UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

ACRSR-2105

November 18, 2004

Dr. Carl J. Paperiello
Director
Office of Nuclear Regulatory Research
Washington, D.C. 20555-0001

SUBJECT: ACRS ASSESSMENT OF THE QUALITY OF SELECTED NRC RESEARCH PROJECTS

Dear Dr. Paperiello

Enclosed is our report on the quality review of the following research projects:

- Effects of Chemical Reactions on Debris-Bed head Loss
  - This project is found to be slightly less than satisfactory. The results meet the research objectives for the most part.
- Experimental Studies of Loss-of-Coolant Accident Generated Debris Accumulation and Head Loss
  - This project marginally satisfies the research objectives. We have identified important deficiencies.
- Improvements to the MACCS Computer Code, Plume Model Adequacy
  - This project is found to be an excellent effort.

This independent evaluation of the quality of selected research projects was undertaken to satisfy the needs of the Office of Nuclear Regulatory Research (RES) and the requirements of the Government Performance and Results Act. The methods used by the ACRS for the quality review of research projects are described in detail in the accompanying report.

Some lessons have been learned from this first effort:

- The ACRS review panels experienced some challenges understanding what exactly had been asked of the researchers and the constraints imposed upon the research. It is imperative that the review panels be provided a copy of the NRC Form 189 and descriptions of any modifications to the scope of the research made by NRC.
- In some cases, the panels encountered delays in getting the documentation. We propose that, for future reviews, RES provide the ACRS the appropriate documents and these be screened by us before the review of a particular research activity is undertaken.

- It proved difficult to delve into large, multi-task projects in sufficient detail to evaluate the work in terms of the performance measures that we are using. We propose that, for future reviews, we work with you to focus reviews on particular efforts. The larger effort can be evaluated as part of our overall review of the NRC research program.

- It appears that it will be difficult to review projects at their very beginning. We propose that formal reviews with numerical scores not be undertaken until a research project has reached sufficient maturity.

We are now poised to undertake review of four additional research projects during fiscal year 2005. In an earlier communication to us, RES suggested that the next projects for review be selected from:

- Thermal Hydraulic Experimental Programs
- LOCA Frequency Determinations
- SPAR3 Quality Assessment
- Associated Circuits Analysis
- Pressurized Thermal Shock Re-evaluation
- Steam Generator Tube Integrity Under Severe Accident Conditions

We propose to meet with your staff to select projects for review over the next 12 months in light of the lessons learned from this first set of research quality reviews.

Sincerely,

/RA/

Mario V. Bonaca
Chairman

Attachment:
As stated

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Assessment of the Quality of Selected NRC Research Projects by the Advisory Committee on Reactor Safeguards

November 2004

U.S. Nuclear Regulatory Commission
Advisory Committee on Reactor Safeguards
Washington, DC 20555-0001

ABOUT THE ACRS

The Advisory Committee on Reactor Safeguards (ACRS) was established as a statutory Committee of the Atomic Energy Commission (AEC) by a 1957 amendment to the *Atomic Energy Act* of 1954. The functions of the Committee are described in Sections 29 and 182b of the Act. The *Energy Reorganization Act* of 1974 transferred the AEC's licensing functions to the U.S. Nuclear Regulatory Commission (NRC), and the Committee has continued serving the same advisory role to the NRC.

The ACRS is independent of the NRC staff and reports directly to the Commission, which appoints its members (currently 11 members). The ACRS is structured to provide a forum where experts representing many technical disciplines can provide independent advice that is factored into the Commission's decisionmaking process

The ACRS provides independent reviews of, and advice on, the safety of proposed or existing NRC-licensed reactor facilities and the adequacy of proposed safety standards. The ACRS reviews power reactor and fuel cycle facility license applications for which the NRC is responsible, as well as the safety-significant NRC regulations and guidance related to these facilities. On its own initiative, the ACRS may review certain generic matters or safety-significant nuclear facility items. The Committee also advises the Commission on safety-significant policy issues, and performs other duties as the Commission may request. Upon request from the U.S. Department of Energy (DOE), the ACRS provides advice on U.S. Naval reactor designs and hazards associated with the DOE's nuclear activities and facilities. In addition, upon request, the ACRS provides technical advice to the Defense Nuclear Facilities Safety Board.

ACRS operations are governed by the *Federal Advisory Committee Act* (FACA), which is implemented through NRC regulations at Title 10, Part 7, of the *Code of Federal Regulations* (10 CFR Part 7). ACRS operational practices encourage the public, industry, state and local governments, and other stakeholders to become involved in Committee activities.

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ABSTRACT

In this report, the Advisory Committee on Reactor Safeguards (ACRS) presents the results of its assessment of the quality of selected research projects sponsored by the Office of Nuclear Regulatory Research(RES) of the NRC. An analytic/deliberative methodology was adopted by the Committee to guide its review of research projects. The methods of multi-attribute utility theory were utilized to structure the objectives of the review and develop numerical scales for rating the project with respect to each objective. The results of the evaluations of the quality of the three research projects are summarized as follows:

- Effects of Chemical Reactions on Debris-Bed Head Loss

  - This project was found to be slightly less than satisfactory . The results meet the research objectives for the most part.

- Experimental Studies of Loss-of-Coolant Accident Generated Debris Accumulation and Head Loss with Emphasis on the Effects of Calcium Silicate Insulation

  - This project marginally satisfied the research objectives. The Committee identified important deficiencies.

- Improvements to the MACCS Computer Code, Plume Model Adequacy Evaluation

  - This project was found to be an excellent effort.

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ACRONYMS

Acronym	Definition
ACRS	Advisory Committee on Reactor Safeguards
BWR	Boiling Water Reactor
GPRA	Government Performance and Results Act
LOCA	Loss-Of-Coolant Accident
MAUT	Multi-Attribute Utility Theory
MACCS	MELCOR Accident Consequence Code System
NPSH	Net Positive Suction Head
NRC	Nuclear Regulatory Commission
PWR	Pressurized Water Reactor
RES	Office of Nuclear Regulatory Research

1 INTRODUCTION

The Nuclear Regulatory Commission (NRC) maintains a safety research program to ensure that its regulatory framework has a sound technical basis. The research effort is needed to support regulatory activities and agency initiatives while maintaining an infrastructure of expertise, facilities, analytical tools, and data to support regulatory decisions.

The Office of Nuclear Regulatory Research (RES) is required to have an independent evaluation of the effectiveness (quality) and utility of its research programs. This evaluation is mandated by the Government Performance and Results Act (GPRA). The Advisory Committee on Reactor Safeguards (ACRS) has agreed to assist RES by performing independent assessments of the quality of selected research projects. Quality assessment of individual research projects constitutes a new undertaking for the Committee; one that is quite different in scope and depth in comparison to the ACRS biennial review of the NRC research activities. During its March 2004 meeting, the ACRS approved a strategy for conducting such reviews [Ref. 1].

In this report, the ACRS presents the results of its quality assessment of three research projects. Two projects were reviewed within the general category of sump blockage research - Effects of Chemical Reactions on Debris-Bed Head Loss and Experimental Studies of Loss-of-Coolant Accident Generated Debris Accumulation on Head Loss. The third project evaluated was Improvements to the MACCS Computer Code: Plume Model Adequacy Evaluation. These projects, which deal with subjects of high current interest, were selected from a list of eight candidate projects suggested by RES.

A panel of three ACRS members was formed to review the sump blockage research projects and a second three-member panel reviewed the MACCS project. Each panel consisted of a chairman, a member with special expertise in the general area of the research program, and one other ACRS member. The panels conducted their detailed reviews of the assigned projects and presented their assessments to the full Committee. The discussions by the full Committee, which were concluded during the November 2004 meeting of the Committee, were intended to ensure consistency among the reviews of the various research projects.

An analytic/deliberative decisionmaking framework was adopted for evaluating the quality of NRC research projects. The ACRS considered the following general attributes in assessing the quality of the NRC research projects:

- Soundness of technical approach/results
  - Has execution of the work used available expertise in appropriate disciplines?

- Justification of major assumptions
  - Have assumptions key to the technical approach and the results been tested or otherwise justified?

- Treatment of uncertainties/sensitivities
  - Have significant uncertainties been characterized?
  - Have important sensitivities been identified?

- Clarity of presentation
- Identification of major assumptions

The methodology for developing the quantitative metrics (numerical grades) for evaluating the quality of NRC research projects is presented in Section 2 of this report. The results of assessment and ratings for the selected projects are discussed in Section 3.

2 METHODOLOGY FOR EVALUATING THE QUALITY OF RESEARCH PROJECTS

To guide its review of research projects, the ACRS has adopted an analytic/deliberative methodology [Ref. 2 and 3]. The analytical part utilizes methods of multi-attribute utility theory (MAUT) [Ref. 4 and 5] to structure the objectives of the review and develop numerical scales for rating the project with respect to each objective. The objectives were developed in a hierarchical manner (in the form of a "value tree") and weights reflecting their relative importance were developed. The value tree and the relative weights developed by the full Committee are shown in Figure 1.

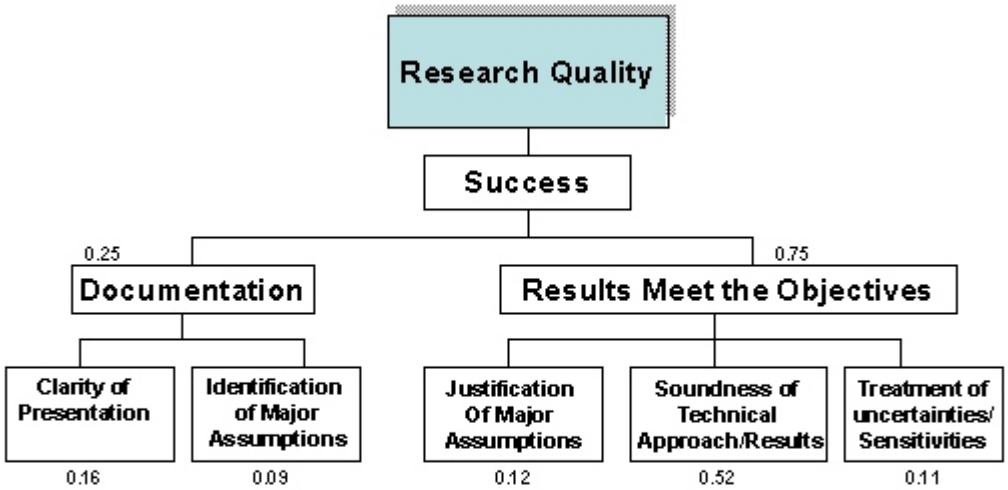

Figure 1 The value tree used for evaluating the quality of research projects

The quality of projects is evaluated in terms of the degree to which the results meet the objectives of the research and of the adequacy of the documentation of the research. It is the consensus of the ACRS that meeting the objectives of the research should have a weight of 0.75 in the overall evaluation of the research project. Adequacy of the documentation was assigned a weight of 0.25. Within these two broad categories, research projects were evaluated in terms of subsidiary "performance measures":

- justification of major assumptions (weight: 0.12)
- soundness of the technical approach and reliability of results (weight: 0.52)
- treatment of uncertainties and characterization of sensitivities (weight: 0.11)

Documentation of the research was evaluated in terms of the following performance measures:

- clarity of presentation (weight: 0.16)
- identification of major assumptions (weight: 0.09)

To evaluate how well the research project performed with respect to each performance measure, constructed scales were developed as shown in Table 1. The starting point is a rating of 5, Satisfactory (professional work that satisfies the research objectives). Often in evaluations of this nature, a grade that is less than excellent is interpreted as pejorative. In this ACRS evaluation, a grade of 5 should be interpreted literally as satisfactory. Although innovation and excellent work are to be encouraged, The ACRS realizes that time and cost place constraints on innovation. Furthermore, research projects are constrained by the work scope that has been agreed upon. The score was, then, increased or decreased according to the attributes shown in the table. The overall score of the project is produced by multiplying each score by the corresponding weight of the performance measure and adding all the weighted scores.

The value tree, weights, and constructed scales were the result of extensive deliberations of the whole ACRS. As discussed in Section 1, a panel of three ACRS members was formed to review each selected research project. Each member of the review panel independently evaluated the project in terms of the performance measures shown in the value tree. The panel deliberated the assigned scores and developed a consensus score, which was not necessarily the arithmetic average of individual scores. The panel's consensus score was discussed by the full Committee and adjusted in response to ACRS members' comments. The final consensus scores were multiplied by the appropriate weights, the weighted scores of all the categories were summed and an overall score for the project was produced. A set of comments justifying the ratings was also produced.

Table 1. Constructed Scales for the Performance Measures

SCORE	LABEL	INTERPRETATION
10	Outstanding	Creative and uniformly excellent
8	Excellent	Important elements of innovation or insight
5	Satisfactory	Professional work that satisfies research objectives
3	Marginal	Some deficiencies identified; marginally satisfies research objectives
0	Unacceptable	Results do not satisfy the objectives or are not reliable

3 RESULTS OF QUALITY ASSESSMENT

3.1 Sump Blockage Research

The 1992 clogging of intake strainers for containment spray water in Barsebäck-2, a boiling water reactor (BWR) in Sweden, renewed the safety questions associated with strainer clogging which, until then, had been considered as resolved. In response to the Barsebäck-2 event, the NRC launched research and development efforts to assess the vulnerability of U.S. BWRs to the loss of net positive suction head (NPSH) margin caused by excessive debris accumulation on suction strainers. Such efforts resulted in a number of corrective actions being taken in U.S. BWRs.

The NRC conducted further research to determine if the transport and accumulation of debris in a containment following a loss-of-coolant accident (LOCA) would impede the operation of the Emergency Core Cooling System (ECCS) in operating pressurized water reactors (PWRs). The research program included debris transport tests, debris settling tests, debris generation tests, debris-bed head loss tests, computational simulations, and various engineering analyses.

Two experimental projects in the area of sump blockage research were selected for review and quality evaluation. The results of these evaluations are discussed below.

3.1.1 Effects of Chemical Reactions on Debris-Bed Head Loss

This study was performed to assess the potential for chemically induced corrosion products to impede the performance of ECCS recirculation after a LOCA at PWR plants. A number of small-scale tests were performed to determine whether post-LOCA debris generation and sump-screen head loss in a PWR containment can be affected by chemical interactions between the ECCS/containment -spray water (which contains boric acid and sodium hydroxide at elevated temperatures) and exposed materials such as a metal surfaces, inorganic zinc-based paint chips, and fiberglass insulation debris. These tests were conducted in the Department of Civil Engineering of the University of New Mexico under the direction of Los Alamos National Laboratory. The results of this study were documented in Reference 6.

The consensus scores for this project are shown in Table 2. This project was found to be slightly less than satisfactory. The results meet the research objectives for the most part. Comments and conclusions within the evaluation categories are:

Documentation

- Clarity of presentation **(Consensus score = 5.0)**

  The report [Ref. 6] on the work included all appropriate material. The testing approach and apparatus were adequately described. Peer review comments were included. The report properly described the chemical environment to be expected in the containment during a large break LOCA. The appropriate literature was consulted for corrosion rates, solubilities and likely precipitants.

However, the executive summary of the report is not fully consistent with the body of the report. Major results were not clearly presented in Table 4-2 of the report and material in the table was not consistent with the text. The report did not indicate how peer review comments were addressed and it appeared that in some cases these comments had not been addressed in the project. Some conclusions did not reflect important insights.

No systematic attempt was made to pull the results together into a summary figure and compare them with theoretical predictions and previous work.

- Identification of major assumptions (Consensus score = 5.0)

  A number of explicit and implied assumptions arise in the research and these were identified satisfactorily.

Table 2. Summary Results of ACRS Assessment of the Quality of the Project on Effects of Chemical Reactions on Debris-Bed Head Loss

Performance Measures	**Consensus Scores**	**Weights**	**Weighted Scores**
Clarity of presentation	5.0	0.16	0.80
Identification of major assumptions	5.0	0.09	0.45
Justification of major assumptions	4.0	0.12	0.48
Soundness of technical approach/results	4.5	0.52	2.34
Treatment of uncertainties/sensitivities	4.0	0.11	0.44
		Overall Score:	**4.51**

Results Meet Objectives

- Justification of major assumptions **(Consensus score = 4.0)**

  Some assumptions were not justified sufficiently:

Limiting the test conditions to just those associated with large-break LOCAs was not justified.

Though a reference was cited for concluding "A high pH is essential to prevent fibers and small particles from coagulating and depositing on the sump screen," no further justification or discussion was provided.

It was asserted that not including phosphate and thiosulphate was a conservative conclusion, but no justification was provided.

It was assumed without justification or confirmation that "qualified application of coating systems are robust with respect to LOCA chemical environments."

- Soundness of technical approach and results **(Consensus score = 4.5)**

  The researchers were asked to conduct tests to determine the technical basis for deciding whether chemical interactions play a significant role in loss of NPSH. Implied in this request is the question of whether conditions will arise that lead to chemical interactions. The approach adopted in the research was insufficient to address this implied question.

  Corrosion rates under well-oxygenated spray conditions were not addressed though such conditions are likely to occur.

  The amount of data developed in the research is insufficient to be useful for quantitative analyses of the overall sump blockage issue.

  The oven used for corrosion tests did not have the capability to cover the range of temperature conditions of interest.

  Small sample sizes and short test durations yielded data that were insufficient to quantify and to resolve the uncertainties.

  Stirred vessels were not used in the corrosion rate studies. Consequently, corrosion rates may be underestimated because of local saturation effects.

  The small-scale loop test was not adequate. It could not maintain either constant approach velocities or constant temperatures that are basic requirements for the tests.

  Setting up artificial saturation conditions with chemicals that are known to precipitate in gelatinous form is not an appropriate approach to answer the fundamental questions to be addressed in the research.

  Labeling weight gains in samples as "negative corrosion" is misleading. A method to convert these weight gain results into corrosion rates should have been developed.

  The formation of gelatinous material is artificial and unrelated to LOCA conditions.

- Treatment of uncertainties and characterization of sensitivities **(Consensus score = 4.0)**

  Head loss characteristics of fibrous beds with different metal species, concentrations, approach velocities, temperature etc. were determined and thereby the important sensitivities were examined.

  The uncertainties in the results were not addressed.

3.1.2 Experimental Studies of Loss-Of-Coolant Accident Generated Debris Accumulation and Head Loss

This experimental program was conducted to generate data on the head loss associated with calcium silicate (CalSil) insulation accumulated on PWR sump screens, with or without other insulation materials such as fiberglass or reflective metallic insulation, and to determine the suitability of the NUREG/CR-6224 [Ref. 7] head loss correlation for CalSil head loss calculations. The results of this study were documented in Reference 8
.
The consensus scores for this project are shown in Table 3. This project marginally satisfied the research objectives. The ACRS identified important deficiencies. Comments and conclusions within the evaluation categories are:

Table 3 Summary Results of the ACRS Assessment of the Quality of the Project on Experimental Studies of LOCA Generated Debris Accumulation and Head Loss

Performance Measures	Consensus Scores	Weights	Weighted Scores
Clarity of presentation	6.5	0.16	1.04
Identification of major assumptions	4.5	0.09	0.41
Justification of major assumptions	3.0	0.12	0.36
Soundness of technical approach/results	3.0	0.52	1.56
Treatment of uncertainties/sensitivities	2.5	0.11	0.28
		Overall Score:	**3.65**

Documentation

- Clarity of presentation **(Consensus score = 6.5)**.

  The report on the work was complete and included all appropriate materials such as tables of raw data and photographs of Scanning Electron Microscopy of debris-bed morphologies. The report adequately described the test apparatus and procedures. The appropriate results as well as the conditions of tests were included in the report. However, there were some concerns about the inclusion of the results of failed and shakedown tests in the report.

- Identification of major assumptions **(Consensus score = 4.5)**

  The report listed a number of major assumptions. However, the list was not complete and the assumptions were scattered throughout the report rather than being listed separately.

Results Meet Objectives

- Justification of major assumptions **(Consensus score = 3.0)**

  Many assumptions were not justified sufficiently:

  No justification was provided on how artificially generated debris properly simulated real debris.

  No technical basis was provided for the assumption that small/medium break LOCAs would be bounded by screen loading of 1 ft^3/ft^2 and large-break LOCA by 10 ft^3/ft^2.

  No justification was provided for the ratio of the volume of CalSil to volume of fibrous debris used in the tests. The report noted that “experience and engineering judgment” were used to “reasonably” represent this parameter. This is a weak justification without having more backup information.

  No real justification was provided for the values of the selected parameters used in the test compared to expected conditions during a PWR LOCA.

  It was assumed that NUKON was representative of the broad class of fiber insulations without any justification for this assumption.

  The report did not clearly define what is meant by a “uniform” accumulation pattern.

  The report did not provide a clear definition of “thin bed”, what criterion should be used to determine its occurrence, and how it is possible for the effective surface area of the particles to increase by almost an order of magnitude when it occurs.

- Soundness of technical approach and results **(Consensus score = 3.0)**

  The technical approach was to simulate appropriate PWR containment debris accumulation and head-loss conditions with flexibility for controlling local flow conditions, debris quantity and other important parameters and with the capability of taking applicable measurements and visual observations of the phenomena under examination. As this was strictly a test of the applicability of a previously developed empirical correlation, there was an insufficient test matrix and number of tests to provide a good assessment. The major objective of the work was not accomplished since there was only a limited set of data, half of which was under failed conditions.

  The range, quality, and amount of data are insufficient to resolve the inconsistencies and anomalies observed.

  Overly optimistic statements are made about validation of the correlation. This is in sharp contrast to the numerous anomalous and inconsistent features of the results which were insufficiently investigated and not resolved.

  The test apparatus appears to be under-designed for the purpose. There was no independent control of temperature or pump speed.

  Not much insight was developed on the real issue of “the thin bed” effect.

  The process of adjusting the value of a major independent variable (specific surface area) to provide a fit to the largest delta-P data point was inappropriate. The obtained data were presented on head-loss versus approach velocity plots along with the NUREG/CR-6224 correlation prediction, and the CalSil specific surface area (and the sludge density when bed compaction occurred) was adjusted until the correlation predicted the higher velocity data points. This circular approach does not “establish a technical basis for extending the applicability of the NUREG/CR-6224 correlation from porous debris beds on boiling water reactor (BWR) suppression pool strainers to debris beds on PWR sump screens or other flow blockages,” as set forth in the objectives of the test program.

  This research did not provide a better understanding of the behavior of particulate filters nor did it provide a good predictive capability.

  The range of the head loss data was limited by the apparatus and cannot be extrapolated with confidence to large LOCA conditions where the bed thickness may be an order of magnitude higher than was tested.

- Treatment of uncertainties and characterization of sensitivities **(Consensus score = 2.5)**

  Sensitivity of the head loss characteristics of fibrous beds to some parameters such as different CalSil volume ratio, approach velocity, and temperature were examined. However, no attempt was made to characterize or quantify the many uncertainties.

The objective of validating a previously developed correlation requires enough data to characterize the uncertainties. However there were insufficient data to do this.

3.2 Improvements to the MACCS Computer Code

The NRC uses MACCS consequence code system for Level 3 Probabilistic Risk Assessment (PRA) consequence analyses, planning for emergencies, and cost-benefit analyses. MACCS uses a Gaussian plume model for atmospheric transport and dispersion . This model has been criticized as being overly simplistic. The justification for its use has been that only average values of metrics of interest over numerous weather consequences are used in the regulatory arena and that this averaging compensates for the loss of fine structure in the meteorology that occurs away from the point of release. The simple Gaussian plume model has been retained because of the desire to have models covering the entire path through the environment, including the food and water pathways and covering essentially a lifetime of exposure to a contaminated environment, which can run in short times on personal computers.

The NRC initiated a research effort to test the assumption about the adequacy of simplified Gaussian plume model through comparison with more complex models. The models compared were: MACCS, the simplified model; LODI (Lagrangian Operational Dispersion Integrator), a state-of-the-art, 3-dimensional advection-diffusion code using a Lagrangian stochastic, Monte Carlo method; and RASCAL (Radiological Assessment System for consequence analysis), which uses a Lagrangian trajectory, Guassian puff model. The objective of this study was to see if the average atmospheric transport and dispersion results from these three codes were sufficiently close that a more complex model is not required for the NRC purposes of emergency planning and cost -benefit analysis or different enough that the NRC code should be modified to provide more rigorous atmospheric transport and dispersion. The results of this study were documented in Reference 9.

The consensus scores for the project are shown in Table 4. This project was found to be an excellent effort. Comments and conclusions within the evaluation categories are:

Documentation

- Clarity of presentation **(Consensus score = 9.0)**

  The research had a clear and unambiguous direction that was followed appropriately.

  A complete, well-written and understandable report was issued. The report was indexed and referenced. Graphics were useful. All appropriate material was included in the main body of the report or in appendices.

  Enough material was included for an independent investigator to make comparisons to results from other codes.

  A peer-reviewed paper was developed from this work.

Table 4 Summary Results of ACRS Assessment of the Quality of the Project on Improvements to the MACCS Computer Code,
Plume Model Adequacy Evaluation

Performance Measures	Consensus Scores	Weights	Weighted Scores
Clarity of presentation	9.0	0.16	1.44
Identification of major assumptions	9.5	0.09	0.86
Justification of major assumptions	7.0	0.12	0.84
Soundness of technical approach/results	8.0	0.52	4.16
Treatment of uncertainties/sensitivities	4.5	0.11	0.50
		Overall Score:	**7.80**

- Identification of major assumptions **(Consensus score = 9.5)**

  All major assumptions that differentiate the modeling of the codes for comparison were identified.

  The approach used for making the code inputs consistent was discussed clearly.

  Few assumptions were necessary in the work.

Results Meet Objectives

- Justification of major assumptions **(Consensus score = 7.0)**

  Assumptions made on input for the codes were well justified.

- Soundness of technical approach and results **(Consensus score = 8.0)**

  Directions given in the statement of work were followed appropriately.

  The project analyzed the only available site for which there are sufficient three dimensional data on year-around wind directions and temperatures to sufficient distances for a useful comparison of code predictions.

The figures of merit adopted for the comparisons of code predictions were appropriate. Only the meteorological aspects of the codes were exercised in the effort.

Comparisons of the predictions of the RASCAL and RACHET codes added to the utility of the results.

The project did not necessarily define the maximum possible differences among code predictions. It might have been possible to do this by developing a fictional site and manufactured meteorological data deliberately chosen to maximize differences in code predictions. This, however, would have been well beyond the scope of the project.

- Treatment of uncertainties and characterization of sensitivities **(Consensus score = 4.5)**

  The uncertainties and sensitivities of the MACCS code and the 3-D LODI code have been addressed extensively in many other studies. The report provided sufficient references to these studies.

  The purpose of the exercise was to gain insight on the level of uncertainty in code predictions and this was accomplished well. The comparison of the discrepancies of the code results, however, should have been placed in the larger context of the uncertainties that are present in such evaluations.

5. REFERENCES

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