Generation IV International Forum – Knowledge Management and Knowledge Preservation: An initiative from the Education and Training Working Group

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INTRODUCTION

Given that the current nuclear energy workforce is approaching the age for retirement, and that a limited number of universities in the world provides advanced reactor systems curriculum, we are faced with a growing demand for training and education on Gen IV reactor systems. In this context the Gen IV International Forum (GIF) – Education and Training Working Group (ETWG) has been established to respond to the challenge of maintaining and developing a well-educated advanced reactor systems workforce and to meet the projected growth in this field by sharing, preserving, and managing knowledge related to Generation IV nuclear systems and associated technologies. Conscious of the various challenges posed by advanced nuclear reactors' performance and demonstration, the ETWG has started a new initiative on knowledge management and preservation. Details and examples of nuclear knowledge management activities among GIF member countries will be discussed.

THE IMPORTANCE OF MANAGING AND PRESERVING THE KNOLWDGE

Knowledge Management (KM) has always been important in the nuclear energy field, but with the influx of the young generation it is at the forefront again. The GIF community recognizes recent challenges in the preservation of advanced reactor knowledge and expertise, with, a near loss of Fast Flux Test Facility (FFTF) data, the access to the French and Japanese Sodium Fast Reactor (SFR) experience, the retirement of knowledgeable experts, and the disappearance of key test facilities. Many developers and start-up companies are in dire need of prior experience with Gen IV technology, but the traditional methods of knowledge management (KM) (e.g., books, coursework, on the job training) may not be the best means of knowledge transfer for the younger generation. Newer technologies have emerged in recent years and are available for archiving the savoir-faire and lessons learned. Several GIF members already have active KM programs, so the ETWG has proposed to undertake a KM initiative to explore opportunities for GIF engagement. The following sections comprise the first step of this initiative, which consists of compiling an overview of the various and diverse national practices and experiences within the GIF member countries related to managing and preserving knowledge related to Generation IV reactors.

FFTF Information Recovery and Knowledge Management in the U.S.

The Information Recovery and Knowledge Management program for the Fast Flux Test Facility (FFTF) in the U.S. is a collaboration between Pacific Northwest National Laboratory (PNNL) and Argonne National Laboratory (ANL) within the Fast Reactor Program (FRP) in the U.S. Department of Energy's Office of Nuclear Energy. The FFTF was a 400 MWt loop-type sodium-cooled fast reactor that operated successfully on the Hanford Site, near Richland, WA from December 1980 until December 1992. The reactor plant that operated during this period is show in Fig 1. The FFTF was the highest flux irradiation test reactor in the U.S. when it was operating.

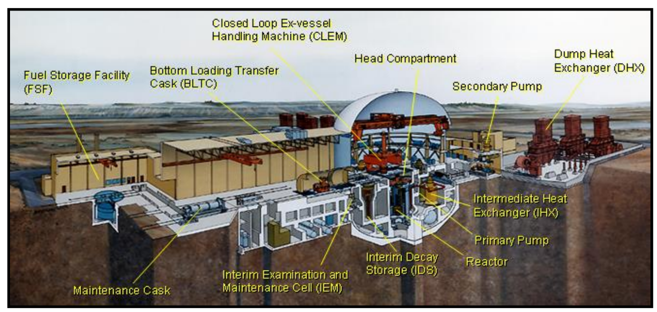

Fig.1. FFTF Reactor Plant

Information from the design, construction, and operation of this reactor, as well as the testing performed in this reactor during its operation, are stored in multiple record holding areas on the Hanford Site. This information is valuable to support industry partners and others in advanced reactor design, licensing, and construction efforts by making the reactor design more efficient, effective, and less expensive. Over eight years ago, ANL and PNNL, working together, developed a unique approach for making this information available to industry partners designing advanced reactors. This lessons learned approach, organizes the information around topical areas important in the design and operations of advanced reactors. Some examples of topic areas include Control Rod Drive Mechanisms, Shielding Design, Argon Gas Management, Thermal Transient Usage, B_4C Swelling in Control Rods, and Thermal Striping. Each Lessons Learned report addresses the following: 1) What was done and why was it important?; 2) What was the outcome?; 3) If we had to do it over, what would we change or do differently? The Lessons Learned reports are on the order of a dozen pages and thus easily readable. The engineering documents that were employed at the time are referenced, digitized, and attached to the report. These FFTF Lessons Learned reports are written by engineers who were working at FFTF at the time and thereby incorporate first-hand and undocumented knowledge and experience. This collaborative ANL and PNNL program, with the support of the FRP in DOE/NE, has been able to document the Lessons Learned on multiple topics over the eight years that it has been funded.

In addition to Lessons Learned, ANL and PNNL have developed a database containing FFTF information. The information in this database falls into two major categories: testing of metallic fuel as conducted in the FFTF and passive safety tests conducted during the operation of the FFTF. This database has been populated with FFTF documents and will soon be made accessible to industry partners designing advanced reactors. The activity for fiscal year 2024 is to modify the database by adding external online access so that the information in it will be accessible to industry partners.

MOLTEN SALT REACTOR KNOWLEDGE PRESERVATION IN THE U.S.

Overall, the historic U.S. Molten Salt Breeder Reactor (MSBR) program did a remarkable job in archiving and preserving the knowledge generated. Most notably the program produced semi-annual reports (quarterly in the early phases of the program). All the reports are publicly available electronically from the DOE Office of Scientific and Technical Information (OSTI). The MSBR program reports are listed front matter of the final report in the series (ORNL-5132). The MSBR program reports reference more detailed technical reports. Nearly all the detailed technical reports are available through OSTI, and all can be retrieved from Oak Ridge National Laboratory's (ORNL's) laboratory records system. The reports from the predecessor Aircraft Nuclear Propulsion Program are also available, publicly in electronic format through OSTI. The (ANPP) reports are listed at the end of the final report in that series (ORNL-3226). In addition, the design and operation of the Molten Salt Reactor Experiment are detailed in a series of reports beginning with ORNL-TM-728 (also publicly available from OSTI). The other MSRE design and operations reports are listed in the frontmatter of ORNL-TM-728. Operation of the Aircraft Reactor Experiment is documented in ORNL-1865 and its disassembly and examination in ORNL-1868. More detailed information on the MSRE operations (160 boxes of information such as console logs for each shift, budget information, maintenance logs, lab notebooks, etc.) are in paper form (and have recently been relocated to a federal repository), so are difficult to access. Detailed blueprints of the MSRE have not been publicly released but are preserved in ORNL's electronic engineering drawing archive. In addition, several MSR supporters have compiled archives of MSR historic documents, most of which come from the historic U.S. program. The Open MSR github archive (https://github.com/openmsr/msr-archive) is fairly comprehensive and easy to navigate.

CURRENT ACTIVITY FOR KNOLEDGE MANAGEMENT IN CHINA

The active strategy of nuclear power deployment in China requires emphasis on nuclear knowledge management and preservation. Supported by the International Atomic Energy Agency (IAEA) , the Chinese nuclear industry invites international experts to instruct on various topics by visiting schools, and diverse organizations. The Chinese nuclear educational institutes also benefit from the IAEA master program of the International Nuclear Management Academy (INMA), launched in 2013, as well as various courses of World Nuclear University (WNU). The WNU short course is an opportunity for emerging and expanding nuclear nations to cost-effectively host in their own country a training program delivered by the world's foremost experts. Since the first course in China in 2007, around fifty WNU short courses have been held in different places around the world with about 7500 attendees. Meanwhile, more than half a century's experience and practice motivates the Chinese nuclear community to summarize and establish its own knowledge management, with some parts based on advanced digital methods as illustrated by Wang et *al.* [1] who introduce a full cycle nuclear power plant knowledge management framework based on digital systems, trying to find solutions to knowledge creation, sharing, transfer, application, and further innovation in nuclear industry.

SODIUM FAST REACTOR KKNLEDGE MANAGEMENT IN JAPAN

The Sodium-cooled Fast Reactor (SFR) is a strong candidate for future energy generation in Japan, however SFR development is delayed. Many researchers and engineers involved in the development of the Japanese prototype reactor Monju have already retired. Under these circumstances, the knowledge accumulated over the years for SFR development, such as R&D results for the safety basis, know-hows of the plant design, sodium treatment techniques, etc., are being impaired. To manage and preserve the knowledge, Japan has been working on knowledge base development, including a lot of R&D results, mechanistic theory-based analysis methods, and design standards and guidelines. In addition to this effort, to assist plant designers in evaluation and design work, and support verification and validation of numerical codes, an innovative design support system, called ARKADIA (Advanced Reactor Knowledge and AI-aided Design Integration Approach through the whole plant lifecycle), is being developed in Japan [2].

Fig. 2 shows the concept of ARKADIA. The purpose of ARKADIA is to perform integrated design evaluation and automatic optimization from various perspectives, such as safety, economy, and maintainability, which has been difficult in the past. ARKADIA enables 1) competitive plant concepts complying with “3E+S” (Energy security, Economic efficiency, and Environment + Safety), 2) reduced development time and costs, and 3) transfer and accumulation of technology and human resource development, while preventing developed technologies from being broken into pieces and lost. Knowledge management and preservation are of great importance for future SFRs development, and Japan is working on educating and training future operators and technicians as well as developing ARKADIA.

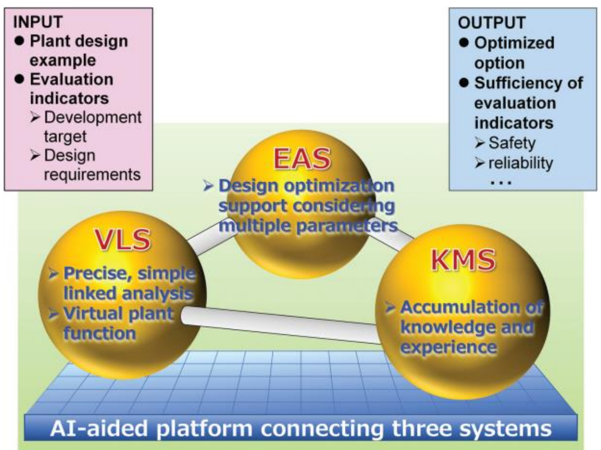

Fig.2. Concept of ARKADIA

CANADIAN NUCLEAR SAFETY COMMISSION (CNSC)’S APPROACH TO KNOWLEDGE MANAGEMENT

KM has been deemed an organizational priority given it enables innovation, better decision making and improves individual/organizational performance. It was also recognized as a strategy to address the CNSC’s high retirement risk of senior technical experts and risk of knowledge loss. In 2016, a CNSC KM initiative was rolled out in a phased approach: 2016 to 2018 - Raise awareness and take stock; 2018 to 2020 - Develop and implement a KM plan; 20220 to 2022 - Influence behaviors. Deliberate prioritization and integration of KM practices by management were required to change employee perceptions and behaviors around KM practices. There have been several deliverables and successes from this initiative, which included but were not limited to: 1) a domestic and international benchmarking report, 2) consolidated a catalogue of best practices in KM, 3) the identification of critical roles and development of succession plans, and 4) implemented a KM policy and plan (with performance indicators), as well as set expectations and accountability for KM in executive performance management contracts. There is also an Effective Knowledge Transfer training course available to all employees, where it is encouraged that retirees and mentees take this course in-tandem to develop a knowledge transfer plan.

CNSC has been active internationally on sharing experiences and best practices with IAEA member states with an annual participation in the IAEA’s Capacity Building Steering Committee. As a result of this participation in the Bureau meeting for this committee, one of CNSC experts was asked to co-develop and facilitate a “Regional Workshop on the Development of a Nuclear Safety Knowledge Management Program for a Regulatory Body” which has been delivered numerous times over the last few years in-person and virtually. KM will continue to be a priority and an ingrained practice at the CNSC.

FRANCE’S KNOWLEDGE MANAGEMENT PRESPECTIVES

In France, the KM methodology is based on an inventory of methods and tools used today for KM at the Commissariat at l’Energie Atomique et aux Energies Alternatives (CEA) (including MOOK). Its implementation is based on 6 pillars: 1) Mapping : Visualize critical knowledge in the form of mind maps, thesauri, dashboards and data visualization tools.2) Capitalize: Collect knowledge in the form of videos, knowledge books, databases, Wiki, etc. and any kind of new tools like MOOK [3], 3) Store and Share: Realize efficient, sustainable, reversible and safe knowledge storage, and at the same time transfer it in the form of training including AFEST (Action de Formation En Situation de Travail = Work Situation in Training Action) which has the particularity of using and promoting work situations as a learning environment, communities of practice .4) Innovate and Create: Facilitate knowledge exchanges to generate new innovative concepts, to overcome a documented technological barrier, by either anticipating technological trends or by requesting knowledge with generative artificial intelligence, etc. Find the best link to transfer knowledge between generations; 5) Organize: Build action plans, by deploying ISO standards related to knowledge management, by communicating and training on the subject; 6) Animate: Define KM mentors and organizers who will overview the transition of the entire company towards a learning organization.

CONCLUSION

The new project of the ETWG focuses on GIF members’ knowledge management related to Generation IV nuclear reactors. The goal of this initiative is to see how GIF country members collect information on the design, construction, and operation of advanced reactors as well as the lessons learned in these processes. The initiative also examines how the transfer of knowledge is captured and passed on, in an international context, to developers and companies planning on building these advanced reactor systems. The second part of this project will be to explore how new IT tools and digital practices could be employed to implement those best practices (e.g., e-learning, natural language processing, and other artificial intelligence tools) at a broader scale. The goal is to ensure that valuable knowledge, experience, and raw data can be preserved and transferred to future generations of nuclear scientists and engineers to foster and support the deployment of these advanced reactor systems.

REFERENCES

1. M. WANG, M. ZHENG, L TIAN, Z QIU, Z LI, "A full life cycle nuclear knowledge management framework based on digital system", *Annals of Nuclear Energy*, **108**, 386 (2017)

2. A. UCHIBORI, N. DODA, M AOYAGI, M. SOGABE, Y. OKANO, T. TAKATA, M. TANAKA, Y. ENUMA, T. wAKAI, T. ASAYAMA, H. OSHIMA, "Numerical simulation technologies for safety evaluation in plant lifecycle optimization method, ARKADIA for advanced reactors" *Nuclear Engineering and Design*, **413**, 112492 (2023)

3. G. RODRIGUEZ, "MOOK: The knowledge management method applied to a Gen IV project, the continuation of a successful story", GIF webinar series #83, https://register.gotowebinar.com/recording/3237115499214374234, November 2023.