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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of PACIFIC GAS AND ELECTRIC (Diablo Canyon Nuclear Power Station Unit Nos. 1 and 2)	)	Docket Nos.: 50-275 and 50-323

TESTIMONY ON AIRCRAFT OPERATIONS IN RESPONSE TO A REQUEST FROM THE BOARD

BY

H. E. P. Krug

POTENTIAL AIRCRAFT HAZARDS ASSOCIATED WITH THE DIABLO CANYON SITE

I. Introduction

The NRC staff has performed an independent analysis of the potential hazards associated with aircraft activity in the vicinity of the Diablo Canyon Nuclear Power Station.

The data upon which the analysis has been based was obtained from Federal Aviation Administration and the Department of Defense sources[1-11] and the calculations were performed using the guidance of Standard Review Plan (SRP) Section 3.5.1.6, "Aircraft Hazards."

II. General Information on Aviation Traffic Practices

Every aircraft flight in the US is required to operate either under visual flight rules (VFR) or instrument flight rules (IFR). A pilot may elect to fly under VFR provided good visibility exists. VFR requires that a pilot "see and be seen" by other aircraft and maintain visual contact with the ground at all times. An aircraft need have no specialized equipment and a pilot need not be specially qualified to fly under VFR rules, although the FAA encourages pilots to file VFR flight plans on VFR flights.

IFR must be chosen when good visibility or visual contact with the ground cannot be maintained at all times. An aircraft must have specialized radio navigational and communications equipment and a pilot must be qualified to use such equipment in order to fly under IFR rules. The installation of excellent radio navigational and communications enroute and terminal facilities and equipment in the U.S. over the past few years permits aircraft with relatively minimum equipment to navigate to their destinations with a high degree of confidence.

While a significant fraction of light general aviation traffic would be expected to be operating under VFR rules, the remaining air traffic, and especially the heavier and faster aircraft (referred to as high momentum aircraft) would be virtually all operating under IFR rules.

Given a choice, most aircraft will fly under instrument flight rules (IFR) whenever they can regardless of the weather, as such status provides them with the maximum benefits offered by the FAA Air Route Traffic Control System (ARTCS).

Altitude separation is but one of the benefits of IFR operations because aircraft flying under visual flight rules (VFR) are prohibited from flying at altitudes reserved for IFR traffic. Of course, under actual IFR weather conditions, there will be no VFR traffic, which has the result of increasing vertical separation in the airways between aircraft in flight because VFR traffic is, depending upon magnetic heading, required to fly at altitudes above mean sea level (1) in magnetic headings between 0 and 179°: odd thousands plus 500 feet and (2) in magnetic headings between 180° and 359°: even thousands plus 500 feet, provided the VFR aircraft are more than 3000 feet above the surface.

IFR aircraft altitudes are assigned by ARTCC which normally uses the same rules as for VFR traffic except without the 500 foot adder.

Thus, under VFR conditions, minimum vertical separation between aircraft is 500 feet, while under IFR conditions it is 1000 feet.

It should also be noted aerial navigation maps depict obstacles to aircraft including heights of the obstacles above mean sea level and above ground level. Also depicted are Prohibited, Restricted and Warning Areas designated to protect transiting aircraft and, in some cases, the designated area. FAA imposes suitable restrictions on flights through these areas.

Emergency procedures have been established by the FAA for all types of aircraft in every type of traffic area.

The trend for the future is away from point-to-point flying between radionavigational facilities and toward area navigational equipment which use the existing VØR and VØRTAC systems in conjunction with on-board flight directors to fly generalized vectors in space independent of the positions of the radionavigational facilities.

Certain of our largest aircraft, especially those used for international service, employ inertial navigation systems which completely free them from the need for ground reference signals. In addition, new navigational systems proposed, such as the ØMEGA network, which requires only 8 stations to cover the entire world, may further simply and reduce the cost of aerial navigation.

The heavier and faster types of general aviation aircraft are multiengine, are usually flown with at least two pilots, and employ redundant radionavigational equipment, including a flight director. They also usually have high altitude breathing equipment or cabin pressurization (for altitudes greater than about 10,000 feet above sea level) whereas the lighter aircraft do not. They also have transponders to enhance their reflections on radar scopes, although aircraft will appear on radar displays even though the aircraft are transmitting no signals. High momentum aircraft include civilian and military high performance single engine as well as the various types of multiengine aircraft. Because the pilots are instrument rated and because of the added safety and convenience achieved by IFR operation, these aircraft almost always fly under an instrument flight plan regardless of actual weather conditions. Scheduled air carriers are required to do so by law. Military aircraft using the airways are required to fly under FAA control to avoid disruption of nonmilitary traffic.[6]

Note that Federal Regulations require all craft to remain well clear of any structures or ground personnel to which the aircraft might present a potential hazard. These regulations are paraphrased in the following paragraphs from Part 91 of FAA Regulations.

Except when necessary for takeoff or landing, no person may operate an aircraft below the following altitudes:

(a) Anywhere

An altitude allowing, if a power unit fails, an emergency landing without undue hazard to persons or property on the surface.

(b) Over Congested areas

Over any congested area of a city, town, or settlement, or over any open air assembly of persons, an altitude of 1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft.

(c) Over other than congested areas

An altitude of 500 feet above the surface, except over open water or sparsely populated areas. In that case, the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure.

Further regulations state that when flying over a congested area, the aircraft must be at least 1000 feet above the highest obstacle, if it is closer than 2000 feet to the obstacle. Over some large cities, this altitude may not be high enough to allow for a safe landing without causing an undue hazard. Regulations specify minimum altitudes under certain conditions. Regardless of the minimum altitudes, a pilot must always comply with paragraph (a) above.

All aircraft flying under instrument flight rules are legally subject to the control of the Air Route Traffic Control Center through which they are flying.

Experience has shown that high momentum aircraft do not fail catastrophically in flight. In particular, such incidents are characterized by the fact that pilots are able to maintain directional control over their aircraft even though they may not be able to maintain altitude.[2,3] In addition, the zero thrust glide ratios associated with large aircraft, such as 747, DC 10, 1011, 707, etc., are about 17 to 1.[2,3] These are considerably higher than those for general aviation aircraft which fall within the range of about 10-13 to 1.[2,3]

In addition, aircraft on instrument flight plans are required to report equipment malfunctions. For such aircraft, the Air Route Traffic Control Center is prepared, when appropriate, to provide vectors to emergency landing locations while avoiding danger to other aircraft and "high consequence" areas as a result of an emergency.[4]

III. Aircraft Activity and Aviation Facilities Within the Site Vicinity

The Diablo Canyon site is just on the western edge of the Victor (low level) Airway designated V-27, five nautical miles from the radionavigational facility (VORTAC) designated San Luis Obispo (SBP VORTAC) and the site is ten nautical miles from the San Luis Obispo County Airport.[7] Another Victor Airway (V-113) terminates at the San Luis Obispo VORTAC.[7] There are no high level airways in the vicinity of the site.[4]

The site is contained within the FAA Los Angeles Air Route Traffic Control Center Sector (ARTCC) which provides radar coverage of the site area via the local Black Mountain Radar Facility remotely operated from the Los Angeles Center.[4,5,7] Table I lists the high momentum aircraft flying in the the vicinity of the Diablo Canyon Site under FAA control during the 1977 peak day of May 12.

IV. Numerical Estimate of Aircraft Impact Probability at Diablo Canyon

Staff inspection of DOD-Area Planning AP/1B Chart, Military Training Routes - Western U.S.,[8] communication with Vandenberg Air Force Base,[6] the FAA Los Angeles Air Route Traffic Control Center,[4] Lemore Naval Air Station,[10] Hunter Liggett Air Station,[9] Fort Ord,[11] and NRC staff inspection of the area sectional and the sector instrument low altitude enroute charts indicates that there are no military operations in the area which pose a significant hazard to the Diablo Canyon Facility. Military operations near the facility have been included in Table I as high momentum aircraft.

Light general aviation aircraft are not considered a significant hazard to nuclear power stations because of their low airspeeds, short distance landing capability, high maneuverability and low penetration capability. Plant protective features against tornado missiles, the inherent strength of the systems and structures, as well as the diversity and redundancy of plant systems reduce the potential hazards to the facility from light aircraft operations to acceptably low levels.

With respect to the Diablo Canyon Nuclear Power Station, the following equation was developed and used to provide an upper bound on the aircraft impact probability P_{FA}. (Note that not all aircraft impacts will result in radiological releases to the environment.)

$$P_{FA} = NDC \left[\frac{A}{(\pi/4)D^2}\right] \left[\frac{IFR}{365.25}\right] RPS$$

An explanation of the symbols follows:

The reader is also referred to Figure I.

Note that the numbers given below associated with the parameter definitions are generally specific to Diablo Canyon.

N is the number of flights per year[4]

= (365.25 days/yr) x (113 flight/day)

= 41274 flights/yr

D is the diameter of a strike zone circle about the airway centerline.

TABLE I

HIGH MOMENTUM* AIRCRAFT FLYING IN THE VICINITY OF THE DIABLO CANYON SITE DURING THE 1977 PEAK DAY
(May 12, 1977 Peak Day)[4,6]

Aircraft Source	No. of Aircraft Per Day	Average Altitude Above Mean Sea Level
V-27 Airway	24	6-7000 ft.
V-113 Airway	20	6-7000 ft.
Takeoff's and Landings at San Luis Obispo County Airport	16	---
VORTAC Approaches to San Luis Obispo County Airport	15	4000 ft.
Aircraft Direct to San Luis Obispo VORTAC from Vandenberg AFB	8**	6-7000 ft.
Military Aircraft Transitioning through San Luis Obispo VORTAC but not landing at Vandenberg but not flying Victor Airways	30	7-8000 ft.
Peak Total	113 aircraft per day	

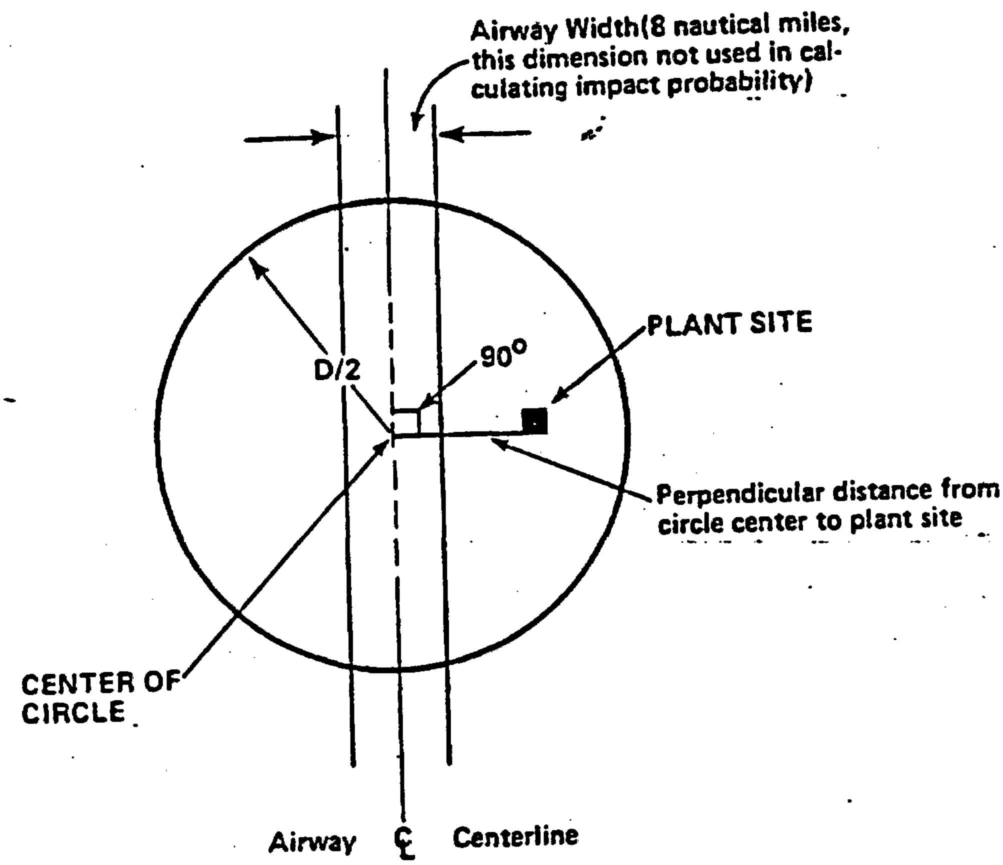
* Some of these aircraft may be light general aviation aircraft flying under instrument flight rules.

** Four rotary aircraft and four fixed wing aircraft.

NOTE: The highest point of the main structures at Diablo Canyon is the Station Vents about 40 feet above the containment (about 340 above mean sea level).

FIGURE I

GEOMETRY FOR THE CALCULATION
OF THE AIRCRAFT IMPACT PROBABILITY



Accordingly, D = 2 x AGL x EGR where AGL is the altitude of the aircraft above the highest point of the facility and EGR is the effective glide ratio of the aircraft being considered.

AGL is the height above ground level (one nautical mile)

EGR = 14-1: conservative since it assumes a glide ratio less than the zero thrust glide ratio for most high momentum aircraft; thus, D = 1 x 14 x 2 = 28 nautical miles.

[IFR/365.25] is the fraction of the time visibility at the plant is less than three miles horizontal and less than 1000 feet above ground level.

= 0.2[4,5]

A is the effective area of a unit

= 0.01 square miles (conservative)

Note that the length of the turbine building containing the generating equipment for both units is 800 feet while the tip of the containment is less than 400 feet high. The product of these two numbers, converted to square miles, is 0.011, so that 0.01 square miles was conservatively taken to be the effective area of a single unit.

P is the probability that the facility is within the strike zone circle of an aircraft in difficulty

= 1.0

R is an index of the operability of the aircraft radionavigational and communications equipment.

In order to fly under instrument flight rules, aircraft must have radionavigational and communications equipment on board with diversity and redundancy requirements prescribed by FAA regulations. Qualification and periodic testing requirements are also prescribed by FAA.

In addition, flight instrumentation, such as sensitive altimeters, turn and bank indicators, pitot tubes, airspeed indicators, etc., must also meet stringent FAA requirements. These requirements are prescribed in detail in 14 CFR Parts 1 through 199.

As a result, the probability that an aircraft will experience loss of control due to failure of the radionavigational or communications equipment is extremely low. Thus, for these proceedings, R has conservatively been taken to be 0.2.

S is the shielding factor for a single or multiple unit facility due to terrain for the facility configuration

$= 0.20$

C is the inflight crash rate per mile for aircraft using the airway

$= 4(10^{-10})$ (conservative)

The quantity C is too low to be reliably estimated; however, the staff and the FAA[2] consider it conservative to assume that a noncatastrophic failure will occur somewhere in the United States once per year. Appendix A reproduced from Reference 1 was used to determine the quantity, C. Since the table shows the total accident rate decreasing for the time period shown (since 1965), a linear average of the aircraft miles flown per year over the 11 year period was found to be $2.396(10^{9})$ aircraft miles flown per year. If, as previously mentioned, it is conservatively assumed that one major enroute failure occurs per year, the enroute crashes per aircraft mile becomes the reciprocal of $2.396(10^{9})$ or about $4(10^{-10})$ failures/(aircraft-mile).

As can be seen from Figure I, $(\pi/4)D^2$ is the area of the strike circle with the aircraft at the center of the circle. The product, DC, is the probability that an aircraft will fail while transiting the circle and the ratio $[A/(\pi D^2/4)]$ is the random probability that an aircraft failing in the circle will impact the plant.

Because the airway radio bearing passes through the center of the airway, traffic is peaked at the center.

Applying the above factors into the equation for P_{FA} yields:

$$P_{FA} = \frac{41274(0.01)\ (0.2)(0.2)(1)(0.2)4(10^{-10})}{(\pi/4)\ 28}$$

or

$$P_{FA} = 6.000(10^{-11}) \text{ impacts/year}$$

An annual compounded growth rate of approximately 4% per year is approximately the long-term growth rate of economic activity in the United States, and air travel is a mature industry which must eventually approach market saturation.

Assuming a traffic growth rate of 4% compounded annually over a forty-year period results in a growth factor of 4.8. Linearly averaging this over the forty-year period yields an increase by a factor of about three, i.e., $(1 + 4.8)/2 \cong 3$ so that the lifetime average P_{FA} (conservative strike probability) is predicted to be about $1.8\ (10^{-10})$ impacts per year which implies the highly conservative assumption that enroute navigation will remain point-to-point. The aircraft strike probability is significantly less than the value of 1×10^{-7} per year stated in S.R.P.2.2.3, and which is used by the staff in judging the acceptability of external hazards.

APPENDIX A

ACCIDENTS, ACCIDENT RATES AND FATALITIES

U.S. CERTIFICATED ROUTE AND SUPPLEMENTAL AIR CARRIERS

(ALL OPERATIONS)

1965–1975

Year	Accidents Total	Accidents Fatal	Fatalities Passg.	Fatalities Crew	Fatalities Other	Fatalities Total	Aircraft-Hours Flown	Aircraft-Miles Flown (000)**	Accident Rate Per 100,000 Aircraft-Hours Flown: Total Accidents	Accident Rate Per 100,000 Aircraft-Hours Flown: Fatal Accidents	Accident Rate Per Million Aircraft-Miles Flown: Total Accidents	Accident Rate Per Million Aircraft-Miles Flown: Fatal Accidents
1965	83	9	226	35	0	261	4,690,882	1,536,395	1.769	0.192	0.054	0.006
1966	75	8	137	27	108	272	5,104,084	1,768,458	1.469	0.157	0.042	0.005
1967	70	12	229	39	18	286	5,868,842	2,179,739	1.193	0.204	0.032	0.006
1968	71	15*	306	37	6	349	6,404,260	2,498,848	1.109	0.203	0.028	0.005
1969	63	10*	132	22	4	158	6,740,199	2,736,596	0.935	0.134	0.023	0.003
1970	55	8	118	24	4	146	6,470,351	2,684,552	0.850	0.124	0.020	0.003
1971	48	8*	174	23	6	203	6,386,662	2,660,731	0.752	0.094	0.018	0.002
1972	50	8	160	17	13	190	6,302,160	2,619,043	0.793	0.127	0.019	0.003
1973	43	9	200	26	1	227	6,504,819	2,646,669	0.661	0.138	0.016	0.003
1974	47	9	421	46	0	467	5,978,480	2,464,205	0.769	0.134	0.019	0.003
1975# Prel.	42	3	113	11	0	124	6,242,000	2,567,967	0.673	0.048	0.016	0.001

* Includes midair collisions nonfatal to air carrier occupants, excluded in fatal accident rates (1968—2, 1969—1, 1971—2).

** Nonrevenue miles of the supplemental air carriers are not reported.

Beginning in 1975, accidents involving commercial operators of large aircraft are included.

NOTE—Sabotage accident occurring 9/8/74 is included in all computations except rates.

V. Conclusion

The staff concludes, on the basis of an independent assessment of the aircraft activities and facilities in the site vicinity, and upon a conservative determination of the probability of an aircraft impact at the site that the probability of aircraft impact is significantly less than 1×10^{-7} per year, and the hazard due to an aircraft impact is therefore sufficiently remote that it need not be considered in the plant operation.

Dick

REFERENCES

(Note: All charts current during the week of July 25, 1977)

1. National Transportation Safety Board, "Annual Report to Congress," 1975.

2. Mr. Bruce Romick, FAA Safety Specialist in Washington, D.C., (301)426-8102 (July 26, 1977).

3. Mr. R. Collie, FAA Statistics Specialist in Washington, D.C., (301)426-8166 (July 26, 1977).

4. Los Angeles Air Route Traffic Control Center (FTS) 8-799-1011: John Curtin, John White, R. Olson (July 25-27, 1977).

5. Flight Service Station at Paso Robles, California (805)238-2448 (July 25-27, 1977).

6. Master Sergeant McDonald, Vandenberg AFB (FTS) 8-986-6034 (July 27, 1977).

7. U.S. Low Altitude Enroute Instrument Charts, L-2 and L-3. U.S. Visual Flight Rules (VFR) Los Angeles Sectional. NOA VOR-A (Amendment 1) Instrument Approach Plate for San Luis Obispo County Airport.

8. DOD-Area Planning AP/IB Chart Military Training Routes-Western U.S.

9. CW2 David L. Johnson, Hunter Legitt (Army) 155M Aviation Group, (408)385-2200 (August 25, 1977).

10. Lt. Schlabaugh (Operations), Lemore Naval Air Station, (209)998-2211 (August 25, 1977).

11. Major Friday, Fort Ord (Operations), (408)242-2211 (August 25, 1977).

PROFESSIONAL QUALIFICATIONS

HARRY E. P. KRUG

ACCIDENT ANALYSIS BRANCH

DIVISION OF SITE SAFETY AND ENVIRONMENTAL ANALYSIS

OFFICE OF NUCLEAR REACTOR REGULATION

I. SUMMARY

I joined the NRC in 1974 as Project Manager responsible for the management, organization, technical coordination and presentation of nuclear reactor safety reviews for assigned applications. I have served as Project Manager for the safety reviews of the San Joaquin Nuclear Project, Browns Ferry Unit 3, Hatch Unit 2, Hartsville Nuclear Power Station and the GESSAR 238 Project and a number of technical review assignments. I am currently assigned as a Nuclear Engineer in the Accident Analysis Branch of NRC.

My background includes a B.S. in Mechanical Engineering (1955) and a M.S. in Nuclear Engineering (1961). My 20 years of experience includes 4 years of power plant operation and 3 years of radiation analysis. In 1969 I left Westinghouse Electric Corporation as a Fellow Engineer after 8 years of nuclear reactor analysis and reactor design methods development and technical project coordination. In 1974, I completed two years as Supervisor of Nuclear Engineering for Illinois Power Co.

I am a member of the American Nuclear Society and the American Society of Naval Engineers. I hold ratings as an instrument rated commercial pilot, single engine land and sea, multi-engine. I hold a U.S. Coast Guard License as a Mercnant Marine Engineering Officer and am a Professional Nuclear Engineer registered in the state of California.

II. CHRONOLOGICAL EXPERIENCE

January, 1973 to December, 1974 - Supervisor, Nuclear Engineering Group, Illinois Power Company, Decatur, Illinois.

Had responsibility for the review of all safety and nuclear engineering systems associated with the Clinton Power Station including technical contract coordination for both the nuclear steam supply system and the initial and reload fuel. This work also involved coordinating the review being conducted by architect engineer on the nuclear steam supply system and components both as part of an engineering surveillance program and participation in quality assurance activities.

Developed the strategy, performed the calculations and provided technical input for the Company's enrichment contracts with the AEC for separative work. In this process, I was one of the original members of the SWAP organizing group, an organization developed to pool the separative work from various enrichment contracts. Evaluated other pooling concepts including the SWUCO, NUS and NAC pools. Was a charter member of a utility BWR-6 fuel owners task force which focused attention on the utilization of plutonium recycle fuel.

August, 1971 to January, 1973, Industry Manager, Atomic/Nuclear Industries, Control Data Corporation, Minneapolis, Minnesota.

For the Atomic/Nuclear Industry and its overlap with the Manufacturing, Process, and Utility Industries, (1) performed marketing analysis, (2) coordinated and participated in executing the resulting marketing, development, and sales strategies including general as well as high level nuclear engineering technical sales support. This work included market projections of corporate revenues achievable in accordance with the proposed strategy by customers in the nuclear industry and by application for (1) Hardware Systems, (2) Data Services (CYBERNET) network of nationally located and publicly available super computers, (3) Professional Services support and consulting personnel, (4) Terminal Sales, and (5) the Educational Division. Also, performed analyses of competitors market positions, strategies and hardware and software capabilities related to the nuclear industry. Reviewed the nuclear codes on CYBERNET and added a substantial number of significant codes. Also, was the Control Data Corporation and Technical Director representative on the Commercial Credit Corporation - Control Data Corporation team which developed a nuclear fuel leasing program for the nuclear electric utilities.

Was the Project Manager and Technical Director for production of a nuclear analysis code system for fuel management, safety, licensing, and shielding calculations called CDC-LEAHS (for Lifetime Evaluations and Analysis of Heterogenous Systems). This work encompassed product design (including milestones, budgets, detailed technical specifications and main implementation), Steering Committee Reviews, identification and interview of technical specialists, and coordination through the iterative approval cycle.

December, 1970 - August, 1971, Principal Nuclear Engineer, Jersey Nuclear Company, Product Design Group.

Participated extensively in most phases and areas of technical proposals and bid preparation for nuclear fuel reload contracts. Responsible for nuclear methods development and nuclear design for Product Design Group and also for coordination and review of certain projects sub-contracted to Battelle Northwest Laboratories.

As Chairman of the Burnup Committee for the company, conducted monthly reviews of calculational methods and design procedures for urania and mixed oxide fuel assemblies for both PWR and BWR including comparisons with operating and experimental data. This work, much of which was directly supervised or actually performed by me, resulted in the establishment of specific code development projects and standardized procedures for design, safety and licensing, and economics calculations, as well as in specific recommendations to the Code Standardizations Committee.

In addition, I developed an inexpensive and rapid survey tool based on the LEOPARD code for fuel cycle analysis, a standard method for calculating the dose rate as a function of time from spent fuel elements which compared well with experiment, participated in contract negotiations with suppliers, reviewed proposals made by sub-contractors, and evaluated external nuclear codes and code systems.

November, 1969 - December, 1970, Vice President and General Manager, Nuclear Computations, Inc., Pittsburgh, Pennsylvania.

Responsibility for directing Nuclear Computations Inc., nuclear engineering and nuclear code development efforts in the areas of marketing, sales, and nuclear code development, with special emphasis in the disciplines of nuclear engineering related to nuclear reactor core methods and code development. This work included contract negotiations, technical sales support, and training of customer personnel.

April, 1963 - November, 1969. Fellow Engineer, Physics and Mathematics Group, Westinghouse Commercial Atomic Power Department (transferred by Westinghouse from the Westinghouse Astro-Nuclear Laboratory).

(1) Coordinated the development of an automated program sequence for core fuel management calculations. As part of this work, personally developed an automated coupled code system, based upon the HAMMER and AIM codes, which provided control rod and burnable poison cross sections for both smooth and resonance absorbers as a function of poison burnout for direct inclusion in the multidimensional neutron diffusion theory programs. The remainder of the sequence included fuel and water region cross section codes for which I also had direct responsibility which provided cross sections as a function of burnup or soluble boron concentration, for one, two, and three dimensional neutron diffusion theory codes for spatial depletion (burnup) calculations and safety studies as well as other components. (2) Development, mathematical formulation, numerical analysis and supervision of coding and/or coding of programs in reactor physics, reactor design and shielding; evaluation and consultation concerning the use of similar programs developed externally. (3) In house consultant in numerical analysis, nuclear cross section generation, reactor physics, reactor design, shielding, and digital computer programming. (4) Supervised or performed significant modifications to the following digital computer programs: LEOPARD, LASER, HAMMER, CINDER, THERMOS, GAKER, PIMG, COMPRASH, REPETITIOUS, TEMPEST, MUFT, VARI-QUIR, ZUT, GAM, STAT, RITEI, SPOTS, and PIMG.

December, 1961 - April, 1963. Nuclear Engineer, Reactor Analysis Section, Westinghouse Astro-Nuclear Laboratory.

Computer-oriented reactor physics and shielding methods development, design and evaluation related to nuclear reactors for rocket propulsion; compared calculational results with experiment.

July, 1960 - December, 1961. Nuclear Engineer, Systems Evaluation Section United Nuclear Corporation.

Physics analysis heat transfer analysis, safety evaluation, shielding, economic analysis, and heat transfer studies on advanced reactors such as steam and sodium cooled uranium, thorium and plutonium fueled fast breeder reactors, a military compact reactor, a cryogenic research reactor and space power units, programmed the Datatron 205 digital computers to reduce manual computation requirements.

October, 1958 - July, 1960. Nuclear Engineer, Special Projects Group, George G. Sharp, Inc., Marine Designers. (1) Completed development of a digital computer program on the LPG-30 digital computer for the evaluation of the effects scattered radiation in marine machinery complexes has on shipboard secondary shielding requirements. (2) Developed a sophisticated hand calculation method for the rapid evaluation of shipboard secondary shielding requirements. (3) Contributed to N. S. Savannah damage control handbook in the area of radiological safety.

April, 1956 - August, 1958. Head, Engineering Department of Destroyer-Escort USS Wantuck (APD-125) including duties as Radiological Safety Officer and Damage Control Officer. Decommissioning Engineering Officer, and COMPHIBPAC Machinery Officer (Diesel).

September, 1955 - April, 1956. Officer-in-Charge, 8 - 12 Watch (Jr. 3rd Engineer), United Fruit Company, SS Fra Berlanga, 12,000 Shaft horse power twin screw cargo vessel.

VII.

PUBLICATIONS:

"Matrix Exponential Calculations and Comparison with Measurement of Isotopic Concentrations in Yankee Core I," by H. E. Krug, R. J. Nodvik, J. Corbett, and N. Azziz. Transactions of the 1969 Annual Meeting of the American Nuclear Society, Vol. 12, No. 1, 1969, p. 52.

"Simple Closed Form Expressions for the Psi and J Doppler Functions," by H. E. Krug and J. E. Olhoeft. Transactions of the 1966 Annual Meeting of the American Nuclear Society, Vol. 9, No. 1, 1966, p. 206.

"Derivation of a Point Kernel for Neutron Attenuation," by H. E. Krug and J. E. Olhoeft. Transactions of the 1966 Winter Meeting of the American Nuclear Society, Vol. 9, No. 2, 1966, p. 364.

"Comparison of Monte Carlo and Resonance Integral Methods in the Determination of Doppler Effects in Fast Reactors," by J. E. Olhoeft, H. E. Krug, and R. N. Hwang, Proceedings of the Conference on Safety, Fuels, and Core Design in Large Fast Power Reactors, ANL-7120, 1965, p. 462.

"Results of Comparisons of Thermal Calculational Models for Heterogenous Light-Water-Moderated PuO_2-UO_2 Reactor Systems," by H. A. Risti and H. E. Krug. Transactions of the 1965 Annual Meeting of the American Nuclear Society, Vol. 8, No. 1, 1965, p. 199.

"Consideration of the One-Speed, One-Node Time Dependent Diffusion Equations Including Consistent Representation of Delayed Neutron Effectiveness; with Application tothe Calculation of the Prompt Neutron Generation Time Using the 1/$\sim$ Poison Method," WCAP-2796, May, 1965.

"Liquid Metal Fast Breeder Reactor Design Study," by H. E. Krug, Contributor, WCAP-3251-1, 1964.

"Summary of the Characteristics of the KIWI-B1A Rocket Reactor," by H. E. Krug, WANL Report, 1962.

"Feasibility Study of a Cryogenic Nuclear Reactor," by G. Sofer, H. E. Krug, and P. Anthony, NDA-2661-1, 1961.

"Construction and Calibration of a Neutron Howitzer," by H. E. Krug, Mater's Thesis, New York University, September, 1961.

"Cryogenic Reactor for Teaching and Research for Joint Use by New York University and Manhattan College," Heat Transfer Section, by H. E. Krug, June, 1960.

VIII.

OTHER CONTRIBUTIONS:

"Activation Source Strength Program, ACT-1, for the IBM-7090 Computer," by P. C. Heiser and L. O. Ricks, WANL-TNR-063, September, 1962, acknowledgement p. 12.

"LASER - A Depletion Program for Lattice Calculations Based on MUFT and THERMOS," by C. G. Poncelet, WCAP-6073, April, 1966, acknowledgement p. 46.

Dear Senator Pastore:

This is in reply to a letter dated April 8, 1971, to the Secretary of the Air Force from Mr. Edward J. Bauser, Executive Director, Joint Committee on Atomic Energy, regarding the Bayshore Michigan (East) Low Altitude, High Speed Training Route.

The Air Force discontinued use of the Bayshore radar bomb scoring route for low altitude training on January 7, 1971. Such training will not be conducted there until a revised route, acceptable to all concerned, has been developed and approved.

A conference of the parties interested in this matter was held on April 6, 1971, at the Atomic Energy Commission (AEC) Headquarters. The discussion centered around an Air Force proposal to utilize an interim route until a permanent relocation of facilities can be accomplished. There consenus of the group was that the interim route would be satisfactory but formal agreement will be delayed until the home offices of the Consumer's Power Company and the insurance representatives have an opportunity to study risk analysis statistics which are being provided by the Air Force through the AEC.

Whenever we can be of assistance, please do not hesitate to call on us.

Sincerely,

Honorable John O. Pastore
United States Senate

UCLA-ENG-7424
MARCH 1974

AIRPLANE CRASH RISK TO GROUND POPULATION

K.A. Solomon
R.C. Erdmann
T.E. Hicks
D. Okrent

Okrent

Prepared for the
U.S. Atomic Energy Commission
Division of Research
Under Contract No. AT(04-3)-34 P.A. 205 Mod. 2

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Los Angeles, California

PREFACE

This report is one of a series of four prepared by UCLA (and a subcontractor, JRB Associates, where Prof. R.C. Erdmann of UCLA was spending a leave of absence) and issued as UCLA Engineering Reports at the request of and with the support of the U.S. Atomic Energy Commission (under Contract No. AT(04-3)-34 P.A. 205 Mod. 2.

The titles and numbers of the four reports are as follows:

1. "Estimates of the Risks Associated with Dam Failure," by P. Ayyaswamy, B. Hauss, T. Hsieh, A. Moscati, T.E. Hicks and D. Okrent, UCLA-ENG-7423.
2. "Airplane Crash Risk to Ground Population," by K.A. Solomon, R.C. Erdmann, T.E. Hicks and D. Okrent, UCLA-ENG-7424.
3. "The Risk of Catastrophic Spills of Toxic Chemicals," by J.A. Simmons, R.C. Erdmann and B.N. Noft, UCLA-ENG-7425.
4. "Estimate of the Hazards to a Nuclear Reactor from the Random Impact of Meteorites," by K.A. Solomon, R.C. Erdmann, T.E. Hicks and D. Okrent, UCLA-ENG-7426.

These reports represent an effort to evaluate the probabilities and consequences associated with some unlikely, potential accidents, most of which a certain degree of intuition regarding risk exists. These estimates represent preliminary, early results that need to be continued, expanded and refined over the next few years so as to better understand technological risks. The mortality and property damage estimates are made to provide some perspective on the current risks of modern technologies. For this purpose, preliminary estimates of probabilities and consequences can be of value, even if there exists considerable uncertainty in the results.

REFERENCES

1. FAA Statistical Handbook of Aviation, 1970 Edition, Department of Transportation, Federal Aviation Administration.

2. FAA Statistical Handbook, 1972 Edition.

3. A Study of US Air Carrier Accidents 1964-1969, National Transportation Safety Board, NTSB-AAS-72-5.

4. Annual Review of Aircraft Accident Data for 1969, National Transportation Safety Board, NTSB-ARC-71-1.

5. Los Angeles International Airport Traffic Comparison, Dec. 1972.

6. Los Angeles International Airport 10 year Summary of Air Traffic, 1963-1972.

7. (a) City of Inglewood-1969 Special Census Tract Map (Available from City Councilman).
   (b) City of Los Angeles-1970 Special Census Tract Map (Available from City Councilman).
   (c) City of Culver City-1970 Special Census Tract Map (Available from City Councilman).
   (d) City of Hawthorne-Special Census Tract Map (Available from City Councilman).
   (e) City of Lawndale-Special Census Tract Map (Available from City Councilman).
   (f) City of Lennox-Special Census Tract Map (Available from City Councilman).
   (g) City of El Segundo-Special Census Tract Map (Available from City Councilman).
   (h) City of Westchester-Special Census Tract Map (Available from City Councilman).
   (i) City of Compton-Special Census Tract Map (Available from City Councilman).
   (j) City of Gardena-Special Census Tract Map (Available from City Councilman).

8. Councilmatic and Census Tract Boundaries-City of Los Angeles (and adjacent areas) 1970. Adjusted for Annexations and Detachments through 1971.

9. Census Details by Zip Codes-L.A. and Orange County 1970, Western Economic Research Co. WER, 13437 Ventura Blvd., Sherman Oaks, California 19403.

10. Population Distribution-1971 Edition, Western Economic Research Co.(WER).

REFERENCES (Cont'd)

11. Census Tract Outline Map-1971 Edition, Western Economic Research Co. (WER).

12. Population Trends Map, Western Economic Research Co. (WER).

13. Numerous maps and aerial photos supplied courtesy of State Dept. of Highways, L.A., California.

14. New High Rise Office Building Map updated Jan. 1972, (WER).

15. Shopping Center Map-1970 Edition (WER).

16. New High Rise Apartment Building-1970 Edition (WER).

17. Personal Communication-Hollywood Park Management.

18. Personal Communication-Forum Management.

19. Karl Hornyik of Oregon State University, "Airplane Crash Probability Near a Flight Target," presented at June 1973 Meeting of the American Nuclear Society, Chicago, Illinois.

20. I.B. Wall, and R.C. Augenstein, "Probabilistic Assessment of Aircraft Hazard to a Nuclear Power Plant-1," Trans. American Nuclear Society, 13, 217 (1970).

21. Shoreham Nuclear Power Station, Docket No. 50-322, Amendment No. 3, Long Island Lighting Company (Feb. 5, 1969).

22. "Section VII and VIII, Rome Point Preliminary Site Evaluation," Yankee Atomic Electric Company (Feb. 16, 1971).

23. Three Mile Island FSAR, Amendment No. 10, Docket No. 50-289, Metropolitan Edison Company.

24. Zion Station, FSAR, Amendment No. 18, Docket No. 50-295, Commonwealth Edison Company, (Dec. 1971).

25. Eisenhut, D.G., of the USAEC, "Reactor Sitings in the Vicinity of Airfields," presented at June 1973 Meeting of the American Nuclear Society, Chicago, Illinois.

26. Eisenhut, D.G., "Testimony on Zion/Waukegan Airport Interaction," presented to the AEC.

27. Addendum to Rebuttal Testimony by the Division of Reactor Licensing, USAEC for the Shoreham Nuclear Power Station Unit 1, May 3, 1971 and April 2, 1971.

REFERENCES (Cont'd)

28. Climate Impact Assessment Program-Proceedings of the Survey Conference.

29 Safety Record of the U.S. Scheduled Airlines 1938-1971, Prepared by the Air Transport Association of America, June 1972, from the National Transportation Safety Board of the Dept. of Transportation.

30. Personal communication LAX Tower.

31. Chelapati, C.V. and Kennedy, R.P., "Probabilistic Assessments of Aircraft Hazard for Nuclear Power Plants," Nucl. Engr. & Design, 19, pp. 333-364, 1972.

32. "Effect of Impact and Explosion," National Defense Research Committee, Summary Technical Report on Division 2, Volume 1, Washington, D.C., 1946.

33. Amirikian, A., "Design of Protective Structures," Report NP-3726, NAVDOCKS P-51, Bureau of Yards and Docks, Dept. of Navy, Aug. 1950.

34. Beth, R.A., "Penetration of Projectiles in Concrete," PPAB Interim Reports No. 3, Nov. 1941.

35. Beth, R.A., "Final Report on Concrete Penetration," OSRD-6459, DNRC Report A-368, Nov. 1946.

36. Kennedy, R.P., "Effects of an Aircraft Crash into a Concrete Reactor Building," Holmes & Narver Inc., Los Angeles, Calif., July 1966.

37. Chalapati, C.V., "Probability of Perforation of a Reactor Building Due to an Aircraft Crash," HN-212, Holmes & Narver Inc., Los Angeles, Calif., Jan. 1970.

38. Saffian, L.W. and Rinder, R.M., "Safety Design Criteria for Storage Facilities," TM 1300, Ammunition Engineering Directorate, Picatinary Arsenal, Dover, New Jersey, Nov. 1963.

39. Hahn, G.J. and Shapiro, S.S., "Statistical Models in Engineering," (John Wiley & Sons, New York) 1967.

40. Beth, R.A., "Concrete Penetration," USRD-4856, NDRC Report A-319, March 1945.

41. Kennedy, R.P. and Chelapati, C.V., "Wall Failure," HM-70-8082-5, Holmes & Narver Inc., Los Angeles, California, June 1970.

42. Benjamin, J.R. and Cornell, C.A., "Probability and Statistics," McGraw Hill, New York, 1970.

43. ACI Standard Building Code, American Concrete Institute, Detroit, Mich., June 1963.

REFERENCES (Cont'd)

44. Mattock, A.H., "Rotational Capacity of Hingeing Regions in Reinforced Concrete Beams," Proceedings of the International Symposium on Flexural Mechanics of Reinforced Concrete, American Society of Civil Engineers, 1963.

45. "Technical Characteristics of Commercial Jet Aircraft," by Kaiser Engineers, Transportation Division, Kaiser Center, Oakland, California, Sept. 1971.

46. Blueprints of Hollywood Park Race Track.

47. Map of San Fernando Valley, California. (Chevron Dealers)

48. Personal Communication with Tower, Hollywood-Burbank Airport.

49. (a) City of Burbank-1970 Special Census Track Map (Available from City Councilman).
(b) City of Sun Valley-1970 Special Census Track Map (Available from City Councilman).
(c) City of Sunland-1970 Special Census Track Map (Available from City Councilman).
(d) City of Pacoima-1970 Special Census Track Map (Available from City Councilman).
(e) City of Van Nuys-1970 Special Census Track Map (Available from City Councilman).
(f) City of North Hollywood-1970 Special Census Track Map (Available from City Councilman).
(g) City of North Hollywood-1970 Special Census Track Map (Available from City Councilman).
(h) City of Encino 1970-Special Census Track Map (Available from City Councilman).
(i) Universal City-Special Census Track Map (Available from City Councilman).
(j) City of Glendale-Special Census Track Map (Available from City Councilman).
(k) Studio City-Special Census Track Map (Available from City Councilman).
(l) City of Eagle Rock-Special Census Track Map (Available from City Councilman).

50. Webster's Dictionary, and unabridged edition.

51. Cornell, C. Allen, "Final Report to Oregon Nuclear and Thermal Energy Council on Naval Aircraft Accident Risks at the Carty Site," Mass. Inst. of Tech., May 31, 1973.

52. "Summary of Aircraft Accidents within 5 miles of USN/USMC Airfields FY 1964-1968," Project Study Group 68-13, prepared by Aircraft Analysis Division, Naval Safety Center, Naval Air Station, Norfolk, Virginia 23511.