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TESTIMONY OF
DR. SHELDON C. PLOTKIN
AND
MR. MIGUEL PULIDO
ON BEHALF OF JOINT INTERVENORS
JANUARY 19, 1982
CONTENTION 1

Background

My name is Sheldon C. Plotkin. I received Bachelor of Science degrees in Electrical Engineering and Aeronautical Engineering from the University of Colorado in 1946 and 1949, respectively. In addition, I received a Ph.D. in Electrical Engineering from the University of California at Berkeley in 1956. My experience over the past 35 years has been at the Los Alamos Scientific Laboratory, U.S. Air Missile Test Center, University of California, Energy Systems, University of Southern California, Hughes Aircraft Company, TRW Systems, and RAND Corporation, and in 1971, I established (and have continued through the present) a private systems and safety engineering consulting firm in Los Angeles, California.

My experience relevant specifically to the subject matter of this proceeding includes many years of systems engineering analysis, automatic highway system synthesis, accident analysis (including highway design), and analysis of dynamic human factors and behavior under emergency conditions. Recently, I testified on evacuation planning and times assessment before the Licensing Board of the Nuclear

Regulatory Commission in the San Onofre licensing proeeding (Units 2 and 3).

My name is Miguel Pulido. I received a Bachelor of Science degree in engineering (with an emphasis in mechanical engineering) in 1980 from California State University at Fullerton. During the past two years, I have been employed as an associate energy systems engineer for the Southern Califoria Gas Company and, since 1980, as a mechanical engineer with McCaughey and Smith Energy Associates, Consulting Engineers. Specific experience has included analysis of energy and engineering systems, computer simulation programs, facility energy loads, and facility energy consumption and preparation of feasibility studies and reports and responses to requests for proposals. Recently, I have assisted in the preparation of a critique of the evacuation times estimates report prepared by Wilbur Smith and Associates in connection with the San Onofre Nuclear Generating Station, Units 2 and 3, licensing proceeding.

<u>Documents Reviewed</u>

In the preparation of this testimony, we have reviewed three documents related to emergency planning for the Diablo Canyon Nuclear Power Plant: the Voorhees and Associates "Evacuation Times Assessment for the Diablo Canyon Nuclear Power Plant, Phase I and Phase II Reports" (September, 1980); the TERA Corporation report "Earthquake Emergency Planning at Diablo Canyon," Chapter 4.0 (September 1981); and the San Luis

Obispo County Nuclear Power Plant Emergency Response Plan, Revision B (October, 1981). The testimony which follows will, therefore, be limited to these documents, specifically to their discussion and calculation of evacuation times for the population surrounding the Diablo Canyon Plant in the event of a serious nuclear accident.

Discussion

We conclude that the calculation of evacuation times estimates set forth and relied upon in the three documents listed above is flawed in a number of respects, some more critical than others but which, taken as a whole, draw into question the utility of these documents as a basis for determination of the appropriate protective actions to be taken in response to a radiological emergency. Before describing some of their principal deficiencies in detail, however, some general remarks regarding systems engineering analysis are in order, noting that we are concerned here with an evacuation system. Proper understanding of system performance can be acquired only by knowing both limiting and anticipated or realistic conditions. Although it is important to be aware of limiting conditions -- e.g. optimum, on the one hand, and worst case, on the other -- they are many times strictly theoretical in nature and are unlikely to be achieved. In contrast, realistic or anticipated conditions comprise the most likely operational mode, an analysis of which will provide the most useful evaluation of system adequacy. Briefly stated, therefore, the specific system conditions requiring study are the following:

(1) optimum (unlikely);

(2) realistic or anticipated (likely);

(3) catastrophic or worst case (unlikely)

An evaluation of each of these conditions is beneficial to a full understanding of system performance, whether an evacuation system or any other type of system.

These general principles are particularly important in this proceeding because the Voorhees Evacuation Times Reports, the TERA report, and the San Luis Obispo County Plan (which refers to and relies on those documents) base their conclusions solely upon an analysis of the evacuation system operating at an <u>optimum</u> level. Although they included a number of small variations or "scenarios," these were all subsumed within the optimum evacuation time category because of the limited extent of the variation considered. For example, perhaps the primary factor in determining evacuation times is the highway capacity, for which the optimum condition requires an assumption of no flow restricting factors (e.g., accidents or malfunctions). Voorhees/TERA assumed both that any accidents, blockages, or malfunctions could and would be quickly cleared and that all entrances to principal evacuation routes would be strictly controlled, thereby maintaining the optimum highway speed of 35 miles per hour average. Those theoretical assumptions in turn result in an optimum evacuation rate of 3,600 vehicles per hour on both North and South Highway 101 and 1,800 vehicles per hour on North Highway 1.

These conclusions contrast sharply with those derived from an analysis of the realistic or anticipated evacuation system condition, a condition, we submit, substantially more likely to occur. Such an analysis includes the uncertainties of human response under emergency conditions acompanying a severe nuclear power plant accident, for example, the possibility that highway entrance controls will be ignored, that directives to use specific evacuation routes will be disregarded, or that road clearance personnel or highway entrance control personnel will be unavailable or leave their posts in order to assure the safety of their own families. Such an analysis anticipates also an increased likelihood of rear-end collisions, along with at least a normal number of stalled vehicles, resulting in increased highway congestion due to lane blockage, ineffective access control, inadequate access by tow trucks to stalled or damaged vehicles on major evacuation routes, and very substantial numbers of vehicles attempting to evacuate in fear of radioactive contamination.

These factors are likely to result in substantially reduced traffic speeds of between 0 and 10 miles per hour, the average speed being about 5 miles per hour. Using Bureau of Public Roads traffic flow data for such reduced speeds, the traffic flow rate is similarly reduced from the 1,800 vehicles per lane-hour maximum assumed by Voorhees/TERA to approximately 600 vehicles per lane-hour. Assuming blockage of one lane in each direction, the total vehicle flow rate on Highway 101 reduces from the theoretical maximum of 3,600 vehicles per hour in each direction to a realistic or anticipated rate of 600 vehicles per hour. Assuming no serious lane blockage, the anticipated flow rate would be approximately 1,200 vehicles per hour. Similar reductions in flow rate could be expected on Highway 1 North. This factor alone -- the reduced traffic flow expected in the realistic or anticipated evacuation system condition -- results in an increase in total evacuation time for the Basic EPZ from between 4 and 8 hours, calculated by Voorhees and incorporated into the County Plan (Table I.5-6), to between 15 and 21 hours (assuming no serious lane blockage) or between 21 and 36 hours (assuming one lane blocked on Highway 101 each direction).

The catastrophic or worst case system condition involves a major natural disaster, such as a tidal wave, tornado, or major earthquake, accompanied by a serious accident at the Diablo Canyon plant leading to a substantial offsite release of radiation. This condition assumes complete or near complete blockage or destruction of principal evacuation routes as a result of the natural disaster and the consequent inability of a major percentage of the population to evacuate. Under such circumstances, evacuation times estimates could reasonably be expected to fall within the range of several days to a week. In other words, under this condition, evacuation cannot be considered a viable protective action for the public.

A related deficiency which pervades each of the documents cited above is the largely implicit and unsupported assumption that the evacuation can and will be accomplished smoothly by those ordered to do so. The Voorhees Phase II

Report, at pages 54-55, raises briefly the question of public "willingness" to abandon the area if directed to do so without first "gathering their families, important personal belongings, and pets, and without securing their houses," and it acknowledges that such a directive might lead to "a great deal of panic," thereby rendering the evacuation "unmanageable." With this limited exception, the reports assume a level of evacuation discipline among the population which, we believe, could be justified only by public participation in annual full-scale evacuation drills. Just as with any system, testing is necessary to determine the system's ability to function. Without the kind of annual testing and training suggested here, the Voorhees/TERA assumption of minimum evacuation times is a questionable foundation for emergency response decision-making.

Experience at TMI indicates that a substantial number of people outside the designated evacuation zone will leave the area voluntarily. None of the three documents here allows for this possibility, despite the fact that many of these additional "voluntary" or "spontaneous" evacuees will necessarily use the same principal evacuation routes -- e.g., North and South Highway 101 and North Highway 1 -- as persons actually ordered to evacuate. This added population could increase the likelihood of highway congestion and evacuation delay <u>inside</u> the designated zone of evacuation due to accidents, stalled vehicles, blocked lanes, or simply increasing the number of vehicles on an already over-burdened highway system <u>outside</u> the evacuation zone. Some segments of the population may even seek to enter the evacuation zone in order to assure the safety of friends or relatives residing there. The Voorhees/TERA evacuation times estimates do not allow for these potential complications.

The Voorhees/TERA calculations of the number of vehicles are questionable for several reasons. First, in the Phase I Report, on page 28, and the Phase II Report, on page 15, the assumption that (1) only 50% of the two-car households would use both cars during an evacuation and (2) none of the households with three or more cars would use more than two cars is not sufficiently conservative. By this assumption alone, Voorhees has potentially underestimated the number of vehicles from car-owning households by approximately 6,724 vehicles, or 21 percent, for the areas covered by the Phase I Report. (Because no breakdown of the car-owning households is provided in the Phase II Report, no similar percentage can be calculated.) We cannot accept so large a discount of the car-owning population, particularly in light of the absence of any stated empirical basis for it.

Second, the number of vehicles and vehicle trips likely to be generated by institutions (e.g., schools, hospitals, convalescent homes, and the California Men's Colony) are not accurately computed in any of the documents. Although the Phase I and Phase II Reports, at pages 31-38 and pages 17-25, respectively, include some discussion and tables with vehicle estimates listed for various types of institutions, those reports acknowledge that the institutional populations will require special transportation and care. For example, ambulance trips for hospitalized persons are not included in Tables IV-4 of Phase I and Phase II, although an unexplained 725 "Hospital Direct Evacuation" trips are added in Table IV-5 of Phase I. Neither the basis for this amount, the type of vehicles (e.g., ambulances) assumed, the number of such vehicles, nor their capacity are accounted for. Similarly, availability of buses is assumed for evacuation of schools and some institutions, including the California Men's Colony. Where those buses are to come from is not addressed nor are the number of trips necessary to evacuate inmates, patients, and staff from convalescent and prison institutions included in the vehicle totals in Table IV-5 of the Phase I Report. In fact, that report states that (1) sheltering "would be the most likely occurrence" for the over 2,500 inmates at California Men's Colony (pages 31-32) and (2) a "detailed analysis of the school busing situation was not performed in the study. . . ." (page 43). Both statements suggest a need for further planning by Voorhees.

Third, according to Table I.5-3 of the County Emergency Plan, there are 3,828 households without automobiles. Each of the documents provides that this population is expected to evacuate with friends and relatives or to gather at designated collection points; those who cannot are to phone for assistance. There is no mention in this figure of car-owning households with automobiles out of service or otherwise unavailable. More important, however, the number of vehicles, vehicle trips, or phone calls necessary to evacuate this population is never calculated, nor is the total time to complete those actions stated. Once again, the availability of buses and drivers is simply assumed, as are adequate phone lines for assistance calls and personnel to staff them. The number of phone lines is never specified, a fact which may affect the evacuation time. For example, assuming ten available phone lines and average one-minute calls from just 50% of the carless households listed in the County Plan, over three hours would be needed just to handle the calls, to say nothing of the evacuation itself. There is no indication that this potential time factor was considered by either Voorhees or TERA.

Voorhees' recommendation (for example, Phase I Report, page 93; Phase II Report, page 51; County Plan, Table I.5-5, Attachment II.7.5-1) that under certain circumstances "wrong-way" traffic flow be used on evacuation routes as a possible means of reducing evacuation times is erroneous. This reverse flow technique increases the risk of accidents -- especially head-on collisions -- as a result of drivers attempting to use the route in the normal direction, even assuming that traffic control measures are promptly implemented. As we discussed above, any accidents could substantially complicate the evacuation process due to blocked lanes or routes, and evacuation delays would undoubtedly result.

The discussion of various evacuation scenarios involving differing routes (Phase I Report, pages 81-94; Phase II Report, pages 39-52) is problematical in its implicit assumption that re-routing of evacuation routes at the time of the emergency can be accomplished without causing great confusion among the evacuees and, consequently, increasing evacuation times. To the extent possible, evacuation routes should be predetermined and as simple and explicit as possible. Each segment of the population should be informed of the routes repeatedly and well in advance of any serious accident so that decisions such as which evacuation route to take need not be debated during an actual emergency. Each driver should, if possible, have only one evacuation route in mind.

The Voorhees assumption that 100% of the population will be notified of the need to evacuate within 45 minutes after the sirens sound is not sufficiently conservative. The assumption seems to ignore such complications as notification of the deaf or hard of hearing, notification of persons outside the sound of the sirens, notification of hikers in remote regions of Montana de Oro State Park, and notification at night when the majority of the populace is asleep. A conservative estimate of time necessary to notify is important because, as the Phase I Report acknowledges, delay in notification means at least an equal delay in evacuation time (page 47). Actual testing of the notification system would provide a more reliable empirical basis for this factor.

Conclusion

In light of the deficiencies discussed above, we do not believe that the Voorhees/TERA evacuation times estimates are sufficiently conservative. Rather than realistic estimates of evacuation time, those assessments assume generally optimum evacuation conditions which are unlikely to be realized in an actual accident situation without periodic full-scale evacuation drills. We conclude, therefore, that they do not provide a reliable basis upon which to make decisions about evacuation of the public in the event of a serious nuclear accident.

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RESUME

Education

BSEE from the University of Colorado in 1946; BSAeroE from the University of Colorado in 1949; and PhDEE from the University of California, Berkeley, in 1956.

Professional Experience (partial description only)

Private Consulting Practice -- 1971 to present.
Alternate energy systems and smog-free engine development. Accident and safety analyses including reconstruction, design, human factors, and mathematical formulation for vehicle accidents, highway design, slip and fall accidents, human impact, electrical explosions, escalator and elevator safety, product design, tire failures, and criminal evidence.

RAND Corporation, Santa Monica, California -- 1969 to 1971.
Senior Engineer in the Engineering Sciences Department working on development of a variety of systems, including communication and transportation.

TRW Systems, Redondo Beach, California -- 1967 to 1969.
Senior Staff Engineer, ESD System Engineering Laboratory, working on automatic highway and high speed ground transportation development, large scale failure modes, automobile safety studies, and train air suspension. Also worked on numerous civil system developments.

Hughes Aircraft Company, Culver City, California -- 1961 to 1967.
Staff Engineer for G&C Advanced Systems Laboratory, Research Laboratories (Malibu), and Mathematics Consultation Department. Performed dynamic analyses, advanced control systems design, communication system analyses, mathematical modeling, and automobile system development. (Originated IR radar concept for vehicle control.)

University of Southern California, Los Angeles, California -- 1958 to 1961.
Assistant Professor in charge of both graduate and undergraduate electronics courses plus redesign of electrical engineering laboratories.

Hoffman Electronics Corporation, Los Angeles, California -- 1959 to 1961.
Consultant in the Communications Systems Department.

Energy Systems (formerly Levinthal Electronic Products), Palo Alto, California -- 1956 to 1958. Senior Project Engineer for design and safety of high voltage, high power pulse modulators.

University of California, Berkeley, California -- 1950 to 1956.
Teaching Assistant (1950 to 1954) in the EE Department. Project Engineer (1954 to 1956) for the Cosmic Ray Laboratory in charge of equipment and operation.

U.S. Naval Air Missile Test Center, Point Mugu, California -- 1949 to 1950.
Conducted and evaluated missile flight tests as an Aero and Electrical Engineer.

Los Alamos Scientific Laboratory, Los Alamos, New Mexico -- 1946 to 1947.
Design and construction of electronic equipment.

Professional Affiliations

Professional Safety Engineer, S.S.S., I.E.E.E., Pi Mu Epsilon, Eta Kappa Nu, and Sigma Xi.

Publications and Seminars

Many papers and reports in the public literature on various systems engineering topics plus several hundred company-private documents. ACCIDENT AND PRODUCT FAILURE ANALYSES (book). "Introduction to Accident, Safety, and Forensic Engineering" (seminar).

RESUME

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Marital Status: Married, 3 children

EDUCATION

BSEE - University of Colorado - 1946

BSAeroE - University of Colorado - 1949

PhD - University of California, Berkeley - 1956
Major: Electrical Engineering

PROFESSIONAL EXPERIENCE

Private Consulting - 1971 to present

RAND Corporation, Santa Monica, California - November 1969 to 1971

Engineer, Engineering Sciences Department

Contributed toward development of control and monitoring of direct broadcast communication satellites, still-picture television, and various transportation system aspects. Also participated in an evaluation study of Project Agile.

TRW Systems, Redondo Beach, California - October 1967 to 1969

Senior Staff Engineer, ESD Systems Engineering Laboratory

Recently completed High Speed Ground Transportation study on the evolution of automatic highways. Also considered enhanced credit card utilization, communication aspects of power utility control systems, and contributed to a low-cost housing proposal. Previous work included a prison security system study, and evaluation of TRW internal security system proposals. Publications include, "External Prison Security Study, Phase I," for the State of California, "Automation of the Highways, An Overview" for the IEEE Transactions on Vehicular Technology, and "Century Expressway, Preliminary Design" for the Department of Transportation.

Hughes Aircraft Company - January 1962 to October 1967

Staff Engineer, G&C Advanced Systems Laboratory, Malibu Research Laboratory Communications Department, and Mathematics Analysis Department of Data Processing Division.

Performed studies of staellite communication and computer-controlled test systems; partially completed a software modeling of the GE265 time-share computer system using the IBM GPSS compiler. Various studies included hardware design details for the telemetry and command system of the HS-308 communication satellite, a mathematical

PROFESSIONAL EXPERIENCE (Continued

maintenance model for an SST study, advanced computer-controlled applications for automobile diagnosis and on-board spacecraft checkout studies. Additional work entailed study of modulation methods, interference problems, and atmospheric effects for satellite communication plus linear/nonlinear AGC and control loop performance for fire-control systems. Publications included several reports on satellite communications plus several papers on nonlinear AGC, automatic checkout for aerospace systems, and FM bandwidth requirements. (One patent disclosure on automatic highways was submitted, but application was not pursued.)

University of Southern California - September 1958 to June 1961

Assistant Professor of Electrical Engineering

In charge of both graduate and undergraduate electronics courses. Published one paper on electrical engineering laboratories.

Hoffman Electronics Corporation - June 1959 to September 1961

Consultant

Performed nonlinear circuit analysis, communication system development, and linear circuit synthesis. One paper, "Regenerative Fractional Frequency Generators" in the Proc. IRE received a national award. Additional published papers were on power amplifier performance and broadband network synthesis.

Levinthal Electronic Products - 19[illegible] - 1958

Senior Project Engineer

Designed and developed high voltage, high power, magnetic and electronic pulse modulators. Publications include one paper on nonlinear circuit analysis and one report on magnetic pulsers. One hardware design of an electronic modulator remains unique to this day.

U.S. Naval Air Missile Test Center - 1949 - 1950

Conducted and evaluated naval missile flight tests.

PROFESSIONAL AFFILIATIONS

IEEE, πME, ΣX

MILITARY SERVICE

Apprentice Seaman, U.S. Navy V-12 program, 1944-1946
Lieutenant J.G., U.S. Naval Reserve (inactive) - 1946 - approx. 1953

PUBLICATIONS (Partial List)

"A Feasibility Study of High Power Magnetic Modulators," Final Report, Contract No. AF30(602)-1177, October 1956.

"Discontinuous Transition Time Between Stable States in Ferroresonant Circuits," Trans. AIEE Pt. 1 (Communication and Electronics), Vol. 76, pp. 410-421, September 1957.

"Regenerative Fractional Frequency Generators," Proc. IRE, Vol. 48, pp. 1988-1997, December 1960. Co-author O. Lumpkin.

"A New Approach to Electrical Engineering Laboratories," Trans. IRE-PG on Education, Vol. E-4, No. 1, pp. 9-11, March 1961.

"On Limitations of Broad-Band Impedance Matching Without Transformers," Trans. IRE-PGCT, Vol. CT-9, No. 2, pp. 125-132, June 1962. Co-author Dr. N. Nahi.

"Improving the Linearity of the Steady State Gain Characteristic by Use of Nonlinear Feedback," Trans. AIEE Pt. 2 (Applications and Industry), Vol. 81, pp. 277-282, November 1962. Co-author Dr. N. Nahi.

"On Nonlinear AGC," Proc. IRE (Correspondence), Vol. 51, p. 380, February 1963.

"Refined Method for Calculating Satellite Interference from Microwave Transmitters," Report No. 2, Contract No. NASw-495, HRL, Malibu, Calif., November 1962. Co-author Dr. S. G. Lutz.

"The Coverage Overlap Area with Satellites of Equal Height," Report No. 3, Contract No. NASw-495, HRL, Malibu, Calif., December 1962. Co-authors Dr. S. G. Lutz and Dr. G. Dorosheski.

"A Feasibility Study of Satellite Communication in the 15-20 Gc. Frequency Range," Report No. 4, Contract No. NASw-495, HRL, Malibu, Calif., January 1963. Co-author Dr. S. G. Lutz.

"Preliminary Study of Modulation Systems for Satellite Communication," Report No. 6R, Contract No. NASw-495, HRL, Malibu, Calif., June 1963.

"Preliminary Study of Compandors for Satellite Communication," informal report on Contract No. NASw-495, HRL, Malibu, Calif., May 1963.

"Some Overall Aspects of Automatic Checkout for Aerospace Systems," Proc. Systems Engineering Conf., N.Y., June 8-11, 1964. Co-authors R. H. Lauschner and Dr. V. Mayper, Jr.

"FM Bandwidth as a Function of Distortion and Modulation Index," IEEE Trans. on Com. Tech., Vol. COM-15, No. 3, pp. 467-470, June 1967.

"External Prison Security Study, Phase I," Final Report, State of Calif., Contract No. 1235, TRW, Redondo Beach, Calif., April 1968.

"Automation of the Highways, An Overview," IEEE Trans. on Veh. Tech., VT-18, August 1969.

MSEA

KEY PERSONNEL

Miguel Pulido

Mr. Pulido is a mechanical engineer with McCAUGHEY & SMITH ENERGY ASSOCIATES, INC. (MSEA), where he specializes in the analysis of energy systems, facility energy loads, and facility energy consumption for a wide range of energy conservation projects.

Recent energy conservation engineering projects in which Mr. Pulido performed the energy analysis or related work include the following:

Energy Audits of Existing Facilities:

- Cerritos College - 12 buildings
- Santa Ana College - 5 buildings
- Corona Community Hospital
- Medical Arts Professional Office Building
- Cal State University, Fullerton - Boiler Room
- Pomerado Hospital
- Palomar Hospital
- Several industrial facilities

Building Energy Analysis (computer) for Design of New Facilities:

- Southwest Woodbridge Passive Solar Elementary School (using DOE 2.1)

Energy Systems Feasibility Study, Design, Start Up, and Testing:

- El Toro Library Solar Heating and Cooling System
- El Camino Real School Solar Heating and Cooling System
- San Anselmo School Solar Heating and Cooling System
- V.A. Hospital, San Diego, Solar DHW System
- V.A. Hospital, San Diego, Solar Steam Generation/Water Distillation System
- Channel Islands National Monument Solar Space Heating and DHW System
- Southwest Fisheries Center Solar Sea Water Heating System
- Guidebook for Solar Heating of Municipal Swimming Pools

Mr. Pulido has specialized in the application of computer programs used in the design and optimization of energy related parameters in buildings. He has participated in teaching a workshop in the use of DOE-2 and BLAST computer programs for building energy analysis. He has had experience working with the integration of passive solar heating and cooling techniques.

MSEA

Miguel Pulido (con't)

Mr. Pulido's energy analyses have also included economic work to determine the cost effectiveness of different designs.

While an associate energy systems engineer with the Southern California Gas Company prior to his association with MSEA, he conducted energy audits on industrial facilities and medical facilities.

Mr. Pulido is a member of the following professional societies: Southern California Chapter of the Association of Energy Engineers, Los Angeles Federation of Scientists (executive board member), American Society of Mechanical Engineers (associate member). American Society of Heating, Refrigeration and Air Conditioning Engineers.

Mr. Pulido graduated from California State University, Fullerton, in June, 1980, with a B.S. in Mechanical Engineering. During his senior year at Fullerton, Mr. Pulido was the head coordinator of a major solar energy exposition on campus featuring commercial and developmental solar exhibits from throughout the Southern California area.