

THREE MILE ISLAND NUCLEAR STATION - DOCKET No. 50-289

Supplemental Testimony on Capacity Factor

By

Dennis K. Rathbun

Contention 10

"The extent to which the NEPA review concerning cost/benefit analysis and alternatives may not be complete in that the following points have not been fully analyzed or included:

* * *

(f) Capacity factors"

In the cost-benefit analysis contained in the Three Mile Island Nuclear Station Final Environmental Statement, the Regulatory staff used an 80 percent plant capacity factor, defined as the ratio of the average load on a plant for a period of time compared to the gross capacity rating of the plant.

Operating data from nuclear power plants comparable to Three Mile Island (TMI) shows a trend which supports the use of the 80 percent plant factor. Using data accumulated by the USAEC Division of Reactor Development and Technology^{1/}, Table 1, following, was prepared. From this table it can be seen that the performance of power reactors shows

^{1/} U. S. Atomic Energy Commission. Operating History, U.S. Nuclear Power Reactors 1972, Table 8, WASH T203-72, (1972).

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a steady improvement with time of operation. Table 1 includes data for reactors believed to be most comparable to TMI-- i.e., base-load water cooled reactors with gross rated generating capacity over 450 megawatts. This data shows that the capacity factor reaches an average of around 80 percent after four years of operation.

Based on the common practice of the nuclear power industry to utilize an 80 percent plant factor in calculations and the trend of the data accumulated by operating experience; the use of an 80 percent plant factor in the original environmental review of the TMI plant completed in December, 1972, seems reasonable.

Another approach has been developed by the staff for computing the sensitivity of generating costs of alternatives at plant capacity factors below 80 percent. By leaving capacity factor variable in present worth calculations of the costs of alternatives, it is possible to determine the lowest capacity factor over the operating life of the plant at which the nuclear plant can supply electricity at lower cost than either the coal or oil fuel alternative. For the TMI plant, the choice of the nuclear fuel alternative is the least expensive alternative for nuclear plant capacity factors down to 40 percent. The methodology is outlined below.

Cost estimates for the TMI plant, Units 1 and 2 combined, including fuel costs, operation and maintenance expenses for nuclear, coal, and oil alternatives were supplied by the applicant and are reasonable, as follows:

Nuclear	\$698,000,000
Coal	\$561,000,000
Oil	\$374,000,000

Annual fuel expenses depend upon the unit cost of the fuel; also, over a broad range of generated output, the annual fuel expenses are assumed directly proportional to the plant capacity factor. Estimates of annual fuel expenses as a function of plant capacity factor are given below.

Nuclear	$(\$20,300,000 \times \% \text{ Capacity Factor})$ per year
Coal	$(\$57,700,000 \times \% \text{ Capacity Factor})$ per year
Oil	$(\$112,000,000 \times \% \text{ Capacity Factor})$ per year

A certain amount of annual operation and maintenance expenses are necessary regardless of whether a plant is run or not. There is also a component of annual operation and maintenance expense which increases with increasing plant capacity factor. Annual operation and maintenance expenses are tabulated below.

Nuclear	$(\$7,120,000)$ per year
Coal	$(\$3,190,000 + \$3,900,000 \times \text{Capacity Factor})$ per year
Oil	$(\$2,660,000 + \$3,120,000 \times \text{Capacity Factor})$ per year

The costs of alternative methods of generating electricity are compared on a present value basis using a 30 year plant life and a discount factor of 8.75%. The variable term in the present worth calculation is dependent upon the plant capacity factor.

Present Value Calculations for 30 Years of Alternatives

<u>Alternative I:</u>	Nuclear Fuel Plant	
	<u>Constant</u>	<u>Variable</u>
Capital Cost	\$697,000,000	
Operation & Maintenance	\$ 74,800,000	
Fuel Cost	_____	<u>\$213,000,000 x % Capacity Factor</u>
Total Costs	\$771,800,000 + \$213,000,000 x % Capacity Factor	

<u>Alternative II:</u>	Coal Fuel Plant	
	<u>Constant</u>	<u>Variable</u>
Capital Cost	\$561,000,000	
Operation & Maintenance	\$ 33,500,000	\$ 41,000,000 x % Capacity Factor
Fuel Cost	_____	<u>\$606,000,000 x % Capacity Factor</u>
Total Costs	\$594,500,000 + \$647,000,000 x % Capacity Factor	

<u>Alternative III:</u>	Oil Fuel Plant	
	<u>Constant</u>	<u>Variable</u>
Capital Cost	\$374,000,000	
Operation & Maintenance	\$ 27,900,000	\$ 32,800,000 x % Capacity Factor
Fuel Cost	_____	<u>\$1,179,800,000 x % Capacity Factor</u>
Total Costs	\$401,900,000 + \$1,212,600,000 x % Capacity Factor	

The total present value costs of alternatives is a linear equation with capacity factor as an independent variable. The present value costs of alternatives are plotted in Figure 1. The data plotted on

the graph demonstrate that operation of the nuclear plant over a 30 year period is less expensive than an oil fired plant at capacity factor greater than 37 percent. The nuclear plant is a less expensive generating alternative than a coal fired plant at capacity factors larger than 40 percent.

A future rise in the fuel costs for either coal or oil would increase the slope of the line representing present worth of the fuel alternative which experienced the price increase. Fuel price increases could occur for oil through restriction in the availability of oil from foreign and domestic sources or for coal through increased competition for scarce supplies of low sulphur coal. An increase in the price of coal would make the nuclear alternative more advantageous than the coal alternative at capacity factors below 40%.

It is not anticipated that in the course of routine operation the plant would be used at capacity factors as low as are mentioned above. However, this calculation does indicate that the choice of the nuclear alternative is not very sensitive to the 80 percent capacity factor used in the original cost calculations in the TMI Final Environmental Statement. Therefore, the 80 % capacity factor is reasonable. In fact, the staff concludes that cost-benefit analysis is favorable to operation of the Three Mile Island plant using any capacity factor higher than 40%.

Table 1

PLANT CAPACITY FACTOR
FOR COMMERCIAL PLANTS OVER 450 MW
BY YEARS OF PLANT OPERATION^{a/}

Years of Plant Operation	1	2	3	4	5	6	7
San Onofre (450.0MW, 1968)	21.3	33.6	69.2	81.0	87.5	74.5	94.8 ^{b/}
Haddam Neck (600.3MW, 1968)	29.8	73.4	75.0	71.3	83.9	86.0	96.5 ^{b/}
Oyster Creek 1 (550.0MW, 1969)	92.7	74.4	77.5	80.0	70.0 ^{b/}		
Nine Mile Point (641.8MW, 1969)	42.4	63.4	60.5	54.7 ^{b/}			
Ginna (517.1MW, 1970)	19.6	57.8	65.6	64.1	80.4 ^{b/}		
Dresden 2 (800.0MW, 1970)	23.3	37.7	47.4	79.8 ^{b/}			
Millstone 1 (652.1MW, 1970)	25.9	63.2	54.9	19.7 ^{b/}			
Point Beach 1 (523.8MW, 1970)	30.0	76.3	69.4	28.9 ^{b/}			
Robinson 2 (700.MW, 1970)	40.7	80.4	33.2 ^{b/}				
Monticello (568.8MW, 1971)	49.2	74.5	44.8 ^{b/}				
Dresden 3 (800.0MW, 1971)	35.7	72.8	36.2 ^{b/}				
A Sample Mean (Exclude Jan-May 1973)	37.3	64.3	64.9	74.1	85.7	80.2	
Sample Size	11	11	8	4	2	2	
Sample Mean (Include Jan-May 1973)	37.3	64.3	57.6	59.9	80.5	80.2	95.7
Sample Size	11	11	11	8	4	2	2

* January-May 1973.

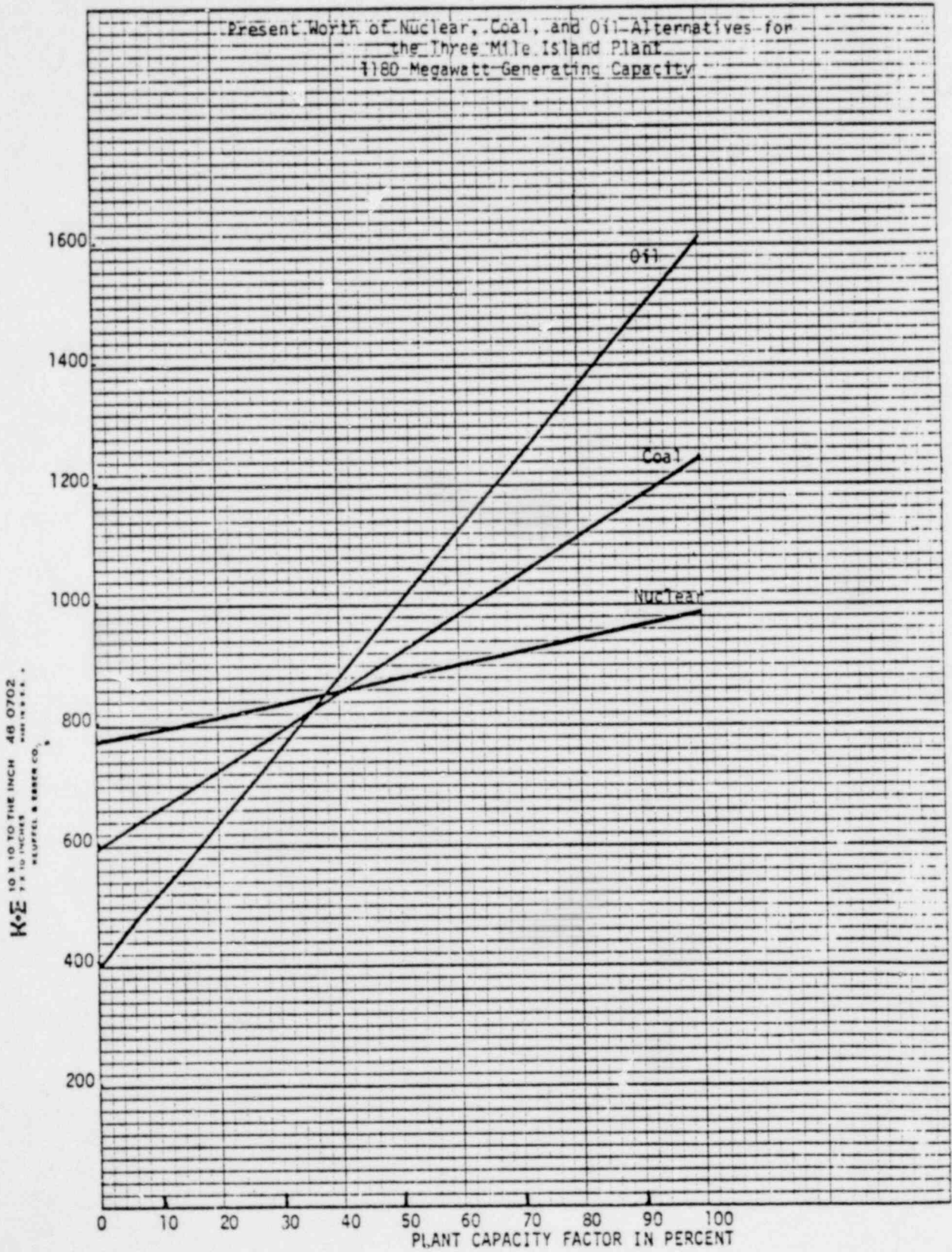
Sources: Data for first five month 1973 from Nucleonics Week, 6/28/73.
Other data from Operating History, U.S. Nuclear Power Reactors, 1972.

^{a/} Figures following the plant name are the gross generating capacity of the plant and the initial year of plant operation.

^{b/} Capacity factor data for the interval January-May 1973.

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FIGURE 1



VICTOR BENAROYA

PROFESSIONAL QUALIFICATIONS

DIRECTORATE OF LICENSING

My name is Victor Benaroya. I am Chief of the Effluent Treatment Systems Branch in the Directorate of Licensing.

I attended Robert College and received a Bachelor in Science Degree in Exact Science. I received a Bachelor's Degree in Chemical Engineering from the University of Michigan, and a Master's Degree in Chemical Engineering from the University of Texas. I also took graduate courses at the University of Southern California.

I was involved in research and development work with American Potash and Chemical Corp., worked for the Southern California Gas Company, a utility, and was involved in the design and erection of chemical plants for C. F. Braun and Company, an Architect-Engineer.

I joined Atomics International, a division of North American Rockwell, in 1958. I was in charge of the design of all process systems of the Piqua Nuclear Power Facility. Then I was responsible for the startup of all the systems outside the reactor of the Piqua facility. On my return from the field, I was made responsible for the design, installation, and start-up of SNAP-8DS, a ground prototype compact reactor for space applications. I joined Combustion Engineering in 1966 as Project Engineer for the Auxiliary Systems of the Fort Calhoun Nuclear Power Plant.

I joined the AEC in September 1967. I was Lead Project Engineer for a number of operating reactors, including Yankee Rowe, Indian Point 1, and Peach Bottom 1. In 1968, I was transferred to Reactor Projects as Project Leader responsible for coordinating health and safety evaluations covering all aspects of nuclear power plant applications as assigned by the branch chief. I have had primary responsibility for the safety review of Ginna (operating license review), Beaver Valley (construction permit review), Monticello (post-operation), and now the Baily construction permit review.

When the Effluent Treatment Systems Branch was established in the recent reorganization of the Regulatory Section of the AEC, I was appointed as its first chief. The functions of the Effluent Treatment Systems Branch are to evaluate the proposed radwaste systems and to determine that the radioactive effluents from nuclear power reactors meet our "as low as practicable" guidelines.

I am a member of the American Institute of Chemical Engineers and American Nuclear Society. I held an AEC Operator's License in 1961-62.

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RICHARD M. LOBEL

PROFESSIONAL QUALIFICATIONS

CORE PERFORMANCE BRANCH

DIRECTORATE OF LICENSING

My name is Richard M Lobel I am a nuclear engineer with the Core Performance Branch within the Directorate of Licensing. As a nuclear engineer I share with other members of the branch the responsibility for technical review of thermal and mechanical aspects of light water cooled power reactors for construction permits and operating licenses.

I was born in Pittsburgh, Pennsylvania on September 30, 1943. I attended schools in the San Francisco Bay Area and entered the California State University at San Jose in 1961. I received my B.S. Degree in Mechanical Engineering in 1966. I was then employed by Lawrence Radiation Laboratory and obtained my M.S. Degree in mechanical engineering at night from the same school.

As a mechanical engineer, I participated in the design of experiments for the Super Kukla Prompt Burst Reactor and worked on the design of prototype nuclear weapons. I also worked in a theoretical group which developed and ran computer codes in the fields of stress analysis, gas dynamics and heat transfer.

I am now on leave from Lawrence Radiation Laboratory assigned to the Directorate of Licensing, U S. Atomic Energy Commission. My responsibilities include the review of calculational procedures used to determine steady state fuel temperatures and thermal gap conductances and thermal and mechanical behavior of the cladding. In particular, I have been involved in the review of the fuel thermal performance models of several vendors as part of the staff review of the effects of densification on light water reactor fuels.

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PROFESSIONAL QUALIFICATIONS

Darrel A. Nash

U. S. Atomic Energy Commission

I am Darrel Nash, Senior Cost-Benefit Specialist with the Cost-Benefit Analysis Branch, Directorate of Licensing. I joined the staff in August 1973. I am responsible for reviewing and analyzing environmental reports and preparing cost-benefit portions of environmental statements. In addition I conduct generic economic research on topics related to environmental impacts of nuclear power plants.

I received a B.S. degree from Colorado State University in 1958, an M.S. degree from Montana State University in 1960, and a Ph.D. degree from the University of Illinois in 1964. All degrees are in agricultural economics. This degree emphasizes studies in economics, mathematics, and statistics as related to land and water resources and agricultural production and marketing. In 1967-68 I took advanced econometrics at George Washington University.

My professional experience has been principally in research and teaching in the areas of land and resource economics and the economics of fishery marketing. A significant responsibility has also dealt with in-depth staff studies to aid directly in decision-making. I was employed one year as a resource economist by the Bureau of Land Management in the U. S. Department of Interior and developed models for determining optimum multiple use of public lands for such activities as grazing, watershed management, recreation, and forestry.

I worked for more than eight years in the National Oceanic and Atmospheric Administration in the U. S. Department of Commerce and its predecessor agencies. This position began with responsibility for research and research supervision in fishery marketing including estimating consumer demand for fishery products and distribution of fishery products. A major project was to conduct a cost-benefit analysis of preservation of fishery products by low level ionizing radiation. Consumer and marketing studies culminated in a study making long range projections of the demand and supply of fishery products on a world wide basis.

During the later period of this appointment my primary responsibility was in fishery management wherein social, economic, and biological studies were conducted to determine needed institutional changes to better allocate the utilization of fishery resources. Studies were also supervised in the economic conditions of fishing vessel owners and environmental analysis of marine fisheries habitats.

Specialized assignments in the NOAA position included work on establishing the PPBS system for Federal commercial fisheries programs. Also under loan to the U. S. Agency for International Development (AID) I traveled to eight countries to evaluate potential for producing and distributing fish protein concentrate within these countries.

I have an appointment of Visiting Assistant Professor in the Agricultural and Resource Economics Department at the University of Maryland and have taught in that Department.

I have authored or coauthored about 15 publications, more important areas being (1) optimum land use patterns, (2) cost-benefit analysis of food preservation by low level ionized radiation, (3) long range projections of demand and supply of fishery products, and (4) demographic patterns of fishery product purchases. Numerous unpublished papers have also been written on these and related areas such as cost-benefit analysis of public land use and analyses of financial assistance programs for marine fishing vessels.

I am a member of the American Agricultural Economics Association and the Society of Government Economists.

PROFESSIONAL QUALIFICATIONS

James E. Carson

Argonne National Laboratory

I am a meteorologist in the Environmental Statement Project (ESP) of Argonne National Laboratory (ANL). My primary task is to write the meteorological sections (climatology and dispersion characteristics of the site, atmospheric effects of the cooling system, etc.) for the Environmental Statements for nuclear power plants.

I joined Argonne's Meteorology Group in May 1961 and transferred to ESP in April 1972. I have a Bachelor of Science degree in chemistry from Kent State University (1943). I did my graduate work in meteorology at The University of Chicago, receiving the Master of Science degree in 1948 and the Ph.D. degree in 1960.

I served as a weather officer and forecaster in the Air Force. While in graduate school, I served in various capacities, such as an instructor and as a research assistant. I was an Assistant Professor in the Meteorology Department at Rutgers University from 1951 to 1953, a meteorologist in the Army Quartermaster R & D Center in Natick, Massachusetts from 1953 to 1955 and an Assistant Professor of Physics at Iowa State University in Ames from 1955 to 1961.

While at Argonne National Laboratory, I have been involved in a variety of projects, including soil temperature and heat flux studies.

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smoke dispersion and plume rise measurements, urban dispersion models and the atmospheric effects of thermal discharges from power plants. I have about 30 technical publications.

I am a member of the following professional societies: (1) American Meteorological Society (professional member); (2) Air Pollution Control Association; (3) Scientific Research Society of America (RESA); and (4) International Association of Great Lakes Research. I am a member of APCA's TT-3 (Meteorology) Committee.

PROFESSIONAL QUALIFICATIONS

Joseph E. Draley

Argonne National Laboratory

I am a member of Argonne's Environmental Statement Project. I specialize in considering the effects of chemical discharges from nuclear power plants on the environment, and in preparing the sections of environmental statements dealing with that subject. In addition, I develop and write other parts of statements, most recently having dealt with plant design alternatives. I joined ESP in September, 1971.

I have a B.S. degree in chemical engineering (1939) and a Ph.D. in physical-inorganic chemistry (1947), both from the Catholic University of America.

Since 1942 I have studied aspects of the design and construction of nuclear reactors, and have done basic research, concentrating on the corrosion and oxidation of metals. From 1942 to 1945 I worked at the Metallurgical Laboratory of the University of Chicago, serving as group leader primarily responsible for compatibility with water of construction materials for nuclear reactors. This work included the effects of minor concentrations of impurities and the composition of natural waters. In 1945-1947 I worked on gaseous diffusion problems and ram-jet development for the Kellogg Corporation, in New York and in Silver Spring, Maryland. From 1947 to 1948 I was Section Chief in the Metallurgy Division of Oak Ridge National Laboratory, studying aqueous corrosion problems of interest in reactor development. Since 1948 I have been employed at Argonne National Laboratory, as Group Leader in the Metallurgy Division (1948-1968; basic and applied research in corrosion by water, steam, and oxygen and the use of materials

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in nuclear reactors) as Laboratory Coordinator of the Sodium Technology Program (1967-1969; research and development related to the AEC's LMFBR program), as Assistant Manager for Sodium Technology (1969-1971), as member of Environmental Statement Project (1971-present); in addition, I am currently Chairman of Argonne's CTR Study Group. I was a consultant to the Atomic Energy Commission on Minimization of River Pollution by Radioactive Effluents, 1966-1968.

In other professional activities, I have been:

Originator of periodic AEC Contractor Corrosion Symposia, 1951

Contributor to International Conferences on the Peaceful Uses of Atomic Energy, Geneva, 1955, 1958, 1964

Chairman, Corrosion Division of the Electrochemical Society, 1956-57

Editor, Corrosion Division, Journal Electrochemical Society, 1957-58

Chairman, Gordon Research Conference on Corrosion, 1958

Organizer, International Symposium on Aqueous Corrosion of Reactor Materials, Brussels, 1959

Member, Corrosion Resistant Metals Committee, TMS, AIIME, 1959-present;

Chairman, 1967-1969

Chief U. S. delegate to International Atomic Energy Agency meeting on Corrosion of Reactor Materials, Salzburg, 1962

Member, Corrosion Research Council, 1963-1965

Advisor to Advances in Corrosion Science and Technology since 1965

Participant, U. S.-U. K. Libby-Cockroft Exchanges on Corrosion, Harwell, 1967; Columbus, Ohio, 1968

Chairman, International Conference on Sodium Technology, Argonne, 1968

Chairman, Symposium on Corrosion by Liquid Metals, The Metallurgical Society, AIIME, 1969.

I have received two awards:

W. R. Whitney Award (National Association of Corrosion Engineers), 1961, for outstanding contributions to the science of corrosion; Merit Award of the Chicago Technical Societies Council, 1970, for outstanding technical and social achievements.

There have been 92 publications of which I was author or coauthor and an additional 59 published by members of the research group I headed. These have been in the form of articles in scientific journals, contributions to books and meetings, and AEC topical reports. Most have dealt with corrosion and the application of materials. Pertinent to environmental impact have been a 1945 report on analytical methods for dilute solutions, a 1967 ANL study group report on environmental pollution, report on the treatment of cooling waters with chlorine (1972), a contribution to a 1972 report for the EPA on discharges into Lake Michigan, a paper on features of the environmental impact of a fusion reactor power plant (1972), a report on chlorine concentrations in the recirculating cooling water in an operating power plant (1973).

I am a member of the following professional societies:

American Chemical Society

Electrochemical Society

American Nuclear Society

American Institute of Mining, Metallurgical, and Petroleum Engineers

American Association for the Advancement of Science.

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PROFESSIONAL QUALIFICATIONS

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Educational and Professional Qualifications

Robert F. Barker

Chief, Product Standards Branch

U.S.A.E.C.

My name is Robert F. Barker. I am Chief of the Product Standards Branch of the Directorate of Regulatory Standards of the U. S. Atomic Energy Commission, 7920 Norfolk Avenue, Bethesda, Maryland. Since assuming this position in January 1961, I have been responsible for the formulation of policy and development of regulatory safety standards, criteria, rules and regulations for the transportation of byproduct, source and special nuclear material in the Commission's licensing program. During the past 11 months, I have been responsible for preparation of the sections on transportation in about 30 environmental statements for individual nuclear power plants.

I received a Bachelor of Science in Electrical Engineering from Ohio University in 1949. I did graduate work toward a Master of Science degree in radiological physics on an AEC fellowship at the University of Rochester in 1949-50, which I received in 1953.

I was employed by the University of California at the Los Alamos Scientific Laboratory from 1950 until 1955. As assistant Leader of the General Monitoring Section, I was responsible for the monitoring operations at nuclear weapons tests, around the test reactors and for shipments coming to or leaving the Laboratory. While in that position, I compiled and edited the first General Monitoring Handbook.

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In 1955, I joined the AEC as assistant Chief of the Radiation Safety Branch of the Isotopes Division and, except for the years 1959 and 1960, I have been with the Commission since that time. During 1959 and 1960, I was employed on the Staff of the International Atomic Energy Agency as a Senior Health Physicist in the Division of Health, Safety, and Waste Disposal. As part of my duties for the IAEA, I was the Secretary to the Panel of Experts called together by the Agency to establish International Standards for the Safe Transportation of Radioactive Materials.

In subsequent meetings of Panels of Experts on Transportation of Radioactive Materials organized by the IAEA, in 1963, 1964, 1970 and 1971, I represented the AEC as participant or advisor to the designated participant.

I am a Health Physicist certified by the American Board of Health Physics.

I am a member of the Health Physics Society, the American Society for Quality Control and the Society for Non-Destructive Testing.

I am author of the Chapter on "Radiation Protection" in the Handbook on Non-Destructive Testing, an A.S.T.M. publication, co-author of a Chapter in the "Safe Transport of Radioactive Materials" edited by Roy Gibson and have written several technical papers on safety in transportation.

PROFESSIONAL QUALIFICATIONS

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NAME:

LEON L. BERATAN

GRADUATE FROM:

Cornell University (2 years) Instructorship
Drexel University (1 year) 1958 MSCE
Northwestern University (2 years) NSF Fellow
Murphy Fellow
New York University (2 years Pt. time)

YEAR OF GRADUATION:

Pennsylvania State University 1948 BSCE

PROFESSIONAL EXPERIENCE:

Truscon Steel Company - Design Engineer - 2 years
Cornell University - Instructor Civil Eng. - 2 years
Dupont Co. Eng'r Design Division - Struct. Eng'r
Foundation and Plant Site Evaluation - 2 years
Drexel Institute - Assoc. Prof. C.E. - Soil
Mechanics, Engineering Mechanics, Strength of
Materials, Fluid Mechanics at Graduate and Under
Graduate Level - 13 years
U. S. Army Corps of Eng'rs, Chief of Dam Design
Section - 2 years
Gibbs and Hill Inc. Nuclear and Fossil Fuel Power
Plant design, industrial design, dams, earth
work and foundations.

AEC EMPLOYMENT:

1970 to Present RC/HQ, Bethesda, Md. Senior
Structural Engineer, Technical Assistance
Branch

OTHER EXPERIENCE:

Registered Professional Engineer since 1953

Consultant Commissions on many structural and
foundation problems

Member of the Civil Service Oral Examination
Board City of Philadelphia, Pa.

1. Design responsibility for process buildings
at Savannah River Plant.
2. Investigation for industrial plant siting.
3. Design of dredging project and submerged and
above grade disposal areas.
4. Design of water front structures i.e., dike,

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C. RICHARD VAN NIEL
OPERATIONAL SAFETY BRANCH
DIRECTORATE OF LICENSING
U.S. ATOMIC ENERGY COMMISSION

PROFESSIONAL QUALIFICATIONS

I presently serve as a professional staff member in the Operational Safety Branch, under the Assistant Director for Reactor Safety, in the Directorate of Licensing. I review and evaluate the operational safety aspects of applications for construction permits and for operating licenses of power reactors. These aspects include licensee competence, organization, and staff adequacy; emergency planning; industrial security programs; training; and the testing programs associated with initial plant startup. I participate in the review and preparation of standards and guides relating to operational and industrial safety at licensed facilities with the Directorates of Regulatory Standards and Regulatory Operations.

I attended the University of Rochester, Rochester, New York and received a Bachelor of Science degree in Mechanical Engineering in 1955. During the period 1959-1962 and in 1968 I attended Augusta College and the University of Georgia (extension) both located in Augusta, Georgia. I completed several night school courses in the Business Administration field during this time.

Upon college graduation I accepted a position as an engineer with the E. I. duPont Co., Terre Haute, Indiana. I investigated process difficulties in the production of heavy water, and made recommendations to improve the process, and solved technical problems involved with diffusion and distillation towers, pumps, and associated equipment.

From November 1955 to March 1959 I was on active duty with the U.S. Navy. I was stationed at the U.S. Naval Torpedo Station, Keyport, Washington, and was

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assigned as Anti-submarine Warfare Project Officer. I was responsible for the in-water ranging of torpedoes, and their overhaul, checkout, repair and issuance to the Fleet.

In 1959 I returned to E. I. duPont as an Engineer in the Reactor Technology Section of the Works Technical Department at the Savannah River Plant, Aiken, South Carolina. In this position I 1) analyzed special components to be charged to the reactors to insure compatibility and safety, and redesigned reactor components to improve production, safety and economy, 2) acted as liaison and consultant for technical groups conducting experiments in the reactors, 3) followed the operation of the production reactors and made recommendations to increase production and improve reactor safety, 4) dealt with operating personnel and with various service groups who install and follow special tests, 5) followed the installation of new equipment and modifications to the reactor building and to the existing equipment, and 6) prepared procedures for equipment checkout and operation, and reviewed and revised existing operating procedures and safety rules.

I was promoted to Shift Supervisor in the Reactor Department in 1963. In this capacity I supervised the operation of a nuclear production reactor, assigned and directed reactor and auxiliary operators in their duties, conducted on-the-job training, took emergency action when required, handled personnel problems, made recommendations to improve reactor safety; reviewed and revised operating procedures, tested safety circuits to insure operability and reliability, analyzed malfunctions and authorized repair of equipment and instrumentation.

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In early 1968 I was transferred to the Raw Material Department where I revised and updated existing operating and emergency procedures, and revised building and equipment safety and criticality rules.

In 1968 I accepted a position as Nuclear Engineer and a year later was promoted to Reactor Safety Specialist with the U.S. Atomic Energy Commission, Washington, D.C. I served from June 1968 through October 1971 as a professional staff member under the Assistant Director for Nuclear Facilities., Division of Operational Safety. In this position I 1) provided technical staff assistance in the planning, promoting, and coordinating of the health and safety aspects as related to AEC-owned nuclear reactors, 2) assisted in developing guides, policies, and procedures to govern the program of AEC Field Office surveillance of AEC-owned reactors through review and analysis of safety requirements, and through a determination of AEC management need in the field of reactor safety, 3) conducted appraisals of AEC Field Office reactor safety and emergency preparedness activities, to make recommendations to Field Office management on the conduct and performance of nuclear safety surveillance activities, 4) evaluated AEC Contractor nuclear safety activities by determining through personal visits, if policies, guides and operating practices are being followed, and 5) recommended new or revised nuclear safety guides, codes, standards, and requirements for governing the conduct of the Division's reactor safety and emergency preparedness programs.

QUALIFICATIONS OF MILLER B. SPANGLER

1. I am presently employed as Chief of the Cost-Benefit Analysis Branch, Directorate of Licensing, U. S. Atomic Energy Commission. I supervise the work of this Branch in reviewing and analyzing social and economic effects of proposed nuclear power facilities including the impacts of alternative fuels for generating electricity, alternative sites, and alternative technologies in nuclear plant design. I also direct methodological research in cost-benefit analysis related to areas of my work responsibility.

2. I have an interdisciplinary background of education appropriate to the multiple facets of cost-benefit analysis. In 1950 I received a B.S. degree with honors from Carnegie Mellon University with a major in chemical engineering and a minor in electrical engineering. I received an M.A. degree in 1953 and a Ph.D. in 1956 from the University of Chicago with a major in planning in the Division of Social Sciences plus a specialization in management sciences in the School of Business. Two of my five years of graduate studies were in economics and regional and national economic development theory. My Ph.D. dissertation, published in 1956 through the University of Chicago Press, was on the subject, New Technology and the Supply of Petroleum: The Treatment of Uncertainty in Resources Planning. In this work, I developed a multidisciplinary methodology for long-range forecasting of technological change.

3. Prior to my present position I have had a diversified work experience in industry, in government, and in a private, non-profit economic and planning research organization. Regarding the latter, I was employed by the National Planning Association of Washington, D. C. from 1966 to 1972, first in the capacity of Manager of the Oceanics Project and subsequently as Director of the newly established Center for Techno-Economic Studies. Multidisciplinary studies of technological applications and the need for new technology in light of various public interests were performed under my supervision for the National Science Foundation, the Marine Sciences Council of the Executive Office of the President, the Polar Transportation Study Requirements Group of the Department of Transportation, the Search and Rescue Plans Staff of the U. S. Coast Guard, and the Office of Water Resources Research of the Department of Interior. Major publications resulting from this work for which I was the principal author include:

New Technology and Marine Resource Development: A Study in Government-Business Cooperation (New York: Praeger Publishers, Inc., 1970), 642 pp.

Long-Range Forecasts of Activities in the Marine Environment with Implications for Planning Coast Guard Search and Rescue Operations, in 3 Parts, Report Nos. AD729-892, 3 and 4 (Springfield, Va.: National Technical Information Service, Sept. 1971), 1050 pp.

The Role of Research and Development in Water Resources Planning and Management for Achieving Urban Goals, Report No. PB-210-133 (Springfield, Va.: National Technical Information Services, May 1972), 650 pp.

All of these works dealt with multidisciplinary analyses involving technological, economic, political, social, institutional, legal and environmental issues. Of particular relevance to my present assignment is that the first of these works had extensive chapters on national interests in marine resource developments; private and public roles in R&D planning; offshore oil developments and policy issues; new technology and the use of living marine resources; marine recreation; the use of nuclear devices for excavating deep water ports; and federal measures including legal, regulatory, and administrative actions. The second study dealt extensively with forecasts of water recreational activities; fishery developments; offshore oil and gas developments; marine research programs; water pollution control measures; and administrative measures, laws and technology affecting safety in the marine environment and the related issue of the value of human life. It also included economic and population forecasts for 12 coastal regions and 394 first-tier coastal counties. The third study had chapters on the requirements of technology assessment focussing on the desirable and undesirable impacts on society of technological options; four modes of water resources planning including public laws and regulations; uses of water and related land areas in achieving urban goals and values; and institutional measures for enhancing urban water uses through R&D. Two chapters from this study appear as Chapters 24 and 35 in Technology Assessment in a Dynamic Environment, ed. by Marvin Cetron and Bodo Bartocha (New York: Gordon and Breach Science Publishers, 1972).

In addition to these studies I was supervisor and contributing editor of a pilot study authored by S. Sterling McMillan on Case Studies of Government Cooperation in Founding New Industries. This study published in 1970 through the National Technical Information Service has an extensive chapter on federal measures of assistance in civilian uses of atomic energy.

4. From 1963 to 1966 I was employed as Program Economist by the U. S. Agency for International Development serving in Turkey and in India. I participated in and supervised a number of economic and industrial planning studies and contributed to a number of capital project loan studies including the Keban Dam hydroelectric project in eastern Turkey, the coal-fired electrical generating project in Durgapur, India and the oil-fired electrical generating project in Baroda, India. In addition, I played a major role in studies involving use of computer systems in industrial and import management programs; price inflation; foreign trade and related balance-of-payments issues; and economic development policies and programs in agricultural and industrial sectors. I also conducted seminars on operations research and economic planning methodologies at several Indian universities.

5. From 1956 to 1963 I was employed by the IBM Corporation, first as Associate Engineer in the Advance Engineering Planning Department of the IBM Research Corporation in Yorktown, N.Y., and later as Manager of Market Research in the Long-Range Planning Department of IBM's Federal Systems Division in Rockville, Md. In the former job I studied applications of

computer systems in simulation, process control technology, and business forecasting. I authored a major confidential report on, Long-Range Forecasts of the Business Environment with Implications for Research Planning. This study included: forecasts of the trends in the U.S. economy to the year 2000; forecasts of IBM's domestic and foreign gross revenues; the socio-economic impact of automation; and diversification opportunities in applying advanced information technology in the fields of education, medicine, transportation, national security, R&D, and business and government planning. In the latter job with the Federal Systems Division I supervised and participated in market analyses and forecasts of advanced information systems technology in federal markets such as DOD, NASA, FAA, and ACDA. I also participated in preparing the Divisional Five-Year Plan.

6. From 1953-1954 I was employed as Research Assistant, Program of Education and Research in Planning, University of Chicago, Chicago, Ill. I prepared migration studies and sector forecasts of the Puerto Rican economy including implications for a family income goal under consideration by the Puerto Rican Government.

7. From 1950 to 1951 I was employed as Chemical Engineer in the Geology Division of Gulf Research Corporation, Harmorville, Penna. I designed experimental apparatus and conducted experiments on fluid flow in porous media, including sedimentology studies in the Gulf of Mexico. I co-authored several research papers.

8. Other useful knowledge from my prior work includes: one year of machine shop experience at York Safe & Lock Co. at York, Pa.; four years as an Outside Machinist in the Pearl Harbor Navy Yard repairing or maintaining ships and submarines including steam turbines, diesel engines, pumps, valves, pipe flanges, etc.; pipe mill machinery maintenance at U.S. Steel Corp. plant at McKeesport, Pa. (2 summers); and one summer in chemical engineering research work on a pilot fluidized roaster unit and waste metals recovery studies at the Zinc Smelting Division of St. Joseph Lead Co. at Monaca, Pa.

9. I am a member of a number of professional societies. I have presented papers at meetings of the Operations Research Society of America, The Institute of Management Sciences, the American Association for the Advancement of Science, the Marine Technology Society, the American Association of Petroleum Geologists, Institute of Electrical and Electronic Engineers, and the International Society for Technology Assessment. The latter paper delivered at The Hague, Netherlands on May 29, 1973 was on the subject, Methodological Problems in Analyzing Cost-Benefit Impacts of Nuclear Power Plants in the United States.

10. Other professional activities include:

Participant, Advance Study Institute for Technology Assessment, sponsored by NATO, the NSF and the International Institute for the Management of Technology at Lake Garda, Italy, September 17-29, 1972.

Program Chairman, Conference/Workshop sponsored by the Marine Technology Society on Technology Assessment of Marine Resource Development, Washington, D.C., May 15-17, 1972.

Testimony on, "U.S. Economic Interests in Marine Resource Developments As Affected by Alternative Boundaries, National and International Management Regimes, Federal Incentives, and Other Factors of National Concern," presented at Hearings of the 91st Cong., 2d Sess., U.S. Senate Committee on Interior and Insular Affairs, Special Subcommittee on the Outer Continental Shelf, Part 2, Washington, D.C., April 1, 1970), pp. 299-321.

Testimony on, "Some Key Issues in the Planning of Action Programs for the Conservation of Natural Resources and the Enhancement of Environmental Quality," presented at the Hearings of the 91st Congress, House of Representatives, Conservation and Natural Resources Subcommittee of the Committee on Government Operations (Washington, D.C., Feb. 2-6, 1970), 9 pp.

Testimony on, "A Commentary on Planning Problems and Issues in Water Resources Management," presented at the National Conference on Water Needs and Problems of the United States sponsored by the National Water Commission (Washington, D.C., Nov. 6-7, 1969), 12 pp.

Member, Advisory Panel, National Sea Grant Program, 1968-1969.

Panel Member, Conference on Government Goals in Science Policy, Organisation for Economic Cooperation and Development, Paris, December 1967.

Member, U.S. delegation, Industrial Promotion Conference, United Nations, ECAFE, Bangkok, Thailand, February 1965.

PROFESSIONAL QUALIFICATIONS

John D. Buffington

Argonne National Laboratory

I am John Douglas Buffington, Biologist with the Environmental Statement Project of Argonne National Laboratory. I joined the Project in June 1972. Since then I have contributed to many environmental impact statements for nuclear power facilities by my authoring, editing, and/or reviewing pertinent portions of their contents. In addition I have served as Team Leader for several of them.

I received my B.S. in biology from St. Peter's College in 1963. After this I studied under S. Charles Kendeigh in the Zoology Department of the University of Illinois with major concentration in animal ecology and minors in plant ecology and entomology. I received my M.S. in 1965 and my Ph.D in 1967.

From 1967-1969 I served in the U. S. Army with the final rank of Captain at the United States Army Biological Research Laboratory at Ft. Detrick, Maryland, investigating some ecological consequences of warfare. From 1969 until I joined Argonne National Laboratory I was Assistant Professor of Biological Sciences at Illinois State University with responsibility for ecology courses at the undergraduate and graduate levels.

My continuing education has included courses and institutes including several in systems ecology.

I have published, in addition to several dozen book reviews, nine papers on a variety of ecological topics ranging from the organism to the ecosystem. I have received grants or contracts for various programs from the National Institute of Health, the National Science Foundation, and the National Park Service.

I am a member of AAAS, AIBS, Ecological Society of America, American Society of Zoologists, Entomological Society of America, the International Association of Ecology, American Mosquito Control Association, and Sigma Xi.

I am professionally certified (No. 685) in the area of Ecology and Population Dynamics on the American Registry of Certified Entomologists.

PROFESSIONAL QUALIFICATIONS

Dennis Keith Rathbun

U. S. Atomic Energy Commission

I am Dennis Keith Rathbun, Cost-Benefit Specialist on loan to the Directorate of Licensing, AEC Regulatory from Sandia Laboratories, Livermore, California. I joined the Cost-Benefit Branch in July 1973. My responsibilities include review of the cost-benefit chapter and other related material in environmental reports submitted by applicants. I prepared several sections for inclusion in the draft environmental impact statement for Bellefonte nuclear power facility. I also provide technical assistance in the cost-benefit area to other branches within AEC Regulatory. In addition, I am responsible for and have made contributions in generic research helpful in performing cost-benefit analysis. In particular, I authored an internal memorandum on recent experience with the plant capacity factor for a sample of nuclear and non-nuclear commercial power plants.

During the period 1963-68 I took a total of ten undergraduate and graduate courses in economics at the University of Maryland and San Jose State University. These courses covered a broad spectrum of the economics field. From 1968 to present I have been enrolled as a Doctoral candidate in economics at the University of California at Berkeley. I have completed the course work and qualifying examinations for a Ph.D. in economics. My primary fields of emphasis have been public finance, industrial organization, and macro-economic cycles and fluctuations. The public finance course work has covered many aspects of the theoretical and practical aspects of cost-benefit analysis. I am preparing a dissertation entitled Public Finance Aspects of Large Scale Community Development; the research for this dissertation is essentially complete. This topic includes a systematic analysis of the local public interest and planning aspects of new community development and land use in California. The assessment includes the needs for public roads, sanitary waste treatment facilities, water system improvements, parks, schools, fire and police protection and the provision of other local public services.

I received a Bachelor degree in electrical engineering from the University of California in 1960 and a Master's degree in electrical engineering from the Catholic University in Washington, D.C. in 1965. My major subject area in graduate engineering was electrical systems analysis. I have also completed a number of graduate courses in probability, statistics, and economic analysis as a minor subject area in both the engineering and economics curriculum described above.

I have been employed by Sandia Laboratories since 1965 as a member of the technical staff. My work has been primarily in technology development for the testing of nuclear systems. Since 1968 I have worked in the area of

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nondestructive test engineering. I have made contributions in technique development which are in use in the areas of eddy currents and ultrasonics. I have work experience in dye penetrant testing and radiography.

Prior to 1968, my principal work area was in the development of electrical test technologies and instrumentation. I developed a single transient analyzing system using superconductive cable operated at cryogenic temperatures.

I served as a general line officer in the U. S. Navy during the period 1960-1965. During 1960-62, I was assigned to the USS OKANOGAN and performed engineering and administrative duties.

In the period 1962-1965, I taught a number of courses while assigned to the Science Department faculty of the U. S. Naval Academy. I left the service in June 1965 with the rank of Lieutenant.

I have written a published article based on my research in acoustic emission entitled Testing of Filament Wound Spherical Test Shapes Via Acoustic Emission. Also I co-authored an article assessing the potential use at low temperature of superconductive cable for long distance data transmission; the title of the article is Data Transmission Through the Use of Miniature Superconductive Cables. I am a member of the IEEE professional society.

Robert M. Bernero

Professional Qualifications

Directorate of Licensing

United States Atomic Energy Commission

I am a project manager in Pressurized Water Reactors Branch No. 4 of the Directorate of Licensing. It is my duty to perform portions of the safety evaluations of nuclear power plants and to coordinate the safety evaluation effort of others for individual plants. I started work at the Atomic Energy Commission early in 1972 at my present position. My initial assignment was as project manager for the operating license review of Arkansas Nuclear One, Unit 1, a plant which uses a nuclear steam supply of the same type as Three Mile Island, Unit 1. I have assisted in the review of other plants and, early in 1973, I also assumed primary responsibility for the site evaluation of the proposed Boardman Nuclear Plant and the completion of the operating license review of Three Mile Island, Unit 1. The Boardman site evaluation is principally concerned with aircraft hazard analysis.

Prior to joining the AEC, I spent 13 years with the General Electric Company in nuclear power work. Initially, I was a fluid systems design engineer for naval pressurized water reactor plants developed by the Knolls Atomic Power Laboratory (KAPL). In that position, I worked principally

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on reactor auxiliary systems which provide vital cooling, shielding, makeup, chemistry control, and radioactive waste management.

While still attached to KAPL, I served as a field engineer for the construction and test of two reactor plants in a U. S. Naval vessel. In that assignment, I worked as a construction engineer for the erection and installation of the reactor plants and as a test engineer for the proof and acceptance testing of those plants.

I later worked at the G. E. Space Division as a program manager of design studies for space power plants and then as the manager of development and fabrication for a thermoelectric power converter for space satellite use.

I received a B.S. degree in Philosophy from St. Mary of the Lake Seminary in Mundelein, Illinois in 1952, a B.S. in Chemical Engineering from the University of Illinois in 1959, and an M.S. in Chemical Engineering from Rensselaer Polytechnic Institute in 1961.

LEWIS G. HULMAN

PROFESSIONAL QUALIFICATIONS

SITE ANALYSIS BRANCH
DIRECTORATE OF LICENSING

I am the Senior Hydraulic Engineer on the staff of the Site Analysis Branch, Site Safety Group, Directorate of Licensing.

My formal education consists of study in Civil Engineering at the University of Iowa where I received a BSCE in 1958, and an MS in Mechanics and Hydraulics in 1967. The graduate study was under total sponsorship of the Corps of Engineers. In addition, I have taken post-graduate courses in structural engineering at the University of Nebraska, coastal engineering at MIT, hydraulics at Colorado State University, advanced mathematics through the University of California and numerous computer utilization courses. I have had courses in hydrology, water resources, dam design, fluid mechanics, engineering construction, soil mechanics, water supply, hydropower developments, sedimentation, geology, and advanced mathematics.

My present employment with AEC dates from February 1971 in the area of hydrologic engineering with both the Division (now Directorate) of Reactor Licensing and the Division (now Directorate) of Reactor Standards, and for consultation on siting of materials utilization facilities and on environmental matters. My responsibility in the licensing review of nuclear facilities is in the areas of flood vulnerability, adequate water supply, and surface and ground water acceptability of effluents. In addition, I participate in the development of the technical bases for safety guides and standards in these areas of interest.

From 1968 to 1971, I was a Hydraulic Engineer with the Corps of Engineers Hydrologic Engineering Center in Davis, California. I worked on special hydrologic engineering projects with most Corps offices, participated as an instructor in training courses, and conducted research. Special projects work included water supply systems analysis for the Panama Canal, planning hydrologic engineering studies for water resource development near Fairbanks, Alaska, regional water supply and flood control studies for the northeastern U. S., design hydropower and water supply studies for a dam in the northeast, and flood control studies in Mississippi.

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From 1963 to 1968, I was a Supervisory Hydraulic Engineer with the Philadelphia District, Corps of Engineer. As Assistant Chief of the Hydraulics Branch, I was responsible for hydrologic and hydraulic design of multi-purpose dams, navigation projects, coastal engineering development and special studies on hydraulic modeling of dams, inlets, water supply, and shoaling, salt water intrusion, and the hydraulic effects of dredging. I acted as advisor to the District Engineer, Philadelphia, on drought problems in the 1960's and represented him in technical meetings of the Delaware River Basin Commission-chaired interagency committee which evaluated the effects of the drought.

From 1958 to 1963, I was a Hydraulic Engineer with the Omaha District of the Corps of Engineers. I was responsible for the hydraulic design of flood control channels, hydraulic design of structures for large dams and several flood control projects. I also received training in hydrologic engineering, structural engineering, sedimentation, river training studies and design, and water resource project formulation.

I have published in journals of the American Society of Civil Engineers, the American Water Works Association, the National Society of Professional Engineers, the American Geophysical Union, and in internal technical papers and seminar proceedings of the Corps of Engineers.

I am a registered Professional Engineer in the states of Nebraska and California. I am a member of the American Society of Civil Engineers, the American Water Resources Association, and the American Geophysical Union.