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UNCERTAINTIES IN SOURCE TERM ESTIMATES FOR A STATION BLACKOUT ACCIDENT IN A BWR WITH MARK I CONTAINMENT*

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A methodology for Quantification and Uncertainty Analysis of Source Terms for Severe Accident in Light Water Reactors (QUASAR) has been developed and discussed in References [1] and [2]. The objectives of the QUASAR program are (1) to develop a framework for performing an uncertainty evaluation of the input parameters of the phenomenological models used in the Source Term Code Package (STCP)[3], and (2) to quantify the uncertainties in certain phenomenological aspects of source terms (that are not modelled by STCP) using state-of-the-art methods.

The QUASAR methodology consists of (1) screening sensitivity analysis, where the most sensitive input variables are selected for detailed uncertainty analysis, (2) uncertainty analysis, where probability density functions (PDFs) are established for the parameters identified by the screening stage and

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propagated through the codes to obtain PDFs for the outputs (i.e., release fractions to the environment), and (3) distribution sensitivity analysis, which is performed to determine the sensitivity of the output PDFs to the input PDFs.

Extensive calculations have been performed with each constituent code of the STCP through Monte Carlo sampling of most of the input parameters (about 100 parameters) permitting wide parameter variations with assumed uniform/log-uniform distributions. Selected outputs of each code were then statistically regressed onto the inputs. Both Partial and Standardized Rank Correlation Coefficients (PRCC and SRCC, respectively) were calculated as a function of time and extensive scatterplots were produced in order to ascertain the most sensitive STCP input parameters. These parameters are listed in Table 1.

The uncertainties associated with the most sensitive parameters listed in Table 1 were characterized using the guidance provided by expert reviewers together with methods based on information theory.[4]

These uncertainty distributions were then propagated through the STCP using 100 Latin Hypercube Samples (LHS) with appropriate correlations between selected parameters.

The 100 LHS vectors cover a wide range of parameters associated with reactor core meltdown, fission product release, containment loading and performance.

In this paper, attention is limited to a single accident progression sequence, namely a station blackout accident in a BWR with a Mark I containment building. Identified as an important accident in the draft version of NUREG-1150 [5] a station blackout involves loss of both off-site power and DC power resulting in failure of the diesels to start and in the unavailability of the high pressure injection and core isolation cooling systems.

Figure 1 illustrates the calculated uncertainties (Probability Density Functions) associated with the radiological releases into the environment for the nine fission product groups at 10 hours following the initiation of core-concrete interactions. Also shown are the results of the STCP base case simulation. It is seen that the uncertainties in the calculated releases are significant.

The calculated uncertainties in Iodine and Cesium release are for the most part governed by the uncertainties in transient release (in-vessel) and in the CsI chemical activity coefficient during core-concrete interactions, and to a lesser degree by the core slump criterion and the containment leakage threshold.

The uncertainties in Te, Sr, Ru, La, Ce, and Ba releases are governed by the uncertainties in the chemical activity coefficients and the containment rupture pressure threshold. The apparent reduced uncertainty for the La group in comparison to other refractory groups is due to the assumed reference state of Nb in the STCP/Mod1 Version of VANESA code, which has been corrected in more recent versions of the VANESA code. On the other hand, the uncertainty in the release of noble gases is only governed by the containment rupture pressure threshold.

References

1. C. Park and M. Khatib-Rahbar, "Quantification and Uncertainty Analysis of Source Terms for Severe Accidents in LWRs (QUASAR), Part 1: Methodology and Program Plan," NUREG/CR-4688 (June 1986).

2. M. Khatib-Rahbar et al., "QUASAR: A Methodology for Quantification of Uncertainties in Severe Accident Source Terms", Trans. Am. Nucl. Soc. 53, 354 (1986).

3. J.A. Gieseke, et al., "Source Term Code Package: A User's Guide (Mod 1)", NUREG/CR-4587 (July 1986).

4. S. Unwin et al., "The Formulation of Probability Distributions for the QUASAR Program," BNL Technical Report A-3286 (August 1987).

5. "Reactor Risk Reference Document", NUREG-1150, Draft (February 1987).

Table 1 Most Sensitive Input Parameters for STCP Together With Their Respective Ranges and Probability Density Functions (Uncertainty Distributions)

Code	Parameter	Definition	Range (Percentile)				Cordinate Basis
			Min.	5th	95th	Max.	
MARCH	DPART (m)	Debris particle size (in-vessel)	10^{-3}	10^{-3}	0.2	0.2	Log-Uniform
	FHEAD	Fraction of bottom head CCI	0	0.01	1.0	1.0	Uniform
	FDROP	Core slump criterion	0	0.01	0.75	0.75	Uniform
	$\Delta H_f^{(1)}$ (MJ/m^3)	Volumetric latent heat of fuel	410	410	2420	2420	Uniform
	RHOCU (MJ/m^3°k)	Volumetric heat capacity of fuel	2.96	2.96	4.44	4.44	Uniform
	TMELT (°K)	Fuel melting temperature	2120	2200	2980	3110	Uniform
	WGRID (kg)	Mass of grid plate	3.4×10^4	3.4×10^4	4.8×10^4	3.4×10^4	Uniform
	P_1(Pa)	Containment leakage pressure threshold	1.0×10^5	4.1×10^5	1.4x10	1.5×10^6	Uniform
	P_r(Pa)	Containment rupture pressure threshold	4.9×10^5	8.9×10^5	1.6x10	2.5×10^6	Uniform
	$C^{(2)}$(mm^2/Pa)	Proportionality constant between Drywell leakage area and drywell pressure	4.7×10^{-2}	4.7×10^{-2}	6.1×10^{-2}	6.1×10^{-2}	Uniform
CORSOR-M	Cs, I, Te$^{(3)}$	Multiplier for the pre-exponential factor	10^{-3}	10^{-2}	2	10	Log-Uniform
	Ba, Sr$^{(3)}$	" " " "	10^{-3}	10^{-2}	10	10^2	Log-Uniform
	Ru, Rh, Pd$^{(3)}$	" " " "	10^{-1}	1	10^2	10^3	Log-Uniform
	Mn, Cr$^{(3)}$	" " " "	10^{-3}	10^{-2}	10	10^2	Log-Uniform
TRAPMELT	GAMMA	Collision shape factor	1.0	1.2	10	15	Uniform
	VTE (mm/sec)	Te deposition velocity	0	0.1	90	100	Uniform
	PDEN (kg/m^3)	Aerosol Density	1000	1000	8000	8000	Uniform
SPARC	DIAM (mm)	Mean bubble diameter	3	4	12	20	Uniform
	RATIO	Bubble aspect ratio	1	1.25	1.5	4	Uniform
	VSWARM (m/sec)	Bubble swarm rise velocity	0.2	0.25	1.0	1.2	Uniform
CORCON	RW (m)	Corium spread (radius of corium pool)	3	5	6.5	6.5	Uniform
	TDC (°k)	Concrete decomposition temperature	1200	1690	1875	1950	Uniform
	EVAP	Weight % of concrete evaporable water	2.3	3.9	7.8	8.0	Uniform
	EM	Metal phase emmissivity	0.2	0.5	1.0	1.0	Uniform
	ES	Emmissivity of Surroundings	0.1	0.1	1.0	1.0	Uniform
VANESA	SIGMA	Aerosol size distribution parameter	1.5	1.5	3.2	3.2	Uniform
	NC	Number concentration of condensed aerosol	10^7	10^7	10^9	10^9	Log-Uniform
	Mo, Te, CsI	Activity coefficient	10^{-4}	10^{-3}	1	10	Log-Uniform
	BaO, SrO$^{(2)}$	" "	10^{-4}	10^{-3}	1	10	Log-Uniform
	La_2O_3, $CeO_2^{(2)}$	" "	10^{-4}	10^{-3}	1	10	Log-Uniform
NAUA	GAMMA	Collision shape factor	1.0	1.0	10	10	Uniform
	CHI	Dynamic shape factor	1.0	1.0	5.0	10	Uniform

(1) With a correlation coefficient of 0.9 with TMELT
(2) $A=C(P-P_1)$
(3) With a correlation coefficient of 0.9

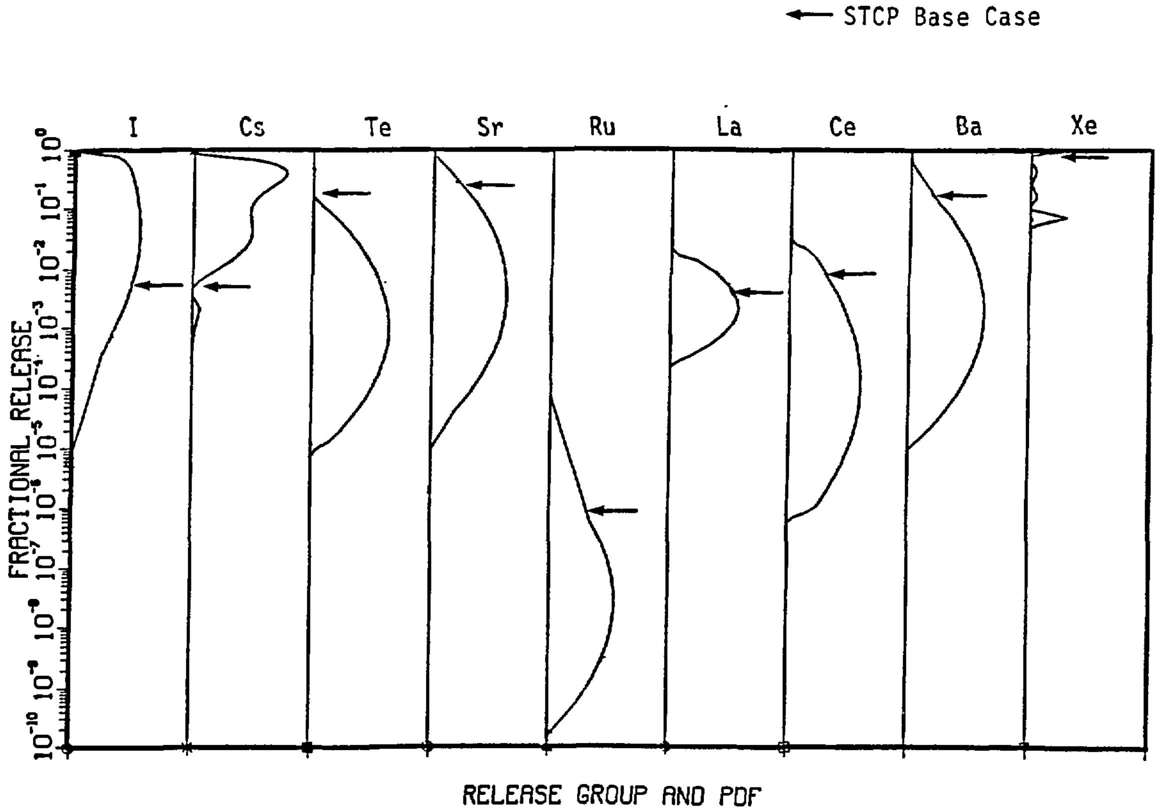

Figure 1 Calculated uncertainties in radiological releases into the environment for a station blackout sequence in a BWR with Mark I containment.