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EVALUATION OF CRITICALITY CRITERIA FOR CLASS II PACKAGES IN TRANSPORTATION*

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A panel knowledgeable in criticality and in transportation was convened in Vienna in 1962 and established by international concensus the criteria for Class II packages.[1] The basic criteria have remained essentially unchanged to this time. Control of criticality for Class II shipments is specifically control of the number of packages which are allowed in a vehicle or temporary storage area. This is accomplished by means of a transport index (TI) assigned to each package. The TI for a package is determined by multiplying the reciprocal of the allowable number, N_A, by 50. Thus, if carriers and temporary storage areas limit the aggregate TI to 50, no vehicle or area will have more than the allowable number of packages. Criticality control is provided even for commingling of shipments composed of different fissile materials provided the aggregate TI does not exceed 50.

The condition establishing the number of allowed undamaged packages is that 5 N_A in any arrangement closely reflected by water shall be subcritical. For packages damaged to the extent of approved tests, 2 N_A in any arrangement closely reflected by water with homogeneous hydrogenous moderation between and within packages consistent with tests in that amount which results in the greatest increase in reactivity shall be subcritical.

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The panel recognized concrete as a more effective reflector than water, but considered thick close-fitting reflection by concrete as not representing a realistic situation in the transport environment. Three-sided concrete reflection was proposed as a more probable occurrence at temporary storage location for shipments enroute and full water reflection was agreed upon as providing equivalent safety, being more amenable to evaluation and much easier to define.

A recent examination of these criteria substantiates the soundness of their bases and has indicated a convenient means for evaluating the nuclear criticality safety of packages in transportation.

Calculations, validated against critical experiments conducted with U(93.2) metal and typical insulating materials, used the KENO Monte Carlo code[2] in combination with the Hansen-Roach[3] sixteen group neutron cross section sets to examine ideal arrays under various reflector conditions. Initial conditions assumed air-spaced spherical units of U(93.2) metal, centered in cubic cells and arranged in cubic arrays reflected on six sides by water 200-mm-thick. The reflector was changed to the various conditions described in Table 1. The cubic arrays consisted of 0.072 m^3 (19 gals) cubic cells having air spaced spherical units centered in the cells. These data show the adequacy of evaluated mass limits for six-sided reflection to provide conservative limits for three-sided reflection by concrete. They also indicate a relative decrease in the effectiveness of concrete as a reflector replacing water for the three-sided reflector condition.

The calculations were repeated for a typical 6M specification container of equal volume. The outer container of the package was a drum of steel having a wall thickness of 1.2×10^{-3} m (0.048 in) and a height to diameter ratio of 1.6. The insulation was celotex at 225 kg/m^3 (15 lbs/ft^3). The inner container was of steel 6.35×10^{-3} m (0.25 in), having a capacity of 8×10^{-3} m^3 (2.1 gal) and a height to diameter ratio of 2.4. The calculated criticality of cubic arrays of these packages for the reflector conditions of Table 1 are presented in Table 2. Comparison of corresponding arrays in Tables 1 and 2 indicate a greatly reduced reflector effect because of the presence of packaging materials. In particular, for the three sided reflector condition, there is not only a reduced effect of concrete in place of water on the array reactivity, but the influence on the array reactivity diminishes with increasing numbers of packages.

It may be concluded that transportation criteria for criticality assessment of Class II packages have practical bases and that mass limits based on air-spaced units are suitable to use as mass limits for packages. Recommended mass limits for storage in water reflected arrays are contained in ANSI Standard[4] N16.5. Air-spaced spherical units of 44 different forms of fissile materials, uranium and plutonium oxides and metals, are specified as a function of number of units in arrays and of the cell volume. These specifications provide definition of mass equivalence among the materials, thus, the evaluation of a package with one form of fissile materials can serve to establish safety limits for the remaining 43 forms. Further, the use of these defined limits would substantiate the safety of commingling of different forms of materials. Additional conservatism, i.e., mass limits less than those for air-spaced units, appears unnecessary.

Table I. Mass in kg U(93.2) per Unit Required for Criticality as Air-Spaced Spheres Centered in 0.072 m^3 Cubic Cells Arranged in Cubic Arrays for Various Array Reflector Conditions

No. of Units in Cubic Array	Array Reflector Condition, Material, and Thickness (mm)			
	Six Sides		Three Sides	
	Water 200	Concrete 406	Water 200	Concrete 406
64	26.4	20.2	35.9	31.1
216	20.4	14.8	29.4	25.0
512	16.6	11.7	24.9	21.0

Table II. Mass in kg U(93.2) per Unit Required for Criticality of Cubic Arrays of a Typical 6 m Specification Container of 0.072 m^3 for Various Reflector Conditions

Number of Packages in Cubic Array	Array Reflector Condition, Material, and Thickness (mm)			
	Six Sides		Three Sides	
	Water 200	Concrete 406	Water 200	Concrete 406
64	30.6	28.3	33.0	30.2
216	27.3	25.9	27.9	27.3
512	25.1	23.9	25.4	24.8

REFERENCES

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3. G. E. Hansen and W. H. Roach, "Six and Sixteen Group Cross Sections for Fast and Intermediate Critical Assemblies," LAMS-2543 (1961).

4. "Guide for Nuclear Criticality Safety in the Storage of Fissile Materials," ANSI Standard N16.5 (1975).