Progress Toward NuPack, the ASME Code for Type-B Containments*

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INTRODUCTION

Within the framework of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, (ASME B&PVC) (ASME 1992) an effort has been under way since 1978 to codify a set of rules for "construction" of casks for spent fuel and for radiologically similar materials referred to as high-level waste. In ASME Code usage, the term "construction" covers materials, design, fabrication, examination, testing, and documentation. Casks are the containment and pressure vessels that are used when radioactive materials are transported. Of the various component types covered by the ASME Code, the reactor vessel of a nuclear power plant is the component that is closest to such casks in structural characteristics and design service as well as in importance to safety. Therefore, the rules for reactor vessels appeared to be a good starting point for developing rules for casks, and ASME B&PVC Section III, Division 1, Class 1 (that is Subsection NB) was selected in 1978 as the basis for nuclear packaging (NuPack) rules. Eventually, the ASME Board of Nuclear Codes and Standards decided to give NuPack its own Division designation. This decision led to a three-way split of Section III into Division 1 for metal construction, Division 2 for concrete construction, and Division 3 for transportation packaging. The new paragraph designator for packaging containments, corresponding to the NB designator for Nuclear "Class I" Containments, is WB. A general requirements subsection, corresponding to NCA, is also included, with the designator WA. At present, the exact title and precise scope of the NuPack subcommittee and of Division 3 of the Code have not been definitively established.

The basic ground rules followed in the development of NuPack were that (1) the new provisions would reflect current practice as accepted by regulatory authorities, and (2) the present ASME Code provisions would be followed where possible. The first premise meant that the requirements for containment vessel design currently imposed by the U.S. Nuclear Regulatory Commission (NRC) and by the U.S. Department of Energy (DOE) would be followed. The second premise results in wording that is identical to the wording in the corresponding paragraphs of the ASME Code Subsection NB or NCA when the same topics are addressed and the same rules are to be applied. Even the same paragraph

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numbering is retained wherever possible. Except for a few specific instances that will be described later, these two ground rules did not lead to any conflicts because the NRC recommends the general approach of ASME NB through its Regulatory Guide 7.6 (NRC 1978). It also follows that the NuPack Subcommittee has not attempted to write a code that would advance the state of the art of transportation packaging with respect to analytical methods, design criteria, materials of construction, or other aspects.

The rationale for imposing a set of rules for transportation casks that is as conservative as the rules used for the design of reactor vessels has frequently been questioned. The service requirements for casks as containment vessels would appear to be much less severe than the service requirements for reactor vessels. After all, the events taking place inside the casks are not dynamic, or highly energetic, and are well defined and totally predictable. However, it must be recognized that a reactor vessel is always under the control of a trained team of operators, is enclosed in another environment (the containment building that is highly engineered for safety) and is located on a site that is controlled and protected against public access. On the other hand, a cask traveling down the highway is in an uncontrolled and unpredictable environment and is the only barrier between the radioactive material and the public, a public that shares the roadway and that generally is not even aware of the cask's presence. In this context, the cask is considered in the same class of "importance to safety" (Class 1 in ASME Section III terminology) as a reactor vessel.

The current status of NuPack Code development is that a final mark-up was generated during the ASME Boiler Code Week meetings in September of 1995 and a final typed version is about to be distributed to subcommittee members for final review. Actually, all subcommittees that must vote on this work have already done so and have approved the version that existed at the time of each vote; however, not all negative ballots have been addressed and there may be some final reballoting as a revised final version is released and reviewed.

SCOPE OF NUPACK

At present, the exact title and precise scope of the NuPack Subcommittee and of Division 3 of the ASME Code have not been definitively established. The NuPack Subcommittee generally uses the name "Subgroup on Containment Systems for Spent Fuel and High Level Waste Transport Packaging." However, this language has not been incorporated into a scope statement of ASME Section III Division 3. This is not necessarily a deficiency because the general approach in ASME Section III, e.g., with respect to "Class 1" components, is that it is up to some authority other than the ASME to determine which rules apply. ASME merely establishes, for each class, *consistent* rules that presumably result in a uniform and consistent level of safety for components constructed under the rules of any particular class. At this time, Division 3 does not define what constitutes spent fuel or high-level waste.

A proposal has been advanced that would apply these rules to all Type B packagings. This would be more restrictive than current practice. Another proposal is that Division 3 rules be applied to packagings for "Category I" contents as defined by current NRC and DOE usage. Under both IAEA and U.S. regulations, transportation contents are classified according to the total amount of radioactive material, as measured using the "A" value of the material. Any quantity that exceeds, in curies, the "A" value of the material is defined as a Type B quantity, and its shipment requires the use of Type B packaging. Current NRC and DOE practice subdivides the Type B classification into three subclassifications, defined as Categories I, II, and III. These categories are used in various documents, most notably NRC Regulatory Guide 7.11 (NRC 1991). They are not to be confused with the three Categories, established in Annex 1 to NRC Regulatory Guide 7.10 (NRC 1986), which relate to the relative safety significance of items that make up the packaging rather than to the packaging contents.

Another option for the definition of the scope of packagings to which ASME Section III Division 3 is to be applied would be to use the safety class concept already in place in ASME Section III Division 1, where the rules for three classes of safety are defined as rules for Class 1, Class 2, and Class 3. Thus, rather than using a Category I definition, a "Class 1" definition could be applied. This definition could then be consistent with the definition of spent fuel and high-level waste, which may or may not be the same as the currently used special definition of "Category I" found in NRC Regulatory Guide 7.11 and in other regulatory guidance documents.

There is interest within the ASME NuPack community in expanding the scope of the rules to other applications, in several directions. The first would be to cover a wider range of contents, to address all radioactive materials, not just spent fuel and equivalent very high-level radioactive materials. This is certainly possible within the established ASME Code structure of addressing various levels of importance to safety, as is now done by the established Section III Classes 1, 2, and 3. The second direction of proposed expansion is to address a wider range of packaging components, not just the containment vessel. The third is to consider packaging applications other than just transportation, in particular, packaging for long-term storage and for multipurpose use as for transportation and storage.

GENERAL PROVISIONS

Division 3, the NuPack Division of ASME Section III, is different from Division 1 with respect to the parties that are addressed in the various Code rules. The overall responsibility for Code compliance in Division 1 rests with the Owner of the nuclear facility, while fabrication and stamping responsibility rests with the N Certificate Holder. The responsibilities in Division 3 are necessarily different because overall responsibility cannot be focused on a unique owner for a packaging. Typically, packagings of a particular design are owned by one or more organizations while "ownership" or responsibility for the design can rest with one of these or with some other organization.

The NuPack Subcommittee dealt with this difference by defining two "owner" parties, the design owner and the packaging owner. Each has distinct responsibilities and is required to hold a special ASME "Certificate of Accreditation." Earlier versions of NuPack Division rules (those drafted before approximately 1992) provided for four responsible parties, defining a separate Designer in addition to the Design Owner. This reflected the typical arrangement of parties in a cask development project. However, after review by the ASME Section III Main Committee, the Designer was eliminated as a separately addressed party, and its responsibilities were assigned to the Design Owner. There were two reasons for this change: the first, was that it was recognized that the design responsibilities could flow through the Design Owner; and the second, that the responsibilities for the inevitable changes to the packaging after it was in service for some time would have had to remain with the Designer, yet it was recognized that the Designer would not necessarily continue to exist as an accessible entity for the same period of time that the packagings of a particular design remained in service. Hence, it was recognized that the design responsibilities had to be placed on the Design Owner.

In terms of current conventional practice in the United States, the Design Owner is the "applicant," that is, the entity that will submit the packaging design to the certifying agency, be it NRC or DOE. The actual designer may be the same entity or an agent or consultant for that entity. As noted, the Design Owner takes responsibility for subsequent changes and for the process of getting revisions to the Certificate of Compliance as needed.

The Packaging Owner, rather than the Design Owner, is responsible for selecting the fabricator and controlling the fabrication process. This includes producing a written agreement with an Authorized Inspection Agency. The fabricator is referred to as the "Class TP Certificate Holder" and is required to have an "N-Type" Certificate of Authorization. There is no infrastructure in place yet for producing the various new certificastions mandated by ASME Division 3, such as (a) the ASME Certificates of Accreditation for the Deign Owner (Applicant) and for the Packaging Owner, (b) the certification of an ASME Authorized Inspection Agency for packaging, and (c) for issuing an ASME N-Type Certificate of Authorization to a Class TP (Transportation Packaging) fabricator.

NEW DOCUMENTATION REQUIREMENTS

All three parties mentioned in Division 3 must have a documented Quality Assurance Program and the applicable ASME Certificate.

The Design Owner (Applicant in packaging terminology) is responsible for three major documents: the Design Specification, the Design Report, and the Certificate of Compliance. Division 3 specifically requires that both the Design Specification and the Design Report be certified by a Professional Engineer (P.E.). In addition, the Design Report must receive an independent review, and under the current wording in Division 3, this independent review is to take place *after* the P.E. Certification so that it cannot be part of the P.E. Certification process. The issue for the packaging community to resolve is how these documentation requirements, in particular for the Design Report and possibly for the Design Specification, correlate with the familiar requirements for a Safety Analysis Report for Packaging (SARP). It appears that for many packagings certified under current review procedures, the SARP contains all of the information that would be required for a Design Report and, in some cases, also the information for a Design Specification.

Additional documents are called out in connection with the fabrication of the packaging. The prospective Packaging Owner is responsible for a Construction Specification that must be certified by a P.E. The Class TP Certificate Holder, that is the fabricator, is responsible for Construction Procedures, Shop Drawings, and a Construction Report. In addition, the fabricator must produce a Certified Data Report. Current Division 3 wording regarding Code Stamping of the final packaging containment is vague. NuPack committee deliberations would suggest that Code Stamping of Cask containment vessels is expected, but the actual wording regarding this issue is not clear.

Current Division 3 wording also states that the Design Specification must specify a Code effectivity date which must be no earlier than 1 year before the date of filing of the Application for the Certificate of Compliance. This is a rather severe requirement because the filing for the Certificate of Compliance can be the culmination of a multiyear design effort, *initiated* by the writing of the Design Specification and *ended* by this filing. The corresponding time period in Division 1 is set at 3 years. There is, however, some allowance for materials produced to a different specification date, provided they satisfy the requirements of the same specification that would apply for the Design Specification Code effectivity date.

SPECIFIED LOADING CATEGORIES

The ASME Code, in Section III Division 1 Subsection NCA and NB, establishes a system of loading classifications and provides design rules based on these classifications. It provides for a design load class, service load classes, and test load classes. There are four service loading levels, A through D, to which the service loadings can be assigned, depending on the service and safety requirements for these loadings, as determined by the Owner and specified in the Design Specification. The ASME Code itself does not assign the service levels. The Code also defines the design loading classification, essentially on the basis of Level A service conditions and other loadings that the Design Specification includes in this classification. In addition, the code provides for a hydrotest loading classification and other loading classifications.

The Division 3 (NuPack) rules limit the loading classifications to only two "service" levels: normal operating conditions service corresponding to the Division 1 Level A service, and the hypothetical accident condition level corresponding to the Division 1 Level D service. In addition, a test service level is defined to control the hydrostatic test loadings. The concept of a defined set of nominal design loadings, as used in Division 1, is not used in Division 3. The normal operating condition loadings include both the normal conditions of transport referred to in transportation packaging regulations and the in-plant handling conditions. As is the current packaging practice, the Maximum Normal Operating Pressure (MNOP) is defined as the maximum pressure that can develop in the cask during the period of 1 year.

There has been some discussion as to whether the normal conditions of transport loadings correspond properly to Level A Service or Level B Service loadings. The argument advanced is that the 1-, 2-, or 4-foot drop (depending on package weight) is not a routinely occurring event but rather the consequence of an upset and hence should be looked upon as a Level B condition. However, as currently written, Division 3 treats the normal conditions of transport loadings as Level A Service loadings.

ALLOWABLE STRESSES

The allowable stress limits in Division 1 for Level A Service are not significantly more restrictive than those for Level B Service. The difference is that Level A Service loadings are used to define the design pressure and temperature envelop, whereas the Level B Service loadings are not. The stress limits adopted in Division 3 for normal conditions of transport loadings are the lower of the limits in effect for Division 1 Level A Service loadings and the Design loadings. So the normal conditions stress "hopper diagram" in Division 3 is quite different from that for Level A Service loadings in Division 1. The difference is a result of creating an envelope of the Division 1 Level A Service limits and the Division 1 Design limits in producing the Division 3 normal conditions limits.

In applying the basic Level D Service stress limits to the hypothetical accident stress limits, the NuPack Committee incorporated one minor change in that Division 3 limits the primary-plus-bending stress to 1.00 times the ultimate stress, whereas Division 1 allows 150% of 0.7, which amounts to 1.05 times the ultimate. However, it should be noted that there is a major difference between the treatment of hypothetical accident loadings in Division 3 and Level D Service loadings in Division 1, namely, that Division 3 rules do not take advantage of the provisions in Division 1 for plastic system analysis, as provided in ASME Section III Division 1 Appendix F, paragraph F-1340. The primary rationale put forth for not incorporating these provisions is that in packaging, containment is generally provided by contact seals, which may be very sensitive to slight deformations, whereas for Division 1 type vessels, containment is based on welded construction, which does not exhibit the same sensitivity.

Allowable stress limits in the ASME Code are keyed to an elaborate classification of stresses-based on the nature of the loading that produces the stress. The rationale for this is that certain stresses, such as stresses produced by internal pressure, are produced by "external" causes, while other stresses, such as those stresses at discontinuities, are produced by the resistance of the structure itself to deformation. The first type of stress will remain even as the structure deforms substantially, whereas the second type of stress may be reduced as the structure deforms slightly to accommodate the stress, and therefore cannot lead to a failure. Lower allowable stresses are prescribed for the first type of stress. Under the Division 1 rules, stresses produced by thermal loads are generally treated as the second type of stress, while that is not the case in Division 3. This distinction was made primarily to force consideration of possible buckling of one of two concentric shells that are rigidly connected at their ends and are subjected to significant differential thermal expansion or thermal gradients. This configuration is typical of casks with lead shielding enclosed between two concentric shells.

Division 1 takes advantage of the self-limiting nature of thermal stresses because, in general, the ASME Code is not concerned with operability. However, a high level of strain needed to reduce thermal load stresses may not be acceptable for a cask. ASME Code Section III Division 1 does recognize potential problems with large thermal load strains by using tighter stress limits for elastic followup thermal stresses, where a large elastic displacement in a large component can cause a large inelastic response in a smaller component. By categorizing some thermal stresses as "primary" stresses, Division 3 follows up on this concern.

Another difference in the current Division 3 draft, when compared with the Division 1 rules is in allowable stress levels in bolts. The bolt stresses due to internal pressure plus gasket reaction loadings are treated as normal operating condition load stresses in Division 3 and are limited to two-thirds of the yield stress. In Division 1 these same stresses must pass the design stress limits for bolts which are one-third of the yield. Thus, under the rules of Division 3, the nominal tensile stress in the bolts of a vessel under a substantial internal pressure could be up to twice that allowed by Division 1 for the same conditions. Stress limits for components *other than* bolts do not exhibit this difference because in generating the stress limits "hopper diagram" for normal conditions, the NuPack Subcommittee modified the Division 1 diagram by incorporating the limits for the design conditions into the original Service Level A diagram. The corresponding modification was not made in the stress limits for bolts. In the most common cask designs the bolt stresses due to internal pressure and gasket reaction would fall below the one-third yield limit because the bolt torquing stresses are likely to govern bolting design; however, high bolt stresses from pressure plus gasket seating forces can occur in casks with significant internal pressure, and these stresses could govern the design of the bolting system. A design that does not provide a safety factor of three against bolt failure due to normal pressure plus gasket seating loads would not comply with ASME Section III Division 1 rules and safety philosophy.

In addition, a minor difference in bolting rules in Division 3 as compared with Division 1 is that Division 3 uses stress intensity to limit bolt stresses, whereas Division 1 simply uses nominal stress.

MATERIALS

The general approach with respect to materials in Division 3 is to follow the rules of Division 1. No new materials have been introduced beyond those sanctioned by Division 1, although the usual Code provisions for introducing new materials still apply. Some packaging applications use materials that are relatively thin compared to those in typical Division 1 applications. In this case, the requirements for volumetric inspection of the base material that are imposed by Division 1 will not apply. This would also apply to small diameter piping that may be used for leak test and drain port connections. Also, the paragraphs relating to fracture toughness have been rewritten to reflect more specifically the needs of packaging containments, especially their response to hypothetical accident impact loads.

FABRICATION AND INSTALLATION, EXAMINATION, AND TESTING

In Division 3, the rules in Paragraphs WB400, 5000, and 6000, which cover Fabrication and Installation, Examination, and Testing, respectively, are almost identical to those in Division 1. The main changes are those that reflect the deletion of references to piping and valves and the recognition that, for some cask configuration, it is not possible to do a complete hydrostatic structural integrity test after final assembly of the packaging. This is especially the case when the containment boundary forms part of the cavity for poured-in-place lead shielding.

CONCLUSIONS

This paper presented a brief status report on the development of an ASME Code Division for nuclear packaging and discussed some of the more interesting policy decisions as to what is and is not covered in terms of analytical methods, criteria, scope, and other aspects. The process of the development of this Division has been very slow and inconsistent. There were many participants with many diverse interests. The Division 3 rules are close to being ready to be issued. They are a compromise between many needs and the result is certainly not perfect. Opportunities for fine tuning and expanding this document will present themselves after it is issued as future needs become clear.

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