not involved in the design and/or implementation of the modification to conduct a comprehensive review to determine the nuclear safety and operational aspects, (including operating procedures) of the modification.

Basis: *IAEA Safety Standard NS-G-2.3 para 3.4: "Independent review of the scope and safety implications of proposed modifications should be carried out by personnel who are not involved in the design and implementation of the modifications."*

5. RADIATION PROTECTION AND RADIOLOGICAL DOSE ASSESSMENT

The team conducted an independent review of the incident, including its radiological consequences. The incident caused a rise in radiation levels within the Paks NPP and a release of radioactivity to the atmosphere. The team concluded that the radiological consequences of the incident were small. Doses to workers were maintained well within the limits set out in the IAEA Basic Safety Standards. Doses to members of the public were only a very small fraction of the public dose limits and less than a day's natural background radiation.

5.1. RESPONSIBILITIES AND FUNCTIONS OF REGULATORY BODIES

5.1.1 Regulatory background

From the documents provided by HAEA and through interviews, the team concluded that the distribution of responsibilities of the relevant regulatory bodies were clearly defined.

The following describe organizational responsibilities;

- The Ministry of Health regulates the radiation protection of the workers and the public and regulates the educational and training requirements for the Paks NPP staff.
- The Ministry of Environment oversees any radioactive discharges (Atomic Energy Act No. CXVI of 1996).
- The HAEA is responsible for "technical radiation protection" at nuclear facilities, including Paks NPP. However, HAEA reported some uncertainty over the scope of "technical radiation protection".
- Emergency response is coordinated and conducted by the Ministry for the Interior.
- Contamination of food and drinking water are evaluated at the Ministry of Agriculture.

Some responsibilities are delegated to lower levels in the governmental structure.

- Radiation protection of workers and the public is devolved to the County Institute for Public Health and Medical Officer's Services, ANTSZ, (Decree No. 16/2000 (VI. 8.) EüM of the Minister of Health).
- Radioactive discharges are regulated by the regional environmental authority, ADVKF, according to Decree No. 15/2001 (VI. 6.) KöM of the Minister of Environment.

5.1.2 Coordination of activities of regulatory bodies

The team noted that the boundaries and connections between the various regulatory agencies with respect to their responsibilities on specific radiation protection requirements are complex. This complexity is recognized by the authorities. However, it provides potential for poor understanding and conflicting activities in a fast moving or abnormal situation. This is exemplified by the involvement of both HAEA and ADVKF with respect to releases to the environment in the period after the initial incident.

HAEA noted that there have been a number of meetings involving the various public bodies and Paks NPP, these are not very frequent, typically annual, and they have in the past been postponed if matters have not reached a suitable point.

The team concluded that there would be an advantage for all parties if a liaison group, involving relevant stakeholders including Paks NPP, were established and met a few times per year. Such meetings would promote open exchange of information, plans and progress as well as developing the multi-agency working group that supports operation in abnormal/emergency conditions.

5.1.2(1) Recommendation: Effective arrangements should be made to ensure that regulatory responsibilities and functions of the various regulatory bodies are clearly defined and co-ordinated.

Basis: IAEA Safety Standard GS-R-1*: 4.2 If the regulatory body consists of more than one authority, effective arrangements shall be made to ensure that regulatory responsibilities and functions are clearly defined and co-coordinated, in order to avoid any omissions or unnecessary duplication and to prevent conflicting requirements being placed on the operator. […] In addition, the authorities responsible for the different disciplines concerned in the regulatory process, such as those responsible for nuclear, radiation, radioactive waste and transport safety, shall be effectively coordinated.*

5.1.3 Clarity of responsibilities for protection of workers and public

HAEA and ANTSZ both have responsibilities that relate to radiation protection of workers and the public. The two organizations are seeking to establish an agreement for liaison, sharing information, conducting joint inspections, etc. Activities carried out under the agreement should support effective regulation and communication. It has however, taken more than a year to prepare a draft document that outlines the principles and objectives. Further work will be required to implement the agreement.

5.1.3(1) Recommendation: HAEA and ANTSZ should expedite their arrangements to conclude their agreement and its working procedures.
Basis: IAEA Safety Standard GS-R-1*: 4.2 If the regulatory body consists of more than one authority, effective arrangements shall be made to ensure that regulatory responsibilities and functions are clearly defined and coordinated, in order to avoid any omissions or unnecessary duplication and to prevent conflicting requirements being placed on the operator. […] In addition, the authorities responsible for the different disciplines concerned in the regulatory process, such as those responsible for nuclear, radiation, radioactive waste and transport safety, shall be effectively coordinated.*

5.1.4 Coordination of responsibilities between regulatory authorities and Paks NPP

Paks NPP retains full responsibility for the on-site radiation safety program and for the decision to notify the regulatory bodies of abnormal situations. In the case of abnormal operation, any of the above mentioned agencies can exercise regulatory authority which could potentially lead to confusing or contradictory instructions to the plant operator. Arrangements suggested under 5.1.2 and 5.1.3 will help to avoid this situation.

5.1.5 Communication relating to authorization of radioactive discharges to the

atmosphere

A decree from the Ministry of Environment (Decree No. 15/2001 (VI. 6.) KöM of the Minister of Environment), revised the responsibilities relating to radioactive discharges to the environment to include:

- The Ministry of Health specifies an annual dose constraint (Decree No. 16/2000 (VI. 8.) EüM of the Minister of Health)
- The applicant (Paks NPP) is responsible for deriving discharge parameters (activity limits etc) and providing this and other information (specified in Decree No. 15/2001 (VI. 6.) KüM of the Minister of Environment) to ADVKF
- ADVKF is responsible for issuing a license or rejecting the application.
- HAEA has responsibilities with respect to technical radiation protection.

Decree No 15/2001 (VI. 6) withdrew the previous regulation under which discharges to the atmosphere were regulated. ADVKF and Paks NPP noted that Paks NPP had provided information specified by Decree 15/2001 (VI. 6.), within the specified six month period. ADVKF reported that regular consultation and discussion took place during the period up to the submission of the application.

ADVKF reported that the application had been rejected because of issues relating to: their ability to assess the application on the basis of the information provided by Paks NPP; mechanisms for issuing a license; and the short period (30 days) which Decree 15/2001 VI. 6. provides to ADVKF to consider an application.

ADVKF reported that presently atmospheric discharges are managed by a combination of the old and new arrangements supported by the plant's original Technical Specifications. ADVKF reported that efforts are being made to review Decree 15/2001 (VI. 6.).

5.1.5(1) Recommendation: ADVKF (involving others such as the Ministry of Environment and HAEA) should review and revise as necessary their information requirements relating to the operator's application to discharge radioactivity with the aim of establishing firm and clear information requirements. This should include review and feedback on the processes involved as well as the outcomes

Basis: IAEA Basic Safety Standard BSS-115*: 5.4. The regulatory body shall issue guidance on the format and content of documents to be submitted by the operator in support of applications for authorization.*

5.1.5(2) Recommendation: Effective arrangements should be made by regulatory bodies to ensure that sufficient input, feedback and advice is provided to operators by the regulatory bodies in order to more effectively implement radiation safety for specific tasks.

Basis: IAEA Safety Standard GS-R-1*: 4.2 […] The main functions of review and assessment and inspection and enforcement shall be organized in such a way as to achieve consistency and to enable the necessary feedback and exchange of information.*

5.2. ACTIVITIES OF THE REGULATORY BODIES DURING THE INCIDENT

5.2.1. Notification by Paks NPP

From the initial notification of the regulatory body at 00:30 on 11 April, HAEA maintained continued close contact with the plant operator. The daily HAEA morning videoconference meetings concerning the fuel cleaning incident were extended to include HAEA on-site inspectors and representatives of Paks NPP.

5.2.2. Actions to obtain initial dose assessments

For a more complete understanding of the situation, regulatory bodies requested additional information from the plant operator. HAEA requested an analysis of the pool water composition and chemistry in order to gain a better understanding of the nature and magnitude of the radioactive release. ANTSZ requested an increase in the frequency of the measurements of iodine concentration in order for them to be able to more closely monitor the release situation. ADVKF asked Paks NPP for additional data from environmental samples and stack measurements and requested frequent reports on the situation and on dose and environmental impact assessments.

Starting on 16 April, HAEA conducted model calculations to assess dose to the public due to radioactive material released to the atmosphere. The source term that served as input for the models were the data provided by Paks NPP. Further calculations concerning the total amount of noble gases, iodine and fission products released indicated that the initial assumptions by Paks NPP that only a few fuel pins had been damaged were incorrect. In fact, based on the information from the total amount of radioactive material released and the video recording of the interior of the cleaning tank, HAEA (as well as the Paks NPP) now considers that most or all of the fuel rods have been damaged in the incident.

5.2.3. Inter-agency communication

Communication was established with other regulatory and expert bodies and for the purpose of assessment of further actions to be taken. To that purpose, a meeting was initiated by HAEA on 28 April, in which representatives of HAEA, the representatives of the competent central and country level Health Physics (Radiation Protection) Authorities and their Scientific Institute (TSO) and also the competent Environment Protection Authority representatives were present.

5.2.4. Checks on the data provided by Paks NPP

Data provided by the Paks NPP staff were collected and evaluated for their credibility by the regulatory body. No obvious discrepancies between expectations, data and model calculations were found. The data collected by the various bodies and agencies appeared to be consistent. For these reasons, no detailed checks were performed on the dose assessment provided by Paks NPP. Further detailed comparison of radiological information was continuing at the time of this expert review mission.

5.2.5. Supervision of the operator in abnormal conditions

Early on in the incident, Paks NPP provided HAEA with an assessment of the doses to the public based on in-plant monitoring. The cleaning process had not been expected to cause release of radioactivity of the scale observed nor was it a recognized situation for which accidental (unplanned) releases had been considered. On recognizing that such an unplanned release had occurred, it would have been appropriate for the operator and the regulator(s) to seek early confirmation that the monitoring equipment and radiological assessment methodologies remained appropriate, in particular, the determination of the mix of noble gas and iodine isotopes.

5.2.5(1) Recommendation: In the case of an abnormal operational mode, the operator, together with the relevant regulatory authorities, should seek to confirm that the monitoring equipment that is in place and that the methods used for radiological dose assessment remain appropriate.

Basis: IAEA Basic Safety Standard BSS-115: III.12 *Registrants and licensees shall, as appropriate and in agreement with the Regulatory Authority, review and adjust their discharge control measures for the sources under their responsibility in the light of operating experience, taking into account any changes in exposure pathways and the composition of critical groups that could affect the assessment of doses due to the discharges.*

5.2.6. Coordination of responding agencies in the event of abnormal conditions

On 21 April 2003, after the severity of the original incident had been revised (on 16 April), ADVKF wrote to HAEA regarding discharges in the previous few days. In response, and recognizing the increased severity of the incident, HAEA invited ADVKF, ANTSZ and a number of other relevant bodies to meet in order to share information, plans etc. This parallels the good practice of multi-agency operation that would be expected in an emergency and recognizes the legitimate and proper interest of a number of bodies in the incident and its radiological consequences.

HAEA is developing agreements with the other relevant bodies to provide mutual notification and information exchange under abnormal conditions.

5.3. RADIATION PROTECTION RESPONSIBILITIES OF THE OPERATOR

5.3.1. Role of the Paks NPP radiation protection department in the planning of work operations

The Paks NPP Radiation Protection Department is involved in the planning of non-routine work activities. The department's involvement covers planning of exposures that workers are expected to receive. However, the Radiation Protection department is not involved in the consideration of potential accidents that might arise from non-routine work activities, such as the fuel cleaning process.

This observation corresponds closely with that identified in 6.3.1. Arrangements recommended in 6.3.1(1) would be relevant.

Paks NPP radiation protection staff noted that their role also included consideration of environmental discharges caused by the work.

5.3.2. Integration of contractor's activities

The AMDA equipment used by FANP included an instrument for detecting Krypton-85 that might be released. However, Paks NPP radiation protection department did not know whether this was for purposes of operational effectiveness or if it had a safety role, namely detecting potential releases that might affect workers or the public. Radiation monitoring of normal operational modes at Paks NPP was appropriate.

5.3.2(1) Recommendation: Effective arrangements should be made by the operator to ensure that potential abnormal operational modes can be detected and the measurement systems in place provide sufficient and appropriate information for timely protective actions. Measurement systems used by contractors should be included in the operator's considerations.

Basis: BSS-115: 2.15. *Registrants and licensees shall bear the responsibility for setting up and implementing the technical and organizational measures that are needed for ensuring protection and safety for the sources for which they are authorized. They may appoint other people to carry out actions and tasks related to these responsibilities, but they shall retain the responsibility for the actions and tasks themselves.*

BSS-115: I.4. Employers, registrants and licensees shall ensure, for all workers engaged in activities that involve or could involve occupational exposure, that […]

(e) suitable and adequate facilities, equipment and services for protection and safety be provided, the nature and extent of which are commensurate with the expected magnitude and likelihood of the occupational exposure; […]

(g) appropriate protective devices and monitoring equipment be provided and arrangements made for its proper use; […].

RS-G-1.1: 5.41. Thus, a programme of monitoring may be used for a number of specific purposes, depending on the nature and extent of the practice. These purposes may include: […]

(b) Provision of information about conditions in the workplace and means of establishing whether these are under satisfactory control and whether operational changes have improved or worsened the radiological working conditions; […]

(f) Provision of information for the evaluation of doses in the event of accidental exposures.

5.4. ACTIVITIES OF THE OPERATOR

At 21:53 on 10 April 2003 the dosimetry control room at Paks NPP was alerted to the fact that elevated gamma dose rates and levels of noble gases were measured at the pool deck in the vicinity of the cleaning tank. The FANP operators were notified. The earlier elevated reading at 21:50 on the ^{85}Kr detector associated with the cleaning tank, which was not connected with dosimetry personnel in the control room, had not resulted in any action.

The dosimetry control room notified the plant shift supervisor who subsequently ordered the evacuation of the reactor hall some time before 23:30 on 10 April. Only after respirators with external oxygen supply had been obtained, two FANP operators and one dosimetry personnel re-entered the reactor hall area in order to assess and, if necessary, stabilize the situation.

5.4.1. Preparedness for use of personal protective equipment

Attempts to lift the lid of the cleaning tank, starting at 00:21 on 11 April required the presence of two FANP operators, the crane operator, the fuel handling machine operator and a member of the dosimetry control staff.

All personnel present were equipped with respirators with external oxygen supply. The crane operator had a full beard underneath his respirator. He had not received formal training in the use of a respirator prior to the incident, but was instructed at the time.

As part of the normal checks for contamination on exiting the reactor area, the crane operator was discovered to be externally contaminated above the prescribed maximum level. He was decontaminated by repeated showering, followed by shaving of his beard and cutting of his hair. These activities reduced his external contamination levels to below prescribed levels.

Subsequent internal monitoring indicated that this person had received the highest committed effective dose from intakes. An assessment of these doses is provided in section 5.4.2.

5.4.1(1) Recommendation: Paks NPP should review arrangements relating to personal protective equipment to ensure that proper instruction is given to staff wearing the equipment and that proper checks are made that the equipment will perform properly.

Basis: BSS-115: I.4. *Employers, registrants and licensees shall ensure, for all workers engaged in activities that involve or could involve occupational exposure, that: […]*

(g) appropriate protective devices and monitoring equipment be provided and arrangements made for its proper use; […].

BSS-115: I.28. Employers, registrants and licensees shall ensure that: […]

(b) when appropriate, workers receive adequate instruction in the proper use of respiratory protective equipment, including testing for good fit; […].

5.4.2. Monitoring and assessment of external and internal doses to workers

Paks NPP is responsible for the radiation protection of staff, contractors and visitors to the site. Personal external dosimeters are provided for everyone entering the main operational areas of the site. A film badge, provided and read by ANTSZ provides the legal dose measurement. A thermoluminscent (TL) dosimeter is also provided by Paks NPP. People entering the reactor areas are issued an electronic dosimeter. Reactor operation and maintenance personnel are equipped with TL neutron dosimeters. Contractors also wear their own dosimeters.

Dosimetric data from external monitoring of the FANP and Paks NPP staff on-site were collected and recorded. Results were provided from the dosimeters of the workers involved in the incident. Results were found to be consistent.

Paks NPP internal dosimetry (whole body monitoring) service is nationally accredited. However, standing internal arrangements provide for an independent dose assessment for personnel having received a committed effective dose in excess of 0.1 mSv. This arrangement was implemented and relevant personnel were measured at the National "Frederic Joliot Curie" Radiobiology and Radio-diagnostic Research Institute, OSSKI. The two sets of results were consistent.

An extensive program of monitoring intakes of radionuclides was initiated by the operator. Priority was given to personnel thought to have had the most potential for intake. The first measurements were performed on the morning of 11 April. Over 600 personnel were measured at the Paks NPP whole body counter. Only 7 of the assessed doses were close to or above 0.1 mSv.

The team concluded that Paks NPP undertook appropriate monitoring and assessments of the radiation exposure to staff. Good records of this activity have been maintained.

From the records reviewed, doses from external gamma radiation for the Paks NPP and FANP staff during and after the incident range up to approximately 7 mSv. Committed effective doses from inhalation of radionuclides range up to approximately 1 mSv.

There is no indication in any of the data or dose assessments, either provided by Paks NPP or by any of the other authorities, that the annual dose limits for occupational exposure specified in the IAEA Basic Safety Standard BSS-115 have been exceeded.

5.4.3. Monitoring of stack releases

The stack monitoring system includes equipment that measures, among other things, airborne releases of radioiodine. The system includes a scintillation detector with a gamma energy window discriminator. The energy range also detects gamma rays from certain noble gases. In an emergency, or under abnormal release conditions, these two isotope groups are both likely to be released. There is no system in place to provide for the automatic subtraction of the noble gas contribution to the signal. This significantly reduces the value of the system and confidence that Paks NPP staff have in the output of the system.

The system uses a filter that is changed after a number of hours, daily under normal conditions. Measurements of sample activity are made in the stack every 10 minutes. If radioiodine is being released, the system in effect provides a record of the integrated release.

To interpret the history of release rates, including the current release rate and trend, the user must interpret the slope of the curve rather than observe a sequence of readings. Again, this undermines utility of and confidence in the system, especially in times of stress or uncertainty about what is being discharged.

This matter is addressed in respect of emergency preparedness in recommendation 6.2.2(2).

Paks NPP has initiated a project to upgrade their equipment to monitor stack releases.

5.4.4. Use and interpretation of on-line environmental monitoring information

The operator has on-line access to a network of 9 continuously operating environmental gamma dose rate monitors located close to the plant. Results from these monitors are relayed to external authorities. The monitors have an alert level (500 nSv h^{-1}) based on the average dose rate over a 10 minute period. The 10 minute average level was not exceeded during the incident, but the dose rate at one monitor rose significantly during the period of the initial release peak. The operations staff did not notice this change until later (see also recommendation 6.2.4(1)). Had they done so earlier, they would have gained additional information that would have helped to build a better understanding of a release for which they did not have specific plans. It was noted by the NPP staff that a contributing factor was the significant number of other information inputs that the staff were confronted with at the time.

The operations staff do not have procedures to follow in the event of abnormal releases to remind them to check this source of information.

5.4.5. Assessment of the types and quantities of radioactivity released

The operator estimated type and quantity of the airborne release. Essentially, it consisted of:

- a few hundred TBq of noble gases, mostly xenon-133 (half life of 5.2 days)
- a few tenths of a TBq of radioiodine, mostly iodine-131 (half life of 8 days)
- less than one hundredth of a TBq of other particulate radionuclides principally ^{134}Cs (half life 2 years) and ^{137}Cs (half-life 30 years).

The meteorological conditions varied during the period of release but at the time of the highest release rate the wind was reported to be blowing approximately to the north. Most of the release took place during the early hours of 11 April.

A release of this nature would be expected to cause a temporary increase in the environmental gamma dose rate within a few kilometers of the release point in the downwind direction of the wind. Subsequently, dose rates in this area would be expected to return to normal levels.

Measurements from the local environmental gamma monitoring network and additional measurements made by a number of institutions are consistent with this expected pattern.

A release of the nature described above would be expected to leave detectable levels of radionuclides in the environment, especially radioiodine.

Measurements of environmental levels of radionuclides made by Paks NPP and other scientific and governmental organizations are consistent with the release described above.

Measurements of airborne radionuclides made within the building where the release occurred also confirm the presence of xenon, iodine and cesium but with a number of other radionuclides.

The operator's assessment of the quantity and characteristics of radioactive material released to the atmosphere during the incident is consistent with environmental measurements that have been made by a number of organizations.

5.4.6. Assessment of doses to the public resulting from the release

The Paks NPP uses specialized computer software to represent the dispersion and deposition of radionuclides released to atmosphere. This software also provides estimates of radiation doses to members of the public. Doses are calculated for a number of locations taking into account the quantity and type of radioactive material released, the weather conditions at the time and the environmental and physical properties of the material released.

Radiation doses to people living within a few kilometers of the Paks NPP were reported to be around the level of microsieverts with some variation as information about the release was gained. Doses to people further away were estimated to be lower.

The dose estimates provided by the operator are consistent with what would be expected from the operator's estimate of the release.

Given the consistency in the environmental data measured by a number of organizations and the dispersion and deposition models used by Paks NPP, the operator's assessment of the amount and nature of radioactive material and its radiological impact are reasonable.

There is no indication in any of the data or dose assessments, either provided by Paks NPP or by any of the regulatory authorities, that the annual dose limits for the general public specified in the IAEA Basic Safety Standard BSS-115 have been exceeded. In fact, the assessed doses are about 3 orders of magnitude below these annual dose limits.

Doses to members of the public were estimated to be less than a day's natural background radiation.

5.4.7. Information provision under abnormal conditions

The NPP has a number of radiation safety regulators including HAEA, ADVKF and ANTSZ. In case of abnormal conditions, a number of them expect to receive information either "immediately" or "within 24 hours".

During the incident, a number of these bodies requested enhanced frequency and detail of information from the operator. These bodies noted that the Radiation Protection department met these requests. However, the Radiation Protection department also receives requests for information from the site management and a number of off-site authorities. Under abnormal conditions these demands could impair the Radiation Protection department's ability to undertake its operational activities.

Criteria exist for notification of the regulatory authorities (HAEA, ANTSZ, and ADVKF) in the event of abnormal radiation conditions or discharges. Appropriate notifications were made by Paks NPP.

6. EMERGENCY PLANNING AND PREPAREDNESS

6.1. GENERAL REQUIREMENTS

6.1.1 Basic responsibilities

With respect to emergency planning and preparedness, the basic respective responsibilities of the HAEA and the plant appear to be well defined and did not contribute to the impact of this incident. Indeed, the plant and the regulator appear to have cooperated closely throughout the incident through, for example, daily video conference calls between the resident inspectors, plant personnel and HAEA personnel in Budapest to assess the situation.

6.1.2 Assessment of threat

Emergency threat for the cleaning tank

There was no specific emergency threat assessment (as described in IAEA Safety Standard GS-R-2) for the operation of the cleaning tank. FANP did prepare a safety assessment, which clearly identified the risk of boiling within a few minutes in case of loss of flow. However, this was not specifically addressed for the purpose of emergency planning and preparedness[1]. This appeared to have been due to two key facts. First, the activity (design and operation) was classified as safety class 3, which only requires licensing in principle and, therefore, was not subject to a review in terms of emergency planning requirements. Second, there was a perception within the HAEA that the cleaning tank was essentially similar to a transport cask. This re-enforced the belief that a threat assessment was not required. As such, it was assumed that the operation would fall under the general umbrella of Paks NPP emergency plan and procedures.

The specific nature of the threat associated with this activity was not recognized. In fact, nearly 10% of the core inventory was present in the cleaning tank. Based on the reactor thermal power, the inventory of long-lived isotopes, and the short cooling time (10 days), this should have been considered an emergency threat category II or III in accordance with GS-R-2, which would have required specific emergency procedures. This was not realized by HAEA/NPP personnel prior to the incident. Furthermore, the safety assessment provided by the contractor stated that it would take 9.2 minutes in mode 'C' for boiling to occur should cooling flow be lost. The fact that the only emergency operating procedure called for the removal of the lid within that time to re-establish cooling, which is unrealistic considering the complexity of the lid removal operation and the fact that the crane was not required to remain available, should have suggested to the HAEA the need for more comprehensive emergency procedures.

Although existing station emergency arrangements may have been adequate, the classification scheme and the ability to recognize a potential emergency situation were not.

Approval process

During discussions, HAEA personnel indicated that, due to the high volume of license

[1] The emergency operating procedures (EOP) to promptly remove the lid was presumed to address this issue. However, emergency planning, which is the last defense in case of failure of such procedures, did not take this emergency threat into consideration.

requests and the wide spectrum of license types within the Hungarian regulatory system, the plant has been given the authority to approve many activities, such as the installation and operation of the fuel cleaning tank (the regulations actually refer to "licensing" but this term, in this context, is interpreted by the HAEA to mean "approval"). However, there is no audit of the approval process implemented by the plant[2]. Decisions are reviewed and approval procedures are approved by the HAEA. However, approval procedures were last reviewed over 6-7 years ago. This *may* have contributed to the lack of a review of this activity for emergency planning purposes.

6.1.2(1) Recommendation: Paks NPP should review and revise as necessary its procedures and processes to ensure that an objective review is carried out to determine if the nature of potential incidents and accidents is adequately covered by the existing facility threat assessment. This process should apply to any proposed operation, activity or modification that involves a change in the existing environment and/or cooling arrangements for a significant inventory of fuel, regardless of the safety class of the affected system or component. If not, a threat assessment should be carried out in order to, as a minimum, develop specific criteria to recognize, classify and evaluate potential alerts or emergencies, and determine the optimal emergency response strategy. The review and the threat assessment, if required, should be performed in cooperation with qualified EPP personnel.

Basis: GS-R-2 para 3.15, "*the full range of postulated events shall be considered in the threat assessment*". GS-R-2 para 3.17, "*appropriate organizations shall periodically conduct a review in order to ensure that all practices or situations that could necessitate an intervention are identified*".

6.1.2(2 Recommendation: HAEA should establish a program to periodically inspect the process used by the plant to authorize proposed modifications.

Basis: GS-R-1 para 4.2, "*The regulatory body should have a system to audit, review and monitor all aspects of its review and assessment process so as to ensure that it is being carried out in a suitable and efficient manner and that any changes to the process necessitated by advances in knowledge or improvements in methods or for similar reasons are implemented.*"

6.2. FUNCTIONAL REQUIREMENTS

6.2.1 Emergency management

The operational responsibilities of the contractor and plant staff were defined. For example, Paks NPP personnel were responsible for loading and unloading of the fuel assemblies in the cleaning tank.

But there was no effort to integrate the contractor's emergency operating procedures with the station's emergency procedures. The impact of possible incidents and the contractor's emergency procedures were not reviewed in terms of the need for an interface with the plant's emergency plan. This created the potential for confusion regarding respective roles in

[2] There is a verification of the decision, but this comment addresses the need for a periodic evaluation not of the results but of the process used to achieve these results.

the management of the incident. However, the early activation of the Extraordinary Maintenance Working Committee (KMB) clearly established the authority for the management of the situation. For example, the decision to lift the lid was made by the KMB, in discussion with FANP[3]

6.2.1(1) Recommendation: Emergency operating procedures and emergency procedures used by contractors involved in safety-significant on-site operations should be reviewed by qualified emergency preparedness staff to ensure that, in case of a potential or actual emergency, the decision-making lines are clear and the management of the emergency response would be well-coordinated. This is particularly important if the contractor's personnel are likely to play a key role in the management of potential emergencies. The plant should also establish a process, for example through better pre-operational training, to ensure that the station staff involved in the activity is fully aware of the respective roles and responsibilities before and during a potential or real emergency.

Basis: GS-R-2 paragraph 4.2, "*The on-site emergency response shall be promptly executed and managed without impairing the performance of the continuing operational safety functions*"; paragraph 4.4, "*The emergency response shall be coordinated between all responding organizations*".

6.2.2 Identifying, notifying and activating

Criteria for declaring an emergency

Fuel cleaning procedures did not include the diagnosis of abnormal conditions that could potentially lead to an emergency situation. For example, the cleaning tank's outlet temperature and differential temperature in cooling mode B was not evaluated to recognize a reduction in cooling of the fuel[4]. In the absence of in tank measurements this could have been the first indication of a problem.

Consequently, the identification of a potential emergency was expected to rely on the station's generic nuclear emergency response plan and procedures. These emergency procedures do include clear general criteria for declaring an emergency in terms of radiological measurements and conditions. However, there were several shortcomings with the existing criteria that can impair the ability of the operators to recognize and classify an emergency:

a. There were no criteria specific to the cleaning operation that could have been used to evaluate the actual severity of the fuel damage. For example, the high krypton levels were a clear indication of a significant gap release but this was not realized at the time.

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[3] FANP personnel did not believe that there was any problem with cooling, that this was a localized problem involving a few fuel rods, and that therefore there was no urgency in attempting to provide alternate cooling.

[4] It should be noted that the temperature of the outlet was expected to drop from cooling mode C to B, but that the differential temperature was expected to increase. Therefore, the observed temperature decrease was not in itself an indication of a reduction in cooling. However, it would have been possible to compare the actual and expected rates of temperature decrease.

b. High radiation levels in the area required the temporary evacuation of personnel. According to GS-R-2 paragraph 4.19, this could have justified the declaration of a facility or site alert, although the readings were below the criterion for declaring a potential emergency (Alert).

c. The criteria includes a trigger based on a 10-minute count of iodine release through the stack. However, the on-line iodine stack monitor is not trusted by the dosimetry staff due to a usually high bias caused by the presence of noble gas. Therefore, this data is not used in practice.

d. The iodine cartridge, if removed and properly analyzed, would provide a reliable indication of iodine releases. However, this cartridge is normally collected only once a day, unless otherwise directed by the emergency management group (or in this case the health authorities). Yet the emergency management procedures do not contain this consideration and there is no procedure for promptly analyzing this cartridge in case of a situation that could lead to a potential emergency[5].

Indeed, in this incident, the iodine release criterion for a potential emergency (Alert) was met, but this was not realized until approximately 5 hours later, when the iodine cartridge's scheduled a retrieval and analysis were finally performed.

Emergency classification scheme

The emergency classification scheme used at the time was confusing and prone to misinterpretation and miscommunication. There are three emergency levels: potential emergency (Alert), site area emergency and general emergency. Within each level, there are criteria (e.g. 'Zapor' 10, 20, etc), which describe conditions upon which a given emergency level can be declared. This resulted in some confusion between the "emergency level" and the "condition" that would justify this level. In faxes and telephone communications, only the 'zapor' condition was used. When it was used, it was accompanied by a comment that the condition had occurred earlier on 11 April but was no longer met. This led to the understanding that no emergency level was in effect, even though the emergency management group was activated, was performing key emergency functions and that the shelter (emergency response center) remained staffed for several days, 24 hours a day. Emergency planning staff indicated that the procedures call for a provisional emergency level to be declared upon the emergency management group activation. However, this was not done. This created a lot of confusion. Some people thought there was a "potential emergency" level in effect; most thought that the emergency was over.

Notification

Plant personnel followed procedures with regard to informing the regulator. The HAEA duty officer was informed at 0030 h 11 April. This was "information" and not a "notification", since no alert or emergency was declared. On the morning of 11 April, HAEA staff discussed the need to activate their emergency organization and decided that it was not required. Based on the information available at the time, this decision was justified.

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[5] For example, in this incident, the iodine cartridge installed at 0700 h on 10 April, was not removed until 0745 on 11 April. It was then discovered that the criterion for declaring a potential emergency (Alert) had been exceeded around 0300 h that morning.

6.2.2(1) Recommendation: The emergency classification scheme should be revised to ensure that it covers all potential alert and emergency situations at the plant. The classification scheme should include emergency action levels based on measured parameters. This will probably require a comprehensive review of the plant hazard assessment to ensure that all potential sources have been identified.

Basis: GS-R-2 paragraph 4.20, "*The emergency classification systems for facilities or practices in threat category I, II, III or IV shall take into account all postulated nuclear and radiological emergencies. The criteria for classification shall be predefined emergency action levels (EALs) that relate to abnormal conditions for the facility or practice concerned, security related concerns, releases of radioactive material, environmental measurements and other observable indications…* ".

6.2.2(2) Recommendation: Procedures should be modified to include the need for the prompt analysis of the iodine cartridge in the stack whenever unplanned and potentially significant releases occur, or to provide an on-line gross iodine count compensated for the presence of noble gas.

Basis: *Same as 6.2.2 (1).*

6.2.3 Urgent protective actions

There was no need for public protective actions based on the stack and environmental measurements available. However, there was a need to protect working personnel in the vicinity of the cleaning vessel. This was carried out through the evacuation of the space and an increase in ventilation flow rate. However, the order to evacuate the reactor hall was made approximately 1.5 hour later. The exact reason for this is not well understood by the reviewer. During a visit of the dosimetry control room, staff present explained the procedure in case of a radiation panel alarm. There was some confusion about the exact process and the procedure describing this process could not be found. As well, it took approximately 5 to 10 minutes at the time to identify the location of an actual alarm shown on the panel (the high level corresponded to the area where the head of unit two reactor pressure vessel is stored).

The personnel present were also requested to display the on-line noble gas stack monitor. This took over ten minutes and the combined work of three dosimetry staff. In the end, the information displayed was not clear and the exercise was stopped.

6.2.3(1) Recommendation: The Paks NPP should ensure that there is an effective ability to recognize potential emergencies so that a smooth transition to emergency procedures can be effected. Procedures should be reviewed to ensure that the diagnostic process is quick and effective. Drills should be conducted to verify that personnel are familiar with these procedures.

Basis: GS-R-2, para 4.51, "*The operator of a facility in threat category I, II or III shall make arrangements to ensure the safety of all persons on the site in the event of a nuclear or radiological emergency. This shall include arrangements: to notify people on the site of an emergency; for all persons on the site to take appropriate actions immediately upon notification of an emergency; to account for those on the site; to locate and recover those unaccounted for; to take urgent protective action; and to provide immediate first aid. The facility shall provide suitable assembly points for all persons on the site and shall be provided with a sufficient number of safe escape routes, clearly and durably marked, with reliable emergency lighting,* *ventilation and other building services essential to the safe use of these routes."*

6.2.4 Public information and warning

Based on GS-R-2 and the nature of the hazard, there was no need to warn the public of impeding protective actions.

6.2.5 Protecting emergency workers

Proper procedures were followed to minimize the dose to personnel involved in the management of the incident.

6.2.6 Assessing the initial phase

This aspect involved the evaluation of the situation and of the trends that may require a revision in the classification of the incident or emergency, and the revision of protective actions for plant personnel and the public. This assessment was indeed carried out, but the findings were incorrect. The full extent of the fuel/clad damage was only discovered 7 days later. Had an appropriate classification scheme specific to this operation been available, based on a proper emergency threat assessment, plant personnel may have been able to recognize the severity of the incident sooner.

The Extraordinary Maintenance Working Committee (KMB), which was convened late on 10 April, assessed the situation and concluded, based on assurances provided by the contractor, that no significant heat-induced damage had occurred and that only 2-3 fuel rods were affected. The senior managers on the KMB and contractors were convinced that they understood the situation well and that there was no need to declare an emergency.

6.2.6(1) Recommendation: This aspect is covered by recommendation 6.1.2 (1).

6.2.7 Keeping the public informed

The public was informed promptly. Two media releases were issued by the plant on 11 April. The second one classified the incident as INES 2. The IAEA was informed on 17 April, after the actual state of the fuel assemblies was discovered, even though there was no "obligation" under the Convention on Early Notification of a nuclear emergency to do so.

However, the use of the INES levels, which is intended to facilitate conveying to the public the severity of a situation, actually undermined the credibility of the authorities in this incident. On 11 April, the station proposed, and the HAEA approved, the INES 2 classification of the incident. On 17 April, after the lid was opened and a visual inspection of the fuel revealed the full extent of the damage, the INES level was revised to level 3. Although this revision was correct, it created a public perception that either the incident was getting worse or the authorities did not tell everything in the first instance.

6.3. INFRASTRUCTURE REQUIREMENTS

6.3.1 Authority, organization and coordination

Based on the activation of the emergency response group and of the work carried out by that group from 11 to 13 April, and from 16 to 20 April, the emergency response organization and authorities appear to be well defined. However, there was a lack of coordination between the on-site emergency groups at the preparedness stage, which can be reflected during the response stage. This is exemplified by the following observations:

a. During discussions with the emergency preparedness group and the dosimetry group, it became obvious that personnel in each group are not fully familiar with the responsibilities of the other group, particularly in areas for which they depend on each other. For example, the emergency planning group did not know what the dosimetry group procedures were to retrieve and measure the stack iodine cartridge, or to evaluate the on-line iodine monitoring data. Conversely the dosimetry group was not fully aware of the importance of the iodine cartridge measurement for the emergency response group's classification of an emergency.

b. Senior managers and working-level personnel interviewed stated that the management system used at the station discourages horizontal communication in favour of a more controlled top-down approach through the line of command. At least in the case of emergency planning and preparedness, this is not conducive to a well-coordinated response.

c. When the incident occurred, the dosimetry group, which is responsible for monitoring off-site releases, was not immediately informed about the increase in the ventilation (and therefore release) rate through the stack.

d. Although the safety manager was informed early in the incident, other emergency preparedness staff was not informed of the situation until 1000 h on 11 April. Hence, the input of knowledgeable specialists was not considered in the decision to declare or not an alert or emergency.

6.3.1(1) Recommendation: The station should establish mechanisms such as an emergency planning coordinating group composed of working-level personnel, to promote coordination of efforts in the emergency planning area and to enhance the degree of cohesion in the emergency procedures of all groups potentially involved in the management of emergencies. Emergency planning specialists (working level staff) should play a key role in this coordination and should be consulted on the need for activity-specific emergency planning and procedures.

Basis: GS-R-2 para 5.10, "*Arrangements for the co-ordination of emergency response and protocols for operational interfaces between operators and local, regional and national governments shall be developed, as applicable.*"[6]*;* GS-R-2 para 5.14, "*Each response organization shall prepare a general plan or plans for coordinating and performing their assigned functions…*".

6.3.2 Plans and Procedures

Standardized format

[6] This requirement refers to coordination in general with an emphasis on the coordination of on-site and off-site plans. However, the principle is equally valid within a single organization, such as the on-site authority, where several groups must manage emergency situations in a consistent manner.

The plant has an effective system of standardized procedure format, organized in three levels: process procedures, execution procedures and operational procedures. As a result, there is an inherent cohesion between procedures of all departments, including control room procedures. However, the fuel cleaning procedures were FANP, not Paks NPP procedures. Following the April incident a new document called Integrated Emergency Plan which covers nuclear, radiological and conventional emergency, went into force. It replaces the old plan and was prepared based on IAEA TECDOCs 953 and955.

Integration with operational procedures

Current emergency response procedures are not fully integrated with operational procedures, which means that the transition from normal operation to emergency response may not be as smooth as it should. This may in part be the cause of the ineffective transition to an emergency mode during the incident on 11 April.

Regulatory review of emergency plan and procedures

In the case of safety class 3 for component modifications, such as the installation and operation of the cleaning tank, there is a requirement for "abnormal operating procedures", or what is commonly referred to as emergency operating procedures (EOPs), but there is no requirement for emergency plans or procedures. It was assumed that emergency arrangements needed for the cleaning tank operation were adequately covered by the station's emergency plan and procedures. It is now realized that this was not the case.

In the case of the cleaning tank, there is an EOP that calls for opening the lid in case of loss of cooling water circulation. There is no procedure for evaluating possible emergency conditions, for example based on the temperature differential between the inlet and outlet of the vessel.

HAEA is responsible for approving the station's emergency plan. Until now, there is no standard against which the station's emergency plan and procedures can be evaluated. The evaluation relies on generic contents requirements and on the experience and knowledge of the inspector/evaluator. HAEA is currently developing guidelines on emergency preparedness to assist in the development and evaluation of on-site plans. These guidelines are scheduled to be published later this year.

6.3.2(1) Recommendation: HAEA should complete the development of guidelines for the evaluation of on-site emergency plans, which should include standards, guidelines on what types of hazards need to be specifically addressed, and requirements on how often and under what circumstances they should be reviewed by plant personnel.

Basis: GS-R-1 para 3.2, "*In fulfilling its statutory obligations, the regulatory body shall establish, promote or adopt regulations and guides upon which its regulatory actions are based*"; para 5.27, "*Guides, of a non-mandatory nature, on how to comply with the regulations shall be prepared, as necessary. These guides may also provide information on data and methods to be used in assessing the adequacy of the design and on analyses and documentation to be submitted to the regulatory body by the operator.*"

6.3.2(2) Recommendation: A process should be established to ensure that all on-site emergency procedures, as well as procedures on the transition from normal operation to emergency situations are coordinated.

Basis: GS-R-2 para 5.10, "*Arrangements for the co-ordination of emergency response and protocols for operational interfaces between operators and local, regional and national governments shall be developed, as applicable.*"[7]*;* GS-R-2 para 5.14, "*Each response organization shall prepare a general plan or plans for coordinating and performing their assigned functions…*".

6.3.3 Logistical support and facilities

Performance of the support and facilities

The plant has an emergency coordination center (the shelter). During the incident, the shelter was staffed (with key personnel only) from 1240 h on 11 April to 1200 h on 13 April (even though no emergency level was formally declared) and again from 2100 h on 16 April to 0900 h on 20 April (when the potential emergency – or Alert – was declared). The shelter provided an effective center for communication with on-site and off-site groups and for the assessment of the situation, from an emergency management perspective.

Regulatory review

Emergency logistical support activities and facilities are evaluated periodically by the HAEA as part of the regular inspection program. However, there is no standard against which these are evaluated. Therefore, the current evaluation process relies on the experience and knowledge of the inspector/evaluator.

6.3.3(1) Recommendation: HAEA should develop guidelines for the evaluation of on-site emergency response logistics, facilities and equipment.

Basis: GS-R-1, para 3.2, "*In fulfilling its statutory obligations, the regulatory body shall establish, promote or adopt regulations and guides upon which its regulatory actions are based*"; para 5.27, "*Guides, of a non-mandatory nature, on how to comply with the regulations shall be prepared, as necessary. These guides may also provide information on data and methods to be used in assessing the adequacy of the design and on analyses and documentation to be submitted to the regulatory body by the operator*."

6.3.4 Training, drills and exercises

Training of cleaning tank staff

Contractors had unrestricted access to the plant but required an escort to work in high

[7] This requirement refers to coordination in general with an emphasis on the coordination of on-site and off-site plans. However, the principle is equally valid within a single organization, such as the on-site authority, where several groups must manage emergency situations in a consistent manner.

[8] This requirement refers to coordination in general with an emphasis on the coordination of on-site and off-site plans. However, the principle is equally valid within a single organization, such as the on-site authority, where several groups must manage emergency situations in a consistent manner.

radiation areas. They did not receive training on station emergency procedures. Their emergency operating procedures were not adequately linked with the station's emergency plan, for which they depended for emergency response matters (see comment in 6.3.2). Whereas this is normally acceptable for most contractor-led work, in this case, better coordination would have led to a more effective plant response.

Regulatory review

Plant personnel are trained in emergency response and the training program is reviewed by the HAEA. However, as for plans and procedures, there is no standard against which to evaluate. Therefore, this evaluation also depends on the experience and knowledge of the inspector/evaluator.

6.3.4(1) Recommendation: See recommendation 1.2(1).

6.3.4(2) Recommendation: HAEA should develop guidelines for the development, implementation and evaluation of on-site emergency training programs and on-site emergency response exercises.

Basis: GS-R-2 para 5.10, "*Arrangements for the co-ordination of emergency response and protocols for operational interfaces between operators and local, regional and national governments shall be developed, as applicable.*"[9]*;* GS-R-2 para 5.14, "*Each response organization shall prepare a general plan or plans for coordinating and performing their assigned functions…*".

[9] This requirement refers to coordination in general with an emphasis on the coordination of on-site and off-site plans. However, the principle is equally valid within a single organization, such as the on-site authority, where several groups must manage emergency situations in a consistent manner.

Recommendation:

A recommendation is advice on how improvements in nuclear safety can be made in the activity or programme that has been evaluated. It is based on IAEA Safety Standards and addresses the root causes rather than the symptoms of the identified concern. Recommendations are specific, realistic and designed to result in tangible improvements.

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