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IMPACT OF SOURCE TERMS ON DISTANCES TO WHICH REACTOR-ACCIDENT CONSEQUENCES OCCUR

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Estimates of the distances over which reactor accident consequences might occur are important for development of siting criteria and for emergency response planning. This paper summarizes the results of a series of CRAC2[1] calculations performed to estimate these distances[2]. Because of the current controversy concerning the magnitude of source terms for severe accidents, the impact of source term reductions upon distance estimates is also examined.

A spectrum of five representative source terms (SST1-SST5)[3] was used for all calculations. The SST1-SST3 releases typify core melt accidents ranging in severity from accidents involving loss of all installed safety features with subsequent breach of containment to accidents where the containment fails by melt-through with other release-mitigating systems functioning. The SST4 and SST5 source terms are for gap release accidents.

All calculations assumed an 1120 MW(e) pressurized water reactor and no emergency response. Each calculation used approximately 100 different weather sequences taken from 1 of 29 meteorological records[4]. For each weather sequence, CRAC2 can calculate the maximum distances at which selected consequences are observed and EPA Protective Action Guides[5] (PAGs) exceeded.*

*A PAG is defined as the "projected" dose to an individual in the general public which warrants the initiation of emergency protective actions.

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By using an appropriate sample of weather sequences, Complimentary Cumulative Distribution Functions (CCDFs) of distances can be constructed. Comparison of results for the 29 meteorological records showed that distance CCDFs are largely insensitive to differences between records.

Table 1 presents estimates for the SST1-SST3 source terms of (1) distances to which early fatalities and injuries might occur, (2) distances to which contaminated property might have to be interdicted for periods of 10 or more years, and (3) distances to which PAGs might be exceeded. Results are not presented for the SST4 and SST5 source terms because significant offsite consequences did not result for these releases.[3] The mean, 99th percentile, and peak distances presented in Table 1 summarize the large number of distance distributions calculated using the 29 meteorologies. The fatality and injury distances presented could be reduced by any effective emergency response actions.

Table 1 suggests that: (1) for severe core melt accidents, early fatalities would generally not occur beyond about 15 miles and in the worst case would be confined to about 25 miles, while early injuries would probably be confined to downwind distances of about 50 miles; (2) for smaller core melt accidents (on the order of SST2 in severity), early fatalities would be confined to about 2 miles, and injuries and land interdiction to about 7 miles; and (3) for accidents on the order of SST3 in severity, PAGs would probably not be exceeded beyond a few miles.

Recent reviews[6,7] of accident phenomenology indicate that source terms for severe reactor accidents may be overconservative. The impact of source term reductions on consequences has been examined by Alpert[3]. To investigate the impact of source term reductions on distances to which consequences occur, an additional series of calculations was performed for the SST1 release reduced by factors of 2, 10, 20, and 100 using a single meteorological record. Table 2 presents the results and shows that reductions in source term substantially reduce distances to which selected consequences might be observed. An order of magnitude reduction in the SST1 release reduced the peak fatal distance from about 20 miles to 5 miles while a two order of magnitude reduction reduced the peak to 1 mile. Similar reductions are shown for early injuries and land interdiction distances.

In summary, this paper provides characteristic distances to which selected consequences might occur for a spectrum of source terms. In addition, consequence distances for severe reactor accidents were shown to be quite sensitive to source term magnitude. The resolution of such uncertainties could, therefore, have an impact on emergency response planning and reactor siting.

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Table 1. Summary of Distances for Consequence*

Source Term	Consequence	Distance (mi) Mean†	99%†	Peak Calculated†
SST1	Early Fatalities	<5	≲15	<25
	Early Injuries	~10	~30	≳50
	Land Interdiction	~20	>50	>50
	PAGs††	≳50	>50	>50
SST2	Early Fatalities	~0.5	<2	≲2
	Early Injuries	<2	<5	~5
	Land Interdiction	<2	~7	~10
	PAGs††	≲20	~20	<50
SST3	PAGs††	≲0.5	<2	<3

*These distances are for a 3412 MW(t) PWR which is comparable in size to many of the most recently sited nuclear reactors.

†Mean distances are the average of the probability distributions of distance; 99 percent distances refer to those beyond which a consequence or dose is calculated to occur in 1 in 100 accidents; and the peaks represent the largest distances calculated.

††A PAG is defined as the "projected" dose to an individual in the general public which warrants the initiation of emergency protective actions. PAGs range from 1 to 5 rem for whole body exposure and from 5 to 25 rem for projected dose to the thyroid.

Table 2. Sensitivity of Fatal, Injury, and Interdiction Distances to Release Magnitude

Assumptions: New York City Meteorology, 3412 MW(t) PWR, and No Emergency Response

Accident Release	Fatal Distance (mi)			Injury Distance (mi)			Interdiction Distance (mi)		
	Mean	99%†	Peak	Mean	99%†	Peak	Mean	99%†	Peak
SST1	3.9	12	18	11	35	50	19	55	85
1/2 SST1*	2.5	10	18	7.0	20	25	14	45	50
1/10 SST1*	0.9	2.2	5.0	2.8	10	18	5.5	18	25
1/20 SST1*	0.5	2.0	2.0	1.9	7.0	10	3.6	12	18
1/100 SST1*	~0	1.0	1.0	0.9	4.0	5.0	1.1	10	10

*Release fractions reduced for all isotopes except noble gases.
†The 99 percent distances refer to those beyond which a consequence is calculated to occur in 1 in 100 accidents.