NRC FORM 189 (3-81)

U.S. NUCLEAR REGULATORY COMMISSION

PROJECT AND BUDGET PROPOSAL FOR NRC WORK

DATE OF PROPOSAL: 8/1/83

☐ NEW

☒ REVISION NO.

PROJECT TITLE: Quantitative Uncertainty Estimation for the Source Term

FIN NUMBER: A-1383

NRC OFFICE:

NRC B&R NUMBER:

DOE CONTRACTOR: Sandia National Laboratories

CONTRACTOR ACCOUNT NUMBER: DE-AC04-76DP00789

SITE: Albuquerque, NM 87185

DOE B&R NUMBER:

COGNIZANT PERSONNEL	ORGANIZATION	FTS PHONE NUMBER
NRC PROJECT MANAGER M. W. Jankowski	NRC/RES	443-5911
OTHER NRC TECHNICAL STAFF		
DOE PROJECT MANAGER R. N. Holton	DOE/ERT	846-5208
CONTRACTOR—PROJECT MANAGER A. W. Snyder	SNL/6400	844-8203
J. V. Walker	SNL/6420	844-2876
PRINCIPAL INVESTIGATOR(S) D. A. Powers	SNL/6422	844-4392
R. J. Lipinski	SNL/6425	844-5092
D. C. Aldrich	SNL/6415	844-9164
L. M. Griesmeyer	SNL/6415	846-0808

PERIOD OF PERFORMANCE
STARTING DATE: 10/1/83
COMPLETION DATE: 9/30/84

STAFF YEARS OF EFFORT (Round to nearest tenth of a year)	FY 83	FY 84	FY 85	FY 86	FY 87
Direct Scientific/Technical	1.2	1.2			
Other Direct (Graded)					
TOTAL DIRECT STAFF YEARS	1.2	1.2			
COST PROPOSAL					
Direct Salaries	135	145			
Material and Services (Excluding ADP)	20	10			
ADP Support	30	30			
Subcontracts					
Travel Expenses — Foreign					
Travel Expenses — Domestic	5	5			
Indirect Labor Costs					
Other (Specify)					
General and Administrative (%)					
TOTAL OPERATING COST	190	190			
CAPITAL EQUIPMENT FIN CHARGED:					
TOTAL PROJECT COST					

FY 84

MONTHLY FORECAST EXPENSE

OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
64	63	63	0	0	0
APRIL	**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEPTEMBER**
0	0	0	0	0	0

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PROJECT AND BUDGET PROPOSAL FOR NRC WORK

FIN NUMBER: A-1383

DATE: 08/01/83

PROJECT TITLE

Quantitative Uncertainty Estimation for the Source Term

OGE PROPOSING ORGANIZATION

Sandia National Laboratories

FORECAST MILESTONE CHART: Scheduled to Start – △ – Completed (Shown in Quarter Year)

PROVIDE ESTIMATED DOLLAR COST FOR EACH TASK FOR EACH FISCAL YEAR

TASK		FY 83				FY 84				FY 85				FY 86				FY 87			
		1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Determine Uncertainty	SCHEDULE			△		→															
	COST			190				190													
	SCHEDULE																				
	COST																				
	SCHEDULE																				
	COST																				
	SCHEDULE																				
	COST																				
	SCHEDULE																				
	COST																				
TOTAL ESTIMATED PROJECT COST				190				190													

PROJECT DESCRIPTION: (Provide narrative descriptions of the following topics in the order listed. Attach on plain paper to the NRC Form 189. If an item is not applicable, so state.)

1. OBJECTIVE OF PROPOSED WORK
2. SUMMARY OF PRIOR EFFORTS
3. WORK TO BE PERFORMED AND EXPECTED RESULTS
4. DESCRIPTION OF ANY FOLLOW-ON EFFORTS
5. RELATIONSHIP TO OTHER PROJECTS
6. REPORTING SCHEDULE
7. SUBCONTRACTOR INFORMATION
8. LIST NEW CAPITAL EQUIPMENT REQUIRED
9. DESCRIBE SPECIAL FACILITIES REQUIRED
10. CONFLICT OF INTEREST INFORMATION

SEE NRC MANUAL CHAPTER 1102 FOR ADDITIONAL INFORMATION

APPROVAL AUTHORITY—SIGNATURE

Donald Powers

DATE

6422 6420 6400 6000

1. Objective of Proposed Work

The objective of this program is to provide a scoping estimate of the uncertainty associated with the radiological source term determined by the present calculational methods being developed in the NRC's Interim Source Term Study. Uncertainty in predictions of these calculational methods is caused by input uncertainties and by inadequacies or omissions in the models of severe reactor accident phenomena.

The first objective of the program is to estimate the uncertainty caused by different, yet reasonable, assumptions concerning input to the codes used to predict the severe accident source term. The second objective of the program is to estimate the overall uncertainty range of predictions caused by inadequate models and omitted phenomena as well as uncertainties in input to the computer codes.

The intention of this work is to quickly provide a scoping estimate of uncertainty to be associated with the source term estimates. The uncertainty estimates produced in this program will be of considerable aid in the interpretation of findings of the Interim Source Term Study.

2. Summary of Prior Efforts

No prior efforts have been made in this particular program. However, much work has been performed by the involved researchers in related programs. The peer reviews of the BMI-2104 drafts have raised a number of sources of uncertainty. The MELCOR program has recently reviewed the important phenomena involved in severe accidents and how to model them. The SAUNA study has identified a large number of uncertainties in severe accident progression. The code validation study at Oak Ridge National Laboratory addresses uncertainties in the codes themselves. The SARRP Phenomena Assessment Task Force is addressing uncertainties in the phenomena of severe accidents. These past and ongoing efforts have laid a broad foundation for the present study which allows its completion in a timely manner.

3. Work to be Performed and Expected Results

The Interim Source Term Study is being sponsored by the U. S. Nuclear Regulatory Commission to determine if improvements in the understanding of the fission product source term during severe accidents will alter source term estimates made in the Reactor Safety Study. Improved understanding of physical and chemical processes during severe reactor accidents has been obtained as a result of much research since the Reactor Safety Study. This understanding has led to the development of

sophisticated computer models of severe reactor accidents. A key precept of the Interim Source Term Study is to use these computer models to provide an integrated mechanistic estimate of the potential fission product release of severe accidents. A consequence of this method is that fission product and aerosol release predictions are unique consequences of the phenomena that arise in severe reactor accidents.

Improved though they may be, the computer models available for source term predictions are not perfect. Some uncertainty must be attached to the predictions from these codes. The uncertainty is caused by the uncertainty in the inputs and by inadequacies or omissions in the codes. The first objective of the program is to estimate the uncertainty caused by different, yet reasonable, assumptions concerning input to the codes used to predict the severe accident source term. The codes used for the Interim Source Term Study are MARCH, MERGE, CORSOR, TRAP-MELT, CORCON, VANESA, NAUA, and SPARC. They will be the basis for this study. The second objective of the program is to estimate the overall uncertainty range of predictions caused by inadequate models and omitted phenomena as well as uncertainties in input to the computer codes. The intention of this work is to quickly provide a scoping estimate of the uncertainty to be associated with the source term estimates.

The quantitative determination of the code uncertainty and the overall uncertainty will be the primary work performed in this study. The determination process will closely follow the procedure suggested in chapter 12 of the PRA Procedures Guide (NUREG/CR-2300) for evaluating PRA uncertainty. An overview of the expected application of that procedure is as follows:

1. "Determine level of analysis to be performed." The analysis will be quantitative and will quickly provide a scoping estimate of the source term uncertainty.

2. "Select treatment and depth of analysis for the uncertainties to be included." Both code input and modeling uncertainties will be considered. Treatment of the completeness uncertainty will be done only with respect to known phenomena that are presently omitted from the codes. For the code input uncertainty determination, MARCH, MERGE, CORCOR, TRAP-MELT, CONTAIN, VANESA, and NAUA will be used (either at SNL or remotely at INEL).

3. "Select parts of the PRA to be included in the analysis." Not applicable.

4. "Identify sources of uncertainty." The SAUNA study has identified a large number of phenomenological uncertainties in a severe accident sequence. The peer reviews of the BMI-2104 drafts have also suggested sources of uncertainties. Other studies which have revealed potential uncertainties are listed in headings 2 and 5 of this proposal.

5. "Decide on Statistical Framework." Since this is not a PRA, probability distributions will not be used. Instead, reasonable ranges for the important source uncertainties will be estimated and then combined and propagated to determine an uncertainty range in the source term.

6. "(Optionally) perform sensitivity analysis." Existing and ongoing sensitivity studies for the codes used in the Interim Source Term Study will be used for guidance in determining the source term uncertainty. These include studies of MARCH and CORSOR, as well as the results of the code validation study being performed at Oak Ridge National Laboratory. In addition, brief scoping studies will be made for those codes not already analyzed. Finally, sensitivity studies of similar codes (e.g. MAEROS, CONTAIN) will also be used.

7. "Estimate input uncertainties." The ranges of the sources of uncertainty will be determined based on the spread in available data. Where direct data are not available, the ranges will be based on the spread in predictions of alternate reasonable models.

8. "Propagate input uncertainties." See step 9.

9. "Combine intermediate uncertainties." The combination and propagation of the many sources of uncertainty in the progression of a severe accident is difficult, especially if the uncertainties are large. It requires a technique which includes the effects of changing more than one parameter at a time (such effects are called synergisms). The technique must also include correlations between parameters and avoid inconsistencies. One approach which satisfies these requirements is the Monte Carlo method. In the Monte Carlo method a set of values for the important phenomena or parameters is chosen at random from their respective uncertainty ranges. This may be done with a bias if the probability distributions for the various phenomena or parameters are known. The selection is also subject to applicable correlations and required consistencies. This set of parameter and phenomena values defines a specific possible accident path which then yields a specific radiological source term. Since each trial path can be checked for internal consistency, the result of the Monte Carlo method

includes synergisms and correlations, and avoids inconsistencies. Unfortunately, a large number of trials is required to map the full possible range in the source term. However, a smaller number of trials can give an estimate of the ultimate range.

Since the objective of this study is to obtain a quick estimate of the reasonable range in the output uncertainty, a modified version of the Monte Carlo approach will be used. In the modified version the trial parameters will not be chosen by chance. Rather, they will by chosen to yield high and low values for the source term. The choice of parameters will be based on sensitivity studies (from step 6) and on scoping calculations. This method might be called a "rigged Monte Carlo" or "limited Latin hypercube." The source term range determined after only a few trials by this technique can not be assured to be the maximum range that is reasonable. But it will be representative and will be produced in a timely manner.

10. "Display uncertainty in result." The uncertainty in the source term will be displayed in two ways. The first will be the upper and lower values for the airborne source term within containment as a function of time. This will be similar to the format used in the BMI-2104 drafts. The second will be the upper and lower values for the total source term released from containment, assuming a specific containment failure time and mode. This second approach will allow the inclusion of such important effects as the resuspension of aerosols or the agglomeration and settling of aerosols after containment has failed.

Steps 4, 6, and 7 will yield important information which will supplement the primary result displayed in step 10.

The limited time of this study (six months) allows the consideration of only a few sequences and plants. The first plant to be considered will be Surry (a large, dry, sub-atmospheric PWR), primarily because it is one of those specifically considered in the BMI-2104 draft and because much previous code work is available for it. The accident sequences in Surry will be TMLB' and S_2D. These sequences were considered in BMI-2104 and dominate the risk for Surry. The second plant considered will be Peach Bottom (a BWR with a Mark I containment) and the sequence will be TW. This sequence is evaluated in BMI-2104, is risk dominant, and is comparable to the TMLB' sequence in Surry.

The expected results of this study are estimates of the total and code uncertainties for each of the initiating sequences and plants described above. It is presently suspected that the uncertainty from code input variation will be a small fraction of the total uncertainty.

4. Description of Any Follow-On Efforts

No follow-on efforts are planned at this time. But an important topic for such an effort is the identification and possible ranking of the important sources of uncertainty. Some identification of sources will result from the present study. But a ranking of the relative importance of those sources will not result. Such a ranking would be useful to the NRC in deciding what specific areas of research to pursue.

The simplest form of ranking involves determining which source of uncertainty yields the largest uncertainty in the source term for a given specified base case. This simple ranking will be dependent on the base case chosen. However, it may be that several sources of uncertainty affect the output uncertainty in parallel so that removal of only one will not much reduce the total uncertainty. Thus a more directly useful ranking might involve determining which set of uncertainties will yield the greatest reduction in the total source term uncertainty when they are all reduced. This latter method requires the identification of all uncertainties of about the same magnitude in order to assure that no dominating uncertainty will remain when those in the suggested set are reduced. It will thus require a larger effort than the former method.

5. Relationship to Other Programs

Related programs which can help identify sources of uncertainty in a timely fashion are listed in Table 1. The obvious start for uncertainty analysis is the review of the BMI-2104 drafts, peer review comments, and the code validation effort sponsored by NRC at ORNL. Additional criticisms and sensitivity information on individual codes may be obtained from the various review projects conducting those codes. In addition, an overall uncertainty review may at SNL (SAUNA) can contribute guidance.

In many cases experimental data will be available to help determine uncertainty ranges. Current experimental programs of relevance are listed in Table 2. These programs will also help identify omitted phenomena.

The results obtained in this project will be of use to the Severe Accident Risk Reduction Program (SARRP). The project has been organized so that within the first two months it can provide SARRP with data necessary for risk rebaselining. Throughout the remainder of the project, information will be generated for SARRP risk calculations. Results of the SARRP risk calculation will be of some use to the project since they provide information on the risk consequences of source term uncertainty.

Table 1. Activities that will Assist Uncertainty Analysis

- Reviews of the Draft BMI-2104 Documents
  - Underway at Various Laboratories
- Spectral Source Term Analysis for Sizewell B
  - Completed by UKAEA
- TRAP-MELT Evaluation
  - Underway UKAEA - Harwell
- CONTAIN Code Recalculation of Containment Responses
  - Underway Sandia National Laboratories
- Code Validation Study
  - Underway Oak Ridge National Laboratory
- MARCH Assessment Program
  - Completed Sandia National Laboratories
- MARCH Sensitivity Program
  - Underway Sandia National Laboratories
- Source Term Sensitivity of Aerosol Behavior
  - Completed Sandia National Laboratories
- SARRP Phenomena Assessment Task Force
  - Underway Sandia National Laboratories
- Severe Accident Uncertainty Analysis (SAUNA)
  - Underway Sandia National Laboratories
- MELCOR Phenomenological Assessment
  - Underway Sandia National Laboratories
- Melt Progression Sensitivity Studies
  - Underway Sandia National Laboratories

Table 2. Experimental Programs Providing New Data of Use in Assessing Uncertainty of Source Term Estimates

ACTIVITY	LOCATION	UTILITY
PBF	INEL	Release and transport of fission products during core degradation
	ORNL	Release of fission products during fuel melting
Resuspension Study	ORNL	Potential effects of aerosol resuspension
NSPP	ORNL (Sandia)	Validation of codes that predict aerosol behavior in saturated steam environments
High Pressure Injection	Sandia	Aerosol generation
High Temperature Fission Product Chemistry	Sandia	Chemistry of fission products under severe accident conditions
Ex-Vessel Core Melt Interactions	Sandia	Definition of aerosols from ex-vessel core/ concrete interactions
ACRR Damage Fuel Relocation	Sandia	In-vessel Melt Progression

6. Reporting Schedule

An allowance has been made for one interim review of the progress of this work. No interim progress reports will be issued concerning this work. Draft documentation of this work will be made available in the form of a report similar to BMI-2104. It is presumed that there will be a peer review of this document similar to that required for BMI-2104.

7. Subcontractor Information

The assistance of Battelle Memorial Institute, Columbus, will be required for obtaining or running some of the codes used in the Interim Source Term Study, but BMI will not be subcontracted by SNL.

8. Capital Equipment

n/a

9. Special Facilities Required

This project will utilize the scientific computing facilities at Sandia National Laboratories, Albuquerque, New Mexico. These consist of a Cray 1, a Cyber 76, three CDC 6600's, a VAX 11/780, and a substantial amount of peripheral equipment. In addition, the computing facilities at the Idaho National Energy Lab will be used via a direct link from SNLA. These facilities include two Cyber 170 computers, peripheral equipment, and equipment which provides access to both computers for remote users.

10. Conflict of Interest

No significant contractual or organization relationships of Sandia National Laboratories, its employees, or anticipated subcontractors and/or consultants exist with industries regulated by the NRC and suppliers thereof that might give rise to an apparent or actual conflict of interest.

March 13, 1984

FY 1984 PROGRAM BRIEF
PROGRAM: AE

TITLE: ACRR SOURCE TERM EXPERIMENTS-PLANNING

FIN NO: A1389
CONTRACTOR: SANDIA
SITE: ALBUQUERQUE
STATE: NEW MEXICO

NRC PROGRAM MANAGERS: R. W. WRIGHT AND L. K. CHAN
PRINCIPAL INVESTIGATORS: D. A. POWERS AND P. S. PICKARD

OBJECTIVE: TO PLAN FOR A SERIES OF EXPERIMENTS IN ACRR ON FISSION-PRODUCT RELEASE FROM REACTOR FUEL, THE CHEMICAL FORM, AND AEROSOL FORMATION UNDER IN-CORE SEVERE-ACCIDENT CONDITIONS AT TEMPERATURES UP TO FUEL MELTING. THIS PLANNING IS TO INCLUDE ANALYSIS OF EXPERIMENT REQUIREMENTS AND DIAGNOSTICS CAPABILITIES, AND ENGINEERING ANALYSIS OF THE PROPOSED EXPERIMENTS THROUGH THE PRELIMINARY DESIGN PHASE. A REPORT ON THIS PLANNING IS TO BE SUBMITTED TO NRC TO FORM A BASIS FOR AN NRC DECISION ON WHETHER TO CARRY OUT THESE EXPERIMENTS AS A MAJOR PART OF THE ALTERNATIVE PROGRAM TO THE PBF PHASE-II TESTS.

BUDGET ACTIVITY:

FY 1984 OBLIGATION: $300K

FY 1984 SCOPE:

1. ANALYZE THE EXPERIMENTAL NEEDS FOR DATA ON FISSION-PRODUCT RELEASE FROM REACTOR FUEL, THE CHEMICAL FORM, AND AEROSOL FORMATION UNDER IN-CORE SEVERE-ACCIDENT CONDITIONS AT TEMPERATURES UP TO FUEL MELTING. THIS ANALYSIS IS TO CONSIDER THE ACCIDENT SEQUENCES AND THE CONDITIONS OF GREATEST RISK AND UNCERTAINTIES IN RISK, AS GIVEN IN THE OUEST AND OTHER REPORTS, AND IS TO RESULT IN A LIST OF EXPERIMENT REQUIREMENTS.

2. ANALYZE THE FISSION-PRODUCT AND AEROSOL DIAGNOSTICS NEEDS AND THE CAPABILITIES OF PRACTICAL ALTERNATIVE DIAGNOSTICS SYSTEMS. SELECT A DIAGNOSTICS SYSTEM FOR THE PROPOSED SERIES OF EXPERIMENTS IN ACRR, AND PERFORM AND REPORT ON A PRELIMINARY DESIGN FOR THIS SYSTEM.

3. ON THE BASIS OF THE EXPERIMENT REQUIREMENTS AND AN ENGINEERING ANALYSIS OF THE ACRR EXPERIMENT CAPABILITY AND A PRELIMINARY SAFETY ANALYSIS, DEVELOP AND REPORT ON A PRELIMINARY DESIGN FOR THE EXPERIMENT SYSTEM.

4. DEVELOP A TEST MATRIX FOR THE PROPOSED PROGRAM OF EXPERIMENTS.

5. OTHER NRC CONTRACTORS PERFORMING SOURCE-TERM RESEARCH ARE TO BE ACTIVE PARTICIPANTS IN THE DEVELOPMENT OF THE EXPERIMENT PLAN, WITH COORDINATION BY HEADQUARTERS.

6. A REPORT ON THIS EXPERIMENT-PLANNING WORK AND THE PRELIMINARY DESIGN IS TO BE SUBMITTED TO NRC BY JUNE 1, 1984 FOR USE IN DECIDING WHETHER THE PROPOSED EXPERIMENTAL PROGRAM IS TO BE CARRIED OUT. A PRELIMINARY REPORT ON THE PLANNING WORK IS TO BE PRESENTED AT THE SEMI-ANNUAL REVIEW MEETING OF THE SEVERE FUEL DAMAGE PROGRAM PARTNERS AT SANDIA ON APRIL 9-11, 1984.