EXECUTIVE SUMMARY

1. Introduction

This report documents the proceedings of the Workshop on "Safety Assessment of Fuel Cycle Facilities – Regulatory Approaches and Industry Perspectives" held in Toronto, Canada, on 27 – 29 September 2011. The workshop was organised by the Committee for the Safety on Nuclear Installations (CSNI) of the OECD/Nuclear Energy Agency (NEA) and hosted by the Canadian Nuclear Safety Commission (CNSC).

More than 60 specialists representing 11 countries and international organisations attended the workshop. A total of 31 papers were presented and discussed in open forum. In addition, an opportunity was taken to consider the impacts of the events at Fukushima on Fuel Cycle Facilities (FCFs) in general.

2. Background

Nuclear fuel is produced, processed, and stored mainly in industrial-scale facilities. Uranium ores are processed and refined to produce a pure uranium salt stream, Uranium is converted and enriched, nuclear fuel is fabricated (U fuel and U/Pu fuel for the close cycle option); and spent fuel is stored and in some countries also reprocessed (close cycle option). Facilities dedicated to the research and development of new fuel or new processes are also considered as Fuel Cycle Facilities.

The safety assessment of nuclear facilities has often been led by the methodology and techniques initially developed for Nuclear Power Plants (NPPs). As FCFs cover a wide diversity of installations, the various approaches of national regulators, and their technical support organizations (TSO), for the Safety Assessment of Fuel Cycle Facilities are also diverse as are the approaches by their industries in providing safety justifications for their facilities.

3. Objectives and structure of the workshop

The objective of this workshop was to review the various approaches of national regulators, and their technical support organizations, in the Safety Assessment of Fuel Cycle Facilities and the experience of their industry in providing safety justification for their facilities. It addressed the present situation in various NEA member countries (MC) and concerned both initial safety assessment of new facilities and reassessment of existing ones (periodic safety review). It also considered trends of future improvement of safety assessment techniques.

The workshop was organised in an opening session, four technical sessions, one special session and a conclusion session. The technical sessions were focussed on:

- General approach including human aspects;
- Front end facilities;
- Chemical hazards – release limits; and
- Back end facilities.

In addition, a special session was held to discuss the lessons learnt for FCFs from the Fukushima accident in Japan. The workshop ended with an organized site visit to Cameco Corporation's Port Hope Conversion Facility in Port Hope, Ontario on the last day of the workshop.

4. Summary of the technical and special sessions

Each session consisted of a number of presentations followed by a panel discussion moderated by the session Chairs. A summary of each session and subsequent discussion that ensued are provided below.

Session 1: General approach including human aspects

This session was split in two sub-sessions which were chaired by Bernhard Gmal (GRS, Germany) and Yoshinori Ueda (JNES, Japan), respectively. Nine papers were presented in those two sub-sessions.

In the first sub-session, four papers were presented by the safety regulatory body of Canada and France (CNSC and ASN), and the technical support organizations of France (IRSN), where different safety items relevant for licensing and/or operation were addressed, covering:

- Regulatory approach for ensuring competence of personnel in FCFs;
- Periodic safety review for FCFs;
- Development of a guidance document for performing safety assessments for different types of FCFs; and
- Evaluation of human and organizational factors for ensuring safe operation in FCFs.

The presentations gave an informative insight into different activities and measures to ensure safe operation of facilities from the regulator's side and the technical advisor's side. Two papers were presented by Nuclear Safety Authorities and two presentations were given by TSOs.

Regarding competence of personnel at nuclear facilities that has direct impact on safety, a regulatory approach for personnel training and ensuring competence in fuel cycle facilities in Canada was presented. Previously, certification requirement for personnel was applied to reactor operators, shift supervisors and health physicists in nuclear power plants and research reactors as well as exposure device operators who use nuclear substances for the purposes of industrial radiography. As a result of a regulatory review process and progress made in implementing risk-informed regulatory oversight activities as well as a formal suggestion from the International Atomic Energy Agency – International Regulatory Review Service (IRRS) conducted on the CNSC in 2009, a regulatory approach to confirming the competence of operators at Fuel Cycle Facilities has been initiated by CNSC staff. In the first step the new approach is being applied at the Port Hope Facility. The presentation explained the concept of education and training as well as certification. Questions from the audience addressed experience from implementation, in particular efforts in manpower and time for implementation.

Another important regime for ensuring safety of nuclear installations is performing a periodic safety review (PSR). This item was addressed in the presentation given by representatives of the French authority ASN. In France basic nuclear installations are subject to a PSR every ten years. In addition, an integrated approach for the PSR is required, asking the licensees to present an evaluation of all types of risks, radiological and/or chemical and to consider also human and organizational factors. Furthermore a reassessment of bounding accidents may be part of the PSR. The primarily deterministic assessment of the bounding accident can be supplemented either by the "operating conditions" method, which contains probabilistic elements, or by a probabilistic safety analyses (PSA). The application and role of PSA to FCFs was addressed during the discussion. Furthermore interconnections between requirements and the authority as well as feedback of experience were discussed. Comments also addressed the basis for development and variation of the categories of events to be considered in the safety evaluation.

A safety guide as a tool for performing assessments for a variety of different types of fuel cycle facilities was presented by IRSN experts. In France a large variety of FCFs, including front and back-end FCFs, laboratories, facilities for storage and/or waste treatment and finally facilities under decommissioning and dismantling have to be assessed by the TSO. A safety evaluation guide for being used by TSO experts in their often multidisciplinary works was introduced in the presentation.

The guide is also used for training of young experts. It is partially posted on the IRSN website for being used by external users and feed-back to the developers. Experiences from the application of the guide and availability to other than IRSN users were addressed in the discussion.

Another important aspect of operational safety of FCFs, human and organizational factors (HOF) was addressed in the next presentation. This issue has to be considered also in the frame of PSR for FCFs in France. A methodology for analysis was presented and illustrated by examples.

The importance of HOF also in other countries was emphasized in the discussion. Besides operation, also dismantling work of nuclear facilities was addressed as an example, were HOF may be a challenge, due to use of external personnel to a major extent.

The five presentations in the second sub-session were given by safety regulatory body of UK (ONR) and USA (NRC), which covered and addressed different methodologies used in accident and risk analysis in FCFs and other industries, as follows:

- Bow-tie methodology used in petrochemical industry, but unique in FCFs;
- Expectation on Design basic accident analysis in UK;
- Severe accident analysis and management in UK's FCFs;
- Comparison of Integrated safety analysis and probabilistic risk assessment;
- Use of Probabilistic risk assessment in Us FCFs.

There are same requirements in place on installations with major hazard in UK, whether nuclear or conventional, to understand and identify the hazards of their operations, the initiating events, the consequences, the prevention and mitigation barriers. However nuclear and "Seveso" type facilities seem to adopt a different approach to the presentation of their safety cases. While safety cases developed for nuclear fuel cycle facilities are rigorous, detailed and complex, this can have the effect of reducing the visibility. Operators in the oil and gas industries are choosing to use "bow tie methodology", one of in which very simple overview diagrams are produced to illustrate key hazards and corresponding protective measure. Presentation concluded that if used in the nuclear industry the diagrams would be readily accessible in the control room; the operators of nuclear facilities could further improve their understanding of the safety significance of their role in preventing major accidents and mitigating consequences.

The UK Health and Safety Executive's Nuclear Installations Inspectorate has published its most recent regulatory expectations in the 2006 version of its safety assessment principles (SAPs). The presentation given and paper submitted described the published design basis accident analysis (DBAA) logic in context with other technical aspects of the regulatory expectation for safety cases. It will further illustrate the BDAA methodology with practical examples from actual experience on reprocessing plant gained over the last 15 years or so. Among the examples the relevance of conventional safety fault initiators to nuclear safety assessment was demonstrated.

Following paper set out the UK nuclear regulatory expectation on what constitutes a severe accident, irrespective of the type of facility, and describes characteristics of severe accidents focusing on nuclear fuel cycle facilities. Key rules in assessment of severe accidents as well as the relationship to other fault

analysis techniques were discussed. The role of severe accident analysis in informing accident management strategies and off-site emergency plans were covered. The paper also presented generic examples of scenarios that could lead to severe accidents in a range of nuclear fuel cycle facilities.

The U.S. Nuclear Regulatory Commission conducted a comparison of two standard tools for risk informing the regulatory process, namely, the Probabilistic Risk Assessment (PRA) and the Integrated Safety Analysis (ISA). The paper provided the background, features, and methodology associated with the PRA and ISA. The application of both methodologies to various inspection and assessment tools were discussed. The paper concluded that, while the ISA method is sufficient to establish an adequate safety basis, PRA is able to provide additional insights such as risk significance, uncertainty assessment, and prioritization of safety features.

As expressed in the Policy Statement on the Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities, the U.S. Nuclear Regulatory Commission has been working for decades to increase the use of PRA technology in its regulatory activities. The last paper in session 1 described the application of PRA technology currently used in NPPs and its application in other areas such as fuel cycle facilities and advanced reactors. It described major challenges that were being faced in the application of PRA into new technical areas and possible ways to resolve them.

Session 2: Front end facilities

This session was chaired by John Kinneman (USNRC, USA) and Veronique Lhomme (IRSN, France).

Five papers were presented during this session by the safety regulatory body of Canada (CNSC), the technical support organizations of Germany (GRS) and Japan (JNES) and two operators from Canada (Cameco) and United States of America (URENCO).

The session began with a review of two recent safety-related incidents at a Canadian uranium hexafluoride (UF6) conversion facility:

- June 20, 2010: release of UF6 during filling of a 48X cylinder;
- March12, 2010: release of uranium tetrafluoride (UF4) slurry due to failure of a diaphragm valve in a slurry line.

Lessons learned from the events include assuring that procedures are written clearly, in an operator friendly manner, and that steps are completed in the proper order and that it is important to have a program for responding to small “upsets” such as small leaks. This program should include adequate maintenance procedures. In the question and discussion session, the point was made that when controls are thorough and effective, operators may become less aware of what is important in the procedures they follow; this may reflect a poor safety culture. An effective practice of posting diagrams communicating important procedural steps was described.

Then, the four following presenters focused on methodologies and practices regarding safety analysis of nuclear fuel cycle facilities, as:

- Developing a safety report for an existing conversion facility (the above mentioned Canadian UF6 conversion facility);
- Using Probabilistic safety assessment (PSA) methodology to assess the risks of complex technical systems such as a fuel fabrication plant in Germany;
- Developing Integrated safety analysis (ISA) procedures for uranium fuel fabrication and enrichment facilities in Japan;

- Performing an ISA to allow a uranium enrichment facility to operate while constructing the remainder of the facility in the USA.

The presenters discussed a number of successes and challenges with these reports and analyses:

- One significant challenge is that of preparing a new safety report for an old, existing facility: in such a facility the analysis is difficult because complete information is not available and the facility does not use modern design features or equipment;
- There were several discussions of the application of ISA methodology to facilities. These discussions included the use of risk matrices and the grading of Items Relied on for Safety (IROFS). It was underlined that, to proceed to this type of analysis, having actual operational data provides the best result, but that such data is often not available (e.g. data on human error rates). As part of this discussion, there were a number of comments on the availability of data and whether mean values were appropriate for matrix calculations. In general, the participants felt that in nearly all cases the assessments could only be semi quantitative at best. One area that received attention was human performance and error rate. There was a suggestion was that data on human error rates was available in some sources, including the US document NUREG 1520, Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility. Others felt that the available data on human performance was not well collected and was difficult to apply. This discussion suggests that human performance data availability and application in ISAs might be a useful topic at a future meeting. It was also mentioned that when needed data for other areas of an ISA or PSA is not available, information and experience at Nuclear Power Plants (NPPs) may provide useful approximations.

There was a short discussion of the importance of encouraging conservative criteria selection and decision making for whichever analytical method (ISA or PSA) was being employed. In addition, one participant expressed the importance of avoiding analysis in isolation and avoiding “group think” when working with a team. This thought leads to a comment on the importance of some sort of independent review of the choices and conclusions made in preparing an ISA or PSA. While peer review is used in evaluating some ISA or PSA determinations, it is more difficult in many others because of proprietary concerns.

One more interesting point was the possible harmonization of the methods for conducting safety assessments between NPPs and FCFs. It seems that even though this would be desirable, it is not likely to be realized soon. In fact several participants expressed their opinion that it would never be possible due to the diversity of processes within and among the facilities. Of course, the experiences at NPPs should be looked at to see how those experiences might apply to FCFs and what benefit could be obtained from the comparison.

There was the observation from one industry representative that the approach to analyzing and accepting criticality controls varies widely among different countries and that this makes it difficult for a company to work efficiently when they have facilities in different countries. Another participant expressed the same concern about changes in transportation requirements from one country to another.

This led to some comments that in addition to harmonizing methodology between NPPs and FCFs, it would be helpful at a number of levels if the various regulators could have more uniform requirements and methods of review and approval. There was extensive discussion of the approaches used by the various countries to evaluate the current status of fuel facilities with respect to the lessons learned from the events at Fukushima.

In summary, Session 2 identified several important points, including that there is a lack of data which makes it hard to do fully quantitative analyses at FCFs; that there is a need for more work to evaluate human error frequencies; that iinformation from analyses at NPP can sometimes provide insights at FCFs; and that independent reviews of the analyses at FCF in addition to those performed by the regulators might provide some benefit.

Session 3: Chemical hazards – release limits

This session was chaired by Neil Blundell (ONR, UK) and Dave Ingalls (Cameco, Canada). Six papers were presented in this session across a diverse range of subjects.

Six papers were presented during this session by an operator from Canada (GE Hitachi), the safety regulatory body of France (ASN) and USA (NRC), the technical support organization of France (IRSN) and USA (BNL).

The papers covered setting emission limits within Canada and France, the assessment of chemical safety and fire safety within nuclear plant in France, and two papers from the United States covering the general regulation of non-reactor facilities and chemical safety within them. Most of the papers included real examples to demonstrate the practical aspects of their methodologies.

The first paper summarized the system of environmental and public protection constraints currently in place at GEH-C including derived emission limits, operational limits and action levels. It discussed the basis of any values chosen and described the methods used to calculate their magnitude. Perspectives on how to ensure operational effectiveness of these constraints were also addressed.

The French regulation in force concerning chemical hazards inside basic nuclear installations (BNI) or nuclear sites was described as a mix between previous regulation settled down in the 1990s, and the new regulation based on the Nuclear transparency and safety (TSN) act at the moment. This TSN act clearly requires taking into account all the risks generated by a BNI, which is a progress compared to the previous regulation that was not that precise. As a result, the regulation in force concerning chemical hazards inside nuclear sites can look quite complex, because it refers to several texts not necessarily linked to each other, but the regulation under development is expected to help to take all kind of risks into account more accurately and more simply.

An authorization process of released limits was described in the following presentation. The determination of release authorized limits for a French nuclear site is initiated by the request of the operator, based on the maximum nuclear and chemical inventory that could be released during normal operating conditions, accompanied with justifications. Request and justifications are analyzed and discussed by the ASN and the IRSN, taking into account nuclear and chemical inventories expected inside BNI, different regulations, operating feedback and best available technologies that can be used to treat liquid or gaseous waste before release. The release authorized limits are set up in specific ASN prescriptions based on the results of the discussion together with potential public suggestions. These prescriptions have to be ratified by the State secretaries in charge of nuclear safety.

A fire safety analysis (FSA) is requested to justify the adequacy of fire protection measures set by the operator in France. Another presentation described a recent document written by IRSN, which outlines a global process for such a comprehensive fire safety analysis. One of the key points of the fire analysis is the assessment of possible fire scenarios in the facility. Given the large number of possible fire scenarios, it is then necessary to evaluate "reference fires" which are the worst case scenarios of all possible fire scenarios and which are used by the operator for the design of fire protection measures.

Another paper of NRC and its support organisations described a methodology used to model potential accidents in fuel cycle facilities that employ chemical processes to separate and purify nuclear materials. The methodology used probabilistic risk assessment related tools as well as information about the chemical reaction characteristics, information on plant design and operational features, and generic data about component failure rates and human error rates. The accident frequency estimates for the specific reaction can be useful to help to risk-inform a safety review process and assess compliance with regulatory requirements.

Final presentation in this session described historical background of NRC in regulation of chemical safety which has been limited and that is why NRC established memoranda of understanding (MOUs) with other regulatory agencies to encourage exchange of information between the agencies regarding occupational hazards. Over the years NRC's regulation of chemical safety at fuel cycle facilities has improved, but coordination and cooperation with other regulatory agencies is essential to maintaining effective oversight of the industry.

Session 4: Back end facilities

This session was chaired by Pierre Nocture (Areva, France) and Jean-Paul Daubard (IRSN, France).

There were six papers presented during this session by the safety regulatory body of Germany (BfS) and USA (NRC), two operators from France (AREVA) and Japan (JNFL), and a research institute from Hungary (NUBIKI), when three presentations were dedicated to dry spent fuel storage facilities and other three were on the reprocessing/MOX facilities.

After introducing the licensing process in Germany, the first presentation described the assessment of the spent fuel storage in extreme events scenarios (BDA). The scenarios are based upon the imaginable impacts onto the facility and a conjecture to the possible results is drawn. By comparing the results with the regulatory framework (limits for Dose rate etc.) the identification of possible cliff edge effects is possible. Additional attention was given to the impact of the given scenarios onto the surrounding area excluding the impacts coming from the storage facility. The talk was summarized with a table were each extreme events are associated with qualitative attributes (radiological consequences, realism, and specific comments on the impacted area) that confirm the robustness of dry storage facility in respect to the given scenarios.

Further in the next presentation an overview of the PSA developed by the designer of the Paks Modular Vault Dry Storage was presented. For the PSR, the licensee decided to review the PMVDS PSA to include a complete list of initiating events, use the feed-back experience, extend the analysis the internal and external hazards, improve the modeling of power supply.

The authors of the third paper on SF storage focused on the benefit of the risk-informed decision making for long term dry storage. The paper dressed two examples, one on marine stress corrosion cracking of stainless steel canisters and a second on Hydrogen effect on Zirconium cladding integrity.

The presentation on the safety assessment implemented by AREVA on its new back-end facilities insisted on the specificities on these facilities when compared with PWR, the importance of implementing a risk by risk approach essential deterministic. The design looks for the practical elimination of accidents that needs emergency countermeasures to protect the public and not anymore a reference to a pre-determined probability/radiological consequences graph.

The first JNFL presentation introduced the simplified PSA called QSA (Quantitative Safety Assessment) thanks to the comparison of these methods for the evaluation of High Active Level Waste (HALW) storage. The supply, a leakage of an external loop, a loss of active component function at internal loop and

then external are similar but the time requested for performing these assessment are quite different: QSA is one fiftieth less demanding than PSA in this example

The second presentation summarized a study performed by the Group on the Hydrogen Consumption Reaction catalyzed by Palladium ions in a simulated HALW. With the assumption of a negligible effect of alpha emitters on the radiolysis of nitrate solutions of HALW, experiments showed the important catalytic effect of PD ions for recombining H_2 with HNO_3 forming H_2O and NOx.

Special session: Lessons learnt for FCFs from the Fukushima accident

This special session was included in the workshop in response to the Fukushima accident in Japan and WGFCS' attempt to exchange information on the principal lessons learnt so far. The session was chaired by Pierre Nocture (Areva, France), the WGFCS Chair.

This special session comprised presentations of Japan, the USA, the UK and France

In the first part of his presentation Yoshinori Ueda (JNES, Japan) gave an overview of the Fukushima accident and an outline of the emergency safety measures and response at the NPP site. The second part was focused on the regulatory issues for FCFs after the accident. The first issue was the emergency safety measures in case of total loss of AC power (loss capabilities of decay heat removal and hydrogen accumulation prevention) and tsunami in the reprocessing facilities and associated spent fuel storages at Tokai and Rokkasho plants. The second issue was the directions to the licensees of these facilities to secure the work environment in the main control rooms in case of complete loss of AC power, to secure communication within the facility in case of such emergency, and to secure material and equipment for radiation protection, and to deploy heavy tools for rubble removal

In the UK, the Secretary of State requested the safety authority to "identify any lessons to be learnt by the UK nuclear industry". Neil Blundell (ONR) presented the findings stated in the interim ONR report. He more specifically highlighted the recommendations relevant to the FCF safety assessment that deals with the need to take into account "cliff-edge effects, the design basis and margins for flooding, the seismic resilience, the analysis of accident sequences for long term severe accidents, the off-site infrastructure resilience, and the human behavior in severe accident conditions. Mr. Blundell provided also 2 examples of extreme weather conditions that occurred in UK FCFs.

On the US side, John D. Kinneman (US NRC) made an introduction of the NRC near term and longer term actions for domestic operating reactors and spent fuel pools. For fuel facilities, the NRC verifies that the licensees' mitigation strategies for the licensing basis events (seismic hazards, flooding hazards, wind and tornado loading, extended loss of AC power and emergency power, fire impacts) are properly implemented with prevention and/or mitigation strategies appropriate for the consequence.

In France, the ASN asked the French licensees to undertake stress test called "complementary safety assessment (CSA). This request covers all the nuclear facilities in France, including the 15 FCFs, according to six issues (flooding, earthquake, loss of electrical power, loss of cooling systems, accidental situations management and management of subcontractors) to determine whether improvements are necessary for each installation. Ms. Dorothee Conte presented also the list of FCF facilities subjects to CSA and the provisional calendar for 2011. She provided the ASN conclusion related to the CSA methodology proposed by the licensees and gave an example of one specific and hypothetical scenario of loss of protections after a dam breach on AREVA Tricastin site. P. NOCTURE then made a presentation on the CSA methodology implemented by AREVA for its FCFs in France. The objectives of this methodology are (a) to determine the extent of facility resistance to external natural phenomena beyond their design basis and to the postulated loss of some safety functions, (b) to verify that resources that can

be called-up are sufficient to limit the consequences of severe accidents that may happen simultaneously on several facilities and to limit the impacts of releases into the environment, and (c) if needed, to identify the arrangements to reinforce the organization and the equipment

Although other countries, such as Canada, did not make a formal presentation on their post-Fukushima activities, they reported that their FCFs were also examining their preparedness for beyond design basis events.

5. General Conclusions and Recommendation

WGFCS has been actively pursuing an agenda of knowledge sharing and interaction between the FCF community among its member countries. This Workshop brought together many specialists involved in the FCFs, to discuss regulatory and operational aspects. The meeting was attended by almost twice the number of participants compared to the previous technical workshop held two years ago.

The above sections have summarized the topic specific ideas that were presented and discussed by the participants. In addition, there were several broad conclusions that were drawn during the 3 day workshop:

- Participants recognized that the March 2011 events at Fukushima have lessons for the FCF communities around the world. They confirmed that the FCF community was actively seeking to learn from these events and were at various stages of review.

- Participants recognized the importance of the impact of chemical hazards on safety assessment of FCFs in addition to radiation hazards. Sometimes, public perception of low risk low radiological consequence accidents are more damaging to the reputation and safety record of the industry.

- Participants felt that there is a need for improved coordination between various regulatory bodies within each country.

- It was also noted that it may be beneficial to benchmark with other industries within the nuclear industries (such as NPPs) as well as outside (such as petrochemical industry) to identify cross-learning opportunities.

- It was recognized that the risk-informed decision making process is an established and useful approach not only at a macro level, but also useful for complex, technical tasks in FCFs.

- Both operators and regulators in member countries are engaged in continuous improvement initiatives, including improved evaluation methods and approaches, and recognize the importance of employing ALARA, in order to achieve better safety analysis and better protection of the workers, environment and the public.

- Ageing FCFs face a challenge in that they don't necessarily have modern design features and equipment, making fully quantitative analysis challenging.

It is clear that the workshop on Safety Assessment of Fuel Cycle Facilities made the exchange of information between technical specialists from different jurisdictions possible, and highlighted some of the common aspects faced by the FCF community. It is recommended that WGFCS continue to support similar technical workshops, and continue to foster similar information exchange.