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ABSTRACT

A study projected employment needs created by growth and employee turnover for the nuclear power industry over the next decade. Only employment by electric utilities in the commercial generation of nuclear power was investigated. Employment data for 1981 were collected in a survey of 60 member utilities of the Institute of Nuclear Power Operations. The data were analyzed statistically to identify factors accounting for variations in power plant staffing and the number of off-site nuclear support personnel employed by a utility. Total employment in the nuclear power industry was predicted to increase from 54,400 in 1981 to 73,600 in 1991. Due to replacements, 36,300 additional employees would also be needed. As more power plants progress from design and engineering, through construction, and into full operation, more on-site employees will be needed. Megawatt capacity, number of reactor units, operation status, and projected completion dates for units under construction were identified as factors influencing the number of employees at a power plant site. Number of off-site personnel was influenced by total megawatt capacity in operation, total megawatt capacity under construction, projected completion dates for units under construction, and whether or not the utility industry does its own architect-engineering work. (Appendixes, amounting to approximately one-half of the report, include questionnaires, technical notes, and utility-projected 1991 employment.) (YLB)

ORAU-205

MANPOWER REQUIREMENTS IN THE NUCLEAR POWER INDUSTRY, 1982-1991

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MANPOWER REQUIREMENTS IN THE NUCLEAR POWER INDUSTRY, 1982-1991

ABSTRACT

The objective of this study is to project occupational employment needs, created by growth and employee turnover, for the nuclear power industry over the next decade. Employment data for 1981 were collected in a survey conducted by the Institute of Nuclear Power Operations of its 60 member utilities. The data were analyzed statistically to identify factors that account for variations in power plant staffing and the number of off-site nuclear support personnel employed by a utility. Total employment in the nuclear power industry is predicted to increase from 54,400 in 1981 to 73,600 in 1991. Nuclear generating capacity will increase from 58 to 124 gigawatts, based on the midline forecast of the Energy Information Administration. The projections assume that current regulations will remain in effect and no new plans for additional generating facilities will be initiated.

EXECUTIVE SUMMARY

The purpose of this study is to project occupational employment needs for the nuclear power industry over the next decade. The projected needs for additional employees include new positions created by increases in generating capacity and replacement positions produced by employee turnover. The study is limited to employment in the commercial generation of nuclear power. The study covers employment positions for normal nuclear power activities but excludes temporary positions such as those for fuel reloading and special maintenance. The study includes employment positions located "on-site", (at a nuclear power plant) and employment positions located "off-site" that support nuclear power plant operations or provide nuclear power plant design and engineering services.

METHOD OF ANALYSIS

Employment data for 1981 and turnover data for 1980 were collected in a survey conducted by the Institute of Nuclear Power Operations (INPO) of its 60 member utilities. The data were analyzed statistically to identify the factors that account for variations in power plant staffing and the number of off-site nuclear support personnel employed by a utility. Megawatt capacity, number of reactor units, operation status, and projected completion dates for units under construction directly influence the number of employees at a power plant site. Within a given utility, the number of off-site personnel in nuclear employment is influenced by total megawatt capacity in operation, total megawatt capacity under construction, projected completion dates for units under construction, and whether or not the utility does its own architect-engineering work.

Econometric models, giving an estimated value for each factor found to influence employment, were used to predict employment for each utility and each power plant site within the utility, given the respective operation and construction status anticipated in 1991. The sum of predicted nuclear employment for the 60 utilities gives predicted employment for the industry, with the occupational distribution based upon projections supplied by the utilities. Needs for additional employees were estimated from projected industry-wide occupational employment figures and estimated turnover rates for employees leaving the industry.

The projections in employment are based upon increases in nuclear generating capacity forecast by the Energy Information Administration. The projections in employment assume that current regulations and staffing patterns will remain in effect and that annual turnover rates will remain constant during the next ten years.

RESULTS

Total employment in the nuclear power industry is projected to increase from 54,400 in 1981 to 73,600 in 1991. Nuclear generating capacity is projected to increase from 58 to 124 gigawatts.

In 1981, 66 percent of those employed in the industry were located at power plant sites, with the remaining 34 percent at off-site locations. By 1991 this distribution is expected to change to 70 percent and 30 percent, respectively, as more power plants progress from design and engineering, through construction, and into full operation.

Of the 51,200 predicted to be employed on-site in 1991, approximately 5 percent are expected to be in management. Engineers will account for 8 percent and scientists 2 percent. Technical employees, including technicians, operators, and skilled craft workers, are expected to comprise approximately 57 percent of on-site employees. Of the 22,400 predicted to be employed off-site in 1991, approximately 8 percent are expected to be managers, 33 percent engineers, 5 percent scientists, 15 percent technicians, and 11 percent skilled craft workers.

An additional 55,500 employees, including 19,200 due to growth and 36,300 to replacements, will be needed by the nuclear power industry in the next ten years. Employee turnover rates do not take into account the movement of employees from nuclear-related and other industries into the nuclear power industry. Therefore, the 55,500 figure should be interpreted as new employees the nuclear power industry needs to recruit and not as number of jobs for new entrants to the labor market.

Of the total number of additional employees needed, approximately three-fourths will be in occupations requiring specialized skills and training. The greatest needs will be for skilled craft workers, technicians, and operators. Among technicians, the greatest need will be for electrical-electronic technicians.

Among the professional occupations, the greatest need will be for engineers, with an estimated 75 percent of the need created by turnover.

UNCERTAINTIES AND NEEDS FOR FURTHER RESEARCH

Uncertainties in the present and future environment for the nuclear power industry create obvious uncertainties in any projections of employment. The projections must be interpreted in view of current conditions and the stated assumptions.

A portion of the March 1981 survey of the 60 INPO-member utilities requested projections of employment in 1991. The utilities' projections were somewhat lower than those from the statistical analysis (70,800 compared to 73,600), although the utilities estimated generating capacity at 139 gigawatts (rather than 124) by 1991. Although the two sets of projections are within a reasonable range, the difference shows that a margin of error exists.

The purpose of this study is to project occupational employment needs of the nuclear power industry. The study does not attempt to devise a "typical" or "model" plan for the staffing of nuclear power plants. This is an area in which further research is needed.

It is expected that data collecting and reporting will be improved in future surveys conducted by INPO. The 1981 survey and study represent an important step for the industry. Improved data and data for additional years will facilitate further insight into employment needs and refinement of projection models.

CHAPTER 1
INTRODUCTION

PURPOSE AND SCOPE OF STUDY

The staffing of nuclear power plants with sufficient numbers of adequately trained personnel over the coming decade is of concern to both the industry and public policymakers. The purpose of this study is to project employment needs by occupation for 1982 through 1991 based upon a statistical analysis of current employment in the industry. The projected needs for additional employees include new positions created by increases in generating capacity and replacement positions produced by employee turnover.

The scope of the study is limited to employment by electric utilities in the commercial generation of nuclear power and does not include such areas as construction of nuclear facilities, research and development, waste disposal, or fuel reprocessing. The study covers employment positions for normal nuclear power activities but excludes temporary positions such as those in fuel reloading and special maintenance. The study includes employment positions located "on-site" (at a power plant) and employment positions located "off-site" that support nuclear power plant operations or provide nuclear power plant design and engineering services.

PROJECTION ANALYSIS APPROACH

Data

The cross-section employment data used in this study were collected by the Institute of Nuclear Power Operations (INPO) through a survey of its 60 member utilities in the spring of 1981. INPO member utilities include all utilities involved in the actual planning, licensing, construction, and operation of nuclear generating facilities, although other utilities and holding companies are joint owners of many of the nuclear power plants. All 60 utilities responded to the survey, although not all respondents answered every question.

The survey consisted of four separate questionnaires: on-site employment specific to a power plant, off-site support personnel, hiring and employee turnover activity, and utility-provided training of employees. Descriptive data collected from the first three questionnaires (see Appendix A) were used in the statistical analysis and employment projections contained in this report.

The questionnaires were designed to reflect differing approaches used by the utilities to meet the design, operation, and normal maintenance requirements for nuclear power plants through off-site support personnel, contractors, and holding company personnel, as well as through utility employees working at the plant site. The reported numbers of positions include utility employees and vacancies, plus contractor and holding company employees required in normal operations. The requested data on hiring and employee turnover activity provided information essential to estimating employee replacement needs during the next ten years.

Method of Analysis

The descriptive data presented in Chapter 2 were compiled to identify and document current employment and vacancies in the nuclear power industry. The occupational employment data for 1981 were then studied using statistical analysis to identify the factors that account for variations in power plant staffing and the number of off-site nuclear support personnel employed by a utility. The resulting econometric models were used to predict employment in 1982 through 1991, taking into account the estimated increases in generating capacity and known characteristics of all units expected to be in operation in a particular year.

Employee replacement needs by year and occupation were calculated from the predicted employment in each year and estimates of annual turnover rates. Estimates of total additional employees, attributed to both growth needs and replacement needs, for the coming decade were thus obtained.

Assumptions

In projecting nuclear power employment for the next decade, it is necessary to make simplifying assumptions in recognition of uncertainties facing the

industry, incomplete data, and lack of precision in the methodology used. The projections must be updated or revised as new information becomes available or if a different set of assumptions becomes more appropriate. In this analysis, the following conditions are assumed:

1. Current regulations and utility staffing practices will remain in effect during the ten-year period.
2. No additional plans for new construction of nuclear generating capacity will be initiated during the next decade.
3. Annual employee turnover rates will remain constant.
4. The factors that currently influence the number of employees needed in the nuclear power industry will also influence employment in the next decade.
5. Current estimates by utilities of 1991 occupational distributions (percent of employment in each occupation) will remain constant.

CHAPTER 2

OCCUPATIONAL EMPLOYMENT IN THE NUCLEAR POWER INDUSTRY, 1981

CURRENT EMPLOYMENT AND NEEDS FOR PERSONNEL

The survey of utilities that are now operating, constructing, and planning nuclear power plants indicates that approximately 54,400 positions were authorized, and approximately 47,000 persons were employed, in the industry as of March 1, 1981. Tables 2-1 through 2-4 report total positions and give breakdowns of on-site versus off-site designations; utility, contractor, or holding company employment; and filled versus vacant positions. The occupational categories provide further detail on employment and current needs for trained personnel in the nuclear power industry.

In Table 2-1 total employment positions in the industry are divided into 35,900 (66 percent) on-site positions and 18,500 (34 percent) off-site support positions. The occupational distribution shows that approximately 19 percent of the total positions are in engineering, and two-thirds of the engineers are at off-site locations. Technicians are second to engineers in numbers and are concentrated at power plant sites. Nuclear reactor operators, numbering 6,000, are 11 percent of total employment positions. Skilled craft workers account for 13 percent of the work force and, as would be expected, most craft workers are assigned to on-site locations. The "all other workers" category, including security force and laborers, is 16 percent of total positions in the industry, and these workers are assigned principally to power plant sites.

By occupational categories, the distribution is 33 percent professional, 30 percent technical, 13 percent skilled crafts, and 24 percent other. At least three-fourths of the positions in the industry require that the employee have either a bachelor's degree or considerable specialized skills and training. The technician and operator occupational categories are of particular concern to the utility industry, because the specialized training for these employees is provided primarily by the utilities.

In Table 2-2 on-site positions are divided into utility, contractor, holding company, and vacant positions by detailed occupational listing. Contractor

TABLE 2-1. TOTAL POSITIONS IN THE NUCLEAR POWER INDUSTRY, 1981

Occupation	On-Site Positions	Off-Site Positions[a]	Total Positions[b]	Percent of Total
Managers	2,000	1,600	3,600	6.6
Engineers	3,300	6,900	10,200	18.8
Scientists	600	800	1,400	2.6
Other professional workers	1,300	1,400	2,700	5.0
Technicians	6,900	3,200	10,100	18.6
Operators	6,000	0	6,000	11.0
Skilled craft workers	5,800	1,300	7,100	13.1
Clerical workers	2,500	2,100	4,600	8.5
All other workers	7,500	1,200	8,700	16.0
Total	35,900	18,500	54,400	[c]

[a] Includes estimates for non-respondents (2 off-site locations).

[b] This includes persons employed by INPO member utilities, vacant positions at the utilities, contractor positions used in normal operations, and holding company positions allocated to the utilities.

[c] Does not add to 100 percent because of rounding.

Source: Survey conducted by the Institute of Nuclear Power Operations, March 1981.

TABLE 2-2. ON-SITE NUCLEAR POWER POSITIONS BY OCCUPATION AND EMPLOYER (UTILITY, CONTRACTOR, AND HOLDING COMPANY), 1981

Occupation	Employment				Total Positions
	Utility	Contractor	Holding Company	Vacancies[a]	
Managers	1,830	35	1	179	2,045
Engineers	2,227	318	1	748	3,294
Chemical	79	5	0	11	95
Civil	40	19	0	0	59
Electrical and electronic	462	39	0	104	605
Mechanical	608	93	0	113	814
Nuclear and reactor	506	10	1	236	753
All other engineers	532	152	0	284	968
Scientists	422	61	0	96	579
Mathematicians	18	0	0	0	18
Chemists	146	1	0	43	190
Physicists	25	4	0	1	30
All other physical scientists	29	0	0	7	36
Biological scientists	30	27	0	1	58
Health physicists	161	20	0	41	222
All other life scientists	13	9	0	3	25
All other professional workers	913	70	0	265	1,248
Technicians	4,684	761	7	1,437	6,889
Draftsmen	52	11	0	13	76
Electrical and electronic	1,672	103	0	400	2,175
All other engineering technicians	740	41	0	165	946
Physical science technicians	231	19	0	92	342
Life science technicians	41	27	0	20	88
Health physics technicians and radiation monitors	1,195	410	7	529	2,141
All other technicians	753	150	0	218	1,121
Operators	4,830	6	0	1,196	6,032
Shift supervisors	663	0	0	141	804
Senior licensed operators	497	6	0	165	668
Licensed operators	1,127	0	0	379	1,506
Non-licensed operators	2,543	0	0	511	3,054
Skilled craft workers	3,975	1,035	0	741	5,751
Electricians	993	223	0	201	1,417
Mechanics	1,729	415	0	396	2,540
Welders with nuclear certification	340	67	0	46	453
All other skilled craft workers	913	330	0	98	1,341
Clerical workers	2,113	111	3	281	2,508
All other workers	3,609	3,140	0	758	7,507
Total	24,603	5,537	12	5,701	35,853

[a]Vacant positions at the utilities.

Source: Survey conducted by the Institute of Nuclear Power Operations, March 1981.

employees account for approximately 15 percent of on-site employment, while holding company employees provide less than 1 percent of the work force. The employment figures show that more than half the work force is concentrated in technician, operator, and skilled craft categories. Nuclear reactor operators are approximately 17 percent of on-site employment.

Table 2-3 shows off-site employment by occupation and type of employer. Approximately 13 percent of total off-site positions are contracted, and about 2 percent are furnished by holding companies. Engineers are the largest occupational group, accounting for 38 percent of off-site employment positions. Draftsmen (9 percent of off-site employment positions) are the largest in number of the technical and skilled craft designations at the present time. As design and engineering of nuclear facilities progress, it is expected that draftsmen will account for a smaller percentage of off-site employment, assuming that no additional plans for new construction are initiated.

Table 2-4 summarizes the job vacancies reported in Tables 2-2 and 2-3. The utilities reported that 13.7 percent of total positions were vacant as of March 1, 1981. The occupation with the highest percentage of vacancies (19.8 percent) was the operators' category, followed by engineers (17.4 percent). This may indicate that the industry is already experiencing difficulty in recruiting and filling positions in certain occupations. The relatively high vacancy rates may be partially explained by the fact that utilities are now in the process of recruiting and training personnel for new units expected to go on line.

EMPLOYEE TURNOVER RATES

Industry spokespersons from individual utilities have expressed concern about problems of recruiting and retaining trained personnel.[1] As a result of these problems, utilities have initiated various plans for career development and upward mobility in an effort to recruit and retain employees. Utility managers have expressed concern about competition for employees and movement within the nuclear power industry, as well as loss of employees from the industry. The hiring and turnover components of the survey attempted to document these expressed concerns and to provide the necessary data for estimating future manpower replacement needs for the nuclear power utilities. The data for year 1980 are reported in Tables 2-5 through 2-8.

TABLE 2-3. OFF-SITE NUCLEAR-RELATED POSITIONS BY OCCUPATION AND EMPLOYER (UTILITY, CONTRACTOR, AND HOLDING COMPANY), 1981

Occupation	Employment			Vacancies[a]	Total Positions
	Utility	Contractor	Holding Company		
Managers	1,313	40	40	72	1,465
Engineers	4,281	1,131	95	953	6,460
Chemical	157	29	3	25	214
Civil	482	141	2	53	678
Electrical and electronic	998	138	15	177	1,328
Mechanical	1,156	608	41	270	2,075
Nuclear and reactor	700	65	20	180	965
All other engineers	788	150	14	248	1,200
Scientists	606	22	6	81	715
Mathematicians	80	0	0	4	84
Chemists	110	3	0	17	130
Physicists	38	0	0	0	38
All other physical scientists	86	4	0	13	103
Biological scientists	149	9	3	13	174
Health physicists	104	6	3	28	141
All other life scientists	39	0	0	6	45
All other professional workers	1,189	81	9	91	1,370
Technicians	2,122	663	86	220	3,091
Draftsmen	847	551	60	66	1,524
Electrical and electronic	228	28	0	8	264
All other engineering technicians	406	69	21	67	563
Physical science technicians	60	2	0	5	67
Life science technicians	34	0	4	1	39
Health physics technicians and radiation monitors	80	5	0	15	100
All other technicians	467	8	1	58	534
Skilled craft workers	1,167	40	0	51	1,258
Electricians	187	11	0	15	213
Mechanics	731	10	0	21	762
Welders with nuclear certification	49	8	0	5	62
All other skilled craft workers	200	11	0	10	221
Clerical workers	1,644	98	31	90	1,863
All other workers	770	192	2	30	994
Total	13,092	2,267	269	1,588	17,216
Adjusted total					18,500[b]

[a]Vacant positions at the utilities.

[b]Includes estimates for non-respondents (2 off-site locations).

Source: Survey conducted by the Institute of Nuclear Power Operations, March 1981.

TABLE 2-4. JOB VACANCIES IN THE NUCLEAR POWER INDUSTRY
(Status as of March 1, 1981)

Occupation	Total Positions[a]	Vacancies[b]	
		Number	Percent of Total
Managers	3,510	251	7.2
Engineers	9,754	1,701	17.4
Scientists	1,294	177	13.7
Other professional workers	2,618	356	13.6
Technicians	9,980	1,657	16.6
Operators	6,032	1,196	19.8
Skilled craft workers	7,009	792	11.3
Clerical workers	4,371	371	8.5
All other workers	8,501	788	9.3
Total	53,069	7,289	13.7

[a] Includes persons employed by INPO member utilities, vacant positions at the utilities, contractor positions used in normal operations, and holding company positions allocated to the utilities. Estimates for non-respondents are not included.

[b] Includes both on-site and off-site utility company vacant positions.

Source: Survey conducted by the Institute of Nuclear Power Operations, March 1981.

In Table 2-5 hiring activity is divided between new positions and replacement positions. New positions accounted for approximately 19 percent of total positions filled, whereas replacement positions were approximately 13 percent of total positions. Thus, growth needs for employees exceeded replacement needs during 1980. The largest portion of new positions (and replacement positions, as well) in an occupational category was that of non-licensed operators. This hiring activity may result from the fact that utilities are expanding their operation needs and training programs for licensed candidates. At the same time, employees who are in training may be leaving because of failure in licensing examinations.

Table 2-6 reports the method of filling positions--whether new hires, promotions, or transfers. New hires were 64 percent of hiring activity, while promotions and transfers accounted for 25 and 11 percent, respectively. The fact that 60 percent of manager positions were filled by promotions indicates an upward mobility plan for certain employee groups. The promotions to shift supervisors, senior licensed operators, and licensed operators reveal the expected progression in licensing and levels of experience. There also appears to be a systematic progression in electrician and mechanic positions.

In Table 2-7 the reasons for employee turnover are tabulated. The purpose of this part of the survey is to separate movement of employees into three discrete categories: movement to another nuclear-related position within the same utility; movement to a nuclear-related job at another utility; and exit from the nuclear power utility industry due to retirement, death, or acceptance of a job outside the nuclear power utility industry. The latter category of turnover is the one relevant to determining replacement needs for the industry.

The tabulations show that the highest number of employee changes was due to transfer or promotion within the same utility. Particularly noteworthy to this survey is the low number (44) in the retirements/death category. Because the nuclear power industry is approaching the 20-year mark, retirements will probably increase during the coming ten years. Demographic data on employees in the nuclear power industry are needed to make this determination.

The calculation of turnover rates was complicated by the large number of terminating employees who were reported in the "all other reasons or unknown" category as to reason for leaving. A turnover rate on the basis of reported

TABLE 2-5. HIRING ACTIVITY IN THE NUCLEAR POWER INDUSTRY, 1980

Occupation[a]	Estimated Ave. Employment for 1980	New Positions Filled		Replacement Positions Filled	
		Number	Percent of Total Positions	Number	Percent of Total Positions
Managers	1,741	233	13.4	152	8.7
Engineers	3,234	790	24.4	390	12.1
Health physicists	204	43	21.1	10	4.9
Other scientists	313	63	20.1	38	12.1
Health physics technicians	832	183	22.0	121	14.5
Electrical & electronic technicians	1,060	161	15.2	154	14.5
Other engineering technicians	575	93	16.2	38	6.6
Other technicians	1,484	183	12.3	145	9.8
Shift supervisors	445	55	12.4	34	7.6
Senior licensed operators	373	49	13.1	43	11.5
Licensed operators	740	99	13.4	158	21.4
Non-licensed operators	1,243	490	39.4	289	23.3
Maintenance electricians	556	62	11.2	79	14.2
Maintenance mechanics	1,166	119	10.2	144	12.3
Other skilled craft workers	1,022	204	20.0	111	10.9
Total	14,988	2,827	18.9	1,906	12.7

[a]Includes both on-site and off-site utility positions but excludes contractor and holding company positions. Occupational categories for other professional workers, clerical workers, and all other workers are not included.

NOTE: This tabulation is based upon information supplied by 47 utilities (77 percent of the survey universe). The reported employment base is less than 77 percent of 1980 employment, however, due to the fact that turnover information and the corresponding employment numbers were apparently not available from all site locations within each utility.

Source: Survey conducted by Institute of Nuclear Power Operations, March 1981.

TABLE 2-6. METHOD OF FILLING POSITIONS IN THE NUCLEAR POWER INDUSTRY, 1980

Occupation[a]	Percent[b]		
	New Hires	Promotions	Transfers
Managers	32	60	8
Engineers	72	15	13
Health physicists	68	30	2
Other scientists	75	15	10
Health physics technicians	80	11	9
Electrical & electronic technicians	73	12	15
Other engineering technicians	56	28	16
Other technicians	72	18	10
Shift supervisors	28	69	3
Senior licensed operators	21	71	8
Licensed operators	29	57	14
Non-licensed operators	82	12	6
Maintenance electricians	43	42	15
Maintenance mechanics	43	32	25
Other skilled craft workers	66	19	15
Total	64	25	11

[a]Includes both on-site and off-site utility positions but excludes contractor and holding company positions. Occupational categories for other professional workers, clerical workers, and all other workers are not included.

[b]Percentages for each occupation category add to 100.

NOTE: This tabulation is based upon information supplied by 47 utilities (77 percent of the survey universe). The reported employment base is less than 77 percent of 1980 employment, however, due to the fact that turnover information and the corresponding employment numbers were apparently not available from all site locations within each utility.

Source: Survey conducted by Institute of Nuclear Power Operations, March 1981.

TABLE 2-7. CATEGORIES OF STAFF TURNOVER IN THE NUCLEAR POWER INDUSTRY, 1980

Occupation[a]	Number				
	Employee Changed to Another Nuclear-Related Position Within Utility	Employee Accepted Nuclear-Related Employment at Another Utility	Employee Took a Non-Nuclear-Related Job in Utility Industry or Left Utility Industry	Retirements/ Deaths	All Other Reasons or Unknown
Managers	79	36	33	7	28
Engineers	103	104	81	4	108
Health physicists	2	5	4	0	3
Other scientists	3	11	9	0	10
Health physics technicians	35	29	29	2	58
Electrical & electronic technicians	30	37	29	6	58
Other engineering technicians	13	11	12	2	21
Other technicians	31	28	35	2	50
Shift supervisors	6	3	2	0	18
Senior licensed operators	12	4	13	0	9
Licensed operators	69	23	20	4	39
Non-licensed operators	103	25	89	3	91
Maintenance electricians	39	5	22	4	7
Maintenance mechanics	67	29	31	9	42
Other skilled craft workers	47	4	16	1	58
Total	639	354	425	44	600

[a]Includes both on-site and off-site utility positions but excludes contractor and holding company positions. Occupational categories for other professional workers, clerical workers, and all other workers are not included.

NOTE: This tabulation is based upon information supplied by 47 utilities (77 percent of the survey universe). The reported employment base is less than 77 percent of 1980 employment, however, due to the fact that turnover information and the corresponding employment numbers were apparently not available from all site locations within each utility.

Source: Survey conducted by Institute of Nuclear Power Operations, March 1981.

employees leaving the industry, assuming that those in the "unknown" category stayed in the industry, gives a lower limit of approximately 3 percent. On the other hand, assuming that employees in the "all other reasons or unknown" category all left the industry, gives an upper limit of approximately 7 percent. The true turnover rate would appear to be somewhere between these two limits. In this analysis, the "all other reasons or unknown" category was distributed proportionately between movement to another utility and exit from the industry under the assumption that retirements, deaths, and movement within the same utility would be documented in most cases. The turnover rates calculated in this manner for intrautility, interutility, and exit from the nuclear power industry are reported in Table 2-8.[2] The overall rates are 4.3 percent, 4.1 percent, and 5.4 percent, respectively.

The average annual turnover rate of 5.4 percent in all occupations for employees leaving the industry compares with a turnover rate of 4.0 percent in the U.S. manufacturing sector.[3] This 4.0 percent turnover rate is for worker exit from the entire manufacturing sector, not just one industry within manufacturing. Therefore, the turnover rate for any one industry would probably be higher than 4 percent because of movement between industries in addition to exits from the manufacturing sector.

The combined turnover rates give an annual turnover figure of 13.8 percent for all occupations and all categories of employee turnover in the nuclear power industry during 1980. This rate is somewhat higher than the rate of 11.3 percent reported in a 1977 study of employee turnover in selected nuclear power plants.[4]

The turnover rates by occupation reveal that the highest employee turnover (exit from the industry) occurred in non-licensed operator, health physics technician, and other skilled craft categories. The lowest turnover rates occurred in the manager, health physicist, and shift supervisor groups.

TABLE 2-8. ESTIMATES OF EMPLOYEE TURNOVER RATES BY OCCUPATION WITHIN THE NUCLEAR POWER INDUSTRY, 1980

Occupation[a]	Turnover (Percent)		
	Intrautility[b]	Interutility[c]	Exit Industry[d]
Managers	4.5	2.9	3.0
Engineers	3.2	5.1	4.1
Health physicists	1.0	3.4	2.5
Other scientists	1.0	5.4	4.2
Health physics technicians	4.2	7.0	7.2
Electrical and electronic technicians	2.8	6.6	5.7
Other engineering technicians	2.3	3.7	4.3
Other technicians	2.1	3.4	4.4
Shift supervisors	1.3	3.1	2.0
Senior licensed operators	3.2	1.6	5.4
Licensed operators	9.3	5.9	5.7
Non-licensed operators	8.3	3.6	13.1
Maintenance electricians	7.0	1.1	5.8
Maintenance mechanics	5.7	4.3	5.2
Other skilled craft workers	4.0	1.6	6.2
Total	4.3	4.1	5.4

[a]Occupational categories for other professional workers, clerical workers, and all other workers are not included.

[b]Promotion and transfers to positions that are nuclear-related within the utility.

[c]Movement to nuclear-related positions from one utility to another.

[d]Exit from nuclear-related work--employees accepting non-nuclear jobs within the utility industry or leaving the utility industry, and retirements and deaths.

NOTE: This tabulation is based upon information supplied by 47 utilities (77 percent of the survey universe). The reported employment base is less than 77 percent of 1980 employment, however, due to the fact that turnover information and the corresponding employment numbers were apparently not available from all site locations within each utility. Staff turnover in the "all other reasons or unknown" category (see Table 2-7) was distributed proportionately between movement to another utility and exit from the industry (see note 2).

Source: Survey conducted by Institute of Nuclear Power Operations, March 1981.

NOTES

[1]"The U.S. Nuclear Power Industry Cries for Help," *Business Week*, August 31, 1981, pp. 102-103; "Are You Ready for the Manpower Crunch?" *Electrical World*, September 1981, pp. 54-55.

[2]Calculation of turnover rates:

$$\text{Intrautility}_j = \frac{T_{1,j}}{A_j}$$

$$\text{Interutility}_j = \frac{\left[\left(\frac{T_{2,j}}{T_{2,j} + T_{3,j}}\right) \times T_{5,j}\right] + T_{2,j}}{A_j}$$

$$\text{Exit}_j = \frac{\left[\left(\frac{T_{3,j}}{T_{2,j} + T_{3,j}}\right) \times T_{5,j}\right] + T_{3,j} + T_{4,j}}{A_j}$$

j = occupations

T_1 = number of employees who changed to another nuclear-related position within utility

T_2 = number of employees who accepted nuclear-related employment at another utility

T_3 = number of employees who took a non-nuclear related job in utility industry or left utility industry

T_4 = number of retirements/deaths

T_5 = number of employees in "all other reasons or unknown" category

A_j = estimated average employment in 1980 for occupation

[3]*Employment and Earnings*, Bureau of Labor Statistics, May 1981.

[4]G.H. Kaig, "Nuclear Plant Staff Turnover," Conference on Reactor Operating Experience, sponsored by the American Nuclear Society, Chattanooga, Tennessee, August 1977.

CHAPTER 3

ESTIMATES OF MANPOWER REQUIREMENTS IN THE NUCLEAR POWER INDUSTRY, 1982-1991

PROJECTED GROWTH IN NUCLEAR GENERATING CAPACITY

An essential prerequisite to predicting growth of labor requirements in the nuclear power industry is a forecast of growth in the industry's generating capacity. A 1978 study estimated total lead times of 12 to 15 years for nuclear power plant projects in the United States.[1] Since 1978, however, the nuclear power industry has been subject to delays, cancellations, and a general climate of uncertainty that would be expected to lengthen the total lead time.[2]

In the 1981 survey of nuclear power utilities conducted by INPO, estimated completion dates of reactor units planned and under construction were reported. Several delays and cancellations have occurred since that time, however. In this analysis, the midline forecast of nuclear generating capacity by the Energy Information Administration (EIA) is used (Figure 3-1). In EIA's forecast the industry will reach a nuclear generating capacity of 124 gigawatts by 1991, compared to 139 gigawatts from the utilities' expected completion dates.

FACTORS INFLUENCING EMPLOYMENT

Statistical analysis of the data showed that certain factors influence the number of employees at power plant sites and in off-site nuclear work of the utilities. Using these factors, econometric models to predict employment to 1991 were developed. The procedures and statistical results are described in Appendix B. The important implications of the analysis are summarized in this chapter.

On-Site

When a power plant is fully operational, megawatt capacity and number of reactor units directly influence the number of employees. These two factors explained 77 percent of the variation in power plant staffing. Other factors, such as type of reactor and years in operation, were insignificant in explaining the number of employees at a plant site.

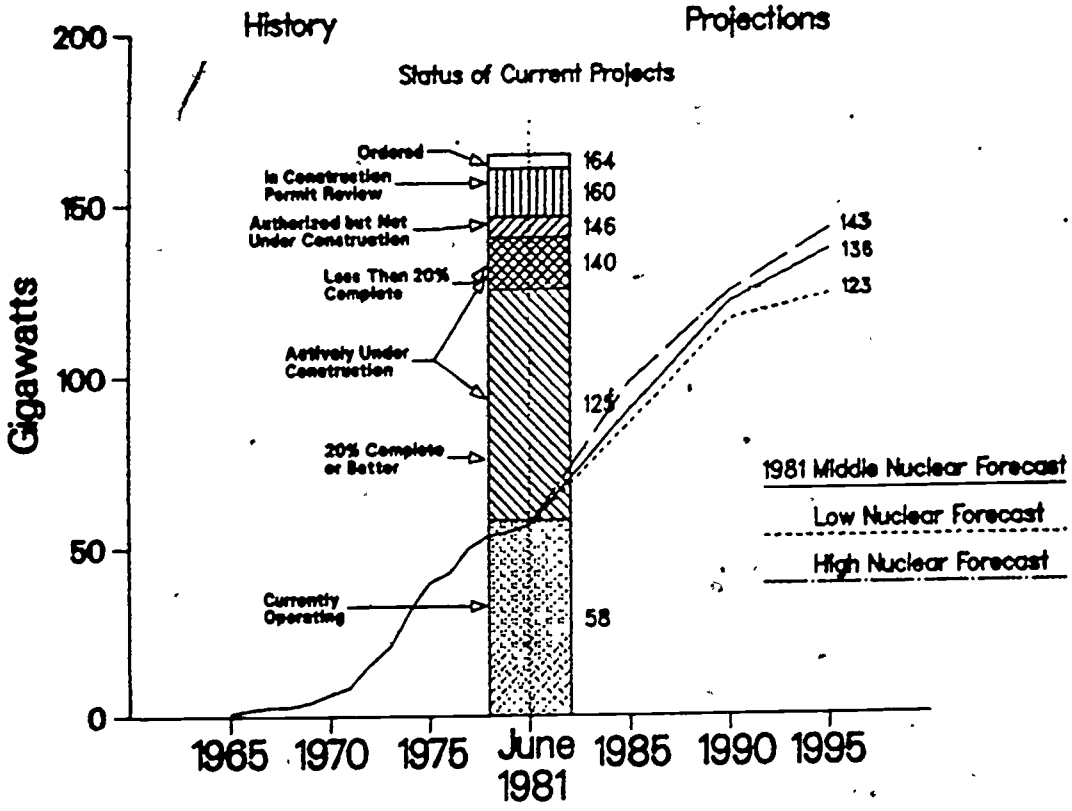

Figure 3-1. Nuclear Electricity Generating Capacity and Status of Current Capacity Expansion Projects, High, Middle, and Low Nuclear Capacity Projections, History and Projections (Nuclear Capacity at Year End in Gigawatts[a])

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[a]One gigawatt equals 1 billion (10^9) watts.

Source: *1981 Annual Report to Congress: Volume 3 - Energy Projections*, Energy Information Administration, U.S. Department of Energy, Washington, D.C. (1982).

Table 3-1 shows predicted employment based on megawatt capacity and number of reactor units at a power plant. The incremental effect on employment of adding a second unit is 346 additional employees. The third unit adds 330 employees indicating the effect of economies of scale.

TABLE 3-1. PREDICTED EMPLOYMENT OF NUCLEAR POWER PLANTS IN FULL OPERATION

Capacity (megawatts)	Reactor Units	Employment
1,000	1	392
2,000	2	738
3,000	3	1,068

During construction, employment progresses from zero toward the level required for full operation. The relationship of staffing levels to years from completion is shown in Figure 3-2. A power plant that is within eight years of coming on line will have employed approximately 3 percent of its full operating staff. The percentage increases to 74 percent when the plant is within a year of coming on line.

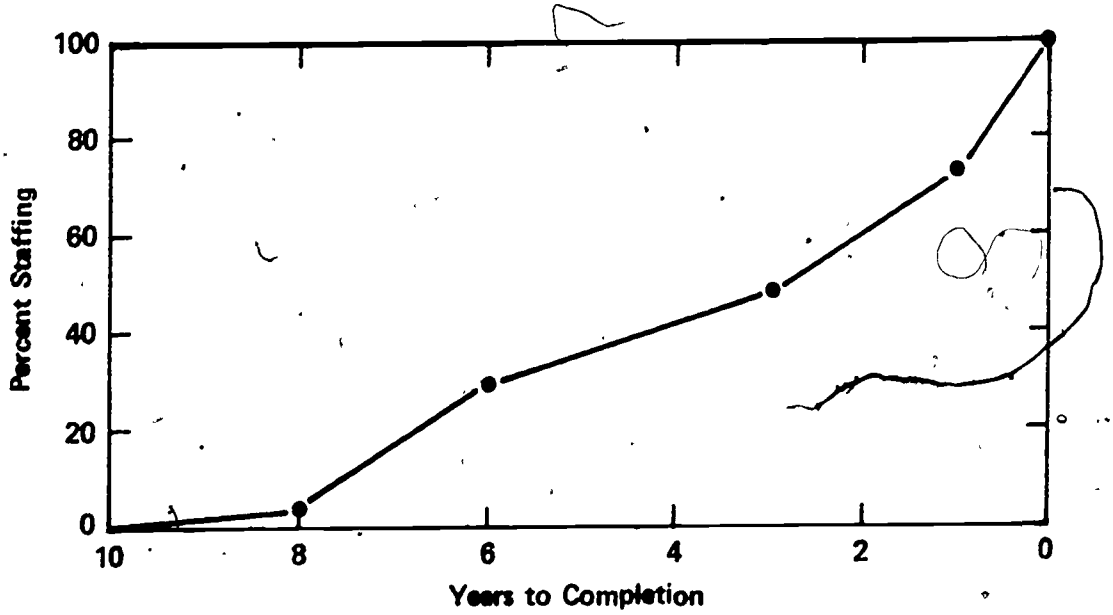

Figure 3-2. Operation and Maintenance Staffing Levels for Nuclear Power Plants During Construction Period

Off-Site

Individual utilities in the nuclear power industry may possess one or more nuclear power plant sites, with operations and no construction, construction and no operations, or a combination of operations and construction. Within a utility the number of off-site personnel in nuclear work is influenced by the utility's total megawatt capacity in operation, total megawatt capacity under construction, projected completion dates for units under construction, and whether or not the utility does its own architect-engineering work. These factors explained 52 percent of the variation among the utilities in off-site employment. The estimates show that for each 1000 megawatts in current operation, approximately 103 persons are employed. For each 1000 megawatts to be completed within 3 years, approximately 76 persons are employed, whereas 41 are employed for each 1000 megawatts to be completed in time periods of more than 3 years. If the utility does its own architect-engineering work for new nuclear facilities, an additional 879 persons are employed.

GROWTH IN EMPLOYMENT

The results of the statistical analysis show that total employment positions in the nuclear power industry (both on-site and off-site) will increase from 54,400 in 1981 to 73,600 in 1991. Nuclear generating capacity is projected to increase from 58 to 124 gigawatts.

In 1981, 66 percent of those employed in the industry were located at power plant sites, with the remaining 34 percent at off-site locations. By 1991 this distribution is expected to change to 70 percent and 30 percent, respectively, as more power plants progress from design and engineering, through construction, and into full operation.

Under the assumptions concerning construction schedules, total employment will increase to 67,200 by 1986. Thus, 67 percent of the growth in predicted employment for the ten-year period will have occurred by 1986.

Predicted employment for 1986 and 1991 is reported in Tables 3-2 and 3-3.[3] An increase of 15,300 (43 percent) is predicted for on-site employment by 1991. Approximately 65 percent of the increase in on-site employment is expected by 1986. The occupation group adding the most employees (1,900) over the ten-year span is that of electrical-electronic technician. The occupation with the

TABLE 3-2. PROJECTED GROWTH IN ON-SITE EMPLOYMENT

Occupation	Employment	Predicted Employment		Growth (1981-1991)	
	1981	1986	1991	Number	Percent
Managers	2,000	2,500	2,800	800	40.0
Engineers	3,300	3,600	4,100	800	24.2
Health physicists	200	400	400	200	100.0
Other scientists	400	500	500	100	25.0
Other professional workers	1,300	1,500	1,600	300	23.1
Technicians	6,900	8,900	10,000	3,100	44.9
Electrical-electronic	2,200	3,500	4,100	1,900	86.4
Other engineering technicians	900	900	1,100	200	22.2
Health physics	2,100	2,800	3,100	1,000	47.6
All other technicians	1,700	1,700	1,700	*	
Operators	6,100	8,100	9,100	3,000	49.2
Shift supervisors	800	1,100	1,200	400	50.0
Senior licensed operators	700	1,600	1,900	1,200	171.4
Licensed operators	1,500	2,100	2,300	800	53.3
Non-licensed operators	3,100	3,300	3,700	600	19.4
Skilled craft workers	5,700	9,100	10,100	4,400	77.2
Electricians	1,400	2,300	2,600	1,200	85.7
Mechanics	2,500	3,300	3,600	1,100	44.0
Welders with nuclear certification	500	700	800	300	60.0
Other skilled craft workers	1,300	2,800	3,100	1,800	138.5
Clerical workers	2,500	3,500	4,000	1,500	60.0
All other workers	7,500	7,700	8,600	1,100	14.7
Total	35,900[a]	45,800	51,200	15,300	42.6

[a] It is assumed that employment for 1981 reaches the level for total positions reported in Table 2-2.

*Less than 50.

TABLE 3-3. PROJECTED GROWTH IN OFF-SITE EMPLOYMENT

Occupation	Employment	Predicted Employment		Growth (1981-1991)	
	1981	1986	1991	Number	Percent
Managers	1,600	1,800	1,900	300	18.8
Engineers	6,800	7,200	7,500	700	10.3
Health physicists	100	300	300	200	200.0
Other scientists	600	800	800	200	33.3
Other professional workers	1,500	1,900	2,000	500	33.3
Technicians	3,200	3,200	3,400	200	6.3
Skilled craft workers	1,400	2,300	2,400	1,000	71.4
Clerical workers	2,100	2,500	2,600	500	23.8
All other workers	1,200	1,400	1,500	300	25.0
Total	18,500[a]	21,400	22,400	3,900	21.1
Distribution of total off-site employment to:					
Operation and maintenance	10,500	13,500	14,700	4,200	40.0
Design and engineering	8,000	7,900	7,700	-300	-3.8

[a]It is assumed that employment for 1981 reaches the level for total positions reported in Table 2-3.

largest percentage increase (171 percent) is senior licensed operator. The growth in skilled craft occupations totals 4,400. The increases in technician, operator, and skilled craft occupations are noteworthy because of the extensive periods of job-specific training which are usually provided by the industry.

Off-site employment is projected to increase by 3,900 (21 percent) by 1991 (Table 3-3). Approximately 74 percent of this growth is predicted by 1986. The distribution of employment to functional areas is expected to change as more utilities move from stages of construction into operations. An increase of 40 percent in operation and maintenance and a decrease of approximately 4 percent in design and engineering by 1991 is predicted.[4]

The off-site occupation group with the largest predicted growth in number (1,000) is that of skilled craft workers. Employment of health physicists is predicted to increase by 200 percent (from 100 to 300). The lowest percentage growth is for technicians and engineers. Within these occupations, however, it is expected that there will be shifts as to type of engineer and technician with the predicted increase in operation and maintenance and decrease in design and engineering.

Figure 3-3 shows the predicted percentage composition of 1991 employment by professional, technical, skilled craft, and other. Of the 51,200 predicted to be employed on-site in 1991, the distribution is 18 percent professional, 37 percent technical, 20 percent skilled craft, and 25 percent other. Of the

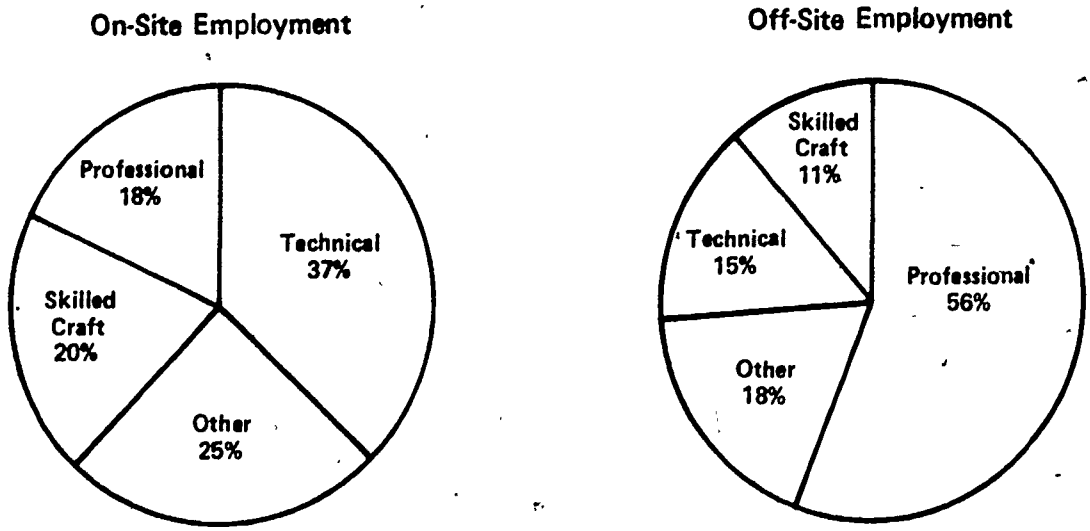

Figure 3-3. Predicted Composition of 1991 Employment in the Nuclear Power Industry

22,400 predicted to be employed off-site in 1991, the distribution is 56 percent professional, 15 percent technical, 11 percent skilled craft, and 18 percent in other occupations.

Sensitivity Analysis

The foregoing predictions of employment are directly affected by the assumptions stated in Chapter 1. For this analysis, a growth pattern of nuclear generating capacity based on the midline forecast of the Energy Information Administration was assumed. The sensitivity of employment projections to differing scenarios concerning delays of reactors under construction is shown in Table 3-4. The lowest predicted numbers occur under the assumption that delays from recent experience (1978-1981) will double in the future. The effect of assumptions as to uniform delays of 2, 4, and 6 years added to the utility's estimated completion date for each reactor under construction is shown.[6]

TABLE 3-4. SENSITIVITY ANALYSIS OF 1991 EMPLOYMENT PROJECTIONS BY VARYING ASSUMPTIONS CONCERNING DATES FOR BEGINNING OPERATION OF REACTORS UNDER CONSTRUCTION

Assumption	Projected Generating Capacity (gigawatts)	Employment Projections	
		On-Site	Off-Site
Utilities' completion schedules as of March 1981	139	54,500	23,100
EIA forecast - midline growth of generating capacity	124	51,200	22,400
Delays doubled (1978-1981 historical pattern)	99	45,800	21,300
2-year delays of completion schedules	131	52,700	22,700
4-year delays of completion schedules	127	51,200	22,300
6-year delays of completion schedules	106	48,000	21,700

Predicted generating capacity ranges from 99 to 139 gigawatts (a difference of approximately 40 percent). Predicted on-site employment ranges from 45,800 to 54,500 (a difference of approximately 19 percent) whereas predicted off-site employment ranges from 21,300 to 23,100 (a difference of approximately 8 percent).

REPLACEMENT NEEDS FROM EMPLOYEE TURNOVER

Replacement needs by occupation were calculated from predicted growth in employment and estimates of annual turnover of employees (Table 2-8). Employment levels for 1986 and 1991 were predicted from the model with growth in employment for intervening years assumed to be linear.

ESTIMATES OF ADDITIONAL MANPOWER REQUIREMENTS

Together, predicted growth and estimated replacement needs from employee turnover make up the employment needs of the nuclear power industry during the next ten years. The total number of additional employees required (both on-site and off-site) will be approximately 55,500 (see Table 3-5). Employee turnover rates do not take into account the movement of employees from nuclear-related and other industries into the nuclear power industry. Therefore, the 55,500 figure should be interpreted as new employees the nuclear power industry needs to recruit and not as the number of jobs for new entrants to the labor market.

TABLE 3-5. ESTIMATES OF ADDITIONAL MANPOWER REQUIREMENTS FOR THE NUCLEAR POWER INDUSTRY, 1982-1991

	1982-1986		1987-1991		
Occupation	Growth	Replacement	Growth	Replacement	Total
Managers	700	600	400	700	2,400
Engineers	700	2,200	800	2,300	6,000
Health physicists	400	100	*	100	600
Other scientists	300	200	*	200	700
Other professional workers	600	900	200	1,000	2,700
Technicians	2,000	3,200	1,300	3,700	10,200
Operators	2,000	3,100	1,000	3,500	9,600
Skilled craft workers	4,300	2,800	1,100	3,500	11,700
Clerical workers	1,400	1,500	600	1,700	5,200
All other workers	400	2,400	1,000	2,600	6,400
Total	12,800	17,000	6,400	19,300	55,500

*Less than 50.

Approximately 65 percent of the total needs for additional employees in the next ten years will be created by replacement needs. Replacement needs exceed growth needs in each five-year interval. Furthermore, replacement needs increase over time as total employment increases.

The greatest needs in total number of employees will be in the skilled craft, technician, and operator occupations. Of the professional occupations, the greatest need will be for engineers, with 75 percent of the need created by the estimated turnover.

Approximately 74 percent of the additional employees needed will be in occupations requiring specialized skills and training. Total needs for employees with specialized training and skills, with breakdowns for professionals, technicians, operators, and skilled craft workers, are shown in Figure 3-4. In 11 of the 14 occupational groupings, replacement needs exceed growth needs. Among technicians, the greatest total need will be for electrical-electronic technicians. Among operators, the greatest need will be for non-licensed operators, because of the high turnover rate in this group. In the skilled craft occupations, the greatest need will be for those in the "other" category, which includes those in trainee or apprenticeship positions.

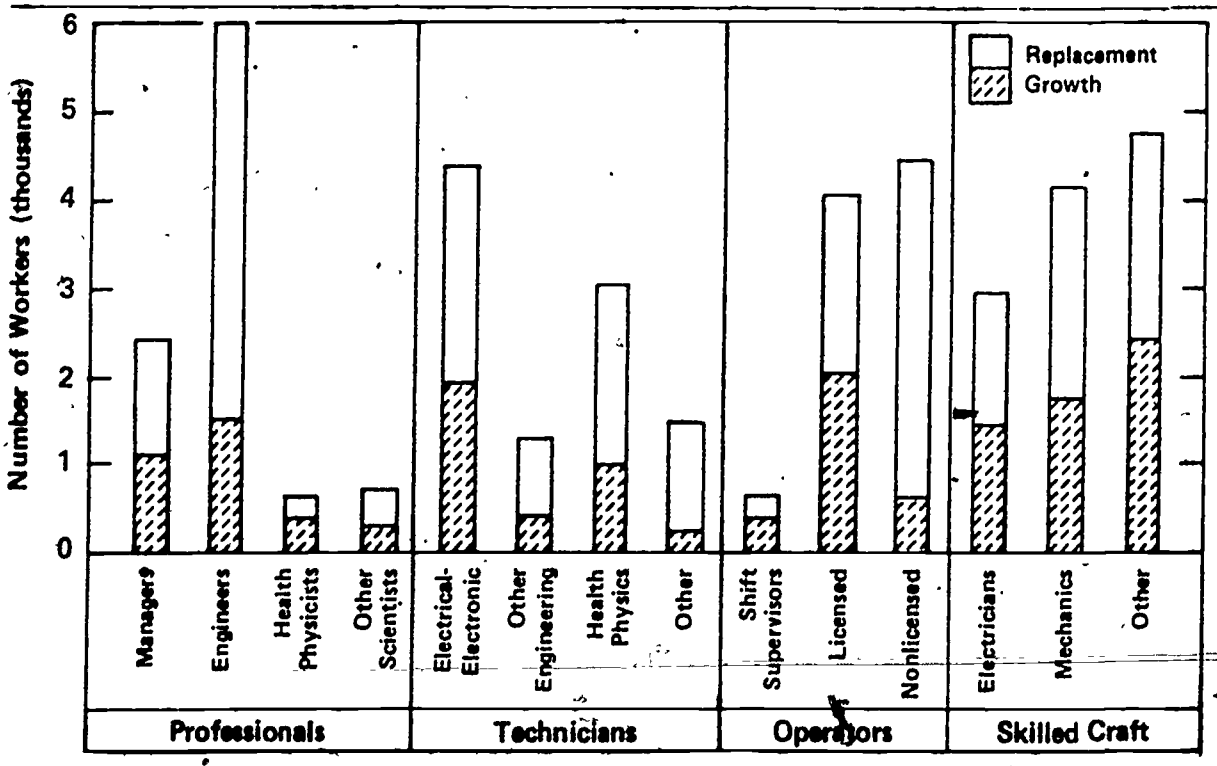

Figure 3-4. Estimates of Additional Manpower Requirements for the Nuclear Power Industry, 1982-1991

NOTES

[1]R.K. Lester, "Nuclear Power Plant Lead-Times," The Rockefeller Foundation, New York, 1978.

[2]Update, Nuclear Power Program Information and Data, Office of Coordination and Special Projects, Office of Nuclear Reactor Programs, U.S. Department of Energy, October-December 1981 and January-March 1982.

[3]The predicted employment was distributed to occupations using the percentage distributions for on-site and off-site reported by the utilities in their employment projections for 1991.

[4]Off-site projections for design and engineering assume that employees accounted for by the AE (architect-engineering) variable in equation (9) of Appendix B remain in employment by the utilities.

[5]Note that an assumption of 4-year delays gives a larger generating capacity but lower total employment than that obtained using the Energy Information Administration's forecast. This is explained by the random pattern of delays using EIA's forecast. Hence, the individual power plants and utilities are affected differently, and industry totals *a priori* could be either higher or lower than under the assumption of uniform delays.

CHAPTER 4
SUMMARY AND CONCLUSIONS

EMPLOYMENT NEEDS OF THE NUCLEAR POWER INDUSTRY

The reported analysis projects total employment of 73,600 in 1991. An additional 55,600 employees will be needed in the ten-year period to meet estimated growth and replacement needs. Approximately three-fourths of this number will be in occupations that require specialized training and skills. Approximately 17 percent of the additional employees needed will be in professions requiring management, engineering, and scientific training.

Concern regarding possible manpower shortages for nuclear power work in the utility industry have been expressed by the industry, those involved with education and training, and government agencies.[1] The projected need for 6,000 additional engineers is notable because of present concerns about shortages and competition for engineering graduates.[2]

Since more than half the additional employees needed are in operator, technician, and skilled craft occupations, there are implications for training institutions and utility-provided training. Recent studies document the enrollments and capacities of training institutions in the nuclear field.[3]

COMPARISON OF PROJECTIONS WITH UTILITIES' PROJECTIONS

A portion of the March 1981 survey of the 60 INPO-member utilities requested projections of employment in 1991. The industry-wide results of this survey are contained in Appendix C.[4] These projections show 1991 employment of 49,400 on-site and 21,400 off-site. These projections are somewhat lower than the projections from the model reported in Chapter 3, although the utilities predicted a generating capacity of 139 gigawatts compared to 124 gigawatts in the model. In Table 3-4, using the construction completion schedule reported by the utilities, estimates from the model are 54,500 on-site and 23,100 off-site. These estimates are higher than the utilities' projections by approximately 10 percent for on-site and 8 percent for off-site.

In a separate analysis, using the average power plant staffing levels developed from the survey data and the construction schedule reported by the utilities, Cook estimates on-site employment at 52,600 in 1991.[5] Thus, it is reasonable to conclude that the model, the utilities' projections, and Cook's analysis are mutually reinforcing; but the possible margin of error may be as high as 10 percent.

HISTORICAL TRENDS IN EMPLOYMENT

Differences in methods of data collection and reporting procedures present problems in direct comparison of historical data with current employment figures and projections. A general trend in relation to increases in generating capacity can be illustrated, however. Past surveys have separated employment in the nuclear power industry into segments within the total nuclear industry, with the two principal segments of nuclear power being operation and maintenance and design and engineering.[6] By subtracting design and engineering from current and projected employment, a trend line for operation and maintenance employment to 1991 is shown in Figure 4-1.

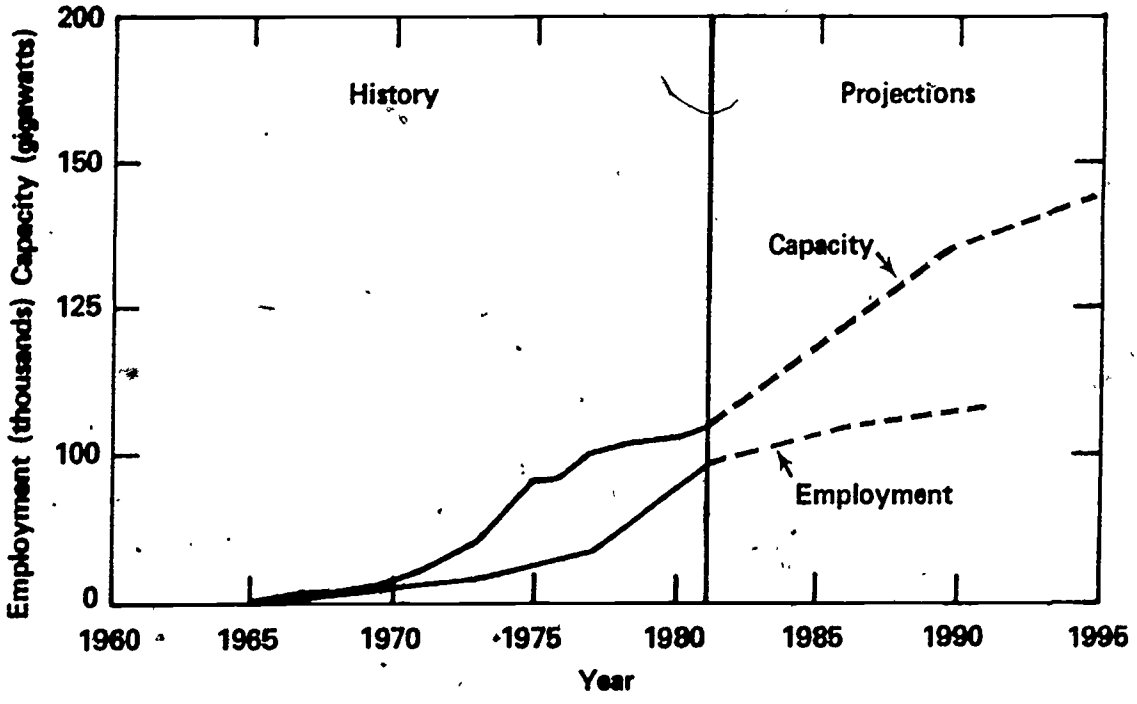

Figure 4-1. Growth in Nuclear Power Generating Capacity and Employment in Nuclear Reactor Operation and Maintenance

Historical trends show that the employment line closely follows the capacity line. In the projections, however, the gap between the two lines widens. This phenomenon can be attributed to several possible factors. First, statistical analysis of current employment [equation (8)] shows that utilities have already expanded employment to cover a portion of future operating needs. A second factor is the marginal impact on employment by utilities adding reactor units to existing generating capacity at the same plant site (Table 3-1). Also, the average capacity of new units (1100 megawatts) will be larger than that of currently operating units (630 megawatts), thereby promoting further economies of scale. In this study the effect of changes in regulation or possible changes in the productivity of labor have not been considered.

UNCERTAINTIES AND NEEDS FOR FURTHER RESEARCH

Uncertainties in the present and future environment for the nuclear power industry create obvious uncertainties in any projections of employment. The projections must be interpreted in view of current conditions and the stated assumptions.

Although the estimated prediction models in most cases explained more than half the variation in staffing patterns, the unexplained variation, tests of statistical significance, and margins of error must be utilized in arriving at conclusions concerning future employment needs.

The purpose of this study is to project occupational employment needs of the nuclear power industry. This study does not attempt to devise a "typical" or "model" plan for the staffing of nuclear power plants. Variables other than those included in the model would have to be considered in establishing "typical" staffing patterns. For example, since the data were cross-sectional, the study does not explain the effect that aging of the facility may have on staffing needs. Data from additional years, along with case studies of power plants, are needed in order to determine staffing requirements of an individual facility.

It is expected that data collecting and reporting will be improved in future surveys conducted by INPO. The 1981 survey and study represent an important step for the industry. Improved data and data for additional years will facilitate further insight into employment needs and refinement of projection models.

NOTES

[1]"Nuclear Employment: The Industry's Cry for Help," *Nuclear News*, Vol. 24, No. 14 (November 1981); Personnel Supply and Demand Issues in the Nuclear Power Industry, prepared by Nuclear Manpower Study Committee, Assembly of Engineering, National Research Council, December 1981, DOE/NE-0026, U.S. Department of Energy, Washington, D.C.

[2]"The Engineer Shortage: Is It for Real?" *Industry Week*, April 15, 1982, pp. 47-51; Joanna R. Little and Duveen L. Shirley, *Nuclear Engineering Enrollments and Degrees, 1981*, May 1982, ORAU-199, Oak Ridge Associated Universities, Oak Ridge, Tennessee.

[3]Lee Howard, *Nuclear-Related Training and Education Offered by Academic Institutions (Less-than-Baccalaureate Degree)*, January 1982, ORAU-194, Oak Ridge Associated Universities, Oak Ridge, Tennessee; Lee Howard, *Nuclear-Related Training and Education Offered by Nonacademic Organizations*, February 1982, ORAU-195, Oak Ridge Associated Universities, Oak Ridge, Tennessee.

[4]For the complete report, see: Ruth C. Johnson, "Occupational Employment in the Nuclear Field," working paper, August 1981, Oak Ridge Associated Universities, Oak Ridge, Tennessee.

[5]Earle W. Cook, Culpeper, Virginia, consultant to Oak Ridge Associated Universities, 1981.

[6]Nuclear-Related Occupational Employment Surveys, 1973 and 1977, conducted by BLS/DOL for predecessor agencies of the U.S. Department of Energy.

APPENDIX A

QUESTIONNAIRES USED IN 1981 SURVEY OF THE NUCLEAR POWER INDUSTRY CONDUCTED BY THE INSTITUTE OF NUCLEAR POWER OPERATIONS

INPO Institute of Nuclear Power Operations

A Survey of Occupational Employment in Nuclear Power Activities, 1981

On-Site Personnel Questionnaire for _____

ON-SITE PERSONNEL are those utility, contractor, or holding company employees used in normal operations who report to work at the location of the nuclear power plant. *EXCLUDE* staff who are involved in actual construction work.

If you have any questions concerning this questionnaire, contact John Pacilio at INPO, (404) 953-7553.

1. Person to be contacted at utility if questions arise concerning this report:

Name and Title (please print or type) _____

Telephone (include Area Code) _____

2. Site Identification

PLEASE VERIFY AND CORRECT, if necessary, the information given in items 2.1, 2.2, 2.3, 2.4, and 2.5.

PLEASE COMPLETE ITEMS 2.6, 2.7, and 2.8.

	Unit #	Unit #	Unit #
2.1 Type of reactor (BWR, PWR, HTGR)			
2.2 Capacity (Net MWE)			
2.3 If unit(s) are now operating, commercial operation began in (year)			
2.4 If unit(s) are now under construction, the portion completed is (percent)			
2.5 Estimated date of completion (year)			
2.6 If unit(s) are now under construction, are members of the operating staff(s) presently on-site? (check)	Yes _____ No _____	Yes _____ No _____	Yes _____ No _____
2.7 If the answer in 2.6 is yes, is the staffing partial or complete for beginning operation of these unit(s)? (check)	Yes _____ No _____	Yes _____ No _____	Yes _____ No _____

2.8 Number of control rooms for units now in operation _____

Number of control rooms when all units are in operation _____

Definitions of Occupation Categories

Managers: Persons concerned with policymaking, planning, organizing, staffing, directing, and/or controlling the activities of an organization, usually through subordinate supervisors.

Engineers: All persons actually engaged in engineering work at a level which requires knowledge of a field of engineering equivalent at least to that acquired through completion of a 4-year college course, regardless of whether they hold a college degree. Typical job titles are electrical engineer, nuclear engineer, and mechanical engineer.

Scientists: All persons actually engaged in scientific work at a level which requires a knowledge of the mathematical, physical, or life sciences equivalent at least to that acquired through completion of a 4-year college course, regardless of whether they hold a college degree. Typical job titles are mathematician, computer scientist, chemist, physicist, biologist, and health physicist.

All Other Professional Workers: All persons (other than managers, engineers, and scientists) engaged in work such as accounting, purchasing, personnel, and finance which requires knowledge at least equivalent to that acquired through completion of a 4-year college course. Typical job titles are accountant, purchasing agent, labor relations representative, and finance officer.

Technicians: All persons actually engaged in technical work at a level which requires knowledge of engineering, mathematical, physical, or life sciences, comparable to two years of college study at technical institutes, junior colleges, or other formal post-high school training or through equivalent on-the-job training or experience. Typical job titles are health physics/radiation protection technician, instrumentation and control technician, chemical technician, and electronic technician.

Non-Licensed Reactor Operators: Persons who spend the greatest proportion of their time in the actual manipulation of the controls of a nuclear reactor who are not NRC licensed operators but work under the supervision of either nuclear or senior operators.

Licensed Reactor Operators: Persons who spend the greatest proportion of their time in the actual manipulation of the controls of a nuclear reactor who have a NRC operator's license.

Senior Licensed Reactor Operators: Persons who spend the greatest proportion of their time in the actual manipulation of the controls of a nuclear reactor or directing others in the manipulation of such controls who have a NRC senior operator's license.

Skilled Craft Workers: All skilled crafts and kindred workers in maintenance, repair, power plant, and material handling occupations that predominantly require a thorough and comprehensive knowledge of processes involved in the work. Workers in these occupations usually become qualified by serving apprenticeships or completing extensive training programs of 2 years or more. Typical job titles are maintenance electrician, maintenance mechanic, and welder.

Clerical Workers: All persons engaged in office clerical, secretarial, and administrative support work. Typical job titles are typist, secretary, accounting clerk, and shipping clerk.

3. **Occupational Employment and Job Vacancies in Nuclear Power Activities (On-Site)** (As of March 1, 1981). *EXCLUDE* staff who are involved in actual construction work.

Please provide data *(see occupation definitions on page 2)* by job position.

Occupation *(see definitions provided on page 2)*	Nuclear Site Positions Status as of March 1, 1981			
	Utility Positions		Contractor Positions Used in Normal Operations (3)	Holding Company Positions Allocated to Utility (4)
	Current Employment (1)	Vacancies (2)		
Managers				
Total Engineers				
Chemical Engineers				
Civil Engineers				
Electrical and Electronics Engineers				
Mechanical Engineers				
Nuclear and Reactor Engineers				
All Other Engineers				
Total Scientists				
Mathematicians				
Chemists				
Physicists				
All Other Physical Scientists				
Biological Scientists				
Health Physicists				
All Other Life Scientists				
All Other Professional Workers				
Total Technicians				
Draftsmen				
Electrical and Electronics Technicians				
All Other Engineering Technicians				
Physical Science Technicians				
Life Science Technicians				
Health Physics Technicians and Radiation Monitors				
All Other Technicians				
Total Operators				
Senior Licensed Reactor Operators				
Licensed Reactor Operators				
Non-Licensed Reactor Operators				
Total Skilled Craft Workers				
Electricians				
Mechanics				
Welders with Nuclear Certification				
All Other Skilled Craft Workers				
Clerical Workers				
All Other Workers (service workers, security staff, laborers, operatives, and all other workers not classified above)				

4. Projected Staffing Plans for This Site

A. Ten-Year Projections (Utility, Contractor, and Holding Company Positions)

Since INPO and the nuclear power industry are interested in future, as well as current, manpower needs, we would appreciate receiving information on your plans for staffing at this site over the next ten years. *We need your projections for 1991.* In addition, we would appreciate receiving the projected on-site staffing levels in any intermediate years (1982-1990) for which you have information available. We suggest that you base these projections on plans for new units to go on line and on current regulations and your organization's standards.

Occupation *(see definitions provided on page 2)*	Nuclear Site Positions									
	please provide 1991	*Please Complete for Intermediate Yeers for which Information is Available*								
		1982	1983	1984	1985	1986	1987	1988	1989	1990
Managers										
Total Engineers										
Health Physics Scientists										
All Other Scientists										
All Other Professional Workers										
Total Technicians										
Electrical and Electronics Technicians										
All Other Engineering Technicians										
Health Physics Technicians and Radiation Monitors										
All Other Technicians										
Total Operators										
Senior Licensed Operators										
Licensed Operators										
Non-Licensed Operators										
Total Skilled Craft Workers										
Electricians										
Mechanics										
Welders with Nuclear Certification										
All Other Skilled Craft Workers										
Clerical Workers										
All Other Workers										

B. Comments Concerning Staffing Needs and Projections (Optional)

1. Preferred Staffing at this Site *(irrespective of regulations)*

Since the industry often finds itself in the position of reacting to regulatory changes, we thought this would be an appropriate opportunity for your organization to state your views concerning various staffing issues. If you wish to comment, please state your organization's preferred staffing pattern *irrespective of regulations* (i.e., the staffing numbers you consider optimum).

Occupation *(see definitions provided on page 2)*	Nuclear-Site Positions	
	1981	1991
Managers		
Total Engineers		
Health Physics Scientists		
All Other Scientists		
All Other Professional Workers		
Total Technicians		
Electrical and Electronics Technicians		
All Other Engineering Technicians		
Health Physics Technicians and Radiation Monitors		
All Other Technicians		
Total Operators		
Senior Licensed Operators		
Licensed Operators		
Non-Licensed Operators		
Total Skilled Craft Workers		
Electricians		
Mechanics		
Welders with Nuclear Certification		
All Other Skilled Craft Workers		
Clerical Workers		
All Other Workers		

2. Other Comments Concerning Nuclear-Related Staffing

INPO Institute of Nuclear Power Operations

A Survey of Occupational Employment In Nuclear Power Activities

Off-Site Personnel Questionnaire

OFF-SITE PERSONNEL are those utility, contractor, or holding company employees used in normal operations who report to work at a location other than a nuclear power plant and who provide supporting and technical assistance in nuclear power-related activities.

Separate questionnaires have been provided for on-site personnel. If you have any questions concerning this questionnaire, contact John Pacillo at INPO, (404) 953-7553.

(This request for information relates to off-site nuclear power-related personnel for:)

Name and Address of Utility

1. Person at utility to be contacted if questions arise concerning this report:

Name and Title (please print or type)

Telephone (Include Area Code)

Definitions of Occupation Categories

Managers: Persons concerned with policymaking,planning, organizing, staffing, directing, and/or controlling the activities of an organization, usually through subordinate supervisors.

Engineers: All persons actually engaged in engineering work at a level which requires knowledge of a field of engineering equivalent at least to that acquired through completion of a 4-year college course, regardless of whether they hold a college degree. Typical job titles are electrical engineer, nuclear engineer, and mechanical engineer.

Scientists: All persons actually engaged in scientific work at a level which requires a knowledge of the mathematical, physical, or life sciences equivalent at least to that acquired through completion of a 4-year college course, regardless of whether they hold a college degree. Typical job titles are mathematician, computer scientist, chemist, physicist, biologist, and health physicist.

All Other Professional Workers: All persons (other than managers, engineers, and scientists) engaged in work such as accounting, purchasing, personnel, and finance which requires knowledge at least equivalent to that acquired through completion of a 4-year college course. Typical job titles are accountant, purchasing agent, labor relations representative, and finance officer.

Technicians: All persons actually engaged in technical work at a level which requires knowledge of engineering, mathematical, physical, or life sciences, comparable to two years of college study at technical institutes, junior colleges, or other formal post-high school training or through equivalent on-the-job training or experience. Typical job titles are health physics/radiation protection technician, instrumentation and control technician, chemical technician, and electronic technician.

Skilled Craft Workers: All skilled crafts and kindred workers in maintenance, repair, power plant, and material handling occupations that predominantly require a thorough and comprehensive knowledge of processes involved in the work. Workers in these occupations usually become qualified by serving apprenticeships or completing extensive training programs of 2 years or more. Typical job titles are maintenance electrician, maintenance mechanic, and welder.

Clerical Workers: All persons engaged in office clerical, secretarial, and administrative support work. Typical job titles are typist, secretary, accounting clerk, and shipping clerk.

2. Occupational Employment And Job Vacancies In Nuclear Power-Related Activities
(As of March 1, 1981)

Please provide the number of nuclear power-related job positions (i.e., jobs which support the design, operation, and maintenance of nuclear facilities) by occupation category. For any positions which involve nuclear-related work only part of the time, include a reasonable estimate for the proportion of these positions necessary to the conduct of nuclear-related activities during the last 12 months.

Example: If there are 10 employees in the Personnal Office who spent 40 percent of their time during the last 12 months in the recruitment and hiring of persons to fill nuclear-related positions, count 4 positions in the appropriate occupation categories (such as All Other Professional Workers and Clerical).
EXCLUDE staff who are involved in actual construction work.

See Occupation Definitions Provided on Page 2.

Occupation *(see definitions provided on Page 2)*	OFF-SITE Nuclear-Related Positions Statue as of March 1, 1981			
	Utility Positions		Contractor Positions Used in Normal Operations (3)	Holding Company Positions Allocated to Utility (4)
	Current Employment (1)	Vacancies (2)		
Managers				
Total Engineers				
Chemical Engineers				
Civil Engineers				
Electrical and Electronics Engineers				
Mechanical Engineers				
Nuclear and Reactor Engineers				
All Other Engineers				
Total Scientists				
Mathematicians				
Chemists				
Physicists				
All Other Physical Scientists				
Biological Scientists				
Health Physicists				
All Other Life Scientists				
All Other Professional Workers				
Total Technicians				
Draftsmen				
Electrical and Electronics Technicians				
All Other Engineering Technicians				
Physical Science Technicians				
Life Science Technicians				
Health Physics Technicians and Radiation Monitors				
All Other Technicians				
Total Skilled Craft Workers				
Electricians				
Mechanics				
Welders with Nuclear Certification				
All Other Skilled Craft Workers				
Clerical Workers				
All Other Workers (service workers, security staff, laborers, operatives, and all other workers not classified above)				

3. Distribution Of Off-Site Occupational Employment To Nuclear Power-Related Activity Segments

Please distribute the current positions (including utility, contractor, and holding company) by percent to the appropriate nuclear-related activity segments. *See definitions of activity segments listed below.*

Occupations *(see definitions provided on page 2)*	Activity Segments (see definitions below)				
	Percent of All Current Off-Site Nuclear-Related Positions (Utility, Contractor, and Holding Company Positions)				
	Design and Engineering of Nuclear Facilities (1)	Nuclear Reactor Operation & Maintenance (2)	Environmental & Ecological Research & Evaluation (3)	Health Physics & Industrial Safety (4)	Miscellaneous (5)
Managers					
Total Engineers					
Total Scientists					
All Other Professional Workers					
Total Technicians					
Total Skilled Craft Workers					

Column — **Definitions of Activity Segments**

(1) **Design and Engineering of Nuclear Facilities:** Design and engineering of all nuclear facilities with the exception of persons working in facility construction.

(2) **Nuclear Reactor Operation and Maintenance:** Operation and maintenance of nuclear power production, test, and research reactors. Includes operation and maintenance of auxillary systems for supply and treatment of power, air, water, etc.

(3) **Environmental and Ecological Research and Evaluation:** Activities to preserve, improve, or restore natural environmental and ecological balance. Types of activities covered are thermal effects and effects of irradiation on plant, animals, and marine life.

(4) **Health Physics and Industrial Safety:** Establishes, evaluates, and monitors working conditions for compliance with industrial safety and radiation exposure standards.

(5) **Miscellaneous:** Activities not classified in any of the above segments.

4. Projected Staffing Plans For Off-Site Nuclear Power-Related Supporting Personnel

A. Ten-Year Projections (Utility, Contractor, and Holding Company Positions)

Since INPO and the nuclear power industry are interested in future, as well as current manpower needs, we would appreciate receiving information on your plans for providing off-site supporting and technical personnel in nuclear power-related activities. *We need your projections for 1991.* In addition, we would appreciate any projections for off-site staffing levels in intermediate years (1982-1990) for which information is available. We suggest you base these projections on planned expansions of nuclear plants, current regulations, and your organization's standards.

Occupation *(see definitions provided on page 2)*	Off-Site Nuclear-Related Positions									
	Please Provide	*Please Complete for Intermediate Years for Which Information is Available*								
	1991	1982	1983	1984	1985	1986	1987	1988	1989	1990
Managers										
Total Engineers										
Health Physics Scientists										
All Other Scientists										
All Other Professional Workers										
Total Technicians										
Total Skilled Craft Workers										

(over)

4. **Projected Staffing Plans For Off-Site Nuclear Power-Related Supporting Personnel (continued)**

B. Comments Concerning Staffing Needs And Projections *(Optional)*

1. Preferred Staffing for Off-Site Nuclear Power-Related Supporting Personnel *(irrespective of regulations).*

Since the industry often finds itself in the position of reacting to regulatory changes, we thought this would be an appropriate opportunity for your organization to state your views concerning various staffing issues. If you wish to comment, please, state your organization's preferred staffing pattern *irrespective of regulations* (i.e., the staffing numbers you consider optimum).

Occupation *(see definitions provided on page 2)*	Off-Site Nuclear-Related Positions	
	1981	1991
Managers		
Total Engineers		
Health Physics Scientists		
All Other Scientists		
All Other Professional Workers		
Total Technicians		
Total Skilled Craft Workers		

2. Other Comments Concerning Off-Site Nuclear-Related Staffing

INPO Institute of Nuclear Power Operations

Survey of Nuclear Power-Related Staff Turnover

(Combined On and Off Site)

INSTRUCTIONS: Please provide estimates, where possible, pertaining to nuclear power related employee turnover (combined on and off site) for the occupations listed below. See the reverse side for definitions of occupations. If you have questions concerning this questionnaire, contact John Pacillo at INPO, (404) 953-7553.

Occupations	Estimated Average Employment for 1980	Number of Positions Filled During 1980		Positions (Columns 1 & 2) Filled by			Replacement Positions (column 2) Created by				
		(1) New Positions	(2) Replacements	(3) New Hires	(4) Promotions	(5) Transfers	(6) Employee Changed to Another Nuclear-Related Position Within Utility	(7) Employee Accepted Nuclear-Related Employment at Another Utility	(8) Employee Took a Non-Nuclear-Related Job in Utility Industry or Left Utility Industry	(9) Retirements/ Deaths	(10) All Other Reasons or Unknown
Managers											
Engineers											
Health physicists											
Other scientists											
Health physics technicians											
Electrical and electronics technicians											
Other engineering technicians											
Other technicians											
Senior licensed reactor operators											
Licensed reactor operators											
Non-licensed reactor operators											
Maintenance electricians											
Maintenance mechanics											
Other skilled craft workers											

Definitions of Occupation Categories

Managers: Persons concerned with policymaking, planning, organizing, staffing, directing, and/or controlling the activities of an organization, usually through subordinate supervisors.

Engineers: All persons actually engaged in engineering work at a level which requires knowledge of a field of engineering equivalent at least to that acquired through completion of a 4-year college course, regardless of whether they hold a college degree. Typical job titles are electrical engineer, nuclear engineer, and mechanical engineer.

Scientists: All persons actually engaged in scientific work at a level which requires a knowledge of the mathematical, physical, or life sciences equivalent at least to that acquired through completion of a 4-year college course, regardless of whether they hold a college degree. Typical job titles are mathematician, computer scientist, chemist, physicist, biologist, and health physicist.

Technicians: All persons actually engaged in technical work at a level which requires knowledge of engineering, mathematical, physical, or life sciences, comparable to two years of college study at technical institutes, junior colleges, or other formal post-high school training or through equivalent on-the-job training or experience. Typical job titles are health physics/radiation protection technician, instrumentation and control technician, chemical technician, and electronic technician.

Senior Licensed Reactor Operators: Persons who spend the greatest proportion of their time in the actual manipulation of the controls of a nuclear reactor or directing others in the manipulation of such controls who have a NRC senior operator's license.

Licensed Reactor Operators: Persons who spend the greatest proportion of their time in the actual manipulation of the controls of a nuclear reactor who have a NRC operator's license.

Non-Licensed Reactor Operators: Persons who spend the greatest proportion of their time in the actual manipulation of the controls of a nuclear reactor who are not NRC licensed operators but work under the supervision of either nuclear or senior operators.

Skilled Craft Workers: All skilled crafts and kindred workers in maintenance, repair, power plant, and material handling occupations that predominantly require a thorough and comprehensive knowledge of processes involved in the work. Workers in these occupations usually become qualified by serving apprenticeships or completing extensive training programs of 2 years or more. Typical job titles are maintenance electrician, maintenance mechanic, and welder.

APPENDIX B
TECHNICAL NOTES

MODEL SPECIFICATION

The reported models analyze on-site employment for a power plant and off-site employment specific to a utility.

On-Site

When a power plant is fully operational the number of employees is expected to be directly influenced by megawatt capacity and the number of reactor units at the site. During stages of construction and partial operation, employment will progress from zero toward the level required for full operation. The expected relationship of operation and construction status to employment in a particular year is

$$Y_t = OY_t + [(TY - OY_t) \times (CY_t/100)] \quad (1)$$

where the unit of observation is the power plant and t = years

Y_t = employment in year t
OY_t = employment in year t for current operations
TY = total employment when plant is fully operational
CY_t = percent of TY employed in year t for portion of plant under construction

and OY_t = TY when CY_t = 0.

OY_t, TY, and CY_t are determined by

$$OY_t = e^{\alpha 0}\, OMW_t^{\alpha 1}\, OU^{\alpha 2} \quad (2)$$

$$OY = e^{\beta 0}\, TMW^{\beta 1}\, TU^{\beta 2} \quad (3)$$

$$CY_t = \lambda_0 + \lambda_1 PCT_1 + \lambda_2 PCT_2 + \lambda_3 PCT_3 - OTHER \quad (4)$$

$$CY_t \geq 0$$

where

e = the base of natural logarithms
OMW_t = megawatt capacity in operation in year t
OU_t = number of reactor units in operation in year t
TMW = total megawatt capacity
TU = total number of reactor units
PCT_1 = percent of megawatt capacity under construction scheduled for completion within one year
PCT_2 = percent of megawatt capacity under construction scheduled for completion within 2-3 years
PCT_3 = percent of megawatt capacity under construction scheduled for completion within 4-6 years
$OTHER$ = dummy variable (0,1) for other operating sites within the same utility.

All variables except OTHER are expected to have a positive effect on employment. The variable OTHER is expected to have a negative effect on employment at a particular power plant during construction because of the possibility for intrautility transfer of employees once the power plant becomes operational. In equations (2) and (3), the effect of the variables is multiplicative, whereas the percentage variables in equation (4) are additive.

Off-Site

Within a utility the number of off-site personnel in nuclear employment is influenced by total megawatt capacity in operation, total megawatt capacity under construction, projected completion dates for units under construction, and whether or not the utility does its own architect-engineering work.[1] The expected relationship of these variables to employment is

$$OFY_t = \rho_0 + \rho_1 OMW_t + \rho_2 MWCON_1 + \rho_3 MWCON_2 + AE \qquad (5)$$

where the unit of observation is the utility and t = years

OFY_t = off-site employment in year t
OMW_t = megawatt capacity in operation in year t
$MWCON_1$ = megawatt capacity scheduled to begin operation within 3 years or earlier
$MWCON_2$ = megawatt capacity scheduled to begin operation in time periods greater than 3 years
AE = dummy variable (0,1) for utility doing its own architect-engineering work.

All variables are expected to have a positive and additive effect upon the number of off-site personnel employed by a utility.

EMPIRICAL RESULTS

The models in the preceding section were estimated using the cross-section data from the 1981 survey of the 60 utilities involved in nuclear power operations and construction.

On-Site

Equation (3) was estimated in a regression analysis of the power plants in full operation. The results (in double logarithmic form) are

$$\ln TY = \underset{(5.85)}{3.0860} + \underset{(5.01)}{0.4176} \ln TMW + \underset{(2.63)}{0.4954} \ln TU - \underset{(-4.90)}{0.8379}\, C1 - \underset{(-1.29)}{0.4491}\, C2 \quad (6)$$

$n = 40$
$R^2 = .77$
$SEE = .32$ (t statistics)

Variables C1 and C2 are control variables for four power plants that exhibit unique patterns of staffing compared to other power plants in the industry.

The R^2 value of .77 indicates that 77 percent of the variation in power plant staffing has been explained by the model. The t statistics indicate that the estimated coefficients for variables TMW, TU, and C1 are significant at the .01 level.

In this functional form, the estimated coefficients for TMW and TU are interpreted as employment elasticities. That is, a 1 percent change in megawatt capacity will increase employment by approximately .42 percent. For example, in Table 3-1, the predicted employment for a 1000-megawatt-capacity plant with one unit is 392. If the megawatt capacity is increased to 1100 (a 10 percent increase), employment will increase to 408 (4.2 percent increase). The elasticity of employment with respect to TU is interpreted in the same manner.

In the predictions, estimated values from equation (6) were also used for predicting OY. Thus,

$$\ln OY_t = 3.0860 + 0.4176 \ln OMW_t + 0.4954 \ln OU_t \quad (7)$$

Equation (4) was estimated in a regression analysis of the power plants in various stages of construction. The results are

$$CY_t = \underset{(0.4)}{3.4213} + \underset{(6.6)}{0.7071}\ PCT_1 + \underset{(3.7)}{0.4446}\ PCT_2 + \underset{(2.2)}{0.2613}\ PCT_3 - \underset{(-0.4)}{3.0925}\ OTHER \quad . \quad (8)$$

$n = 39$
$R^2 = .59$
$SEE = 21$ (t statistics)

The R^2 value indicates that the model explains 59 percent of the variation in percentage of total staffing requirements of power plants under construction. The t statistics for PCT_1 and PCT_2 show that the coefficients are significant at the .01 level. The estimated coefficient for PCT_3 is significant at the .05 level.

The equation shows that the progression in staffing toward full operations is dependent upon the expected completion dates. This relationship is illustrated in Figure 3-2. Thus, a power plant with 100 percent of its megawatt capacity expected to come on line within one year would have employed approximately 74 percent of its full operating staff (3.4213 + 0.7071 x 100). If the utility has other operating sites (OTHER=1), the percentage would be reduced by approximately 3 percent.

In this model specification, the later time period (more than 6 years to beginning operation) is the omitted variable. Therefore, a power plant with megawatt capacity expected to go into operation in the later time period would have employed approximately 3.4 percent (the intercept term) of its predicted operating staff.

Estimated equations (6), (7), and (8) were used to predict values for TY, OY_t, and CY_t, given the operation and construction status anticipated for each power plant in 1986 and 1991. Y_t (employment in each year) was then predicted from equation (1). The sum of predicted employment for the power plants gives predicted on-site employment for the industry.

Off-Site

Regression analysis of the utilities providing usable data on off-site nuclear employment gave the following estimate for equation (5):[2]

$$OFY_t = \underset{(1.0)}{63.99} + \underset{(2.26)}{0.1025}\ OMW_t + \underset{(1.49)}{0.0756}\ MWCON_1 + \underset{(0.4)}{0.0412}\ MWCON_2 + \underset{(4.6)}{878.50}\ AE \quad . \quad (9)$$

$n = 46$
$R^2 = .52$
$SEE = 305$ (t statistics)

The R^2 value indicates that 52 percent of the variation in off-site employment has been explained. The t statistics indicate that the estimated coefficient for the AE variable is significant at the .01 level, and the estimated coefficient for OMW_t is significant at the .05 level. The estimates show that for each 1000 megawatts in operation, approximately 103 persons are employed. For each 1000 megawatts to be completed within 3 years approximately 76 persons are employed, whereas 41 are employed for each 1000 megawatts to be completed in later time periods. If the utility does its own architect-engineering work an additional 879 persons are employed. The intercept term adds 64 persons for each utility.

The activities of off-site personnel can be divided into two broad functional areas: operation and maintenance, and design and engineering.[3] Design and engineering work was found to be an on-going component of off-site employment for utilities in operations, as well as for utilities in construction. The relationship of the two components to total employment was found to differ, however, among utilities in construction only, utilities in operations only, and all utilities as a group. The functional equation (10) was estimated for the three groups of utilities.

$$OM_t = \alpha + \beta OFY_t \qquad (10)$$

where OM_t = operation and maintenance support staff employed in year t
OFY_t = total off-site nuclear employment in year t.

Therefore,

$$DESIGN_t = OFY_t - OM_t$$

where

$DESIGN_t$ = design and engineering staff employed in year t.

Estimated equations for the respective groupings of utilities are

(a) Utilities in construction only

$$OM_t = \underset{(-0.6)}{-10.47} + \underset{(8.3)}{0.5897}\ OFY_t \qquad (11)$$

$n = 15$
$R^2 = .84$
SEE = 46 (t statistics)

(b) Utilities in operations only

$$OM_t = -26.32 + 0.76\ OFY_t \qquad (12)$$
$$\quad (2.7)\ \ (25.9)$$

$n = 17$
$R^2 = .98$
SEE = 33 (t statistics)

(c) All utilities

$$OM_t = -20.42 + 0.6658\ OFY_t \qquad (13)$$
$$\quad (-1.6)\ \ (26.6)$$

$n = 46$
$R^2 = .94$
SEE = 71 (t statistics)

The high R^2 value for each equation indicates that 84 to 98 percent of the variation in operation and maintenance support staff is explained by the variable OFY_t. In each of the three equations the estimated coefficient for OFY_t is significant at the .01 level.

Estimated equation (9) was used to predict off-site nuclear employment for each utility, given the operation and construction status anticipated in 1986 and 1991. Equations (11), (12), and (13) were used to predict the distribution of employment between operation and maintenance and design and engineering. The sum of predicted employment and the distribution of the employment gives predicted off-site employment for the industry.

ALTERNATIVE MODEL SPECIFICATIONS

In this analysis the appropriate level of aggregation of the data, selection of variables, and choice of functional forms were not known *a priori*. The data were, therefore, studied through a series of correlation tests and multiple regression analyses. As frequently happens with a set of data, multicollinearity among the reported variables caused statistical problems of estimation and prevented the inclusion of certain variables that may influence levels of employment.

The results of different model specifications were judged on:

1. goodness of fit,
2. tests of statistical significance of variables, and
3. predictive power of model.

Several of the specified models passed the first two tests but failed the third because the models produced predicted values that were theoretically unsound.

Levels of Aggregation

Multiple regression analysis was used to study the data at levels of aggregation ranging from occupation-specific employment at a plant site to total nuclear employment within a utility. In on-site employment the estimated coefficients of the subsets (plants under construction and those in full operation) differed significantly from those of the regression with the pooled data, indicating that the data set should be partitioned. The small sample size of the data set composed of plants in both operation and construction prohibited estimation for this group.

The regressions for occupation-specific employment at plant sites failed to produce statistically significant results in all cases. The percentage distribution reported by the utilities for 1991 provided an alternative means of distributing predicted employment by occupation.

Separation of off-site data into functional components of design and engineering and operation and maintenance, and further disaggregation by operation and construction status, failed to produce the desired levels of statistical significance and fit of the models to the data. The selected model, therefore, predicted off-site employment which was distributed to the two functional areas by a second set of regressions [equations (11), (12), and (13)].

Other Explanatory Variables

Several alternative explanatory variables, in addition to those in the specified models, were tested in other model specifications. In the on-site employment regressions, the type of reactor, age of plant (specified as average age of units operating and as age of oldest operating unit), and the ratio of off-site nuclear personnel to number of operating units in the utility system were not statistically significant. In the regressions for off-site employment, variables for number of plant sites, number of reactor units, and years in nuclear operations were not statistically significant.

Other Functional Forms

The various specified models were tested to find the best fit to the data, using linear, quadratic, semilogarithmic, and double logarithmic forms. The quadratic form, although it provided good statistical properties for both on-site and off-site data, was rejected for use in prediction because of the point at which the function reaches a maximum. That is, in predictions, the power plants and utilities in the upper range of megawatt capacity showed the anomaly of having lower levels of employment than those of somewhat smaller size.

NOTES

[1]Information on architect-engineering work by utilities was taken from "World List of Power Plants," *Nuclear News* (February 1981).

[2]Of the 60 utilities, two did not provide off-site employment data and 11 provided insufficient data for the regression analysis.

[3]See definitions of functional areas (operation and maintenance, design and engineering) in the off-site questionnaire (Appendix A). Three additional functional areas are specified in the questionnaire. Respondents reported minor activity in these areas and, therefore, they are not included in this analysis.

APPENDIX C

1991 EMPLOYMENT IN THE NUCLEAR POWER INDUSTRY
AS PROJECTED BY THE UTILITIES

TABLE C-1. GROWTH IN ON-SITE STAFFING REQUIREMENTS
(As Projected by the Utilities)

Occupation	Employment 1981	Predicted Employment 1991	Growth (1981-1991) Number	Percent
Managers	2,100	2,700	600	28.6
Engineers	3,300	3,900	600	18.2
Health physicists	200	400	200	100.0
Other scientists	400	500	100	25.0
Other professional workers	1,300	1,600	300	23.0
Technicians				
Engineering	3,100	4,800	1,700	54.8
Health physics	2,100	3,000	900	42.9
Other technicians'	1,700	1,800	100	5.9
Operators				
Shift supervisors	800	1,200	400	50.0
Senior licensed operators	700	1,800	1,100	157.0
Licensed operators	1,500	2,200	700	46.7
Non-licensed operators	3,100	3,600	500	16.1
Skilled craft workers				
Electricians	1,400	2,500	1,100	78.6
Mechanics	2,500	3,500	1,000	40.0
Welders with nuclear certification	500	800	300	60.0
Other skilled craft workers	1,300	3,000	1,700	130.8
Clerical workers	2,500	3,800	1,300	52.0
All other workers	7,500	8,300	800	10.7
Total	35,900	49,400	13,400	37.3

NOTE: The utilities provided 1991 staffing projections for 74 sites (81 percent) which are now in operation, under construction, or in the planning stage. Estimates of 1991 requirements for the remaining sites were projected from current employment and mean values (1991) for plants of the respective type, size, and number of units. *These projections assume current regulations.*

Source: Survey conducted by Institute of Nuclear Power Operations, March 1981.

TABLE C-2. GROWTH IN OFF-SITE STAFFING REQUIREMENTS
(As Projected by the Utilities)

Occupation	Employment 1981	Predicted Employment 1991	Growth (1981-1991) Number	Percent
Managers	1,600	1,800	200	12.5
Engineers	6,800	7,200	400	5.9
Health physicists	100	300	200	200.0
Other scientists	600	800	200	33.3
Other professional workers	1,500	1,900	400	26.7
Technicians	3,200	3,200	0	0
Skilled craft workers	1,400	2,300	900	64.3
Clerical workers	2,100	2,500	400	19.0
All other workers	1,200	1,400	200	16.7
Total	18,500	21,400	2,900	15.7

NOTE: Projections for 1991 off-site staffing requirements were provided by 44 utilities (72 percent). Estimates of projections for the industry were derived by inflating the reported figures. *These projections assume current regulations.*

Source: Survey conducted by Institute of Nuclear Power Operations, March 1981.

TABLE C-3. ESTIMATES OF ADDITIONAL MANPOWER REQUIREMENTS FOR THE NUCLEAR POWER INDUSTRY, 1982-1991

Occupation	Number of Employees		
	Growth	Replacement	Total
Managers	800	1,300	2,100
Engineers	1,000	4,400	5,400
Scientists	700	600	1,300
Other professional workers	700	1,800	2,500
Technicians	2,700	6,400	9,100
Operators	2,700	7,000	9,700
Skilled craft workers	5,000	6,100	11,100
Clerical workers	1,700	3,200	4,900
All other workers	1,000	5,100	6,100
Total	16,300	35,900	52,200

Source: Survey conducted by Institute of Nuclear Power Operations, March 1981.