UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

# SAFETY EVALUATION REPORT
# DOCKET NO. 71-9215
# MODEL NO. NPI-20WC-6 MkII
# CERTIFICATE OF COMPLIANCE NO. 9215
# REVISION NO. 16

## SUMMARY

By letter dated May 7, 2018 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML18127B734), as supplemented by letter dated August 27, 2018 (ADAMS Accession No. ML18254A186) and April 5, July 26, September 4, and November 11, 2019 (ADAMS Accession Nos. ML19127A154, ML19219A149, ML19263A668 and ML19323A745), Neutron Products, Inc. submitted an amendment request to the Nuclear Regulatory Commission (NRC) to revise the certificate of compliance (CoC) for the Model No. NPI-20WC-6 MkII package. The applicant submitted a consolidated safety analysis report (SAR) which contained revised packaging component weights, structural calculations and additional shielding information. The staff reviewed the application using the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material." Based on the statements and representations in the application, as supplemented, the staff agrees that these changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

## 1.0 GENERAL INFORMATION

The applicant removed comparisons of the NPI-20WC-6 MkII package to another package, whose certificate of compliance was terminated, from the consolidated SAR submitted as part of their amendment request. In addition, the applicant made editorial and formatting changes which did not impact the description of either the package or the contents. Based on a review of the statements and representations in the application, the staff concludes that the package has been adequately described to meet the requirements of 10 CFR Part 71.

## 2.0 STRUCTURAL

The objective of the structural review is to verify that the structural performance of the package meets the requirements of 10 CFR Part 71, including the tests and conditions for normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

### 2.1 Background and Evaluations

The applicant increased the shield plug weight used in the design basis calculations from 133 pounds to 202 pounds to allow more extensive use of tungsten alloy shield plugs, and minor editorial changes. The staff reviewed the impact on the structural design performance due to the increased weight, and found that there is no structural safety issues related to the increased weight of the shield plugs. The total weight of the package increased to approximately 5,210 pounds with the increased shield plug weight. However, this change does not exceed the maximum weight of the package used in the calculations of 6,000 pounds in the which was previously reviewed and approved by the staff. The applicant also proposed minor changes in the revised SAR. After reviewing the proposed changes, the staff determined that they are relocations and minor editorial revisions of the SAR paragraphs. Therefore, the staff

finds the changes acceptable because the corrections requested by the applicant do not affect the structural capability of the package to meet the requirements of 10 CFR Part 71.

### 2.2 Findings

Based on a review of the statements and representations in the application, the staff concludes that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71.

## 3.0 THERMAL EVALUATION

The staff reviewed the proposed changes and determined that they did not impact previous SER findings regarding the package thermal design. Therefore, the staff finds that a new evaluation is not needed.

## 4.0 CONTAINMENT EVALUATION

The staff reviewed the proposed changes and determined that they did not impact previous SER findings regarding the package containment design. Therefore, the staff finds that a new evaluation is not needed.

## 5.0 SHIELDING EVALUATION

The objective of this shielding review is to determine if the model NPI-20WC-6 Mk II package will continue to meet the dose rate requirements of 10 CFR 71 under NCT and HAC. Aside from changes to the minimum shielding in the CoC conditions, the packaging remained unchanged. Therefore, staff review focused on the following: confirmation of the applicant-determined minimum axial shielding for a uniform source of maximum activity allowed per the CoC; confirmation of dose rates of a 21-inch, 4000 Curie (Ci) Cs-137 pencil source with reduced axial shielding; and evaluation of the applicant's method to determine suitability of long, pencil sources for shipping in the NPI-20WC-6 Mk II package.

### 5.1 Background

The model NPI-20WC-6 Mk II package consists of a spherical shield assembly with a cylindrical hole through the middle. This hole is designed to accept three drawer types, the -2, -4, and -5. The -4 and -5 type drawer assemblies each have three cylindrical through-holes to hold the sources and appropriate plugs and spacers. The -2 type drawer has two through-holes with a square cross-section to accept the sources and appropriate plugs and spacers. The open ends are capped with lids that mate to a steel flange, with a rubber gasket in between. The center of each lids has additional lead shielding.

The applicant requested multiple changes to the CoC to reflect the need to accommodate source assemblies that are too long for the minimum shielding requirements incorporated into Condition 9 in CoC No. 9215, Revision 15 (ADAMS Accession No. ML18150A419), and to clarify the conditions on the maximum allowable activity in the Certificate. The applicant explained that some sources presented for transport have threaded studs to facilitate handling which can make the source too long to ship in the NPI-20WC-6 Mk II package with the existing minimum shielding requirements. Therefore, additional handling is required to remove the threaded stud which increases occupational exposure. The applicant requested that the

minimum axial shielding thickness be reduced to one inch from the current two inches for pencil sources with less than 4000 Ci Cs-137.

## 5.2 Pencil Source Methodology

For sources not evaluated as a single point source (i.e., pencil sources), the applicant modeled the source as eight, equally spaced point sources with an equal portion of the total activity (i.e., $1/8^{th}$ source strength for each point). The applicant modeled the first point source on the end surface of the source closest to the detector and shifted all remaining point sources closer to the detector to maintain equal spacing. Staff finds this acceptable since this conservatively moves the sources closer to the package surface. In addition, this modeling assumption removes the effects of self-shielding from the first point source, which contributes most of the external dose (ADAMS Accession No. ML19127A154) and minimizes it for all subsequent points increasing the calculated dose. See also Staff Confirmatory Analysis below. The applicant's measurements confirmed the location of maximum dose for long sources to be around the closure lid flange. For each of the source points, the applicant determined the amount of shielding material for a one-dimensional analysis by drawing a line between a source and the dose rate measurement point. The applicant estimated the dose rate using both attenuation factors, which account for photons that scatter and do not travel to the area of interest, and buildup factors, which account for photons that scatter multiple times and still travel to the area of interest. The applicant generated these factors either by computational tools (e.g., Microshield or Rad Pro Calculator) or manually interpolated tabular values from shielding texts. Since these tools and methods have long been used to quickly estimate dose rates, staff finds them acceptable when used in conjunction with the applicant's conservative approach to modeling the source and shielding material (ADAMS Accession No. ML19219A149). See also Staff Confirmatory Analysis below.

## 5.3 Shielding Model

The applicant evaluated the maximum dose rate with a single pencil source, modeled as eight, equally spaced point sources shifted toward the end cover (ADAMS Accession No. ML19127A154), of maximum allowed activity for each drawer type. The applicant assumed a Co-60 source spectrum which staff finds acceptable because the Co-60 source spectrum bounds the Cs-137 source spectrum. The applicant modeled the source as steel or iron with nominal density. Staff finds this acceptable since both materials are less dense than cobalt and have less gamma attenuation. For the -4 and -5 drawer types, the applicant modeled the source in the center of the through-hole. Staff finds this acceptable since Condition 7 in the CoC requires annular and axial spacers to limit shifting. For the -2 drawer type, the applicant modeled the source toward the radial center of the packaging, increasing the amount of shielding provided by the inserts. Staff finds this acceptable since the -2 drawer type has a square cross-section, and rotation of the spacer is not credible. The applicant used nominal dimensions in its analysis with a known reference source. The applicant's model did not account for potential gaps allowed under CoC conditions. Staff finds this acceptable since the applicant's measurements show their method consistently over-predicts external dose rates (ADAMS Accession No. ML18127B742). See Staff Confirmatory Analysis.

### 5.3.1. Co-60 Pencil Sources

The applicant provided a combination of predicted and actual dose rates in SAR Table 5.4.1 (ADAMS Accession No. ML18127B742) and supplemented this information with a specific case

in the July 26, 2019 RAI response (ADAMS Accession No. ML19219A149). In the July 26, 2019 RAI response, the applicant used a 5.6-inch long, 0.772-inch diameter source with 5290 Ci Co-60 as a reference source. The applicant measured dose rates with this source loaded into a -5 drum assembly. With this as a reference point, the applicant used their calculated attenuation factor to scale the dose rate for various thicknesses of axial shielding using the multiple point source method described in Neutron Products, Inc. Procedure R-2014-G (ADAMS Accession No. ML18127B744). Since gamma dose rate can be scaled by source strength and shielding thickness when the attenuation factor is known, staff finds the applicant's procedure acceptable.

5.3.2. Cs-137 Pencil Source

In their RAI response dated August 27, 2018, the applicant specified the pencil source as 15.94 inches long and 0.89 inches in diameter, pinned to a 3.61-inch long tungsten rod (ADAMS Accession No. ML18254A186). Since the tungsten rod is at the opposite end of the package being evaluated, it is not significant to the dose rate calculation. The applicant evaluated a separate scenario with the same geometry but with the CoC maximum activity of 20,600 Ci Cs-137 in their July 26, 2019 RAI response (ADAMS Accession No. ML19219A149) by scaling the results using the ratio of source activity. The applicant used scaling to evaluate the two cases to determine minimum axial shielding required for the maximum activity allowed and 4000 Ci Cs-137 sources. Staff finds this acceptable since gamma dose scales predictably with source strength and shielding thickness.

## 5.4 Maximum Activity Limits

Since the package is authorized to ship small teletherapy sources that have much higher activity than the pencil sources, the applicant evaluated the effect of reduced axial shielding as source length increased. The applicant modeled 9.625-inch and 11.625-inch Co-60 sources, and modeled spacers and plugs as tungsten alloy with steel end sections. The applicant split the sources into eight point-sources as discussed above. The applicant also stated that, for some scenarios, dose rates are maintained below the regulatory limits using the package position and orientation within the conveyance (i.e., maximizing distance). Staff reviewed the applicant's methodology and finds that they adequately demonstrated that the outermost section of axial plugs has negligible effect on the maximum dose rates. Staff analysis confirmed this finding. Staff also finds acceptable the applicant's manipulation of the package position and orientation within the conveyance since the results showed the requirements of 10 CFR 71.47(b) are met.

## 5.5 Staff Confirmatory Analysis

After reviewing Drawing Nos. 240116, Rev. J, and No. 240112, Rev H., staff developed a three-dimensional model with MONACO, a fixed-source, Monte Carlo radiation transport code in the SCALE 6.2.2 code package. Staff used the 19-group multi-group gamma cross-sections from the ENDF/B-VII library. Staff conservatively reduced shielding material in the model by using the minimum dimensions due to fabrication tolerances for the shield assembly except for the baseline Co-60 source configuration for which the applicant had dose measurements. For the baseline Co-60 source configuration, staff matched the MONACO model dimensions to those of the applicant to provide a basis for comparison. Staff modeled the shield assembly as a sphere with truncated ends where the cover assemblies are located. Due to the geometry of the packaging, the highest dose rate location is at the flange of the closure lid and not axially in-line with the source. As the source length increases, two geometrical factors come into play: the thickness of the spherical lead shielding decreases toward the end of the package; and the

aspect angle increases for streaming through the steel flange between the spherical, lead shield and the lead slab in the lid. This also means that the shielding provided by axial plugs at the lid may not be as important as the geometry advantage of increasing distance between the source and the closure lid. Since changes to axial shielding were the primary focus of the review, staff modeled neither the base nor other lifting and closure hardware because these components are external to the shielding assembly and provide minimal shielding. Since minimal shielding is provided by the over-pack, staff modeled the over-pack with the nominal dimensions given in Drawing No. 240116, Rev. J. Staff modeled the protective, stacked plywood jacket as balsa wood. The applicant identified streaming paths through the liners and sleeves that contribute to the maximum dose rate being around the flange of the cover assembly rather than at the center (SAR Figure 5.3.1). This streaming effect becomes more pronounced the closer the radiation source is to the cover assembly which is the case for the pencil sources being evaluated. For its comparative analyses, staff evaluated dose rates at this cover assembly flange, the closure lid face and the over-pack surface outward of the cover assembly flange. Staff also evaluated one-meter dose rates at two locations: one straight out from the closure lid, and another above to evaluate streaming along a path through the closure flange.

Staff evaluated the applicant's methodology in the April 5, 2019 RAI response (ADAMS Accession No. ML19127A154). Staff modeled the applicant's example source (7-inch long, 0.75-inch diameter Co-60 source) as both a volumetric source and as 8 discrete point sources. Staff ran a series of MONACO calculations with each point source and added the results to determine the total dose rate from the split point sources. Staff results show splitting the source into a series of points is acceptable to estimate dose rate for a pencil source. Staff results confirmed that the point source at the end of the source volume closest to the measurement location is the major contributor to the external dose. Staff results confirmed that, as subsequent points are evaluated, the contribution drops off with the last few point sources contributing relatively little to the total dose rate. Staff finds it acceptable not to calculate all eight points provided the applicant assumes the remaining points contribute the same dose as the closest calculated point source. Staff also evaluated the effect of self-shielding on dose rates by shifting the point sources $1/16^{th}$ of the source length away from the end cover (i.e., a more uniform distribution). Staff's results confirmed the applicant's method provides sufficient conservative margin to compensate for any uncertainties and non-conservative assumptions in the calculation.

Staff modeled the Co-60 example the applicant provided in the July 26, 2019 RAI response (ADAMS Accession No. ML19219A149) as a volumetric source with no gaps between components to match the applicant's analysis and to calibrate staff's results to the applicant's measured results. Since the applicant did not model all its cases with the most conservative shielding configuration, staff evaluated the effect of gaps between spacers and plugs at the maximum value allowed per the CoC as follows. Staff shortened the axial shielding plug behind the source to allow the annular spacer to shift back, increased the diameter of the cavity within the annular spacer, and left the Co-60 source in place before repeating the calculation with the same Co-60 pencil source. As a result, staff's model has 0.25 inches of source not covered by the annular spacer, with a 0.25-inch gap above the source and above the axial plug to evaluate potential streaming toward the closure lid flange. This is conservative as the total play allowed will occur amongst several components and the space around the axial plug will be smaller to meet CoC conditions. Staff's evaluation showed an increase in dose rate that is well within the conservative margin provided by the applicant shifting the series of point sources in its calculations. Therefore, staff finds the applicant's analysis acceptable.

For the scenario with the 19.925-inch long source assembly (a 15.94-inch Cs-137 source attached to a 3.61-inch tungsten rod with a 0.375-inch threaded stud), staff evaluated the effect of reducing the axial shielding by 0.3 inches. Staff's results showed that a reduction of the axial shielding from 2 inches to 1.7 inches of tungsten alloy increases the dose rates at the overpack surface and one meter from the overpack surface by less than 90% and 75% respectively. Staff repeated this example after the applicant requested a minimum of 1-inch axial shielding in their September 4, 2019 RAI response (ADAMS Accession No. ML19263A668). When scaled for lower activity Cs-137 sources (i.e., the 4000 Ci Cs-137 condition), staff's analysis confirmed one inch of axial tungsten alloy shielding is sufficient for the package to meet the dose rate requirements of 10 CFR 71.47 and eliminate the need for additional handling of such sources.

### 5.6 Findings

Based on a review of the statements and representations in the application, the staff concludes that the package has adequate shielding to meet the requirements of 10 CFR Part 71.

## 6.0 CRITICALITY EVALUATION

The package is not authorized to transport fissile material. Therefore, the staff did not perform a criticality evaluation.

## 7.0 PACKAGE OPERATIONS

The applicant incorporated the methodology for determining if a content presented for transport could be shipped in the package. Staff reviewed the proposed changes and determined that they are consistent with the shielding models and analytical methods provided by the applicant. Therefore, the staff finds that the revised operating procedures are acceptable.

## 8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM REVIEW

Staff reviewed the proposed change and determined that it did not impact the staff's previous SER findings regarding the package acceptance tests and maintenance program. Therefore, the staff finds that a new evaluation is not needed.

## CONDITIONS

The CoC includes the following condition(s) of approval:

Condition No. 5(b)(2) was changed to provide more specificity on the shipping configuration (i.e., the amount of shielding needed for a given quantity of radioactive material in a specific drum assembly).

Condition No. 7 was amended to clarify the maximum amount of movement allowed by the contents within the package as well as the minimum amount of spacing required between the contents and the S/TC cover.

Condition No. 9 was removed from the CoC since the pertinent requirements have been incorporated into other conditions, and subsequent conditions were re-numbered accordingly.

The references section has been updated to include this request.

Minor editorial corrections were made.

**CONCLUSIONS**

Based on the statements and representations contained in the application, as supplemented, and the conditions listed above, the staff concludes that the design has been adequately described and evaluated, and the Model No. NPI-20WC-6 MkII package meets the requirements of 10 CFR Part 71.

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