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Development Strategies for Nuclear Fuel Cycle Standardization in China

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Abstract: Standardization of the nuclear fuel cycle is important for the safe and innovative development of the nuclear fuel cycle industry. This is especially true considering China has recently entered a high-quality development stage. Therefore, strategic research on nuclear fuel cycle standardization now offers a significant means of boosting China's nuclear industry. In this article, we analyze the development of nuclear fuel cycle standardization in China and abroad; investigate the key problems related to standardization in China from the perspective of its working mechanism, development balance, leading role, and support ability; and propose major tasks and relevant countermeasures to nuclear fuel cycle standardization. More specifically, the major tasks involve seven aspects of standardization: (1) post-stage standards of the nuclear fuel cycle, (2) standards for key technologies, (3) advanced standards, (4) frontier basic standards, (5) safety and environmental protection standards, (6) international standardization, and (7) basic capacities for standardization. Furthermore, the countermeasures include incorporating nuclear fuel cycle standardization into the 14th Five-Year Plan of the nuclear industry, improving the standardization mechanism, increasing investment in standardization, and strengthening the construction of standardization talent teams.

Keywords: nuclear fuel cycle; high-quality development; technical standards; basic ability; international standardization

1 Introduction

The nuclear fuel cycle is an important part of the nuclear industry, and the development of advanced nuclear fuel and related materials is the most important means of ensuring the safe and efficient development of nuclear power [1]. Standardization has played an important role in the development of the nuclear fuel cycle industry and its related technology. At present, the research into nuclear fuel cycle standardization is highly concerned with issues in China and abroad, and the related research results involve uranium mining and metallurgy standardization [2,3], nuclear fuel standardization [4], nuclear facility decommissioning standardization [5], nuclear safety standardization [6], and other fields. At present, the countries with advanced nuclear fuel cycle technology, such as the United States and France, have established a relatively complete standard system. Driven by the export of nuclear power, such countries have promoted their own standards to reach actual international standards. After years of development, China has established an initial nuclear fuel standard system that consists of national standards, professional standards, and enterprise standards. Under the guidance of nuclear power globalization, the

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nuclear fuel cycle industry is facing new opportunities and challenges, and there is an urgent need for nuclear fuel cycle standardization to provide support and play a leading role in these opportunities and challenges.

As an academic achievement exhibition of the "Research on the Development Strategy of Chinese Nuclear Industry Standardization" project, this article analyzes the current development of nuclear fuel cycle standardization, studies the strategic objectives and tasks of nuclear fuel cycle standardization, as well as the key problems in need of urgent solutions, and puts forward relevant policy suggestions with a view to providing support and reference for the development of nuclear fuel cycle standardization in China and the decision-making of relevant departments.

2 New requirements for nuclear fuel cycle standardization

2.1 Requirements of the new concept of development

In the nuclear fuel cycle industry, standards are the hard constraints of environmental protection. Therefore, it is necessary to strengthen the development and implementation of energy savings, safety, and green standards and promote the transformation and upgrading of the nuclear fuel cycle industry. With ecological environmental protection requirements becoming increasingly stringent, existing standards can no longer meet the development needs of the green nuclear fuel industry. For example, in the field of uranium exploration, some traditional mountain engineering for uranium exploration will no longer be permitted. Therefore, it is necessary to make technological breakthroughs in the key areas of green exploration to ensure the green and sustainable development of the uranium industry, and there is an urgent need to develop relevant standards for green exploration technology and digital exploration technology.

2.2 New requirements of high-quality development

Compared with advanced foreign development levels, the development level of some key links in China's nuclear fuel cycle industry still lag far behind. For example, in the field of underground uranium mining, a considerable gap remains between China and Canada, Australia, Namibia, South Africa, and other uranium-producing countries in terms of high-efficiency mining technology and advanced mining equipment; in the field of uranium purification and conversion, the continuous and stable operation time of the main equipment in China is relatively short, and the overhaul/maintenance requirements are relatively frequent, resulting in a poor working environment, excessive production personnel, and low production efficiency. Therefore, nuclear fuel cycle standards are required to comprehensively improve the quality and efficiency of industrial development, strengthen the leading role of standards, and promote quality and efficiency changes in the nuclear fuel cycle industry.

2.3 New requirements of autonomous controllability

Some core technologies in China's nuclear fuel cycle industry do not have independent intellectual property rights; therefore, only foreign standards can be implemented in China in a passive way. Key core technologies are controlled by others, a situation that has not fundamentally changed, and there remain many bottlenecks that need to be solved urgently. For example, in the field of nuclear fuel elements, relevant standards are not autonomously controllable. Therefore, China's nuclear fuel element industry urgently needs to increase its technological research and development, as well as build and improve the standards system and the nuclear fuel element technology system with independent intellectual property rights.

2.4 New requirements of international development

With the implementation of China's Belt and Road initiative and the nuclear power "going global" strategy, the technology and products of nuclear fuels, as an important support for nuclear power's globalization, will also enter the international market. The core component of product competition is standards competition, so there is an urgent need for nuclear fuel standards to act as a bridge to seize the international technological frontier and commercial market. At present, China has not formed standards with independent intellectual property rights in key areas of the nuclear fuel cycle industry. To cope with international competition, there is urgent need to build a nuclear fuel cycle standards system with independent intellectual property rights held in China, to break the restrictions of technical and trade barriers, and to actively promote the nuclear fuel cycle industry to "go global."

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3 Current development of nuclear fuel cycle standardization

3.1 Current development of nuclear fuel cycle standardization in foreign countries

3.1.1 The United States

Most U.S. standards are developed by government agencies and non-governmental standardization organizations, with the latter playing a predominant role. This is a model that allows for a quick, accurate, and flexible response to market demand. In the field of the nuclear fuel cycle, the standards issued by the relevant U.S. government departments include the "Code of Federal Regulations – Title 10 – Energy" (10 CFR series), "NRC Regulatory Guides" (RG series), and DOE Technical Standards; the standards developed by non-governmental standardization organizations include those issued by the American Nuclear Society (ANS), the American Society for Testing and Materials (ASTM), and the American Society of Mechanical Engineers (ASME). Rather than being isolated from one another, the standards at these two levels promote the implementation of the standards of the other through a large number of cross-references. For example, in the development of the 10CFR and RG series, more than 5000 references were made to standards issued by non-governmental organizations.

3.1.2 France

France has actively assumed its responsibilities of the Secretariats of the Standardization Technical Committee of the International Organization for Standardization (ISO) and has a strong influence in the field of international standardization. France has both the Secretariat of the ISO/ Nuclear Energy Technical Committee (ISO/TC85), and the Secretariat of ISO Sub-Committee 2 on Radiological Protection of the Technical Committee 85 (ISO/TC85/SC2). Using its strong technical capacity in standardization and the platform offered by the Secretariats of the Standardization Technical Committee of the ISO, France has transformed most of its national standards in the fields of uranium product testing methods and radiation protection into international ISO standards. In addition, the standardization institutions for the nuclear industry of France are relatively concentrated, with the French Society for Design and Construction Rules for Nuclear Island Components (AFCEN) being the main body for standardization in the country's nuclear industry. The Design and Construction Rules for Nuclear Power Plants (RCC) series, prepared by AFCEN, cover many fields of the nuclear industry, such as nuclear power, nuclear fuels, and nuclear fusion, which also have a strong international influence.

3.1.3 Russia

Russia attaches great importance to standardization and has established a unified management system to actively promote the development of international, national, and professional standards; it also attaches importance to the review of standards and actively shortens the preparation cycle of national standards. To better promote the development of the nuclear industry and the export of nuclear power technologies, Russia is gradually strengthening the construction of a standardization system in terms of nuclear technology standards. Rosatom, the core enterprise of Russia's nuclear industry, is actively involved in the standardization work and has developed a strategy for nuclear technology standardization.

In summary, by analyzing the efforts made by the United States, France, Russia, and other countries in nuclear fuel cycle standardization, we can conclude the following: first, we should emphasize the role of non-governmental standardization organizations and strengthen the development of group standards; second, we should pay attention to international standardization so as to allow standards to drive and lead the industry to "go global"; third, we should strengthen the development of enterprise standards to lay a solid foundation.

3.2 Current development of nuclear fuel cycle standardization in China

3.2.1 China's nuclear fuel cycle standards system has taken its basic shape

There are nearly 900 current effective standards regarding the nuclear fuel cycle in China, including 180 national standards, 700 nuclear industry standards, and 20 nuclear power standards for the energy industry, covering uranium mineral exploration, uranium mining and metallurgy, uranium purification and conversion, nuclear fuel elements, nuclear facility decommissioning and radioactive waste treatment, radiation protection and nuclear safety, among other fields.

In terms of the total number of standards, the current effective nuclear fuel cycle standards are not sufficient to meet the needs of China's developing nuclear industry, especially with regard to the standards for the later stages of the nuclear fuel cycle, where a large gap remains. In terms of the technical advancement of standards, compared with the United States, France, and other countries, China's current effective nuclear fuel cycle standards continue

to lag behind on the whole. Furthermore, the standards with independent intellectual property rights cannot cover all of the core key technologies, and the number of standards that can lead industrial development is too small. Therefore, China's nuclear fuel cycle standards have much room for improvement in terms of quantity and advancement.

3.2.2 China's nuclear fuel cycle standards have been implemented with remarkable results

The construction of nuclear fuel cycle standards in China started in the 1980s. Due to the industry's susceptibility and foreign control, most of the relevant standards were prepared based on a summary of China's scientific research and production experience in the nuclear fuel cycle; for example, existing standards in areas such as uranium mineral exploration, uranium mining and metallurgy, uranium purification and conversion, nuclear fuel elements, nuclear facility decommissioning, and radioactive waste treatment were largely developed based on China's independent technologies. A small number of standards were developed on the basis of foreign standards, in combination with China's practical experience; for example, existing standards in nuclear safety, radiation protection, and other areas were developed by drawing on the relevant guidelines and technical documents of the International Atomic Energy Agency (IAEA). The construction of China's nuclear fuel cycle standards system reflects the needs of China's scientific research and production and has been well promoted and applied, and it plays an important supporting role for scientific research and production.

4 Challenges faced during the development of nuclear fuel cycle standardization

4.1 Unsound working mechanisms restrict the supporting and safeguarding role of standardization

Since the introduction of the 12th Five-Year Plan, China, through independent research and development, has made a number of important scientific research achievements that feature independent intellectual property rights and has accumulated valuable experience in the nuclear fuel industry, but these achievements have not been compiled into relevant technical standards in a timely manner; for example, China has built, with fully independent intellectual property rights, the world's first industrial-scale production line for high-temperature gas-cooled reactor components, but preparation for relevant standards has just started.

The promotion and feedback mechanisms for standards implementation need to be improved. At present, laws and standards are not well integrated. Compared with the United States, France, and other countries, Chinese laws contain few references to standards. The status of technical standards needs to be improved, and the implementation of standards needs to be strengthened. In contrast, the United States has quoted a large number of domestic technical standards in the 10CFR, and France has cited RCC standards in its *Safety Regulations for Nuclear Facilities of France*. At present, the implementation feedback mechanism of standards in China is not sound, the standards issuing departments do not know enough about the use of standards, and the channels for standards implementation units to provide feedback opinions are not smooth, which, to a certain extent, restricts the further improvement of standard quality.

The incentive mechanism for standardization needs to be improved. Standardization work requires continuous investment and long-term accumulation from scientific research and production units, but the resulting economic and social benefits are not obvious in the short term and cannot be quantified. Therefore, the enthusiasm and initiative of the scientific research and production units for standardization work in China's nuclear fuel cycle industry need to be further stimulated.

4.2 Uneven development of nuclear fuel cycle standards, with large gaps in standards for later stages

For many years, driven by the development needs of nuclear power and other industries, China has conducted a lot of standardization work specific to the early stages of the nuclear fuel cycle, for example, uranium geological exploration, uranium mining and metallurgy, uranium purification and conversion, and nuclear fuel elements, and a standards system supporting scientific research and production was initially established; however, due to insufficient investment in the later stages of the nuclear fuel cycle, the standards gap in the later stages is large. For example, specific to the fields of spent fuel transportation, reprocessing, nuclear facility decommissioning, and radioactive waste treatment, the number of existing standards still cannot meet the needs of industrial development.

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4.3 The technical level of nuclear fuel cycle standards needs to be improved, as their leading role is insufficient

Some technical standards in the Chinese nuclear fuel cycle have been introduced and modified, and the technical level of nuclear fuel cycle standards lag behind other international examples. Compared with the United States, France, and other advanced countries, China still has a long way to go in the field of fuel element manufacturing, reprocessing, nuclear facility decommissioning, and radioactive waste management. Some core technical standards in the field of basic materials do not have independent intellectual property rights, and the number of high-level standards with a leading role is relatively small.

4.4 The supporting and safeguarding capabilities of standardization are not strong

The supporting and safeguarding capabilities of China's standards system in the nuclear fuel cycle need to be improved. Specifically, the standards system is insufficient in supporting the standardization of major projects; some standards are not well combined with the actual research, production, and engineering needs; and its supporting and safeguarding role is not prominent. The ability to internationalize standards needs to be strengthened. Compared with advanced standardization organizations, such as ASME and AFCEN, China has a weak voice in international standardization work and is in a follower's position in international competition; the basic research ability on standardization is not strong. Due to insufficient basic data for key indicators in some technical standards, we have no choice but to refer to those listed in foreign standards. In addition, due to a lack of test verification equipment, it is impossible to carry out compliance verification suitable for China's reality.

5 Main tasks for standardizing the nuclear fuel cycle

To give full play to the standardization and leading role of nuclear fuel cycle standards, the standards system in China should be basically improved and standards in key areas should be generally improved by 2025. By 2035, a complete nuclear fuel cycle standards system should be established, the overall quality and advancement of standards should be improved, the international standardization level must be greatly improved, and the international influence should be significantly enhanced. To achieve these goals, the following tasks must be conducted.

5.1 Addressing the standards shortage for the later stages of the nuclear fuel cycle, and promoting the sustainable development of the industry

Specific to spent fuel transportation, nuclear facility decommissioning, and radioactive waste treatment, we shall construct standards and demonstrate, deploy, and implement standardization together with nuclear facility decommissioning and other major engineering tasks to address the standards shortage that exists in the later stages of the nuclear fuel cycle. In doing so, we will maximum the supporting and safeguarding role that standards play in the later stages. With this task, we aim to address worries about the development of nuclear energy and contribute to the sustainable development of the nuclear fuel cycle and the nuclear energy industry.

5.1.1 Standards for spent fuel transportation

Research and development work on the standards system for the road–sea–rail intermodal transportation of spent fuels shall be conducted based on the international and domestic requirements for spent fuel transportation. Emphasis will be placed on the department/revision of relevant standards, such as spent fuel transportation containers, packaging, online monitoring during transportation, radiation monitoring, route selection, transportation stations, means of transportation, transportation organization, comprehensive management, and quality assurance, among others. Furthermore, a technical standards system for the road–sea–rail intermodal transportation of spent fuels shall be established and improved upon to ensure the orderly transportation of spent fuels.

5.1.2 Construction of reprocessing standards

A standards system suitable for China's reprocessing development route will be constructed. We shall focus on developing standards for the following fields: the critical safety, radiation safety, and industrial safety of wet reprocessing; the overall and main process systems, as well as the auxiliary process system of reprocessing; the design of buildings (structures); the commissioning of chemical reprocessing equipment, mechanical equipment, instrument and control electrical equipment, monitoring equipment, and special materials for the purpose of

reprocessing; process control and analysis; the inspection and maintenance of products; operation restrictions and conditions; spent fuel transport containers; radiation monitoring; and emergency safety.

5.1.3 Construction of standards on the decommissioning of nuclear facilities and radioactive waste disposal

We shall, according to the latest requirements of the IAEA, develop standards in the following fields: the decommissioning of uranium mining and metallurgy facilities, radiological security and environmental protection after decommissioning, radioactive waste minimization, high-level liquid waste processing, the control of slightly contaminated radioactive materials, radioactive waste disposal, decommissioning technology, the final state in the case of decommissioning, the costs for decommissioning nuclear facilities, and deep geological disposal. We shall develop standards for the geological disposal of high-level waste, including standards for site selection and site evaluation technology, geological disposal field test technology, engineering and process technology, and geological disposal safety evaluation technology; we shall develop said standards in parallel with underground laboratory projects for the geological disposal of high-level waste. In parallel with the decommissioning project of the No. 101 Reactor, we shall develop standards for the decommissioning of research reactors and establish a comprehensive standards system for the same.

5.2 Increasing the development of key core technical standards to promote the autonomously controllable development of the nuclear fuel cycle industry

We shall focus on the standardization of key equipment, instruments and meters, and key materials in the nuclear fuel cycle. On one hand, we shall avoid allowing production in the nuclear fuel cycle to be enslaved to others and ensure the stable supply of nuclear materials and nuclear fuels. On the other hand, we shall strengthen the interaction between intellectual property rights/patents and standardization and develop and promote them in a harmonized way, thus occupying the technological highland and enhancing the industry's core competitiveness.

We shall construct a standards system and key standards for advanced nuclear fuel elements, and, on the basis of summarizing the experience on fuel elements of third-generation pressurized water reactors, high-temperature gas-cooled reactors, and AP1000, we shall study and construct a standards system for the fuel elements of third-generation pressurized water reactors and high-temperature gas-cooled reactors. We shall develop the corresponding key standards in parallel with the research and development of new fuel elements, such as micro-reactor fuel elements, plutonium-uranium oxide mixture (MOX) fuel elements of thorium-based molten salt reactors and fast reactors, accident-tolerant fuel (ATF) elements, annular fuel elements, and the fuel elements of lead-cooled fast reactors. We shall develop standards for key materials, strengthen the development of standards for key materials based on independent research and development technologies (e.g., nuclear-grade zirconium alloy and radiation-resistant material technologies), combine patents with standardization, and maximize the leading role of standards.

5.3 Strengthening the development of advanced standards to promote the high-quality development of the nuclear fuel cycle industry

Advanced standards can promote the industry's ability to improve basic materials, key equipment, key processes, major equipment, and even the whole industrial chain. With the goal of comprehensively improving the quality of standards, we shall focus on developing technical standards for the upgrading of uranium purification and conversion in the industrial fields, in which the core technologies have largely been mastered, on promoting industrial quality and efficiency, supporting industrial transformation and upgrading, and giving full play to the role of standards in promoting green and high-quality development.

5.4 Strengthening the construction of cutting-edge basic standards to promote the innovative development of the nuclear fuel cycle industry

Based on material irradiation tests, we shall collect and sort relevant data and develop material irradiation performance standards to provide parameters for fuel design and development. We shall use such standards as a standards support for the decommissioning of nuclear facilities and other work, and on the basis of the critical tests, we shall develop standards for critical calculations to guide the transport and storage of spent fuels. We shall make full use of existing test and verification equipment resources to verify the accuracy of key elements and core technical standards indexes, strengthen basic research on standards, increase independent research on standards, and comprehensively enhance the applicability of standards.

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5.5 Strengthening the construction of safety and environmental protection standards to promote the green development of the nuclear fuel cycle industry

Based on the need for safe and green development, we shall focus on standards for green and digital geological exploration and the mining and metallurgy of uranium mines to promote the sustainable development of the nuclear fuel cycle industry. We shall develop green exploration technology, conduct digital explorations, and develop related standards for the design and operation of green and digital mines, as well as the development of associated radioactive resources, to build a green mine standards system. We shall focus on the development of nuclear and radiation safety standards and promote the development of standards for the shielding performance test methods of radiological protection materials and the on-site protection of transuranic nuclide operating facilities and workplaces. We shall also promote the development of standards related to occupational exposure, public exposure and ecological environment protection, safety analysis and the technical review of nuclear fuel cycle facilities, and nuclear and radiation emergency preparedness and response.

5.6 Participating in international standardization to increase the international influence of Chinese standards

5.6.1 Actively exporting Chinese proposals to contribute wisdom to international standards

We shall increase the push of international standards proposals and report said proposals to the ISO in a timely manner using advanced technology and mature conditions. On one hand, we shall actively put forward Chinese proposals and lead the formulation of international standards in the fields of radiation safety, uranium products and analysis methods, and decommissioning and radioactive waste processing; on the other hand, we shall develop international standards and apply for proposals based on China's advanced nuclear fuel technologies and products with independent intellectual property rights, such as "Hualong No. 1" nuclear power fuel, uranium exploration and mining, high-temperature gas-cooled reactor fuel, and low-concentration nuclear fuel elements for research reactors.

5.6.2 Actively conducting exchanges and cooperation in all aspects of international standards

We shall organize Chinese experts to join the draft group for international standards and actively participate in standards development activities and international academic activities about standardization to further enhance China's influence in ISO organizations. We shall enhance the international standardization ability of China's standardization institutions and actively organize regional or international conferences. Furthermore, we shall promote the development of international standards and conduct related technical management processes in an orderly manner; we shall sponsor relevant working groups and provide them with quality technical coordination and guidance; we shall perform well in the technical reserve and training of professionals; and we shall provide timely reports to the secretariats of other ISO/TC85 sub-technical committees.

5.6.3 Promoting the construction of regional standards and improving the adoption rate of international standards

We shall strengthen cooperation and exchanges with countries and regions involved in the Belt and Road Initiative and the *Regional Comprehensive Economic Partnership*, promote the construction of regional standards, share standardization achievements, and contribute to the cooperation between the nuclear power and nuclear fuel industries. We shall support the domestic transformation research of ISO/TC85 international standards and improve the adoption rate of international standards. Meanwhile, we shall actively follow the standards issued by foreign advanced standardization organizations, such as ASTM and AFCEN, and actively learn from foreign advanced experience.

5.7 Strengthening the basic capacity building of standardization to promote the long-term development of the nuclear fuel cycle industry

With the goal to comprehensively improve the nuclear fuel cycle standardization capability, we shall focus on establishing the nuclear industry's standards high-end think tanks and standards service platforms, as well as the nuclear fuel cycle standards test and verification platforms to promote the construction of high-end professionals. We shall also informatize and test the verification capabilities of nuclear fuel cycle standardization and provide high-quality standardization support for the nuclear fuel cycle industry.

5.7.1 Establishing a high-end think tank for nuclear industry standards

We shall give full play to the interaction and spillover effects of nuclear industry standardization information, resources, and talent highlands and jointly establish high-end think tanks for nuclear industry standardization with enterprises, institutions, industry associations, and institutions of higher learning operating in the nuclear industry. We shall form a high-level work team, study the nuclear industry development plan, technical route, demand docking, and others, and provide professional and technical support for the top-level design of nuclear industry standardization. Finally, we shall provide professional and technical services for the development of nuclear industry standardization.

5.7.2 Building a standardization service platform for the nuclear industry

We shall establish a database of nuclear industry standards that covers product standards, technical standards, and other standards to provide technical support for authorities at all levels, as well as technical support for scientific research and production departments related to the nuclear industry. We shall build an open and shared nuclear industry standard service platform for information consulting, develop service portals and mobile applications (i.e., an app), and build a new model for intelligent digital service; finally, we shall improve the standardization service capability covering the full life cycle of standards, including the preliminary study, formulation/revision, use and effect evaluation of standards, and information feedback stages.

5.7.3 Building up the test and verification platform for nuclear fuel cycle standards

We shall organize all relevant units to jointly establish the nuclear fuel cycle standards test and verification platform. In doing so, we shall make full use of the advantages of existing resources, share test equipment and instruments, and strengthen the collaborative innovation of production, education, research, and application. We shall enhance the verification and evaluation of standards, promote quality improvement, perform the verification and evaluation of nuclear fuel cycle test standards, and improve the authority of nuclear fuel cycle standards based on the advantages of platform resources.

6 Policy recommendations

6.1 Incorporating the standardization of the nuclear fuel cycle in the 14th Five-Year Plan of the nuclear industry

The standardization of the nuclear fuel cycle is an important part of scientific research and production in the nuclear industry. It is recommended that the relevant state departments incorporate this standardization into the 14th Five-Year Plan of the nuclear industry, create an associate special topic regarding the standardization of the nuclear fuel cycle, consider standardization to be an overall priority, and promote the development of nuclear fuel cycle standardization to provide standards support for the development of China’s nuclear industry.

6.2 Strengthening the working mechanism of standardization

6.2.1 Establishing a collaborative mechanism between the implementation of major scientific research and engineering projects and the development of standards [7]

We shall learn from the advanced experience of standardization projects in aviation, aerospace, and other fields to strengthen the coordinated development of standardization and scientific and technological innovation and to establish a collaborative mechanism between the standardization and major scientific research and engineering projects. It is recommended that full-time personnel be placed in charge of standardization in major scientific research and engineering projects, special funds for standardization be provided, the coordination mechanism between standardization and major scientific research and engineering projects be strengthened, and synchronous planning, construction, and acceptance be realized. Furthermore, it is recommended that an acceptance mechanism for the standardization of major projects and scientific research projects be established, standardization acceptance be taken as an important component of the acceptance of major projects and scientific research projects, technical research achievements be collected and consolidated in a timely manner, and channels that allow innovation achievements to be transformed into standards be created. Finally, we recommend establishing a standardization evaluation system for nuclear fuel cycle engineering projects, improving the degree of the standardization of projects, providing technical support for engineering copying and large-scale development, and giving full play to the role standardization plays in supporting and guaranteeing major scientific research and engineering projects.

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6.2.2 Establishing a mechanism for implementation of standards

We shall improve relevant rules and regulations; guide the adoption of Chinese standards in the areas of government procurement, national major project bidding, project evaluation, and safety production evaluation; and take the proportion of adopted independent standards as an important reference index for the government to conduct related work and as an important basis for preferential measures, such as corporate tax incentives and the simplification of market access procedures, so as to improve the enthusiasm of industry research and the application of independent standards.

We shall strengthen the supervision intensity of standards implementation, establish a normalization working mechanism for standards rechecks, and clarify the evaluation methods of standards implementation and the supervision and management requirements. We shall strengthen the multichannel and multilevel publicity and implementation of nuclear fuel cycle standards through training and technical exchanges; we shall conduct research on the standard implementation effect and the mechanism of standard supervision and management, build a feedback platform for standard implementation, collect relevant data related to standard implementation, and analyze and master the implementation of standards. We shall optimize the implementation and feedback mechanism to form a virtuous "implementation–feedback–improvement" cycle for standards.

6.3 Increasing funding for the standardization of the nuclear fuel cycle

The nuclear fuel cycle industry, which is a national strategic industry, has a low degree of marketization. Therefore, it is recommended that the national competent department establish a special subsidy mechanism for the standardization of the nuclear fuel cycle; increase funding and financial support for the preparation, implementation, and basic research of standards; maintain continuous investment; and give special work funds to the professional institutions working on nuclear industry standardization to enhance the support and guarantee for standardization work.

6.4 Strengthening the cultivation of standardization professionals

We shall increase the cultivation of technical talents and internationalized talents regarding the standardization of the nuclear industry. In the field of technology, we shall cultivate a group of authoritative industry experts and front-line experts who have excellent technology and are keen on standardizing the nuclear industry. We shall establish a talent exchange mechanism with international standardization organizations, such as the ISO and the International Electrotechnical Commission, and foreign standards organizations, such as ASME and AFCEN, select standardization-related technicians and managerial personnel for the exchange visits, and cultivate a group of standardization-related compound professionals who are knowledgeable in nuclear industry standardization and rules or international standardization activities, and who have corresponding abilities in terms of organization and coordination, as well as the ability to communicate in a foreign language [8].

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