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: Containment Analysis

FIN NUMBER: A-1198

NRC OFFICE: Accident Evaluation

NRC B&R NUMBER: 60190201

DOE CONTRACTOR: Sandia National Laboratories

CONTRACTOR ACCOUNT NUMBER: DE-AC04-76DP00789

SITE: Albuquerque, NM 87185

DOE B&R NUMBER: 401001060

COGNIZANT PERSONNEL	ORGANIZATION	FTS PHONE NUMBER
NRC PROJECT MANAGER: S. B. Burson	NRC/RES	427-4562
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): K. D. Bergeron (Task Leader)	SNL/6424	844-2507
K. K. Murata	SNL/6424	844-3552
M. E. Senglaub	SNL/6424	844-1431

PERIOD OF PERFORMANCE

STARTING DATE: 10/1/83

COMPLETION DATE: 9/30/84

[redacted]

STAFF YEARS OF EFFORT (Round to nearest tenth of a year)	FY 83	FY 84	FY 85	FY 86	FY 87
Direct Scientific/Technical	5.4	5.9	7		
Other Direct (Graded)					
TOTAL DIRECT STAFF YEARS	5.4	5.9	7		
COST PROPOSAL					
Direct Salaries	555	660	846		
Material and Services (Excluding ADP)	551	99	15		
ADP Support	25	21	19		
Subcontracts		26			
Travel Expenses — Foreign	2	5	2		
Travel Expenses — Domestic	7	9	6		
Indirect Labor Costs					
Other (Specify)					
General and Administrative (%)					
TOTAL OPERATING COST	1140	820	888		
CAPITAL EQUIPMENT FIN CHARGED: ______					
TOTAL PROJECT COST	1140	820	888		

FY 84 MONTHLY FORECAST EXPENSE

OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
68	68	68	68	68	72
APRIL	**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEPTEMBER**
68	68	68	68	68	68

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1. Objective of Proposed Work

This program will develop a computer model for analyzing physical and radiological conditions inside a reactor containment building following a severe accident. The code, called CONTAIN, is designed to be highly modular and adaptable so that new state-of-the art phenomenological models can be integrated into the code as they are developed. It is also intended to be highly flexible, so that a broad variety of accident sequences can be handled. CONTAIN has the ability to model both Light Water Reactors (LWR's) and Liquid Metal Fast Breeder Reactors (LMFBR); it is intended that other reactor types (e.g., gas-cooled) may also eventually be treatable with the code. The code analyzes conditions outside the primary system, but inside the containment building, from the time of accident initiation through the possible release of radioisotopes to the environment. It is intended that the code be used at a variety of laboratories and on different computers, so a high level of portability is required.

2. Summary of Prior Efforts

2.1 CONTAIN Status at End of FY83. The CONTAIN code is unique among accident analysis codes in a number of respects: (1) it incorporates a high degree of physical realism for a wide variety of processes which can occur during a severe accident; (2) in part because of this physical realism, the code is suitable for analysis of both LWR's and LMFBR's; (3) a substantial effort has gone into verification and validation activities, providing a relatively high level of confidence in the predictions of the code, compared to most other system level reactor safety codes currently in use (which have had little or no such validation.)

2.2 Achievements during FY83. A substantial effort was devoted during FY83 towards assuring the quality and accuracy of CONTAIN through a systematic testing and validation program. The test program, which consists mainly of hand-calculational checks and code comparisons, initiated in FY82 was expanded to include almost all features of the code at some level of testing. This effort was culminated in a report on the test program documenting the 90-odd test cases run to date; it will be published in the summer of 1983.

Validation activities for CONTAIN involved participation in three code validation exercises, two of them involving blind predictions of experimental results. The ABCOVE test series conducted at HEDL provided a unique opportunity to demonstrate the superior predictive capability of the aerosol models in CONTAIN. Overall agreement between blind predictions of CONTAIN

(or MAEROS) and experimental results were significantly better than for the other participating codes. Additional aerosol model validation efforts involved the NSPP experiments being conducted at ORNL. Although this was not a blind validation exercise, these comparisons established confidence in the diffusiophoresis model in CONTAIN, since there was a significant amount of condensation of water on walls in this experiment.

The HDR blind code validation program coordinated by KfK provided an opportunity to test the thermal-hydraulic features of numerous reactor safety codes from many different countries. The experiment series simulated a full-scale design basis LOCA at the decommissioned HDR reactor near Frankfurt, Germany. CONTAIN predictions for pressure and temperature were in quite good agreement with experimental results, particularly over the long-time regime for which the code is designed.

These validation exercises, combined with the extensive test program, establish CONTAIN's predictive credibility to a greater extent and over a broader range of phenomena, than any other existing severe accident analysis code.

Despite these encouraging results, and despite distribution of the code to selected institutions in FY81 and FY82, the code has not seen widespread use outside of the developing organization. This is due in part to a number of operational difficulties which stem from the size and complexity of the code. An effort was initiated in FY83 to rewrite the code into standard FORTRAN 77, and to restructure it so that it can be easily adapted to run accurately even with short word-length machines (IBM, Amdahl). This task will be completed before the end of FY83.

Another important area of new activity for the CONTAIN development group was to demonstrate that the code could perform useful accident analyses by participating in a number of severe accident research studies requiring actual code calculations. The draft reports for the LWR severe accident source term study was reviewed and a number of accident sequences were selected for calculations. These include two AB sequences and TMLB' at the Surrey plant. In some cases, these calculations were confirmatory of the results from the codes used for the draft source term report; in other cases, however, significant discrepancies were found which were traceable to simplifications inherent in the codes used for the original calculations. An important part of the work needed to participate in the source term studies was to construct an interface between CONTAIN and MARCH. Such a program (designated MARCONI) was written in FY83,

and is currently being used for the comparison calculations. Follow-on activities involving the source term study include participation in the Quantitative Uncertainty Estimate of the Source Term (QUEST) project being conducted at Sandia under the auspices of the Accident Source Term Program Office.

The development and improvement of the models in CONTAIN continued to be an important activity during FY83. In particular, significant progress was made in the following areas:

- Models for the following engineered safety features are now operational: fan cooler, containment spray, ice condenser, and intercell liquid network. The spray model now includes the effect of washout of fission products and aerosols from the atmosphere.

- The MEDICI reactor cavity model for LWR's now has all the features intended for the first version of the code. These include models for debris mixing, fragmentation, and quenching, steam explosions, expulsion of material from the cavity, hydrogen generation, debris bed formation, dryout and remelt.

- A need for a sodium pool model which was simpler and more robust than the existing one was recognized, and such a model was developed as a stand-alone code, then integrated into CONTAIN as an option. The model is designated SMSCI (Semi-Mechanistic Sodium Concrete Interaction Model).

- A number of improvements have been made in the aerosol model oriented chiefly towards speeding up calculations involving evaporation and condensation on aerosols. Models for additional deposition mechanisms (thermophoresis, diffusiophoresis) were also added to the code.

- The behavior of the gas jet which can form at the point of containment breach was studied, and model development for this phenomenon was initiated. Strictly speaking, the jet forms just outside the containment building, but it is not properly analyzed in any ex-plant model, and it is quite natural to treat it as part of a containment code like CONTAIN.

- The effect of deposited aerosols on heat transfer from the atmosphere to heat sink structures was modeled and included as an option in CONTAIN. A series of calculations was performed for an LMFBR accident sequence to quantify this effect.

* The new model for condensation and evaporation from structure surfaces was completed and thoroughly tested. The success of the HDR code validation exercise was largely attributable to the accuracy of this model.

3.0 Work to be Performed and Expected Results

Task 1: Completion of the First Releaseable Version of CONTAIN

A significant fraction of the CONTAIN development group's resources will be devoted to completing the first version of CONTAIN intended for general use by the reactor safety community. This code will be designated CONTAIN 1.0, and will be produced to high standards of quality assurance, documentation, completeness, and consistency. To meet the goal of being available for release in the second quarter of FY84, a number of milestones must be met on a rather tight schedule. Several key phenomenological models must be completed. Numerous operational features essential to a widely used code must be implemented or improved. Model development must be frozen, and the complete phenomenological model system be subject to intensive testing. Input and output must be made more consistent and easier to use. Finally, adequate documentation on the use of the code must be available at the time of release, and must be completely consistent with the code as written.

A large number of models and features are now implemented and operating reliably in CONTAIN, so that only a few details remain for the complete specification of the capabilities of CONTAIN 1.0. Regarding new features, the approach to be followed will involve prioritizing development efforts and, if necessary, postponing the inclusion of some non-essential models in order to meet the release schedule. The reactor cavity will be the focus for most of the new features. A general processing scheme is being developed which will allow models from various stand-alone codes to be easily integrated into the rest of the system. For LWR applications, most if not all of the models developed for the MEDICI reactor cavity code will be incorporated. For LMFBR's there will be two options available: a pool model which utilizes the SLAM model for sodium concrete interactions will allow analysis at a high level of detail; when such detail is unnecessary, a simpler and faster model will be available.

The completed CONTAIN 1.0 code will be made available to selected users along with a User's Manual and instructions on bringing the code to the operational level for a variety of computers and operating systems. Input decks for a number of standard test problems which have been developed in the code

testing program will also be provided. It is expected that some support will be provided to these users as they develop familiarity with the code and its operation.

Task 2: New model development

A number of other model development efforts will be pursued which are unlikely to be ready to be included in the released version of the code. These include the following:

* An improved model for hydrogen burn phenomena. This will probably be the same model as in the HECTR code, though some simplifications may be desirable. It is possible that some of the desired changes will be implemented in CONTAIN 1.0, but the goals of the complete remodeling effort are probably more ambitious than can be accomplished within the schedule constraints for the first release.
* A model for the generation of aerosols from core-concrete interactions. The VANESA code will be rewritten in a form compatible with the rest of CONTAIN and incorporated into the larger code.
* The MEDICI code for reactor cavity phenomena. The stand-alone first version of MEDICI will be completed, including a number of features which will probably not be ready in time for the release of CONTAIN 1.0. These may include models for aerosol generation at the vessel breach, hydrogen generation during the debris bed quench phase, and dryout/remelt of an uncoolable debris bed.
* Models for plugging of vents by aerosol deposits. The principal interest in this phenomenon is for LMFBR's, but it may be of use for analyzing filtered vents in LWR's as well. Models for the effect of severe accident conditions on other engineered safety features will also be developed, e.g., deposited aerosol effects on heat transfer to fan coolers.
* A model for pressure suppression pools. Such a model must deal with design-basis-accident phenomena (steam absorption) as well as severe accident phenomena (radionuclide decontamination, response to high pressure pulses, etc.)

* An implicit numerical solution scheme for the intercell flow equations. This should decrease running time for certain types of multi-cell configurations substantially. In addition more logic will be built into the code to select and control the time step for calculations, reducing the burden on the user, and simplifying operation of the code.

* A model for intercell flow due to buoyant forces. This will allow atmospheres in cells located at different heights to mix through convective loops.

Task 3: CONTAIN Code Assessment

Testing and validation efforts will continue as part of a systematic Code Assessment for CONTAIN. A report will be prepared reviewing the steps which have been taken in the areas of quality assurance, verification, and validation of CONTAIN. Participation in the ABCOVE aerosol experiment series will continue as part of this program.

Task 4: LWR Accident Analysis Applications

A variety of accident progression calculations will be made with CONTAIN in support of other analysis programs. These programs may include the Containment Loads Working Group, the Severe Accident Risk Reduction Program, the Quantitative Uncertainty Estimate of the Source Term project, and the Accident Source Term Program. In particular, multi-cell calculations for the AB and TMLB' sequences at the Surrey plant planned for early in FY84 will provide additional understanding of baseline source term calculations already performed for the Source Term Study using other codes.

4. Follow-on Efforts

The containment analysis program is a continuing research effort, though funded on a year-to-year basis. When CONTAIN 1.0 is completed, applications of the code can be expected to take on more importance, and a continued code maintenance and user support effort can be anticipated as long as the code is actively used.

The need for new or improved models can be expected following the release of CONTAIN 1.0. Corrections sets incorporating these extended features will be made available to interested users on a regular, but controlled basis. Major changes in key models would be accomplished by the development of a new version of the code, designated CONTAIN 2.0.

5. Relationship to Other Programs

Similar but complementary work is underway in the Molten Fuel Concrete Interactions Program (A-1019) which is developing the CORCON code. It is possible that a simplified version of CORCON mod 2 as described in the phenomenological assessment for the MELCOR program will be produced. If so, it would be highly desirable to incorporate this as a subroutine in CONTAIN.

The incorporation of the hydrogen combustion models from the HECTR code will insure that CONTAIN has state-of-the-art capabilities in this area. This integration will be facilitated by active cooperation with personnel in the Hydrogen Behavior Program (A1246).

CONTAIN provides the basic code capabilities needed for the analysis of containment response to Hypothetical Core Disruptive Accidents at the Clinch River Breeder Reactor, and a separate program (A1362) will cover a variety of such analyses.

The MELCOR code now under development will be NRC's principal tool for probabilistic analyses of severe LWR accidents. The CONTAIN code will provide a basis for many of the models and methods to be used in MELCOR, and it is anticipated that extensive interaction between personnel in the two projects will be needed during FY84.

6. Reporting Schedule

Reports completed in fiscal 1983:

D. C. Williams, "Effects of Steam Upon LWR Radionuclide Release Plumes", summary submitted to LWR severe accident meeting in Cambridge, MA.

K. D. Bergeron, "Standardized Test Procedures for the CONTAIN Code," RS4450/82/42, Sandia National Laboratories, June 1982.

K. D. Bergeron et al, "The Status of the CONTAIN Computer Code for LWR Containment Analysis," SAND82-2242C, presented at the 10th NRC Water Reactor Safety Mtg., Gaithersburg, Md, October 14, 1982, and the German-American Core Melt Information Exchange Meeting, KfK, Germany, October 25, 1982.

K. D. Bergeron and W. R. Trebilcock, "The MEDICI Reactor Cavity Code," SAND83-0810A, submitted to Cambridge LWR Severe Accident Mtg.

M. J. Clauser et al. "A Computer Model of Containment Phenomena Following Severe Reactor Accidents," SAND83-0885A, Sandia National Laboratories, March 1983, submitted to Cambridge LWR Severe Accident Meeting

K. K. Murata et al."Recent Highlights in the CONTAIN Testing and Validation Program" SAND83-0822A, Sandia National Laboratories, March 1983, submitted to Cambridge LWR Severe Accident Meeting

W. R. Trebilcock, "CONTAIN with CORCON Option," Sandia National Laboratories.

M.J.Clauser, et al. "CONTAIN, A Code for Analysis of Breeder Reactor Containment Response to Hypothetical Severe Accidents, Proc. International Topical Meeting on LMFBR Safety, July 19-23, 1983, Lyon, France

K. D. Bergeron, J. R.Tills, "Results of Blind Predictions of HDR Steam Blowdown Experiments Using the CONTAIN Code," SAND83-1368A, Sandia National Laboratories, June 1983, submitted to SanFrancisco ANS Meeting

F. W. Sciacca, "Testing of the CONTAIN Code," SAND833 NUREG/CR-3310, Sandia National Laboratories, May 1982
P. R. Shire, "Semi-Mechanistic Sodium-Concrete Interaction, SMSCI," Sandia National Laboratories, July 1983

G. G. Weigand, editor, "The Thermal Hydraulic Phenomena for Risk - A Summary." Contributions by M. J. Clauser (Containment, Introduction, Overview, and Flow Thermodynamics), K. D. Bergeron (Reactor Cavity Phenomena), K. K. Murata (Interfaces between Thermophysical Processes and Aerosol and Fission Product Processes in Containment), and P. E. Rexroth (Containment Engineered Safety Features).

Reports expected in fiscal 1984:

1. CONTAIN User's Manual
2. CONTAIN Reference Manual
3. Report on CONTAIN Validation
4. Code Assessment Plan

7. Subcontractor Information

n/a