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An International Comparison of Commercial Nuclear Power Plant Staffing Regulations and Practice

1980 – 1990

Prepared by
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Prepared for
U.S. Nuclear Regulatory Commission

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Abstract

In this report an international review of regulatory and industry practices is provided in the area of nuclear power plant staffing during the 1980s in Canada, France, Germany, Japan, Sweden, and the United Kingdom. The objective of this review is to highlight trends in staffing regulatory approaches, industry practices, and issues of concern in other countries that have potential relevance to nuclear power plant staffing issues in the United States.

The decade of the 1980s was marked by a great deal of growth in nuclear power operations internationally; however, growth of nuclear power is not expected to continue in the 1990s except in France and Japan. A continuum of regulatory approaches to staffing was identified, ranging from prescribed regulations that are applied to all licensees (Germany is most similar to the United States in this regard), to indirect staffing regulations where the regulatory authority oversees plant operating practices that are agreed to in the plant operating license (most notably, France and the United Kingdom). Most of the changes observed in staffing regulations and practices in the early 1980s were made in response to the accident at the Three Mile Island Unit 2 nuclear power plant (TMI) in 1979. These changes included the widespread issuance of new operator and licensing requirements and the establishment of national training centers. After the post-TMI changes were implemented, a period of relative stability followed. Changes in the latter half of the 1980s have focused on continuing improvements and additions to training curricula and methods, most notably increased reliance on simulator training.

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Executive Summary

In this report an international review of regulatory and industry practices is provided in the area of nuclear power plant staffing in Canada, France, Germany, Japan, Sweden, and the United Kingdom. The objective of this review is to highlight staffing regulatory approaches, industry practices, and issues of concern in other countries that have potential relevance for the continued development of nuclear power plant staffing policy in the United States. A review was conducted of the published literature and of available government and industry documents. Subject matter experts in the countries of interest were contacted whenever possible to supplement the written information.

First, a brief description of the role of nuclear power in each country is presented, followed by a discussion of the industry and regulatory bodies and functions. Then, following a discussion of regulatory approaches to personnel and staffing, a description of regulations and practices in the areas of operator qualifications (including licensing, education, and training), selection and career progression, and shift composition is presented. The implications of these findings for the United States are discussed in terms of specific approaches, practices, and experiences that are relevant to staffing policy in the United States.

International Trends in Nuclear Power Development

The decade of the 1980s was marked by a great deal of growth in nuclear operations internationally. The following trends were seen in every country's nuclear power industry:

- the number of operating nuclear power plants increased;
- the use of nuclear energy in comparison with other energy sources increased; and
- the total amount of electrical capacity in operation from nuclear power increased.

As of 1990, the percent of electricity derived from nuclear energy ranged from 13% in the United Kingdom to 75% in France; by way of contrast, the United States obtains approximately 19% of its electricity from nuclear sources. Overall, the rapid international growth of nuclear power in the 1980s is expected to level off in the 1990s, except in France and Japan, where nuclear power plant construction continues.

International Comparison of Industry Organization and Regulatory Framework

Reviews were conducted of the nuclear industry organization and the regulatory approach in the six countries in the study. Three types of nuclear industry structure were identified in this report: (1) countries in which electrical production is government owned and operated (France, Canada, and the United Kingdom); (2) countries in which private and public entities are involved, even though the government provides significant investment and support (Japan); and (3) countries that are similar to the United States, where utility ownership and operation is highly diverse in terms of public and private ownership and operation (Germany and Sweden). There have been no major changes during the 1980s in terms of industry organization, with the exception of the United Kingdom. In the United Kingdom, state-run utilities were privatized, even though the government remains the largest shareholder.

A continuum of regulatory approaches to staffing was identified by a regulatory review of the countries in the study. This continuum ranges from prescribed regulations that are applied to all licensees, to indirect regulation where the regulatory authority oversees plant operating practices that are agreed to in the plant license. Germany is most similar to the United States in that there is a greater emphasis on generic or industry-wide prescriptive staffing requirements that apply to all licensees and relatively less emphasis on plant-specific requirements contained in the plant license. Canada, Japan, and Sweden lie to varying degrees in the middle of the continuum because they rely more on plant-specific staffing requirements contained in the plant license and less on generic prescriptive requirements than the United States or Germany. France and the United Kingdom are least similar to the United States because their staffing requirements are contained exclusively in the plant license. There have been no significant changes to these regulatory approaches over the past decade.

International Trends in Staffing Regulation and Practice

Several changes in staffing regulation and industry practices were implemented in response to the accident at the Three Mile Island Unit 2 nuclear power plant (TMI) in 1979. These changes ranged from the issuance of specific regulatory requirements (for instance, new requirements in operator licensing and training) to the establishment of new international standards in utility practice (for instance, the widespread the use of national training centers and simulators for accident scenarios).

In the first half of the 1980s a number of new requirements and practices in nuclear power operator licensing, education, training, and shift composition were implemented in the countries reviewed. Some of the changes in staffing requirements were:

- new licensing requirements for shift supervisors;
- new operator educational requirements;
- the establishment of simulator training and retraining requirements for operators;
- the formation of national training centers; and
- the addition of engineering expertise on shift.

The former Federal Republic of Germany made the most extensive changes in regulatory requirements, motivated partly in response to an accident at a nuclear power plant in Germany as well as in response to TMI.

In the latter half of the 1980s, there has been no deregulation or decrease in staffing standards. Some additional changes have been made in regulatory requirements. A number of new staffing practices were also identified. The most significant changes to staffing regulations and practices in the latter half of the decade have been:

- educational levels for operators have risen;
- utility training programs and their effectiveness are receiving increasing regulatory oversight; and
- the average number of operating shifts on rotation has risen from four to five, and at some sites may go as high as seven shifts.

Although significant staffing changes were made in the earlier part of the 1980s, some areas of nuclear power operator staffing have remained essentially unchanged in the latter half of the 1980s:

- there has been little activity in operator licensing requirements;
- new operators are hired primarily into entry level positions and provided with extensive in-house training to prepare them for operations;
- operator career progression involves entering at the auxiliary operator level, progressing to reactor operator, and then working up to the position of senior reactor operator or shift supervisor;
- the average number of operators on shift has remained stable, with most single-unit sites employing seven to ten operations personnel on shift.

Conclusion

After TMI a great deal of attention was given to nuclear power plant operator staffing in the areas of operator qualifications, licensing, training, and shift composition. After a number of changes were implemented, a period of relative stability has followed. However, one staffing area that continues to receive international attention is operator training. This attention parallels the situation in the United States nuclear industry. Unlike other countries, however, the United States has no national training center.

While many countries, including the United States, were prompted to consider instituting new educational requirements for operators after TMI, Germany was the only country to adopt such regulations. Other countries' responses to the post-TMI concerns about operator qualifications have focused on recruiting new operations staff with some post-secondary education and upgrading training programs.

Another issue of relevance to current United States nuclear power staffing policy is the provision of engineering expertise on shift. In France, the safety engineer has been introduced on shift, similar to the shift technical advisor in the United States. Engineering expertise on shift has been addressed in other countries by increasing training and education requirements for shift supervisors.

The conclusion drawn from this analysis is that the same key staffing issues are experienced in all countries studied; individual countries vary in their responses to these issues.

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Many individuals provided valuable assistance and insights which contributed to the preparation of this report. We would like to thank the following people for their assistance in providing information used in this study: Iréne Blom, Kerstin Dahlgren, Erik Jende, and Per-Olof Sandén, Swedish Nuclear Power Inspectorate (SKI), Bengt-Goran Olofsson, Nuclear Training Safety Center (KSU) (Sweden), Yves Dien, Electricité de France (EDF), Gerhard Becker, Technical Supervisory Inspectorates (TÜV) Rheinland (Germany), Elizabeth Swaton, International Atomic Energy Agency (IAEA), Vince Madden and Howard Kirby, Nuclear Electric (United Kingdom), H. Nishimura and Yoichi Koga, Ministry of International Trade and Industry (Japan), and Kazuo Shimomura, Science and Technology Agency (STA) (Japan).

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Abbreviations

ACRS: Advisory Committee on Reactor Safety (United States)
AEC: Atomic Energy Commission (Japan)
AECB: Atomic Energy Control Board (Canada)
AECL: Atomic Energy of Canada Limited
AGR: Advanced gas-cooled reactor
AKU: Swedish Nuclear Power Training Center
ASME: American Society for Mechanical Engineers (United States)
BAS: Federal Office of Radiation Protection (Germany)
BMU: Federal Minister for the Environment, Nature Conservation, and Nuclear Safety (Germany)
BWR: Boiling water reactor
CEA: Atomic Energy Commission (Commissariat a l'Energie Atomique) (France)
CEGB: Central Electric Generating Board (United Kingdom)
CISN: Interministry Coordinating Committee (France)
CSA: Canadian Standards Association
CSSN: Supreme Council for Nuclear Safety (France)
DIN: Deutsches Institut for Normung (Germany)
DSIN: Direction de la Sûreté des Installations Nucleaires (France)
EDF: Electricité de France
EPRI: Electric Power Research Institute (United States)
FNM: Materials Testing (Fachnormenausschuss Meterialprufung) (Germany)
GCR: Gas-cooled reactor
GPR: Groupe Permanent Réacteurs (France)
GRS: Reactor Safety Company (Gesellschaft Für Reaktorsicherheit) (Germany)
INPO: Institute of Nuclear Power Operations (United States)
JAERI: Japan Atomic Energy Research Institute
KSU: Nuclear Training and Safety Center (Kärnkraftsäkerhet och Utbildning) (Sweden)
KTA: Safety Standards Commission (Germany)
MITI: Ministry of International Trade and Industry (Japan)
NAK: National Board for Spent Nuclear Fuels (Sweden)
NAR: Technical Committee on Radiology (Normenausschuss Radiologie) (Germany)
NII: Nuclear Installations Inspectorate (United Kingdom)
NKe: Technical Committee on Nuclear Engineering (Germany)
NRC: Nuclear Regulatory Commission (United States)
NSC: Nuclear Safety Commission (Japan)
NSSS: Nuclear Steam Supply Systems
NUMARC: Nuclear Utilities Resources and Management Council (United States)
OPM: Office of the Prime Minister (Japan)
PWR: Pressurized (light-) water reactor
PHWR: Pressurized heavy-water reactor
RKS: Nuclear Safety Board of the Swedish Utilities (Raadet für Karnkraftssakerhet)
RSK: Reactor Safety Commission (Germany)
SA: Swedish Plant Inspectorate
SCSIN: Service Central de Sûreté des Installations Nucleaires (France)
SKI: Swedish Nuclear Power Inspectorate
SSEB: South of Scotland Electric Board
SSI: National Institute of Radiation Protection (Sweden)
SSPB: Swedish State Power Board
SSK: Radiation Protection Commission (Germany)
STA: Science and Technology Agency (Japan)
TÜV: Technical Supervisory Inspectorates (Technische Überwachungsvereine) (Germany)
UKAEA: United Kingdom Atomic Energy Authority

1 Introduction

In this report, an overview of regulatory and industry practices is provided in the area of nuclear power plant staffing in selected foreign countries. The purpose of investigating practices in foreign countries is two-fold: (1) to consider the range of approaches and practices used in the area of nuclear power plant staffing, and (2) to draw from this review common international themes as well as insights that are potentially relevant to the continued development of nuclear power plant staffing policy in the United States. At the same time, care must be taken to understand the situational context of staffing policy in each country: unique government, utility, plant, and operating practices affect the potential applicability of certain policies and practices to the United States nuclear industry.

In gathering information for this study, a review was conducted of the published literature and of available government and industry documents from a sample of foreign countries. The countries for this study were selected based on their potential relevance for applications to the United States nuclear power industry. Similarities in level of industrialization, national political system, and experience with commercial nuclear power were used as the principal selection criteria. On this basis, Canada, France, Germany, Japan, Sweden, and the United Kingdom were chosen for review. The review of Germany is limited to the nuclear power industry in the former Federal Republic of Germany. Changes to the unified German nuclear power industry are likely due to the decommissioning of East German nuclear power facilities (*Nuclear News*, March 1991a). Total integration of the former Federal Republic of Germany's and East Germany's nuclear power industries is expected to occur by 1996. The unification of the German nuclear power industry in 1990 is beyond the scope of this review; the former West German nuclear power industry is used for the review of Germany in this report.

In conducting this comparative review of nuclear power staffing experience, several sources of information were used: (1) the published literature; (2) the Nuclear Regulatory Commission (NRC); (3) the International Atomic Energy Agency (IAEA); and (4) individuals who are knowledgeable about the nuclear industry staffing regulations and practices in their respective countries. The Nuclear Regulatory Commission (NRC) report entitled *Survey of Foreign Reactor Operator Qualification, Training, and Staffing Requirements* (Au, Di Salvo, and Merschoff, 1982) and a Battelle study of staffing regulation and practice changes in response to the 1979 accident at the Three Mile Island Unit 2 nuclear power plant (TMI) were particularly useful in providing a baseline of information for the countries discussed in this study. In addition, information from the published literature was drawn from international conference proceedings and from international journals and newsletters covering issues in the nuclear industry. Comparative information on training experience across the countries of interest was also obtained from the IAEA. Finally, the NRC Office of Regulatory Research and Office of International Programs provided contacts for additional information. Contacts were made with individuals who had experience in their country's nuclear industry. The information provided by these individuals was used to complement the literature review.

In order to provide a comparative perspective on staffing practices, it is necessary to understand the role of nuclear power as an energy source and the context of the regulatory framework for each country. In this report, a brief description of the role of nuclear power in each country is presented first, followed by a discussion of the country's nuclear power industry and regulatory bodies and their functions. Then, following a discussion of regulatory approaches to personnel and staffing, a description of licensing, education, and training is presented, along with a discussion of operator selection and career progression and shift composition. Finally, the findings are discussed in terms of specific approaches, practices, and experiences that are relevant to nuclear power staffing policy in the United States.

2 Role of Nuclear Power in Selected Countries: 1980-1990

In this section nuclear power development is described for selected countries from 1980 through December 31, 1990. The purpose of this discussion is to present the context under which commercial nuclear power plants operate within each country. The rate of growth of the industry and the significance of nuclear power as an energy source can affect the economic situation of utilities and the availability of qualified personnel. In this review, the countries of interest are Canada, France, Germany, Japan, Sweden, the United Kingdom, and the United States. Similarities in level of industrialization, national political system, and commercial nuclear power experience were the major selection criteria. Particular emphasis is given to comparative nuclear power industry growth patterns during the 1980s and future directions for the role of nuclear power.

Nuclear power development in the 1980s is summarized below for each country of interest.

2.1 Canada

Canada used nuclear energy moderately in the 1980s and is expected to continue doing so in the 1990s. While the number of Canadian nuclear power plants in operation almost doubled in number since 1981, nuclear energy continues to represent approximately one-fifth of Canada's total electrical supply. One new Canadian plant (Darlington-2) started operation in 1990 (*Nuclear News*, February 1991). Three Canadian nuclear power plants were recently completed and started commercial operation.

2.2 France

France pursued nuclear energy development aggressively in the 1980s and is likely to continue doing so at least through the early 1990s. The number of French nuclear power plants has almost doubled since 1980, with France now obtaining 75 percent of its electricity from nuclear power. France is by far the heaviest user of nuclear energy worldwide. In terms of experience, France has a somewhat "middle-aged" nuclear industry, in the sense that the age of its plants is average among the countries surveyed (23 years of calendar experience). One new plant started operation in 1990 (Penly-1). France plans to continue pursuing an aggressive nuclear energy policy this decade, and an additional six plants are expected to come on-line in the early 1990s.

2.3 Germany

Germany pursued an aggressive nuclear energy development policy in the 1980s, with a total of 21 nuclear power plants supplying almost one-third of the country's electricity. Germany's nuclear energy development is likely to remain stable in the 1990s. As discussed previously, the review of Germany is limited to the former Federal Republic of Germany's nuclear power industry. The unification of the German nuclear power industries is beyond the scope of this report.

2.4 Japan

Like Germany, Japan obtains almost one-third of its electricity from nuclear energy. Unlike Germany, however, Japan is continuing to pursue nuclear energy development aggressively in the 1990s. Two new plants in Japan started operation in 1990: Kashiwazaki Kariwa-2 and -5. Currently, Japan has the largest number of plants in the pipeline among the countries surveyed, with eleven plants being planned or constructed. It is likely that Japan will obtain close to one-half of its total electricity from nuclear energy once these plants come on line.

2.5 Sweden

Sweden has the smallest nuclear power industry in terms of output (MWe produced) of the countries surveyed. However, Sweden relies heavily on nuclear energy as a principal source of electricity. Currently, almost one-half (45%) of Sweden's electricity is generated by nuclear energy. As a result of the 1980 Swedish Nuclear Referendum, no additional nuclear units will be constructed and the existing twelve nuclear power plants will be decommissioned by the year 2010. However, recent initiatives recognize the lack of energy alternatives in Sweden so there is continuing debate about the long-term prospects for the Swedish nuclear power industry.

2.6 United Kingdom

The United Kingdom has the oldest nuclear power industry in terms of calendar year experience (35 years). The United Kingdom continued using nuclear energy moderately throughout the 1980s, and its nuclear power industry is not expected to grow substantially in the 1990s. Currently, the United Kingdom draws about one-fifth of its total electricity from nuclear energy. One new plant is scheduled for commercial start in 1994.

2.7 United States

With almost one-third of the world's nuclear power plants, the United States has the largest nuclear power industry and the most experience in terms of number of operating nuclear power plants (111 plants), MWe capacity in operation (almost 100,000 MWe), and cumulative reactor years of experience (about 1,500 years). In the 1980s, the use of nuclear energy in the United States grew from 11% of total electricity produced to approximately 20%. In 1990, three United States nuclear power plants came on-line: Comanche Peak-1, Limerick-2, and Seabrook (*Nuclear News*, February 1991). Further nuclear energy development will undoubtedly abate in the 1990s; only two plants are currently scheduled for commercial start in the 1990s.

Table 2.1 presents an overview of the role of nuclear power in each country. The following topics are addressed:

- number of nuclear power plants in operation (1981 versus 1990);
- percent of total electricity generated by nuclear energy (1980 versus 1989);
- megawatts of electricity (MWe) capacity in operation (1981 versus 1990);
- date of initial commercial operation, i.e., calendar years of experience;
- reactor operating years of experience (1981 versus 1989); and
- principal reactor types used.

The number of nuclear power plants expected to come on line in the 1990s is discussed later in this chapter.

2.8 Number of Nuclear Power Plants in Operation

Comparing the number of operating nuclear power plants across countries in 1981 and 1989 indicates the relative size and growth of each country's nuclear industry during the 1980s. Figure 2.1 presents a graph comparing the number of plants in operation by country for 1981 and 1990.

In 1981 the United States had 76 nuclear power plants, a far greater number of plants than any other country. The United Kingdom followed with 32 operating plants, one-half the number of United States operating plants. France had 29 operating plants, almost as many as the United Kingdom, and Japan had 23 operating plants. Germany, Canada, and Sweden had similar numbers of nuclear power plants, with 11, 10, and 9 plants, respectively. Each country added operating nuclear power plants during the 1980s ranging from 3 new plants in Sweden to 35 new plants in the United States.

The German and Canadian nuclear power industries showed the greatest growth, almost doubling the number of operating nuclear power plants in the past decade (about a 90% increase). France and Japan also increased their number of power plants significantly, with growth rates of 83% and 74%, respectively. The United States (with a 46% increase), Sweden (with a 33% increase), and the United Kingdom (with a 16% increase) showed relatively modest growth.

2.9 Percent Nuclear of Total Electricity Generation

The percent of electricity produced by nuclear energy indicates a country's reliance on nuclear power. Comparing nuclear electricity production with available data for 1980 and 1989 shows which countries aggressively pursued nuclear energy development in the 1980s and which countries pursued nuclear energy development at a more moderate pace. Figure 2.2 presents a graph comparing the percent of total electricity generated by nuclear power by country for 1981 and 1989.

In 1980 the proportion of total electricity generated by nuclear power ranged from 11% to 29% among the countries surveyed. In 1980 Sweden generated the highest proportion of electricity from nuclear energy, with 29% or almost one-third of the country's total electricity generation. France's nuclear power industry produced a relatively high proportion of electricity (25%), second only to Sweden. Japan followed next, obtaining 16% of its total electricity from nuclear energy. Germany produced a moderate proportion of the country's total electricity (12% of total electricity generation), similar to the United States and Canada (both 11%--the lowest proportion of nuclear energy produced among the countries surveyed).

Throughout the 1980s, the proportion of total electricity produced by nuclear power increased significantly across all countries.

Table 2.1 Role of nuclear power in the 1980s

Country	Nuclear Plants in Operation(n)		Percent Nuclear of Total Electricity Generation		MWe Capacity in Operation		Date of Initial Commercial Operation[2]	Calendar Years of Experience as of 12/90	Reactor Years of Experience		Principal Reactor Types Used[2,3,4]
	1981[1]	1990[2]	1980[1]	1989[2]	1981[1]	1990[2]			1981[1]	1989[2]	0
Canada	10	19	11	16	6,106	12,799	7/71	20	84	224	PHWR
France	29	53	25	75	20,118	51,938	4/67	24	176	543	PWR (GCR)
Germany	11	21	12	34	8,576	22,408	3/69	22	104	303	PWR (BWR)
Japan	23	40	16	28	15,047	30,317	3/70	21	149	432	PWR (BWR)
Sweden	9	12	29	45	6,400	9,769	2/72	19	45	147	BWR (PWR)
United Kingdom	32	37	13	22	8,648	12,620	10/56	35	559	850	GCR (AGR)
United States	76	111	11	19	57,874	99,559	7/61	30	620	1371	PWR (BWR)

1 Compiled from 12/90 data in *Nuclear News*. February 1991. "World List of Nuclear Power Plants." *34*(2):53-72.

2 Compiled from 1989 data in *Nuclear News*. June 1990. "Worldwide Nuclear Capacity, 1989." *33*(8):61.

3 Second most common type of reactor in parentheses.

4 AGR: Advance Gas Cooled Reactor
BWR: Boiling Water Reactor
GCR: Gas Cooled Reactor
PHWR: Pressurized Heavy-Water Reactor
PWR: Pressurized Water Reactor

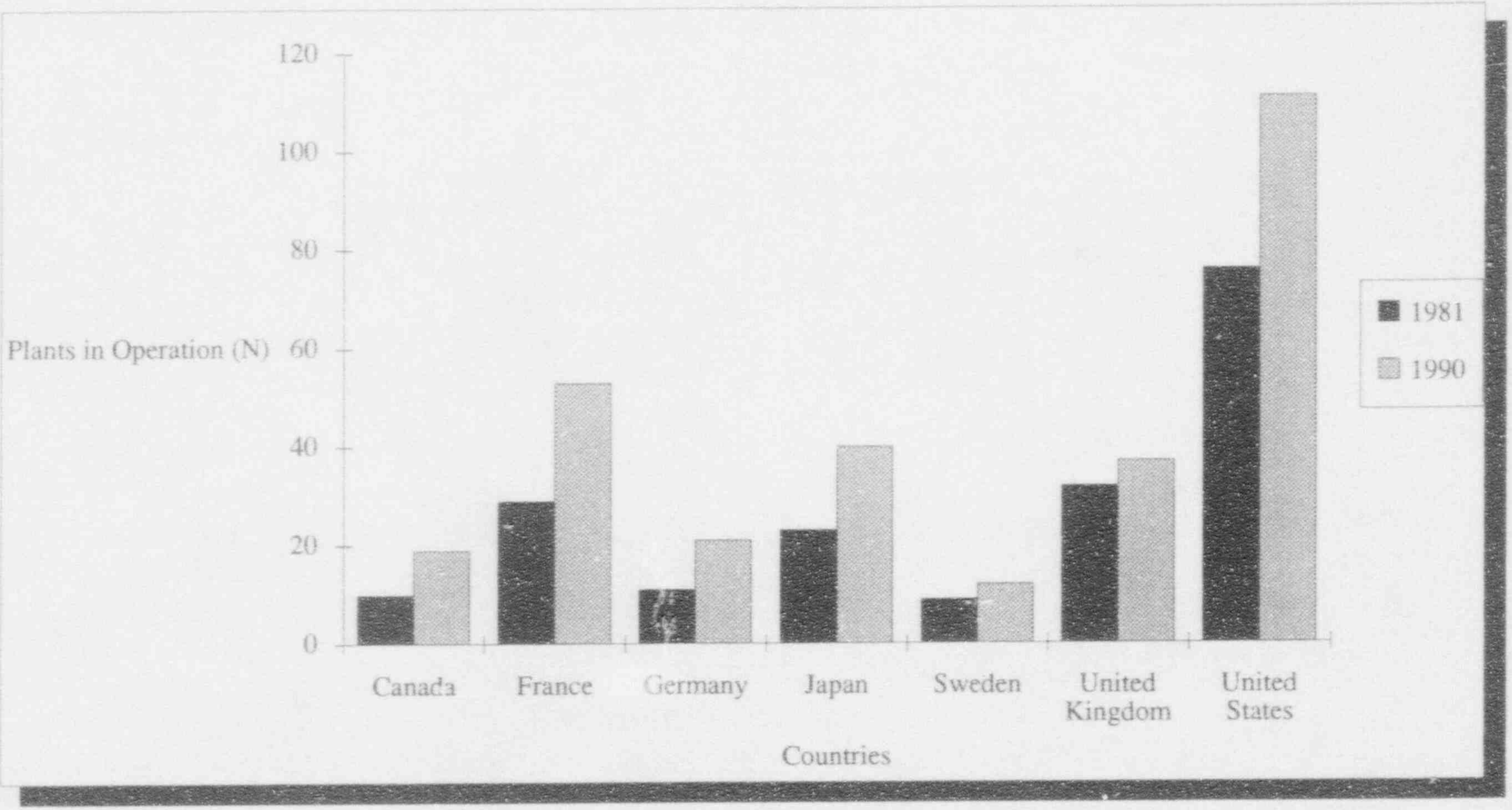

Figure 2.1 Nuclear power plants in operation by country: 1981 versus 1990

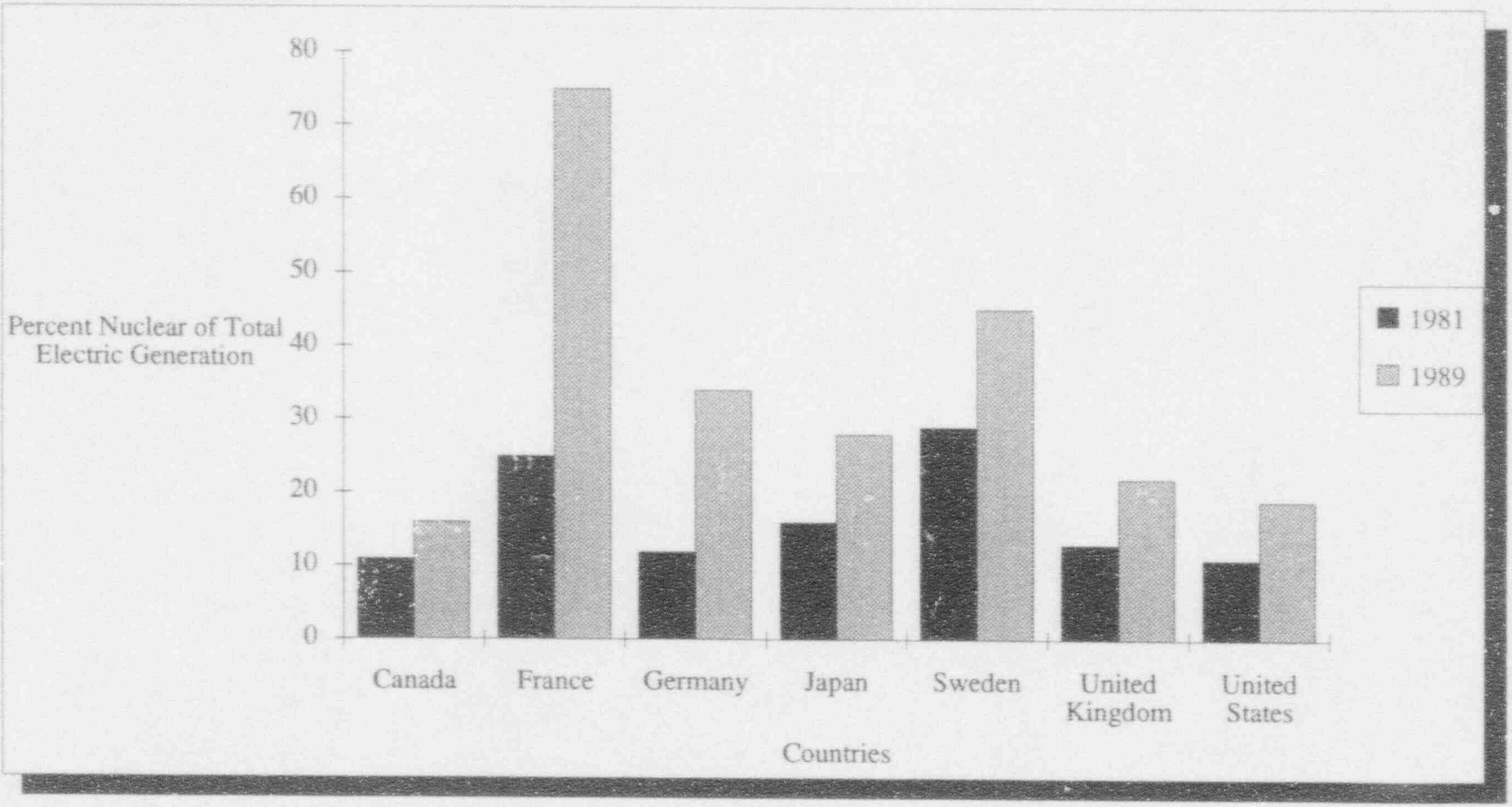

Figure 2.2 Percent of total nuclear electric generation by country: 1981 versus 1989

In 1989 France's nuclear power industry generated the highest proportion of electricity: 75% of France's total electricity is now obtained from nuclear power. Since 1980 France has tripled its relative use of nuclear energy.

Germany and Japan also increased their relative use of nuclear energy significantly in the 1980s. In 1989 Germany had increased its use of nuclear generated electricity from 12% in 1980 to 34% in 1989, and Japan increased its use of nuclear generated electricity from 16% to 28% over the same period.

The United States, the United Kingdom, and Canada continued using nuclear energy moderately throughout the 1980s. The United States increased its relative use of nuclear energy in 1989 to 19%, about one-fifth of total electrical production. This represents a 73% relative increase in overall reliance on nuclear energy since 1980. The United Kingdom also increased its use of nuclear energy in 1987 to almost one-fifth of the country's total electrical production, an increase of 69% since 1980.

Sweden obtained nearly half (45%) of its total electricity in 1989 from nuclear energy, a 55% increase in its relative use of nuclear energy since 1980. Canada increased its use of nuclear energy to 16% of the country's total electricity production, a 45% increase in overall reliance on nuclear energy since 1980.

2.10 Megawatts of Electricity (MWe) Capacity in Operation

Comparing MWe capacity in operation figures for 1981 and 1990 shows the total amount of growth in operating capacity for each country's nuclear power industry. Figure 2.3 presents a graph comparing the MWe capacity by country for 1981 and 1989.

In 1981 the United States nuclear power industry's operating capacity (57,874 MWe) was almost three times greater than France's (20,118 MWe); almost four times greater than Japan's (15,047 MWe); almost seven times greater than the United Kingdom's (8,648 MWe) and Germany's (8,576 MWe); and about nine times greater than Sweden's (6,400 MWe) and Canada's (6,106 MWe) operating capacity.

Table 2.2 presents the percent increase in the amount of MWe operating capacity by country, in order of greatest percentage increase. Germany showed the highest percent increase from its 1981 MWe nuclear generating capacity. Germany's nuclear operating capacity grew 161% since 1981. Germany's growth rate in nuclear MWe operating capacity during the 1980s was almost identical to France's growth rate of 158% (i.e., two and one-half times greater than the 1981 level). Viewed from another perspective, France's and Germany's net generating capacity in operation grew over twice as fast overall as the United States' rate throughout the 1980s.

Canada's net operating nuclear generating capacity grew to 12,799 MWe, more than double its 1981 operating capacity. Japan maintained its position as third in operating capacity. By the end of 1990 Japan's nuclear operating capacity had grown to 30,317 MWe. This represents an overall increase of 101%, about double its 1981 level.

In absolute terms, however, the United States nuclear power industry's capacity in operation is still twice as great as its closest foreign counterpart, France (99,559 MWe versus 51,938 MWe). By 1990, the United States nuclear generating MWe capacity in operation had grown to 99,559 MWe, a net increase of 72% over its 1981 level. Sweden's net generating capacity grew to 9,769 MWe, an increase of 53% since 1981.

In 1989 the United Kingdom followed behind Japan and Germany's net operating capacity with 12,620 MWe in operation, reflecting the smallest MWe operating capacity increase since 1981 of 46%.

2.11 Calendar Years of Experience

Comparing calendar years of experience shows the age of nuclear power since initial commercial operation began in each of the selected countries. Calendar years of experience were calculated as of December 1990 and provide a yardstick of nuclear power experience between countries.

The United Kingdom has the oldest commercial nuclear power plant in operation, with date of initial commercial operation in October 1956, or 35 calendar years of experience. The United States nuclear power industry is slightly younger than its United Kingdom counterpart, with a cumulative 30 calendar years experience the date of its initial commercial operation was July 1961. France's nuclear power industry is 24 years old, with a date of initial commercial operation of April 1967. Germany's nuclear power industry is slightly younger than France's with 22 calendar years of experience, with a date of initial commercial operation of March 1969. Japan's nuclear power industry is 21 years old, with a

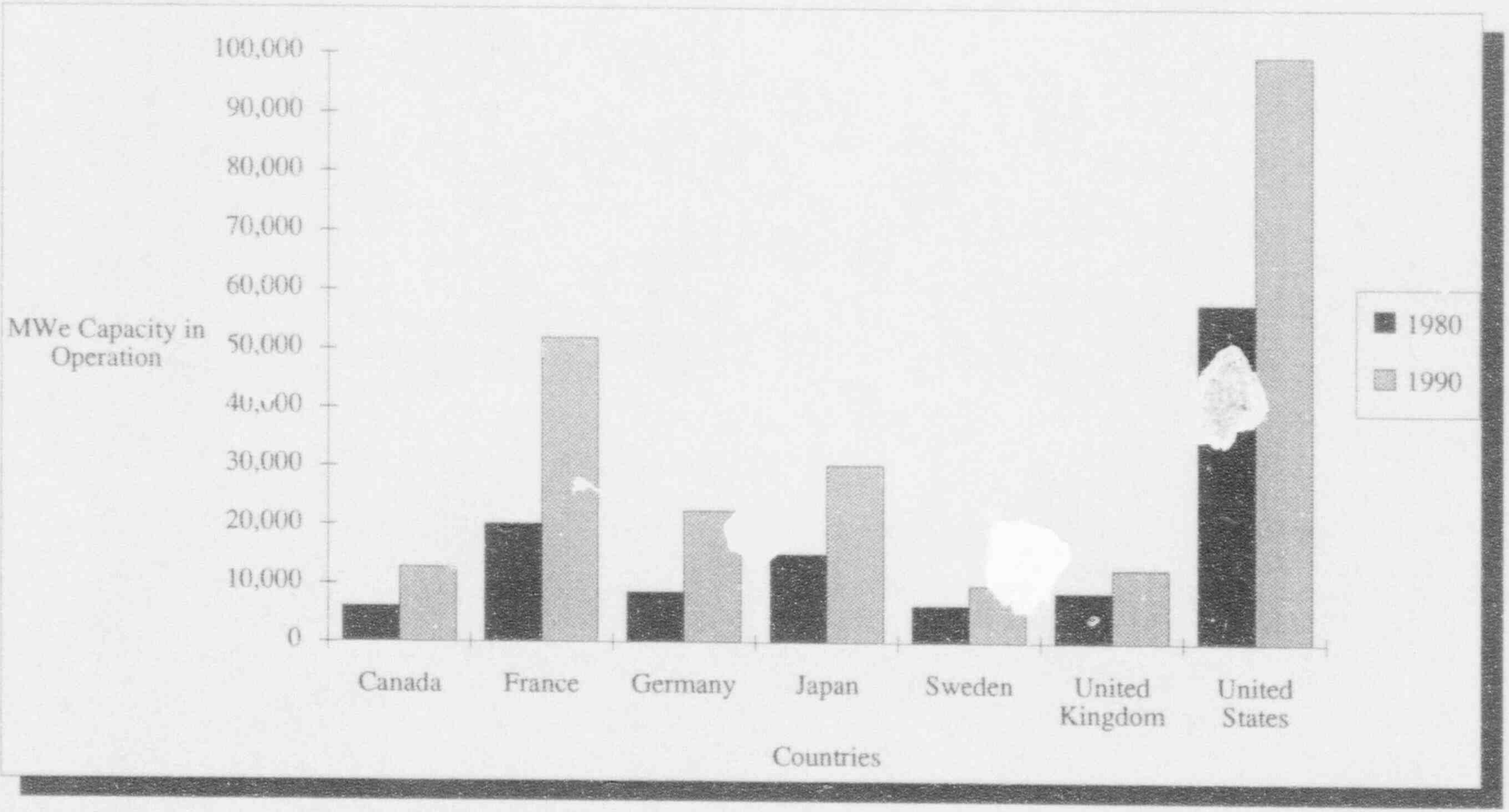

Figure 2.3 MWe capacity in operation by country: 1980 versus 1990

Table 2.2 Percent increase in MWe operating capacity by nuclear power industry by country: 1981 to 1990

Country	MWe Capacity In Operation: 1981	MWe Capacity In Operation: 1990	Percent Increase
Germany	8,576	22,408	161
France	20,118	51,938	158
Canada	6,106	12,799	110
Japan	15,047	30,317	101
United States	57,874	99,559	72
Sweden	6,400	9,769	53
United Kingdom	8,648	12,620	46

date of initial commercial operation of March 1970. Canada's and Sweden's nuclear power industries are 20 and 19 years old, respectively, and represent the youngest nuclear power industries surveyed; their dates of initial commercial operation are July 1971 and February 1972, respectively.

2.12 Reactor Years of Experience

Reactor years of experience provides a comprehensive measure of cumulative nuclear power plant experience. Reactor years of experience for each country is calculated by determining the age of each country's nuclear power plants at a specified time and determining the cumulative total reactor years of experience. Comparing reactor years of experience between countries provides an absolute measure of nuclear power plant experience. Figure 2.4 presents a graph comparing reactor years of experience by country for 1981 and 1989.

The reactor years of experience for 1981 were calculated as of December 1980. Based on these calculations, the United States had 620 reactor years of experience, slightly more than the United Kingdom's 559 reactor years of experience; both countries share relative seniority over their counterparts. France followed behind the United States and United Kingdom with 176 reactor years of experience, followed by Japan with 149 reactor years of experience. Germany had 104 reactor years of experience.

As of December 1980, Canada and Sweden had the fewest reactor years of experience, with Canada having 84 and Sweden having 45 reactor years of experience, respectively.

The 1989 reactor years of experience were calculated as of December 1989. Based on these calculations, the order from the country with the most reactor years of experience to the country with the least reactor years of experience remained constant. However, there were minor variations in relative experience levels: some countries rapidly increased the size of their nuclear power industry, while other countries expanded at a slower rate.

This directly affected reactor year experience, as well as the number of reactors installed during this period. For instance, if two countries were planning to install the same amount of MWe operating capacity, and one country installed many small reactors while the other country installed a few large reactors, ultimately the country with the smaller yet greater number of reactors would gain more reactor operating experience (assuming roughly equivalent capacity load factors).

Although it has the least overall experience, Sweden showed the greatest growth in reactor year experience. Sweden more than tripled its reactor year experience to 147 reactor years, an increase of 227%.

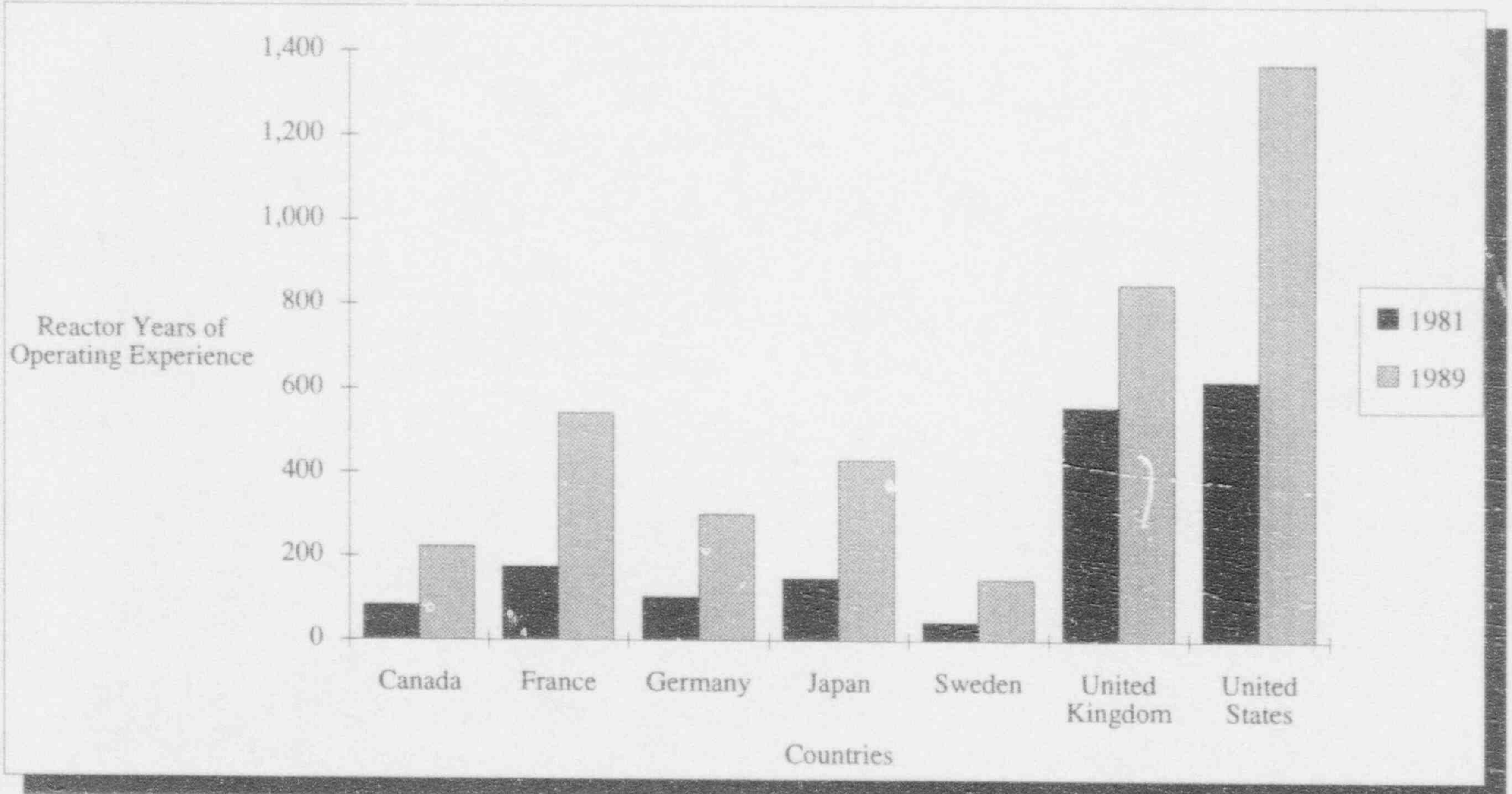

Figure 2.4 Reactor years of operating experience by country: 1981 versus 1989

By the end of 1989 France had more than tripled its reactor year experience since 1981 to 543 reactor years of experience; this was an increase of 209%. Germany reached 303 reactor years of experience (an increase of 191%).

Japan reflected a similar percent increase in reactor years of experience, going from 149 reactor years of experience in 1981 to 432 reactor years of experience in 1990, an increase of 190%. Canada more than doubled its reactor year experience to 224 reactor years, an increase of 167%. The United States and the United Kingdom continued sharing relative seniority over other countries in terms of reactor year experience, although their experience levels increased at a slower rate than their counterparts. In 1989 the United States had 1,371 reactor years of experience, over twice its 1981 reactor year experience level (an increase of 121%). At the same time, the United Kingdom reached 725 reactor years of experience, representing the smallest increase among the countries surveyed (52%) in reactor year experience.

2.13 Principal Reactor Types Used

All countries in the survey, except the United Kingdom and Canada, use light-water reactors for generating nuclear energy (i.e., ordinary water is the neutron moderator and primary source of reactor coolant). The United Kingdom uses gas-cooled reactors (GCRs) and advanced gas-cooled reactors (AGRs). Canada uses pressurized heavy-water reactors (PHWRs) and is the only country to use this reactor design.

Light-water reactors include both boiling water reactors (BWRs) and pressurized water reactors (PWRs); these are the principal reactor types used by France, Germany, Japan, Sweden, and the United States. Germany, Japan, and the United States rely principally on PWRs; BWRs are the second most commonly used type of reactor. France relies principally upon PWRs, but also uses gas-cooled reactors (GCRs). Sweden relies principally on BWRs for commercial operation, followed by PWRs.

2.14 Nuclear Power Plants Expected to Come On-Line in the 1990s

In this section the comparable descriptive information regarding nuclear power plants in the pipeline is discussed; in this context, "in the pipeline" means nuclear power plants in the planning stage, under construction, or operable, but not currently operating. This information is presented in Table 2.3. The information presented here provides the most recent information available as of June 30, 1993.

Canada has no nuclear power plants in the pipeline. Commercial operation of three plants began in the early 1990s. On December 19, 1989, Ontario Hydro released its 25-year plan. The plan calls for at least 8 new units and 7,000 MWe of new electricity generation to come on-line from 2002 to 2014. The high-growth scenario requires as many as 22 new nuclear units to be operating by 2014 (*Nuclear News*, February 1990).

As of June 1993, France had six plants under construction, all of which were expected to come on-line in the 1990s. Two of these plants have achieved initial criticality. The Creys-Malville plant generated power, but commercial operation was postponed indefinitely pending remedial work (*Nuclear News*, February 1991).

Germany is currently planning no additional new plants. A liquid metal fast breeder reactor, a high temperature reactor, and a nuclear materials reprocessing plant faced numerous regulatory obstacles and strong public opposition to their operation (Rippon, 1989; *Nuclear News*, July 1989). Due to public opposition against further nuclear power development, and because of moderate energy consumption projections, it is unlikely at this time that the German nuclear power industry will expand within the next several years (Beckjord et al., 1987; *Nuclear News*, June 1990; *Nuclear News*, March 1991a).

Japan has the greatest number of plants planned, under construction, or expected to come on-line shortly. As of June 1993, eleven plants were in the pipeline. All of these nuclear power plants are expected to come on-line in the 1990s. According to past projections issued by government agencies, Japan will require 122 additional nuclear units by 2030 in order to satisfy the country's growing electricity needs (*Nuclear News*, September 1986). The Ministry of International Trade and Industry (MITI) wants to add 40 new nuclear power plants by 2010 (*Nuclear News*, July 1990).

Japan has several nuclear units that have been in service for 15 years or more, with additional plants between 10 and 15 years old. Plant aging is an increasingly important concern for the nation's utilities, especially if newer plants are not constructed in light of public concerns regarding nuclear power. Assuming a 40-year commercial lifespan, 1 plant will close before 2010;

Table 2.3 Nuclear power plants operable but not operating, under construction, or on order (30 MWe and over) as of June 30, 1993[1]

COUNTRY (N)	PLANT	REACTOR TYPE[2]	CONSTRUCTION STAGE (%)	INITIAL CRITICALITY	COMMERCIAL START
Canada (0)					
France (6)	Creys-Malville	LMFBR	100	9/85	Indefinite*
	Golfech 2	PWR	100	12/92	10/93
	Chooz B1	PWR	87	7/95	2/96
	Chooz B2	PWR	65	2/96	7/96
	Civaux 1	PWR	15	12/96	4/97
	Civaux 2	PWR	5	7/98	11/98
Germany (0)					
Japan (11)	Hamaoka 4	BWR	98	12/92	9/93
	Shika 1	BWR	99	11/92	7/93
	Genkai 3	PWR	96	5/93	3/94
	Genkai 4	PWR	39	--	7/97
	Ikata 3	PWR	82	5/94	3/95
	Onagawa 2	BWR	79	11/94	7/95
	Kashiwazaki Kariwa 3	BWR	97	10/92	7/93
	Kashiwazaki Kariwa 4	BWR	83	--	7/94
	Kashiwazaki Kariwa 6	BWR	27	--	12/96
	Kashiwazaki Kariwa 7	BWR	9	--	7/97
	Monju	LMFBR	99	/94	/95

[1] Compiled from data in *Nuclear News*, June 1993, "World List of Nuclear Power Plants." *37*(9, 43-62.

[2] BWR: Boiling Water Reactor
LMFBR: Light Metal Fast Breeder Reactor
PHWR: Pressurized Heavy Water Reactor
PWR: Pressurized Water Reactor

Table 2.3 Nuclear power plants operable but not operating, under construction, or on order (30 MWe and over) as of June 30, 1993[1] - (cont.)

COUNTRY (N)	PLANT	REACTOR TYPE[2]	CONSTRUCTION STAGE (%)	INITIAL CRITICALITY	COMMERCIAL START
Sweden (0)					
United Kingdom (1)	Sizewell B	PWR	90	1/94	3/94
United States (8)	Watts Bar 1	PWR	86	--	/94
	Watts Bar 2	PWR	70	--	Indefinite
	Commanche Peak 2	PWR	100	3/93	8/93
	WNP-1	PWR	65	--	Indefinite
	WNP-3	PWR	75	--	Indefinite
	Bellefonte 1	PWR	80	--	Indefinite
	Bellefonte 2	PWR	45	--	Indefinite
	Perry 2	BWR	57	--	Indefinite

1 Compiled from data in *Nuclear News*, June 1993, "World List of Nuclear Power Plants." *37*(9):43-62.

2 BWR: Boiling Water Reactor
PWR: Pressurized Water Reactor

however, between 2010 and 2020, 18 units face closure. MITI wants to add 40 new reactors by 2010 to allow for this lost capacity, to limit fossil-fuel consumption, and to keep pace with rising energy demands (*Nuclear News*, December 1989; *Nuclear News*, June 1990; *Nuclear News*, July 1990; *Nuclear News*, December 1990).

Sweden has no new plants scheduled for construction or commercial start in the 1990s; a plan to close several plants beginning in 1995 was recently dropped (*Nuclear News*, April 1988; *Nuclear News*, June 1990; *Nuclear News*, March 1991b).

The central issue facing Sweden's nuclear power industry is the result of the 1980 Swedish Nuclear Referendum: no additional nuclear units will be constructed and the existing 12 nuclear power plants will be decommissioned by the year 2010 (Beckjord et al., 1987).

Recent technical studies have highlighted the undesirability of decommissioning these plants, in terms of the economic costs involved and in terms of the well-established safety record of the industry. Public opinion polls also show that the majority of Swedes do not believe that nuclear power will be phased out in Sweden by 2010, and that increasingly more people are in favor of nuclear power. Sweden's high level of reliance on nuclear power and an excellent performance record are strongly influencing public acceptance, especially in the absence of alternative energy sources. Financial concerns are also apparent. The Sydkraft utility announced that it would seek damages estimated at $2.5 billion if it was forced to shut down a reactor before the end of its planned life (Beckjord et al., 1987; Pershagen and Nilson, 1984; *Nuclear News*, April 1988; *The Economist*, March 1990; Hoegberg, 1988).

The United Kingdom's nuclear power industry is not expected to grow substantially in the 1990s. One new PWR is scheduled for commercial start in 1994 (*Nuclear News*, May 1990).

The United States has eight nuclear power plants in the pipeline; two are expected to come on-line in the 1990s. Commanche Peak 2 is expected to come on-line in 1993 and Watts Bar 1 is expected to come on-line in 1994. The completion of six additional plants have been postponed indefinitely.

2.15 Conclusion

The 1980s were marked by a great deal of growth across the countries surveyed, reflecting a greater reliance overall on nuclear energy. Although some countries that were reviewed have stabilized their growth in terms of nuclear power (the United States, the United Kingdom, Germany, and Sweden), several others continue to increase their reliance on nuclear power (France, Japan, and to a lesser extent, Canada). The relative contribution of nuclear power to overall electric production in all countries surveyed should remain somewhat stable as nuclear power industry growth projections are aimed toward consolidating the gains made by nuclear power in the 1980s. It is likely that nuclear power will remain a strong contributor to electric power production in all the countries that were surveyed throughout the 1990s.

3 Industry and Regulatory Framework in Selected Countries

In this chapter, the nuclear power industry regulatory framework in Canada, France, Germany, Japan, Sweden, and the United Kingdom is discussed. The review of Germany is limited to the nuclear power industry in the former Federal Republic of Germany. Presumably, changes to the unified German nuclear power industry can be expected in terms of decommissioning and decontaminating obsolete East German nuclear power facilities (*Nuclear News*, March 1991a). Total integration of the former Federal Republic of Germany's and East Germany's nuclear power industries is expected to occur by 1996. The unification of the German nuclear power industries is considered beyond the scope of this review.

Following the discussion in Chapter 2 on the role of nuclear power in these countries, the purpose of this chapter is to review regulatory practices affecting the context of staffing regulation and practice. The discussion focuses on identifying common themes driving the context of staffing regulation and practice in the post-TMI era and into the 1990s. Table 3.1 provides an overview of nuclear power industry ownership and regulatory framework by country. Table 3.2 describes nuclear power industry regulatory characteristics by country. A country-by-country review of industry and regulatory frameworks is provided in Appendix A.

3.1 Function and Character of Regulatory Bodies

In analyzing the characteristics and functions of regulatory bodies in the countries that were surveyed, the responsibilities for nuclear power safety, plant licensing, regulation, research and development, and plant ownership and operation were considered. Of the countries that were reviewed, Germany and, to a lesser extent Sweden, have the most comparable utility ownership and regulatory systems to the United States. First the regulatory framework in all of these countries is compared with that in the United States. Then the regulatory frameworks of the two countries that are most comparable to the United States are discussed further.

3.2 Government Power Production, Operation, Regulation, and Manufacturing

In three countries--Canada, France, and the United Kingdom--government bodies are exclusively responsible for nuclear power plant operations.

Although the United Kingdom privatized its two major nuclear utilities, the government remains the major shareholder. In France, power production is federally owned and operated. In Canada, nuclear power operations are owned and operated by the state (provincial) government in which they operate.

Government involvement in nuclear operations in these countries also extends to plant design, construction, and research and development. In Canada and France these activities are state run and operated. In the United Kingdom these related activities are carried out by a statutory corporation, the United Kingdom Atomic Energy Authority (UKAEA) and is managed by a government-appointed board. In addition to research and development pertaining to nuclear power plant safety and reliability research, the UKAEA also operates several nuclear power plants.

Regulation of nuclear power operations in these countries is also carried out by the federal or state government. The French Parliament has called for greater separation of responsibilities among agencies within the Ministry of Industry, which houses the power producing utility (Electricité de France, or EDF), the principal regulatory agency (Direction de la Sûreté des Installations Nucleaires, or DSIN), and the principal research and advisory committees (Commissariat a l'Energie Atomique, or CEA). This has resulted in major reorganizations within the Ministry. In the United Kingdom, the privatization of the government power producing utilities has also led to a greater separation between the power producing and regulatory agencies. Across countries then, a major change has been a move toward government decentralization of the state-run nuclear power industry, albeit for different reasons (in France, the prime motivator is the desire for greater separation between nuclear research and regulatory activities; in the United Kingdom, privatization is the prime motivator).

3.3 Shared Government and Private Power Production, Operation, Regulation, and Manufacturing

Japan has significant government involvement in its nuclear power operations, although many Japanese nuclear utilities are also privately owned. Japan's utilities continue to remain investor-owned. However, stock may be owned by the prefectural government in which the utility is located. As was the case in the early 1980s, the federal government continues to play an important role in

Table 3.1 Nuclear power industry overview by country

Country	Industry Description	Utility Structure/Ownership	Regulatory Framework
Canada	Small nuclear power industry; moderate growth expected.	Small set of utilities (3); provincially owned.	Regulations carried out by AECB; research carried out by AECL.
France	Large and growing nuclear power industry.	Single utility: State owned and operated (EDF).	Regulations carried out by DSIN; research carried out by CEA.
Germany	Moderate size and not expected to grow further.	Diverse: 16 utilities, publicly and privately owned.	Complex: Federal and state responsibilities shared between public and private organizations.
Japan	Large and rapidly growing nuclear power industry.	Diverse: 11 utilities, publicly and privately owned.	Regulations carried out by MITI (with interagency reviews); research carried out by AEC and NSC.
Sweden	Small nuclear power industry; no growth expected.	Diverse: Combination of state-owned utility (1) and publicly/privately owned utilities (2).	Regulations carried out by SKI with Parliamentary and other government agency oversight; research carried out by Studsvik and Energiteknik.
United Kingdom	Moderate size and not expected to grow substantially.	Small set of utilities (4); state- and privately-owned.	Regulations carried out by NII; research carried out by UKAEA.
United States	Largest nuclear power industry; not expected to grow substantially.	Diverse: 52 utilities, publicly and privately owned.	Regulations carried out by NRC (with other federal, state and local involvement).

AEC: Atomic Energy Commission
AECB: Atomic Energy Control Board
AECL: Atomic Energy of Canada Limited
CEA: Atomic Energy Commission (Commissariat a l'Energie Atomique)
DSIN: Direction de la Sûreté des Installations Nucleaires
MITI: Ministry of International Trade and Industry
NII: Nuclear Installations Inspectorate
NRC: Nuclear Regulatory Commission
NSC: Nuclear Safety Commission
SKI: Swedish Nuclear Power Inspectorate
UKAEA: United Kingdom Atomic Energy Authority

Table 3.2 Nuclear regulatory characteristics by country

Country	Regulatory Control	Approach	Practice
Canada	Centralized (separate regulation and research agencies).	Basic safety rules with specific criteria and instructions; special technical requirements applied during licensing.	Case-by-case review of plant operating practices; application of industry standards in small industry (3 utilities, 18 plants).
France	Centralized (separate regulation and research agencies).	Basic safety rules with specific criteria and instructions; special technical requirements applied during licensing.	Regulations (DSIN) carried out in direct contact with the state-run utility (EDF); both are in the Ministry of International Trade and Industry.
Germany	Diffuse and diversified (combination of federal, state, private).	Basic safety rules applied through industry standards developed by KTA and enforced by State Licensing Authorities.	Regulations and standards coordinated by State Licensing Authorities in each state (variation in terms of regulatory practices and enforcement).
Japan	Centralized (separate regulation and research agencies).	Basic safety rules with specific criteria and instructions; special technical requirements applied during licensing.	Formal regulatory compliance process between MITI and licensees.
Sweden	Centralized (separate regulations and research agencies).	SKI establishes general guidelines and regulations, and sets safety goals as well as specific criteria and instructions (performance-oriented).	Informal and formal group decision-making process concerning plant technical and safety issues; process noted for simplicity and effectiveness between key actors in small industry.
United Kingdom	Centralized (separate regulation and research agencies).	Basic safety rules with specific criteria and instructions; special technical requirements applied during licensing.	Formal regulatory compliance process between NII and licensees enforced through site license; little reliance on prescriptive regulation.
United States	Diffuse and diversified (combination of federal and state).	Basic safety rules with specific criteria and instructions; special technical requirements applied during licensing.	Formal regulatory compliance process between NRC and licensees.

DSIN: Direction de la Sûreté des Installations Nucleaires
EDF: Electricité de France
KTA: Safety Standards Commission
MITI: Ministry of International Trade and Industry
NII: Nuclear Installations Inspectorate
NRC: Nuclear Regulatory Commission
SKI: Swedish Nuclear Power Inspectorate

utility affairs by providing direct financial assistance through the Ministry of Trade and Industry (MITI). The federal government also has the principal responsibility for regulation, research and development, and construction. MITI is the principal regulatory authority and works very closely with the utilities while controlling their activities through its regulatory functions. The Japanese nuclear power industry is thus characterized by a great deal of overlap between government and private organizations in nuclear power production, operation, regulation, and manufacturing.

3.4 Regulatory Frameworks Comparable to the United States in Power Production, Operation, Regulation, and Manufacturing

Sweden and Germany have regulatory frameworks comparable to that of the United States, in that power production facilities are separately owned by both public and private entities, construction is largely a private sector responsibility, regulation is carried out by an independent government agency, and various independent industry groups participate in regulatory and research related activities. As in the United States, nuclear power plants in Sweden and Germany are fully owned by both public and private utilities. In the 1980s construction activities in Germany were carried out by private industrial firms, with indirect guidance from the government. In Sweden, power plant construction activities were carried out by ASEA/ATOM, a joint venture between the Swedish government and a group of Swedish industrial firms. The consortium designed and built nuclear power plants and manufactured reactor components and nuclear fuel.

These countries are also similar to the United States in that presently no new nuclear power plants are currently planned for construction. There are similar reasons for this. In Sweden and Germany as well as the United States there is strong public opposition to increasing the number of nuclear power plants. In Germany and Sweden this opposition is largely motivated by environmental concerns. In the United States this opposition is motivated by financial concerns as well as environmental concerns.

The German regulatory framework remains the most complex of all countries that were surveyed. This complexity is the result of Germany's federalist system, which requires that each of the 11 state governments license and regulate nuclear power plant operations within their jurisdiction. Although each State Licensing Authority must follow broad regulatory guidance and administrative guidelines issued by the Federal Minister for the Environment, Nature Conservation, and Nuclear Safety (BMU), there is considerable variation between state enforcement practices. The State Licensing Authorities are responsible for coordinating activities between various public advisory groups, standards groups, and state and regional agencies. State Licensing Authorities are also responsible for licensing nuclear power plants, although the federal BMU must consent to this action.

In Sweden, nuclear power utilities are licensed and regulated by the Swedish Nuclear Power Inspectorate (SKI), which is within the Ministry of Industry. Although SKI closely oversees nuclear power plant operations, final responsibility for plant operation and safety resides with the individual utility. In addition, the nuclear utilities have an industry organization, Raadet für Karnkraftssakerhet (RKS), which is active in several aspects of operational safety, serves as a communication channel, and represents industry views before SKI. This organization is similar in function to activities variously carried out by the Institute of Nuclear Power Operations (INPO), the Electric Power Research Institute (EPRI), and the Nuclear Utilities Resources and Management Council (NUMARC). Unlike the German or United States regulatory framework, Swedish nuclear power research and development activities are largely carried out by a statutory corporation, called Studsvik/Energiteknik.

3.5 Conclusions

Across the countries that were surveyed there have been no major changes to their respective regulatory frameworks in terms of fundamental re-organizations or rewriting of basic laws governing nuclear power operations. In Germany, which has a nuclear power regulatory framework similar to that of the United States, there has been a move toward greater centralization of authority within the federal government. However, Germany remains highly diverse in terms of regulatory responsibilities between federal, state, and industry organizations, and in terms of utility structure and ownership.

France and the United Kingdom have made some changes to their regulatory framework. In France, there has been a move toward decentralization. This change is the result of calls by the French parliament and others for more accountability and input into the nuclear power regulatory decision-making process. In the United Kingdom, the most significant change has been the privatization of its state-run utilities; the Central Electric Generating Board (CEGB) is now a private company called Nuclear Electric. Similarly, the South of Scotland Electric Board (SSEB) is now Scottish Electric. Canada, Japan, and Sweden have remained relatively stable. A review of specific changes in staffing regulation and practice is discussed in the following chapter.

4 Trends in Staffing Regulations and Practices: Changes from 1980 to 1990

Several trends and changes in staffing regulations and practices during the 1980s are reviewed in this chapter. In response to the TMI accident, a number of countries instituted major changes in regulatory requirements and utility practices in the areas of licensing, qualifications, training, and shift composition in the early 1980s. These changes in Canada, France, the former Federal Republic of Germany, Japan, Sweden and the United Kingdom are discussed in this chapter.

A comparative review of recent changes in staffing across the countries of interest is provided in the following sections. First, the regulatory approaches to personnel and staffing are discussed. Next, trends in regulation and practices during the 1980s are reviewed across countries in the areas of education, training, and licensing. Then personnel selection and career progression are discussed. Finally, the last section discusses changes in shift composition. For comparative purposes, Appendix B provides the executive summary from the survey of staffing practices in the United States (Melber et al., 1993).

4.1 Regulatory Approaches to Personnel and Staffing

In order to understand changes in regulations and practices across countries as well as across time, it is necessary to compare the approaches to staffing regulations within each country. In this report, countries were reviewed in terms of where they fall on a continuum, ranging from direct regulatory control enforced through specific prescriptive regulations, to indirect regulation where the regulatory agency, through its station licensing process, either approves or rejects operating practices proposed by the utility. Table 4.1 provides a summary of regulatory control over staffing and personnel issues by country.

Countries with direct staffing control mechanisms are characterized by having regulations that dictate specific requirements, often in such areas as licensing, education, training, and shift composition. Countries with indirect staffing control mechanisms are characterized by having plant licensing processes that give utilities the discretion to satisfy broad performance requirements with a license application that specifies how the utility will meet the general safety objectives. Countries that fall somewhere in between have some requirements set by regulatory agencies through specific regulations as well as some utility discretion in determining how to meet other safety performance requirements of the regulatory agency. Of the countries in this study, Germany has the most direct staffing control mechanisms in place, which specify detailed, prescriptive regulations and guidelines. The United Kingdom and France represent the least prescriptive end of the spectrum. These countries use indirect staffing mechanisms through the issuance of plant licenses that conform to broad safety and operating objectives. Canada, Japan, and Sweden fall in the middle of the regulatory control continuum, with a mixture of utility discretion and regulatory specifications.

Germany has established minimum requirements pertaining to the education, training, and experience of control room personnel. Training guidance and course content, for instance, are prescribed by the Federal Minister for the Environment, Nature Conservation, and Nuclear Safety (BMU). German utilities must submit their retraining programs to the BMU for approval and must report the results of retraining testing. Training and retraining are supported by Germany's national training center, the VGB, which is utility-operated (International Atomic Energy Agency, 1980).

France and the United Kingdom have regulatory mechanisms enforced through the issuance of a broad plant operating license. In France, the state-run national utility, Electricité de France (EDF), determines recruitment, education, training, and promotion standards for operators. The regulatory agency, Direction de la Sûreté de Installations Nucleaires (DSIN), does not license operators individually. Instead, it reviews EDF's management plan for assuring the competence of its personnel. Authorization to operate the plant indicates that the management policy for personnel is acceptable to DSIN (International Atomic Energy Agency, 1980). This framework is supported by the highly centralized nature of the French nuclear power regulatory framework, where EDF and DSIN are housed within the same government ministry.

The United Kingdom shares some characteristics with France. In the United Kingdom, the Nuclear Installations Inspectorate (NII) either approves or denies the plant's proposed plan according to compliance with broad regulatory requirements such as conditions for plant start-up, operation, and shut-down. This is in contrast to the United States approach in which regulations, regulatory requirements, and licensing requirements specify acceptable operating practice. The formerly state-run national utility, the Central Electricity Generating Board

Table 4.1 Nuclear staffing regulatory characteristics by country

Country: Regulatory Approach	Minimum Requirements for Education, Training Experience	Personnel License Required	Government Agency Administers/ Supervises Exams	Prescribed Training/ Course Content	Retraining Requirements
Canada: Mixed system; direct staffing control and utility discretion.	Positions have set qualification levels; plant license implies acceptance of personnel.	Yes. Shift supervisors, shift operating supervisors and authorized nuclear operators (ANOs).	Yes.	No.	No, but subject to regulatory approval (AECB).
France: Indirect regulation through plant license.	Utility discretion (EDF).	No requirement; utility management responsible for competence of personnel.	No.	No.	No.
Germany: Direct staffing control.	Specified by regulatory agency (BMU).	Yes.	Yes.	Yes.	Programs must be approved by regulatory agency (BMU).
Japan: Mixed system; direct staffing control and utility discretion.	No. Administrative guidance provided by MITI.	Yes. Supervisory license mandated.	No.	No, training provided in part through BWR and PWR Training Centers.	No, retraining offered by the BWR and PWR Training Centers.
Sweden: Mixed system; direct staffing control and utility discretion.	Utility discretion; plant license implies acceptance of personnel.	No, but SKI has monitoring system to review the competence of operators and supervisors.	No.	No, but norms imposed by relatively small number of educational institutions.	No.
United Kingdom: Indirect regulation through plant license.	Utility discretion.	No.	No.	No, but National Training Center run by the state utility establishes norms.	No, but retraining courses proved by National Training Center.
United States: Direct staffing control.	Specified by regulatory agency (NRC).	Yes. Senior reactor operators and reactor operators.	Yes.	Yes.	Programs must be approved by regulatory agency (NRC).

See Abbreviations listing on page xii.

(CEGB), renamed Nuclear Electric after recent privatization of this utility, interprets these broad regulatory requirements into specific plans and practices. The plant manager is responsible for setting standards related to recruitment, education, training, and promotion standards for operators (V. Madden, Nuclear Electric, Personal Communication, June 1991; Courvoisier et al., 1981; Au et al., 1982). However, there are certain limits to this discretion. For instance, as in France, education and training standards in the United Kingdom's nuclear power industry are developed by the state-run national training center (Myerscough, 1980a). Also, by virtue of operating experience, Nuclear Electric and NII have well-established norms for acceptable plant practices.

Canada, Japan, and Sweden have systems in common that have a mixture of direct regulation and utility discretion. In Canada the regulatory agency, the Atomic Energy Control Board (AECB), sets and enforces personnel qualification standards. Although the plant manager recommends detailed plans for operator training programs, for instance, the AECB approves or denies these recommendations. This approach is different from the models of France and United Kingdom in several respects. First, in Canada personnel qualification requirements are established in the regulations and the plant must comply with these requirements. The exception to this rule is cases where individuals with special backgrounds or qualifications may be considered on a case-by-case basis. The AECB then approves or denies the assignment of the individual to his or her position. Second, the candidate must meet AECB examination requirements as well as plant requirements. Third, the AECB must license shift supervisors, shift operating supervisors, and authorized nuclear operators (ANOs), a position similar to the licensed reactor operator in the United States (Howey, 1980; Gummer, 1982).

The Japanese regulatory system is comparable to that of Canada in that the Ministry of International Trade and Industry (MITI), Japan's nuclear regulatory authority, issues few written prescriptive regulations. Instead, informal administrative guidance is directed at utilities, usually based upon annual reviews of licensee performance. Since MITI also sets power-production rates, this guidance is followed carefully. In the early 1980s, MITI moved toward making more specific directives to utilities. In particular, Japan added a qualifications certificate regulation requiring that shift supervisors be licensed (Thermal and Nuclear Power Engineering Society, 1981; Tokuno, 1981).

The Swedish system is similar to Canada and Japan: licensees are regulated indirectly through the issuance of a plant operating license that signifies acceptance of the plant's selection, training, and qualification personnel program, coupled with more direct regulatory control over personnel selection and training. In 1980 the Swedish nuclear regulatory authority, the Swedish Nuclear Power Inspectorate (SKI), issued a set of regulations specifying recruitment, training and competence evaluation criteria and procedures for operators. Due to the relatively small industry, professional norms are also shared; most of the nuclear operators in Sweden have received training in the same educational institutions (Backström, 1982). No major changes in overall approach to regulatory control of staffing were found over the past decade. These regulatory descriptions will be useful in interpreting the changes or stability that have taken place in each of the countries in the areas of licensing, education, and training.

4.2 Operator Qualifications: Licensing, Education, and Training

After the accident at TMI, regulators throughout the countries discussed in this study immediately took a number of steps in the area of nuclear power plant staffing requirements. These steps were witnessed in the adoption and expansion of several licensing programs, educational regulations, and training programs. However, in recent years, such changes have become less common. Licensing and educational regulations in particular have experienced few changes. Three of the countries currently have personnel licensing programs; changes that were made to these programs in terms of adoption or expansion were primarily made prior to 1985. In contrast, training continues to receive a high level of regulatory oversight and industry attention. The role of simulator training using generic or plant-specific simulators increased during the 1980s across all countries surveyed.

4.2.1 Operator Licensing Regulations

Over the decade covered in this study there has been only a slight increase in nuclear power operator licensing activities within two of the countries that were studied. In the early 1980s, Japan adopted a program to license its shift supervisors. Canada expanded its existing licensing program to require licensing of authorized nuclear operators (ANOs), who are similar to reactor operators in the United States. Licensing programs in the other countries have remained stable.

Prior to 1980, Germany and Canada required supervisory operations staff to be licensed. In Germany, guidelines were written in 1974 specifying that shift supervisors, their deputies, and reactor operators pass a written and oral examination (Martin, 1988). The federal nuclear regulatory authority in Germany, the BMU, also administers or supervises the administration of position-specific licensure examinations. This is more extensive than Canada's regulation requiring that shift supervisors, shift operating supervisors, and authorized nuclear operators (ANOs) be "authorized," which is functionally equivalent to licensing (Howey, 1980; Gummer, 1982).

The third country to require personal licensing of operations staff was Japan. It began licensing supervisors in the early 1980s. Its license examination is similar to that of senior reactor operator in the United States. Prior to this time, only the nuclear reactor chief engineer was required to pass an exam administered by the Safety and Technology Agency (STA). By June 1982 all utilities were also required by MITI to have one licensed shift supervisor per shift. The Thermal and Nuclear Power Engineering Society (TANPES) was designated by MITI as the organization responsible for testing and licensure, with MITI specifying only that license certificates be reactor specific, and be limited to terms of three years (Thermal and Nuclear Power Engineering Society, 1981; Tokuno, 1981).

Additional information about Japan's licensing program is provided as an example. In Japan, the operator is qualified for three years by the issuance of a certificate. To receive a license, candidates must pass a written exam, take several technical seminars, and pass an oral exam. The written examination tests a candidate's ability to conduct normal and emergency operations in the presence of an instructor who is designated by TANPES at each training center. The seminars are provided by TANPES and provide knowledge and skills for the operation of nuclear reactors. The oral examination tests candidates on their practical knowledge essential to fulfilling their duty as an operating supervisor. Oral exams are given after the candidate has taken the written test and received the technical seminars (H. Nishimura, MITI, Personal Communication, September 1992).

Twelve months before the license expires, qualification licensing certificates may be renewed and relicensed after operators receive the technical seminars training and simulator training (simulator training is discussed in greater detail in Section 4.2.3 below). If the applicant has been away from operations within the term of the license certificate, he or she may be required to retake the oral and written tests (H. Nishimura, Personal Communication, September 1992).

France, the United Kingdom, and Sweden do not require that reactor operators or their supervisors be licensed. As indicated earlier, the French nuclear utility, EDF, is responsible for all decisions relating to the competence of its personnel, with the nuclear power plant superintendents authorizing individuals to perform specific functions (Courvoisier et al., 1981; International Atomic Energy Agency, 1980). In the United Kingdom, it is the responsibility of the British national utility, Nuclear Electric, and the Scottish national utility, Scottish Electric, to translate that authorization into particular practices.

Although the Swedish nuclear regulatory authority, SKI, currently does not examine or license individual operators, plans were made in the early 1980s to implement a system to monitor operator competence (Backström, 1981). This monitoring system has since been implemented and is discussed further in the review of training programs.

4.2.1.1 Summary

Few changes in licensing have occurred over the past decade. Currently, three of the countries in this study (Germany, Canada, and Japan) require personnel to be licensed via regulatory requirements. Of these, Germany and Canada had existing licensing programs prior to the 1980s. Only Japan adopted a new operator licensing program within the time frame of this study. However, Japan made this change in the early 1980s. Thus, no additional countries have adopted a licensing program since 1985. Overall, then, there has been a slight increase in operator licensing requirements in the 1980s.

4.2.2 Educational Regulations

Over the past decade, few countries have adopted or changed regulations dictating minimum educational requirements. Germany, which introduced a regulation in 1979 for shift supervisors to be university graduate engineers, is an exception. In Sweden, from the early 1980s to the present, the minimum educational standards are regulated in the form of plant technical specifications. All plants in their technical specifications have committed to operators having two years of post-high school training. SKI reviews plant hiring requirements to ensure that utilities have minimum educational standards in place. These technical specifications were implemented after TMI as a result of a review of post-TMI training requirements.

Canada, France, Japan, and the United Kingdom do not have regulations specifying educational requirements. In each of these countries the utilities are responsible for establishing educational criteria for operators as opposed to complying with prescriptive regulatory requirements. In the United Kingdom, as in France, education and training norms are established de facto through the national training center run by the state utility. The United Kingdom continues to have no formal regulations dictating specific education requirements. There are no planned changes in education or experience requirements (V. Madden, Nuclear Electric, Personal Communication, June 1991). Similarly, Japan does not have regulations specifying educational minimum requirements (H. Nishimura, Personal Communication, September 1992).

4.2.2.1 Summary

There appears to be little change in educational requirements across the six countries that were studied. Germany requires that shift supervisors be graduate engineers. Sweden added the requirement for operations personnel to have an associate degree.

However, the majority of countries studied do not have educational regulations. In Canada, France, Japan, and the United Kingdom utilities are responsible for establishing educational criteria for operators.

4.2.3 Operator Training

Several trends in operator training among the countries surveyed are reviewed in this section.

4.2.3.1 Training Program Structure and Oversight

In France, Canada, and the United Kingdom, nuclear power training programs are highly standardized because there is one primary utility in each of these countries that has one or two major training centers (e.g., EDF in France, Ontario Hydro in Canada, and Nuclear Electric in the United Kingdom). In Germany, Japan, and Sweden there are national training centers that are jointly owned and operated by utilities. National training centers were established after TMI in the former Federal Republic of Germany and the United Kingdom. There has been more attention to operator training in regulation and practice throughout the 1980s.

4.2.3.2 Simulator Training

Simulators are a central component of these national training programs. All of the countries that were surveyed have used simulators in their training programs since TMI and continue to do so. In Sweden and Germany, the use of training simulators is required. In Canada, Japan, France, and the United Kingdom, the use of simulators is determined by the utility. Simulators are usually housed at the national training centers, although plant-specific simulators may also be used. In Japan, for instance, utilities use the national training centers (the BWR Operator Training Center for BWRs and the National Power Training Center for PWRs), as well as on-site compact simulators and computer-assisted training facilities. In Canada, only licensed operators receive regular simulator training, although unlicensed operators who supervise other unlicensed operators such as auxiliary operators are beginning to receive simulator training. In 1984, the former Federal Republic of Germany nuclear regulatory authority, the BMI, increased operator simulator training requirements (Martin, 1988).

In countries that use a combination of direct and indirect regulatory mechanisms, such as Canada and Sweden, there has been a move toward greater oversight of utility training programs. The Canadian nuclear regulatory authority, the AECB, has in recent years placed more emphasis on training programs that allow trainees to be tracked through their development. In the early 1980s the Swedish regulatory authority, SKI, was developing a monitoring system for nuclear operator training. In 1980 SKI issued the first regulations for operator training. In 1986 the regulations were revised, and SKI eliminated some detailed demands on utility training organizations. In 1989 SKI expanded training requirements for all plant personnel and expanded the training requirements for control room personnel (Jende, 1989). These regulations specify the training elements for control room personnel (shift supervisor, assistant shift supervisor, reactor operator, assistant reactor operator, and turbine operator). Utility training program elements such as course structure, evaluation, course descriptions and records, general competence levels, and retraining are monitored. SKI annually reviews training and qualification regulations with Swedish utilities.

4.2.3.3 Training Content

In the early 1980s a number of countries immediately responded to TMI by improving their operator training programs. Training requirements implemented in the former Federal Republic of Germany most closely reflected regulatory changes instituted at that time in the United States. The regulatory agency, BMI, specified the content and duration of operator simulator training and retraining, recommended that licensing examinations be given at simulators, and proposed additional training in thermodynamics and thermohydraulics. The BMI also issued training guidelines for non-operating personnel and developed retraining programs for supervisors and training staff. Similarly in Sweden, special courses on heat transfer and thermohydraulics were implemented (Pfeffer and Kraut, 1985). These fundamentals of nuclear operator training are well established among all of the countries that were reviewed. Table 4.2 provides a summary of operator training courses at the BWR Operator Training Center in Japan to illustrate a typical operator training program.

During the 1980s, several new training content issues arose throughout the countries that were surveyed. In Canada, plant aging concerns and increasing automation have changed the training methods and objectives to accommodate these complexities. The United Kingdom and Germany have increased training requirements in the areas of emergency planning and accident management. In the United Kingdom the NII requires the national utility, Nuclear Electric, to define new duties and responsibilities for staff in the area of emergency planning. This requirement has entailed the development of new training requirements for these designated staff by Nuclear Electric (similar changes were made by Scottish Electric, Scotland's national utility). In Germany, accident management measures were introduced in the mid-1980s as part of utility training requirements (Martin, 1988).

Among several of the countries that were surveyed, an emerging concept affecting the philosophy and practice of nuclear power plant operator training has been the expansion of training into non-technical areas. As discussed above, training programs in the early- and mid-1980s focused on technical competency requirements for operators and supervisors. New programs in the last several years have been established to ensure that these skills are adequately communicated to subordinates and colleagues through improved supervision and team interaction. Although shift supervisor training has traditionally involved training in communications, direction, and oversight, new emphasis on team skills training is evident in Canada, France, Japan, and the United Kingdom. For instance, in Japan, "family training" is provided to shift crews to improve their team work. Problem solving in the simulator is used to facilitate team solutions.

As of 1991, the NII in the United Kingdom was in the process of developing a new site licensing document that may entail new requirements for supervisory training and teamwork. The United Kingdom's national utility, Nuclear Electric, has been developing training specifications in support of these anticipated requirements in the areas of management skills, interpersonal skills (such as self-awareness, communication, and how to recommend a course of action), problem solving/decision making skills, stress management, team work and team building skills, and financial and commercial awareness of nuclear operations. (V. Madden, Nuclear Electric, Personal Communication, June 1991).

4.2.3.4 Summary

In many of the countries that were surveyed, training is highly standardized because of a large utility with one or two major training centers (e.g., France, Canada, and the United Kingdom), or national training centers that are utility-owned and operated (e.g., Germany, Japan, and Sweden). This means that training program standards are well established industry wide and the overall impact of training is monitored closely. Simulators, a relatively new training aid prior to TMI, are now used extensively across all of the countries that were surveyed. In the 1980s new training issue areas emerged, especially in the areas of supervisory skills training, team skills training to complement existing technical programs, and emergency planning and management. Many of the changes to training programs in these countries build upon the initial training focus that was set after TMI, namely, to establish and ensure operator competency.

4.3 Selection and Career Progression

A dominant approach in the early 1980s that has continued into the 1990s is the practice of developing operations staff in-house by hiring at the entry level position (e.g., auxiliary operator or equivalent) and offering in-house training programs. All countries provide considerable specialized training for recruits to the system.

Table 4.2 BWR training courses (Japan)

Course Title	Description	Duration
Standard Operator Training	Designed for personnel experience as suboperators (auxiliary operators) with basic skills and knowledge of nuclear operations. The purpose of this course is to develop trainees to become operators. The course consists of lectures, plant observation, and simulator training	12 weeks
Intensive Operator Training	Same as above except that course focuses on developing operational skills in the simulator	4 weeks
Operator retraining	Simulator refresher training for current operators	9 days
Advanced Operator training	Designed for higher ranking operators and is designed to upgrade supervisory skills and knowledge in emergency situations, decision making, management, supervision, and direction	5 days
Family training	Team skills training designed to improve crew competence and teamwork	1 day
Basic lecture	Course designed for those taking the standard or intensive training course and provides basic knowledge about nuclear technology	2 weeks

Source: MITI (1992).

Utilities in the majority of countries in this study continue to hire recruits at the entry level position. The majority of these countries provide a career progression that extends from an entry-level position to a supervisory position (e.g., shift supervisor or equivalent). An exception to this is Germany, which established a requirement in 1979 that shift supervisors be graduate engineers. Entry-level recruits who do not have graduate engineering degrees cannot be promoted beyond deputy shift supervisor.

Sweden, Japan, and the United Kingdom currently offer opportunities for shift supervisors to move to higher management positions in operations and other plant departments.

4.3.1 Recruitment Into Operations Positions

All of the countries in this study hire operations staff at an entry level assistant operator position and promote these operators after they have acquired specified experience and training. For instance, Sweden, the United Kingdom, France, and Germany typically bring hires into operations at the technician or equivalent level and provide training and experience opportunities to become reactor operators. Germany uses the apprentice model in which workers are brought in at the beginner's level and trained for a particular specialty (Farber, 1988).

In the post-TMI period, three countries created paths to allow individuals who met specified criteria to enter operations at a higher level. Germany added this career path due to the regulation initiated in 1979 that shift supervisors be graduate engineers. France added this additional career path in the early 1980s due to labor shortages that existed within the senior operator position. Shortly thereafter, Japan added an additional entry route – hiring individuals with requisite experience directly into the reactor operator position, then promoting them to senior operator (Au et al., 1982).

In the early 1980s more labor supply sources were used to hire operations staff than are used currently. The labor sources for entry into reactor operator positions differed considerably by country, although the majority of countries provided multiple routes for entry into operations. The basic streams of labor in the early 1980s came from the following sources:

- conventional power plant personnel;
- high school level vocational background;
- technical training programs equivalent to an associate degree; and
- university level degree.

In the early 1980s, operations staff were hired primarily from educational institutions. Specifically, five countries used entry-level operators from high school programs. To a lesser extent, hires were from technical schools and universities. In Sweden operators were recruited who held a two-year technical degree; this degree appears to be equivalent to an associate degree in the United States. The United Kingdom recruited associate degree level individuals, and tended toward hiring university degree level individuals in the early 1980s (Backström, 1982).

Recently, there has been a declining reliance on individuals with conventional power plant or other industry experience as a source from which to recruit operations personnel. On occasion, plants in Sweden will hire operators from other process industries or refineries, such as paper plants (I. Blom, SKI, Personal Communication, July 1992).

Today, as in the early 1980s, the primary source of recruits to entry level positions is educational institutions. In the 1990s, technical schools are the primary source, as compared to high schools in the early 1980s. Five countries in the early 1980s hired new operators at the high school level. Just one country (Japan) currently relies on high schools as a source. In contrast, Canada, France, Sweden, and the United Kingdom hire from technical schools. The United Kingdom has increased the required number of technically qualified engineers from one per shift crew to all operator positions in newer stations (P. Gardner, NII, Personal Communication, 1992). Germany currently hires individuals with ten years of elementary school training plus three years of practical and theoretical vocational training. Thus four countries currently hire from technical schools, which are broadly defined to include engineering schools and community colleges.

Universities continue to be a less central source from which to recruit operations staff. Germany recruits individuals with four-year degrees for entry to the shift supervisory position. Sweden hires individuals with four-year degrees on occasion.

In the early 1980s, labor supply, recruitment, and retention problems were significant, particularly in Germany and France; the same was true in the United States at that time. Work conditions (e.g., shift work, limited advancement opportunities, required requalification) and the nature of the job (boredom, lack of challenge) were seen as significant contributing factors to this problem. Labor supply issues are currently not regarded as problematic in France, Sweden, Japan, or the United Kingdom. As discussed in following sections, labor supply issues have been ameliorated in part by increasing operator retention either through promotion or transfer into other departments such as training. In France in particular, nuclear operations is regarded favorably as an occupation due to its monetary and career benefits. In Japan, lifetime employment at corporations, including utilities, is common practice. Thus, across all of the countries in this study operator labor supply does not appear to be the problematic issue it was in the early 1980s.

4.3.2 Operator Career Progression

All countries except Germany have promotion systems that enable entry level hires to work their way up to the shift supervisor position. In Sweden, the United Kingdom, and France, there are four levels from entry level to shift supervisor level. A typical career progression proceeds as follows: auxiliary operator, reactor operator, assistant shift supervisor, shift supervisor. In Sweden newly hired workers start as station technicians and advance to shift supervisors within a period of 11 to 22 years. In France, it takes slightly longer--from 15 to 25 years--to become a shift supervisor. Differences in the time it takes to advance to the next level are often based on educational level. As an example, in Canada college graduate recruits would be required to obtain four years of experience prior to being promoted to supervisory positions, whereas high school graduates would be required to obtain 12 years of experience (Gummer, 1982). Currently, the professional, qualified staff from universities or other places in the United Kingdom typically qualify as desk operators in three to four years (similar to reactor operators in the United States), with possible advancement to supervisor within five additional years.

In contrast, the careers of operators in Germany who do not have a graduate engineer degree (i.e., craftsmen) are limited. Craftsmen can only be promoted to deputy shift supervisor. The 1979 education regulation served to shorten their career path. This regulation was a significant change from prior practice, partially in response to an accident in the Brunsbuttel power plant in 1978. In some cases implementation of this regulation has required the demotion of existing shift supervisors who do not hold the required degree (Au et al., 1982). Some German states, such as Bavaria, already had this as established practice prior to the 1979 change. In 1980, approximately 40 percent of shift supervisors were graduate engineers; the completion date for the transition to shift supervisors with graduate engineering backgrounds was January 1984.

The majority of countries continue to use a single career path for promoting operators. These countries include Sweden, the United Kingdom, Japan, and Germany. Typically, recruits are hired and trained to become auxiliary operators or an equivalent. Following set training and experience criteria, operators move up a pre-determined path.

Two exceptions to this are Canada and France, which offer a choice to the operator in terms of the roles they will occupy as they advance. Operators in France have four possible routes from which to choose: (1) from assistant shift supervisor to shift supervisor or trainer; (2) from shift supervisor to trainer; (3) directly to trainer; or (4) directly to another department, such as maintenance (Y. Dien, EDF, Personal Communication, October 1992).

In Canada there are essentially two career paths an operations hire may pursue. Both paths start out from the Nuclear Operators-in-Training (NOIT) position. Following approximately two years of training, NOITs are promoted to Nuclear Operators (NO)--the equivalent to an auxiliary operator in the United States. At this point, two separate paths may be chosen. One path advances the NO to the position of Supervisory Nuclear Operator position (SNO)--an unlicensed position, charged with supervising the work of the NOs in the field. SNOs are paid nearly as much as a licensed operator. From here individuals may move into planning or other departments. The other path advances the NO to the Authorized Nuclear Operator (ANO) position, a licensed position, that is the equivalent of a reactor operator in the United States. To become an ANO, one must receive training and pass an examination for a license. ANOs may advance to Shift Operating Supervisor (SOS), or make a lateral move to training, planning, or other departments.

Germany, France, and Japan continue to offer career paths that begin at higher (non-entry level) positions. At this time Germany is the only country that has established an exclusive route (via engineering degrees) to the shift supervisor position. Due to this regulation, engineering graduates--those with a university level engineering degree--are eligible for the shift supervisor position after obtaining one and a half years of nuclear power plant experience.

4.3.3 Shift Supervisor Progression Opportunities

Three countries offer career advancement or placement options to shift supervisors, typically in the form of lateral moves to other managerial positions within the plant or advancements to more advanced managerial positions. These countries are Sweden, Japan, and the United Kingdom. Sweden offers flexibility to shift supervisors by allowing them to be managers for other departments within the plant. Although shift pay is much higher than pay for regular day jobs, some people want to go to a day job after many years of shift work (I. Blom, SKI, Personal Communication, July 1992).

As in Sweden, Japan currently has many opportunities for movement from operations into supervisory positions or into other plant departments. Japanese utilities have a "life-long employment system" that bases promotions from operations into supervisory positions on "devotion to duty and ability" (H. Nishimura, MITI, Personal Communication, September 1992).

In the United Kingdom, shift supervisors with backgrounds from universities are viewed as a hiring pool from which station senior management are selected.

Unlike in Sweden and Japan, Canadian shift operating supervisors are not able to move to the position of department manager or other equivalent positions if they do not have college degrees.

4.3.4 Summary

Currently, educational institutions continue to be the primary source from which personnel are recruited. This trend could be seen starting in the early 1980s. Technical schools, more than high schools or universities, continue to be primary sources from which personnel are recruited.

The continued practice of training and educating newly hired workers seems to be a way to achieve and maintain a quality workforce, as opposed to hiring individuals with related work experience or with four-year degrees.

There is considerable variation in the educational background of those individuals who are selected for reactor operator positions. Canada, France, and Japan followed a pattern similar to the United States in the early 1980s of hiring at the high school level, while Sweden and the United Kingdom tended to recruit from institutions of higher education at the associate degree, and sometimes, university degree levels. During the 1980s, there has been a clear trend toward hiring more highly educated workers, i.e., those with vocational or higher post-secondary education.

Most countries that were reviewed provide for career progression from assistant operator to shift supervisor, the highest level of advancement. This is the common career path in the United States. The following examples are several exceptions that have developed since TMI. In the United Kingdom, progression beyond shift supervisor to operations management appears to be a common practice. In France, Canada, and Japan, multiple career paths are available to operations staff to progress into other plant departments such as training or maintenance. Germany introduced the engineering degree requirement for shift supervisors, limiting the career path for typical entry level recruits. Germany's response was made due to an accident in the Brunsbüttel Nuclear Power Plant in 1978.

4.4 Shift Composition: Regulations and Practice

In the early 1980s there was little variation across countries concerning shift organization. The shift complement generally included the positions of shift supervisor, assistant or deputy supervisor, reactor operators, auxiliary or equipment operators, and some additional support personnel. The major differences at that time were the extent to which the shift complement was augmented by other support staff such as maintenance, health physics, and engineering staff (Pfeffer and Kraut, 1985).

Today the operations shift complement remains largely unchanged. France was the only country to add a new position on shift. Following TMI, a safety engineer was added to advise the shift during emergencies or other incidents. This position is similar to the shift technical advisor in the United States.

4.4.1 Number of Operations Staff on Shift

The typical full operating shift complement (on shift at the plant, but not necessarily in the control room) for a single unit plant ranges from six to eight staff in the United Kingdom; from eight to ten staff in Germany and Sweden; from nine to twelve staff in Japan; and from eleven to thirteen staff in Canada. Canada maintains the largest shift staff, primarily due to maintenance being organized on a shift basis. Two countries that were reviewed provided additional engineering expertise in response to TMI: France added the safety engineer, the equivalent to the shift technical advisor position in the United States (Melber and Schreiber, 1983; SECY-92-026). Germany added the interim shift engineer (which has since been replaced by the degreed shift supervisor, as discussed previously in Section 4.3). The addition of engineering expertise was intended to provide an additional safety measure in the event of emergency events; staff on-shift with engineering expertise can assist the operating crew in diagnosing a problem and recommending a course of action. The French safety engineer is also responsible for taking control of the plant during an accident.

Current typical shift complements for each of the countries surveyed are provided in Table 4.3. At one Canadian utility, one shift crew provides coverage for four units. This configuration includes maintenance staff on shift. The integration of maintenance staff in operations is due to the reactor design used in Canada (CANDU), which allows continuous refueling and maintenance during operation.

In 1980, France had three operators for two 900 MWe units. Today there are four principal operators and more auxiliary operators. A second assistant shift supervisor has been added to the shift complement. A safety engineer (ISR), similar to the shift technical position in the United States, is also assigned to each shift. At 900 MWe dual-unit sites, the shift supervisor and assistant shift supervisor are simultaneously responsible for both units. Technical personnel are not assigned to one specific unit. Specific unit assignments are made only at the unit operator and assistant unit operator levels. Overall, the shift complement in France is higher than it was in the early 1980s.

In Germany, shifts are composed of a shift supervisor, a deputy shift supervisor, a licensed reactor operator, non-licensed operators, and equipment or field operators (Farber, 1988). In the control room, the regulated minimum of personnel must include one shift supervisor, one assistant shift supervisor, and one reactor operator (Pfeffer and Kraut, 1985).

In Japan, most plants have the same shift composition as shown in Table 4.3; the main difference between plants is the number of auxiliary equipment operators (AEOs). There may be one, two, or three AEOs, depending on the utility's operating practice. MITI has no requirements for the minimum number of operators required on shift. However, MITI holds a meeting with each utility every year and confirms the shift crew composition according to the plant license and technical specifications.

Sweden requires utilities to establish the minimum number of shift operators in its technical specifications. In the shift composition there is no shift engineer and no senior reactor operator. However, Sweden does have an engineer who is on call within the plant, not in the control room, and who is in charge of external communications in the event of an incident until plant management arrives (Pfeffer and Kraut, 1985).

In the United Kingdom, the control room crew is supported on shift by engineering, maintenance, and health physics staff. A dedicated relief engineer is now under the control room supervisor. Table 4.3 shows the typical staffing for a two-unit/one control room plant, with engineering, maintenance, and health physics staff on shift.

In several countries that were reviewed, engineering expertise is used to analyze complex technical problems at hand in case of an accident or event (Melber and Schreiber, 1983). In some cases (the former Federal Republic of Germany, Sweden, and the United Kingdom), engineering expertise was integrated into the requirements for the shift supervisor. France introduced a safety engineer on shift as a post-TMI requirement. This position is also responsible for health physics (Pfeffer and Kraut, 1985). Thus, across the countries that were reviewed, the importance of engineering expertise to complement the operating crew is apparent either in established engineering skill requirements for senior-level operators, or in the addition of a safety engineer on site during operations.

4.4.2 Number of Operating Shift Crews

The number of shift crews maintained at nuclear power plants ranged from four to seven in the early 1980s. Japan typically maintained four shifts, Federal Republic of Germany power plants ranged from four to six shifts, with five shifts being the most common; Canada and the United Kingdom maintained five shifts; and Sweden used seven shift crews. In comparison, the United States maintained from four to six shifts. Across countries, a six to seven shift crew rotation means that one shift was assigned to training.

In France, plants were previously operated on a six-shift cycle, which left little time for training. Now, for all sites there are seven shifts (six on shift while a seventh is in training) (*Nucleonics Week*, June 28, 1990). In Germany, a five-shift rotation pattern is common, although a few plants use six shifts. For example, at the German utility, RWE, a five-shift rotation pattern is used: three eight-hour shifts six days a week, and two twelve-hour shifts on Sundays. From Tuesday to Friday, an additional day shift is available. Retraining time is made available for the day shift (Pfeffer and Kraut, 1985). In Japan, plants now usually operate on a five-shift system instead of on four shifts, which was more common in the early 1980s.

Table 4.3 Typical shift configuration by country

Canada[1]	France[2]	Germany[3]	Japan[4]
Four Unit Site: • 1 Shift Supervisor (supervising all staff, about 80 total) • 1 Shift Operating Officer • 4 to 6 Authorized Nuclear Operators (ANO) (similar to ROs in United States) • 4 Supervisor Nuclear Operators • 14 - 30 Nuclear Operators • 10 Nuclear Operators in training	Two Unit Site: Twin Units 900 MWe: • 1 Shift Supervisor • 1 or 2 Assistant Shift Supervisors • 4 Operators • 6 or 7 Auxiliary Operators • 1 Safety Engineer per plant One Unit Site: • 1 Shift Supervisor • 1 Assistant Shift Supervisor • 2 Operators • 4 Auxiliary Operators • 1 Safety Engineer per plant	One Unit Site: • 1 Shift Supervisor • 1 Assistant Shift Supervisor • 1 Reactor Operator • 1 Auxiliary Operator • 2 skilled workers (mechanics) • 1 skilled worker (electronics)	One Unit Site: • 1 Shift Supervisor • 1 Assistant Shift Supervisor • 1 Senior Operator • 1 Assistant Senior Operator • 1 Reactor Operator • 1 Auxiliary Equipment Operator (AEO)

Sweden[5]	United Kingdom[6]	United States[7]	
One Unit Site: • 1 Shift Supervisor • 1 Reactor Operator • 1 Turbine Operator (works outside of control room) • 2 Station Technicians (usually outside of control room)	Two Unit Site: • 1 Shift Charge Engineer Control Room: • 1 Control Room Supervisor • 2 Reactor Operators • 1 Relief Engineer Plant Operations: • 1 Assistant Shift Charge Engineer • 1 Plant Engineer • 2 Assistant Engineers • 1 Operations Foreman • 9 Operators • 1 Fuel Route Engineer • 1 Fuel Foreman • 4 Operators Maintenance: • 3 Shift Maintenance Engineers • 2 Shift Maintenance Foremen • 17 Shift Craftsmen • 6 Craft Attendants	Single Unit Site: • 2 SROs • 1 STA • 2-3 ROs • 4 AOs	Twc Unit Site: • 4-5 SROs • 1 STA • 4 ROs • 8 AOs

[1]Source: Ontario Hydro (1992)
[2]Source: Electricité de France (1992)
[3]Source: Pfeffer and Kraut (1985)
[4]Source: Ministry of International Trade and Industry (1992)
[5]Source: Swedish Nuclear Power Inspectorate (1992); Pfeffer and Kraut (1985)
[6]Source: Nuclear Electric (1991)
[7]Source: NUREG/CR-6122 (Melber et al., 1993)

4.4.3 Support Staff

It appears from the available information there have been few changes made to the way support staff are integrated with shift operations. Canada was the only country in the early 1980s to have an extensive maintenance crew on shift at all plants. This was due to the CANDU reactor design, which allows maintenance work and refueling during plant operation. In the United Kingdom, a maintenance crew was on shift. However, maintenance was generally separate from shift operations. In both Canada and United Kingdom, shift organization in regard to support staff remains largely unchanged. Maintenance staff on shift also varied across plants in the Federal Republic of Germany. Again, no fundamental regulatory changes or new practices in this regard have been reported over the past decade.

In the early 1980s health physics was represented on shift in France, Sweden, and the United Kingdom, as in the United States, and the same remains largely true today. Canada, however, is unique in that operators are trained in radiation protection and are responsible for monitoring their own radiation levels. In Sweden, an electrical technician, chemical engineer, and radiation protection engineer are on shift, while an engineer is on call.

4.4.4 Summary

Shift composition and scheduling practices in the countries that were studied are similar to practices in the United States. However, there are several noteworthy differences. Canada maintains the largest shift crews due to maintenance and refueling activities being carried out during plant operation. France and Germany require an engineer with a university degree to be on shift. In France, the safety engineer position is similar to the shift technical advisor position in the United States. In Germany, the shift supervisor must hold an engineering degree. The other countries that were reviewed do not require a university-degreed engineer on shift, although Sweden and the United Kingdom have access to engineering expertise either through an engineer on call, or, through shift supervisors who hold engineering degrees (even though this is not a regulatory requirement). The number of operating shifts overall has expanded slightly in the 1980s. Overall, fewer plants among the countries that were reviewed appear to use a four-shift rotation pattern anymore. France added an additional shift for training and now has seven shifts. Swedish nuclear power plants also operate on a seven-shift rotation pattern. German nuclear power plants use five to six shifts. Canada, the United Kingdom, and Japan usually employ a five-shift rotation. Japan has expanded its average number of operating shifts from four to five. The average number of shifts used appears to be between five and seven. The integration of support staff does not appear to have changed. The number of operators on shift appears to have remained largely stable.

5 Summary and Conclusions

A number of changes in staffing requirements and practice were implemented immediately following the accident at TMI in 1979. A summary of key findings in operations staffing regulation and practice during the period from 1979 to 1990 is provided below.

5.1 International Trends in Nuclear Power Development

The decade of the 1980s was marked by a great deal of growth across all of the countries in both the number of nuclear power plants that began operating and the growing reliance of each country on nuclear energy as a proportion of their total electrical production. During the 1980s the total amount of electricity produced by nuclear energy doubled in four of the six countries reviewed. Today, the percent of electricity produced by nuclear power varies widely internationally. In the countries that were studied, the percent of electricity derived from nuclear energy ranges from 13% in the United Kingdom to 75% in France; by way of contrast, approximately 19% of the United States electricity is from nuclear sources. Although the United States remains the world's largest producer of nuclear energy, France, Germany, and Japan expanded their nuclear power capacity at a faster rate than the United States during the 1980s. Japan and France will continue building nuclear power plants in the 1990s. Canada and Germany recently finished constructing several plants, and their industries are not expected to grow in the near term. The United Kingdom is expected to construct few if any new plants and Sweden is not expected to construct any new plants in the 1990s. The rapid international growth of nuclear power in the 1980s thus, is not expected to continue in the 1990s.

5.2 International Comparison of Industry Organization and Regulatory Framework

Three types of nuclear industry organization were found in this international comparison: (1) countries in which electrical production is government owned and operated (France, Canada, and the United Kingdom), (2) countries with private and public ownership but with significant government investment (Japan), and (3) countries similar to the United States, where utilities are highly diverse in terms of public and private ownership and operation (Germany and Sweden). Aside from in the United Kingdom, no major changes have been made to each country's regulatory framework in terms of fundamental re-organizations, rewriting of the basic laws and statutes governing nuclear power operations, or utility ownership and operations. In the United Kingdom, where state-run utilities have been privatized, there have been some changes in station licensing requirements and utility operation. Although the nuclear industry in the United Kingdom is privatized, the government remains the largest shareholder.

A continuum of regulatory approaches to staffing was revealed by a regulatory review of the countries in this study. This continuum ranges from direct regulatory control enforced through specific prescriptive regulations, to indirect regulations where the regulatory authority uses the station licensing process to either approve or reject operating practices proposed by the utility. Germany is most similar to the United States in that it regulates its utilities through specified regulatory requirements. Canada, Japan, and to a lesser extent, Sweden, use a mix of direct prescriptive requirements and agreements contained in the station license. France and the United Kingdom are regulated primarily through the station license where staffing practices are agreed to between the utility and the regulatory agency. No major changes in overall approach to regulatory control of staffing were found over the past decade.

There appears to be an association between industry type and position on the regulatory continuum. Countries with historically government-owned and operated nuclear industries tend to use the indirect regulatory approach (e.g., France and the United Kingdom before privatization). The direct, prescriptive regulatory approach is associated with a highly diverse nuclear industry organization, as in Germany and the United States. Because nuclear industry and regulatory approaches are linked, the best sources of regulatory lessons learned for the United States may be countries with a similar nuclear industry and a similar regulatory approach. While a country's approach to and implementation of new requirements is determined by the configuration of its nuclear industry and regulatory approach, regulatory issues are common across all countries that were studied.

5.3 International Trends in Staffing Regulation and Practice

Since the TMI accident in 1979 there has been a clear trend toward increased regulation and oversight of nuclear power plant staffing practices in the six countries that were studied. This experience is similar to that in the United States. Most of these changes in requirements and practices were instituted in response to TMI in the first half of the 1980s. Several changes in regulation in the period immediately following TMI include the following:

- The former Federal Republic of Germany instituted new operator educational requirements.
- Japan required licensing of shift supervisors.
- National training centers were formed in the former Federal Republic of Germany and in the United Kingdom.
- A safety engineer position was added to the shift complement in France.
- Canada and the former Federal Republic of Germany established simulator training and retraining requirements for operators.
- Sweden began monitoring operator competency requirements.

The former Federal Republic of Germany made the most extensive changes in the period following TMI. For example, shift supervisors were required to have an engineering degree, and a number of new training requirements were instituted. These changes were motivated in response to a nuclear power accident in Germany and to TMI.

Throughout the 1980s the increase in staffing regulation was most pronounced immediately following TMI, and levelled off as a number of post-TMI requirements were implemented. (There has been no decrease in staffing standards or deregulation since TMI.) There have been only a few changes in regulatory and industry practices regarding operations staff in the latter half of the decade of the 1980s. Several changes have to do with training:

- In two countries, Canada and Sweden, there has been a trend toward more direct oversight of utility training program effectiveness.
- National training centers (all utility-operated) have been developed, with highly standardized training programs that make extensive use of simulators.
- New training issues have emerged within operations, especially in the area of supervisory skills and team skills training to complement existing technical programs, and in the area of emergency planning and management.

These changes are similar to those that have occurred in the United States, except that the United States has no national training centers. Other changes include the following:

- Operator educational levels have risen. Prior to TMI, a high school or equivalent level of education was the norm for entry-level auxiliary operator hires. Since then common practice is to hire entry-level operators with two years of post-secondary training.
- Several countries have established additional entry routes at higher level positions. In Germany, France, and Japan, direct entry into operations at a higher level has been established by allowing certain applicants to go directly into operations without working up through the auxiliary operator position.
- The average number of shifts on rotation now ranges from five to seven shifts. Previously, most plants employed four shifts.

Several staffing areas have remained essentially unchanged or have been modified slightly:

- There has been little activity in operator licensing requirements.
- All countries continue to rely heavily on recruiting entry-level operators and providing extensive in-house training to prepare recruits for their job responsibilities.
- The typical career progression route for operators is essentially unchanged for entry-level hires. New hires enter operations at the auxiliary operator or reactor operator level (depending on educational and experience level) and work up to the positions of senior reactor operator and shift supervisor.
- The average number of operators on shift appears to have remained relatively stable. Most countries that were reviewed have 7 to 10 operations personnel for a single-unit site. In Canada, a four-unit site has 11 to 13 operations personnel on shift.

5.4 Conclusion

Immediately following the accident at TMI, a great deal of regulatory and utility attention was given to nuclear power plant operator staffing in other countries as well as in the United States. After implementing a number of changes, a period of relative stability followed. While staffing continues to receive a great deal of regulatory attention, regulations have not changed significantly in recent years; this pattern of regulatory change parallels the United States experience. Important changes have occurred primarily in the area of training.

Recent changes in training regulations and practices are relevant to the United States nuclear industry. For example, training programs have been developed for positions outside of operations such as in maintenance and health physics. Growing attention is being paid to team performance training in addition to technical training, and simulators are now used extensively. These changes generally parallel changes in training in the United States nuclear industry. The United States departs from other countries only in that it has no national training center.

While several countries, including the United States, gave lengthy consideration to educational requirements for operators in the early 1980s, only Germany instituted new educational regulations. In other countries, recruitment practices were modified to draw recruits with post-secondary education increasingly from technical schools. Combined with upgraded training for new recruits, this modification presents an alternate response than changing minimum educational requirements to the post-TMI concerns about operator qualifications. Thus, all the countries, including the United States, have addressed this issue, although the specific ways of enhancing shift crew competency have differed.

Another related issue relevant to current nuclear power staffing policy in the United States is how engineering expertise is provided on shift. In some countries (Germany, Sweden, Canada, and the United Kingdom) engineering expertise on shift has been addressed by increasing training and education standards for shift supervisors either in regulation or practice. France's and the United States were the only countries to add a new shift position, the safety engineer and the shift technical advisor, respectively, to provide engineering expertise on shift.

In conclusion, the six countries that were studied are similar to each other and to the United States, both in the pattern of significant regulatory activity in the early 1980s and in the recent continued activity in the area of training.

6 References

Atchison, R.J., Boyd, F.C., and Domaratzki, Z., "Canadian Approach to Nuclear Power Safety," *Nuclear Safety*, *24*(4):439-458, 1983.

Au, M.L., Di Salvo, R., and Merschoff, E. "Survey of Foreign Reactor Operator Qualification, Training, and Staffing Requirements," U.S. Nuclear Regulatory Commission, Washington, D.C., 1982.

Backström, T., "Letters from Foreign Regulatory Authorities Surveyed: Sweden," (M. L. Au, R. Di Salvo, and Merschoff, eds.), *Survey of Foreign Reactor Operator Qualification, Training, and Staffing Requirements*, U.S. Nuclear Regulatory Commission, Washington, D.C., Appendix C, 1982.

Beckjord, E., Golay, M., Gyftopoulos, E., Hansen, K., Lester, R., and Winje, D.K., "International Comparison of LWR Performance," Massachusetts Institute of Technology, Cambridge, MA, MIT EL 87-004, 1987.

Boegel, A.J., Chockie, A.D., Huenefeld, J.C., Morgenstern, M.H., and Olson, J., "Analysis of Japanese-U.S. Nuclear Power Plant Maintenance," U.S. Nuclear Regulatory Commission, Washington, D.C., NUREG/CR-3883, 1985.

Chockie, A.D., Geisendorfer, C.L., Hauth, J.T., Morgenstern, M.H., Olson, J., Scott, W.B., Terrill, E.S., Thurber, J.A., and Yost, P.R., "Maintenance Approaches and Practices in Selected Nuclear Power Programs and Other U.S. Industries: Review and Lessons Learned," Pacific Northwest Laboratory, Richland, WA, BHARC-700/88/016, 1988.

Courvoisier, P., Stadie, K.B., Stephens, M.E., "Qualification and Training of Nuclear Power Plant Operating Staff in the NEA Member Countries," *Current Nuclear Power Plant Safety Issues, Vol. 1: Conference Proceedings, Stockholm, 20-24 October, 1980*, International Atomic Energy Agency, Vienna, Austria, IAEA-CN-39/3.2:121-130, 1980.

"Turning backwards," *The Economist*, *315*(3):19-20, March 1990.

Farber, G.H., "Experience Gained from the Impact of Regulation and Training Measures on Shift Personnel Qualifications in the Federal Republic of Germany," *Proceedings of the CSNI*, U.S. Nuclear Regulatory Commission, Washington, D.C., NUREG/CP-0089, 1988.

Freund, J., Philip, G., and Schwarzer, W., "The Nuclear Safety Standards Commission of the Federal Republic of Germany," *Nuclear Safety*, *25*(5):623-632, 1984.

Gummer, W.K., "Letters from Foreign Regulatory Authorities Surveyed: Canada," (M. L. Au, R. Di Salvo, and E. Merschoff, eds.), *Survey of Foreign Reactor Operator Qualifications, Training, and Staffing Requirements*, U.S. Nuclear Regulatory Commission, Washington, D.C., Appendix C, 1982.

Hibbs, M., "Amendment to atomic act will limit German regulatory waste role," *Inside N.R.C.*, *13*(2):6, January 28, 1991.

Hoegberg, L., "The Swedish Nuclear Safety Program," *Nuclear Safety*, *29*(4):421-435, 1988.

Howey, G.R., "Ontario Hydro Hires Staff Centrally," *Nuclear Engineering International*, *25*(296):29-32, 1980.

International Atomic Energy Agency, *Manpower Development for Nuclear Power: A Guidebook*, International Atomic Energy Agency, Vienna, Austria, TRS No. 200, 1980.

"French Legislators Recommend Changes in Nuclear Safety Oversight," *Inside N.R.C.*, *12*(26):7-8, December 17, 1990.

"The Institut de Protection et de Sûreté Nucleaire (IPSN)," *Inside N.R.C.*, *12*(3):6, January 29, 1990.

Jende, E., "Training and Qualifications," *SKI*, Swedish Nuclear Power Inspectorate, Stockholm, Sweden, July 31, 1989.

MacLachlan, A., "French Regulatory Agency Moves Toward More Independence," *Inside N.R.C.*, *13*(10):7, May 1991.

MacLachlan, A., "Industry Minister Raises Status of French Regulatory Agency," *Inside N.R.C.*, *13*(2):6, January 1991.

MacLachlan, A., "French Regulators Escape Oversight, but MPs Will Debate Safety," *Inside N.R.C.*, *11*(26):7-8, 1989.

Madden, V.J., "The CEGB Approach to the Selection and Training of Nuclear Power Station Personnel Within the UK Regulatory Framework," *Proceedings of the CSNI*, U.S. Nuclear Regulatory Commission, Washington, D.C., NUREG/CP-0089, 1988.

Martin, H., "The Manufacturer's Part in NPP Personnel Training in the FRG," *Proceedings of the CSNI*, U.S. Nuclear Regulatory Commission, Washington, D.C., NUREG/CP-0089, 1988.

Matsuda, Y., Suehiro, K., and Taniguchi, S., "The Japanese Approach to Nuclear Power Safety," *Nuclear Safety*, *25*(4):451-471, 1984.

Melber, B.D., and Schreiber, R.E., "Engineering Expertise on Shift in Nuclear Power Plants: The Foreign Experience," U.S. Nuclear Regulatory Commission, Washington, D.C., NUREG/CR-2952, 1983.

Melber, B.D., Roussel, A., Baker, K., Durbin, N., Hunt, P., Hauth, J., and Terrill, E., "Staffing Decision Processes and Issues: Case Studies of Seven U.S. Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, D.C., NUREG/CR-6122, 1993.

Mysercough, P.B., "Training of Engineers for Nuclear Power Station Operation," *Nuclear Energy*, *19*(2):105-109, 1980.

"World List of Nuclear Power Plants," *Nuclear News*, *37*(9):43-62, June 1993.

"Four Companies Set Up for East's Nuclear Sites," *Nuclear News*, *34*(3):51, March 1991a.

"Plan Dropped for Closure of Two Units in 1995," *Nuclear News*, *34*(3):50-51, March 1991b.

"World List of Nuclear Power Plants," *Nuclear News*, *34*(2):53-72, February 1991.

"Nuclear Need Stressed in Three Government Acts," *Nuclear News*, *33*(15):51-54, December 1990.

"MITI Wants to Add 40 New Reactors by 2010," *Nuclear News*, *33*(9):54-55, July 1990.

"Worldwide Nuclear Capacity, 1989," *Nuclear News*, *33*(8):61, June 1990.

"Nuclear Electric Assumes CEGB Nuclear Properties," *Nuclear News*, *33*(7):72, May 1990.

"Ontario Hydro's 25-year Plan Calls for New Nuclear Units," *Nuclear News*, *33*(2):41-44, February 1990.

"Annual NSC White Paper Call Attention to Aging," *Nuclear News*, *32*(15):67, December 1989.

"Work Halt at Wackersdorf Agreed by Federal Cabinet," *Nuclear News*, *32*(9):62-67, July 1989.

"Closure of Two Units Seen for 1995, 1996," *Nuclear News*, *31*(5):70, April 1988.

"Add 122 New Units by 2030, Report Advises," *Nuclear News*, *29*(11):59, September 1986.

"France," *Nucleonics Week*, [illegible], June 28, 1990.

Olson, J., and Terrill, B., *Review of European Maintenance Experience*, Battelle Human Affairs Research Centers, Seattle, WA, 1988.

Pershagen, B., and Nilson R., "Nuclear Safety in Sweden - Policy and Practice," *Nuclear Safety*, *25*(1):1-18, 1984.

Pfeffer, W., and Kraut, A., "Qualification, Training, Licensing, and Retraining of Operating Shift Personnel in Nuclear Power Plants," *Nuclear Science and Technology*, 1985.

Rippon, S., "An Obituary for Germany's Advanced Projects," *Nuclear News*, *32*(8):76, 1989.

Schnurer, H.L., and Seipel, H.G., "The Safety Concept of Nuclear Power Plants in the Federal Republic of Germany," *Nuclear Safety*, *24*(6):743-782, 1983.

SECY-92-026, *Implementation of the Shift Technical Advisor at Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, Washington, D.C., 1992.

Tanguy, P., "The French Approach to Nuclear Safety," *Nuclear Safety*, *24*(5):589-606, 1983.

Thermal and Nuclear Power Engineering Society, "Qualification Licensing System for Supervisory Operators at Nuclear Power Plants," Tokyo, Japan, 1981.

Tokuno, Y., "Genshiryoku Hatsuden Unten Sekininsha no Shikaku Nintei Seido (Licensing System for Supervisory Operators of Nuclear Power Plants)," *Nihon Genshiryoku Gakkaishi* (*Journal of the Nuclear Society of Japan*), *23*(11):20-22, 1981.

Appendix A: A Comparative Review of Nuclear Power Regulatory Frameworks

This appendix provides a comparative review of nuclear power regulatory frameworks in Canada, France, Germany, Japan, Sweden, and the United States. Each section begins with a brief description of the number of nuclear utilities within the selected country to indicate the relative complexity of the nuclear power regulatory framework. Legislation, regulatory agencies and their regulatory philosophy and practices are described. Major changes in any of these areas in the 1980s are discussed where appropriate.

Canada

Canada has a small set of nuclear utilities (three total). Ontario Hydro is the largest utility with 16 of Canada's 18 nuclear power plants, and is owned by the Ontario provincial government. The other two Canadian utilities with nuclear power plants are also provincially owned: Hydro Quebec and New Brunswick Electric Power Commission.

Atomic Energy Control Board (AECB)

The Atomic Energy Control Act authorizes and defines the powers of the Atomic Energy Control Board (AECB) and Atomic Energy of Canada Limited (AECL). The AECB, within the Ministry of Energy, Mines, and Resources, is the Canadian nuclear power plant licensing and regulatory authority. The AECB consists of a 5-member board, one of whom is appointed President and Chief Executive Officer. The AECB is supported by several hundred staff members at headquarters, and at plant sites through its Reactor Regulation Directorate (Atchison, Boyd, and Domaratzki, 1983).

The AECB issues general, skeletal regulations; the Atomic Energy Control Regulations are procedural with the exception of the basic radiation protection regulations. Specific plant safety requirements are applied during the licensing process, and are based principally on probabilistic risk assessment (PRA) methods.

The AECB issues relatively few regulatory documents related to nuclear power plant safety. Case-by-case review and reference to industry standards are the preferred regulatory practices. The Canadian regulatory framework allows nuclear power plant designers a large amount of discretion in designing plants to meet the basic regulatory criteria. These designs are submitted to the AECB for approval on a case-by-case basis. This has led to the gradual establishment of acceptable safety-related design standards which are evaluated against each new plant design. The second, more common regulatory safety approach is to apply detailed industry-wide standards. In Canada, nuclear power plant safety standards are produced by the Canadian Standards Association (CSA), one of a few Canadian standard development organizations. Some CSA nuclear standards adopt United States standards such as the American Society for Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. Generally, these standards are supported by the AECB with few exceptions (Atchison, Boyd, and Domaratzki, 1983).

Atomic Energy of Canada Limited (AECL)

Atomic Energy of Canada Limited (AECL), also within the Ministry of Energy, Mines, and Resources, is responsible for nuclear reactor design in Canada, and is the principal nuclear research and advisory group. The AECL initially developed the CANDU design nuclear power plant, and is currently the sole supplier of the CANDU reactor, twenty of which have been bought exclusively by Ontario Hydro. The AECL's Advisory Committee on Radiological Protection and Advisory Committee on Nuclear Safety advise the AECB on generic issues, regulations, requirements, and specific problems, although these agencies are not directly involved in plant licensing (Atchison, Boyd, and Domaratzki, 1983).

France

Nuclear power regulation in France is based on a series of acts covering various nuclear power activities, which were followed by a series of executive orders and regulatory edicts. There is no comprehensive atomic energy bill. However, a Parliamentary report recently recommended that the French government study the possibility of drafting an atomic energy bill (*Inside N.R.C.*, December 17, 1990). Figure 1 illustrates the French nuclear power industry regulatory framework.

Two essential characteristics of the French nuclear power industry's regulatory framework are standardization and centralization. In 1973, Electricité de France (EDF), France's single national utility, embarked on developing a standard series of basic plant designs. The majority of plants are one of three PWR designs: 600 MWe, 900 to

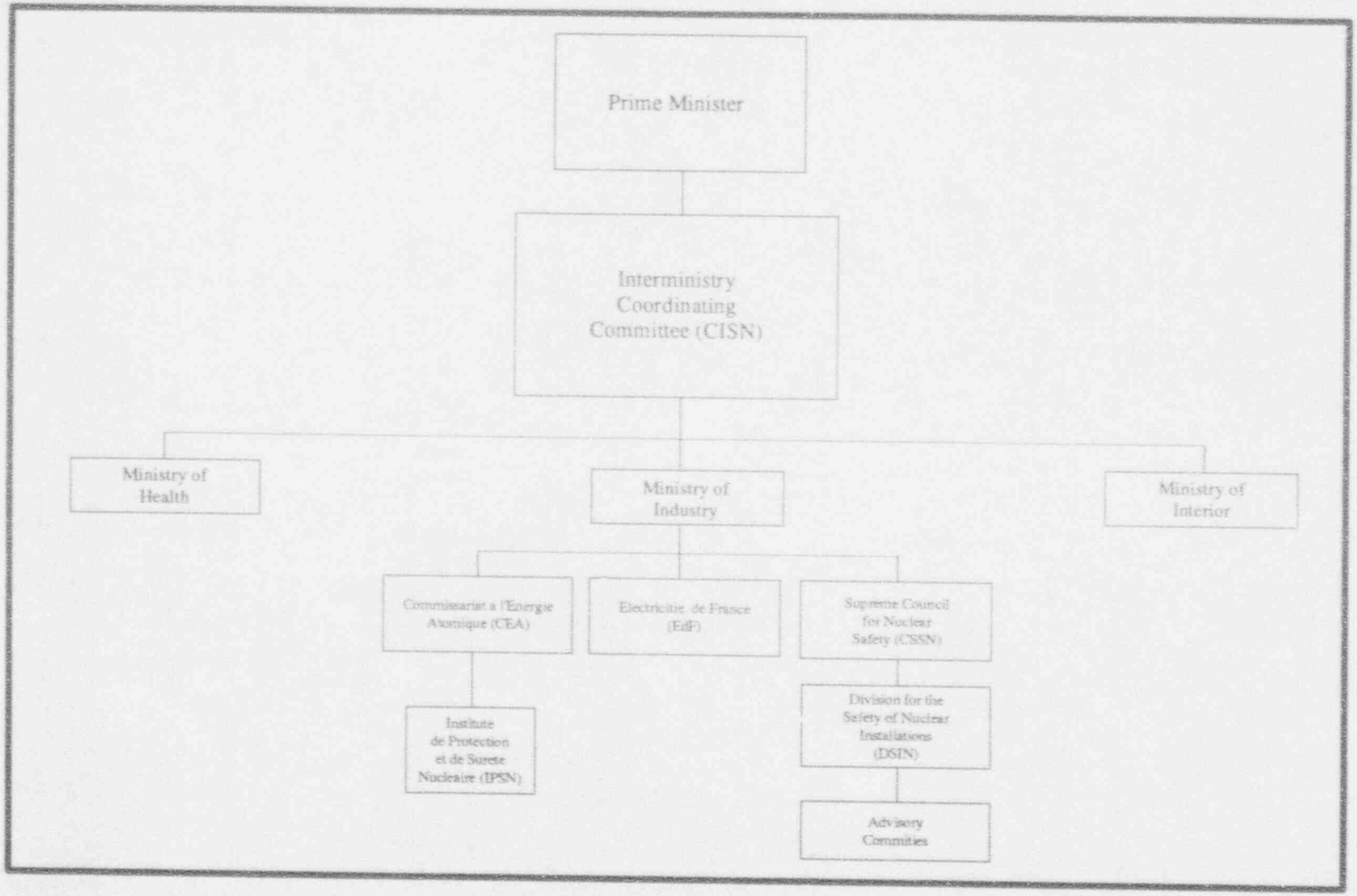

Figure 1. French nuclear power industry regulatory framework

Source: Olson, J., and Terrill E., *Review of European Maintenance Experience*, Battelle Human Affairs Research Centers, Seattle, WA., May 1988.

1,000 MWe, and 1,300 MWe. Most recently, units with 1,450 MWe operating capacity were added. Successive plant designs build upon past experience and lessons learned in design, construction, and operation. EDF also standardized its selection of vendors supplying balance-of-plant equipment. Many advantages to the standardized plant type approach are cited, most notably, the development of stable working relationships with suppliers, cost effectiveness in all phases of nuclear power plant planning, construction, and operation, and effective performance monitoring and feedback (Beckjord et al., 1987). Housed within the Ministry of Industry, EDF has a monopoly on electrical production in France. EDF is responsible for producing about 90 percent of France's total electricity supply, 75 percent of which is obtained from nuclear power. In addition to its role as nuclear power plant operator, EDF is the major architect and engineer (A/E) of nuclear power plants in France. As of 1987, EDF employed approximately 120,000 employees: 74,000 personnel are involved in distribution-related activities; 37,000 personnel are involved in power generation and transmission (nuclear and fossil); 6,000 personnel are involved in construction; and 3,000 personnel are involved in research and development activities (Olson and Terrill, 1988).

The French nuclear power industry's regulatory framework is also characterized by a high degree of centralization. The Ministry of Industry is primarily responsible for regulating nuclear power operations in France through its various agencies. The Ministry also plays a major role in nuclear power plant research and development, design, manufacture of nuclear steam supply systems (NSSS), construction, operation, regulation, and safety research.

Direction de la Sûreté des Installations Nucleaires (DSIN)

The former Service Central de Sûreté des Installations Nucleaires (SCSIN) which reported to the Industry Division of the Ministry of Industry and Land Use since its creation in the 1970s was recently elevated in 1990 to the Division level (MacLachlan, May 1991). It is now consequently called the DSIN.

The DSIN is responsible for nuclear power plant licensing after detailed technical assessments, establishing safety criteria and regulatory guidance, and conducting inspections. The DSIN also oversees the quality and safety of primary pressure components. Currently the Minister of Industry and the Environment Minister share responsibility for issuing nuclear licenses in France. Both agencies receive technical input from the DSIN.

The DSIN Industry and Research Directors are responsible for regulating operating nuclear installations within their regional jurisdiction. Altogether, the nine French regions are regulated by approximately 100 DSIN inspectors at regional offices. The regional offices represent both the Industry and Environment ministries in the field. At the beginning of 1991, there were approximately 70 permanent staff at the central office and about 100 total staff to regulate the French nuclear power industry as well as a number of fuel cycle facilities, research reactors, and other nuclear installations (MacLachlan, May 1991).

The DSIN inspectors report their findings to the DSIN's headquarters in Paris. The DSIN then sends a letter to the EDF, describing its findings and seeking a response. The majority of problems are solved using this approach. Depending on the severity of the problem (local or general), the report may be sent to the site manager or to headquarters. This process is usually noted for its cooperative rather than punitive nature (Beckjord et al., 1987). Other agencies in charge of special areas of nuclear safety are the Ministry of Health for radioactive releases, and the Ministry of Interior for emergency preparedness. The Secretary of the Comité Interministériel coordinates all regulatory actions (Beckjord et al., 1987; Tanguy, 1983).

French nuclear power plants operate in accordance with the provisions of Safety Analysis Reports (SARs) and technical specifications. The technical specifications are comparable to those used in the United States, and are based in part on United States standards (e.g., ASME standards). The DSIN does not prescribe specific operating practices; instead, the DSIN either allows or terminates certain plant practices. Essentially, the DSIN uses what is referred to as a three-tiered regulatory structure, and is similar to nuclear regulatory approaches used in the United States and other countries surveyed (Tanguy, 1983), albeit with more orientation toward performance (i.e., specific practices) as opposed to compliance with applicable regulations. The basic safety rules, which are risk-oriented, comprise the first level of this three-tiered approach.

Safety criteria and instructions comprise the second level of the French regulatory approach. These prescriptive regulations are applied during design, construction, testing, and surveillance of primary plant systems.

At the third level, special technical requirements are issued, for example, as part of the plant construction permit. For instance, documents titled, *Régles Fondamentales de Sûreté* (RFS) provide guidance on compliance with French regulatory practice. Rules regarding design and construction of nuclear power plants are contained in a document titled, *Recueil Des Régles de Conception et de Construction* (or RCC) (Tanguy, 1983).

Atomic Energy Commission (CEA)

Similar to the DSIN, the Commissariat a l'Energie Atomique (CEA or Atomic Energy Commission) is also housed within the Ministry of Industry. Whereas the DSIN is responsible for nuclear regulatory activities, the CEA is the lead research and advisory group responsible for promoting nuclear energy through basic nuclear research, research and development of commercial reactors, safety evaluations, and basic nuclear training. The CEA is also a principal shareholder in Framatome, the sole manufacturer and supplier of nuclear steam supply systems (NSSS) for French nuclear reactors. Until 1963, nuclear safety was the sole responsibility of the CEA. After 1963, responsibility for issuing construction permits and operating licenses was given to the Ministry of Industry by government decree. Today, the CEA is the lead scientific and technical advisory committee for the French nuclear power industry (Beckjord et al., 1987; Tanguy, 1983).

The CEA houses the Institut de Protection et de Sûreté Nucleaire (IPSN). The IPSN is responsible for performing safety analyses of French nuclear power plant operations. The IPSN assists all government agencies in licensing, regulation, inspection, emergency planning, public education, and documentation, and performs all technical safety evaluations at nuclear installations. Nuclear regulatory decisions are based on evaluations performed by the IPSN. Final decisions are made only after special advisory expert groups are consulted. For instance, the Groupe Permanent Réacteurs (GPR) may be consulted (which is similar to the Advisory Committee on Reactor Safety [ACRS]).

In the past, the CEA's IPSN performed safety analyses for the DSIN nuclear regulatory board, and for the CEA itself, in support of nuclear power plant design and operation. In effect, the CEA, by assisting both the DSIN and the IPSN, was responsible for promoting and regulating nuclear power operations. This was similar to the role of the former United States Atomic Energy Commission. In response, however, to parliamentary demands for greater separation of powers between the two agencies, the IPSN is expected to become more autonomous, if a proposed reorganization is adopted. A new CEA reorganization plan moved some staff from IPSN to other parts of the new CEA, and prevents people from working on both technical support and licensing support projects (MacLachlan, 1989; *Inside N.R.C.*, January 29, 1990).

Advisory Committees

Two separate advisory committees within the Ministry of Industry report directly to the Minister regarding matters of nuclear energy development and safety: the Conseil Supérieur de la Sûreté Nucléaire (CSSN) and the Interministerial Commission for Nuclear Installations. The CSSN, created in 1973, advises the Ministry on scientific, technical, economic, social, trade union, environmental, and administrative issues involved in nuclear energy (e.g., nuclear power plant accidents, the safety of irradiated fuel reprocessing plants, and waste disposal). Members are chosen from the scientific community, environmental groups, and labor unions. The Interministerial Commission for Nuclear Installations is responsible for defining the state's role in promoting nuclear energy, and reconciling this role with public security and the environment (Beckjord et al., 1987).

Parliamentary Oversight

The French Parliament has recommended significant changes to the country's nuclear regulatory structure. Proposals include giving French regulators more independence, money, and staff. Another proposal calls for allowing the DSIN (discussed previously) to directly suspend plant operating licenses -- this right is currently reserved to the Minister of Industry. These and other proposals were developed as part of an eight-month parliamentary study of nuclear safety control (*Inside N.R.C.*, December 17, 1990). The Parliamentary Office for the Evaluation of Science and Technology Options, for whom the study was conducted, voted unanimously on December 12, 1990 to pursue a "mission" of monitoring French nuclear power regulation as a permanent mandate of the 32-member group.

Recently the French Parliament attempted to secure formal parliamentary oversight over nuclear regulation by creating a High Authority for Nuclear Safety independent from the executive branch (this attempt failed to gain the required support for passage) (MacLachlan, 1989). Legislators opposed the measure stating that it will unnecessarily complicate the plant licensing process. However, increasing oversight of the French nuclear power industry by the French Parliament has been seen in recent years (MacLachlan, January 1991).

Other Regulatory Changes

In 1990, a government advisory panel, the College for the Prevention of Technological Risks, recommended that the Ministry of Environment be given greater authority over nuclear regulatory activities, especially over the Central Safety Department for Nuclear Facilities (SCSIN) (now the DSIN). The organization also recommended that the DSIN be provided the means to do its own safety analyses instead of depending on outside entities, and that some of this technical support could be absorbed from the CEA. The college also called for the establishment of a National Evaluation Commission composed of domestic and foreign nuclear safety experts (MacLachlan, May 1991). Thus, the French nuclear power industry is increasingly subject to external oversight and regulatory reform which seeks to decentralize some of the highly centralized regulatory and research responsibilities held by several agencies.

Germany

The nuclear power industry framework in Germany is characterized by a great deal of diversity in terms of regulatory framework and utility structure and ownership. Germany has 16 nuclear power producing utilities which are publicly and privately owned. In recent years there has been a tendency toward centralization (i.e., greater federal oversight) of nuclear power operations in Germany. However, Germany's regulatory framework is still highly distinguished by complex regulatory linkages between public and private organizations involved in the regulatory process (Schnurer and Seipel, 1983). Figure 2 illustrates Germany's nuclear power industry regulatory framework.

Federal Minister for the Environment, Nature Conservation, and Nuclear Safety

The German regulatory framework is highly decentralized, involving various public and private actors in developing standards and regulating nuclear operations. The regulation of commercial nuclear power in Germany is based on the Atomic Energy Act of 1959. Up until 1986, the Federal Minister of the Interior (Bundesminister des Innern, or BMI) was responsible for enforcing the Atomic Energy Act. Today, the Federal Minister for the Environment, Nature Conservation, and Nuclear Safety (or BMU) is the responsible federal agency (Beckjord et al., 1987).

Several recent changes have been proposed to the German Atomic Act. The major changes currently being considered include: 1) striking nuclear energy promotion from the government's legal obligations; and 2) increasing regulatory control over costly nuclear power plant post-license backfits. This would reduce the protection currently afforded licensees under the principle of Bestandschut--proprietary rights over currently existing facilities (Hibbs, 1991).

Reactor Safety Commission (RSK)

The federal Reactor Safety Commission (Reaktorsicherheitskommission, or RSK) develops scientific and technical guidelines for designing, constructing, and operating nuclear power plants. The RSK consists of 20 members appointed by the BMU. Guidelines issued by this commission are used for reference when regulations are developed. The BMU then issues the safety criteria for nuclear power plants (Sicherheitskriterien für Kernkraftwerke) which describe the basic requirements for the design and operation of nuclear power plants. These regulations implement the general safety goals of the Atomic Energy Act.

Safety Standards Commission (KTA)

In 1972 the BMI established the Safety Standards Commission (Kerntechnischer Ausschuss, or KTA) for the purpose of bringing together the following member groups in developing nuclear power plant safety regulations:

- manufacturers and constructors
- owners and operators
- independent experts
- federal authorities
- technical experts

The KTA is responsible for developing and promoting the use of nuclear safety standards. The KTA develops specific safety criteria and provides detailed requirements for nuclear power plant quality assurance, design, manufacture, operations, and surveillance in support of safety criteria for nuclear power plants. These are then issued by the BMU.

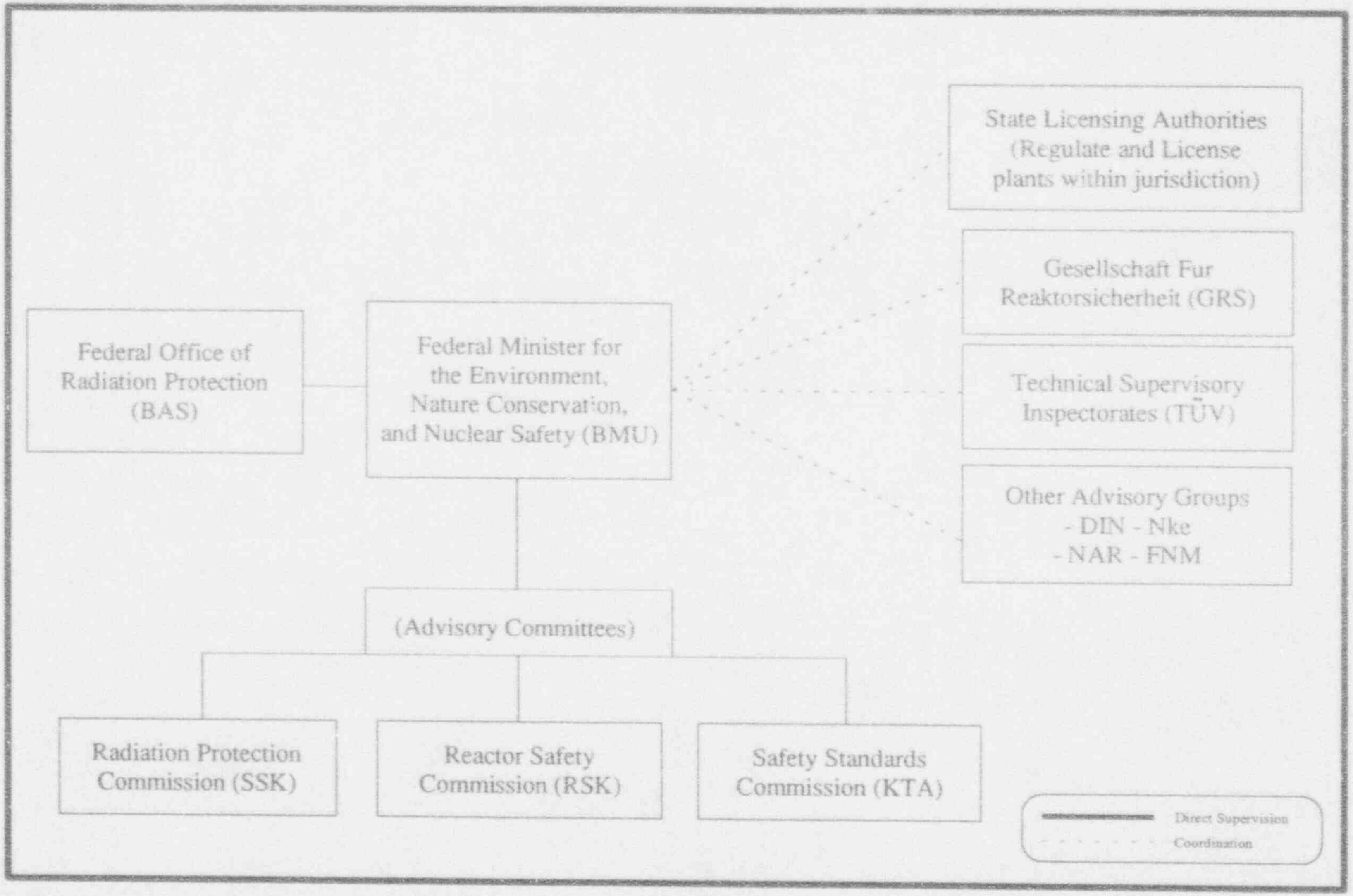

Figure 2. German nuclear power industry regulatory framework

Source: Olson, J., and Terrill E., *Review of European Maintenance Experience*, Battelle Human Affairs Research Centers, Seattle, WA., May 1988.

The KTA was formed to take advantage of experiences in the early days of commercial nuclear power development in the Federal Republic of Germany, when detailed standards were lacking and plant licenses were evaluated on an individual basis. Since the industry was expected to grow rapidly, the KTA was intended to capture industry experience and create uniform written technical standards to ensure high safety standards throughout the industry. The KTA is typically composed of 50 members, 10 members from 5 industry groups. The group is composed of scientists, engineers, and executives.

In developing a safety standard, literature and plant experience are reviewed. A proposal regarding the scope and content of the safety standard is then drafted. The safety regulations are reviewed and submitted for public comment. After final review, the regulation is submitted for approval. In order to pass, the regulation must be approved by a 5/6 majority vote by the KTA member groups. After the safety standard is approved by the KTA, it is passed on to the BMU, which publishes the standard in the Bundesanzeiger (Federal Gazette). On average, it takes approximately 5 years to draft a safety standard from time of commencement to publication. (Freund, Philip, and Schwarzer, 1984).

Other Industry Standards Development Groups

In addition to the KTA, other industry groups are involved in developing nuclear power safety standards, most notably, the Deutsches Institut for Normung, or DIN); the Technical Committee on Nuclear Engineering (Normenausschuss Kernteknik, or NKe); the Technical Committee on Radiology (Normenausschuss Radiologie, or NAR), and Materials Testing (Fachnormenausschuss Meterialprufung, or FNM) (Chockie, et al., 1988).

Independent Oversight Organizations

The German federal government relies extensively on independent oversight organizations to evaluate nuclear power plant safety. The Reactor Safety Company (Gesellschaft Für Reaktorsicherheit, or GRS) performs technical studies of nuclear power plant safety using probabilistic risk assessments (PRAs), coordinates international and domestic activities, and provides advice on nuclear energy issues. It also participates in formulating guidelines and regulations. The GRS is also responsible for Germany's light water reactor safety program (Beckjord et al., 1987).

The Technical Supervisory Inspectorates (Technische Überwachungsvereine, or TÜV) is another type of non-profit organization with responsibilities similar to the GRS. There are eleven TÜVs total. The TÜVs, which have operated as independent inspectors for over a century, are similar to Underwriters Laboratories in the United States, but with a much broader scope of expertise and application. Although the TÜVs act as independent experts, focusing on inspection and control of in-plant safety measures, they are supervised by the federal government (Beckjord et al., 1987).

State Licensing Authorities

The Atomic Energy Act requires each state to enforce laws governing nuclear power operations. Consequently, primary responsibility for regulating nuclear power plant operations is located at the state level with a State Licensing Authority in each of the 11 German states. State Licensing Authorities also coordinate the involvement of various public advisory groups and relevant state and regional agencies. In practice, there is broad latitude and variation between State Licensing Authorities, both in terms of their authority and enforcement (Olson and Terrill, 1988).

Japan

The Japanese utility industry assumed its current form in 1951 as a result of the United States occupation and reorganization of Japanese government and industry following World War II. This reorganization created nine new regionally based, private utilities. Today a total of eleven Japanese utilities operate nuclear power plants. Japanese utilities are owned by both public and private investors. Stock in some of the utilities is owned by the prefectural (district) government in which the utility is located. Thus, some of the country's utilities are partly government owned and controlled. Figure 3 illustrates Japan's nuclear power industry regulatory framework.

Ministry of International Trade and Industry (MITI)

In the 1950s Japar itiated the use of nuclear power with the creation of the Atomic Energy Act. The regulation of commercial nuclear power in Japan is based on the Electric Utility Industry Law and the Law for Regulation of Nuclear Source Material, Nuclear Fuel Material, and Reactors. These laws assign primary responsibility for commercial nuclear power plant operation to the Ministry of International Trade and Industry (MITI). MITI is

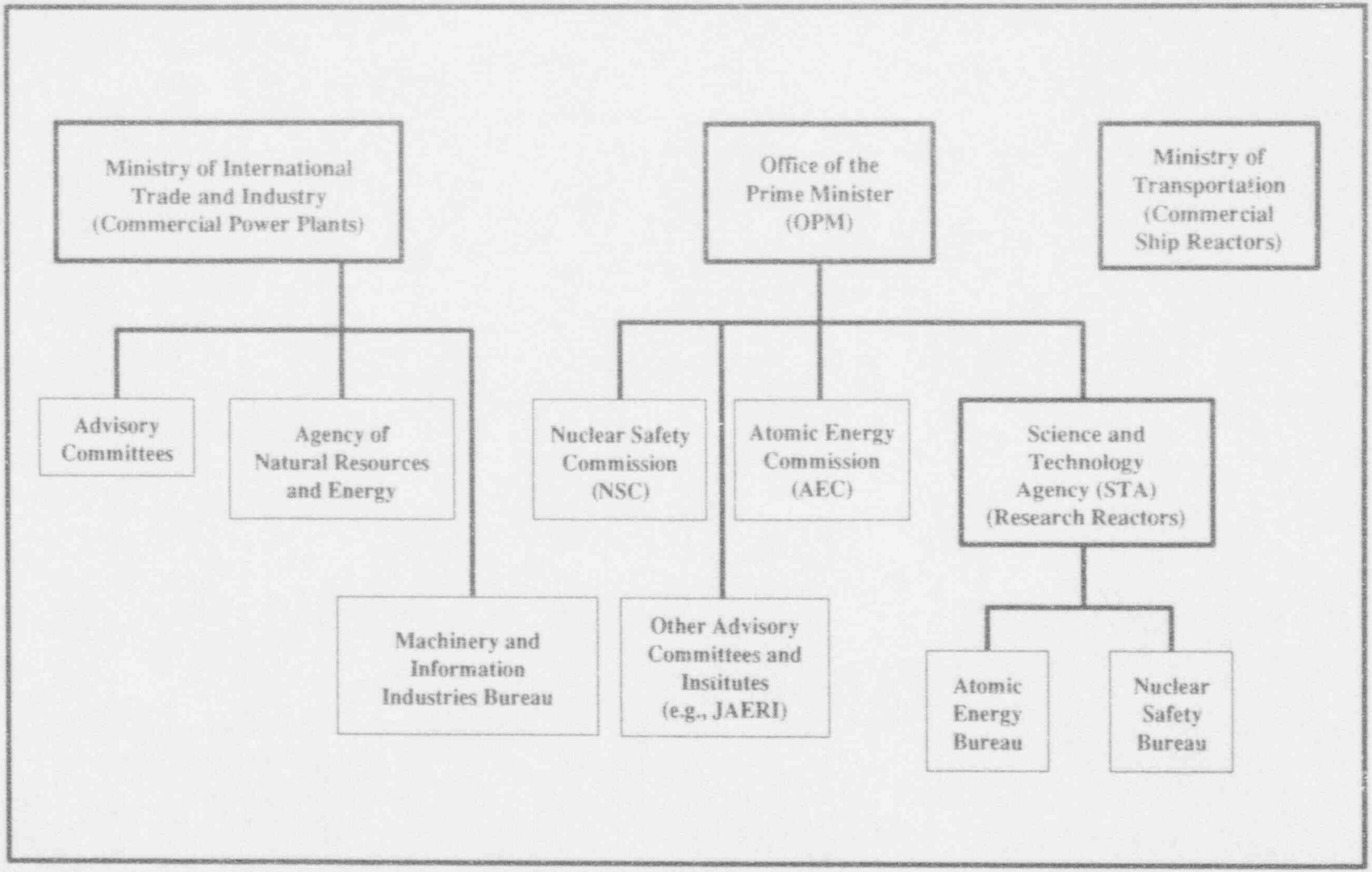

Figure 3. Japanese nuclear power industry regulatory framework

responsible for the following regulatory functions (Matsuda, Suehiro, and Taniguchi, 1984):

- investigating accidents and situations that might contribute to hazardous operations;
- directing electric utility companies to take effective countermeasures against accidents and hazardous situations;
- executing safety regulations based on preventive maintenance; and
- strictly enforcing changes and modifications resulting from annual inspections that last 3 to 4 months.

MITI has overall jurisdictional responsibility during planning, plant design, design alteration, plant construction, preparation, and annual inspections. Commercial nuclear power plants in Japan are shut down annually for inspection by MITI. MITI also supervises all training.

Similar to the role of the now defunct United States Atomic Energy Commission (AEC), MITI has organizational units responsible for commercial nuclear power safety regulation and nuclear power promotion. Many of the traditional safety regulation functions are carried out by the Public Utilities Department of the Natural Resources and Energy Agency.

Divisions within this department deal with power plant siting, licensing for construction, inspection, and enforcement (Boegel et al., 1985).

MITI also houses the Machinery and Information Industries Bureau which is engaged in the promotion of nuclear power technology. MITI also uses several advisory committees in the regulatory decision making process such as the Advisory Committee on Environmental Affairs and the Technical Advisory Committee on Nuclear Power Generation.

Other Advisory Agencies

In accordance with the Atomic Energy Fundamental Act amendment of 1978, extensive cooperation and advice is provided to MITI from various agencies within the Office of the Prime Minister (OPM), most notably the Science and Technology Agency (STA), and its two agencies, the Atomic Energy Commission (AEC), and the Nuclear Safety Commission (NSC). Both the AEC and the NSC advise the Prime Minister on issues of nuclear energy policy. These agencies were created in 1978 as a result of the reorganization of the old Atomic Energy Commission (AEC). The new AEC is responsible for promoting nuclear power and the NSC is responsible for overseeing nuclear safety (Beckjord et al., 1987).

Sweden

The nuclear power industry in Sweden is a combination of the state-owned Swedish State Power Board (SSPB) utility and a number of privately owned utilities. The SSPB is the largest utility in Sweden, providing half of Sweden's total electric generating capacity. The other two utilities, OKG Aktiebolag and Sydkraft AB, operate three and two nuclear power plants, respectively.

As noted by Beckjord et al. (1987), the Swedish nuclear power regulatory framework has several distinguishing characteristics:

- The Swedish nuclear power industry has an uncomplicated legal framework.
- Because the industry is small, safety committees can be contacted and problems resolved quickly.
- Sweden's nuclear power industry regulator, SKI, is fully empowered by the Swedish government to make decisions.
- The nuclear power plants are directly responsible for plant safety, not SKI.
- High concerns for plant investment costs are reasonably matched with safety concerns.
- Swedish utilities often take the initiative on solving problems.

Figure 4 illustrates the Swedish nuclear power industry's regulatory framework.

Swedish Nuclear Power Inspectorate (SKI)

The Swedish Nuclear Power Inspectorate (Statens Kärnkraftinspektion, or SKI) is the regulatory body under the Nuclear Activities Act. The Nuclear Activities Act, in place since 1984, covers nuclear activities in Sweden. It requires that a license be obtained from the government (or a designee) to construct and operate a nuclear facility, and that a nuclear power reactor may only be loaded with fuel if the licensee can demonstrate that the spent nuclear fuel will be disposed of safely. As a regulatory authority,

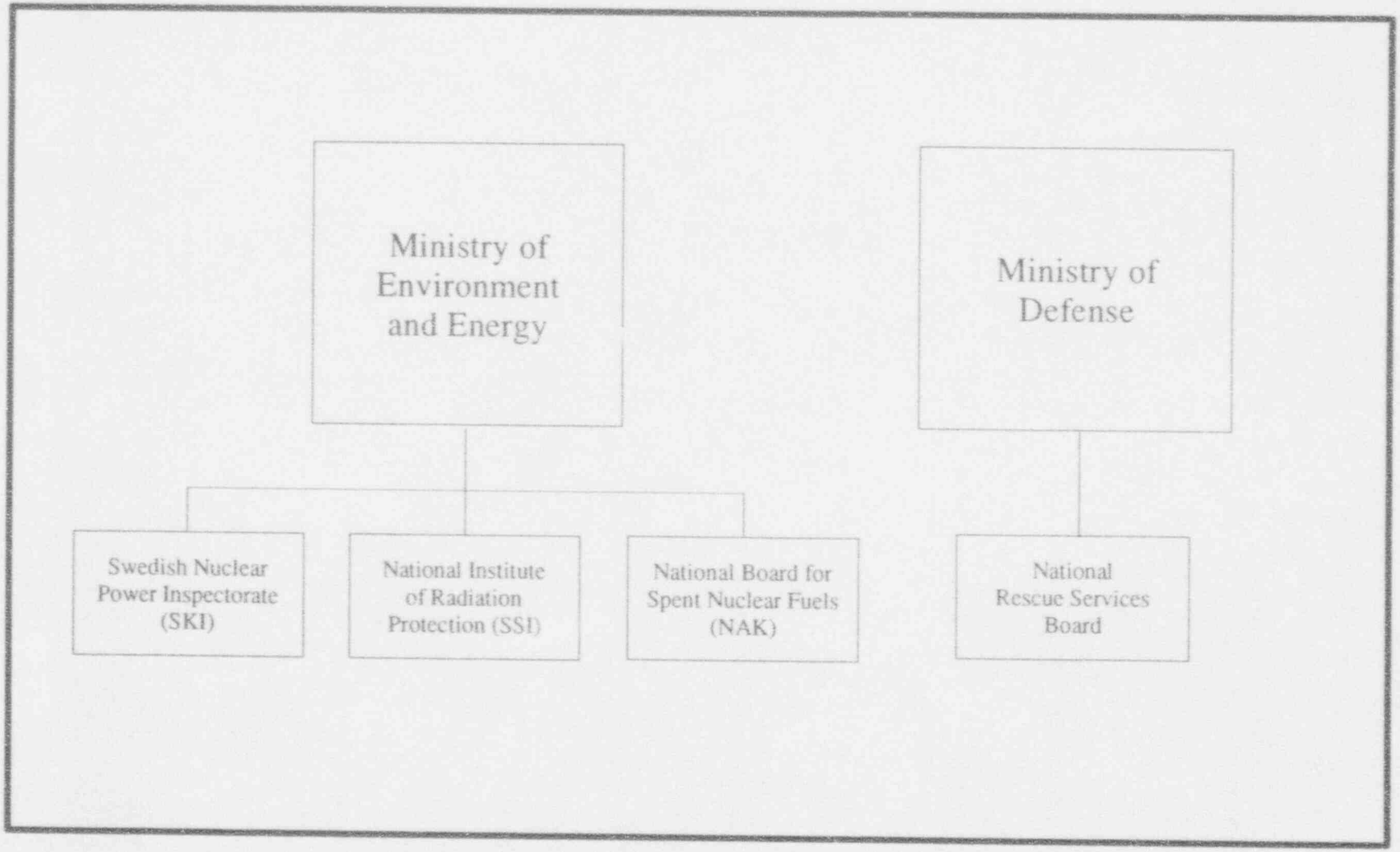

Figure 4. Swedish nuclear power industry regulatory framework

Source: *SKI*, 1991

SKI's principal duties are to oversee and promote nuclear power plant safety. Direct responsibility for nuclear safety resides with the owners who are required to comply with SKI's regulatory authority.

The Swedish Atomic Energy Act of 1956 regulates the basic rights to build, own, or operate nuclear reactors and to handle nuclear fuel materials. A special authority called the Delegation for Atomic Energy Matters was created to advise the government on nuclear power plant policy, licensing, and inspection. This delegation was the forerunner of SKI (Pershagen and Nilson, 1984; Hoegberg, 1988).

There have been no significant reorganization changes in the Swedish nuclear power regulatory framework since 1981. However, in 1986 SKI was moved into the Ministry of Environment and Energy. The Swedish government appoints members of the SKI Board and the Director General, who acts as the Board Chairman. SKI is composed of three advisory committees, all of which report directly to the Director General: reactor safety; safeguards; and research. The advisory members are experts in various fields, not employees of SKI, and are drawn from government, industry, and universities (Beckjord et al., 1987). The SKI is similar to the NRC in function. However, Sweden's Atomic Energy Act assigns final responsibility for plant operation and safety to each of the three individual utilities. The SKI issues general guidelines and regulations, and sets safety goals. The plant owners propose designs and solve problems as they develop, with SKI oversight. During plant design, construction, and operation, the SKI evaluates how various jobs are performed and their influence on safety. Finally, the SKI frequently conducts safety analyses of plants. These activities are carried out principally through two main offices: the Office of Inspection and the Office of Regulation and Research. The Office of Inspection's principal duty is to supervise nuclear facilities and safeguard fissionable material. The Office of Regulation and Research is concerned with examining nuclear facilities and regulating safety-related matters.

The SKI has a staff of approximately 90 personnel, almost equally divided between the two offices. The relatively small staff at the SKI reflects a general principle of Swedish nuclear regulatory practice, namely, to avoid overly detailed or prescriptive regulation. The SKI's main objective is to establish general safety performance standards, and to ensure they are achieved by the licensees rather than adhering to prescriptive regulations. Due to the small size of the Swedish nuclear power industry (3 utilities, 4 sites, and 2 reactor manufacturers), key personnel from the SKI and the utilities can meet to resolve technical issues with the SKI as they arise. Often this can be accomplished relatively quickly in a small gathering of technical experts who are well acquainted. Beckjord and others (1987) have argued that since this process is not encumbered by the legal and formal requirements found in the United States nuclear power industry regulatory system, resolution of technical issues related to nuclear power plant operations and safety is expedited (See also, Pershagen and Nilson, 1984; Hoegberg, 1988).

Simply put, SKI's regulatory philosophy is oriented more toward performance than compliance with prescribed standards. SKI's task is to ensure that utilities achieve performance goals established jointly by SKI and the utilities, as opposed to assuring compliance with prescriptive regulatory requirements. For example, there is no formal licensing of operators by SKI. Instead, utilities are responsible for annually testing and evaluating operator performance both in the simulator and on the job.

Raadet für Karnkkraftsakerhet (RKS)

The Swedish utilities jointly own and operate several industry organizations. Figure 5 illustrates the principal Swedish nuclear power industry groups. In 1980, following the accident at TMI, the Swedish nuclear utilities formed an industry representative organization called the Raadet für Karnkkraftsakerhet (RKS). The RKS is involved in nuclear power plant operational safety, and serves as a communication channel representing industry views before the SKI. The principal tasks of the RKS are:

- Safety analysis and experience feedback.
- Education and training.
- Quality assurance.
- Emergency preparedness.

The RKS has cooperative agreements with the Institute of Nuclear Power Operations (INPO) in the United States and with nuclear utilities in other countries. The RKS thus plays an important part in information exchange between the Swedish plants and with other foreign operators. The RKS also cooperates closely with the

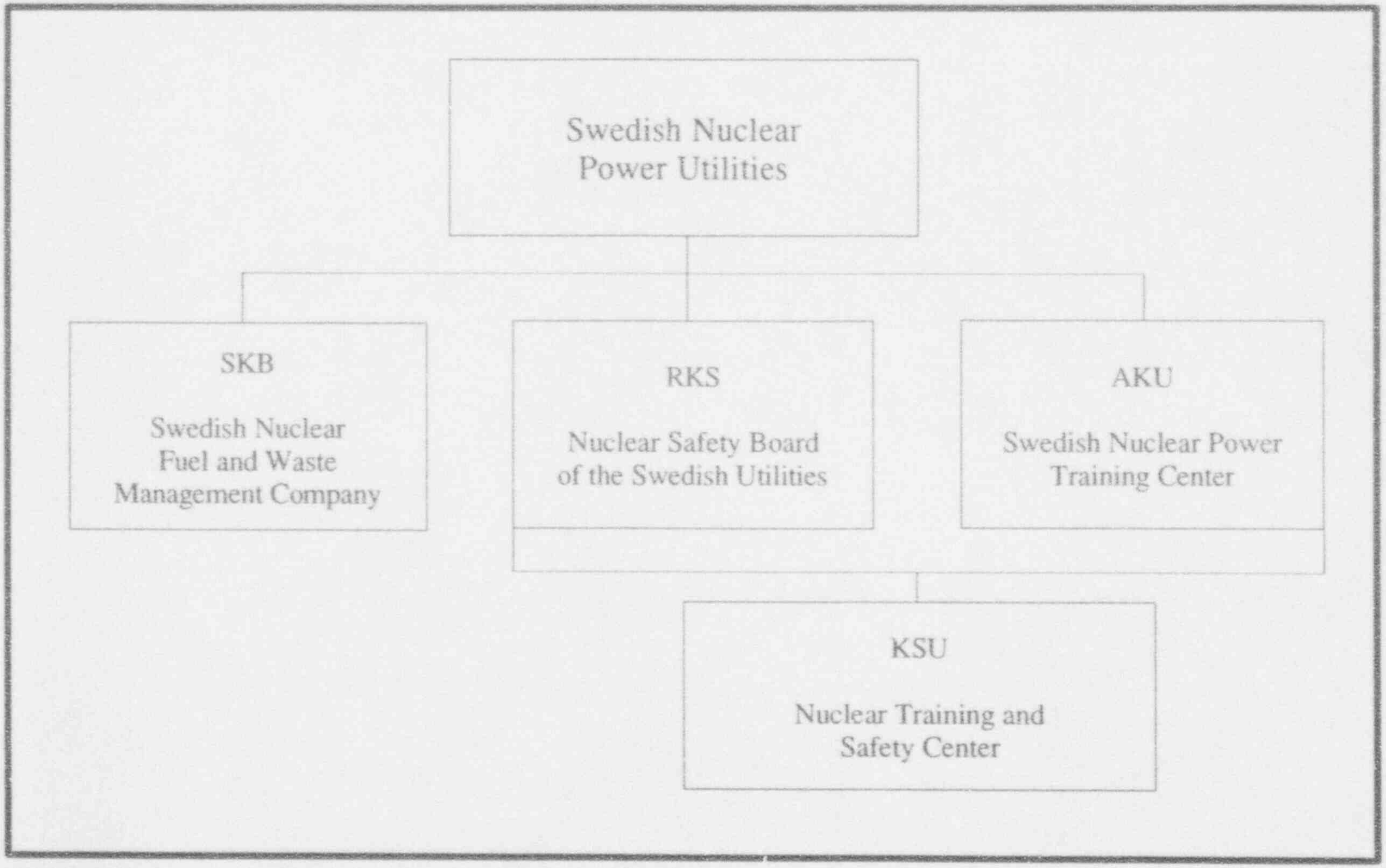

Figure 5. Swedish nuclear power industry groups
Source: *SKI*, 1991

Swedish Nuclear Power Inspectorate (SKI), the Swedish nuclear power regulatory agency. For example, RKS and SKI jointly prepared a Reliability Data Book on Swedish nuclear power plants describing components, failure modes, and statistics of Swedish nuclear power plants (Beckjord et al., 1987).

Nuclear Training Safety Center (KSU)

The Nuclear Training Safety Center (Kärnkraftsäkerhet och Utbildning, or KSU) is another jointly owned utility group. This organization specializes in operational feedback, education and training, safety analysis, human factors, quality assurance and nuclear power information. Nuclear power plant operators are trained at its simulator center.

Other Regulatory Agencies

Other Swedish government agencies and committees are directly and indirectly involved in regulating nuclear power plant operations. The National Institute of Radiation Protection (SSI) is similar in function to the U.S. National Council on Radiation Protection. The SSI establishes standards for radiation protection and compliance measures. The SSI's nuclear regulatory activities are managed by the Office for Nuclear Energy, which inspects nuclear facilities and their environments and handles emergency preparedness matters (Pershagen and Nilson, 1984; Hoegberg, 1988).

The Swedish Plant Inspectorate (SA) is responsible for all official testing of pressure retaining components at nuclear facilities. The National Board for Spent Nuclear Fuels (NAK) independently reviews each plant's waste management decommissioning activities. The National Board of Shipping regulates the shipment of radioactive materials. The National Board of Occupational Health and Health and the National Electrical Inspectorate exercise the same public surveillance at nuclear facilities as at other industrial enterprises. Nuclear research and development activities in Sweden are largely carried out by a state-owned corporation, Studsvik/Energiteknik (Beckjord et al., 1987). Finally, local safety committees review safety and radiation protection matters at the four nuclear power municipalities.

Parliamentary Oversight

The 1980/81 energy bill to the Swedish parliament (Swedish Government Energy Bill, 1980/81: 90, Appendix 1) set the course for Swedish nuclear power plant safety policy throughout the 1980s. The energy bill placed a great emphasis on plant-specific reliability programs based on probabilistic risk assessments and the area of severe accident management. Major revisions were made to the SKI safety requirements for operating nuclear power plants. There has also been a major emphasis on human factors research throughout the Swedish nuclear power industry during the 1980s (Hoegberg, 1988).

United Kingdom

The Central Electric Generating Board (CEGB), formerly the United Kingdom's largest national government utility, was privatized in 1989, into a new corporation titled Nuclear Electric. Nuclear Electric is the largest nuclear utility in the United Kingdom, responsible for 24 operating nuclear power plants and the construction of one new nuclear power plant (Sizewell B). Although privatized, Nuclear Electric is still under government ownership (private, government owned). In other words, the government is Nuclear Electric's largest shareholder. South of Scotland Electric Board (SSEB) was privatized into Scottish Nuclear, and is responsible for four nuclear power plants. In 1994 Nuclear Electric operations will be reviewed in light of privatization and its achievements in a privatized environment. Nuclear Electric is seeking approval to continue building nuclear power plants. As noted above, Nuclear Electric is constructing Sizewell B, the only plant under construction in the United Kingdom.

Nuclear Installations Inspectorate (NII)

The Nuclear Installations Inspectorate (NII), under the Health and Safety Executive (HSE), is responsible for licensing and regulating commercial nuclear power plant operation.

The Nuclear Installations Act of 1965 subjects all commercial nuclear installations in the United Kingdom to safety controls enforced through licensing carried out by the Health and Safety Executive's Nuclear Installation Inspectorate (NII). The conditions attached to site licenses provide the conditions for nuclear power operations. The general regulatory requirements are broad and are enforced through the licensing mechanism. In contrast to the approach used in the United States, the NII does not prescribe detailed standards or codes of practice for nuclear plants. Instead, each license applicant is required to develop plant-specific design safety criteria and requirements. These criteria are not approved as standards or codes; plant-specific design criteria may adopt by reference international standards such as those issued by the British Standards Institution or the American Society of Mechanical Engineers.

Atomic Energy Authority (UKAEA)

The Atomic Energy Authority (UKAEA) is a statutory corporation managed by a government-appointed board. It is involved in nuclear power plant research and development, safety and reliability research, and operation of two nuclear power plants. The UKAEA participates directly in designing and constructing commercial nuclear power plants through its subsidiary (government-owned) corporations, the National Nuclear Corporation and the Nuclear Power Company.

The nuclear site license is issued by the Health and Safety Executive (a regulatory body). As a condition of the site licenses, authorization of staff to operate a nuclear power plant is given by the Central Electric Generating Board (CEGB) and not by the regulatory body (Madden, 1988).

Appendix B: Executive Summary from NUREG/CR-6122, "Staffing Decision Processes and Issues: Case Studies of Seven U.S. Nuclear Power Plants"

Appendix B provides the executive summary from NUREG/CR-6122, "Staffing Decision Processes and Issues: Case Studies of Seven U.S. Nuclear Power Plants" (Melber et al., 1993). This information is provided for comparison with the information presented in this international review of staffing practices. For detailed information pertaining to staffing practices in the U.S. nuclear power industry, the reader should refer directly to NUREG/CR-6122.

The objective of this report is to identify how decisions are made regarding staffing levels and positions for a sample of U.S. nuclear power plants. In this report, a framework is provided for understanding the major forces driving staffing and the implications of staffing decisions for plant safety. The focus of this report is on driving forces that have led to changes in staffing levels and to the establishment of new positions between the mid-1980s and the early 1990s. Processes used at utilities and nuclear power plants to make and implement these staffing decisions are also discussed in the report. While general trends affecting the plant as a whole are presented, the major emphasis of this report is on staffing changes and practices in the operations department, including the operations shift crew.

The findings in this report are based on interviews conducted at seven nuclear power plants and their parent utilities. A discussion of the key findings is followed by a summary of the implications of staffing issues for plant safety.

Changes in Staffing Levels and Positions

Plant-wide, the most significant staffing changes are:

- an increase in overall staffing levels at all seven plants;
- increases in operations, maintenance and engineering staffing at all seven plants;
- increases in training staffing at six of seven plants.

Departmental decreases in staff size were not typical.

In the operations department, the major trends seen in staffing are:

- addition of a sixth shift crew in six of seven plants;
- addition of coordination positions in five of seven plants;
- addition of administrative positions in four of seven plants;
- addition of licensed operators on shift in three of seven plants; and
- addition of supervisory staff on shift in two of seven plants.

Driving Forces

The general forces driving staffing changes are pressures from external organizations, economics, and performance issues.

External pressures include regulations and requirements. Plant staff reported feeling pressures not only from the Nuclear Regulatory Commission (NRC), but from the Institute for Nuclear Power Operations (INPO), the Nuclear Management and Resources Council (NUMARC), and the Public Utilities Commissions (PUCs) as well. Specific examples of these pressures include increased training requirements, the maintenance rule, design basis reviews, and the NUMARC procurement initiative. In most instances, new requirements or regulatory pressures lead to new work initiatives that drive staffing needs upward.

Economic factors tend to constrain staffing growth. Pressures toward cost-effectiveness and increased efficiency were cited by respondents at six of seven plants as curbing staff growth.

Major performance issues include specific performance concerns identified by the NRC or INPO and continuous increases in performance standards in general. These factors also tend to drive staffing levels upwards.

Impact of Driving Forces on the Operations Department

The general forces of external pressures, economics, and performance issues affect the operations department in several specific ways. The external pressure that affects operations staffing the most is the initiative to improve operator training programs. Other external pressures affecting operations staffing include design basis reviews of plant systems and reviews of procedure upgrades. Because a high level of regulatory attention is paid to licensed operator staffing and to the centrality of operations to plant safety, economic pressures appear to have less of an impact on operations staffing than on staffing in other departments. Finally, plant performance concerns have led to additional administrative and coordination demands on operations staff. For example, operations input into other departments' planning and work activities is increasing.

Processes for Staffing Decisions

Management at most plants in this study rely on periodic efforts to assess their departmental organization and staffing patterns. These assessments result in a recommended organizational structure and staffing levels that are retained for several years.

The most common justifications given for the addition of new positions are increased workload due to new programs or regulatory requirements, backlogs of work, and overtime use.

Plant Staffing Mechanisms

A variety of staffing policies and mechanisms are used at plants to meet regulatory and performance expectations while curtailing the expansion of economic costs. The most common mechanisms seen in the site visits were sometimes conflicting:

- reorganization of functional groups, usually based on a utility-wide initiative aimed at increasing efficiency and reducing costs;
- contractor use, including both reliance on contractors to augment authorized staffing levels and replacement of contractors with permanent staff to reduce costs;
- hiring freezes or caps on hiring; and
- overtime policies, including the us ' overtime to meet workload demands and constra... overtime use to reduce costs.

Shift Staffing Mechanisms

Mechanisms for staffing the operations shift crew include retention programs, recruitment practices, and career paths.

In general, turnover in operations staff at the plants that were visited is relatively low, with rates estimated at around 5-13% for 1991. At some plants, shift scheduling policies are viewed as a mechanism for addressing turnover issues, with the 12-hour shift being offered as a way to retain staff.

In terms of recruitment practices, recruits for operator position are sought from a variety of sources, including the Nuc ear Navy, regional technical schools, and commur ity colleges.

The most significant concern mentioned in terms of career paths is limited opportunity for advancement. In general, operators at the plants in this study face fewer promotion opportunities and a longer time between promotions than five years ago.

Staffing Issues and Plant Safety

The findings presented in this report suggest several implications for plant safety. The following four issues are addressed:

- the potential conflict between economic pressures and safe operations;
- the increasing workload demands on the operations shift crew;
- the effort to maintain an appropriate number of licensed operators; and
- the impact of performance evaluations by the NRC and industry review groups on staffing.

The tension between economic constraints and increased workload demands has been central to staffing decisions at the nuclear power plants in this study. To the extent that economic constraints limit the plants' ability to meet increased work demands, there is the potential for an adverse effect on the safe operation of nuclear power plants. However, at this time, there is no evidence to indicate that economic constraints faced by utilities have taken precedence over meeting safety-related workload demands, particularly within nuclear divisions of utilities and within the operations departments of plants. Continued attention by the NRC to utility responses to economic pressures is important to ensure that economic constraints do not lead to inadequate staffing in the future.

The involvement of operators in special initiatives such as training program improvement and design basis reviews has increased the responsibilities of the operations shift crew. Increased participation of operators in a broader set of tasks has the potential to negatively affect safe operations if these new demands interfere with plant operations. However, operator involvement in these tasks also has the potential to enhance plant safety if staffing levels are sufficient to carry out plant operations and if operator expertise on these tasks results in improved plant functioning.

In staffing licensed operator positions, management at plants face the difficulty of maintaining enough licensed staff to cover unexpected needs for operators (e.g., due to examination failures or illness), while not establishing an oversupply of "back up" licensed staff. Insufficient numbers of licensed staff can lead to heavy use of overtime to cover shift staffing when regular shift operators are not available. However, as the number of licensed operators increases, there is a decrease in the time these operators are assigned on shift with responsibility for running the plant. Considerable experience with on-shift responsibility is important for ensuring safe operations, and a very large pool of licensed operators can reduce individual experience levels.

Plant performance reviews carried out by the NRC and INPO have had a significant impact on staffing decisions at the plants in this study. These reviews can serve as an important mechanism for ensuring that plant management continues to emphasize safety-related needs as a basis for staffing decisions.

Conclusion

The results of this study of seven nuclear power plants indicate that there are strong and opposing pressures on staffing decisions. Pressures to reduce staffing levels to be economically efficient are countered by regulatory and industry pressures for new safety-related initiatives and higher performance standards that add to workload and increase staffing levels.

The identification of the major forces driving staffing decisions is useful for anticipating where imbalances between workload and staffing levels are likely to occur in the future. The ability of staff in operations departments to assume many additional responsibilities is limited. Regulatory attention that focuses on the extent to which new activities are undertaken, the approaches to carrying out these new activities, and the bases for changes made in staffing levels can contribute to early identification of potential safety concerns.

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A review of nuclear power plant staffing regulatory and industry practices in Canada, France, Germany, Japan, Sweden, and the United Kingdom is presented in this report. International trends in staffing regulatory approaches, industry practices, and issues of concern that have potential relevance for the continued development of nuclear power plant staffing policy in the United States are highlighted.

The 1980s were marked by significant growth in nuclear power operations internationally; however, growth of nuclear power is not expected to continue in the 1990s except in France and Japan. A continuum of regulatory approaches was identified, ranging from prescriptive regulations applied to all licensees to staffing requirements agreed to in the plant operating licenses. Most of the changes observed in staffing regulations and practices in the early 1980s were made in response to the accident at the Three Mile Island Unit 2 nuclear power plant in 1979. These changes included widespread issuance of new operator and licensing requirements and the establishment of national training centers. A period of relative stability followed these changes. Changes in the latter half of the 1980s focused on continuing improvements and additions to training curricula and methods, most notably increased reliance on simulator training.

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