

NEW DIRECTIONS FOR THE ASME SECTION III, DIVISION 3 NUCLEAR PACKAGING CODE

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ABSTRACT

On May 30, 1997 ASME issued the initial version of Division 3 of Section III of the Boiler and Pressure Vessel Code. As of March 2000, Division 3, usually referred to as "NuPack," is limited to containment systems for casks designed to transport spent fuel and other high level radioactive materials. This paper describes NuPack's present evolution in two directions: first, making significant modifications to the rules already issued; and second, developing a new subsection within Division 3 to cover spent fuel storage systems.

The most significant modification is a comprehensive revision of Subsection WA, the general requirements. The assignment of responsibilities is being revised to define an "N3 Certificate Holder" in place of the previously defined Design Owner. This new party will have full responsibility for everything from package design through fabrication, inspection, maintenance and lifetime records retention. Another modification is the elimination of any reference to regulatory requirements and activities; for example, reference to "Type B."

The major new direction for NuPack is the development of rules for vessels for spent fuel storage systems.

INTRODUCTION

The release of Section III Division 3 of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (B&PVC) in 1997 (ASME 1997) provided the first set of ASME rules to deal with nuclear packaging. Division 3 was also issued as part of the 1998 edition of the full Code (ASME 1998) with some minor editorial changes. It is the result of about 20 years of effort by the special ASME Subgroup for nuclear packaging and various working groups, referred to here as the NuPack committee. This work is described in previous papers. (Eggers 1994, Adams 1998) The 1997 release is limited to containment systems in casks designed to transport nuclear reactor spent fuel and other high level radioactive materials including radioactive waste. It is important to note that only the containment system of the packaging is addressed by the current rules. The NuPack committee is part of the ASME B&PVC, hence the emphasis is on the pressure and/or containment boundary. Consideration of other components has been proposed to the ASME on many occasions, but no significant discussion has taken place to address any other components.

ASME B&PVC Section III, which covers Nuclear Power Plant (NPP) Components, is presently divided into three Divisions: Division 1 covers metal NPP structures, Division 2 covers concrete NPP structures, and Division 3 covers packaging for nuclear materials. Division 3 is divided into Subsections as follows: WA provides general ASME Code

requirements for packaging containments, WB provides specific requirements for transportation packaging, and WC provides specific requirements storage packaging. WA and WB have been released. Work on WC is in progress as will be described later in this paper.

OVERVIEW

The continuing evolution of Division 3 is described here under two broad headings: non-technical and technical. The primary focus of this paper is on the non-technical developments, separated into two groups: continued work on old issues, and evolving new issues. Technical issues were addressed in detail in prior papers (Turula 1996, Turula 1998) and the only technical issue that will be detailed here relates to the stress limits for bolts which have been revised to correct some inconsistencies and to be more in line with the other divisions of Section III. Some technical discussions related to buckling, impact loads, and thermal stresses that are in the process of being revised or are being re-examined, will be noted briefly in non-technical terms.

Several items are covered under developments in **old** non-technical issues. The first, is the elimination of all reference to regulatory requirements and activities; in particular, deletion of the reference to "Type B" from the scope statements and from the title of Subsection WB. Another significant change is related to the code effectivity date. Other developments related to old issues are consideration of modifications to rules for buckling, fracture toughness and thermal stresses.

Two items are covered as developments in **new** non-technical areas. The first is the development of the new subsection for containments for spent fuel storage packagings to be referred to as "Class SP" construction. The rules will be in a new Subsection WC which is based on the present Subsection NC rules for Class 2 NPP vessels, just as the transportation packaging "Class TP" construction rules in Subsection WB were based on Subsection NB rules for Class 1 NPP vessels. The second is a comprehensive rewrite of Subsection WA (general requirements for packaging containments). This rewrite was actually motivated by the development of the WC storage packaging rules, since the revised WA will have general requirements for both transportation and storage packaging containments. Subsection NCA (general requirements for Divisions 1 and 2) and WA (general requirements for Division 3) could eventually be combined into a single general requirements subsection covering all of Section III, possibly reverting to the original NA designation. WA revisions establish a single party with full responsibility for everything related to the packaging, from design through fabrication, inspection and maintenance. This follows nuclear power plant (NPP) practice where the plant owner has overall responsibility. It is different from the present Division 3 arrangement in which responsibility for design and regulatory certification is separated from responsibility for individual packaging procurement and ownership.

Finally, an interesting note is the committee's intention to drop the word "Hypothetical" in denoting the Accident Condition loadings.

OLD NON-TECHNICAL ISSUES: TYPE B REFERENCE

The intended scope of Division 3 has been a topic of discussion since the inception of the NuPack committee. Division 3, as issued in 1997, used the terminology "Type B" to indicate the intended scope. However as will be shown below, this was not consistent with current practice. Regulations require the application of the stringent ASME Class 1 rules only to packagings for the most severe part of the Type B contents range. Late in 1999 the

committee finally agreed to eliminate the Type B designation from the scope and title of Division 3 and from its subsections. In the process it also agreed to eliminate any reference to governmental regulatory requirements and authorities involved with packaging. This is consistent with the international nature of the ASME Code and the realization that the code provides a technically consistent set of rules that can be invoked at the discretion of a governmental regulatory body.

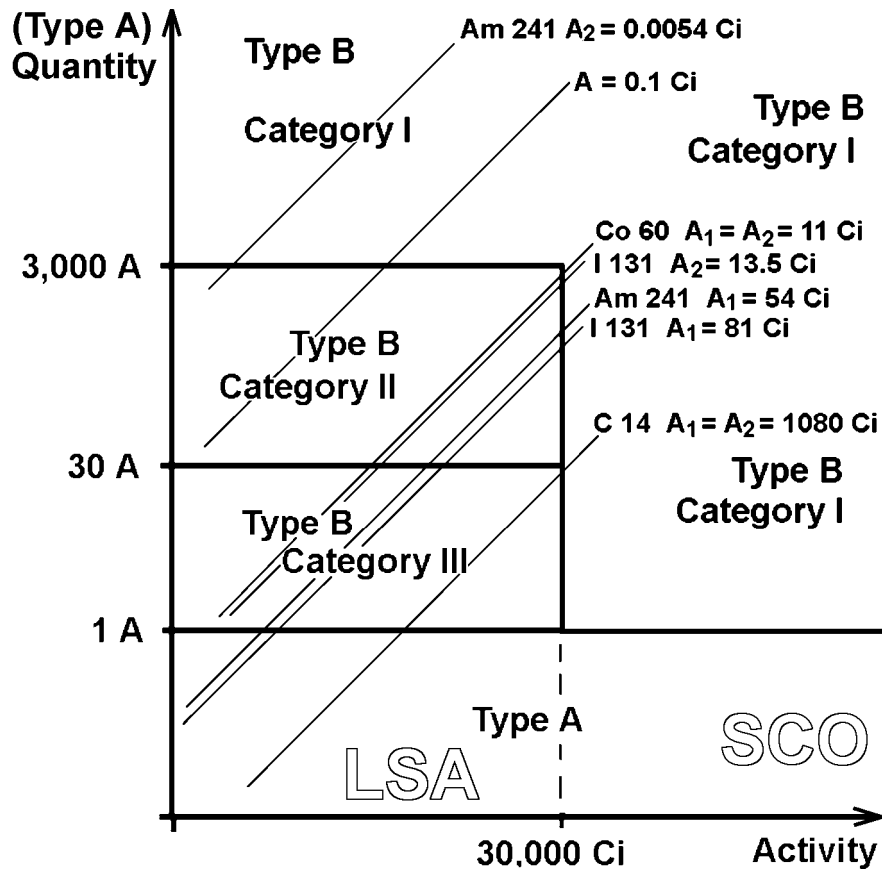
The use of Type B terminology in the scope of ASME Section III Division 3 and the definition of Type B categories is described and discussed extensively in the internet document "www.turula.com/b" which also provides various related examples of categorizing specific contents. U.S. regulatory practice divides the Type B range into Categories identified as I, II and III based on the level of hazard to the public associated with the material being transported. Note that the terminology "Category" is not consistent with ASME terminology since the classification of Type B into Categories I, II and III is exactly analogous to the classification of Section III Division 1 construction into Classes 1, 2 and 3. The term "Category" is particularly confusing because it is used by ASME and by government regulations to signify other classifications related to packaging, such as weld types, quality levels, shipping labels, etc. Categories I, II and III relate to completely different issues in these cases.

The Type B Categories are based on curies (Ci) or becquerels (Bq), and Type A quantities. The becquerel (or curie) is a measure of activity in terms of the number of disintegration events per unit time in a mass of radioactive material. It is not a material property such as specific activity which is measured in curies per gram (Ci/g). The numerical magnitude of activity is not itself a measure of relative hazard because the type and energy of the disintegrations, not just the number, must be considered.

The Type A quantity of any particular material is the maximum quantity of that material that the regulations deem to be sufficiently non-hazardous to be transported in a Type A packaging. For any material, the Type A quantity of that material is defined to represent the same level of radiological hazard, regardless of what that material is. Obviously the Type A quantity refers to the total activity rather than to the specific activity; thus, if some quantity of material exceeds the amount that may be transported in a Type A packaging, it is possible that this quantity may still be transported in Type A packagings if it is subdivided into smaller quantities. Type A quantities for various radionuclides are defined by tables in both IAEA ST-1 (IAEA 1996) and in 10 CFR 71 (U.S. Code 1997). A distinction is made between tabulated A_1 values and A_2 values, with A_1 applying to materials in "special form" and A_2 applying to materials in "normal form." Special form refers to a form that is not dispersible as demonstrated by a series of tests specified in the regulations referenced above.

Materials to be shipped that exceed a Type A quantity and are not exempt as limited quantity, low specific activity (LSA), or surface contaminated objects (SCO), must be packaged in a Type B packaging. In addition, transport by air of certain special radioactive materials requires a Type C packaging. As noted previously, DOE and NRC (but not IAEA) define three Categories for packaging contents in excess of a Type A quantity, that is for contents in the Type B range. These are: Category I for contents greater than $3,000 A_2$ or greater than $30,000 Ci$; Category II for contents between $30 A_2$ and $3,000 A_2$, and not greater than $30,000 Ci$; and, Category III for contents less than $30 A_2$ and less than $30,000 Ci$. These definitions are for normal form. For special form just substitute A_1 for A_2 .

These limits are best visualized on a plot of Type A Quantity vs. Curies, using a log-log scale, as shown in the following figure.



For special form, A is the A₁ value.

For normal form, A is the A₂ value.

Categories for Type B Contents

Both NRC and DOE require the application of ASME Section III NB (Class 1) or WB *only* to Category I packaging containments. For Category II application of Class 3 is considered adequate, and for Category III application of Section VIII is considered adequate. This is presented in the table on the following page. The table is adapted from the DOE "Packaging Review Guide" (Sheaffer 1999). Similar information is also provided by the U.S. Nuclear Regulatory Commission in their standard review plan (U.S. NRC 1999) and in other guidance documents (U.S. NRC 1991).

Table: Sections of ASME B&PV Code Applicable to Type B Packages

Component Function	Category I	Category II *	Category III **
Containment	Section III, Division 1, Subsection NB; or Section III, Division 3	Section III, Division 1, Subsection ND	Section VIII, Division 1
Criticality (structural support)	Section III, Division 1, Subsection NG (NF for Buckling)		
Shielding and Other Safety Items	Section VIII, Division 1 (for vessels); or Section III, Division 1, Subsection NF (for supports)		

* Category I criteria are also acceptable.

** Category I or II criteria are also acceptable.

The U.S. DOE has released a computer program called Radcalc (McFadden 1999) designed to compute the radiolytic generation of hydrogen gas and perform other sophisticated physics calculations; however, it also conveniently performs all the computations discussed above, including the determination of the tabulated A_1 or A_2 quantities and specific activities, identification of the required packaging Type, as well as the selection of the appropriate Category.

The above considerations lead to the conclusion that ASME Section III Division 3 should not define its scope as "Type B Containments" as this is a much broader scope than justified by current practice and regulatory requirements. As a result, the NuPack committee has accepted "containments for spent fuel and other high level radioactive materials and wastes" as its present scope without using the term Type B. This accepts the philosophy that it is not the function of Subsection WB, or any other segment of The Code, to invoke itself. Rather it is the prerogative of the owner, following the appropriate regulatory jurisdiction's guidance, to select the applicable Code Part.

In the same spirit, the committee has gone further and eliminated all reference to regulatory requirements and activities.

CODE EFFECTIVITY DATE

The 1997 edition of Division 3 states that the Design Specification must specify a Code effectivity date that must be no earlier than one year before the date of filing of the Application for the Certificate of Compliance. This is a rather severe requirement, especially considering that the corresponding time period for Division 1 construction is three years. This requirement has been questioned on several occasions in the past, and each time the NuPack committee had declined to revise it. But early in 2000 the committee revisited this issue and decided to completely eliminate this provision, partly because the reference to the Application for the Certificate of Compliance is no longer appropriate considering the elimination of all references to regulatory functions.

OTHER OLD ISSUES

As noted previously, other NuPack committee developments related to old issues include consideration of modifications to rules for inelastic analysis, buckling, fracture toughness

and thermal stresses. These are difficult technical issues and the current provisions of WB are recognized as being quite conservative, and not up-to-date with respect to today's analysis and materials engineering capabilities. However, evidence presented to date to justify a set of appropriate stress or strain limits for state-of-the-art inelastic analysis, for example, to allow the use of such techniques in lieu of linear elastic analysis while still maintaining the necessary safety margins, has not been acceptable to NuPack. The original (1997) version of WB-3229 stated that Division 3 does not cover the application of inelastic analysis. This was revised in the 1998 issue to state that inelastic design rules are in preparation. So far the only recognition of inelastic analysis is in a new code case N-626 (ASME 1999) which allows the use of plastic analysis, subject to the limits of Section III Appendix F, for hypothetical accident puncture bar impact evaluation.

Regarding buckling, WB-3133 states that rules to evaluate the buckling and instability of containment component structural members are under development. In 1999, a proposal to accept buckling criteria from other parts of Section III was presented to the NuPack committee. The method proposed is the "chart method" using the provisions of Section III Appendix VII. (ASME 1998) Two additional methods are being proposed for those cases where the chart method is not applicable: the experimental method presented in Section III Appendix II; and, a load factor method. Until these, or other provisions are accepted, and the committee has been slow to act on such issues in the past, the designer is left without ASME guidance on the buckling issue.

On fracture toughness, a code case is being proposed to expand the range of materials that can be used for packaging containments. Similar proposals have been presented in the past; however, to date, the committee has declined to act on any of these.

Finally, on the issue of thermal stresses, there is a proposal to eliminate the differences between Division 1 and Division 3 treatment of certain thermal stresses. Division 3 classifies thermal stresses that can cause containment shell buckling as primary, whereas Division 1 consistently classifies thermal stresses as secondary. Division 3 could have followed Division 1 precedent, identifying all thermal stresses as secondary and then imposing special rules to handle the containment shell thermal buckling case; but it decided not to, and is not likely to revise its approach on this issue at this time. For design purposes the result would be the same with either approach.

NEW NON-TECHNICAL ISSUES: SUBSECTION FOR SPENT FUEL STORAGE

The major interest in the NuPack committee since the initial release of the Division 3 rules in mid 1997 has been the development of rules for radioactive spent fuel and high level waste storage containers. This is a high priority development area for several organizations world wide and as a result recent NuPack committee meetings have been rather well attended. ASME has decided to develop the technical rules as a new subsection designated WC and to model it after the existing Subsection NC for Class 2 NPP components. ASME also decided that the general requirements for storage packagings would be merged with those for transportation packagings in Subsection WA, and as a result Subsection WA had to be rewritten. Since the general rules are considered to be a basis for the new development effort, the highest priority was assigned to the rewrite of Subsection WA and as a result progress on WC has been rather slow. As of March 2000, the first draft, a mark-up of NC, has been prepared and is under review.

As in WB for transportation packaging, the rules in WC for storage packagings will only address the primary packaging boundary, and will generally reflect current industry and regulatory practice. However, ASME has decided to use the term *containment* to denote the boundary, contrary to the current practice of referring to it as the *confinement* boundary.

To date, the major result of this new development work is its impact on the general requirements for *transportation* packaging containments, as described in the following section.

REVISION OF GENERAL REQUIREMENTS

Drafts produce by NuPack through about 1992 envisioned rules governing four parties related to transportation packagings. The four parties represented a logical, but perhaps simplistic scenario related to the development of a new packaging design. It envisioned the design process initiated by [1] a prospective *design owner* who would produce a design specification, and then engage [2] a *designer* to execute the engineering design. The design would then be acquired by [3] a prospective *packaging owner* who would produce a fabrication specification, drawings, etc. and engage [4] a *fabricator* to fabricate the packaging.

However, circa 1995, after review by the main committee of ASME Section III, the Designer was eliminated as a separately addressed party and the Designer's responsibilities were assigned to the Design Owner. There were two reasons for this change. It was recognized, first, that the design responsibilities would flow through the Design Owner; and 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 the Designer would not necessarily continue to exist as an accessible organization for the long period of time that the packagings of a particular design remained in service. To maintain continuity of responsibility, the design responsibilities had to be placed on the Design Owner. Thus the initial release of Division 3 in 1997 subsumed the Designer into the Design Owner and defined responsibilities in terms of only three parties.

In 1999 as part of the process of generalizing Subsection WA to cover both Subsection WB Class TP transportation packaging containments and the new Subsection WC class SP storage packaging containments, ASME decided that the above scheme needed revision. The reasoning was that it failed to establish a single point of responsibility for the packaging. So the decision was made to follow the familiar NPP model with a single owner as the party with total responsibility. In the current draft of Subsection WA this total responsibility is assigned to the old design owner, but he is now referred to as "the N3 Certificate Holder." The N3 has responsibilities that are much broader than those of the old design owner, assuming some responsibilities previously assigned to the packaging owner and to the fabricator. To avoid confusion the term "owner" no longer appears in relation to the definition of the N3 Certificate Holder.

The other two parties are still addressed in the new draft of Subsection WA: the old "packaging owner" is now referred to as simply "owner"; and, the fabricator is now referred to as the NPT Certificate Holder. (NPT denotes a certified *nuclear part* fabricator.) Obviously the term "fabricate" is still used in the definition of the NPT Certificate Holder. The term "certificate holder" is now ambiguous, but it generally refers to the N3 rather than to the NPT when the context does not clearly indicate the contrary.

A key reassignment of responsibilities is that the N3 (design owner) is given responsibility for the fabrication specification and fabrication oversight. In the 1997 issue of Subsection WA the packaging owner had this responsibility, and the design owner's responsibilities ended when the design received the regulatory authority's certificate of compliance. Any prospective packaging owner could take the certified design and get it fabricated on his own (ignoring the practical complications of the design owner's intellectual property rights, etc.) using the information in the design specification, design drawings, design report and safety analysis report.

In the present draft of Subsection WA, the N3 Certificate Holder has the same complete responsibility for the design of the containment as the old design owner had. In addition, his responsibilities include the complete "construction," interpreting that term in the ASME Code sense meaning design, materials control, fabrication, examination, testing, inspection, certification and Code stamping. The N3 may subcontract work, including Code stamping, to other certified parties, in particular to the NPT (fabricator), but the N3 Certificate Holder still retains over-all responsibility, including responsibility for ASME Certification and Code Stamping even when the NPT performs these functions. The N3 also has responsibility for all required record retention, both for lifetime records and for non-permanent records.

Responsibilities assigned specifically to the NPT Certificate Holder (fabricator) are very similar to those of the fabricator in the 1997 version of WA. The key difference is that the NPT now shares all his responsibilities with the N3. The new draft states that the N3 may perform all the duties of the NPT provided these are in the scope of his certification. So the N3 may obtain his own fabrication certification, or ensure that his NPT has such certification; but, in either case the N3 has the over-all responsibility to ensure that all work is performed by properly certified parties.

Most of the responsibilities assigned to the packaging owner in the 1997 Code have been transferred to the N3. In the current draft of WA the (packaging) owner is responsible for accepting delivery of the completed containment. He also has responsibility for designating which records are to be retained in those cases where the Code provides an option, and he has responsibility for "ensuring" that required records are maintained, but the actual retention is the responsibility of the N3. The reasoning behind this is that the regulatory authorities look to the packaging owner as the responsible party rather than to the N3.

The current draft of WA adds new complexity to the practical implementation of the Code provisions. However, it should be noted that the prospective owners under the guidance of the regulatory authorities have the option of applying parts of the code rather than applying the code in its entirety. You don't have to buy into WA to use WB or WC. In general, the technical requirements in WB and WC are conveniently segregated from the administrative requirements in WA. The only exception is that, at this time, the quality assurance aspects are not totally segregated; so, it may be necessary to implement parts of the quality assurance rules in WA-4000, supplementing the quality assurance provisions of WB, to retain the desired level of construction quality when using WB without WA.

TECHNICAL ISSUES - BOLT STRESS LIMITS

Changes have been made to WB-3230 (stress limits for bolts) to resolve some internal ambiguities and to make the rules more consistent with the other divisions of Section III. In addition to several editorial changes there are two significant technical changes. First, as

presented in the current (1997) version, WB-3231.1(a) imposes a limit on the "membrane stress intensity averaged across the bolt cross section." The problem with this wording is that stress intensity is a scalar value computed at any given point from the stress tensor, incorporating the axial and shear stress components. The intensity cannot be computed after the axial stresses are averaged to generate a membrane stress, so that "membrane stress intensity" is an unintelligible expression in the context of a bolt cross section. This expression was originally used because of a concern for high shear stresses due to the application of bolt torque producing in a stress intensity at the periphery of the bolt higher than the nominal stress in the bolt. However this concern is already addressed in WB-3231.1(c). So the wording in question was changed to "axial stress component averaged over the cross section," which corresponds to the nominal bolt stress.

The revised wording is consistent with ASME Section III Division 1 NB-3232.1. It is also consistent with NRC guidance provided in NUREG/CR-6007 Table 6.1 (Mok 1993) which invokes the same limits as those in ASME NB. Note that the basic limit in the NUREG is S_m with S_m defined as $2/3 S_y$, while the limit in NB is $2S_m$ with S_m defined as $1/3 S_y$ for bolting materials. The concern for increased stress intensities at the bolt periphery is resolved in both the NUREG and in NB by limiting the peripheral stress intensity to 1.5 times the nominal stress limit. In general, it can be shown that the nominal stress limit will govern, except in cases where the bolt bending stresses are very high or (theoretically) for extremely coarse thread bolts.

The second change to WB-3230 is more complex. As published in 1997, paragraphs WB-3231.1(c) and WB-3231.2(c), addressing stress intensity at the bolt periphery for Normal Operating Conditions and Hypothetical Accident Conditions respectively, are essentially identical. The nominal bolt stress under Hypothetical Accident Conditions is limited in WB-3231.2(a) to the same value as specified in WB-3231.2(c) for the stress intensity, so if WB-3231.2(c) were to apply then WB-3231.2(a) would never govern. The committee agreed to eliminate WB-3231.2(c) on the basis that it was copied erroneously from WB-3231.1(c). This change makes the hypothetical accident conditions limits on bolts consistent with corresponding NB limits as imposed through Section III Appendix F (ASME 1998). It also makes the WB hypothetical accident load limits for bolts consistent with Table 6.3 of the NRC NUREG referenced above which imposes limits identical to those in ASME Section III Appendix F.

However, the designer should be warned that, as stated in F-1300, Appendix F is not concerned with operability (leak-tightness) of the containment boundary either during or following the Level D loading or hypothetical accident event. Appendix F rules are only intended to assure structural integrity of the pressure retaining boundary. The designer is responsible for assuring sufficient leak-tightness following hypothetical accident events. Simply satisfying the ASME rules does not provide such assurance.

SUMMARY

The major thrusts of ongoing ASME Code work related to nuclear packaging have been presented. The items discussed describe the status and decisions of the subgroup on containment systems for packaging, but not necessarily the decisions of the Subcommittee on Nuclear Power which has the formal decision authority in these matters. Code development is a slow and sometimes deliberate process so that it is uncertain as to when the

provisions discussed will actually appear in a printed edition of the Code. Designers hold the ultimate responsibility for their designs and they need to understand the provisions of the Code because rigorous application of the provisions of the Code is not sufficient to guarantee an adequate design.

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