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COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

Summary Report on the Licensing Process of New Reactor Applications

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COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES (CNRA)

The Committee on Nuclear Regulatory Activities (CNRA) is responsible for NEA programmes and activities concerning the regulation, licensing and inspection of nuclear installations with regard to both technical and human aspects of nuclear safety. The committee constitutes a forum for the effective exchange of safety-relevant information and experience among regulatory organisations. To the extent appropriate, the committee reviews developments which could affect regulatory requirements with the objective of providing members with an understanding of the motivation for new regulatory requirements under consideration and an opportunity to offer suggestions that might improve them and assist in the development of a common understanding among member countries. In particular it reviews regulatory aspects of current safety management strategies and safety management practices and operating experiences at nuclear facilities including, as appropriate, consideration of the interface between safety and security with a view to disseminating lessons learnt. In accordance with *The Strategic Plan of the Nuclear Energy Agency: 2017-2022*, the committee promotes co-operation among member countries to use the feedback from experience to develop measures to ensure high standards of safety, to further enhance efficiency and effectiveness in the regulatory process and to maintain adequate infrastructure and competence in the nuclear safety field.

The committee promotes transparency of nuclear safety work and open public communication. In accordance with the NEA Strategic Plan, the committee oversees work to promote the development of effective and efficient regulation.

The committee focuses on safety issues and corresponding regulatory aspects for existing and new power reactors and other nuclear installations, and the regulatory implications of new designs and new technologies of power reactors and other types of nuclear installations consistent with the interests of the members. Furthermore, it examines any other matters referred to it by the NEA Steering Committee for Nuclear Energy. The work of the committee is collaborative with and supportive of, as appropriate, that of other international organisations for co-operation among regulators and consider, upon request, issues raised by these organisations. The committee organises its own activities. It may sponsor specialist meetings, senior-level task groups and working groups to further its objectives.

In implementing its programme, the committee establishes co-operative mechanisms with the Committee on the Safety of Nuclear Installations (CSNI) in order to work with that committee on matters of common interest, avoiding unnecessary duplications. The committee also co-operates with the Committee on Radiological Protection and Public Health (CRPPH), the Radioactive Waste Management Committee (RWMC), and other NEA committees and activities on matters of common interest.

Foreword

The Committee on Nuclear Regulatory Activities (CNRA) of the Nuclear Energy Agency (NEA) is an international committee composed primarily of senior nuclear regulators. The CNRA was set up in 1989 as a forum for sharing information and experience among regulatory organisations and for reviewing developments which could affect regulatory requirements. The CNRA is responsible for the NEA programme concerning the regulation, licensing and inspection of nuclear installations and it reviews practices and operating experience.

The CNRA created the Working Group on the Regulation of New Reactors (WGRNR) at the Bureau meeting of December 2007. The WGRNR is responsible for the programme of work of the CNRA with regard to regulatory activities in the primary programme areas of siting, licensing and oversight for all new commercial nuclear power reactors. The WGRNR constitutes an international forum for exchanging information and experience and, with the agreement of the CNRA, plans its work to ensure improvements in nuclear safety including, as appropriate, consideration of the interface between safety and security through more effective and efficient regulation.

In 2009, the WGRNR created a task consisting of three phases to share information among participating countries regarding the licensing process for new reactors: 1) general information; 2) the design process; and 3) construction. This report summarises the results of surveys conducted to compile information for the three phases.

The WGRNR is grateful for the support from Hanry Wagage from the United States Nuclear Regulatory Commission in preparing this report.

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List of abbreviations and acronyms

AFCEN	Association Française pour les règles de Conception, de construction et de surveillance en exploitation des matériels des Chaudières Electro Nucléaires (French association for design and manufacturing rules of PWR and FBR)
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
B&PV	Boiler and pressure vessel
CNRA	Committee on Nuclear Regulatory Activities (NEA)
CRPPH	Committee on Radiological Protection and Public Health (NEA)
CSNI	Committee on the Safety of Nuclear Installations (NEA)
ESF	Engineered safety features
FBR	Fast breeder reactor
IAEA	International Atomic Energy Agency
I&C	Instrumentation and control
IEC	International Electrotechnical Commission
NEA	Nuclear Energy Agency
OECD	Organisation for Economic Co-operation and Development
PWR	Pressurised water reactor
RCS	Reactor coolant system
RWMC	Radioactive Waste Management Committee (NEA)
SAR	Safety analysis report
TSO	Technical support organisation
US NRC	United States Nuclear Regulatory Commission
V&V	Verification and validation
QA	Quality assurance
WGRNR	Working Group on the Regulation of New Reactors (NEA)

1. Introduction

During the six decades of commercial nuclear power operation so far, nuclear programmes in Nuclear Energy Agency (NEA) member countries have grown significantly. Effective communication among member countries has been a major reason for the steady improvements in nuclear power plant safety and performance around the world. Member countries continue to learn from each other, incorporating experience and lessons learnt. They consult each other when reviewing applications and maintain bilateral agreements to keep the communication channel open. This has been vital and will continue to be extremely important to the success of the new fleet of reactors being built.

This document provides summary results of licensing process surveys conducted by member countries during the 2009-2016 period and will provide valuable information on the design-related technical topics that are reviewed by regulatory organisations.

It should be noted that this report covers the position on the reported licensing issues at the time the surveys were conducted and the respective reports subsequently compiled and approved. It is recognised that in many of these areas, processes and standards have advanced significantly and this report does not seek to reflect these developments or the latest position. Rather, this report aims to summarise the position at the time of each of the surveys and the information in the subsequent chapter reports listed in Chapter 3 below.

2. Task motivation and objectives

This Working Group on the Regulation of New Reactors (WGRNR) task was focused on sharing information among member countries regarding the licensing process for new reactors. The task consisted of surveys grouped in three distinct phases: 1) general information; 2) design process; and 3) construction. Following this information gathering, seven reports were published between 2011 and 2017. The purpose of this report is to summarise the key results and insights from these seven reports. Fourteen NEA member countries participated in this activity, as well as Partner countries India, a Participant in the Committee on Nuclear Regulatory Activities and the United Arab Emirates, an Invitee to the same committee).

3. Task activities

Task activities were divided into three phases. Phase I, which focused on the structure and regulatory processes of member countries, was completed with publication of the "Report on the Survey of the Review of New Reactor Applications" (NEA, 2012).

Phase II consisted of detailed review of 11 specific design issues, including instrumentation and control; civil engineering and structures; the reactor; the reactor coolant system; classification of systems, structures and components; engineered safety systems; electric systems; auxiliary systems; power conversion systems; assessment and verification of safety; and technical specifications. WGRNR completed reports of the first five design issues with the publication of the following reports:

- "Report on the Survey of the Design Review of New Reactor Applications-Volume 1: Instrumentation and Control Volume 1 Instrumentation and Control" (NEA, 2014);
- "Report on the Survey of the Design Review of New Reactor Applications-Volume 2: Civil Engineering Works and Structures" (NEA, 2015a);
- "Report on the Survey of the Design Review of New Reactor Applications-Volume 3: Reactor" (NEA, 2016);
- "Report on the Survey of the Design Review of New Reactor Applications-Volume 4: Reactor Coolant and Associated Systems" (NEA, 2017);
- "Report on the Survey of the Design Review of New Reactor Applications-Volume 5: Classification of Structures, Systems, and Components" (NEA, 2018).

Although reports were not published for the remaining six Phase II areas, some survey information was collected. Given the dynamic changes that had occurred in new reactor licensing following the accident at the Fukushima Daiichi Nuclear Power Plant, the Working Group on the Regulation of New Reactors (WGRNR) recognised that a continuation of developing reports in the remaining six areas would involve a significant effort to update the information contained in the surveys. Therefore, the WGRNR concluded that its resources could be better used for tasks more relevant to the current situation in member countries. As such, reports for the remaining six areas will not be completed but the information collected in surveys has been made available to the WGRNR members on the WGRNR protected website or upon request from the NEA.

Phase III, which addressed construction oversight activities, was completed with publication of the "Report on the Construction Oversight Survey" (NEA, 2015b).

4. Summary of task insights

4.1 Insights from specific task activities

4.1.1 Phase I: Survey of the review of new reactor applications

The survey of the review of new reactor applications, which consisted of four stages − pre-construction, consent for construction, commissioning and operation − was based on the IAEA Safety Guide No. SSG-12, *Licensing Process for Nuclear Installations* (IAEA, 2010) because most of the participating member countries use similar processes. Pre-construction involves siting, site evaluation, basic design, and other aspects for environmental assessment and site selection. Consent for construction involves detailed site evaluation and design review for issuing a permit to start construction. Commissioning involves progressive transition from construction to operation of the plant.

While most regulators review the basic design and site safety issues during pre-construction, some countries like the United States do in-depth reviews. For example, the new licensing process in the United States allows an applicant to submit the complete design in a combined construction and operating licence application. All regulators perform construction oversight during the construction stage. Some regulators, such as Finland, also review and approve the detailed design. All regulators begin commissioning reviews during construction, which continues well beyond construction. The regulators are directly involved in issuing the licence for operating and loading of fuel during commissioning. In France, the regulator may grant an authorisation for partial commissioning to allow the licensee to bring fuel on site or to perform tests using radioactive substances.

The survey of the review of new reactor applications covered in 13 different areas as summarised below.

Governing authorities

In Canada, Hungary, Poland, the Slovak Republic, the United Arab Emirates, the United Kingdom and the United States, the nuclear regulator has the authority to grant a licence for a new nuclear power plant. However, in other countries other organisations, in addition to the regulatory body, may also be involved in the licensing process:

- In the Czech Republic, Japan, Slovenia, Spain and Switzerland, government ministries, in addition to the nuclear regulator, approve the construction of a nuclear power plant.
- In Hungary, Finland and Switzerland, the parliament is directly involved in issuing a licence for a nuclear power plant.
- In the Czech Republic, the local authority also must approve the location of the new nuclear power plant.
- In Finland, the parliament ratifies the decision-in-principle for a new nuclear plant. In addition, other stakeholders, such as environment centres, the public and

neighbouring countries are involved in the licensing process by providing statements for the Environmental Impact Assessment.

- In France, the nuclear regulator reviews the licensee's dossier and the government ministries approve the plant authorisation. The local public authority decides when the construction can begin and the nuclear regulator approves the operating licence.

Legal decision

Legal decisions are made at different stages of the process and in different forms, but they are all based on current legislation. In some countries, the decision is a simple consent while in others, a full licence is needed. The authorisation is usually granted by the government (often the Ministry of Environment), but in some cases the authorisation is granted through a regulatory decision, e.g. the decision for commissioning. The applicant can be a company requesting a licence, an existing operator requesting a new licence or a company that has a site licence and would like to apply for a construction licence or to start commissioning.

Phase implementation/time frame

The long duration of the licensing process is one of the main challenges associated with the building of a nuclear power plant. Although time is necessary to ensure the safety and security of the public, it affects the applicant's ability to obtain funding for the project. However, this time frame is also affected when the regulator receives incomplete applications for a licence.

Regulatory reviews may take from three to eight years from the beginning of the review to the start of construction. Table 1 provides average times for the licensing process for different countries based on survey data collected for this task. In the table, pre-construction involves environmental assessment or licence for site preparation and a general design licence.

Level of effort

Only the skills required to review the applications received for pre-construction, construction and commissioning were available from most of the countries and efforts (hours) necessary were available from only three countries.

Many countries use technical support organisations (TSOs) to assist them in the reviews and oversight. In some countries, the TSO function is part of the nuclear regulatory organisation. Skilled professionals with a minimum of an engineering degree or equivalent were required by all regulators to perform the work. During the pre-construction phase, siting and site evaluation were the most prevalent issues, which needed the expertise of geologists, meteorologists, hydrologists, seismologist, civil engineers, project managers and environmental project managers. For the basic design review, the expertise needed were in structural, civil, mechanical, electrical, nuclear, chemical and material engineering, and project management. When construction begins, through commissioning and beyond, oversight is necessary by qualified inspectors, specialists and technical experts in addition to the normal staff.

A rough estimate of the level of effort needed, including technical support, averages between 25 to 50 person-years throughout the processes.

Table 1. Average time for licensing before construction and commissioning

Country	Average time (years)		
	Pre-construction	Consent for construction*	Commissioning and operating licence*
Canada	1.5 (RR)	2 (RR)	1 (RR)
Czech Republic	3 (P)	1 (RR)	0.5 (RR)
Finland	2 (P), incl. 1(RR)	3 (P), incl. 1.5 (RR)	1.5 (P), incl. 1(RR)
France	3 (RR)		1 (RR)
Hungary	0.5 (RR)	0.5 (RR)	0.5 (RR)
Japan	4 (P), 2 (RR)	5 (P)	
Korea	4 (P)		5 (P)
Poland	2 (P)		1.25 (P)
Slovak Republic	0.4 (RR)	1 (RR)	0.5 (RR)
Slovenia	4 (P)	2 (RR)	3 (P)
Switzerland	4 (P)	4 (P)	4 (P)
United Arab Emirates	3 (P)		6 (P)
United Kingdom	3 (P)		5 (P)
United States	6 (P)		5 (P)

Notes: * Estimates do not include the time frame of construction or commissioning but some reviews by the regulator that may be performed during the construction stage.
(RR) A regulatory review is carried out for each step (indicated as RR for regulatory review).
(P) The regulatory review involves the entire licensing process (indicated as P for process).

Documents submitted

The regulatory authorities require that documentation be submitted to support siting, construction, commissioning and operations. Typically, regulations or regulatory guidance describing the content and details of the documentation should be provided. The information provided by the proponent should show that the safety basis required by the legislative and regulatory framework is satisfied. In most cases, information submitted early on in the process provides environmental and design-related information that the regulatory authority uses as the basis for its siting and construction decisions. This preliminary information includes assessments of the environmental impacts on the surrounding environment and population, and an assessment of the safety performance of the plant, based on design information. Typically, as construction is completed additional documentation is submitted to show that the as-built plant meets the design requirements. This also includes an updated safety analysis using as-built information that shows the as-built plant can be operated safely, details on the commissioning activities and schedules, descriptions of the security, physical protection and emergency preparedness programmes,, as well as the operational parameters and technical specifications that govern operation.

Guidance documents

Most countries have developed or are developing guidance documents for the pre-construction, construction and commissioning phases as shown in Table 2. Canada, Hungary and the United Arab Emirates use IAEA guides to prepare the documents.

Table 2. The availability of guidance documents

Country	Pre-construction	Construction	Commissioning
Canada	Yes	Yes	Yes
Czech Republic	Yes	Yes	Yes
Finland	Yes	Yes	Yes
France	Yes	Yes	Yes
Hungary	Yes	Yes	No
Japan	Yes	Yes	Yes
Korea	Yes	Yes	Yes
Poland	No	No	No
Slovak Republic	No	Yes	Yes
Slovenia	Yes	No	No
Spain	No	No	No
Switzerland	No	Yes	Yes
United Arab Emirates	Yes	Yes	Yes
United Kingdom	Yes	Yes	Yes
United States	Yes	Yes	Yes

Note: Yes: available or to be developed; No: none at this time.

Safety assessment

For all the phases of the safety assessment, regulators are involved and perform some type of oversight of the applicant's or licence holder's pre-construction, construction and commissioning project. Some regulators rely on outside TSOs to provide detailed technical analysis or assessment of the operator's safety information.

Pre-construction

Most participating countries perform an environmental assessment and some level of site characterisation. Topics include site geography and demography; near industrial, transport and military objects; meteorology, hydrology, geology, seismology and geotechnical aspects; external hazards impact, e.g. earthquake, extreme meteorological conditions, fire and airplane impact.

Construction

The operator (licensee or applicant) prepares a safety assessment consistent with the approval sought, typically a construction approval. In Japan and the United States, regulators perform a detailed review of the design[1] at this stage and issue an approval to construct with a conditional provision for operation. The conditional provision is focused on verification of the as-built conformance of the nuclear power plant with the approved design documents. The scope of this review focuses on the demonstration of the design of the nuclear island and the postulated safety performance of the nuclear systems, including systems that support the safety functions. Most regulators observe and/or review the initial testing of the nuclear power plant and the results of the pre-operational test programmes, including non-nuclear and nuclear testing.

1. Options are also available to submit a less detailed design for a construction permit and apply later for an operating licence.

Commissioning

The operator (licensee) provides a Safety Analysis Report (SAR) that demonstrates the safety case for the nuclear power plant. All regulators either perform or have performed a review of the SAR. In some cases, the review is performed with assistance from a technical support organisation; in Slovenia, review by a TSO or an authorised radiation and nuclear safety expert is mandatory for approval.

Public participation

All member countries have public participation while the degree of participation varies among member countries. The greater part of public consultation for most member countries takes place during the pre-construction phase. Generally, some level of public participation is mandated by law and sometimes led by a government department apart from the nuclear regulatory body. Many member countries require the prospective licensee to produce an environmental impact assessment which is publicly available. Public participation varies from being informed by letter or other means, being provided with information, being able to raise issues, to a full public enquiry. Further public participation may also take place in the construction and commissioning phase.

Oversight

In most member countries, regulatory authorities provide oversight during construction and operation. During construction, TSOs working on-site support many of the regulatory authorities. In France, Japan and Korea, experts from the TSOs may also join the inspections during operation. In Switzerland and the United Kingdom, other authorities besides the regulator have oversight roles during construction. In the Slovak Republic, the members of the Slovak chamber of civil engineers perform the construction oversight and UJD SR (the Nuclear Regulatory Authority of the Slovak Republic) performs the operation oversight. In some countries, such as Canada and France, the licensee is responsible for oversight, but the regulator verifies that the licensee fulfils its responsibility. In Finland, several parties, including the regulator, perform construction oversight but during operation, the licensee provides oversight and the regulator verifies this oversight responsibility is fulfilled.

Independent advisory committee

Most of the countries use independent advisory committees with members representing different academic circles dealing with a broad range of topics related to the nuclear field. Some countries require considering the committee's advice during their licensing review, while others do not and only use committees for consultation. Depending on the country, an advisory committee may perform the following:

- examine the fundamental issues concerning nuclear safety;
- evaluate the regulatory agency's work during licensing steps;
- participate in the legislative work necessitated by nuclear safety.

4.1.2 Phase II: Survey of the design review of new reactor applications

The member countries provided survey information in the following six areas:

- the design information provided by the applicant;
- the analysis, reviews, and/or research performed by the regulatory authority's reviewer(s) and the scope of the review;

- the technical basis[2] (standards, codes, acceptance criteria) for regulatory authorisation;
- the skill sets required to perform the review;
- the specialised training, experience, education, and/or tools needed to perform the regulatory review;
- the level of effort needed for the regulatory authority to perform the review.

As stated above, the survey was completed only for 5 of the 11 design issues considered (instrumentation and control; civil engineering and structures; the reactor; the reactor coolant system; and classification of systems, structures and components). The WGRNR completed reports for these technical areas and the summary of results is provided in this section. For the remaining six design issues (engineered safety systems; electric systems; auxiliary systems; power conversion systems; assessment and verification of safety; and technical specifications) the WGRNR decided not to complete the reports and the information collected in surveys are available upon request from the NEA.

4.1.2.1 Instrumentation and control

Consistent with the *IAEA Safety Guide No. GS-G-4.1, Format and Content of the Safety Analysis Report for Nuclear Power Plants* (IAEA, 2004), the survey on instrumentation and control consisted of 12 technical topics: reactor trip system, actuation systems for engineered safety features, safe shutdown system, safety-related display instrumentation, information and interlock systems important to safety, controls systems, main control room, supplementary control room, diverse instrumentation and control (I&C) systems, data communication systems, software reliability and cybersecurity. The information provided by member countries on the 12 technical topics is summarised below under six areas stated in Section 4.1.2.

Design information provided by the applicant

In most countries, the applicant provides a description of the I&C system design, design bases, functions and requirements and is required to provide information on verification and validation (V&V) programmes as well as provisions for analysis, testing and inspection of various I&C systems. In several countries, the applicant provides human factors and human machine interface related to the main control room and the supplementary control room.

In Canada, Finland, India, Korea, Slovenia and the United States, a cybersecurity programme or plan is provided by the applicant. In Finland, the applicant also provides cybersecurity risk assessment plans and results. In the Slovak Republic, the applicant provides cybersecurity design basis and safety analysis information in addition to describing a change control programme for all life cycle phases. France, Japan, Russia and Sweden currently do not review cybersecurity as part of granting regulatory authorisation,

2. IAEA standards tend to be more general and high-level in nature than national codes and standards. Furthermore, some IAEA standards harmonise with the use of national codes, standards or practices without providing specific technical details about how they should be implemented. Therefore, the use of IAEA standards – while useful – is not a substitute for adherence to national codes and standards.

but Russia is currently developing regulations and rules to address issues of information protection in software for systems important to safety.

Analysis, reviews and/or research performed

Some regulatory organisations perform separate design reviews related to each technical topic, while others address several of topics as part of a broader design review. Japan and Sweden review safety-related display instrumentation as part of the design review of the main control room. Finland and France review the information and interlock systems important to safety as part of the design review of the actuation systems for engineered safety features (ESF) and the safe shutdown systems.

All countries review the information provided by the applicant for compliance with the applicable regulatory requirements. Some countries perform on-site audits and inspections in addition. Finland, India, Korea, Sweden and the United States, audit or inspect various I&C related technical topics. Korea audits or inspects nine of the 12 technical topics covered in the survey to evaluate design processes and V&V activities. Finland and Sweden audit and inspect actuation systems for ESF, safe shutdown systems, and diverse I&C systems. India audits the system development life cycle documents (including V&V and quality assurance [QA] documents) for software reliability. The United States inspects the implementation of a licensee's cybersecurity programme. Most countries perform confirmatory analyses.

Technical basis

In all countries, regulations and regulatory guidance provide basis for regulatory authorisation. Most countries use national or international consensus standards in addition. Canada, Korea, Sweden, and the United States use IEEE standards: IEEE Standard 7-4.3.2, *IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations* (IEEE, 2010) and IEEE Standard 603, *IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations* (IEEE, 2018). France has defined a basic safety rule related to the use of software, which defines principles and objectives that have to be followed by the licensee.

Finland, India, Russia, Slovenia and Sweden use IAEA standards. Finland and Sweden use *IAEA Safety Standards/Safety Requirements No. GS-R-3, The Management System for Facilities and Activities* (IAEA, 2006). Slovenia uses *IAEA Safety Guide No. NS-G-1.1, Software for Computer Based Systems Important to Safety in Nuclear Power Plants* (IAEA, 2000) and general IAEA standards. Russia uses *IAEA Safety Guide No. NS-G-1.3, Instrumentation and Control Systems Important to Safety in Nuclear Power Plants* (IAEA, 2002) and *IAEA Draft Safety Guide DS-431, Design of I&C Systems for Nuclear Power Plants* (IAEA, 2014). India uses IAEA standards and other codes for areas where its own documents have not been developed.

Canada, Finland, France, Russia, the Slovak Republic, and Sweden also use the International Electrotechnical Commission (IEC) Standards: IEC 61513, *Nuclear Power Plants – Instrumentation and Control Important to Safety – General Requirements for Systems*; IEC 62138, *Nuclear Power Plants – Instrumentation and Control Important for Safety – Software Aspects for Computer-based Systems Performing Category B or C Functions;* and IEC 60880, *Nuclear Power Plants – Instrumentation and Control Systems Important to Safety – Software Aspects for Computer-based Systems Performing Category A Functions* (IEC, 2001; IEC, 2004; IEC, 2006).

Skill sets required to perform review

Electrical and I&C engineers were the main technical experts needed and others included nuclear engineers, computer engineers, health physicists, human factors engineers, inspectors, mechanical engineers, quality engineers and reactor systems engineers.

Computer engineers review I&C related design in Canada, Finland, France, Korea and Slovenia; and software reliability in the Slovak Republic. Nuclear engineers review all I&C topics in Finland; the reactor trip system, control systems, safety-related display instrumentation, and information and interlock systems important to safety in Korea; the reactor trip system, control systems in Slovenia; and the actuation systems for ESF in the Slovak Republic. Human factors engineers review most I&C topics in Canada; the main and supplementary control room and the safety-related display instrumentation in Korea and the United States; and the main and supplementary control room in Sweden. Mechanical engineers review the main control room and supplementary control room and systems not required for safety (control systems) in Korea and the main control room and supplementary control room in the Slovak Republic and Slovenia. Reactor systems engineers review all I&C topics in India; diverse I&C systems, the reactor trip system, and the main control room in the United States, and diverse I&C systems and actuation systems for ESF in Korea.

Specialised training

All countries identified the importance I&C experience and the regulators in Finland, India, Japan, Korea and the United States offer formal training programmes.

Level of effort

Table 3 provides the total estimated level of effort need for I&C review by member countries.

Table 3. Total estimated level of effort needed for instrumentation and control review

Country	Total estimated level of effort (hours)	Basis
Canada	3 000	Construction licence application review
Finland	20 040	Construction licence
France	11 160	Review of nuclear power plants with digital I&C systems
India	-	Resources (hours) are not set up for each individual review area
Japan	-	Resources (hours) are not set up for each individual review area
Korea	12 880	Review of digital I&C and control room modernisation at Shin-Kori 3 and 4
Russia	5 120 – 7 680	Current review experience and planned future activities
Slovak Republic	-	Level of effort defined by regulation and dependent upon the activity to be approved
Slovenia	3 540	Review of a licensing process for I&C systems design approval
Sweden	5 400	Review of digital I&C and control room modernisation for Ringhals Unit 2
United States	27 180	Standard Design Certification review

4.1.2.2 Civil engineering works and structures

Consistent with IAEA Safety Guide No. GS-G-4.1 (IAEA, 2004), the survey on civil engineering works and structures consisted of five technical topics: containment design and other safety-related design, external natural event loadings, external man-made hazards, internal hazards, and aircraft impact assessment. The information provided by member countries on the five technical topics is summarised below under six areas stated in Section 4.1.2.

Design information provided by the applicant

In all countries, the applicant provides a description of the design and analysis of the containment and other applicable structures. In most countries, the applicant provides information on construction, testing, and inspection of the containment and other structures. In Canada, India, Japan, Korea, Russia and the United States, the applicant provides information on quality control and quality assurance programmes.

In most countries, the applicant provides facility design information on protecting against natural phenomena, including earthquakes, flooding, snow, fire, weather, tsunami, ice, wind and extreme temperatures. In most countries, the applicant provides the following characteristics of the proposed plant site: geological, geophysical, geotechnical, hydrological, meteorological and seismic. In all countries, the applicant provides an analysis of the effects of natural event loadings on the facility, commonly on seismic-related analysis.

In most countries, the applicant provides a description of protection against man-made hazards, such as those associated with military facilities, industrial facilities and transportation routes. Common man-made hazards include explosions, dam failures, missiles, toxic gas releases and aircraft impact.

In most countries the applicant describes the facility design against internal hazards more commonly fire, explosions, and internally generated missiles and, less frequently, flooding and pipe whip.

In most countries, the applicant provides analysis of the probability and effects of aircraft impacts on the plant site.

Analysis, reviews and/or research performed

All regulatory organisations review applicants' analysis for compliance with the applicable regulatory requirements and guidelines and most have the framework in place to perform separate design reviews. Some regulatory organisations perform comparative or confirmatory analysis as part of the design review.

Technical basis

In all countries, the technical basis for regulatory authorisations is provided by regulations and regulatory guidance. Most countries use country-specific building codes and national or international consensus standards in addition.

Canada, Russia and Slovenia use IAEA standards: Russia for containment design and external hazards; Slovenia for reviewing all technical topic; Canada for external man-made hazards and aircraft impact assessment;

Canada, Korea, Slovenia, the United Kingdom and the United States use the American society of civil engineers standards; all four countries for external natural event loadings; Korea, Slovenia and the United States for containment design and safety-related structural design and the United Kingdom for aircraft impact assessments. The most commonly used standards were *ASCE 7, Minimum design loads for buildings and other structures* and ASCE 4-98, *Seismic analysis of safety-related nuclear structures* (ASCE 2003; ASCE 2017).

Canada, Korea, Slovenia and the United States use the American concrete institute standards: Canada, Slovenia and the United States, for external natural event loadings; and Korea, Slovenia and the United States use ACI 349, *Code requirements for nuclear safety related concrete structures* (ACI, 2001) for containment design and safety-related structural design.

American National Standards Institute (ANSI) standards were identified as part of the technical basis for granting authorisation in four of the five technical topics. For example, Korea, Slovenia and the United States use *ANSI/AISC N690, Specification for the Design, Fabrication and Erection of Steel Safety* (AISC, 2012) as part of the technical basis for granting regulatory authorisation for containment design and safety-related structural design. Other ANSI standards that were identified include ANSI/ANS-2.8-1992, *Determining design basis flooding at power reactor sites* (ANS, 1992), which Slovenia and the United States listed as part of the technical basis for containment design and external natural event loadings, and ANSI/ANS-58.21-2003, *External events in PRA methodology* (ANS, 2003), which Slovenia identified as part of the technical basis for external man-made hazards and aircraft impact assessment.

Korea, Slovenia and the United States use several ASTM International (formerly known as the American Society for Testing and Materials) standards for external natural event loadings: ASTM D 1587, *Standard practice for thin-walled tube sampling of soils for geotechnical purposes*; ASTM D 4044, *Standard test method (field procedure) for instantaneous change in head (slug) tests for determining hydraulic properties of aquifers* ASTM D 6913; *Standard test method for particle size distribution (gradation) of soils using sieve analysis*; and ASTM D 1586, *Standard test method for penetration test and split-barrel sampling of soils* (ASTM International, 2015a; 2015b; 2017; 2018).

Skill sets required to perform review

Civil and structural engineers were the main technical experts needed and others included geologists, geophysicists, geotechnical engineers, hydrologists, meteorologists, mechanical engineers, fire protection engineers, reactor systems engineers, physical scientists, process engineers and risk analysts.

Fire protection engineers review internal hazards in Canada, Finland, Korea, Russia and the United States and aircraft impact assessments in the United States. Mechanical engineers review all technical topics in France and Japan; external man-made hazards and aircraft impact in Finland and Slovenia; containment design and internal hazards in Slovenia; and internal hazards and aircraft impact assessments in Russia. Geologists, geophysicists and/or hydrologists review external natural event loadings in Japan, Korea, Russia, Slovenia and the United States. Geophysicists review containment design and safety-related structural design in Japan and Slovenia.

Specialised training

All countries identified experience related in civil engineering works and structures is important and the regulators in Finland, India, Japan, Korea and the United States offer formal training.

Level of effort

Table 4 provides the total estimated level of effort need for I&C review by member countries.

Table 4. Total estimated level of effort needed for civil engineering works and structures review

Country	Total estimated level of effort (hours)	Basis
Canada	10 900	Construction licence application review
Finland	15 760	Construction licence review and assessment of Olkiluoto 3
France	-	Hours not estimated for each review area
India	-	Resources (hours) are not set up for each individual review area
Japan	-	Resources (hours) are not set up for each individual review area
Korea	12 200	New nuclear power plant review
Russia	-	Resources (hours) are not set up for each individual review area
Slovak Republic	-	Level of effort defined by regulation and dependent upon the activity to be approved
Slovenia	8 200	Review of a licensing process for Civil Engineering Works and Structures design approval
United Kingdom	-	Generic design assessment and/or site licensing process
United States	26 750	Standard design certification review

4.1.2.3 Reactor

Consistent with IAEA Safety Guide No. GS-G-4.1 (IAEA, 2004), the survey on reactor consisted of six technical topics: fuel system design, reactor internals and core support, nuclear design and core nuclear performance, thermal and hydraulic design, reactor materials and functional design of reactivity control system. The information provided by member countries on the five technical topics is summarised below under six areas stated in Section 4.1.2.

Design information provided by the applicant

In all countries, the applicant provides a description of the design and design basis of the fuel system, mainly the mechanical design of the fuel assembly, including geometric data and loadings. The applicant describes the performance of the fuel under normal operation and accident conditions; the calculations, methods, or computer codes used to assess the fuel performance; and the plans for, or results of, testing, inspection and surveillance. In several countries, the applicant provides a description of operating experience with fuel systems of the same or similar design.

In most countries, the applicant provides a description of the design of the reactor internals and core supports, including the materials of construction, fabrication and processing, mechanical aspects, and thermal-hydraulic characteristics. In some countries, the applicant describes the effects of service on the reactor internals and plans for inspection, surveillance, or testing.

In all countries, the applicant provides a description of nuclear design and core nuclear performance, including properties and burn-up of the fuel, power distributions, peaking factors, shutdown margins, control rod patterns, reactivity parameters and coefficients, neutron absorbers or poisons, and reactor core stability. In all countries, the applicant also provides supporting calculations or computer codes. In some countries, the applicant also provides an analysis of the uncertainties associated with the nuclear parameters and the requirements for instrumentation, including calibration and calculations involved in their use.

In most countries, the applicant provides a description of the thermal-hydraulic design, including the critical heat flux, parameters characterising the distribution of flow, pressure, temperature, and voids in the reactor, the hydraulic loads on the core and reactor coolant system components, and the analytical tools, methods, or computer codes used to calculate thermal and hydraulic parameters.

In most countries, the applicant provides a description of reactor materials, including the chemical, physical, mechanical properties of the materials, irradiation effects, and the programmes used to address or manage degradation of the components during service. In some countries, the applicant provides information on the fabrication and processing of the materials, justification for using new or novel materials.

In all countries, the applicant provides a description of functional design of reactivity control systems, including the reactivity control systems, their design, design bases, functional requirements, operating conditions and limits, and provisions for functional testing and qualification of each reactivity control system.

Analysis, reviews and/or research performed

All regulatory organisations review applicant's analysis for compliance with the applicable regulatory requirements and guidelines and most have the framework in place to perform separate design reviews. Several regulatory organisations also verify the acceptability of calculations, computer codes, or models and perform comparative or confirmatory analysis as part of the design review.

Technical basis

In all countries, the technical basis for regulatory authorisation is provided by regulations and regulatory guidance. Most countries use international consensus standards in addition.

Canada, the Slovak Republic and Slovenia use IAEA standards: Slovenia uses IAEA standards for all six of the reactor technical topics; Canada uses IAEA standards for fuel system design, nuclear design and core nuclear performance, thermal and hydraulic design, and functional design of reactivity; and the Slovak Republic uses IAEA standards for fuel system design.

Canada and the United States use American Society of Mechanical Engineers (ASME) codes: ASME Boiler and Pressure Vessel (B&PV) code, Section 3, *Rules for construction of nuclear facility components for reactor internals and core support and reactor materials*. Some countries use ASME code, Section 2, *Materials*, Section 5, *Nondestructive examination*, and Section 9, *Welding and brazing qualifications*.

Finland, France and the United Kingdom use AFCEN (Association Française pour les règles de Conception, de construction et de surveillance en exploitation des matériels des Chaudières Electro Nucléaires – French association for design and manufacturing rules of PWR and FBR) standards: Finland uses the AFCEN RCC-M code, *Design and Conception*

Rules for Mechanical Components of PWR nuclear islands, for reactor internals and core supports and reactor materials; and France and the United Kingdom use the AFCEN RCC-C code, *Design and Construction Rules for Civil Nuclear Fuel, for the fuel system design*.

Skill sets required to perform review

Nuclear engineering was the main technical expertise needed and others included fuel behaviour, structural mechanics, reactor physics, thermal-hydraulics, reactor physics and mechanical engineering.

Materials engineers more commonly review, and reactor internals and core support and mechanical engineers and nuclear engineers less commonly review the reactor materials.

Mechanical engineers more commonly review, and nuclear engineers, materials engineers, reactor systems engineers and risk analysts less commonly review the functional design of the reactivity control system.

Specialised training

All countries identified importance of experience related reactor, including fuel design, fuel behaviour, structural mechanics, reactor physics and thermal-hydraulics.

Level of effort

Table 5 provides the total estimated level of effort need for reactor review by member countries.

Table 5. Total estimated level of effort needed for reactor review

Country	Total estimated level of effort (hours)	Basis
Canada	4 280	Pre-licensing vendor design review
Finland	25 280	Review of a construction licence application preliminary safety assessment report
France	-	Resources (hours) are not set up for each individual review area
Japan	-	Resources (hours) are not set up for each individual review area
Korea	8 260	Safety review of licence application documents
Russia	3 240	Resources (man-hours) are not set up for each individual review area, but a best estimate was provided
Slovak Republic	-	Level of effort defined by regulation and dependent upon the activity to be approved
Slovenia	3 400	The level of effort was estimated from the analysis, which was prepared to assess the resources needed in case of construction of new nuclear power plants
United Kingdom	4 000	Technical review of a pre-construction safety report
United States	8 550	Standard design certification review

4.1.2.4 Reactor coolant and associated systems

Consistent with IAEA Safety Guide No. GS-G-4.1 (IAEA, 2004), the survey on reactor coolant and associated systems, consisted of four technical topics: overpressure protection, reactor coolant pressure boundary, reactor vessel and design of the reactor coolant system. The information provided by member countries on the four technical topics is summarised below under six areas stated in Section 4.1.2.

Design information provided by the applicant

In most countries, the applicant provides a description of the design and design basis of the overpressure protection system, including the materials specifications, applicable codes and standards, the description of applicable instrumentation, the reliability, failure analysis, and the plans for, or results of, testing and inspections.

In most countries, the applicant provides a description of the reactor coolant pressure boundary, including the materials (specifications and compatibility with the reactor coolant), fabrication/manufacturing processes, applicable codes, provisions for leakage detection and monitoring, the in-service inspection and testing. In several countries, the applicant performs analysis of the reactor coolant boundary, including stress or strength analysis, brittle fracture analysis, and leak before break analysis.

In most countries, the applicant provides a description of the design and design bases of the reactor vessel, including the materials specifications, fabrication processes, limits on operating pressure and temperature, maintaining the reactor vessel under radiation embrittlement, inspection, testing, and/ surveillance.

In most countries, the applicant provides a description of the reactor coolant system (RCS), including the design, design bases, and performance requirements for components and sub-systems.

Analysis, reviews and/or research performed

All regulatory organisations review the applicant's analysis for compliance with the applicable regulatory requirements, guidelines, or codes and standards. Most regulatory organisations perform confirmatory analyses/assessment or independent evaluation/verification of the applicant's analysis.

Technical basis

In all countries, the technical basis for regulatory authorisation is provided by regulations and regulatory guidance. The member countries also use international consensus standards: Finland and the United Kingdom use the AFCEN RCC-M code, *Design and conception rules for mechanical components of PWR nuclear islands*; the United Kingdom and the United States use ASME codes for overpressure protection; Korea and the United States use ASTM E185, *Design of surveillance programmes for light-water moderated nuclear power reactor vessels*.

Skill sets required to perform review

Mechanical engineering and materials engineering were the main technical experts needed and others included civil/structural engineers, chemical engineers, nuclear engineers, reactor systems engineers and risk assessment engineers.

Specialised training

All countries identified experience related in reactor coolant and associated systems is important.

Level of effort

Table 6 provides the total estimated level of effort need for reactor coolant and associated systems review by member countries.

Table 6. Total estimated level of effort needed for reactor coolant and associated systems review

Country	Total estimated level of effort (hours)	Basis
Finland	7 640	Construction licence application review of Olkiluoto 3
France	-	Resources (hours) are not set up for each individual review area
India	-	Resources (hours) are not set up for each individual review area
Japan	-	Resources (hours) are not set up for each individual review area
Korea	4 520	Application review of APR1400 type nuclear power plant
Slovak Republic	-	Level of effort defined by regulation and dependent upon the activity to be approved
Slovenia	2 320	The level of effort was estimated from the analysis, which was prepared to assess the resources needed in case of construction of new nuclear power plants
United Kingdom	-	Technical review of a pre-construction safety report
United States	4 040	Standard design certification review

4.1.2.5 Classification of structures, systems and components

Consistent with IAEA Safety Guide No. GS-G-4.1 (IAEA, 2004), the survey on classification of structures, systems, and components consisted of four technical topics: classification of systems, structures and components; plant design for protection against postulated piping failure; seismic and dynamic qualification of safety-related mechanical and electrical equipment; and environmental qualification of mechanical and electrical equipment. The information provided by member countries on the four technical topics is summarised below under six areas stated in Section 4.1.2.

Design information provided by the applicant

In most countries, the applicant provides a description of classification of Structures, Systems and Components (SSCs), including the design and safety requirements, the safety functions, the applicability of codes and standards, and a list SSCs and their classification (i.e. the safety classification, seismic classification and quality group classification).

In most countries, the applicant describes the measures used to prevent or mitigate the effects of postulated piping ruptures, specially the ruptures related to moderate and high energy piping systems. In many countries, the applicant describes the structural integrity of plant SSCs, including the containment, main coolant piping and design protection against the effects of piping breaks. In some countries, the applicant provides an analysis of the effects of various pipe breaks, including the location of potential pipe breaks, the environmental effects, and dynamic effects (e.g. pipe whip and fluid jet impingement).

On the seismic and dynamic qualification of safety-related mechanical and electrical equipment, in most countries, the applicant identifies all equipment that should be designed to withstand the effects of earthquakes and the full range of normal and accident loadings. The applicant describes the tests and analyses used to ensure the integrity, functionality and reliability of the applicable equipment. The most common analysis was the seismic or seismic hazard analysis.

On the environmental qualification of mechanical and electrical equipment (e.g. temperature, humidity, radiation, pressure), in several countries, the applicant identifies all equipment important to safety that is to be environmentally qualified and describes the design, location, applicable environmental conditions of the equipment of interest, and the environmental qualification approach (analyses, calculations, testing, to ensure that the equipment is capable of performing its safety function). Some countries require the applicant to submit an environmental qualification programme.

Analysis, reviews and/or research performed

All countries review the information provided by the applicant for compliance with the applicable regulatory requirements, guidelines, or codes and standards. Many countries perform confirmatory analyses using computer programs, inspections, technical assessments, the verification of test results, and probabilistic analysis.

Technical basis

In all countries, regulations, regulatory guidance, and national and international standards provide basis for regulatory authorisation. Canada, Finland, the Slovak Republic and Slovenia use IAEA standards for the seismic and dynamic qualification of safety-related mechanical and electrical equipment. Canada and Slovenia use IAEA standards for the classification of systems, structures and components; and the environmental qualification of mechanical and electrical equipment. Canada, Finland, and the United States use ASME codes: Canada for every technical topic; Finland uses the ASME Section 3, Division 2, *Requirements for containment design in relation to the plant design for protection against postulated piping ruptures*; the United States uses the ASME Section 3 in relation to classification of SSCs and ASME AG-1 in relation to seismic and dynamic qualification. Canada, Finland and the United Kingdom use the International Electrotechnical Commission standards.

Skill sets required to perform review

Mechanical engineers were the main technical experts needed and others included plant systems engineers, structural engineers, electrical engineers, materials engineers, nuclear engineers; and human factors, radiological protection and risk assessment experts.

Specialised training

All countries identified the importance of experience in classification of structures, systems and components.

Level of effort

Table 7 provides the total estimated level of effort need for classification of structures, systems and components review by member countries.

Table 7. Total estimated level of effort needed for classification of structures, systems and components review

Country	Total estimated level of effort (hours)	Basis
Canada	4 140	CNSC regulatory framework and licensing experience
Finland	2 560	European Pressurised Reactor construction licence application review
France	-	Resources (hours) are not set up for each individual review area. The effort needed to review a new plant design strongly depends on the degree of novelty of this design
Japan	-	Resources (hours) are not set up for each individual review area
Korea	4 770	APR1400 Nuclear Power Plant application review
Slovak Republic	-	Level of effort defined by regulation and dependent upon the activity to be approved
Slovenia	2 500	The level of effort was estimated from the analysis, which was prepared to assess the resources needed in case of construction of new nuclear power plants
United Kingdom	6 240	Technical review of a pre-construction safety report and associated documents
United States	4 300	Standard design certification review

4.1.3 Phase III: Survey of construction oversight

The survey of construction oversight covered three basic areas of which summary results are provided below: on-site inspection of new reactor construction, assessment of licensee performance during new reactor construction, and enforcement.

On-site inspection of new reactor construction

All regulatory organisations have established legal authority to conduct on-site construction inspections and have or plan to develop programmes.

In all countries, office-based inspectors conduct or plan to conduct on-site construction inspections. Canada, Finland, Hungary, Korea and the United States have, or plan to have, resident inspectors. All countries use construction and operating experience for inspection planning. Finland, France, Hungary, Korea, Russia, the United Kingdom and the United States have systematic, well-defined approaches to select construction activities for inspection.

France, Hungary, Korea, Russia and the United Kingdom have inspection hold points beyond which authorisation is required to proceed past the hold point. The United Stated does not employ hold points; however, licensees must meet certain licence conditions prior to proceeding with construction activities.

All countries communicate inspection findings with the licensee in a meeting at the end of the inspections and document findings in an inspection report. The licensees are required to develop corrective actions to address the inspection findings and the regulatory body conducts reviews of the actions in subsequent inspections.

Finland, France, Hungary, Korea, Russia, the United Kingdom and the United States have various approaches for reviewing safety culture. All consider safety culture to be an important aspect of new reactor construction.

Assessment of licensee performance during new reactor construction

In all cases, the regulatory body either conducts or plans to assess licensee performance, the results of which can influence subsequent inspection activities.

Enforcement

In all countries, the regulatory body has authority to take actions against licensees to enforce its regulations.

5. Conclusions

This task consisted of three phases (licensing structure and process, the design process, and construction oversight) and used surveys to solicit information from the Working Group on the Regulation of New Reactors (WGRNR) participating countries across a broad range of topics. This significant effort resulted in the publication of seven topical reports covering general licensing review information, the design process and construction. Although the initial scope of the task was not completed, in light of the dynamic changes that had occurred in new reactor licensing following the accident at the Fukushima Daiichi Nuclear Power Plant, the WGRNR recognised that a continuation of developing reports from surveys information collected in the remaining areas would involve a significant validation effort. Therefore, the WGRNR concluded that its resources could be better used for tasks more relevant to the current situation in member countries and suspended further work on this activity. However, the seven reports developed as a result of this task provide valuable insights into the new reactor licensing process in WGRNR participating countries.

Common themes and lessons learnt

The following is a summary of common themes and lessons learnt:

- The long time involved in the regulatory review of licensing process – from three to eight years – is one of the main drawbacks in building a nuclear power plant. Although time is necessary to ensure the safety and security of the public, it can affect the applicant's ability to obtain funding for the project.
- The regulator is the sole authority to grant a licence for a new nuclear power plant in some countries (Canada, Hungary, Poland, the Slovak Republic, the United Arab Emirates, the United Kingdom and the United States) while in others, government ministries, parliament, local authorities, technical support organisations, the public, and neighbouring countries may also be involved in the licensing process.
- Although the description of information provided by the applicant may differ in scope and the level of detail, the information required by member countries is similar.
- In addition to the regulations and guidance documents, member countries refer to national and international standards to provide the technical basis of regulatory authorisation.
- During their reviews of new reactor designs, member countries consider emerging issues, operating experience and lessons learnt from operating reactors.
- In addition to reviewing applicant's analysis for compliance with the applicable regulatory requirements and guidelines, regulatory organisations also verify the acceptability of calculations, computer codes, or models and may perform comparative or confirmatory analysis.

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