THE PEOPLE'S REPUBLIC OF CHINA

THE SEVENTH NATIONAL REPORT UNDER THE CONVENTION ON NUCLEAR SAFETY

（2013-2015）

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Beijing

Table of Contents

Abbreviations

ANSN	Asian Nuclear Safety Network
CGN	China General Nuclear Power Group Co., Ltd.
CNEA	China Nuclear Energy Association
CNNP	China National Nuclear Power Co., Ltd.
CNNO	CNNP Nuclear Power Operations Management Co., Ltd.
DCS	Digital Control System
GNSSN	Global Nuclear Safety and Security Network
INES	International Nuclear Events Scale
IAEA	International Atomic Energy Agency
IRRS	Integrated Regulatory Review Service
MDEP	Multinational Design Evaluation Programme
MEP (NNSA)	Ministry of Environmental Protection (National Nuclear Safety Administration)
NPP	Nuclear Power Plant
OECD /NEA	Nuclear Energy Agency of Organization for Economic Cooperation and Development
OSART	Operational Safety Review Team
PSA	Probabilistic Safety Analysis
PSUR	Pre-startup Peer Review
PSR	Periodic Safety Review
PWR	Pressurized Water Reactor
SAMG	Severe Accident Management Guideline
SOER	Significant Operating Experience Report
WANO	World Association of Nuclear Operators

A. Introduction

The Chinese government has consistently attached high importance to nuclear safety, earnestly performed all obligations committed to international community, undertaken the safety responsibilities for its nationwide NPPs, and made unremitting efforts to meet and keep a high-level nuclear safety standard accepted internationally.

A.1 General Situation of the Peaceful Uses of Nuclear Energy in China

Nuclear power is a clean, efficient and high quality modern energy source, and developing nuclear power constitutes an important component of China's energy strategy. China consistently gives top priority to nuclear safety in its peaceful use of nuclear energy, follows the principle of enhancing safety for the development and promoting development by upholding safety, and makes great efforts to bring the dual goals of development and safety in alignment with each other. China implements the policy of developing nuclear power in a safe and efficient manner by adopting the most advanced technologies and most stringent standards.

From 2013 to 2015, 13 nuclear power units had been put into commercial operation in China, and 9 nuclear power units started construction. As of December 31, 2015, there were 28 nuclear power units in commercial operation in China, with total installed capacity of 26,148MW; and 26 nuclear power units under construction, with total installed capacity of 29,000MW. Furthermore, construction permits of 2 units were issued at the end of 2015, but construction has not yet been started.

The operating nuclear power units maintained their good operation performance records. From 2013 to 2015, the annual accumulative electricity generated by nuclear power units in commercial operation in China increased steadily, being 112.1 billion kWh, 130.58 billion kWh and 168.319 billion kWh in these three years respectively, accounting for about 2.1%, 2.35% and 3.01% respectively in the total electricity generated in the whole country.

After the Fukushima nuclear accident, Chinese government launched comprehensive safety inspections on civil nuclear facilities, and carried out evaluation on external event safety margin for NPPs in operation and under construction. According to the experience feedback from Fukushima nuclear accident and results of comprehensive safety inspections, the MEP (NNSA) issued the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident* in June 2012, so as to formalize the common improvement actions in NPPs, and provide guidance for the post-Fukushima improvements conducted in NPPs in China. The capacity of NPPs in China on the resistance of extreme natural disasters, the prevention and mitigation of severe accidents, the emergency preparedness and emergency response, and the communication to the public, has been further upgraded through these improvements.

From 2013 to 2015, there are 113 licensed operating events of INES scale 0 in China's nuclear power units in operation. The event of INES scale 2 or above did not take place. The units under construction can generally satisfy China's current nuclear safety regulations and meet the requirements of the latest safety standards of IAEA. The effective management is secured in the process of siting, design, manufacture, construction, installation, commissioning and others. The quality assurance system functions well, the construction quality meets the design requirements and the overall quality is under control.

A.2 Policies and Objectives for Nuclear Power Development in China

The strategic policy of "economic, clean and safe" development of energy is adhered in China, so as to push ahead energy revolution, energetically promote reform in the energy production and utilization forms, optimize energy supply structure, raise energy utilization efficiency and build clean, low-carbon, safe and efficient modern energy systems. China develops non-fossil energy in parallel with the efficient and clean utilization of fossil energy, gradually lowers the proportion of coal consumption, raise the proportion of natural gas consumption and substantially increase the consumption proportions of renewable energy such as wind power, solar energy, geothermal energy and the nuclear power. By 2020, the proportion of non-fossil energy in primary energy consumption in China will reach 15%, the proportion of natural gas will be over 10%, and the proportion of coal consumption will be controlled below 62%.

From 2013 to 2015, the proportion of thermal power generation in China was lowered step by step, dropping from 78.36% in 2013 to 74.94% in 2015; The proportion of electricity generated by wind power and solar energy increased from 2.78% in 2013 to 4.32% in 2015, and that of nuclear power increased from 2.10% in 2013 to 3.01% in 2015.

In the 13th Five-Year Plan period, China will construct safely demonstration projects of self-designed NPPs mainly along the coastal nuclear power belt, and complete the construction of AP1000 projects in Sanmen and Haiyang and other nuclear power projects will be completed. The HPR1000 demonstration projects in Fuqing and Fangchenggang will be constructed. The construction of CAP1400 demonstration project in Rongcheng as well as other new nuclear power projects along coastal areas will be started. Phase III project of Tianwan Nuclear Power Station will be speeded up; and the prophase works for inland nuclear power projects will be actively carried out. By 2020, the installed capacity of operating nuclear power units will reach 58GW, and that of units under construction will be over 30GW.

A.3 Nuclear Safety Policy in China

China insists on developing nuclear power on the premise of ensuring safety. The policy of Safety First shall be followed at the stages of siting, design, construction, operation and decommissioning. Sufficient measures must be taken to ensure quality and operation safety, prevent nuclear events and minimize potential adverse impacts, and protect the staff, the public and the environment from excessive exposure and contamination beyond the national limits, that is, exposure and contamination should be reduced to a level as low as reasonably achievable (ALARA).

In March 2014, China pointed out "rational, coordinated and balanced" nuclear safety outlook in Hague Nuclear Summit, which stressed that the nations should fulfill nuclear safety responsibilities and obligations. China has integrated nuclear safety into the overall national security system, and specified the strategic positioning for nuclear safety. In the *State Security Act* issued in July 2015, it is specified in Article 31 that, "The state adheres to the peaceful utilization of nuclear energy and nuclear technologies, strengthens international cooperation, prevents nuclear proliferation, complete the anti-proliferation mechanism, strengthens the safety management, supervision and protection of nuclear facilities, nuclear materials, nuclear activities and nuclear waste disposal, strengthens the construction of nuclear accident emergency systems and emergency response capacity, prevents, controls and eliminates hazards of nuclear accidents on the life and health of general public and ecological environment, and continually enhance the ability to effectively cope with and prevent nuclear threat and nuclear attacks."

In April 2016, China proposed to strengthen the nation responsibility, deployment and implementation of nuclear safety strategy, and establishment of strict and enduring line of defense; In addition, nuclear safety culture shall be strengthened to form an atmosphere of coordinated building and sharing. China will establish nuclear safety capability network and promote the national regulation system of nuclear power safety.

In 2012, China issued the "*12th Five-Year*" *Plan and Prospective Targets of 2020 on Nuclear Safety and Radioactive Pollution Prevention and Control(hereinafter referred to as "Nuclear Safety Plan")*, which set clearly the safety goal and regulatory principle for nuclear safety work. For reaching the safety goal, specific targets and associated projects and guarantee measures were set on aspects of raising the nuclear facility safety level, lowering the safety risks in radiation environment, accident defense, contamination treatment and control, scientific and technological innovation, emergency response and safety regulation. The overall goal set for nuclear safety is: to further improve safety level of nuclear facilities, to substantially reduce safety risk of radiation environment, to basically form accident defense, contamination control, scientific and technical innovation, emergency response and safety regulation capability, so as to ensure sound nuclear safety, environment safety, public health and radiation environment quality. The basic principles of "preventing first, defending in depth; stressing both the new and old issues, combining prevention with control; relying on science and technology, making continual improvements; sticking to the rule of law, implementing strict regulation; staying open and transparent and maintaining harmonious development" shall be followed, and the supervision concept of being "independent, open, legal, rational and effective" shall be carried out.

China actively advocates nuclear safety culture. By issuing the *Nuclear Safety Culture Policy Statement*, the basic attitude towards nuclear safety culture is clarified, and the principle requirements on cultivating and practicing nuclear safety culture are established. The nuclear safety regulatory body and relevant authorities, all nuclear energy organizations, engineering and service organizations and stakeholders should jointly observe and practice the attitude, positions and principles in the policy statement, enhance the awareness on rule of law, responsibilities, risks and honesty, and create a cultural atmosphere to attach importance to nuclear safety, safeguard nuclear safety, and cherish nuclear safety. China implements the national responsibility on nuclear safety and international obligation on nuclear safety, energetically cultivate and develop nuclear safety culture, to raise the nuclear safety level and guarantee the safe, healthy and sustainable development of the nuclear energy undertakings.

China will continue to deepen the exchanges and cooperation with all countries and international organizations in the world in nuclear energy including nuclear safety field, properly fulfill the obligations under nuclear energy conventions already signed, put the multilateral and bilateral commitments on nuclear safety into practice, and prevent and cope with nuclear safety risks jointly with international society to improve the global nuclear safety level.

A.4 Preparation and Structural Features of the National Report

In terms of structure, the report consists of three parts: introduction, overview and detailed reports. "Introduction" gives a comprehensive and brief description of current situation of the peaceful uses of nuclear energy in China, describes the development status and objective of nuclear power in China and illustrates China's policies and opinions in respect of nuclear safety. "Overview" expounds China’s response to the sixth review results, the focused areas and improvement actions taken on nuclear safety, the response to the *Vienna Declaration on Nuclear Safety*, the good practice and challenges.

Please refer to the part "Detailed Reports" for more details of the above mentioned contents. This part covers Chapters 6 to 19 of this report, and is prepared according to contents of Article 6 to Article 19 of the *Guidelines Regarding National Reports under the Convention on Nuclear Safety*. All chapters of this part begin with the original text of the *Convention on Nuclear Safety* and expound how to fulfill the obligations specified in *Convention on Nuclear Safety* by China through presentation of requirements of laws and regulations, important activities, practices and corresponding progresses.

In preparing the report, the requirements in the *Guidelines Regarding National Reports under the Convention on Nuclear Safety* (INFCIRC/572/Rev.5) was referenced, with emphasis on the three principles set in the *Vienna Declaration on Nuclear Safety* for the goal to prevent accident and mitigate accident consequences, at the same time, the framework and contents of the national report was completed by comparing with the latest template for national report (Chapter 17 and Chapter 18) formulated by the IAEA, to finally compile this report.

In the report, data concerning NPPs in Taiwan Province of China are not available.

B. Overview

B.1 Summary on the Sixth Implementation of Convention and Follow-up Actions

With a view to strictly performing commitments by the Chinese Government in the *Convention on Nuclear Safety* and obligations of contracting party prescribed in the Convention, Chinese government has set up Chinese Implementing Group of the *Convention on Nuclear Safety*, which is in charge of organizing and coordinating China's implementation of the Convention and ensures that the requirements to the contracting parties made by the Convention and that all resolutions made in the previous review meetings related to the national reports under the *Convention on Nuclear Safety* will be fulfilled.

B.1.1 Summary on the Sixth Implementation of Convention

In September 2014, China submitted *The Sixth National Report of the PRC under the 'Convention on Nuclear Safety* to the contracting party review meeting of the *Convention on Nuclear Safety*. In the meantime, all written questions raised to China by other contracting parties on the sixth national report were well addressed.

In the sixth review meeting, contracting parties seriously reviewed China's implementation of the Convention by means of report review, site statement and question answering, and spoke highly of the practices and progresses made in China since last review meeting.

The peer review meeting of contracting parties considered that it is a good practice that China requires all newly built NPPs to complete the relevant Fukushima improvement actions required after the inspection by the NNSA before first fuel loading. The review meeting also pointed out the challenges China confronted with and the fields which to be further improved, including:

(1) Various reactor types and multi standards: The situation of importing from different countries, having various reactor types and coexisting of multi standards and technologies exists in nuclear power industry of China, which poses challenges to the nuclear safety regulation.

(2)Training and development of regulatory body staff: Different types of reactors and technologies are in service for NPPs of China. However, regulatory teams include many young people lacking in experience. Therefore, strengthened training is required to raise the regulation capability of regulatory personnel.

(3) Improving the nuclear safety laws, regulations and standards: China needs to further strengthen the development of nuclear safety laws, regulations and standards, especially the legislation of relevant laws such as Nuclear Safety Act.

(4) Regulation on NPPs under construction: by the time of the sixth review meeting, there were 31 units under construction in China, which constituted a great challenge to the inspection by regulatory bodies. Therefore China needs to prepare and implement relevant inspection programs.

(5) Capacity building of regulatory body:the regulatory body need to strengthen their capacity building, including technical capacity, human resources and financial resources.

B.1.2 Response Actions to the Challenges from the Sixth Review Meeting

China worked out and implemented follow-up actions to address all challenges from the sixth review meeting, specifically as follows:

(1) Various reactor types and multi standards

The multiple reactor types, technologies and standards existing in China are both challenges and opportunities to nuclear safety regulation. The nuclear and radiation safety regulatory personnel in China have accumulated rich working experience in nuclear and radiation safety regulation in the long-term work of safety review, safety inspection and on-site inspection, and after long time contact, understanding, comparison and analysis of different nuclear industrial systems, technologies, reactor types and standards. They worked out a regulation pattern not only consistent with international practices but also suitable in China, and eventually formulated standard supervisory inspection programs. On the basis of the standard inspection programs, regional supervisory offices refined and implemented inspection programs for specific reactor types and suitable at different stages, in the meantime, detailed inspection implementation procedures have been worked out for the inspection of systems, equipment and activities important to safety.

On the basis of meeting the nuclear safety laws and standards requirements of China, the MEP (NNSA) made full reference to the laws and regulations and regulatory experience of technology origin countries, conducted active exchanges and cooperation with nuclear safety regulatory body in other nuclear power countries, to learn from each other and raise the efficiency and effectiveness of nuclear safety regulation.

After the Fukushima nuclear accident, the MEP (NNSA) carried out research work on the safety requirements for new NPPs, and set fairly unified and operable safety requirements for subsequent new NPPs on the aspects including safety goal, site safety, core characteristics, severe accidents and engineering verification. In addition, the MEP (NNSA) actively participated in and followed up the revision of *Safety of Nuclear Power Plant： Design* published by IAEA. Recently, the MEP (NNSA) will complete the modification of *Code on the Safety of Nuclear Power Plant Design*.

In the subsequent development of nuclear power, China will mainly adopt two technical lines: one is the generation III nuclear power technologies backed by the AP1000 type reactor, and the generation III nuclear power technologies with proprietary intellectual property rights of China represented by HPR1000. In addition, China is now building a 200MW HTGR demonstration project featuring the fourth generation nuclear technology characteristics.

(2) Training and development of regulatory body staff

The MEP (NNSA) compiled training programs for nuclear safety regulatory personnel, which determined the basic requirements for the training work of nuclear safety regulatory personnel, and consolidated the training contents for them. Gradually a multi-level and multi-way of nuclear and radiation safety training system is formed.

To establish a stable team matching with the regulation tasks, the MEP (NNSA) has developed qualification training course for the nuclear and radiation safety inspection personnel with nuclear and radiation safety regulation initial training and intermediate training as the main items, on-the-job training course for the nuclear and radiation inspection personnel with radiation environment monitoring management and technologies and nuclear and radiation emergency as the main contents, and special subject training course focused on important position personnel and key professional work such as simulator, non-destructive examination, civil nuclear safety equipment regulation and nuclear quality assurance and so on. These measures provide powerful manpower support for the nuclear and radiation safety regulation. In the meantime, selected people were dispatched to attend international conferences, training sessions or further studies through international institutions or bilateral cooperation to raise the capacity and level of nuclear and radiation safety regulatory personnel.

The MEP (NNSA) has purchased a full-scope simulator for 1000MW NPPs with the function to simulate severe accidents, dispatched people to participate in the NPP reactor operator licensing training, trained its own simulator tutors, and continually carried out the simulator training for various regulatory personnel, to further upgrade the regulation skill and strengthen the review and verification work on emergency procedures and SAMG of NPPs.

The MEP (NNSA) has being continued to provide the qualification training and on-job training for nuclear safety inspectors. In 2013 to 2015, 5 nuclear safety inspector qualification training course were held. 207 people were trained. 5 on-the-job training for nuclear safety inspectors were held and 124 people were trained. By December 31, 2015, nuclear safety inspector certificates had been issued to 325 qualified people.

In addition, to further strengthen the capability enhancement of regulatory personnel and promote the accumulation and sharing of regulation experience, the MEP (NNSA) has actively carried out people-to-people exchanges and post rotation between the headquarter and all regional offices; The experts with rich working experience in nuclear have been hired from NPP operating organizations and relevant technical support organizations to continually replenish the core technical personnel team for nuclear safety regulation.

(3) Improving the nuclear safety laws, regulations and standards

China has actively carried out the legislative work for laws including the *Nuclear Safety Act* and *Atomic Energy Act* to keep on completing the nuclear safety laws and regulations system. The work to formulate and amend nuclear safety laws, regulations and standards has been strengthened, and the work to formulate nuclear power industry standards is going on.

The draft of *Nuclear Safety Act* and *Atomic Energy Act* has been completed and listed in the legislation plan of the Standing Committee of the National People's Congress, which shall be submitted to the Standing Committee of the National People's Congress for deliberation as soon as possible.

In addition, the MEP (NNSA) has closely followed and participated in the IAEA safety standard revision plan after the Fukushima nuclear accident, actively studied countermeasures, established the dynamic reporting mechanism for regulations, and issued regulations status reports regularly, to enable the industry and the public to promptly master the currently effective regulations. In 2015, the MEP (NNSA) formulated the *Five-year Plan for the Development and Revision of Nuclear and Radiation Safety Regulations (2016-2020)*, to direct the work to revise nuclear and radiation safety laws and regulations.

The standardization work in nuclear power industry is pushed ahead steadily. The National Energy Administration (NEA) has started the work to prepare, revise and complete a series of industrial standards. Nuclear group corporations have also developed relevant enterprise standards.

(4) Regulation on NPPs under construction

The MEP (NNSA) has organized and formulated the standard inspection programs for NPPs at various stages, covering construction, commissioning and operation. On this basis, the regional offices have worked out and implemented inspection programs and implementation procedures for specific plants.

According to the progress and actual conditions of units under construction, the MEP (NNSA) organized the formulation and implementation of national annual schedule for nuclear safety inspection to carry out comprehensive/ special inspection for important milestones and activities. The regional offices formulate the annual nuclear safety inspection schedule for the areas under its jurisdiction, and mainly carry out daily inspection and specific inspection.

In April 2013, the MEP (NNSA) issued the *Nuclear Safety Inspection Program for Construction Stage (Civil Works and Installation) of 1000MW Class Modified PWR* and *Nuclear Safety Inspection Program for Commissioning Stage of 1000MW Class Modified PWR*, which further improved the regulation on inspection of units under construction

As new design has been adopted for AP1000 and EPR, commissioning regulation faces totally new challenges. In 2014, the MEP (NNSA) prepared the *Commissioning Inspection Work Plan for AP1000 and EPR NPPs* and *Commissioning Review and Inspection Preparation Plan for the First AP1000 and EPR Reactors*, which made clear the inspection program and the list of inspection items for the commissioning stage of NPPs at Sanmen, Haiyang and Taishan. The preparation of inspection procedures for major tests had been made accordingly. In the meantime, China actively participated in the work of AP1000 and EPR work group of MDEP, proposed suggestions on commissioning, and reached agreement. The Sino-US AP1000 commissioning technology exchange meeting was held for exchanges and exploration on the topic of commissioning regulation with American experts The Sino-US and Sino-French commissioning cooperation patterns and contents with the NRC and ASN has also determined. Inspectors from NRC were invited to supervise the commissioning of AP1000 projects in Sanmen and Haiyang. It is planned to invite inspectors from ASN to supervise the commissioning of EPR project in Taishan.

(5) Capacity building of regulatory body

China has further strengthened its nuclear safety regulation capability by strengthening independent audit calculation and test verification, completing the nuclear and radiation safety regulation integrated management system and the construction of radiation environment monitoring state control network, building up National Regulation Technical R&D Base on Nuclear and Radiation Safety, strengthening human resources and inputting more financial resources and building a complete technical support system.

1) Strengthening independent audit calculation and test verification

The MEP (NNSA) has basically established a fairly complete analysis software system for safety review by importing safety analysis software from other countries and purchasing commercial grade analysis software with extensive application and acceptance. More audit calculation work is being done in the review of new reactor types based on the established safety review analysis software system. The independent calculation and evaluation had been performed on seven aspects of core physics, design basis accident, severe accident, radiation protection, stress and structure anti-seismic analysis, PSA, and effluent discharge source term. In the meantime, the objectives and requirements of audit calculation have been made clear, and the audit calculation process and methods established.

For the review of new reactor types, additional work has been done on test witness and independent test verification. Test witness includes document review and field witness, mainly effective witness is arranged for critical tests on safety systems and equipment carried out by design organization to ensure the authenticity of test data The independent test verification is mainly performed for important safety issues in review. On the basis of tests already made by design organization, the reviewer independently performs some important condition tests to further verify the safety performance of systems important to safety. The MEP (NNSA) has strengthened the independent audit calculation and test verification for units of HPR1000, AP1000, EPR and CAP1400 on critical and typical safety issues and accident sequences.

To evaluate the design safety of CAP1400 and verify relevant safety analysis procedures, the witnesses of six key tests were organized, including passive core cooling system performance test, passive containment cooling system performance test, in-vessel retention test, reactor structure hydraulic simulation test, reactor internals flow-induced vibration simulation test, steam generator and its key components performance test. In addition, three test verifications were performed based on the safety margin and boundary effect of CAP1400 design, including passive core cooling system (PXS) in Station Blackout condition and passive residual heat removal system rupture upstream or downstream the isolating valve, passive containment cooling system (PCS) heat conducting capacity margin test, and test on effect of flow pass change of in-vessel retention(IVR) on heat exchange characteristics of pressure vessel. The establishment and validation of primary big model for AP1000 was completed, which promoted the solution of review issues and strengthened the building of review capacity.

2) Improving the Radiation Environment Monitoring State Control Network

By building automatic stations in the state control network, the MEP (NNSA) has established a radiation monitoring network covering the whole country, with 1389 state control points for radiation environment monitoring. The NPP radiation environment site supervisory monitoring network system has been established, and nuclear safety pre-warning and radiation environment supervisory monitoring work is carried out around important nuclear and radiation installations such as Qinshan NPP. The national and provincial radiation monitoring data collecting center have been completed. The nuclear and radiation accident emergency decision-making support and commanding system has been completed also. These measures have further strengthened the radiation environment monitoring capacity in the whole country, and increased the radiation environment emergency monitoring capacity to cope with nuclear accidents. Furthermore, the capabilities of monitoring teams have been fully upgraded by organizing training for key monitoring personnel and on monitoring technology and operation, conducting monitoring quality examination and arranging skill competition for monitoring items.

3) Building National Regulation Technical R&D Base on Nuclear and Radiation Safety

To upgrade the nuclear and radiation safety regulation capacity comprehensively, China has approved the construction of the National Regulation Technical R&D Base on Nuclear and Radiation Safety. On this base, 10 new major projects will be built, including 6 scientific research and verification laboratories and 4 sets of shared supporting facilities, covering all links of siting, design, construction, commissioning, operation and decommissioning for NPP. The construction of this base will further strengthen the capacity of China on nuclear and radiation safety review, inspection, monitoring, education and international cooperation. The construction of this base has been officially started.

The MEP (NNSA) has carried out the special project on design for nuclear and radiation safety research, and organized the preparation of the *National Key R&D Program – Proposal on Nuclear Safety Key Special Research Task*. The preparation is under way for the construction of the nuclear and radiation safety key laboratory and engineering and technical center, to further upgrade the safety supervision and management capacity for nuclear installations.

4) Strengthening human resources and financial resources

On human resources, in 2012, China expanded the functions on nuclear and radiation safety regulation in the MEP (NNSA) from one department to three departments, based on the experience from Fukushima nuclear accident and in conjunction with the actual conditions. China approved to increase the staffing for nuclear and radiation safety regulation in the MEP (NNSA) to 1103 people by the end of 2015, with the number of staff members increasing to 82 in the headquarter, to 331 in the six regional offices, to 600 in the nuclear and radiation safety center and to 90 in the radiation monitoring technical center. These people have been assigned to positions step by step. The increase of nuclear safety regulatory personnel ensures that the human resources in nuclear safety regulation can meet the current needs in nuclear power development.

In financial resources, to meet the needs in nuclear power development, China has increased the budget for capacity development in nuclear safety supervision and management year by year to ensure the performance of nuclear safety supervision and management functions. In 2015, the daily supervision and management financial budget for the MEP (NNSA) was 379 million (excluding funds for capacity development and scientific research), which has doubled that in 2011.

5) Building a complete technical support system

Under the precondition of independence, the MEP (NNSA) has selected important scientific research institutes and enterprises in the nuclear energy industry as external technical supporters according to the need in work and capacity and qualification requirements, to provide it with stable technical supports and services on a long-term basis, such as the Nuclear Equipment Safety and Reliability Center, Suzhou Nuclear Safety Center, Beijing Nuclear Safety Review Center and China Institute of Atomic Energy. The environmental protection departments in various provinces and some prefecture level municipalities have also established corresponding technical support organizations on radiation environment regulation, forming an organizational system of nuclear safety regulation technical support organizations with full coverage and clear division of levels.

For important regulation and review items, internal and external technical support organizations are required to carry out parallel safety review, to promote mutual comparison and learning, so that the suitability and correctness of review conclusions can be ensured, to reduce mistake in regulation, and continually upgrade the technical capability of technical support organizations.

B.2 Activities Carried out and Planned for Safety Improvement

To improve safety in nuclear power, China has carried out and planned the following activities:

(1) To strengthen the cultivation of nuclear safety culture

In 2014, the MEP (NNSA) , National Energy Administration and China Atomic Energy Authority jointly issued the *Nuclear Safety Culture Policy Statement*. This statement revealed the connotation of nuclear safety and nuclear safety culture, expounded the eight main features of cultivating and practicing good nuclear safety culture, and advocated cultivating, practicing and continually promoting nuclear safety culture. The issuance of the *Nuclear Safety Culture Policy Statement* pointed out the direction for promoting the cultivation of nuclear safety culture and enhancing the nuclear safety culture quality of people working in the nuclear industry.

To enhance the law awareness of practitioners in nuclear and radiation safety, and upgrade nuclear safety culture in all aspects, MEP (NNSA) organized the nuclear safety culture publicity activities in all nuclear and radiation safety licensee utilities and their key personnel. The regional offices organized publicity activities for over 19300 people, and the provincial level environmental protection departments organized publicity activities for over 500,000 people. These activities effectively raised the understanding and cognition of practitioners on nuclear safety culture, and promoted the nuclear safety culture development in the operating organizations.

Nuclear group corporations in China have also carried out a series of nuclear safety culture development activities. They developed principles for nuclear safety culture and the associated assessment standards and criteria, carried out a series of nuclear safety culture trainings and assessment activities, established nuclear safety culture promotion organizations, worked out management rules and long-term plans for development of nuclear safety culture, and established long-term mechanism to publicize nuclear safety culture.

(2) To actively track IAEA safety standards and complete the nuclear safety regulation system of China

To further strengthen the management of nuclear safety regulation system, the MEP (NNSA) introduced the censorship of expert committee review during the approval and the drawing-up of regulations. The expert committee evaluates the set-up project report before the approval, and reviews the outline of regulations before the drawing-up. Review has been strengthened for the format of drafts of regulations.

Before the official approval and release of regulations, comments are solicited from the public. Status reports on regulations are issued periodically, to keep the industry and the public master the status of current effective regulations.

The MEP (NNSA) closely tracks and participates in the preparation and revision of IAEA safety standards. It carried out in-depth research on the IAEA differential analysis reports in 77 areas, performed re-evaluation of the nuclear safety regulations and guidelines of China in conjunction with the nuclear safety practice in China after the Fukushima nuclear accident, proposed suggestions on preparation and revision, and carried out preparation and revision work by phase step by step.

The MEP (NNSA), with reference to the latest version of SSR-2/1 issued by the IAEA in February 2016, is organizing revision of *Code on the Safety of Nuclear Power Plant Design* . Furthermore, according to the lessons learned from Fukushima nuclear accident, China has actively carried out preparation and revision of nuclear safety regulations with respect to issues in siting, design and licensing, external disasters, including earthquake and tsunami risk evaluation, the possible combinations of initial events, emergency preparedness and response, deterministic safety analysis and PSA. The guidelines *Emergency Action Development of PWR* and *Nuclear Emergency Drills at Operating Organizations of Nuclear Power Plant* are being developed; and guidelines *Safety Provision on Siting for Nuclear Power Plant", "Earthquake Problems in Nuclear Power Plant Siting* and *External Human-induced Events in Nuclear Power Plant Siting* are being revised.

(3) To improve national nuclear emergency system

Sticking to the guidelines of versatile compatibility, resource integration, interdisciplinary support, and integration of military and civilian capabilities, China builds and maintains national nuclear emergency capabilities commensurate with the safe and efficient development of nuclear energy, and forms a fully-fledged national system of nuclear emergency response capabilities.

On the basis of the 2005 Version of *National Nuclear Emergency Plan*, China has summed up and absorbed the practical experience in nuclear emergency preparedness and response in recent years, especially the experience feedback from Fukushima nuclear accident, and issued the new version of *National Nuclear Emergency Plan* in 2013. It has clearly and accurately defined the scope of management for nuclear emergency work, further pinpointed the principles and relevant responsible body for national nuclear emergency work, further enhanced the national nuclear emergency commanding mechanism, further improved the operability of emergency response actions to nuclear accidents, further replenished and made detail the emergency preparedness and guarantee measures, further formalized the information reporting and releasing procedures, and made stipulations for the aftermath of nuclear accidents on nuclear installations.

China has built up the nuclear emergency system with three levels in joint action at the national, provincial and nuclear installation operator levels, constructed 8 types of national-level nuclear emergency technical support centers, i.e., radiation monitoring; radiation protection, aviation monitoring, medical rescue, marine radiation monitoring, meteorological monitoring and forecast, aided decision-making and response actions, along with 3 national-level nuclear emergency training bases and over 30 national-level professional rescue teams, to take charge of various professional rescue tasks. On the basis of the available capabilities, China has formed a national nuclear emergency rescue team composed of over 300 people to be mainly responsible for undertaking unexpected rescue missions in serious nuclear accident scenarios and emergency treatment tasks, and stand ready to take part in international nuclear emergency rescue operations.

Nuclear emergency response forces have been established at the provincial (regional and municipal) levels in areas where NPPs are sited, including nuclear emergency command centers, radiation monitoring networks, medical treatment networks, meteorological monitoring networks, decontamination points, evacuation roads and shelters for evacuees, along with specialized technical support and rescue task forces.

Nuclear installation operating organizations in China have set up their own nuclear emergency response facilities and forces, including emergency command centers, emergency communication facilities, and emergency monitoring and consequence evaluation facilities. In addition, emergency facilities, equipment and instrumentation, such as emergency power supply, are in place. On-site rescue teams specializing in radiation monitoring, accident control, decontamination and cleansing have been established.

According to the *Requirements on the Buildup of Site Rapid Rescue Teams for Nuclear Accidents Emergency in NPP for Nuclear Group Corporation* issued by the MEP (NNSA) and the *Technical Requirements on the Buildup of Site Rapid Rescue Teams for Nuclear Accidents Emergency in NPP for Nuclear Group Corporation* jointly issued by the MEP (NNSA) and National Energy Administration, the nuclear group corporations started the buildup of nuclear emergency support systems and capacities at the group level in 2014, with emphasis on the buildup of the nuclear emergency support bases and of nuclear emergency support teams. The nuclear group corporations have jointly established a mutual support collaborative mechanism, the nuclear emergency mutual support and cooperation mechanism, adjacent NPPs have signed agreements for mutual support, and nuclear emergency response resource reserve and deployment assistance capabilities between nuclear power group corporations has taken initial shape, to realize complementation of superiorities and mutual coordination.

On June 26, 2015, China organized the first national-level nuclear emergency joint exercise after the issuance of the new version of *National Nuclear Emergency Plan*. This exercise fully inspected the effectiveness of the nuclear emergency plans and their implementation procedures and the collaboration of emergency rescue forces at all levels, and effectively raised the capacity of nuclear organizations and personnel at all levels to deal with and dispose of emergencies.

(4) To continually improve the safety level of NPPs

After the Fukushima nuclear accident, China's NPPs in operation and under construction, in accordance with the results and improvement requirements of comprehensive safety inspection, took effective measures in terms of technology, management, engineering, etc. to continuously strengthen the safety level of the existing NPPs and improve the capability of preventing and mitigating severe accidents through technology upgrading, engineering modification and optimization of operating experience system.

Operating NPPs carried out a series of safety analysis and improvement work, including perfecting SAMG for NPPs, adding or rebuilding hydrogen elimination facilities, performing PSA for external events, in-depth assessment of earthquake and tsunami risks, research to increase the power supply capacity of batteries, evaluating the necessity to implement containment depressurization, studying the response plan when multi-units entering the emergency status at the same time, the firefighting modification of active carbon and iodine absorber for M310 type operating nuclear power units, implementing 10-year periodic safety review, and cultivating and communicating nuclear safety culture. At present, active efforts are being made to carry out item of completing emergency plan, upgrading the emergency response capacity of NPPs, improving the information release procedures of NPPs and strengthening science and technology popularization of nuclear knowledge.

For NPPs under construction, re-evaluation of design safety level has been completed on the basis of the current nuclear safety regulations of China and latest standards of IAEA. All units with initial fuel loading after the Fukushima nuclear accident have completed the following items before fuel loading: flooding prevention improvement for nuclear safety related buildings and equipment, adding facilities such as portable power supplies and pumps, increasing the earthquake monitoring and anti-seismic response capacity, improving SAMG for NPPs, in-depth assessment of earthquake and tsunami risks, PSA for external events, completing emergency plan and increasing emergency response capacity to nuclear accidents, preparing and completing information release procedures of NPPs, completing anti-disaster plans and management procedures, reliability analysis and evaluation of safety level digital control system, level II PSA and improvement of radioactive wastes treatment system.

NPPs under construction control the project construction quality and safety in the whole processes and in an all-round way, properly arrange the supervision by the third party, implement the nuclear island construction team access system, raise the professional level in construction of nuclear power projects, continually improve the construction quality assurance system for nuclear power projects, strengthen commissioning regulation and strictly implement event reporting system and non-conformance management system.

For new nuclear power projects applying for construction permit, siting and design are performed according to the latest nuclear safety regulations of China and with reference to the IAEA standards and good practices, and reactor types with mature and advanced technologies are selected so as to improve inherent safety.

(5) Upgrade the nuclear safety review technical ability

China has taken a series of measures to fully upgrade the nuclear safety review technical ability, including: organizing professional review teams, establishing review requirements and working outlines, carrying out test verification and assessment and independent audit calculation, building test apparatus and verification benches.

For generation III NPPs, review requirements on four aspects have been established: document review, audit calculation, test verification and witness and specific area review. The audit calculation covers seven aspects of core physics, design basis accident, severe accident, radiation protection, stress and structure anti-seismic analysis, PSA and effluent discharge source term, the audit calculation targets and requirements have been defined for the preliminary safety analysis phase and final safety analysis phase, and audit calculation processes and methods have been established. Audit calculation work has been finished for units of AP1000, CAP1400 and HPR 1000.

Test verification and witness work has been carried out for CAP1400 and HPR1000, and independent test verification system and requirements have been established. Witness assessment and test verification have been carried out for critical tests, mainly including: test of passive core cooling system in Station Blackout condition and passive residual heat removal system rupture upstream or downstream the isolating valve, passive containment cooling system heat conducting capacity margin test, and test on effect of flow pass change of in-vessel retention on heat exchange characteristics of pressure vessel.

Theoretical analysis of malicious impact by large commercial aircraft, test research on dynamic loading characteristics of shielded buildings and verification test research on radioactive liquid waste treatment system of large PWR NPPs have been carried out. With CAP1400 as the backup, research work has been carried out on containment sump filter, mechanism phenomena and management guidelines for severe accidents, anti-seismic technologies of steel plate and concrete structure, PSA for fire and risk-informed management technology, and environmental impact assessment of warm water discharge.

Development of important software for nuclear safety review has been planned according to the need in developing nuclear safety review technology. The contents mainly cover the nuclear safety review software development specification, integrated comprehensive platform, core physics software, thermos-hydraulic and accident analysis software, shield and source term analysis software, and software testing, verification and validation work is conducted concurrently. Independent calculation validation has provided powerful support to technical review, giving strong guarantee for the independence, authoritativeness and effectiveness of nuclear safety regulation.

On the construction of testing apparatus and benches, construction of testing bench for studying the gas behavior inside containment and testing bench for PWR safety system overall performance verification has been planned, and by now, initial work of testing target, testing contents and bench preliminary design has been completed.

(6) To research on extending the valid period of NPP operation license

In 2015, the MEP (NNSA) issued the *Technical Policy for Extending the Valid Period of NPP Operation License(for trial implementation)*to guide the relevant work to extend the valid period of NPP Operation License. This technical policy specifies the necessary conditions and documents to be submitted for NPP operating organizations to apply for extension of license, and the safety justification basis for the license extension.

Qinshan NPP was put into operation in 1991, with 30 years for valid life of operational license, is now approaching the end of valid life. This plant is working actively to extend the valid period of its operation license, and has completed the feasibility study report for it.

B.3 Improvement for Safety of NPPs in China after Fukushima Nuclear Accident

After the Fukushima nuclear accident, to formalize the common improvement actions in NPPs in China, the MEP (NNSA) issued the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident*, and organized NPP operating organizations to discuss technical schemes a number of times, to keep known the progress in implementation. In addition, site surveys against the implementation of improvements were made in September 2012 and September 2013, to ensure that all post-Fukushima improvement actions are completed with assured quality and quantity in NPPs.

B.3.1 Safety Improvement of Operating Units

The MEP (NNSA) set the deadline for NPPs according to the degree of influence on safety and urgency of improvement actions. The improvement for operating NPPs is divided into short-term, medium-term and long-term actions, and short-term and medium-term actions were required to be completed in 2011 and 2013 respectively.

B.3.1.1 Short-term Improvement Actions

The MEP (NNSA) set the deadline for NPPs according to the degree of influence on safety and urgency of improvement actions. The improvement for operating NPPs is divided into short-term, medium-term and long-term actions. The short-term and medium-term actions were required to be completed in 2011 and 2013 respectively.

(1) Implementing water-proof plugging

Each operating NPP carried out examination and checking against the relevant positions of units, evaluated the possible highest blocked water level in the plant area with reference to the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident*, and generally implemented water-proof plugging. Also, water-proof dampers and emergency anti-flooding materials are provided at important buildings. Meanwhile, all NPPs amended or added relevant contingency plans and procedures based on the improvements, and organized necessary effect validation or emergency drills.

(2) Adding portable power supplies and portable pumps

Each operating NPP added a number of portable power supplies and portable pumps before the end of 2011 by equipment procurement and signing sharing agreements. After the specifications and quantities of relevant equipment were clearly stipulated in the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident*, the NPPs re-evaluated the ability demand for cooling, protection and monitoring, made supplementary procurement of emergency equipment meeting the latest requirements, based on existing equipment, and completed the interface matching. At present, the portable power supplies and portable pumps in all NPPs basically meet the relevant provisions in the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident*, and necessary drills have been performed.

(3) Improving earthquake monitoring and anti-seismic response capacity

Each operating NPP straightened out and analyzed systems and equipment associated with earthquake monitoring, optimized and improved the maintenance program and routine test procedures of relevant equipment, and evaluated and revised post-earthquake response and accident management procedures.

(4) Other short-term improvement requirements

Short-term improvement requirements with respect to specific NPPs also include the re-check of Daya Bay dam design, demolition of Daya Bay reservoir under the ridge, and formulating the management method for the second emergency road in Daya Bay site. These have been implemented and completed on schedule by the NPP as required.

Details of this part were completely described in the Sixth National Report.

B.3.1.2 Medium-term Improvement Actions

The operating NPPs have also implemented and completed the medium-term improvement actions according to schedule, mainly including perfecting SAMG, adding or rebuilding hydrogen elimination facilities, modification of spent fuel pool monitoring and water makeup, PSA for external events, anti-flooding reconstruction of Qinshan base, and in-depth assessment of earthquake and tsunami risks.

(1) Improving SAMG

Daya Bay NPP and The Third Qinshan NPP amended and improved the existing SAMG. Other operating NPPs developed and completed their new SAMG. The MEP (NNSA) entrusted CNEA to organize peer review of the SAMG of NPPs and put forth modification and improvement comments.

(2) Adding or rebuilding hydrogen elimination facilities

Each operating NPP analyzed and evaluated the risk of hydrogen explosion of units. The result showed that the hydrogen elimination system of Tianwan NPP already met the requirements, and renovation was required in all other NPPs. At present, the work to add or rebuild hydrogen elimination facilities has been completed in all NPPs.

(3) Modification for spent fuel pool monitoring and water makeup

Each operating NPP carried out modification for operation monitoring of spent fuel pool and water makeup system, including improving and revising the operation manual and procedures for spent fuel pool, modifying the spent fuel pool water makeup system and adding spent fuel pool monitoring instruments.

(4) PSA for external events

Each operating NPP has implemented and completed the safety margin assessment work(similar to the NPP stress test on the implementation of the EU) in case of extreme external events according to unified requirements, confirming that the units in all operating NPPs have certain ability to deal with external events beyond design basis.

(5) Qinshan site anti-flooding modification

After the Fukushima nuclear accident, the MEP (NNSA) believed after the comprehensive nuclear safety inspection that the anti-flooding measures for Qinshan NPP is insufficient with the possible flooding under extreme conditions (the maximum storm surge combined with maximum astronomical tide) Therefore, Qinshan NPP needed to implement anti-flooding reconstruction. For this reconstruction project, site construction was started in December 2012, and the whole works was completed at the end of 2013. In the meantime, Qinshan NPP further raised the height of water-proof plugging for relevant buildings according to special subject analysis report. The anti-flooding and anti-flooding evaluation was also completed for Qinshan Phase Ⅱ NPP and The Third Qinshan NPP. The evaluation result showed that, even if based on the new design basis flood level, the existing anti-flooding facilities (seawall and wave walls) can satisfy the relevant safety requirements and need no modification. In addition, anti-flooding dampers were added for important plant buildings according to the evaluation report.

(6) In-depth assessment of earthquake and tsunami risks

After the Fukushima nuclear accident, the MEP (NNSA), together with the National Energy Administration, China Earthquake Administration and oceanologic departments, carried out re-evaluation with more conservative approach for the Manila Trench and Ryukyu Trench that might generate earthquake tsunami threat to NPPs of China. The preliminary results showed that the Manila Trench is a major source of earthquake-induced tsunami. Conservative assumption is that the maximum possible earthquake in Manila Trench could be 8.8 magnitude. The earthquake-induced tsunami could affect NPPs on the coast of Guangdong, and the maximum tsunami wave height offshore near Daya Bay NPP could be about 2.7m. For this tsunami evaluation result, Daya Bay NPP carried out detailed numerical model calculation and physical model test, and further confirmed that the potential earthquake tsunami risk will not affect the operation safety of nuclear power units at Daya Bay site.

(7) Formulating emergency response plans

Each operating NPP has formulated emergency response plans for simultaneous accident conditions of two units on a multi-reactor site, and submitted them to the MEP (NNSA) for approval.

Other medium-term safety improvement actions for specific operating NPPs also include the study to raise the power supply capacity of batteries, evaluating the necessity to depressurize the containment, the modification of fire fighting system in Qinshan NPP, the firefighting improvement for active carbon and iodine absorbers of M310 type operating nuclear power units, and construction of water-retaining wall inside the east revetment of Tianwan NPP. All these safety improvement actions have been completed.

B.3.1.3 Long-term Improvement Actions

The on-going long-term actions in operating NPPs mainly include improving emergency plans, raising the emergency response capacity of NPPs, completing the NPP information release procedures and strengthening nuclear knowledge popularization and so on.

(1) Improving emergency plans

Each operating NPP has established communication channels with local meteorological, oceanic and anti-seismic departments, combed and improved disaster prevention plans and organized relevant drills. Qinshan nuclear power site has integrated and built up a unified emergency framework, Daya Bay nuclear power site and Tianwan NPP have also further improved their emergency organizations, and replenished emergency resources. Some NPPs have carried out study on management of the planned restricted areas, and communicated with local governments.

(2) Raising the nuclear accidents emergency response capacity

Nuclear power group corporations have completed emergency resources census for NPPs, formed nuclear accident emergency rescue teams at the group level, jointly signed NPP nuclear accident emergency in-site support and cooperation agreement, and established emergency support mechanism between groups and between NPPs. In the meantime, the nuclear power group corporations have established three major nuclear accident emergency support bases respectively in East China, South China and North China, specifically for daily drills of nuclear accident emergency rescue teams and emergency support and response during nuclear accidents.

(3) Updating information release procedures and strengthening nuclear knowledge popularization

Each operating NPP has compiled or improved relevant schemes and management procedures for information release and disclosure, and persistently carried out popularization and public communication for nuclear knowledge in various forms such as holding press conferences, public opening day, setting up information exchange platform, and building new public information centers. NPPs will also carry out further relevant researches according to the implementation results, to continually optimize the improvement schemes and ensure their long-term implementation.

B.3.2 Safety Improvement of Nuclear Power Units Under Construction

For units under construction, the main improvement actions implemented before the initial fuel loading include: anti-flooding improvement for nuclear safety related buildings and equipment, adding facilities such as portable power supplies and pumps, increasing the earthquake monitoring and anti-seismic response capacity, improving SAMG, in-depth assessment of earthquake and tsunami risks, PSA for external events, completing contingency plan and increasing emergency response capability to nuclear accidents, preparing and completing information release procedures, completing the disaster prevention plans and management procedures, etc. All nuclear power units realizing the initial fuel loading after the Fukushima nuclear accident have completed improvements on schedule.

(1) Improvement on flooding prevention for nuclear safety related buildings and equipment

Each NPPs under construction checked and evaluated their functions of anti-flooding and flood draining facilities, and those requiring modification improved flooding control for facilities such as nuclear island building, pump station, diesel engine building and underground corridor, so that systems and components important to safety can maintain their functions to the maximum extent under the conditions of beyond design basis flood events. For loaded units, all physical modification were completed, emergency anti-flooding materials were get ready and relevant emergency procedures and plans were revised or added.

(2) Adding facilities such as portable power supplies and portable pumps

Each NPPs under construction carried out work of scheme design, equipment procurement, installation and operation drills. For loaded units, analysis and justification have been completed for the measures to remove residual heat with primary and secondary loops and emergency makeup water to spent fuel pool; and secondary loop emergency makeup water physical modification, primary loop emergency makeup water modification, containment spray modification and configuration of 6.6kV and 380V portable emergency power have been completed, relevant technical requirements and operation procedures formulated, and emergency drills carried out.

(3) Improving earthquake monitoring and anti-seismic response capacity

Each NPPs under construction performed evaluation and analysis of anti-seismic margin of units, made comprehensive review on the habitability of emergency control centers, and formulated improvement schemes for identified weakness. For loaded units, justification and consolidation of completed facilities and design and construction of new facilities have all been finished.

(4) Updating SAMG

As required, each NPPs under construction should compile the SAMG, perform analysis and monitoring the distribution of hydrogen inside containment as well as evaluation of control measures under severe accidents according to the experience from the Fukushima nuclear accident, and carry out the relevant work for spent fuel pool accident analysis and monitoring improvement. SAMG has been worked out for loaded units, and improvement for hydrogen monitoring and control system and spent fuel pool water makeup and monitoring have been completed.

(5) PSA for external events

Each NPPs under construction has carried out assessment of earthquake and tsunami risks and the investigation, study and evaluation of safety margins under external extreme events, and performed PSA for external events. The relevant work has been finished for loaded units.

(6) Updating contingency plan and raising emergency response capability against nuclear accidents

Each NPPs under construction has carried out studies on the capability and reliability in mitigating consequences of severe accidents, worked out disaster prevention plans and management procedures for plants and NPP emergency response and evaluation documents, and assessed the rationality and representativeness of environment monitoring schemes, the improvement for environment monitoring stations and emergency monitoring scheme for loaded units have been completed, and relevant facilities have been put into service.

(7) Formulating and improving NPP information release procedure

Each NPPs under construction has completed their information release management procedures. They conducted public information and communication on nuclear knowledge in areas around NPPs in various forms.

(8) Updating disaster prevention plans and management procedures

Each NPPs under construction has established the mechanism to promptly notify severe weather and external disaster messages with the meteorological, oceanic and seismic departments, and formulated in-site warning grading and early warning mechanism; they have further improved the disaster prevention plans against extreme external events, and conducted topical training on earthquake combating and prevention and disaster mitigation and emergency drills, raising the early warning and responding capability against external events.

Main improvement actions now being implemented in NPPs under construction include: analysis and evaluation of the reliability of safety-grade digital control system, the level II PSA, and improvement of radioactive wastes treatment systems. In the analysis and evaluation of the reliability of safety-grade digital control system, each NPPs under construction analyzes and evaluates the reliability of safety-grade digital control system on design, verification and failure analysis, to identify weaknesses and implement corresponding improvements. On level II PSA, these plants have already finished the initial analysis and calculation work, and some NPPs have completed level I and level II internal PSA reports. In improving the radioactive wastes treatment systems, each NPPs under construction has completed the effectiveness research work plan and schedule toward radioactive wastes treatment systems, and are working on the improvement analysis reports; some NPPs have finished the analysis reports and availability analysis of liquid waste quantity and liquid waste source terms, and some have complete design schemes.

B.4 International Peer Review

China periodically accepts peer review and follow-up of IRRS performed by IAEA for continuously improving China’s nuclear and radiation safety regulation system, and send high-level officials and technical experts to participate in the IRRS missions implemented by IAEA on the regulatory bodies of other contracting parties.

At the request of Chinese Government, IAEA dispatched a review team to conduct the IRRS mission on China in July 2010. The Chinese Government has invited IAEA to make an IRRS follow-up visit in third quarter 2016, which will cover 10 important fields of the nuclear and radiation safety regulation system of China. At the same time, it will address the response actions and improvement measures of China on nuclear safety regulation after the Fukushima nuclear accident, and review the implementation of the 39 recommendations and 40 suggestions in the 2010 IRRS review report by the Chinese Government. The results of review and follow-up visit will be made public via the IAEA website and the web portal of the MEP (NNSA).

The NPP operating organizations in China actively participated in peer reviews. Up to the end of 2015, NPPs in China accepted 11 OSART missions and 32 WANO peer review activities. In addition, China actively selected experts to participate in peer review activities in foreign NPPs performed by IAEA or WANO.

After the Fukushima nuclear accident, WANO required that all operating NPPs would receive peer review every 4 years, and PSUR should be carried out for a unit under construction before the first startup. From 2013 to 2015, NPPs of China received 22 WANO peer review and 4 follow-up activities including 16 PSUR activities and 2 corporation peer review activities. The peer review experts identified good practice worth popularizing to other power plants, such as "public communication", "planning and implementation of outage", "effectively solving the copper tube corrosion by increasing the PH value of stator cooling water", and "increasing nuclear safety margin by reducing core damage probability and increasing backup cooling for safety-related components". In the meantime, the areas for improvement were identified in peer reviews, such as "insufficient analysis of recurring events" and "management observations not carried out in a strict way". The NPPs actively formulated and implemented corrective actions.

China's NPPs plan to undergo four IAEA PRE-OSART missions and 14 WANO peer review activities in the coming three years.

Furthermore, China's NPPs also actively carried out domestic peer review activities at different levels while accepting international peer reviews, as detailed in section 10.3 of this report.

B.5 Typical Events in this Implementation Circle of Convention on Nuclear Safety

(1) Reactor shutdown caused by loss of heat sink or safety abnormally

Event description:

On July 21, 2014, during full power operation of Unit 2 of Hongyanhe NPP, large amount of jellyfish swarmed into the Circulating Water Filtration (CFI) water intake. The differential pressure across the drum screen increased abnormally, which caused trip of circulating water pump, then the trip of turbine and finally automatic shutdown of Unit 2 reactor. The operator controlled the unit by implementing the accident management procedure. Unit 1 was shut down with the similar processes and cause.

On August 7, 2015, when Unit 3 of Ningde NPP was in power operation, as large amount of acaudina molpadioides swarmed into the CFI water intake, entered and gathered inside the drum screen, the high differential pressure across the screen caused trip of circulating water pump, forced Unit 3 turbine to shut down. The rapid drop of condenser vacuum triggered the condenser fault signal, which tripped the reactor.

In addition, during the commissioning and operation for Fangchenggang NPP, LingAo NPP, Fuqing NPP and Changjiang NPP, marine organisms have also caused loss of heat sink or safety abnormally, and even caused automatic scram.

INES: All events are INES 0.

Cause analysis:

Risks of marine organisms in the sea area around NPPs were underestimated. The monitoring and early warning mechanism for marine organisms is not complete and there is no strong countermeasure. The marine organisms explosively swarmed into the CFI water intake and blocked the CFI drum screen. The irrational design that the CFI drum screen flushing water flows back to the front pool for water intake also further increased the gathering of marine organisms in the screen.

Corrective actions:

To study the marine organism proliferation mechanism in the sea areas around NPPs, and the species, habits and detection technology of marine organisms. To strengthen monitoring and early warning mechanism, continually monitor the movement traces and characteristics of marine organisms, and judge their threat and impact. To take targeted measures including eliminating, intercepting and changing the pump operation mode, such as studying the temporary facilities to intercept and stop marine organisms according to their characteristics.

(2) Unavailability of computer information and control system (KIC)

Event description:

On Aug. 4, 2014, Unit 1 of Fuqing NPP was in power operation, with nuclear power at 0.95% of full power, all control rods in manual mode, and pressure and level of pressurizer in automatic control mode. When operation personnel verified the 1ARE003KU function as planned, operator stations KIC were unavailable. The main control room operator immediately implemented the *Procedure to deal with accident of KIC operator workstation unavailability (the IKIC procedure)*, and to transfer the unit to the backup panel (BUP) for control. After the KIC was successfully re-booted, the IKIC procedure was quitted and the unit was put under control by KIC again. Operators stabilized and restored the status of unit.

On December 26, 2014, when the employee of Fuqing NPP was installing test data acquisition system software and performing communication verification, in re-booting the SAR8 historical data memory, operator station KIC was unavailable. The main control room operator implemented the *Procedure to Deal With Accident of KIC Operator Workstation Unavailability (The IKIC Procedure)*, to transfer the unit to the backup panel (BUP) for control. After the KIC was successfully re-booted, the operator quitted from the IKIC procedure.

On December 17, 2014, when Unit 2 of Fangjiashan NPP was in the steam generator cooling normal shutdown mode (NS/SG), the I&C personnel handled the historical memory problem with the SAR8STR8GTW2 server. When the operation personnel reduced the temperature and pressure according to schedule to the RRA cooling normal shutdown mode (NS/RRA), all KIC operator stations were unavailable. The main control room (MCR) operator immediately implemented the procedure *Switchover from MCM to Backup Panel* to switch the unit to the backup panel for control, and at the same time notified the I&C personnel to repair and treat it. Afterwards the KIC was re-booted, MCR operator quit from the procedure *Switchover from MCM to Backup Panel*. The unit was restored to KIC control and the event ended up.

INES: All events are INES 0.

Cause analysis:

The main cause of the events was defect in software design, with the problems of unreasonable distribution of KIC system buffer capacity and processor stack capacity and process priority order setup.

Corrective actions:

The NPP operating organizations updated twice the relevant software of KIC, and the present operation conditions show that it was effective in solving the problems of easy overflow of relevant space in CCT stack and unreasonable setup of process priority orders.

B.6 Response to Vienna Declaration on Nuclear Safety

The IAEA issued the *Vienna Declaration on Nuclear Safety* at the diplomatic conference on Convention on Nuclear Safety held in February 2015, which indicated the international society the concerns and efforts of all Contracting Parties to improve nuclear safety. The *Vienna Declaration on Nuclear Safety* requires all Contracting Parties to act as follows to implement the objective principles in Convention on

Nuclear Safety to prevent accidents with radiological consequences and mitigate consequences should they occur:

(1) New NPPs are to be designed, sited and constructed, consistent with the objective of preventing accidents in the commissioning and operation. the target of mitigating possible releases of radionuclide causing long-term off site contamination and avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions should be met when an accident occurs.

(2) Comprehensive and systematic safety assessments are to be carried out periodically and frequently for existing installations throughout their lifetime in order to identify safety improvements that are oriented to meet the above objective. Reasonably practical or achievable safety improvements are to be implemented in a timely manner.

(3) National requirements and regulations for addressing this objective throughout the lifetime of NPPs are to take into account the relevant IAEA Safety Standards and, as appropriate, other good practices as identified inter alia in the Review Meetings of the Convention on Nuclear Safety.

China has taken a series of actions to implement the objectives in the *Vienna Declaration on Nuclear Safety*.

B.6.1 Modifying and Improving Nuclear Safety Regulations, and Pointing Out Far-range Goal of Nuclear Safety

China has collected extensively and studied carefully the laws and regulations on nuclear safety in developed nuclear power countries, and established the nuclear safety regulation system of China step by step with reference to the IAEA safety requirements and standards.

The MEP (NNSA) actively tracked and participated in the safety standard formulation and revision work of IAEA. After the Fukushima nuclear accident, the MEP (NNSA) organized systematic and in-depth study on the IAEA analysis reports in 77 areas, and performed gap analysis on lessons learned from the Fukushima nuclear accident and the current nuclear safety regulations in China. Meanwhile, preparation and revision of the Nuclear Safety Act and regulation system of China was proposed in conjunction with the nuclear safety practice in China after the Fukushima nuclear accident, and the preparation and revision work was carried out by phases.

After the Fukushima nuclear accident, China issued the *Nuclear Safety Plan* at the end of 2012. It stated that new nuclear power units should have fairly complete measures to prevent and mitigate severe accidents. The probability of annual severe core damage per reactor shall be lower than 1/100,000, and the probability of annual large release of radioactive substance per reactor shall be lower than 1/1,000,000. Efforts shall be made to realize the far-range goal of actually eliminating the possibility of large release of radioactive substance in design for the nuclear power units to be built in and after the 13th Five-Year Plan period.

Revolving around the definition, safety objective and technical feasibility of "eliminating large release of radioactive in practice", the MEP (NNSA) carried out special subject investigation and research work. On this basis, the MEP (NNSA) is organized the revision of the *Code on the Safety of Nuclear Power Plant Design* in conjunction with the research results and experience of Fukushima Nuclear Accident and revision of safety objective from IAEA, the EU and the United States, and with reference to the new version of SSR-2/1 issued by the IAEA in February 2016. The newly revised *Code on the Safety of Nuclear Power Plant Design* will further study and complete the contents of design extended conditions, eliminating large release of radioactive in practice as well as supporting system and auxiliary systems design to maintain integrity of containment under extreme conditions.

B.6.2 Design Characteristics of New Nuclear Power Units and Safety Improvement

New nuclear power units under construction in China include 4 AP1000 units, 2 EPR units and 4 HPR1000 units with proprietary intellectual property rights of China. In addition, China has approved the initial works for the CAP1400 demonstration project before its official start of construction.

(1) AP1000

For AP1000 units, the prevention and mitigation of severe accidents has been taken into full account at design stage, including the adoption of passive core cooling system, passive containment cooling system, passive main control room habitability system, large capacity rapid depressurization valves, passive reactor cavity cooling system and containment isolation system. The design, including two passive recombiners, 66 igniters and 3 non 1E class hydrogen analyzers, is able to effectively control the hydrogen concentration in the containment. In the spent fuel pool, 3 1E class meters and 1 non 1E class level meter are provided. This design has taken into full account the diversity and reliability.

After the Fukushima nuclear accident, more improvements were made for AP1000 units as required by the safety inspection by the MEP (NNSA), including addition of water proof gates, portable power supplies, portable pumps and matching interface, setup of backup emergency commanding center, formulating a complete SAMG. Furthermore, the radioactive wastes treatment system has been improved by adding steel cladding in the liquid waste tank room, modification of the nuclear island liquid waste system process and developing final package. These improvements have further raised the capacity of AP1000 units to prevent and mitigate severe accidents.

The structure design of the steel reactor containment of AP1000 unit has taken into account the design basis accident conditions such as break of primary pipe, main steam pipe and main feed water pipe. To prevent reactor vessel failure, the accident management strategy of flooding the reactor cavity and reactor vessel with the water from the in-containment refueling water storage tank inside has been considered. Outside the steel containment is the shield building in concrete structure, able to effectively resist missiles caused by typhoon and tornado. For beyond design basis accidental conditions, to ensure containment cooling, additional portable power supplies and portable pumps are provided in Sanmen NPP and Haiyang NPP in China. These equipment are stored at high places that cannot be flooded externally under the condition of beyond design basis flood water level. These measures can ensure the containment integrity of AP1000 unit under accidental conditions.

(2) EPR

For EPR units, the corresponding design extended conditions has been taken into account in design, including the beyond design basis accidents that will not lead to core damage (DEC-A) and the beyond design basis accidents that can possibly lead to core damage (DEC-B). In the meantime, to prevent and mitigate severe accidents, dedicated systems are provided, including the containment spray system, emergency core cooling water and emergency feed water system, to remove heat in the core and containment after a severe accident, the passive hydrogen recombiners arranged in a distributed pattern can avoid hydrogen gathering and explosion in the containment.

After the Fukushima nuclear accident, safety improvements were made as required by the safety inspection by the MEP (NNSA), including addition of portable power supplies, portable pumps and matching interfaces, improvement of spent fuel pool level and temperature monitoring system, addition of portable water makeup for spent fuel pool, addition of portable water makeup for containment residual heat removal system, and addition of passive steam vent channel in fuel building. In case of a severe accident, the primary pressure can be reduced by the primary rapid depressurization system, combustible gas control system and containment spray system, to prevent core damage under high pressure and control the pressure, hydrogen concentration and temperature in the containment. The core catcher is equipped to prevent core molten material-concrete interaction so as to maintain containment integrity. The leaking materials in the annular space between the inner and outer containment and the leaking materials in containment not vented to the stack are collected by the filtration and ventilation system provided in the annulus between the two containment layers, to reduce discharge.

(3) HPR1000

For HPR1000 units, safety provisions combining active and passive features are taken. In the design, the methods combining deterministic, probabilistic and engineering judgment are used to analyze important event series that can possibly lead to severe accidents, and corresponding accident prevention and mitigation measures are adopted, therefore it has complete provisions to prevent and mitigate severe accidents. In addition to provisions to prevent and mitigate severe accidents already adopted in improved PWR such as pressurizer for pressure relief, passive hydrogen recombiners, containment filtration and exhaust, and high level venting for reactor vessel, the secondary side passive residual heat removal system, passive containment heat removal system and active and passive reactor cavity cooling system are added. The rapid depressurization valves with redundant design are provided. The double-layer containment can withstand the impact of large commercial aircraft. The reactor coolant pump shutdown sealing function the diverse actuation system that can meet the anti-seismic requirements for safety shutdown earthquake(SSE), and the containment filtration and exhaust system are provided to further improve the capacity of the unit to prevent and mitigate severe accidents. To prevent radiological fluid from leaking out of containment via penetrations under beyond design basis accident, isolating valves are provided for fluid pipes in the containment section. In case of a severe accident, the containment integrity can be maintained by the large volume containment, containment hydrogen eliminating system, containment spray system, reactor cavity cooling system and containment filtration and exhaust system.

(4) CAP1400

The CAP1400 demonstration project are provided with 6 additional non-safety class hydrogen recombiners, on the basis of AP1000, as diversified setup of hydrogen igniters to control the hydrogen concentration in containment. CAP1400 has further improved the containment filtration and exhaust system, and increased the defense in depth capacity. CAP1400 has enhanced the anti-seismic performance of system and equipment to remove heat to the seawater, making it a diversified ultimate heat sink. CAP1400 has also increased the anti-seismic performance of diverse actuation system, hydrogen igniters and power supply system, and enhanced the reliability of these systems. These have further increased the capacity to prevent and mitigate severe accidents.

B.6.3 Implementing Comprehensive Safety Inspection and External Events Margin Evaluation

After the Fukushima nuclear accident, the MEP (NNSA), together with the National Energy Administration and China Earthquake Administration, performed comprehensive safety inspection for NPPs, and carried out safety margin evaluation on external events for operating NPPs. Requirements for nuclear safety improvement were pointed out.

External events evaluation results showed that the operating NPPs in China had the ability to respond to external events beyond design basis, with safety margin not less than the international level of similar NPPs. The anti-seismic safety margin of all operating NPPs is not less than 1.5 times of earthquake design basis. Except for Qinshan NPP, all operating NPPs have the safety margin to deal with beyond design basis flood, while Qinshan NPP, located on wet site, has the safety margin to deal with beyond design basis flood after taking improvement actions. For station blackout accident, NPPs have taken better countermeasures to keep at least 8 hours of batteries in case of loss power.

Improvements for operating NPPs are classified as short-term, medium-term and long-term actions. The short-term and medium-term actions are required to be completed respectively in 2011 and 2013. The short-term improvements include the implementation of waterproof plugging, the addition of portable power and portable pumps, the enhancement of earthquake monitoring and response capability, etc. Medium-term improvements mainly include improving the SAMG, adding or modifying the hydrogen elimination facilities, PSA for external events, anti-flooding modification at Qinshan NPP, in-depth assessment of seismic and tsunami risks. Long-term actions mainly include completing emergency plan, raising the emergency response capacity, completing the information release procedure and strengthening nuclear knowledge publicity, etc. Operating NPPs have completed the short-term and medium-term improvement actions as required, and long-term actions are being implemented according to schedule. For the actual fulfillment of improvements, refer to B.3.1 of this report.

For nuclear power units under construction, the main improvement actions include: anti-flooding improvement for nuclear safety related buildings and equipment, adding facilities such as portable power supplies and pumps, increasing the earthquake monitoring and anti-seismic response capacity, improving SAMG, in-depth assessment of earthquake and tsunami risks and PSA for external events, completing emergency plan and increasing emergency response capacity to nuclear accidents, preparing and completing information release procedures of NPPs, completing the disaster prevention plans and management procedures, etc. After the Fukushima nuclear accident, the nuclear power units with the initial fuel loading have completed improvements on schedule. The specific information about such improvements can be referred to B.3.2 of this report.

B.6.4 Periodic Safety Review of Operating Nuclear Power Units and Performing Reasonable & Achievable Improvements

For operating NPPs in China, systematic safety reviews are carried out periodically, to identify existing weaknesses and implement reasonably practicable corrective actions. Periodic safety review is performed every ten years after start of operation for NPP according to requirements in nuclear safety regulations. Systematic safety re-assessment is performed for NPP based on operating experience and relevant important safety information and existing safety standards and practices. The scope of review covers all important aspects of nuclear safety, including 14 safety factors in 5 subject areas, the 14 safety factors are respectively plant design, actual conditions of SCCs, equipment qualification, aging, deterministic safety analysis, PSA, hazard analysis, safety performance, use of experience from other plants and research findings, organization and administration, procedures, human factors, emergency planning and radiological impact on environment. In the process of periodic safety review, according to result of review, NPPs identify reasonably practical corrective actions and/or safety improvements and their implementation plans, take into full account interaction and overlap between safety factors, and hence of the effects of corrective actions and/or safety improvements on all safety factors.

By December 31, 2015, as required by regulations, Qinshan NPP and Daya Bay NPP had completed the second PSR. Units 1&2 of Qinshan Phase Ⅱ NPP, Units 1&2 of LingAo NPP, Third Qinshan NPP and Units 1&2 of Tianwan NPP had completed the first PSR. All NPPs identified relevant weaknesses and formulated and implemented related corrective actions. For example, in Daya Bay NPP, for the deviation found in the small branch pipe vibration fatigue review, measures such as adding support for sensitive pipelines and improving support were included in the medium and long-term improvement plan; in Units 1&2 of LingAo NPP, a containment pressure meter with wider range was added, to increase the measurement range of pressure sensor, for monitoring of containment pressure under severe accident condition.

B.7 Follow-up Actions of China with Respect to the Five Challenges identified by IAEA on post-Fukushima Nuclear Accident

During the Sixth Review Meeting of the Convention on Nuclear Safety, the following five challenges were identified with respect to the Fukushima nuclear accident. China took relevant actions to address each challenge.

(1) How to minimize the gap between Contracting Parties' safety improvements

After the Fukushima nuclear accident, the MEP (NNSA) organized and implemented the comprehensive safety inspection for NPPs on the basis of self inspection by all NPPs under construction and in operation. In the meantime, the nuclear safety improvement requirements after the post-Fukushima were put forth in conjunction with the experience of IAEA and all Contracting Parties from the Fukushima nuclear accident. To formalize the common improvement actions in all NPPs in China, the MEP (NNSA) prepared the *General Technical Requirements on* *the Improvement of NPPs after the Fukushima Nuclear Accident*. In preparing the General Technical Requirements, reference was made to the safety improvement plans of the IAEA and all developed nuclear power countries after the Fukushima nuclear accident.

China described in detail the safety improvement requirements with respect to the Fukushima nuclear accident and the implementation of improvements at the second extraordinary meeting of the Convention on Nuclear Safety and the Sixth National Report. The experience can be shared with international peers.

(2) How to achieve harmonized emergency plans and response measures

China has established a unified nuclear emergency organization and coordination mechanism. At the national level, the National Nuclear Accident Emergency Coordination Committee has been set up. to uniformly coordinate the nationwide emergency activities, and decide, organize and command emergency assistance response actions. At the provincial (regional and municipal) levels, nuclear emergency coordination bodies are established. The operating organizations of nuclear installations have set up their respective nuclear emergency bodies. At the national and provincial (regional and municipal) levels and within the operating organizations of the nuclear installations, committees of experts or the support organizations thereof have been established to provide advice and suggestions on nuclear emergency preparedness and response.

The nuclear power group corporations in China have established nuclear emergency support bases and support teams, and jointly signed the *Nuclear Accident Emergency On-site Support Cooperation Agreement of Nuclear Power Group Corporations*, and established the mutual support cooperation mechanism between groups. All adjacent NPPs have signed mutual support agreement, prepared mutual support action plans, established nearby rapid mutual support mechanism, materialized the nuclear accident emergency mutual support requirements and mechanism, and formed support capacity of nuclear emergency resources reservation and deployment, to realize complementation of superiorities and mutual coordination.

China actively carries out multilateral, bilateral and regional international exchanges and cooperation in nuclear emergency field, actively performs the international obligations specified in relevant international conventions, responses to various proposals from the IAEA council and conference, and participate in the emergency drill activities organized by the IAEA. China has entered into bilateral agreements on nuclear energy cooperation with 30 countries including Brazil, Argentina, the UK, the US, Korea, Russia and France, to conduct cooperation and exchange which include nuclear emergency preparedness. China, Japan and Korea established nuclear accident early notification framework and expert exchange mechanism, to carry out cooperation and exchange in relevant fields. In May 2014, China joined the International Nuclear Emergency Response and Assistance Network, to provide support for the construction of the international nuclear emergency preparedness network. China has always taken an honest and open attitude, to carry out nuclear safety international cooperation including nuclear emergency.

(3) How to make better use of operating and regulatory experience and international peer review services

China has established internal and external operating experience systems at different levels in nuclear safety regulatory body, CNEA, power group corporations, NPP operating organizations and nuclear power engineering companies. China has set up professional operating experience teams, formulated relevant management rules and procedures, developed and maintained operating experience databases, and continually made screening, analysis and usage of important internal and external experience, for NPPs safety improvement in China.

The MEP (NNSA) has also constructed operating experience system suitable to nuclear safety regulation, covering all NPP operating organizations, Nuclear and Radiation Safety Center, regional office and other technical support organizations. The NPP operating organizations provide information such as non-conformance, deviations, events and experiences from overseas nuclear installations periodically via the information platform, according to the specified event screening principles. The Nuclear and Radiation Safety Center undertakes the work of operation and maintenance management of the system and analysis and assessment of information. The regional offices mainly perform site inspections and supervision to confirm whether management requirements are satisfied, and upload inspection reports periodically. Technical support organizations provide technical support and consultancy services in the system through cooperation. The operating experience system has established the information exchange channels between regulatory body, operating organizations and technical support organizations, conducive to sharing the operation management experience of NPPs, identifying their weaknesses in safety and tracking the effectiveness of corrective actions.

China actively receives the peer review activities carried out by international organizations, and works out corresponding improvement actions for issues or weaknesses identified. The nuclear safety regulatory body of China periodically apply for and accept the IRRS mission by the IAEA, and NPPs in China actively carry out peer review activities according to the requirements of the IAEA and WANO.

(4) How to improve regulators' independence, safety culture, transparency and openness

China has established and maintained effective nuclear safety regulation and standard system and governmental framework. The MEP (NNSA) is the regulation body for nuclear safety in China, and implements unified and independent regulation on nuclear safety for NPPs in China. The MEP (NNSA) is directly affiliated to the State Council, without administrative affiliating relationship with the nuclear energy development department and supervised organizations. All funds required in the operation of regulatory body are included in the national financial budget so as to ensure the organizational independence of regulation. External technical support organizations and external experts also have no direct stakes with the supervised organizations.

Nuclear safety is an important part in national security, and is the lifeline in the development of nuclear energy undertakings. To implement the responsibilities on national nuclear safety and the obligations of international nuclear safety facing the situation of rapid development of nuclear power in China and daily increasing safety requests from the public, in December 2014, China issued the *Nuclear Safety Culture Policy Statement*, which states the basic attitude towards nuclear safety culture, and the principle requirements for cultivating and practicing nuclear safety culture. Immediately nuclear safety culture communication and promotion actions are carried out to foster a good nuclear safety culture atmosphere in the nuclear industry and to jointly enhance nuclear safety with the forces of the whole society.

China attaches great importance to regulation transparency and openness, and has made major progress in ensuring the right of the public to know, to participate and to supervise. The MEP (NNSA) issued the *Scheme of Nuclear and Radiation Safety Regulatory Information Publicity(for trial implementation)* and *Notice on Strengthening Information Publicity of Nuclear and Radiation Safety in NPPs*, and promulgated the *MEP (NNSA) Work Scheme of Nuclear and Radiation Safety Public Communication* to enhance information publicity. The MEP (NNSA) has made great efforts to construct public communication platforms, develop and maintain its independent regulation web portal, to promptly issue and publish important information such as the policies and regulations of the nuclear industry, radiation monitoring data, licensing and review information, and operating experiences of NPPs in operation and under construction, and information written in China's national reports on Convention on Nuclear Safety and Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The MEP (NNSA) publishes on its official website to the public the real-time monitoring data of 167 radiation environment automatic monitoring stations in the whole country, including 79 automatic monitoring station in cities at prefecture and above level, and 88 automatic monitoring stations around 9 operating NPP sites in Qinshan of Zhejiang, Daya Bay and Yangjiang of Guangdong, Tianwan of Jiangsu, Fuqing and Ningde of Fujian, Hongyanhe of Liaoning, Changjiang of Hainan and Fangchenggang of Guangxi.

The MEP (NNSA) has developed the official Wechat public platform, to release information covering the organization and responsibilities of the NNSA, the nuclear safety culture, policies and regulations, science popularizing, distribution of NPPs, radiation environment, annual reports on nuclear safety and publicity announcements, also, the latest news in the nuclear industry, analysis articles and science and technology popularization and knowledge are published periodically. The "Administrator of NNSA Mail Box" is set up to realize direct interaction and exchange of the MEP (NNSA) with the public and respond to public concerns promptly.

The MEP (NNSA) has established a series of communication platforms with China Environment News, Environment and Life journal, Environment TV column and multimedia science and technology popularization websites. China Environment News has a journalist residing at MEP (NNSA), to collect and write daily news in nuclear energy and nuclear technology and nuclear and radiation safety regulation areas, media communication, web portal construction and other publicity work on nuclear and radiation safety.

Since 2013, a number of nationwide nuclear emergency preparedness publicity activities with the theme "Joining Efforts to Establish Defense on Nuclear Emergency and for Nuclear Safety, and to Foster the Scientific Development of Nuclear Energy Sector" have been held, including interpreting laws and regulations in nuclear emergency field, presenting to the public the achievements China obtained on nuclear emergency in recent years, and the relevant science and technology popularizing knowledge on nuclear emergency, arousing extensive attention both at home and abroad.

In July 2015, the Chinese Government launched the series activities of "public opening day" of national nuclear industry with the theme "safety and transparency". Through site visit, dialogue and communication, the public had the chance to observe closely the operation and management and nuclear safety work in the nuclear industry. The "Light of Charm" secondary school student scientific and technological knowledge competition was organized every year, to promote the public understanding of nuclear power knowledge, and enhance the understanding and trust of the public on the safety status of nuclear installations in China. In addition, the MEP (NNSA) also organized the public communication peer review activities for Taohuajiang NPP and Lufeng NPP.

NPP operating organizations have also worked out and issued the corresponding nuclear and radiation safety information release and publicity systems, and established information publicity platforms. The information are released through periodical new releases, setting up official microblog and Wechat platforms, publishing white papers and social responsibility reports, holding public symposium and exchanges and arranging public opening and visiting days. Public opinion pooling, nuclear power industrial touring, nuclear power science and technology popularization in schools and communities, internet science and technology popularization platform and nuclear power science and technology popularization competition activities are carried out for public communication and information on nuclear power.

In 2014, WANO carried out a Corporate Peer Review (CPR) in CNNP. The "public communication" was identified by the WANO review team as strength, for promoting to the worldwide NPPs. The WANO experts unanimously believed that the CNNP "has formulated working standards for headquarter general planning and linking all levels, effectively carried out external communication activities to obtain public support, built up professional teams to carry out medium and long-term work in a planned manner, and adopted expert experience and benchmarking results, to realize the best performance. All activities comply with WANO criteria and are used to enhance nuclear safety behavior."

(5) How to engage all countries to commit and participate in international cooperation

China attaches great importance to the international exchanges and cooperation in nuclear safety area, maintains close cooperation relationship with international organizations including the IAEA, OECD/NEA and EU, and also actively carries out multilateral, bilateral and inter-regional nuclear safety international cooperation.

China supports and actively participates in various international exchange activities organized by IAEA all the time. For example, actively participating in various activities organized by the IAEA related to the Convention, taking full part in the work of IAEA committee and sub-committees of safety standard, and providing China practice and experiences for the formulation and amendment of safety standards. China assisted IAEA in sponsoring international conferences such as the 3rd IAEA Technology Support Organizations Conference on Nuclear Safety and Nuclear Security, actively sponsored or participated in the application and implementation work for seminars, training sessions and technical cooperation program of IAEA, to share knowledge, experience and technologies with technical experts of all countries. China continually participated in various activities under the framework of ANSN and GNSSN, and established the nuclear safety regulatory web portal of China under the GNSSN framework, as a platform to carry out international cooperation with other nuclear safety regulatory body.

The MEP (NNSA) fully participated in the activities of the policy group, technical steering committee and various special subject working groups under the MDEP framework of the OECD/NEA, and signed with OECD/NEA the *Memorandum of Understanding on Cooperation in the Nuclear and Radiation Safety Regulation Field*. Evolving round the important and difficult issues in new reactor design safety review and inspection, the design review experience and technical views are exchanged, common position documents are developed and implemented so as to better understand and master the technical issues and international nuclear safety status quo, and definitely raise the regulation strength.

China actively carries out nuclear safety cooperation with the EU, learns and borrows the ideas, methods, practice and experience of main nuclear power countries in Europe in the nuclear and radiation safety area, to upgrade the capacity of national nuclear regulatory body and their technical support organizations of China with international standards and best practice, and at the same time share the experience of China.

China continually deepens its bilateral cooperation with nuclear energy countries, signed bilateral nuclear safety cooperation agreements with the nuclear safety regulatory bodies of the United States, France, Canada, the United Kingdom, Spain, Germany, Japan, Korea, Pakistan, Brazil and Ukraine, carries out multi-level and diversified international cooperation in the form of high level reciprocal visits, joint review and consultancy, information exchange, personnel training, experts exchange visits and cooperative research. The fields of cooperation cover the construction and operation of nuclear installations, formulation of safety standards and safety improvements, joint review, inspection and scientific research, nuclear safety equipment oversight, emergency response to nuclear accidents, nuclear safety regulatory personnel training and exchange visits, and radioactive wastes management. In the meantime, China received regulatory personnel from nuclear energy countries such as Indonesia and Argentina for on-the-job training in China.

China has established China-Japan-Korea regional nuclear safety regulation high official meeting mechanism with Japan and Korea, to carry out efficient and pragmatic cooperation in the forms of high level interaction by the nuclear safety regulatory body and technical support organizations of the three countries, sharing supervision experience and exchanging information and technologies, playing an important role in ensuring the nuclear safety in the region and promoting regional nuclear safety cooperation.

B.8 Good Practices and Challenges

B.8.1 Good Practices

The good practices achieved by China on nuclear safety during this Implementation of Convention mainly include:

(1) Establishing the nuclear safety regulations system fully geared with the IAEA safety standards

Since the start of establishing its national nuclear safety regulation system, China has extensively collected and conscientiously studied the nuclear safety laws and regulations of developed nuclear power countries, and with reference to the IAEA safety requirements and standards, gradually established the nuclear and radiation safety laws and regulations system fully geared with the IAEA safety standards, to cover all nuclear installations and activities. In the meantime, China send experts to participate in activities of IAEA Safety Standard Committee and the formulation and amendment of safety standards, continually tracks and analysis the status of IAEA safety standards, and carries out the preparation and revision of the nuclear and radiation safety regulations system of China, in conjunction with the actual conditions in China.

(2) Issuing and implementing the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident*

After the Fukushima nuclear accident, China made comprehensive safety inspections and carried out evaluation on external event safety margin in NPPs. Improvement requirements were put forth based on the inspection and evaluation results and according to the experiences and safety action plans of the international society from Fukushima nuclear accident. To formalize the common improvement actions of NPPs in China, The MEP (NNSA) issued the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident*. The overall implementation of these technical requirements in NPPs in China has basically eliminated the possible difference in cognition between the regulatory body and NPP operating organizations on safety improvement strategy, achieving the expected effect.

(3) Building and completing the rapid nuclear emergency response teams

China has integrated nuclear safety into the national overall security system, and the cyber and information security in NPPs is an important component part of nuclear safety. The nuclear safety regulatory body and NPP operating organizations of China have carried out relevant work on cyber and information security, including the investigation and study, special subject symposium and training on information security technologies, and strengthening the construction of cyber hardware and software. However, it is still urgent to complete the regulations on cyber and information security for NPPs. NPPs should also further enhance the defense in depth on plant cyber and information security and establish a guarantee system combining management with technology to cope with the risks and challenges on cyber and information security.

(4) Continually innovating and improving peer review system in NPPs under construction and in operation

With the sustained rapid development of nuclear power in China, the relevant organizations in the nuclear industry and their employees have accumulated rich knowledge and experience on the nuclear safety regulation, nuclear power construction and operation. In the meantime, people at key positions in organizations are changed more quickly, the number of new comers increases rapidly, and the teams of key technical personnel are diluted. This situation poses a challenge to the knowledge management and experience transition in the nuclear industry.

In the meantime, according to the construction practice and experience in NPPs in China, the peer review concept and methods of operating NPPs are applied in the construction of nuclear power projects, the peer review standards for NPPs under construction have been formulated, to carry out comprehensive review in the nuclear power project construction stage for NPP owners and nuclear power project EPC contractors, and specific area reviews on public communication, documentation management, outage management, commissioning and operation preparation. The multi-level peer review system has been continually extended in depth, achieving good results and wide acceptance and approval in the industry.

B.8.2 Challenges

The challenges faced by China on nuclear safety during this Implementation of Convention mainly include:

(1) The nuclear safety culture fostering of nuclear power contractors and suppliers

Despite the long-term and arduous efforts made in China for the construction of nuclear safety culture at different levels of regulatory body, CNEA, nuclear power group corporations and NPP operating organizations, with the rapid development of nuclear power in China, the human resources in the contractors/suppliers in the nuclear area have expanded rapidly, and more and more contractors/ suppliers of non-nuclear area are participating in the construction and operation of NPPs. These organizations and employees have different foundations and experience, especially, the line worker have great difference in the cognition and practice of nuclear safety culture, and this has resulted impact and challenge to the construction of high level nuclear safety culture in the whole industry.

2) Public trust and acceptability of nuclear power

The Fukushima nuclear accident has reduced the public trust and acceptability of nuclear power. At present, China will continue to develop nuclear power, and will start construction of new nuclear power projects in coastal areas and carry out justification on the construction of nuclear power project in inland areas. The public trust and acceptability of nuclear power will be one of the important factors influencing the sustained development of nuclear power in China.

3) Cyber and information security management in NPPs

China has integrated nuclear safety into the national overall security system, and the cyber and information security in NPPs is an important component part of nuclear safety. The nuclear safety regulatory body and NPP operating organizations of China have carried out relevant work on cyber and information security, including the investigation and study, special subject symposium and training on information security technologies, and strengthening the construction of cyber hardware and software. However, it is still urgent to complete the regulations on cyber and information security for NPPs, and NPPs should also further enhance the defense in depth on plant cyber and information security and establish a guarantee system combining management with technology, to cope with the risks and challenges on cyber and information security.

4) Knowledge management and experience transition in nuclear industry

With the sustained rapid development of nuclear power in China, the relevant organizations in the nuclear industry and their employees have accumulated rich knowledge and experience on the nuclear safety regulation, nuclear power construction and operation. In the meantime, people at important positions in organizations are changed more quickly and the number of new comers increases rapidly, the teams of key technical personnel are diluted, posing a challenge to the knowledge management and experience transition in the nuclear industry.

5) Aging management of NPPs

With the accumulation of the operation time of NPPs in China, the aging management for the structures, systems and components in NPPs faces more challenges. NPP operating organizations need to continually optimize their aging management programs and procedures, study the aging mechanism of items important to safety, reasonably identify and assess the degrading, residual life and safety margins of items, and work out and implement corresponding maintenance strategies to ensure that items important to safety can continually meet the requirements in nuclear safety codes and standards, and lay a good foundation for the renewal of operation license or decommissioning of NPPs.

6. Existing Nuclear Power Plants

> Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

6.1 List of Existing NPPs

Up to December 31, 2015, there were 28 units in commercial operation and 26 units under construction and construction permit had been issued to 2 units in China. Cumulatively, construction permits of 10 units and the first fuel loading permits of 14 units had newly been issued within the three years from 2013 to 2015. The list of existing NPPs is shown in Appendix 1. The distribution of China's NPPs is shown in Fig. 1.

6.2 General Situation of Existing NPPs

The light-water PWR predominated in China's existing NPPs. Third Qinshan NPP is Pressurized Heavy Water Reactors (CANDU-6), and Shidao Bay NPP Demonstration Project is Graphite Pebble Bed modular High-temperature Gas-cooled Reactor (HTR-PM).

All operating nuclear power units in China have maintained safe and steady operation. The integrity of fuel element cladding in all units meets the requirements of technical specifications for NPPs, the leak rate of reactor coolant system and containment is also far below the limits set in technical specifications. The safety barriers of units are intact and effective.

The basic conditions of Qinshan NPP, Daya Bay NPP, Qinshan Phase IINPP, Unit 1, Unit2, Unit3 and Unit 4,LingAo NPP Unit 1, Unit 2, Unit 3 and Unit 4, Third Qinshan NPP and Tianwan NPP Unit 1 and Unit 2 have been described in the Fourth, Fifth and Sixth National Reports. Hongyanhe NPP Unit 1, Unit 2 and Unit 3, Ningde NPP Unit 1, Unit 2, Unit 3, Yangjiang NPP Unit 1 and Unit 2, Fuqing NPP Unit 1 and Unit 2, Fangjiashan NPP Unit 1 and Unit 2 and Changjiang NPP Unit 1 and Unit 2 are all generation II plus PWR units, their post-Fukushima safety improvements are described in detail in B3.1.

Among 26 nuclear power units under construction at the present in China, 14 units adopted million-kilowatt PWR unit, four units are adopted AP1000 technology, three units adopted HPR1000 technology, two units based on VVER technology, two units adopted EPR technology and one unit adopted graphite pebble bed high-temperature gas-cooled reactor technology.

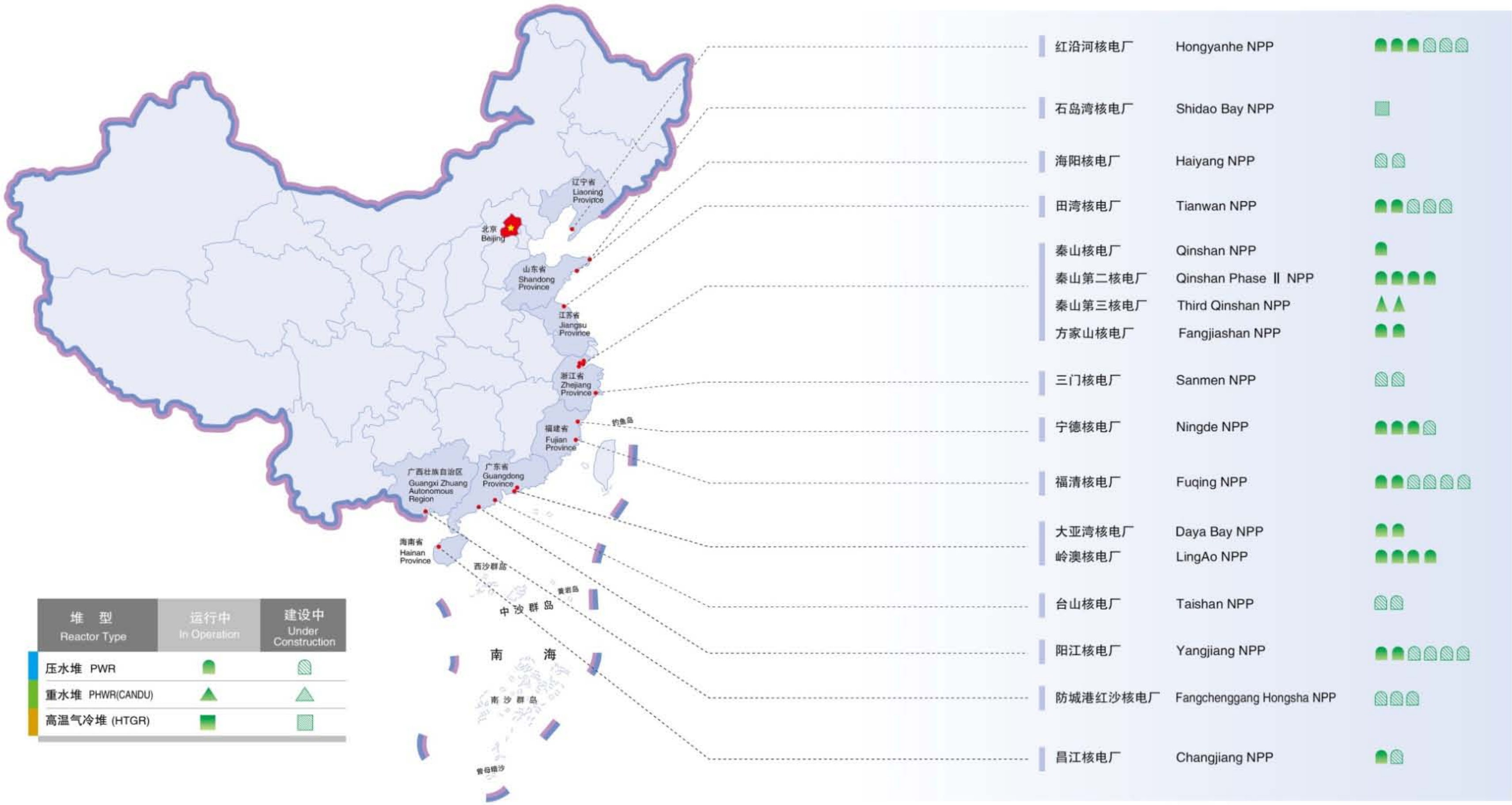

Fig. 1 Distribution of NPPs in China

Hongyanhe NPP Unit 4, Unit 5 and Unit 6, Ningde NPP Unit 4, Yangjiang NPP Unit 3, Unit 4, Unit 5 and Unit 6, Changjiang NPP Unit 2, Fuqing NPP Unit 3 and Unit 4, Fangchenggang NPP Unit 1 and Unit 2, Tianwan NPP Unit 5 are generation II plus PWR units, which were designed on the basis of reference NPPs which had successful experience and good performance, and improvements were made based on the experience from similar units in China and other countries, further improving the inherent safety characteristics of the NPPs. Furthermore, after the Fukushima nuclear accident, some major improvements similar to generation II plus units in operation were made according to the requirements proposed by the MEP (NNSA) after comprehensive safety inspection, further improving the capability to prevent and mitigate severe accidents.

Sanmen NPP Unit 1 and Unit 2, and Haiyang NPP Unit 1 and Unit 2 adopted AP1000 technology, prevention and mitigation of severe accidents was taken into full consideration at design stage and passive safety systems are adopted; they were designed with passive recombiners to effectively control the hydrogen concentration in containment; the spent fuel pool is provided with 3 1E class level meter and 1 non-1E class level meter, taking into full account the diversity and reliability. After the Fukushima nuclear accident, some improvements were made according to the requirements of the MEP (NNSA) in comprehensive safety inspection, including the addition of water stop gates, portable power source, portable pumps and matching interface, setup of backup emergency commanding center, and so on. Furthermore, the radioactive wastes treatment system has been improved by adding steel cladding in the liquid waste tank room, renovating the nuclear island liquid waste system process and developing final package. These improvements have further improved the capacity of AP1000 units to prevent and mitigate severe accidents.

Taishan NPP Unit 1 and Unit 2 adopted EPR technology, the corresponding design extended conditions (DEC) was defined and taken into account in design. Also, special systems are provided, including the containment spray system, emergency core cooling system, emergency feed water system, core molten material stabilizing system, containment annular space ventilation system, etc. In addition, the containment is provided with the passive hydrogen catalytic recombiners to prevent and mitigate severe accidents. After the Fukushima nuclear accident, some safety improvements were made as required by the safety inspection by the MEP (NNSA), including addition of portable power source, portable pumps and matching interfaces, improvement of spent fuel pool level and temperature monitoring system, addition of portable water makeup for spent fuel pool, addition of portable water makeup for containment residual heat removal system, and addition of passive steam vent channel in fuel building.

Fuqing NPP Unit 5 and Unit 6, Fangchenggang NPP Unit 3 adopted HPR1000 technology of the independent generation III nuclear power brand of China, and the design notion of combination of active and passive safety characteristics is adopted. In design, the methods combining deterministic, probabilistic and engineering judgment are used to analyze significant events series that can possibly lead to severe accidents, and corresponding accident prevention and mitigation measures are adopted, therefore it has complete provisions to prevent and mitigate severe accidents. It is provided with double-layer containment that can withstand the impact of large commercial aircraft, and the RCP shutdown sealing function, the diversified drive system that can meet the anti-seismic requirements for SSE, the secondary side passive residual heat removal system, passive containment heat export system and active and passive reactor cavity water injection cooling system are added, rapid pressure relief valves for severe accidents that meet multiplicity requirements are provided, the IVR cooling plan is adopted, and the containment filtration and discharge system are provided to further improve the capacity of the unit to prevent and mitigate severe accidents.

Tianwan NPP Unit 3 and Unit 4 are based on VVER technology, with Tianwan NPP Units 1 and Unit 2 as reference units. For the new units, design modifications were made in conjunction with the experience from Units 1 and 2 and requirements in latest regulations, including the modification of nuclear island low radioactivity wastewater collection and monitoring and discharge system, modification of containment pit screen, addition of gas detection system for damaged fuel assemblies, and portable equipment used to make up water to the primary circuit, steam generators and spent fuel pool. In addition, 6kV and 400V portable power supplies are added. These improvements have further upgraded the safety performance of units.

Shidao Bay NPP demonstration project will be installed with a pebble-bed modular high-temperature gas-cooled reactor, its fuel assemblies feature excellent resistance to high temperature, very high core heat capacity, automatic residual heat removal, and very high negative reactivity coefficient, so no core melting accident as in a PWR reactor will happen. Shidao Bay NPP is designed with a series of engineered safety features such as ventilated low pressure resisting containment, passive residual heat removal system, passive reactor pressure vessel support cooling system, main control room habitability system, primary circuit pressure relief system, secondary circuit isolation, and steam generator accident discharge system.

6.3 Overall Safety Status of NPPs in China

Based on constantly summing up its own experiences, China paid attention to assimilating internationally advanced experiences and established nuclear power safety management system in conformity with circumstances of China. The Chinese government and NPP operating organizations adhere to the principle of "Safety First", strengthen safety surveillance and management for operating units, attach high importance to safety management and quality control for units under construction, and have gained a series of results.

During the three years, there were 113 operating events in Chinese NPPs, including 61 operating events in the trial operation stage before commercial operation and 52 operating events after commercial operation, and with no operating events at INES Level-2 or above. For statistics of operating events, refer to Appendix 2.

In China, all operating NPPs have established and are completing step by step their respective performance indicator systems. Also, they periodically submit related relevant information and data to the MEP(NNSA), the nuclear industry administration departments and international organizations such as the IAEA and WANO at their request.

The operating NPPs in China are generally at fairly good level in the world, some of them at the advanced international level with some units among the best. In 2013, there were respectively 12 and 17 units (a total of 17 units were covered in indicators calculation) with at least 10 of the 14 individual WANO indicators reaching the first quartile and median values of WANO, among them, all 14 individual WANO indicators of Unit 2 of Third Qinshan NPP reached the first quartile value. In 2014, there were respectively 10 and 16 units (a total of 20 units were covered in indicators calculation) with at least 10 of the 14 individual WANO indicators reaching the first quartile and median WANO values, among them, Unit 2 of Ningde NPP and Unit 1 of Yangjiang NPP newly put into commercial operation respectively had 13 and 12 of the 14 individual WANO indicators reaching the first quartile WANO value. In 2015, there were respectively 13 and 21 units (a total of 26 units were covered in indicators calculation) with at least 10 of the 14 individual WANO indicators reaching the first quartile and median WANO values, among them, all 14 individual WANO indicators of Unit 2 of Daya Bay NPP reached the first quartile WANO value.

The WANO performance indicators of all operating NPPs in China from 2013 to 2015 are listed in Appendix 3, these data presented a good overall trend in the WANO indicators within three years.

7. Legislation and Regulation

1. Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.

2. The legislative and regulatory framework shall provide for:

(i) The establishment of applicable national safety requirements and regulations;

(ii) A system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a license;

(iii) A system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of license;

(iv) The enforcement of applicable regulations and of the terms of licenses, including suspension, modification or revocation.

7.1 Framework of Legislation and Regulation

Since 1982, China has collected extensively and studied carefully the laws and regulations on nuclear safety usage in nuclear power developed countries, and the nuclear safety regulation system of China was established step by step with reference to the IAEA nuclear safety guidelines and stipulations. As more NPPs are being put into operation in China, and with the practical experience accumulated on the siting, design, construction, commissioning, safety operation and other aspects for nuclear power projects, China closely tracks and participates in developing and revising IAEA nuclear safety codes and guides, by continually incorporating the newest requirements of international nuclear energy industry. China has been continually improving its system of nuclear safety laws and codes with reference to the nuclear safety codes and guides of the IAEA and in conjunction with the nuclear safety practice in China.

7.1.1 General Description of Nuclear Safety Laws, Codes and Guides

The system of laws, regulations and guides on nuclear safety of China consists of laws, administrative regulations, department rules, guiding documents and reference documents.

(1) Laws

The laws applicable to nuclear safety field in China are enacted by the National People's Congress and its Standing Committee, issued through the Presidential Decree and have legal effects higher than administrative regulations and department rules.

(2) Administrative regulations of the State Council

Administrative regulations of the State Council, which have legal binding effects, are promulgated by the State Council according to the Constitution and laws. The existing administrative regulations applicable to nuclear safety field are regulations to stipulate the scope of nuclear safety management, administrative organization and its rights, principles and procedures of surveillance and other important issues.

(3) Department rules

The nuclear safety codes and the detailed rules of Administrative Regulations of the State Council are department rules; they are prepared and promulgated by related departments of the State Council within extent of their authority according to the laws and the administrative regulations of the State Council and have legal binding effects. Nuclear Safety Codes are department rules enacting nuclear safety objectives and basic safety requirements, and the detailed rules of Administrative Regulations of the State Council stipulate specific implementing measures according to these regulations on nuclear safety management.

(4) Guiding documents

Nuclear safety guides, which are prepared and promulgated by related departments of the State Council, are guiding documents that explain or supplement nuclear safety codes and recommend relevant methods or procedures to implement safety code.

(5) Reference documents

Nuclear safety technical documents are reference documents in the technical fields of nuclear safety, and are promulgated by related departments of the State Council or their entrusted institutions.

The hierarchy of nuclear safety laws, codes and guides is listed in Fig 2.

Fig. 2 Hierarchy of nuclear safety laws, regulations and guides of China

7.1.2 Issued Laws, Regulations and Guides on Nuclear and Radiation Safety

The Chinese government always attaches high importance to nuclear safety. Since October 1986 when the State Council promulgated the *Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China*, China has already enacted a series of laws, regulations and guides which cover NPPs, reactors other than those in NPPs, installations for nuclear fuel production, processing, storage and reprocessing, and facilities for radioactive waste processing and disposal, etc. All these formed an available law system that shall be obeyed by nuclear installations in siting, design, construction, operation and decommissioning.

In addition, the MEP (NNSA) and the related departments have promulgated in succession a series of nuclear safety codes and detailed rules of Administrative Regulations of the State Council, which are divided into different series according to the technical fields covered by them, related to siting, design, operation and quality assurance of NPPs and so on. China Atomic Energy Authority and national health and family planning commission and other related department have also promulgated some department rules.

After the Fukushima nuclear accident, the public paid daily increasing attention to the nuclear power safety, and raised daily increasing requirements on nuclear safety. China has actively carried out the legislation for laws including the *Nuclear Safety Act* and *Atomic Energy Act*. Now these two laws have been included in the legislation planning of the Standing Committee of the National People's Congress with their drafts already completed.

7.1.3 Newly Issued Laws, Regulations and Guides on Nuclear Safety during this Implementation of Convention Period

The MEP (NNSA) carries out preparation and revision work of regulations according to its preparation and revision working mechanism for nuclear and radiation safety regulations and the regulation preparation and revision plan, and four regulation and standard review meetings are held yearly, to review relevant regulations and standards.

During this implementation of convention period, China has promulgated a series of new laws, regulations and guides on nuclear safety, and carried out the following work:

In Dec. 2013, the MEP (NNSA) issued the *Rules for the Management of Nuclear and Radiation Safety Supervision and inspection Personnel Certificates*(HAF004-2013) and *Rules for the Management of Solid Radioactive Waste Storage and Disposal License*(HAF402-2013).

In May 2013, the MEP (NNSA) issued *The Recruitment, Training and Authorization of Nuclear Power Plant Personnel* (HAD103/05-2013), *Location of Geological Disposal Facility of High Level Radioactive Waste* (HAD401/06-2013), *Decommissioning of γ Irradiation Device* (HAD401/07-2013), *Simulator Production of the Civilian Nuclear Safety Mechanical Equipment(for trial implementation)* (HAD601/01-2013) and *Technical Conditions of Installation License Application Organization of the Civil Nuclear Safety Equipment (for trial implementation)* (HAD601/02-2013). In June 2014, the MEP (NNSA) issued the *Standard Format and Contents of Nuclear and Radiation Safety Analysis Report of Radioactive Material Transport* (HAD701/02-2014). For the index of current laws and regulations, rules and guides on NPPs and nuclear safety in China, refer to Appendix 4.

7.1.4 Participation Relating to International Convention on Nuclear Safety

China has acceded into *Convention on Early Notification of a Nuclear Accident*, *Convention on Assistance in the case of Nuclear Accident or Radiological Emergency*, *Convention on the Physical Protection of Nuclear Materials* and its amendments, *Convention on Nuclear Safety*, *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* and other international conventions, and strictly implements the duties under these conventions.

The *Convention on Early Notification of a Nuclear Accident* was effective to China as of Oct. 11, 1987; the *Convention on Assistance in the case of Nuclear Accident or Radiological Emergency* was effective to China as of Oct. 14, 1987; the *Convention on the Physical Protection of Nuclear Materials* was effective to China as of Jan. 2, 1989, on Oct. 28, 2008 China approved the Amendment to the *Convention on the Physical Protection of Nuclear Materials* adopted in Vienna on July 8, 2005;

the *Convention on Nuclear Safety* was effective to China as of Mar. 1, 1996; the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* was effective to China as of Apr. 29, 2006.

China actively implemented international conventions including the *Convention on Early Notification of a Nuclear Accident*, within the mechanism of these conventions, China always endeavors to work together with all countries in establish a peaceful, cooperative and win-win international nuclear safety emergency system, and fully plays its constructive role.

From 2013 to 2015, China actively participated in and completed the sixth implementation of the *Convention on Nuclear Safety* and the fifth implementation of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. As required by the conventions, China prepared and submitted national reports periodically, carried out peer reviews between the Contracting Parties, attended Implementation Review Meetings and accepted reviews and supervisions by the international society, summarized and analyzed the results of Implementation Meetings, and worked out subsequent improvement action plans.

China also takes an active part in activities organized by the IAEA and related to the implementation of conventions, including: attending the inter-session organization meetings and officials meetings, to make preparation for the smooth convening of review meetings; attending meetings of working groups without quota limit, the meeting of effectiveness and transparency working group of *Convention on Nuclear Safety* and the technical discussion meeting on convention revision proposals in Switzerland, to carry out sufficient discussions on the revision of procedural rules of the convention and the revision proposals from Contracting Parties; and attending the diplomatic conference on the *Convention on Nuclear Safety*, playing a constructive role in the drafting and issuance of the *Vienna Declaration on Nuclear Safety*.

China has kept on adjusting and optimizing its organizational structure and working mechanism, including: ensuring the representativeness, professional coverage and personnel stability of the implementation participating organizations, making the implementation as an important means in promoting nuclear and radiation safety in the country; formulating the implementation management procedures for *Convention on Nuclear Safety*, to perform formalized management of all links and elements in the implementation, and improve the systematicity, formalization and extensiveness of implementation work; and classifying and sorting out information collected in the implementation processes, to form a complete implementation information library.

7.2 Licensing System

China implements licensing system for NPPs. Nuclear safety license is a legal document with which the national regulatory body approves the applicant to perform specific activities related to the nuclear safety (such as siting, construction, commissioning, operation and decommissioning of NPPs, etc.). Operating organization of the NPPs is required to systematically conduct safety assessment and verification activities at different stages in line with requirements of regulations and standards, produce corresponding analysis reports and submit them to nuclear safety regulatory body for review. Only after passing the review and obtaining relevant license or approval document, can subsequent activities marketization as siting, construction, fuel loading, operation and decommissioning be carried out. By means of the examination and approval, surveillance, enforcement of laws, rewards and sanction related to license, the MEP (NNSA) supervises and inspects the nuclear safety activities by licensees, and ensures that licensees can bear the responsibilities for nuclear safety and carry out nuclear activities pursuant to law.

At the siting stage for a NPP, the applicant must submit to the MEP (NNSA) the application documents including the *Site Safety Analysis Report*. The MEP (NNSA) must determine the suitability of the NPP and the selected site from the safety point of view.

At the construction stage of NPP, the applicant must submit to the MEP (NNSA) the *Nuclear Power Plant Construction Application*, *Nuclear Power Plant Preliminary Safety Analysis Report* and other relevant documents before the start of construction,. The MEP (NNSA) must review the design principles of the NPP, and make a conclusion whether the NPP can operate safely after its completion. After review and approval, the applicant will obtain the *Nuclear Power Plant Construction Permit*, and then the construction can be started.

At the commissioning stage of NPP: before the first fuel loading, the applicant must submit to the MEP (NNSA) the *Application for Nuclear Power Plant First Fuel Loading*, the *Nuclear Power Plant Final Safety Analysis Report* and other relevant documents. The MEP (NNSA) must determine if the NPP has been completed according to the approved design, if it complies with requirements in nuclear safety regulations, and if it has attained the required quality and has complete and qualified quality assurance records. Nuclear fuel can be loaded for commissioning only after review and approval and the applicant has obtained the *Instrument of Ratification for the First Fuel Loading of NPP*.

At the operation stage of NPP, after 12 months of trial operation after the first full power operation date, the applicant must submit to the MEP (NNSA) the *Revised Final Safety Analysis Report of the Nuclear Power Plant* and other relevant documents. The MEP (NNSA) shall determine if the results of trial operation meet the design, and verify the revised operation limit and conditions. Commercial operation can be started only after review and approval and the applicant has obtained the *Nuclear Power Plant Operation License*.

At the decommissioning stage of NPP, the applicant must submit the *Report on Decommissioning the Nuclear Power Plant* and other relevant documents to the MEP (NNSA). After review and approval by MEP (NNSA), the *Approval for Decommissioning of the Nuclear Power Plant* will be issued.

According to the requirements in the State Council Decree No. 500 *Regulations on the Safety Regulation for Civilian Nuclear Safety Equipment*, the nuclear safety regulation authority of the State Council implements the licensing system for the design, manufacturing, installation and non-destructive testing organizations of civilian nuclear safety equipment.

The MEP (NNSA) has set up the Nuclear Safety Equipment Supervision Technical Center, which undertakes the technical review of license applications and the safety inspection of imported nuclear safety equipment, and accepts the guidance and supervision by business departments. The North China Nuclear and Radiation Supervision Station performs daily supervision of the civilian nuclear safety equipment and activities in the whole country, the routine and non-routine nuclear safety inspections for licensees and overseas registered organizations, and performs residing supervision for important nuclear safety equipment. The daily supervision of site installation activities of civilian nuclear safety equipment and the site supervision for inspection and testing of imported nuclear safety equipment are performed by the regional offices.

7.2.1 Types of Licenses for NPP

In China, the types of licenses for NPPs include:

(1) Review comments on NPPs siting;

(2) Construction permit of NPPs;

(3) Instrument of Ratification for the first fuel loading of NPP;

(4) Operation license of NPP;

(5) License for operators of NPP;

(6) Other documents subjected to approval, including the instrument of ratification for decommissioning of NPPs.

7.2.2 Issuance of NPP Licenses

The procedures of application and issuance of licenses are as shown in Fig. 3.

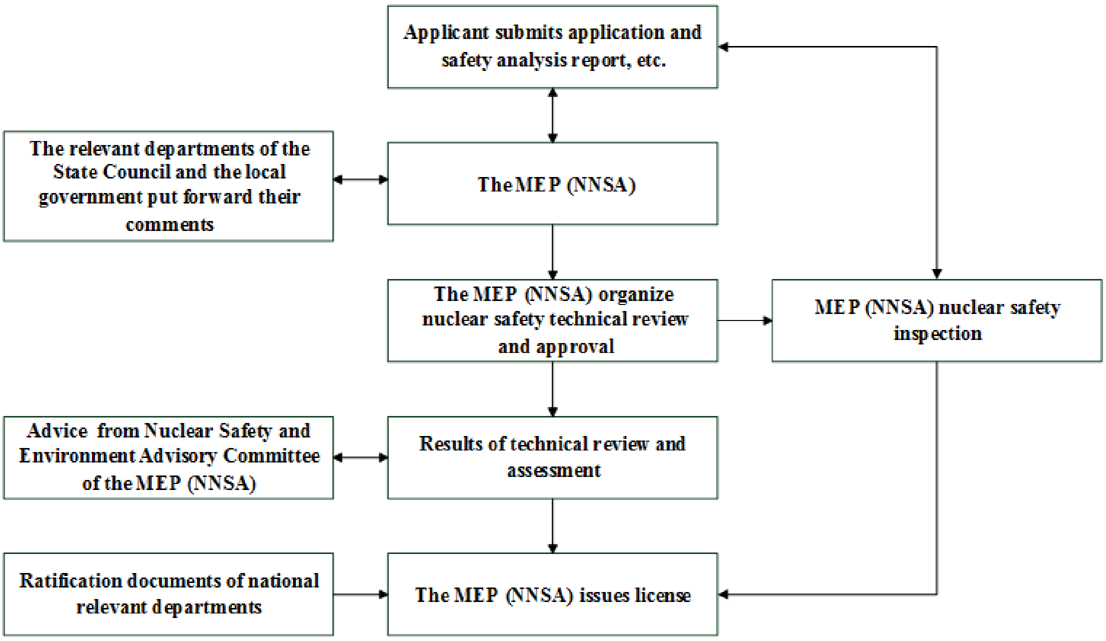

Fig. 3 The process of application and issuance of licenses

The applicant should submit the application, safety analysis report and other related documents required by regulations to the MEP (NNSA). Only after appraisal and approval, the applicant is allowed to carry out relevant nuclear activities.

During the process of review and approval, the MEP (NNSA) should ask for opinions from the related departments of the State Council as well as the governments of province, autonomous region or municipality directly under the central government where NPPs are located.

After getting the results of technical appraisal, asking for comments of the related departments from the State Council and local governments, and also through consultancy by the Nuclear Safety and Environment Expert Committee, the MEP (NNSA) decides independently whether a license is to be issued or not, meanwhile the MEP (NNSA) stipulates the necessary conditions for the license.

7.2.3 Nuclear Safety Review and Inspection System

(1) Nuclear safety review

The nuclear safety review constitutes the technical basis of the nuclear safety licensing system.

The MEP (NNSA) is the organizer and responsible body for the safety review of nuclear and radiation installations in China, and organizes technical support organizations to perform overall review and assessment of the application documents submitted by the nuclear and radiation installation operating organizations. The Nuclear and Radiation Safety Center is the permanent technical support organization of the MEP (NNSA). For important projects, external technical support organizations will be designated to perform parallel safety review, to ensure the adequacy and correctness of review conclusions.

The MEP (NNSA) requires that, all technical support organizations shall organize review teams of A-B roles, to form the A-B role pattern, that is, when the review mission is not conflicting, the two review teams should conduct review work concurrently and independently, each working on specific main aspects, and they cooperate and support with each other and promote each other without intersection; the MEP (NNSA) shall review the independence of relevant technical support organizations every year, for any possible conflict of interests identified, the technical support organization is required to make rectification and correction and submit a correction report, to ensure the independence of technical support activities.

The MEP (NNSA) confirms upon review and assessment that:

1) The existing information proves that the activities proposed by the NPP are safe;

2) Information submitted by the operator is accurate enough to confirm it is in conformity with surveillance requirement;

3) Technical solutions, especially new solutions, can reach required safety level as proved or examined by inspection / test or both.

The issuance of the nuclear safety licenses depends on the nuclear safety review conclusions.

Review and assessment by the MEP (NNSA) cover the relevant activities in the whole life-time of the NPP, including its siting, construction, non-conformance disposition during construction, commissioning program and schedule, setting of control points for commissioning, first fuel loading, operation, modification during operation, refueling safety analysis report, periodic safety review, decommissioning etc. In order to normalize nuclear safety supervisory inspection activities of NPP, the MEP (NNSA) developed the safety supervisory inspection program of NPP, which is applicable to the whole stage of the NPP from building to decommissioning.

Nuclear safety regulations require the NPP operating organizations must review the NPP operation status periodically and submit specified documents and information for review by the MEP (NNSA), to ensure that the basis for issuance of license remains valid.

The MEP (NNSA) performs supervisory inspection of the nuclear safety activities by licensees through review and approval, surveillance, enforcement of laws, rewards and sanction with respect to the licenses, to ensure that licensees undertake the safety responsibilities and carry out nuclear activities pursuant to law.

(2) Nuclear safety inspection

The MEP (NNSA) has established six regional offices, which are respectively responsible for the routine inspection of nuclear and radiation safety in North China, East China, South China, Northwest, Southwest and Northeast.

The main duties of regional offices include:

1) The daily inspection of nuclear and radiation safety and radiation environment management for nuclear installations;

2) The daily inspection of radiation safety and radiation environment management for nuclear technology utilization project under the direct regulation by the MEP (NNSA);

3) The daily inspection of emergency preparedness work for nuclear and radiation accidents (including nuclear and radiation terrorist attack events) in nuclear operating organizations and nuclear technology utilization organizations under the direct regulation by the MEP (NNSA), and the supervision of emergency response on accident sites;

4) The inspection of radiation monitoring work for nuclear installations and nuclear technology utilization projects under the direct regulation by the MEP (NNSA) and the necessary supervisory monitoring, sampling and analysis on site;

5) The supervisory inspection of radiation safety and radiation environment management for local environmental protection departments;

6) The daily inspection of civilian nuclear safety equipment erection activities on nuclear installation site and the site supervision for the inspection and testing of imported nuclear safety equipment of civilian nuclear installations;

7) The inspection of radioactive materials transport activities inside civilian nuclear installations;

8) Handling other matters assigned by the MEP (NNSA).

The North China Regional Office, in addition to the above duties, also performs daily inspection of the design, manufacturing and non-destructive testing activities of civilian nuclear safety equipment in the whole country; the routine and non-routine nuclear safety inspections for the licensees of civilian nuclear safety equipment in the whole country and overseas registered organizations; the supervision of qualification examination activities of special process personnel for civilian nuclear safety equipment in the whole country; and the supervision of class I radioactive materials transport vessel manufacturing activities in the whole country.

The MEP (NNSA) and its dispatched institutions send inspection groups (inspectors) to the site of plant siting, construction and operation of NPPs to exercise the following duties:

1) Examine whether the documents submitted reflect the actual situation;

2) Inspect whether the construction is carried out in accordance with the approved design;

3) Inspect whether the management is performed in accordance with the approved quality assurance program;

4) Inspect whether the NPPs are constructed and operated in accordance with the nuclear safety regulations and the conditions specified in the licenses;

5) Investigate whether the operating organization has an adequate capability for safe operation and carrying out emergency response plan;

6) Perform other necessary supervisions.

When performing a mission, the nuclear safety inspectors have the right to access the sites of equipment manufacturing, construction and operation of NPPs to make investigations and collect information related to nuclear safety.

According to the *Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China* and its detailed rules of implementation and the requirements of the *Rules for the Management of Nuclear and Radiation Safety Supervision and inspection Personnel Certificates*, nuclear safety inspectors shall meet specified conditions, including education level, working experience, capability and basic professional quality, to ensure the quality of nuclear safety inspection. The MEP (NNSA), according to requirements in regulations and need in work, prepares the teaching program for nuclear safety inspectors and certificate management requirements for them, and perform selection, training and examination of personnel. The relevant person, after receiving the initial professional training organized by the MEP (NNSA) and passing the examination, will participate in the medium level or senior training on nuclear and radiation safety regulation organized by the MEP (NNSA) and pass examination, or obtain the practice qualification of certified nuclear safety engineer, before being issued with the nuclear safety inspector certificate by the MEP (NNSA). The certificate holders will perform nuclear safety inspection according to the duties, scope of area and valid period of certificate indicated on the certificate, and also have the corresponding rights and obligations.

The MEP (NNSA) and regional offices mainly adopt the following approaches to perform nuclear and radiation safety regulation and inspection for nuclear installations and activities:

1) Daily Inspection

It is mainly be the responsibility of regional offices, including field patrol, documents and record inspection, field inspection, measurement or test for activities important to safety (such as the civil works, installation, commissioning, maintenance and reconstruction, design modification etc. for important safety items), field dialogue and coordination, etc.

2) Routine Inspection

It is a fairly formal inspection method with notice in advance. The inspection team inspects according to the inspection plan and question sheets, including checking documents (program procedures, records and reports), discussion with site staff, site inspection/ survey, and measurement and testing when necessary. The inspection reports are noticed to nuclear installation operating organizations and copied to the competent authority of the operating organizations and relevant organizations. The regional offices track the implementation of requirements proposed in the reports when necessary, inspection team should be assigned by the NNSA to conduct verification.

As license conditions for nuclear installations approved by the MEP (NNSA) or requirements in relevant documents, inspection is performed on selected control points at the construction, installation, commissioning and operation stages. In general, it may include control points for inspection of foundation subsoil in ditch, the first concrete casting(FCD), cold/hot functional test, fuel loading, criticality, evolution, etc.

3) Non-routine Inspection

It is performed according to abnormal conditions at the construction, commissioning and operation stages of nuclear installations, the nuclear safety related events or other emergency/unexpected cases that may affect safety and quality. Non-routine inspection is proposed by technical departments in the headquarter or regional office, with or without notice in advance, and may also include investigation of nuclear safety related events.

When necessary, the MEP (NNSA) has the right to take compulsory actions, including ordering a NPP to stop operation.

7.2.4 Newly Issued Licenses in this Implementation Circle of Convention on Nuclear Safety

The MEP (NNSA) has newly issued the following licenses to NPPs from 2013 to 2015:

(1) Siting review comments

— On March 2, 2014, approving the review comments for siting and environmental impact assessment report for siting stage for Units 3 and 4 of Haiyang NPP.

— On April 8, 2014, approving the review comments for siting and environmental impact assessment report for siting stage for Units 1 and 2 of Xudabao NPP.

— On June 18, 2014, approving the review comments for siting and environmental impact assessment report for siting stage for the CAP1400 demonstration project.

— On June 19, 2014, approving the review comments for siting and environmental impact assessment report for siting stage for Units 1 and 2 of Lufeng NPP.

— On June 19, 2014, approving the review comments for siting and environmental impact assessment report for siting stage for Units 3 and 4 of

Fangchenggang NPP.

(2) Construction permits

— On September 16, 2013, construction permit was issued for Units 5 and 6 of Yangjiang NPP.

— On March 13, 2015, construction permit was issued for Units 5 and 6 of Hongyanhe NPP.

— On May 6, 2015, construction permit was issued for Units 5 and 6 of Fuqing NPP.

— On December 23, 2015, construction permit was issued for Units 5 and 6 of Tianwan NPP.

— On December 23, 2015, construction permit was issued for Units 3 and 4 of Fangchenggang NPP.

(3) The instrument of ratification for the First Fuel Loading

— On September 2, 2013, *the Instrument of Ratification for the First Fuel Loading for Unit 2 of Hongyanhe NPP* was issued.

— On October 25, 2013, *the Instrument of Ratification for the First Fuel Loadingfor Unit 1 of Yangjiang NPP*was issued.

— On November 8, 2013, *the Instrument of Ratification for the First Fuel Loadingfor Unit 2 of Ningde NPP*was issued.

— On May 30, 2014, *the Instrument of Ratification for the First Fuel Loading for Unit 1 of Fuqing NPP*was issued.

— On September 1, 2014, *the Instrument of Ratification for the First Fuel Loadingfor Unit 1 of the Extension Project of Qinshan NPP (Fangjiashan Nuclear Power Project)*was issued.

— On September 11, 2014, *the Instrument of Ratification for the First Fuel Loadingfor Unit 3 of Hongyanhe NPP*was issued.

— On December 3, 2014, *the Instrument of Ratification for the First Fuel Loading for Unit 2 of the Extension Project of Qinshan NPP (Fangjiashan Nuclear Power Project)* was issued.

— On December 15, 2014,*the Instrument of Ratificationfor the First Fuel Loading for Unit 3 of Ningde NPP*was issued.

— On January 23, 2015, *the Instrument of Ratificationfor the First Fuel Loading for Unit 2 of Yangjiang NPP*was issued.

— On May 15, 2015, *the Instrument of Ratification for the First Fuel Loading for Unit 2 of Fuqing NPP*was issued.

— On August 25, 2015, *the Instrument of Ratificationfor the First Fuel Loadingfor Unit 1 of Changjiang NPP*was issued.

— On September 2, 2015, *the Instrument of Ratification for the First Fuel Loadingfor Unit 1 of Fangchenggang NPP*was issued.

— On September 08, 2015, *the Instrument of Ratificationfor the First Fuel Loadingfor Unit 3 of Yangjiang NPP*was issued.

— On December 31, 2015, *the Instrument of Ratification for the First Fuel Loadingfor Unit 4 of Ningde NPP* was issued.

(4) Operation license

On December 5, 2014, operation license was issued for Units 3 and 4 of the Second Qinshan NPP.

8. Regulation

> 1. Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfill its assigned responsibilities.
>
> 2. Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.

8.1 Regulation System

The MEP (NNSA) is the regulatory body for nuclear safety in China, implementing the unified and independent regulation of the nuclear safety of NPPs throughout the country. The licensing system is one of main measures of the MEP (NNSA) in regulation, and inspection is also implemented for NPPs, nuclear materials and nuclear activities.

The MEP (NNSA) is in charge of regulation of environmental protection of NPPs throughout the country.

The China Atomic Energy Authority is the nuclear industry administration of the Chinese Government, which is responsible for researching, drafting out and organizing the implementation of the policies, regulations, programs, plans and industrial standards for the peaceful utilization of atomic energy in China. It is also in charge of the communication and cooperation among governments and also among international organizations in the nuclear field, and takes the lead in managing the nuclear accident emergency in the country.

The National Energy Administration is the administrative department of energy industry of China. It is responsible for drafting out and implementing developing program, conditions for access and technical standards of nuclear power; putting forward the opinions about review of significant nuclear power projects; organizing coordination and guidance of scientific research of nuclear power; and organizing the emergency management of the NPPs.

The National Health and Family Planning Commission, together with relevant authorities, formulate laws and regulations on prevention of radioactive occupational diseases, organize for the formulation and issuing of standards on radioactive occupational diseases and conduct emergency medical rescue in nuclear and radiation accidents.

According to nuclear safety regulations in China, the licensees (or applicant) of nuclear safety licenses bear overall responsibilities for the safety of NPPs, nuclear materials and nuclear activities.

8.2 MEP(NNSA)

8.2.1 Organizations Structure

The MEP (NNSA) implements unified and independent regulation on the safety of NPPs.

The nuclear and radiation regulation system of China consists of the headquarters of the MEP (NNSA), the regional offices and technical support organizations. The MEP (NNSA) is headquartered in Beijing and has established six regional offices as East China Regional Office of Nuclear & Radiation Safety Supervision (located at Shanghai), South China Regional Office of Nuclear & Radiation Safety Supervision (located at Shenzhen), Southwest China Regional Office of Nuclear & Radiation Safety Supervision (located at Chengdu), North China Regional Office of Nuclear & Radiation Safety Supervision (located at Beijing), Northwest Regional Office of Nuclear & Radiation Safety Supervision(located at Lanzhou) and Northeast Regional Office of Nuclear & Radiation Safety Supervision (located at Dalian) respectively, and these regional offices are responsible for the routine regulation of nuclear and radiation safety in corresponding regions.

In order to perform the regulation better, the MEP (NNSA) has established the Nuclear and Radiation Safety Center as its technical support center, and has designated Zhejiang Radiation Environment Monitoring Station as the Radiation Environment Monitoring Technical Center of the MEP, to provide technical support in terms of nationwide radiation environment monitoring and management. Furthermore, technical support team of long-term stability has been established by the form of project contract management, with core technical support organizations including the Nuclear Equipment Safety and Reliability Center, Suzhou Nuclear Safety Center and Beijing Nuclear Safety Review Center, and more than ten universities and research institutes including the Research Institute of Nuclear Power Operation, China Institute for Radiation Protection, China Institute of Atomic Energy, Tsinghua University and Shanghai Jiaotong University, etc.

The MEP (NNSA) has established the Nuclear Safety and Environment Advisory Committee and the Nuclear and Radiation Safety Regulation and Standard Review Committee, to provide technical consultancy on formulation of nuclear safety regulations, nuclear safety technology development, nuclear safety review and inspection, regulation and standard review.

Other departments and bureaus of the MEP (NNSA) related to nuclear and radiation safety include the General Office, the Department of Planning and Finance, the Department of Policies, Laws and Regulations, the Department of Human Resources Management and Institutional Arrangement, the Department of Science, Technology and Standards, the Department of International Cooperation, and the Department of Education and Communications, and they undertake the work on daily administration, financial management, legislation, human resource, nuclear safety technology and standard, international cooperation, communication and education. The organization structure of the MEP (NNSA) are as shown in Fig. 4.

8.2.2 Main Duties and Responsibilities

The main duties and responsibilities of the MEP (NNSA) include:

(1) Responsible for regulation of nuclear safety and radiation safety, drafting out, organizing and implementing policies, programs, laws, administrative regulations, department rules, systems, standards and specifications relating to nuclear safety, radiation safety, electromagnetic radiation, radiation environment protection as well as nuclear and radiation accident emergency;

(2) Responsible for unified regulation of nuclear facility safety, radiation safety and

radiation environment protection;

(3) Responsible for regulation of licensing, design, manufacture, installation and non-destructive testing activities for nuclear safety equipment and the safety inspection of imported nuclear safety equipment;

(4) Responsible for control of nuclear materials and regulation of physical protection;

(5) Responsible for regulation of radiation safety and radiation environment protection of nuclear technology application projects, uranium (thorium) mines and associated radioactive mines, and taking charge of radiation protection;

(6) Responsible for regulation of safety and radiation environment protection of treatment and disposal of radioactive waste, and for supervisory inspection of radioactive contamination prevention and control;

(7) Responsible for regulation of safety transport of radioactive materials;

(8) Responsible for nuclear and radiation emergency response, investigation and treatment of the MEP (NNSA) and participation in prevention and handling nuclear and radiation terrorist event.

(9) Responsible for qualification management of reactor operators, special process personnel of nuclear equipment, etc.;

(10) Organizing and developing radiation environment monitoring and supervision monitoring of nuclear equipment and key radiation sources;

(11) Responsible for domestic implementation of international conventions relating to nuclear and radiation safety;

(12) Directing relevant professional work in regional offices of nuclear and radiation safety supervision.

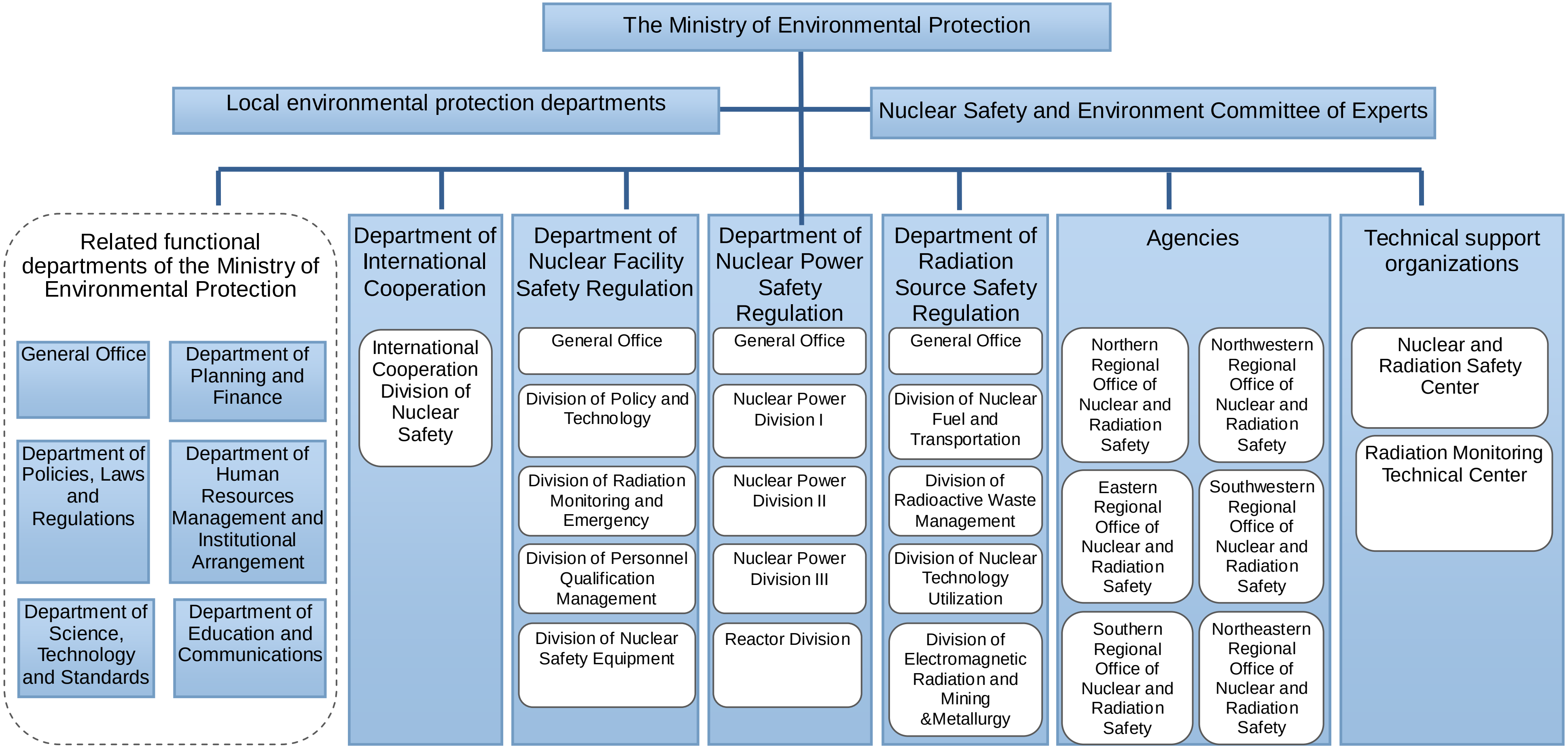

Fig. 4 Organization structure of the MEP (NNSA)

It is specified in Article 8 of the *Law of the People's Republic of China on Prevention and Control of Radioactive Pollution* that: "The competent environmental protection administrative department under the State Council shall exercise unified regulation on radioactive pollution prevention and control work for the whole country in accordance with this Law. The health administrative department under the State Council, as well as other relevant departments, in accordance with the stipulated duties of the State Council, and in accordance with this Law shall supervise and manage radioactive pollution prevention and control work".

The daily inspection work is carried out mainly according to the provisions in the law and the relevant procedures and coordination mechanism, inspections concerning important nuclear safety issues and major safety inspection programs (such as the comprehensive safety inspection of nuclear installations in the whole country after the Fukushima nuclear accident) are usually carried out jointly by the nuclear safety regulatory body (NNSA) and the industry competent authorities (China Atomic Energy Authority and National Energy Administration); when some special fields are involved, the relevant professional departments on nuclear safety also participate in the law enforcement activities, for example, seismological and meteorological departments would participate in the evaluation on earthquakes and tsunami for sites of nuclear installations, and when transport and traffic issues are concerned, the transport department is invited to the relevant activities.

For sanctions in law enforcement, the nuclear safety regulatory body (NNSA) would usually solicit opinions from the competent authorities, and impose sanctions in strict accordance with the administrative sanction procedures. Sanction notice is sent first, with appealing procedures indicated, after the final sanction is made, the letter of sanction is usually copied selectively to the competent authorities of the industry (China Atomic Energy Authority and National Energy Administration), the guarantee departments of the nuclear industry (the Ministry of Finance and State-owned Assets Supervision and Administration Commission) and relevant professional departments.

In 2013, China launched a new round reform of administrative approval system, to further streamline administration and delegate power to the lower levels. The MEP (NNSA) made partial exploration and practice in this regard for the nuclear and radiation safety regulation. For some items with low risks and assured safety, the review and approval process has been simplified or exemption management adopted. In the meantime, licensing matters are streamlined. At present, there are 20 administrative licensing items on nuclear and radiation safety directly undertaken by the MEP (NNSA) as approved by the State Council, concerning the licensing of NPP operators, nuclear materials licensing, and the design, manufacturing, erection and NDT of nuclear safety equipment.

8.2.3 Human and Financial Resources

To meet the needs in the development of nuclear power, the Chinese government increases the manpower and financial input in nuclear safety regulation year by year, to ensure implementation of the functions in nuclear safety regulation. Till the end of 2015, the central government approved that the staffing of the MEP (NNSA) for nuclear and radiation safety regulation increased to 1,103 persons, including 82 people in the headquarters, 331 people in its six regional offices, 600 people in the Nuclear and Radiation Safety Center and 90 people in the Radiation Environment

Monitoring Technical Center.

The MEP (NNSA) attaches high importance to the training of nuclear safety inspectors. It prepared the *Planning for Training of Nuclear and radiation Safety Regulation Inspector*, to further complete the training system and mechanism for nuclear and radiation safety regulatory personnel; it has strengthened the overall planning and coordination for training of nuclear and radiation safety regulatory personnel, made full use of training resources, carried out diversified study and symposium activities, established long-term mechanism for study and research, and continually strengthened the professional training of nuclear safety inspector via various channels and in diversified ways, such as special professional training (simulator, non-destructive testing, civilian nuclear safety equipment regulation and nuclear quality assurance), training, dispatching young people to participate in on-site inspection of regional offices, technical meetings and exchanges abroad. From 2013 to 2015, the MEP (NNSA) held 5 training sessions on qualification of nuclear safety inspectors, for a total of 207 trainees, and held 5 on-the-job training sessions for nuclear safety inspectors, for a total of 124 trainees.

To ensure the quality of nuclear safety inspection, the *Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China* put forth clear requirements on the main conditions of nuclear safety inspectors, including education, working experience, capability and basic professional quality. The MEP (NNSA) performs selection, training and examination for personnel according to regulation requirements and need in work. The examination includes written test and oral test, and those qualified are issued with certificate of nuclear safety inspector by the MEP (NNSA). In 2014, the NNSA promulgated for implementation the *Rules for the Management of Nuclear and Radiation Safety Supervision and inspection Personnel Certificates*, to further formalize the management of nuclear and radiation safety inspector. By Dec. 31, 2015, the MEP (NNSA) had issued Certificate of Nuclear safety Inspector for 325 person.

In 2015, the daily financial budget of the MEP (NNSA) on regulation was 379 million, doubling that of 2011. In addition, the Chinese Government approved nuclear safety regulation capacity development and scientific research fund of 530 million. In the meantime, the MEP (NNSA) obtains technical research and development projects by technical cooperation with the IAEA, international cooperation with the EU, and cooperation with associated nuclear energy enterprises and with the regulatory bodies of other countries and international institutions.

8.2.4 Integrated Management System

The MEP (NNSA) has made overall sorting, analysis and assessment of the existing regulations, procedures and management practice based on the latest safety standards of IAEA and good practice of international counterparts. In 2015, it organized the preparation and issued the *Integrated Management System Manual for Nuclear and Radiation Safety Regulation*. This manual describes in detail the basic requirements and measures for the internal organizations of nuclear and radiation safety regulation bodies, regional offices and technical support organizations to establish, implement, assess and continually improve their management systems, makes clear the structure and elements of nuclear and radiation safety regulation integrated management systems, and expounds the organizations, management responsibilities, stakeholders and interfaces of the MEP (NNSA), to effectively identify and manage various resources, plan and control the core work and support processes, so as to provide strong support for the MEP (NNSA)to perform its management responsibility with effective and high-quality operation of the management system..

The integrated management system for nuclear and radiation safety regulation mainly consists of four parts:

(1) Management responsibility

To fulfill the organization mission, vision and core value, the MEP (NNSA) has published the policies, safety objectives and management commitment on nuclear and radiation safety, worked out organization strategy and plans, specified the organization structure and responsibilities, advocated nuclear safety culture, and paid attention to the needs of stakeholders. Besides, it is responsible for planning, establishing and implementing the management system, providing the required resources, and performing assessment and self-improvement on a periodic basis.

(2) Support and guarantee

Adequate resources and their efficient management help to enhance regulator's capability and raise the satisfaction level of stakeholders by offering a strong support and guarantee for implementation, maintenance and improvement of the management system. These resources include infrastructure and working environment, human resources, information and knowledge, scientific and technological research and development, financial resources, suppliers and technical support organizations, and international cooperation. Appropriate planning of various resources is required to ensure sufficient resources available for regulatory activities and high regulatory competency.

(3) Process implementation

Process management involves planning, implementation, control and coordination of general management process and core work process to ensure the quality and efficiency of each activity. The interlinked activities in a process should have a procedure, stating the transition, interface and completion of activities among different departments to avoid redundancy, conflict or omission.

(4) Assessment and improvement

Based on the self-assessment of managers at all levels, internal and external independent assessments and operating experience, the monitoring and assessment system and self-improvement mechanism are established for the integrated management system to create a learning organization, through which continuous improvement can be achieved by identifying the problems and deficiencies in the management system in a timely manner.

In this system, "process method" is reflected, regulation concepts put into practice, nuclear safety culture advocated, activities managed by classification and grading approach, and allocation of available resources optimized; the system meets the demand and expectation of stakeholders, and provides the MEP (NNSA) with methods and tools for fully fulfilling its responsibilities for nuclear and radiation safety regulation, with higher quality, efficiency and authority.

8.2.5 Public Communication

China attaches great importance to information publicity and public communication, and ensures the right of the public to know, to participate and to supervise. The MEP (NNSA) issued the *Scheme of Nuclear and Radiation Safety Regulatory Information Publicity(for trial implementation)*and *Notice on Strengthening Information Publicity of Nuclear and Radiation Safety in NPPs* and promulgated the *MEP (NNSA) Work Scheme of Nuclear and Radiation Safety Public Communication* and *Administrative Measures of Nuclear and Radiation Safety Regulatory Information Publicity*, clearly specifying the scope of application and division of responsibilities for information publicity, and the contents, timing, methods and channels of information publicity.

The main contents of nuclear and radiation safety regulation information publicity cover: the laws and regulations, standards, policies and planning of the state on nuclear and radiation safety, release of administrative licensing procedures and licensing documents for nuclear and radiation safety, safety supervisory inspection reports on relevant nuclear and radiation safety activities, general safety state of nuclear installations, radioactive environment monitoring results, nuclear and radiation emergency plans, important nuclear and radiation events (accidents) and their investigation and treatment conclusions.

The MEP (NNSA) communicates with the public and media mainly by the following:

(1) Important information about regulation activities is issued in good time on the official website of the MEP (NNSA), such as license issuance, important review and inspection activities and their results, reports on construction and operating events of nuclear installations, radioactive environment monitoring results, and relevant information on nuclear and radiation accident emergency;

(2) Publicizing the knowledge and information related to nuclear and radiation safety on websites, newspapers, periodicals, TV, publications and publicity materials;

(3) Soliciting public opinions by information publicity, distributing investigation questionnaires, and holding symposium and hearings before publishing important regulatory documents or decisions, to accept public inquiry and supervision;

(4) Inviting media to participate in important experience exchange activities on nuclear safety regulation, and organizing experts to answer and explain questions of public concerns at media.

8.3 China Atomic Energy Authority

The China Atomic Energy Authority includes Administration Department, System Engineering Department, International Cooperation Department, Comprehensive Planning Department, Science and Technology Quality Control Department as well as National Nuclear Accident Emergency Office, Nuclear Material Control Office and Isotope Management Office. The duties and responsibilities of the China Atomic Energy Authority include:

(1) Responsible for researching and drafting out policies and regulations for the peaceful use of atomic energy in China;

(2) Responsible for researching and establishing developing program, planning and nuclear industry standard for the peaceful use of atomic energy in China;

(3) Responsible for organizing the justification, review and approval of relevant

science and technology research projects on the peaceful use of nuclear energy in China; and supervision and coordination of the implementation of scientific research projects;

(4) Responsible for control of nuclear materials and physical protection of nuclear facilities;

(5) Responsible for the review and management of nuclear export;

(6) Responsible for the exchange and cooperation in nuclear field among governments and among international organizations; taking part in the IAEA and its activities on behalf of the Chinese government;

(7) Undertaking emergency management of national nuclear accidents; taking the lead in organizing the National Nuclear Accident Emergency Coordination Committee, and responsible for the development and preparation of the *National Nuclear Emergency Plan* and organizing its implementation;

(8) Responsible for decommissioning of nuclear facility and treatment of radioactive waste.

8.4 National Energy Administration

In June 2013, internal departments of the National Energy Administration were adjusted to twelve after institutional restructuring, including the General Affairs Department, Legal and Institutional Reform Department, Development and Planning Department, Energy Conservation and Scientific and Technological Equipment Department, Electric Power Department, Nuclear Power Department, Coal Department, Oil and Gas Department (National Oil Reserve Office), New Energy and Renewable Resources Department, Market Supervision Department, Electric Power Security Regulation Department and International Cooperation Department.

Duties and responsibilities of the National Energy Administration in nuclear field include:

(1) Responsible for nuclear power management and taking the lead in drafting out laws and regulations related to nuclear power;

(2) Drafting the developing program, access conditions and technical standards of nuclear power, and organizing their implementation;

(3) Putting forward the layout of nuclear power and review opinions on major projects;

(4) Organizing the coordination and guidance of scientific research of nuclear power;

(5) Organizing the nuclear accident emergency management of in NPPs;

(6) Responsible for the international cooperation and exchange among governments in the field of nuclear power and the negotiating and contracting for agreements on peaceful utilization of nuclear energy with foreign countries.

8.5 National Health and Family Planning Commission

Main duties and responsibilities of the National Health and Family Planning Commission in nuclear power safety management include:

(1) Formulating laws and regulations on prevention of radioactive occupational diseases together with relevant authorities and organize for the formation and issuing of relevant standards.

(2) Organization and coordination of national nuclear emergency medical preparedness and rescue, and guiding local health departments in proper nuclear emergency medical preparedness and disposal.

9. Responsibilities of the Licensees

> Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such license holder meets its responsibility.

China has made clear its main responsibility for the safety of the personnel or organizations of the nuclear installations or activities causing radiation hazards, and the government issues nuclear safety licenses to the operating organizations or individuals operating the installations or carrying out such activities. Nuclear safety license is a legal document with which the national regulatory body approves the applicant to perform specific activities related to the nuclear safety (such as siting, construction, commissioning, operation and decommissioning of NPPs, etc.).

It is specified in Article VII of the *Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China* that:

The operating organization of the NPP is directly responsible for the safety of the NPP in operation. Its main responsibilities are as follows:

(1) To comply with the relevant laws, administrative regulations and technical standards of the country to ensure the safety of NPPs;

(2) To accept the safety inspection from the MEP (NNSA) and other Ministries, to report the safety situation timely and faithfully and to provide relevant information;

(3) To take overall responsibility for the safety of the NPPs operated by them, the safety of nuclear materials, and the safety of the working personnel, the public and the environment.

As the licensee, the operating organization is fully responsible for safe operation of the NPPs, and such responsibility will not be mitigated or transferred due to the activities and responsibilities of the design, manufacture, construction and regulatory personnel. Organizations performing design, manufacture and construction also undertake corresponding responsibilities of nuclear and radiation safety within their respective scopes of work.

The policy of "safety first and quality first" and nuclear safety objectives are principle requirements for all organizations engaged in work for NPPs. Operating organizations shall commit themselves to the nuclear safety of NPPs. All other organizations, such as design and construction organizations, suppliers should make commitment on their respective responsibilities on safety, and include such commitment into the policy statement of their quality assurance programs, and accept inspection by the operating organization and the nuclear safety regulatory bodies. All organizations shall fulfill the task of commitment in their respective management by objectives.

Commitments to safety: All important activities related to the NPP safety shall accord with the standards in safety codes. Nuclear safety is placed at top priority, which shall not be restricted and affected by production schedule and economic benefit. NPPs shall establish and maintain effectively defense-in-depth, to protect its employees, the public, and the environment from radioactive hazards. Safety review and assessment system shall be established to supervise and assess relevant activities, to keep on identifying and correcting errors and deficiencies in work, pursue high quality work target and achieve continual improvement of safety performance.

The MEP (NNSA) and its regional offices shall implement nuclear safety inspection tasks. Nuclear safety inspections are carried out continuously throughout the whole process of siting, design, construction, commissioning, operation and decommissioning as well as all important activities for NPP. Nuclear safety inspections are classified as daily, routine and non-routine (special) types. The main methods include document inspection, site observation, informal discussion, interview, measurement or test.

The MEP (NNSA) shall perform legal surveillance for activities of the licensees in accordance with the *Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China*, *Regulations on Nuclear Materials Control of the People's Republic of China*, *Regulations on the Emergency Management for Nuclear Accidents of Nuclear Power Plant*, *Regulations on the Safety Regulation for Civilian Nuclear Safety Equipment*, *Regulations on the Safe Transportation of Radioactive Materials*, *Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China - Part Two: Safety Surveillance of Nuclear Installations* as well as their supporting regulations and relevant administrative provisions.

In 2011, the MEP (NNSA) issued the *Notice on Strengthening Information Publicity of Nuclear and Radiation Safety in NPPs*, specifying requirements to licensees on information publicity and public communication. The licensees in China actively respond to this circular, and carry out the work on information publicity and public communication in various ways, such as establishing and further completing the information publicity system, setting up information publicity platforms and official microblog and WeChat, holding news release, publishing white papers and report on social accountabilities, carrying out activities to open to the public for experience, nuclear power knowledge publicity in campuses and public organs, building platforms for science and technology popularization, and distributing booklets on scientific knowledge.

The nuclear power group corporations have established nuclear emergency support bases and support teams of groups, signed the *NPP Nuclear Accident Emergency On-site Support Cooperation Agreement of Nuclear Power Group Corporations*, and established the mutual support cooperation mechanism between groups; all neighboring NPPs have signed one after another mutual support agreements, prepared mutual support action plans, established nearby rapid mutual support mechanism, and materialized the nuclear accident emergency mutual support requirements and mechanism. These measures will ensure that NPP licensees have sufficient resources required to effectively manage accident and mitigate consequences of accident on site.

10. Priority to Safety

Each Contracting Party shall take the appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

10.1 Safety Policies and Safety Management Arrangement

In activities related to nuclear safety, China always adheres to the fundamental policy of "safety first and quality first", carries out the safety notion of defense in depth, and takes effective measures to ensure nuclear safety. In all activities of siting, design, construction, operation and decommissioning of NPPs, safety must be put at top priority. Organizations and individuals engaged in these activities must conscientiously carry out the policy of "safety first and quality first".

NPP operating organizations formulate and issue nuclear safety policies according to requirements of regulations, so that all activities of NPPs can first ensure the safety of the employees, the public and the environment, and meet the objective of nuclear safety management. The nuclear safety policies of NPPs include the guiding policy of "safety first and prevention crucial"; the safety notion of "safety is supreme and pursuing for excellence"; strictly observing the nuclear safety laws and regulations of the state, and all commitments made to the nuclear safety regulatory bodies.

10.2 Nuclear Safety Culture

To realize good safety performance and raise the safety culture level, all NPP operating organizations have set long-term plan for nuclear safety culture development, including diversified nuclear safety culture publicity and cultivation, nuclear safety culture self-assessment and external independent assessment, to raise the awareness of all employees on responsibility, so that the decision-making level, management level and implementation level can all act consciously to ensure nuclear safety. In the past three years, NPPs mainly carried out the following continual improvement work in the development of nuclear safety culture:

(1) Further completing the nuclear safety culture assessment system

All nuclear power group corporations in China, according to the *Traits of a Healthy Nuclear Safety Culture* published by WANO, prepared the nuclear safety culture assessment guidance/guides and a series of technical documents for nuclear safety culture assessment. All NPPs carry out all-round nuclear safety culture assessment activities periodically, each assessment period lasting for nearly 2 months from the preparation, questionnaire investigation to interviews with employees. In the assessment process, leaders of NPPs pay high attention and employees take an active part, the demonstrated assessment results well agree with the status quo of the nuclear safety culture in the plant, and good practices and weaknesses in nuclear safety culture are identified, realizing closed-loop management for the development of nuclear safety culture. The nuclear safety culture assessment system documents of NPPs has taken initial shape, which attach importance to establishing unified and standardized requirements, assessment methods and procedures, to allow accurate determination of the nuclear safety culture status in the NPPs and identifying strong and weak points in the development of nuclear safety culture.

(2) Systematically pushing forward the cultivation of nuclear safety culture

All NPP operating organizations have established safety culture promotion organizations. The top management attaches importance to the input and participation in cultivation of nuclear safety culture, takes the lead to lecture on nuclear safety culture courses; they emphasize on the resource input concerning safety issues, make efforts to establish a non-accusatory safety culture environment and encourage employees to report all deviations occurring or identified in a conscious, timely, complete and precise manner; they advocate establishing learning-oriented enterprises, keep on setting up and completing various rules and procedures, and advocate a transparent culture to report problems and enhancing the awareness of safety of employees by building learning-oriented enterprises.

(3) Strengthening the construction of safety management system

Establishing safety management system for defense in depth: following the policy of "safety first and quality first", organizations in NPPs at all levels attach importance to active defense and conservative decision-making. Advanced safety management concepts and methods are applied to establish safety management systems, including technical management safety system and safety supervision system. The multilevel and in-depth safety management mechanism has been established in all links of safety management, such as organization, rules, control, supervision, feedback, emergency preparedness, and improvement, to well combine all rules in safety management with culture through the penetration of safety culture and upgrading the basic quality of employees.

(4) Maintaining an open attitude

Regulatory bodies and the NPPs attach importance to international exchange and cooperation. On the one hand, they take initiative to apply for the OSART and IRRS of the IAEA and WANO peer review activities, and actively participate in the operating experience and information sharing platforms of international organizations including the IAEA and WANO, to contribute their operating experience and information; on the other hand, they identify gaps for further improvements through international benchmarking and exchange.

(5) Attaching importance to growing together with contractors

NPPs attach importance to the cooperative relationship with contractors, and constantly push development of contractors' nuclear safety culture to develop a unified nuclear safety culture language. Within the contractors, there are team safety culture cultivation with their own characteristics as well as all kinds of safety culture education and practice activities carried out simultaneously with NPPs.

(6) Formalizing behavior of people to prevent human errors

All NPPs pay high attention to cultivating good behavior and habits of working personnel, incorporate the requirements on using human error prevention tools in daily work, improve the behavior of people by all management means, and transmit management standards and expectation, including the strengthened training on use of human error prevention tools and observation of behavior.

(7) Completing of NPP operating experience system

All NPPs in China, both in operation and under construction, have established fairly complete operating experience systems, which operate well. After integrating resources, all nuclear power groups have prepared the operating experience activity guidelines and standardized implementation procedures for operating experience processes of groups, and established a unified operating experience information platform. The China Nuclear Energy Association has built up the operating experience system of the industry, and established China Information Network for Nuclear Power Operation (CINNO), realizing information sharing in the whole nuclear power sector.

(8) Creating good communication relationship

Good interaction relationship has been established between regulatory bodies and NPPs through the periodical coordination meetings, nonscheduled dialogues, symposiums, exchange visits, communication every year, and these have enhanced transparency and credibility of nuclear safety review and safety supervision. In the meantime, regulatory bodies perform comprehensive assessment of safety management in NPPs and assist them in identifying areas for improvement, to promote the cultivation of nuclear safety culture.

10.3 Peer Review and Self-assessment of NPPs

To ensure safe and reliable operation, NPPs in China continually learn the advanced management experience from foreign NPPs, and constantly improve their internal and external assessment system in combination with the practices from nuclear power development in China, see Fig. 5.

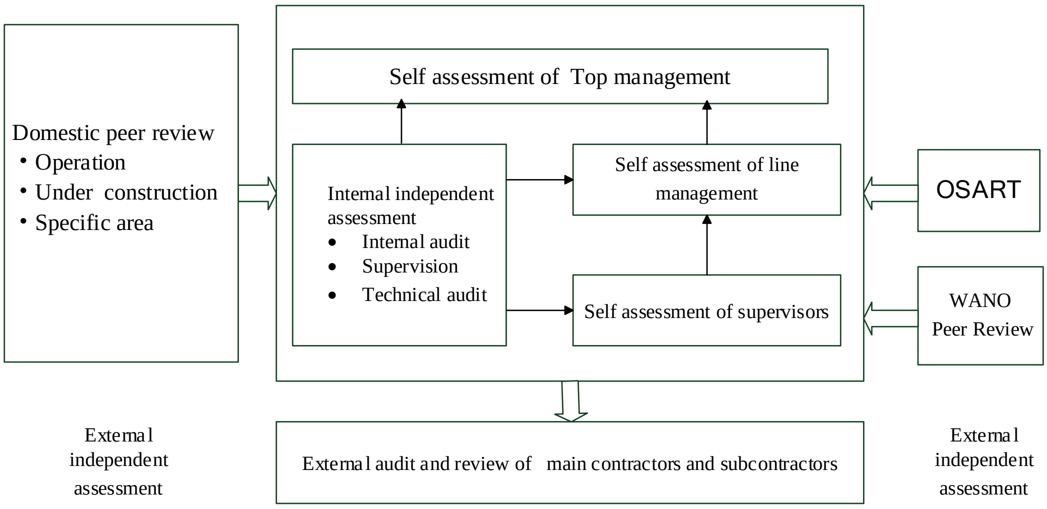

Fig.5 Assessment system of NPP

The internal assessment system of a NPP includes the independent assessment in the plant and self-assessment at different management levels. Independent assessment is conducted by authorized departments or organizations, through audit, supervision and technical review to check and verify each job done by plant personnel and contractor. The results of independent assessment are an important input for self-assessment.

Self-assessment at different management levels is performed in routine jobs. Its purpose is to determine the effectiveness on establishing, promoting and achieving the objectives of nuclear safety, and identify and correct managing weaknesses and obstacles to achieving nuclear safety objectives. Self-assessment of top management departments focuses on meeting the strategic objectives of the organization, including safety objectives. The primary level management pays more attention to supervision and audit of working process, including the supervision of items, services and processes, audit and verification of design documents, audit of procedures and records, observation of independent assessment, and periodical walk-down of facilities.

Peer review of NPPs is an important means to improve nuclear power management level and safety performance. The NPPs in China actively perform peer review and energetically carry out special assessment activities on plant production operation, maintenance, technology and nuclear safety culture. Through the relevant special and comprehensive assessment activities, items for improvement in the operation and project construction of NPP are identified, and then improvement actions could be implemented after analyzing the causes, to upgrade the management level.

The Nuclear and Radiation Safety Center of the MEP has prepared the *Nuclear Safety Culture Characteristics of the NNSA* according to the *Nuclear Safety Culture Policy Statement*, and plans to carry out the nuclear safety culture evaluation/assessment activities of regulatory bodies on this basis. China National Nuclear Corporation and China General Nuclear Power Group have published their own nuclear safety culture criterion documents, and have carried out nuclear safety culture assessment.

From 2013 to 2015, Qinshan NPP, Daya Bay NPP, Qinshan phase II NPP, LingAo NPP, Third Qinshan NPP, Tianwan NPP, Fangjiashan NPP, Fangchenggang NPP, Taishan NPP, Sanmen NPP and Shidao Bay NPP respectively received nuclear safety culture assessment, as an active exploration to make the nuclear safety culture understood, assessable and measurable, through the assessment, areas for improvement are identified, and cause analysis are performed to implement improvement actions and upgrade management level.

For three years, China continued domestic comprehensive operation assessment and special assessment activities for operating NPPs. At the level of the industry, NPP peer review, experience exchange and technical support and service are actively performed as backed up by the Nuclear Power Plant Peer Review and Experience Exchange Committee. This committee prepared and completed in 2013 the five-year peer review rolling schedule (2014-2018) for operating NPPs and the five-year peer review rolling schedule (2014-2018) for nuclear power projects under construction, to make overall arrangement for the review work and optimize the resources allocation for review. From 2013 to 2015, the Nuclear Power Plant Peer Review and Experience Exchange Committee completed 13 peer review campaigns and 5 training sessions for reviewers, and the peer review campaigns carried out include comprehensive operation review and specific area review on personnel performance, public information and PSA.

At the level of nuclear power groups, according to the actual demand of NPPs, specific area review activities are carried out for specific areas, so that the operation review activities in China continually develop in depth, such as the specific area reviews in areas of documentation management, outage management and operation preparation.

In the large-scale construction of NPPs in China, in the meantime, China applied innovatively the idea and method of peer review of operating NPPs to nuclear power projects under construction. At different levels of the industry as a whole and of groups, relevant technical support organizations are organized to develop performance objective and criteria of assessment on NPPs under construction, peer review for project construction has been organized and implemented for project owners and EPC contractors, and on the basis of construction review practices, standard and method for review have been constantly improved and perfected.

In addition, NPPs in China also actively receive WANO peer reviews. From 2013 to 2015, NPPs of China received 22 WANO peer reviews and 4 follow-up visits, including 16 PSUR activities and 2 peer reviews on fleets. The peer review experts identified good practices worth popularizing to other power plants, such as "effectively solving the copper tube corrosion by increasing the pH value of stator cooling water", and "increasing nuclear safety margin by reducing core damage frequency and increasing backup cooling for safety-related components", in the meantime, for the areas for improvement identified in peer reviews, such as "insufficient analysis of recurring events" and "management rounds not strict enough", the NPPs actively formulated and implemented improvement measures. China National Nuclear Power Corporation received the WANO power company peer review in 2014, which was the first WANO fleet peer review carried out in China, and in this review, "public communication" and "planning and implementation of outage" was listed by the WANO review team as strong items.

The results of all above reviews have shown that the reviewed NPPs on the whole were in good safety condition and the quality of project construction was under control. At the same time, review activities helped the plants or projects being reviewed identify the difference and set improving objectives and standards to be achieved, and promoted further improvement of safety and quality management. The list of domestic and international review activities performed in NPPs of China (2013 to 2015) is presented in Appendix 5, and the list of domestic and international review activities planned for NPPs of China (2016 to 2018) is presented in Appendix 6.

10.4 Regulatory and Control Activities

10.4.1 Promotion of Nuclear Safety Culture

To carry on the nuclear safety outlook and national security strategy of China, advocate and push the cultivation and development of nuclear safety culture, promote the overall upgrading of national nuclear safety level, and guarantee the safe, healthy and sustainable development of the nuclear energy undertaking, China actively promote the building of nuclear safety culture in the whole industry.

(1) Issuing the Policy Statement on Nuclear Safety Culture

Administration and China Atomic Energy Authority, issued the *Nuclear Safety Culture Policy Statement*, which has expounded the basic attitude of China towards nuclear safety culture, and the principle requirements for cultivating and practicing nuclear safety culture. It accurately defines and describes nuclear safety and nuclear safety culture based on the actual condition of China, illustrating the eight major characteristics of nuclear safety culture.

The *Nuclear Safety Culture Policy Statement* has fully integrated and absorbed the advanced experience and practice results of all countries, and also taken into full account the practice in China. It is a major move to push the nuclear safety culture development in the nuclear industry and provides a guide for the nuclear industry in cultivating and developing nuclear safety culture.

(2) Carrying out nuclear safety culture publicity campaign

To implement the requirements and propositions of *Nuclear Safety Culture Policy Statement*, the MEP (NNSA) worked out the action plan to push ahead the nuclear safety culture publicity and examination plan for its implementation, and prepared publicity materials including the collection of codes and standards, typical case analysis and collection of cases. In addition, it organized large scale special campaign on nuclear safety culture publicity and implementation. This publicity campaign was carried out in diversified forms, such as publicity meeting, lectures and discussions, publicity exhibition panels, publicity video with the theme of nuclear safety culture, theme exhibition, special issue of periodical on nuclear safety culture, video meeting, and the use of new media platforms such as QQ and Wechat to spread nuclear safety culture idea, requirements, expectations and knowledge. The special campaign covered all license holding organizations in the nuclear energy field and all their key personnel, featuring zero tolerance on concealing and false report and on operation in violation of rules. During the campaign, an examination group was established and corresponding examination and inspection schemes worked out, to perform examination and assessment of all license holders, for deficiencies identified in examination, rectification and correction was tracked, and operating experience was made.

(3) Further completing the nuclear safety culture assessment system

The MEP (NNSA) takes nuclear safety culture assessment as important content in development of nuclear safety culture, on the basis of reference to international experience, it plans to, according to the requirements of the *Nuclear Safety Plan* and *Nuclear Safety Culture Policy Statement*, formulate nuclear safety culture assessment system documents covering all areas of the nuclear industry, establish the nuclear safety culture assessment mechanism for independent implementation by regulatory departments, mobilize nuclear safety supervisors to carry out daily culture observation, and organize comprehensive assessment teams to carry out special assessment. Later on, the MEP (NNSA) will arrange pilot work on the basis of nuclear safety culture assessment model for NPPs, to gradually expand nuclear safety culture assessment to fields such as nuclear safety equipment.

10.4.2 Safety review, licensing and inspection

The MEP (NNSA), according to the requirements in relevant nuclear safety laws and regulations, plans and organizes the implementation of safety review and licensing activities for the nuclear installations/activities under its charge, to ensure that NPP operating organizations comply with the requirements of national nuclear safety codes and standards, and that sufficient safety provisions are in place to protect the people in the plant area, the public and environment from hazard of excessive radiation. The MEP (NNSA) will issue licenses only after the safety review has been passed.

The MEP (NNSA), by inspecting the performance of nuclear and radiation safety management requirements and conditions specified in licenses, urges the licensees to promptly correct defects and anomalies, and items not complying with the nuclear safety management requirements and conditions specified in licenses, when necessary, compulsory actions can be taken to protect the safety of nuclear installations/activities. The MEP (NNSA) mainly performs daily inspections, routine/non-routine inspections, and the work carried out mainly includes:

(1) Formulating and effectively implementing safety inspection programs, implementation procedures and inspection schedule for various nuclear installations/nuclear power, organizing the implementation of field inspections, and preparing corresponding supervisory inspection records and reports.

(2)Informing, assessing and tracking problems identified in inspection until their effective solution. Making investigation and analysis for important nonconformance and events, and carrying out special-subject symposium or special research when necessary.

(3)For serious violation of nuclear safety codes and regulations of any supervised party which has not been effectively handled, the law enforcement procedure can be launched, including issuing written warning/instructions, terminating or reducing specific activities, changing, suspension or cancellation of permit/license and penalty.

(4)Formulating and effectively implementing training programs for nuclear and radiation safety inspectors, select, train, examine, qualify and authorize nuclear and radiation safety supervisors, so that they have the knowledge, experience and ability for the supervised areas, and performing periodical assessment of their working performance.

(5)Inspecting and verifying the supervision processes and inspection quality, and performing periodical assessment of the independence and inspection quality for external technical support organizations and external experts.

(6)Establishing nuclear and radiation safety regulation database and management system, promoting the application of IT technology, and carrying out internal and external information exchange and operating experience.

11. Financial and Human Resources

1. Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.

2. Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life.

11.1 Financial Resources

The Chinese Government allocates funds of certain amount for use in the development of nuclear power technologies and researches on nuclear safety technologies. The Chinese Government gives full play to the guiding role of government, establishes effective fund guarantee mechanism, increases financial input to nuclear safety and radioactive contamination prevention and control, and promotes implementation of programmed projects; improves fund management and control mode in nuclear safety management; clearly defines fund source, method of capital contribution, approval process and application of funds for expenses to be jointly undertaken by the government and enterprises and involving nuclear emergency, nuclear insurance, nuclear compensation, radioactive contamination prevention and treatment of civilian nuclear installations and construction of public welfare nuclear safety infrastructure; and strictly examines fund flow to ensure appropriate fund raising and use for the designated purposes.

In China, all expenses for safety operation and improvement of NPPs every year are borne by the NPP operating organizations. After a NPP has been put into operation, a specified percentage of the revenue from power generation is drawn for use in safety improvement, radioactive waste management and final decommissioning of the plant. Items for improving the safety and their expenses have a priority in the annual plan and financial budget. The NPPs in China have made safety improvements after the Fukushima nuclear accident at about RMB 100 million per unit.

The *Law of the People's Republic of China on Prevention and Control of Radioactive Pollution* clearly specifies that:

The operating organization of NPP shall draw up plans for decommissioning of such installations. The expanses for decommissioning of nuclear installations and for disposing of radioactive waste shall be withdrawn in advance and shall be included in the budgetary estimates of investment or in production cost.

The administrative department for environmental protection under the State Council shall be responsible for supervisory monitoring of the NPPs. The expenses for establishment, operation and maintenance of the system for supervisory monitoring shall be covered by the financial budget.

The *Regulations on the Emergency Management for Nuclear Accidents of Nuclear Power Plant* specifies: on-site emergency preparedness fund for nuclear accident shall be borne by the NPP and included in the budgetary estimates of investment and operating cost of the NPP project. The emergency preparedness fund for off-site nuclear accident shall be jointly borne by the NPP and the local people's government, and amount of the fund shall be examined and approved by the department designated by the State Council with relevant departments. The fund to be borne by the NPP shall be paid at a certain proportion determined according to capacity of the NPP before operation and the actual amount of power generated after the operation, and be used for emergency preparedness of local off-site nuclear accidents after comprehensive balancing by the planning department of the State Council; the rest part shall be raised by the local people's government.

To further regulate collection and application of emergency preparedness fund for nuclear accident and strengthen management of special revenue for emergency preparedness of nuclear accidents of NPPs, the *Rules on Management of Special Revenue for Emergency Preparedness of Nuclear Accident was prom*ulgated in 2007, which contains further clear stipulations on the sources of special revenue for nuclear emergency preparedness, the standard, proportion, time and method of payment, the scope of application, budget and final accounting mechanism, and regulatory mechanism.

China has established nuclear accident liability insurance system and requires that NPPs place insurance on third party liability. In 2007, the Chinese Government required operators of NPPs to adjust the ceiling of compensation for third-party liability insurance in one nuclear accident from the original RMB 18 million to RMB 300 million. In case the amount of payable compensation for damage due to nuclear accident exceeds the specified ceiling of compensation, the state will provide financial compensation up to RMB 800 million. For the compensation for damage due to unusual nuclear accident, the financial compensation to be provided by the state will be determined after assessment by the State Council.

11.2 Human Resources

In NPPs, human resources management department is staffed as required by nuclear safety regulations, and is staffed with competent management personnel and sufficient number of qualified working personnel. According to the nuclear safety guide *Periodic Safety Review for Nuclear Power Plant*, operating NPPs perform the PSR every ten years after the start of operation. The PSR is carried out for 14 safety elements in five categories, including the examination of human resources deployment in NPPs.

11.2.1 Human Resource Assurance Measures

The Chinese Government is actively preparing talents education and cultivation plan to meet the increasing demand for human resources in the development of nuclear power in China. The state, enterprises, academies of science and colleges and universities vigorously strengthen talents cultivation and increase input for talent reserve for science research, design, fuel, manufacture, operation and maintenance, as well as in nuclear power design, nuclear engineering technology, nuclear reactor engineering, nuclear and radiation safety, operation management and other professional fields.

(1) Completing talents cultivating system: in the form of governmental support and close cooperation between universities and enterprises, majors related to nuclear power are established in universities, more students are enrolled into nuclear major in higher schools, and discipline and specialty structure optimized, the universities have well combined fundamental education and specialty education with the pre-job training and on-job training of enterprises, and the pattern of "university and enterprise joint education" or "order plus joint education" has gradually taken shape.

(2) Broadening the way to talent cultivation and recruitment: the demands for human resources are met by enrolling more students in colleges and universities, social recruitment, and engaging experts at home and abroad. Different patterns of cultivation have been built up with respect to the characteristics of professionals required by development of nuclear power in design, engineering and operation.

(3) Attaching importance to demand of high-end talents: before launching a new project, all kinds of high-end core talents are selected and trained in advance; through expanding exchange and cooperation of education in nuclear power field, key talents with international vision in management and technology are trained; also, active use is made of social resources, to import high-end talents required by nuclear power industry.

(4) Actively building up the nuclear power experts support system: by setting up nuclear power experts committee at different levels and technology working groups in special fields, talent information is extensively collected at home and abroad or inside and outside the nuclear power industry, talent information pools are established, and shared platform for nuclear power talents built up; the talents and technical resources of nuclear power technical support organizations are used to provide expert consultancy and suggestions for major activities and decision-making of regulatory bodies, industry competent authority and the nuclear power operating organizations.

(5) Exchange of talents: job rotations are arranged between departments in NPPs, between different plants in a nuclear power group and between senior managements of nuclear power groups, to realize circulation of nuclear power professionals, and accumulate and exchange management experience.

11.2.2 Examination and License Management for Operation Personnel

In the *Application and Issuance of Safety License for Nuclear Power Plant*, the detailed *Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations*, it is specified that only holders of the *Reactor Operator License* or the *Senior Reactor Operator License* of the People's Republic of China are allowed to operate the reactor control system of a NPP, the validity period of the license is two years; if the operator is absent from the post for six months or more, the original license will become invalid automatically. In addition, the detailed rules for implementation *Issuance and Management Procedures for Operator License of Nuclear Power Plants* have set definite requirements on the issuance and management of operator's licenses.

According to the requirement of the regulations, the competent authority of the nuclear industry shall issue the *Management Methods for License Examination of Nuclear Power Plant Operators*, *License Examination Rules for Nuclear Power Plant Operators* and the *Standards for License Examination of Nuclear Power Plant Operators*, to specify the examination and license management activities for NPP operation personnel. The National Health and Family Planning Commission of the People's Republic of China has issued the *Specification of Health Standards and Medical Surveillance for Nuclear Power Plant Operators,* clearly specifying the health requirements for operators and the specific requirements for medical surveillance over operators.

The NPP operators shall receive strict training, and pass the license examination and the qualification review organized by the Review Committee on Qualification for of Nuclear Power Plant Operators of the National Energy Administration. After the review and approval of the Authorization Committee on Qualification for of Nuclear Power Plant Operators of the MEP (NNSA), the *Reactor Operator License* or *Senior Reactor Operator License* will be issued by the MEP (NNSA). The MEP (NNSA) shall track and supervise the whole course of examinations.

In 2014, the National Energy Administration revised the *Standards for License Examination of Nuclear Power Plant Operators* by adding the contents and scope of written test in the license examination for operators of AP1000, ERP and high-temperature gas-cooled reactors, and the results of psychological test of NPP operators shall be taken as reference of qualification for NPP operators. For the licensing examinations, in addition to written test, test on simulator and oral test, field test has been added. In the meantime, to strengthen the training for operators in new built NPPs, the MEP (NNSA) actively explores the management mechanism to optimize qualification of personnel, and proposed that new built NPPs can entrust operating NPPs to train operators by shadow training.

According to the stipulations by the MEP (NNSA), each operation shift in a NPP shall have at least one shift supervisor, and when more than one reactor is operated, the number of senior operators in an operation shift shall be at least one more than the number of operating reactors. The licensing of operator in NPPs in commercial operation in China at the end of 2015 is as shown in Appendix 7.

11.2.3 Training and Examination of Personnel in NPPs

The *Code on the Safety of Nuclear Power Plant Operation* promulgated and implemented by the MEP (NNSA) in April 2004 put forward specific requirements for personnel qualification and training of NPP operating organizations. Recruitment, training, retraining and authorization of operating personnel are conducted according to the nuclear safety guide entitled *The Recruitment, Training and Authorization of Nuclear Power Plant Personnel*. The MEP (NNSA) made an overall revision to this guide in May 2013, setting detailed stipulations on the competence, qualification, recruitment and selection, training and authorization for personnel in NPPs.

NPPs determine the qualification requirements of posts and prepare and implement the training/retraining programs and procedures for all categories of personnel in accordance with the requirement of relevant regulations, guides and standards, and in conjunction with specific division of posts and task analysis. Working personnel in NPPs can perform the relevant work only after appropriate training, qualification in examinations and obtaining the qualification or authorization to work at specific posts.

NPPs manage the personnel qualification and authorization with valid period, at the expiration of valid period, formalities for extension or change of certificate shall be handled according to requirements of specific posts, and retraining and re-qualification will be made to ensure that personnel can continually meet the needs of their posts. NPPs in China manage the training, authorization and qualification of personnel of Chinese and foreign contractors with the same requirements as for NPPs, implement strict control and supervision with the contractor management policy, include the training of contractors and suppliers into the training program of NPPs for enhanced training, to ensure effective performance of work by contractors.

In the recent three years, NPPs made continual improvement on the training and examination of personnel, specifically as follows:

(1) Strengthen the construction of training organizations

NPPs in China all have specific training organizations, responsible for the planning, implementation, assessment and improvement of training, and provided with training center and training rooms with complete facilities, including full scope simulators (simulating both normal and abnormal conditions), various principle simulators, training simulators/simulation skill training center, human error prevention behavior training center, skill drill rooms and industry safety rooms.

(2) Continually increase capability of training instructors

At present, the training organizations in China have organized instructor teams "with full-time instructors and the main body and part-time instructors as supplement", and it is required that simulator instructors, technical theory instructors and skill training instructors all have rich site experience and technical capability. The instructor incentive system has been established, to encourage teaching and maintain and continually raise the training skill and standard of instructors. Long-term and in-depth cooperation partnership has been established with training organizations of international advanced nuclear power enterprises such as the FA3 training center of EDF, relevant tutor technical support mechanism has been established between two sides, and instructors are selected and dispatched to foreign countries for teaching support, to upgrade the capability of instructors.

(3) Build up network learning platform step by step

In recent years, all nuclear power groups have completed the construction of network learning course systems step by step, such as video courses and micro lectures, and brought them online with the portable learning platforms of nuclear power enterprises. In the meantime, portable teaching platform for post-accident analysis simulator has been completed independently, and can be run on portable phones or ordinary PCs, providing a platform support for the implementation of new training patterns such as remote portable teaching.

(4) Effectively incorporate operating experiences into training courses

All nuclear power groups have established personnel training bases through integration of resources and unified input, and have established the training course joint development and operation mechanism step by step, also, the operating experiences of all plants are effectively incorporated into courses of operation, maintenance, production management, safety and quality and human error prevention.

(5) Strengthen the training and examination of NPP operators

NPP operating organizations have adjusted the training and drill plans for licensed personnel on beyond design basis accidents, strengthen the training of NPP personnel on management of severe accidents, especially beyond design basis accidents, and worked out new training program and re-training period for SAMG. The reactor licensed personnel studied again the accident procedures related to loss of power supplies. In 2013, the first full-scope simulator for severe accidents in China, built by combining the first imported internationally advanced severe accident analysis program MAAP5 with the CPR100 full-scope simulator, was put into service for training. This simulator can be used to train senior operation personnel, emergency support and commanding personnel on severe accidents, and also be used in drills for severe accidents, verification of severe accidents guides and study of mitigating measures. In the meantime, the crew performance observation (CPO) has been used in peer review, for effective assessment of the performance of operators, shift supervisors and safety engineers, to help them improve performance.

By learning international experience such as INPO,NPP operating organizations have completed the construction of training systems for senior operation posts such as operation shift supervisors, safety engineers and isolating managers, formalized and optimized the training pattern for people at senior operation posts, and effectively ensured their awareness on safety and skill level.

(6) Further complete the application of Systematic Approach to Training

At present, Systematic Approach to Training has been widely applied in the nuclear power sector of China. Post task analysis, training demand analysis, formulation of training target and training programs, and implementation and assessment of training/examination have covered all posts related to operation in NPPs, with contents covering all aspects of training system design, training facility construction and implementation of training. In recent years, NPPs have paid increased attention to training demand investigation, designed effective courses specifically, and carried out teaching evaluation activities covering training fields of nuclear power technology, safety and quality, human error prevention, simulator and skill operation, to realize the closed-loop management of training activities.

The training materials are continually improved and completed according to the status and operation operating experience of NPPs, and popularized to nuclear power projects under construction; aiming at specialties and posts specific in the nuclear power industry, corresponding skill training and authorization are carried out; more importance has been attached to the systematized training and capability development of management skills, skill training and assessment of important maintenance posts, skill training and capability development for preventing human errors, and skill training and development in important technology support field; Systematic Approach to Training is used for overall planning and arrangement of the training management system in NPPs right from the beginning of nuclear power projects in their construction.

11.2.4 System of Registered Nuclear Safety Engineer

In 2002, the Chinese Government enacted the *Tentative Regulations on the Practicing Qualification of Registered Nuclear Safety Engineer*, the state then adopted the practicing qualification system for professional technical personnel working at key posts related to nuclear safety in organizations providing technical services on nuclear energy application and nuclear safety according to the regulation, and included it into the professional qualification certificate system of the state for professional technical personnel, for unified planning and management; in 2003, the Ministry of and the State Environmental Protection Administration (SEPA) jointly promulgated the *Implementing Measures for Practicing Qualification Examination of Registered Nuclear Safety Engineer* and *Authentication Methods for the Practicing Qualification Examination for Registered Nuclear Safety Engineer*. In 2004, the *Tentative Measures for Practicing Qualification Registration Management of Registered Nuclear Safety Engineers* was promulgated, in 2005, the *Tentative Regulations on Continuing Education of Registered Nuclear Safety Engineers* was promulgated. In the meantime, the serial books for posts training of registered nuclear safety engineers were compiled and published, which refer to laws and regulations relevant to nuclear safety, comprehensive knowledge of nuclear safety, professional practice of nuclear safety and case analysis of nuclear safety.

China organizes unified examination every year after going through corresponding systematic training and qualifying the personnel applying for examination. Those qualified in the examination are issued with the *Certificate of Practicing Qualification for Registered Nuclear Safety Engineer of the People's Republic of China*, and can start practicing after registration. The valid period of registered nuclear safety engineer is two years. Continuing education system is adopted for registered nuclear safety engineers.

The scope of practicing of registered nuclear safety engineer is: nuclear safety review, nuclear safety supervision, NPP manipulation and operation, nuclear quality assurance, radiation protection, radiological environmental monitoring and other fields closely related to nuclear safety as specified by the MEP (NNSA).

The practicing qualification determination and examination for first batch of registered nuclear safety engineers was performed in 2004, and at the end of 2015, there were 1900 people in total with valid registration. From 2013 to 2015, the MEP (NNSA) arranged 3 practicing qualification examinations for registered nuclear safety engineers in the whole country, 1048 people passed examinations, and 3046 people went through registration.

In 2014, the MEP (NNSA) arranged 2 training sessions for the continued education of registered nuclear safety engineers. In 2015, the *Circular on Strengthening the Registration Management of Registered Nuclear Safety Engineers* was issued, and the registration frequency was increased and the step of Internet publicity was added.

12. Human Factors

Each Contracting Party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

12.1 Regulatory Requirements on Prevention and Correction of Human Errors

China attaches importance to the research on human factors to find out management measures and effective methods to prevent and correct human errors, so as to maintain and improve the safety level of NPPs. These measures are carried out in the whole life-time of the NPPs, and are clearly specified in relevant nuclear safety code and guides, mainly including:

(1) Implementing the concept of "defense-in-depth" in design, construction and operation management, to ensure that all activities related to safety (include those related to organization, design or personnel behavior) are defended by overlapped measures, and compensation or correction can be obtained even in case of failure of one means of defense.

(2) Human factors and human-machine interfaces are taken into full account in the initial phase of NPP design, and throughout the whole process of design, and the human factors are validated and confirmed in appropriate phases;

(3) The working area and working environment for the workers in the NPP are designed in accordance with the principle of ergonomics, to optimize the layout and procedure of the NPP, including operation, maintenance and inspection;

(4) In the design of control rooms in NPP, consideration is taken for the working environment, possibility of human error, response time of operation personnel, and reduction of the intensity of physical and brainwork of operation personnel, to ensure that safety operation procedures are effectively implemented under normal or accidental conditions.

(5) Important operation posts in NPPs are staffed with sufficient number of qualified personnel, and their duties, authority and communication channels are clearly specified; sufficient and effective training and examination are provided, and personnel performing work important to safety must hold qualification certificates issued or accepted by the nuclear safety authority of the state; duties shall be strictly performed according to the procedures and operation procedures of NPPs , and procedures shall be strictly reviewed and approved, periodically examined and updated in a timely manner;

(6) The operation status of NPPs shall be periodically reviewed by utilizing independent internal and external assessment and self-assessment, to consolidate and strengthen the safety awareness and prevent overconfidence and self-complacence; systematic assessment and operating experience on internal and external human factors shall be used, and technical or management measures be taken to prevent or correct human error for continual improvement;

(7) Human factors shall be included in the PSR of the NPPs. The inspection of human factor status is required in the PSR, to determine that human factor status complies with the accepted good practices, without unacceptable contribution to risks.

After the Fukushima nuclear accident, design consideration on optimizing the operation by operators was proposed for new NPPs, including the following:

- Human-machine interfaces must be designed to be able to provide operators with complete and easily processing information, and adaptive to the time required to make decisions and take actions, and similar measures must be taken for auxiliary control rooms.
- In the whole design, human factors shall be taken into full account, not only for MCR operation personnel, but also including site operation, testing and maintenance personnel. Good and sound human-machine interfaces shall be provided on all aspects with the possibility of human-machine interaction, to reduce the possibility of human errors, and sufficient importance shall be attached to operation operating experience.
- In the design, the ergonomic principles shall be fully taken into account, to rationally design systems and their automation control functions, and reduce the burden of operation personnel; operation personnel shall be provided with sufficient and easily manageable information, so that they can clearly know the status of the NPP, including the status of severe accidents. Sufficient tolerance time shall be left for operation personnel before their intervention.

12.2 Measures to be Taken by Licensees and Operators

According to requirements of codes and guides on nuclear safety in China and actual status of the NPP, the NPP operating organization adopts the following measures to strengthen human factors management:

(1) Defining organizations structure and duties of posts for human factors management explicitly. Through constantly strengthening posts responsibility system and peer- checking system, building up and executing response and decision-making mechanism for unexpected events and putting various interfaces and working process in order, so as to decrease human errors in the process of coordinating management and decision-making.

(2) Reducing human error with "hard barriers" such as adding voice prompts at units and in rooms, formalizing unit labels and performing engineering modification.

(3) Continually improving various management system and human behavior specifications, to strengthen plant management by leader demonstration, management walk down in various forms, human error clock management, work permit system, root cause analysis system on human factor event, and internal and external operating experience system.

(4) Popularizing the use of human error prevention tools to prevent human error. Developing human error prevention tool cards, to indicate on the cards the most common error types and error traps at work sites and the correct methods to use common tools, including pre-job brief, procedures use and adherence , self-checking, peer-checking , concurrent verification, three-way communication, questioning attitude and stop when unsure , and printing them into booklets to distribute them to plant employees and contractors.

(5) Actively carrying out observation and coaching with respect to human error

prevention tools, specific assessment on the performance in using human error prevention tools, personnel performance interviews and questionnaire investigations, to assess the application and effect of human error prevention tools. Establishing personnel performance database to collect personnel behavior data for analysis, monitoring, tracking and correction, so as to achieve the purpose of continually improving performance level of NPP personnel.

(6) Carrying out special personnel performance assessment, for overall assessment on three aspects of employee behavior, leaders' performance and the process and value of organization. It is accepted to be good practices worth popularizing that NPP construct buildings with high standards, improve equipment operation environment and promote personnel performance through positive incentives.

(7) Strengthening the set-up of human error prevention course system, from the start of the course(i.e. the basic theory on human factor), then through the individual drills on human error prevention tools, and finally establishing comprehensive work scenario in laboratory, the theoretical knowledge, skills and work specification of various personnel can be merged together for comprehensive behavior drills. Special human error prevention manuals and training materials in some fields (such as operation, maintenance and chemistry) have been developed.

(8) Continually strengthening the construction and improvement of human error prevention laboratory, to develop drill equipment, design training scenario and select and train tutors according to the requirements of human error prevention tools. The drill course system on human error prevention has been initially established, and targeted training is conducted in conjunction with operation practice for personnel at different levels, to regulate and drill trainees on the good ways of thinking and behavior habits .

(9) Developing a human factor management program in combination with the own situation, and some NPPs have incorporated human error prevention trainings into the basic safety authorization trainings.

(10) Cultivating and enhancing the awareness and skills of employees on human error prevention by carrying out diversified activities such as human error prevention competition. Experience exchanges between NPPs have been further strengthened by running NPP human factor management training sessions, human factor management field study and seminars in NPP, and organizing human factor management experience exchange meeting for NPPs.

(11) Actively carrying out human factors research at the level of the nuclear industry, making in-depth research in the aspects of individuals, institutional systems, organization management and culture, to explore and seek for approaches to reduce human errors.

12.3 Supervision Management and Control Activities

The nuclear safety regulator in China have clearly specified the technical and management requirements related to human factors in relevant nuclear safety codes and guides, and ensure that all requirements related to human factors are effectively implemented in the course of design, construction and operation by nuclear safety review and inspection. Main contents of review include: technical and administrative measures related to human factors in the application documents for license; NPP organization structure setup; staffing, training, examination and authorization of personnel at posts related to quality and safety; report, analysis and feedback on defects/events related to human factors in NPPs.

In the past three years, the supervision and management activities of the MEP (NNSA) on human factor aspects include:

(1) The MEP (NNSA) attaches importance to the effect of human factors on nuclear safety. In the safety analysis reports of NPPs, a specific chapter is arranged for review and assessment of the NPP design inputs after considering the human factor engineering; the Nuclear and Radiation Safety Center of the MEP has also set up a corresponding division for the review and assessment of human factor issues.

(2) The MEP (NNSA), NEA, CAEA, the NPP operating organizations, nuclear corporate group and technical support organizations held topical workshop on human factors periodically, to make analysis and feedback of human-factor events.

(3) In-depth researches have been made on the respects of individuals, institutional system, organization management and culture, to explore and seek for approaches to reduce human error. In 2015, the investigation and study was organized on the psychological health of operators, and the *Investigation and Study Report on the Psychological Health and Psychological Testing for NPP Operators* was prepared.

(4) The MEP (NNSA) actively carried out the research for regulation on NPP post suitability assessment, has planned to carry out investigation, research and seminar on such special subject in China, to work out technical guide for NPP post suitability assessment.

(5) In 2014, the MEP (NNSA), jointly with the NEA and CAEA, issued the *Nuclear Safety Culture Policy Statement*. The MEP (NNSA) carried out the publicity action for nuclear safety culture. Also, the Nuclear and Radiation Safety Center of the MEP has organized the nuclear safety culture expert team, to establish the nuclear safety culture assessment model and prepare nuclear safety culture assessment procedures, to provide technical support for on-site supervisors in carrying out nuclear safety culture inspections, and promote the nuclear safety culture supervision and management by regulatory bodies. At the requests of NPP operating organizations and contractors, the MEP (NNSA) dispatched nuclear safety culture experts for lecturing and training.

13. Quality Assurance

> Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation.

13.1 Quality Assurance Policies

NPPs in China always adhere to the policy "safety first and quality first", work out and implement the Quality Assurance Program (QAP) at each phase of NPPs in accordance with the requirements of the *Code on the Safety of Nuclear Power Plant Quality Assurance*, to specify the management on all work related to the quality in NPPs, and provide the appropriate control conditions for accomplishing all activities affecting quality.

The top management of NPP takes the overall responsibilities for effectively implementing the QAP. All personnel taking part in the activities related to safety and quality in the NPP shall comply with the requirements of QAP and take the responsibility and duties for reporting quality problems identified. An independent quality assurance department is set up to be responsible for the establishment and management of QAP, and inspection, supervision and audit are performed to verify the effective implementation of the QAP. The quality assurance department has the authority and sufficient independence from cost and schedule when handling quality problems until the quality problem are handled and resolved effectively.

13.2 Basic Elements in Quality Assurance

The respective basic quality assurance requirements are clearly defined in the *Code on the Safety of Nuclear Power Plant Quality Assurance*, which mainly include:

(1) Establishing and effectively implementing the overall Quality Assurance Program (QAP) in NPPs and the QA subprogram for each activity; establishing the procedures, instruction and drawings in written form, and periodically reviewing and revising them; performing periodically management review to ensure the status and adequacy of QAP, and taking corrective action if necessary.

(2) Establishing a documented organizational structure, clearly defining the functional responsibilities, levels of authority and channels of internal and external communication; controlling and coordinating the working interfaces between organizations; controlling the selection, staffing, training and qualification examination of personnel to ensure that sufficient proficiency of work is achieved and maintained by working personnel.

(3) Controlling the preparation, review, approval, distribution and change of the documents necessary for the execution and verification of the work to preclude the use of outdated or inappropriate documents.

(4) Controlling design processes, design interfaces and design changes, and performing design verification to ensure that specified design requirements are correctly translated into specifications, drawings , procedures or instruction .

(5) Controlling the preparation of procurement documents, evaluating and selecting

the suppliers, and controlling the procured items and services to ensure that the requirements of procurement documents are satisfied.

(6) Identifying and controlling materials, parts and components, controlling the handling, storage and shipping of items, and appropriately maintaining important items related to safety so as to ensure that the quality is not degraded.

(7) Controlling the processes affecting quality used in the course of design, fabrication, construction, testing, commissioning and operation of NPPs, to ensure that the processes are performed by qualified personnel, using qualified equipment in accordance with approved procedures.

(8) Establishing and effectively implementing inspection and test program, verifying that item and activity meet specified requirements, and demonstrating that the structures, systems and components can work satisfactorily. Controlling the selection, calibration and usage of measuring and testing devices, and performing identification and control on inspection, test and operating status.

(9) Controlling the identification, review and disposition of non-conformance, defining the responsibilities and authority for review and disposition, and re-inspecting the repaired and reworked items.

(10) Identifying and correcting conditions adverse to quality. For conditions seriously adverse to quality, determining the cause of such conditions, and taking corrective actions to prevent recurrence.

(11) Establishing and executing quality assurance recording system, controlling the coding, collection, indexing, filing, storage, maintenance and disposal of records, to ensure that records are legible, complete and correct, and can provide sufficient evidence on quality of item and/or activity.

(12) Establishing and executing internal and external auditing system to verify the implementation and effectiveness of QAP. Taking corrective actions for the deficiencies identified in audit and taking follow-up actions for tracking and verification.

In addition, ten safety guides on quality assurance are formulated, to put forth a series of complementary requirements and implementing recommendations to the above-mentioned basic requirements.

13.3 Establishment, Implementation, Assessment and Improvement on QAPs of NPPs

All NPPs in China attach great importance to the establishment of quality assurance system. Massive manpower and material resources are invested every year to ensure the effective operation of the system and the realization of the safety objectives. A dedicated quality assurance department is set up and authorized with adequate power, to effectively prevent and control activities endangering safety and quality until the problems are effectively resolved.

13.3.1 Formulation of QA Program

The QAP of a NPP is normally formulated for four phases: design and construction, commissioning, operation and decommissioning, prepared by the operating organization of the NPP according to requirements of nuclear safety codes and relevant guides, and submitted to the MEP (NNSA) for review and approval as one of documents for application for corresponding licenses. Important contractors of the NPP, according to requirements of nuclear safety codes and relevant contracts, establish and implement separate QAP applicable to the work undertaken by them. The separate QAP of contractors shall be submitted to the NPP operating organization for review and approval. For organizations engaged in the design, manufacture, installation and non-destructive test of civilian nuclear safety equipment, their separate QAP shall also be submitted to the MEP (NNSA) for review.

13.3.2 Implementation of QA program

Quality assurance is an important tool for effective management in the NPP of China. The QA program is implemented effectively through analysis of the tasks to be performed, identification of the skills required, the selection and training of appropriate personnel, the use of appropriate equipment and procedures, the creation of a satisfactory working environment, defining the responsibilities of the individuals who are to perform the tasks, verification that each task has been satisfactorily performed , and the production of documentary evidence to demonstrate that the required quality has been achieved.

13.3.3 Assessment and Improvement of QA Program

The quality assurance department of NPP is in charge of formulation, management, supervision, assessment and improvement of the QA program. The quality assurance department is independent of other departments and directly reports its work to the top management. The quality assurance department identifies deficiency existing in the quality assurance system by carrying out planned internal and external quality assurance surveillance, audit, review and assessment, and taking corrective actions timely. Furthermore, non-conformance and corrective actions are controlled rigorously. Various quality information and trends are collected, analyzed and reported to high level management periodically. Relevant corrective action is taken promptly as necessary.

The quality assurance department periodically reviews the applicability and effectiveness of the QA program. The review is focused on the results of internal and external quality assurance audit and surveillance within the review period and other related information, such as quality problems, status of corrective actions, quality trend, accidents and faults, qualification and training of personnel, etc. According to defects relating to the QA program, management and quality identified in the review, their causes are analyzed, specific corrective actions are formulated and implemented, and relevant organizations and departments are notified in written form promptly.

Over the past three years, the NPPs completed the following work and improvements in the field of quality assurance while implementing the nuclear safety codes of China:

(1) The NPPs, to continually perform proper quality management work, promote the continual improvement and steady upgrading of quality work and enhance the awareness of quality and sense of responsibility of all employees, organized Quality Month activities in diversified forms and rich contents, such as quality culture publicity, quality knowledge lectures, quality knowledge competitions, quality inspections, professional skill competitions, and quality operating experience etc..

(2) All NPPs actively promoted the construction of quality culture in the forms of formulating, issuing and popularizing quality policy, quality value, quality behavior criteria, quality behavior standard and quality motto. After appraisal, Qinshan nuclear power base was awarded with the honorable title *National Quality Culture Establishment Benchmarking Organization*.

(3) All NPPs actively carry out QC group activities, and work results of QC groups are appraised and published at various release meetings organized by the power industry, power group corporations, provincial and municipal level quality associations or quality management organizations.

(4) All NPPs have established the integrated quality, environment and occupational health management system, to review the adequacy of management system documents and the effectiveness of implementation, management review are performed every year, to find weakness, identify opportunities of improvements and need for change, and determine preventive actions and improvement actions. In the meantime, certification of the quality, environment, occupational health and safety management system in NPP is performed periodically by an independent third party institution.

(5) NPPs revise and update the QA program at appropriate time according to changes of organizations and implementation of the program, and submit it to the national regulatory bodies for review in time, to ensure the continual suitability of the quality assurance system and the effectiveness of the implementation of QA program.

(6) NPPs effectively carry out internal and external quality assurance audit. According to quality assurance audit procedures, and in combination with their own characteristics and work practices, the QA department plans and prepares an overall annual plan for internal and external QA audit, performs internal audit on each department, and assess the effectiveness of program implementation within the scope of responsibility of each department, with audit scope covering all production related departments in the plant and all elements of QA program. For contractors, external QA audit is performed, to verify the implementation of the contract and their quality assurance system. For a contractor common to several NPPs , audit is performed jointly by the operation organizations within the nuclear power group corporation, to share the audit results and resources and increase the efficiency of audit activities.

(7) Nuclear power group corporations have integrated and optimized the resources of qualified suppliers for all NPPs, established the list of qualified suppliers in the group corporation, and performed unified, classified and hierarchical management on suppliers of equipment, materials, spare parts and services, etc., and evaluated the qualification of suppliers within the group corporation in unified mode. All NPPs supervise, assess and share the information of the suppliers’ quality assurance system, working process and actual performance, perform in- factory supervision for the manufacturing of the key nuclear safety equipment, and strengthen quality supervision, validation and acceptance in key process.

(8) NPPs in operation focused on activities related to units operation to carry out QA supervision, with emphasis on outage activities, to strengthen the awareness of obeying the rules and regulations and strictly implementing the procedures; for each outage, an outage quality assurance organization is established, and outage QA supervision plan worked out,

to perform QA surveillance in phases of outage preparation and execution.

(9) According to the requirements of QA program, NPPs under construction have built up a multi-level quality management verification system of the owner, supervising organization, general contractor, contractor/supplier, etc. to make the design, procurement, construction and commissioning activities of the plant under control, and ensure that the quality of activities related to safety and quality meets the requirement of applicable codes and standards. Meanwhile, management and supervision from the group corporation, the industry and government are accepted.

(10) To enhance the effectiveness of the quality assurance system, NPPs under construction prepare human resources demand schedule according to the project progress, to allocate the working personnel required at posts, and conducted overall quality assurance trainings to meet the needs in project construction. Furthermore, they organize experts to review major construction schemes and strengthen the process inspection; manage non-conformance by classification and grading, and work out corresponding review, approval, tracking and disposition procedures; quality problems found are recorded, tracked and handled according to their severity and urgency in forms such as oral notice e-mail informing, Quality Observation Report (QOR), Corrective Action Request (CAR), Stop-Work Order (SWO).

13.4 Supervision Management and Control Activities

The MEP (NNSA) and regional supervision offices perform a series of supervision and inspections on major activities relating to safety and quality in each NPP by strictly following the requirements of the nuclear safety codes and relevant policy, conscientiously fulfilling the function on nuclear safety supervision. The following supervision management and control activities have mainly been carried out over the three years.

(1) On the basis of the current HAF003, the MEP (NNSA) organized the revision of the *Code on the Safety of Nuclear Power Plant Quality Assurance* by incorporating the latest concepts and methods of IAEA GS-R-3, in conjunction with the years of quality assurance management practical experience in China, the revision has ensured both the continuity and renewal of the code.

(2) Review work was carried out for the QA program (for design and construction phase) of the four HPR1000 units, for the self-designed demonstration nuclear power projects of HPR1000.

(3) Nuclear safety supervision and inspection was carried out, to ensure the effectiveness of the QA systems in operating organizations, with emphasis on the implementation of the design and construction QA program and operation QA program of nuclear installations, the implementation of operation QA program of NPP in the joint licensing mode, the implementation and results of operation site management, in-service inspection program, periodical test program and maintenance program. For major safety and quality activities, control points were selected on relevant quality plans, and supervision and witness were performed on site; for results of major safety and quality activities, technical review and verification were organized.

(4) The non-conformance reporting system was formalized, the management requirements for significant non-conformance were formulated, and non-conformance

information was summarized and analyzed. Main points of supervision were determined according to operating experience, investigation and disposition of non-conformance in the construction of NPPs were enhanced, and significant non-conformance were strictly reviewed and properly handled in prudent way. The assessment and tracking of a series of major non-conformance in the research, development and manufacturing phase of AP1000 RCP were organized and completed, and review was organized for significant non-conformance including the AP1000 blast valve, SG tube plate melting damage in Yangjiang NPP, and RPV bolt hole damage in Tianwan NPP.

(5) Identified quality problems were quickly responded and effective actions were taken. For the composition segregation problem of the forged RPV head cover of EPR project, the MEP (NNSA) requested Taishan NPP to quickly carry out inspection and analysis, organized expert teams to perform in-depth evaluation and research on similar problems that may exist in Taishan NPP, and performed an overall inspection for all manufacturing factories for nuclear installations.

14. Assessment and Verification of Safety

Each Contracting Party shall take the appropriate steps to ensure that:

(i) Comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented and filed, subsequently updated in the light of operating experience and significant new safety information, and reviewed under the authority of the regulatory body;

(ii) Verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.

14.1 Regulatory Requirements on Safety Assessment and Verification for NPPs

The *Code on the Safety of Nuclear Power Plant Design* requires that the safety assessment shall be performed comprehensively for NPPs, so as to prove the design of manufacture, construction and completion delivered satisfies the safety requirements purposed at the beginning of the design. The safety assessment must be made part of the design process, in the meantime an iterative process exists between the design and verifying analysis activities, and its scope will keep on expanding with increasing extent of detail with the progress of the design schedule. The safety assessment must be based on the data obtained in safety analysis, the previous operation experience, results of supportive researches and verified engineering practice. Before the safety assessment is submitted to the national nuclear safety regulatory bodies, the NPP operating organization must ensure that it has been independently verified by individuals or group having not participated in relevant design.

The MEP (NNSA), with reference to the corresponding nuclear safety standards of the IAEA and other relevant national standards, formulated the *Safety Assessment and Verification of Nuclear Power Plant* and a series nuclear safety guides about the safety assessment and verification for NPPs. The *Safety Assessment and Verification of Nuclear Power Plant* provides recommendations for safety assessment of NPP by design organizations in the initial design and in design modification processes, and also provides recommendations for independent verification of safety assessment by operating organizations for new NPPs (based on either new or existing design). Recommendations for implementing safety assessment are also applicable to guiding the safety review for existing NPPs. Safety review is performed for existing NPPs based on the current standards and practices, with the purpose to determine if any deviation exists that affects the NPP safety. The methods and recommendations in the *Safety Assessment and Verification of Nuclear Power Plant* are also applicable to the regulatory review and assessment by the national nuclear safety regulatory bodies. The *Safety Assessment and Verification of Nuclear Power Plant* has determined the key recommendations in implementing safety assessment and independent verification, and provides detailed guidance to support the *Code on the Safety of the Nuclear Power Plant Design*, especially in the field of its safety analysis. In addition, for some systems in the NPP, such as reactor containment system, reactor core, reactor coolant system, ultimate heat sink and their directly related heat transfer systems, protection systems and associated facilities, the emergency power system, safety-related instrument and control system, fuel handling and storage system, firefighting associated system, the *Code on the Safety of the Nuclear Power Plant Design* has formulated specific nuclear safety guides for their safety assessment and verification.

14.2 Safety Assessment and Verification Practices in NPPs

14.2.1 Deterministic Safety Analysis

As required by relevant nuclear safety regulations of China, for NPP design, safety analysis shall be performed by using two complementing analysis methods, the deterministic and probabilistic methods. The current nuclear safety regulations and the safety assessment and analysis for NPPs in China are mainly founded on the deterministic basis. The deterministic safety analysis methods are a set of methods based on the concept of defense in depth, and aimed at ensuring three basic safety functions of reactivity control, residual heat removal and radioactivity containment, adopting conservative assumptions and analysis methods for the determined design basis conditions, and meeting the specific acceptance criteria. Their safety performance is demonstrated by the reliability, redundancy, diversity, independence and single failure criterion for systems and components. Defense in depth is embodied in all activities of a NPP, including the siting, design, manufacturing, construction, operation, decommissioning, management and human factor, to ensure that these activities are defended by multiple provisions, and compensation or correction can be obtained even in case of failure of one defense. The deterministic design safety has formed a complete set of codes, standards, implementation methods and review approaches. The deterministic assessment methods assume that an accident has already occurred, rational or conservative assumption is taken to analyze the response by systems in the whole NPP, until the radioactive consequences of the accident have been obtained. Nuclear power operation experience for years has proved that the deterministic safety analysis method has played an important role in nuclear safety.

Safety analysis reports of the NPP constitute an important part in the license review and approval foundation for NPP, and also an important part of the safe operation foundation of NPP. There is preliminary safety analysis report (PSAR) and final safety analysis report (FSAR) for a NPP. The PSAR mainly analyzes and justifies the reliability and safety of the NPP design, and the safety provisions set up by the NPP to protect the personnel in the plant area, the public and the environment from excessive radiation hazard. It covers the site features of the NPP, the design of structures, components, equipment and systems, reactor nuclear design, reactor coolant system, engineered safety features, radioactive waste management, accident analysis, human factor engineering and probabilistic safety assessment. The PSAR is an important application document prepared by the NPP design entity and submitted by the NPP operating organization to the nuclear safety regulatory bodies of the state, and one of the important application documents specifically for the application for the *Construction License for Nuclear Power Plant*. The FSAR is prepared by the NPP design entity and submitted by the NPP operating organization to the nuclear safety regulatory bodies of the state, for the application for the certificate of approval for first fuel loading. The FSAR and PSAR are consistent in preparation format and contents, only with difference in the depth of contents.

Safety analysis reports of NPPs include accurate and precise information of NPPs and their operation status, such as safety requirements, design basis, site and plant characteristics, operation limits and conditions, and safety analysis information, to enable regulatory bodies to independently assess the safety of plants.

14.2.2 Probabilistic Safety Analysis

According to the requirements in relevant nuclear safety regulations, the design of NPPs must adopt the analyzing method of deterministic methodology and probabilistic methodology to carry out safety analysis. In the meantime, in the periodic safety.

The *Policy of Technology: Application of Probabilistic Safety Analysis Technology in Nuclear Safety Field* promulgated by the MEP (NNSA) in 2009 clearly pointed out that the use of PSA method should be actively promoted in nuclear safety activities, which should be suitable to the extent of support given by the present technology and data of probabilistic safety analysis, encourage, encourage continuous improvement of PSA method and collection of data, encourage information sharing, technological exchange and peer review, jointly advance development and application of the PSA technology. The *Safety Assessment and Verification of Nuclear Power Plant* also provided definite guidance for the method, scope and objectives to be met of PSA.

For all NPPs in China, PSA is carried out in design phase with reference to the relevant codes and standards in China and the industrial technical standards of PSA and taking into full account the latest progress of PSA technology, to assess the overall safety level of NPPs, and identify weak links in design. At present, in design phase, the PSA work already completed or being actively carried out in NPPs of China includes internal event class I PSA, internal fire class I PSA, internal flooding class I PSA, external disaster class I PSA and class II PSA, and spent fuel pool PSA under power conditions and low power and shutdown conditions. In the preliminary design phase, due to limit of information for the NPP, usually relatively simplified and conservative analysis methods are used in PSA, to justify that the NPP meets the safety objective; in the final design phase, the NPP will refresh the completed PSA model according to the completion of relevant design information.

In operation phase, PSA is extensively used in the daily production management activities, for example, PSA tools such as risk monitor, mitigation system performance index (MSPI), safety matter importance determining procedure and equipment reliability database are used to make real-time risk monitoring for the NPP, follow up and make statistics of the safety performance of safety systems, the risk guiding method is used to classify NPP events and collect and analyze the NPP operation experience and refresh PSA model input data, to raise the safety management level of NPP Furthermore, all operating NPPs have established the Risk-Informed production risk management system, to closely combine PSA with deterministic safety analysis, identify the safety importance degree of all production activities, reduce the resources outlay for activities not important to safety and increase the resources outlay for activities important to safety, to optimize the utilization of resources. In CNNO, core monitoring daily report is prepared on the basis of monitoring using risk monitor, and provided to the operation, production planning and nuclear safety departments, to inform them of the short-term risk level and key equipment to be paid attention in the NPP. Tianwan NPP pushed the PSA result conversion on the aspects of online maintenance and optimization and in-service inspection program. It has completed the optimization analysis of periodical tests period and allowed out time (AOT) for emergency diesel generator set and its supporting system. For the pilot item of in-service inspection optimization with risk guiding, the optimization analysis work has been completed and now submitted to the NNSA for review. This is the first primary coolant system in-service inspection optimization pilot project in China.

All NPPs also take PSA as an important tool in quantitative assessment, to assess production activities of NPP such as change and renovation, risk analysis for maintenance schedule, improvement of operation procedures and detailed rules of testing. After the Fukushima nuclear accident, Qinshan NPP performed special analysis and assessment for the safety rectification and correction for "configuration and connection of high level AAC power supply", the result showed that the safety rectification and correction could effectively reduce the core damage frequency (CDF). Tianwan NPP performed PSA analysis for technical renovation items such as connecting portable pumps into the emergency feed water system and adding portable emergency diesel generator set, and for the fault of failure to open the check valve in LP safety injection system and event of control rod seizure. Yangjiang NPP performed PSA assessment for a number of improvement made for Units 3&4, including the reactor cavity water injection technology, the improvement to increase cooling capacity for the reactor refueling pool and spent fuel pool cooling and treatment system (PTR) and the improvement of main feed water isolating valve.

14.2.3 Surveillance for Items Important to Safety

As required by nuclear safety regulations, NPPs have developed surveillance program for items important to safety on the basis of learning the experience of NPPs overseas and in China, summarizing their own experience and the surveillance requirements for equipment supplied by nuclear equipment manufacturers, the contents cover the surveillance of plant parameters and system status, surveillance of chemistry and radiological chemistry sampling, calibrations of the instrumentation, inspection and functional testing structures, systems and components (SSC) important to safety, and assessment of monitoring and calibration results.

Periodical tests are the main measures for implementing plant surveillance program, which are used to determine whether or not the safety-related systems and components can continuously perform their functions as required by design. The procedures of periodical tests are required to be implemented and verified in the phase of commissioning, and fully implemented after commercial operation. The periodical tests are used by NPPs to confirm the sound functions of safety-related systems and equipment.

Since commercial operation, NPPs have performed surveillance, inspection and testing on safety-related systems in strict accordance with the items, frequency and other requirements specified in Technical Specifications, the testing results are recorded and assessed, defects and anomalies identified are repaired and eliminated promptly, and test was made again for verification until functions and parameters meet acceptance criteria, systems are recovered in strict accordance with time limit in Technical Specifications. Nuclear safety engineers independently review and witness the implementation of nuclear safety-related regular test items to make sure that the regular test items are controllable. From 2013 to 2015, the annual accumulated one-time success rate of periodical tests was over 96% in all NPP, meeting the target value in management requirements, and it has been maintained above 99% at all times in some NPPs. The results of surveillance inspection and testing of the safety system show that in phases of NPP startup and normal operation, safety system have stable and reliable functions which meet design and technical requirements, ensuring the safe operation of NPPs.

The NPPs in China constantly improve the surveillance technical means and managing processes, develop and apply online performance testing system based on computer and internet technology, use this system as data platform in conjunction with the management system of specific fields such as operation, maintenance, chemistry and radiation protection, to make analysis and feedback on all sorts of collected monitoring data, timely identify unfavorable trend and take corresponding measure for correction or improvement.

To further implement the management requirements in the *Regulations on the Safety Regulation for Civilian Nuclear Safety Equipment* and its associated rules and to strengthen the surveillance and management of civilian nuclear safety equipment, the MEP (NNSA) has made clear the relevant requirements in the Regulations and its associated rules, including:

(1) According to the requirements of the *Regulations on the Safety Regulation for Civilian Nuclear Safety Equipment*, it organized the revision of the *Catalog of Civilian Nuclear Safety Equipment (Batch I)* and the explanation and notes, to further clarify the regulatory requirements and complete the contents and scope of regulation; for 4 categories of equipment including classes II and III pressure vessels with large number of license holders and outstanding contradictions, the qualification conditions were set or revised, to raise the access threshold; the *Regulation Work Plan for Imported Equipment* was prepared, to ensure that imported nuclear equipment are regulated according to procedures and specifications in a scientific and technological and refined manner.

(2) Performance requirements on license applicants for civilian nuclear safety equipment.

(3) Requirements for making imitation items on license applicants for civilian nuclear safety equipment.

(4) Requirements on qualification and performance of overseas registration applicants.

14.2.4 In-Service Inspection

According to relevant technical codes and guides on in-service inspection, and with reference to good practices of foreign peers, NPPs have formulated in-service inspection outlines, programs and technical procedures, to perform various in-service inspection work systematically, covering the NI, CI and BOP. The main inspection methods include visual check, radiographing, eddy current testing, ultrasonic testing, liquid penetrate testing and endoscope inspection. For systems and equipment important to safety in reactor building, such as RPV, containment components, pressure pipes, heat transfer branches and steam generator heat transfer tubes; and for systems of CI and BOP, such as components of turbo-generators, various pressure vessels, pressure pipes, condenser titanium tubes and other metal parts, corresponding in-service inspection schedules have been prepared, submitted to the MEP (NNSA) for review, and implemented according to schedule during unit outage.

From 2013 to 2015, a total of 49 in-service inspections were carried out in NPPs during shutdown for outage. Defects identified in outage and daily in-service inspections and requiring treatment were recorded, assessed and qualified. The defects identified in inspections included damage of bolt threats of main components such as RPV, SG, pressurizer and RCP, wearing of thimbles of in-core instrumentation system, defects in SG heat transfer tubes, dent and weld seam flaws in condenser titanium tubes, significant thinning due to scouring in hydro test pumps and turbo-generator steam pipelines, carbon deposit, blackening and fatigue cracks in turbo-generator bearing pad/thrust pad and so on. In the 208 refueling outage for Unit 2 of Tianwan NPP, after flaw was found in the sampling check of SG3 heat transfer tubes, expanded inspection was immediately made for other heat transfer tubes, and the inspection result was normal. In addition, quality defect reports (QDR) were opened for heat transfer tubes exceeding acceptance limit and restricted for inspection, and plugging was made.

In-service inspections are all performed by qualified inspection personnel using qualified inspection equipment in accordance with approved inspection procedures, and QA program and quality control procedures are strictly implemented in inspections, to ensure that inspection results are effective. Through the in-service inspections, some weak links in NPPs have been discovered and corrected, ensuring the integrity of three safety barriers and operation safety of NPPs. The results of in-service inspections are subject to review by MEP(NNSA).

In recent years, in order to decrease the risks in NPPs and the possibility of lacking or omitting non-destructive testing or mistaken judgment in the course of in-service inspection, China is gradually building up capability verification system for in-service inspection according to the latest industry standards and practices. All NPPs actively carry out capability verification for in-service inspection according to relevant codes and standards. Ningde NPP, completed the in-service inspection capability verification for the CGN Testing Company in the plant, and Yangjiang NPP completed the comprehensive verification for the item "automatic ultrasonic testing (UT) for RPV flange bolt hole and ligament zone", and both got approval by the MEP (NNSA). Taishan NPP completed all 56 items for capability verification in 4 batches, verifying the procedures, personnel and equipment for pre-service and in-service inspections, laying the foundation for performing these inspections on site. Starting from 2008, according to the requirements of *Regulations on the Safety Regulation for Civilian Nuclear Safety Equipment*, organizations engaging in non-destructive testing of civilian nuclear safety equipment will be able to undertake pre-service and in-service inspections of NPP only after passing the capability and qualification review conducted by safety regulatory departments and obtaining corresponding licenses, and are continually subjected to supervision by the safety regulatory departments.

In addition, all NPPs actively track the development of new technologies and processes for in-service inspection. Daya Bay NPP developed the NDT new process for major components in NPPs, and adopted new processes to perform the inspection of bottom neutron flux instrument testing penetrate inspection (BMI) for RPV, the eddy current testing for heat transfer tubes in HP and LP heaters, inspection of reactor internals baffle bolts and SG water chamber partition weld seams in outages. Ningde NPP adopted new processes to perform the eddy current testing for heat transfer tubes in HP and LP heaters and eddy current/phase control array inspection for turbine LP casing rotor weld seams in outages.

14.2.5 Aging Management

To further perfect the nuclear and radiation safety regulation system, and improve the nuclear safety surveillance level, in 2012, the MEP (NNSA) organized to formulate and release the nuclear safety guide *Aging Management of Nuclear Power Plants*, which is the explanation and supplement to the provisions on aging management in the *Code on the Safety of the Nuclear Power Plant Design* and *Code on the Safety of the Nuclear Power Plant Operation*, it provided the methods for NPPs to carry out aging management and determines the elements for NPPs to perform aging management, for use by operating organizations to formulate, implement and improve aging management programs for NPPs.

The aging management work in NPPs is carried out mainly according to the nuclear safety regulation requirements such as *Periodic Safety Review in Nuclear Power Plant* and *Aging Management of Nuclear Power Plants* and the advanced experience in aging management of the IAEA and NRC, and with reference to the good practices in the nuclear power industry in China and other countries. Various aging management work is carried out systematically in all phases of construction, commissioning and operation of NPPs, including the establishment and improvement of plant aging management system, for both aging management organizations and documentation system, the activities of monitoring, testing, sampling and inspection, assessment of the aging mechanism predicted at the design of NPP, and identification of conditions or performance deterioration that may occur in service but has not expected.

CNNO carried out aging management review and time limit aging analysis for the work on extending the operation permit of the 300MW unit in Qinshan NPP, and established the standard system for aging management and operation permit extension of NPPs in China.

In the NPP PSR already performed, special safety review was carried out for aging management, to confirm that NPPs performed effective management for aging, maintained the required safety functions, and realized effective control for aging and deterioration. In the first PSR performed for Units 1 and 2 of Qinshan Phase II NPP, Third Qinshan NPP, Units 1 and 2 of Tianwan NPP and the second PSR performed for Qinshan NPP, review was performed on aging elements, the aging management system and its effectiveness were systematically assessed, and corrective actions plans were worked out and implemented for weak items identified. Daya Bay NPP and LingAo NPP carried out investigation and study of thermal fatigue monitoring, preparation of aging management programs for ventilation system and batteries and assessment of the effectiveness of aging management program according to the corrective action recommendations made in PSR.

All NPPs carried out screening and classification of aging sensitive equipment. Tianwan NPP has completed the screening and review of aging management parts of Units 1 and 2, and is planning the implementation of aging management for Units 3 and 4, working schedule has been worked out and it is planned to start the screening and analysis of parts for aging management in 2016, to prepare the overall plan for the implementation of aging management for the new units. Hongyanhe NPP has completed the screening for 334 systems and 93 categories of structures in the plant, screening 145 systems, 10 categories of structures and 760 categories of parts in need of concern. Yangjiang NPP has determined the levels 1, 2 and 3 lists for concern in aging management for Units 1 and 2, and worked out different aging management actions and strategies, the relevant work for Units 3 and 4 is in preparation.

In all NPPs, samples have been retained for aging management of structures and equipment. Tianwan NPP carried out aging study for important power cables, screened out critical and sensitive power cables, retained samples for them and performed aging status monitoring and assessment. Hongyanhe NPP has completed the sample retention for Units 1~4, and the samples are maintained and analyzed on a unified basis by the CGN technical platform (Suzhou Nuclear Power Institute). Fangchenggang NPP has completed the cable sample retention for Unit 1, prepared the management working procedure for the retained cable, and established cable aging management database and started data entry. Taishan NPP has initially screened out the list of cable samples to be retained for Unit 1.

All NPPs have carried out aging management work for civil structures and pipes, and developed NPP aging management databases. Taishan NPP has developed the aging data collection and record reservation system, to collect basic data for 9 categories of important equipment including RPV and SGs. Fangchenggang NPP has developed and brought online the data collection and record reservation system for important equipment. In addition, Tianwan NPP has carried out the online life assessment for primary equipment, and Ningde NPP carried out aging management work for fluid accelerated corrosion (FAC).

14.2.6 Periodic Safety Review

According to requirements in regulations, a PSR shall be performed every ten years after the start of commercial operation of a NPP. According to operating experience and relevant important safety information, and current safety standard and practice, systematically safety re-assessment shall be performed for NPPs. The scope of review covers all aspects of nuclear safety, including 14 safety elements in five categories. The *Periodic Safety Review Program* of all NPPs are prepared according to the requirements in the *Periodic Safety Review for Nuclear Power Plant*, specifying the methods and scope of PSR review. The general method is comparing the original design bases of all plants and the current latest basis, to review the plant according to the difference in bases, analyze the effect of the difference, determine the weak item, and work out targeted rectification and correction actions. The original design bases are the safety standards in the design and construction period of the NPP(including the nuclear safety codes, specifications, guides and standards) and design documents, and the current latest bases are the existing safety standards and good practices.

The duration of PSR shall not exceed three years. according to result of review, NPPs identify reasonable and achievable corrective action/safety improvement and the execution plan, fully take interaction and mutual cover of all safety elements into consideration, and pay attention to corrective action/safety improvement‘s influence on all safety elements. NPPs comprehensively assess the weakness which weren‘t reasonably resolved, identify related risks and provide corresponding certificates for sustainable operation. During the Periodic Safety Review, repeated work should be minimized by fully utilizing relevant research results and comments from regular safety review, special safety review, probabilistic safety analysis, etc.

In 2012, the *Periodic Safety Review Program* for the second PSR of Qinshan NPP, and for the first PSR of Units 1 and 2 or Qinshan Phase II NPP and Units 1 and 2 of Third Qinshan NPP were approved by the MEP (NNSA). From 2012 to 2015, Qinshan NPP, Qinshan Phase II NPP and Third Qinshan NPP respectively completed the site review and the preparation of review reports, and which were submitted to the MEP (NNSA).

In the PSR, Qinshan NPP identified 26 weaknesses, including 18 requiring major renovation by the plant, of which renovation is going on for 1 item and feasibility analysis is under way for 17 items. Qinshan Phase II NPP identified 49 weak items, including 9 requiring major renovation by the plant, of which 1 has been completed and feasibility analysis is under way by design institute for the remaining 8 items. Third Qinshan NPP identified 33 weak items, including 3 requiring major renovation by the plant, for which relevant work for renovation is under way. The weak items, when assessed as risks acceptable, will not affect the continual operation subsequently. The PSR review reports are evaluated after being submitted to the NNSA. By the end of 2015, Qinshan NPP was organizing replies to evaluation questions, and it is expected that that the PSR work will be completed in Q3 2016. Qinshan Phase II NPP had completed all replies to evaluation questions, and was waiting for evaluation conclusions from the MEP (NNSA), the review work has been basically completed, and later it will perform continual follow-up for the rectification and correction of weak items. Third Qinshan NPP was organizing the replies to the last batch of evaluation questions, and it is expected that the review work will complete in Q2 2016.

Daya Bay NPP completed the second PSR review and LingAo NPP completed the first PSR review for Units 1 and 2. In the review, the PSR review program, detailed rules for review and review procedures for relevant elements were prepared, forming the PSR review management system documents. Also, review standards were prepared for all elements, and now they have been accepted. In addition, the relevant PSR review website and database were established during PSR review, for storing the relevant process and result documents of PSR review.

According to the results of two PSR reviews, the Daya Bay Nuclear Power Operations and Management Co., Ltd. (DNMC) proposed relevant major improvements, and at present, the work for safety injection system RIS/containment spray system EAS and containment pit filter clogging has been completed, the pit filter replaced to eliminate design defect. for the deviation found in the small branch pipe vibration fatigue check in Daya Bay NPP, measures such as adding support for sensitive pipelines and improving support were included in the medium and long-term improvement plan; the problem of aging with the cables of intermediate range measurement channel (CNI), source range measurement channel (CNS) and power range measurement channel (CNP) of the nuclear power measuring system (RPN) has been included in the intermediate and long-term renovation plan, and it has been planned to replace them with new cables on a unified basis when shifting to the status oriented procedure (SOP). In Units 1 and 2 of LingAo NPP, the reactor building was installed with passive hydrogen recombiners to reduce the risk of hydrogen explosion. Units 1 and 2 of LingAo NPP have been added with containment pressure meter with wider range, to increase the measurement range of pressure sensor, for monitoring of containment pressure under severe accident condition. For Units 1 and 2 of LingAo NPP, the effect of the environmental conditions resulted from high energy pipe rupture accident (outside the containment) on the performance of electrical instruments was not taken into consideration in the design phase, therefore, the pressure transmitters of main steam system VVP was upgraded so that the relevant equipment in the main steam and main feed water cells and their lines can withstand class C environmental conditions, to raise the safety level of the units. The overall renovation for the radiation protection monitoring system (KRT) of Units 1 and 2 of Daya Bay and LingAo NPPs has been basically completed.

The PSR for Units 1 and 2 of Tianwan NPP was started at the end of 2012, and was completed and the approval from the nuclear safety regulatory bodies was obtained at the end of 2015. In the PSR, a complete "health examination" was performed in all fields and specialties of the plant in design, actual status, accident analysis, emergency, environment supervision, operating experience, organization and management and documentation, and 14 element reports, 1 PSR overall report and 1 improvement action plan was prepared.

PSR has not yet been performed for the new NPPs including Hongyanhe NPP, Ningde NPP, Yangjiang NPP, Taishan NPP and Fangchenggang NPP, but they are actively doing the initial preparatory work for PSR according to their own conditions and with reference to the good practices and experience of other plants, including the initial planning for project, operating experience and event. Hongyanhe NPP has made exchange with Suzhou Nuclear Power Institute on the operation plan of PSR, and Suzhou Nuclear Power Institute will carry out the PSR in Hongyanhe NPP in the form of "daily review plus centralized review".

14.2.7 Re-assessment of Hazard Assumptions

For NPPs in China, overall review was performed for the possible hazards caused by external environment in the license review and approval for the siting, construction and operation phases of the plants, and corresponding re-assessment is performed in the 10-year PSR, the review results showed that in general, the re-assessment of hazard assumptions has been well performed in NPPs in China.

The MEP (NNSA) formulated and issued the *Notice on Carrying out Safety Margin Assessments on External Events of NPPs in Operation*, requiring operating NPPs to further assess their safety margins to cope with beyond design basis external events, optimize and implement improvement provisions and raise the effectiveness of such provisions. In July 2012, the MEP (NNSA) organized peer review on safety margins of operating NPPs on important external events, and proposed comments and suggestions on the margin assessment work in NPPs. All NPPs of China improved and updated the preliminary analysis and assessment report on safety margin.

CNNO carried out re-assessment for all plants at Qinshan Nuclear Power Base on earthquake and external flooding risks. It also performed analysis of the seismic margin analysis respectively for Qinshan NPP, Qinshan Phase II NPP and Third Qinshan NPP in conjunction with actual conditions, and the results showed that all operating units meet the anti-seismic requirements. Based on the latest meteorological data, assessment and analysis was performed again for the design basis flood levels of Qinshan NPP, Qinshan Phase II NPP, Third Qinshan NPP and Fangjiashan NPP, and the assessment results showed that the units at Qinshan Phase II NPP, Third Qinshan NPP and Fangjiashan NPP met the requirements in codes, only the original design basis flood level of Qinshan NPP was low, therefore the sea embankment for this plant was consolidated and heightened. At present, CNNO is performing re-assessment work for other risks, including the fire probabilistic safety analysis work for units of Fangjiashan NPP, the risk assessment for loss of power generation capacity of Qinshan Phase II NPP, and later, it will carry out the relevant work for seismic probabilistic safety analysis for units of Fangjiashan NPP and level II probabilistic safety analysis for Third Qinshan NPP.

Daya Bay NPP and LingAo NPP started the development of seismic PSA model in 2014, specifically including the seismic hazard analysis for Daya Bay Base, the seismic vulnerability assessment for SSCs important to safety of the 6 units, and establishment of the seismic response model for the 6 units. From 2013 to 2015, Daya Bay NPP made major upgrading for the PSA model. The upgraded model takes into account the pending issues in the PSA peer review for Daya Bay NPP, support the PSA special application in this plant, and embodies and assesses the effect of the accident handling procedures of this plant shifting from the event oriented procedure (EOP) to status oriented procedure (SOP) on the safety performance of the plant; it has put forth a series of safety upgrading and improvements such as "improvement of residual heat removal system inlet valve control mode" and a series of procedure optimization suggestions such as "components cooling water system back cooling diagnosis optimization". LingAo NPP completed the internal disaster PAS model development for Units 3 and 4 in 2014 and 2015, and developed the level II PSA model for Units 3 and 4 on the basis of the latest internal event class I PSA model for Units 1 and 2, including power conditions and shutdown conditions.

At Hongyanhe NPP, for problems of cooling source degradation and the solution to inability to perform some periodical tests due to long time temporary shutdown, in addition to carrying out the corresponding deterministic safety assessments, it entrusted technical support organizations to carry out probabilistic safety analysis, and took the result as reference for comprehensive decision-making. Later, this plant will further strengthen the application of probability theory on the basis of the traditional deterministic analysis, to improve the risk management in the plant.

Ningde NPP has completed the development and online of the mitigation system performance indicators for Units 1 and 2 and Units 3 and 4, and the level I PSA for internal event under power conditions. For Units 1 and 2, the development and online of large scale early release frequency risk analyzer for radioactive nuclides (LERF RM) under power conditions and shutdown has been completed. It is expected that the nuclear safety status assessment system will be brought online in 2016. Later the levels I, II and III PSA models for internal event in operation phase and the LERF model for internal event in operation phase will be developed; plans for longer term include the development of PSA for superposed earthquake, strong wind, external flooding and external disaster.

Yangjiang NPP is a new plant, and no re-assessment work for hazard assumptions has been carried out for a time being. Later, further PSA analysis will be performed for units already in commercial operation as required.

Fangchenggang NPP performed anti-seismic margin assessment for units after the Fukushima nuclear accident, the result showed that most equipment have high anti-seismic capacity and meet the requirements on anti-seismic capacity. For structures or equipment with high confidence and low probability of failure (HCLPF) identified in assessment, renovation was implemented or renovation plan worked out, for example, renovation has been made for component cooling water fluctuating tank, and renovation plan is in place for the masonry wall.

At Fuqing NPP, systematic re-assessment for hazard assumptions is under way according to the actual operation conditions of units, and the FSAR and technical specifications are revised and updated according to the assumed risk re-assessment and PSR conclusions. Fuqing NPP plans to complete the development of internal event level I operation PSA model for power operation conditions, low power and shutdown conditions establish and complete the plant PSA equipment reliability database, develop the PSA application tools such as risk monitor, mitigation system performance indicators, safety issue importance determination procedure in five years, to gradually apply the PSA analysis methods to the plant production activities, and finally establish the complete risk guided management system in the plant.

Taishan NPP has re-checked the design standard adopted for the plant flood discharge trench and budget discharge system when it is attacked by external flood exceeding the current design basis, the result showed that all relevant specification requirements are met, and under the current design standards, it is not necessary to adopt the relevant later phase plugging; tsunami numerical simulation calculation and impact evaluation and study have been performed, as the testing basis for safety re-check of marine structures under the action of the calculated maximum possible tsunami waves.

14.3 Supervision Management and Control Activities

It is specified in Chinese law that the operating organization of NPP undertakes the overall safety responsibility. The MEP (NNSA) implements independent nuclear safety monitoring for NPPs in siting, design, construction, operation and decommissioning phases, including technical review, administrative licensing, supervision and inspection. Moreover, the MEP (NNSA) dispatches site supervisor to all NPPs to perform supervision on activities of the NPPs on site.

The MEP (NNSA), by way of formulating codes, guides, policies and standards of nuclear safety, put forward requirements for safety assessment and verification of NPPs, and by way of nuclear safety review, nuclear safety inspection, Periodic Safety Review, etc., perform supervision on related activities within the lifetime of NPPs, to confirm the NPPs and their activities are in conformity with the safety objectives, principles and criteria.

At different phases of NPPs, regulatory bodies place different emphases on review. At the phase of siting, the MEP (NNSA) performs technical review on *Safety Analysis Report of Siting* and *Environmental Impact Report (Siting Phase)* submitted by the NPP operating organization to review and determine that the chosen plant site complies with related codes and standards from safety and environmental aspects; the emphasis is laid on the suitability of the chosen plant site and the feasibility of design basis relating to surroundings of the plant site and implementation of plan for emergencies; At the phase of construction, before the construction of main building of the NPP, i.e. placing foundation concrete for nuclear island, the MEP (NNSA) reviews the design of structures, systems and equipment of the NPP important to safety to confirm the design of the NPP meets nuclear safety and environmental protection requirements; During construction, the site supervisors of the MEP (NNSA) supervise the whole process (civil construction, system and equipment erection, cold and hot function tests, preparations before fuel loading and other activities) and conduct technical review on various safety and quality problems of the NPP and put forth requirements. At the phase of commissioning, the MEP (NNSA) reviews and determines whether the NPP has been completed according to the approved design, whether the NPP reaches requirement for quality and whether it has completed with eligible records of quality assurance; At the phase of operation, MEP (NNSA) reviews and determines whether the result of trial operation is in line with design or not, and approves the revised operation limits and conditions. During the operation life of the NPP, the MEP (NNSA) dispatches supervisors to work on the site of the NPP to implement on-site supervision on operation status and operation activity of the NPP, put forth nuclear safety requirements for the abnormal conditions and violation on operation procedures in the NPP identified in the supervision, to ensure the operation safety of the NPP. At the phase of decommissioning, the MEP (NNSA) reviews and determines whether the steps of decommissioning and status of all phases of decommissioning of the NPP are in line with the safety requirements.

At the same time, the MEP (NNSA) inspects the implementations of nuclear safety management requirement and conditions stipulated in the licenses by way of nuclear safety surveillance, and urges the NPP to correct those items which are not in conformity with nuclear safety management requirements and conditions stipulated in the licenses. Through the whole life of the NPP, in consideration of operating experience and new important safety information acquired from relevant resources, the MEP (NNSA) requires the NPP operating organization to systematically assess safety of the NPP by taking the method of Periodic Safety Review.. The review strategy and safety elements to be assessed must be subjected to approval or consent from the MEP (NNSA), to determine the extent of validity of the existing safety analysis report.

The MEP (NNSA) has further strengthened the nuclear safety surveillance, review and operation operating experience work for operating NPPs, the supervision and management in the whole course of construction and commissioning for NPPs under construction and the audit calculation and testing verification for new built NPPs. The MEP (NNSA) mainly carried out the following supervision management and control activities in the past three years:

(1) The MEP (NNSA) has energetically promoted the application of PSA technology, and has started the basic work to establish the basis for PSA application by regulatory bodies, and promote the establishment of reliability databases. The MEP (NNSA) has revised and completed the *Acquisition of Equipment Reliability Data in Nuclear Power Plant(for trial implementation),* and collected the equipment reliability data of all NPPs up to the end of 2013 since their operation on this basis by using the established equipment reliability general database of operating NPPs, analyze and sort out the relevant data, and compiled and issued the first equipment reliability data report of NPPs – *Equipment Reliability Data Report of Nuclear Power Plant in China* (2015 Rev.).

(2) The MEP (NNSA) requires NPP operating organizations to carry out pilot work for PSA application according to their own actual conditions, thus laying the foundation and gaining experience in the preparation of the PSA-based regulatory mode, standards and regulations. NPPs in operation select their own PSA application pilot projects in combination with the actual situation, such as the application in optimizing in-service inspection at Daya Bay NPP. At present, the MEP (NNSA) is carrying out the related work according to the application pilot plan of each NPP, to gradually spread the application of PSA in NPPs in operation.

(3) The MEP (NNSA) proposed the requirements of full-scope PSA (both internal and external events), and the analysis objects shall cover the core and spent fuel pool. The PSA review work for new built NPPs have been fully implemented, level I and II PSA and PSAR and FSAR are reviewed concurrently, and the work of PSA for full scope and all conditions are pushed ahead in an all-round way.

(4) Further formalizing the review and approval management of nuclear safety equipment, and strengthening the supervision and management for imported civilian nuclear safety equipment. The MEP (NNSA) has imposed administrative sanction on some design, manufacturing, installation and NDT organizations for civilian nuclear safety equipment that have produced fake quality documents and violated relevant laws and regulations, such as Jiangsu Changyan Cable Co., Ltd., Changshu Huaxin

Special Steel Co., Ltd., and Zhejiang Sanfang Control Valve Co., Ltd., and revoked the license from those with serious cases; for the event of batch welding in violation of rule by Dongfang Electric (Guangzhou) Heavy Machine Co., Ltd., a national operating experience on-the-spot meeting for civilian nuclear safety equipment was called, at which the main problems and root causes existing in the industry were analyzed comprehensively by feeding back together domestic and overseas typical cases, and corresponding rectification and correction requirements were put forth; the special general inspection for nuclear safety equipment and "special rectification and control action against patch welding in violation of rule" were organized, and reporting cases were set up in all licensees, for better supervision effect.

(5) Speeding up the construction of operating experience system and safety performance indicator assessment system of operating NPPs, pushing ahead the application of PSA, and making proper technical review and site supervision; urging the full implementation of post-nuclear accident safety improvement requirements, and producing the corresponding report on implementation of improvement actions.

(6) The MEP (NNSA) implemented special inspections for important activities such as erection of important equipment and commissioning of safety systems by strengthening the process surveillance for construction and commissioning, and made more efforts in the investigation and disposition of construction event and major nonconformance, to promptly identify and properly handle problems in the construction of NPPs.

(7) Innovative design of the NPP communication supervision pattern and getting well prepared for commissioning supervision for AP1000 an EPR NPPs; completing the commissioning review and supervision preparation plans for the first reactor of that type, clearly specifying the supervision and inspection program and list of supervision items for the commissioning phase of Sanmen and Haiyang NPPs (AP1000) and for Taishan NPP (EPR), and organizing the formulation of supervision procedures for major tests.

(8) Strengthening the review work for NPPs of independent design, for the NPP based of independently designed HPR1000, detailed technical review plan has been conscientiously studied and worked out, joint review team has been formed, and experts were invited extensively to participate in specific area review, thus the review work for the preliminary safety analysis report, environmental impact assessment report of construction phase and QA programs (engineering and construction phases) of the 4 HPR1000 units were carried out with high efficiency, and the issuance of the construction permit and the environmental impact assessment report for construction phase of the 4 HPR1000 units were approved.

(9) The MEP (NNSA) has strengthened the audit calculation with the purpose to perform in-depth review of the correctness and reliability of safety analyses of NPPs. The audit calculation has been made mainly on seven aspects of core physics, design basis accident, severe accident, radiation protection, stress and structure anti-seismic analysis, probabilistic safety analysis and effluent discharge source term, it is performed for two phases of preliminary safety analysis and final safety analysis, covering the whole process of review work for NPPs to be new constructed. Now audit calculation work has been finished for units of AP1000, CAP1400 and HPR1000. At the same time, a fairly complete analysis software system for safety review has been basically established by importing safety analysis software from other countries and purchasing commercial grade analysis software with extensive

application and acceptance, including the neutron physics and critical safety analysis program, thermo hydraulic analysis procedure, severe accident analysis procedure, containment thermo hydraulic program, structure mechanical analysis program, radiological consequence analysis program and probabilistic safety analysis program. In the meantime, the software system was verified with existing standard examples and relevant test data. This application software system has been used to complete the audit calculation work for units of AP1000, CAP1400 and HPR1000.

(10) To verify the effectiveness of safety design, the suitability of safety analysis software, the correctness of safety analysis calculation models and the reliability of the use of data and assumptions, the MEP (NNSA) carried out test verification and witness work for CAP1400 demonstration project and HPR1000, and established independent test verification system and requirements. Test verification and witness work has been carried out for CAP1400 demonstration project and HPR1000, and independent test verification system and requirements have been established. Witness assessment for six critical tests and test verification for three items have been carried out for CAP1400: test of passive core cooling system in SBO condition and passive residual heat removal system rupture upstream or downstream the isolating valve, passive containment cooling system heat conducting capacity margin test, and test on effect of molten materials retention in reactor and flow pass change on heat exchange characteristics of pressure vessel. Theoretical analysis of malicious impact by large commercial aircraft, test research on dynamic loading characteristics of shielded buildings and verification test research on radioactive liquid waste treatment system of large PWR NPPs have been carried out. For Units 5 and 6 of Fuqing, verification has been carried out for 3 tests: the performance test of passive containment heat export system, test of secondary side passive residual heat removal system and test of reactor cavity water injection and cooling system. For Units 3 and 4 of Fangchenggang, verification has been carried out for two tests: test of secondary side passive residual heat removal system and test on effect of molten materials retention.

(11) The safety analysis reports on siting and environmental impact assessment reports for NPPs to be constructed were reviewed, and the corresponding *Review Comments on Siting* and certificate of approval for environmental impact assessment report were issued; according to the requirements of relevant nuclear safety codes and guides, after nuclear safety review and on-site supervision, construction permit was issued to a total of 10 units from 2013 to 2015.

15. Radiation Protection

Each Contracting Party shall take the appropriate steps to ensure that in all operational states the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed prescribed national dose limits.

15.1 Basic Requirements of Radiation Protection

The Chinese Government has promulgated a series of laws, regulations and national standards to ensure the implementation and achievement of radiation protection objectives.

(1) On June 28, 2003, the Standing Committee of the National People's Congress promulgated the *Law of the People's Republic of China on Prevention and Control of Radioactive Pollution*, specifying on the prevention and control of radioactive pollution by NPPs:

- The operating organization of NPPs shall be responsible for prevention and control of radioactive pollution in their own units, subject themselves to supervision by the administrative department for environmental protection and the relevant departments, and are responsible for all consequences caused by radioactive contaminations required by the law.
- The operating organization of NPP shall monitor the types and concentration of radioactive nuclides in the environment surrounding the NPP as well as the total quantity of the radioactive nuclides in the effluents from the NPP and shall, at regular intervals, report the monitoring results to the administrative department for environmental protection under the State Council and to such department under the people's government of a province, autonomous region, or municipality directly under the Central Government where the unit is located.
- The operating organization of NPP shall minimize the quantity of radioactive waste produced. Any unit that discharges gaseous or liquid radioactive waste into the environment shall conform to the national standards for prevention and control of radioactive pollution, and report the discharge quantity calculated to the administrative department for environmental protection on a regular basis.

(2) The Standing Committee of the National People's Congress deliberated and adopted the *Act of Prevention and Treatment on Occupational Diseases of the People's Republic of China* on Oct. 27, 2001, and approved the revision of the code on December 31, 2011, which specifies prevention and treatment of occupational diseases in enterprises such as NPPs as follows:

- The Employer should equip protective equipment and alarm devices, and ensure the employees exposed to radiation are equipped with individual dosimeters.
- The Employer shall appoint a person responsible for making routine supervision over occupational-disease-inductive factors and ensure the normal operation of the monitoring systems.

(3) On Oct. 8, 2002, the national standard *Basic Safety Standard on the*

Ionization Radiation Protection and Radioactive Source was promulgated, which specifies the limits of individual dose as follows:

- Occupational exposure
  - The annual average effective dose for 5 consecutive years determined by the regulatory body (no retroactive average shall be made) shall be 20mSv;
  - The limit of effective dose in any single year shall be 50mSv;
  - The limit of annual equivalent dose to the eye lens shall be 150mSv;
  - The limit of annual equivalent dose to the extremities (hands and feet) or the skin shall be 500mSv;
  - In special circumstances, the period of annual average dose of 20mSv can be extended to 10 consecutive years, and in this period, the annual average effective dose received by any worker shall not exceed 20mSv, and shall not exceed 50mSv in any single year; and the circumstances shall be reviewed when the accumulated dose received by any worker since the start of the extended period reaches 100mSv; the temporary change of the dose limit shall not exceed 50mSv in any single year, and the period of the temporary change shall not exceed 5 years.
- Exposure to the general public
  - The annual effective dose limit is 1mSv;
  - In special circumstances, if the annual average dose does not exceed 1mSv in 5 consecutive years, the effective dose limit in a single year can be increased to 5mSv;
  - The limit of annual equivalent dose to the eye lens shall be 15mSv;
  - The limit of annual equivalent dose to the skin shall be 50mSv.
- Emergency exposure

When intervention is performed in the following circumstances, except for actions to rescue life, all reasonable efforts shall be made to keep the dose subjected to working personnel below 2 times the maximum dose limit for a single year; for actions to rescue life all efforts shall be made to keep the dose subjected to working personnel below 10 times the maximum dose limit for a single year, to prevent the occurrence of deterministic health effect. In addition, when the dose exposed to the working personnel taking the action may possibly reach or exceed 10 times the maximum dose limit for a single year, such action can be taken only when the benefit brought by the action to the others is obviously greater than the danger sustained by the working personnel themselves.

- Rescuing life or avoiding serious damage;
- Avoiding big collective dose;
- Preventing the evolution to a disastrous condition.

(4) The nuclear safety regulatory bodies of the state have put forth all principle requirements on radiation protection that should be observed by NPPs in all phases in a series regulations for the siting, design and operation of NPPs:

- In the siting for a NPP, it shall be ensured to protect the general public and environment from over exposure due to release caused by radiation accident, and in the meanwhile, the normal radioactive substance release from the NPP should also be considered;

- The design of a NPP shall take into full account the radiation protection requirements, such as optimization of layout, setup of barriers, minimizing the number of activities and staying time of people in radiation area, and radioactive substance shall be treated to suitable forms;
- NPPs shall adopt measures to reduce the quantity and concentration of radioactive substances in plant or released to environment;
- NPPs shall take into full account the possible accumulation of radiation level in personnel staying areas with time, and minimize the production of radioactive wastes;
- Operating NPPs shall assess and analyze the radiation protection requirements and actual conditions of the plants, establish and implement radiation protection programs, verify the correct implementation of programs and the achievement of goals through supervision, inspection and audit, and take corrective actions when necessary;
- The operating organization of NPP shall formulate and implement the radioactive waste management program and environment monitoring program, to access the radiological effect of radioactive release to the environment.

(5) In 2004, the MEP (NNSA) promulgated the *Code on the Safety of the Nuclear Power Plant Design*, which requires that NPPs shall complete nuclear safety analysis in their design, to evaluate the acceptable radiation dose of NPP employees and the general public, and potential consequence to the environment. It is also required that the NPPs shall take measures to control exposure of radiation and decrease the possibility of accidents. The safety design of NPPs shall follow the principle that the probability of events that may cause high radiation dosage or high radioactive substance release is extremely low, and that events with comparatively high probability have no or little radiation consequence.

(6) On September 1, 2011, the MEP (NNSA) revised the *Regulation on the Environmental Radiation Protection of Nuclear Power Plant*, clearly specifying the effective dose equivalent caused to any individual (adults) of the general public by the release of radioactive substances of a NPP to the environment and the annual emission limit of the airborne and liquid radioactive effluents.

- The effective dose of radioactive substance released by all nuclear power reactors on any site to any individual of the general public must be less than the dose constraint value of 0.25mSv every year. Operating organizations of NPPs shall respectively set dose management target values respectively for airborne and liquid radioactive effluents according to the dose constraint values approved by examination and regulatory department.
- NPPs shall control the annual total discharge of radioactive effluents for every reactor. The control values of the reactors with thermal power of 3,000 MW are shown in Table I and Table II. For the reactors with the thermal power higher than or less than 3,000 MW, the control values shall be adjusted appropriately according to their power.

Table I Control of Radioactive Airborne Effluents (Unit: Bq)

	Light water reactor	Heavy water reactor
Noble gas	6×10^{14}	
Iodine	2×10^{10}	
Particles (Half life≥8d)	5×10^{10}	
^{14}C	7×10^{11}	1.6×10^{12}
Tritium	1.5×10^{13}	4.5×10^{14}

Table II Control of Radioactive Liquid Effluents (Unit: Bq)

	Light water reactor	Heavy water reactor
Tritium	7.5×10^{13}	3.5×10^{14}
^{14}C	1.5×10^{11}	2×10^{11} (except tritium)
Other nuclides	5.0×10^{10}	

- For a plant site with multiple reactors of the same type, the annual total discharge from all units shall be controlled within 4 times the values specified in Table I and Table II. For a plant site with multiple reactors of different types, the annual total discharge from all units shall be approved by the regulatory bodies.

(7) After the Fukushima nuclear accident, China required that all NPPs formulate and implement radiation protection program and procedures before the first fuel loading. The radiation protection program must meet the safety non-operation of national nuclear safety regulatory bodies and comply with relevant national standards on radiation protection and safety of radiation sources. The radiation protection program shall be updated at least every 5 years. The radiation protection program shall set reasonable dose management target values respectively for different types of activities under the dose constraint values. Within the lifetime of a NPP, the average collective dose must not exceed 1 person Sv/reactor· year.

15.2 Application of ALARA Principle in NPPs

15.2.1 Application of ALARA Principle in NPP Design

(1) General design considerations

- Proper layout and shielding shall be adopted for the SSCs which contain radioactive substances.
- In design, attention shall be paid to minimizing the number of activities and staying time of personnel in radiation areas, and reducing the possibility of personnel within the plant area being subject to contamination.
- The radioactive wastes shall be processed into proper forms to facilitate transportation, storage and disposal.
- Provisions shall be made to reduce the quantity and concentration of

radioactive substance dispersed in the plant and released to the environment.

(2) Design consideration for equipment

- Reliable and durable equipment, components, and materials shall be selected to reduce or eliminate the need for maintenance;
- The coating materials for equipment and components shall be so selected to facilitate flushing and decontamination;
- Modularized designs shall be adopted for equipment and components to facilitate disassembly and replacement, or moving to a low radioactive area for repair;
- Redundant equipment and components shall be prepared to reduce the demands for immediate repair when radiation levels may be too high and there is no feasible method to reduce the radiation level;
- It shall be possible to perform operation, repair, maintenance, monitoring and inspection of equipment and components remotely.

(3) Design consideration for equipment layout

- Improve accessibility of equipment;
- Provide radioactive equipment with shielding;
- Provide proper and sufficient ventilation and lighting;
- Provide proper detection system equipment;
- Control contamination, conduct distinct isolation between contaminated area and non-contaminated area, and decontaminate the contaminated area;
- The processing technology and detection of radioactive substance;
- Arrange equipment, instrumentation and sampling spots in low radiation area.

15.2.2 Application of ALARA Principle in NPP Operation

For three years, operating NPPs have implemented the ALARA commitment by improving source term control technology, technical renovation, and volume-reduction processing of radioactive wastes, and all possible and reasonable radiation protection provisions have been adopted to ensure realization of the radiation protection target:

(1) Improving radiation protection management system: while maintaining the effective operation of existing management system, according to the previous experience and practice, NPPs have constantly amended and improved radiation protection programs and relevant procedures. By way of management of radiating control areas, training of radiation protection for all employees (including contractors), special work management for work with high radiation risks, working process management of operation in controlled areas, etc., it has been guaranteed that all the radiation related activities are conducted and normalized in a planned manner, and are supervised independently.

(2) Dosage target Management: NPPs periodically monitor and assess the target management values for radiation protection, and keep on optimizing the dose target values based on previous experience and practice and by way of management

intensification and technical transformation. For example, rationally arrange the outage and regular maintenance items by continuously optimizing the maintenance program and in-service inspection program and balance the collective dosage and personnel dosage during continuous optimization of work organization.

(3) Improving source term control technology: for example, replacing antimony-containing parts such as RCP water guiding bearings with parts containing no antimony, using the primary circuit water strainer with smaller aperture; replacing silver-containing gaskets in NPPs, developing and researching the equipment for eliminating local hot radiation spots, etc.

(4) Volume-reduction processing for radioactive wastes: research has been carried out to minimize radioactive wastes, management guide to minimize wastes have been formulated, and work to un-confine spent resin, activated carbon and spent filters has been successfully carried out, further reducing the amount of radioactive wastes produced.

(5) Technical renovation: such as reducing the aperture of filters upstream the chemical and volume control bed, to increase the cleaning efficiency of the system; special shield pads were designed and made for the video inspection of SG secondary side, reducing the expose dose to inspection personnel; the use of machined dummy cover special shield tools to reduce ambient dose level on site and reduce outage time.

(6) Strengthening contamination protection measures: such as strengthening surveillance for the work starting conditions of radioactive systems and equipment, and setting witness point of radiation protection for open ended work.

Because most of radiation exposure of NPP employees occurs in the period of outage, NPPs have attached high importance to radiation protection activities during outage. The above-mentioned measures have been applied and strengthened effectively during the refueling outage, such as following up major items by designated persons, enhancing contamination control on site, preparing and implementing ALARA plan as well as training and examination of outage contractor personnel and strengthening boundary management of radiation protection, item transfer control, contamination control, site shielding, area isolation and simulation exercises. By strictly performing these measures, nuclear power plants have guaranteed the integrity of radiation control zone boundary during the outage, effectively controlled radioactive substance in the course of transfer and reduced exposure dose to working personnel.

15.3 Personnel Exposure Control

The monitoring results of occupational exposure show that the annual average effective dose equivalent for the site personnel in the operating NPPs of China is far below the dose equivalent limit set by the national standards, and the normalized collective effective dose does not exceed 0.3man·mSv/GWh. For details, refer to Appendix 8.

15.4 Environmental Radioactivity Monitoring

China has further strengthened the construction of radiation environment monitoring network. The radiation environment monitoring network, nuclear and radiation emergency technical center and radiation environment monitoring technical center have been established to perform conventional radiation environment monitoring for major cities. The number of radiation environment quality monitoring stations in China radiation environment monitoring network has been increased to 987, including 161 radiation environment air automatic monitoring stations, 328 land radiation level monitoring stations, 201 water body radioactivity level national control monitoring sections, 37 marine organism monitoring stations, 175 soil radioactivity level monitoring stations, and 85 electromagnetic radiation monitoring stations; nuclear safety pre-warning and radiation environment supervision monitoring work is carried out at 41 important nuclear and radiation facilities and around uranium mining and smelting venues, basically realizing all-round monitoring and pre-warning for radiation environment quality and important nuclear installations in the whole country. The national radiation monitoring data summarizing center and 31 provincial level data summarizing centers have been completed; the daily operation management system and periodical reporting mechanism based on "monitoring every day and patrol inspection every month" have been established and implemented, the data acquisition rate at automatic stations have been raised to 90%, and real-time publication of air absorbed dose rate monitoring results at automatic stations has been realized at website of the MEP.

On the basis of the critical nuclides, critical exposure and transfer paths and critical groups of people determined in the environmental impact report (EIR), operating organizations of NPPs have prepared environment monitoring programs to monitoring the radioactivity level in the environment, to ensure that the requirements in related national laws and regulations are met, the discharges of effluents are kept within discharge limits, and the public are protected from radiation caused by nuclear plant operation. NPPs use environmental radioactivity monitoring data to perform the following assessment and analyses:

- The effectiveness of controlling the release of radioactive substance to the environment;
- The radiation exposure to the public by the radioactive effluents from NPPs;
- The long-term variation tendency of environment radioactivity level;
- The diffusion and migration of radioactive nuclides in the environment;
- Verifying the effectiveness of assessment models and the accuracy of environment parameters used in preparing and approving limits.

(1) Background investigation before operation

Before operation, a NPP must complete a two-year radioactivity background investigation. Before operation, NPPs have measured and recorded the environmental background, to ensure the scope and frequency of environment monitoring are representative and meet the requirement of related regulations.

(2) Environmental radiation monitoring

NPPs make full use of the data obtained in the investigation before operation, to optimize environmental monitoring while meeting the need in environmental impact assessment. The environmental monitoring is focused on critical paths and critical nuclides with major contributions to the dose of critical groups of people. NPPs have prepared environmental monitoring programs according to the environmental protection regulations and environmental radiation monitoring standards of the state, to perform effective monitoring and assessment of surrounding environment. The medium measurement and analysis results for the γ radiation level, organisms, air, soil and sea around NPPs during the recent three years show that: the operating NPPs in China have produced no adverse effect to the environment.

(3) Monitoring of radioactive effluents

After a NPP is put into operation, monitoring must be performed for airborne and liquid radioactive effluents. The measuring contents include the total discharge amount, the discharge concentration and the main nuclides to be analyzed. The monitoring results indicate that the radioactive effluents from each plant during operation are below the control values specified in national standards.

(4) Meteorological observation

To get information about atmospheric diffusion, NPPs have developed meteorological monitoring programs; representative locations are selected to perform continuous monitoring of the wind direction, wind speed and air temperature at different elevations above ground, as well as conventional meteorological elements of wind, temperature, pressure, humidity, solar radiation and precipitation at ground meteorological stations. Moreover, NPPs have established communication channels with the meteorological department of provinces where they are located, to obtain necessary meteorological data of larger range.

(5) Environmental emergency monitoring under accident

NPPs established environmental emergency monitoring plans before their trial operation, which specify some exported intervention levels, to enable assessment of monitoring results and determining as early as possible whether it is necessary to take relevant actions.

Under nuclear accident emergency condition, the operating organization of the NPP and local nuclear and radiation environment monitoring department undertake mainly the radiation environment monitoring responsibilities; the off-site emergency committee (usually the local provincial government) exercises the leadership and coordination to fully coordinate the resources and activities of all related parties and unify the action. At early phase of a nuclear accident, mainly the on-site emergency monitoring resources and forces of the NPP operating organization perform the environmental radiation monitoring around the site. At later phase of the accident, as restoration activities in large areas are involved, mainly the off-site monitoring resources and forces perform the environmental radiation monitoring. At the medium phase of the accident, environmental monitoring is performed by both on-site and off-site resources and forces.

(6) Radiation effect on the public from NPPs in operation

NPPs evaluate the radiation effect on the general public in their operation by using the data obtained from the monitoring of the accumulative γ radiation dose at the boundary of plant area and the sampling analyses of the environment media such as the atmosphere dust, the land-living organisms, the soil, the water.

The radiation environment monitoring stations of provinces where NPPs of China are located have performed the monitoring of the environment around NPPs. The results indicate that, the discharge of radioactive effluents from NPPs in operation is far below the control values specified in national standards, and the maximum individual annual effective dose caused to the general public is far below the dose constraint values specified in national standards.

15.5 Control Activities and Capacity Development of the Regulatory Bodies

Supervision activities by regulatory bodies on the radioactive effluents from NPPs include:

- Formulating codes and guides on radioactive waste management;
- Formulating codes, guides and standards on radiation protection and the discharge of radioactive effluents;
- Assessing whether a NPP conforms to the related codes and standards by reviewing the design, construction and operation of the radioactive waste management installations, as well as the personnel qualifications and records;
- Requiring remedial and corrective actions to be taken for the items not complying with the requirements of relevant guides and standards;
- Reviewing and approving the EIR submitted by the operating organization of the NPP;
- Reviewing and approving the annual discharge amount of airborne and liquid radioactive effluents requested by NPPs;
- Reviewing the environment monitoring report submitted by NPP operating organizations, and organizing the environmental monitoring center of the local province to perform environment radioactivity monitoring.

Environmental protection department of each province with NPP has established peripheral supervisory monitoring system for NPP to monitor and assess the surrounding environment of the plant, compare the data obtained with those measured by NPP, and also compare the results with those from NPPs in other countries. The MEP (NNSA) and the environmental protection department in charge in provinces with NPP review the monitoring reports respectively submitted by NPP operating organizations and local radiation environment monitoring stations, to ensure the accuracy and authenticity of measurement results.

For three years, nuclear and radiation safety regulatory bodies have mainly carried out the following activities:

(1) Promoting the revision and management of standards. The *Rules for the Management of Solid Radioactive Waste Storage and Disposal License* and *Standard Format and Contents of Nuclear and Radiation Safety Analysis Report of the Radioactive Material Transport* have been revised.

(2) Actively carrying out training to upgrade the capacity of teams. In 2013, the radiation safety and protection training program and quality control procedure were issued, quality control and site supervision were continued for the medium and junior training sessions on radiation safety and protection, and all training institutions were further urged to conduct training in strict accordance with schedule and requirements, to ensure training quality.

(3) Energetically promoting the development of national radiation environment monitoring capacity, and strengthening the design of radiation environment monitoring system. The three-level radiation environment monitoring teams of the state, provinces and localities have been established, the national radiation environment monitoring network system has been preliminarily completed, the final acceptance of the national radiation environment monitoring data summary and

release system has been completed, and the data release plan prepared; the national radiation environment monitoring work performance examination and radiation environment monitoring institution capacity evaluation mechanism have been established and improved, the provincial-level radiation monitoring institutions in the whole country were organized to carry out quality examination an skill competitions; the formalized management of radiation environment monitoring has been promoted and the operation, maintenance and monitoring quality management system for the national control network has been further improved.

(4) Formulation has been started for the *Guide for Minimizing Wastes in Nuclear Power Plant*. The guide has clearly required that the safety analysis report must include the plan for minimizing wastes, the draft of the guide has been adopted at the nuclear and radiation safety code and standard review meeting of the MEP (NNSA).

16. Emergency Preparedness

1. Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency.

For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.

2. Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of the nuclear installation are provided with appropriate information for emergency planning and response.

3. Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.

16.1 Basic Requirements for Emergency Preparedness

China has promulgated the *Law of the People's Republic of China on Prevention and Control of Radioactive Pollution*, *Emergency Response Law of the People's Republic of China*, *Regulations on the Emergency Management for Nuclear Accidents of Nuclear Power Plant* and a series regulations and guides, which specify the national emergency management system and emergency preparedness of NPP operating organization.

In accordance with the *Emergency Response Law of the People's Republic of China*, *Regulations on the Emergency Management for Nuclear Accidents of Nuclear Power Plant*, *National General Plan of Emergency Preparedness on Unexpected Public Events* and relevant international conventions, in 2013, the State Council officially approved the revised *National Nuclear Emergency Plan* after its issuance, further defining the scope of management for nuclear emergency work, making clear the work principles and major bodies of responsibilities, enhancing the commanding mechanism, setting detailed rules for emergency preparedness and guarantee measures, formalizing the information reporting and release procedures, and also specifying the work after an accident with nuclear installation.

It is clearly specified in the *Regulations on the Emergency Management for Nuclear Accidents of Nuclear Power Plant* and *National Nuclear Emergency Plan* that: for the nuclear accident emergency management, the basic policies of unremitting preparedness, positive compatibility, unified command, energetic coordination, protection of the public, and protection of the environment shall be carried out, and the basic principles of unified leadership, different levels of responsibility, tiered arrangements, coordination between the locality and the military, quick response, and scientific handling shall be adhered.

In 2013, the MEP (NNSA) revised and issued the *Nuclear Accident Emergency Plan of the MEP (NNSA)* and *Radiation Accident Emergency Plan of the MEP (NNSA)*.

All the above mentioned laws, regulations, department rules, nuclear safety guides and all sorts of technical documents constitute a relatively complete nuclear emergency regulations system for China, which enable necessary and effective emergency response actions to be taken quickly in case of a severe accident with a NPP.

After the Fukushima nuclear accident, the MEP (NNSA) issued the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident*, putting forth the technical requirements on emergency water supply and associated equipment, on the habitability and functions of emergency control center, and requirements at technical level such as emergency improvement after multi-units in one plant site enter the emergency status at the same time.

China actively follows and studies the international movement on trends of nuclear safety regulations and standards, and has promptly revised relevant nuclear safety codes and standards of China. The National Coordinating Committee for Nuclear Accident started the revision of the *Regulations on the Emergency Management for Nuclear Accidents of Nuclear Power Plant* in 2014, the MEP (NNSA) is organizing the revision of the nuclear safety guide *Nuclear Emergency Drills in Nuclear Power Plant Operators* and *Setting of Emergency Action Level in PWR Nuclear Power Plant*, and has started the preparation of the nuclear safety guide *Habitability of Emergency Facilities in Nuclear Power Plant*.

After the Fukushima nuclear accident, the MEP (NNSA) put forth requirements on the assessment of implementation reliability of emergency plans, emergency utility supply, emergency control center and emergency preparedness and actions.

16.2 Emergency Organizational System and Duties

Sticking to the guidelines of versatile compatibility, resource integration, interdisciplinary support, and integration of military and civilian capabilities, China builds and maintains national nuclear emergency capabilities commensurate with the safe and efficient development of nuclear energy, and forms a fully-fledged national system of nuclear emergency response capabilities. According to the general layout of building a unified nuclear emergency capability system, and with three distinct tiers of capabilities are maintained, viz. national, provincial and nuclear installation operator levels, with a view to pushing forward with the building of various capabilities related to nuclear emergency response., including the national nuclear emergency response professional technical support center, the national level nuclear emergency rescue forces, provincial level nuclear emergency rescue forces and the nuclear emergency response forces on the part of nuclear installation operating organizations.

According to the principle of positive compatibility, the relevant departments of the government in China at all levels have established and strengthened the capability system that can serve and guarantee nuclear emergency with their respective duties, based on the tasks specified in the *National Nuclear Emergency Plan*. Within the framework of the national nuclear emergency institutional mechanism, the nuclear emergency forces at all levels and of all categories can be deployed and used on a unified basis, to jointly response to and deal with nuclear accidents.

A three-level emergency organization system has been formed for nuclear accident emergency in China, which consists of Nuclear Accident Emergency Organizations of State, those of the Provinces (autonomous regions and municipalities) where the NPP is located and those of NPP operating organizations, as See Fig 6.

In the three-level nuclear emergency organization system, the National Coordinating Committee for Nuclear Accidents Emergency organizes and coordinates the nuclear accident emergency preparedness and emergency disposal in the whole country. The daily work is undertaken by the National Nuclear Emergency Office. When necessary, the National Nuclear Accident Emergency Headquarters is set up to lead, organize and coordinate the work to response to nuclear accident in the whole country. The National Nuclear Accident Emergency Coordination Committee has an Expert Committee, to provide consultancy and suggestions for major decision-making, important planning in the nuclear emergency work in the state and the nuclear accident response work; and it has a liaison officer group, to handle matters arranged by the National Nuclear Accident Emergency Coordination Committee.

Nuclear emergency committees at provincial level shall be in charge of the nuclear accident emergency preparedness and emergency disposal in their administrative areas, and command the offsite emergency response actions for nuclear accidents in their own administrative areas. A provincial level nuclear emergency committee has an expert group, to provide consultancy in decision-making; and a provincial level nuclear accident emergency office is set up for daily work. Where no nuclear emergency committee is in place, a department designated by the provincial level people’s government will be in charge of the nuclear accident emergency preparedness and emergency disposal in the administrative area. When necessary, the provincial level people’s government will directly lead, organize and coordinate the offsite nuclear emergency work in the administrative area, and support the onsite nuclear emergency response actions to cope with a nuclear accident.

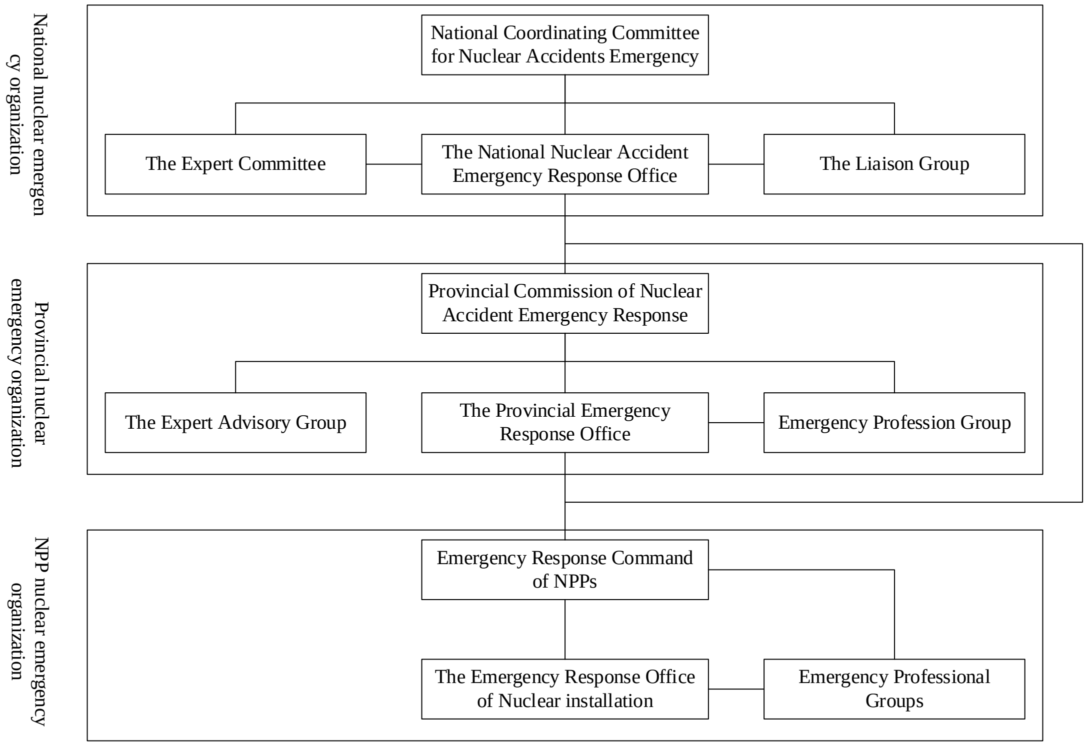

Fig6 Organizational Structure of National Nuclear Emergency Response System

The nuclear emergency headquarters of nuclear installation operating organizations shall organize the onsite nuclear emergency preparedness and emergency disposal work, command the nuclear emergency response actions in their organizations, cooperate with and assist in the offsite nuclear emergency preparedness and response work, and promptly put forth suggestions on entering the offsite emergency state and taking offsite emergency protection measures. The group corporations of nuclear installation operating organizations shall lead and coordinate the nuclear emergency preparedness work in these organizations, allocate its emergency resources and forces under accident conditions and support the response actions of nuclear installation operating organizations.

The main responsibilities and duties of nuclear accident emergency organizations at all levels are as follows:

(1) The National Nuclear Accident Emergency Coordination Committee shall organize and coordinate the national nuclear accident emergency management work.

— Carrying out the national nuclear accident emergency work policies, and drawing up national nuclear accident emergency work policies.

— Organizing and coordinating the emergency accident emergency work of relevant subordinate to the State Council, the nuclear industry administration, local government, NPPs and other nuclear installations as well as the Army.

— Reviewing the national nuclear accidents emergency work program and annual work plan.

— Organizing the preparation and implementation of the national nuclear accident emergency plan, reviewing and approving off-site emergency plans.

— Approving the declaration and termination of off-site emergency status at appropriate time, when responding to emergency.

— Deciding, organizing and commanding on a unified basis emergency response support and response actions, and reporting to and requesting instructions from the State Council at any time.

— Proposing suggestions to the State Council on implementing special emergency actions at appropriate time.

— Fulfilling relevant international conventions and bilateral or multilateral cooperation agreements on nuclear accident emergency, reviewing and approving bulletin and international notification on nuclear accident, and working out schemes for requesting international aids.

— Handling other affairs assigned by the State Council.

— When necessary, the State Council will lead, organize, and coordinate national nuclear accident emergency management.

(2) The National Nuclear Accident Emergency Response Office is an administrative organization for national nuclear accident emergency work. It is a subordinate department of CAEA. Its main responsibilities are as follows:

— Carrying out nuclear accident emergency policies of the State Council and the National Coordinating Committee for Nuclear Accidents Emergency.

— Taking charge of routine work of the National Coordinating Committee for Nuclear Accidents Emergency.

— Implementing national nuclear accident emergency plan, inquiring, coordinating and supervising emergency preparedness activities of member organizations of the National Coordinating Committee for Nuclear Accidents

Emergency; inspecting, guiding, and coordinating related emergency preparedness work of local governments, NPPs and their superior organizations.

— Taking charge of receiving, verifying, handling, transmitting, notifying, and reporting nuclear and radiation emergency information of the state; managing the national nuclear emergency response center; undertaking the relevant affairs for implementing relevant international conventions, bilateral or multilateral cooperation agreements, and requesting international aids as a national nuclear accident emergency liaison point to the external.

— Preparing national nuclear accident emergency work programming and annual work plan, working out scientific research plan and scheme of technical support system for emergency.

— Organizing review of the off-site emergency plans, off-site integrated exercise plans, and on-site and off-site joint exercise plan; making the review comments.

— Organizing activities of liaison persons and experts advisory group.

— Organizing relevant training and exercises on nuclear accident emergency.

— Collecting information, putting forward reports and proposals, timely communicating and executing decisions and orders from the State Council and the National Coordinating Committee for Nuclear Accidents Emergency, inspecting and reporting the implementation results when responding to emergency.

— Handling related affairs decided by the National Coordinating Committee for Nuclear Accidents Emergency after the ending of emergency situation.

(3) The Nuclear Accident Emergency Response Commission of the province where the NPP is located shall take charge of the nuclear accident emergency management in its district, and its main duties are:

— Implementing the national regulations and policies on nuclear accident emergency work.

— Preparing off-site nuclear accident emergency plans and making nuclear accident emergency preparedness work.

— Commanding on a unified basis the off-site nuclear accident emergency response actions in the province.

— Organizing supports to on-site nuclear accidents emergency response actions.

— Notifying timely nuclear accident situations to the neighboring provinces, autonomous regions and municipalities directly under the Central Government or special administrative regions.

— When necessary, the provincial government shall lead, organize and coordinate nuclear accident emergency response management within the own administrative area.

(4) The main responsibilities and duties of nuclear accident emergency organizations of NPPs are:

— Implementing the national regulations and policies on nuclear accident emergency work.

— Preparing on-site emergency response plans and performing emergency preparedness for nuclear accidents.

— Determining the grade of nuclear accident emergency status and commanding on a unified basis the nuclear accident emergency response actions of their own plants.

— Reporting timely the accident situation to the state and provincial nuclear emergency organizations and the designated departments, and putting forward recommendations on declaration of entering off-site emergency condition and implementing emergency protective measures.

— Assisting and coordinating the provincial nuclear emergency response committee to conduct the nuclear accident emergency work.

(5) The MEP (NNSA), the National Health and Family Planning Commission, the Army and member units of the National Coordinating Committee for Nuclear Accidents Emergency as well as other related departments shall perform corresponding nuclear accident emergency work within their respective scopes of responsibilities.

16.3 Classifying and Reporting of Emergency Conditions

In China, NPP emergency situations are classified into the following four scales:

(1) Emergency on Standby: In case of some specific situations or external events which may endanger the safety of nuclear power plan. Relevant plant personnel will be on standby, and some off-site emergency organizations may be notified.

(2) Plant Emergency: The radiation consequences of the accident are confined within a partial area of the NPP, personnel in the plant will take action according to the emergency plan of the plant and relevant off-site emergency organizations are notified.

(3) On-site Emergency: The radiation consequences are confined within the site, on-site personnel will take action, off-site emergency organizations are notified, and some off-site emergency organizations may also take action.

(4) Off-site Emergency (overall emergency): The radiation consequences have gone beyond the site boundary, both on-site and off-site personnel will take action and the on-site and off-site nuclear accident emergency plans are to be implemented.

The above-mentioned emergency status respectively corresponds to level IV response, level III response, level II response and level I response. For the first three levels, the implementation will be organized mainly for the emergency need within the site area. When release of large amount of radioactive materials has occurred or will possibly occur, and the consequences of accident have gone beyond the site boundary and may possibly seriously endanger the public health and environmental safety, it will enter off-site emergency, and level I response will be launched.

When the NPP has entered emergency on standby, the nuclear emergency organization of the NPP shall promptly report to its authorities at a higher level and the MEP (NNSA), and also report to the provincial nuclear emergency committee. In case radioactive substance may release or have released, it shall promptly decide the start of plant emergency condition or site emergency condition, and quickly report to authorities at a higher level, the MEP (NNSA) and the provincial level nuclear emergency committee.

In case radioactive material may spread or have spread beyond the site boundary, suggestion on entering the off-site emergency condition and taking corresponding emergency prevention measures shall be promptly proposed to the provincial level nuclear emergency committee. Upon receiving emergency report from nuclear emergency organization of NPP, the provincial level nuclear emergency committee shall promptly take corresponding emergency countermeasures and preventive measures against the nuclear accident, and report promptly to National Nuclear Accident Emergency Response Office. When it is necessary to decide to enter the off-site emergency condition, approval shall be obtained from the National Coordinating Committee for Nuclear Accidents Emergency. In some special cases, a provincial level nuclear emergency committee can decide first to enter the off-site emergency condition, and then make an immediate report to the National Coordinating Committee for Nuclear Accidents Emergency.

Under the off-site emergency condition, relevant departments such as the National Nuclear Accident Emergency Response Office and the MEP (NNSA) shall promptly send personnel to the site and direct the nuclear accident emergency response actions.

16.4 NPP On-site and Off-site Emergency Plans

For possible nuclear accidents in NPPs, NPP operating organizations shall prepare on-site emergency response plan, local government shall prepare off-site emergency response plans, and the National Coordinating Committee for Nuclear Accidents Emergency shall prepare the national nuclear emergency plans. The contents of the three levels of emergency plans are mutually linked and coordinated. For plans at each level, there shall be implementing procedures as supplement and detailed stipulations to them. Besides, main member units of the National Coordinating Committee for Nuclear Accidents Emergency, support organizations and the Army also prepare their own emergency schemes. The emergency plans and schemes are prepared, reviewed and approved, and revised periodically according to regulations.

The contents of emergency plans at various levels shall cover the emergency response organizations and their responsibilities, the detailed schemes of emergency preparedness and response, facilities and equipment, coordination and supports from the organizations concerned, and other technical aspects. According to the principle of positive compatibility, full use is made of the existing conditions, to establish and maintain necessary technical support centers or supporting units, for such as emergency decision-making support, radiation monitoring, medical treatment, meteorological service, NPP emergency operation technical supports, to form the national nuclear emergency technical support system and guarantee the nuclear accidents emergency response capacity of the country.

The emergency plan of a NPP operating organization, after being approved by the National Energy Administration, is submitted to the MEP (NNSA) for review and to the National Nuclear Accident Emergency Response Office for filing; the nuclear accident emergency plan of the provincial government of the locality of the NPP will be reviewed and approved by the National Coordinating Committee for Nuclear Accidents Emergency, and the national nuclear accident emergency plan shall be reviewed and approved by the State Council.

After the Fukushima nuclear accident, the Chinese Government arranged scientific research institutions to research jointly with NPPs on the response measures to be taken by NPPs after multi-units in one plant site have entered emergency status simultaneously, and evaluate the emergency commanding capability and the deployment and coordination plans for emergency rescue personnel and materials, also, requirements have been raised on the capability of multiple units to cope with severe accidents in the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident*. All NPPs, based on their actual conditions, implemented improvement actions and updated their emergency plans and accident procedures, and established the emergency management system to cope with possible multi-unit accident; the emergency response scheme for multi-units entering emergency status simultaneously has been prepared, to ensure that rapid and effective emergency response actions can be taken under the emergency condition of multi-unit accident; the emergency decision-making and response, emergency status approval and ending processes have been formalized, the internal and external support and emergency capability coordination processes are made clear, to optimize the allocation of emergency resources. In the meantime, the new revised emergency response plans are submitted to the MEP (NNSA) for filing.

In the review of on-site emergency plans of NPPs, the MEP (NNSA) focuses on the case of simultaneous accident conditions at two units, studies and analyzes the emergency response capability of NPPs, with emphasis on the emergency organization system, manpower, materials and technical measures of NPPs, to ensure that NPPs can effectively take emergency response actions when two units go to emergency status simultaneously.

16.5 Training and Exercises for Emergency

China attaches great importance to nuclear emergency preparedness drills and exercises, has issued rules and regulations including *Emergency Management Regulations of Nuclear Accidents at Nuclear Power Plant*, *Contingency Measures for Unexpected Events*, *Guideline on Emergency Exercises for Unexpected Events*, *Regulations on Nuclear Emergency Preparedness Exercises*, organizes emergency exercises according to codes and regulations, made clear requirements on nuclear emergency exercises at all levels and of various types, and specified the policy principles, organization structure, contents and formats, classification and frequency, guarantee preparation and implementation procedures for nuclear emergency exercises.. To meet the need in nuclear energy development, China launches national nuclear emergency joint exercises periodically; the relevant provinces (municipalities and autonomous regions) organize a joint on-site and off-site nuclear emergency exercise of that level every 2 to 4 years; NPP operating organizations organize a comprehensive exercise every 2 years, and hold a number of special exercises every year, and a site with 3 or more operating units increases the frequency of exercises as appropriate.

To enhance the professional level of people engaged in nuclear emergency work and provide enough manpower for nuclear emergency preparedness and response, the national and local emergency organizations at all levels conduct training activities by means of workshop, technical training and emergency knowledge exam to strengthen training and drills of human resource on nuclear emergency. A three-level nuclear emergency training system has been established. The national nuclear emergency management institution is in charge of training of nuclear emergency management personnel in the whole country, the nuclear emergency management institutions of provinces (municipalities and autonomous regions) provide training of nuclear emergency personnel in their own administrative areas, and nuclear installation operating organizations conduct professional and technical training for their own nuclear emergency working personnel.

Emergency trainings in NPPs include basic emergency training, special emergency training and on-the-job emergency training, conducted respectively for ordinary working personnel in NPPs (including contractors), personnel in emergency response organizations and those at posts with high technical and skill requirements in emergency response organizations. The contents of trainings cover many aspects of emergency preparedness and response in NPPs. After the Fukushima nuclear accident, organizations at different levels in China held over 110 training sessions, having trained for nearly 10,000 person-times. At present in China, all nuclear emergency management personnel and professional technical personnel have participated in trainings of different levels and specialties. NPPs in China would conduct systematic training and examination for all personnel related to emergency (including emergency commanding personnel) before the first fuel loading; in the operation lifetime of a NPP, they receive training and examination at least once a year related to the emergency tasks expected to be fulfilled by them.

To verify the effectiveness of nuclear emergency preparedness for new NPPs built in recent years, according to the requirements of nuclear safety codes, a joint nuclear accident emergency exercise is organized with the local government before the first fuel loading of the NPP. For NPPs already in operating, different types emergency exercises are held regularly, to inspect, complete and enhance their emergency preparedness and emergency response capability. The state organizes regular national level joint exercises among three-level emergency organizations. After the Fukushima nuclear accident, NPPs performed emergency response exercises according to the requirements for multi-unit accident, to verify their emergency response capability.

On June 26, 2015, China launched the first national level joint nuclear accident emergency exercise "Shendun-2015" after the issuance of the *National Nuclear Emergency Plan*, the exercise featured three-level joint actions of the national and provincial levels and nuclear installation operating organizations, participated by 27 member units of the National Coordinating Committee for Nuclear Accidents Emergency, it also mobilized 9 national nuclear emergency professional technical support centers, 10 rescue detachments and the associated rescue forces. It fully inspected the effectiveness of nuclear emergency plans and their implementation procedures, and the collaborating level of emergency rescue forces at all levels, and effectively raised the responding and disposition capability of nuclear organizations and personnel at all levels. France, Pakistan and the IAEA dispatched officials and experts to observe and emulate the exercise, and for this exercise, information was notified to the IAEA according to the *Convention on Early Notification of a Nuclear Accident*.

In recent years, the NPPs in China have conducted a number of single item drills, comprehensive exercises and joint exercises according to the requirements in nuclear emergency codes. The provincial level nuclear emergency committees of Liaoning, Fujian, Guangdong, Guangxi and Hainan have respectively organized and implemented the off-site nuclear emergency exercises before the first fuel loading of NPPs in their jurisdiction areas, to inspect the effective connection of onsite and offsite emergency response actions and the collaborated military and locality response efficiency, and accept the guidance and evaluation by National Coordinating Committee for Nuclear Accidents Emergency; to inspect their construction results of nuclear emergency support forces, all nuclear power groups input material guarantee, technical support, rescue assisting and other support forces of groups with real teams and equipment in the comprehensive nuclear emergency exercises conducted in their NPPs, to cooperate in joint exercises and review, well inspecting and upgrading the emergency support capability. At nuclear power bases of Qinshan, Daya Bay and Tianwan with units in operation, regular nuclear accident comprehensive emergency exercises are organized according to the requirements in nuclear safety codes, and dozens of special item drills are also held every year. Hongyanhe NPP, Ningde NPP, Fuqing NPP, Yangjiang NPP, Changjiang NPP and Fangchenggang NPP respectively held the on-site comprehensive emergency exercises before the first Fuel Loading, and held regular comprehensive nuclear emergency exercises and single item drills after the fuel loading. The details of comprehensive and joint exercises carried out in NPPs of China are presented in Appendix 9.

16.6 Information Publicity and Public Communication on Emergency

With the rapid development of China's nuclear power industry, the attention and participation awareness of the public to nuclear safety is continuously increasing. China attaches great importance to the public communication and information disclosure on nuclear emergency, has formulated relevant stipulations and made clear the working principles of transparency, objectivity, trustworthiness and scientific accuracy. The nuclear emergency organizations at all levels have established special nuclear emergency publicity teams, to publicize to the whole society the nuclear energy policy, nuclear safety policy and nuclear emergency policy of the state, and make nuclear energy development more transparent, to ensure the rights of the public to nuclear safety supervision, and to know the nuclear emergency preparedness and response.

China has formulated and established nuclear and radiation safety supervision information disclosure system, all departments concerned are allocated with corresponding personnel and supplies to adapt to the situation of nuclear power development, promote and normalize nuclear and radiation safety information disclosure of NPPs and realize the right to know of the public.

The National Nuclear Accidents Emergency Response Office has established information communication network to enhance communication with relevant ministries and commissions, local governments, the NPPs and the public.

Local governments are responsible for the popularized education of the public around the NPPs on the basic knowledge of nuclear safety and radiation protection, and propagating knowledge on emergency protection, such as alarm, shielding, evacuation and taking preventive anti-radiation medicine in case of an emergency, and giving directions on how to take these actions.

The operating organizations of NPPs take various measures such as utilizing local broadcast and TV, publicizing propaganda material and inviting local public to visit plant and to take part in or to watch emergency exercises, to eliminate nuclear panic among the public, and also enable them to effectively participate in emergency response activities in case of emergency.

The NPPs and the environmental protection departments of the provinces (municipalities and autonomous regions) where the plants are located publish the annual environmental monitoring results of NPPs to the public via proper news media every year.

Emergency organizations at different levels have established relatively broad social foundation for nuclear emergency to promote the harmonic coexistence among NPPs and their neighboring communities and environment through various kinds of public communication activities on nuclear energy.

In case of severe nuclear accidents and off-site emergency status, China performs centralized and unified standardized management on the information of nuclear accident and emergency response, with corresponding regulations and requirements for information channel, information classification, information disclosure, etc., so as to ensure the information of nuclear and radiation accident is released and reported to the public timely, uniformly, transparently and accurately.

Since the Fukushima nuclear accident, the Chinese government, with reference to the IAEA nuclear safety action plan, perfected the information release mechanism, information communication mechanism and channel for occurrence of nuclear and radiation accidents, made more efforts on science popularization education of nuclear and radiation safety knowledge to the social public, and conducted public psychology social effect research of nuclear and radiation accidents. Aiming at the characteristics of the nuclear accident, China has also formulated and perfected the management procedure of public information standard release to timely eliminate the worries of the public to nuclear power safety.

Since 2013, China has organized a number of nationwide nuclear emergency publicity activities with the theme of *Joining Efforts to Establish Defense on Nuclear Emergency and for Nuclear Safety, and to Foster the Scientific Development of Nuclear Energy Sector*, with were actively participated by the nuclear emergency committees of relevant provinces (autonomous regions and municipalities), relevant group corporations and all nuclear installation operating organizations, the activities included interpreting codes and regulations in nuclear emergency field, presenting to the public the achievements China obtained on nuclear emergency in recent years, and the relevant science and technology popularizing knowledge on nuclear emergency, with audience of over 1 billion person-times in China and overseas. In Nov. 2015, the interview activity of "pushing the development of nuclear energy and boosting the ‘Belt and Road Initiative" was launched, the relevant media prepared reports on the nuclear power enterprises of China, to demonstrate the advanced nuclear power technologies, the high safety and reliability of nuclear power, the formalized management in nuclear power and the sufficient nuclear emergency preparedness in China, producing positive response from the public.

The Chinese government is continually perfecting the information release system for occurrence of nuclear and radiation accident, public information communication mechanism and effective communication channel, and making more efforts on the science popularization education of nuclear and radiation safety knowledge.

16.7 Supervision Management and Control Activities

According to China's nuclear safety code *Regulations on the Emergency Management for Nuclear Accidents of Nuclear Power Plant*, in case of off-site emergency, relevant departments of the army, public security, fire-fighting, sanitation and civil administration, etc. shall carry out corresponding rescue work jointly.

The National Health and Family Planning Commission (NHFPC) has set up a medical emergency center for nuclear accidents, consisting of three clinical medicine departments; and constructed 17 radiation injury rescue and treatment bases nationwide, including two national level rescue and treatment bases and 15 provincial level rescue and treatment bases. Meanwhile, it has set up two national nuclear and radiation emergency medical rescue teams, which are well equipped and carry out trainings and drills, able to set out quickly for national and international rescue activities in case of a sudden nuclear and radiation accident.

The Nuclear Accident Medical Emergency Center of the NHFPC has established medical emergency communication and contact system and nuclear accident medical emergency technical support system, and opened the communication contact with departments such as the National Nuclear Accidents Emergency Office, etc., to guarantee effective medical emergency handling of nuclear accidents.

In case of any severe accident in a NPP, under the leadership of local nuclear accident emergency committee, competent communication and transportation departments of the province, autonomous region or municipality will set up a communication and transportation leading group and join the supporting forces of other areas and departments, and conduct organization and leadership on transportation on a unified basis.

The preparation and organization of transportation resource and power is multilevel and multipath. The transportation departments of relevant provinces, autonomous regions and municipalities will transfer and organize emergency response transportation force jointly with other departments concerned. Local transportation force shall be the main component of emergency transportation force. When it is insufficient, the governments of relevant provinces, autonomous regions and municipalities will issue command to transfer the force of transportation departments in other neighboring areas for support. Request will be made to nearby army units to dispatch transportation force for supporting when necessary. Water transportation and air transportation force can be dispatched by local authority or the army.

16.7.1 Development of Radiation Environment Monitoring Capacity

To raise the radiation environment monitoring capacity, the MEP (NNSA) has established the national radiation environment monitoring network system, to perform daily monitoring and emergency monitoring of the radiation environment nationwide; the NPP radiation environment field supervisory monitoring network system has been built up, covering all sites and surrounding areas (20km) of all NPPs in operation and under construction in the whole country; the nuclear and radiation accident emergency decision-making, support, commanding and dispatching system has been completed, covering all civilian nuclear installations, to obtain critical safety parameters in real time and perform video liaison and consequence assessment; a national level and over 20 provincial level nuclear and radiation emergency monitoring and dispatching platform systems have been established, making it possible to obtain in real-time the data from national radiation environment automatic monitoring network, to allocate and dispatch radiation emergency monitoring forces through overall planning, and to make video liaison; and two national level radiation environment monitoring laboratories have been completed.

16.7.2 Development of Capacity for NPP to Cope with Severe Accidents

To raise the emergency preparedness and response capacity of NPPs, the MEP (NNSA) has taken corresponding improvement measures, especially, after the Fukushima nuclear accident, the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident* was issued, setting specific requirements on improvement measures for NPPs to raise their capacity to deal with severe accidents. The improvement actions implemented by NPP operating organizations include: additional portable power supplies and portable pumps for all plants, with at least two sets of portable pumps and portable power supplies for a multi-unit site, and with additional elevated diesel generator set; the anti-seismic evaluation, upgrading renovation and consolidation of nuclear accident emergency commanding center; the radiation emergency monitoring forces of NPPs have been strengthened, including the additional emergency portable monitoring vehicles and on-board equipment, tear drop emergency continuous real-time monitoring equipment, and densifying the land area distribution of radiation environment automatic monitoring stations; the nuclear accident marine area monitoring and consequence assessment system was researched and developed; the NPP nuclear accident emergency exercise scenario library was developed and applied, so that emergency exercises can be better inspected, more practical and effective; and the emergency response plan for simultaneous accident condition of two units on a multi-unit site has been worked out.

16.7.3 Construction of Nuclear Emergency Support System

To deal with possible severe nuclear accidents, achieve rapid response and effective handling of accident, and meet the relevant requirements in the IAEA nuclear safety action plan on strengthening emergency preparedness and response, China has formed a national nuclear emergency rescue team of over 300 people with the existing capacity as the backup, mainly to undertake rush rescue and emergency treatment tasks for severe and major nuclear accidents under complicated conditions, and it can also participate in international nuclear emergency rescue actions. To meet the needs in the layout of NPP construction, over 30 national level professional rescue detachments have been built up in the principles of regional deployment, modular setup and professional association, to undertake various professional rescue tasks in nuclear accident emergency treatment.

In 2014, with the guidance by the MEP (NNSA), and according to *General Requirements on the Buildup of Site Rapid Rescue Teams for Nuclear Accidents Emergency in NPP for Nuclear Group Corporation* and *Technical Requirements on the Buildup of Site Rapid Rescue Teams for Nuclear Accidents Emergency in NPP for Nuclear Group Corporation (for trial implementation)*, all nuclear power group corporations organized nuclear emergency support teams and nuclear emergency support bases, built up professional emergency support forces, forming the practical responding and supporting capacity, and initially realizing the capacity and mechanism able to cope with severe nuclear accidents like that of Fukushima. The nuclear power group corporations jointly signed the *NPP Nuclear Accident Emergency On-site Support Cooperation Agreement of Nuclear Power Group Corporations*, and established the mutual support collaboration mechanism between groups. The rescue teams of nuclear power groups will implement on-site emergency rescue missions and undertake rapid support between nuclear power groups in case of severe nuclear accident in a NPP, to mitigate and control accident conditions, rush repair and restoration of buildings and critical equipment, core diagnosis and assessment, critical emergency position substitution and supplement. All neighboring NPPs have also signed mutual support agreement, prepared mutual support action plans and established nearby rapid mutual support mechanism. China has basically realized the objectives of joint buildup of nuclear accident emergency capacity and emergency resources sharing among all NPPs in the whole country, and further completed the emergency support system.

16.8 International Arrangements for Nuclear Accidents Emergency

China is a member country of the IAEA, and is always endeavoring to establish the international nuclear safety emergency system together with all countries, promote all countries to share the results of peaceful utilization of nuclear energy, and unswervingly support and promote international cooperation and exchange in the nuclear emergency field. China carries out multi-level and all-round cooperation in the nuclear emergency field with IAEA and other international organizations, and keeps on expanding the cooperation and exchange with relevant nuclear countries in the world in the nuclear emergency field. In the meantime, China has maintained an honest and open attitude to carry out cooperation and exchange with surrounding countries on nuclear emergency.

China supports the IAEA in playing its dominating role in fields of promoting the application of nuclear energy and nuclear technologies, strengthening nuclear safety and nuclear emergency, and implementing safeguarding and supervision. China actively performs the international obligations specified in international conventions such as *Convention on Early Notification of a Nuclear Accident* and *Convention on Assistance in the case of Nuclear Accident or Radiological Emergency*, and responds to all advocates proposed by the IAEA Council and Conference. The Chinese delegation attended all nuclear emergency authority conferences organized by the IAEA. China has participated in a number of convention exercises activities organized by the IAEA. Experts and scholars in the nuclear emergency field of China have been recommended to participate in the work carried out by the IAEA for hundreds of person-times.

China actively carries out bilateral cooperation and exchange in nuclear emergency field. China has signed bilateral nuclear energy cooperation agreement with 30 countries including Brazil, Argentina, the UK, the US, Korea, Russia and France, to carry out cooperation and exchange including nuclear emergency. In the framework of Sino-US Agreement on Peaceful Utilization of Nuclear Energy, the CAEA and the DOE have jointly carried out a number of training activities such as nuclear emergency medical rescue training session and nuclear emergency consequence assessment symposium. Within the framework of regular meetings of China-Russia premiers, the China-Russia Nuclear Issue Subcommittee mechanism was set up, to study and discuss regularly issues on cooperation and exchange in the nuclear emergency field. China has established China-France nuclear energy cooperation coordination committee mechanism with France, and China-Korea nuclear energy cooperation joint committee mechanism with Korea, to carry out relevant activities regularly. China has aided Pakistan in building a NPP, and carried out extensive cooperation and exchange in the nuclear emergency field.

China actively develops multi-lateral cooperation, adheres to the principle of win-win cooperation, and carries out cooperation and exchange in nuclear emergency field with all countries. In July 2014, China held in Fujian Province the Asia-Pacific Region training session on *Nuclear Emergency Preparedness and Response under Severe Nuclear Accidents*, providing an exchange platform for experts from 11 countries and regions; in Oct. 2015, at the first Global Nuclear Emergency and Response Conference, China presented its nuclear emergency policies, and shared with over 90 attending countries and more than 10 international organizations its achievements on nuclear emergency preparedness and response. China plays an active role in regional cooperation and exchange via the mechanisms such as Asia Nuclear Safety Network, Asia Nuclear Cooperation Forum, and Asia-Pacific Region Nuclear Technology Cooperation Protocol. China officially joined the radiation emergency medical preparedness and rescue network of WHO in Jan. 2004. China has continually sponsored international academic exchange activities in nuclear emergency field. China, Japan and Korea established nuclear accident early notification framework and expert exchange mechanism, to carry out cooperation and exchange in relevant fields. In May 2014, China joined the *International Nuclear Emergency Response and Aid Network*, to provide support to the international society on construction of nuclear emergency system.

Since the Fukushima nuclear accident, the governmental departments, enterprises and institutions, colleges and universities and scientific research institutes of China cooperated with international organizations in various forms, to summarize and explore on major issues in the nuclear emergency field in the post-Fukushima era. These cooperation and exchange activities not only promoted improvement and upgrading of nuclear emergency in China, but also promoted operating experience by the international society on the Fukushima nuclear accident. The nuclear safety regulatory bodies of China, Japan and Korea established the China-Japan-Korea Senior Officials Meeting mechanism on nuclear safety supervision since 2008, in the China-Japan-Korea Nuclear Safety Cooperation Proposal signed in 2011, the establishment of information exchange framework (IEF) and strengthening emergency response capacity were listed as action items. In Nov. 2013, the Sixth China-Japan-Korea Senior Officials Meeting on Nuclear Safety Supervision adopted the implementation plan for nuclear safety cooperation actions of the three countries, strengthening the information exchange and sharing on NPP supervision, also any party can participate as observer in the emergency exercise activities conducted by the other two parties, indicating that the three countries endeavored with a pragmatic attitude to carry out prior actions in the two fields of information exchange and emergency response capacity development and cooperation.

On June 26, 2015, France, Pakistan and the IAEA dispatched officials and experts to view and emulate the "Shendun-2015" nuclear accident emergency joint exercise held in China, for this exercise, notification was made to the IAEA according to the *Convention on Early Notification of a Nuclear Accident*.

17. Siting

> Each Contracting Party shall take appropriate steps to ensure that appropriate procedures are established and implemented:
>
> (i) for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;
>
> (ii) for evaluating the possible safety impact of a proposed nuclear installation on individuals, society and the environment;
>
> (iii) for re-evaluating as necessary all relevant factors referred to in sub-paragraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installation;
>
> (iv) for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the possible safety impact on their own territory of the nuclear installation.

17.1 Evaluation on site-related factors

There are altogether 13 NPP sites in operation and under construction in China mainland, all located in coastal areas. Siting of most of these NPPs were started from the end of the last century, and the siting procedures and external event evaluation were all as required in the nuclear safety codes, and reviewed and confirmed by the MEP (NNSA).

17.1.1 Regulations and Requirements on NPP Siting

China takes the relevant codes and standards of IAEA as the basic criteria for siting assessment at all times. The nuclear power construction in China was started late, therefore for the codes and standards on nuclear power siting and on siting assessment, China can better learn the international experience, the corresponding siting codes and standards can be more complete, and meet the regulatory demand in China in the present stage, the siting requirements can be strictly implemented. In the meantime, in conjunction with the revision of relevant IAEA codes and the experience accumulated by China on NPP siting assessment in recent years, China has revised the code requirements on NPP siting at appropriate time.

Currently, the main codes applicable to the siting for NPPs are as follows: *Application and Issuance of Safety Licenses for Nuclear Power Plant*, *Codes on Safety of Nuclear Power Plant Siting*, *Earthquake Related Issues in Nuclear Power Plant Siting*, *Population Distribution Related Issues in Nuclear Power Plant Siting and Evaluation*, *External Human-induced Events in Nuclear Power Plant Siting*, *Extreme Meteorological Phenomenon in Nuclear Power Plant Sitting*, *Determination of Design Basis Flooding for Nuclear Power Plants on River Sites*, *Determination of Design Basis Flooding for Nuclear Power Plants on Coastal Sites*, *Foundation Safety of Nuclear Power Plants*, *Atmospheric Dispersion Related Issues in Nuclear Power Plant Siting*, *Hydrological Dispersion of Radioactive Material in Nuclear Power Plant Sitting*, *Relationship between Nuclear Power Plant Siting and Hydrogeology*, *Site Survey for Nuclear Power Plants*, *Design Basis of Tropical Cyclone for Nuclear Power Plants* and so on.

17.1.2 Assessment Criteria and Assessment of Site-related Factors

The siting for NPPs in China is based on the requirements in the *Code on Safety of Nuclear Power Plant Siting*. The following factors must be taken into considerations in the assessment of a site for its suitability to NPP.

(1) Effects of possible external events induced either by natural disasters or human elements on NPPs in the region of a particular site.

(2) Characteristics of the site and its environment which could influence the transfer of released radioactive substance to human body.

(3) Density and distribution of the population and other characteristics in the external zone which could affect the possibility of implementing emergency response actions and could be needed to evaluate the risks to individuals and to the population.

The general assessment criteria include:

(1) The site characteristics that could affect the NPP safety shall be investigated and assessed. The regional environmental characteristics that may possibly be affected by radiation consequences under operation and accident conditions shall be investigated. All these characteristics shall be observed and monitored throughout the whole lifetime of the NPP.

(2) The safety of the recommended NPP site shall be reviewed on the basis of the occurring frequency and severity of natural events and external human events and various phenomena affecting the safety of the NPP.

(3) The natural factors and human factors affecting the NPP safety in the area where the NPP is located shall be assessed for predictable evolution in the expected lifetime, and these factors must also be monitored throughout the whole lifetime of the NPP, especially the population growth rate and the population distribution characteristics. If necessary, appropriate measures shall be taken to ensure that the total risks are maintained at an acceptable low level.

(4) Overall consideration shall be taken for the recommended site and for the nuclear power plant to determine its design basis external events. All external events related to major radiation risks shall be selected for consideration, and their design basis shall be determined.

(5) The design basis related to external events used in NPP design shall be determined. For an external event (or combination of events), the design basis parameter values for the NPP shall be so selected to ensure that the structures, systems and components important to safety related to such event (or combination of events) can maintain their integrity without losing their functions at the time of or after the occurrence of a design basis event.

(6) After an overall assessment of the site, if it is proved that the recommended measures cannot provide sufficient protection against the damage resulted from design basis external events, it shall be concluded that it is not suitable to build the recommended NPP on such a site.

(7) In determining the design basis of relevant external events, their combination with the surrounding conditions (such as hydrological, hydrogeological and meteorological conditions) shall be taken into consideration. And the operation status of reactor shall also be taken into consideration.

(8) The design basis related to site shall be assessed, and be included into the

application documents for review by national nuclear safety authority. The construction of relevant parts of the NPP can be started only after these design basis have been approved by the national nuclear safety authority. In case of any dispute on the design basis related to such a site and it is not possible to actually provide sufficient protective provisions, therefore such a site has been determined as inappropriate, the construction of the NPP can be started only after such issues with dispute have been settled.

(9) The results of investigation and researches shall be documented in detail, for independent review by the national nuclear safety authority.

(10) When a selected site is analyzed for suitability, issues of storage and transportation of new fuel, spent fuel and radioactive wastes shall be taken into consideration.

(11) The possibility of interaction between radioactive effluents and non-radioactive effluents shall be taken into consideration. For example, the interaction of hot or chemical substances with radioactive materials in liquid effluents.

(12) For each recommended site, consideration shall also be taken for factors including the population distribution, diet habit, land and water utilization， including the site and the radiation effect produced by other radiological releases in the area, to assess the radiation effect that the NPP may bring under the operation and accident conditions (including those accident conditions that may lead to the need to adopt emergency actions) on the residents in the area where the site is located.

(13) The total installed capacity of the site shall be determined as far as possible in the first phase of siting process. If it is necessary to increase the total nuclear power installed capacity above the originally approved level, the suitability of that site shall be re-evaluated.

(14) The quality assurance program shall be implemented for all activities that may influence the safety and performed to determine the site design basis parameters. The quality assurance program can be implemented according to relevant stipulations.

During the siting for NPPs in China, natural factors affecting the safety of NPPs are investigated and assessed in detail, and the engineering design basis are determined according to the investigation results and the related safety requirements. According to the siting investigation and assessment for NPPs in China, the natural factors affecting the NPP safety mainly include earthquake, ground foundation stability, side slope stability, strong wind, flood (including storm surge produced by a tropical cyclone and flood produced by extreme precipitation), tornado and other extreme natural disasters and the possible combination of disasters.

During the siting for NPPs in China, investigations are made for the potential sources of external human-induced events that may affect the NPP safety, such as aircraft crashes, external explosions, storage and transport of toxic chemicals, dangerous gas clouds and fire. The investigation and assessment results for the current NPP sites show that, these factors constitute no impact on the safety of current NPP sites in China, therefore they are not taken into consideration as external event design basis in the design of NPPs,. For the possible collision of transport vessels to the water intake in navigation channels close to the NPP and the possible spillage of corrosive liquid and oil, it is fully possible to limit their affect to the nuclear power plant safety within the acceptable range by taking appropriate engineering provisions.

In the selection of NPP sites, as required by relevant regulations, the MEP (NNSA) requires that non-residence and planning restricted zones shall be set up around a NPP, to take into full account the possible effect of external human-induced event sources in the development planning for site area, and to control the future human activities in the area during the lifetime of the NPP.

In the siting for NPPs in China, the implement ability of offsite emergency plan is justified considering the current and expected environmental characteristics in the surrounding areas of the site. Meanwhile, China has established the nuclear emergency management system with hierarchic responsibilities, completed 3 national level nuclear emergency training bases, established over 30 national level professional rescue detachments and formed a national emergency rescue team with over 300 people, and made planning and deployment for rush rescue and emergency missions for major and extra nuclear accidents under complicated conditions. The nuclear emergency mutual support and cooperation mechanism has been established between nuclear power group corporations, and neighboring NPPs have signed agreements on mutual support.

17.1.3 Criteria for Defining Effects of External Events

17.1.3.1 Criteria of Defining Design Basis for External Natural Events

(1) Recommended sites shall be investigated and studied adequately with respect to all site characteristics that could affect safety in relation to design basis natural events.

(2) The internal and external natural events in the site area shall be classified according to the extent of their effects on the safe operation of NPP, to determine those significant natural phenomena that shall be considered in the NPP design basis.

(3) Historical records of the occurrences and severity of the significant natural phenomena mentioned above in the region of the site shall be collected and carefully analyzed for their reliability, accuracy and completeness.

(4) Appropriate methods shall be adopted to establish the design basis for protection against these significant natural phenomena. The methods should be proved to be compatible with the characteristics of the region of the site and the current state-of-art technology.

(5) The scope of the area to be studied in determining design basis natural events shall be large enough to cover all the characteristics and areas which could contribute to the determination of the design basis natural events and their effects.

(6) The assessment of NPP design basis shall be made on the basis of the site specific data, if such data are not available; the applicable data from other regions similar to that where the site is located may be used.

17.1.3.2 Criteria for Defining Design Basis for External Human-induced Events

(1) Recommended sites shall be adequately investigated and studied with respect to all site characteristics that could affect safety in relation to design basis external human-induced events.

(2) All facilities and human activities that could endanger the NPP safety in the area where the NPP site is located shall be identified, and classified according to the severity of their effects on safety, so as to determine the important human-induced events to be used for design basis.

(3) Information concerning the frequency and severity of those important human-induced events shall be collected and analyzed for their reliability, accuracy and completeness.

(4) Appropriate method shall be adopted to define design basis human-induced events. The method should be compatible with the characteristics of the site area and the current state-of-the-art technology.

17.1.4 Regulatory Review and Control Activities

According to the national nuclear safety guides, the period of siting are divided into three phases, i.e. site survey, site assessment and pre-operation phases. The site survey phase roughly consists of three steps: in step I, regional analysis is made to find out possible sites; in step II, the possible sites are screened to select the candidate sites; and in step III, the candidate sites are compared and ranked in the preference order to get the prior candidate sites. In the site assessment phase, more detailed assessment is made for the recommended prior sites, and the main tasks include: first, proving the suitability of the site from the safety point of view; second, determining the design basis related to the site. The *Codes on the Safety of Nuclear Power Plant Siting* and its affiliated series of guides are determined mainly for the site assessment phase. The MEP (NNSA), after review and confirmation of the safety analysis report for site and the environmental impact assessment report for the siting phase, issues the *Review Comments on siting of Nuclear Power Plant*, which is the prerequisite for the approval of the project.

It is specified in the *Regulations on the Safety Regulation for Civilian Nuclear Installations* and its detailed rules of implementation that before the feasibility study report of a NPP is approved by the state, the applicant for NPP construction must obtain the *Review Comments on siting of NPP* from the MEP (NNSA); and must submit to the MEP (NNSA) the documents about site safety in the *Feasibility Study Report for Nuclear Power Plant* six months before the determination of NPP site. From 2013 to 2015, the MEP (NNSA) approved the review comments on site selection and the environmental impact assessment report for 4 sites, including: the CAP1400 demonstration project, Unit 1 and 2 of Xudabao NPP, Unit 3 and 4 of Haiyang NPP and Unit 1 and 2 of Lufeng NPP respectively.

17.1.5 Screening of NPP Sites in China

The MEP (NNSA) has performed assessment for all potential NPP sites in China on three aspects of nuclear safety, environmental protection, regional planning and environmental zonation, by using two technical frameworks of "grading" and "classification". The construction of the assessment indicator system has taken into account the codes and standards of China on siting for NPPs, in conjunction with the practical questions raised in the selection of NPP sites in China.

The specific steps of assessment include:

(1) Determining the influence factors to be considered, including nuclear safety, environmental protection, regional and energy development planning and environmental functional zoning compatibility.

(2) Determining the grading indicators for all influence factors. The relevant influence factors are graded into I, II, III and IV according to their properties and magnitude. This process is the assessment of the considered influence factors, referred to as the "grading" assessment.

(3) The sites assessed are classified into I, II, III and IV with overall consideration of the "grading" assessment results of all influence factors. This process is the classification of sites based on overall consideration of the grading assessment results of all influence factors, referred to as "classification" assessment. For site classification, the site grading assessment results are taken as the main technical basis, without considering the "weight" of influence factors, and only the classes of sites are given. If the grading assessment result of an influence factor of a site is IV, no grading assessment will be made for other influence factors of that site, and this site is directly classified as a class IV site.

Class I sites are those with good compatibility with regional planning and environmental function zoning, and also with good characteristics on nuclear safety and environmental protection, as the "best" sites relatively; while class IV sites have outstanding defects in some aspects of compatibility with regional planning and environmental function zoning, nuclear safety and environmental protection, for such sites, special attention should be paid in site review or approval, and relatively regard them as the "worst" sites.

17.2 Effect of NPP on People, the Society and Environment

In the siting phase, the NPP license applicants of China, according to the requirements in the *Codes on Safety of Nuclear Power Plant Siting*, perform assessment on the possible effect of the proposed NPP on individuals, the society and environment and the feasibility of implementing emergency plans.

17.2.1 Criteria for Defining Potential Impact of NPP on Residents and Environment

17.2.1.1 Criteria for Defining Potential Impact of NPP on the Region

(1) In assessing the radiation impact on the site area from the NPP under operating condition and accident condition that may need emergency measures to be taken, appropriate estimates must be made for the potential releases of radioactive substances and its impact after taking into account the design of the plant and its safety features, and the radiation source terms used for site assessment shall be properly determined.

(2) In the evaluation of the direct or indirect path by which radioactive substances released from the NPP could affect the people, abnormal characteristics of the region and site shall be taken into account, and special attention shall be paid to the role of the biosphere in accumulation and transport of radioactive nuclides.

(3) The relationship between the site and the NPP design shall be examined comprehensively, to ensure that the radiation risks to the public and the environment arising from the radioactive substance releases determined by the source terms is lowered to an acceptable level.

(4) The design of the NPP must be able to compensate for any unacceptable effects on the region where the NPP is located, otherwise the site shall be deemed as unsuitable.

17.2.1.2 Criteria for Considering Population Factor and Emergency Plan

(1) The population distribution characteristics and utilization of land and water in the site area at present and in the predictable future must be assessed, and any specific characteristics that could influence the potential consequences of radiological

releases to individuals and groups shall be taken into consideration.

(2) With respect to characteristics and distribution of the population, the site and plant combination must satisfy the following:

— The radioactive exposure to the residents shall be kept at a level as low as reasonably achievable under operating conditions, at least within national limits in any cases.

— The radiation risk to the residents shall be acceptably low under accident conditions, including those which may lead to taking emergency measures, at least within national limits.

After an overall assessment of the site, if it is proved that no appropriate measure can be taken to meet the above requirements, the site is then deemed unsuitable for the construction of the proposed NPP.

(3) A peripheral zone (planned restricted zones) around a recommended site shall be established in view of the potential radiation consequences to the public and the capability of implementing emergency plans, as well as any effect of external events which may hinder the implementation of emergency plan. In site assessment, it shall be proved that no fundamental problem exists in the peripheral zone of the NPP that will hinder the formulation of emergency plan, and the feasibility of implementing such emergency plan shall be justified.

17.2.1.3 Non-residence zone and planned restricted zone

A non-residence zone is an area with a certain range around the reactor, in which permanent residents are strictly prohibited, the NPP operating organization exercises effective control over the area, including the withdrawal of any individual and property from it. Highway, railway and water way may pass through the area, provided that they must not interfere with the normal operation of the NPP. Under accident conditions, appropriate and effective arrangement can be made to control the traffic, to ensure the safety of working personnel and residents. In a non-residence zone, activities not related to the operation of the NPP are permissible, provided that they do not affect the normal operation of the NPP and endanger the health and safety of residents.

A planned restricted zone refers to an area confirmed by a provincial level people's government and directly neighboring with the non-residence zone. Within the planned restricted zone, the mechanical growth of population must be restricted, and projects to be new built or expanded in this area shall be guided or restricted, to take into account the possibility to take appropriate protective measures in case of accident emergency status.

According to the provisions of the *Law of the People's Republic of China on Prevention and Control of Radioactive Pollution*, the surrounding areas of important nuclear installations such as NPP shall be delimited as restricted areas. The delimitation and management measures of the planned restricted areas are specified by the State Council. Planned restricted areas are delimited for all NPPs in China.

The *Regulation on the Environmental Radiation Protection of Nuclear Power Plant* requires that non-residence zone and planned restricted zones must be delimited around NPPs. The boundaries of non-residence zones and planned restricted zones shall be determined by taking into account the radiological consequences of postulated accidents for siting, non-residence zones are not required to be circular, and can be determined according to the specific conditions of the landform, topography, meteorology and traffic of the site, provided that the distance of the non-residence zone boundary to the reactor must be no less than 500m; the radius of a planned restricted zones must be no less than 5km. There shall be no township or town with a population over 10,000 within a planned restricted zone, and no city or town with a population over 100,000 within a radius of 10km from the site. For a multi-reactor site, the boundaries of the non-residence zone and planned restricted zone shall be determined by taking into comprehensive account of the characteristics of all reactors. In case of a postulated accident for siting, taking into account conservative atmospheric dispersion conditions, the effective dose received by any individual on the boundary of non-residence zone within any 2h after the occurrence of accident through smoke cloud immersion external exposure and inhalation internal exposure must not exceed 0.25Sv; and the effective dose received by any individual on the boundary of the planned restricted zone during the entire duration of the accident (it can be taken as 30 days) via the above-mentioned two exposure paths must not exceed 0.25Sv. During the entire duration of the accident, the collective effective dose received by the public groups within a radius of 80km from the site via the above-mentioned two exposure paths shall be less than 2×10^4 man·Sv.

17.2.2 Implementation of Criteria for Potential Impact of NPP on Residents and Environment

During NPP siting in China, the risks imposed by the potential releases of radioactive substances to the surrounding environment and the residents have been adequately considered, and the possible pathways leading to the risks have been studied and controlled.

Factors such as the dispersion of radioactive substances in the atmosphere, in the surface water and the ground water, the population distribution, the utilization of land and water, etc. have been extensively investigated, periodically observed, studied and analyzed by using the computerized models, so as to effectively control the radiation risks caused by the potential radioactive releases to the surrounding environment and residents.

According to the requirements of the nuclear safety guides related to NPP siting, NPP operating organizations perform monitoring and assessment for factors affecting the site safety of a NPP, such as seismic, meteorological, hydrological and geological phenomena, to ensure the safety of NPPs.

China has meteorological, hydrological and seismic observation stations and networks with fairly complete coverage, NPP operating organizations can timely know the changes of relevant natural elements in the areas where the NPPs are located with the observation data of nearby stations. The *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident* has further emphasized on coping with external natural disasters that NPPs shall establish cooperation relationship with meteorological and oceanological departments, to ensure obtaining forecast information in a rapid, accurate and timely manner; it also further emphasized that NPPs shall strengthen communication with seismological departments, to obtain the latest data promptly, to evaluate the suitability of the seismic capacity of NPPs.

17.3 Re-assessment of Site-related Factors

17.3.1 Re-assessment of Site-related Factors after Siting

The relevant nuclear safety codes of China have set clear requirements on factors to be assessed in the siting for NPPs. The MEP (NNSA) will perform overall re-examination in the review and approval of licensing documents in different phases after siting (application for construction permit, the licensing phase for the First fuel loading and the licensing for operation), and re-assessment work shall be carried out in the Periodic Safety Review performed every ten years.

The safety analysis reports analyze and justify the reliability and safety of NPP design, and the conditions of safety provisions provided by NPPs to protect the site personnel, the public and the environment from excessive radiation hazards. Chapter II of the safety analysis report describes the geological, seismic, hydrological and meteorological information and data about the NPP site and its nearby areas, the presently planned population distribution, use of land and the activities on the site and their management methods, and assesses and justifies how the site characteristics affect the NPP design and operation criteria, to verify the suitability of site characteristics from the safety point of view. In the preparatory phase before the construction, the NPP operating organization must submit to the MEP (NNSA) the *Preliminary Safety Analysis Report of Nuclear Power Plant* (PSAR), to describe the design principles of the NPP and if the plant can operate safely after its completion, including the preliminary description and analysis of site characteristics. Before the First fuel loading of the NPP, the operating organization must submit to the MEP (NNSA) the *Final Safety Analysis Report* (FSAR), which shall include supplement to the updated documents related to site characteristics, and the re-assessment on how the site characteristics will affect the NPP design and operation criteria.

The *Code on the Safety of the Nuclear Power Plant Operation* clearly specifies that Periodic Safety Review must be performed for systematic re-assessment of NPPs, and the NPPs in China perform a Periodic Safety Review every ten years. The objective of this safety review is to perform a comprehensive review of the actual status of the NPP according to the current nuclear safety standards and practice, to examine if it meets the current nuclear safety requirements. Problems (deviations) identified in the review are analyzed and assessed, to determine how corrective actions will be taken to ensure that the NPP maintain a high nuclear safety level at all times in its subsequent operation lifetime. Disaster analysis is an important element taken into consideration in the ten-year safety review, by which the changes of site characteristics resulted from changes of external environment are analyzed on the basis of the assessment of previous operation historical records of the operating NPP, to determine the capability of the NPP to defend internal and external disasters, including flood (and tsunami), strong wind, extreme air temperature, earthquake, aircraft crash, poison gas and explosion.

17.3.2 Re-assessment after a Significant Accident or Extreme Event

After the Fukushima Accident, the MEP (NNSA) conducted comprehensive safety inspection on NPPs in operation and under construction in China jointly with relevant ministries and commissions. According to the *Implementation Programme on the Comprehensive Safety Inspection on Civilian Nuclear Facilities*, the emphasis was laid on rechecking and evaluating the appropriateness of evaluated external event during siting, as well as the prevention and mitigation measures for flood prevention ability and plans of NPPs, and the anti-seismic capacity and plans of NPPs in this inspection.

It was concluded after the inspection that, as nuclear power construction in China mainland was started late, the IAEA codes and standards were adopted as the assessment basis for NPP siting, and international practical experience has been extensively learned and implemented conscientiously in NPP siting. Therefore, the assessment on extreme external event during siting is appropriate and can meet relevant requirements of current nuclear safety codes and the latest international standards. Refer to Chapter 1 and Chapter 2 in the *National Report of the PRC on Second Extraordinary Meeting under the Convention on Nuclear Safety* for details.

After the Fukushima nuclear accident, the MEP (NNSA) formulated targeted inspection procedures, with emphasis laid on eleven aspects of the suitability of external events evaluated in siting, the evaluation of anti-flooding plans and capacity of nuclear installations, and the evaluation of nuclear installation anti-seismic plans and site anti-seismic capacity.

According to the conclusions of comprehensive safety inspection, the MEP (NNSA) put forth the post-Fukushima nuclear safety improvement technical requirements for all civilian nuclear installations, and all NPPs have completed them as required. The improvements related to site include:

(1) Evaluation of safety margins for external events

All NPPs have implemented and completed the safety margin evaluation work in case of extreme external events according to the unified requirements (similar to the pressure test for NPPs implemented in the EU), confirming that the units in all operating NPPs have fair capacity to cope with beyond design basis external events, and safety can be guaranteed.

(2) Increasing the anti-flooding capacity of NPPs

All NPPs in operation and under construction were combed and checked about all factors that could induce flooding events according to their site conditions, and rechecked the effectiveness of the design basis flood level adopted in the original designs. In the recheck, operating NPPs took into account the latest analysis data and the factors such as changes in the surround environment of the site. The appropriate beyond design basis flooding scenario (such as design basis flood level superposed with precipitation with a return period of 1000 years) according to their site conditions, to recheck the flood discharge capacity of the plant area and evaluate the blocked water depth in the plant area. According to the evaluation result, anti-flooding provisions were made on ground, to prevent blocked water in the plant area from entering safety important buildings uncontrollable. Overall checks were made for passages such as underground pipe galleries connected with safety important buildings, with emphasis on underground pipe galleries and rooms that, if flooded, could lead to failure of the three major safety functions of the plant, and provisions against underground flooding were adopted according to actual conditions. It is required to ensure that at least one residual heat removal safety train is available under the specified flooding scenario and before the connection of emergency water makeup capacity.

All NPPs in operation and under construction have been carried out special technical research on underground anti-flooding provisions according to the above principles, and implemented effective underground anti-flooding provisions for penetrating sections. Permanent water-proof plugging or temporary anti-flooding provisions were implemented for both ground and underground flooding defending, and appropriate procedures were established to guide the use of temporary provisions.

For the anti-flooding project at Qinshan NPP, site construction was started in Dec. 2102, and the project was all completed at the end of 2013; Qinshan NPP and other coastal NPPs all carried out flood risk evaluation after the Fukushima nuclear accident. And plugging matures were adopted to prevent external flooding, in order to further increase the anti-flooding capacity and safety margin of the plants.

(3) In-depth assessment of earthquake and tsunami risks

After the Fukushima nuclear accident, the MEP (NNSA), together with the National Energy Administration, China Earthquake Administration, oceanologic departments and other organizations, carried out new assessment with more conservative approach for the Manila Trench and Ryukyu Trench that might produce earthquake tsunami threat to NPPs of China. The preliminary assessment results showed that the main source of possible earthquake and tsunami threat is Manila Trench, a conservative assumption is that the maximum possible earthquake in Manila Trench could be M8.8, the tsunami triggered by it could affect the NPPs on the coast of Guangdong, and the maximum tsunami wave height offshore near Daya Bay NPP could be about 2.7m. For this tsunami evaluation result, Daya Bay NPP carried out detailed numerical model computation and physical model test, and further confirmed that the potential earthquake tsunami risk will not affect the operation safety of nuclear power units at Daya Bay Site.

(4) Increasing the capability of NPPs to cope with severe accidents

For nuclear power units under construction, the main improvement items implemented before the First fuel loading include: anti-flooding improvement for nuclear safety related buildings and equipment, adding facilities such as portable power sources and pumps, increasing the seismic monitoring and anti-seismic response capacity of plants, improving SAMG for NPPs, in-depth assessment of earthquake and tsunami risks and probabilistic safety analysis for external events, completing emergency plan and increasing emergency response capacity to nuclear accidents, preparing and completing information release procedures of NPPs, completing the anti-disaster plans and management procedures, etc. After the Fukushima nuclear accident, operating nuclear power units completed the improvements in 2013, and units with the First fuel loading have also completed improvements on schedule.

According to the requirements of the MEP (NNSA), NPPs both under construction and in operation must establish and complete their emergency plans. In the event of any extreme natural event affecting a given site, the NPP operating organization and associated design institute shall make timely recheck and evaluation of the relevant design basis.

The MEP (NNSA) organized relevant professional technical personnel to carry out a number of rechecks and evaluations of design basis with respect to sudden extreme natural events, and completed several investigation and evaluation reports, including the *Investigation and Evaluation of Effect of Typhoon Rammasun on Relevant Nuclear Power Plants* (2014), *Effect of Typhoon Mujigea and its Associated Tornado on Relevant Nuclear Power Plants* (2015) and *Effect of "Century Cold Wave" at the Beginning of 2016 on Nuclear Power Plants in China* (2016). The results of the reports showed that all the extreme natural events mentioned above can be enveloped by the design bases of relevant NPPs; the relevant design bases for NPPs in China have taken rational values, also with fair safety margin.

17.4 Consultation with Other Contracting Parties Possibly Influenced by NPPs

NPPs of China are mainly distributed in the coastal areas in the east and south. For plant sites close to the border, China consulted with relevant countries to solve the cross-border influence of potential nuclear accidents and issues of nuclear emergency field possibly involved via bilateral or multilateral cooperation in accordance with relevant requirements of the signed *Convention on Early Notification of a Nuclear Accident*, *Convention on Assistance in the case of Nuclear Accident or Radiological Emergency* and *Convention on Nuclear Safety*.

China has established China-Japan-Korea regional nuclear safety regulation high official meeting mechanism with Japan and Korea, and signed the "China, Japan and ROK Initiative on Nuclear Safety Cooperation", determining to establish cooperation framework and undertaking to carry out cooperation actions in fields of regional nuclear safety standards, regional emergency response mechanism and regulatory capacity.

China continues its close cooperation with the IAEA, and takes an active part in the activities of the MDEP Steering Committee and all working groups under it in the framework of OECD/NEA; China continually deepens the bilateral cooperation with developed nuclear power countries, strengthens the development of nuclear safety regulation capability and actively carries out cooperation with developing nuclear power countries, China has signed bilateral nuclear safety cooperation agreement or memorandums with the nuclear safety regulatory bodies of neighboring countries including Japan, Korea and Pakistan.

China has set up radiation environment automatic monitoring stations in key cities, and arranged monitoring stations for atmospheric environment, marine environment, land water design, soil, living organism and electromagnetic radiation around NPPs, for real-time continuous monitoring, and the radiation environment quality and radiation monitoring data of operating NPPs are released to the public periodically, to enable neighboring countries to promptly get information and raise the regional nuclear safety emergency response capability.

18. Design and Construction

Each Contracting Party shall take the appropriate steps to ensure that:

(i) The design and construction of a nuclear installation provides for several reliable levels and methods of protection (defense in depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur;

(ii) The technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;

(iii) The design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the human-machine interface.

18.1 Implementation of Defense in Depth

18.1.1 Regulations and Requirements for the Design and Construction of NPPs

18.1.1.1 Regulations and Requirements for the Design of NPPs

By reference to the corresponding nuclear safety standards of the IAEA and other relevant national standards, the *Code on the Safety of the Nuclear Power Plant Design* and a series of guides related to NPP design have been formulated by the MEP (NNSA). After the Fukushima nuclear accident, the MEP (NNSA) put forth higher safety objectives and requirements for new NPPs, to guide the relevant nuclear safety activities of siting, design and construction and the associated review and inspection activities for new NPPs.

In the review of the design of imported NPPs, the MEP (NNSA) requires the applicant for the *Nuclear Power Plant Construction Permit* shall illustrate that the standards and specifications to be used comply with the requirements of the nuclear safety codes and guides of China. For such standards and specifications not available in China, the standards and specifications adopted should be approved by the MEP (NNSA).

The safety of NPP relies on the guarantee of three fundamental safety functions (reactivity control, residual heat removal, and the confinement of radioactivity). The defense in depth concept is helpful to performing these three fundamental safety functions, and is conducible to protecting the general public and the environment from radioactive hazard.

The MEP (NNSA) revised the *Code on the Safety of the Nuclear Power Plant Design* and issued it for implementation in April of 2004. This regulation has clearly specified the safety objectives, safety management requirements, technical requirements and design requirements for the design of NPPs.

(1) The nuclear safety objectives in the *Code on the Safety of the Nuclear Power Plant Design*

To protect individuals, society and the environment from harm by establishing and maintaining in NPPs effective defenses against radiological hazards. The general nuclear safety objective is supported by two complementary safety objectives dealing with radiation protection and technical aspects. They are interdependent: the technical aspects in conjunction with administrative and procedural measures ensure defense against hazards due to ionizing radiation

For NPPs in China, the concept of defense in depth has been carried out in the entire design, and all reasonable and feasible technologies and management means have been adopted to guarantee the effectiveness of all defensive measure for NPPs and the integrality of multiple barriers to prevent occurrence of nuclear accidents and mitigate their consequences should they occur. They are mainly embodied in the following aspects:

— Providing multiple physical barriers to prevent the radioactive substance from releasing to the environment without control.

— NPPs are designed conservatively and constructed and operated with high quality, to minimize the possibility of failure and abnormal operation of NPPs.

— Controlling the behavior of NPPs during and following the postulated initiating event by using inherent characteristic and engineered safety features, to minimize and even exclude uncontrolled transient process to the extent possible.

— Providing supplementing controls of NPPs, by the use of automatic activation of safety systems in order to minimize operator actions in the early phase of postulated initiating event.

— Providing equipment and procedures to control the course and limit the consequences of accidents.

— Providing multiple means to ensure that each fundamental safety function, that is, reactivity control, heat removal and the confinement of radioactive materials, is performed, thereby ensuring the effectiveness of every barrier and mitigate the consequences of any postulated initiating event.

To ensure that the overall safety concept of defense in depth is maintained, the design of NPPs in China has been conducted to prevent as far as practicable:

— Challenges to the physical barriers.

— Failure of a barrier when challenged.

— Failure of a barrier as a consequence of failure of another barrier.

As a basic requirement, every defense level shall be available according to the specification of different operation modes at all times. The existence of multiple levels of defense is not a sufficient basis for continued operation in the absence of one level of defense.

The Fukushima nuclear accident has proved the importance of carrying out the principle of defense in depth in NPPs. After the Fukushima nuclear accident, the MEP (NNSA) put forth a series of requirements for NPPs, including: in-depth assessment of earthquake and tsunami risks; analysis and evaluation of margins against external events; carrying out PSA on external events, etc. The proposing and implementation of these requirements have further consolidated and improved the defense in depth capability of NPPs. The MEP (NNSA) raised requirements for new NPPs to improve the capability of plants to defense extreme external events, especially extreme natural disasters, and to strengthen the multi level defense in depth provisions in plants, to ensure the effectiveness of all levels of defense in depth provisions and the independence of every level; it also raised the requirements to further enhance diversified design and the concept to utilize the latest technologies and research results to continually improve nuclear safety.

(2) The safety management requirements in the *Code on the Safety of Nuclear Power Plant Design*

1) Management responsibility

Operating organizations shall take full responsibilities for safety. All organizations engaged in activities important to safety have a responsibility to ensure that safety matters are given the highest priority.

2) Design management

The necessary reliability of SSCs important to safety shall be guaranteed, to ensure that the safety functions of a NPP can be performed and the plant can operate safely during its whole design lifetime, and to prevent the occurrence of accidents to protect the site personnel, the public and the environment.

3) Proven engineering practice

Wherever possible, structures, systems and components important to safety shall be designed according to the approved latest or currently applicable standards and specifications; their design shall be of a design proven in previous equivalent applications, and the items shall be selected to be consistent with the reliability objectives necessary for safety.

When an unproven design or installations is introduced, or there is any deviation from an established engineering practice, safety shall be demonstrated to be adequate by appropriate supporting research programmes, or by examination of operating experience from other relevant applications.

4) Operating experience and safety research

The relevant operating experience that has been gained in operating NPPs and research results shall be given full consideration.

5) Safety assessment

Comprehensive safety assessment shall be carried out on design, to confirm that the design as delivered for fabrication, as for construction and as built meets the safety requirements set up at the beginning of the design.

6) Independent verification of safety assessment

Before submitting to the MEP(NNSA), operating organizations shall ensure that independent verification is performed for the safety assessment by individuals or groups separate from those carrying out the design.

7) Quality assurance

The quality assurance program, which describes the general arrangement for management, implementation and assessment of NPPs design, shall be established and implemented. This program shall be supported by more detailed plans for each structure, system and component, so as to ensure the quality of design at all times.

(3) The main technical requirements in the *Code on the Safety of Nuclear Power Plant Design*

1) Defense in depth

The concept of defense in depth shall be maintained in all safety-related activities, including related aspects with organization, human behavior and design, to provide a series of multi-level preventive measures, such as the inherent safety characteristics, equipment and procedures, to prevent accidents or provide appropriate protection when an accident cannot be prevented.

2) Safety functions

It shall be considered in the design that the following fundamental safety functions shall be performed in all operating conditions, during and after a design basis accident, and whenever possible, on the occurrence of those selected accident conditions that are beyond the design basis accidents:

— Reactivity control;

— Heat removal from the reactor core;

— Radioactive materials containment, operational discharge control and, accident releases limitation.

3) Accident prevention and safety characteristic of NPPs

The NPP design shall be such that its sensitivity to a postulated initiating events is minimized. The expected response of NPP to each postulated initiating event shall be the following reasonably achieved situations (in the order of importance):

— By the inherent characteristics of NPP, the postulated initiating event produces no significant safety related effect, or produces only a change in the NPP towards a safe condition;

— Following a postulated initiating event, the NPP is rendered safe by passive safety features or by the action of safety systems that are continuously operating in the state necessary to control the postulated initiating event;

— Following a postulated initiating event, the NPP is rendered safe by the action of safety systems that need to be brought into service in response to the postulated initiating event;

— Following a postulated initiating event, the NPP is rendered safe by specified procedures.

4) Radiation protection

The design shall have as an objective the prevention or, if this fails, the mitigation of radiation exposures resulting from design basis accidents and selected severe accidents. Design provisions shall be made to ensure that potential radiation doses to the public and the site personnel do not exceed acceptable limits and are as low as reasonably achievable. Plant states that could potentially result in high radiation doses or radioactive releases shall be restricted to a very low likelihood of occurrence, and it shall be ensured that the potential radiological consequences of plant states with a significant likelihood of occurrence shall be only minor.

(4) The main design requirements in the *Code on the Safety of Nuclear Power Plant Design*

1) Safety classification

All structures, systems and components, including instrumentation and control software, that are items important to safety shall be identified, and then classified on the basis of their safe functions and importance to safety. They shall be designed, constructed and maintained such that their quality and reliability is commensurate with this classification.

2) General design basis

The design basis shall specify the necessary capabilities of the NPP to cope with a specified range of operational states and design basis accidents within the defined radiological protection requirements. The design basis shall include the specification for normal operation, plant states created by the postulated initiating events, the safety classification, important assumptions and, in some cases, the particular methods of analysis. In addition to the design basis, the performance of the NPP in specified accidents beyond the design basis, including selected severe accidents, shall also be addressed in the design.

3) Reliability design of Structures, systems and components

Methods such as preventing common cause failures, applying single failure criterion and adopting fail-safe design shall be considered to ensure that items important to safety such as structures, systems and components important to safety can withstand all identified postulated initiating events with sufficient reliability.

4) Provisions for in-service testing, maintenance, repair, inspection and monitoring

Structures, systems and components important to safety shall be designed to be calibrated, tested, maintained, repaired or replaced, inspected and monitored with respect to their functional capability over the lifetime of the NPP to demonstrate that reliability targets are being met.

5) Equipment qualification

The procedure of equipment qualification shall be adopted to confirm that items important to safety can meet the requirements for performing their safety functions, throughout the design operation lifetime, while being subject to the environmental conditions (such as vibration, temperature, pressure, jet impingement, electromagnetic interference, irradiation, humidity or any likely combination thereof) prevailing at the time need.

6) Aging

Appropriate safety margins shall be provided for all structures, systems and components important to safety in the design, to take into account the relevant aging and wear-out mechanisms and potential age related degradation, so as to ensure the capability of these structures, systems or components to perform the necessary safety functions throughout their whole design lifetime.

7) Design for optimal operator performance

The working place and environment for site personnel shall be designed according to ergonomic principles.

The human factors and human-machine interfaces shall be considered systematically at the beginning of the design, and carried through the entire process of design.

The design of human-machine interfaces shall be "operator friendly", and be aimed at limiting the effects of human errors. The human-machine interfaces shall be designed to provide operators with comprehensive but easily manageable information, compatible with the necessary decision and action times..

8) Safety analysis

Safety analysis of NPPs design shall be carried out in which methods of both deterministic and probabilistic analysis shall be applied. It shall be demonstrated through safety analysis that the NPP as designed is capable of meeting any prescribed limits for radiological releases and the acceptable limits of potential radiation doses for each category of NPP states, and that defense in depth has been effected.

9) Other design considerations

The design regulations have also specified requirements on aspects such as the sharing of structures, systems and components between reactors, transport and packaging of nuclear fuel and radioactive wastes, escape route and communication means, as well as access control and decommissioning of NPPs

In addition, the *Code on the Safety of Nuclear Power Plant Design* has also made detailed stipulations on the design requirements for important systems in NPPs, such as reactor core, reactor coolant system, containment system, instrumentation and control system, emergency control, emergency power supply and radiation protection.

18.1.1.2 Codes and Requirements for Construction of NPPs

The basic requirements for NPP construction are mainly embodied in the nuclear safety regulation *Code on the Safety of Nuclear Power Plant Quality Assurance* and its guides. Focused on the concrete features of the construction activities, the nuclear safety guide *Quality Assurance in the Construction of Nuclear Power Plants* specifies the following requirements:

(1) General requirements include:

— Prepare plans for site construction (including the verification) and document.

— Stipulate and fulfill the required activities according to the written procedures, working instructions, specifications and drawings suitable to such activities.

— Perform housekeeping, to preserve the requisite quality of the items to be constructed or installed.

— Control the receiving, storage and handling of materials and equipment, and strictly prevent their abuse, misuse, damage, deterioration or loss of identification.

— Specify and implement cleaning requirements for fluid systems and associated components and the management requirements of the cleanness.

— Perform the painting or coating activities for quality/safety-related items and surfaces according to the approved procedures.

— Manage the measuring and test equipments, and control their selection, identification, calibration and application.

— Personnel shall receive training as necessary in order to develop proficiency in the tasks they performed.

(2) Installation, inspection and testing of items

The construction of NPP mainly involves three categories of activities: the installation, inspection and testing of soil, ground foundation, concrete and steel structure; the installation, inspection and testing of mechanical equipment and systems;

and the installation, inspection and testing of instrumentation and electrical equipment.

All important links of the above activities must be strictly controlled, including:

— The verification of the prerequisites before construction and installation;

— The management and control during construction and installation;

— The inspection and testing of the completed structures and installed equipment and systems after the completion of construction and installation activities.

(3) Analysis and assessment of inspection and testing results

The inspection and testing results are collected, rearranged, analyzed and assessed, to judge whether the structures, equipments and systems have met the required operational level, and then to determine the subsequent actions.

18.1.2 Application of Defense in Depth

18.1.2.1 Five Levels of Defense in Depth

The first application of the defense in depth concept in the design process of NPPs in China is that a series of multi-level defenses (inherent features, equipment and procedures) are provided to prevent accidents or to ensure appropriate protection in the event that prevention fails.

(1) The purpose of the first level defense is to prevent deviation from normal operation and prevent failure of systems.

(2) The purpose of the second level defense is to detect and intercept deviations from normal operation conditions, in order to prevent an anticipated operating occurrences from escalating to accident conditions. To meet this objective, in the design process of NPPs in China, special systems are provided and operating procedures are established..

(3) For the third level of defense, it is assumed that: although very unlikely, the escalation of certain anticipated operation occurrences or postulated initiating events might not be arrested by a preceding levels and a more serious event may develop.

(4) The fourth level defense is to address severe accidents in which the design basis may be exceeded and to ensure that radiological consequences are kept at a level as low as reasonably achieved (ALARA).

(5) The fifth level of defense is to mitigate the radiological consequences caused by potential release of radioactive materials resulted from accident conditions.

To enhance the capability of NPPs to prevent and mitigate severe accidents and realize the safety objective of actual elimination of massive release of radioactive materials as required in the *Nuclear Safety Plan*, China is revising the *Code on the Safety of the Nuclear Power Plant Design*, in conjunction with the safety consideration to cope with design extended conditions in the SSR-2/1 issued by the IAEA. The contents of revision include the adjustment and enhancement of defense in depth system and consideration of design extended conditions.

18.1.2.2 Three Physical Barriers of the Defense in Depth

In the design for NPPs in China, three physical barriers are provided to prevent the escape of radioactive materials to the outside. These barriers include the fuel matrix and fuel cladding, the reactor coolant system pressure boundary and the containment.

18.1.2.3 Consideration in NPP Design

The nuclear safety regulations of China required that in the NPP design, postulated initiating events shall be analyzed to identify all internal events that could affect the safety of the NPP. These events may include equipment failures or maloperation, and are selected with the deterministic method or probabilistic method or the combination of the two.

For external events, the regulations required that investigation and assessment shall be made for the external events that could affect the safety of NPP, including external natural events such as earthquake, geological, flood and meteorological events and external human-induced events such as aircraft crash and explosion of dangerous materials, in conjunction with the natural and social and environmental characteristics of the site and its surrounding areas, to determine the suitability of the site and design basis for defending external events. In determining the hazard of relevant external events, the effect of possibly combination events (such as the combination of hydrological and meteorological elements) shall be taken into consideration.

Items important to safety in NPP shall be capable of defending design basis flood. All NPPs, after comparing the locations and elevations of safety-related facilities with the static and dynamic effect of design basis flood, determine the anti-flooding measures applicable to their plants. On the basis of the historical disasters in the coastal regions of China and the existing engineering practice experience, the following measures are mainly adopted in NPPs design to prevent design basis flood according to the nuclear safety regulations:

(1) Maintaining the dry site design, to ensure that the plant ground level is above the design basis flood level, also taking into account the effect of wind and waves.

(2) Building permanent external barriers, such as anti-flooding dyke, wave wall and other anti-flooding structures, and also take the breakwaters as a safety-related item.

(3) The anti-flooding design shall take into account the effect of local flood resulted from possible local overtopping waves and possible maximum precipitation, including the appropriate water drain facilities and the corresponding emergency anti-flooding measures.

(4) Formulating and completing the corresponding anti-flooding plan, management system and implementation procedures, and make anti-flooding exercises periodically.

For NPPs in China, the determination of design basis earthquake, the anti-seismic classification and qualification of items important to safety and the setup of seismic instruments meet the requirements in the current nuclear safety regulations and standards and the latest IAEA nuclear safety standards. The actual anti-seismic design of all NPPs can envelope the earthquake during site assessment. Some NPPs have fairly large anti-seismic safety margin when compared with the site earthquake parameters. All plants have worked out fairly complete anti-seismic plans, and further completed the emergency action plans for nuclear accidents.

After the Fukushima nuclear accident, China organized research work on safety requirements for new NPPs, and put forth relevant requirements on the prevention and mitigation of severe accidents. The site with multiunit shall also meet the following requirements:

— For special systems or facilities designed to prevent and mitigate severe accidents, such as reactor coolant pump gland seal water injection system, containment filtration and exhaust system or facilities, the availability of their functions shall be guaranteed in case of simultaneous accident with multiple units.

— On the basis of stationary addition power supplies on the existing site, each multiunit site shall be equipped with at least two sets of portable power supplies and portable pumps, and available water sources shall be assessed and arranged.

— The usage of available means and supports from other units shall be considered provided that the safety operation of other units is not comprised.

Appropriate safety margin shall be provided in the protection design of NPP against beyond design basis external events, to improve its capability to resist extreme external events, especially extreme natural disasters. For the anti-seismic design of the NPP, seismic margin or seismic PSA shall be performed in conjunction with different types of reactors and the earthquake background of the site area, to evaluate the effect under the beyond design basis conditions. NPPs shall also, according to the evaluation results, formulate necessary mitigation measures and contingency. The anti-flooding design of NPP shall take into account the effect of extreme flood event and combination of flood event. In coping with beyond design basis external events, the superposition of low probability events shall be taken into appropriate account, for example, in the flood analysis of NPP, the design basis flood level combination with rainfall once in thousand years.

18.1.3 Application of Design Principles

All NPPs in China are provided with engineered safety features or safety facilities and supplementary safety provisions, such as safety injection system, containment spray system, containment hydrogen concentration control and air monitoring system, steam generator auxiliary feed water system, containment isolation system, primary rapid depressurization, reactor cavity water injection or core catcher, portable power supplies and portable water injection facilities. Engineered safety features are used to limit the consequences caused by postulated accident that might lead to damage of radioactive product shielding, or design basis. The engineered safety features are designed to cope with selected beyond design basis accidents, the sequence of which are obtained with deterministic, probabilistic safety analysis and engineering judgments, to prevent and mitigate beyond design basis accidents. The supplementary safety provisions are adopted to strengthen defense in depth, so as to mitigate the accidental consequences exceeding the beyond design basis accidents.

In the design of NPPs in China, full consideration is taken for design principles such as passive safety functions or fail-safe functions, automatic operation, physical and functional separation, redundancy and diversity. The design principles are embodied mainly in the design of the following types of reactors, also with slight difference for different types of reactors:

For VVER units, to improve safety, a series of important provisions to prevent and mitigate severe accidents are taken in design. On passive safety, passive safety injection tank water makeup is provided to deal with large break loss of coolant accident, passive containment hydrogen recombiner to limit hydrogen concentration, and core catcher to prevent melting through of containment ground foundation. The units is designed as fully automatic operation by DCS. Four trains safety systems with completely independent and physically separation, double-layer containment for reactor building, high pressure emergency concentrated boron injection system for diversified reactivity control are equipped to ensure redundancy, independence and physical separation. Safety equipment and systems such as four emergency diesel generator sets, two emergency diesel generator sets for station blackout and the seventh channel power supply are provided to deal with common cause failures.

For AP1000 units, diversified safety class and non-safety class instrumentation and control systems are designed to avoid common mode failure. Redundant automatic pressure relief systems are designed to avoid high pressure melt ejection and steam explosion. A total of 66 non-safety-related igniters in two trains are designed to effectively control the hydrogen concentration in the containment after a severe accident. The spent fuel pool is provided with 3 1E class level meter and 1 non-1E class level meter, taking into consideration diversity and reliability. The AP1000 has passive safety features with the passive core cooling system, passive containment cooling system, passive main control room habitability system, and passive reactor cavity flooding system. These passive safety systems can maintain accident mitigation over long time without operator action and without AC power supply. The design of AP1000 passive safety systems meet the single failure criterion. To further enhance the capability of accident management over long time (after 72 hours) following an accident, additional portable pumps and portable power supplies are provided in Sanmen NPP and Haiyang NPP, and the corresponding accident procedures have also been further completed.

The CAP1400 unit is provided with 6 additional non-safety class hydrogen recombiners, on the basis of AP1000, as diversified setup of hydrogen igniters to control the hydrogen concentration in containment. The containment filtration and exhaust system is further improved to enhance the defense in depth capacity. The anti-seismic performance of the cold chain system and equipment to remove heat to the seawater is enhanced, making it a diversified ultimate heat sink. The anti-seismic performance of diverse actuation system, hydrogen igniters and plant power supply systems are improved to enhance the reliability of these systems.

Taishan NPP was designed as the single reactor layout, and physical separation and protection are provided for the 4 trains of engineered safety features of each reactor. The safety system design to mitigate Design Basis Condition(DBC) accidents has taken into account redundancy or diversity, and redundant components are physically or geographically separated to mitigate the loss of safety functions. Zoning separation has been extended to support functions, such as cooling water, power supply and instrumentation and control system. The air convection system, containment with large free volume and a number of passive hydrogen recombiners are designed to meet the requirement on hydrogen elimination. In Taishan NPP, the design of mechanical, electrical and instrumentation and control systems performing F1 safety functions meets the single failure criterion. In addition, after the Fukushima nuclear accident, Taishan NPP also adopted a series of improvements to improve the capability to prevent and mitigate severe accidents. To prevent possible common cause failure, diversity has been introduced to different extent into instrumentation and control system, design for anticipated transient without scram(ATWS) mitigation system and protection systems, the emergency shutdown breaker devices and controls and displays in Taishan NPP.

HPR1000 was designed as single reactor layout, realizing optimization and physical separation in layout. The double-layer containment is used to increase the safety of NPP. The reactor building and fuel building are fully protected with APC shell and the safety building has realized full physical separation. The diesel generator set building is geographically separated to ensure that at least one train of diesel generator set is available. The item of ultimate heat sink, such as essential service water pump station and the corresponding pipe trenches are protected with redundant trains and geographic separation In case of failure of auxiliary feed water system, the reactor can be maintained safe shutdown status for 72 hours by the residual heat removal with passive provisions and the reactor coolant. Under the severe accident condition of the NPP, the passive reactor cavity water injection cooling system can remove the heat released from core melt by cooling the external surface of reactor vessel. The passive containment heat removal system is designed for passive long-term heat removal from containment under accident conditions. Emergency boron injection system is provided for diversified means of shutdown. Components with sufficient redundancy and independence are arranged to provide necessary safety actions to eliminate the effect of single failure of active components.

The pebble bed modular high-temperature gas-cooled reactor has good negative feedback characteristics. In some transients or the occurrence of accidents, the negative reactivity introduced by temperature rise will realize automatic reactor shutdown or reduce the power to a very low level, therefore core damage accident as with a PWR reactor will not occur. Shidao Bay NPP is designed with engineered safety features such as ventilated low pressure resisting containment, passive residual heat removal system, passive reactor pressure vessel support cooling system, main control room habitability system, secondary loop isolation system and steam generator accident discharge system. In the design of engineered safety features, full consideration has been taken for physical separation, single failure criterion and redundancy.

18.1.4 Countermeasures against Beyond Design Basis Accidents

NPPs in China can withstand various risks within the scope of design basis accidents and have certain control and mitigation capabilities to cope with beyond-design basis severe accidents. NPPs are designed to take prevention or mitigation actions against extreme natural disasters. For accident combined with a number of extreme natural events, NPPs have developed and completed provisions at various levels including emergency operation procedures, SAMG and emergency response systems, to effectively mitigate consequences of accidents. Also, NPPs have performed in-depth analysis and assessment of the provisions to prevent and mitigate accidents via PSR, and increase the capability to control and mitigate beyond design basis severe accidents by implementing improvement of plant flood-prevention capability, improvement of emergency water makeup and associated equipment, adding portable power supplies, improvement of hydrogen monitoring and control, improvement of elevated water tank and high energy batteries, and building new emergency control and commanding center.

(1) Requirements on new NPP

After the Fukushima nuclear accident, China organized research work on safety requirements for new NPPs, and put forth relevant requirements on the prevention and mitigation of severe accidents. The main contents of these requirements are embodied in the updated documents on code of safety for design of NPPs:

- Important event sequences that may lead to a severe accident shall be identified using a combination of probabilistic methods, deterministic methods and sound engineering judgment.
- Potential design changes or procedural changes that could either reduce the likelihood of these selected events, or mitigate their consequences should these selected events occur, shall be evaluated and shall be implemented if reasonably practicable.
- Consideration shall be given to the plant's full design capabilities, including the possible use of some systems (i.e. safety and non-safety systems) beyond their originally intended function and anticipated operational states, and the use of additional temporary systems, to return the plant to a controlled state and/or to mitigate the consequences of a severe accident, provided that it can be shown that the systems are able to function in the environmental conditions to be expected.
- SAMG (including that for spent fuel pool) or other procedures shall be formulated, to take into account power operation, low power and severe accidents leading to shutdown conditions, and situation of large scale damage to the NPP resulted from external events, and be revised periodically.

— For severe accidents, main issues that shall be taken into account include but are not limited to the following:

- The possibility and management measures for station blackout shall be taken into account in design. Appropriate design measures shall be adopted to exclude the possibility of serious core damage resulted from rapid injection of cold water or non-borated water; the reliability of residual heat removal function in shutdown status and when the containment is opened shall be considered.
- Highly reliable means shall be taken to avoid high pressure melt ejection. Assessment shall be made to the molten core-concrete interactions according to the site and structure conditions, and reasonable engineering measures shall be determined.
- Measures to maintain the containment integrity under severe accidents shall be considered.

— The following requirements shall also be met for a multi-unit site:

- For systems or facilities specially designed to prevent and mitigate severe accidents, such as reactor coolant pump gland seal water injection system, containment filtration and exhaust system or facilities, the availability of their functions shall be performed in case of simultaneous accident with multiple units.
- On the basis of stationary addition power supplies on the existing site, each multi-unit site shall be provided with at least two sets of portable power supplies and portable pumps, and available water sources shall be assessed and arranged.

- Consideration shall be given to the use of available means and/or support from other units, provided that the safe operation of the other units is not compromised..

After the Fukushima nuclear accident, the MEP (NNSA) required that units under construction must complete the following improvement actions before the initial fuel loading, including the anti-flooding improvement for nuclear safety related buildings and equipment, adding facilities such as portable power supplies and portable pumps, increasing the earthquake monitoring and anti-seismic response capacity of plants, improving SAMG, in-depth assessment of earthquake and tsunami risks, carrying out PSA for external events, completing emergency plan and increasing emergency response capacity to nuclear accidents, preparing and completing information release procedures of NPPs, completing the anti-disaster plans and management procedures. All units that realized the initial fuel loading after the Fukushima nuclear accident have completed the improvements with required quality and on schedule.

(2) Countermeasures taken by operating NPPs

All operating NPPs, with reference to the above requirements and international experience, and in conjunction with their own actual conditions, have performed the studies related to severe accidents and planned to gradually adopt reasonable and feasible prevention and mitigation measures:

— Actively investigating and studying up-to-date development of severe-accident research by foreign organizations and NPPs.

— Initiating the research and formulation of SAMG, including the SAMG covering all conditions of NPPs, so as to protect the pressure vessel boundary containing fission-product and the containment under the possible severe accident conditions, to specifically mitigate the consequences of severe accidents, decrease the radiological releases to the environment, and to finally recover the NPP to a controllable and steady state.

— Carrying out the research and development of Flexible Coping Strategies(FLEX) Support Guidelines(FSGs) and Extensive Damage Management Guidelines (EDMGs).

— Performing engineering evaluations and modifications for systems and facilities designed to mitigate severe accidents, to enhance the capability of mitigating severe accidents.

— Developing emergency response plan for multi-unit nuclear accidents.

(3) Actively promoting management of severe accidents

Operating NPPs have established the SAMG on the basis of reference with the practices of similar foreign plants and in full conjunction with the actual situation of their own plants. Among the nuclear power units in China already in commercial operation, Qinshan NPP, Daya Bay NPP, Qinshan Phase II NPP, Third Qinshan NPP, LingAo NPP, Tianwan NPP, Hongyanhe NPP, Ningde NPP, Yangjiang NPP, Fangchenggang NPP have already completed the formulation and have implemented their SAMG. Some of them has worked out full-scope SAMG that can deal with severe accidents under all operation modes of NPPs by fully incorporating the latest research results on the full-scope SAMG both domestic and abroad. Compared with the SAMG for power conditions already implemented extensively in NPPs, the full-scope SAMG has greatly extended the scope of application of SAMG, to ensure that the severe accident management procedures of NPPs can deal with power operation, low power, shutdown conditions and severe accident with spent fuel pool and cases of large scale damage of NPP resulted from external events. In addition, some NPPs have carried out special subject research on FSGs and EDMGs that cover extreme plant damage conditions that cannot be covered by the existing procedure system, which further improve the safety of NPP as supplement and completion to the existing accident management system.

After the Fukushima nuclear accident, the MEP (NNSA) required NPPs to work out emergency response plans and the allocation and coordination plans of emergency personnel and materials after multi-units on the same site entered the emergency status simultaneously and to complete the SAMG. All NPPs actively carried out research on countermeasures against emergency status with multi-units entering emergency status simultaneously, implemented corresponding improvements and updated the NPP emergency plans. CNNO has unified the emergency plans for the nine units on Qinshan Nuclear Power Base to cope with multi-unit accidents, and also taken into comprehensive account the effect of multi-unit accidents on the emergency action level. The unified dispatching procedure for emergency portable equipment and the emergency management system to respond to multi-unit accidents for Qinshan Nuclear Power Base has been established. Emergency response exercises for multi-units is performed to verify the emergency response capability of Qinshan Nuclear Power Base to multi-unit accidents. DNMC organized relevant forces for investigation, analysis and research, and completed the emergency response plan for possible multi-unit nuclear accidents that might exist for the six units in Daya Bay NPP and LingAo NPP, and later it will work out detailed implementation procedures for multi-units.

18.1.5 The Measures to Maintain the Integrity of The physical Containment

NPPs in China are provided with containments to enclose radioactive materials released from the core, and to reduce the emission of radioactive materials to the environment to protect the public and the environment. According to the features of their techniques, the NPPs in China adopt appropriate measures to maintain the integrity of containments to prevent long-term offsite contamination. The main measures include the prevention of overpressure and negative pressure from threatening the integrity of containments, the consideration to add fire protection zones to improve the result of physical separation, the prevention of hydrogen combustion from producing serious threat to the containments, and the prevention of core molten materials from burning through the containment base.

For generation II plus PWR NPPs, mainly the following measures are adopted to maintain the containment integrity:

(1) Adopting prestressed concrete containment to mitigate the effect of beyond design basis accidents on the containment integrity. The pressure within the containment conservatively calculated under design basis accident conditions (loss of coolant accident and main steam pipe rupture accident) is lower than the design pressure, and also with some margin. The containment limit loading capacity evaluation has been performed, proving that the containment can withstand a limit pressure over 1.5 times its design pressure.

(2) Passive containment combustible gas control system has been provided or completed. Passive hydrogen recombiners is added to control the hydrogen concentration inside containment under the design basis accident and beyond design basis accident conditions and prevent explosion resulted from local accumulation of hydrogen.

(3) The containment filtration and exhaust system has been provided to depressurize the containment to ensure its integrity when the pressure inside the containment has increased to its opening set value following a severe accident of core meltdown.

(4) The safety class containment spray system has been provided to actuate to control the containment pressure and also reduce irradiation when the pressure in the containment has reached the actuating set value of the containment spray system.

(5) Considering the function extension of pressurizer, the primary pressure is reduced to avoid high pressure core meltdown threatening the containment integrity in case of a severe accident.

(6) Adding portable diesel generator sets, portable pumps and elevated water tank. These improvements have greatly increased the capability to prevent and mitigate severe accidents, conducive to mitigating the accident consequences and preventing expansion of accident, therefore they can effectively reduce the risk of containment break under the beyond design basis accident conditions.

(7) Full-scope SAMG has been formulated to further complete the management system for NPPs to deal with severe accidents under the power and shutdown conditions. SAMG has been established to protect the pressure vessel fission product boundary and the containment as the third layer barrier under severe accident conditions, to specifically mitigate the consequences of severe accidents, decrease the radiological releases to the environment, and to finally recover the unit with accident to a controllable and steady state.

For AP1000 units, mainly the following measures are adopted to maintain the containment integrity:

(1) The structural design of steel reactor containment has taken into account the design basis accident conditions such as rupture of primary pipe, main steam pipe and main feed water pipe. Under the design basis accident conditions, especially in the condition of a large break in the reactor coolant system, the passive containment cooling system can provide cooling of the containment to prevent its overtemperature and overpressure, and thus maintaining the containment integrity.

(2) To prevent failure of reactor vessel, the accident management strategy of flooding the reactor cavity and the reactor vessel with the water in the refueling water storage tank inside the containment is taken into consideration. During a postulated severe accident, water will be used to cool the external surface of reactor vessel and to prevent the core molten debris at the lower head from melting through the vessel wall and entering the containment. Containing the core molten materials inside the reactor vessel can prevent severe accidents outside the reactor vessel, such as steam explosion outside the reactor and the chemical reaction of core materials with the concrete. The hydrogen igniters and hydrogen recombiners are provided to avoid hydrogen combustion and explosion inside the containment. Redundant large capacity rapid pressure relief valves are provided to reduce the primary pressure, to avoid reactor melting under high pressure, and also increase the possibility of successful reactor

cavity water injection to protect the containment integrity.

(3) For natural disasters, the site meteorological conditions for Sanmen NPP and Haiyang NPP can be enveloped within the scope of analysis for natural disasters taken into account in the AP1000 standard design. The shield building in concrete structure outside the steel containment is able to effectively resist missiles caused by typhoon and tornado. The design has also taken into account the effect of transient negative pressure caused by extreme weather on the containment integrity. Also, the containment is provided with vacuum break subsystem to prevent external pressure from exceeding internal pressure, so as to maintain the containment integrity. For beyond design basis accidental conditions, additional portable power supplies and portable pumps that are stored at places that cannot be flooded externally under the condition of beyond design basis flood water level are provided in Sanmen NPP and Haiyang NPP to ensure containment cooling.

For EPR units, mainly the following measures are adopted to maintain the containment integrity:

(1) The containment of an EPR unit with the volume of about 80000cu.m can maintain the containment pressure below its design value without starting any system to reduce pressure within 12 hours after a severe accident.

(2) Under severe accident conditions, the dedicated primary pressure relief system can release pressure for the reactor coolant system to prevent high pressure core melting and its ejection.

(3) Under severe accident conditions, the hydrogen inside the containment can be controlled with the combustible gas control system to prevent hydrogen explosion.

(4) During the period of severe accidents, the spray by the containment residual heat removal system can control the pressure inside the containment.

(5) The in-vessel retention system is designed to prevent molten core-concrete interaction under the severe accident conditions..

(6) The filtration and ventilation system collects the leaks in the annulus between the inner and outer containment layers and those in the safety building not discharged into the stack, and filtrate and discharge them.

(7) After the Fukushima nuclear accident, portable water makeup was added to the containment residual heat removal system for the EPR units to ensure control of containment pressure so as to maintain the containment integrity when the containment residual heat removal system spray is not available and in case of station blackout.

For HPR1000 units, isolating valves are provided for all fluid pipes in the containment section to prevent radiological fluid from leaking out of containment via penetrations under beyond design basis accidental conditions. Under the beyond design basis accident conditions such as overpressure in the containment, the containment filtration and exhaust system will actuate to release pressure, so that the pressure in the containment will not exceed the limit, and the radioactivity of the discharged gas is filtered by the filtering device for controlled discharge of radioactive fission product to ensure the containment integrity. The passive containment hydrogen elimination system and containment hydrogen monitoring system are provided for passive and active hydrogen elimination and monitoring in containment to limit the hydrogen concentration in the containment below the safety limit and avoid failure of the containment caused by hydrogen combustion and explosion.

The pebble bed modular type high-temperature gas-cooled reactor is provided with a ventilated containment of low pressure resisting type. The principle of the containment is slightly different from the containment for traditional PWR and BWR units, because the primary loop radiological release of a pebble bed modular type high-temperature gas-cooled reactor is very low and with very big delay. After an accident of loss of pressure in the primary loop, it will take quite a long time for fuel temperature to reach the maximum temperature because of the high heat capacity of core. The delay can provide a long tolerance time to take accident control actions. Analysis shows that even if there is no nuclear island negative pressure exhaust system, the dose released into environment without filtration is lower than the acceptance dose for accident conditions, and will not cause serious offsite consequences.

18.1.6 NPP Design Improvement

On the basis of the results of deterministic safety assessment and PSA and the requirements of current nuclear safety regulations, national and industrial technical standards of China, NPPs in operation have carried out highly effective technical modifications for their structures, systems and components with respect to the design and equipment problems identified during the commissioning and operation period by using proven and qualified technologies to increase safety and reliability since the commercial operation of the units.

Dozens of significant technological modification projects, such as the replacement of pressure vessel head and related component systems, the reactor protection and associated equipment and I&C systems and modification of the containment sump filter have been carried out in Qinshan NPP since the unit was put into operation.

Significant technical improvement actions including improvement to prevent inadvertent dilution, improvement to prevent core uncovering, modification of inlet dead pipe section of the residual heat removal system, installation of passive hydrogen recombiners in reactor building and Farley-Tihange modification have been completed in Daya Bay NPP.

Unit 1 and Unit 2 of Qinshan II NPP carried out a series of design improvements according to construction and operating experience of similar plants during the design. Further improvements were made to Unit 3 and Unit 4 on the basis of fully absorbing the experience of Unit 1 and Unit 2, such as the use of new AFA3G type fuel assemblies, the adoption of new-model containment sump filter, the addition of hydrogen elimination measures under beyond-design basis accident, the addition of inadvertent boron dilution prevention, etc.

Dozens of significant design improvement actions on the basis of Daya Bay NPP and its own operating practice, such as reactor coolant pump fire detection, multi-point hydrogen measurements in containment, K1 level AIR-LB connection improvement for penetration pieces, test pipeline modification of containment spray system, etc. have been implemented in LingAo NPP.

Units 3 and 4 of LingAo NPP have made a number of technical improvements with reference to Units 1 and 2, of which the main design improvements related to safety include the use of advanced AFA 3G fuel assemblies, the use of solid forging for core activity segment of reactor pressure vessel, the extension of pressure relief function of pressurizer to prevent high pressure core melt condition, the modification of containment sand filter pressure relief discharge system, etc. For Units 1 and 2, passive hydrogen recombiners have been installed in reactor building, and the Farley-Tihange renovation has been completed for Unit 1, and is scheduled for Unit 2 in 2016.

Third Qinshan NPP, since 2003 when its first unit was put into commercial operation, has made necessary design improvement according to the operation experience of CANDU-6 PHWR reactor and the actual conditions of China. A total of 2840 change and renovation items were approved, and over 2000 have been completed and implemented, including over 100 major changes and technical renovation items, such as changing the stainless steel adjusting rods to cobalt adjusting rods to produce Co-60, the spent fuel dry storage project, the addition of re-circulating cooling water repair backup system, the addition of two reactor shutdown system data acquisition systems, and the addition of auxiliary feed water pumps.

Unit 1 and Unit 2 of Tianwan NPP have made some improvements in the design based on VVER-1000 type PWR and their own operating experience, such as the use of double-layer containment and four-train safety system, the consideration of anticipated transient in case of severe accidents and inability to shut down, the addition of emergency boron injection system, fuel pool being located inside the containment and capable of storing spent fuel for ten years, modification on ventilation units of negative pressure system in safety building, overall modification of rotary filter screen, etc.

Among the NPPs under construction in China, a series of design improvements have been made to the independently designed generation II plus PWR units based on the introduction, digestion and absorption of mature technologies in foreign countries and in conjunction with years of operating experience of similar units at home and abroad and the results of safety research and continuous improvement. Compared with similar international units, a higher safety level has been achieved.

All generation II plus nuclear power projects constructed later, such as Hongyanhe NPP, Ningde NPP, Yangjiang NPP, Fangjiashan NPP, Fuqing NPP and Fangchenggang NPP, have adopted the improvements of reference plants.

In Tianwan NPP, Units 3 and 4 are constructed with its Units 1 and 2 as reference unit, and necessary design improvements have been made, including the improvement of nuclear island low radioactivity wastewater collection and monitoring and discharge system, improvement of nuclear island fire protection system and of coolant purification system. In addition, according to new regulations, standards and technical requirements, measures including improvement of containment sump screen and addition of gas detection system for damaged fuel assemblies have been made to ensure the advanced performance and safety of unit design. In the meantime, it has been determined to use portable equipment to make up water to the steam generators and spent fuel pool, as extra measures to further improve safety.

The operating NPPs in China have ensured safe and stable operation through continuous technological improvements. After the Fukushima accident, each operating NPP actively carried out appropriate improvements in conjunction with the results of national comprehensive safety inspection and self-inspection, and based on the plans formulated by the MEP (NNSA). The short-term improvements include the implementation of waterproof plugging, the addition of portable emergency power supplies and portable pumps, the enhancement of earthquake monitoring and response capability. The medium safety improvements include improving the SAMG, adding or modifying the hydrogen eliminating facilities, PSA for external events, anti-flooding modification at Qinshan Site and in-depth assessment of earthquake and tsunami risks, and they have all been completed on schedule. Long-term safety improvements mainly include completing emergency plan, raising the emergency response capacity of NPPs, completing the information release procedure and strengthening nuclear knowledge publicity, etc. All NPPs actively carry out relevant researches and have adopted a series of effective measures, achieve significant progress.

The NPPs in China under construction basically meet the requirements of current national nuclear safety regulations and the latest IAEA standards, and have implemented effective management in all links such as siting, design, manufacturing, construction, installation and commissioning, the quality assurance system and quality monitoring system are in normal operation, and the engineering construction meets the design requirements.

18.1.7 Regulatory Review and Control Activities

(1) The MEP (NNSA) has established special subject working group by organizing relevant organizations on nuclear safety review, nuclear power design and universities to carry out technical investigation and in-depth research on actually eliminating possible release of massive radioactive materials from the design of NPPs, and completed the special subject evaluation reports on the nuclear power technologies of AP1000, CAP1400 and HPR1000, and produced relevant research reports on actually eliminating release of massive radioactive materials from the design. It plans to issue the technical policy on actually eliminating the massive release of radioactive materials, enhance the measures to prevent and mitigate severe accidents, and raise the protection bases against external events to further push up the design safety level for nuclear power.

(2) For the major and hot issues in nuclear power construction, the MEP (NNSA), closely contact with other relevant departments and CNEA, worked out proper management plans. In addition, special subject investigations or assessment and re-checks have been carried out on loose parts and vibration monitoring system, NPP network information security investigation, dry storage of spent fuel, temporary storage of low-radioactive wastes and impact of strong typhoons to coastal NPPs.

(3) The MEP (NNSA) has strengthened the assessment and treatment of major nonconformance in NPPs, especially, in the disposition of major nonconformance such as the DCS cable insulation constant failing to comply with procurement specifications in 14 nuclear power units of CGN, the defects in control rod driving mechanism nozzles and aligning deviation of primary pipes in Fangjiashan NPP. The *Notice on recent construction quality problems in NPPs under construction* and *Comprehensive report on construction events in nuclear power plants under construction in China* were prepared and issued to promote the sharing of construction experience among NPPs in China.

(4) The MEP (NNSA) requires that defense in depth shall be performed in the design of NPPs. The implementation of the defense in depth principle are confirmed through the review of the preliminary safety analysis report and final safety analysis report of NPPs. In addition, the relevant design changes since the commissioning and

operation of NPPs are subjected to the review and approval by the MEP (NNSA) as required.

18.2 Use of Proven Technologies

18.2.1 Codes and Regulatory Requirements

It has been over 30 years since China started the design and construction of its first NPP – Qinshan NPP. In this period, the nuclear power technologies have been developing continuously both home and abroad, and some new versions of codes and standards have also been issued. To promote the progress of nuclear power technologies, and continually improve the safety and economic performance of nuclear power units, the NPPs in China, while meeting the conditions in the new versions of codes and standards, have made continual design improvements for nuclear power units both in operation and under construction according to the operating experience at home and overseas and relevant progress in technologies. Especially for new nuclear power units, new technologies are adopted to ensure the advanced level and safety of design based on the construction and operation experience of similar plants and reference units.

In China, the requirements for NPPs to adopt proven technologies in design, construction and improvement include the following:

(1) The MEP (NNSA) requires that operating organizations of NPPs shall adopt the proven and up-to-standard processes and technologies. Documents (e.g., the safety analysis report) submitted to the MEP (NNSA) by operating organizations of NPPs shall describe the technologies adopted, which must be validated and verified.

(2) The codes and standards used in the design of NPPs in China shall be identified and assessed before their application in order to determine their applicability and adequacy and to ensure that the quality of equipment is commensurate with the necessary safety function.

(3) The manufacture and construction methods shall be laid down carefully. The staff members shall be selected correctly and trained, and their qualification reviewed. The manufacture and construction of SSCs shall be performed by experienced domestic and foreign contractors or suppliers. Operating organizations shall review their contracting and supplying capability, engineering experience of manufacturing and construction, and documents and records that can demonstrate their qualification.

(4) Design and design improvement of NPPs in China

For nuclear power units for which construction has been newly started, their design improvement shall comply with the common principles below:

— Meeting the requirements of nuclear safety regulations and standards of China;

— Complying with the requirements for nuclear power technology development;

— Taking into account the construction and operating experience of similar units in China and other countries;

— Taking into account the requirements on improving weaknesses put forward by PSA;

— Making reference to the applicable parts of design requirements of the

AP1000 and EPR and other advanced nuclear power reactor types in the world.

18.2.2 Measures to Be Taken by Licensees

On the basis of the results of deterministic safety assessment and PSA and the requirements of current nuclear safety regulations, national and industrial technical standards of China, NPPs in operation have carried out highly effective technical modifications for their structures, systems and components with respect to the design and equipment problems identified during the commissioning and operation period by using proven and qualified technologies to increase safety and reliability since the commercial operation of the units.

A series of design improvements have made to the independently designed PWR units in NPPs under construction based on the introduction, digestion and absorption of proven technologies from other countries and in combination with years of operating experience of similar units at home and abroad and the results of safety research and continuous improvement. Compared with similar units in other countries, a higher safety level is achieved.

In Tianwan NPP, Units 3 and 4 are constructed with its Units 1 and 2 as reference unit, and necessary design improvements have been made, including the improvement of NI low radioactivity wastewater collection and monitoring and discharge system, improvement of NI fire fighting system and of coolant purification system. In addition, according to new codes, standards and technical requirements, measures including improvement of containment pit screen and addition of gas detection system for damaged fuel assemblies have been made to ensure the advanced performance and safety of unit design. In the meantime, it has been determined to use portable equipment to make up water to the steam generators and spent fuel pool, as extra measures to further improve safety. Units 5 and 6 of Tianwan NPP are built with Units 1 and 2 of Fuqing NPP already in operation as the reference units, 42 major safety-related technological improvements have been implemented according to the latest safety standard in China and other countries after the Fukushima nuclear accident, and its main safety indicators have reached the technical standards for generation III NPPs.

All generation II plus nuclear power projects constructed later, such as Hongyanhe NPP, Ningde NPP, Yangjiang NPP, Fangjiashan NPP, Unit 1, Unit 2, Unit 3 and Unit 4 of Fuqing NPP, Unit 1 and Unit 2 of Fangchenggang NPP and Unit 5 and Unit 6 of Tianwan NPP, have adopted the improvements of reference plants.

18.2.3 New Technologies and Methods for Analysis, Inspection and Testing

The nuclear safety regulations of China require that, where an unproven design or feature is introduced or there is a departure from an established engineering practice in the design and construction of NPPs, safety shall be demonstrated to be adequate by appropriate supporting research programmes, or by examination of operational experience from other relevant applications. The development shall also be adequately tested before being brought into service and shall be monitored in service, to verify that the expected behavior is achieved.

Sanmen NPP and Haiyang NPP are based on the AP1000 nuclear power technology. For the passive design features and special engineered safety features of AP1000 units, China have carried out analysis for accidents such as rupture of reactor vessel direct injection pipeline, rupture of core makeup water tank pipeline, inadvertent actuation of automatic pressure release system, and rupture of passive residual heat removal system pipeline, in addition to traditional analysis on the design basis accident analysis. The main contents of severe accident analysis include: phenomenological analysis for severe accidents, analysis and justification of the effectiveness of severe accident mitigation measures, level I PSA success criterion analysis, level II PSA success criterion analysis and source term analysis, and preparation of SAMG. In addition, special analysis for AP1000 units has been made for the long-term station blackout exceeding 72 hours and the conditions of loss of normal heat sink by lessons learned from the Fukushima nuclear accident. The improvement of long-term period water make up has been proposed based on the analysis results, and analysis and evaluation have been made for relevant improvements. China has also performed safety assessment independent verification and qualification tests for certain AP1000 units, the safety assessment independent verification is mainly focused on functions of passive safety systems, and the feasibility and effectiveness of design important to safety and new accident mitigation measures; the qualification tests are mainly to verify if the system and equipment functions meet the design requirements via testing of equipment design, equipment performance and system design. According to the relevant requirements in the conditions for construction permit, NPPs in China have carried out control rod driving mechanism anti-seismic test, which has verified the rationality of safety classification and anti-seismic grading for control rod driving mechanism, and that its due safety functions have been met.

The demonstration nuclear power project CAP1400 is constructed with AP1000 as reference, and the core thermal power has been increased. The CAP1400 is provided with 6 additional non-safety class hydrogen recombiners, on the basis of AP1000, as diversified setup of hydrogen igniters to control the hydrogen concentration in containment. CAP1400 has further improved the containment filtration and exhaust system, and increased the defense in depth capacity. CAP1400 has enhanced the anti-seismic performance of the cold chain system and equipment to discharge heat to the seawater, making it a diversified ultimate heat sink. The anti-seismic performance of DAS, hydrogen igniters and plant power supply systems have been improved to enhance the reliability of these systems.

Taishan NPP adopts the EPR technical line, with similar units now under construction in France as reference, and also making reference to similar units under construction in Finland on certain systems and equipments, including the addition of passive steam exhaust channel in the fuel building. On the analysis of design basis accident, the EPR units have taken into account the initial conditions of each type of accident when it occurs. For many accidents, not only condition A in the plant standard operation condition is analyzed, the analysis has been made up to conditions B, C and D of refueling outage. For each design basis accident, not only the process to bring the plant to the controllable status has been analyzed, analysis is also made on how it can reach the safe shutdown status from the controllable status. In the analysis of design basis accident, consideration has been given not only to the single failure criterion, but also to the assumption that a train of safety system is in preventive maintenance. The N+3 principle has been applied in the design of safety systems. On analysis of beyond design basis accidents, analysis has been made for EPR on both DEC-A condition (the severe accident prevention condition) and DEC-B condition (the severe accident mitigation condition), the function demand analysis for a series of severe accident prevention and mitigation systems has been completed, the complete level I and level II PSA analyses have been carried out, and based on deterministic analysis, the severe accident management documents covering power operation and shutdown conditions have been prepared.

In Tianwan NPP, Units 3 and 4 are constructed with its Units 1 and 2 as reference unit, and necessary design improvements have been made, including the improvement of nuclear island low radioactivity wastewater collection and monitoring and discharge system, improvement of nuclear island fire protection system and of coolant purification system. In addition, according to new regulations, standards and technical requirements, measures including improvement of containment sump filter and addition of gas detection system for damaged fuel assemblies have been made to ensure the advanced performance and safety of unit design. In the meantime, it has been determined to use portable equipment to make up water to the steam generators and spent fuel pool, as extra measures to further improve safety.

HPR1000 technology which are adopted in Unit 5 and 6 of Fuqing NPP and Units 3 and 4 of Fangchenggang NPP are designed according to the requirements in the *Code on the Safety of the Nuclear Power Plant Design* and the relevant requirements of User Requirement Document (URD) and Europe User Requirement Document (EUR). Meanwhile, a lot of testing and verification work has been carried out for HPR1000. HPR1000 is designed with reactor core with 177 fuel assemblies, safety systems with multiple redundancies, single reactor layout, double-layer containment, and combination of active and passive systems. The design principle of defense in depth has been fully carried out in a balanced way, and complete provisions to prevent and mitigate severe accidents have been made for HPR100. On the basis of the overall list of initial event conditions, full-scope accident analysis and PSA have been carried out, including levels I and II PSA for internal and external events, also covering the spent fuel pool and other facilities containing large amount of radioactive materials. The accident analysis has indicated that HPR1000 meets the requirements of 15% thermal engineering margin and no intervention by operator for 30 minutes with the optimized core type and safety system design plans; the use of a series of provisions to prevent core damage and mitigate severe accidents can ensure fairly low core damage frequency and radioactive materials release.

For new NPPs, simulation design verification has been performed for DCS. The verification is backed up by the simulation platform software, which integrated technologies of simulation for NPP process systems, control strategy and human-machine interface, and imported a number of design documents. The simulation design verification was performed in the dynamic form for both classified verification and special verification. From 2008 to 2015, a number of NPPs such as Fangjiashan NPP, Fuqing NPP and Changjiang NPP developed DCS design verification platform and completed the design verification work. Fangchenggang NPP has completed the independent verification for DCS devices, and reliability analysis and model research for DCS systems. In 2014, the design verification was carried out for Units 5 and 6 of Fuqing NPP, with the scope of verification extending from the design of main control room human-machine interfaces to the control continuous casting and accident guides.

18.2.4 Regulatory Review and Control Activities

The complete analysis software system for safety review has been basically established by the MEP (NNSA) through introducing the safety analysis software of the NRC and Westinghouse and AREVA and purchasing commercial analysis software generally applied and accepted in the nuclear power industry. By the end of

2015, the MEP (NNSA) had completed the verifying calculation for the final safety analysis report for Sanmen NPP (AP1000 units) and the preliminary safety analysis report for the nuclear power demonstration project (CAP1400 units), and the verifying calculation for HPR1000 technology is under way at present. For AP1000, the MEP (NNSA) mainly carried out verifying calculation for accidents such as loss of coolant, reactor coolant pump shaft block, rupture of a single SG heat transfer tube, small break loss of coolant with breaking of both ends of direct injection pipeline and rupture of primary feed water pipe. The MEP (NNSA) mainly carried out verifying calculation on reactor physics, accident analysis, radiation protection, effluent discharge source term, probabilistic safety assessment and verification and stress analysis and structure anti-seismic analysis for CAP1400 and HPR1000.

18.3 Design for Reliable, Stable and Manageable Operation

18.3.1 Codes and Regulatory Requirements

China requires that human factors, especially human-machine interfaces, shall be taken into systematic consideration for the design of NPPs. The *Code on the Safety of the Nuclear Power Plant Design* set forth the following design requirements on optimal operator performance:

(1) The working areas and working environment for site personnel shall be designed according to ergonomic principles.

(2) Systematic consideration of human factors and the human–machine interface shall be included in the design process at an early stage and shall continue throughout the entire process..

(3) Verification and validation of aspects of human factors shall be included at appropriate stages to confirm that the design adequately accommodates all necessary operator actions.

(4) The design shall be ‘operator friendly’ and shall be aimed at limiting the effects of human errors. The human–machine interface shall be designed to provide the operators with comprehensive but easily manageable information, compatible with the necessary decision and action times.

Furthermore, the *Design for Main Control Rooms of Nuclear Power Plants* (GB/T 13630-2015) has specified the design principles, function design methods and function design and staffing requirements for main control room in NPPs, and also specified the procedures to verify and validate the control room function designs. The *Design Criterion for Supplementary Control Points of Nuclear Power Plants* (GB/T 13631-2015) specified the design requirements for supplementary control points of NPPs, including the functional selection, design and organization of human-machine interfaces, and also specified the procedure requirements for system verification and approval of supplementary control point design.

There are four types of human-machine interfaces in Chinese NPPs: main control room, remote shutdown station, technical support center and local control. The main control room can provide all process information, control and communication means under all conditions, and monitor and control the plant status. When the main control room is not available, the remote shutdown station will be used to bring the plant to and maintain it in the safe shutdown status. The technical support center provides information and information evaluation and communication means under accident conditions for use by the expert group. The local control is independent of the main control room or is operated independently. The reactor power is reduced to hot shutdown condition by the actuation of protection system under accident conditions in NPPs. The operator intervention is not necessary in a reasonable period of time following an anticipated operation event or a design basis accident because of the automatic safety actions. Furthermore, operators can obtain sufficient information to monitor the result of automatic actions.

18.3.2 Measures to be Taken by Licensees

Optimization design has been made for the operator working areas and equipment arrangement according to ergonomic principles in Chinese NPPs:

(1) Necessary measures are taken to ensure that the lighting, humidity and temperature of the working environment are appropriate.

(2) Monitors and instruments are arranged on a unified basis, so that operators move the minimum distance when monitoring and controlling the plant.

(3) On the main control console, signals and operation pushbuttons are grouped by functions. Different function blocks are distinguished with different colors, and different signs are used to indicate the control of valves and pumps.

(4) Different sounds and videos are used to make operators distinguish alarms of different levels.

(5) Alarm signal sources are carefully selected and arranged with priorities to avoid too many and too complicated display and alarm system in the main control room..

(6) The operators have sufficient time to check and confirm automatic response, and implement specified procedures because of automatic safety actions. The need for intervention by the operator on a short time-scale are decreased as possible to reduce psychological burden of operator.

(7) It shall be quite easy to link the control and display function marks with the devices being monitored or controlled.

(8) Control devices and their displays are designed where it is easy for operators to operate and observe.

The design organizations in China pay great attention to the control room since it is the area with most centralized human-machine interface and the direct working place of operating personnel. The following practices have been successfully employed according to the operating experience and with reference of the design ideas of other advanced NPPs in the design of new NPPs and the modification of operating NPPs in recent years:

(1) Fully adopting the design ideas of DCS and the advanced control room. Digital human-machine interfaces were used in the main control room, the logical relation of human-machine interface, operating display graphs and rules and the alarm systems were designed with digital principles.

(2) In designing the backup panel, operating practices of operators on aspects of function zoning, function grouping and equipment standardization were taken into full consideration to reduce human errors.

(3) The human-machine interface equipments used in remote shutdown stations were the same with main control room to ensure that operators can learn the ropes

quickly without accustoming to another interface when using the remote shutdown station.

(4) The main control room environmental design were carried out by applying the basic research results of ergonomics, physiology and psychology.

(5) Carried out the physical design verification and ensured the independence of the verification team. Formulated design rules relevant to human factors and integrating the design team.

(6) Full consideration of human factor and human-machine interfaces in the design and modification of NPPs, voice prompts have been added for units and rooms in the NPP design and modification, and unit labeling specification has been worked out, such as unit color distinction and direction indication, and the focus subject to prevent entering wrong interval has been carried out.

18.3.3 Regulatory Review and Control Activities

The MEP (NNSA) has paid attention to the effect of human factors on safety, and issued in 1992 the nuclear safety regulatory technical document — *Standard Format and Contents of Nuclear Power Plant Safety Analysis Reports – Chapter 18: Ergonomics and Control Room*, which proposed the requirements on the organization and structure and design criteria, safety parameters and display functions for control room design. the ergonomic principle shall be considered and applied in the control room design and safety parameters display. Corresponding divisions and office are set up in the Nuclear and Radiation Safety Center of the MEP to review and evaluate human factor issues. The main control room design is described in preliminary and final safety analysis reports of NPPs according to the requirements in the above-mentioned nuclear safety regulatory technical document. In most NPPs of China, the advanced main control room with computer technology is designed and realized based on the operator structure and digital economic and many other technical means. The conventional analog monitoring measures are the backup to computerized monitoring means, the application of both has taken into full consideration the ergonomic principle. In the review of the preliminary and final safety analysis reports of NPPs, the MEP (NNSA) placed their stress on the relevant contents of ergonomics and control room.

The MEP (NNSA) has required NPPs under construction to analyze and evaluate the reliability of safety class DCS on aspects of design, verification and failure analysis to identify weaknesses and implement corresponding improvements. The *Special Subject Report on the DCS Anomalies in Operating Nuclear Power Plants* were prepared to fully analyze the problems existing in DCS and their effect and propose corresponding recommendations according to investigation and analysis on a number of operating events related to the computer information and control system (KIC) in Chinese NPPs by the MEP(NNSA).

19. Operation

Each Contracting Party shall take the appropriate steps to ensure that:

(i) the initial authorization to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme demonstrating that the installation, as constructed, is consistent with design and safety requirements;

(ii) operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;

(iii) operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;

(iv) procedures are established for responding to anticipated operational occurrences and to accidents;

(v) necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;

(vi) events significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body;

(vii) programmes to collect and analyze operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies;

(viii) the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.

19.1 Initial Approval

19.1.1 Review, Approval and Inspection for Operation Related Licenses of NPPs

The process to obtain operation license of NPPs of China is divided into two phases: Phase 1, before operation, the operating organization applies for the *Certificate of Approval for the First Fuel Loading of Nuclear Power Plant* at first. Phase 2, after the first fuel loading, the operating organization applies for the *Operation License of Nuclear Power Plant* 12 months after the trial operation on full power.

The operating organization must submit the Application for the first fuel loading of the NPP to the MEP (NNSA) prior to the first fuel loading of the NPP together with the prescribed documents:

— *Final Safety Analysis Report for Nuclear Power Plant*;

—*Instrument of Ratificationof the Environmental Impact Assessment Report of Nuclear Power Plant (one month before the first fuel loading)*;

—*Nuclear Power Plant*; *Commissioning Program*;

— *Qualification Certificates of Nuclear Power Plant Operator* (one month before the first fuel loading);

— *Emergency Plan of the Operating Organization of Nuclear Power Plant(six months before the first fuel loading)*;

—*Construction Progress Report of Nuclear Power Plant (six months before the first fuel loading)*;

—*Nuclear Power Plant In-service Inspection Program*;

— *The results of the pre-service inspection (one month before the first fuel loading);*

— *Commissioning Report of Nuclear Power Plant Before Fuel Loading (one month before the first fuel loading);*

—*Certificate Proving Operating Organizations of Nuclear Power Plant Holding Nuclear Material License (one month before the first fuel loading);*

— The list of operation procedures of NPP (one month before the first fuel loading);

— *Maintenance Program of Nuclear Power Plant (six months before the first fuel loading);*

— *Quality Assurance Program of Nuclear Power Plant(during commissioning).*

Among them, the safety analysis report of the NPP is an important part of the basis for NPP permit review and approval and also an important part of the basis for the safety operation of an installation. The safety analyses of NPP are presented in the preliminary safety analysis report (PSAR) and final safety analysis report (FSAR). Safety analysis reports of NPPs include accurate and precise information of NPPs and their operation status, such as safety requirements, design basis, site and plant characteristics, operation limits and conditions, and safety analysis information, to enable regulatory bodies to independently assess the safety of plant.

The MEP (NNSA) is the organizer and responsible body for the safety review of nuclear and radiation installations in China, and organizes technical support organizations to perform overall review and assessment of the application documents submitted by the nuclear and radiation installation operating organizations. The Nuclear and Radiation Safety Center of MEP is the permanent technical support organization of the MEP (NNSA). For important projects, external technical support organizations such as the Nuclear Equipment Safety and Reliability Center, Suzhou Nuclear Safety Center and Beijing Nuclear Safety Review Center will be designated to perform parallel safety review. The MEP (NNSA) organizes review to confirm that these documents submitted by the operating organizations comply with the requirements of national nuclear-safety regulations, on-site and off-site nuclear accident emergency plans of the new built NPPs have been reviewed and approved, and in the meanwhile emergency exercises of on-site and off-site nuclear accident have been organized by the emergency response organizations of the NPP and the department designated by people's government at the provincial level, then the *Instrument of Ratification for the First Fuel Loading of Nuclear Power Plant* can be issued to the applicant.

The operating organization of the NPP shall timely submit the following documents to the MEP (NNSA) after 12-month trial operation from the date when the first full power of the NPP is realized:

— *Revised Final Safety Analysis Report of Nuclear Power Plant*;

—*Instrument of Ratificationof the Environmental Impact Report of Nuclear Power Plant*;

— *Reports of Commissioning and Trial Operation of Nuclear Power Plant after the Fuel Loading*;

— *Quality Assurance Program of Nuclear Power Plant(during operation)*.

The MEP (NNSA) will organize review, and the *Operation License of Nuclear Power Plant* will be issued to the applicant after confirming that the contents of these documents comply with the requirements of national nuclear safety regulations.

In addition, in the commissioning and operation phases, the MEP (NNSA) performs inspections at control points including the cold/hot functional tests, the first fuel loading, the initial criticality, and power transition/ascension. Nuclear safety inspections are performed in the whole processes and for all important activities in the commissioning, operation and decommissioning phases of nuclear installations, to confirm that all items and activities of operating organizations in all phases of the nuclear installation related to safety meet the nuclear safety management requirements and conditions specified on the license, and comply with the requirements and commitments in the relevant nuclear safety codes and license (operation permit) application documents.

19.1.2 Commissioning of NPP

The trial operation of NPPs in China today is performed to prove that the constructed NPP is consistent with the requirements of design, related safety analysis, and commissioning program.

Commissioning program is drawn up and implemented by NPP operating organizations to ensure that the commissioning activities are safely and effectively implemented according to written procedures. The commissioning program is subjected to the approval from the MEP (NNSA). The preparation of the commissioning program shall be strictly based on the upstream design documents, and incorporate the existing review results and operating experience from similar unit; also, the interface management between commissioning and the design and construction, and the coordination and communication between commissioning specialties of the project should be strengthened, to further improve the preparation quality of the commissioning program. All necessary tests and relevant activities are listed in the commissioning program to verify that the design and construction of the NPP are appropriate to ensure the safe operation of the NPP. In the meantime, operating personnel have the opportunities to get familiar with the operation of NPP.

The commissioning activities of operating organizations shall strictly follow the safety criteria in the commissioning program, any revision to the safety criteria due to change of upstream design documents must be submitted in advance to the MEP (NNSA) for review and approval. The operation criteria can be made an annex to the commissioning program for reference in implementation. If any change is found necessary to the operation criteria, change and revision shall be made promptly according to relevant procedures, and be filed with the MEP (NNSA).

The commissioning program of the operating organization is divided into several phases, in order to indicate the tests required to be finished in the expected period of each phase and define the "control points" at which the testing results must be reviewed before continuing with the next phase. The necessary tasks to be prepared for the next phase, especially the availability requirements of the systems to be used in the next phase, are included in each phase.

The operating organization can carry out the commissioning of the next phase only after finishing the assessment and review of the commissioning and testing results of the previous phase, and confirming that all objectives have been realized and all the nuclear safety management requirements have been satisfied. For testing items with prerequisite, process parameter and result not complying with commissioning program requirements, the regional office will urge the operating organization to perform analysis and assessment or to do it again.

All commissioning tests shall be performed according to the approved written procedures. For commissioning procedures important to safety and their change, a report must be submitted to the MEP (NNSA). In order to achieve the target of safe commissioning, the whole commissioning work is completely managed, controlled and coordinated by the operating organizations. Practical working plans are worked out for this purpose, to ensure best use of the personnel, equipment, methods and time.

The MEP (NNSA) organizes the formulation of standard supervision and inspection program for nuclear installations/activities, for the commissioning supervision and inspection for specific nuclear installations, regional offices work out detailed implementation procedures for the commissioning supervision and inspection of systems and equipment important to safety by expanding and setting detailed requirements for them on the basis of the standard supervision and inspection program. In Apr. 2013, the MEP (NNSA) issued the *Nuclear Safety Supervision and Inspection Program for Commissioning Phase of 1000MW Class PWR Nuclear Power Plants*, to strengthen the supervision over the whole process of commissioning. It also worked out the *Commissioning Supervision Work Plan for AP1000 and EPR Nuclear Power Plants*, and prepared and issued the commissioning supervision program for AP1000 and EPR NPPs, to get prepared for the commissioning supervision for AP1000 and EPR NPPs.

19.2 Operation Limits and Conditions

The operation limits and conditions constitute important basis for NPP operating organizations to operate NPPs with authorization. The operation limits and conditions cover the requirements on all operation states (including shutdown). These operational conditions include startup, power operation, shutdown, maintenance, testing and refueling. Operational requirements should be determined in operation limits and conditions to ensure that safety systems including engineered safety features can perform necessary functions in all operating states and design basis accidents. The operational personnel in NPPs who are directly responsible for operation are familiar with and strictly comply with the operation limits and conditions.

The *Code on the Safety of the Nuclear Power Plant Operation* has set forth principle stipulations on the operation limits and conditions and procedures for NPPs, also, the *Operation Limits, Conditions and Procedures of Nuclear Power Plant* has been issued, to make supplement and remarks to the relevant provisions in the *Code on the Safety of the Nuclear Power Plant Operation*, to provide guidance for NPPs to establish and implement the operation limits, conditions and procedures of the NPP. The NPP operating organizations set the operation limits and conditions and have them approved by the MEP (NNSA).

The operation limits and conditions include the limits and operational requirements to be followed for SSCs significant to the safety in the NPP to implement intended functions that are assumed in the safety analysis report on the technical aspects. Operation limits and conditions also include the actions to be taken and the limits to be observed by operating personnel. For operating personnel, the operation limits and conditions include the principles and requirements on necessary supervision, correction or supplementary activities to the equipment designed to maintain the operation limits and conditions in implementing their functions. Some operation limits and conditions may include the combination of automatic functions and manual operation.

The operation limits and conditions of NPPs include:

— Safety limits;

— Set values of safety systems;

— Normal operation limits and conditions;

— Supervision requirements;

— Actions to be taken in case of deviation from operation limits and conditions.

The operation limits and conditions are based on the analyses of specific NPP and its environment, and are in accordance with the provisions in the final design. Some necessary amendments are made according to the test results in the commissioning phase, and the reasons and the necessities to adopt each of the operation limits and conditions are justified in the written form.

NPP operating organizations shall carry out periodical review to the operation limits and conditions throughout the operating life of the NPP, in order to ensure that they remain applicable to the intended purpose, and make periodical modifications in light of accumulated experience and technological developments. Even if no modification is made to the NPP, this periodic review shall also be carried out. NPP operating organizations shall prepare the working procedures to revise operation limits and conditions and revise the operation limits and conditions according to the procedures.

The application of probabilistic safety analysis on the aspects of operation limits and conditions optimization should be considered by NPP operating organizations. Probabilistic safety assessment method and operational experience can be used together in the justification and revision of operation limits and conditions.

Assessments and reports of anticipated operational events are important bases for determining whether or not the operation limits and conditions need to be revised. Any modification to operation limits or conditions in NPPs of China is subjected to review and approval by the MEP (NNSA).

19.3 Operation, Maintenance, Inspection and Test of NPP

Before the operation of a NPP, written operational procedures are worked out by the operating organizations in cooperation with the design institutes and the suppliers. The compilation, review and revision of the operational procedures accord with the approved operation limits and conditions with adaptable safety margins. The necessary actions that should be taken in normal operation, anticipant operational events and accident conditions are included in the formulated operational procedures. The operational procedures facilitate the operational personnel to perform the manipulations according to the correct sequence, and define explicitly the responsibilities and the communication means of the operational personnel in case of being forced to deviate from the written procedures. All the operational procedures shall be reviewed regularly and any modification shall be noticed to operational personnel and other holders of these documents. The modifications are carried out according to the procedures in written form

Prior to the operation of a NPP, the necessary programs for periodic maintenance, testing, inspection and verification of the structures, systems and components are prepared by the operating organization for safe operation. The programs are re-assessed according to the operating experience. The programs of the maintenance, test, verification and inspection satisfy the operation limits and conditions, as well as the applicable nuclear safety regulatory requirements.

Prior to the maintenance, testing, verification and inspection of the SSCs, written procedures and programs which clearly define the standards and the periods of the maintenance, testing, verification and inspection of SSCs important to safety, are compiled by the operating organization of NPP in cooperation with the suppliers of the plant and the equipment. After the maintenance, the SSCs are inspected by authorized personnel, and relevant verification experiments are performed if necessary.

For the in-service inspection of NPP, provisions are made in the design phase, and reviews have also been performed for the design of systems, components and their configuration, so that the inspecting personnel can access the components to be inspected and perform smoothly the required inspections and tests while the personnel exposure is kept at a level as low as reasonably achievable (ALARA). The NPP operating organizations prepare the in-service inspection programs before operation, to determine the systems and components to be inspected and the inspection frequencies according to their safety importance and the rate of the equipment quality degradation, and to check the integrity of the nuclear pressurized components through the in-service inspection. In addition, all NPPs track the development of new technologies and processes of NDT testing, and developed a number of new processes for major components in NPPs, improving the equipment reliability.

The CNNO has realized formalized management of implementation for in-service inspection items by supplementing the relevant management requirements on six aspects of in-service inspection into the plant management system and the industrial specifications for item implementation: item management, pre-job briefing, equipment operation, work guidelines, implementation logic diagram and item re-check, reducing the work intensity, improving the work quality, lowering the risks, optimizing the schedule and solidifying the experience, thus promoting the effective management and control of in-service inspection items in safety, quality and schedule.

NPP operating organizations assess all inspection results, to determine if they comply with the qualification, standards the components not suitable for further service as determined in the assessment will be repaired or replaced.

In three years, more efforts have been made by the nuclear safety regulatory bodies and operating NPPs in China on following aspects, on the basis of safe operation, maintenance and periodic tests:

(1) The reliability-centered maintenance optimization (RCM) method has been used continually to analyze plant systems, and preventive maintenance programs and procedures are optimized in the viewpoint of ensuring system reliability, in the meantime, supervision and monitoring are performed for equipment/system performance, to identify any degradation of equipment/system performance earlier, and initiative preventive and corrective actions are taken to prevent functional failure.

(2) In 2015, the MEP (NNSA) required all NPP operating organizations to formally carry out the work to collect reliability data for plant equipment, and those already submitting data to report all data together once a year; for new nuclear power units being put into operation, this work should be started after full power has been reached, to collect relevant data and start submitting data in 24 months. On this basis, the MEP (NNSA), by using the established general database for equipment reliability of operating NPPs, collect the equipment reliability data of all NPPs; on the basis of analysis and sorting-out of relevant data, the *Equipment Reliability Data Report of Nuclear Power Plant in China* (2015 Rev.) was prepared and published, and this was the first NPP equipment reliability data report officially published by China.

(3) PSA has been applied more to optimize resource allocation and increasing nuclear safety level. The MEP (NNSA) approved the PSA pilot application at Daya Bay NPP, for the research program *Optimization of Risk-informed Technical Specification and Optimization of Risk-informed In-service Inspection*. In the meantime, peer review was carried out for power condition internal event level I and shutdown condition internal event level I PSA at Tianwan NPP. Other items included special safety assessments such as regular operation risk assessment, event assessment, indicator assessment, project renovation, license application, and nonconformance, and decision-making support for sudden events.

(4) Outage optimization management has been further advanced, best outage practices for NPPs have been accumulated, and new technologies actively used to improve outage management and increase working efficiency. All NPPs have continually optimized outage schedule by means of optimizing outage organization, parallel advancing main and secondary critical paths in outage, and optimizing procedures and testing methods.

19.4 Accident Procedures

All NPPs have worked out relevant response procedures on anticipated operation events and accidents, tried to verify accident procedures on full scope simulator and/or onsite, and performed training to operators.

At present, the accident response procedures in NPPs fall into two categories: the event-oriented approach and symptom-oriented approach.

According to the principles for handling design basis accidents and the functions of engineered safety features, the accident response procedures of NPPs in China are classified into two categories by design methods:

— Single-event deterministic procedures are based upon the accident evolution premeditatedly studied in order to maintain the reactor in a safe condition or lead it to a safe condition. These procedures include Abnormal-Condition Handling Procedures, Design-Basis Accident Handling Procedures, and Beyond Design-Basis Accident Handling Procedures.

— Procedures based on status approximation approach are prepared using the reactor physical status approximation approach to deal with difficulties resulted from combination of a number of events that may occur based on the accumulated failure of equipment and/or human factor, including Severe Accident Handling Procedures, Continuous-Monitoring Procedures of Abnormal Conditions, and Continuous-Monitoring Procedure under Limit Conditions.

According to the up gradation and renovation of plant systems, research results of PSR and PSA, operating experience of accident procedures and research on accident evolvement, NPPs in China actively followed the international development to assess and modify accident procedures. After Fukushima accident, MEP (NNSA) took the lead in organizing safety inspection and proposing rectification requirements for the management of severe accidents, requiring all NPPs to develop or optimize SAMG, analyze the availability and accessibility of important equipment and monitoring instruments in severe accidents by taking into account various accident conditions and common cause failure at a multi-unit site. In accordance with the requirements, a series of work was carried out by the plants, and plus the operation procedures of NPPs already in place, fairly complete handling and management system after severe accidents in NPPs will be formed. Detailed fulfillment of this job is described in 18.1.4.

Furthermore, according to the actual conditions, NPPs have worked out the emergency response plans and response procedures after a number of units have entered the emergency status at the same time, by taking into account the risk of simultaneous accident with both units resulted from common cause event and external common cause event (such as typhoon, earthquake and flood) and the corresponding emergency action level and emergency response process. The revised emergency response plans have been submitted to the MEP (NNSA) for filing.

19.5 Engineering and Technical Support

After years of development and practice, China has basically established its own engineering and technical support system for NPPs.

The Chinese government and every nuclear power corporation groups have made appropriate restructuring or recombination of the existing nuclear power engineering design and research organizations, to establish a technical support system oriented to NPPs, covering areas of operation research, safety analysis, radiation protection, in-service inspection, plant modification, special tests, equipment maintenance and safety reviews. The technical support organizations include China Nuclear Power Engineering Co., Ltd., Nuclear Power Institute of China, China Nuclear Power Design Co., Ltd., Shanghai Nuclear Engineering Research and Design Institute, China Academy of Machinery Science and Technology, Research Institute of Nuclear Power Operation, Suzhou Nuclear Power Institute, China Institute for Radiation Protection, and China Institute of Atomic Energy.

Through practices of independent construction and operation, NPPs have gradually established directly affiliated technical support departments required for operation safety, to provide all-round technical support for operational safety.

Through cooperation and information exchange channels with international organizations such as IAEA and WANO, NPPs of China can get technical supports from the international peers when necessary.

Under accident conditions, all NPPs can obtain multi-directional technical supports. In the overall layout for nuclear emergency at three capability levels, the national level nuclear emergency professional technical support center and national nuclear emergency professional rescue detachments will provide the technical support at the highest capability level, and in the meantime, the provincial level and local governments will also do corresponding coordination and support. NPPs can also obtain technical support forces from inside the group. In addition, with the cooperation agreements on nuclear accident mutual emergency rescue between nuclear power groups in China, technical support will be provided between nuclear power groups when necessary.

Under their respective accident management systems, all NPPs actively cooperate with various organizations and sign support agreements with them, for example, with hospitals, fire brigades, police, the army and anti-terrorism forces, and meteorological, geological and hydrological organizations, these organizations will provide professional technical support under accident conditions when necessary.

19.6 Event Reporting System of Operating NPPs

The operating NPPs in China shall report to the MEP (NNSA) all operation events meeting the reporting criteria according to the stipulations in the *Regulations on the Safety Regulation for Civilian Nuclear Installations* and Appendix 1 *Reporting System for Operating Organizations of Nuclear Power Plant* (HAF001/02/01) to *Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations.*

The event reporting criteria for operation phase cover the following events:

(1) Any event that violates the Technical Specifications of the NPP;

(2) Any event that seriously damages the performance of safety barriers or important equipment of the NPP, or leads to one of the following conditions:

1) An unanalyzed working condition that would significantly endanger safety;

2) A working condition beyond the design basis of the NPP;

3) A working condition having not been taken into account in the operation procedures or emergency response procedures of the NPP.

(3) Any natural event or other external event that would pose actual threat to the safety of the NPP or clearly hinder site personnel on duty in their performance necessary for the safety operation of the NPP.

(4) Any event that would result manual or automatic activation of the engineered

safety features and the reactor protection system (with the exclusion of the preplanned tests of this kind);

(5) Any event that may prevent a structure or system from realizing the following safety functions;

1) The shutdown and the maintenance of the safe shutdown conditions;

2) Residual core heat removal;

3) The control of release of radioactive substance; and

4) The mitigation of the accident consequences.

(6) Any common cause event that would lead to simultaneous failure of a number of independent systems, trains or channels with the following functions;

1) The shutdown and the maintenance of the safe shutdown conditions;

2) Residual core heat removal;

3) The control of release of radioactive substance; and

4) The mitigation of the accident consequences.

(7) Any event that would result in uncontrolled radiological release;

(8) Any internal event that would pose actual threat to the safety of the NPP or clearly hinder site personnel in their performance of duties necessary for the safety operation of the NPP.

(9) Other events.

The ways of event reporting:

— Oral notification, which must be sent out within 24 hours after the occurrence of the event;

— Written notification, which must be submitted within three days after the occurrence of the event and in a specified format;

— Event report, which shall be submitted within 30 days after the occurrence of the event and in the specified format for the report;

— Accident report of NPP under emergency status, refer to 16.3 of this report.

NPPs of China identify root causes of operation events using the root cause analysis methods recommended by the MEP (NNSA), work out correct corrective actions, prepare and complete the operation event report within the specified time period, and submit it to the MEP (NNSA). The MEP (NNSA) assesses the submitted operation event report on the basis of this report and the relevant information known to it about the operation event, and presents the assessment comments; if investigation is required for the operation event, the MEP (NNSA) will organize an investigation group to conduct the investigation. NPPs of China would modify the operation event report on the basis of the assessment comments from the MEP (NNSA) on the event, and implement corresponding corrective actions, the regional offices on nuclear and radiation supervision will follow up and supervise the implementation of the corrective actions.

Also, according to *Management Measures for Operating Experience of Operating Nuclear Power Plants (for trial implementation)*, operating NPPs need to submit lists and abstracts of their internal events periodically, and submit the corresponding internal event reports as required by the MEP (NNSA), to facilitate the nuclear safety regulatory bodies to identify other important events, and promptly find any detrimental trend in the safety of NPPs.

In 2013, for the operating NPPs in China, a total of 30 operation events occurred, including 18 events after the unit commercial operation and 12 before the unit commercial operation; in 2014, for the operating NPPs in China, a total of 38 operation event occurred, including 13 events after the unit commercial operation and 25 before the unit commercial operation; and in 2015, for the operating NPPs in China, a total of 45 operation events occurred, including 26 events after the unit commercial operation and 19 before the unit commercial operation. There was no operation event at INES scale 2 or above in the operating NPPs in China during the three years.

19.7 Operating Experience

China has actively carried out operating experience and exchange activities among NPPs, at present, operating experience system has been established at all levels, including those of plants themselves, of nuclear power group corporations, of the nuclear industry and of the MEP (NNSA).

NPPs in China submit operation event reports to the corresponding operating experience platforms on a regular basis according to the stipulations of nuclear safety regulatory bodies, the management requirements of the belonging nuclear power group corporations and relevant stipulations of the nuclear industry, to ensure sufficient sharing of operation event information of all plants in the industry. In the meantime, as a supplement to the operating experience platform, the nuclear safety regulatory bodies, nuclear power group corporations, nuclear industrial association and all NPPs further promote the exchange of operation experience in the forms of preparing and releasing quarterly and annual operation reports, weekly reports of domestic and overseas events, annual operating experience report and report on critical performance indicators.

Nuclear safety regulatory bodies, nuclear power group corporations and nuclear industrial association also hold experience exchange meetings regularly for operating NPPs, to study and discuss important operation events having occurred, to identify loopholes or weak links in the nuclear safety supervision or plant safety management, and raise the safety level of plants. Also, to raise the professional ability of working personnel doing operating experience and the cognition of ordinary employees on operating experience, the relevant institutions would organize operating experience training activities periodically.

For frequent common cause or common mode events, the MEP (NNSA), nuclear power group corporations and nuclear industrial association often organize technical forces to carry out in-depth investigations, and prepare corresponding operating experience reports. In recent years, the MEP (NNSA) have prepared and issued many operating experience reports for common cause events such as plant working personnel entering a wrong room, the cooling source of essential service water system in plant, events with digital I&C system and reactor shutdown resulted from improper adjustment of SG level. These reports, on the basis of statistics and analysis of root causes of events and in conjunction with the design features of relevant plant, operation experience and actual safety management conditions, put forth corresponding regulatory recommendations and corrective actions, to avoid or reduce the recurrence of similar operation events.

While strengthening and improving feedback and exchange of operation experience domestically, China has also strengthened feedback and exchange of operation experience internationally, by maintaining close ties with the national nuclear safety regulatory bodies and nuclear power operators of the EU, the United States, Russia, Japan and Korea, and the international organizations and research institutions including IAEA, WANO and INPO, carrying out operating experience and exchange activities with them on a regular or irregular basis, dispatching personnel to each other for study and training activities, and providing event reports according to the respective event report criteria and requirements, to share experience with each other. To further track and analyze international hot nuclear safety issues, the MEP (NNSA) also established special teams for international information research and operating experience, to enhance the analysis and research capability on major international issues on nuclear and radiation safety, and provide important reference for the nuclear safety supervision decision-making and implementation.

According to the actual demand in nuclear safety international cooperation, the MEP (NNSA) has designed and developed the management information platform for international cooperation, and established fairly complete nuclear safety international cooperation electronic archives, to facilitate the retrieval, inquiry and use of historical documents, and increase the utilization rate and value of international exchange information.

The MEP (NNSA) has carried out feedback and exchange with the NRC and ASN on the PMS testing plan for AP1000 projects, the CRDM moving armature current exceeding tolerance in CPR1000 project and the equivalent carbon content of RPV head exceeding standard in EPR project; also, combing and checking were carried out in China on problems such as supplier counterfeiting as fed back from other countries, promoting the use of relevant results.

In the past three years, China mainly carried out the following activities in feedback of operation experience of NPPs:

(1) Establishing and completing the operating experience system of the MEP (NNSA), which includes three aspects: the document system, information platform and operating experience expert pool.

The document system is comprised of documents at three tiers, those at the top tier are the *Management Measures for Operating Experience of Operating Nuclear Power Plants* and *Guideline for Operating Experience of Operating Nuclear Power Plants*. The *Management Measures for Operating Experience of Operating Nuclear Power Plants* is the outline document of the whole operating experience system, it defines the responsibilities of the nuclear safety regulatory bodies and NPPs in the operating experience system. The *Work Guideline for Operating Experience of Operating Nuclear Power Plants* specifies the operation mechanism of the operation operating experience system, including the sources and collection of operating experience information, the screening and assessment of operating experience information, corrective actions, follow-up of supervision and inspection results, assessment of safety status of operating NPPs, the application and release of operating experience information, and the assessment of effectiveness of the operating experience system; it has also raised relevant requirements on the operating experience exchange and training in operating NPPs, and lists the lower tier specific working procedures applicable to them. Tier II is the operating experience working procedures, which specify the management process flows in the operating experience work, and the responsibilities of relevant organizations. The tier III is technical documents, with the objective to formalize the various technical methods and means to be used in the operating experience work, for example, the root cause analysis methods for events, and event screening criteria.

The operating experience platform (hereinafter referred to as "platform") is the network portal and platform for interaction of operating experience related information in the system, in this network platform, database modules of various specialties of the operating experience information system are provided, to allow centralized access and management. The scope of platform functions include eight modules: the regulatory information, operating experience, safety status assessment, training and exchange, effectiveness assessment, operating experience system documents, expert pool, and maintenance management.

The MEP (NNSA) can effectively run the operating experience system via the platform, and use the developed modules and tools on the platform to conveniently make in-depth analysis and summary of the causes, processes and consequences of various nuclear events having occurred in China and in the world. The applications of its operating experience information in the nuclear safety regulatory activities mainly include the improvement of supervision and inspection activities, improvement of licensing review and modifying codes and guides. The MEP (NNSA) is in charge of the release of operating experience results and regulatory requirements, and the release forms can be information notification, management requirements and improvement requirements. The regional offices for nuclear and radiation supervision can track the timeliness and effectiveness of the implementation of improvement and corrective actions by NPPs by using the operating experience platform.

The operating experience experts pool is formed by people with high academic level and rich practical experience in the field of nuclear and radiation safety, and its main responsibilities and duties are:

- Providing technical support to the screening, assessment and application of operating experience information;
- Providing technical support to the investigation and assessment of events in NPPs;
- Providing technical support to the safety status assessment in NPPs;
- Providing technical support to the activities to assess the effectiveness of the operating experience system;
- Providing other required extra technical support for the operating experience system.

The construction of the operating experience system has enabled the MEP (NNSA) to effectively collect and screen important safety information, and issue regulatory requirements promptly through analysis and research, to raise the efficiency in nuclear safety regulation.

(2) China Nuclear Energy Association continually pushes forward the work of experience exchange and information sharing among NPPs of China. 17 special subject working groups including equipment root cause analysis (RCA) and human factor management of the nuclear energy industry have been set up, to carry out relevant research work specifically. In the meantime, industrial symposiums with the themes of probabilistic safety analysis (PSA), NPP aging and life management, in-service inspection and NDT, and technology of nuclear class pumps are held regularly, to promote the upgrading of management level and technological progress in the nuclear industry.

(3) All nuclear power group corporations have established and completed unified platforms for operating experience for integrated management. The status report standardization and operating experience information sharing mechanism are carried on with this unified platform as backup, to collect in real-time the event information of other NPPs both at home and abroad, draw experience and lessons and compile them into operating experience documents for release, and make adaptive analysis. All nuclear power groups have realized combing and screening of operation events within the groups, can quickly respond to important common cause or common mode events, find out the root causes of events, help the management promptly improve safety management measures, and raise the operation safety level of all subordinated NPPs.

(4) NPPs of China continually improve and optimize the operating experience information processing plans and processes and the external event feedback mechanism. At present, all NPPs of China have established informative management platforms, realizing informatization of operating experience work and having raised the efficiency of operating experience work. In the meantime, NPPs of China keep on improving the organization system and management procedures, to raise the position of operating experience work in the daily work. Special operating experience engineers are staffed in departments at all levels, and each NPP also has its specific operating experience organization, to take charge of the organization and coordination work for the operating experience in the whole plant. The NPP management has included operating experience into the safety management policy, actively publicized operating experience among NPP employees, and encourages them to identify problems existing in the safety of NPPs. The belonging nuclear power groups regularly organize evaluation of the effectiveness of operating experience in all NPPs, and NPPs also take an active part in various peer review activities, to identify problems existing in operating experience work and raise the level of operating experience work.

19.8 Management of Spent Fuel and Radioactive Wastes

The Chinese government promulgated the *Law of the People's Republic of China on Prevention and Control of Radioactive Pollution*, further making clear all requirements for managing the radioactive waste on the law bases, promoting the realization of the management objects of the radioactive waste. In order to prevent and remedy the radioactive contaminations, China has implemented the policy of "Combining prevention with remedy with prevention as the main, strict management with safety first" and established radioactive contamination monitoring systems. The administrative competent department of environment protection of the State Council conducts the unified surveillance and management for the prevention and remedy of the radioactive contamination nationwide. Operating organizations of NPPs discharge the radioactive waste gas and waste liquid meeting the requirements of national standards on prevention and remedy of radioactive contamination into the environment in specified emission modes. These operating organizations shall apply to the authority examining their environmental impact assessment documents for the discharge amount of radioactive nuclides, and periodically report the metering results of their discharges. The radioactive waste liquid which must not be discharged into the environment is processed and stored. Low and medium-level radioactive solid wastes are disposed of near surface in the regions complying stipulations of the state, and high-level radioactive solid wastes are disposed of in a concentrated way in deep geological layers.

The *Regulations on the Safety Management of Radioactive Waste* promulgated in 2012 specifies the treatment, storage, disposal of radioactive wastes and their supervision and management activities. The safe management of radioactive wastes shall stick to the principles of volume reduction, harmlessness, proper disposal and permanent safety. Classification management is carried out for radioactive wastes by the state. The Ministry of Environmental Protection is in charge of the safety supervision and management of radioactive wastes throughout the country and establishes management information system of radioactive wastes across the country together with relevant administrative departments of nuclear industry under the State Council and other relevant departments to realize information sharing.

It is clearly stated in the *Nuclear Safety Plan* issued by China in 2012 that, the specific goal of contamination treatment and rectification is to build an advanced and highly efficient radioactive contamination treatment and rectification and waste treatment system adapting to the development level of nuclear industry, and basically complete disposal ground for low and medium level radioactive wastes in association with the development of the nuclear industry. The far term goal of 2020 is to carry out treatment and rectification of radioactive contamination in all aspects, achieve obvious result in the decommissioning of nuclear installations constructed early, basically eliminate the safety risks of radioactive wastes left over in history, accomplish the top level design for treatment and disposal of high-level radioactive wastes and complete the underground laboratory.

China is preparing the *Guide for Minimizing Radioactive Wastes from Nuclear Power Plants*, and the draft for comments has been completed. The guide proposes that the minimization of radioactive wastes from NPPs shall be based on ensuring the plant operation safety and safety of wastes, with the safe disposal of wastes as the core, shall ensure the un-confined discharge of gas and liquid effluents produced in the normal operation of NPPs by reducing the generation of wastes, treatment to reduce volume, recirculation and re-utilization and the corresponding management measures, so that the performance of the finally produced waste mass and packages produced can meet the disposal requirements and the amount of wastes produced is as low as reasonably achievable. The target values set for minimizing solid wastes is $55m^3$ for inland NPP per year and $50\ m^3$ for coastal NPP per year.

The NPP operating organizations in China have prepared and implemented waste management programs, and worked out various measures for waste treatment, storage and disposal and to effectively restrict the discharge of effluents. The waste management systems are run with detailed procedures and according to design intents and assumptions, and appropriate supervision, training and quality assurance measures are implemented to perform effective management of all activities related to the operation and maintenance of waste management systems, to reduce the probability of abnormal events related to waste management systems, and to keep the amount of radioactive wastes produced as low as practically achievable. Radioactive wastes are treated to reduce their volume, and the management guide for minimizing wastes has been worked out with the purpose to limit the amount of radioactive solid wastes produced within the management target values, to reduce the radioactive dose exposed to people in the treatment of radioactive wastes; to reduce the radioactivity and the quantity of radioactive materials in the course of treating the radioactive wastes, and reduce the radioactive waste management cost of NPPs.

In NPPs of China, measures such as source term control, using the best available process, optimizing equipment management, strict control and classified collection, recycling utilization, reducing volume of wastes, strict access management for controlled zones and clean un-confinement are used, to effectively control and reduce the amount of radioactive wastes produced, and monitor the technological processes producing wastes, to provide the information about the sources and characteristics of radioactive wastes and to prove that it is consistent with operational procedures. Monitoring results show that the discharge amount of radioactive effluents during operation of NPPs is far below the discharge limit stipulated by the national standards.

NPPs in China have sufficient facilities to store radioactive wastes produced during the normal operation and anticipated operational events. Excessive accumulation of untreated wastes is avoided during waste treatment. Records and documents of the amount of stored wastes are well kept according to the requirements of relevant regulations and quality assurance.

In order to ensure the integrity and subcriticality of the spent fuel, the NPP operating organizations in China handle and store the spent fuel according to written procedures by using approved equipment inside the approved facilities. The underwater storage conditions of the spent fuel and the water quality comply with the chemical and physical characteristics specified. With the accumulation of plant operating time, corresponding preparation has been done for subsequent off-plant storage of spent fuel. Each operating NPP has signed service agreement for outward transport and disposal of spent fuel with related technical service units, clearly specifying the corresponding responsibilities for disposal mode, off-site transportation and storage of spent fuel. In the meantime, research and development has been carried out for spent fuel shipping containers, as preparation for the transport of spent fuel. Each NPP under construction has also signed long-term service agreement for spent fuel transport and service agreement for spent fuel receiving and storage with technical service units. This marks that NPPs in China have got ready for off-plant disposal of spent fuel.

The off-plant storage facilities for spent fuel comply with design and safety requirements. Operating organizations have established the safe operation plan for spent fuel storage, including operation procedures, commissioning plan, quality assurance program, training schedule, radiation protection program and emergency preparedness, to prevent lease of radioactive substance into the environment. The operation limits and conditions for facilities have been defined, including keeping subcriticality, radiation safety and residual heat removal, for example, the temporary dry storage facilities for spent fuel require that any spent fuel bundle to be put into the fuel basket must have been cooled in the spent fuel pool for at least 6 years, and the dose rate limit value in the module preparation zone and spent fuel storage zone is 25μSv/h.

The operation, maintenance, monitoring, inspection and testing of temporary dry storage facilities for spent fuel are performed according to the prepared and approved procedures. The above-mentioned plans, stipulations, procedures and requirements include: spent fuel storage plan, management stipulations for storage module, storage cylinder, fuel basket position and numbering, fuel basket inspection and putting under water, loading, drying up and welding, transport and lifting requirements; management stipulations for continuous γ monitoring, radiation protection supervision and management stipulations for storage module area, daily inspection and supervision stipulations for storage cylinders, inspection and maintenance schedule for storage modules, storage cylinders, fuel baskets and shielded working cases, and the equipment maintenance, testing and acceptance procedures. The temporary dry storage facilities for spent fuel can obtain all safety-related engineering and technical supports.

After the Fukushima nuclear accident, to maintain reactor cooling, spent fuel pool cooling and maintain the necessary post-accident monitoring capacity of NPPs under SBO condition, all NPPs have made improvement according to the requirements on spent fuel pool monitoring means, monitoring scope, monitoring instruments and system availability in the *General Technical Requirements on the Improvement of NPPs after the Fukushima Nuclear Accident*, and added spent fuel pool monitoring equipment and means, such as level and temperature monitoring, to obtain necessary information of spent fuel pool after an accident.

19.9 Network Information Safety of NPPs

Recently, following the continuous improvement of digitalization and networking of control systems in NPPs, attention are increasingly drawn to the threat suffered by the network safety of NPPs.

Various nuclear power corporations and NPPs in China have carried out relevant work on network information safety, established management organizations for network information safety and formulated network information safety management system and relevant management procedures. Network information safety of NPPs is protected based on the principle of definition of safety zone, boundary isolation, hierarchical protection and multiple-level control. NPPs divide the management information network into many zones with safety equipment and isolation measures arranged at the boundary of each zone. In addition, safety policies are set up and multiple safety protection equipment is adopted. For example, such measures as firewall, intrusion prevention, malicious code detection, Junk mail gateway and intermediary computer are deployed for internal network.

Furthermore, nuclear power corporations have organized emergency drills on network information safety and emergency drills on important information systems such as information system DDOS for external portal website and external services, unauthorized intrusion and malicious attacks. Each year, nuclear power corporations invite the third party company to simulate Hacker to attack the corporate network and information system through internet, so as to check the capability on protection of network information system safety and on response to unexpected events regarding information safety.

APPENDIX 1: THE LIST OF NPPS IN CHINA (BY DECEMBER 31, 2015)

NPP Name		Unit No.	Reactor Type MW(e)	Installed capacity MW(e)	Date of the Construction	Date of the First Connection to Grid	Date of Commercial Operation
Qinshan NPP		CN-01	PWR	310	1985-03-20	1991-12-15	1994-04-01
Daya Bay NPP	Unit 1	CN-02	PWR	2×984	1987-08-07	1993-08-31	1994-02-01
	Unit 2	CN-03			1988-04-07	1994-02-07	1994-05-06
Qinshan Phase II NPP	Unit 1	CN-04	PWR	4×650	1996-06-02	2002-02-06	2002-04-15
	Unit 2	CN-05			1997-04-01	2004-03-11	2004-05-03
	Unit 3	CN-14			2006-04-28	2010-08-01	2010-10-05
	Unit 4	CN-15			2007-01-28	2011-11-25	2011-12-30
LingAo NPP	Unit 1	CN-06	PWR	2×990	1997-05-15	2002-02-26	2002-05-28
	Unit 2	CN-07			1997-11-28	2002-09-14	2003-01-08
	Unit 3	CN-12		2×1080	2005-12-15	2010-07-15	2010-09-15
	Unit 4	CN-13			2006-06-15	2011-05-03	2011-08-07
Third Qinshan NPP	Unit 1	CN-08	PHWR	2×700	1998-06-08	2002-11-19	2002-12-31
	Unit 2	CN-09			1998-09-25	2003-06-12	2003-07-24
Tianwan NPP	Unit 1	CN-10	PWR	2×1060	1999-10-20	2006-05-12	2007-05-17
	Unit 2	CN-11			2000-09-20	2007-05-14	2007-08-16
	Unit 3	CN-45		2×1060	2012-12-27		
	Unit 4	CN-46			2013-09-27		
	Unit 5	CN-55		2×1080	2015-12-27		
	Unit 6	CN-56			Approved		
Hongyanhe NPP	Unit 1	CN-16	PWR	6×1080	2007-08-18	2013-02-17	2013-06-06
	Unit 2	CN-17			2008-03-28	2013-11-23	2014-05-13
	Unit 3	CN-26			2009-03-07	2015-03-23	2015-08-16
	Unit 4	CN-27			2009-08-15		
	Unit 5	CN-49			2015-03-29		
	Unit 6	CN-50			2015-07-24		

Ningde NPP	Unit 1 Unit 2 Unit 3 Unit 4	CN-18 CN-19 CN-34 CN-35	PWR	4×1080	2008-02-18 2008-11-12 2010-01-08 2010-09-29	2012-12-28 2014-01-04 2015-03-21	2013-04-15 2014-05-04 2015-06-10
Fuqing NPP	Unit 1 Unit 2 Unit 3 Unit 4 Unit 5 Unit 6	CN-20 CN-21 CN-42 CN-43 CN-51 CN-52	PWR	4×1080 2×1150	2008-11-21 2009-06-17 2010-12-31 2012-11-17 2015-05-07 2015-12-22	2014-08-20 2015-08-05	2014-11-22 2015-10-16
Yangjiang NPP	Unit 1 Unit 2 Unit 3 Unit 4 Unit 5 Unit 6	CN-22 CN-23 CN-40 CN-41 CN-47 CN-48	PWR	6×1080	2008-12-16 2009-06-04 2010-11-15 2012-11-17 2013-09-18 2013-12-23	2013-12-31 2015-03-10 2015-10-18	2014-03-25 2015-06-05
Fangjiashan NPP	Unit 1 Unit 2	CN-24 CN-25	PWR	2×1080	2008-12-26 2009-07-17	2014-11-04 2015-01-12	2014-12-15 2015-02-12
Sanmen NPP	Unit 1 Unit 2	CN-28 CN-29	PWR	2×1250	2009-04-19 2009-12-15		
Haiyang NPP	Unit 1 Unit 2	CN-30 CN-31	PWR	2×1250	2009-09-24 2010-06-20		
Taishan NPP	Unit 1 Unit 2	CN-32 CN-33	PWR	2×1750	2009-11-18 2010-04-15		
Changjiang NPP	Unit 1 Unit 2	CN-36 CN-37	PWR	2×650	2010-04-25 2010-11-21	2015-11-07	2015-12-25
Fangchenggang NPP	Unit 1 Unit 2 Unit 3 Unit 4	CN-38 CN-39 CN-53 CN-54	PWR	2×1080 2×1180	2010-07-30 2010-12-23 2015-12-24 Approved	2015-10-25	
Shidao Bay NPP	Demonstration Project	CN-44	HTGR	210	2012-12-09		

APPENDIX 2: OPERATIONAL EVENTS IN NPPS OF CHINA (FROM 2013 TO 2015)

Status of NPP when events occur / NPP Name		2013		2014		2015	
		Before commercial operation	After commercial operation	Before commercial operation	After commercial operation	Before commercial operation	After commercial operation
Qinshan NPP	Unit 1	/	1	/	0	/	1
Daya Bay NPP	Unit 1	/	0	/	1	/	0
	Unit 2	/	0	/	0	/	1
Qinshan Phase II NPP	Unit 1	/	1	/	0	/	1
	Unit 2	/	1	/	1	/	1
	Unit 3	/	1	/	0	/	2
	Unit 4	/	1	/	0	/	0
LingAo NPP	Unit 1	/	0	/	0	/	0
	Unit 2	/	0	/	1	/	0
	Unit 3	/	1	/	1	/	0
	Unit 4	/	0	/	1	/	0
Third Qinshan NPP	Unit 1	/	0	/	0	/	1
	Unit 2	/	0	/	0	/	1
Tianwan NPP	Unit 1	/	1	/	0	/	0
	Unit 2	/	0	/	0	/	2
Hongyanhe NPP	Unit 1	10	0	/	0	/	0
	Unit 2	2	/	3	2	/	3
	Unit 3	/	/	3	/	4	0
Ningde NPP	Unit 1	4	5	/	4	/	2
	Unit 2	1	/	4	1	/	0
	Unit 3	/	/	/	/	3	2
Yangjiang NPP	Unit 1	1	/	6	0	/	0
	Unit 2	/	/	/	/	3	0
	Unit 3	/	/	/	/	2	/
Fangjiashan NPP	Unit 1	/	/	3	0	/	0
	Unit 2	/	/	1	/	1	1
Fuqing NPP	Unit 1	/	/	5	1	/	6
	Unit 2	/	/	/	/	3	2
Fangchenggang NPP	Unit 1	/	/	/	/	1	/
Changjiang NPP	Unit 1	/	/	/	/	2	0
Total		18	12	25	13	19	26

APPENDIX 3: WANO PERFORMANCE INDICATORS OF OPERATIONAL NUCLEAR POWER UNITS IN CHINA (FROM 2013 TO 2015)

Table 1 WANO Performance Indicators of Operational Nuclear Power Units (2013)

Indicator (unit) / NPP		Unit Capability Factor (%)	Unplanned Capability Loss Factor (%)	Forced Loss Rate (%)	Grid Related Loss Factor (%)	Unplanned Automatic Scrams per 7,000 Hours Critical (Times)	Unplanned Scrams per 7,000 Hours Critical (Times)	Safety System Performance			Fuel Reliability (Bq/g)	Chemistry Performance	Collective Radiation Exposure (man·Sv)	Industrial Safety Accident Rate	Contractor Industrial Safety Accident Rate
								High-Pressure Safety Injection System	Auxiliary Feed-Water System	Emergency AC Supply System					
Qinshan NPP	CN01	81.61	0.02	0.02	0.00	0.97	0.97	0.0003	0.0001	0.0002	0.037	1.00	0.495	0.00	0.00
Daya Bay NPP	CN02	86.83	0.01	0.01	0.00	0.00	0.00	0.0000	0.0005	0.0004	0.037	1.00	0.892	0.00	0.00
	CN03	85.93	0.02	0.02	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.877		
Qinshan Phase II NPP	CN04	85.79	0.75	0.86	0.00	0.00	0.00	0.0000	0.0000	0.0189	0.037	1.00	0.362	0.00	0.00
	CN05	88.74	1.10	1.23	0.00	0.88	0.88	0.0000	0.0000		0.037	1.00	0.362		
	CN14	93.50	0.15	0.16	0.00	0.84	0.84	0.0003	0.0003	0.0001	0.037	1.01	0.226	0.00	0.00
	CN15	84.28	0.00	0.00	0.00	0.00	0.00	0.0001	0.0000		0.037	1.03	0.226		
LingAo NPP	CN06	82.94	0.02	0.02	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.00	1.862	0.00	0.00
	CN07	88.58	0.02	0.02	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	1.377		
	CN12	90.11	0.65	0.72	0.00	0.00	0.00	0.0000	0.0000	0.0003	0.037	1.00	0.252	0.00	0.00
	CN13	88.95	0.24	0.27	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.325		
Third Qinshan NPP	CN08	89.91	1.10	1.21	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.00	0.502	0.00	0.00
	CN09	99.86	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.128		
Tianwan NPP	CN10	90.70	0.01	0.01	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.00	0.283	0.00	0.00
	CN11	89.14	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000		0.381	1.00	0.184		
Hongyanhe NPP	CN16	99.90	0.01	0.01	1.42	0.00	0.00	0.0000	0.0000	0.0003	163.444	1.39	0.006	0.00	0.00
Ningde NPP	CN18	99.95	0.00	0.00	0.00	0.00	0.00	0.0023	0.0000	0.0484	250.441	1.01	0.995	0.00	0.00

Table 2 WANO Performance Indicators of Operational Nuclear Power Units (2014)

Indicator (unit) / NPP		Unit Capability Factor (%)	Unplanned Capability Loss Factor (%)	Forced Loss Rate (%)	Grid Related Loss Factor (%)	Unplanned Automatic Scrams per 7,000 Hours Critical (Times)	Unplanned Scrams per 7,000 Hours Critical (Times)	Safety System Performance			Fuel Reliability (Bq/g)	Chemistry Performance	Collective Radiation Exposure (man·Sv)	Industrial Safety Accident Rate	Contractor Industrial Safety Accident Rate
								High-Pressure Safety Injection System	Auxiliary Feed-Water System	Emergency AC Supply System					
Qinshan NPP	CN01	91.41	1.97	2.11	0.00	0.00	0.00	0.0001	0.0001	0.0001	0.037	1.02	0.253	0.00	0.00
Daya Bay NPP	CN02	99.66	0.32	0.32	0.00	0.80	0.80	0.0000	0.0000	0.0000	0.037	1.00	0.052	0.00	0.09
	CN03	75.58	0.03	0.04	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	1.460		
Qinshan Phase II NPP	CN04	83.53	0.00	0.00	0.00	0.00	0.00	0.0000	0.0002	0.0000	0.037	1.00	0.455	0.00	0.00
	CN05	85.01	1.84	2.12	0.00	0.92	0.92	0.0000	0.0000		0.037	1.00	0.450		
	CN14	91.86	0.00	0.00	0.00	0.00	0.00	0.0000	0.0003	0.0006	0.037	1.00	0.123	0.00	0.12
	CN15	89.56	1.18	1.30	0.00	0.00	0.00	0.0000	0.0001		0.037	1.00	0.082		
LingAo NPP	CN06	90.44	2.71	0.03	0.60	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.00	0.612	0.00	0.11
	CN07	94.55	0.20	0.21	0.05	0.83	0.83	0.0000	0.0000		0.037	1.00	0.246		
	CN12	89.42	0.05	0.05	0.16	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.00	0.302	0.00	0.00
	CN13	90.31	0.00	0.00	0.12	0.00	0.00	0.0000	0.0000		0.037	1.00	0.322		
Third Qinshan NPP	CN08	96.01	3.95	3.96	0.00	0.00	0.00	0.0010	0.0000	0.0006	0.037	1.00	0.143	0.00	0.00
	CN09	89.75	0.03	0.03	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.578		
Tianwan NPP	CN10	89.83	0.44	0.09	0.00	0.00	0.00	0.0000	0.0000	0.0000	17.035	1.00	0.316	0.06	0.05
	CN11	91.11	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.181		
Hongyanhe NPP	CN16	70.04	7.25	9.17	0.00	1.06	1.06	0.0000	0.0005	0.0000	0.037	1.12	0.745	0.00	0.00
	CN17	75.69	9.37	11.01	0.00	2.01	4.02	0.0000	0.0000		0.037	1.14	0.250		
Ningde NPP	CN18	57.31	20.46	22.77	0.00	0.00	1.26	0.0003	0.0000	0.0009	0.037	1.01	0.763	0.00	0.00
	CN19	99.83	0.01	0.01	0.00	0.00	0.00	0.0004	0.0000		0.037	1.00	0.008		
Yangjiang NPP	CN22	99.93	0.04	0.04	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.01	0.008	0.00	0.00

Table 3 WANO Performance Indicators of Operational Nuclear Power Units (2015)

Indicator (unit) / NPP		Unit Capability Factor (%)	Unplanned Capability Loss Factor (%)	Forced Loss Rate (%)	Grid Related Loss Factor (%)	Unplanned Automatic Scrams per 7,000 Hours Critical (Times)	Unplanned Scrams per 7,000 Hours Critical (Times)	Safety System Performance			Fuel Reliability (Bq/g)	Chemistry Performance	Collective Radiation Exposure (man·Sv)	Industrial Safety Accident Rate	Contractor Industrial Safety Accident Rate
								High-Pressure Safety Injection System	Auxiliary Feed-Water System	Emergency AC Supply System					
Qinshan NPP	CN01	90.92	0.09	0.10	0.00	0.00	0.00	0.0001	0.0001	0.0003	0.037	1.00	0.405	0.00	0.00
Daya Bay NPP	CN02	78.83	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.00	0.990	0.00	0.00
	CN03	98.65	0.01	0.01	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.045		
Qinshan Phase II NPP	CN04	88.93	0.68	0.76	0.00	0.88	0.88	0.0000	0.0000	0.0000	0.037	1.00	0.332	0.00	0.00
	CN05	90.84	4.71	4.93	0.00	0.87	0.87	0.0000	0.0003		0.037	1.00	0.035		
	CN14	85.60	6.06	6.61	0.00	0.00	0.00	0.0073	0.0000	0.0002	0.037	1.72	0.197	0.00	0.00
	CN15	90.65	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.119		
LingAo NPP	CN06	86.80	0.34	0.07	0.00	0.00	0.00	0.0000	0.0004	0.0000	1661.6	1.00	1.284	0.00	0.08
	CN07	93.64	0.05	0.05	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.334		
	CN12	90.10	0.35	0.24	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.00	0.312	0.22	0.00
	CN13	90.29	0.88	0.00	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.285		
Third Qinshan NPP	CN08	83.17	0.00	0.00	0.00	0.00	0.00	0.0006	0.0000	0.0024	0.037	1.00	0.649	0.00	0.00
	CN09	97.47	2.51	2.51	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.155		
Tianwan NPP	CN10	91.07	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.00	0.297	0.00	0.00
	CN11	88.22	0.78	0.87	0.00	0.89	0.89	0.0000	0.0000		0.037	1.00	0.223		
Hongyanhe NPP	CN16	87.75	0.01	0.01	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.00	0.347	0.00	0.00
	CN17	65.53	0.35	0.17	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.670		
	CN26	100.00	0.00	0.00	0.00	0.00	0.00	0.0002	0.0000		0.037	1.00	0.003		
Ningde NPP	CN18	88.22	0.17	0.19	0.00	0.00	0.00	0.0003	0.0000	0.0012	0.037	1.00	0.805	0.00	0.00
	CN19	80.73	0.17	0.21	0.00	0.00	0.00	0.0005	0.0012		0.037	1.00	1.022		
	CN34	94.37	5.61	5.61	0.00	1.59	1.59	0.0011	0.0000		1.212	1.09	0.005	0.00	0.00
Yangjiang NPP	CN22	79.45	0.01	0.01	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.037	1.00	0.630	0.00	0.00
	CN23	99.64	0.35	0.35	0.00	0.00	0.00	0.0000	0.0000		0.037	1.00	0.009		
Fuqing NPP	CN20	74.08	3.58	2.09	0.00	2.05	2.05	0.0000	0.0003	0.0026	78.788	1.06	0.781	0.00	0.00
Fangjiashan NPP	CN24	83.65	0.00	0.00	0.00	0.00	0.00	0.0002	0.0000	0.0001	1.384	1.05	0.657	0.00	0.00
	CN25	91.89	0.03	0.03	0.00	0.00	0.00	0.0000	0.0001		1.343	1.00	0.437		

APPENDIX 4: LAWS, REGULATIONS AND RULES OF CHINA ON NUCLEAR SAFETY(Up to December 31, 2015)

I. National Laws

1. Act of Prevention and Treatment on Occupational Diseases of the People's Republic of China

(Promulgated in the Twenty-fourth Meeting of the Standing Committee, the Ninth National People's Congress of the People's Republic of China, on October 27, 2001; and amended in the Twenty-fourth Meeting of the Standing Committee, the Eleventh National People's Congress of the People's Republic of China, on December 31, 2011)

2. Law on Environmental Impact Assessment of the People's Republic of China

(Promulgated in the Thirtieth Meeting of the Standing Committee, the Ninth National People's Congress of the People's Republic of China, on October 28, 2002)

3. Law of the People's Republic of China on Prevention and Control of Radioactive Pollution

(Promulgated in the Third Meeting of the Standing Committee, the Tenth National People's Congress of the People's Republic of China, on June 28, 2003)

II. Decrees of the State Council

1. Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China (HAF001)

(Promulgated by the State Council on October 29, 1986)

2. Regulations on the Emergency Management for Nuclear Accidents of Nuclear Power Plan (HAF002)

(Promulgated by the State Council on August 4, 1993)

3. Regulations on Nuclear Materials Control of the People's Republic of China (HAF501)

(Promulgated by the State Council on June15, 1987)

4. Regulations on the safety Regulation for Civilian Nuclear Safety Equipment

(Promulgated by the State Council on July 11, 2007)

5. Regulations On the Safety Transportation of Radioactive Material

(Promulgated by the State Council on September 14, 2009)

6. Regulations for the Safety Management of Radioactive Waste

(Promulgated by the State Council on December 20, 2011)

7. Regulations on the Safety and Protection of Radioisotopes and Radiation Devices

(Promulgated on September 14, 2005)

8. Regulations of the People's Republic of China on Nuclear Export Control

(Promulgated on September 10, 1997)

9. Regulations of the People's Republic of China for Export Control on Nuclear Dual-purpose Goods and Related Technologies

(Promulgated on June 10, 1998)

III. Department Rules

1. Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People’s Republic of China.

- Part One: Application and Issuance of Safety License for Nuclear Power Plant (HAF001/01)

(Issued by NNSA on December 31, 1993)

2. Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China – Part One

Appendix One: Issuance and Management Procedures for Operator License of NPP (HAF001/01/01)

(Issued by NNSA on December 31, 1993)

3. Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People’s Republic of China.

- Part Two: Safety Surveillance of Nuclear Installations (HAF001/02)

(Issued by NNSA on June 14, 1995)

4. Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People’s Republic of China-Part Two

Appendix One: The Reporting System for Operating Organization of Nuclear Power Plant (HAF001/02/01)

(Issued by NNSA on June 14, 1995)

5. Rules for the Implementation of Regulations on Emergency Management of Nuclear Accident for Nuclear Power Plan

- Part One: Emergency Preparedness and Response for Operating Organization of Nuclear Power Plant (HAF002/01)

(Issued by NNSA on May 12, 1998)

6. Code on the Safety of Nuclear Power Plant Quality Assurance (HAF003)

(No.1 Decree, Promulgated by NNSA on July 27, 1991)

7. Rules for the Management of Nuclear and Radiation Safety Supervision and inspection Personnel Certificates(HAF004)

(Promulgated by Ministry of Environmental Protection (NNSA) on December 2013)

8. Code on the Safety of Nuclear Power Plant Siting (HAF101)

(No.1 Decree, Promulgated by NNSA on July 27, 1991)

9. Code on the Safety of Nuclear Power Plant Design (HAF102)

(Promulgated by NNSA on April 18, 2004)

10. Code on the Safety of Nuclear Power Plant Operation (HAF103)

(Promulgated by NNSA on April 18, 2004)

11. Code on the Safety of Nuclear Power Plant Operation

Appendix One: Management of Refueling, Modifications and Accidental Shutdown of Nuclear Power Plant (HAF103/01)

(Promulgated by NNSA on March 2, 1994)

12. Code on the Safety of Civilian Nuclear Fuel Cycle Installations (HAF301)

((No.3 Decree, Promulgated by NNSA on June 17, 1993)

13. Code on the Safety Regulation for Radioactive Waste (HAF401)

(Promulgated by NNSA on November 5, 1997)

14.Rules for the Management of Solid Radioactive Waste Storage and Disposal License (HAF402)

(Promulgated by Ministry of Environmental Protection (NNSA) in December 2013)

15. Rules for the Implementation on Regulations on Nuclear Materials Control of the People’s Republic of China (HAF501/01)

(Promulgated by NNSA, the Ministry of Energy and Commission of Science, Technology and Industry for National Defense on September 25, 1990)

16. Rules on Civilian Nuclear Safety Equipment in Design, Manufacture, Installation and Non-destructive Testing (HAF601)

(Promulgated by the State Environmental Protection Administration (NNSA) on December 28, 2007)

17. Rules for Qualification Management on Non-destructive Testing Personnel of Civilian Nuclear Safety Equipment (HAF602)

(Promulgated by the State Environmental Protection Administration (NNSA) on December 28, 2007)

18. Rules for Management of Qualification Management on Welder and Welding Operator of Civilian Nuclear Safety Equipment (HAF603)

(Promulgated by the State Environmental Protection Administration (NNSA) on December 28, 2007)

19. Rules on the Safety Regulation for Imported Civilian Nuclear Safety Equipment (HAF604)

(Promulgated by the State Environmental Protection Administration (NNSA) on December 28, 2007)

20. List of Classification Management for Environmental Impact Assessment on Construction

(Promulgated on April 9, 2015)

21. The Measures for the Administration of Security License for Transportation of Radioactive Substances (HAF701)

(Promulgated by NNSA on September 25, 2010)

22. The Measures for the Administration of Security License for Radioisotopes and Radiation Devices (HAF801)

(Promulgated by NNSA on December 6, 2008)

23. The Measures for the Administration of Safety and Protection of Radioisotopes and Radiation Devices (HAF802)

(Promulgated by NNSA on April 18, 2011)

24. The Measures for the Administration of Electromagnetic Radiation Environmental Protection

(Promulgated by NNSA in 1997)

IV. Nuclear Safety Guides

1. Emergency Preparedness and Response for Operating Organization of Nuclear Power Plant (HAD002/01)

(Promulgated by NNSA on August 20, 2010)

2. Emergency Preparedness of Local Government for Nuclear Power Plant (HAD002/02)

(Issued by NNSA, the National Environmental Protection Administration and the Ministry of Health on May 24, 1990)

3. Principles and Levels for Public Protection Intervention During the Nuclear Accidental Radiation Emergency (HAD002/03)

(Issued by NNSA, the National Environmental Protection Administration on April 19, 1991)

4. Levels of Derived Intervention of Public Protection During the Nuclear Accident Radiation Emergency (HAD002/04)

(Issued by NNSA, the National Environmental Protection Administration on April 19, 1991)

5. Emergency Preparedness and Response of Medicine During Nuclear Accident (HAD002/05)

(Issued by the Ministry of Health and NNSA on June 24, 1992)

6. Preparation of the Quality Assurance Programme for Nuclear Power Plants (HAD003/01)

(Issued by NNSA on October 6, 1988)

7. Quality Assurance Organization for Nuclear Power Plants (HAD003/02)

(Issued by NNSA on April 13, 1989)

8. Quality Assurance in the Procurement of Items and Service for Nuclear Power Plants (HAD003/03)

(Issued by NNSA on October 30, 1986)

9. Quality Assurance Record System for Nuclear Power Plants (HAD003/04)

(Issued by NNSA on October 30, 1986)

10. Quality Assurance Audit for Nuclear Power Plants (HAD003/05)

(Issued by NNSA on January 28, 1988)

11. Quality Assurance in the Design of Nuclear Power Plants (HAD003/06)

(Issued by NNSA on October 30, 1986)

12. Quality Assurance in the Construction of Nuclear Power Plants (HAD003/07)

(Issued by NNSA on April 17, 1987)

13. Quality Assurance in the Fabrication of Items for Nuclear Power Plant (HAD003/08)

(Issued by NNSA on October 30, 1986)

14. Quality Assurance During Commissioning and Operation of Nuclear Power Plants (HAD003/09)

(Issued by NNSA on January 28, 1988)

15. Quality Assurance in the Procurement, Design and Manufacture of Nuclear Fuel Assemblies (HAD003/10)

(Issued by NNSA on April 13, 1989)

16. Earthquake Related Issues in Nuclear Power Plant Siting (HAD101/01)

(Revised in 1994)

17. Atmospheric Dispersion Related Issues in Nuclear Power Plant Siting (HAD101/02)

(Issued by NNSA on November 20, 1987)

18. Population Distribution Related Issues in Nuclear Power Plant Siting and Evaluation (HAD101/03)

(Issued by NNSA on November 20, 1987)

19. External Human-induced Events in Nuclear Power Plant Siting (HAD101/04)

(Issued by NNSA on November 28, 1989)

20. Hydrological Dispersion of Radioactive Material in Nuclear Power Plant Sitting (HAD101/05)

(Issued by NNSA on April 26, 1991)

21. Relationship between Nuclear Power Plant Siting and Hydrogeology (HAD101/06)

(Issued by NNSA on April 26, 1991)

22. Site Survey for Nuclear Power Plants (HAD101/07)

(Issued by NNSA on November 28, 1989)

23. Determination of Design Basis Flooding for Nuclear Power Plants on River Sites (HAD101/08)

(Issued by NNSA on July 12, 1989)

24. Determination of Design Basis Flooding for Nuclear Power Plants on Coastal Sites (HAD101/09)

(Issued by NNSA on May 19, 1990)

25. Extreme Meteorological Phenomenon in Nuclear Power Plant Sitting (HAD101/10)

(Issued by NNSA on April 26, 1991)

26. Design Basis of Tropical Cyclone for Nuclear Power Plants (HAD101/11)

(Issued by NNSA on April 26, 1991)

27. Foundation Safety of Nuclear Power Plants (HAD101/12)

(Issued by NNSA on February 20, 1990)

28. General Design Safety Principles for Nuclear Power Plants (HAD102/01)

(Issued by NNSA on July 12, 1989)

29. Seismic Design and Qualification for Nuclear Power Plants (HAD102/02)

(Revised in 1996)

30. Safety Functions and Component Classification for BWR, PWR, and Pressure Tube Reactor (HAD102/03)

(Issued by NNSA on October 30, 1986)

31. Protection against Interior Missiles and Their Secondary Effects in Nuclear Power Plants (HAD102/04)

(Issued by NNSA on October 30, 1986)

32. External Human-induced Events in Nuclear Power Plant Design (HAD102/05)

(Issued by NNSA on November 28, 1989)

33. Design of the Reactor Containment Systems for Nuclear Power Plants (HAD102/06)

(Issued by NNSA on May 19, 1990)

34. Safety Design of Reactor Core Safety for Nuclear Power Plants (HAD102/07)

(Issued by NNSA on July 12, 1989)

35. Reactor Coolant Systems and Associated Systems in Nuclear Power Plants (HAD102/08)

(Issued by NNSA on April 13, 1989)

36. Ultimate Heat Sink and Directly Associated Heat Transport Systems for Nuclear Power Plants (HAD102/09)

(Issued by NNSA on April 17, 1987)

37. Protection System and Related Facilities in Nuclear Power Plants (HAD102/10)

(Issued by NNSA on October 6, 1988)

38. Fire Protection in Nuclear Power Plants (HAD102/11)

(Revised in 1996)

39. Radiation Protection Aspects of Design for Nuclear Power Plants

(HAD102/12)

(Issued by NNSA on May 19, 1990)

40. Emergency Power Systems in Nuclear Power Plants (HAD102/13)

(Revised in 1996)

41. Safety-related Instrumentation and Control Systems in Nuclear Power Plants (HAD102/14)

(Issued by NNSA on October 6, 1988)

42. Design of Fuel Handling and Storage System in Nuclear Power Plants (HAD102/15)

(Promulgated by NNSA on January 23, 2007)

43. Software for Computer Based Systems Important to Safety in Nuclear Power Plants (HAD102/16)

(Issued by NNSA on December 8, 2004)

44. Safety Assessment and Verification of Nuclear Power Plants (HAD102/17)

(Issued by NNSA on June 5, 2006)

45. Operational Limits, Conditions and Operating Procedures of Nuclear Power Plants (HAD103/01)

(Promulgated by NNSA on January 1, 2005)

46. Commissioning Procedures of Nuclear Power Plants (HAD103/02)

(Issued by NNSA on April 17, 1987)

47. Reactor Core and Fuel Management for Nuclear Power Plants (HAD103/03)

(Issued by NNSA on November 28, 1989)

48. Radiation Protection in Operation of Nuclear Power Plants (HAD103/04)

(Issued by NNSA on May 19, 1990)

49. The Recruitment, Training and Authorization of Nuclear Power Plant Personnel(HAD103/05)

(Issued by NNSA on May 24, 2013)

50. Organization and Safe Operation Management of Nuclear Power Plants Operating Organization (HAD103/06)

(Issued by NNSA on June 5, 2006)

51. In-service Inspection of Nuclear Power Plants (HAD103/07)

(Issued by NNSA on October 6, 1988)

52. Maintenance of Nuclear Power Plants (HAD103/08)

(Revised in 1993)

53. Surveillance of Items Important to Safety in Nuclear Power Plants (HAD103/09)

(Revised in 1993)

54. Fire Protection Safety in Operation of Nuclear Power Plants (HAD103/10)

(Issued by NNSA on December 8, 2004)

55. Periodic Safety Review of Nuclear Power Plants (HAD103/11)

(Issued by NNSA on June 5, 2006)

56. Aging Management of Nuclear Power Plants (HAD 103/12)

(Issued by NNSA on May 23, 2012)

57. Management of Radioactive Effluents and Wastes in Nuclear Power Plants (HAD401/01)

(Issued by NNSA on May 19, 1990)

58. Design of Radioactive Waste Management System for Nuclear Power Plants (HAD401/02)

(Promulgated by NNSA on January 16, 1997)

59. Design and Operation of Radioactive Waste Incinerators (HAD401/03)

(Issued by NNSA on February 15, 1997)

60. Classification of Radioactive Waste (HAD401/04)

(Issued by NNSA on July 6, 1998)

61. Siting of Near-surface Disposal Area of Radioactive Waste (HAD401/05)

(Issued by NNSA on July 6, 1998)

62. Location of Geological Disposal Facility of High Level Radioactive Waste(HAD401/06)

(Issued by NNSA on May 23, 2013)

63. Decommissioning of γ Irradiation Device (HAD 401/07)

(Issued by NNSA on May 24, 2013)

64. Technical Requirements on Siting, Design and Construction of Radioactive Waste Repositories for Nuclear Technology Utilization (Provisional) (HAD4XX)

(Issued by NNSA on March 17, 2004)

65. Nuclear Material Accounting of Low-enriched Uranium Conversion and Element Fabrication Plants (HAD501/01)

(Issued by NNSA on September 1, 2008)

66. Physical Protection of Nuclear Facilities (Provisional) (HAD501/02)

(Issued by NNSA on September 1, 2008)

67. Intrusion Alarm System at the Perimeter of Nuclear Facilities (HAD501/03)

(Issued by NNSA on July 22, 2005)

68. Access Control of Nuclear Facilities (HAD501/04)

(Issued by NNSA on September 1, 2008)

69. Physical Protection of Nuclear Material Transportation (HAD501/05)

(Issued by NNSA on September 1, 2008)

70. Format and Content of Physical Protection of Nuclear Facilities, Nuclear Material Accounting and Safety Analysis Report (HAD501/06)

(Issued by NNSA on September 1, 2008)

71. Nuclear Material Accounting of Nuclear Power Plants (HAD501/07)

(Issued by NNSA on September 1, 2008)

72. Simulator Production of the Civilian Nuclear Safety Mechanical Equipment(Trial) (HAD601/01)

(Issued by NNSA on May 24, 2013)

73. Technical Conditions of Installation License Application Organization of the Civil Nuclear Safety Equipment (Trial) (HAD601/02)

(Issued by NNSA on May 24, 2013)

74. Standard Format and Contents of the Design Safety Assessment (Analysis) Report of Radioactive Material Transport Containers (HAD701/01)

(Issued by NNSA on May 31, 2010)

75. Standard Format and Contents of Nuclear and Radiation Safety Analysis Report of Radioactive Material Transport (HAD701/02)

(Issued by NNSA on June 9, 2014)

APPENDIX 5: LIST OF DOMESTIC AND OVERSEAS REVIEW ACTIVITIES RECEIVED BY NPPS IN CHINA (FROM 2013 TO 2015)

NO.	Time	Host Plant	Review Content	Review Organization
1	2013.04.15-04.26	Yangjiang NPP	PSUR of Unit 1	WANO
2	2013.06	Sanmen NPP	Specific area review on commissioning readiness	CNNP
3	2013.06.24-07.01	Hongyanhe NPP	WANO CPO and SOER of Unit 2	WANO
4	2013.07.15-08.02	Ningde NPP	8 areas, e.g. nuclear safety management, operation, maintenance, technical support, fire fighting, radiation protection, chemical environment, plant building management	CGN
5	2013.08.15-08.16	Fangjiashan NPP	Follow-up on commissioning readiness of Unit 1 and 2	CNNP
6	2013.08.19-08.23	Hongyanhe NPP	OSART follow-up of Unit 2	IAEA
7	2013.08.26-09.06	Ningde NPP	PSUR of Unit 2	WANO
8	2013.08.31-09.08	Shidao Bay NPP	Peer review during construction phase	CNEA
9	2013.09.08-09.13	Third Qinshan NPP	Specific area review on human performance of Unit 1 and 2	CNEA
10	2013.09.23-09.25	Fuqing NPP	Specific area review on documentation management	CNNP
11	2013.10.14-10.18	Qinshan Phase II NPP	Follow-up of peer review for Unit 1 and 2	WANO
12	2013.10.14-11.01	Hongyanhe NPP	8 areas, e.g. nuclear safety, operation, maintenance and technology, etc.	CGN
13	2013.10.27-11.01	Daya Bay Nuclear Power Base	Model and report of Level I PSA for internal event under power operation	CNEA
14	2013.11.03-11.08	Qinshan Phase II NPP	Specific area review on outage management of Unit 3	CNNP
15	2013.11.23-11.29	CNNO	Specific area review on nuclear safety culture in operation and maintenance areas	CNNP
16	2013.12.02-12.04	Qinshan Nuclear Power Base	Public communication	CNEA
17	2014.01.04-01.17	Fuqing NPP	PSUR of Unit 1	WANO
18	2014.01.06-01.17	Fangjiashan NPP	PSUR of Unit 1	WANO
19	2014.02.17-02.21	Daya Bay Nuclear Power Base	WANO peer review follow-up	WANO

20	2014.04.12-04.24	Hongyanhe NPP	PSUR of Unit 3	WANO
21	2015.01.05-01.07	Shidao Bay NPP	Follow-up for peer review during construction phase	CNEA
22	2015.04.13-04.25	Hongyanhe NPP	PSUR of Unit 4	WANO
23	2014.05.12-05.30	LingAo NPP	8 areas, e.g. nuclear safety, operation, maintenance and technology, etc.	CGN
24	2014.11.10-11.14	LingAo NPP	Specific area review on severe accident management for Unit 1 and 2	CNEA
25	2014.03.31-04.04	Tianwan NPP	Outage activities in maintenance area for Unit 2 and simulator training in training area	WANO
26	2014.05.18-05.27	Yangjiang NPP	PSUR of Unit 2	WANO
27	2014.06.16-06.20	Qinshan NPP	Specific area review on outage management of Unit 1	CNNP
28	2014.08.25-08.29	Fuqing NPP	Specific area review on operation preparation for Unit 3 and 4	CNNP
29	2014.09	Sanmen NPP	Nuclear safety culture	CNNP
30	2014.09.09-09.12	Qinshan Phase II NPP	SOER for Unit 1, 2, 3 and 4	WANO
31	2014.09.12-09.26	Tianwan NPP	11 areas, e.g. operation, maintenance, technical support, radiation protection, training, etc.	WANO CNEA
32	2014.09.15-09.19	Qinshan NPP	WANO peer review follow-up	WANO
33	2014.10	Sanmen NPP	Follow-up of commissioning preparation review	CNNP
34	2014.10.13-10.21	Yangjiang NPP	8 areas, e.g. nuclear safety, operation, maintenance and technology, etc.	CGN
35	2014.10.18-11.01	Fuqing NPP	Peer review on construction of Unit 1, 2, 3 and 4 and peer review before FCD for Unit 5 and 6	CNEA
36	2014.10.18-10.24	Jiangsu Nuclear Power Corporation	Company leadership, governance, supervision and monitoring, independent oversight, support and performance, HR and communication	WANO
37	2014.10.19-10.31	Ningde NPP	PSUR of Unit 3	WANO
38	2014.10.20-10.22	Fuqing NPP	CNNP Corporate Peer Review (Fuqing Group)	WANO
39	2014.11.15-11.28	CNNO	Comprehensive Review of 7 units of CNNO	CNEA
40	2014.11.24-11.28	Third Qinshan NPP	Follow-up of Human performance assessment	CNEA
41	2014.12.08-12.15	Fangjiashan NPP	PSUR of Unit 2	WANO

42	2015.01.19-01.26	Fuqing NPP	PSUR of Unit 2	WANO
43	2015.03.12-03.26	Third Qinshan NPP	WANO peer review for Unit 1 and 2	WANO
44	2015.03.16-03.27	Fangchenggang NPP	PSUR of Unit 1	WANO
45	2015.03.30-04.05	Ningde NPP	Follow-up in 8 areas, e.g. nuclear safety management, operation, maintenance, technical support, fire fighting, radiation protection, chemical environment, plant building management	CGN
46	2015.06.28-07.10	Yangjiang NPP	PSUR of Unit 3	WANO
47	2015.07	Sanmen NPP	Specific area review on spare parts	CNNP
48	2015.07.27-07.31	Fangjiashan NPP	Follow-up for PSUR of Unit 2	WANO
49	2015.07.30-08.13	Qinshan Phase II NPP	WANO peer review for Unit 1, 2, 3 and 4	WANO
50	2015.09	Sanmen NPP	Specific area review on operation preparation	CNNP
51	2015.09	Sanmen NPP	Specific area review on design management	CNNP
52	2015.09.07-09.11	Fuqing NPP	Specific area review on human behavior in the operation area	CNNO
53	2015.09.09-09.18	Taishan NPP	Nuclear safety culture	CGN
54	2015.09.14-09.18	Fuqing NPP	Specific area review on operation procedure system	CNNP
55	2015.10.08-03.16	Fangchenggang NPP	Nuclear safety culture	CGN
56	2015.10.20-10.22	Fuqing NPP	Specific area review on foreign affairs	CNNP
57	2015.10.26-10.30	Fuqing NPP	Specific area review on outage management of Unit 1	CNNP
58	2015.11.16-11.20	Fuqing NPP	Specific area review on project investment management	CNNP
59	2015.11.09-11.21	Ningde NPP	PSUR of Unit 4	WANO

APPENDIX 6: LIST OF SCHEDULED DOMESTIC AND OVERSEAS REVIEW ACTIVITIES FOR NPPs IN CHINA (FROM 2016 TO 2018)

NO.	Time	Host Plant	Review Content	Review Organization
1	2016.01	Changjiang NPP	PSUR of Unit 2	WANO
2	2016	Fuqing NPP	Nuclear safety culture	CNNP
3	2016.01	Fangjiashan NPP	Outage management of Unit 2	CNNP
4	2016.03	Fuqing NPP	PSUR of Unit 3	WANO
5	2016.03	Fangchenggang NPP	PSUR of Unit 1	WANO
6	2016.04	Daya Bay Nuclear Power Base	WANO peer review	WANO
7	2016.05	Sanmen NPP	Fire fighting	CNNP
8	2016.06	Sanmen NPP	Radiation protection	CNNP
9	2016.06	Taishan NPP	WANO CPO and SOER review	WANO
10	2016.09	Ningde NPP	Independent safety oversight	CGN
11	2016.09	CNNO	Follow-up for comprehensive review of 7 units	CNEA
12	2016.10	Yangjiang NPP	PSUR of Unit 4	WANO
13	2016.11	Sanmen NPP	PSUR of Unit 1	WANO
14	2016.11	Fangjiashan NPP	WANO peer review for Unit 1 and 2	WANO
15	2017.01	Taishan NPP	Pre-OSART	IAEA
16	2017.03	Fuqing NPP	PSUR of Unit 4	WANO
17	2017	Fuqing NPP	Foreign Material Exclusion	CNNP
18	2017.06	Ningde NPP	Peer review of Phase I project	WANO
19	2017.07	Shidao Bay NPP	PSUR	WANO
20	2017.12	Jiangsu Nuclear Power Corporation	Follow-up	WANO

21	End of 2017 or early of 2018	Yangjiang NPP	OSART	IAEA
22	2018	CNNO	OSART	IAEA
23	2018	Sanmen NPP	OSART	IAEA
24	2018	Hongyanhe NPP	WANO peer review for Unit 1, 2, 3 and 4	WANO
25	2018	Fuqing NPP	Spare parts	CNNP
26	2019.01	Fuqing NPP	Peer Review	WANO

APPENDIX 7: LICENSED REACTOR OPERATORS AND SENIOR REACTOR OPERATORS OF CHINESE NPPS IN COMMERCIAL OPERATION (BY DECEMBER 31, 2015)

Item \ NPP	Qinshan NPP	Daya Bay NPP	Qinshan Phase II NPP	LingAo NPP	Third Qinshan NPP	Tianwan NPP	Hongyanhe NPP	Ningde NPP	Fuqing NPP	Yangjiang NPP	Fangjiashan NPP	Changjiang NPP	Fangchenggang NPP
Reactor Operators (RO)	35	45	57	109	53	51	82	57	92	138	38	61	86
Senior Reactor Operators (SRO)	36	63	114	145	51	100	88	98	45	49	35	27	22

APPENDIX 8: OCCUPATIONAL EXPOSURE IN NPPS OF CHINA

Item NPP (Project)			Annual Man Average Effective Dose （mSv）	Annual Maximum Individual Effective Dose （mSv）	Annual Collective Effective Dose (man.Sv)	Normalized Collective Effective Dose （man.mSv/GWh）
Qinshan NPP	2013		0.281	6.073	0.495	0.215
	2014		0.143	4.035	0.253	0.096
	2015		0.201	4.278	0.405	0.157
Daya Bay NPP	2013		0.549	13.345	1.769	0.119
	2014		0.462	6.906	1.512	0.100
	2015		0.331	7.190	1.035	0.067
Qinshan Phase II NPP	2013		0.385	8.730	1.170	0.058
	2014		0.336	8.980	1.110	0.055
	2015		0.163	5.120	0.485	0.029
LingAo NPP	2013	(Unit 1 and 2)	0.887	13.696	3.238	0.220
		(Unit 3 and 4)	0.188	5.660	0.577	0.034
	2014	(Unit 1 and 2)	0.300	7.731	0.858	0.054
		(Unit 3 and 4)	0.185	4.098	0.624	0.037
	2015	(Unit 1 and 2)	0.502	8.505	1.619	0.105
		(Unit 3 and 4)	0.193	5.261	0.597	0.035
Third Qinshan NPP	2013		0.324	6.362	0.630	0.053
	2014		0.342	7.192	0.721	0.062
	2015		0.366	4.964	0.804	0.072
Tianwan NPP	2013		0.177	2.615	0.467	0.028
	2014		0.180	2.994	0.497	0.030
	2015		0.169	2.866	0.520	0.031

Hongyanhe NPP	2013	0.0158	1.112	0.033	0.006
	2014	0.2977	8.076	1.005	0.089
	2015	0.2949	5.623	1.028	0.075
Ningde NPP	2013	0.012	1.272	0.026	0.004
	2014	0.311	6.604	0.786	0.068
	2015	0.497	12.008	1.841	0.094
Fuqing NPP	2013	/	/	/	/
	2014	0.016	3.323	0.028	0.017
	2015	0.258	6.072	0.787	0.094
Yangjiang NPP	2013	/	/	/	/
	2014	0.008	1.023	0.017	0.002
	2015	0.176	6.715	0.669	0.052
Fangjiashan NPP	2013	/	/	/	/
	2014	0.012	2.528	0.016	0.039
	2015	0.389	6.904	1.102	0.071
Changjiang NPP	2015	0.0004	0.016	1.22E-04	0.002

APPENDIX 9: LIST OF EMERGENCY DRILL OF NPPS IN CHINA (FROM 2013 TO 2015)

List of comprehensive drills, single drills and joint drills in NPP

Year	Plant	Times of joint drills	Times of comprehensive drills	Times of single drills
2013	CNNO	0	4	79
	Daya Bay Nuclear Power Base	0	1	18
	Tianwan NPP	0	0	31
	Hongyanhe NPP	0	1	9
	Ningde NPP	0	0	11
	Yangjiang NPP	1	1	16
2014	CNNO	1	1	102
	Daya Bay Nuclear Power Base	0	2	19
	Tianwan NPP	0	1	31
	Hongyanhe NPP	0	1	31
	Ningde NPP	0	1	16
	Fuqing NPP	1	1	23
	Yangjiang NPP	0	0	25
	Changjiang NPP	0	0	3
2015	CNNO	0	1	90
	Daya Bay Nuclear Power Base	0	1	15
	Tianwan NPP	1	0	30
	Hongyanhe NPP	0	1	42
	Ningde NPP	0	1	13
	Fuqing NPP	0	0	50
	Yangjiang NPP	0	1	28
	Changjiang NPP	3	3	22
	Fangchenggang NPP	2	2	23

Note: According to the definitions in 9.2.2 of the *Emergency Preparedness and Emergency Response of Operating Organization of NPP* (HAD 002/01-2010) issued by NNSA on August 20, 2010, emergency drill includes single drill (exercise) and comprehensive drill of on-site emergency organization as well as joint drill of off-site emergency organization, and the drill can be a part of the drill.