MDEP
Technical Report
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Related to: Codes and Standards Working Group

Technical Report on Lessons Learnt on Achieving Harmonisation of Codes and Standards for Pressure Boundary Components in Nuclear Power Plants

Participation

Countries involved in the MDEP working group discussions:	Canada, Finland, France, India, Japan, Korea, Russian Federation, South Africa, the U.A.E., the U.K., and the U.S.
Countries which support the present technical report	
Countries with no objection:	China and Sweden
Countries which disagree	
Compatible with existing IAEA related documents	Yes

Executive Summary

This report was prepared by the Multinational Design Evaluation Programme's (MDEP's) Codes and Standards Working Group (CSWG). The primary, long-term goal of MDEP's CSWG is to achieve international harmonisation of codes and standards for pressure-boundary components in nuclear power plants. The CSWG recognised early on that the first step to achieving harmonisation is to understand the extent of similarities and differences amongst the pressure-boundary codes and standards used in various countries. To assist the CSWG in its long-term goals, several standards developing organisations (SDOs) from various countries performed a comparison of their pressure-boundary codes and standards to identify the extent of similarities and differences in code requirements and the reasons for their differences. The results of the code-comparison project are documented in a separate report in the MDEP library [Ref. 1].

The results of the code-comparison project provided the CSWG with valuable insights in developing the subsequent actions to take with SDOs and the nuclear industry to pursue harmonisation of codes and standards. The results enabled the CSWG to understand from a global perspective how each country's pressure-boundary code or standard evolved into its current form and content. The CSWG recognised the important fact that each country's pressure-boundary code or standard is a comprehensive, living document that is continually being updated and improved to reflect changing technology and common industry practices unique to each country. The rules in the pressure-boundary codes and standards include comprehensive requirements for the design and construction of nuclear power plant components including design, materials selection, fabrication, examination, testing and over-pressure protection. The rules also contain programmatic and administrative requirements such as quality assurance; conformity assessment (e.g., third-party inspection); qualification of welders, welding equipment and welding procedures; non-destructive examination (NDE) practices and qualification of NDE personnel.

In the course of reviewing the results of the SDO's code-comparison project, the CSWG found that the similarities and differences between each county's code and standard varied considerably amongst different countries. For example, one country's code was almost identical to another country's code in technical areas while others contained vastly different requirements. Regardless of the similarities and differences, the CSWG found that each pressure-boundary code has been determined by each country to result in a component with an acceptable level of quality and safety. It should be recognised that the rules for component design is just one aspect of the entire component design and construction process addressed by a pressure-boundary code. In addition, there are also philosophical and cultural factors involved that play a major role in the overall quality of the design and construction of a pressure-boundary component. In other words, the implementation of the code requirements alone does not always provide a true representation of the component's quality and safety without consideration of these philosophical and cultural factors. Mixing different country's codes and standards requirements might be detrimental and should be carefully evaluated when attempted. A collaborative evaluation by knowledgeable experts in each code or standard is one approach that may enable the use of different countries' code requirements.

Overall, the CSWG concludes that each country's pressure-boundary code provides the necessary design and construction requirements to produce components with an acceptable level of quality and safety when (1) the code is used in conjunction with its country's standard industry practice, (2) the code is supplemented with industry and regulatory guidance documents, and (3) the code is implemented in a manner consistent with its cultural and philosophical factors. Furthermore, the CSWG concludes that harmonisation of pressure-

boundary codes is a long-term goal that will require the cooperation and coordination of SDOs, nuclear industry (e.g., vendors, designers, manufacturers, and owners) and regulators on an international scale. It is achievable if one acknowledges that code harmonisation is a continual process – not an end product unto itself.

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Acronyms and abbreviations

AFCEN	*Association Française pour les régles de Conception, de constructioin et de surveillance en exploitation des matériels des Chaudières Electro Nucléaire* (French Association for Design, Construction, and In-service Inspection Rules for Nuclear Island Components)
ASME	American Society of Mechanical Engineers
BWR	Boiling Water Reactor
CANDU	CANada Deuterium Uranium
CORDEL	Cooperation in Reactor Design Evaluation and Licensing
CSA	Canadian Standards Association
CSWG	Codes and Standards Working Group
ENES	Engineering Center of Nuclear Equipment Strength, Reliability and Lifetime
GEN II	Generation II
GEN III	Generation III
GEN IV	Generation IV
JSME	Japanese Society of Mechanical Engineers
KEA	Korea Electric Association
KEPIC	Korea Electric Power Industry Code
MDEP	Multinational Design Evaluation Programme
METI	Ministry of Economy, Trade and Industry
MITI	Ministry of International Trade and Industry
NDE	Non-Destructive Examination
NIKIET	Dollezhal Research and Development Institute for Power Engineering
PWR	pressurized-water reactor
RCC-M	*Règles de Conception et de Construction des Matériels Mécaniques des Ilots Nucléaires REP* (Design and Construction Rules for Mechanical Components of PWR Nuclear Islands)
SDO	standards developing organisation
WNA	World Nuclear Association

I. Introduction

As part of its Programme Plan, the CSWG established as its long-term goal the harmonisation of code requirements for design and construction of pressure-retaining (or pressure-boundary) components in order to improve the effectiveness and efficiency of the regulatory design reviews, increase quality of safety assessments, and to enable each regulatory body to become stronger in its ability to make safety decisions. The CSWG's intermediate objectives included encouraging standards developing organisations (SDOs) to conduct code comparisons, study the similarities and differences between codes, and develop a strategy and process for achieving code harmonisation.

This report documents the findings and overall conclusions of the CSWG pertaining to (1) the adequacy and sufficiency of several MDEP-member country's pressure-boundary codes and standards and (2) the potential for harmonisation of those pressure-boundary codes and standards based on the code-comparison work performed by the SDOs from April 2008 to December 2012. This report also documents a strategy and process proposed by the SDOs for achieving code harmonisation.

II. Background

The MDEP Codes and Standards Working Group (CSWG) was established in early 2008. At its first meeting in April 2008, the CSWG recognised that the first step towards achieving harmonisation was to better understand the similarities and differences between the pressure-boundary codes used in the design and construction of components in nuclear power plants for several MDEP member countries. The initial task was to have several member-country SDOs compare their code requirements for vessels that are part of the reactor coolant pressure boundary (i.e. Class 1) such as the reactor pressure vessel. The task was subsequently expanded to include Class 1 piping, pumps, and valves in their code comparison.

The CSWG established the codes and standards to be included in the scope of the CSWG project. The codes and standards were limited to the major pressure-boundary design codes and standards for nuclear power plants developed by the SDOs (or equivalent organisation) from the United States (American Society of Mechanical Engineers or ASME), France (French Association for Design, Construction, and In-service Inspection Rules for Nuclear Island Components or AFCEN), Japan (Japanese Society of Mechanical Engineers or JSME), Korea (Korea Electric Association or KEA), Canada (Canadian Standards Association or CSA), and the Russian Federation (Engineering Center of Nuclear Equipment Strength, Reliability and Lifetime/Dollezhal Research and Development Institute for Power Engineering or ENES/NIKIET).

The CSWG envisioned that a comparison of the pressure-boundary codes and standards used in each member country would identify the similarities and differences between the major pressure-boundary codes by utilising a database table that would provide a line-by-line comparison of the code requirements. The table would be prepared by the SDOs through a cooperative effort with each country's SDO. The code-comparison table could be used by the regulators to enhance efficiency and effectiveness in regulatory decision-making when reviewing the acceptability of pressure-boundary components designed to foreign codes and standards. The code-comparison table would also increase stakeholders' understanding of the significance of code differences and promote knowledge transfer of international code requirements. The CSWG planned to put the code-comparison table into a retrievable database within the MDEP electronic library.

The CSWG also envisioned that the results of the code-comparison effort would identify the most beneficial areas for convergence of codes and provide information to establish possible strategies to achieve harmonisation of pressure-boundary codes and standards.

III. SDO Code-comparison Project

The CSWG believed that development of a code-comparison database table by the SDOs was the first step necessary for achieving harmonisation of pressure-boundary codes and standards because it was not known how similar or different each code's rules were. The first step of the SDO's plan was to document the extent of similarities and differences on a line-by-line basis between the five pressure-boundary codes for France, Japan, Korea, Canada, and the Russian Federation with the pressure-boundary code of the United States. All five countries originally used the requirements from the ASME *Boiler and Pressure Vessel Code* as a foundation for developing their base code. Each country's code requirements changed over the years to reflect their government's specific regulatory policy, their industry's standard design and construction practices, their culture, their operational experience and their specific types of nuclear power plants.

The initial work by the SDOs involved a detailed line-by-line comparison of code requirements for Class 1 vessels, piping, pumps and valves. Each member-country SDO provided input into a database spreadsheet table describing its specific code rules on scope, classification, responsibilities, materials, design, fabrication, examination, testing, overpressure protection, and administrative requirements.

The pressure-boundary codes (and specific version) that were selected by the SDOs for comparison were the ASME's Boiler and Pressure Vessel Code (2007)[Ref. 2], AFCEN's RCC-M Code (2007)[Ref.3], JSME's S-NC1 Code (2008)[Ref. 4], KEA's Korea Electric Power Industry Code or KEPIC (2005 Edition including the 2008 2nd Addendum)[Ref. 5], CSA's N285.0 Standard (2008)[Ref. 6] and Russia's PNAE G-7-002 Code (1986)[Ref. 7].

In a table format, the SDOs prepared a comparison of these code requirements, provided a description of each difference, and, in some cases, discussed the reason or significance of the difference. The CSWG deliberated the need to resolve code differences and concluded that a comparison of code differences and their reason or significance would, in itself, be a valuable and practical tool for a regulator to use in decision-making. The CSWG also recognised that reconciling code differences for the sole purpose of achieving convergence of codes might cause conflicts with a country's regulatory policy or standard industry practice. For example, changing rules for welding might significantly affect standard industry welding practices long established in a country. Arbitrary changes to code rules or changes for the sole purpose of achieving convergence might even cause unintentional or inappropriate design changes.

As a result, the CSWG members believed that having an understanding of code differences and their significance would enable a regulator to determine how best to reconcile those differences on a case-by-case basis as the need arises. Resolving differences between each country's code requirements on a generic basis may be desirable in some cases, but might not be practical or achievable in others without revising regulatory policy or changing standard industry design and construction practices.

Instead, the CSWG decided to work with the SDOs to evaluate the identified differences and their significance and identify which of those code differences would be most beneficial for pursuing convergence. For those code differences where convergence of code requirements is not practical, the CSWG identified a need to develop alternative paths for a regulator to use in reconciling those differences.

In reviewing the results of the code-comparison effort by the Korean, Japanese, French, Canadian and Russian SDOs, several important points and conclusions are discussed for each country's code-comparison effort as highlighted below. Details of these highlights are discussed in the SDOs' code-comparison report [Ref. 1].

Korea's KEPIC Code-comparison Results

KEA's Korea Electric Power Industry Code (KEPIC) should be noted that it provides comprehensive requirements not only for mechanical design, but also for quality assurance, electrical, structural, nuclear, and fire protection design.

KEPIC is an industrial code which was developed with the support of the government to secure the stability, reliability, and quality of electric power industry facilities and equipment. It is the industry technology standard that comprehensively provides the technological guidelines for the overall stages from design, fabrication and installation to construction, testing, inspections, operation, etc.

After the feasibility study performed in 1987 as part of the government's policy of self-reliant nuclear power technology, KEPIC was being developed by the KEPCO from 1992, and the related works have been transferred to the nonprofit organisation, the KEA, in accordance with government policy of 1995. KEPIC committees were formed and KEPIC 1995 edition was issued. New KEPIC editions are issued every 5 years and addenda are issued every year and incorporated into new KEPIC edition.

The mechanical part of the original 1995 KEPIC Code was developed based on the 1992 ASME Boiler and Pressure Vessel Code, Section III (ASME Code) and a format similar to ASME Code was introduced. The KEPIC administrative requirements are based on ASME Code, Section III, Subsection NCA, "General Requirements," but are modified to be compatible with Korea's industry practices (e.g., KEA has its own nuclear accreditation system similar to ASME's N-Type certification, authorised nuclear inspection system, registered professional engineer qualification, etc.). In addition, KEPIC certification system includes the certification of service organisation (for heat treatment, design, and NDE) to enhance the reliability and safety of NPPs, which is different from ASME practice. KEA's database provides the comparison table showing the differences between the administrative requirements of KEPIC and those of the 2007 ASME Code, Section III, Subsection NCA, "General Requirements" on a paragraph-by-paragraph basis.

As a result, the technical requirements in the KEPIC are identical except for editorial and numbering system differences, and the Code comparison between the KEPIC and ASME Code was completed relatively easily. The KEPIC Code-comparison results show that the requirements of the KEPIC and ASME Code are generally identical (or equivalent).

Japan's JSME Code-comparison Results

In Japan, the development of nuclear codes has a long history. To briefly summarise, before 2005, the government regulatory body, Nuclear and Industry Safety Agency (NISA), issued and controlled technical requirements for nuclear power plant design. MITI Order No. 62 and Notification No. 501 provided detailed technical requirements for seismic and structural design, and technical requirements were originally derived from the ASME Code, Section III requirements of the early 1970s. In the late 1990s, the private sector of the nuclear industry began development of the JSME nuclear code for design and construction of nuclear power plants based on METI Notification No. 501. The JSME Code for light water reactors (S-NC1) was first published in 2001. Since the early 1970s, the ASME Code has changed substantially, and METI Notification 501 and the JSME S-NC1 Code have continually evolved based on domestic industry design and construction practices as well as regulatory policy. Consequently, there are many differences between the 2008 JSME S-NC1 Code and the 2007 ASME Code. For example, the JSME Code does not have a section for general requirements. Rather, general requirements are incorporated into each specific code requirement. Furthermore, JSME does not adopt the ASME NQA document and has its unique approach to address quality assurance reflecting its regulatory environment and industry practice. As a result, the JSME clarified JSME Code differences in the use of NQA, "Quality Assurance Requirements," by providing an overview of the differences in the QA approaches used in Japan and in the United States. It did not provide a line-by-line comparison of the quality assurance differences in its code-comparison table consistent with the approach used by the other SDOs (except for KEA's paragraph-by-paragraph comparison as previously discussed). The code-comparison table by JSME focused on differences between technical aspects only.

The JSME has identified many technical differences between JSME's S-NC1 and the ASME Code. With regard to the rules on materials, design, fabrication, examination, testing and over-pressure protection, the JSME confirmed that the basic technical requirements are the same between ASME and JSME codes. The differences were found to be primarily minor in nature or were related to requirements that were addressed in one code, but not the other. In many cases, ASME Code requirements that were not addressed in JSME's S-NC1 were addressed in other Japanese codes, standards or specifications.

France's RCC-M Code-comparison Results

The French AFCEN Code (RCC-M) was originally based on a combination of the ASME Code of the late 1970s, Westinghouse PWR design specifications, and French construction practices. Over the years, the RCC-M Code changed to reflect French industry operating experience and regulatory requirements as well as international regulations.

The code-comparison performed by AFCEN found many technical differences between the RCC-M Code and the ASME Code. Many of these differences were found in materials use and fabrication methods. For example, France does not adopt all materials in the ASME Code and does not generally use brazing methods in the fabrication of components. AFCEN also found that, in some areas, the ASME Code contained more detailed requirements than the RCC-M Code. This is partly due to the fact that some French design requirements are specified in other French standards. In other areas, the RCC-M Code contained more detailed requirements than the ASME Code because those requirements are specified as guidance in the United States typically through NRC regulatory guides or industry design specifications.

One primary reason for the many technical differences identified between the RCC-M Code and the ASME Code was attributed to cultural factors. The French have adopted a single pressurised-water reactor (PWR) plant design as its standard plant. The RCC-M Code is written with this specific design in mind, and, therefore, the code requirements can be prescriptive and technically detailed. Many of the RCC-M Code requirements are equivalent to requirements found in design specifications or guidance documents in other countries. In general, the RCC-M Code provides more complete and prescriptive design and construction rules than other country's codes. On the other hand, other country's codes (e.g., the ASME Code, Section III) are written for different types of nuclear power plant designs including light-water reactor boiling-water reactors (BWRs) as well as PWRs and, therefore, these codes cannot afford to be as prescriptive or detailed as the RCC-M Code. Instead, codes like the ASME Code rely on the experience and engineering judgment of designers to select the appropriate materials and use design and construction rules applicable to that specific plant design. Some codes like the ASME Code rely on third-party reviews and conformity assessments to ensure that the final pressure-boundary component meets Code requirements while other countries' codes do not. From this perspective, it is apparent that cultural factors play an important role in establishing a code's philosophy and its technical and administrative requirements.

Canada's N285.0 Code-comparison Results

Canada performed a comparison of its CSA N285.0 Standard to the requirements of the ASME Code, Section III for Class 1 components. Several years ago, the CSA initiated a similar code comparison between its N285.0 Standard and the ASME Code for the Advanced CANDU Reactor (ACR)-700 standard plant design. This previous comparison was used as a starting point for the MDEP/CSWG code-comparison project. The Canadian jurisdiction adopts the technical requirements of the ASME Code, Section III as a basis for pressure-boundary design construction, and it participates in the development of the ASME Code rules. CSA N285.0 Standard was developed to provide the approach of adopting ASME Code rules as well as to specify some unique requirements for CANDU-type reactors. Because the CANDU design does not utilise a light-water reactor vessel with fuel assemblies typically found in the United States, but rather uses a calandria vessel with fuel channels in which the fuel channels serve as the reactor coolant pressure boundary. The CSA selected the 2008 version of the CSA N285.0 Standard for its comparison effort. Using this version, the CSA N285.0 standard was found to be identical or equivalent to the ASME Code except for CANDU-specific requirements, some administrative requirements and a relatively few minor technical differences.

Russia's PNAE G-7 Code-comparison Results

The Russian Code comparison was performed by the Engineering Nuclear Equipment Strength (ENES) a daughter company of Russia's Dollezhal Research and Development Institute of Power Engineering (NIKIET RF will compare the existing PNAE G-7-002-87, PNAE G-7-008-89, PNAE G-7-009-89 and PNAE G-7-010-89 documents. The Russian Design Regulation PNAE G-7-002 was first developed in 1969 using the 1968 ASME Boiler and Pressure Vessel Code, Section III, Subsection NB (Class 1 components) requirements as its main basis taking into account specific Russian Design Rules for thermal power engineering.

For background purposes, ENES NIKIET was established in 1992 by merging three NIKIET departments. The main responsibilities of ENES are (1) developing codes and standards, (2) performing strength analysis, and (3) addressing material problems that might arise from a variety of sources, and aging.

The structure of the Russian regulatory requirements for codes and standards are governed by two Federal Laws, “On Technical Regulation (2009),” and “On Nuclear Power Uses (2004),” with certain corrections and changes. For nuclear components and piping, Federal regulations and rules as well as technical regulations are mandatory in Russia. The current Russian pressure-boundary document PNAE G-7-002, “Regulations for Strength Analysis of Components and Pipelines of Nuclear Power Plants,” is a mandatory requirement because it is one of the basic Federal regulations and rules currently in force. The Russian representative from ENES NIKIET noted that there are major differences between the Russian Design Regulations PNAE and the ASME Codes including Section III (Subsection NB Class 1 rules), Section II and Section IX. Even though the Russian Design Regulations PNAE G-7-002 was initially based on the ASME Code, the technical differences with the 2007 Edition of the ASME Code appear to be quite significant relative to the technical differences identified by the other code-comparisons completed by Korea, Japan, France, and Canada.

Overall Conclusions from the Code-comparison Project

In discussing their overall conclusions of the code-comparison effort, the SDOs noted many code differences were identified in some comparisons. But, overall, each code produces a safe component design. The SDOs noted that the final design and construction of a component is more than just implementing code rules. There are philosophical and cultural factors involved that must be taken into consideration. Code differences alone do not always provide a true comparison of the final design without consideration of these philosophical and cultural factors.

Perspectives of the CSWG on the SDOs’ Code-comparison Project

The long-term goal of the CSWG is to achieve harmonisation of pressure-boundary codes and standards. The code-comparison project performed by the SDOs from Japan, France, Korea, Canada, the Russian Federation and the United States represents the first major step towards this goal. The results of the code comparisons provided the necessary information for the CSWG to develop a strategy and working plan for the next steps towards achieving its long-term goal of harmonisation of code and standards. These steps involved working with SDOs and nuclear industry vendors to select code differences for convergence, converge on the code differences, and minimise further divergence of code rules. They are discussed in more detail later in Section V of this report.

As discussed in the previous section, the SDOs compared requirements of their pressure-boundary codes and standards for Class 1 vessels, piping, pumps and valves. The results provided a significant amount of information about the comprehensiveness and technical adequacy of these countries’ pressure-boundary codes and standards and produced a wealth of useful information about the technical and programmatic similarities and differences between each country’s code including the background and reasons for these differences. Consequently, the results should enable regulators as well as other users of the code-comparison report to determine the impact of those differences and their safety significance as well as provide insights into the level of effort needed to converge or reconcile those differences.

The results of the code-comparison project enabled the CSWG to understand from a global perspective how each country’s pressure-boundary code or standard evolved into its current form and content. This allowed the CSWG to recognise the important fact that each country’s pressure-boundary code or standard is a comprehensive, living document that is continually being improved to reflect the changing technology and common industry practices unique to each country. The SDO’s code-comparison project compared specific editions of each country’s code to a specific edition of the ASME Code, and, thus, it represented only a snapshot in time. The CSWG recognised that if code harmonisation is to be achieved, measures must be established to prevent or minimise further divergence of pressure-boundary code requirements amongst countries. Accordingly, the MDEP Steering Technical Committee issued letters to each SDO from France, Japan, Korea, Canada, the Russian Federation, and the United States requesting that the SDOs inform the MDEP's CSWG of their plans for communicating with each other and for developing a process to prevent further divergence between pressure-boundary codes and standards. The SDOs' plans to control further divergence between pressure-boundary codes and standards are discussed in Section V of this report.

The CSWG also recognised that the feedback from the nuclear industry (e.g., vendors, manufacturers, and utilities) on the value of harmonisation of codes and standards and how to achieve it are vital elements in developing the next steps towards harmonisation. The CSWG collaborated with a nuclear industry group to obtain industry views and feedback on harmonisation as part of its next steps towards achieving harmonisation of pressure-boundary codes, and this collaborative effort is discussed in Section V of this report.

Considerations for Expanding the Code-comparison to Class 2 and 3 Components

The question arose as to whether the SDOs should expand the code-comparison effort to Class 2 and 3 components. This paper discusses the views of the SDOs, nuclear vendors, and the CSWG on whether it is worthwhile to expand the code-comparison effort.

The CSWG and SDOs both agreed to select code requirements for Class 1 pressure-boundary components for the initial code-comparison scope based on safety considerations. Because Class 1 components form the reactor coolant pressure boundary, the CSWG and SDOs concluded that these components play an important safety function in that they are a major part of the overall plant defence-in-depth philosophy for containing radioactive fission products and are subjected to high temperatures and pressures compared to Class 2 and 3 components. Typical light-water reactors tend to have few Class 1 components and would include a single reactor pressure vessel, a single pressurizer, a few steam generators and reactor coolant pumps, and short sections of piping. These few components could be manufactured by a single vendor or supplier and shipped overseas relatively easily.

On the other hand, there are thousands of Class 2 and 3 components in a typical light-water reactor nuclear power plant consisting of many different sizes of piping, pumps and valves. Accordingly, harmonisation of code requirements for Class 2 and 3 components might be desirable because of the much larger scope of Class 2 and 3 components compared to that of Class 1 components and the potential value that could be gained by reactor vendors and plant owners.

From the SDOs' perspective, the SDOs were uncertain of the extent to which the results of their Class 1 code-comparison will be used by nuclear vendors, designers, plant owners and regulators. Accordingly, the SDOs decided to complete and issue their code-comparison for their initial scope consisting of Class 1 components because the world-wide nuclear industry is currently manufacturing large Class 1 forged equipment (e.g., reactor vessels, steam generators, reactor coolant pumps), and there is a more urgent need to support these components first. Depending on the need of the nuclear industry, the SDOs would consider expanding the code-comparison effort to Class 2 and 3 components. But, the SDOs wanted first to determine the usefulness of its Class 1 code-comparison results. The SDOs noted that an expansion in scope to include Class 2 and 3 components would not be difficult because most of the work completed for Class 1 components is also applicable to Class 2 and 3 components.

In obtaining the vendors' perspective, the CSWG discussed this question with representatives from Westinghouse, General Electric-Hitachi, and Ishikawajima-Harima Heavy Industries (IHI). The vendors' perspectives were similar to those of the SDOs in that they wished to wait and see how the Class 1 code-comparison results would be used before expanding the code comparison to Class 2 and 3 components. The IHI representative noted that for the US-APWR standard plant design planned to be built in the United States, Mitsubishi Heavy Industries (MHI) made its decision to procure Class 2 and 3 components manufactured in the United States to the ASME Code rather than to procure Class 2 and 3 components manufactured in Japan to the JSME Code for economic reasons. MHI found that it was less costly to procure the thousands of Class 2 and 3 components in the United States where the plant will be built instead of procuring the thousands of Class 2 and 3 components in Japan and having them shipped overseas.

In summary, it appears that while expanding the code-comparison effort to include Class 2 and 3 components would not be difficult, the SDOs and vendors are uncertain of its value. The CSWG agrees with the SDOs' approach and believes that the code-comparison effort should not be expanded to Class 2 and 3 components until the value of such an expansion becomes more apparent.

IV. What is "Harmonisation" of pressure-boundary codes?

Defining "Harmonisation" of Pressure-boundary Codes

At this time, the SDOs' code-comparison report is viewed by the CSWG as an interim result and the first major milestone of CSWG's goal to achieve harmonisation of code requirements. Based on the results of the code-comparison project, the CSWG members recognised the need to define several terms related to codes and standards such as "harmonisation," "convergence," and "reconciliation." Therefore, the CSWG has defined "harmonisation" as a product of "convergence" and "reconciliation." In other words:

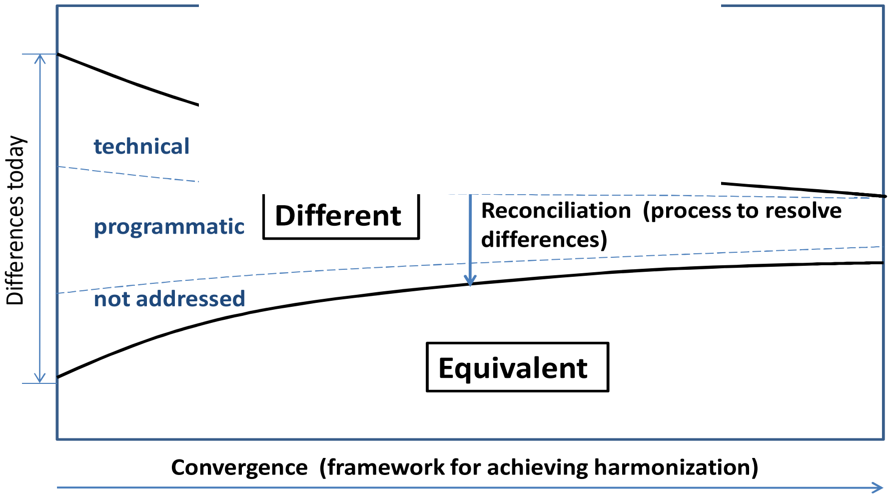
> **Harmonisation = Convergence + Reconciliation**, where:
>
> *"Harmonisation of codes"* means a process by which different countries can achieve convergence or reconciliation of differences in code requirements in order to ensure an acceptable level of quality and safety in nuclear power plants.
>
> *"Convergence"* means establishing the same or equivalent code requirements in order to reduce the areas identified as "different," and
>
> *"Reconciliation"* means to accept differences in code requirements by justifying their acceptability.

The key to achieving harmonisation is in understanding the differences in code requirements in order to assess their significance from the perspective of the overall quality and safety of the component.

The SDOs' code-comparison effort categorised the code comparison results into one of four categories: (1) same or equivalent requirements, (2) administrative or programmatic differences, (3) technical differences, and (4) requirements addressed in one code only. Convergence of code requirements is a long-term effort, and it is prudent to begin with easier code differences. However, the SDOs noted that it might not be feasible to converge on some code differences especially certain administrative or programmatic differences or differences that are addressed only in one code. The reasons for administrative or programmatic differences are usually attributable to different standard industry practices between countries, national policy or cultural factors. For these differences, it may be appropriate to establish a process for different countries to evaluate the overall acceptability of a program (e.g., quality assurance program) rather than to evaluate requirements on a line-by-line basis. For technical differences, it may be appropriate to allow a justification that the different code requirement provides an acceptable level of quality and safety. Similarly, for code requirements specified in only one code, the difference may be reconciled by documenting that the code requirement is addressed elsewhere (e.g., in a regulatory guide or design specification) or describing why the code requirement is unnecessary. Reconciliation of code differences in this manner can, thus, achieve harmonisation of codes without the need to converge on the different code requirements.

Figure 1 (below), “Harmonisation of Codes,” provides a diagrammatic model of the process for the harmonisation of pressure-boundary codes as discussed above.

Figure 1. Harmonisation of Codes



As depicted in the above model for pressure-boundary codes, “harmonisation” is a process involving a combination of convergence and reconciliation. The left side of the model diagram shows the results of an example code comparison in which many differences in code requirements exist today when comparing two pressure-boundary codes (e.g., RCC-M Code versus the ASME Code). These “Different” areas include *technical* differences, *programmatic* (or administrative) differences, and code requirements addressed in one code, but not another (“*not addressed*”). In code-comparisons with other codes, the left side might show fewer differences today (e.g., KEPIC versus the ASME Code). As one moves from left to right in the model, convergence of code requirements is achieved by establishing the same or equivalent code requirements in order to decrease the *different* code requirements (or to increase the areas identified as “Equivalent”). However, complete convergence might not be achievable, and, thus, the converging lines do not meet on the right side of the diagram.

The model also shows that complete convergence of the area of *technical* requirements might be achievable. However, complete convergence of the area in which requirements are addressed in one code (i.e., *not addressed*), but not the other is difficult to achieve because many of these code requirements are addressed in other industry or regulatory guidance documents. Changing non-mandatory guidance into a mandatory requirement (or vice versa) might be difficult to achieve or undesirable for some countries due to national policy or the need to allow flexibility in design implementation. The most difficult area of code differences to achieve convergence is the area identified above as "*programmatic*." The area of programmatic (or administrative) differences includes quality assurance, conformity assessment, welding, qualification of welders and equipment, non-destructive examination, and qualification of NDE personnel requirements. These programmatic requirements tend to be developed consistent with the standard industry practice applicable to a specific country. Some of these standard industry practices apply to national construction practices that go beyond the construction of nuclear power plants and would be extremely difficult to change. Other programmatic requirements were developed due to regulatory requirements or cultural factors. Consequently, the model above depicts the difficulty in achieving convergence in the "*programmatic*" area.

The model also depicts "*reconciliation*" as a process to resolve code differences. The ability to reconcile code differences recognises that certain different code requirements might be difficult to achieve convergence. Thus, the reconciliation of code differences is envisioned as a process that would evaluate the acceptability of code differences by technical code experts who understand the bases for code rules. The process would allow these differences to exist in harmony if the differences are evaluated to ensure that the different code requirement produces an acceptable level of quality and safety and can be substituted for the other with recognition of the need for any modifications or supplemental requirements, if necessary.

More importantly, the model shows that harmonisation of pressure-boundary codes can be achieved if one acknowledges that harmonisation is a continual process and not a final end product.

Perspectives of the CSWG on Achieving Harmonisation of Codes and Standards

The CSWG notes that many differences arose over time, in part, due to industry practices and regulatory policy. Large number of differences was especially evident in those codes that were based on an earlier version of the ASME Code. Those codes that were based on later versions of the ASME Code—or that continue to adopt subsequent ASME Code editions and addenda—were found to have only minor differences. Those codes that were developed independently from the ASME Code saw the most significant differences.

Furthermore, each country's standard industry practices for design and construction plays a large role in the development of each country's code requirements. Consequently, some code requirements for one country might not be applicable to nor appropriate for use in another country. Lastly, many other documents beyond the code itself, often plays an important role in the final component (e.g., other industry standards, regulatory guidance, and manufacturer's or owner's design specifications).

One of the most significant findings of the CSWG is that complete convergence of pressure-boundary codes on an international scale would be extremely difficult to achieve because of the vast differences in each country's design and construction practices, regulatory policies, cultural patterns, and the manner in which codes are adopted by regulatory agencies. Also, the information from the code-comparisons has shown that the code itself is only part of the overall component design, manufacturing and installation process. For example, in some countries, government regulations provide certain requirements that might be addressed in another country's code itself. In addition, a code might reference numerous industrial standards specific to that country (e.g., The French RCC-M Code references approximately 200 standards). In addition to meeting the requirements of the pressure-boundary code itself, the overall design, qualification, and construction process for a component involves meeting the requirements and guidance of other codes and standards that provide a comprehensive set of design, qualification, and construction requirements for producing a safe and quality component. Accordingly, the overall design, qualification, and construction process for a nuclear pressure-retaining component should also follow guidance provided in design and procurement specifications, regulatory guidance documents, standard national industry practices, and lessons learned from each country's operating experience. It would be nearly impossible to achieve complete code convergence (or to develop a single, harmonised international code) without reconciling all these other contributing factors.

Another factor in achieving harmonisation of codes is recognition of the fact that, as comprehensive as each pressure-boundary code is, each code does not fully address all aspects of a component design. For example, most pressure-boundary codes do not define the safety classification for safety-related components. Although codes provide rules for designing and constructing components to various safety classes (e.g., Code Classes 1, 2 and 3), most codes do not define how components are to be categorised into a safety class. JSME's code includes rules on component safety classification while ASME's and AFCEN's codes do not.

In addition, most codes do not address specific application of loadings to various service levels. For example, all codes contain a graded approach in establishing stress limits for components under design, transient and accident conditions (e.g., Service Levels A, B, C and D; or Design, Upset, Emergency and Faulted plant conditions), but few codes address which loadings shall be included for design, transient and accident conditions. Rather, these codes rely on the Owner's design specifications or regulatory guidance to specify which service condition each of these loading (or combination of loadings) are to be analysed.

The above two examples are important from a code-harmonisation perspective because harmonisation of codes will not necessarily ensure harmonisation of the entire design and construction process of a component. In other words, how a component is classified and how loadings and service limits are applied to a component also play an important role in the design and construction of a component, but is generally outside the scope of most codes. In some countries, the safety classification and application of loadings are addressed in regulatory guidance documents, design specifications or other industry standards. These examples also point out a need to ensure good communication between countries when harmonising code differences in order to understand each code's development and its philosophy. An unexpected benefit from the code-comparison effort was the fact that the code-comparison process resulted in the SDOs interacting and communicating with each other and, thus, becoming familiar with each other's code requirements, code organisations, and code philosophy. This type of interaction and communication is a central element to successfully reconciling technical and programmatic code differences if code harmonisation is to be successfully achieved.

V. How can harmonisation be achieved?

In the previous section, the CSWG noted that harmonisation of pressure-boundary codes and standards could be achieved through a process involving (1) convergence of code requirements, (2) reconciliation of different code requirements, and (3) minimising further divergence of code requirements amongst countries. The CSWG believes that harmonisation of pressure-boundary codes and standards will enhance the safety of standard nuclear power plant designs that might be licensed in multiple countries. However, establishing such a process for the harmonisation of pressure-boundary codes and standards is not a simple proposition. A new framework and additional resources will be needed from the international nuclear community in order to more fully delve into the technical differences among these codes and standards if harmonisation is to be further pursued and achieved.

The international nuclear industry recognised the benefits of standardisation and associated challenges in parallel with the MDEP activities. In addition to the safety benefits, the industry recognised that standard designs will reduce the overall engineering and construction time and cost compared to the non-standardised approach used in the past construction of nuclear power plants [Ref. 8]. Consequently, the World Nuclear Association (WNA) established its Working Group on Cooperation in Reactor Design Evaluation and Licensing (CORDEL Group) in January 2007 with the aim of promoting the achievement of a worldwide regulatory environment where internationally accepted standardised reactor designs can be widely deployed without major design changes. The CORDEL Group consists of members representing major vendors, interested utilities, service organisations and observers from other international organisations. As part of the step-wise integrated approach to harmonisation, the CORDEL Group proposed a plan for international acceptance of foreign codes and standards used in the design of nuclear power plants [Ref. 9]. One of CORDEL Group’s goals is to promote harmonisation of international pressure-boundary codes and standards; a goal similar to that of the CSWG’s long-term goal. The CORDEL Group established its Codes and Standards Task Force to pursue this specific goal.

The CSWG met with CORDEL’s Codes and Standards Task Force representatives several times to discuss its proposal for harmonising pressure-boundary codes and standards. At this time, CORDEL’s scope of code differences to be considered for convergence is still under development. The CORDEL task force is working with the SDOs to identify the most beneficial areas for code convergence that can reasonably be achieved. In the meantime, the SDOs are developing a framework and process for accomplishing convergence of code requirements, reconciliation of code differences, and controlling further code divergence. The CORDEL Group’s proposed pilot project and the SDOs’ proposed framework for pursuing harmonisation of pressure-boundary codes are discussed further below.

CORDEL’s Pilot Project for Convergence of Code Differences

Representatives of WNA’s CORDEL Group met with the CSWG to present information about its plans for achieving international standardisation of reactor designs. As part of its plan, the CORDEL Group identified an urgent need for the international harmonisation of codes and standards. The CORDEL Group is seeking to achieve international cooperation in design reviews, mutual acceptance of design approvals, and a long-term goal of international certifications of nuclear power plant designs. The Director of the CORDEL Group clarified that CORDEL is not designing an international standard nuclear power plant, but rather is developing a framework to enable a nuclear power plant design to be used in different countries. One of CORDEL’s goals is to promote harmonisation of codes and standards on an international basis—similar to the goals of the CSWG.

The CORDEL Group noted that for current new-reactor designs (i.e., GEN II and III reactors which include evolutionary and passive light-water reactor designs), achieving a convergence of codes is not feasible because the designs are already well established, although the CORDEL Group noted it might be possible for GEN IV plants (e.g., thermal reactors including high- and very-temperature reactors and fast reactors including sodium-cooled reactors). The CORDEL Group believed that harmonisation of codes and standards should be led by the industry. The CORDEL Group is supportive of the CSWG's long-term goals and the SDOs' code-comparison effort and proposed to take harmonisation to the next level by piloting a project to converge on selected code differences that have the most impact and are relatively easy to achieve. To this end, the CORDEL Group is hoping to unite the industry in this effort towards harmonising pressure-boundary codes and standards.

Based on the results of the SDOs' code-comparison, the CORDEL Group and the SDOs will select a few specific code rules where differences have the most significant industrial impact and convergence is relatively easy to achieve. The CORDEL Group has obtained independent technical experts to propose a "harmonised" version for the code requirements that are different in the current version or to demonstrate equivalence of these differences. The results of the technical experts' work will be discussed and will need to be approved by the SDOs through a framework and process to be established by CORDEL and the SDOs.

SDOs' Establishment of a Code-Convergence Board

The SDOs developed a plan for the establishment of a framework and process to evaluate code convergences and preclude further code divergences. The SDOs are planning to form an SDO Code-Convergence Board. This Board will consist of SDOs from several countries including France, Japan, Korea, Canada and the United States. Other countries may join later. The purpose of the Board is to pursue convergence of code requirements where realistic and practical. The SDO's Code-Convergence Board will collaborate with MDEP, CORDEL's Codes and Standards Task Force, and other stakeholders. The scope of the Board's review will initially address Class 1 mechanical components in light-water reactors with possible expansion to other reactor types as well as to other classes and components. The SDOs noted the benefit of using code cases to introduce alternative rules for allowing the use of provisions from foreign code and standards. The role of the Board is not to identify which rules it will consider for alternatives, but rather it will work with stakeholders, (e.g., CORDEL, vendors, licensees, regulators, etc.) to identify potential areas of convergence. The CORDEL Codes and Standards Task Force noted that it plans to survey nuclear vendors of their needs of potential candidate requirements for code convergence.

The Board will also limit further divergence of code requirements. It plans to establish protocols for communication, share code updates, share the basis for code changes, and create a centralised database and website. The establishment of such a Board would provide a path to allow the use of foreign codes and standards for pressure-boundary components. This would represent a significant step forward in achieving MDEP's goal of enhancing multi-national cooperation and harmonisation of codes and standards. However, such a project would need the support and mutual adoption by each country's regulatory body.

The SDO Code Convergence Board first met in August 2012 in order to administratively set up the board and prepare a plan to move toward selected objectives. The MDEP will continue to support the Code Convergence Board as necessary.

CSWG's Plans to Achieve Harmonisation of Nuclear Pressure-boundary Codes and Standards

Independent of the activities of the SDOs and CORDEL, the CSWG developed two documents that provide fundamental attributes and essential performance guidelines that should be addressed in all codes and standards for nuclear pressure-boundary components. The fundamental attributes document provides overarching requirements for designing and constructing pressure-boundary components in nuclear plants. They represent most basic and fundamental concepts to be considered in design, materials selection, fabrication, examination, testing and over-pressure protection requirements for pressure-boundary components. The fundamental attributes document was based on IAEA's Specific Safety Requirements SSR-2/1, "Safety of Nuclear Power Plant: Design." The CSWG supplemented the IAEA requirements with additional basic principles of design for nuclear pressure-boundary components to enhance its overall completeness. The CSWG issued its fundamental attributes document as MDEP Technical Report TR-CSWG-03, "Technical Report: Fundamental Attributes for the Design and Construction of Pressure-boundary Components." [Ref. 10]

The essential performance guidelines document provides qualitative performance descriptions of the rules and practices derived from nuclear pressure-boundary codes and standards that are described in codes and standards of MDEP member countries or in other referenced industry standards or regulatory documents. The document provides recommendations for essential performance guidelines that are common to the pressure-boundary codes and standards of MDEP countries and that should be included in all pressure-boundary codes and standards. The essential performance guidelines represent an equivalent safety-tier document to that of IAEA's safety guides. The CSWG views the essential performance guidelines as guidance that may be used for developing, modifying, or adopting pressure-boundary codes for nuclear power plants to ensure a complete scope of items to be addressed by the code or in other referenced industry standards. The CSWG issued its essential performance guidelines document as MDEP Technical Report TR-CSWG-04, "Technical Report: The Essential Performance Guidelines for the Design and Construction of Pressure Boundary Components." [Ref. 11]

The fundamental attributes and essential performance guidelines documents may be used for a variety of purposes. For example, they may be used for developing, modifying, or adopting pressure-boundary codes for nuclear power plants to ensure the scope of items to be addressed by the code or in other referenced industry standards is complete. They may be used as a baseline from which discussions on harmonisation can be started and further divergence of code requirements can be limited. They can also be used on an international basis when a regulatory body chooses to endorse a foreign code. Lastly, the fundamental attributes and essential performance guidelines documents can also be included in the IAEA safety standards, as appropriate.

The CSWG also developed a document that describes how each MDEP regulatory authority utilises nuclear pressure-boundary codes and standards in its country for safety reviews and licensing new reactors. The CSWG views this document to be useful to regulators, vendors and other stakeholders that wish to understand the regulatory practices applicable to the use of pressure-boundary codes and standards in each MDEP member country. The CSWG issued its regulatory practices documents as MDEP Technical Report TR-CSWG-01, "Technical Report: Regulatory Frameworks for the Use of Nuclear Pressure Boundary Codes and Standards in MDEP Countries." [Ref. 12]

Lastly, the CSWG identified several common positions amongst MDEP-member countries relative to the findings from the SDOs' comparisons of pressure-boundary codes and from lessons learned in its harmonisation efforts. These common positions are documented in MDEP Common Position CP-CSWG-01, "Common Position: Findings from Code Comparisons and

Establishment of a Global Framework towards Pressure-Boundary Component Harmonisation." [Ref. 13]

The CSWG's intent for developing the four documents described above is to provide information, guidance, and lessons learned that might be useful, or even necessary, for achieving harmonisation of codes and standards for pressure-boundary components in nuclear power plants on a global basis.

VI. Conclusions

The primary, long-term goal of MDEP's CSWG is to achieve international harmonisation of codes and standards for pressure-boundary components in nuclear power plants. The first step in achieving harmonisation is to understand the extent of similarities and differences amongst the pressure-boundary codes and standards used in various countries. Accordingly, several standards developing organisations (SDOs) from various countries performed a comparison of their pressure-boundary codes and standards to identify the extent of similarities and differences in code requirements and the reasons for their differences. In reviewing the results of the SDO's code-comparison effort, the CSWG found that the similarities and differences between each county's code and standard varied considerably amongst different countries. Some country's code or standard was almost identical to another country's code or standard in technical areas while another country's code or standard contained vastly different technical requirements. Regardless of the similarities and differences, the CSWG found that each pressure-boundary code produces a safe component design. It should be also recognised that code-compliance in component design is just one aspect of the entire component design and construction process. In addition, there are also philosophical and cultural factors involved that play an important role in the overall quality of the design and construction of a pressure-boundary component. The implementation of code requirements alone does not always provide a true representation of the component's quality and safety without consideration of these philosophical and cultural factors.

The efforts to date by the SDOs, WNA/CORDEL and the CSWG have resulted in major progress towards harmonisation of pressure-boundary codes and standards. Harmonisation is a long-term goal that can be achieved only through the combined efforts of SDOs, vendors and other nuclear industry groups and stakeholders. The SDOs' code-comparison project has shown that international code organisations can work together in a cooperative venture to bridge lines of technical communication and to understand each other's code organisation, code philosophy and code differences. This cooperation and communication can play a major role in ensuring that one country's code can be used safely in another country.

The CSWG concludes that each country's pressure-boundary code produces components of high quality when the code is used in conjunction with its country's standard industry practice, is supplemented with industry guidance and regulatory requirements, and is implemented in a manner consistent with its cultural and philosophical factors. Furthermore, the CSWG concludes that harmonisation of pressure-boundary codes is a long-term goal that will require the cooperation and coordination of SDOs, nuclear industry (e.g., vendors, designers, manufacturers, and nuclear power plant owners) and regulators on an international scale. Harmonisation is achievable if one acknowledges that harmonisation of code requirements is a continual process – not an end product unto itself.

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