RAS J-305

November 22, 2010

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	)	
	)	
Entergy Nuclear Generation Company and	)	Docket No. 50-293-LR
Entergy Nuclear Operations, Inc.	)	ASLBP No. 06-848-02-LR
	)	
(Pilgrim Nuclear Power Station)	)	

ENTERGY'S NOTICE OF FILING AFFIDAVIT

Notice is hereby given that, in accordance with the Atomic Safety and Licensing Board ("Board") majority's Order of October 26, 2010 and the Board's Order of November 5, 2010, Entergy Nuclear Generation Company and Entergy Nuclear Operations, Inc. (collectively "Entergy") are submitting the Affidavit of Kevin R. O'Kula, dated November 19, 2002 which responds to the Board majority questions concerning the MACCS2 computer code's process, order and mechanics for performing calculations leading to mean SAMA consequences.

Respectfully submitted:

[signature]

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Dated: November 22, 2010

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November 19, 2010

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION,

Before the Atomic Safety and Licensing Board Panel

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Entergy Nuclear Operations, Inc.	)	ASLBP No. 06-848-02-LR
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(Pilgrim Nuclear Power Station)	)	

AFFIDAVIT OF KEVIN R. O'KULA

Kevin R. O'Kula states as follows under penalties of perjury:

I. INTRODUCTION

1. This Affidavit is pursuant to the Atomic Safety and Licensing Board's ("Board") October 26, 2010 Order (Questions from Board Majority Regarding the Mechanics of Computing "Mean Consequences" in SAMA Analyses). My response below addresses each of the questions posed by the Board in its Order.

II. ANSWERS TO BOARD QUESTIONS

A. Explain (briefly and succinctly) what is computed within each of the three modules.

2. For a SAMA analysis, MACCS2 calculates two consequences, the off-site population dose and the off-site economic cost, from a set of postulated accident releases to the atmosphere (referred to as *postulated releases* in the remainder of this discussion). For each postulated release, three modules, ATMOS, EARLY and CHRONC, sequentially calculate consequences for a set of randomly chosen and different weather sequences. The sequential steps are described below.

3. The ATMOS module models atmospheric transport and dispersion of radioactive material to determine the concentration of radioactive material in the air and the amount deposited onto ground surfaces for a single postulated release under a set of specific weather conditions (i.e., a weather sequence defined by the initial and subsequent weather data following the release). The primary inputs to ATMOS are: (1) core inventory (amount of each radionuclide present in the reactor core); (2) characteristics of the postulated release including the amount of each radionuclide released, release height, release duration, and the energy from radioactive decay; (3) one year of hourly weather data (8,760 hours) including wind direction, speed, stability category, and precipitation intensity from which the weather sequences are randomly chosen; and (4) a polar coordinate grid to divide the 50-mile region around the plant into defined locations. The primary outputs of ATMOS are air concentrations and ground deposition of radioactive material for each grid location for each weather sequence. These data are stored for subsequent use by MACCS2 modules, EARLY and CHRONC.

4. The EARLY module calculates the off-site population dose from the plume as it transports downwind across the 50-mile grid during the initial period following the postulated release under a specific weather sequence. This phase, defined as the "emergency phase," lasts for seven days. The primary inputs to EARLY are (1) emergency response thresholds and other data from the plant's evacuation time study, such as the time for people to begin sheltering and evacuating and the speed of evacuation; (2) protective action criteria; (3) dose conversion factors; and (4) population distribution over the 50-mile grid. The outputs of EARLY include the population dose incurred from inhalation, cloudshine, and groundshine pathways as a function of grid location for one weather sequence. This information is stored for later use once all weather sequences for the postulated release are completed.

5. The CHRONC module calculates the long-term off-site population dose from contaminated areas, and contaminated food and water ingestion due to the postulated release for the period following the seven-day emergency phase, and assessed for approximately thirty years. The population dose from groundshine, inhalation of resuspended surface contamination, and food and water ingestion are considered in this phase, along with the effects of mitigation due to protective actions. CHRONC also models the economic cost associated with both the emergency phase and the long-term phase. The primary inputs to CHRONC are the (1) dose conversion factors; (2) protective action criteria (e.g., sheltering and evacuation during the emergency phase and decontamination and interdiction during the long-term phase); (3) population distribution over the 50-mile grid; and (4) site-related information such as land use, agricultural and economic regional data. The outputs of CHRONC are the off-site population dose incurred during the long-term phase and economic costs of both phases of one weather sequence. This information is stored for later use once all weather sequences for the postulated release are analyzed.

6. MACCS2 uses ATMOS, EARLY and CHRONC to calculate the consequences that would occur for each weather sequence selected from the randomly chosen set of weather sequences. The results are stored and the calculation process continues until the entire set of randomly chosen weather sequences from the year's worth of weather data is processed for the single postulated release. Such computations are generally repeated for 160 weather sequences (based on standard practice for Probabilistic Safety Assessment (PSA) and SAMA calculations of using 40 weather bins, and randomly selecting four weather sequences from each bin), and evaluating the weather sequence for each of the 16 primary compass directions for a total of 2,560 consequence results. Each result is obtained using the same models and input, with the only differences due to variation in the weather conditions.

7. In summary, the consequences are computed for 2,560 weather conditions, and the mean consequences are computed from those results for each postulated release.

8. In the Pilgrim SAMA analysis, 19 postulated releases are simulated representing different hypothetical, severe or beyond-design basis accident conditions defined in the plant's PSA. Thus, nineteen sets of mean consequences, i.e., the mean off-site population dose and mean off-site economic cost, are generated.

B. Explain briefly the process of dealing with the fact that many independent variables (such as source term, meteorological conditions, evacuation) cannot be definitively predicted to be occurring at any given time and must be addressed probabilistically, and how that leads to the computation of many different potential "consequences."

9. The MACCS2 analysis uses a probabilistic model for sampling of meteorological conditions with deterministic models for all other input variables, such as, the source term, evacuation times, and other variables. In this context, a deterministic model is one that yields one set of outcomes from one set of inputs. In the case of SAMA analysis, the MACCS2 code calculates one mean off-site population dose and one mean off-site economic cost for each postulated release input.

10. The only probabilistic model in the MACCS2 simulation is the meteorological sampling model. Because the postulated release could occur at any time of the year, the MACCS2 computer code uses a probabilistic sampling approach for selecting weather sequences in estimating population dose and economic cost consequences. Once a weather sequence is selected, the MACCS2 code will calculate one set of consequences for each postulated release. A distribution of results is calculated and sorted by the MACCS2 output module by their likelihood of occurrence and their magnitude. MACCS2 calculates the means for the population dose and off-site economic costs from these distributions.

11. Except for the meteorological sampling model, other MACCS2 models are deterministic. The major models are source term release (the radioactive material assumed to be released and its related characteristics), atmospheric transport and dispersion, plume rise, deposition, evacuation and other protective actions.

12. Input values to the deterministic models are the best available data that accurately describe the postulated release, the state of the plant and region following a postulated release, along with data for calculating population dose and economic costs. The sources of data are (1) international technical body-recognized radiological inputs such as dose conversion factor, radio-dosimetry, health effects models and data; (2) emergency response data from the plant's evacuation time study, such as the time for people to begin evacuating and the speed of evacuation; (3) emergency protective action planning and response criteria inputs from federal agencies and the states; (4) input data for the source term, site and regional characteristics; and (5) plant-specific, studies including environmental, safety analysis, and probabilistic safety assessment documents.

13. In summary, MACCS2 models one postulated release at a time with a probabilistic meteorological sampling model and a set of deterministic models with specific, best-available input data. MACCS2 generates a distribution of results for population dose and economic cost, and stores them for statistical evaluation. Each distribution includes a calculated consequence value and a probability of occurrence based on the likelihood of the set of weather conditions from a year's worth of hourly data. The expected value or mean of the distribution is calculated by MACCS2 and is the average consequence determined statistically from the distribution.

C. Describe generally the process for determining the consequences of each particular scenario (i.e., describe generally the selection process used for the values to be used for independent variables, and generally how those determine input or select model usage within a particular code module).

14. The general process of determining consequences from each particular postulated release follows a three-step calculation sequence.

1. Execution of the three MACCS2 computational modules: ATMOS, EARLY, and CHRONC are run for a specific set of weather conditions, i.e., a weather sequence, to produce a single value of population dose and economic cost for each postulated release.
2. Simulation of each postulated release for multiple weather sequences: A total of 160 sets of randomly selected weather sequences, postulated to occur in 16 principal compass sector directions, are analyzed. This results in a total of 2,560 individual consequence results for each postulated release.
3. Determination of the mean or expected value: The mean population dose and economic cost consequence from the 2,560 sets of calculated consequence values and their corresponding probabilities are calculated by applying a mathematical formula for determining the mean of a statistical distribution. Statistically, these are the "expected" or mean consequence values for the postulated release being modeled.

15. The MACCS2 input data preparation is in accordance with standard industry guidance for selecting input values for a SAMA analysis. The input is prepared for the MACCS2 models from the best available data to describe the postulated release being modeled, and the plant, site, and regional environment being analyzed. In each MACCS2 execution of a postulated release, all inputs are held constant using the same set of models. The choice of models within each of the MACCS2 modules is limited; except for a choice of evacuation models in EARLY and a choice of food ingestion models in CHRONC, there is only one model for each of the primary phenomenological areas. The models used and the type of data that are applied in these models are summarized below for each of the three MACCS2 modules.

16. In all MACCS2 cases, the single atmospheric transport and dispersion (ATD) model that is applied is the Gaussian plume segment model that is executed in the ATMOS module. The primary phenomenological models and examples of input data for the ATMOS module are shown in Table 1. The user cannot substitute other ATD or phenomenological models into ATMOS. The MACCS2 ATMOS module models the postulated release in nine groups of radionuclides based on their physical/chemical behavior and characteristics once the group of radionuclides is released from the reactor core and into the atmosphere. A fifty-mile polar grid is input in ATMOS to define grid regions

.Table 1. ATMOS Module Phenomenological Models and Input Types

Phenomenological Model	Examples of Input Data*
Source Term Specification	core inventory, amount released by radionuclide, timing of release, height, and decay energy
Meteorological or weather sampling model	• Specification of sequence selection • Weather sequence categorization • Spatial boundary weather Site weather observations for a representative year of data supplemented by regional precipitation measurements
Initial Plume Dimensioning	building dimensions; height of release; duration of release
Plume rise (due to decay heat from radionuclides)	decay energy from radionuclides
Gaussian plume segment model	Internal to the code.
- Gaussian plume equations	Dispersion parameters (crosswind and vertical release growth input parameters due to atmospheric turbulence)
- Surface roughness	Surface roughness length for region accounting for surface features
- Plume meander	duration of the release
Plume depletion	Internal to the code.
- Radioactive decay	Half-life data for radionuclides
- dry deposition	dry deposition velocity for particulate by radionuclide chemical group and size particulate as a function of downwind distance
- wet deposition, i.e., precipitation	washout coefficients for precipitation by duration and intensity

* The listing is representative but not necessarily complete. Shaded right-hand column boxes indicate that the model uses information mostly from elsewhere in the code.

17. For the EARLY module, the primary phenomenological models and examples of input data are shown in Table 2. Radiological dose conversion factors and protective action criteria are based on international radiological protection standards, NRC, EPA, and state-specified requirements. Each of the primary phenomenological areas in EARLY has a single model, except for evacuation, where the user has a choice. In the Pilgrim SAMA analysis, the radial evacuation model is selected, which assumes that all persons within the 10-mile emergency planning zone evacuate.

Table 2. EARLY Module Phenomenological Models and Input Types

Phenomenological Model	**Examples of Input Data***
Dosimetry Model Exposure Pathways	Dose conversion factors by pathway for each radionuclide. These pathway models are internal to the code.
- Cloudshine	shielding factors (fraction of pathway that is reduced by normal activity, evacuation, and sheltering).
- Groundshine	shielding factors (fraction of pathway that is reduced by normal activity, evacuation, and sheltering).
- Direct & Resuspension Inhalation	breathing rate; shielding factors (fraction of effect that is reduced by normal activity, evacuation, and sheltering).
Countermeasures	These countermeasure models are internal to the code.
- Evacuation models: • Network • Radial	Fraction of people participating; plant-specific evacuation time study; timing
- Sheltering	fraction of people participating; timing
Dose-Dependent Relocation	dose thresholds and criteria

* The listing is representative but not necessarily complete. Shaded right-hand column boxes indicate that the model uses information mostly from elsewhere in the code.

18. For the CHRONC module, the primary phenomenological models and examples of input data are shown in Table 3. In addition to population distribution, site data, and dose conversion factor data, most economic data for farm and non-farm activities, including decontamination, interdiction, and condemnation data sets and individual parameter values, are based on the best available economic information. These inputs are developed from mostly federal agency, state and local data collections. Economic models are those developed by the NRC over the last

twenty years to support PRA studies. Each of the major phenomenological areas in CHRONC has a single model, except for food consumption, where the user has a choice. In the Pilgrim SAMA analysis, an updated food ingestion model is applied.

Table 3. CHRONC Module Phenomenological Models and Input Types

Phenomenological Model	Examples of Input Data*
Exposure Pathways	Long-term pathway models are internal to the code
- Groundshine	dose factors; shielding factors
- Resuspension inhalation	breathing rate; shielding factors, decay constants
Food ingestion models: • MACCS model • COMIDA2 model	Ingestion model parameters; (Analysis performed separately & independently of MACCS2 model)
Water ingestion model	transfer factors, land use factors
Mitigative action models	protective action dose criteria; time factors
Economic cost model for emergency-phase	evacuation, sheltering, and relocation cost inputs
Economic cost model for long-term phase	decontamination, interdiction, and condemnation cost indices; dose criteria; economic wealth and farm wealth inputs; site data inputs

* The listing is representative but not necessarily complete. Shaded right-hand column boxes indicate that the model uses information mostly from elsewhere in the code.

D. Describe how the results of the separate computations of consequences are used to develop a representative "consequence" which is to be used for comparison to the cost of mitigation mechanisms, where in the foregoing process the computation of "mean consequences" is done or accomplished, and its relationship to the representative consequence used for the foregoing purpose.

19. The mean population dose and economic cost consequences are calculated for each postulated release following the three-step calculation sequence described in Subpart C. There are nineteen postulated releases, from the Pilgrim PSA study and subsequent plant-specific safety reports, representing a spectrum of severe accidents for the Pilgrim plant. For each postulated release, MACCS2 computes a mean population dose and a mean economic cost. The remaining steps of the SAMA cost-benefit study are performed outside of the MACCS2 code.

20. The first step is calculating the mean population dose risk and the mean economic cost risk. The mean consequences from the MACCS2 analyses are multiplied by the corresponding mean annual frequency for each postulated release (also obtained from the Pilgrim PSA). The products of mean consequence and mean frequency are mean population dose risk and mean off-site economic cost risk for each postulated release. In the second step, the nineteen population dose risk products are summed to yield the aggregate plant Population Dose Risk (PDR), with units of person-rem/year. The same summing process is used with the nineteen off-site economic cost risks to yield the aggregate plant Offsite Economic Cost Risk (OECR), with units of $/year.

21. The method used to determine potentially cost beneficial SAMAs is based on Nuclear Regulatory Commission guidance for performing cost-benefit analysis. This method compares the sum of the off-site exposure and economic costs (calculated by MACCS2), and the on-site exposure and economic costs (calculated with a method prescribed by cost-benefit regulatory guidance), with the cost of the enhancement, i.e., the cost of implementing the SAMA through changes to the nuclear plant or its operations to reduce the risk. The benefit is in terms of cost averted, calculated on a twenty-year basis, and includes: (1) the averted public exposure, APE ($), based on the MACCS2-calculated PDR and converted to cost; (2) the averted off-site economic cost, AOC ($), based on the MACCS2-calculated OECR and converted to cost; (3) the averted occupational exposure (AOE) cost ($); and (4) averted on-site cost (AOSC) ($), i.e., on-site clean-up and decontamination cost, and replacement power cost. The overall averted cost is the sum of APE, AOC, AOE, and AOSC. The averted cost is the "representative" metric or benefit to be compared against the cost of individual SAMAs, or mitigation mechanisms.

I declare under penalty of perjury that the foregoing is true and correct.

Kevin R. O'Kula 19 November 2010

Kevin R. O'Kula

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NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

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	)	
(Pilgrim Nuclear Power Station)	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of Entergy's Notice of Filing of Declaration and the November 19, 2010 Affidavit of Kevin R. O'Kula were served on the persons listed below by deposit in the U.S. Mail, first class, postage prepaid, and where indicated by an asterisk, by electronic mail, this 22nd day of November, 2010.

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