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COMMENTS ON THE USE OF THE MONTE CARLO METHOD FOR CRITICALITY CALCULATIONS†

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As evidenced by recent papers given at Nuclear Criticality Safety Division meetings, the use of the Monte Carlo method has become a very popular computational tool. The ease of use has undoubtably been a primary reason for this popularity. This ease of use, however, may lead to a false sense of security when using the method. It is the purpose of this paper to offer some guidance on the effective use of the method and to provide some suggestions on how to avoid some of the pitfalls that can occur.

In order to minimize the statistical error per unit computer time, a number of modifications are made to the analog Monte Carlo procedure. In almost all cases these modifications can have "side effects" which may be undesirable and in some cases may lead to erroneous conclusions.

The most common technique used to minimize the error per unit time is the use of weighted tracking. When using weighted tracking, neutrons are not allowed to die by absorption. Instead, an initial weight is assigned, and the weight is reduced at each collision site by the absorption probability. In this procedure (described more fully in Ref. 1), a weight which we shall call WTLOW is chosen. When the neutron falls below

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this weight, Russian Roulette is played to determine if it dies or if it survives with a weight WTSUV. The choice of WTLOW and WTSUV have been shown to exhibit a minimum for a given combination of values[1]. The optimum choice of the value of the variables depends on a number cf factors. Fortunately, the "side effects" of choosing values of WTLOW between .02 and .3 and WTSUV between .2 and 1.0 seems only to be a variation in the computed statistical error and almost no effect on the computed k-eff. Unfortunately, when using adjoint biasing[2], values of WTLOW and WTSUV may be assigned outside this "safe" range for certain portions of the system being computed. The purpose of adjoint biasing is to minimize the computer time spent tracking neutrons in regions of low importance. The "side effect" observed when using the method correctly is the failure to accurately compute effects such as absorptions and leakage in these regions of low importance. By using values of WTLOW and WTSUV which are too high in the regions of low importance, the effect almost always will be to compute a k-eff which is too low. Care should be taken to stay on the low side when choosing and applying adjoint biasing parameters.

In the original paper on the use of differential albedos[3], a tendency of the method to overestimate k-eff in cases where the reflector face dimensions were too small was reported. Long[4], in a later paper, pointed out that the error can be quite large, particularly for array in which the fissile material touches the reflector face. Where applicable, the differential albedo can be a very effective saver of computer time. The "side effect" of this method has -een to overestimate k-eff for all cases observed. Theoretically, the case where this is not true may exist. When beginning a study using a material and configuration whose behavior is unfamiliar to the user, a safe practice would be to check the use of the differential albedo against actual tracking for a few representative cases.

Another area of concern when using the Monte Carlo method is determining whether adequate sampling in important regions has occurred. In a paper dealing with this subject[5], it was pointed out that it is possible to compute the wrong answer with no hint of trouble if only the k-eff's as a function of generation are observed. While no foolproof method to prevent this from occurring can be described for the general case, the user can minimize the failure to recognize the problem by observing activities, such as fission densities, in localized sections of the system. Significant differences in the fission density between regions of the system, particularly large regions with low fissions densities in a system with a small region with a high fission density, should be examined carefully for adequate sampling. Limiting the problem description to look at only a portion of the system often can provide valuable information.

An unresolved difficulty with Monte Carlo calculations which continues to cause concern is the inability to compute accurately the error estimates for the differential quantities (such as flux, fission densities, etc.) as a function of region and energy group[6]. While there is no indication of error in computing the differential quantities themselves, the standard assumption when computing the statistical error that the "sample estimates" are independent is often not valid. To be correct, the statistical error calculation must take into account the correlation between "sample estimates". There is currently no general method to do this. While research on this problem continues, error estimates computed by standard techniques should be used with caution.

The Monte Carlo method provides the criticality safety specialist a rigorous, easy-to-use, technique for evaluating many problems. A good understanding of the method and its limitations is essential if the user is to escape the pitfalls which can lead to erroneous results. Undetected, these erroneous results could lead to erroneous safety recommendations.

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