UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the matter of

DUKE POWER COMPANY) License Amendment for Transportation and) Storage of Oconee Spent Fuel at McGuire) Nuclear Station)	Docket No. 70-2623

TESTIMONY OF DR. B. JOHN GARRICK

My name is B. John Garrick. I am a licensed nuclear engineer with 27 years of experience in technical management, systems analysis and design, risk and safety analysis, and reliability engineering. I am presently Vice President of Pickard, Lowe and Garrick, Inc., of Washington, D.C., and Irvine, California. My office address is 2070 Business Center Drive, Suite 125, Irvine, California 92715. Pickard, Lowe and Garrick, Inc., is a consulting engineering firm primarily in the field of nuclear power. Prior experience includes a Director and Senior Vice President of Holmes & Narver, Inc., and President of that engineering and construction firm's Nuclear & Systems Sciences Group; Physicist and member of the first Reactor Hazards Evaluation staff, U.S. Atomic Energy Commission; and Physicist, Phillips Petroleum Company at the National Reactor Testing Station in Idaho. My training includes a Ph.D. and M.S. in Nuclear Engineering from the University of California, Los Angeles. I am a graduate of the Oak Ridge School of Reactor Technology and hold a B.S. in Physics from

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Brigham Young University. My Ph. D. thesis was one of the first theses on the application of fault tree analysis* to assess nuclear power plant risks. I have authored approximately seventy papers and reports on nuclear power, reliability, safety, and technology. I have taught numerous courses on reliability, risk, and safety analysis, primarily as the special sem... rs and short courses at UCLA and more recently for the Electric Power Research Institute, the U. S. Department of Energy, and several electric utilities.

My involvement in safety analysis of shipping containers began in 1952 at the National Reactor Testing Station in Idaho where I was a member of a team to redesign the final product shipping containers for the Idaho Chemical Processing Plant. My area of work was nuclear criticality and accident analysis. My experience has included numerous safety and risk analysis assignments:

- Project director of a comprehensive risk analysis of a large operating nuclear power plant.
- Expert witness in numerous hearings involving the transport of spent nuclear fuel and radioactive wastes.

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*Fault tree analysis is a technique of system safety assessment based on: (1) a graphical display of events and failures representing possible failure paths to an undesired event (the top event) such as the release of radioactivity and (2) a mathematical analysis of the resulting failure logic to compute the probability of the top event.

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- U. S. representative on International Atomic Energy Agency missions to Pakistan and South Korea on nuclear plant siting and safety.
- U. S. representative on USAEC exhibit, Reactor Safety Research and Development, Second International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland.
- Principal investigator on several studies sponsored by the USAEC in the areas of reliability and safety.
- Pr[illegible]ipal investigator in the preparation of a "Risk Model for the Transport of Hazardous Materials" for the U. S. Army.
- Project director of a risk study for the State of California on power plant siting to the year 2000.
- Project director of a study for the U. S. Environmental Protection Agency, "Transportation Accident Risks in the Nuclear Power Industry 1975-2020."
- Advocate and prime mover for many years in developing and gaining acceptance of the general idea of applying more quantitative probabilistic methods to decision questions involving risk, safety, and reliability.

APPLICATION OF RISK ANALYSIS TO THE TRANSPORT OF SPENT NUCLEAR FUEL

In my judgment the risk to the public from the shipment of spent nuclear fuel is extremely small both in terms of the likelihood of a release of radioactive material and as to its consequences. My conclusion is based in general on the excellent safety record of shipments of radioactive material and the testing program of such casks under extreme loads and specifically on my risk analysis of the shipment of spent fuel by truck from Oconee to the McGuire Nuclear Station.

My analysis made use of several risk studies (References 1, 2, and 3) that have been performed on the transport of radioactive materials. In particular, the analysis performed was primarily based on: (1) the combining of selected results of several transportation studies into a suitable form for conveying risk; and (2) specialization of generic risk studies to the Oconee/McGuire shipping conditions.

In my analysis, I adopted as an expression of risk the frequency that N or more people would receive D or more dose per shipment of fuel from Oconee to McGuire. In the conduct of the risk analysis it was important to identify the specific steps involved. These steps are presented as Figure 1. Underlying Figure 1 is a risk analysis methodology which is outlined as follows.

To begin with, we divided the proposed route between Oconee and McGuire into sections, and placed each section into one of three categories: rural, urban, or suburban. From tabulated statistical data, we then obtained:

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$$\phi_r \equiv \begin{pmatrix}\text{accident rate on road type r,} \\ \text{accidents per kilometer}\end{pmatrix} . \qquad (1)$$

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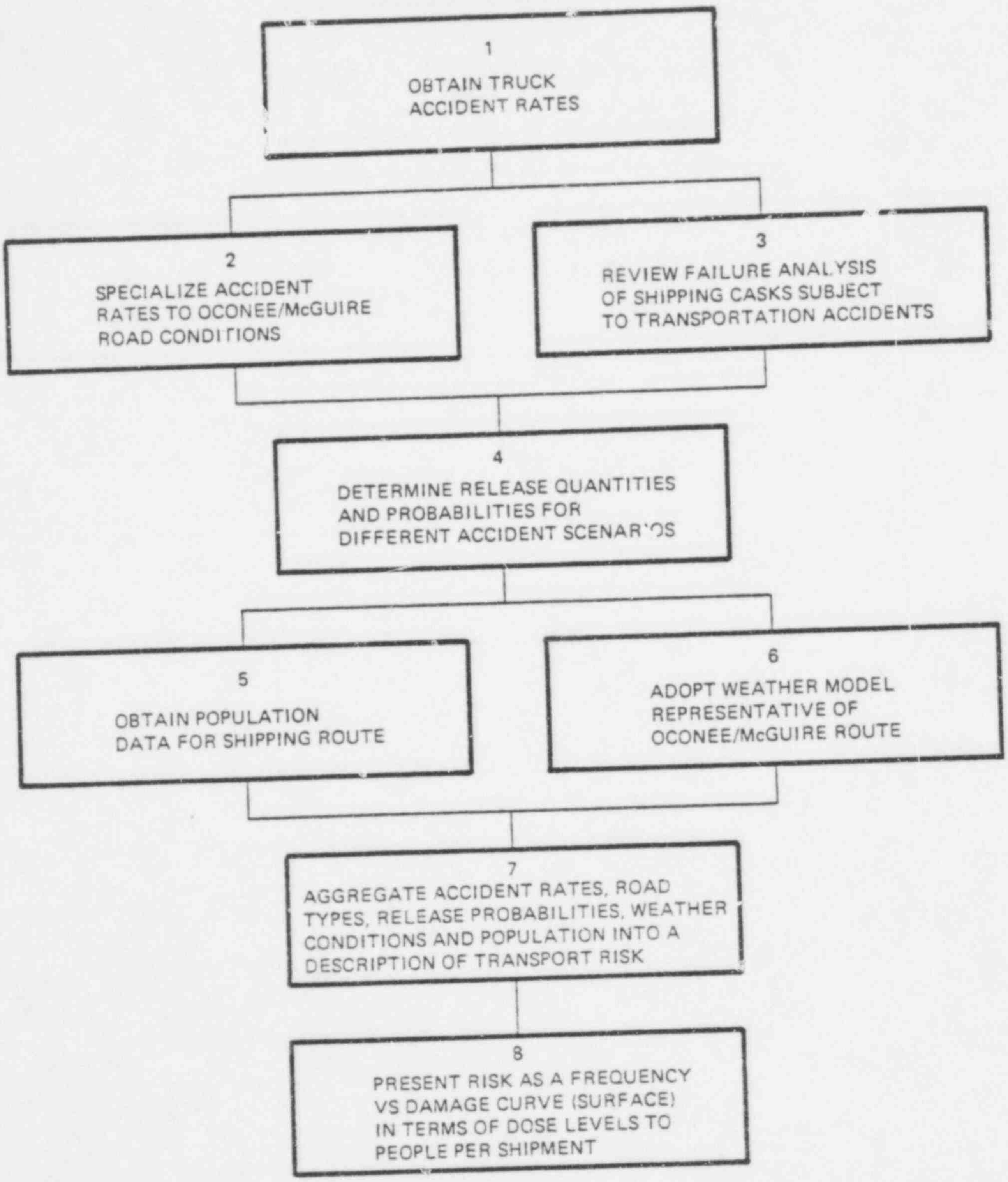

Figure 1. Sequence of Risk Analysis Tasks

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From Reference 2, which is an extensive study of the consequences of accidents on shipping casks, we obtained:

$$p(R) \equiv \begin{pmatrix} \text{probability of radioactive release} \\ \text{of type R, given an accident} \end{pmatrix} . \tag{2}$$

R is a discrete variable which ranges over eight release categories. Each release category (or accident "case") is defined by specific quantities of various isotopes released.

The dispersion of isotopes, once released, depends of course on the weather at the time. The degree of contamination is measured by a dose parameter $\mathcal{D}$, which can be related to actual dose, D, using the actual quantities of isotope released. Thus

$$D = D(\mathcal{D}, R) . \tag{3}$$

Let

$$A(\mathcal{D}, w) = \begin{pmatrix} \text{area in square miles contaminated to degree} \\ \mathcal{D} \text{ or greater under weather condition, w} \end{pmatrix} . \tag{4}$$

If we take f_w as the fraction of time that each weather condition is experienced in the vicinity of the Oconee/McGuire route, then for a given $\mathcal{D}$ let

$$F(\mathcal{D}, \alpha) \equiv \sum_{A \geq \alpha} f_w \tag{5}$$

where the summation is over all weather conditions w, having the property that

$$A(\mathcal{D}, w) \geq \alpha . \tag{6}$$

Thus $F(\mathcal{D}, \alpha)$ is the probability, given a release, that α square miles or more will be contaminated to level $\mathcal{D}$, or greater.

Now if h_r is the population density in the vicinity of the release, then we may also give $F(\mathcal{D}, \alpha)$ the interpretation:

$$F(\mathcal{D}, \alpha) = \begin{pmatrix} \text{the probability, given a release in road type r,} \\ \text{that } h_r\alpha \text{ or more people will experience dose} \\ \text{parameter } \mathcal{D} \text{ or more} \end{pmatrix} . \quad (7)$$

Turning this around slightly, by defining

$$N = h_r \alpha \quad (8)$$

and

$$P_r(N, \mathcal{D}) = F\left(\frac{N}{h_r}, \mathcal{D}\right) \quad (9)$$

we have

$$P_r(N, \mathcal{D}) = \begin{pmatrix} \text{the probability, given a release in road} \\ \text{type r, that N or more people will} \\ \text{experience dose parameter } \mathcal{D} \text{ or more} \end{pmatrix} . \quad (10)$$

Now if we multiply this probability by the probability $p(R)$ of release type R, we obtain:

$$P_r(N, \mathcal{D})\, p(R) = \begin{pmatrix} \text{the probability, given an accident in road r,} \\ \text{that there will be a release of type R, and} \\ \text{as a result, N or more people will experi-} \\ \text{ence dose parameter } \mathcal{D} \text{ or more} \end{pmatrix} . \quad (11)$$

Recall now that we can convert the dose parameter $\mathcal{D}$ to an actual dose using Equation (3). We thus write:

$$P_r(N, R, D) \equiv P_r(N, \mathcal{D})\, p(R) \quad (12)$$

where $D = D(\mathcal{D}, R)$.

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Thus

$$P_r(N, R, D) = \begin{pmatrix} \text{the probability, given an accident} \\ \text{in road r, that there will be a} \\ \text{release of type R, and as a result} \\ \text{N or more people will get dose D} \\ \text{or more} \end{pmatrix} .$$

If we now multiply this by ϕ_r, the accident rate per kilometer on road type r, and by L_r, the number of kilometers of type r in the shipping route, we obtain:

$$\Phi_r(D, N, R) = \phi_r L_r P_r(D, N, R)$$

$$= \begin{pmatrix} \text{frequency, in occurrences per shipment, of N or} \\ \text{more people receiving dose D or more as a result of} \\ \text{an accident in road type r with release category R.} \end{pmatrix} . \qquad (13)$$

Summing over release categories, we obtain:

$$\Phi_r(D, N) = \sum_{R=1}^{8} \phi_r L_r P_r(D, N, R)$$

$$= \begin{pmatrix} \text{frequency, in occurrences per shipment, of N or} \\ \text{more people receiving dose D or more as a result} \\ \text{of an accident in road type r.} \end{pmatrix} .$$

Similarly summing over road types we have

$$\Phi(D, N) = \sum_{r=1}^{3} \sum_{R=1}^{8} \phi_r L_r P_r(D, N, R)$$

$$= \begin{pmatrix} \text{frequency, occurrences per shipment, of N or more} \\ \text{people receiving dose D or more.} \end{pmatrix} .$$

The quantity $\Phi(D, N)$ as a function of D and N is the final expression of risk. It is shown tabulated in Table 1 for D expressed as whole body dose.

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TABLE 1. FREQUENCY OF N OR MORE PEOPLE RECEIVING D OR GREATER WHOLE BODY DOSE FROM ALL CATEGORIES ON ANY TYPE OF ROAD

Dose, D	Number of People, N						
MREM	1	10	100	1,000	10,000	100,000	1,000,000
1	1.16×10^{-4}	5.45×10^{-5}	2.77×10^{-5}	1.13×10^{-5}	4.51×10^{-6}	1.68×10^{-6}	4.78×10^{-7}
5	5.79×10^{-5}	3.86×10^{-5}	1.79×10^{-5}	5.72×10^{-6}	1.90×10^{-6}	3.82×10^{-7}	0.
10	4.77×10^{-5}	2.86×10^{-5}	9.51×10^{-6}	2.86×10^{-6}	4.78×10^{-7}	0.	0.
50	3.76×10^{-5}	1.89×10^{-5}	4.22×10^{-6}	1.37×10^{-6}	0.	0.	0.
100	2.76×10^{-5}	9.92×10^{-6}	1.65×10^{-6}	3.82×10^{-7}	0.	0.	0.
500	1.97×10^{-5}	4.89×10^{-6}	5.48×10^{-7}	0.	0.	0.	0.
1,000	1.12×10^{-5}	2.11×10^{-6}	0.	0.	0.	0.	0.
5,000	3.96×10^{-6}	5.48×10^{-7}	0.	0.	0.	0.	0.
10,000	1.23×10^{-6}	0.	0.	0.	0.	0.	0.
50,000	0.	0.	0.	0.	0.	0.	0.

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Table 1 is our final risk surface. It enables us to look at the frequency of occurrence of essentially any combination of numbers of people and dose levels. For example, the dose due to natural background radiation is approximately 100 millirems per year to the whole body. Suppose then we want to know the frequency of one person or more receiving 1 year's worth of background dose as a result of these shipments. We observe from Table 1 that the frequency is 2.76×10^{-5} per shipment. For 300 shipments between Oconee and McGuire, the frequency per year is

$$(2.76 \times 10^{-5})(3 \times 10^{2}) = 8.28 \times 10^{-3}$$

i.e., the frequency of one or more people receiving 100 millirems or more as a result of 300 shipments is 8.28×10^{-3}. Thus, it will happen less often than once in 100 years that anyone would receive a dose from a transportation accident equal to what every member of the entire population receives each year from natural background. As another example of the use of the table, note that the threshold for observable radiation sickness in man is about 50 rems = 5×10^{4} millirems. From the table, the likelihood that even one person would receive 50 rems or more is below our roundoff, i.e., below about 1×10^{-7} per shipment. So, we are able to conclude that the risk of transporting spent fuel from Oconee to McGuire is indeed extremely small.

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REFERENCES

1. "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes," NUREG-0170, December 1977, U. S. Nuclear Regulatory Commission.

2. "An Assessment of the Risk of Transporting Spent Nuclear Fuel by Truck," PNL-2588, November 1973, Pacific Northwest Laboratory.

3. "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants," WASH-1238, December 1972, U. S. Atomic Energy Commission.

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