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A METHOD FOR MANAGING THE STORAGE OF FISSILE MATERIALS USING CRITICALITY INDICES

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SUMMARY

This paper describes a method for criticality control at fissile material storage facilities. The method involves the use criticiality indices for storage canisters. The logic, methodology, and results for selected canisters are presented. A concept for an interactive computer program using the method is also introduced. The computer program can be used in real time (using precalulated data) to select a Criticality Index (CI) for a container when it is delivered to or packaged at a site. Criticality safety is assured by controlling the sum of the CIs at each storage location below a defined limit value when containers are moved.

INTRODUCTION

As a result of dismantlement and environmental restoration and cleanup activities at DOE sites, there are large numbers of fissile items that need to be stored. These items may be processed and/or moved to alternate locations for long term storage, reapplication (e.g., as commercial reactor fuel), or disposal. Sandia National Laboratories/New Mexico, for example, has approximately 5000 fissile material items in its inventory. Many of those items contain only a few tens of grams of fissile material (or less) but some have masses that exceed 10 kg. Some of the items are spare reactor fuel elements and others are parts of irradiated reactor experiments that contain fissile material and fission products. Highly trained people are required to manage the safe storage of this material because of its inherent criticality potential and, at least in the case of the irradiated items, its high level of radioactivity. Failure to follow "precisely" the sometimes complex storage procedures for fissile materials can have serious consequences -- a violation of a criticality safety limit or, far worse, a criticality incident.

Facility operators typically use well-defined unit spacing, unit mass limits and a maximum number of units in a well-defined linear or multi-dimensional array as an acceptable method of criticality safety control. If more units needed to be stored in a room, a criticality safety engineer must spend a considerable amount of time calculating a "reconfigured" array or sets of arrays that utilize the floor space of the room (or vault) more efficiently. This reevaluation and the new criticality calculations are expensive tasks, by themselves. In addition, however, the reevaluation usually requires an independent review and additional training for the operators. Typically, all these related activities cause delays in operations at the facility adding further to the cost of operations.

The DOE facilities could benefit from a new technique that is safe and efficient and can easily be used to manage the storage of fissile materials without requiring frequent recalculation and reconfiguration.

This paper describes a systematic method for determining a "criticality index" (CI) for a storage canister containing fissile material. The CI can be added to the CIs of other canisters in a storage array and compared to the CI Limit Value to assure that the array is

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DISCLAIMER

criticality safe. The CI of an individual storage canister is a function of the mass of fissile material stored in the canister, the H/U ratio of the fissile sample, the canister size and other parameters like the moderating properties of the packing material, moderation from additional materials in the array, adjustments for accident scenarios, if appropriate, etc.

Bounding CI values as a function of fissile mass have been derived for several different standard canister sizes. The systematic method for deriving the bounding CI values is the subject of this paper. These bounding value curves are easily used by trained criticality technicians in the field on a real time basis. SNL has used CIs exclusively at its primary fissile storage location since 1992. The system will be the method of choice at other locations throughout the laboratory when the system is fully automated. The method has potential for application at other DOE and non-DOE facilities, as well.

DEFINITION OF CRITICALITY INDEX

The CI is based upon the criticality portion of the Transportation Index (TI), as described in 10 CFR ¶71.59 b (1) for fissile class II packages [1]. Since we are interested in criticality limits for storage, we do not consider the radiation component of the TI. A CI, ranging from 0.0 to 10.0, can be calculated and assigned to a container based upon the mass and type of fissile material (and its packaging configuration) within that container.

The CI has traditionally been calculated (at SNL) by a knowledgeable criticality safety engineer using tables or by modeling the problem on a neutron transport criticality code (e.g., KENO [2] or MCNP[3]). The CI is obtained by determining the number, N, of containers which, when stacked in a nearly cubic array, have a multiplication factor of 0.95. The CI is defined as the CI Limit Value (50 to be consistent with the definition of the TI above) divided by one fifth of the number of units in the array, rounded up to the nearest tenth. For this calculation, the unit is modeled using the geometry and materials present as it would be stored.

For some units, the array is undermoderated and the addition of moderation (e.g. full or partial flooding) could increase the array multiplication factor. However, flooding is a low probability event, even incredible for some storage locations at Sandia, and is treated as an accident. In this case, the CI is defined as the CI Limit Value (again 50) divided by one half of the number of units in the optimally flooded array, N_a,

Simple Rules for Calculating and Assigning CIs:

$CI_0 = 50 / (N/5)$ with the units in the "normal" condition

$CI_a = 50 / (N_a/2)$ with the units in the "accident" condition

CI = the larger of CI_0 and Ci_a

$0 \leq CI \leq 10$

Storage Management Rule for CI Arrays:

$\sum CI \leq 50$

again rounded up to the nearest tenth. This formulation also comes from the CFR section referenced above.

The CI assigned to a unit is the higher of the two CIs defined above. If the multiplication factor for an infinite array of a given unit is less than 0.95, the CI for that unit is 0. If the multiplication factor for the infinite array is greater than 0.95, the minimum CI for the unit is 0.1. Unit CIs must be less than or equal to 10. Units having a CI greater than 10 cannot be handled using this method.

Once the CI is calculated and assigned, it remains with the container unless the fissile material, the container, or the packaging are added to, removed, or altered. If any of these occur, the CI must be recalculated based on the new configuration and contents.

There is a safety factor of 2 for accident conditions and 5 for normal conditions built into this methodology.

Criticality safety is assured by controlling the cumulative sum of CIs at a given storage location or isolated array within a storage room to a value of 50 or less. There is no limitation on spacing except to isolate neighboring arrays from one another. The containers within an array can be touching and can be stacked, if structurally approved for stacking.

If a calculated CI is greater than 10 for a single item, it is not assigned a CI and it must be stored as a single unit (isolated by sufficient distance from other single units and CI arrays) or the array must be verified criticality safe using traditional calculational methods and procedures.

In the method described below, a parametric set of CI values is calculated in advance for a given container. The CI for a specific mass stored in the container can be obtained from a chart or a database as a function of the fissile mass, the H/U ratio of the mass, and a few other parameters that are usually known or that can be bounded. The availability of this information eliminates the usual "few-day" delay encountered when new container arrives and needs a CI assignment or some reconfigured array must be verified.

METHOD FOR CALCULATING CI BOUNDING VALUES FOR CONTAINERS

A canister to be characterized is physically examined and measured. If inner cans and packing material, e.g., Celotex, are used, this is noted. Then a set of calculations is performed modeling a range of fissile masses and selected H/U ratios in the mass centered in "cell" having the same height and diameter as the outer can. Initially, the structural material is not modeled, just the fissile material. This is done so that additional materials can be introduced serially to determine the sensitivity of the CI to each. In the cases reported below, the first material added to the model was the Celotex "filler" material, basically a low-density cellulose composite. The nominal density of Celotex is about 0.25 g/cc. However, to avoid the necessity of verifying the density of the Celotex in each container, the CI was obtained for a given mass at a number of different Celotex densities. The CI used for a given mass is the CI obtained with the density adjusted to the value that gives the highest CI. This optimal density for the results reported here varies from about 0.02 to 0.4 g/cc.

Figure 1 shows the CI obtained for a range of masses of uranium dioxide in a 15 gallon drum in three different configurations. The curves give the CI obtained with optimum Celotex moderation and no structural material; with moderation by Celotex at its nominal density and no

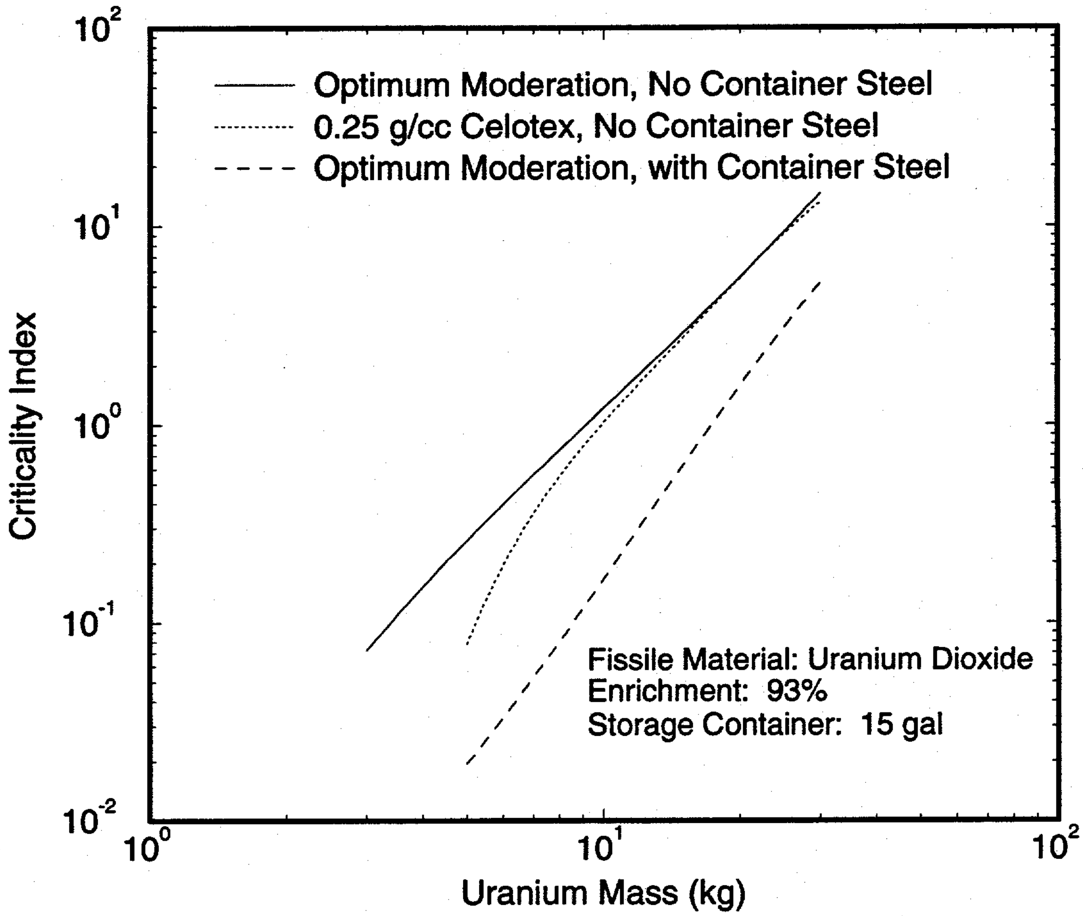

Figure 1. CIs for a 15 gallon container.

structural material; and with optimal moderation by Celotex, structural materials included.

Each point on the CI vs. uranium mass curve represents a number of KENO-Va calulations. Determining the CI for a given configuration typically requires six or more calculations, each for a different array size. Finding the optimal moderator density is typically done by obtaining the CI for seven different moderator densities. A final CI is then determined at the optimal moderator density. A complete characterization of a canister involves a set of CI curves that would cover the range of H/U expected for the material to be stored in that canister and potential "moderator" or "reflector" scenarios and so forth.

For the cases reported here, the Celotex contained in the canister is the only moderator included. Other moderator cases can be modeled, depending on the scenarios one wishes to explore. For example, if flooding is credible (from natural causes or from fire protection equipment), water could be modeled between cans or inside the cans, as appropriate.

CI DATA FOR SELECTED CONTAINERS

Parametric calculations have been performed for two standard size storage containers used at SNL: 15 gallon and 55 gallon. Figure 2 shows the results of the calculations for selected configurations. The figure shows a family of curves as a function of mass for the two material types and different H/U ratios that would be typical of sample material stored in the cans. In all configurations shown in the figure, the structural material was not modeled.

APPLICATION CONCEPTS

CI data are available for a few standard containers. As new containers are added to the inventory, the CI data for them is generated. An interactive data-base program has been designed to automate the process of assigning a CI to a given container using the data. By design, a trained criticality technician can operate the program by entering a few basic values that describe the container and its contents. These input values include: a) container type (from a list of standard containers), b) mass of fissile material, c) fissile material type (from a list of isotopes and chemical forms of those

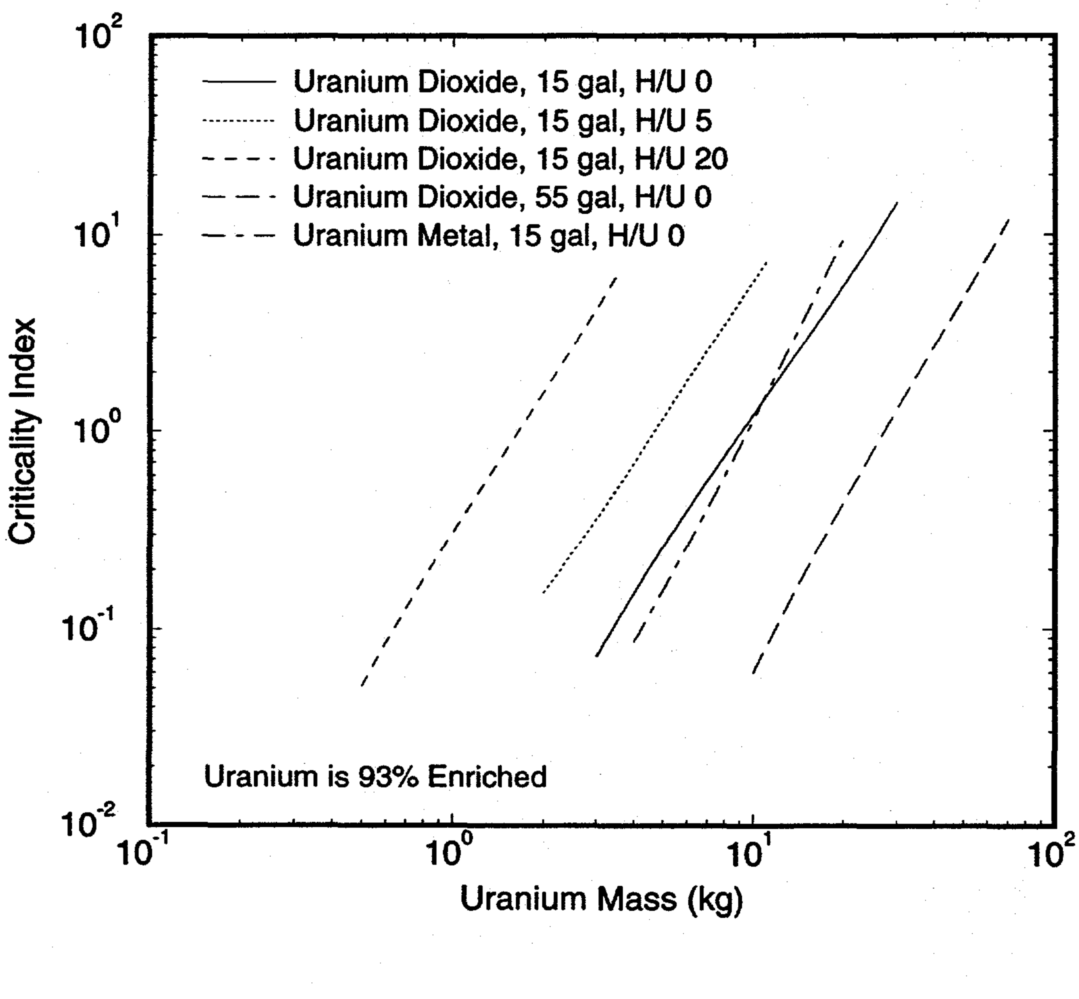

Figure 2. CIs for selected configurations.

isotopes), d) H/U ratio of the fissile material matrix, e) description of packaging material (from a list of standard packaging materials and configurations).

If the "standard" values for input are not appropriate for the container being characterized, the container is handled as an exception. For example, if the container is not one of the standard containers, the container dimensions will be requested by the interactive computer program. These dimensions are used to obtain a conservative CI from curves calculated for cubic arrays of material with optimum moderation. Any unit found to be outside the bounds of the standard container data or the cubic array data requires a separate analysis.

The interactive program analyzes the input and seeks the correct CI from a set of pre-calculated parametric curves. The program interpolates between data points and returns the most appropriate CI. The CI is printed along with a label, for immediate use by the criticality technician. The label can be laminated immediately and attached to the canister. The input, the name of the criticality technician, and the recommended CI are also saved in a data record on the computer for independent verification, quality records, and for review by the technician's supervisor or by auditors at a later date.

An accountability option keeps track of the CI sum at each storage location. The program database generates an up-to-date report for each storage location each time the inventory at that site is altered (i.e., containers transferred in or out).

CONCLUSIONS

This paper describes a method for criticality control at fissile material storage facilities. The method involves the use criticiality indices for storage canisters. The logic, methodology, and results for selected canisters have been presented. We also presented a concept for an interactive computer program that can be used by technicians in real time (using precalulated data) to select a Criticality Index (CI) for a container when it is delivered to or packaged at a site. Criticality safety is managed by tracking the CIs at each storage location and verifying that the cumulative CI is maintained at less than 50 (at each isolated storage location) as containers are transferred in and out.

REFERENCES

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