3.1 Weather Sequence Sampling Method

The atmospheric dispersion of radioactive material from a postulated accident depends on the weather from the start of the accident through a period of tens to hundreds of hours following the accident. The character of the accident together with the weather coincident with and immediately following the accident determines the transport and dispersion process that follows, and thus, the magnitude of the consequences that will result. Since the weather that could occur coincident with the accident is diverse, representative weather data sequences are selected as input to the dispersion model to reflect the dependence of the transport and dispersion process on the site weather. The selection process is done by means of sampling techniques from a full year of hourly weather data characteristic of the plant site. The CRAC2 model allows a choice between four sampling techniques: (1) random sampling; (2) stratified random sampling; (3) stratified sampling; and (4) importance sampling.* Whatever sampling technique is chosen, the goal is to realistically represent the distribution of dispersion model results as a function of the site characteristic weather.

The first three of these sampling methods were included in the original CRAC model. A description of these three methods can be found in Section 13 of Appendix VI of the Reactor Safety Study [1]. The sampling method recommended for use in CRAC, and used in most CRAC applications, is the stratified sampling method. The stratified sampling method ensures a complete coverage of diurnal, seasonal, and four day cycles without the statistical noise of methods that utilize random sampling [1]. Sensitivity studies performed using CRAC indicate considerable variability in predicted results attributable to sampling by this method, however [2]. The importance sampling method available in CRAC2 greatly reduces the variability due to sampling observed with any of these three other techniques.

The basis of the importance sampling method is an initial assessment of the full set of hourly weather data. This initial assessment provides information about the types of weather sequences contained in the data and the frequency of these weather types. With this information, weather sequences can be sampled to reflect the full year's weather data. This ensures representation of each type of weather sequence, those important to realistic representation of the weather data set, and those important to the occurrence of the most serious accident consequences.

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*The sampling methods described in this section are implemented in subroutines BINMET and RANBIN and parts of MAIN and DAMAGE.

NUCLEAR REGULATORY COMMISSION

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In the matter of Philadelphia Electric

Staff ____ IDENTIFIED ✓

Applicant ✓ RECEIVED ____

Intervenor ____ REJECTED ____

Cont'g Off'r ____

Contractor ____ DATE 5/22/84

Other ____ Witness ____

Reporter Ann Bailey

The weather data assessment is done by sorting it into weather categories, categories that provide a realistic representation of the year's weather without overlooking those kinds of weather that are instrumental in producing major consequence impacts. A set of 29 weather categories has been selected for the CRAC2 model to reflect these requirements.

Heuristic judgment played a significant role in the choice of the 29 categories into which the data is sorted. Experience with the CRAC model revealed the impact of weather events on the consequence magnitudes resulting from the accident. Given a postulated large accident, large numbers of early deaths and injuries are normally associated with relatively low probability weather events such as rainfall or wind speed slowdowns within 30 miles of the plant site or with stable weather and moderate wind speeds at the start of the release. In CRAC2 these weather data types have been selected to be among the 29 categories utilized in the assessment process.

The 29 categories are described in Table 3.1-1. An example of weather data sorted into these categories is shown in Table 3.1-2. The weather data for this example represent one year of meteorological data for the City of New York. The entire year of data, 8760 hourly recordings, are sorted into the 29 weather categories. Each sequence is examined to determine (1) the first occurrence of rain within 30 miles of the site, or (2) the first occurrence of a wind speed slowdown within 30 miles of the accident site, or (3) the stability category and wind speed at the start of the sequence. The first of these conditions that is satisfied by the sequence determines the weather category to which it is assigned. Following the assessment process, the start hour of each weather sequence will have been assigned to one and only one weather category. Each of the weather categories then includes a set of weather sequences representing the corresponding weather type. The probability of occurrence of that weather type is the ratio of the total number of weather sequences in the category to the total number of sequences in the year's weather data set.

The sampling procedure now has two key items of information available to it: (1) the category of each weather sequence, and (2) the probability of occurrence of each category of weather. A sample consists of a set of weather sequences selected from each of the categories. Normally, four sequences are selected from each category by the "Latin hypercube" sampling scheme [3]. With this sampling method, random samples are drawn from sets evenly spaced within the weather category. This assures that the model uses an even representation of the weather data over the full year. Assume that a weather category contains N_i weather sequences and that K_i of the sequences are to be selected as samples, $0<K_i\leq N_i$. The N_i weather sequences are then grouped into K_i evenly spaced sets, $S_1, \ldots, S_{K_i}$.

Set S_j contains

$$\left[j \left(\frac{N_i}{K_i} \right) \right] - \left[(j-1) \left(\frac{N_i}{K_i} \right) \right] *$$

weather sequences**. One weather sequence is then randomly selected from each set. Since the total number of weather sequences selected from category i would be K_i, the total number of sequences selected from all 29 of the categories would be

$$\sum_{i=1}^{29} K_i$$

The assigned probability for a meteorological sequence sampled from category i would be

$$\frac{N_i/K_i}{\sum_{i=1}^{29} N_i}$$

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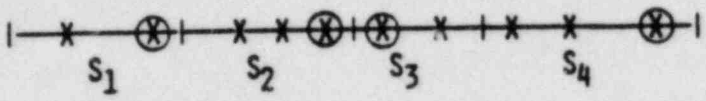
*The notation

$$\left[j \left(\frac{N_i}{K_i} \right) \right]$$

means the largest integer contained in the number $j\left(\frac{N_i}{K_i} \right)$.

**Since the N_i weather sequences of category i have a natural order determined by the initial time of each of the weather sequences, the evenly spaced sets S_1, ..., S_{K_i} are ordered; i.e., S_1 consists of the first $[N_i/K_i]$ elements of category i, S_2 consists of the next $\left\{ \left[2(N_i/K_i) \right] - \left[N_i/K_i \right] \right\}$ elements of category i, and so on.

Consider a simple example. Let category i contain 10 weather sequences from which four are to be sampled. Then $N_i = 10$, $K_i = 4$, and S_1 contains two sequences, S_2 contains three sequences, S_3 contains two sequences, and S_4 contains three sequences. One sequence is randomly drawn from each set S_j, $j = 1, \ldots, 4$, as in the figure below.



The assigned probability for a sequence chosen from this category would be $\frac{10/4}{8760}$, since CRAC2 requires the year's weather data to contain 8760 sequences.

The technique of importance sampling described here selects weather sequences that accurately represent the range of weather sequences in the weather data and their probability of occurrence, and assures selection of sequences that yield severe consequences. The inclusion of these severe accident consequences and of weather sequence probabilities representing each category is key in the realistic representation of the probability distribution function of consequences. The technique is simple and does not require significant additional computation time compared to other sampling methods.

References for Section 3.1

1. WASH-1400 (1975), Reactor Safety Study, Appendix VI: Calculation of Reactor Accident Consequences, NUREG75/014, US Nuclear Regulatory Commission.

2. Ritchie, L. T. , Aldrich, D. C. and Blond, R. M. (1981), "Weather Sequence Sampling for Risk Calculations," Transactions of the American Nuclear Society, Vol. 38.

3. Iman, R. L. and Conover, W. J. (1982), Short Course on Sensitivity Analysis Techniques, NUREG/CR-2350, SAND81-1978.