

“Nuclear Knowledge Management” : A Review of Research and Practice (Postprint)

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Abstract

[Purpose/Significance] Against the backdrop of the nuclear industry confronting challenges such as workforce aging, talent shortage, and knowledge loss, this study analyzes the development status of nuclear knowledge management domestically and internationally, aiming to provide a crucial foundation for domestic nuclear organizations to conduct research and practice in nuclear knowledge management. [Method/Process] Focusing on knowledge management strategy, implementation, human resource management, and technological aspects, this paper investigates and analyzes research and practices in the nuclear knowledge management field both at home and abroad, summarizes relevant techniques and experiences, and elucidates the necessity for nuclear organizations to implement knowledge management. [Results/Conclusion] This paper proposes recommendations for nuclear knowledge management, suggesting that nuclear organizations should formulate nuclear knowledge management strategies, establish management systems, promote knowledge transfer and sharing, construct industry knowledge bases, and develop management platforms, thereby reducing the risk of knowledge loss, improving knowledge utilization, fostering scientific and technological innovation, and enhancing enterprise competitiveness.

Full Text

Review of Research and Practice of “Nuclear Knowledge Management”

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Abstract

[Purpose/Significance] Against the backdrop of an aging workforce, insufficient talent supply, and loss of nuclear knowledge in the nuclear industry, this paper analyzes the current development status of nuclear knowledge management both domestically and internationally to provide an important basis for domestic nuclear organizations to conduct research and practice in nuclear knowledge management. **[Method/Process]** This study systematically investigates research and practice in the field of nuclear knowledge management at home and abroad from the perspectives of knowledge management strategy, implementation, human resource management, and knowledge management technology, summarizes relevant techniques and experiences, and clarifies the necessity for nuclear organizations to implement knowledge management. **[Result/Conclusion]** The paper proposes recommendations for nuclear knowledge management work: nuclear organizations should formulate nuclear knowledge management strategies, establish nuclear knowledge management systems, promote knowledge transfer and sharing, build industry knowledge bases, and develop nuclear knowledge management platforms to reduce the risk of nuclear knowledge loss, improve knowledge utilization, promote scientific and technological innovation, and enhance enterprise competitiveness.

Keywords: nuclear knowledge; nuclear knowledge management; nuclear industry; nuclear safety

Classification Numbers: F272; F49

1. Introduction

In the early 21st century, the nuclear industry gradually lost its appeal to young people, with declining enrollment rates in relevant majors, while simultaneously facing workforce aging and employee retirement. These factors created risks of losing nuclear knowledge and experience, impacting the development of the nuclear industry and prompting attention to the necessity of strengthening nuclear knowledge management [?]. The nuclear industry system is vast, involving extensive fields characterized by high technical difficulty, high R&D costs, high complexity, long life cycles, and stringent safety requirements, making it a typical knowledge-intensive industry. Throughout the entire life cycle of nuclear facilities from R&D to decommissioning, vast amounts of data, information, and knowledge are generated, which are crucial for the long-term safe operation of nuclear facilities [?].

Knowledge management is a process and method that achieves organizational knowledge management and performance improvement through knowledge creation, structuring, and dissemination [?]. In 2002, the International Atomic Energy Agency (IAEA) applied knowledge management to the nuclear field and proposed the concept of Nuclear Knowledge Management (NKM) [?], which has

greatly promoted the preservation, dissemination, sharing, and transfer of nuclear knowledge. NKM plays an important role in fostering innovation and promoting nuclear power, nuclear fuel cycle, and nuclear technology applications in medicine, industry, and agriculture [?]. Therefore, based on knowledge management technology, formulating effective NKM strategies and policies, establishing mature NKM systems, promoting the creation, storage, and dissemination of nuclear knowledge, reducing the risk of nuclear knowledge loss, and promoting the application and development of knowledge management in the nuclear industry are crucial for the safety and long-term stable development of the nuclear industry. This paper systematically investigates domestic and international research in the NKM field in terms of knowledge management strategy, implementation, human resource management, and knowledge management technology, summarizes relevant techniques and experiences, and proposes recommendations for NKM work to provide reference for NKM research and application in China.

2. Overview of Nuclear Knowledge Management

2.1 Definition and Characteristics of Nuclear Knowledge Knowledge is understanding, judgment, or skills acquired through learning, practice, or exploration, while knowledge management is the activity of planning and managing knowledge, the knowledge creation process, and knowledge application [?]. It can be considered that knowledge management, with the help of modern information technology, captures both external and internal knowledge to provide new pathways for enterprises to achieve sharing of explicit knowledge and tacit knowledge [?]. The basic processes of knowledge management include knowledge identification, acquisition, generation and creation, processing and conversion, storage, query and retrieval, representation, transfer and sharing, and maintenance and updating [?].

Nuclear knowledge is knowledge related to nuclear activities. Various nuclear organizations generate and accumulate large amounts of nuclear knowledge in their daily work, most of which manifests as explicit knowledge in the form of standards, specifications, systems, reports, literature, and databases, while a small portion manifests as implicit knowledge and tacit knowledge, primarily existing in the minds of practitioners and forming their experiential knowledge.

IAEA defines nuclear knowledge management as a comprehensive, systematic approach applicable to all stages of the nuclear knowledge life cycle, including knowledge identification, sharing, protection, dissemination, preservation, and transfer. It involves human resource management, information and communication technology, processes and management methods, document management systems, and corporate and national strategies [?].

From the perspective of knowledge management, nuclear organizations face particularly challenging environments. The main issues include [?]: (1) complex technical foundations and infrastructure; (2) long technology and facility life cycles; (3) changing regulatory requirements over time; (4) highly capital-intensive

assets; (5) dependence on multidisciplinary technical expertise; (6) competing operational objectives involving safety, economics, and production; (7) potential high risks that must be systematically managed; and (8) continuous need for coordination of complex physical and human systems.

When managing nuclear knowledge, five main characteristics must be considered [?]: (1) **Complexity**: Nuclear knowledge is extremely complex at both micro and macro scales. (2) **Cost**: Due largely to its complexity, the cost of creating nuclear knowledge is quite high. (3) **Time scale**: The time interval between knowledge creation and use can be very long. (4) **Collaboration**: Many individuals, organizations, and countries have access to or opportunities to edit the nuclear knowledge base. (5) **Education**: Education is essential if people are to gain the experience and insights needed to create new knowledge and apply it to new challenges.

2.2 Components of Knowledge Management IAEA believes knowledge management consists of three components [?]: (1) **People**: Motivating and cultivating the personnel and organizational culture required for knowledge sharing and use, which is the most important component. (2) **Process**: Focusing on processes or methods for discovering, creating, acquiring, and sharing knowledge. Nuclear facilities must strictly follow procedural requirements to ensure their safe operation and process integrity. (3) **Technology**: Focusing on technologies for knowledge storage, sharing, and use, which is an important driving force for successful knowledge management. Information technology solutions for knowledge management include IT and knowledge management strategies, information management, scientific information access (e.g., access to scientific libraries, journals, and databases), tools for acquiring and transferring knowledge, concept maps, collaboration tools, content management, knowledge bases, simulation tools, enterprise resource planning, portals, search engines, yellow pages, expert systems, wikis, and blogs.

2.3 Knowledge Transfer Mechanisms IAEA points out that mentoring and coaching are two practical and effective approaches in knowledge management and transfer [?]. Mentoring plays an important role in transferring knowledge and skills from experienced professionals to newcomers or less experienced personnel, while coaching is important for instilling correct behaviors and values. Mentoring and coaching help learn knowledge and experience, enhance technical capabilities, improve management, promote the transfer of ideas and experiences, thereby cultivating skills, confidence, and maturity, and improving employees' ability to perform specific tasks [?].

Nuclear safety knowledge refers to knowledge needed for or related to nuclear safety and is a subset of nuclear knowledge [?]. Nuclear safety knowledge management helps follow safety culture, support safety leadership and management, establish comprehensive nuclear safety programs, achieve safe operation throughout the entire life cycle of nuclear facilities, improve efficiency, support inter-

generational knowledge transfer, promote innovation and learning, identify and protect sensitive knowledge, enable efficient and effective emergency response, support public communication, enhance public confidence, and support capacity building [?].

3. International Research Status

IAEA began knowledge management research in 2001 and established a specific department, the “Nuclear Knowledge Management Section,” to promote NKM. Its main responsibilities include [?]: (1) developing NKM-related knowledge and compiling relevant guidelines and technical reports; (2) promoting nuclear knowledge education, training, and information exchange; (3) assisting member states in formulating knowledge management policies and plans and establishing NKM systems; and (4) establishing nuclear knowledge education websites.

IAEA’ s assistance to member states mainly includes two aspects: (1) implementing NKM within nuclear organizations, promoting standards, methods, and tools, and providing services and support such as field visits and expert support and resources; and (2) providing continuous NKM education and training such as training courses, online education, and e-learning. Additionally, IAEA has developed several information management systems to provide services and support to member states:

- (1) **International Nuclear Information System (INIS)**: As a platform for member states to exchange information and preserve nuclear knowledge, INIS provides comprehensive information reference services for publications and various documents in the nuclear field [?].
- (2) **Global Nuclear Safety and Security Network (GNSSN)**: GNSSN is an IAEA-supported nuclear safety knowledge platform available to all member states. GNSSN operates through Microsoft SharePoint, with basic maintenance and technical support provided by IAEA, and member states can use this platform to establish national platforms [?].
- (3) **Radiation Safety Information Management System (RASIMS)**: RASIMS is a tool for member states to conduct nuclear safety knowledge exchange and collaboration at the national level under the IAEA Technical Cooperation Programme, enabling member states and IAEA to jointly collect, analyze, and view basic infrastructure information on national radiation and waste safety [?].
- (4) **Emergency Preparedness and Response Information Management System (EPRIMS)**: EPRIMS is a web-based interactive tool developed by IAEA for member states, containing a static nuclear reactor knowledge management database for assessing national emergency preparedness and response capabilities, as well as sharing information and knowledge related to emergency preparedness and response to promote planning and response for nuclear and radiation emergencies [?].

Education and training are considered important tools for preserving and maintaining knowledge, and networks of educational institutions have been adopted as key strategies for capacity building and effective utilization of educational resources. The World Nuclear University was established by the World Nuclear Association in 2003 to strengthen international exchange and guide further development of: (1) safe and widespread use of nuclear energy; and (2) application of nuclear science and technology [?]. The Asian Network for Education in Nuclear Technology (ANENT), promoted by IAEA in 2004, aims to promote, manage, and preserve nuclear knowledge, ensure continuous provision of competent and qualified staff in the nuclear field in Asia, and improve human resource quality to achieve sustainability of nuclear technology [?]. IAEA is also promoting the establishment of regional nuclear and radiation safety networks to preserve existing knowledge and strengthen new knowledge sharing and creation, such as the Asian Nuclear Safety Network and the Ibero-American Radiation Safety Network [?].

The Radioactive Waste Management Committee (RWMC) under the Organisation for Economic Co-operation and Development Nuclear Energy Agency (OECD/NEA) established a Working Group on Information, Data and Knowledge Management specifically responsible for radioactive waste disposal and decommissioning. Its work includes safety management, knowledge management, and archiving and preservation of data and information, with the goal of ensuring that all information related to repository design, construction, operation, and decommissioning remains accessible and understandable over century-long time scales, reducing knowledge loss [?].

High-level, long-lived radioactive waste and spent fuel require geological disposal, with technology R&D cycles lasting decades and disposal facilities needing to ensure protection of humans and the environment from radioactive hazards for hundreds of thousands of years. Therefore, relevant data, information, and knowledge should be preserved for as long as possible and remain interpretable, meaningful, credible, and usable to facilitate intergenerational knowledge transfer. To this end, RWMC launched the “Preservation of Records, Knowledge and Memory” (RK&M) initiative in 2011, with objectives to: (1) preserve long-term information about radioactive waste repositories and their stored waste, developing theoretical foundations and broad understanding in technical, management, institutional, social, and cultural aspects; and (2) develop a practice-oriented “toolbox” of RK&M preservation methods to formulate strategic action plans [?].

The United Kingdom’s AMEC NNC and its partners in the nuclear field focus primarily on developing and preserving the professional skills and related expertise required for nuclear power unit operation. As shown in Figure 1 [Figure 1: see original paper], they adopt a holistic approach to implement knowledge management programs, proposing and implementing the Qualifications and Experience (Q&E) registration method to identify qualifications, skills, and experience, which is considered one of the key knowledge management tools. Through

Q&E, specific expertise can be quickly located [?]. Additionally, the nuclear department of AMEC NNC uses risk assessment to identify potential departing personnel, then conducts knowledge acquisition work for departing or key employees. The overall knowledge acquisition method is subdivided into six stages: identifying departing personnel, risk analysis (employee departure risk and knowledge importance), developing individual transition plans, acquiring knowledge (organizing knowledge, structured interviews), reviewing knowledge, and transferring knowledge [?].

Some knowledge management methods and techniques, such as oral history and exit interviews, cannot acquire knowledge instantly. The UK Nuclear Group proposed an alternative method for instant knowledge acquisition and used this method to establish a database as a knowledge management tool to support collaborative engineering planning, desktop conferences, and data capture and reporting, making research more efficient and information collection and management more accurate [?].

France' s Andra, addressing high regulatory requirements, cumbersome formal documents that are difficult to manage and share, risks of tacit knowledge loss due to personnel turnover, and needs for human resource management, experience transfer, and document traceability, developed knowledge management tools including a quality assurance system, electronic document management system, Sinequa search engine, and DIAMS (database for integrated assessment and modelling of radwaste storages) to achieve information management of large numbers of documents, supporting document reading, similar document recommendation, metadata management, field retrieval, full-text retrieval, and document classification management and traceability management functions.

Germany' s Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) began NKM research in 2001 and developed a knowledge management system in 2005. GRS adopts a process-oriented knowledge management approach, integrating knowledge activities such as identification, acquisition, development, use, dissemination, preservation, and evaluation into daily work based on knowledge models, and has established an information and document management system using an enterprise portal to provide a central access point for all documents and information, thereby improving cooperation and communication throughout the organization. GRS' s research experience shows that knowledge management systems need continuous improvement combined with expert knowledge methods [?].

To acquire and preserve existing knowledge, advance nuclear technology development, cultivate talent, and maintain key R&D capabilities, Canada established the University Network of Excellence in Nuclear Engineering (UNENE) and the CANTEACH platform. UNENE trains qualified nuclear engineers and scientists, while the CANTEACH knowledge platform is a web-based open repository providing technical documents related to the CANDU (Canada Deuterium Uranium) nuclear energy system for education, training, design, and operation [?]. Canada' s NKM strategy includes three basic elements [?]: (1) human

resource management and training to maintain nuclear capabilities in light of the retirement of current generation experts; (2) development of advanced products and effective engineering tools to maintain current technology and design foundations; and (3) effective information management systems to promote information pooling and sharing among different entities.

During nuclear power plant operation and maintenance, timely detection and mitigation of component, equipment, and system degradation or aging are required to achieve production and safety reliability targets. Therefore, Atomic Energy of Canada Limited (AECL) developed a knowledge-based decision support system enabling nuclear power plant engineers to quickly identify and diagnose problems and predict the impact of current conditions on future performance. The decision support system collects data from various sources, organizes and presents data in an easily interpretable manner, and connects it with diagnostic tools and predictive models to support proactive and informed decision-making [?].

Belgium established the online information system STRESA (Storage of Thermal Reactor Safety Analysis Data) to promote exchange of severe accident experimental data and provide secure storage for relevant knowledge, containing three technical databases of European nuclear research facilities, nuclear experiments, and result data [?].

Romania's National Commission for Nuclear Activities Control (CNCAN) is the competent authority responsible for regulation, licensing, and control in the nuclear field. CNCAN's knowledge management measures include unrestricted internet or intranet information access, acquisition of specific publications, annual training plans meeting employee and organizational needs, knowledge dissemination courses, and improvement of employee motivation [?].

The Slovak Republic's Nuclear Regulatory Authority (Úradu Jadrového Dozoru, UJD) utilizes knowledge management to better perform its duties and optimize products and services. UJD spends considerable effort and resources on managing and preserving knowledge and information, and conducts regular assessments and improvements. Sharing knowledge and information with partners or stakeholders is an important method for maintaining UJD's knowledge base. UJD staff can participate in IAEA and NEA training courses, technical visits, workshops, and conferences. According to UJD's internal regulations, every departing employee must transfer all relevant information, data, and documents to designated colleagues or superiors and undergo exit interviews [?].

To preserve and reuse important knowledge from departing employees, the Swiss Federal Nuclear Safety Inspectorate employs a series of methods for knowledge preservation and transfer, including written reports from departing employees, exit interviews, mentoring programs, observation, job rotation, interviews, and other methods to document, preserve, and transfer knowledge as much as possible, ensuring that successors can obtain most of the important knowledge needed when taking over positions [?].

In 2002, the U.S. Tennessee Valley Authority (TVA) nuclear department formulated and implemented a process to preserve critical knowledge and skills that might be lost due to a large number of key employees approaching retirement. The process includes the following steps: (1) assess the risk of losing critical knowledge and skills and determine their priorities; (2) develop and implement plans to acquire critical knowledge or adapt to its loss; and (3) monitor and evaluate action plans and priorities. Lessons learned from this process implementation include: the amount of critical knowledge at risk is usually less than expected; current management procedures rely on experienced personnel rather than robust processes and detailed work plans; and there is a range of options to reduce knowledge loss, including codification, use of alternative resources, education, and training [?].

The U.S. Department of Energy (DOE) utilized a process-based knowledge preservation approach to carry out knowledge preservation work at three DOE facilities, encoding critical task knowledge through process mapping to promote process improvement and capture expertise from veteran employees. The main steps include identifying processes to be acquired and their priorities, preparing process maps using process mapping methods, collecting process documents, acquiring tacit information, modifying process maps to integrate overall design and operational knowledge, and identifying roles and corresponding work [?].

To avoid loss of critical nuclear knowledge due to organizational evolution and workforce aging, Argentina's Atomic Energy Commission promoted three projects with specific strategic objectives: the Research Reactor Knowledge Handbook LICREX, knowledge preservation for Atucha-type reactors, and the Latin American Nuclear Medicine Knowledge Network CLAMN. These projects use knowledge management techniques and benefit from information and communication technology, aiming to protect, preserve, and acquire knowledge generated by Argentina's nuclear sector [?].

Chile's Nuclear Energy Commission (CCNE) compiled a human resource management strategic plan to reduce risks posed by personnel retirement and workforce aging to its development. Its objectives are: to establish a national expert database for the nuclear and radiation sector; implement human resource management practices to maintain CCNE capabilities; implement an NKM system to promote identification, collection, preservation, and transfer of knowledge generated by CCNE; and implement incentive mechanisms to achieve CCNE's goals and mission [?].

Brazil's Nuclear Energy Commission proposed a hierarchical document clustering method based on frequent concept sets for semi-automatic extraction of nuclear knowledge concepts and evaluation of results, while conducting case studies to generate nuclear knowledge classification to conceptually map CNEN's scientific production [?].

Japan's Atomic Energy Research Institute began knowledge management research in 2005. Focusing on safety assessment and disposal concept require-

ments, it utilized information technologies such as expert systems, artificial intelligence, and neural networks to develop a knowledge management system (KMS) for radioactive waste disposal, establishing a comprehensive knowledge management system and knowledge base [?]. The KMS includes an explicit knowledge editor (knowledge mining tool), implicit knowledge editor (expert system tool), autonomous knowledge processing tool, and knowledge representation tool (visualization tool), enabling functions such as knowledge acquisition, training, transfer and processing, and knowledge base construction, archiving, and maintenance.

Reactor testing research is a complex systematic engineering project requiring multidisciplinary collaboration in structural mechanics, fluid mechanics, materials science, chemistry, dynamics, etc., and demanding extremely high research literacy from researchers, requiring substantial knowledge support. To address problems such as lack of knowledge accumulation systems, inefficient knowledge teaching methods, high talent cultivation costs, and few knowledge acquisition means, the China Nuclear Power Research Institute proposed conducting research on a knowledge engineering-based reactor testing knowledge management system. This system would integrate data generated in scientific research and production activities, make tacit knowledge explicit and explicit knowledge shared, form intelligent services and applications based on knowledge, deeply integrate knowledge with scientific research processes and activities, provide comprehensive guidance to researchers, achieve management of knowledge assets, efficient service to scientific research, help employees grow, and promote innovative development [?].

4. Domestic Research Status

Ma Jing [?], based on the special management model of nuclear power engineering projects, clarified the overall approach of knowledge management in nuclear power projects, proposed that the nuclear power knowledge base should consist of a product knowledge base, management knowledge base, and innovation knowledge base, and formulated and implemented knowledge management solutions with the knowledge base as the core, ultimately providing a standard solution for knowledge management in nuclear power project management companies.

Guan Rong [?], focusing on the Yangjiang Nuclear Power Project of China General Nuclear Power Group, analyzed its knowledge management status and deficiencies, pointing out problems such as insufficient attention from senior management to knowledge management, relatively young age structure of personnel, non-unified information management platforms, and ineffective training and experience feedback. The study proposed improvement strategies and knowledge management platform solutions for the Yangjiang Nuclear Power Project, including transformation of knowledge management organizational structure, knowledge base construction, implementation of employee mentoring systems, and periodic experience summarization and feedback.

To adapt to the batch construction needs of nuclear power general contracting projects, replicate and accumulate project experience, and precipitate R&D design and engineering practice knowledge, China Nuclear Power Engineering Co., Ltd. relied on the “Hualong One” global first-of-a-kind demonstration project to construct a nuclear power engineering knowledge management system. Specific measures include [?]: (1) overall planning and deployment, formulating the overall knowledge management strategy; (2) establishing the “Hualong One” experience summary leadership group and knowledge management working group to escort knowledge management system construction; (3) strengthening research, benchmarking, and training to plan knowledge management system construction; (4) integrating, processing, and refining tacit and explicit knowledge to accumulate knowledge assets; (5) building knowledge bases and developing knowledge platforms to achieve multi-project knowledge assetization; (6) focusing on knowledge engineering to promote knowledge contextualization and improve work efficiency; (7) conducting multi-dimensional research and evaluation to continuously optimize the knowledge management system; and (8) establishing operational systems, formulating assessment and incentive mechanisms to solidify knowledge management system achievements.

China Institute of Atomic Energy proposed that knowledge management research should be carried out as soon as possible, integrating knowledge management into top-level management, establishing a standardized NKM system and knowledge innovation incentive mechanism, creating a knowledge sharing environment, constructing core business process-oriented knowledge process management, promoting innovation, improving fund utilization efficiency, enhancing employee skills, and avoiding nuclear knowledge loss due to researcher retirement or departure. To this end, the following work should be carried out [?]: (1) develop a business process-based knowledge management portal website to build a knowledge base and establish better internal communication channels to promote information or knowledge transfer and achieve full-process knowledge management; (2) assess the quality and integrity of core knowledge and the risk of loss, carry out knowledge backtracking and capture projects, digitize or archive data, documents, and materials scattered among individuals, and capture core knowledge and experience of retiring or departing personnel through training, lectures, discussions, interviews, and compilation of teaching materials and documents, integrating them into corresponding databases.

China Nuclear Industry 23 Construction Co., Ltd., addressing problems such as difficulty in knowledge sharing, poor information transmission, and insufficient control, constructed a knowledge management system framework and built a technical innovation management system platform based on knowledge management, integrating all business knowledge resources, reconstructing technical management business processes, establishing a corporate core capability system, establishing a knowledge management culture orientation, strengthening technical control capabilities at all levels, gradually building a knowledge-based organizational culture, and significantly improving technical management benefits [?].

China General Nuclear Power Group Research Institute Co., Ltd., addressing problems such as low resource sharing rates, low departmental cooperation efficiency, lack of information support means, and ineffective summarization, management, and application of historical data and knowledge, developed a lean R&D collaborative design platform to achieve functions such as knowledge base management, knowledge retrieval, hierarchical control and process approval of knowledge resources, and user management. The platform tightly integrates knowledge with R&D work, establishes engineering management processes and knowledge management systems, truly achieves knowledge accumulation and application, and reaches the goals of improving R&D efficiency, shortening R&D cycles, and reducing R&D costs, thereby supporting nuclear power's full life cycle work [?].

5. Summary and Outlook

As a knowledge-intensive industry, the nuclear industry urgently needs to introduce knowledge management technology to improve industry efficiency and empower industry development. By formulating effective knowledge management strategies and policies, establishing knowledge management systems, building industry knowledge bases, and developing knowledge management platforms, it can promote the creation, storage, and dissemination of nuclear knowledge, precipitate experience accumulated by enterprises or industries in R&D, design, construction, and operation management activities into nuclear knowledge, reduce the risk of nuclear knowledge loss, improve nuclear knowledge utilization, ensure nuclear safety, reduce organizational costs, promote scientific and technological innovation, and enhance enterprise competitiveness.

NKM has generally received attention from organizations worldwide. Due to workforce aging, insufficient talent reserves, and loss of experience and knowledge, European and American nuclear sectors began NKM research in the early 21st century to preserve expert knowledge, experience, and technical capabilities and avoid impacts on nuclear industry development and safety. However, some countries have not yet carried out systematic knowledge management work or established mature and usable knowledge management platforms. China has gradually realized the importance of NKM in recent years, and individual nuclear organizations have begun to carry out knowledge management work, but overall, NKM application is not widespread, and nuclear organizations generally have not yet recognized the necessity, importance, and significance of knowledge management.

Based on research of domestic and international NKM status, this paper summarizes and proposes the following experiences and recommendations to provide reference for nuclear organizations to carry out knowledge management work:

(1) Knowledge Management Strategy. First, NKM needs to be considered at the corporate or even industry level, starting from a strategic height to enable NKM work to be carried out as early as possible and as comprehensively

as possible to identify, acquire, preserve, and share nuclear knowledge at individual, corporate, and industry levels, reducing the risk of nuclear knowledge loss. Second, knowledge management should combine top-down and bottom-up approaches, using the top-down approach to ensure clear knowledge management objectives and guarantee strategic advancement, and using the bottom-up approach to ensure knowledge creation, acquisition, sharing, and management.

(2) Knowledge Management Implementation. First, integrate the spirit of knowledge sharing and knowledge management objectives into organizational culture and integrate knowledge management processes into daily work and management to unleash the full potential of knowledge management and maximize organizational benefits. Second, leadership understanding and support are crucial for knowledge management, requiring the establishment of a knowledge management leadership group for coordination, guidance, review, and decision-making, as well as a knowledge management working group covering all departments. Third, conduct extensive learning, research, and benchmarking to comprehensively review knowledge management status, organizational systems, and key processes, formulate knowledge management implementation plans, and then build knowledge management systems and formulate knowledge management strategies and systems. Fourth, when carrying out knowledge acquisition and preservation work, first preserve explicit knowledge, and then further preserve tacit knowledge as knowledge management technology matures and experience accumulates. Fifth, acquire tacit knowledge through key knowledge identification, heuristic interviews, on-the-job training, mentoring and coaching, concept mapping, and process mapping.

(3) Human Resource Management. First, address workforce aging, expert retirement or departure, and critical knowledge loss by conducting human resource management work, assessing critical knowledge loss risks, conducting human resource planning and recruitment to ensure the organization maintains a qualified workforce, and conducting exit interviews with departing or retired personnel to preserve experience and knowledge as much as possible. Second, establish mentoring and coaching mechanisms and a mentoring-based training model to help new employees quickly adapt to the work environment and assist their career development, while reducing knowledge learning and transfer costs and promoting internal knowledge inheritance. Third, address the problem of employees hindering knowledge management strategy advancement and implementation due to concerns that sharing knowledge will reduce their importance and competitiveness by establishing incentive mechanisms in knowledge management work to enhance employees' willingness to share knowledge.

(4) Knowledge Management Technology. First, establish active knowledge management communities as the main platform for knowledge exchange and transfer, creating an atmosphere and conditions for employees to share and exchange knowledge. Second, develop document management systems to uniformly manage regulations, standards, specifications, management methods, and project documents. Third, build knowledge bases to achieve knowledge col-

lection, preservation, management, and sharing, and develop knowledge management application platforms to support all aspects of knowledge management activities, meeting the needs of knowledge base analysis, management, evaluation, and acceptance, and supporting employees in uploading, editing, querying, retrieving, downloading, sharing, learning, and utilizing various materials and knowledge to achieve organizational knowledge assetization.

Given that current nuclear knowledge management uses relatively traditional technology and is not widely or comprehensively applied, future efforts should actively learn from and integrate advanced concepts, technologies, and experiences from other industries in knowledge management, and strengthen the digitalization, informatization, and intelligence of nuclear knowledge management, deeply integrating artificial intelligence technology into the entire NKM process to promote NKM development. Main directions include: (1) using machine learning and natural language processing technologies to achieve large-scale automatic knowledge acquisition and creation, expanding the scale and application fields of nuclear knowledge bases; (2) using knowledge graph technology to achieve nuclear knowledge structuring, standardization, and graphization, disseminating and sharing nuclear knowledge in more intuitive and understandable ways; (3) using knowledge Q&A and semantic search technologies to achieve intelligent nuclear knowledge management and application, providing users with more intelligent, convenient, and smooth nuclear knowledge retrieval services through interactive query retrieval; and (4) the nuclear industry chain is huge and complex, involving numerous fields and high public attention, but due to the strong professionalism of nuclear technology and difficulty in mastering and understanding it, popular science communication and public communication are challenging. In the future, nuclear knowledge management can be applied to nuclear popular science to provide users with more systematic, standardized, and intelligent nuclear knowledge learning experiences, promote public communication, and reduce barriers to nuclear technology promotion and application.

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