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Consensus Position on the Qualification of Existing and New Material Manufacturing Techniques within Codes and Standards

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NUCLEAR ENERGY AGENCY
COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 34 countries: Argentina, Australia, Austria, Belgium, Bulgaria, Canada, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Romania, Russia (suspended), the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, the United Kingdom and the United States. The European Commission and the International Atomic Energy Agency also take part in the work of the Agency.

The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes;
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management and decommissioning, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES (CNRA)

The Committee on Nuclear Regulatory Activities (CNRA) addresses 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 Nuclear Energy Agency (NEA) Committee on Nuclear Regulatory Activities (CNRA) believes that sharing experience and regulatory practices is a major element in the efforts made by regulatory bodies and industry to maintain and improve the safe operation of nuclear power plants. Considering the importance of codes and standards topics, the CNRA established a Working Group on Codes and Standards (WGCS) to facilitate and promote international co-operation, convergence and reconciliation of codes, standards and regulatory requirements for pressure boundary components in nuclear power plants. The WGCS reports on a regular basis to the committee. The WGCS is an international forum for nuclear regulatory organisations to co-operate in the development of consensus positions (CPs) representing the common understanding and harmonisation of regulatory practices. The CPs provide a consistent set of regulatory expectations for industry and may be used by members in the development of guidance in their own national regulatory frameworks.

The audience for these CPs is primarily regulatory bodies, although the information and ideas are expected to be of interest to licensees, other nuclear industry organisations, the general public, as well as of special interest to emerging nuclear countries that have yet to develop well-established regulatory regimes.

The goal of the WGCS is not to independently develop new regulatory standards. CPs are not legally binding and do not constitute additional obligations for the regulators or the licensees but are guidelines, recommendations or assessments that the WGCS participants agree are good to highlight during their safety reviews of new reactors and operating plant upgrades. All members of the WGCS are encouraged to implement CPs through their national regulatory processes.

Acknowledgements

The members of the Nuclear Energy Agency (NEA), the NEA Committee on Nuclear Regulatory Activities (CNRA) and the NEA Working Group on Codes and Standards (WGCS) acknowledge the significant contributions of those individuals who had a key role in the preparation of these consensus positions. Additional thanks are extended to those working group members who participated in its development and to Sangmin Lee, chair of the WGCS, for his leadership and guidance.

This report was approved by the CNRA at its 48th meeting on 30 November to 1 December 2022 (NEA, 2023, not publicly available).

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List of abbreviations and acronyms

CP	Consensus position
CNRA	Committee on Nuclear Regulatory Activities (NEA)
HIP	Hot isostatic pressing
IAEA	International Atomic Energy Agency
NDT	Non-destructive testing
NEA	Nuclear Energy Agency
OECD	Organisation for Economic Co-operation and Development
SDOs	Standards development organisations
SSCs	Structures, systems and components
WENRA	Western European Nuclear Regulators Association
WGCS	Working Group on Codes and Standards (NEA)

Executive summary

The Nuclear Energy Agency (NEA) Working Group on Codes and Standards (WGCS) has agreed that a consensus position on the topic of the qualification of existing and new material manufacturing techniques within codes and standards is warranted given their impact on the quality of the material used for safety significant structures, systems or components.

This action follows the WGCS examination of Western European Nuclear Regulators Association (WENRA) activities on positive macro-segregation issues in large forgings leading to recommendations on the qualification of material manufacturing techniques.

The WGCS proposes a consensus position gathering common expectations from regulators on the qualification of existing and new material manufacturing techniques.

The guidance herein is not to be construed as a requirement or regulation; instead, it is intended to serve as a source of information to be used for licences, manufacturers and standards development organisations (SDOs).

1. Introduction

To maintain integrity and secure the safety functions of pressure boundary components, it is necessary to design, monitor and maintain safety significant properties such as strength and resistance to fracture. In this context, problems emerged related to macro-segregation in large ferritic forgings for use in the pressure boundary components of French reactors. While these events are specific to the risk of macro-segregation in large components, they have brought attention to the importance of the control of variations of these properties as the risks are generic (for example, hydrogen-induced cracking). Similar considerations apply to novel manufacturing processes (e.g. additive manufacturing, powder metallurgy), where items such as qualification and control of the manufacturing process can impact the quality and consistency of material properties and component behaviour.

In this context, the NEA Committee on Nuclear Regulatory Activities (CNRA) Working Group on Codes and Standards (WGCS) identified an opportunity for regulators to provide guidance to improve the process for qualifying existing and new material manufacturing techniques used for the pressure boundaries of nuclear power plants within codes and standards.

While this consensus position (CP) is based on the lessons learnt from the macro-segregation issue affecting large forgings, its scope is broader; it encompasses manufacturing techniques used for components of high nuclear safety significance, particularly nuclear pressure systems.

This CP establishes common expectations from regulators on the technical qualification of material manufacturing techniques used for pressure boundary components.

This CP contains examples of expectations associated with special processes.

The principles of this consensus position are established for the manufacture of material constituting pressure boundary components. They can be extended to cover other safety significant structures, systems and components (SSCs) in nuclear power plants.

2. Definitions

Graded approach: A process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control. (Adapted from IAEA, 2019).

Qualification: Process of determining whether a system or component is suitable for operational use.

System important to safety: A system that is part of a safety group and/or whose malfunction or failure could lead to radiation exposure of the site personnel or members of the public. (Adapted from IAEA, 2019).

3. Consensus position on the qualification of existing and new material manufacturing techniques within codes and standards

3.1. General principles

1. This guidance is intended to serve as a source of information to be used for stakeholders including licensees, designers, manufacturers, standards development organisations (SDOs) and regulators consistently with their respective roles; it is not to be construed as a requirement or regulation.
2. All equipment affecting the operation of a nuclear reactor must fulfil its safety functions and meet all applicable regulatory requirements.
3. The expectations for a safety significant structure, system or component (SSC) must be reflected in its design and manufacture, especially through the definition and achievement of expected characteristics throughout its service life.
4. In the case of the materials constituting pressure boundary components, the expected characteristics are those that guarantee their integrity, such as resistance to fracture and susceptibility to degradation in service. These are demonstrated through evidence described in item 8 below.
5. The expected characteristics for the material may vary through the volume of parts consistently with the design need, especially for massive metallic parts.
6. A material manufacturing technique qualification is specific to a type of component, its material, its manufacturing programme and the suppliers. Any change in one of these conditions may compromise the effectiveness of the qualification.
7. Such a qualification provides for checks and controls on processes so that components manufactured as defined within the qualification meet the expected characteristics throughout their volumes and maintain their integrity, thus fulfilling their safety functions.
8. Such a qualification should be based on relevant evidence, particularly on the fitness for purpose (including the absence of unacceptable defects from non-destructive testing) and on chemical and mechanical properties.
9. The level of rigour that is applied to a material manufacturing technique qualification should reflect the nuclear safety significance of the component, the complexity of the design, the manufacturing process, and the capability of the supplier.

These principles and guidance are consistent with the approach already in use for the qualification and control of welding processes in that, for both, the objective is to provide evidence to demonstrate that the process is fit for purpose.

3.2. Guidance to the licensees, designers, manufacturers, SDOs and regulators

10. All parties involved in design and manufacturing should develop adequate means for preserving knowledge related to the understanding of the manufacturing processes and their significance for the integrity of the components.

11. The relation between the licensee, designers, manufacturers, SDOs and regulators should be reinforced so that all the parties work openly and promptly share information regarding any potential manufacturing issue that affects the integrity of the components.

3.3. Guidance to the regulators

12. The role of the regulator is to ensure that the licensee addresses the guidance below.
13. In cases where a manufacturing route raises a risk to compromise the nuclear safety functions of components, regulators should ask licensees to provide justification for use of the components.

3.4. Guidance to the licensees

14. The licensee is expected to require a material manufacturing technique qualification for components according to the nuclear safety significance of the equipment. The qualification must demonstrate that each component meets its nuclear safety functions by maintaining its integrity and satisfies the requirements of the designers, manufacturers, and regulators.
15. For reactors and equipment under design or construction, the licensee should ensure that the material manufacturing technique qualification integrates a thorough understanding of the manufacturing process, including relevant knowledge (extending across all industries) and potential technical issues.
16. The licensee should ensure that manufacturing parameters that materially affect the integrity of components are identified, controlled and monitored in order to ensure their expected quality.
17. The licensee is responsible for ensuring that adequate means are developed and used to keep manufacturing data and records, archive materials and experience feedback on design and manufacturing, both internally and by designers and manufacturers. Attention should be paid to this when selecting and making agreements with the designers and manufacturers of components.
18. The licensee should recognise the importance of record keeping for safety significant knowledge related to the design and manufacturing and ensure that it is properly documented in accordance with applicable quality assurance requirements.
19. The licensee should provide justification for any deviations from applicable consensus codes and standards or regulatory requirements or for alternate approaches not covered by existing codes and standards and regulatory requirements.

3.5. Guidance on codes and standards

20. This CP encourages SDOs to work with licensees, manufacturers, designers and regulators to:
    a. improve the qualification of manufacturing techniques so that all components meet their safety requirements throughout their volumes;

b. base the qualification of manufacturing techniques on a breakdown of manufacturing step by step to identify and control any threat that a process presents to nuclear safety (risk analysis);

c. review the design and manufacturing provisions in existing codes to identify and address any potential shortfalls;

d. provide a framework in codes and standards for the qualification process steps of defining, reviewing, and updating acceptance criteria and controls. It enables the user (licensee or manufacturer) to meet the criteria (by means of non-destructive testing, mechanical testing, metallurgical examination, chemical analysis) and to align with expectations for the characteristics of safety significant components as mentioned in items 3 to 5.

3.6. Guidance for large forgings

21. For large forgings, the acceptance tests for a component generally include compositional checks and mechanical tests at specific locations, generally corresponding to the top and bottom of the ingot, and non-destructive testing (NDT) of the entire volume of the forged part to detect any unacceptable flaws.

    In the case of a qualification, a thorough consideration of the adequacy of the test locations is expected to provide a complete and representative qualification that allows for the entirety of the manufacturing processes, including casting, forging and heat treatment.

    In addition to these tests, it may be necessary to carry out destructive tests on a full-scale replica or representative mock-up as part of the qualification of a component to prove that the expected characteristics are met throughout the volume.

22. Topics needing a reinforced relation between the licensee, designers and manufacturers include evaluation of the risk of spatial variation of the expected characteristics as mentioned in items 3 to 5, location of test coupons, thermal treatment, forging stages and non-destructive testing.

23. More specifically, a topic needing a reinforced relation between the licensee, designers and manufacturers is the presence of welds versus size of ingot. There is an expectation that manufacturers strike a balance between the benefits of minimising the number of welds and the difficulties of producing large forgings with acceptable properties and inspectability throughout their volumes.

24. Essential variables for the manufacturing processes that affect the metallurgical phenomenon of segregation and that are expected to respect the guidance of item 17 above for large forgings must be determined and meet the applicable codes and standards and/or regulatory requirements.

3.7. Considerations for advanced manufacturing processes

25. The guidance in item 21d is applicable to novel manufacturing processes.

26. Similarly to the need for qualification of a new or changed process for large forgings, non-destructive and destructive tests would be important for zones at risk for a novel manufacturing process. For example, uneven consolidation of metallic powder used for hot isostatic pressing (HIP) components or uneven buildup in an additive manufacturing process could challenge the ability of components to meet their nuclear safety functions throughout their volumes.

4. Conclusions

While there may be different approaches to the qualification of existing and new material manufacturing techniques within codes and standards, the WGCS concludes that the guidance herein represents an effective and technically viable approach. This conclusion is based on the collective scientific and technical knowledge and experience of the WGCS members who were brought together to develop this consensus position (CP). As such, this CP represents the common standpoint of the WGCS members on the qualification of existing and new material manufacturing techniques within codes and standards.

5. References

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