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TRAINING COURSES ON ASME PRESSURE VESSEL CODE FOR NUCLEAR TRANSPORT AND STORAGE AND QUALITY ASSURANCE FOR RADIOACTIVE MATERIAL PACKAGING

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ABSTRACT

The U.S. Department of Energy (DOE)'s Packaging Certification Program has sponsored a suite of training courses conducted by Argonne National Laboratory since 2015. Two of these week-long courses are: (1) ASME Pressure Vessel Code for Nuclear Transport and Storage, and (2) Quality Assurance for Radioactive Material Packaging. The purpose of the ASME Code course is to provide guidance for the application of the ASME Boiler and Pressure Vessel Code to transportation packaging and storage casks of radioactive materials, including spent nuclear fuel and high-level waste, and the purpose of the Quality Assurance (QA) course is to help participants gain a working knowledge of the QA principles and methods for satisfying the regulatory requirements for packaging and casks. Both courses cover federal regulations 10 CFR Parts 71 and 72, which govern transportation packaging and storage casks, along with relevant DOE Orders and U.S. Nuclear Regulatory Commission guidance documents. The ASME Code course describes the ASME Code requirements as well as application of the code requirements to material, design, fabrication, welding, examination, testing, QA, aging management, and inspection and monitoring technologies. The QA course emphasizes the ASME NQA-1 requirements for organization, QA program, design control, inspection, test control, and corrective action, among others, and discusses the graded approach used to establish the QA requirements for components important to safety, commercial-grade dedication, and software QA. This paper provides summary descriptions of the two courses and updates of lessons learned from two recent QA courses, given in 2022 and 2023, and their application to future DOE training courses conducted by Argonne National Laboratory.

INTRODUCTION

As part of its Packaging University Program, the U.S. Department of Energy (DOE)'s Packaging Certification Program (PCP), under the auspices of the Office of Packaging and Transportation within the Office of Environmental Management, has sponsored a suite of training courses conducted by Argonne National Laboratory (Argonne) since 2015. Two of these training courses are (1) ASME Pressure Vessel Code for Nuclear Transport and Storage and (2) Quality Assurance for Radioactive Material Packaging. Argonne began offering the packaging Quality Assurance (QA) training course in the early 1990s and the ASME Code course in 2000, covering only transportation packaging for fissile and Type B radioactive materials (RAM). After 2009, the courses were

expanded to include dry cask storage systems for spent nuclear fuel (SNF) and high-level waste (HLW). The history and evolution of these two courses can be found in References [1] and [2]; they will not be repeated here. Because of COVID-19, Argonne suspended all training courses in 2020 and 2021. A hybrid QA training course was held at Argonne in March 2022, and an in-person QA course was held onsite in March 2023. The following sections provide brief descriptions of the ASME Code and QA courses and updates of lessons learned from the two recent QA courses, which will be applied to the ASME Code course to be convened in person at Argonne in September 2023.

ASME PRESSURE VESSEL CODE FOR NUCLEAR TRANSPORT AND STORAGE

Transportation packaging of Type B radioactive and fissile materials must maintain its primary safety functions of containment of radioactivity, shielding for radiation protection, and nuclear subcriticality during normal conditions of transport and hypothetical accident conditions as prescribed in Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Material* (2014). Dry cask storage systems containing SNF are required to prevent release of RAM, prevent excessive external radiation levels, dissipate heat by passive cooling, maintain subcriticality, and provide for ready retrieval of SNF assemblies when necessary, as stipulated in Title 10, Code of Federal Regulations, Part 72 (10 CFR 72), *Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste* (2014). 10 CFR 71 and 10 CFR 72 do not, however, establish design standards and acceptance criteria that can be used for the design and evaluation of the structural integrity of transportation packaging and storage casks for RAM and SNF/HLW.

The ASME Boiler and Pressure Vessel Code (ASME Code) establishes rules of safety for the design, fabrication, examination, and testing of boilers, pressure vessels, nuclear power plant components, and transportation packaging and storage casks for RAM and SNF/HLW. It is a preeminent pressure vessel code that is accepted in the United States and by many other countries around the world. For specific application to packaging and casks used for transportation and storage, the ASME Code is acceptable to the U.S. Nuclear Regulatory Commission (NRC) and DOE with respect to material selection, design, welding, examination, and inspection. NRC and DOE initially recommended the use of Section III, Division 1 of the Code for RAM transportation packaging in 1978, because it was the only available authoritative guidance for structures and components that are similar to nuclear power plant components. Since then, Code Section III, Division 3 has been developed specifically for RAM containment systems for packaging and casks, and is referenced in the Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities - Final Report (NUREG-2215), April 2020; the Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material: Final Report (NUREG-2216), August 2020; and the DOE Packaging Review Guide for reviewing radioactive material transportation Safety Analysis Reports for Packages [3].

Depending on the level of radioactivity of the contents being transported in the packaging and the safety function of the packaging's components, different ASME Code Sections, Divisions and Subsections are used for the design and fabrication of metal containments for the packaging and casks. Table 1 shows the selection of applicable ASME Code Sections based on Component Safety Groups. For Category I containment, Section III, Division 1, Subsection NB contains rules for the design of nuclear power plant components, whereas Division 3, Subsections WB and WC contain rules for the design of containment systems for transportation and storage, respectively, of spent fuel and HLW. Portions of the ASME Code Section III that use a "*design-by-analysis*" approach for Class 1 components have been adapted in the NRC Regulatory Guide (RG) 7.6, Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels, Revision 1, March 1978, as acceptable design criteria for transportation packaging and shipping cask containment vessels. The design criteria for normal transport conditions, as defined in 10 CFR 71, are similar to the criteria for Level A Service Limits in Section III of the ASME Code. The design criteria for off-normal (storage only) conditions are similar to those for Level C Service Limits, and the design criteria for accident conditions are similar to those for Level D Service Limits in Section III of the ASME Code.

Table 1 Selection of Applicable ASME Code Sections Based on Component Safety Groups [1]

Increasing Radioactivity →

Component Safety Group	Container Contents		
	Category III	Category II	Category I
Containment	Section VIII, Division 1	Section III, Division 1, Subsection ND	Section III, Division 1, Subsection NB, or Division 3, Subsection WB/WC
Criticality	Section III, Division 1, Subsection NG		
Other Safety	Section VIII, Division 1, or Section III, Division 1, Subsection NF		

Course Description and Objective

The objective of the ASME Code course is to help participants gain an understanding of the regulatory basis, current design practice, and engineering rationale for applying the ASME Code to transportation packaging of RAM and fissile material and storage casks of SNF/HLW. The course consists of technical presentations, in-class discussions, exercises, examples, tours and a final exam. Figure 1 shows the design flowchart of the course; a list of the highlights follows.

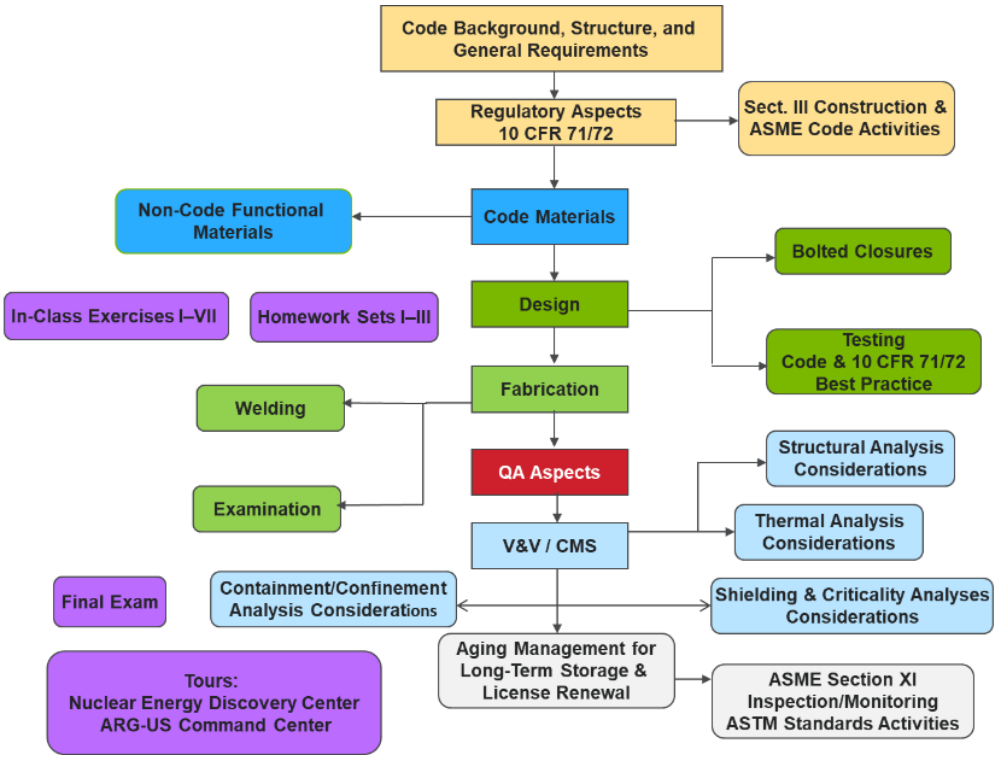

Figure 1. Design Flowchart of the ASME Code Course

- Overview of federal regulations that govern packaging and transportation of radioactive material and dry cask storage systems for SNF.
- DOE Orders and NRC guidance documents, including standard review plans, RGs, and NUREG reports.
- DOE/NRC lessons learned from certifying transportation packages and licensing dry cask storage systems.
- Discussion of the ASME Code, with emphasis on Section III, Division 3, and discussion of Section III, Division 1; Section VIII, Division 1; and Sections II, IX, and XI.
- Code and non-Code materials, containment loadings, design considerations with emphasis on design-by-analysis rules, design of internal support structures, and buckling analysis.
- Fabrication, welding, examination, QA, test requirements, design qualification by physical testing, and containment/confinement requirements for leakage rates.

- Structural, thermal, containment/confinement; shielding and criticality safety analysis considerations.
- Aging management programs and time-limited aging analyses.
- Inspection and monitoring technologies.

Aging management for structure, system, and components in transportation packaging and dry cask storage systems is a major topic of interest, as are inspection, monitoring, mitigation, and repair. Progress and selected examples and case studies on these topics can be found in References [4] and [5].

QUALITY ASSURANCE FOR RADIOACTIVE MATERIAL PACKAGING

Personnel working on the design, fabrication, evaluation, certification, use, and maintenance of Type B radioactive and fissile material transportation packaging and SNF dry cask storage systems need to have a working knowledge of, and familiarity with, the specific QA requirements in Subpart H and Subpart G of 10 CFR 71 and 10 CFR 72, respectively. NRC has issued RG 7.10, Establishing Quality Assurance Programs for Packaging Used in Transport of Radioactive Material, Revision 3, 2015, which establishes QA programs for packaging used in transport of RAM, whereas DOE Order 460.1D, *Packaging and Transportation Safety*, contains specific QA requirements that satisfy Subpart H of 10 CFR 71.

The purpose of the QA training course is to help participants gain a working knowledge of the QA principles and methods for satisfying those regulatory safety requirements for packaging and casks used in the transportation and storage of RAM and SNF/HLW. Issues that are addressed in the course include methods for not only satisfying the QA requirements of Subparts H and G, but also applying the graded approach to QA for packaging elements, and satisfying a recently promulgated requirement that each DOE entity subject to DOE Order 460.1D "*that participates in the design, fabrication, procurement, use or maintenance of a hazardous materials packaging must have a QA Program approved and audited by the Headquarters Certifying Official (HCO) that satisfies the requirements of 10 CFR 71, Subpart H, Quality Assurance for certified Type B and fissile radioactive material packagings*." The course highlights the applicable QA requirements from relevant DOE Orders, federal regulations, and NRC RGs; discusses the application of ASME NQA-1 (see bveow) to Type B and fissile material packaging; and elaborates on issues resulting from the differences in emphasis between a compliance-based QA program (in Subpart H, 10 CFR 71) for packaging and a performance-based QA program for DOE nuclear facilities (based on 10 CFR 830, "Nuclear Safety Management"), and from the final rule changes in 10 CFR 71 that became effective on October 1, 2004.

Course Description and Objectives

U.S. Department of Transportation (DOT) Regulation 49 CFR 173.7(d) states that the DOE can certify Type B and fissile material packagings if they are evaluated against packaging standards equivalent to those in 10 CFR 71. DOE Order 460.1D requires that an application for a fissile or Type B package certification must include a safety analysis report for packaging (SARP), which is the basis for demonstrating that the package design and the packaging procured or fabricated to that design conform with the requirements of 10 CFR Part 71, Subparts E, F, G, and H, and any other applicable standards that the Assistant Secretary for Environmental Management or a Secretarial Officer/Deputy Administrator in the National Nuclear Security Administration may determine applicable for granting a certificate.

Subpart H of 10 CFR 71 describes the QA requirements that a compliance-based QA program for packaging that must satisfy. The key characteristics of the QA program are that it is process-oriented and requires independent verification and documentation of the planned actions. The QA program must be based on 18 QA criteria set forth in Subpart H, and must provide requirements for the design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, testing, operation,

maintenance, repair, and modification of packaging components that are important to safety (ITS). For package designs reviewed and certified by DOE, the SARP must contain a Chapter 9, which addresses packaging-specific QA requirements.

Figure 2 is a flowchart depicting the topics covered in the QA training course. The course begins with a discussion of basic QA principles and concepts, regulatory aspects, DOE orders and compliance versus performance, the role of QA in the safety and performance of transportation packaging, and the relationship between QA and the development of the ASME Code. The course also provides a specific discussion of the 10 CFR 71 Subpart H and 10 CFR 72 Subpart G QA program requirements and inspections, followed by information on (a) DOE's QA approval program and QA audits, (b) packaging QA related to commercial-grade dedication (see below), and (c) a general description of ASME NQA-1. Applications of QA for design control; software development; maintenance and use; and welding are also discussed, as is the use of the graded approach in QA. The course emphasizes the importance of integration of QA into all aspects of the life cycle of RAM transportation packaging and SNF storage casks, including design, procurement, fabrication, testing, use, maintenance, and decommissioning. Like the ASME Code course conducted by Argonne, the QA course is also a classroom course and consists of technical presentations, in-class discussions, exercises, examples, tours and a final exam. Some selected key topical elements of the course are described further below.

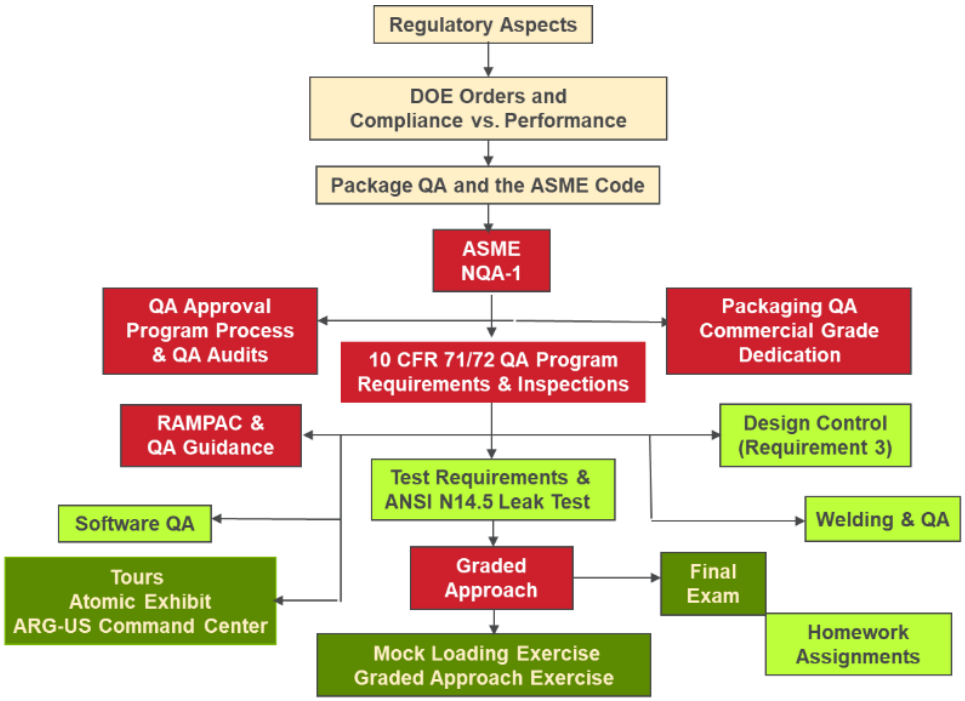

Figure 2. Design Flowchart of the Packaging QA Course

Compliance-based QA Approach

Subpart H of 10 CFR 71 and Subpart G of 10 CFR 72 describe QA requirements that a compliance-based QA program for packaging must satisfy. The key characteristics of the QA program are that it is process-oriented and requires independent verification and documentation of the planned actions. The QA program must be based on 18 QA criteria set forth in Subparts H and G, and provides requirements for design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, testing, operation, maintenance, repair, and modification of components of packaging that are important to safety. A compliance-based QA system is a system that satisfies all requirements in a multitude of processes, e.g., design control, welding, and nondestructive examination; whereas a performance-based QA system is a system that achieves overall results and objectives, e.g., a leak-tight shipping container. DOE applies a performance-based system of QA programs to its facilities, while DOT in 49 CFR 173.7 requires that DOE transportation activities relating to Type B and fissile

material packages comply with 10 CFR 71, and that QA follow the compliance-based QA system specified in Subpart H. The QA course selects two major elements, design control and QA program, for in-depth discussion and illustration of how to effectively apply the requirements of NQA-1 in concert with the 18-point criteria of Subparts H and G and provides guidance to address the gap between a 10-criteria QA program and the required 18-criteria QA program.

ASME NQA-1 Requirements

The ASME NQA-1-2008 Quality Assurance Requirements for Nuclear Facility Applications satisfies the QA requirements specified in 10 CFR 71, Subpart H, and 10 CFR 72, Subpart G. The ASME NQA-1 standard represents a unified QA standard; it includes 18 requirements and describes essential features of each requirement. The 18 requirements in ASME NQA-1 are fully consistent with the 18-point QA criteria of Subpart H of 10 CFR 71 and Subpart G of 10 CFR 72. Organizations that invoke this standard can specify the extent of the requirements to be used; for example, designer and user generally do not follow the same set of requirements. The QA course covers topics of the regulatory basis, guidance, and application of the requirements of NQA-1 to satisfy the regulatory requirements.

Graded Approach in QA

In applying 10 CFR 71.101(b) and 10 CFR 72.140(b), the licensee, certificate holder, and/or applicant for a Certificate of Compliance is required to apply each of the applicable criteria for each component of a packaging, following a graded approach to the extent that the approach is consistent with each component's importance to safety. The training course provides a method for application of the graded approach for QA requirements, using guidance in NUREG/CR-6407 (Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety) as to whether a packaging component or related activity is to be classified in quality category A, B, or C, with decreasing level of importance to safety.

Commercial-Grade Dedication

Commercial-grade dedication is the acceptance process through which a commercial-grade item can be designated for use as a basic component that will perform its intended safety function and, in this respect, is deemed equivalent to an item designed and manufactured under a QA program, e.g., 10 CFR 71 Subpart H and 10 CFR 72 Subpart G, with reasonable assurance. This assurance is achieved by identifying the critical characteristics of the item and verifying their acceptability by inspections, tests, or analyses by the purchaser or third-party dedicated entity.

CURRENT STATUS OF THE TWO COURSES AND LESSONS LEARNED

As mentioned before, Argonne suspended all training courses in 2020 and 2021 because of COVID-19. In March 2022, Argonne conducted the QA course onsite in a hybrid environment. In March 2023, Argonne conducted the QA course onsite with 22 students attending in person. The ASME Code course was last held in June 2019, and will be offered in September 2023 as planned. The following updates of the QA and the ASME Code courses include lessons learned from the two recent QA courses in 2022 and 2023 that will be applied to the ASME Code course in September 2023.

One common improvement suggested by past participants in these two courses is to allow more time for Q&A and discussion. Other suggestions included providing additional real-life examples and more time for in-class exercises and discussion. Using the participants' feedback and suggestions, the two courses were re-designed to allow more time for discussions and in-class exercises, to give more real-life examples to enhance class interactions, and to include additional topics, such as extended long-term storage of SNF and HLW, vacuum drying of SNF, hydride reorientation and embrittlement of high-burnup fuel cladding, aging management for extended long-term storage, and monitoring and inspection of packaging and casks during long-term storage. Other course enhancements included improved individual and group exercises, homework problems, new

teaching tools, and exams. The 2023 QA training course also incorporated a new lecture on NQA-1 Lead Auditor Training and Certification. The training courses are brought up to date each time they are offered, for example, by updating the NRC regulatory framework documents on standard review plans (NUREG-2215, NUREG-2216) and Managing Aging Processes in Storage (MAPS) Report: Final Report (NUREG-2214).

Poll-everywhere, an audience survey and response system, was used in the 2023 QA course and greatly enhanced classroom interactions between lecturers and students. Polling questions are designed and embedded in PowerPoint presentations to elicit class response in real time, using their own electronic devices, cell phone, tablet, or laptop. The aggregated class response led to discussions that benefited everyone in the class; the survey results at the beginning and end of the QA course also provided metrics on achievement of the learning objective of the course. For example, the exit survey asked 10 questions, and most of the class reported significant or good increases of knowledge on QA for RAM transportation packaging and SNF dry storage casks; found course materials extremely or very useful; and will definitively or probably recommend the course to others.

SUMMARY AND CONCLUSION

Two DOE PCP-sponsored training courses, the ASME Pressure Vessel Code for Nuclear Transport and Storage, and Quality Assurance for Radioactive Material Packaging, have been developed by Argonne National Laboratory as part of DOE's Packaging University Program (https://rampac.energy.gov/home/education/packaging-university). The ASME course was last held in June 2019 and the QA course was most recently convened at Argonne in March 2023 and attended by 22 students from U.S. government agencies, national labs, industry, and Canada. Class surveys conducted at the beginning and end of the course indicated that the course had met its objectives and that each participant would recommend the course to others who might benefit from the future offerings. The training courses will be brought up to date and will continue to be offered by Argonne National Laboratory, which is located in a suburb of Chicago, Illinois.

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This paper was updated by Zenghu Han and Yung Liu in honor of Ronald Pope, who passed away on March 24, 2023, just before the start of the QA training course on March 27–31, 2023. Mr. Pope played a seminal role in the development of the Packaging QA and the ASME Code training courses at Argonne, and he made numerous contributions to the packaging community worldwide over the 64 years of his professional career.

REFERENCES

1. Zenghu Han, R. B. Pope, Y. Y. Liu, and J. M. Shuler, "ASME Pressure Vessel Code for Nuclear Transport and Storage," 19th International Symposium on The Packaging and Transportation of Radioactive Materials, August 4–9, 2019, New Orleans, LA, US.
2. Zenghu Han, R. B. Pope, Y. Y. Liu, And J. M. Shuler, "Quality Assurance for Radioactive Material Packaging," 19th International Symposium on The Packaging and Transportation of Radioactive Materials, August 4–9, 2019, New Orleans, LA, US.

3. DOE Packaging Certification Program, Packaging Review Guide for Reviewing Radioactive Material Transportation Safety Analysis Reports for Packages, LLNL-TR-815389, Revision 4, August 9, 2021.
4. Y. Y. Liu and J. M. Shuler, “Aging Management of Radioactive Material Packaging and Dry Storage Systems,” 20th International Symposium on The Packaging and Transportation of Radioactive Materials, PATRAM 2022, June 11–15, 2023, Juan-les-Pins, France.
5. Y. Y. Liu and H. Takeda, “Gas Leakage Detection from Canisters Containing Spent Nuclear Fuel,” 20th International Symposium on The Packaging and Transportation of Radioactive Materials, PATRAM 2022, June 11–15, 2023, Juan-les-Pins, France.