UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of

Philadelphia Electric Company   Docket No. 50-352

(Limerick Generating Station,
Unit 1)

AFFIDAVIT OF E. ROBERT SCHMIDT AND GEOFFREY D. KAISER CONCERNING THE RISKS TO THE INMATES OF THE STATE CORRECTIONAL INSTITUTE AT GRATERFORD ARISING FROM ACCIDENTAL RELEASES OF RADIOACTIVE MATERIAL FROM LIMERICK GENERATING STATION, UNIT 1

E. Robert Schmidt and Geoffrey D. Kaiser, being duly sworn according to law, hereby depose and state:

1. I, E. Robert Schmidt, am director of the Systems Analysis Group of the Consulting Division at NUS and as such am responsible for directing all systems analysis consulting services associated with nuclear and non-nuclear technology, including radiological and nonradiological accident analysis, thermal-hydraulic and heat transfer analysis, and risk assessment and probabilistic safety analysis. I have been with NUS Corporation since 1963 and during that time I have been involved in all facets of the design, operation and analysis of nuclear power plants. I directed the Limerick Severe Accident Risk Assessment (SARA) and provided the technical monitoring of the earlier Limerick Probabilistic Risk Assessment (PRA). I have previously appeared in this proceeding as

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an expert witness on contentions relating to the consequences of severe accidents at the Limerick Generating Station. A statement of my professional qualifications is presented in attachment A, which is attached hereto and incorporated by reference herein.

2. I, Geoffrey D. Kaiser, am manager of the Consequence Assessment Department at NUS Corporation. I have had extensive experience in the prediction of the offsite consequences of nuclear reactor accidents. I have participated in a managerial and technical capacity in the Limerick Severe Accident Risk Assessment (SARA), including responsibility for the sections dealing with offsite consequences. I have previously appeared in this proceeding as an expert witness on contentions relating to the consequences of severe accidents at the Limerick Generating Station. A statement of my professional qualifications is presented in Attachment B, which is attached hereto and incorporated by reference herein.

3. In conjunction with the NRC review of the application for an Operating License for the LGS, Philadelphia Electric Company submitted analyses of severe reactor accidents. These analyses consisted of two major parts. The first was a risk assessment of accidents due to random failures in plant equipment and to operator error (Limerick Generating Station Probabilistic Risk Assessment, Philadelphia Electric Company, 1982). The second part was performed by NUS Corporation (NUS Corporation, Limerick Generating Station Severe Accident Risk Assessment, 1983). SARA had two purposes; to update the original PRA by including external events such as hurricanes, tornadoes, floods, fires and earthquakes,

and to calculate the environmental consequences of severe accidents.

4. The code CRAC2 (L.T. Ritchie, et. al., "CRAC2 Model Description", NUREG/CR-2552, 1984) was used in SARA to evaluate the consequences of accidental releases of radioactive material to the atmosphere. CRAC2 is an updated version of the CRAC code (Calculation of Reactor Accident Consequences), which was originally developed for the Reactor Safety Study (U. S. Nuclear Regulatory Commission, "Reactor Safety Study", WASH-1400, 1975). CRAC2 has been extensively used by Applicant to perform parametric studies and evaluations in response to contentions dealing with the consequences of severe accidents before this Board. (See testimony following Tr. 11,114).

5. In brief, CRAC2 accepts data on a) fission product source terms - the predicted frequency, magnitude and timing of the release of radioactive material to the atmosphere; b) five years of hourly data for the Limerick site which include windspeed and direction, atmospheric stability, and precipitation intensity; c) the distribution of population around the site; d) the expected behavior of the population when evacuating the Plume Exposure Emergency Planning Zone (EPZ); e) the sheltering characteristics of structures in the area surrounding the site; f) dosimetry and the response of people to radiation doses; and g) the pathways whereby people can be exposed to radiation.

6. CRAC2 models the dispersion of the radioactive material in the atmosphere for a representative sample of the spectrum of weather conditions in the meteorological data file. It considers the depletion of the cloud by both

dry and wet deposition. It calculates the radiation doses received by people at various distances downwind due to the inhalation of radioactive material and the irradiation of people by gamma rays emitted by the passing cloud and by deposited fission products. Additional material with regard to CRAC2 is found in the testimony (following Tr.11,114) and in Chapter 10 and Appendix F of SARA.

7. SARA and this analysis model the impact of severe, but highly improbable, core-melt accidents on the population around the LGS. It must be recognized that any accident which is less severe than those resulting in core melt would not require initiation of any protective action outside the site boundary. Examples of such non core-melt accidents are given in Section 7.1.3 and in Table 7-1-20 of the Limerick Environmental Report, Operating License stage and lead to very small radiation doses beyond the site boundary. (See also the Limerick Final Enviromental Statement, NUREG-0974, at p. 5-72 and 5-73). In order to assess the effect of accidental releases of radioactive material resulting from these highly improbable core melt accidents at LGS on the inmates of the State Correctional Institution at Graterford, CRAC2 has again been used, incorporating input assumptions which conservatively model the facility and expected protective measures. The use of input assumptions which are specific to the particular population being examined is consistent with the previous use of CRAC2 in SARA and in prior testimony before this Board. The probability that individuals will receive whole body doses of greater than 5 rem to the whole body,

or greater than 25 rem to the whole body have been calculated. These quantities give an indication of the risks incurred by the inmates. The figure of 5 rem to the whole body is chosen becasue it corresponds to a Protective Action Guide (PAG), promulgated by the Environmental Protection Agency (EPA) (Manual of Protective Action Guides and Protection Actions for Nuclear Incidents, EPA-520/1-75-001, 1980)*. If the radiation doses to members of the public are predicted to exceed 5 rem, then the EPA states that protective actions should be taken. The figure of 25 rem to the whole body is the level of dose below which early health effects are clinically undetectable in most people (LGS Final Environmental Statement, NUREG-0974, P. 5-91, 1984).

8. The CRAC2 calculations were carried out with the same assumptions as are given in Chapter 10 of SARA, with the following changes which conservatively model the Graterford Institution.

9. The institution is approximately 8.3 miles from LGS and is located in the sector due east of the plant.

10. While preparing to evacuate, after notification of the need to evacuate has been given, the inmates of the prison will be protected by the excellent shielding characteristics of the Graterford buildings. According to information provided by the Federal Emergency Management Agency (FEMA), Graterford contains 3,483 spaces with

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*The Pennsylvania Emergency Management Agency has accepted the use of EPA's PAGs as a decision making tool for the purposes of planning. See Commonwealth of Pennsylvania Disaster Operations Plan, Annex E Fixed Nuclear Facility Incidents p. E-12-45.

a range of protection factors from 40-99, and 1,620 spaces with a protection factor of greater than 100 (National Shelter Survey Facility List, September 30, 1984 p. 1543). The protection factor gives the predicted ratio between the radiation dose received by a person standing in the open on flat, contaminated ground and the dose received by a person inside the building. Thus, the inverse of the protection factor is the shielding factor needed as input to CRAC2 in order to model the shielding provided by the building from deposited fission products while waiting to evacuate. Hence, a shielding factor of 1/40 = 0.025 while waiting to evacuate, which was used in this analysis, is a conservative (i. e. pessimistic) estimate of the attenuation of gamma rays emitted by deposited fission products.

11. The FEMA reference does not contain a shielding factor for irradiation by gamma rays from the passing cloud. However, a shielding factor of 0.2 for such gamma rays is typical of large buildings such as office blocks or large facilities (U. S. Nuclear Regulatory Commission, PRA Procedures Guide, NUREG/CR-2300, 1983, p. E-8).

12. Finally, the inmates will be further protected by closing windows and doors and minimizing the intake of the radioactive plume and thus reducing the resulting inhalation doses. (Pennsylvania Bureau of Correction Radiological Emergency Response Plan (RERP), Page E-1-D-1, Item B). Studies of sheltering in the basements of houses show that this effect can reduce the amount of radionuclides inhaled by a factor of two. (U. S. Nuclear Regulatory

Commission, PRA Procedures Guide, NUREG/CR-2300, 1983, p. E-12). It is assumed that a similar reduction will hold true at Graterford.

13. Once notification to evacuate the prisoners has been given, it is expected that it will take 6-10 hours before the last prisoner is ready to leave (Private Communication between Theodore G. Otto, III, Commonwealth of Pennsylvania Assistant Counsel, Department of Corrections, and G. D. Kaiser, NUS Corporation, 1-31-85). This applies both during the day and at night. In order to span this preparation time, two cases, one with a 6 hour and one with a 10 hour delay time have been chosen for the purposes of CRAC2 calculations (delay time being the time between notification of the need to evacuate and the time at which evacuation begins). However, recognizing that a spectrum of delay times is possible, CRAC2 calculations have also been carried out using delay times of 24 and 48 hours. Once evacuation begins, it is assumed that the buses transporting the prisoners will move out of the EPZ at an average speed of 10 mph.

14. The results of the CRAC2 calculations are summarized in Table 1. All of the risks shown on Table 1 are extremely small. For perspective, a member of the public living near Graterford whose movement with respect to the plume was the same as that of the inmates would be expected to have a slightly greater chance of receiving individual doses in excess of 5 rem or 25 rem. The principal reason for this is the excellent shielding characteristics of the facility as discussed in Paragraph 10.

15. There are several conservatisms in the calculations. For example, the shielding effectiveness of the Graterford structure has if anything been underestimated, since FEMA's National Shelter Survey shows that Graterford has many spaces with protection factors greater than the value of forty that was discussed in paragraph 10. The fission product source terms which are given in SARA, Tables 12-7 and 12-8, are also highly conservative*. All of these factors taken together suggest that even the very small risks assessed for the inmates on Table 1 are considerably overestimated.

16. Finally, note that the prisoners will be issued potassium iodide tablets (Pennsylvania Bureau of Correction Radiological Emergency Response Plan, p. E-1-A-2), a protective measure that was conservatively not included in this analysis and would not be available to the general public.

Sworn and Subscribed Before

Me This 7th Day
of February, 1985

E. R. Schmidt

G. D. Kaiser

Joanne W. Wega
Notary Public

My Commission Expires July 1, 1986

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*Much development work on source terms has been done since the SARA analysis was carried out. Studies have been carried out by such organizations as the Battelle Columbus Laboratories (for NRC), the Industry Degraded Core Rulemaking Program, and the American Nuclear Society. There seems to be a developing consensus that source terms such as those contained in SARA are too large by perhaps an order of magnitude or more. The effect of this, if factored into the analysis, would be to make more than an order of magnitude reduction in the risks given in Table 1.

Table 1

Results of CRAC2 Calculations

	Probability (chance) per reactor year of individual doses exceeding 5 rem to the whole body	Probability (chance) per reactor year of individual doses exceeding 25 rem to the whole body
Inmate - 6 hour delay	5.0×10^{-8} (1 in 20 million)	2.8×10^{-9} (1 in 360 million)
Inmate - 10 hour delay	8.4×10^{-8} (1 in 12 million)	3.1×10^{-9} (1 in 320 million)
Inmate - 24 hour delay	1.1×10^{-7} (1 in 9 million)	5.0×10^{-9} (1 in 200 million)
Inmate - 48 hour delay	1.3×10^{-7} (1 in 8 million)	9.2×10^{-9} (1 in 110 million)

ATTACHMENT A

PROFESSIONAL QUALIFICATIONS

E. ROBERT SCHMIDT
Director, Systems Analysis
NUS Corporation

My name is E. Robert Schmidt. My business address is 910 Clopper Road, Gaithersburg, Maryland 20878. I am Director of the Systems Analysis Group of the Consulting Division and as such am responsible for directing all systems analysis consulting services associated with nuclear and nonnuclear technology, including radiological and nonradiological accident analysis, thermal-hydraulic and heat transfer analysis, and risk assessment and probabilistic safety analysis.

I received a Bachelor of Science degree in Mechanical Engineering from the University of Missouri in 1958 and a Master of Science degree in Nuclear Engineering from the same institution in 1959. After graduation I worked for General Electric for one year. I then worked for Internuclear Company from 1960 to 1963. During that time I developed design criteria and analyzed in-pile loops of the experimental gas-cooled reactor at Oak Ridge National Laboratory and participated in the design of several small reactors.

I have been with NUS Coporation since 1963 and during that the time I have been involved in all facets of the design, operation, and analysis of nuclear power plants. I was onsite startup consultant to the Government of India, the Japan Atomic Power Company, and the Toyko Electric Power Company for the startup of four BWR units.

I have directed a vast amount of licensing and safety analysis work and have participated in many special nuclear technologies studies. Some of the most significant include a study of steam cycle conditions for a prototype large breeder reactor, safety analysis report review for foreign licensing authorities and domestic utilities, industrial and aircraft impact hazards analysis, containment and subcompartment temperature and pressure analyses, and the design and safety analysis of several spent fuel shipping casks.

Prior to my current position, I was Manager of the Reliability and Risk Assessment Department. I performed and directed risk assessments, degraded core accident evaluations, safety goal analyses, and detailed assessments of the probabilities and consequences of accidents involving hazardous material transport near a nuclear power station. I was also involved in a study of aircraft impact probabilities which included providing hearing board testimony.

Most recently I have been responsible for directing the Kuosheng, Susquehanna, and Ringhals 2 risk assessments. I also directed the Limerick external event risk assessment, and with Mr. Saul Levine, provided the technical monitoring of the Limerick inplant failure risk study. I also managed limited scope, mini-PRAs for six nuclear power plants.

I am a Registered Professional Engineer in the District of Columbia. I am a member of the American Nuclear Society, the American Society of Mechanical Engineers, and the Society for Risk Analysis.

ATTACHMENT B

PROFESSIONAL QUALIFICATIONS

GEOFFREY D. KAISER
Manager, Consequence Assessment Department
NUS Corporation

My name is Geoffrey D. Kaiser. My business address is 910 Clopper Road, Gaithersburg, Maryland 20878. I am manager of the Consequence Assessment Department. In that position, I am responsible for managing projects relating to the consequences of accidental releases of radioactive, toxic, and flammable chemicals.

I received a Bachelor of Arts degree in Physics from Cambridge University (UK) in 1964; a Master of Arts degree in Physics from Cambridge in 1967; and a Doctor of Philosophy in Elementary Particle Physics, also from Cambridge University in 1968. Subsequently, I had postdoctoral research fellowships in theoretical particle physics at the Cavendish Laboratory at Cambridge and the University of Miami. I held a temporary lectureship in applied mathematics at the University of Durham (UK) during the academic year 1970/71 and served as a Senior Research Associate in theoretical particle physics at the Daresbury Nuclear Physics Laboratory, Warrington, UK, from 1971 to 1974.

From 1974 to 1980 I worked at the United Kingdom Atomic Energy Authority's Safety and Reliability Directorate (SRD) in the Environmental and Fission Product Group. In 1976, I was appointed Head of Physics and led a group which grew to include 10 people involved in the development of methods with which to predict the consequences of the accidental release of radiotoxic, chemically toxic, and flammable materials to the environment. During my time at SRD, I developed the nuclear consequence modeling code TIRION, which was widely used in the United Kingdom and abroad in applications to reactors, reprocessing plant, nuclear shipping, and the transport of plutonium by road, rail, and sea. The most important application of TIRION was at the Windscale Inquiry into the building of a reprocessing plant for oxide fuel. I also participated in and/or managed multidisciplinary projects relevant to the safety and environmental impact of advanced technologies, including participation in the well-known Canvey Island Study.

I was a frequent speaker at seminars and international conferences, and participated as a lecturer at courses arranged by the United Kingdom Atomic Energy Authority. I chaired several international working groups on consequence analysis.

In 1981, I joined NUS Corporation and in 1982, became Manager of the Consequence Assessment Department. Since that time I have been involved in many significant projects. I provided overall technical management for the phenomenological and consequence analysis portions of the Susquehanna Probabilistic Risk Assessment, and for the consequence analysis and transportation accident analysis for Limerick. I have recently been managing the Phase 2 probabilistic safety study for the Swedish State Power Board's Ringhals 2 plant, the purpose of which is to develop source terms for severe accidents. I am also responsible for the consequence analysis for the Industry Degraded Core Rulemaking Program. I have managed "mini-PRAs" for the Palo Verde and Hope Creek Nuclear Generating Stations and have written Chapter 7 of the environmental reports for Hope Creek and Limerick. I was a founder member, and also an author and co-editor, of the committee on the Safety of Nuclear Installations International Benchmark Comparison of Consequence Modeling Codes.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
	)	
Philadelphia Electric Company	)	Docket Nos. 50-352
	)	50-353
(Limerick Generating Station,	)	
Units 1 and 2)	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of "Applicant's Motion for Exemption from the Requirements of 10 C.F.R. §50.47(a) and (b) as They Relate to the Necessity of Atomic Safety and Licensing Board Consideration of Evacuation Provisions of the Emergency Plan for the State Correctional Institution of Graterford" " dated February 7, 1985 in the captioned matter have been served upon the following by deposit in the United States mail this 7th day of February, 1985:

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