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AN INTEGRAL APPROACH FOR CALCULATING UNCERTAINTIES IN CONSEQUENCES FROM NUCLEAR REACTOR ACCIDENTS*

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The Reactor Safety Study (RSS) presented the first comprehensive assessment of the risk to society from nuclear power plant accidents. The CRAC model was developed as part of the RSS to calculate the health and economic consequences of accidental releases of radionuclides into the atmosphere [1]. Following RSS, several other consequence models were developed [2]. CRAC2, an improvement over CRAC, became available in 1982 [3]. This was followed by the development of the MELCOR Accident Consequence Code System (MACCS) [4].

CRAC2 and MACCS are used as the basis for severe accident risk assessments by the U.S. Nuclear Regulatory Commission. However, uncertainties in estimated consequences are large and have not been quantified as part of the recently published Reactor Risk Reference Document [5]. Due to major differences in the predictions of these detailed and complex computer models, a need exists for an independent capability to address modeling and health consequence assumptions embodied in the various models. This verification tool should be efficient and sufficiently accurate in order to carry out sensitivity and uncertainty analyses.

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This paper presents a Personal Computer-based model that uses an integral approach for calculation of early off-site consequences resulting from nuclear power plant accidents. The computing time requirements for a typical calculation on a mainframe computer using this model are two orders of magnitude lower than those of CRAC2 and MACCS codes, thus providing a valuable tool for sensitivity and uncertainty studies. The model predicts time-integrated air concentration of each radionuclide at any location from release as a function of time-integrated source strength using the Gaussian plume model [6]. The concentration can be calculated at the centerline of a Gaussian profile or, optionally, as an average over the cross-section based on a top-hat distribution. The solution procedure involves direct analytic integration of air concentration equations over time and position. This is different from the differential approach currently used in CRAC2 and MACCS codes.

The present model uses simplified meteorology. Dispersion parameters are calculated from exponential fits to the Pasquill-Gifford curves for six atmospheric stability classes designated A to F, and from an approximation as indicated in Reg. guide 1.145 for the seventh stability class G (extremely stable).

Following the approach in CRAC2 and MACCS, special features are modeled which effectively modify the basic Gaussian plume formulation. They include dry and wet deposition, radioactive decay and daughter buildup, reactor building wake effects on plume mixing, the inversion lid effect, the effect of plume rise due to buoyancy or momentum of the released activity, release duration, and grass height. The building wake correction to the dispersion parameters is derived from Reference [6]. Also included are options for CRAC2 and MACCS building wake effects in order to facilitate sensitivity and uncertainty studies.

Once the air and ground concentrations of the radionuclide are estimated, the early dose to an individual is calculated via three pathways: cloudshine, short-term groundshine, and inhalation. The dose calculations are performed in the same manner as CRAC2 or MACCS depending on which health effects model is chosen as the input option. The health effects models in both CRAC2 and MACCS are included in the code for calculation of early fatalities and injuries.

Figure 1 illustrates results of a benchmark comparison of the present integral model with CRAC2 and MACCS differential models, respectively, assuming identical dispersion parameters and building wake effects in each case. Excellent agreement is observed.

As a part of sensitivity and uncertainty analyses with this model, several constant weather cases for a postulated high-release accident at a typical PWR [7] were calculated using in turn the dispersion parameter formulations as used by MACCS, CRAC2, and the present model. The spread in dispersion parameters is no more than 30% at 800m from release location. Figure 2 shows the total marrow dose versus distance for stability class D and an average wind speed of 5 m/s. The spread in calculated dose is seen to be about 100% at 800m, diminishing further away. Similar results were found for other stability classes and wind speeds.

The impact of this uncertainty on risk of early fatalities was only apparent beyond 3 miles using the MACCS health effects model. However, for low releases, this uncertainty will have a significant impact on the calculated risk even within a mile from the reactor.

In conclusion, an efficient, accurate, and flexible tool has been developed that permits a detailed uncertainty analysis for off-site consequences, using a methodology similar to the QUASAR approach [8] developed for source term uncertainty studies.

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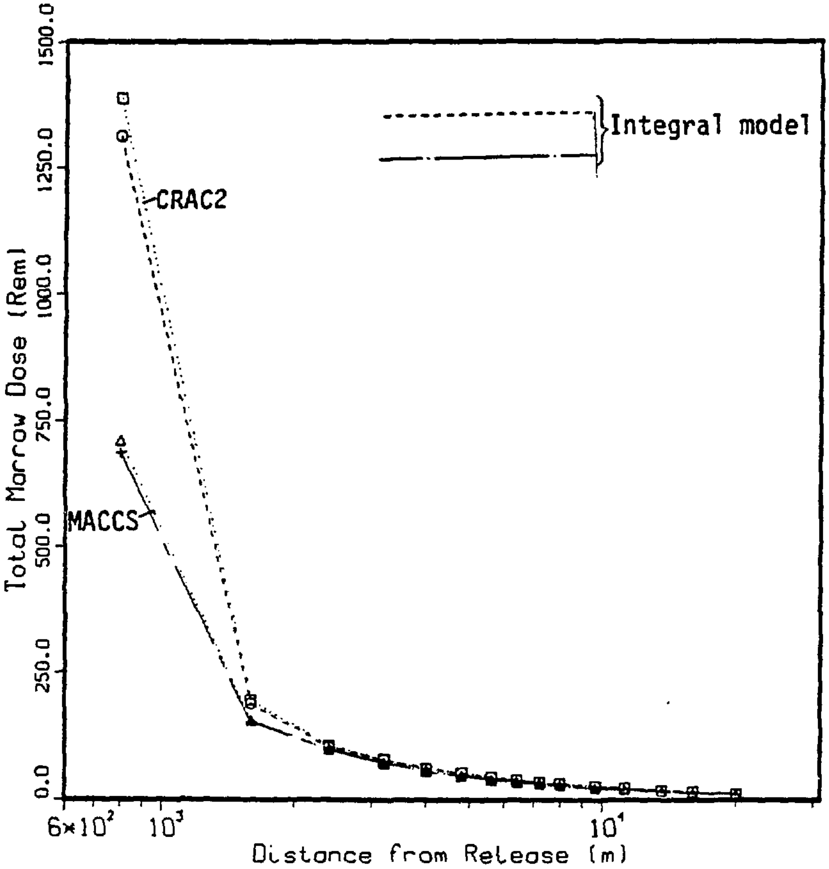

Figure 1 Benchmark comparison of integral model with CRAC2 and MACCS.

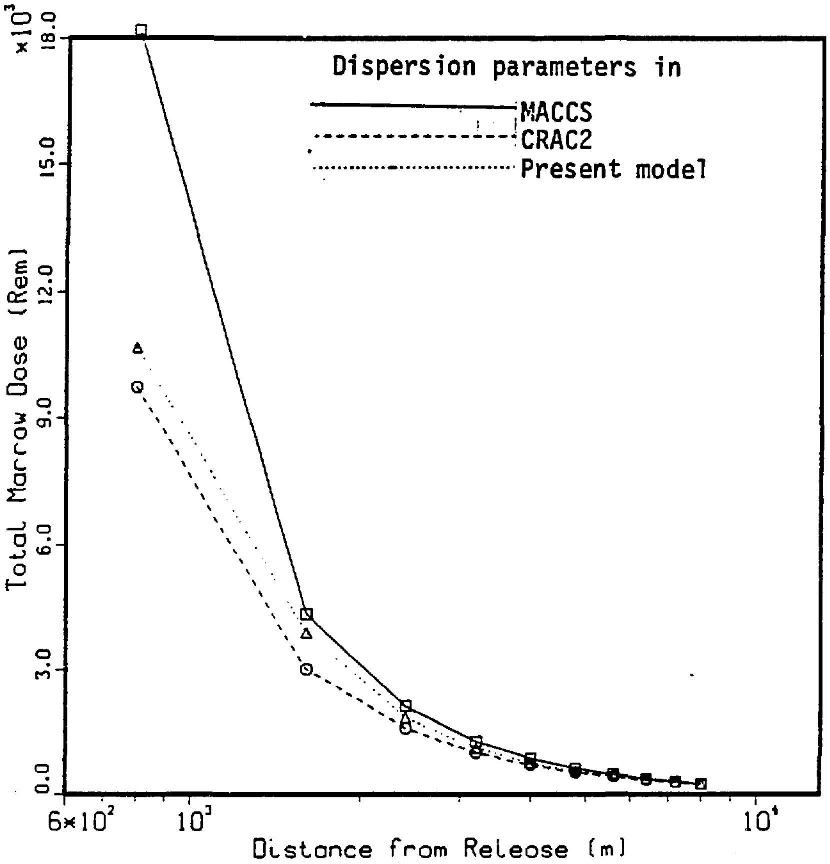

Figure 2 Effect of dispersion parameters on total marrow dose for class D, wind speed 5 m/s.