SWEDEN´S FIRST NATIONAL REPORT UNDER THE

Convention on Nuclear Safety

Swedish implementation of the obligations of the Convention

Ds 1998:54

CONTENTS

Foreword

This report is issued according to Article 5 of the Convention on Nuclear Safety. Sweden signed the Convention on September 20, 1994, the first day it was open for signing, during the ongoing General Conference at IAEA. About 40 states signed the Convention during that week. Sweden ratified the Convention about a year later, on September 11, 1995 and the Convention entered into force on October 24, 1996.

The Chernobyl accident in 1986 showed very clearly that a reactor accident can lead to serious consequences for people and the environment even far from the site. After the accident a discussion started about internationally binding obligations concerning nuclear safety. The initiative to a Convention was taken 1991 at the international IAEA Conference on Nuclear Safety. The initiative was taken by the German environmental minister with support from Sweden and the European Commission.

Sweden has been active for many years in the international work to enhance nuclear safety. This Convention on Nuclear Safety is seen as an important step in this work. The areas included in the Convention are since long incorporated in the Swedish nuclear safety work. Sweden is also actively engaged, bilaterally and multilaterally, to support nuclear safety in Eastern Europe, especially in Lithuania and the northwest of Russia.

The Swedish Government anticipated already at the signing of the Convention that both the safety philosophy, legislation and the safety work conducted by the utilities and the authorities in Sweden comply with the obligations of the Convention. This is confirmed in the present report.

This report has been produced by a four persons working group with one representative each from the Nuclear Power Inspectorate, the Radiation Protection Institute, Vattenfall AB and Sydkraft AB. The Swedish Government assigned the Nuclear Power Inspectorate the task of coordinating the work. Before submission to the Government the report was sent for comments to the nuclear industry, regulatory authorities in the energy field, industry organizations and environmental organizations. It was also discussed in the SKI Advisory Committee on Nuclear Safety and in the boards of SKI and SSI. The Swedish Government adopted the report on August 13, 1998.

Part A of the report provides general information about the Swedish nuclear programme and a brief political history of nuclear power in Sweden, in order to give the reader a background to the governmental decision to start the phase-out of nuclear power with Barsebäck 1 on June 30, 1998.

Part B provides information as a basis for the conclusions drawn about the compliance with the obligations of the Convention. By necessity this information is rather brief and strongly focused on those aspects which are addressed in the articles. Too many details and additional information would overload the report and make the review process difficult. We have tried to provide enough details to make the Swedish practices understandable. Data that might be missing will be added on request in the review process.

The general conclusions about the Swedish compliance with the obligations of the Convention are reported in the executive summary.

List of abbreviations

ALARA	As Low As Reasonable Achievable (a principle applied in radiation protection)
ANS	American Nuclear Society
ANSI	American National Standard Institute
ASAR	As operated Safety Analysis Report
ASME	American Society of Mechanical Engineers
ASSET	Assessment of Safety Significant Events Team (a service of IAEA)
BKAB	Barsebäck Kraft AB
BSS	The Basic Safety Standards Directive of the Euratom
BWR	Boiling Water Reactor
CCF	Common cause failure
CCI	Common cause initiator
DBA	Design Basis Accident
EPRI	Electric Power Research Institute
EUR	European Utility Requirements
FKA	Forsmarks Kraftgrupp AB
FSAR	Final Safety Analysis Report
GDC	General Design Criteria
HRA	Human Reliability Analysis
HPES	Human Performance Enhancement System (a programme developed by INPO to improve human reliability)
I&C	Instrumentation and Control
ICRP	International Commission on Radiological Protection
IEEE	Institute of Electrical and Electronics Engineers
IGSCC	Inter Granular Stress Corrosion Cracking
INES	International Nuclear Event Scale
INPO	Institute of Nuclear Power Operations
KSU	KärnkraftSäkerhet och Utbildning AB (the Swedish Nuclear Training and Safety Center)
LER	Licensee Event Report (see RO)

LOCA	Loss of Coolant Accident
MTO	Interaction between Man-Technology and Organization
NDT	Non Destructive Testing
NEA	Nuclear Energy Agency within OECD
NPP	Nuclear Power Plant (including all nuclear power units at one site)
NUREG	Nuclear Regulatory Guide (issued by the USNRC)
OH	Onormal händelse (Unusual Event)
OSART	Operational Safety Review Team (a service of IAEA)
PSA	Probabilistic Safety Analysis (or Assessment)
PSAR	Preliminary Safety Analysis Report
PWR	Pressurized Water Reactor
QA	Quality Assurance
RAMA	Reactor Accident Mitigation Analysis
R&D	Research and Development
RO	Rapportervärd omständighet (Licensee Event Report)
SKB	Svensk Kärnbränslehantering AB (the Swedish Nuclear Fuel and Waste Management Company)
SKI	Statens kärnkraftinspektion (Swedish Nuclear Power Inspectorate)
SKIFS	Statens kärnkraftinspektions författningssamling (the SKI Code of Regulations)
SSI	Statens strålskyddsinstitut (Swedish Radiation Protection Institute)
STF	Säkerhetstekniska föreskrifter (Technical Specifications)
TMI	Three Mile Island (a US NPP)
TSO	Technical Support Organization
USNRC	US Nuclear Regulatory Commission
WANO	World Association of Nuclear Operators

EXECUTIVE SUMMARY: GENERAL CONCLUSIONS

The National Reports to the Review Meetings according to Article 5 of the Convention call for a self-assessment of each Contracting Party with regard to compliance with the obligations of the Convention. For Sweden this self-assessment has demonstrated full compliance with all the obligations of the Convention, as shown in detail in part B of this National Report.

Having taken a very active part in the creation of the Convention, Sweden wishes to emphazise the incentive character of the Convention. In the opinion of Sweden, the Convention implies a commitment to continuous improvement of safety whenever analysis of operating experience, as well as safety research and technical development, indicate that there is room for such improvement. Continuous learning from experience and a proactive approach to safety improvement are in fact corner stones of Swedish current nuclear safety work both for the industry and the regulatory bodies.

Therefore, Sweden has found it important that a National Report highlights strong features in national nuclear practices as well as areas where improvements have found to be justified. Implementation of such improvements should then be followed up in the National Reports to subsequent Review Meetings.

As general conclusions with regard to strong features in national nuclear practices, Sweden would like to point out the following

- The responsibility for safety is very well defined in the Swedish legal framework. In order not to dilute the responsibility of the licence holders the Swedish regulations are designed to define what is required to be achieved, not the detailed means to achieve it. Within the framework given by the regulations, the licence holders have to define their own solutions, and demonstrate the safety level achieved for the regulatory bodies.

- There is an open and on the whole a very constructive relationship between the regulatory bodies and the licence holders. Examples of this are the conduct of joint research projects and an open dialogue, to define reasonable safety objectives for the Swedish NPPs, where the roles of both sides are well defined and fully respected.

- The licence holders are well established companies with good financial records. They have so far demonstrated a strong commitment to upgrade the safety of the NPPs as a result of safety assessments and verification programmes, even if this involves substantial, but still reasonable, increases to their normal production costs.

- Notwithstanding the increased competition on the deregulated electricity market in Scandinavia, the nuclear utilities continue to cooperate in solving important issues for safety. This includes experience feed-back analysis, a component reliability database, qualification of NDT-companies, coordination of outages, nuclear waste management, auditing of vendors, and, most recently, a joint group defining the requirements and objectives for future safety improvements.

- The nuclear infrastructure in Sweden is on the whole well developed with competent and adequate support to the licence holders inside as well as outside the utilities. Also the regulators in Sweden have been assessed as well qualified for their tasks by an international Review Commission. The international cooperation networks of both regulators and utilities are well devloped. This is also demonstrated in the Swedish support to the eastern countries concerning nuclear safety and radiation protection, which has received international recognition.

These features have contributed to make the Swedish NPPs quite competitive internationally from the safety and environmental impact point of view. However, this does not mean that everything is completely satisfactory. Sweden would like to point out the following areas where there is room for improvement

- The older reactors in Sweden are not designed according to current safety standards with regard to the redundancy and diversification of the safety systems and the physical and functional separation. However, considerable efforts are going on to assess the situation and modernization programmes are under way or planned for all units. The newer units will also be assessed. The regulatory bodies, as well as the utilities, are working to define the specific requirements on defence in depth to apply to operating reactors in Sweden after the year 2000. These requirements will be developed taking into account the best international standards.

- The International Commission for review of Swedish Nuclear Regulatory Activities pointed out that the regulatory requirements were not always clear and coordinated in the Swedish system. The Commission also pointed out that in particular SKI needed to define regulatory tasks better and to implement a modern internal quality assurance system. Extensive work has been done, as reported in part B, to clarify the missions and tasks of SKI, to issue general safety regulations in coordination with SSI and the Rescue Services Agency, and to define a new regulatory role with the focus on the activities and processes of the licensees. The implementation of the new regulations and the development and the implementation of the new internal quality system of SKI will have high priority over the next years.

- The number of qualified nuclear engineering staff at the NPPs and at the regulatory bodies seems to be rather small for all important tasks to be done. This is demonstrated by events in recent years at the NPPs indicating a shortage of human resources for a comprehensive preventive safety work. The qualified engineering staff have frequently been overloaded with event triggered tasks and plant modification projects. The increasing number of experienced staff retiring, new regulatory requirements and all the new tasks to be done as a result of the extensive modernization programmes at the Swedish NPPs, will even more emphasize the demand for qualified nuclear engineers and other specialists.

  On the regulatory side event triggered activities have also resulted in delays of long term tasks such as issuing of regulations, development of quality assurance and management of research and development projects. This situation was also pointed out by the 1995 International Review Commission. The Swedish Government and Parliament have responded by increasing the budget of SKI by about 10% and the budget of SSI by about 6 %.

Both the utilities and the regulatory bodies are now recruiting more personnel. However, at present the supply in Sweden of engineers with the adequate nuclear experience seems to be insufficient for all future needs identified by the nuclear utilities, vendors, consultants and the regulatory bodies. There is also a general shortage in Sweden of qualified, university trained engineers and researchers in areas such as structural integrity, reactor physics, reactor technology, instrumentation and control systems.

The situation is being somewhat balanced by the use of international contractors in the ongoing or planned modernization programmes and the possibilities, within the safety requirements, to extend these programmes over time. An initiative has been taken by SKI to assess the present and the future nuclear competence situation in Sweden in more detail and to propose necessary measures.

Sweden is looking forward to reporting on progress in the areas where room for improvement have been identified in its report to the second Review Meeting under the Convention.

A. INTRODUCTION

1. The background of the Nuclear Power programme in Sweden

1.1 General

The total energy consumption in Sweden was 477 TWh during 1997. Of this the electrical power consumption was about 142 TWh, or about 16 000 kWh per person – one of the highest in the world. About 71 TWh of this electrical energy was used for heating and other electrical needs of homes, offices, schools, hospitals etc. About 53 TWh was used by the industry. About 6,5 TWh was used for district heating and in refineries of oil products. About 10 TWh was lost in transmission and about 2,5 TWh was used for transportation[1].

The consumption level has been rather stable since the beginning of the 1990´s and it is, according to official sources, expected to grow slowly, less than 1% per year until 2010[2]. In a year with normal water supply to the hydro power stations, about 65 TWh (about 46 %) of the electrical power is produced in nuclear power plants and almost the same amount by hydro power. About 10 TWh is produced in conventional thermal power plants, using various types of fuel, mainly in plants for the combined production of electricity and hot water for district heating. 0,2 TWh was produced in wind power plants during 1997.

Half of the electricity is produced by companies completely or partly owned by the state and the other half by companies with private and/or municipal ownership.

For a long time Sweden was included in a regulated Nordic electricity market cooperation in which electrical power was bought and sold at the lowest prices based on the current production costs. From 1 January 1996 the electrical power market has been deregulated and competitive, in principle, for both the production and sale of electricity. In practice it is regulated as in most countries by means of environmental rules, environmental taxes and energy taxes. The national high voltage grid is today managed by a state utility, Svenska Kraftnät. In 1995 a new law appointed this utility to be the national system operator responsible for the short-term planning and operation of the national grid with regard to voltage quality, continuity of service and the national balance between generation and consumption. Regional and local grids are operated by various grid companies as regulated monopolies.

1.2 A historical – technical review[3]

The first interest in atomic energy shown by the Government appeared in 1947, when AB Atomenergi was constituted as a Government research organization. Until 1955 the atomic energy programme was orientated

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[1] Statistics Sweden, SCB, 1998.
[2] Swedish Electricity Market. Work material from the Swedish Energy Agency, 1998. (in Swedish)
[3] The text is modified from SOU 1996:74: Swedish Nuclear Regulatory Activities. Vol 2- Descriptions.

towards basic research concentrated to a small natural uranium/heavy water reactor R1, located in a rock shelter at the Royal Institute of Technology in Stockholm. This reactor went critical for the first time in July 1954.

In 1958 AB Atomenergi moved most of its research activities to a newly established national state-owned laboratory, Studsvik (located at the east coast 100 km south of Stockholm). A materials testing reactor R2 started operation in 1960 and is still in use (now 50 MW thermal).

Vattenfall (the State Power Board) and AB Atomenergi decided in 1957 to build a small heavy water reactor for the production of heat and electricity. The reactor, named Ågesta, was situated in a rock cavern, and started production in 1964 at a power level of 85 MW (th). 55 MW was used for heating of a suburb of Stockholm and 10 MW for electricity production. The power level was later increased to 105 MW (th). The Ågesta reactor was decommissioned in 1974.

In 1963 construction started of a a heavy water power reactor, located in Marviken on the east coast about 40 km south of Studsvik. This project was also a cooperation between Vattenfall and AB Atomenergi. The Marviken plant was based on slightly enriched uranium, with the option of changing to natural uranium, and with an electrical output of 140 MW. The design included several advanced features, e.g. direct cycle boiling heavy water, nuclear superheating, and refuelling during operation. These features caused several complications from a technical and safety point of view. In 1970 it was found that the Marviken concept could not compete commercially with the light water reactor concept and the project was abandoned. The installation was converted to a conventional thermal power plant to be used as a peak power reserve. The old reactor installation and containment has later been used as an experimental site for severe accident research. The stop of the Marviken project marked the end of the ”Swedish nuclear line” with heavy water, natural uranium reactors.

In 1965 OKG, a power company which had just been formed by private industrial companies, ordered from ASEA (now ABB Atom) a commercial nuclear power reactor based on a boiling water reactor (BWR) concept of Swedish design. The 440 MW unit Oskarshamn 1 started commercial operation in 1972. Oskarshamn 1 was the first light water reactor in the western world built without a licence from US vendors. There are now three nuclear units (all BWRs) in operation at the Oskarshamn site.

In 1968 Vattenfall ordered Ringhals 1, a 750 MW BWR from ASEA and Ringhals 2, a 800 MW pressurized water reactor (PWR), from Westinghouse. The official reason for the two orders signed with two different vendors, one Swedish and one foreign, was that Vattenfall wanted to establish a truly competitive market in Sweden for the future development of nuclear power. Later, Vattenfall ordered two more Westinghouse PWRs to be built at Ringhals.

In 1970 Sydkraft, the second largest power utility in Sweden, started construction of two ASEA BWRs at Barsebäck. Some years later Vattenfall, together with a group of non state-owned utilities, started the construction of a new nuclear power plant at Forsmark. There are now three BWRs in operation at Forsmark.

After the TMI accident in 1979, measures for mitigation of severe accident consequences were proposed by a state commission and decided by the Government. These measures included accident management procedures, and new systems for diversified containment cooling and for filtered containment venting. These systems were designed to reduce the release of fission products (excl noble gases) in a core melt accident to below 0.1% of the core inventory of a 1800 MW(th) reactor. This will reduce the land contamination to a very low level, such that permanent evacuation of people living close to the plant would not be necessary even in a core melt accident. The new systems were completed at Barsebäck in 1985, and at the other sites in 1988.

Between 1985 and 1990 the owners were granted permission by the Government to increase the licensed thermal power levels of the nuclear power units by 6-10 percent. Applications were made for all units except Oskarshamn 1 and Ringhals 2.

On 28 July 1992, an incident at Barsebäck 2 showed, after an in-depth analysis that there were weaknesses in the emergency core cooling systems in the five oldest BWRs. As a result, the five units were shut down from mid September and the systems were modified over a period of about five months.

OKG announced in mid 1993 that the 21 year old unit Oskarshamn 1 would remain out of operation for some years. A programme including modernization of the plant and a thorough examination of the reactor pressure vessel and primary piping was undertaken. Oskarshamn 1 was brought back into operation in the beginning of 1996.

As a result of the five reactor stop in 1992, all the units in Sweden are undergoing a thorough analysis and reevaluation of their safety cases. Upgrading and modernization programmes are also under way or are planned for all twelve units.

1.3 A historical – political review[4]

The Swedish Parliament has debated and decided on issues about the use of nuclear energy in Sweden several times since the beginning of the 1970´s. Since 1976 nuclear power issues have, from time to time, completely dominated the political debate in Sweden. This review describes the most important political decisions taken concerning the use of nuclear power in Sweden.

Conditions concerning the loading of new reactors

In 1976 the new three party Center/Liberal/Conservative Government issued a bill concerning the reactors not yet in operation (the ”Conditional Act”). Based on the bill, Parliament decided that a government permit was needed to load nuclear fuel into a new reactor. A permit could be issued if the utility presented an agreement on reprocessing of the spent fuel, and a plan for safe final storage of the high radioactive waste. Alternatively safe final direct disposal of the spent fuel could be accepted.

After presentation of a reprocessing agreement with Cogema, Sydkraft was permitted to load Barsebäck 2 in 1977. As a result of the ”Conditional Act” the nuclear industry started a joint project on nuclear fuel safety (KBS) and issued a first safety report (KBS-1) in November 1977 on final repository safety. This report was used by Vattenfall in the application to load Ringhals 3 and Forsmark 1.

The Government approved the KBS-1 report but authorized SKI to make the decision regarding loading. Shortly thereafter the three party Government resigned because of disagreements over having an advisory

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[4] The text is mainly based on: KSU AB The Analys Group. Background Nr 1, Februari, 1995 and Leijonhufvud S. A history about Nuclear Power in Sweden. Issued in connection with the 25 year jubilee of ABB Atom (both in Swedish).

referendum on nuclear power, and over the permit to erect Forsmark 3. The new Liberal minority Government proposed in a bill, in early 1979, that the nuclear power programme should include 12 reactors. No limitation in time was stated. After an expert review, the SKI Board approved the loading of Ringhals 3 and Forsmark 1 in accordance with the ”Conditional Act”. The day after this decision the TMI-2 accident occurred.

The TMI- accident and the advisory referendum

A week after the TMI-accident in Harrisburg, on 28 March 1979, all the parties in Parliament agreed on an advisory referendum about the future of nuclear power in Sweden. A new bill (the ”Respite Act”) was presented in May, with the provision that the start of all new reactors (including Ringhals 3 and Forsmark 1) should be postponed until after the referendum.

Directly after the TMI accident a committee of experts was appointed (the Reactor Safety Committee). Its report was published in November 1979, and it was very influential on later decisions concerning the safety of the Swedish nuclear power plants. Based on this report, the Government later decided on requirements regarding severe accident mitigation measures, which resulted in the installation of filtered venting systems to the containments of all Swedish units and the development of symptom based accident management procedures. The filters were installed between 1985 and 1988. Other important results from the work of the Reactor Safety Committee were a stronger emphasis on human factors issues in the safety work, and the start of a periodic safety review programme including PSA.

The advisory referendum was held in March 1980. The referendum had three different ballots. Two of these (line 1 and 2) were identical on the front side but the line 2 ballot had additional text on the reverse side about energy conservation, development of renewable energy sources, safety improvements of the nuclerar power plants and public ownership of major electricity production facilities.

The result was a majority (58%) for line 1 and 2 saying that: ”Nuclear power will be phased out at the pace possible with regard to the need for electric power in the maintaining of employment and welfare. To reduce the dependency on oil and waiting for renewable energy sources, only the 12 present reactors in operation or under construction will be used. No further nuclear power expansion shall take place. Safety considerations will be decisive for the order in which to phase out the reactors”.

A large minority (38,7%) voted for an option (line 3) saying no to further expansion of nuclear power and that phase-out of the present six reactors in operation should be accomplished within 10 years.

The year 2010

No final year for the phase-out was stated on the ballots. In a brochure sent to every household in Sweden by the National Tax Authority, which was responsible for organizing the referendum, it was mentioned as an explanation that, in waiting for other safer energy sources, the 12 reactors in operation or under construction will be used only during their technically safe life, which was assumed to be 25 years. This assumption originated in a declaration by the parliamentary standing committee on Industry.

Directly after the referendum the Government issued a bill saying that, according to the referendum, units 11 and 12 could be completed and taken into operation. A maximum of 12 reactors could be used during their technical life, which in the bill was assumed to be 25 years. No further expansion of nuclear power may be undertaken and safety aspects will be decisive for the order in which the units will be taken out of operation.

In Parliament the Social Democratic party proposed an amendment to this text saying that it should now be established that the last reactor in Sweden must be closed at the latest by the year 2010. They also proposed that provisions about the number of reactors and the length of the phase-out period should be included in the legislation on atomic energy. Parliament decided in accordance with this amendment.

The Chernobyl accident and the prohibition to plan for new reactors in Sweden

In May, after the Chernobyl accident on 26 April 1986, the Minister of Energy appointed an expert group to report on the consequences of the accident on energy policy, nuclear safety, radiation protection and environmental protection.

While the expert group worked, the Government issued a bill which resulted in two amendments to the Act on Nuclear Activities:

(1) Permits to erect a nuclear power reactor shall not be issued.

(2) Nobody is allowed to make design drawings, calculate costs, order equipment and take other such preparatory measures with the purpose of erecting a nuclear power plant within the country.

The motives for issuing these amendments were to further clarify that the energy policy directives are firm, and to point out that preparation for more reactors in Sweden is a waste of resources. It was especially pointed out that these provisions must not prevent the possibilities for technical development work, important for the safety of the present reactors, for Swedish participation in international nuclear cooperation or for the free public debate on nuclear issues.

The decision to close down two reactors in 1995 and 1996

In 1987 an energy bill was issued on the basis of the Chernobyl report. The main conclusion of the bill was that nothing essentially new had been revealed, giving a reason for finishing the phase-out of nuclear power earlier, but that it would be an advantage to start the planning early for decommissioning, for alternative electricity production and for methods for energy conservation. It should be possible to take one reactor out of operation during 1993-95 and another reactor during 1994-96. Parliament approved these conclusions.

In 1988 another bill was issued with more definite plans for the phase-out. The phase-out was to start with a first reactor at Barsebäck in 1995 and a second reactor at Ringhals in 1996. Which units were selected, would depend on the national costs for different alternatives. The expert group ”after Chernobyl” had concluded that there are no reasons to reconsider the technical risk picture for accidents in Swedish plants, and that a phase-out based on a parliamentary decision will require a special law, if it is not possible to make a volontary agreement with the reactor owners. Parliament approved this conclusion and the phase-out of the two reactors, one at Barsebäck and one at Ringhals.

The three party agreement

In 1991 the Social Democratic-, Center - and the Liberal parties made an agreement which resulted in a new energy bill. The bill confirmed the earlier decisions on decommissioning, but the connection, between the phase-out and employment and welfare, was made clearer. It was established that the start and the pace of the phase-out must be dependent on the results of energy conservation, acceptable alternative electrical production, and the possibility of maintaining competitive prices for electricity. A programme for development of alternative energy sources and methods for conservation was also proposed.

In Parliament the Minister of Industry, who was now made responsible for nuclear power production issues, declared that the method, with a fixed starting point for the phase-out, had now been replaced by a method with annual examinations to check if the preconditions existed to start the phase-out. A proposal, by the Conservative party, to declare that the earlier decision specifying 1995 and 1996 would no longer be valid, was rejected.

A new energy commission

In 1994 the Social Democratic party proposed in Parliament that a parliamentary commission should be appointed with the task to propose how the three party agreement from 1991 should be fulfilled. The consequenses of the proposed deregulation of the electrical market should also be analysed. The commission was appointed and its final report was expected to be ready by the end of 1995.

As an important reason for appointing the commission, Parliament stated that important changes had taken place since 1991, for instance the signing of the Climate Convention, the negotiations on Swedish membership of the EU, and the important political changes in Central- and Eastern Europe. The Commission was supposed, with due regard to these changes, to propose programmes and time schedules for the conversion of the energy system. The objective should be that the proposals could lead to durable political decisions.

The work of the Energy Commission proved to be difficult, with strongly divided opinions between members, and between members and experts of the Commission. The final report was issued in December 1995[5]. With regard to nuclear power, the majority of the Commission recommended that the date for final phase-out of the nuclear programme should be abolished and the phase-out pace be determined by the phase-in of acceptable alternative energy production, results of energy conservation, and the possibility of keeping internationally competitive prices for electricity. With regard to industrial needs and environmental effects, one reactor could be closed during the 1990´s without any major effects on the electrical power balance. Closure of another smaller reactor, would considerably reduce the margins. The Commission recommended that phase-out should start early in order to begin the conversion of the energy system.

A new three party agreement

In spring 1997 a three party agreement (Social Democtratic/Center and Left Wing parties, representing a majority in Parliament) on nuclear power was achieved. The agreement stated that one reactor at Barsebäck should be taken out of operation at the latest on 30 June 1998. The other reactor at Barsebäck should be taken out of operation in 2001, if the energy production situation permits. Negotiations with the owner Sydkraft AB should start immediately. The other reactors were supposed to be phased-out as soon as possible, with due regard to the phase-in of renewable energy sources.

The year 2010 was not mentioned as the final year for this process.

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[5] SOU 1995:139: Conversion of the Energy System (in Swedish).

The Act on the phase-out of nuclear power

After the agreement, an Act on the phase-out of nuclear power was prepared by the Government and finally approved, after a minor debate in Parliament in December 1997[6]. The Act authorizes the Government to decide that the right to use a nuclear power reactor for energy production shall expire as a consequence of the conversion of the energy system. The geografical location, age, design and importance to the energy system of a particular reactor shall be considered when taking such a decision. The Act also includes provisions about reimbursement to the reactor owner in the case of a shut down decision according to the Act.

As a consequence of this new act, an amendment was made to the Act on Nuclear Activities.

Based on the new act, the Government decided on 5 February 1998 that Barsebäck Kraft AB is not allowed to continue the operation of Barsebäck 1 after 30 June 1998. In March, Sydkraft AB the owner of Barsebäck NPP appealed this decision to the supreme administrative court of Sweden, and in May was granted an inhibition of the decision until the legal procedure has been completed.

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[6] SFS 1997:1320. Act on phase-out of the Nuclear Power (in Swedish).

2. Nuclear power installations in Sweden

At present, in mid 1998, there are 12 nuclear power units in operation in Sweden as specified in Table 1.

All the BWRs were designed by ASEA ATOM (now ABB Atom) and the PWRs except Ågesta by Westinghouse.

The operating Swedish BWRs could be grouped into five design generations and the PWRs into two generations with the main design features as given in table 2.

Ownership, organization and staffing

The utility structure and owner relations are shown in Figure 1. The licence holders for the nuclear power plants are:

- Barsebäck Kraft AB (Barsebäck NPP),
- Forsmarks Kraftgrupp AB (Forsmark NPP),
- OKG AB (Oskarshamn NPP), and
- Vattenfall AB (Ringhals NPP).

Name	Licensed thermal power level MW[1]	Electrical gross output MW[7]	Type	Operator	Construction start	Commercial operation
Ågesta	105	12	PHWR	AB Atomenergi, Vattenfall	1957	1964[8]
Barsebäck 1	1800	615	BWR	Barsebäck Kraft AB	1970	1975
Barsebäck 2	1800	615	BWR		1972	1977
Forsmark 1	2928	1006	BWR	Forsmarks Kraftgrupp AB	1971	1980
Forsmark 2	2928	1006	BWR		1975	1981
Forsmark 3	3300	1200	BWR		1978	1985
Oskarshamn 1	1375	465	BWR	OKG AB	1966	1972
Oskarshamn 2	1800	630	BWR		1969	1975
Oskarshamn 3	3300	1200	BWR		1980	1985
Ringhals 1	2500	860	BWR	Vattenfall AB	1968	1976
Ringhals 2	2660	910	PWR		1969	1975
Ringhals 3	2783	960	PWR		1972	1981
Ringhals 4	2783	960	PWR		1973	1983

Table 1. Nuclear power installations in Sweden. Main data.

[7] According to SKI documentation.
[8] Decommissioned in 1974. The installation is slightly maintained by Vattenfall AB and AB SVAFO. All fuel and heavy water as well as some parts of the primary system (i.e. steam generators), have been removed from the site.

Vattenfall AB and Sydkraft AB are the two dominating owners with large shares of the Swedish electricity market. Both companies have long experience of electricity production, transmission and distribution in Sweden. Vattenfall AB is a fully state owned company. Sydkraft AB is a private company, owned by several Swedish municipalities and foreign utilities. The foreign ownership is 54 % which corresponds to 58% of the votes.

A principle adopted early by the nuclear utilities was that the nuclear power plants should have their own comprehensive competence in all areas included in the operation and maintenance of the plants. In addition, a great deal of technical and economic responsibility was delegated from the executive utility level to the plants. They were practically independent of the head offices in all operational matters, other than the procurement of fuel and matters related to the final disposal of waste. The head offices also provided qualified engineering support, for instance concerning safety analysis, accident analysis and other analysis and calculation work requiring highly qualified experts.

In recent years the operating organizations have employed more of their own experts and have become even more independent of the head offices. A tendency also exists to outsource general service activities and

Unit	Design generation	Main technical design features
BWR		
Oskarshamn 1	BWR 1	External main recirculation loops. No explicit requirements regarding physical separation. Diversification by auxiliary condenser. Fine motion control rods, diversified shut down system.
Ringhals 1	BWR 2	Similar to O1 but improved physical separation of the electrical supply systems (partial four-train electrical separation). Diversification by steam driven emergency cooling and auxiliary feed water pumps.
Barsebäck 1 and 2 Oskarshamn 2	BWR 3	Stronger requirements on physical separation of the safety systems. Full two-train electrical separation. Improved electrical supply reliability instead of diversification.
Forsmark 1 and 2	BWR 4	Full four-train electrical separation. Internal main recirculation pumps. Pipe-whip restraints.
Forsmark 3 Oskarshamn 3	BWR 5	Complete physical separation of the safety systems. Single-failure- and repair criterion. Seismic safety.
PWR		
Ringhals 2	PWR 1	Three loop PWR. Diversification by steam driven auxiliary feed water pumps. Partial four-train electrical separation.
Ringhals 3 and 4	PWR 2	As R2 but some improvements in layout for fire separation and in fuel design.

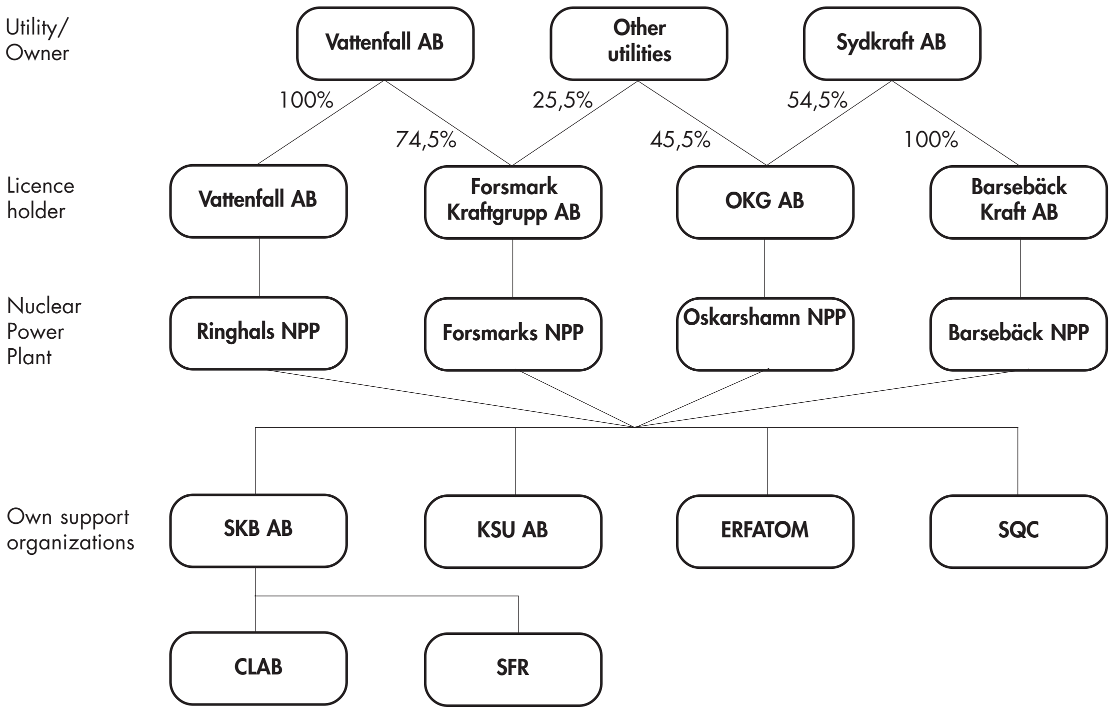
Table 2. Swedish NPP design generations.

make them available in the open market. Experts at the head offices have become consultants to a great extent acting on a competitive market in relation to the nuclear power plants. All the NPPs, except Ringhals, are separate power companies since 1994, with the full responsibility for safety, production and economy. The Director of Ringhals, although formally subordinate to the Executive Vice President for Generation at Vattenfall AB, also has the full delegated responsibility for safety, production and economy.

The Swedish NPPs have all implemented the organizational principle of production control. This means that the production departments determine and order all services and technical support from other departments of the organization or from outside the organization. As an example the organization of Barsebäck NPP is shown in Figure 2.

A considerable amount of maintenance, materials control and service work is contracted out to companies which are independent from the utilities. Such companies range from large corporations such as ABB Atom, Westinghouse, Siemens and General Electric, to small local enterprises. The licence holders are however ultimately responsible for all work conducted by the contractors in the nuclear power plants.

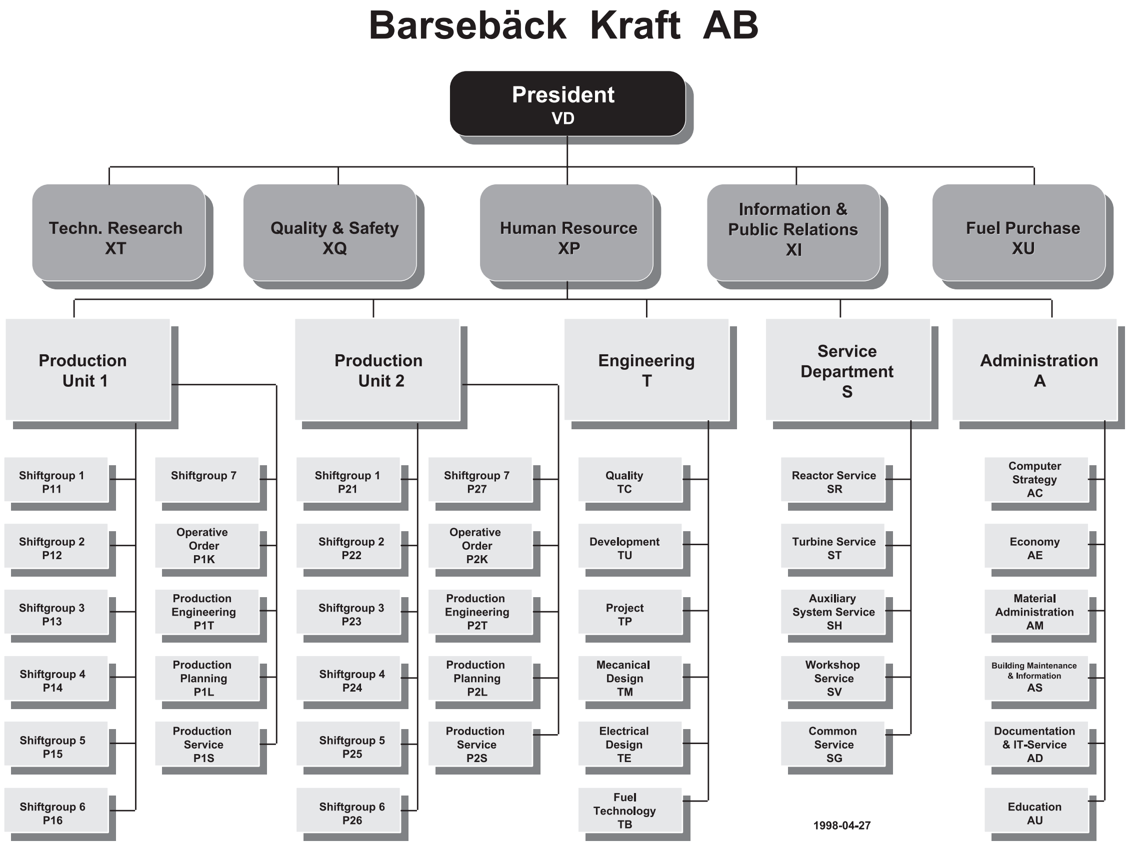
Figure 1. Utility structure and owner relations.



The Swedish NPPs employ altogether about 3500 people, whereof 2500 are technical staff of different qualification levels. Distributed over the different sites the figures are:

Barsebäck NPP	430
Forsmark NPP, incl. SFR	850
Oskarshamn NPP, incl. CLAB	1050
Ringhals NPP	1200

Figure 2.



To these figures another 100-200 persons per site could be added assigned on a more or less permanent basis for non-technical tasks like guarding, canteen-services, house-keeping, etc. and for technical services provided by contractors and consultants. During annual refuelling and maintenance outages typically 500-1000 persons are added to the ordinary staff at each unit. Outage planning is co-ordinated between the 12 Swedish units and the two Finnish BWR units at Olkiluoto.

Own support organizations

The Swedish Nuclear Training and Safety Center (KSU) runs a training facility at Studsvik with seven full scale simulators in operation, corresponding to the seven design generations, listed in table 2. For the conduct of the practical training of the control room operators, Sweden has chosen a centralized training center instead of locating the full scale simulators to the plant sites. This principle is however questioned and some simulators may be moved to the plant sites in the future. KSU also develops nuclear training material and arranges advanced courses for nuclear power plant technicians and engineers. KSU is owned jointly by the Swedish utilities (Vattenfall AB 50%, OKG AB 25% and BKAB 25%).

KSU participates in the work on experience feed-back analysis of events at domestic and foreign NPPs and co-ordinates these efforts. KSU also provides information regarding operating experience in the Swedish plants internationally and acts as the liasion between the Swedish utilities and WANO. KSU is also a member of INPO.

The Swedish and Finnish BWR operators agreed a few years ago to cooperate in safety issues under the name of NORDSÄK. The primary objectives of the agreement are to ensure cooperation between the reactor operators, the main suppliers and other reactor suppliers on safety issues; to ensure the competence and an efficient experience feed-back programme, particularly among the Nordic BWR-operators. NORDSÄK is the initiator of among other efforts ERFATOM (see below), the classification of MTO-related events, and cooperation for establishing criteria for modernizing the Swedish BWRs.

For analysis of events relevant to Swedish BWRs and for trend analysis, the plants cooperate with the Finnish Olkiluoto NPP and ABB Atom within an organization called ERFATOM located at ABB Atom in Västerås. The plants also cooperate in running a common database on the reliability of plant equipment and systems, called the TUD-database, and a common data base, for occupational doses in all Swedish nuclear facilities, called CDIS.

As a consequence of new SKI regulations on testing and control of mechanical devices in nuclear power plants, a new company, SQC, was formed in 1995. The company is jointly owned by the nuclear power plants and is acting as an independent qualification body for NDT-companies qualifying their NDT-systems. If the qualification of equipment, procedure and personnel fulfills the requirements in the qualification procedure, SQC issues a qualification certificate.

Other commercial services in the nuclear power field

ABB Atom (former ASEA-ATOM) has designed and delivered the nine BWRs in Sweden and two in Finland. ABB Atom has since then specialized in modernization, maintenance and services of nuclear power plants in operation.

ABB Atom also operates a fuel factory with a capacity of 600 tonnes per year of BWR and PWR fuel. Half of the production is exported.

Another ABB company, ABB TRC, is together with SAQ, a major supplier of services in the NDT-field to the Swedish NPPs.

Also the other big vendors (General Electric, Westinghouse, ABB Combustion, Siemens and Framatome) are active on the Swedish market offering technical and fuel services.

AB Atomenergi started in the late 1950´s the national nuclear power laboratory at Studsvik. Later it was transformed into a general energy laboratory, but now most of the activities at the site are managed by companies of the Studsvik Group (parent company Studsvik Holding AB), still heavily involved in the nuclear area. One of the main tools is the materials testing reactor R2 (50 MW) with extensive material laboratory facilities including a hot-cell laboratory. Studsvik is today a privately owned commercial industry group, which offers components, services and consulting.

Nuclear waste

The spent fuel from all Swedish nuclear power plants is transported by a specially designed ship (m/s Sigyn) to a central interim storage facility for spent nuclear fuel - CLAB. This facility commenced operation in 1985 and is situated close to the Oskarshamn nuclear power plant. CLAB has at present a storage capacity of about 5000 tonnes of spent fuel. With a planned expansion in 2004 to 8000 tonnes, it will have sufficient capacity to handle the entire Swedish nuclear programme.

Some waste with low level of radioactivity is finally disposed of in shallow land burials on some of the sites and some of it is incinerated at Studsvik. Waste with low level of radioactivity can be declassified in accordance with general criteria given by SSI. There is also a possibility for ”case by case” declassification if approved by SSI. All other waste from reactor operations is transported by Sigyn to an underground final repository for low- and intermediate-level waste, SFR, operational since 1988. SFR is located close to the Forsmark nuclear power plant. Most of the waste from decommissioning the reactors will be disposed in SFR. With a planned expansion SFR will be sufficient for the entire Swedish nuclear programme.

Svensk Kärnbränslehantering AB, SKB (the Swedish Nuclear Fuel and Waste Management Company) has built and owns CLAB, SFR, the Äspö Hard Rock Laboratory and the Encapsulation Development Facility. SKB is jointly owned by the Swedish utilities (Vattenfall AB 36%, Forsmarks Kraftgrupp AB 30%, OKG AB 22% and Barsebäck Kraft AB 12%) and on behalf of utilities is conducting the extensive research and development and demonstration work, which is required with regard to the remaining facilities for the final disposal of long-lived spent nuclear fuel. SKB is further responsible for co-ordination and investigations regarding the costs associated with nuclear waste and future decommissioning.

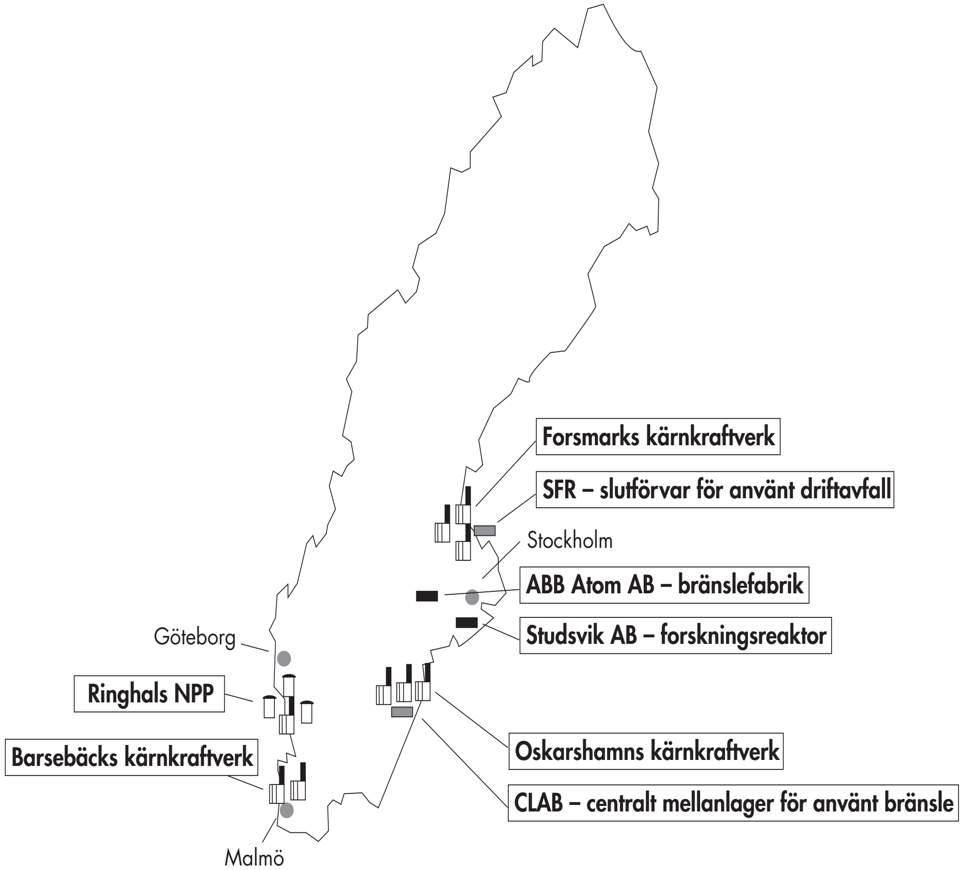
SFR and CLAB are operated by Forsmarks Kraftgrupp and OKG respectively on behalf of SKB.

AB SVAFO is another company owned by the utilities and operating in cooperation with SKB, formed to manage all the nuclear waste which has been or will be generated when decommissioning the facilities at Studsvik. The responsibility of SVAFO includes Studsvik's share (50%) in the decommissioned Ågesta plant.

According to the Financing Act from 1981 the nuclear utilities have to pay a waste fee to a state fund. The fund is to cover all present and future costs for the handling and final disposal of nuclear fuel used in the reactors, the decommissioning of all the facilities and the research and development activities required to achieve this (see further section 11.3).

The location of the nuclear facilities in Sweden is shown in Figure 3.

Figure 3. The location of nuclear facilities in Sweden.



Facilities for nuclear education, research and development

Academic education in nuclear technology in Sweden today is mainly concentrated to the Royal Institute of Technology (KTH) in Stockholm and the Chalmers Institute of Technology (Chalmers) in Gothenburg. In addition limited courses are given at the universities of Uppsala and Lund.

At the KTH department for Energy Technology there are two professorships in nuclear technology subjects:

- Reactor Technology
- Nuclear Power Safety

The professorship in Nuclear Power Safety is sponsored by SKI. In the Nuclear Power Safety department an extensive research programme on severe accidents phenomenology is being carried out and considerable experimental and professional resources have been built up over the last few years.

In addition to the above there is one vacant professorship in Applied Neutron Physics and a lecturer's post in Reactor Physics. It has been proposed that these two posts be discontinued but a final decision has not yet been taken.

At KTH the Nuclear Technology Centre was established in 1992 with the objective to strengthen the cooperation between KTH and the Swedish organizations in the nuclear energy sector and to promote and support education and research in nuclear subjects. The centre has been active in encouraging contacts between institutions at KTH and the industry to support doctorate studies and research projects at KTH and other universities.

At Chalmers there are active institutions with professors in Reactor Physics and Nuclear Chemistry.

In addition to the above basic education, the KSU company offers academic level courses primarily directed towards engineers without a nuclear background or education , who are recruited by the utilities and need an introduction in nuclear technology.

The resources for nuclear research and development in Sweden comprise the laboratories and expertise in Studsvik including the R2 materials research reactor and hot-cell laboratory mentioned above, the research and test facilities at the ABB Atom LWR Service Center in Västerås, where a complete reactor hall, mock-ups, a mechanical workshop and a laboratory are available; the Älvkarleby laboratory for fluid mechanics and hydraulics owned by Vattenfall Utveckling AB. The development work at Älvkarleby with relevance to safety comprises studies of boron dilution transients, flow-induced vibrations and the development of new, more efficient strainers for the BWR emergency core cooling systems.

In total about 5800 people with some specific nuclear competence are employed in the nuclear sector of Sweden[9]. This figure includes the utilities, the supplier, the consultants as well as research institutions and the regulatory authorities.

[9] SOU 1990:40: Nuclear Power phase-out- competence and employment (in Swedish).

3. The Swedish participation in international activities to enhance nuclear safety

The participation in international nuclear safety activities and cooperation is regarded in Sweden as very important both by the authorities and the utilities. Representatives from Sweden have traditionally taken an active part in such activities.

3.1 Regulatory authorities

Important international work for the regulatory authorities follows as a consequence of the Swedish ratification of international conventions and the signing of bilateral and multilateral agreements. In these cases the Government often assigns to the authorities the tasks of providing expert knowledge and fulfilling Swedish obligations.

In addition, international sharing of efforts and results is considered in Sweden as crucial for efficiency in the regulatory work. From a quality assurance point of view, it is also important that national regulatory programmes are open to international scrutiny and peer review. For these reasons SKI participates actively in a number of OECD/NEA, IAEA and EU committees and working groups. SKI has also been invited to become a founding member of INRA (the International Nuclear Regulatory Association).

Several other safety assessments performed both by SKI and the utilities have been subjected to various types of international peer review. Furthermore OSART missions have been performed at all Swedish reactor sites. 1995 at the request of SKI, the Swedish Government invited an international group of experts as a governmental Commission to make a thorough review of the Swedish nuclear regulatory activities. Their reports were issued in 1996 and will be referred to further in the present report[10].

Senior experts from SSI are active participants in, for example, the International Commission on Radiological Protection (ICRP), the OECD/NEA, the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the IAEA . SSI has participated for many years in the EU activities within, for example, research and transportation, and in particular the work with the new Basic Safety Standards Directive.

In total the international activities are very extensive in the fields of nuclear safety and radiation protection. Even if the activities in general are regarded as important, SKI and SSI constantly have to prioritize their participation, because of limited staff resources. Cases, where the tasks are directly regulated by conventions or special agreements signed by Sweden, have the highest priority. Participation in standing groups of international organizations are also given high priority. Other international tasks are given priority according to the estimated importance of the individual case.

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[10] SOU 1996:73: Swedish Nuclear Regulatory Activities- Volume 1- An Assessment and SOU 1996:74: Swedish Nuclear Regulatory Activities- Volume 2- Descriptions.

3.2 Utilities

The Swedish utilities have also taken an active part in international cooperation to enhance nuclear safety by sharing experience, contributing to work with international regulation and guidelines and participation in safety assessments and peer reviews. The current participation in major activities comprises:

- Membership through the jointly owned company KSU in the WANO and INPO organizations. Participation includes liaison engineers in the WANO Paris Centre and the INPO Atlanta Office on a continuous full-time basis. In addition active part is taken in various activities such as conferences and seminars, information and experience exchange, peer reviews, committees and twinning arrangements.

- Membership in owners group associations of the major European and US vendors. Important items in this cooperation are investigations and development to resolve safety issues and improve safety by introducing new technology and analysis methods.

- Swedish utilities, represented by FKA (Forsmark Kraftgrupp AB) participate in the EUR project (European Utilities Requirements) to develop requirements for new reactor designs. One important aim of the Swedish participation is to share ideas and concepts for enhanced safety in the future which might be introduced in existing plants.

- Participation in various IAEA activities by experts from the utilities such as OSART and ASSET missions, conferences and seminars, technical committees, workshops and task groups. Personnel on leave of absence from the utilities also frequently serve at various positions in the IAEA organization.

- Participation in a great number of various organizations and task forces representing most of the disciplines to be found in a nuclear facility, such as maintenance, fuel and core issues, radiation protection, and mechanical, electrical and nuclear instrumentation design and testing.

3.3 Joint authority-utility international participation

In the area of research and development there is comprehensive cooperation by Swedish utilities and authorities in international projects and research organizations. One particular example of this are the NKS programmes (Nordic Safety Research Project) which have been carried out since 1977, following cooperation between the Nordic countries in other forms since the late 1940´s. The programmes involve the five Nordic countries and each programme has a duration of four years, the current one covers 1998-2002. The NKS programme has a budget of about 12 MSEK per year in addition to which in-kind contributions by the participants of at least the same amount should be provided.

Other international research programmes where Sweden participates are the Severe Accident Research Programme, SARP, of the USNRC, various research projects within the European Union and the OECD

Halden project located at the Energy Technology Institute in Halden, Norway. The Halden project deals with nuclear fuel and materials issues and research on the man-machine interfaces and computerized process models.

In 1992 NEA launched the ISOE (Information System on Occupational Exposure). ISOE is a three-level database system providing occupational data for trending, cost-benefit analyses, technique comparison, information exchange, and other analyses based on the ALARA principle. Sweden is a member and participates in this work as well as other utilities and regulatory agencies throughout the world. In 1997 a NEA/IAEA joint ISOE secretariat was created.

3.4 Nuclear safety cooperation with other countries

Since 1991 SKI and SSI have been involved in technical cooperation and support to the states of Central and Eastern Europe. With regard to nuclear safety Sweden early concentrated these efforts to Lithuania and the Ignalina Nuclear Power Plant (INPP). This priority was quite natural as Lithuania is a neighbouring country, lacking to a large extent resources and nuclear infrastructure when it in 1991 received responsibility for the INPP. In addition the RBMK-reactor concept was little known in detail in the west at the time, and in Sweden there was a considerable public concern about the safety of INPP after the Chernobyl accident.

The Swedish bilateral nuclear safety cooperation with Lithuania has been organized in three programmes:

- authority support
- industry and NPP cooperation, and
- technical projects.

Authority support includes assistance in the build-up of the regulatory body in Lithuania (VATESI). It also covers assistance to the Lithuanian Government in developing the legal framework for nuclear power operations and advise on the organization of the nuclear energy production in order to enable a strict and undivided responsibility for safety. Authority support has also, more recently, been directed to the development of Technical Support Organizations to VATESI.

Industry and NPP cooperation include a combination of technical projects and a transfer of western knowledge and experience on how to develop and organize functions and activities. Projects within this programme have dealt with materials inspection, PSA, fire hazards analysis, quality assurance, management development, emergency preparedness and information service.

Technical projects include support in the evaluation of needs, specification of proposed solutions, tender evaluations, and in some cases financing of new technical systems and components. Within this programme Sweden has delivered equipment and engineering support for fire protection, physical protection, tele- and radio communication, radioactive waste handling, radioactive monitoring and dosimetry at the INPP site.

In total about 285 MSEK have been allocated to the Lithuanian programmes including the fiscal year 1998. About 120 MSEK have been spent on equipment deliveries to INPP.

Since 1995 the Swedish nuclear safety cooperation has been handled by a special project management organization: The Swedish International Project Nuclear Safety (SIP) which reports directly to the Director General of SKI. SIP contracts industry suppliers, and consultants in Sweden and abroad to deliver equipment and engineering services as specified in cooperation with SIPs eastern counterparts. The radiation protection support, which also deals with radiation protection outside the nuclear power sector has been handled since 1997 by a special department within SSI: The International Development Cooperation.

Today there is extensive international cooperation concerning the safety of the RBMK-reactors. Sweden is represented in all the relevant groups within the EU, G-24 and IAEA as well as the EBRD. In the bilateral programme there is increased cooperation with other countries. Sweden today has agreements with the UK, USA and Norway about bilateral cooperation in Lithuania, and Sweden has the role of coordinating the international assistance to VATESI regarding the urgent licensing of INPP unit 1. Sweden has also become more active in tendering on EU- projects within the TACIS and PHARE nuclear safety programmes, which include authority support as well as industrial projects in the states of Central- and Eastern Europe and in the CIS.

In 1996 Sweden started to be engaged in nuclear safety support activities in Russia. At the Leningrad NPP probabilistic and deterministic safety analyses are under way in a joint USA, UK, Sweden and Russia project. Sweden also provides training and support in the development of methodolgy for non-destructive testing at the Leningrad NPP in Sosnovy Bor. In spring 1998 an agreement was also made with Kola NPP about a support programme, which is coordinated with earlier and ongoing efforts by EBRD, USA, Finland and Norway.

In total the Swedish Government has allocated the following funds for nuclear related support to the Central- and Eastern European countries since 1991.

Administrating organization	**Purpose**	**Amount MSEK**
SKI/SIP	Nuclear safety, on-site waste management	301
SSI	Radiation protection, waste management	110
SKI	Non-proliferation measures	36
EBRD/NSA[11]	Nuclear safety	73
Chernobyl Shelter Fund	Containment of Chernobyl 4	22

Table 3. The total Swedish funding of nuclear related support to other countries since 1991

[11] The Nuclear Safety Account within the European Bank for Reconstruction and Development.

B. COMPLIANCE WITH ARTICLES 4 TO 19

4. Article 4: IMPLEMENTING MEASURES

Each Contracting party shall take, within the framework of its national law, the legislative, regulatory and administrative measures and other steps necessary for implementing its obligations under this Convention.

The legislative, regulatory and other measures to fulfil the obligations of the Convention are discussed in this report.

5. Article 5: REPORTING

Each Contracting Party shall submit for review, prior to each meeting referred to in Article 20, a report on the measures it has taken to implement each of the obligations of this Convention.

The present report constitutes the first Swedish report issued in obligation with Article 5.

6. Article 6: EXISTING NUCLEAR INSTALLATIONS

Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonable practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

6.1 The general safety status

At the time the Convention entered into force, the general safety status of the Swedish nuclear power plants was satisfactory. In the last ten years, between 100 to 200 MSEK have been invested on average per year and unit for maintenance and upgrading of safety and availablility. This includes replacement of worn or unreliable mechanical components, of old instrumentation and control equipment and other backfitting measures. It also includes some major renovation projects.

The operating permits of five oldest BWR plants: Oskarshamn 1, Ringhals 1, Barsebäck 1 and 2 and Oskarshamn 2 were revoked by SKI, for about five months in 1992 –93, for extensive renovation of the emergency core cooling systems. Additional installations were made during the annual outages in 1993. These projects included extension of the strainer area on the suction side of the pumps to the core- and containment emergency cooling systems, changing of insulation material in the containments, and installation of diversified systems for back-flushing of the strainers.

The oldest plant Oskarshamn 1 was kept shut down for about three years for additional renovation of the primary system, which after an extensive chemical decontamination, included partial replacement of piping, welds and nozzles, an in-depth inspection and verification of the reactor pressure vessel and internal parts, installation of a leak detection system, installation of pipe-whip restraints in the main circulation circuits and steam lines, verification of blow paths to protect the reactor building in the event of a LOCA outside the containment, measures to improve the separation of safety systems, new separated cabling in containment and change of motor drives for control rods and isolation valves, modification of the electrical supply systems and auxiliary systems to remove dependencies, modification of the systems for RPV level- and pressure measuring, increased capacity of the boron system, additional isolation valve in the residual heat removal system, introduction of a new independent scram condition, seismically safe electrical battery supply and structural reinforcements of the containment and reactor building.

Additional modernization measures are in progress (see below) and will be finalized in 1999. In parallel with the renovation measures, OKG carried out an extensive upgrading of the safety analysis and the safety case of Oskarshamn 1. These measures will complete a modernization of Oskarshamn 1 which started already in the late 1970´s with the backfitting in a separate building of an additional electrical supply system and an auxiliary feed-water system.

SKI made the assessment when granting the restart permits, after the shut-down of the five reactors, that the safety level of the older BWRs had been restored to the original safety level according to the Final Safety Analysis Reports, and in the case of Oskarshamn 1 that there had been considerable upgrading towards modern safety codes and standards.

In the Ringhals 1 unit, extensive upgradings have also been undertaken or are under way. Besides the replacement of insulation material and strainers in the emergency cooling system mentioned above, this includes exchange of Inconel welds in the primary system to material with higher resistance to defects and lower crack growth rate.

The PWRs have also been objects of renovation and the exchange of major parts in the primary system because of material degradation. The steam generators of Ringhals 2 were replaced in 1989 and the Ringhals 3 steam generators in 1995. The reactor pressure vessel head at Ringhals 2 has also been replaced.

During the last few years occupational radiation doses at the BWR:s have deviated from the earlier decreasing trend. More extensive in-service inspection of primary piping and construction work in the modernization programmes of the reactors has contributed to increasing occupational radiation doses, especially for units from the first two reactor generations. In connection with the 1997 outage at Ringhals 1, long time measures to reduce dose rates in the reactor containment were performed. The situation for the PWR:s is, however, quite the opposite. Since the replacement of steam generators at Ringhals 2 and 3, occupational radiation doses have decreased substantially and today all the PWR:s are well below the ambition levels issued by SSI.

At Ringhals 1, after an extensive decontamination, replacement of cobalt containing material in valves has also been carried out. This measure is expected to result in decreasing occupational radiation doses in a couple of years. A similar exchange of cobalt containing material is being considered at the other NPPs in the near future.

Current safety concerns

Every year SKI and SSI submit a joint report to the Government about the safety and radiation protection status of the Swedish nuclear power plants. In the report issued in November 1996[12], the regulatory authorities pointed out that the safety level is satisfactory in general, but some issues need attention. Such issues identified in the operating experience during the last years were:

- age related material degradation, for example in material earlier considered to be less sensitive to IGSCC,
- fuel bending in the PWRs accompanied by increased insertion time of control rods,
- a small increase of fuel damage, even if the long term trend is decreasing,
- organizational and safety culture issues, and
- an increase of radiation doses to staff (BWRs).

As a result of the review of the Oskarshamn 1 safety case, before permission was granted for restart, several long term safety issues were identified. In 1996 SKI required all licence holders to review and report on the status of these issues for their reactor units. These reports showed that many issues were specific for Oskarshamn 1, but there was also a need to verify the situation at other units. The reports also showed that there was room for technical improvement, especially in the older reactors, where for instance secondary effects of accidents are handled in a more primitive manner than in the newer designs. This applies for effects of LOCAs on building structures and different types of safety equipment. Some of the more long-term safety concerns are listed below. They will be analysed further and evaluated in the ongoing projects to review and upgrade the safety cases of all the units in Sweden.

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[12] The safety- and radiation protection status of the Swedish Nuclear Power Plants 1995-96. SKI Report 96:71, SSI Report 96-12 (in Swedish).

- Environmental qualification of equipment, for instance of electrical penetrations of the containment. Exchange of penetrations and cabling are ongoing, or have been completed at all units.

- Dependencies in the electrical supply systems. A detailed analysis is needed for all the BWRs.

- Separation and dependencies in the cooling chains. The sensitivity for this varies with the plant designs and the consequences should be evaluated.

- The function of the isolation valves. This has been a generic issue for a long time and the closing times have been verified experimentally. A large number of valves have been replaced. Some critical penetrations have been equipped with three valves in order to safeguard the function. This is especially urgent for the older reactors Oskarshamn 2, Barsebäck 1 and 2 and Ringhals 1 with external main recirculation pumps.

- Damage resulting from pipe-breaks. This is mainly a problem for the older external pump reactors, the newer units are constructred with pipe-whip restraints. An analysis was completed for Oskarshamn 1, has been started for Ringhals 1, and is also needed for Barsebäck 1 and 2 and Oskarshamn 2.

- The level-measurement system for the reactor pressure vessel is essential for the initiation of reactor safety systems. Investigations have been carried out as how to diversify the level- measurement system for the BWRs except the two oldest ones, which have a diversified measurement, but no acceptable solution has been found.

- Diversification of the pressure relief system. Installation has been started in Forsmark. For the other units solutions are still being investigated. As this is one of the most vital safety functions in a BWR a diversification is motivated.

- Seismic verification. This is ongoing with the objective to have a clear picture in 1998 of the resistance of all the Swedish units to seismic loads which could affect the site with a probability of 1 per 100 000 reactor years.

- Possibilities for operators to handle fast accident sequences in the PWRs. In these units manual operations are needed quite early after a disturbance, compared with the BWRs. Improved automatic support or other solutions to assist the operators better might be necessary.

As a consequence of the governmental decision to start the phase-out of nuclear power with Barsebäck 1, another important current safety concern is how such a decision affects the personnel and the organization, in the first hand at Barsebäck but also at the other reactor units in Sweden. Earlier only very marginal effects on personnel motivation and turnover have been detected as a result of the political debate and decisions about the nuclear phase-out. More substantial effects were found on the recruitment to nuclear engineering courses and post graduate research training programmes[13].

The situation is now different, and it is necessary to follow this situation closely.

In oder to identify all the important regulatory issues in connection with decommissioning SKI has started to collate experience from other countries. So far a report on US experience has been published[14]. This report shows that there are specific safety concerns attached to every step in a decommissioning process.

In the most recent report to the Government on the safety and radiation protection status issued in April 1998[15], the regulatory authorities confirm that the above mentioned safety concerns are still valid. The recent operational experience shows that an increased attention is needed on some issues such as:

- routines and operator aids for operability control of systems and components,
- material degradation of primary system piping and corrosion damage in the containment structure,
- deficiences in individual control rods mainly due to material degradation,
- radiation doses to the staff, which in 1997 resulted in the largest collective dose so far in Sweden (27,9 manSv).

SKI and SSI conclude, on the basis of inspections and reviews, that the utilities are working in a competent way with these problems and that they also have improved their methods and routines. Concerning the control of material degradation, planning strategies, methodology and control routines should be further improved.

As the most important safety concern, the regulatory authorities report that there are indications of work overload of the NPP organizations, and keen competition to get qualified specialists, at the same time as the economical competition becomes harder on the deregulated electricity market. This problem is reinforced by all the well founded investments now going on in the Swedish NPPs, the implementation of new technology, the retirement of experienced staff, and the political decision to start the phase-out of nuclear power. The situation has caused SKI to take the initiative to an official investigation about how Sweden can safeguard the competence necessary to operate nuclear power in a longer perspective.

6.2 Overview of safety assessments performed

The Swedish utilities today use an integrated safety analysis approach in order to be well informed about the safety characteristics of the plants. This includes deterministic analysis, probabilistic safety analysis, analysis

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13 SOU 1990:40: Nuclear Power phase-out- competence and employment (in Swedish).
14 Durbin N & Harty R. US Experience with Organizational Issues During Decommissioning. SKI Report 98:3.
15 The safety- and radiation protection status of the Swedish Nuclear Power Plants 1997. SKI Report 98:10, SSI Report 98:06 (in Swedish).

of the man- technology-organizational interface and experience feed-back analysis. Assessment by PSA is today regarded as a safety assessment programme of its own, in line with the living PSA-concept, and not only as a part of the periodic safety reviews where the use of PSA started. Safety assessment has become an activity which is continuous. PSA is used to an increased extent as an analytical tool in strategic planning for all types of modernization projects[16], and in connection with other decision making concerning nuclear safety. Below follows a summary of the recent major assessment projects and their generic findings.

Probabilistic Safety Assessments[17]

Plant specific level-1 PSAs (analysis of the core damage probability) have now been performed for all the 12 operating units, which was required as a part of the periodic safety reviews (see below). In 1986 SKI initiated a comparative review of all the PSAs (the SUPER-ASAR- project). This project led to recommendations concerning PSA modelling as well as the use of PSA in safety decision making. The findings from the SUPER-ASAR- project are being implemented in the current cycle of PSAs. A stronger focus is placed on providing an integrated risk picture, suitable for the living PSA approach. This includes extensions of PSA to other operating modes than full power operation, external initiating events, level-2 analysis (analysis of the probability of releases to the environment), analysis of Common Cause Initiators (CCI), more detailed modelling of LOCA categories, modelling of electrical power supply and signals. In principle all types and operating conditions should be included in the probabilistic assessments. The only exception is intentional damage by sabotage, terrorist attack, etc, which are counteracted by special physical protection measures. Table 4 summarises the latest versions of PSA in Sweden.

There is no explicit regulatory requirement in Sweden regarding maximum core damage frequency. The utilities have established probabilistic safety objectives for their internal use which corresponds to an internationally recommended objective for the probability of severe core damage in new reactors[18]. Thus, safety measures shall be prioritized if

- the core damage frequency exceeds 10^{-5} per reactor year with a high confidence,

- the probability of a release of more than 0,1% of the radioactive core inventory, excluding noble gases, is higher than 10^{-7} per reactor year.

These objectives are regarded by SKI as a contract to be accomplished. The core damage frequencies for the older Swedish reactors are calculated to be a little over 10^{-5} per reactor year, and the newest designs are below this frequency. Preliminary results from a recent and very refined PSA of Oskarshamn 2 show a total core damage frequency considerably higher than the safety objective, mainly due to dependencies in the emergency power supply systems generic to the design of the BWR 3 generation. This analysis, which is very conservative, was made in order to identify and evaluate possible technical challanges to the defence in depth

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[16] Hagberth R & Lindfors A. Swedish nuclear power plants: balancing safety and kwh costs in the long term. Nuclear Europe Worldscan 11-12/1996.

[17] The text is based on Current practices of PSA in Sweden. Vattenfall report GES 91/97, 1997.

[18] Basic Safety Principles for Nuclear Power Plants. IAEA Report INSAG-3. Vienna, 1988.

system, of Oskarshamn 2, as an input to the modernization project. Based on the preliminary results, OKG AB has already planned short term measures to improve the reliability of the emergency power supply systems and a major design improvement will be investigated after verification of the PSA results. A similar analysis is under way of the Barsebäck units.

The exact PSA figures are not regarded as very important in Sweden, and are not used to compare different units. Even if the PSAs have been refined over the recent years, they still contain many uncertainties in models, in reliability data and in other parameters. This makes the results very sensitive to changes in the presumptions. However, the information provided by the analyses is anyhow regarded as very useful and important to identfy weaknesses in the design of the plants.

Several plant modifications have been implemented and are still ongoing as a consequence of PSA results. Generally they cover measures to protect against common cause failures, measures to improve the physical and functional separation, improvement of operator support, and improvement of maintenance and testing.

Treatment of human reliability in PSA has received considerable attention. This has also influenced the modification of emergency procedures and operator training. Two principal human interactions involved in the risk dominant sequences for BWRs are: (1) manual depressurization of the reactor vessel after transients with loss of main feed-water and auxilliary feed-water systems and (2) back-flushing of strainers in the emergency core cooling system and containment cooling spray system after a large or medium LOCA. For PWRs, one of the human interactions related to dominant sequences is the failure to depressurize and failure to switch over to high-head recirculation after a small LOCA.

Modelling of human behaviour and organizational factors in the PSAs are still in need of considerable improvement.

Analysis	**B 1-2**	**F 1-2**	**F3**	**O1**	**O2**	**O3**	**R1**	**R2**	**R3-4**
Level 1									
· Internal initiating events	1995	1994	1995	1997	1998	1998	1992	1992	1992
· LOCA outside containm							1994	1993	1993
· Fire	1991	1996	1995x	1997	1999pl	1998	1993	1994	1997
· Flooding	1991	1997		1997	1999pl	1998	1994	1994	1999pl
· External (earthquake etc)									
· Low power	1995	1999pl	1995x				1995	1993	1990
Level 2	1995	1999pl	1995	1988pl	1999pl	1998	1995	1994	1999pl

B= Barsebäck pl= planned x=pilot study
F= Forsmark
O= Oskarshamn
R= Ringhals

Table 4: Latest PSA versions in Sweden.

Design basis reconstitutions

As one consequence of the five reactor stop in 1992 and 1993 to improve the emergency core cooling systems, the nuclear utilities initiated major reassessments and modernizations of the final safety analysis reports of their older reactors. The reassessments started with pilot projects in 1993/94 and are scheduled for completion before 2000. The motives behind these substantial efforts are, in summary, the following[19]:

- a need to verify the safety level of the plants by questioning existing work and performing those evaluations which are found to be missing or deficient,

- a need to investigate possibilities, benefits and consequences of applying modern requirements and guidelines to the plants for modernization and safety improvement purposes, and

- a need to preserve and carry further the knowledge and experience of those who participated in the original design work and building of the plants before they retire. This includes the transfer of knowledge to a younger generation.

For the Swedish BWRs the work is being carried out in four different projects:

BOKA design reconstitution of Oskarshamn 2, Barsebäck 1 and Barsebäck 2. This project started with a pilot project in 1993 and is planned to be completed at the end of 1998.

REDA design reconstitution of Ringhals 1. This project started with a pilot project in 1993 and is also expected to be completed in 1998. In a second phase a comparison to modern safety requirements will be made.

RAK design reconstitution of Forsmark 1 and Forsmark 2. This project started with a pilot project in 1994. The main project started in 1995 and is planned to be completed in 1998.

FOKA design reconstitution of certain mechanical equipment of Oskarshamn 3 and Forsmark 3. This project started in 1997 and the first step is planned to be completed in 1998. The project will investigate differences between the two units and will clarify some identified uncertainties in the design prerequisites of mechanical equipment. Plans exist to continue as BOKA; if so decided, the project will be completed by the end of 2000.

DART design reconstitution of Ringhals PWRs. This project started as a pilot project in 1996. The main project started in 1997 and is planned to be completed in 2001. The project was somewhat delayed because of extensive work to locate all the original design basis documents and to retrieve documents from Westinghouse.

[19] Jonsson N-O. Design Basis Reconstruction in Sweden. ABB Atom, 1995.

The main contractor for the BWR projects are ABB Atom and for the PWRs Westinghouse, but the work is being done in close cooperation with the operating organizations. The invested efforts are calculated to about 250 manyears for BOKA and about 100 manyears for REDA. The RAK- and FOKA project efforts are significantly less, since these reactors have a more modern design.

In general the project steps are the following:

- general safety analysis work: identification, interpretation and application of safety requirements and guidelines for the plant,

- system reverification work: significant improvements in the documentation of the major process mechanical, power generation and distribution, instrumentation and control systems of the plant. An evaluation of the design of major systems is also performed against new standards as they result from the general safety analysis work and design evolution between different generations of reactors including the vendors newest designs,

- analysis work: identification and verification that the standards and requirements as provided by the general safety analysis work are satisfied, and tests of these verifications in view of present knowledge.

A general planning principle has been to group the work according to safety functions. Safety functions considered are: reactivity control, reactor core cooling, reactor coolant pressure boundary integrity protection, emergency core cooling, residual heat removal, containment protection, and reactor building emergency ventilation. In principle this can also be considered as reevaluating the plant with respect to each barrier against release of radioactivity.

In addition to evaluating safety functions, the plant-wide supportive functions of emergency power generation, distribution and instrumentation are evaluated. Another group of work relates to external events such as fire and flooding protection, waste handling and lifting heavy objects. A further group of work includes deterministic calculations of loads on structures and components and structural mechanics evaluation of these loads against acceptance criteria.

All results from these projects have not yet been summarized. Some general important findings are:

- a significantly enhanced understanding of loads, load combinations, aging of materials, and structural mechanics since the plants were designed,
- a better understanding of transient and accident phenomena within the primary system by the use of modern computer codes,
- significant changes have taken place in the design of the reactor core and the fuel since the plants were originally designed, present day reactor cores contain significantly more reactive fuel than considered in the original design of the plants,
- some limits and conditions in the Technical Specifications were found to be not verified against the design requirements for the plant.

SKI follows the design reconstitution projects closely by inspections and regular meetings with the utilities to discuss the work status and results. SKI is also performing some additional studies of different safety issues. This is included in the ongoing work to define the technical safety requirements for operating reactors in Sweden after 2000. SKIs considers that the design reconstitution projects on the whole are well defined and well carried out, and that they provide a good foundation in reactor safety for the remaining nuclear operating time in Sweden.

Periodic safety reviews

As a result of the Reactor Safety Committee recommendations (see section 1.3) Parliament decided in 1981 that all Swedish power reactors shall undergo at least three comprehensive safety reviews during their operating lifetime. This has been interpreted as one periodic safety review every 10 years. SKI was authorized to issue directives for these reviews.

The periodic safety reviews, in Sweden called ASAR[20], are submitted by the licensees to SKI. SKI reviews these reports in the light of regulatory requirements and regulatory experience with the specific plant, and submits a review report to the Government (SKI-ASAR). SSI also submits a review report to the Government on the radiation protection issues. SKI and SSI cooperate to some extent in the review work. The first cycle of ASAR (ASAR-80) has been completed and the second cycle, ASAR-90, is completed to 50 percent:

Reactor unit	Licensee report completed	SKI review report completed
Oskarshamn 1	1992	1995
Barsebäck 1 and 2[21]	1995	1996
Ringhals 2	1994	1995
Oskarshamn 3	1996	1997
Forsmark 3	1997	1998
Ringhals 1	1995 partly	1998 pl
Oskarshamn 2	1999 pl	
Forsmark 1	2000 pl	
Forsmark 2	2001 pl	
Ringhals 3 and 4	2002 pl	

pl= plannned

Table 5: ASAR-90 project status in spring 1998.

The ASAR-80 projects were to a large extent focused on technical experience and a PSA level-1 study, which was developed as a part of the periodic safety review. For ASAR-90 the perspective has been changed

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[20] As operated Safety Analysis Report

[21] One common ASAR is allowed for twin units if the conditions for safety are the same

from a very strong focus on technical issues to an extensive analysis and evaluation of how safety work is organized and implemented at the plant. This includes the major preventive safety programmes of the plant, as well as investigation of significant events and analysis of operational experience. In particular, the licensees are expected to demonstrate their abilities to identify safety problems and to analyse, implement and evaluate the solutions. Still included in SKIs directives is an evaluation of technical experience and plant modifications, and also a PSA level-2 study. Finally it is required a report on the safety improvements to be implemented as a result of the periodic safety review.

In general the periodic safety reviews have led to constructive discussions between the regulators and the licensees. The 10 year perspective is a useful assessment period to follow up long-term issues and trends in the quality and safety work, which have a tendency to be lost in the ordinary

day-to-day perspective. The utility reports have been quite self critical on many issues and have indicated that there is room for improvement expecially in organization and administrative routines. Typically very few results have come out of the periodic safety reviews requiring urgent measures, but rather topics to be handled in a five year perspective. These measures have to do with ageing of systems and components, measures identified by PSA in order to increase redundancy and diversification of safety systems, improvement of the safety assessment models and improvements in organization and adminstrative routines.

MTO-assessements

Licensee Event Reports (LER), where some underlying deficiency in the interaction between man, technology and organization (MTO) is estimated to have strongly contributed to the event, are as a rule screened and analysed in the operating organizations of the NPPs. The conclusions drawn are reviewed by the safety departments or the safety committees. In the beginning of the 1990´s, SKI started to make a special annual review of these LERs submitted by the respective NPP. The reports are reviewed with regard to underlying trends and generic safety issues. Based on these reviews discussions have been held with the responsible managers at the NPPs to benchmark the conclusions drawn by the plants and to evaluate the actions taken.

Deficiences in organization, plant documentation, management and work routines, for instance in operability control, have been discussed during these meetings. No evaluation has been made of the effects of the meetings in terms of decreasing the number of MTO-related LERs, but it is quite clear that the meetings have resulted in increased attention to the MTO-issues from the plant management side. In general the Swedish plants are today considered by SKI to be well aware of the importance of organizational- and safety culture issues. However, the experience from recent years shows, that even if the operational records are very good it is continuously necessary to attend to the MTO issues.

6.3 Overview of reactor modernization programmes

Operational experience has shown that ageing of components and materials in the plants proceeds, control equipment becomes obsolete, spare parts are difficult to find, modifications and replacements have to be made. According to the utility policies, improvement, technical renewal and backfitting have been carried out on a continuous basis since the plants were taken into operation. In the first half of the 1990´s it was however realized that a more comprehensive modernization and renewal programme was needed for the older reactors. The importance of this issue was of course emphasized by incidents such as the five reactor stop in 1992-93.

The modernization programmes comprise comprehensive investments at the different sites as outlined below. The above mentioned design basis analyses and revised documentation, as well as efforts to renew competence by transfer of knowledge and experience to the younger generation, are other components of the modernization. The main objective of all the programmes is to implement the measures necessary for maintaining high availability and safety by technically up-to-date plants operated by competent people.

The earlier mentioned renovation of Oskarshamn 1 showed that the reactor pressure vessel was in good condition and capable of operating for more than its 40-year design lifetime. The utility OKG therefore decided to further modernize the unit in order to ensure safe and economical operation for at least another 20 years. Three projects are included in this modernization programme:

- further checking of the reactor pressure vessel and main circulation pipes, and exchange of reactor internals (moderator vessel, moderator vessel head and steam separators),

- further safety improvements in the core cooling systems, electric power system (two additional trains) and the I & C system (introducing digitalised systems for neutron flux monitoring and the reactor protection systems) including modernization of the control room,

- improvement of the turbine (main exchange of HP and LP turbines) to increase availability and thermal efficiency, adding at least 20 MWe to the power output.

This modernization programme will be implemented during extended outages and will be completed in 1999. The costs for the first two items are calculated to about 1000 MSEK and will be met in the long run by better availability and longer plant life. The costs of the turbine project will be met through higher income due to the extra capacity over a 20-year period and reduced maintenance costs as a result of the installation of modern equipment.

For the triplet units Oskarshamn 2 and Barsebäck 1 and 2, planning and preparation of modernization measures are mainly based on the BOKA-project and its re-constituted safety report (F-FSAR). Consideration is also taken to the analysis made in the BOKA-project on the requirements for plants built to modern standards and the recently completed level 1 PSA. A dialogue is also being held with the major reactor vendors, as potential suppliers, concerning their views on modernising concepts for the three units. The project started as a pre-study in 1996 with the involvement of the operating organizations making an inventory of known weaknesses and experience from operation of the units.

The modernization measures will most probably include a chemical decontamination of the reactor pressure vessel (RPV) and the primary systems, as in Oskarshamn 1 in order to reduce the dose-rates, followed by tests of the RPV and its internal parts, and the replacement of IGSCC-sensitive piping in the primary systems. Other measures will be improved functional and physical separation of safety and electrical systems, exchange of the instrumentation and control systems in favour of digitalised equipment, and modernization of the control rooms.

For the Forsmark plant a comprehensive programme for modernization and plant renewal started in 1995 (Program 2000). It was preceded by a systematic analysis to determine what investments would be needed to maintain the current high availability and keep production costs at a constant nominal value (decreasing costs in real terms). The decision was taken to carry out the Program 2000, which includes investments of about 2000 MSEK by the year 2000. The programme is divided into seven different areas: reactor internals, reactor systems, reactor control equipment, turbine/generator, turbine systems, turbine control equipment and electric power systems. A large part of the programme is safety related and aims at improved safety and radiation protection.

FKA is also a member of the EUR (European Utility Requirements) group representing Vattenfall (and Sweden). Work is going on to develop a requirements document (EUR Volume 3) for the ABB Atom design BWR 90 conforming with the EUR general requirements (Volume 1 and 2). The overall objective of the Swedish participation is to obtain a basis for further development of the safety of the existing plants in Sweden.

A similar plant renewal programme, Ringhals Development Programme 1997-2001, has been decided and started at the Ringhals plant. The total investment is estimated to be 3400 MSEK for the four units and the stated objectives are to maintain present generation capability and develop safety. The technical renewal items are estimated to 54%, safety improvements to 37%, environment/radiation protection to 5% and general efficiency improvements to 4% of the total investment.

A large part of the programme consists of the replacement of instrumentation and control equipment, which is gradually becoming obsolete and difficult to maintain. The safety improvements to be included will depend on the outcome of the design reconstitution projects and the results of the on-going work to define requirements and goals for safety in the next century.

6.4 Assessement of further operation

All the 12 units operating today in Sweden comply with the deterministic licensing requirements, as described in the Final Safety Analysis Reports. These reports contain the technical requirements which are the basis for the operating permits. However, the licence holders are further expected to improve safety throughout the service life of the installation until further efforts are not reasonable justified. It is also the responsibility of SKI to initiate such improvements whenever justified by operational experience, or research and development. Some current safety concerns, however, not of a nature to question the present operating permits, have been mentioned in this chapter. Most of them are dealt with in the design basis reconstitution and modernization programmes under way for all units. The concern about the staffing situation, and other concerns connected to the initiation of decommissioning Swedish units, will be dealt with in separate projects.

With regard to safety improvement of the older reactors, SKI has concluded that there is not today any unified opinion about how modern design requirements and safety standards shall be applied to reactors built to earlier standards, in order to reach a safety level compatible with the newest designs. This is a most important and challenging issue, not least in the light of the modernization projects and plans for the Swedish reactors. SKI has started a project to clarify the regulatory requirements on reactors operating in Sweden after the year 2000. This work will be conducted in dialogue with the Swedish utilities and in active contact with the discussion about European requirements on new reactor designs.

In addition to this SKI project, the utilities are active in investigating the development of modern safety requirements and setting goals for future improvements. Work is going on within both the Vattenfall and Sydkraft groups, and a joint committee and an expert task force have recently been established on initiative of NORDSÄK to produce a document before the end of 1999 showing the joint view of the reactor owners on the development of the reactor safety during the next years. The purpose is to create internationally based common principles and requirements stimulating a cost effective and continuous development of reactor safety after the year 2000.

The document will be based on deterministic requirements supplemented with quantitative safety objectives as well as qualitative objectives. It will be described how the present safety reports (FSARs), the design basis reconstitutions, the utilities safety policies, Swedish and US regulatory requirements, IAEA-INSAG documents and the EUR- documents have been considered in the development of the new principles and requirements. These shall be applicable to all the Swedish units. There will be no detailed regulation in the joint document of specific unit designs. The work plan to produce the document was presented to SKI in May 1998 and a dialogue will continue during the work process.

The safety assessments made so far, results from the projects mentioned above, and completed or planned modernization measures, indicate that the Swedish reactors could continue to operate with a high safety level for their design lifetime of 40 years. One important precondition for further operation, with high requirements on quality and safety is, however, good preventive safety work including continuous learning, as an indication of a good safety culture, based on domestic and international operational experience, as well as research and development of new technology and safety standards. To accomplish this, the necessary human and financial resources have to be allocated despite stronger competition on the deregulated electricity market and the governmental decisions on decommissioning.

6.5 Conclusion

The Swedish Party complies with the obligations of Article 6.

7. Article 7: LEGISLATIVE AND REGULATORY FRAMEWORK

1. *Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.*

2. *The legislative and regulatory framework shall provide for:*

   (i) the establishment of applicable national safety requirements and regulations;

   (ii) a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a licence;

   (iii) a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences;

   (iv) the enforcement of applicable regulations and of the terms of licences, including suspension, modification or revocation.

7.1 Nuclear safety legislation and regulatory framework

The legal basis for the regulatory acitivities in Sweden is given in a number of documents of various types: laws, governmental ordinances, annual government letters of appropriation, and specific governmental decisions, including specific licensing decisions. Through government ordinances and specific decisions, the Government delegates to the regulatory bodies SKI and SSI (see chapter 8) specified parts of the legal authority given to the Government by the Parliament through legislation.

With respect to nuclear safety, the key legal documents are the Act on Nuclear Activities and the Ordinance on Nuclear Activities[22]. The general tasks for SKI and SSI are given in separate Ordinances (instructions) and, in later years, in the annual letters of appropriation (see section 8.1.2).

7.1.1 The Act on Nuclear Activities

The main law in Sweden regulating nuclear safety is the Act on Nuclear Activities (1984:3). This law replaces the Atomic Energy Act from 1956. The Act on Nuclear Activities entered into force in 1984 and was amended in 1992 and 1994.

The Act on Nuclear Activities contains basic provisions on safety in connection with nuclear activities and applies both to the operation of nuclear plants and to the handling of all nuclear material and nuclear waste.

[22] The full texts of the Acts on Nuclear Activities and Radiation Protection and the respective Ordinances are available in English: Swedish Environmental Legislation. Booklet 4, Nuclear safety and protection against radiation. Ministry of the Environment. Stockholm, 1996.

It also contains regulations on the obligation to obtain a licence and on the obligations entailed by the licence requirements. Against the special political background, the Act also states that no licence to erect a nuclear-power reactor may be issued (see section 1.3).

Great importance has been attached to provisions about the management of nuclear waste and research concerning nuclear waste. The Act also contains some basic provisions about the financing of waste disposal.

Finally, the Act also contains some provisions about international agreements with other countries aimed at preventing the proliferation of nuclear weapons.

The Act on Nuclear Activities contains no provisions about radiation protection. This is regulated in a special law, the Radiation Protection Act (see below). As far as nuclear installations are concerned, the Radiation Protection Act is implemented in close connection with the Act on Nuclear Activities.

Definitions

Nuclear activities are defined as (1 §)

1. the erection, possession or operation of a nuclear plant,

2. the handling, transport or other dealings with nuclear material or nuclear waste,

3. the import of nuclear material or nuclear waste,

4. the export of nuclear material

Nuclear material is defined as (2 §)

1. uranium, plutonium or any other substance that is or may be used as nuclear fuel, or any compound containing such a substance,

2. thorium or any other substance that is intended to be converted into nuclear fuel, or a compound containing such a substance,

3. spent nuclear fuel that has not been placed for final disposal

Nuclear waste is defined as (2 §)

1. material or other items that have belonged to a nuclear plant and become contaminated with radioactivity, and are no longer to be used in such a plant,

2. any radioactive substance that has been formed in a nuclear plant and which has not been produced at or removed from the plant to be used in education or research, or for medical, agricultural or commercial purposes,

3. radioactive parts of a nuclear plant that is being decommissioned,

4. spent nuclear fuel that has been placed for final disposal.

In principle, all dealings with nuclear material or nuclear waste are deemed to constitute nuclear activity for which a licence is required. The application, however, of the Act to very low-level nuclear waste and to material which contains a nuclear substance in extremely small quantities, as for example for the purpose of research, constitutes a special issue. Therefore, it is possible to prescribe exceptions to the Act for this kind of material.

Requirements on safety

Nuclear activities shall be conducted in such a way so as to meet safety requirements and fulfil the obligations that are pursuant to Sweden´s agreements for the purpose of preventing the proliferation of nuclear weapons and unauthorised dealing with nuclear material and with nuclear waste consisting of spent nuclear fuel (3 §).

Safety in nuclear activities shall be maintained by the taking of those measures required to (4 §)

1. prevent errors in or defective functioning of equipment, incorrect handling or anything else that may result in a radiological accident, and
2. prevent unlawful dealings with nuclear material or nuclear waste.

The Government or the authority appointed by the Government may issue more detailed provisions on these matters.

Requirements on licences

A licence is required for nuclear activities. Matters on licensing are decided upon by the Government or the authority appointed by the Government (5 §).

The Government or the authority appointed by the Government may prescribe that, in matters relating to licences under the Act, an environmental impact assessment should be made of the impact on the environment and health of a planned plant, activity or measure (5 b§).

A licence to conduct nuclear activities may be revoked by the authority issuing the permit if (15 §)

- conditions have not been complied with in some essential respect,

- the licensee has not fulfilled his obligations concerning research and development work and there are very particular reasons from the viewpoint of safety to revoke the licence,

- there are any other very particular reasons for revocation, from the viewpoint of safety.

This means that a revocation of a licence may be decided only in cases of severe misconduct from the operator or otherwise for exceptional safety reasons. In 1997 an addition to this provision was made as a result of the new act on the phase-out of nuclear power. According to this act the Government may close a nuclear power plant for the sake of the conversion of the energy system (see section 1.3).

General obligations of licensees and licence conditions

The holder of a licence for nuclear activities shall be responsible for ensuring that all measures are taken that are needed for (10 §)

1. maintaining safety, with reference to the nature of the activities and the conditions in which they are conducted,

2. ensuring the safe handling and final disposal of nuclear waste arising in the activities or nuclear material arising therein that is not reused and

3. the safe decommissioning and the dismantling of plants in which nuclear activities are no longer to be conducted.

The holder of a licence for nuclear activities has to ensure that all measures are taken that are needed for maintaining safety. This is a very general obligation and it has to be complemented with licence conditions. The licence conditions are imposed when a licence is issued. But licence conditions can also be imposed during the period of validity of a licence.

The safe decommissioning and the dismantling of plants

If a licence is revoked or the period of validity of a licence expires, the reactor-owner is responsible for the safe handling and storage of all spent fuel and radioactive waste. To make this fully clear it is stated directly in the act.

Supervision

The Government assigns a regulatory body to supervise the compliance with the Act on Nuclear Activities and of conditions or regulations imposed pursuant to the Act (16 §).

A licensee shall if it is required by the regulatory body (17 §)

- submit all information and documentation necessary to execute the supervision,

- provide access to a nuclear installation, or site for nuclear activities, for investigations and tests in the extent needed for the supervision.

The regulatory body may decide on all measures necessary and all conditions and prohibitions needed in individual cases to implement the Act on Nuclear Activities, or regulations or conditions issued as a consequence of the Act (18 §).

Public insight

It is considered very important to give the public insight into and information on nuclear activities. Basic information to the public is given by the two regulatory authorities, SKI and SSI.

In municipalities where major nuclear power facilities are located it is particularly important that the residents are given qualified information. For this purpose so-called local liaison safety committees have been established in these municipalities.

The holder of a licence for a major nuclear plant is bound to allow the local liaison safety committee insight into the work of safety and radiation protection at the plant. The licensee shall, at the request of the committee (21 §),

1. give the committee information on the facts available and allow the committee to study the documents available,
2. give the committee access to plants and sites.

The functions of the committee are to obtain insight into safety and radiation protection matters and to inform the public about it. It is therefore important to point out that the committee is not supposed to impose requirements on or to prescribe safety-enhancing or other measures for nuclear plants. These functions rest exclusively with the regulatory authorities.

Sanctions

The Act on Nuclear Activities also contains rules about inspections, safeguards, punishments etc. A person who: (1) conducts nuclear activities without a licence, or (2) disregards conditions or regulations shall be sentenced to pay a fine or to imprisonment for a maximum of two years (25 §).

If the crime is to be regarded as gross, he shall be sentenced to imprisonment for a minimum of six months and a maximum of four years.(25 a §). On the other hand, liability shall not be adjudged if the crime is trivial.

Finally, it must be pointed out that the Act on Nuclear Activities contains nothing about civil liability for nuclear damage. Instead, there is a special act on civil liability for nuclear damage (The Atomic Liability Act, 1968:45) which came into force in 1968. Sweden is party to the Paris Convention and to the Brussels Supplementary Convention on this subject and the Swedish act is adapted to these agreements.

The ordinance on Nuclear Activities

The Ordinance on Nuclear Activities (1984:14) contains detailed provisions on such matters as definitions, applications for licenses, examination, testing and inspection. Permits for transports of nuclear materials and high active waste are issued by SKI after consultation with SSI concerning radiation protection. Permits on handling of medium and low active waste are issued by SSI after consultation with SKI concerning safety. The Ordinance also authorizes SKI to be the regulatory authority under the law. SKI is authorized to issue licensing conditions (20 §) and to issue general regulations on measures to maintain safety in nuclear activities (20 a § and 21 §). Within their respective spheres of competence and responsibility, SKI and SSI, according to the Ordinance, share the responsibility for regulatory supervision in the fields of reactor safety and nuclear waste management.

7.1.2 The Radiation Protection Act

The Radiation Protection Act (1988:220) entered into force on 1 July 1988. The Act is to a great extent the result of international cooperation. The purpose of the Act is to protect people, animals and the environment against the harmful effects of radiation. Persons engaged in activities involving radiation are obliged to take the requisite precautionary measures, supervise and maintain radiation protection and properly maintain the technical devices and the measuring and radiation protection equipment used in the activities. They are also responsible for the proper handling of the radioactive waste produced.

The Act applies to both radiation from nuclear activities and to harmful radiation, ionising as well as non-ionising, from any other source. The Radiation Protection Act is thus a general protection law and covers all activities involving radiation. As far as nuclear installations are concerned, the act is implemented in close connection with the Act on Nuclear Activities.

The Government or the competent authority may, in so far as it does not conflict with the purpose of the act, prescribe exemptions or certain provisions concerning radioactive substances or technical devices capable of generating radiation. Thus, it is possible to adjust the licensing and supervisory procedures to the level of danger from the individual radiation source.

The Government and the competent authority may also issue any further regulations required for protection against, or control of, radiation in the respects specified in the act. The Ordinance on Radiation Protection (see below) and the special regulations issued by the competent authority contain detailed provisions on such matters as definitions, import and export of equipment and material, etc.

Basic requirements

Anyone who conducts activities involving radiation shall, taking into account the nature of the activities and the conditions in which they are conducted,

- take measures and precautions required to prevent or counteract harm to people and animals and damage to the environment,
- supervise and maintain radiation protection at the site, on the premises and in other areas where radiation occurs,
- properly maintain the technical devices and the measuring and radiation protection equipment used in the activities.

Licensing

According to the Radiation Protection Act a licence is required for

- the manufacture, import, transport, sale, transfer, lease, acquisition, possession or use of a radioactive substance,
- the manufacture, import, sale, transfer, lease, acquisition, possession, use, installation or maintenance of a

technical device capable of, and intended for, emitting ionising radiation, or a part of such a device that is of substantial importance from the viewpoint of radiation protection,

- the manufacture, import, sale, etc. of technical devices, other than those referred to in 2 above and which are capable of generating ionising radiation, and for which the Government or the competent authority has prescribed a licence requirement.

Licensing conditions

When a licence is or has been issued in agreement with the Radiation Protection Act the competent authority may impose conditions needed for the radiological protection. Such conditions can also be imposed on activities licensed within the legal frame of the Act on Nuclear Activities.

Supervision

The Government assigns a regulatory body to supervise the compliance with the Radiation Protection Act and licenses and conditions issued based on the act. The regulatory body may decide on all measures necessary and all conditions and prohibitions needed in individual cases to implement the Radiation Protection Act, or regulations or conditions issued as a consequence of the act.

At the request of the competent authority all who conduct activities involving radiation shall submit to the authority the information and provide the documents required for its supervision. The authority should also be given access to the installation or site where the activities are conducted, for investigations and samples, to the extent required for the supervision.

Sanctions

Matters regarding licences under the act are decided upon by the Government and the competent authority. A licence under the act may be revoked if certain regulations or conditions have not been complied with in any significant respect, or if there are other very particular reasons.

Liability under the act is not adjudged if responsibility for the offence may be assigned under the Penal Code or the Act on penalties for illicit trafficing. Nor is liability adjudged in the case of minor offences to be a trivial case. The police authority shall provide the assistance necessary for the supervision.

The Ordinance on Radiation Protection

The Ordinance on Radiation Protection (1988:293) designates the Swedish Radiation Protection Institute (SSI) as the competent authority in the area of radiation protection. The Ordinance contains detailed provisions pursuant to authorisation in the Radiation Protection Act. It stipulates for example that certain provisions in the Act do not apply to very low-level radioactive material and technical equipment emitting only low-level radiation.

7.1.3 Other important laws for safety

In addition to the mentioned laws regulating nuclear safety, radiation protection and atomic liability there are a number of other laws which must be considered by operating nuclear power plants. Two other important safety related laws are:

The Rescue Services Act (1986:1102) contains provisions on how the community rescue services shall be organized and operated. According to the act, the County Administrative Board is responsible for the rescue operations in cases where the public needs protection from a radioactive release from a nuclear installation or in cases where such a release seems imminent. The act also stipulates that a rescue commander with a specified competence, having far reaching authority, is to be engaged for all rescue operations. In addition the act requires the owner of a hazardous installation to take the necessary measures to minimize any harm to the public or the environment should an accident take place in the installation.

The Rescue Services Ordinance (1986:1107) contains general provisions on emergency planning. The County Administrative Board is obliged to make a radiological emergency response plan. The Swedish Rescue Services Agency is, at the national level, responsible for the coordination and supervision of the preparedness for the rescue services response to radioactive releases. It is left to SKI and SSI to decide on necessary measures for the nuclear power plants.

The Occupational Safety and Health Act (1977:1160) contains requirements on the work environment and provisions on protection from accidents caused by technical equipment, dangerous material or other work conditions. It also contains detailed rules on responsibility and authority with respect to occupational safety issues.

7.2 National safety requirements and regulations

The safety case as a basis for licensing and nuclear supervision

The safety level to be achieved and maintained by the owner of a nuclear power reactor was originally defined in the licensing process. For the currently operating Swedish NPPs this process was the following:

The original licence to build, be in possession of and operate each nuclear power reactor was granted by the Government. This government licensing decision was applied for and granted early in the reactor design process. Consequently, this licensing decision was based on a rather general technical description of the reactor. In each licensing decision, the Government prescribed that a number of licence conditions had to be fulfilled, as proposed by the Commission on Atomic Energy, the predecessor of SKI as the regulatory body. These licence conditions included that a preliminary safety analysis report (PSAR) should be submitted to and approved by the regulatory body before major construction activities started, and that a final safety analysis report (FSAR) and technical specifications for operation (STF) should be submitted to and approved by the regulatory body before starting commercial operation. As to the structure and content of the PSAR, FSAR and STF documents, the regulatory body issued general guidelines. Reference was made to USNRC 10CFR50 documents as they became available. These guidelines were also referred to in the recommendation to the Government to grant the original licence.

The PSAR, FSAR and STF documents were reviewed by SKI and its predecessor, supported by external consultants, to ensure compliance with fundamental safety principles and criteria, such as the defence in depth principle, and that the safety level of the plant was as high as reasonably achievable. The review process featured in-depth technical discussions between SKI and licensee experts on many safety issues.

Based on this licensing procedure, and on approval by SKI and its predecessor, the FSAR and STF documents became the legally binding documents regulating the technical configuration of each reactor and its operating limits and conditions, often referred to as ”the safety case of the reactor”. This ”safety case” may be regarded as defining the minimum safety level that the licensee is legally committed to maintain as a condition for a permit to operate the reactor. Hence, the safety case also provides the basis for regulatory supervision. Changes in safety-related systems and in the STF documents require the approval of SKI on a case by case basis. Copies of the FSAR and the STFs are kept both at the plant and at SKI.

Additional licence conditions are prescribed by SKI over time, based on national and international operating experience and new research results. Such licence conditions may be permanent or applicable for a limited time, e.g. stricter in-service-inspection requirements pending replacement of parts found to be in an accelerated process of degradation. They may be specific to one reactor or they may apply to a group of reactors. In all cases such additional licence conditions are issued in a regulatory letter to each individual licensee.

Thus, although there are a number of common features, regulatory supervision of the nuclear power reactors is in fact legally based on twelve individual sets of regulatory documents, one for each reactor.

The development of general regulations

The formal authority to issue general regulations under the Act on Nuclear Activities was given to SKI from the beginning of 1993 by an amendment to the Act on Nuclear Activities. Using this new authority, SKI has so far issued general regulations concerning the structural integrity of mechanical components. These regulations are published in SKIs Code of Regulations (SKIFS).

Before 1993 ”common regulations” were formally issued by the SKI as licence conditions applicable to each nuclear installation. Legally, such ”common regulations” issued as licence conditions are as binding for the licensee as general regulations and they are also supported by the same enforcement provisions in the Act on Nuclear Activities. SKI has issued such ”common regulations” concerning quality assurance, training and competence of staff operating and maintaining nuclear power reactors, and transportation of fissile materials and nuclear waste. Other ”common regulations” concern physical protection and safeguards. Also, the government requirements on release mitigation measures in the event of severe accidents were formally issued as licence conditions.

It may be noted that many provisions in the general or ”common” regulations serve to specify the obligations of the licensee as stated in the the Act on Nuclear Activities, namely to take the necessary measures to maintain safety. In this context, it should also be noted that in the special comments to the act, included in the bill to the act adopted by Parliament, it was clearly stated that the licensee was obliged to take any necessary measures to maintain safety, whether such actions were prescribed in the licence conditions or regulations or not. In the Swedish legal system, such special comments included in the bill have a legal status as guidelines for the interpretation of the act in courts.

According to present general principles for the issuing of general regulations by Swedish government authorities, the formal regulatory text should preferably prescribe what is required to be achieved, not the detailed means to achieve it. Attached to the formal regulations, there should be a text under the heading ”General Recommendations” indicating means and criteria that can be used to demonstrate compliance with the regulations. However, other means and criteria may be used if it can be demonstrated that they give at least equivalent results.

In nuclear safety regulation, application of this general principle has the effect that the responsibility of the licensee is not diluted by prescribing detailed technical approaches and solutions to safety issues. The use of USNRC 10 CFR50 regulations as guidelines rather than binding requirements in the licensing process can be regarded as an early application of this principle.

Current SKI regulations and ”common licence conditions” follow the same approach. For example, licensees are required to have an internal quality assurance (QA) system; however, strict compliance with e.g. ISO or IAEA standards is not prescribed, although applicable parts of such standards may be used in the SKI review and evaluation of licensee QA systems.

New basic safety regulations

In 1997 SKI started a project to develop general basic safety regulations for those nuclear installations which have a government permit to operate, i.e. the nuclear power reactors, the Studsvik materials testing reactor, CLAB, SFR, the ABB fuel factory, and some nuclear waste repositories at Studsvik. The new regulations will replace a lagre number of individual licence conditions. The work to unify the requlatory requirements has been carried out in order to increase the possibility to obtain an overview of all the requirements, and to improve coordination between regulations issued according to the Act on Nuclear Activities and the Radiation Protection Act. It was also a strong recommendation from the International Review Commission to clarify the regulatory requirements and to issue general regulations[23]. The Government confirmed this in the 1998 letter of appropriation as a task to be accomplished by SKI.

Other motives for the new regulations are to

- create a basis for further development of regulations by SKI,
- adapt the Swedish regulations to internationally accepted principles for reactor safety work, and
- improve the possibility to organize more effective regulatory supervision.

The new regulations contain basic provisions on defence-in-depth, obligations to assess, investigare and correct deficiences in the defence-in-depth, on quality assurance, on design and construction, on verification and reporting of the safety level, on operations, on nuclear material and waste, on reporting to SKI and on documentation and archiving. Some of the provisions are the same as applied earlier but on a number of issues the requirements have been extended and reinforced.

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[23] SOU 1996:73: Swedish Nuclear Regulatory Activities. Volume 1- An Assessment.

These basic requirements, issued in order to protect the personnel, the environment and society from radiological accidents, and to make possible an efficient regulatory supervision, are the same for quite different nuclear installations and the they will of course be applied in different ways, depending on the type of installation.

The new regulations are very clear concerning the responsibility for safety, and include strong requirements on quality assurance, competence and safety reviewing in two steps, by the licensees. A clear regulatory philosophy is also expressed in the new regulations. SKI requires control over the basic conditions needed for a licensing decision. For instance the original safety cases and technical specifications, emergency response plans, physical protection plans and measures taken after a serious deficiency in the defence-in-depth system, shall be submitted for approval by the regulatory body. Changes in the approved documentation, e.g. in the form of plant modifications or modifications of technical specifications shall, after safety review and before implementation, be submitted as notification to the regulatory body. SKI is then free to add further reguirements if it is considererd necessary. A third group of issues is left for the licensees to handle without any specific notification requirement to SKI, but with a general requirement on safety review and experience feed-back analysis. There are strict reqiuirements on prompt assessment, classification, analysis, actions and safety review after events indicating deficiences in barriers or the defence-in-depth. Reports shall be sent to SKI with the urgency depending on the safey significance. Major safety issues shall also be summarized in annual reports to SKI.

The new regulations will allow for SKI to implement an activity oriented supervision without spending most of its resources on in-depth analysis and review of technical issues. The regulations were decided by the SKI Board in August 1998, are issued as SKIFS 1998:1 and will enter into force on 1 July 1999.

SKI also plans and work has begun to issue the following general nuclear safety related regulations to be published in SKIFS over the next few years:

- SKI regulations on design and construction of technical systems for the defence-in-depth of nuclear power plants,
- SKI regulations on design and operation of reactor cores and nuclear fuel,
- SKI regulations on reactivity control,
- SKI regulations on physical protection of nuclear facilities,
- SKI regulations on the control of competence of operational personnel at the nuclear power plants,
- SKI regulations on safety in transportation of nuclear material and nuclear waste.

Radiation protection

The Radiation Protection Ordinance states that SSI may, in so far as it does not conflict with the purpose of the Radiation Protection Act, issue regulations concerning the provisions in the Act. SSI has had this possibility since 1976 and the first regulation in SSI:s Code of Statutes was issued in 1977. Today there are 39 regulations in force covering all areas wherever radiation may occur. In general these requirements and regulations are in agreement with those recommended by international organizations, e.g. IAEA, ICRP, EU. Of the 39 regulations, 13 are of particular interest for the nuclear industry:

- Regulations for medical examinations on radiological protection activities
  SSI FS 1981:3

- Regulations etc. for dose limits at work with ionising radiation
  SSI FS 1989:1

- Regulations for restrictions on emissions of radioactive substances from nuclear power plants
  SSI FS 1991:5

- Regulations for a radiation protection adviser within a nuclear plant
  SSI FS 1994:1

- Regulations for the protection of workers in activities involving ionising radiation at a nuclear plant
  SSI FS 1994:2

- Regulations amending the regulations SSI FS 1989:1.
  SSI FS 1994:5

- Regulations on control of shipment of radioactive waste
  SSI FS 1995:4

- Regulations supplementing the EC-Directive on shipment of radioactive substances between Member States
  SSI FS 1996:1

- Regulations on removal of goods and oil from controlled areas in nuclear plants
  SSI FS 1996:2

- Regulations on outside workers at work with ionising radiation
  SSI FS 1996:3

- Regulations on archives for documentation at nuclear plants
  SSI FS 1997:1

- Regulations amending the regulations SSI FS 1991:5
  SSI FS 1997:2

- Regulations amending the regulations SSI FS 1994:2
  SSI FS 1997:3

As most of these were issued before Sweden entered the European Union, they will be brought in line with the European BSS before 2000-05-13. These are regulations for, dose limitation, medical examination, effluents, waste, filing of certain documents etc. Additional information is given in chapter 15.

7.3 Licensing system

As decribed in section 7.1, the Act on Nuclear Activities prescribes a licensing system and that legal sanctions shall be imposed on anyone who conducts nuclear activities without a licence. The licensing system which was applied in Sweden for the power reactors is described in section 7.2. As mentioned, no new licences may be issued, but the procedure described also applies for the relicensing of existing plants, in cases where licenses are limited in time or proposed plant modifications are extensive enough to justify a new licence.

7.4 Regulatory inspection and assessment

In accordance with legal authorizations and the mandates defined by the Government, SKI and SSI conduct regular inspections and assessments of the Swedish reactors to ascertain compliance with regulations and licence conditions.

The major assessment programmes are described in chapter 6. Inspections are conducted as follows:

Essentially three types of regulatory inspections are performed:

1. regular or routine inspections,

2. topical inspections, and

3. special inspections or investigations triggered by events of special safety significance.

According to SKI regulations, detailed inspections related to structural integrity are performed by third party control and testing organizations (see chapter 14). The SKI programme of inspections is in a process of development towards putting more emphasis on systematic evaluations of the quality of safety-related work at the installations. A similar development is in progress at SSI. All inspection procedures will be described and documented in internal quality manuals. For SKI the following documents have been developed so far and are presently used as guidance, i.e. not formally adopted procedures, in the conduct of inspections:

- the Inspection Procedure, a SKIQ- document,

- the Inspection Manual, a handbook containing the rules that apply to the inspection work, check lists and general guidance,
- the SKI Reference Book - Maintenance,
- the Inspection Guide Book - Maintenance with guidelines for performing inspection of systems for maintenance,
- the Quality Systems Inspection Book with guidelines for inspecting and assessing the quality systems of the licensees.

Regular or routine inspections

Routine inspections are carried out by inspectors from SKI and SSI on a regular basis. The SKI inspectors visit each site several days per month. The annual outages for overhauls and refuelling are subject to intensified inspections from SKI as well as SSI.

The SKI inspectors use specific forms for planning and following-up the routine inspections, which are performed by the Department of Inspection. The forms provide a means for checking the coverage of the inspections, both those performed and those planned, by means of a table showing all items subject to inspection, and the specific items visited or to be visited according to plans. Written inspection reports are required by both authorities.

Topical inspections

Topical inspections aim at deeper insight into the quality of licensee activities in particular topical areas. Such areas include maintenance, emergency preparedness, fire protection, core operation practices, radiation protection, quality assurance, training, the licensee´s management of event investigations, etc. The responsibility for initiating topical inspections is, when it comes to safety-related activities, assigned to the department responsible for the SKI regulatory activities in that area. The Department of Inspection is responsible for co-ordinating the various topical inspections, with proper consideration of the situation at the NPPs. Several topical inspections are carried out every year. The programme for these inspections is decided in advance and documented in the SKI annual Activity Plan. Topical inspections can also be included in the SKI review tasks related to large licensee projects. For example, the quality assurance within the OKG project for the renovation of Oskarshamn 1 was subjected to an SKI topical inspection.

A topical inspection is documented in an extensive report which is sent to the licensee concerned. Any regulatory decision-making that may result from it, is subjected to the same internal procedures as other regulatory review tasks.

Topical inspections, concerning radiation protection, are usually performed during a short period of time when all the four nuclear sites are visited by a delegation, four to five inspectors, from SSI. This type of inspection typically covers one or sometimes two topics, and tries to cover each topic in depth. The most recent topical inspection was performed in March 1997 when dose reduction programmes and training of workers were examined in detail. The results of such a topical inspection are always presented in an official SSI report.

Special inspections or investigations triggered by events of special safety significance
According to the licensee event reporting (LER) procedures in the STF (see chapter 19), incident investigations shall in the first place be performed by trained staff at the utilities and be reported to SKI. Depending on the circumstances, SKI may in addition decide to perform its own special inspections or investigations. Examples of NPP events subjected to investigation by SKI in recent years, include the strainer incident (se chapter 6), a failure to detect a leaking crack in the residual heat removal system when performing in-service inspection, and an observed increase of the rate of LERs at one NPP.

Similar special inspections are performed by SSI inspectors whenever unexpected and significant occupational exposures have, or might have, occurred.

The decision to set up and dispatch a special inspection team is normally taken at Office Director level, as it most often involves a redeployment of resources compared with the activity plan. The special inspections, and any regulatory decision-making that may result from it, are subjected to the same internal procedures as other regulatory review tasks.

Joint SKI-SSI inspections
As is further discussed in section 8.3, there is an overlap of responsibilities between the two regulatory bodies which means that they must cooperate in the supervision of the nuclear facilities. Usually the two authorities cooperate in major safety assesments, e.g. ASAR, and in reviews of licensees applications for different plant- or technical specficication modifications. Joint inspections are carried out occasionaly. During the last years two joint topical inspections of the licensees emergency preparedness planning were carried out (see chapter 16).

7.5 Enforcement of regulations

Although the primary task of SKI is to ensure that the licensees exercise their responsibility for safety in the best possible way, SKI has extensive legal regulatory and enforcement powers. Thus SKI may acccording to the Nuclear Activities Act stop the operation of a nuclear plant for safety reasons and also temporarily revoke a licence on the basis of serious misconduct of the licensee or for other exceptional safety reasons. This has occured in a few instances, most notably in the fall of 1992, when SKI, revoked the operating licenses of five reactors, pending major improvements to the emergency cooling functions. On a number of occasions, the restart of a plant after annual maintenace and refuelling outage has been delayed due to some additional tests and/or repairs being required by SKI.

It is stated in the Nuclear Activities Act (18 §):

- the regulatory body may decide on measures needed in single cases in order to pursue the Act or regulations or licensing conditions issued according to the Act,
- if anyone does not take a measure in obligation of this Act, or according to a regulation or licence condition issued according to the Act, or in compliance with the regulatory body, the regulatory body can have the measure taken at his expence.

This provision means that the regulatory body may order a test, repair or modification to be implemented contrary to the opinion of the licensee and at his expense, if it is considered necessary for safe operations until the plant is shut down. Furthermore, the regulatory body is in the Act (22 §) authorized to impose fines if regulations or conditions are not met, or if the regulatory body is prevented from execution of its regulatory activities. The police must, if necessary, assist the regulatory body in such a case (17 §). Todate it has never been considered necessary to apply these provisions in Sweden.

In cases of more serious misconduct or negligence the SKI Director General may decide to hand over the case to a public prosecutor. In that case the responsible person could be sentenced to fines, or imprisonment from six months up to four years if the crime is considered gross. A public prosecutor is free also to prosecute in cases in which SKI has decided not to hand over a case for legal investigation.

7.6 Conclusion

The Swedish Party complies with the obligations of Article 7.

8. Article 8: REGULATORY BODY

1. *Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.*

2. *Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.*

8.1 Regulatory bodies and their mandates

8.1.1 General

There are two regulatory bodies in Sweden authorized to supervise the nuclear power plants. They are the Swedish Nuclear Power Inspectorate (SKI) and the Swedish Radiation Protection Institute (SSI). SKI exercises supervision in compliance with the Act on Nuclear Activities. Supervision in compliance with the Radiation Protection Act is exercised by SSI. In addition the Swedish Rescue Services Agency is responsible for evaluating the major emergency preparedness exercises on-site the NPPs and off-site according to the Rescue Services Act and Ordinance (see section 7.1.3).

SKI and SSI are both central administrative authorities reporting to the Ministry of the Environment. In the Swedish public administration system the central administrative authorities are quite independent within the legislation and the statutes given by the Government. An individual minister cannot according to the Swedish Constitution interfere in specific administrative cases which are being handled by an administrative authority under the Government.

The ministries are small units, each as a rule consisting of no more than about 100 persons. They are concerned with (1) preparing the Government´s bills to Parliament on budget appropriations and laws; (2) issuing of laws and regulations and general rules for the administrative authorities; (3) international relations; (4) appointment of higher officials in the administration; and (5) certain appeals from individuals which are addressed to the Government.

The Cabinet as a whole is responsible for all governmental decisions. Although in practice a great number of routine matters are decided upon by individual ministers, and only formally confirmed by the Government, the principle of collective responsibility is reflected in all forms of government work.

SKI and SSI are headed each by a Director General appointed by the Government, normally for a period of six years. Both authorities are supervised by boards chaired by the respective Director General. The SKI Board normally consists of nine persons: the Director General, members of Parliament representing the major parties, senior officials from other ”safety agencies”, such as the Civil Aviation Board, and a couple of independent specialists. The Director General of SKI is a member of the SSI Board and vice versa. The tasks of the Board are mainly to advise the Director General, but on a few issues, such as applications for appropriations and the issuing of general regulations, the Board has to make the decisions.

The Ministry of the Environment can be said to act as a channel between SKI, SSI and the Government. Every year SKI and SSI have to submit reports to the Government (see below). These reports are all submitted to the Ministry. In addition, all matters, for instance licensing issues, to be decided by the Government are sent to the Ministry. SKI and SSI also every year submit proposals or recommendations to the Ministry on issues which have been assigned to the authorities in the annual letters of appropriation. Often, on the basis of their practical experience, SKI and SSI propose, in their respective fields, amendments to laws and regulations to be decided upon by Parliament and the Government.

The system and means by which the Swedish Government control the activities of government authorities have been thoroughly changed during the 1990´s. Earlier, the activities of authorities were controlled by detailed rules for each type of activity and detailed control of each type of cost, such as salaries, foreign travel, domestic travel, etc.

In the present system, the emphasis is on objectives set by the Government for each authority, in their annual letter of appropriation, after an evaluation of the results and effects of the authority´s activities in relation to the costs. This evaluation shall be made in the Annual Activity Report of each authority. In the new system, the rules controlling the activities, are less detailed, and the authorities have more flexibility within their annual total appropriation.

There are very high requirements on SKI and SSI regarding openness and the provision of information services to the Government, the media and the public. Most official documents in Sweden are accessible to the media and to private citizens. All files of any administrative office are open to the public unless ”secret”, according to the Freedom of the Press Act and the Secrecy Act. Reasons for secrecy could be related to military security, international relations or the privacy of individuals concerned, because for instance they contain criminal or medical records, etc. Nobody is obliged to justify his wish to see a public document or to reveal his identity to get access to the document.

8.1.2 The SKI organization, mission and tasks

Organization

The organization of SKI is shown in Figure 4. Under the Director General, SKI is organized in three Offices, namely

- **Office of Reactor Safety (R)** with departments for
  - Inspection
  - Plant Safety Assessment
  - Reactor Technology
  - Structural Integrity and
  - Human Factors (or the interaction between man, technology and organization, MTO)

- **Office of Nuclear Materials Control (M)**

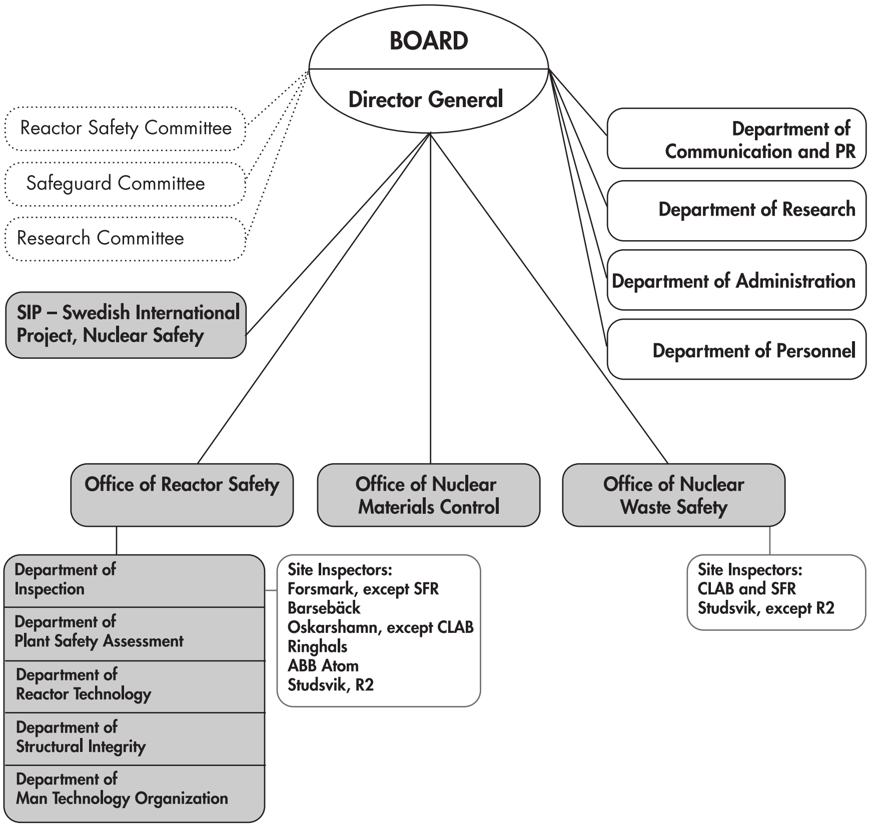
- **Office of Nuclear Waste Safety (K)**

and four departments reporting directly to the Director General, namely

- Department of Communication and PR
- Department of Research
- Department of Administration
- Department of Personnel

The Swedish International Project Nuclear Safety (SIP), which administers the Swedish nuclear safety assistance and participates in the multilateral assistance to the Central and East European countries, is operationally independent from SKI but reports directly to the Director General.

Figure 4.



Three advisory committees are associated with SKI, namely

- The Reactor Safety Committee
- The Safeguards Committee
- The Research Committee

The distribution of responsibilities, authorities and tasks are regulated in detail in the SKI Administrative Manual and the annual Activity Plan. The Office of Reactor Safety is responsible for all regulatory tasks in connection with the 12 nuclear power units, the materials testing reactor in Studsvik, and the ABB fuel factory. The Office is also responsible for all development of regulatory activities, including regulations and research, concerning reactor safety and criticity safety. The advisory Reactor Safety Committee, comprising six senior specialists in reactor safety related fields, is consulted before any major regulatory decisions are taken.

Mission and tasks

The general responsibilities of SKI are stated in the Ordinance (1988: 523, last revised 1995:1549) with instructions for the Swedish Nuclear Power Inspectorate. These responsibilities have lately been updated and specified. In 1997 Parliament adopted objectives for the preparedness against severe strains on society in peacetime. These objectives pose the following requirements on the nuclear regulatory supervision:

- that Swedish nuclear installations shall have satisfactory protection in several barriers to prevent serious accidents and incidents originating in technology, organization or competence, and which also prevent or reduce the dispersion of radioactive substances to the environment if an accident were to occur,
- that nuclear installations and nuclear material under Swedish law shall have sufficient protection against terroist attacks, sabotage and theft,
- that the Swedish Government, in cooperation with authorised international control organizations, shall have full information and control of the possession, use of and trade of nuclear material and nuclear technology under Swedish jurisdiction, in such a way that the nuclear material and the nuclear tetchology are not used contrary to Swedish law and Swedish international non-proliferation obligations,
- that final disposal of spent fuel and nuclear waste shall be carried out in such a manner that potential leakage of radioactive substances to the environment over different time-scales can be expected to be below tolerable limits, so that coming generations are not exposed to larger risks for health and environment than is tolerated today,
- that the nuclear industy shall conduct a comprehensive and appropriate research and development programme so that safe handling and final disposal of spent fuel and nuclear waste is accomplished and

that methods will be in place for decommissioning and dismantling nuclear installations, and that sufficient funds are built up for the future financing of this,

- that decision makers and the public shall be well informed about nuclear risks and safety, and about the handling and final disposition of spent fuel and nuclear waste, and

- that an active contribution shall be made to the development and strengthening of the international nuclear safety and non- proliferation work, especially within the EU. Sweden shall as a member of EU actively work to accomplish efficient and increasing environmental achievements in the neighbourhood of Sweden, i e. in the Baltic region and in the Central and Eastern Europe.

With these requirements as a background SKI has clarified its regulatory missions and tasks, which were confirmed by the Government in the letter of appropriation for 1998:

First and foremost, according to the Act on Nuclear Activities, the licensees have the full and undivided responsibility to take all measures necessary to achieve safety, to meet non-proliferation requirements, and to achieve safe final disposal of spent nuclear fuel and nuclear waste. SKI shall define the detailed purport of this responsibility and supervise how the licensees execute it. Thus, SKI shall carry out the following regulatory missions, according to the strategies associated with each mission:

1. **Provide a clear definition of requirements**
   SKI shall give a clear definition of requirements, both with regard to the technical design of plants, and with regard to licensee obligations to achieve high quality in safety-related activities. These requirements shall be general and functional so as not to have a negative impact on licensee responsibilities. The requirements should be published in regulations, guidelines and licence conditions.

2. **Check compliance with requirements by supervision focusing on processes and activities**
   By supervision focusing on processes and activities, SKI shall convince itself that the licensees have a fully satisfactory control with regard to the safety of plant processes as well as organizational processes (the interaction man-technology-organization). SKI shall clearly define the type of control activities required. As a basis, licensee internal control functions of high quality shall be required. In some areas, accredited third-party control may be required. Using such control functions, routine issues and decisions should be handled by licensees. For issues of major safety significance, SKI review and approval shall be required.

3. **Initiate safety improvements**
   SKI shall initiate safety improvements, whenever justified by operating experience, or research and development. Such initiatives may be taken by revising regulations and as a part of regulatory reviews and inspections. SKI analysis of operating experience and the SKI R&D programme shall provide support for such initiatives.

4. **Maintain and develop competence**
   SKI shall promote the maintenance and development of competence for safety and non-proliferation activities, at licensees, at SKI, and nationally. This shall be included in regulatory requirements as well as in SKI's own staff training and R&D programmes.

5. **Maintain emergency preparedness at SKI**
   SKI shall be prepared to advise emergency management authorities in case of radioactive releases from nuclear activities or situations where there is a threat of such releases.

6. **Report and inform**
   SKI shall issue regular reports on the safety state of plants and the quality of licensee safety work, and, in general, implement active public information services.

7. **Implement the SKI QA programme**
   To ensure the quality of regulatory performance SKI shall implement an internal quality assurance programme according to modern principles. 'SKI shall do what it requires others to do'.

These missions and tasks given by the Government are broken down by SKI to concrete regulatory objectives, priotities and production requirements. Since 1997 this is done in a new structure with missions and submissions for the Offices with allocated resources and accountable leaders. The missions are of a long-term, strategic character and the submissions are annual production requirements given by the Director General. The mission structure defines what is to be done; how it should be done in principle is regulated in SKIs internal quality system (SKIQ) which is under development. The production results of the submissions are evaluated by the Office directors and the Director General according to a regular schedule.

8.1.3 The SSI organization, mission and tasks

SSI operates within four main areas:

- The general supervision of man-made and natural radiation
- The supervision of nuclear installations, including waste disposal
- The emergency preparedness against radiation accidents
- Radiation protection research

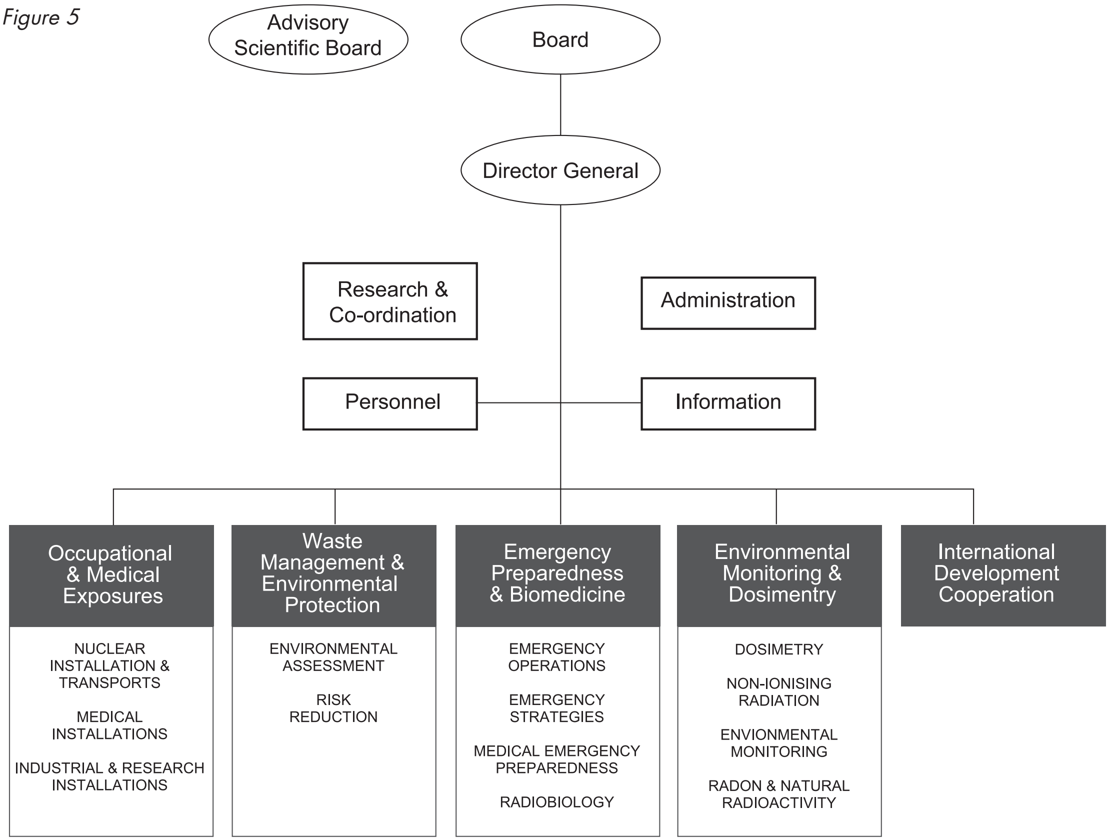
Organization
The organization of SSI, is shown in Figure 5. SSI is organized in four departments.

- **Department of Occupational and Medical Exposures** with programmes for:
  - Nuclear Installations and Transport
  - Medical Installations
  - Industrial and Research Installations

- **Department of Waste Management and Environmental Protection** with programmes for:
  - Environmental Assessment
  - Risk Reduction

- **Department of Emergency Preparedness and Biomedicine** with programmes for:
  - Emergency Operations
  - Emergency Strategies

Figure 5



- Medical Emergency Preparedness
- Radiobiology

- **Department of Environmental Monitoring and Dosimetry** with programmes for:
  - Dosimetry
  - Non-ionising Radiation
  - Environmental Monitoring
  - Radon and Natural Radioactivity

and four offices reporting directly to the Director General:

- Office for Information
- Office for Administration
- Office for Personnel
- Office for Research and Co-ordination

In addition to the four departments there is a special department for radiation protection support to the East European countries: the International Development Coorperation. This department administers the Swedish radiation protection assistance and participates in the multilateral assistance to the Central- and East European countries. The programme is operationally independent from SSI but reports directly to the Director General.

Two Advisory Committees, the Research Committee and the Advisory Scientific Board, are associated with SSI.

The supervision of nuclear installations is thus divided between three departments. The programme for Nuclear Installations and Transport coordinates the supervision of nuclear activities within SSI and between the departments.

Mission and tasks

The missions and tasks of the Swedish Radiation Protection Institute (SSI) are regulated in the Ordinance of Radiation Protection (1988:293) and the Instruction for the Swedish Radiation Protection Institute (1988:295). The SSI role in radiation protection is to issue regulations and directives and ensure that they are adhered to through inspections, to inform, educate and give advice, and to monitor radiation levels in the environment. SSI also has a central role in the national accident management organization in the event of a radiation accident and administers research projects with the purpose to increase the knowledge of the occurrence and effects of radiation. In addition to the Ordinance and the Instruction, the Government in a special letter has pointed out some areas that should be addressed especially. One of these areas is that the decommissioning of nuclear installations should be performed in such a way that radiation doses to workers and the general public, and the radioactive waste produced, as well as the transportation of waste, is dealt with in a safe way from radiological point of view.

The Instruction for SSI identifies a number of special responsibilities:

- acquire accurate knowledge about the risks related to radiation and pay attention to the development in disciplines concerned with the biological effects of radiation and radiation physics,
- have the main responsibility for co-ordinating applied research in the field of radiation protection,
- carry out applied research and development work in the field of radiation protection,
- promote the creation and preservation of international standards in the field of radiation protection, be a co-ordinating body for different radiation protection interests in the country, and to that end cooperate with authorities and associations concerned with radiation protection issues,
- give information on radiation protection and on properties of radiation and its fields of applications,
- maintain an emergency preparedness for guidance to the authorities responsible for protection of the population, and to the rescue service, on radiation protection issues related to nuclear accidents within as well as outside the country, and decontamination after releases of radioactive substances,
- be responsible for the long-term follow-up of decontamination after releases of radioactive substances,
- have in readiness material for the application, within the Institute's area of responsibility, of the Planning and Building Act (1987:10) and the Act on the Management of Natural Resources etc. (1987:12).

The areas of high priority today are:

- operation of nuclear power plants,
- radioactive waste management,
- emergency preparedness against radiation accidents,
- medical radiation exposures,
- powerful sources of ionising radiation,
- ultra violet radiation,
- radon in dwellings,

- magnetic fields, and
- international collaboration.

Thus, the SSI activities in the field of nuclear energy is only one of SSIs many tasks.

8.1.4 Reporting requirements

According to the annual letters of appropriation, government decisions and ordinances, the authorities are required to submit the following reports concerning regulatory activities to the Government on a regular basis:

In *Annual Activity Reports,* the authorities are required to summarize results, effects and costs of their activities, according to general regulations issued by the Government and the Swedish National Audit Office for such annual reports that are to be issued by all government authorities.

In cooperation SKI and SSI is required to submit an annual *Report on the Status of Safety and Radiation Protection at the Swedish NPPs.* The SKI parts of the report summarize important findings and conclusions from operational experience and regulatory inspections and reviews, both with regard to the technical safety status of the plants and the quality of the safety work at the plants. The SSI part reports on occupational and environmental dose and radiological data.

SKI is required to perform a periodic safety review of each operating nuclear power reactor every ten years, and report the findings, conclusions and recommendations to the Government, in the form of an *As operated Safety Analysis Report (SKI-ASAR)*. Thus, on average one such report per year is submitted, although the intervals may vary. The periodic safety review programme is further described in section 6.2 and chapter 14.

Every three years, the SKI is required to submit a *Review Report on the Nuclear Industry Research, Development and Demonstration Programme on Final Disposal of Spent Fuel and Nuclear Waste and the Dismantling and Decommissioning of Nuclear Installations* (the SKB R&D programme). In addition to the findings, conclusions and recommendations as to the purposefulness and quality of the programme, the review report also proposes conditions for the future conduct of the SKB R&D programme that the Government may wish to prescribe in accordance with the Act on Nuclear Activities.

Every year, SKI is required to submit a *proposal for the fees per produced kWh* to be paid by the owners of the nuclear power reactors to cover the costs for the final disposal of spent fuel and nuclear waste and the dismantling and decommissioning of nuclear installations. Attached to the proposal is a SKI review report on the cost estimates provided by the SKB. In the SKI review use is also made of the technical insights gained in the review of the R&D programme mentioned above.

SSI also on a regular basis, in agreement with international conventions, issues reports to a number of organizations, such as UNSCEAR, OECD, IAEA etc. The major part of that reporting is within the environmental radiation protection area but some parts also consider occupational radiation protection.

In addition to the above mentioned reports, SKI and SSI also issue *periodic reports* to inform of major activities. Some examples from SKI are:

- A tertial report on plant operation, significant events and regulatory measures.

- NUCLEUS, a publication reporting on research projects and results, including special reports on some long term safety issues.

- Special reports, included in the SKI Report series, where R&D reports and more important regulatory assessments are published.

All the reports published by SKI and SSI can be ordered by the media and the public.

8.2 Human and financial resources for regulatory activities

8.2.1 Human resources

SKI presently has a staff of 111 employees (1998). Of these, 45 belong to the Office of Reactor Safety. With the exception of the administrative personnel, most of the SKI staff are professional scientists or engineers, seven persons have a qualified behavioural science training. In 1997 the distribution of educational level was the following[24]:

Level	Women	Men	Total
Post graduate degree (lic, PhD)	2	15	17
Bachelor, master	28	31	59
Secondary high school	14	10	24
Other education	8	3	11
Total	52	59	111

Table 6: The educational level of the SKI staff

121 persons are employed at SSI (1998). Of these 27 are occupied with matters in direct connection to the nuclear fuel cycle. Most of the staff are engineers and scientists in the area of physics and radiation physics. There are also physicians, biologists, communication experts and administrative personnel. The distribution of education level was in 1997:

Level	Women	Men	Total SSI	Total in Nuclear activities
Post graduate degree	3	17	20	9
Bachelor, master	19	35	54	16
Secondary high school	23	13	36	2
Other education	7	4	11	0
Total	52	69	121	27

Table 7: The educational level of the SSI staff

[24] SKI Personnel-economical Report 1997.

SKI and SSI are on average clearly ahead of other public and private administrative organizations in Sweden when it comes to educational level. The international review Commission concluded in 1996 that the personnel of both SKI and SSI are well qualified for their tasks:

"The staff of both authorities have a high level of technical and scientific competence, and enjoy high international esteem. About 20% of the staff have a post-graduate degree, and more than half of the staff have graduated from university, the situation is almost identical for both authorities"[25].

In 1997 the average employment time at SKI was nine years, and about 40% of the staff had been employed at SKI more than 10 years. At SSI the average employment time was 15 years and more than 50% of the staff had been employed more than 10 years. As both organizations are knowledge-based organizations quite large resources have to be spent on personnel development, in order to maintain and develop competence. About 10% of the working time is allocated to the development of competence.

45 persons, inspectors and specialists, at SKI and 27 persons at SSI are directly involved in the supervision of the NPPs. For each nuclear site there are 2-3 assigned SKI inspectors and one SSI inspector. Both authorities have one inspector per site assigned as site-responsible, who serves as the main contact person between the NPP and the authority. This assignment as site-responsible is circulated every 4-5 years. All the inspectors are stationed at the main offices in Stockholm.

The SKI Department of Inspection has 15 inspectors with the competence to inspect most technical issues at the NPPs. Two of these inspectors are specialized, on emergency preparedness and human factors, the others have a more general background. Inspections of special issues are carried out with participation from the specialist departments within the Office of Reactor Safety. The SSI site-specific inspectors are mainly concerned with occupational radiation protection. In addition to inspections of NPPs they also have a special area of expertise. There are five such areas of expertise; uranium (mining, milling, handling etc), dose reduction (ALARA), internal dosimetry, dose registration and decommissioning. In addition at, SSI 6 inspectors are dealing with occupational radiation protection and transport, 6 inspectors for emergency preparedness matters, 4 inspectors for waste and 4 for environmental radiation protection.

Internationally the numbers of regulatory staff at SKI and SSI are quite small for the size of nuclear programme in Sweden. The professional staff at SKI corresponds approximately to one inspector per nuclear power reactor or other major installation, and one or sometimes two experts in each specialist area (such as core physics, fracture mechanics, non-destructive testing, quality assurance, etc). Each professional staff member, including department heads in the Office of Reactor Safety is typically involved in several tasks, for instance inspections, regulatory reviews and approval tasks, revision of regulations, handling of research contracts and participation in public information activities, each requiring his or her expertise. Experience during the recent years has shown that the staff is sufficient to carry out normal routine regulatory work, but as soon as some major event happens which requires a mobilization of investigation and assessment resources, the number of staff is not sufficient to handle also the regular and more long-term issues without delays, for instance the ASAR programme, revision and development of regulations, as well as research, staff training programmes and development of internal quality assurance.

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[25] SOU 1996:73, p 78.

This situation is to a certain extent foreseen in the annual activity planning, but even if tasks are prioritized and there are some allowances made for ”event-triggered tasks”, redeployment of resources have often had to be made during the recent years. These experiences have resulted in an extended resource planning for event triggered tasks. For 1998 about 20% of the resources in the Office of Reactor Safety are reserved for such tasks.

8.2.2 Economical resources

The SKI and SSI nuclear regularory activities are financed as part of the state budget. Proposals from the two authorities for activities in the coming financial year are considered by the Government, in the same way as for other agencies. Proposed activities are evaluated by the Government, and the result of the evaluation is presented in the budget bill. Resources are allocated in the Government's letter of appropriation, prescribing in addition directives for the activities.

Contrary to what is normal for state budget financed agencies, the costs for the nuclear regulatory activities have a neutral impact on the state budget. The costs are paid by the nuclear facilities to the Government as regulatory and research fees.

Two types of appropriations are available to SKI and SSI: Administration costs and Research costs. The resources available for 1998 are shown in table 8. Administration includes all costs for staff salaries and operational activities.

For SKI the budget has been quite stable, in fixed prices, during the the 1990´s with a slight decrease of money for administration in 1995/96. Due to the governmental policy, to reduce public spending, most governmental authorities received heavy savings directives. This did not affect SKI administration resources as much as it did most other agencies. SKI was allowed instead to make a 13% cut in the research appropriation. Despite this, SKI did not receive full compensation for salary increases to professional personnel, which resulted in the necessity to hold a few posts vacant.

In the 1997 budget bill it was proposed that the resources of SKI be increased by about 12 MSEK for administration and about 5 MSEK for research. The increase was confirmed in the letter of appropriation

Appropriation	SKI total	SSI total	SSI NPP supervision	SSI Emergency preparedness
Administration	76 279[26]	78 645	19 641	15 583
- salaries	49 700	44 036	9 129	5 202
- operational costs	26 579	34 609	10 512	10 381
Research	63 950	12 000	8 000	500
Total	**140 229**	**90 645**	**27 641**	**16 083**

Table 8: The SKI and SSI budgets for 1998 in KSEK

[26] Including 800 KSEK for extra financed activities.

for 1998 in which the new tasks for SKI were also confirmed (see section 8.1.2). It was recognized by the Government that SKI needed more resources as a result of new challenges, for instance the decision to start the phase-out of nuclear power, which will mean an increase in regulatory supervision of the NPPs concerned, and a need to increase the general knowledge base concerning decommissioning. The Government also realized that SKI needs more resources to carry out research management and other long-term issues. The increase of resources will allow an expansion of the staff with about nine qualified persons.

About 75% of the SKI administration budget is fixed costs, such as salaries and costs for premises, telecommunications, etc. The remaining 25% is variable costs, mainly travelling and consultancy costs. About 60% of the resources is estimated to be used for reactor -and nuclear materials saftey work and about 10% for information activities. The remainder is used for safeguards and nuclear waste safety work.

In contrast to SKI, SSI has been notably affected by the public savings programme. To some extent the savings has had an influence on the supervision of the NPPs, but the major cuts, are in the area of the supervision of non-nuclear installations. However SSI also received an increase of resources for nuclear supervision 1998 with 5,5 MSEK.

The total research budget of SKI is distributed over research programmes as shown in table 9.

Research programme	**Appropriation 1998**	**Reservation**[27]	**Total budget for 1998**
Safety evaluation	700	0	700
Safety analysis	7 000	1 500	8 500
Human factors	4 000	0	4 000
Material and chemistry	4 000	1 000	5 000
Structrual integrity	4 000	250	4 250
Material testing and control	3 000	1 000	4 000
Thermohydraulics	6 500	500	7 000
Nuclear fuel	5 000	0	5 000
Severe accidents	5 000	1 300	6 300
Process control	2 000	0	2 000
Nuclear waste safety	11 000	7 000	18 000
Safeguards	3 000	0	3 000
Transport of nuclear fuel	800	0	800
Information and risk com-munication	500	0	500
QA research	700	0	700
Emergency preparedness	300	550	850
Other projects	6 450	10 669	17 119
Total KSEK	**63 950**	**23 769**	**87 719**

Table 9: The SKI research budget for 1998.

[27] Reservations are made from earlier years due to unfinished projects or projects which were planned but not started.

About 60% of the budget is used for reactor and nuclear materials safety research. The research budget is used to contract university institutions and consultant companies in Sweden and abroad. It is also used to contribute to the OECD Halden Project, and to finance two professorships, one at The Royal Institute of Technology in Stockholm (KTH) in nucelar safety, and one at the University of Stockholm in the interaction between man, technology and organization (MTO), with special regard to nuclear safety. As mentioned in chapter 2, SKI also in cooperation with the nuclear industry, has initiated and supports a Nuclear Technology Center at the KTH, to facilitate cooperation between various departments and intitutions in joint research projects sponsored by the industry and/or SKI.

The actual research expenditure for a given year, expecially in the area of reactor safety, has been very dependent on the total workload situation for the staff. In the recent years some balances have been built up as a result of the necessity to prioritize event-triggered tasks before the contracting of research efforts. The situation is expected to improve as a result of the extended resources received 1998.

The SSI research budget is used for research in all fields of radiation protection. Approximately 45% of the budget is used for research directly connected to nuclear energy production, such as radioecology, radiation protection of power plant workers, nuclear waste matters, and questions related to risk perception and acceptance of waste disposal. 30% of the budget is used for basic research of importance to all areas of radiation protection, mainly radiobiology and epidemiology. The remaining 25% are used for non-nuclear research, i.e. mainly medical and technical applications and uses of radiation, including non-ionising radiation.

8.2.3 Independent assessment of the needs for resources

A major task for the International Review Commission was to evaluate if the available resources for SKI and SSI were adequate and used in an efficient way. To do this the Commission recognized some challanges to take into account when the activities of SKI and SSI are considered:

- For the Swedish nuclear reactors, operating licences are based on the level of technical requirements from the 1970´s and 1980´s. The corresponding level of requirements now emerging in the European reactor designs of the 21st century is enhanced, and the question arises as to which level of technical requirements should be applied for the existing Swedish reactors in the years to come.

- The nuclear power plants are ageing and may need more continuous surveillance, maintenance and repairs; such projects, where safety and radiation protection demands have to be balanced against each other, are gradually growing and becoming more complex. One example is the recent major renovation of one reactor at Oskarshamn (O 1).

- The operators´ present willingness to initiate investments for improving safety, without necessarily being requested to do so by the regulatory authorities, might be affected negatively as nuclear reactors approach the end of their operational lifetime.

- During the phasing out of nuclear reactors SKI and SSI will be confronted with new tasks concerning the supervision of the decommissioning and the dismantling of the reactors.

- Developments in the field of nuclear waste management especially spent nuclear fuel and high-level waste, will demand that the regulators change their focus, as the measures taken by the utilities proceed from research and development work to a phase with design, demonstration and implementation of possible methods for disposal.

- The issues concerning spent nuclear fuel management call for close collaboration between the two authorities. The siting programme for a repository for spent nuclear fuel requires extensive contacts with the inhabitants and local politicians in municipalities where a repository might be located in the future. Inhabitants and local politicians in those municipalities demand to be advised and informed by independent government authorities with expert knowledge in relevant fields. The regulatory authorities are expected to meet such increased demands for information and consultation.

- Sweden´s ratification, in 1995, of the Convention on Nuclear Safety will require the active participation of SKI in the implementation and the review process foreseen in the Convention. Preparatory work within IAEA on a Convention on Nuclear Waste Management will also require active participation both by SKI and SSI.

- It is increasingly important for all government authorities, and especially in complex fields such as nuclear safety and radiation protection, to be able to explain to laymen and the general public what they are doing and why.

- The Government and the Parliament are putting pressure on all government authorities to use their resources in an efficient way and to report, on an annual basis, the results of their activities with regard to goal attainment and cost-effectiveness[28].

Also the Energy Commission of 1994 discussed the resources of SKI. It was recognized by both commissions that SKI may need more resources. The Review Commission had the impression that the resources for SKI were scarce, considering the fact that services from a national technical support organization was not available. However the Commission concluded that changes in the organization and in work methods should also be considered to increase efficiency. The same conclusion was made regarding SSI.

The Commission especially recommended the Government to consider the provision of outside technical support to SKI (TSO-support) for major analysis and review work[29]. The resources for research were considered to be adequate, but SKI was recommended to improve the management of the R & D programmes in order to safeguard that the highest priority work to support SKI regulatory activities is funded and performed[30].

As mentioned above both SKI and SSI in the appropriations for 1998 received an increase of resources for nuclear supervision as a result of new challenging tasks. In the 1997 Activity Report to the Government

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[28] SOU 1996:73, p 25.
[29] SOU 1996:73, p 104.
[30] SOU 1996:73, p 87-88.

the SKI Board concludes that the negative resource trend pointed out in earlier Activity Reports now has been broken. However it will take a couple of years to build up the increased competence and capacity which has been made possible by the new resources. It was also reported that SKI in 1997 already started to direct its work towards the new and more distinct task for the regulatory supervision.

8.3 The relations between SKI and SSI

The rational for having two regulatory bodies has been officially discussed on several occasions. In the Government bill 1984 on the Act on Nuclear Activities it was stated:

”... A double supervisory organization may provide a greater guarantee that the problems will come to light ... At the same time ... two supervisory authorities in this area imposes heavy demands on cooperation and co-ordination of the activities. Some overlap of the activities of the two authorities would appear to be unavoidable. However, such overlap does not always have to be a drawback and must be accepted in view of the construction and character of the act and the careful weighing-together of safety and radiation protection aspects that must be done[31].”

On several occasions the Government has requested SSI and SKI to investigate and report on the possibilities to increase and improve the cooperation on nuclear issues. In most cases the division of responsibilities is clear and straight forward, but in some cases ambiguities exist. In particular this is the case in matters concerning nuclear waste management. Also in the area of emergency preparedness some overlapping responsibilities exist. From time to time insufficient communication and cooperation has caused some friction between the authorities. The difference in view, which generally exists concerning the basis for requirements on radiation protection and safety, also contribute to make the communication between the two independent authorities a little more difficult:

- the optimization principle applied in radiation protection, according to which requirements are based on optimization of resources with due regard to health and safety aspects (cost/benefit, ALARA), and;

- the precautionary principle applied in safety work, according to which requirements are related to what is achievable, in a technical and quality sense, with regard to safety margins encompassing existing uncertainties.

This difference in view is clearly seen in the assessment of major repairs or replacements of parts in the primary systems of the NPPs where safety improvements are achieved at the price of larger doses to the staff.

The possibility for overlapping responsibilities was acknowledged in the preparation of both the Act on Nuclear Activities and the the Radiation Protection Act and was again confirmed in the revision of the Act on Nuclear Activities in 1991.

[31] Government bill 1983/84:60, p 55.

”The overlap is necessary in order to avoid that any safety issue fall outside of the regulatory system. Safety issues are to make sure that all different barriers, in the fuel, the reactor, the containment, transport casks, packages and storage facilities work as intended in order to prevent any harmful amounts of radiation to reach the environment. In parallel it is a radiation protection issue to prevent the radiation, which anyhow could arize during normal operation, abnormal barrier functions or accidents, to produce harmful effects on people and the environment. This means that both authorities should coordinate their licensing and regulatory activities concerning the handling of nuclear material and waste, if it is not obvious from the Acts and the Ordinances how to divide the responsibility[32].”

Coordination between SKI and SSI is established in several formal ways. The Director General of SKI is a member of the SSI board and vice versa. Both authorities are represented on the respective research committees. Regular management meetings are held between the authorities. Coordination between SKI's and SSI's inspectors exists in several ways:

- organized consultations in connection with specific issues. This means for example that personnel from the two authorities participate in regulatory assessment groups which are organized for large projects at the nuclear plants,

- co-ordination of inspections in preparation for annual maintenance outages where an assessment of the extent of the different activities and expected doses is carried out,

- production of the joint annual report to the Government on the status of the safety and radiation protection;

- participation of SSI in the periodic safety assessments of the nuclear power plants initiated by the SKI;

- representation of SSI as an observer on the SKI Reactor Safety Committee[33].

A formal cooperation also exists between the emergency preparedness organizations of the two authorities, and the information service is coordinated for nuclear emergencies.

The overlap of responsibilities between SKI and SSI was also studied by the International Review Commission. Its opinion was that the division of responsibilities was not quite clear. However the Commission did not recommend a merger between SKI and SSI. The authorities were recommended to continue improving their cooperation and dialogue, especially in the regulatory activities concerning nuclar waste management[34]. In the work to develop the new general safety regulations of SKI, constructive discussions were held between the authorities, and more clear definitions have been achieved concerning the regulatory responsibilities of the two authorities, especially concerning emergency preparedness and nuclear waste handling.

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[32] SOU 1991:95.
[33] SOU 1996:72, p 103-104.
[34] SOU 1996:73, p 97.

8.4 Separation between regulation and promotion of nuclear energy

Two different ministries are handling nuclear issues ín order to separate clearly issues of safety regulation from other aspects on the use of nuclear energy. The Ministry of Environment handles all safety and radiation protection issues within the Government. The Ministry of Industry and Trade is responsible for all issues on the use of nuclear energy. SKI and SSI are both central authorities under the Ministry of Environment. The statutes for SKI and SSI and the government letters of appropriation quite clearly define the mandate and the tasks of the regulatory bodies. They are only to be concerned with regulatory tasks in relation to nuclear energy. There is no authorization to engage in any promotional activity. Information obligations are to give the media and the public an unbiased, research based, information on nuclear safety and radiation protection and associated risks.

The managements of SKI and SSI cannot, according to the Swedish Constitution, prevent any employee from declaring in public his personal opinion about the use of nuclear energy, or prevent anyone from participating in the nuclear power debate in Sweden. But the policies of the regulatory bodies are very strict not to be involved as organizations in the political debate or any promotional activity.

The nuclear industry and associated organizations, for instance KSU are of course free to engage in promotional activities. Industry promotional activities are also often coordinated by the Swedish Industry Association. Promotion in the sense of making plans for new reactors for use in Sweden is prohibited, as mentioned earlier, by the Act on Nuclear Activities.

8.5 Conclusion

The Swedish Party complies with the obligations of Article 8.

9. Article 9: RESPONSIBILITY OF THE LICENCE HOLDER

Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.

9.1 The legal requirement

As mentioned in section 7.2 a licence to build and operate a nuclear installation is based on a safety case, presented by the licensee in safety analysis reports which are reviewed by SKI. When a licence is granted, the safety case is regarded as the safety level the licensee has contracted to maintain, at least, as a condition for permission to operate the installation.

The Act on Nuclear Activities is very clear about the prime responsibility for the safety of a nuclear installation:

10 §: The holder of a licence shall be responsible for ensuring that **all measures are taken** which are needed for

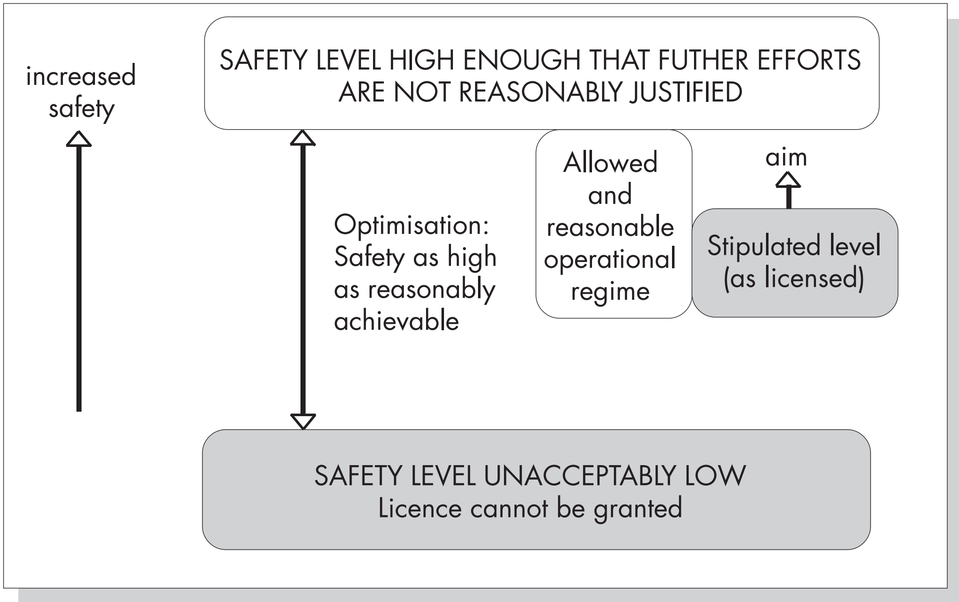
(1) maintaining safety, with reference to the nature of the activities and conditions in which they are conducted,

(2) ensuring the safe handling of the final disposal of nuclear waste arising in the activities or nuclear material arising therein and not reused, and

(3) the safe decommissioning and dismantling of plants in which nuclear activities are no longer to be conducted.

Thus, the licensee's responsibility is not limited to mere formal compliance with the requirements imposed when the licence was granted. The licensee is thereafter expected to sustain a reasonably operational regime, which includes to increase safety, until further efforts are not reasonably justified, throughout the entire service life of the installation. The safety case should consequently be developed to demonstrate not only that a minimum acceptable safety level is achieved, but that the safety is as high as reasonably achievable with respect to the fundamental safety objectives discussed in later sections. This concept of the safety case is graphically displayed in Figure 6. It will also be formally incorporated in the new general safety regulations of SKI (see section 7.2).

Figure 6: The licensee responsibility for safety.



9.2 Measures taken by the utilities

A number of measures taken show that the Swedish licensees have accepted the prime responsibility for safety. The following can be mentioned as examples:

Safety policies

Vattenfall AB and Sydkraft AB have issued safety policies for the operation of their nuclear power plants. These policies are the highest level documents expressing the most important corporate values and valid for all divisions and subsidaries of each company. The policies are supplemented with guidelines as to how operations are to be conducted, and every employee at the NPPs is expected to follow the guidelines.

The policies contain a basic view on the safety issues and establish ambitions and priorities. The ambition of the utilities is to take their own safety initiatives, to maintain an open dialogue with the regulators, and an open dialogue with other companies regardless of the competition on the electricity market, to regard regulations as the minimum standard to be met with reassuring margins, to take an active and leading role in research and development, and to strive for the continuous improvement of safety. It is for instance stated in these policies that measures to raise safety levels shall be given priority if safety analysis shows that the core damage frequency exceeds, with a high level of confidence, 10-5/year. As mentioned in section 6.2, this corrresponds to an internationally recommended objective for new reactors.

Maintenance and backfitting measures
As mentioned in section 6.1, considerable amounts of money have been invested every year in the Swedish NPPs to maintain safety and availability. This is evidence of the utilities intentions to prevent safety problems, and to keep the plants operable.

Design reconstitution projects and plant modernization programmes
These projects are described in sections 6.2 and 6.3. It is clear from these descriptions that the utilities have taken substantial initiatives to assess and upgrade the older reactors to modern safety standards.

International experience feed-back, research and development work
As described in section 3.2, the utilities participate in extensive international work both in cooperation with other utilities and with the regulatory authorities to increase knowledge, learn from others and contribute with their experience on safety issues.

Corrective measures
On certain occasions the regulatory bodies have issued remarks or requirements in connection with safety assessments or inspections. In these cases the licensees have in general responded in a very constructive manner and taken measures to re-evaluate and achieve the required improvements in an efficient manner. In the Swedish regulatory history there are, as in other countries, examples of different views between the regulators and the utilities, and that measures taken by the utilities have been assessed as inadequate by the regulators, but these issues have all been resolved to the regulators satisfaction.

9.3 Regulatory control

As was mentioned in section 8.1.2, the Government in the 1998 letter of appropriation has confirmed a revision of SKIs mission and regulatory tasks, in order to make the division of roles between the regulatory authority and the licensees even more clear. It is stated in the directives from the Government that it is a fundamental prerequisite for the SKI activities that the licensees have the full and undivided responsibility for safety. The basic missions of SKI are to define the contents of this safety responsibility, and to supervise how the licensees execute it. For this SKI shall in particular:

- provide a clear definition of requirements,
- check compliance with requirements by supervision focusing on processes and activities, and
- initiate safety improvements.

Activities at SKI to implement these regulatory missions are the following:

Provide a clear definition of requirements

Intensive work is going on to replace a variety of individual licensing conditions with general regulations to be published in the SKI Code of Regulations. These regulations are principal and functional in order not to have a negative impact on licensee responsibility. Details about this are provided in section 7.2.

Check compliance with requirements by supervision focusing on processes and activities

Since a couple of years ago, SKIs supervision focuses more and more on processes and activities as the most cost-effective way to assess that the licensees have a fully satisfactory control over safety as displayed in plant processes and organizational processes. For this purpose the inspection instruments described in section 7.4 have been adapted, as well as the assessment instruments described in section 6.2. A prerequisite for his type of supervision is that SKI clearly defines the controls necessary, in terms of licensee internal control functions, accredited third party control in some cases and, for issues of major safety significance, SKI review and approval.

In order to implement the new regulatory strategy SKI is in the process of defining and developing internal guidance documents within the internal quality system (SKIQ). New inspection methodology has been tried out in real cases. As an example, SKI performed a major in-depth inspection in 1996 of the quality of the safety work at one plant. This decision was triggered by several incidents which indicated a need for improvement in safety related organizational processes and routines. Experience gained from this inspection, which covered 10 different activity areas, has been an important input into the new methodology.

Initiate safety improvements

Supervision focusing on processes and activities means that SKI will not spend as much resources as earlier on in-depth reviews of technical issues, if it is not obviously needed in connection with licensing decisions. However, in order to identify safety improvement possibilities, it is necessary to have an extensive analysis and feedback of operating experiences. Considerable improvements and strengthening of these efforts have taken place both within SKI and within the utilities, in the past decade. Significant events are screened out and analyzed in depth, including on-site investigations by SKI teams if appropriate. Learning from operating experience is most important, including:

- early identification of trends, indicating deteriorating performance of systems or organizations, followed by appropriate corrective actions,

- identification of precursor events with a frequency of occurrence as low as 1 in 100 reactor years to 1 in 1000 reactor years or even less; events which give warning signals for potential weaknesses in critical safety functions, including those related to human errors. This is necessary to ensure the high reliabilty of safety functions implied by the core damage frequency objective of 10-5 per reactor year. Identifying and acting upon such rare events requires efficient international cooperation in incident reporting and analysis, with some redundancy between work performed by industry and regulatory bodies.

The concept of an on-going safety dialogue between SKI and the licensees is still a key element in the SKI regulatory approach. This concept includes the concept that regulatory actions and decisions are based on in-depth technical reviews, when necessary, of the safety case, using state-of-the-art assessment methods, including PSA. Open and frank dialogue between SKI and licensee experts is a key element in this review of the safety case, focusing on achieving fundamental safety objectives. Such a dialogue is also a key element in the development of regulations and guidelines.

Such a safety dialogue must be based on high professional competence on both sides. For SKI, support by an extensive research programme is of fundamental importance in this respect. In the model developed in Sweden for interaction between the regulatory body, SKI, and the licencees, safety improvements are often initiated through R&D efforts, partly carried out jointly with the nuclear utilities, with publication of results, so that they are open for public scrutiny and scientific peer review. Such joint R&D efforts are furthermore limited to the definition of scientific and technical issues and developing the tools, e.g. the scientific models and methods of analysis suitable for attacking the issues. It is then the responsibility of the utilities to use this improved knowledge in the development and implementation of plant-specific safety improvements. SKI will in this phase return to its supervisory role, evaluating the actions taken by the utilities, and making its own decisions whether specific inspection or rule-making actions are called for.

9.4 Conclusion

The Swedish Party complies with the obligations of Article 9

10. Article 10: PRIORITY TO SAFETY

Each Contracting Party shall take the appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

10.1 Regulatory requirements

Even if priority to safety is one of the basic principles to pursue in regulatory work, there has only been one explicit regulatory requirement on such a safety policy in Sweden up to 1999. This requirement is to include a general clause in the technical specifications (STF) of the reactor units. The general clause says that the reactor shall be brought to a safe state if there are any doubts as to whether the operation can be conducted safely, or whether the safety status can be assessed. This is a most important policy as it directly concerns the operation of the nuclear power plants.

In the SKI licence conditions on quality assurance it is required that there is a documented quality policy, approved by the licensee, to guide the work on safety and quality. No specific requirements are stated concerning this policy. A safety policy could be seen as included in a quality policy according to the principle: ”no safety without quality”.

The new general safety regulations of SKI (see section 7.2) are more explicit on this issue:

”The licensee shall establish documented guidelines for how safety shall be maintained at the facility as well as ensuring that the personnel performing duties which are important to safety are well acquainted with the guidelines”. It is further stated in the general recommendations to this paragraph:

”Guidelines for safety are the safety policy and the safety goals which determine the direction of safety-related work, as well as a strategy describing how the goals are to be attained. The safety policy should be concrete and demonstrate a high level of ambition with regard to ensuring priority to safety. The safety goals may be both quantitative and qualitative. The goals should be formulated so that they can be followed up”.

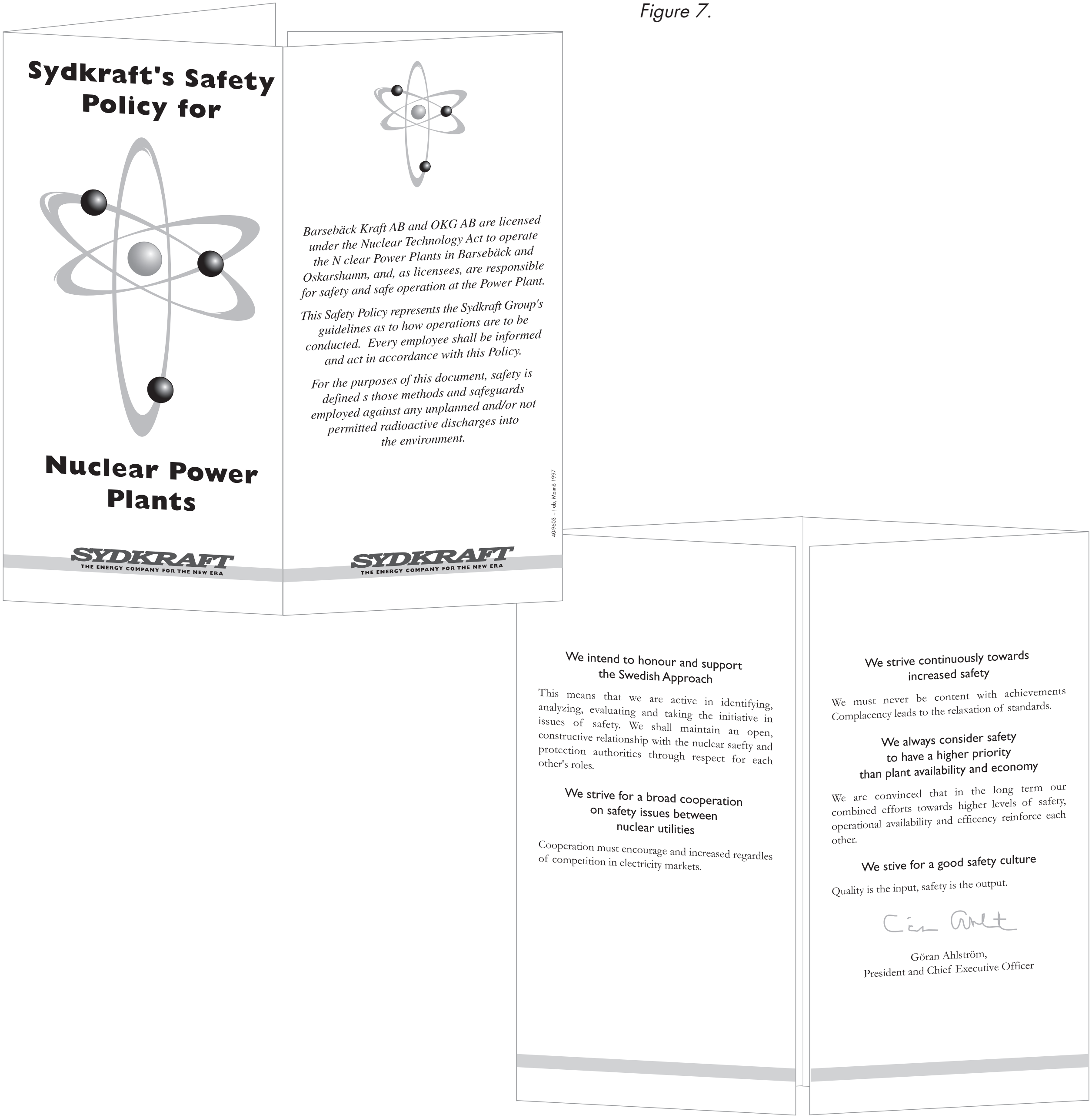
In the continuous safety dialogue with the licensees, and in different licensing decisions, of course SKI has to make sure that safety is always prioritized, especially where conflicting goals might occur. In this dialogue the safety policies adopted by the licensees are useful.

10.2 Measures taken by licence holders

The management system of the utilities includes several instruments used to prioritize safety.

- The safety policy defines the overall priorities and major guiding principles in the safety work. The policy establishes the first priority of safety in all decisions and emphasizes the importance of a good safety culture. As an example the safety policy of Sydkraft is shown in Figure 7. The safety policy is interpreted and guidelines defined for explicit guidance at various organizational levels. In the safety guidelines the principles are stated for prioritizing measures to improve safety and overall objectives with respect to core

Figure 7.



Sydkraft's Safety Policy for Nuclear Power Plants

SYDKRAFT
THE ENERGY COMPANY FOR THE NEW ERA

Barsebäck Kraft AB and OKG AB are licensed under the Nuclear Technology Act to operate the N clear Power Plants in Barsebäck and Oskarshamn, and, as licensees, are responsible for safety and safe operation at the Power Plant.

This Safety Policy represents the Sydkraft Group's guidelines as to how operations are to be conducted. Every employee shall be informed and act in accordance with this Policy.

For the purposes of this document, safety is defined s those methods and safeguards employed against any unplanned and/or not permitted radioactive discharges into the environment.

SYDKRAFT
THE ENERGY COMPANY FOR THE NEW ERA

We intend to honour and support the Swedish Approach

This means that we are active in identifying, analyzing, evaluating and taking the initiative in issues of safety. We shall maintain an open, constructive relationship with the nuclear saefty and protection authorities through respect for each other's roles.

We strive for a broad cooperation on safety issues between nuclear utilities

Cooperation must encourage and increased regardles of competition in electricity markets.

We strive continuously towards increased safety

We must never be content with achievements Complacency leads to the relaxation of standards.

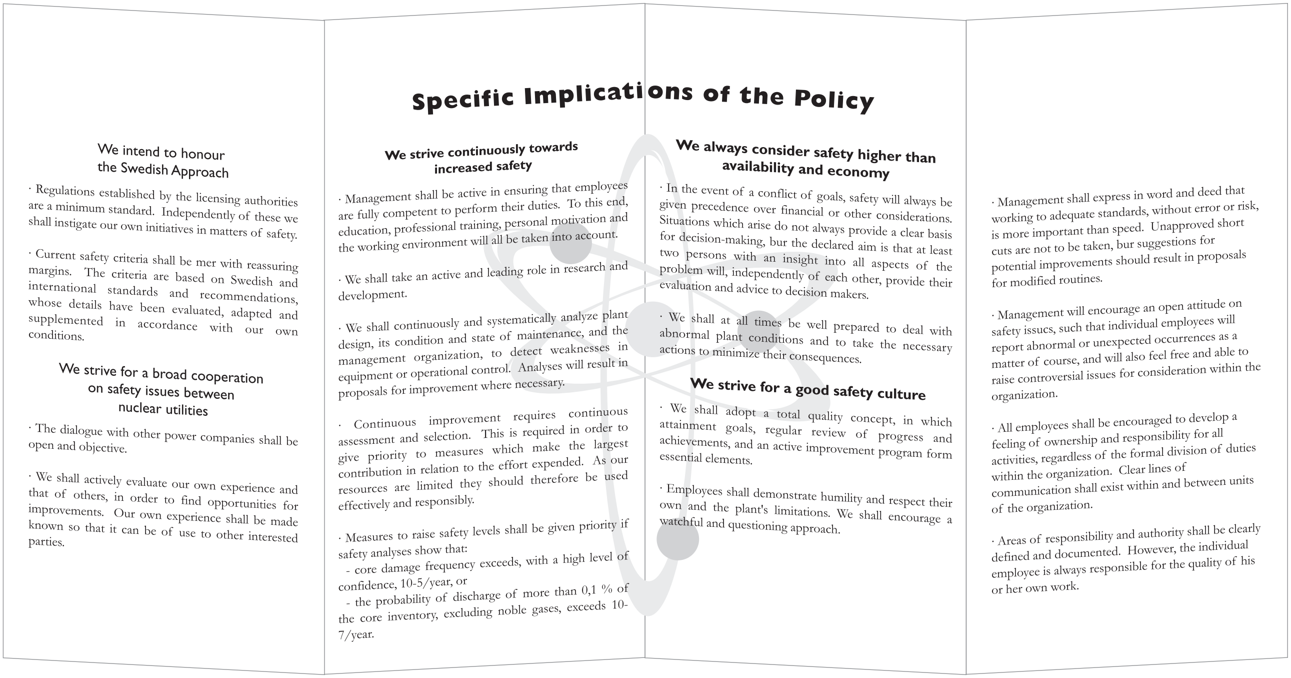
We always consider safety to have a higher priority than plant availability and economy

We are convinced that in the long term our combined efforts towards higher levels of safety, operational availability and efficency reinforce each other.

We stive for a good safety culture

Quality is the input, safety is the output.

Göran Ahlström,
President and Chief Executive Officer



We intend to honour the Swedish Approach

· Regulations established by the licensing authorities are a minimum standard. Independently of these we shall instigate our own initiatives in matters of safety.

· Current safety criteria shall be mer with reassuring margins. The criteria are based on Swedish and international standards and recommendations, whose details have been evaluated, adapted and supplemented in accordance with our own conditions.

We strive for a broad cooperation on safety issues between nuclear utilities

· The dialogue with other power companies shall be open and objective.

· We shall actively evaluate our own experience and that of others, in order to find opportunities for improvements. Our own experience shall be made known so that it can be of use to other interested parties.

Specific Implications of the Policy

We strive continuously towards increased safety

· Management shall be active in ensuring that employees are fully competent to perform their duties. To this end, education, professional training, personal motivation and the working environment will all be taken into account.

· We shall take an active and leading role in research and development.

· We shall continuously and systematically analyze plant design, its condition and state of maintenance, and the management organization, to detect weaknesses in equipment or operational control. Analyses will result in proposals for improvement where necessary.

· Continuous improvement requires continuous assessment and selection. This is required in order to give priority to measures which make the largest contribution in relation to the effort expended. As our resources are limited they should therefore be used effectively and responsibly.

· Measures to raise safety levels shall be given priority if safety analyses show that:
- core damage frequency exceeds, with a high level of confidence, 10-5/year, or
- the probability of discharge of more than 0,1 % of the core inventory, excluding noble gases, exceeds 10-7/year.

We always consider safety higher than availability and economy

· In the event of a conflict of goals, safety will always be given precedence over financial or other considerations. Situations which arise do not always provide a clear basis for decision-making, bur the declared aim is that at least two persons with an insight into all aspects of the problem will, independently of each other, provide their evaluation and advice to decision makers.

· We shall at all times be well prepared to deal with abnormal plant conditions and to take the necessary actions to minimize their consequences.

We strive for a good safety culture

· We shall adopt a total quality concept, in which attainment goals, regular review of progress and achievements, and an active improvement program form essential elements.

· Employees shall demonstrate humility and respect their own and the plant's limitations. We shall encourage a watchful and questioning approach.

· Management shall express in word and deed that working to adequate standards, without error or risk, is more important than speed. Unapproved short cuts are not to be taken, bur suggestions for potential improvements should result in proposals for modified routines.

· Management will encourage an open attitude on safety issucs, such that individual employees will report abnormal or unexpected occurrences as a matter of course, and will also feel free and able to raise controversial issues for consideration within the organization.

· All employees shall be encouraged to develop a feeling of ownership and responsibility for all activities, regardless of the formal division of duties within the organization. Clear lines of communication shall exist within and between units of the organization.

· Areas of responsibility and authority shall be clearly defined and documented. However, the individual employee is always responsible for the quality of his or her own work.

melt frequency and the release of radioactive material in the event of an accident. For radiation protection the ALARA principle is adopted and a cost/benefit value for dose-reducing measures is given.

- In the Vattenfall as well as the Sydkraft groups an advisory safety committee/council on the corporate level monitors how the policy is implemented, and advises the management as to how the policy could be further developed and improved.

- Each plant has a strategic development plan in which measures for continuous improvement of safety are defined and given priority according to the policy and guidelines.

- The level of safety in plant operation is monitored in several ways, one of the main instruments being performance indicators, which are used at several levels of the organization using appropriate indicator sets. In Figure 8 some examples are provided. On the company level a majority of the WANO performance indicators are regularly evaluated. These are supplemented by a few company specific indicators, eg. one which is based on the number of LERs, classified as safety related and another based on actions taken as a consequence of identified quality audit deviations. Attempts are also being made to implement specific indexes that are condensed from several indicators. Within Vattenfall, for instance, a Quality Index is being tried out since 1998. This is based on a comparison of the values of six selected

WANO indicators to international performance statistics. The indicators described in the appendix are analysed, and the result is presented in the companies' safety councils/committees, together with trendgraphs of the indicators, where they form a basis for discussions with the plant representatives.

- The main tool to ensure that the plant is operated according to the regulatory requirements and the conditions stated in the FSAR is the technical specifications (STF). They contain the formal basis for the safety work of the licensee. As mentioned, the STF includes a general clause requiring that the plant is to be brought to a safe state if any doubt arises as to whether the operation can be continued safely or whether the safety status can be assessed. Modifications of the STF are proposed by the plant operator to SKI for formal approval (see further section 19.2.2).

- The quality requirements of all safety-related equipment are governed by the system for safety classification. This system is essentially based on US codes. All equipment is referred to one of four safety classses, and for each of these classes the requirements are defined with respect to quality and functioning. For equipment of importance for the mitigation of severe accidents seismic requirements are added.

Figure 8.

Performance indicators used by the Swedish plants

The performance indicators below are examples of safety indicators used on the company and plant management levels. All indicators are not necessarily used by all plants and utilities. As for the specific indicators, the definitions may vary somewhat among the plants:

WANO - Performance Indicators

- Unplanned Automatic Scrams per 7000 hours critical
- Fuel Reliability Indicator
- Safety System Performance
- Collective Radiation Exposure
- Chemistry Index
- Industrial Safety Accident Rate

Specific indicators

- LER Significance Index
- Temporary Modifications
- Isolation Valve Tightness
- Failure Recurrence
- Quality Audit Index

- The quality assurance system (see chapter 13) is an essential part of the management system, based on a quality policy and outlined in the management- and quality handbook. The tools used to verify compliance with the quality requirements include audits of all parts of the organization at regular intervals. The audits also comprise all suppliers of safety-related equipment.

- Safety training programmes include the operator training programmes with the use of simulators (see chapter 11), and a variety of training courses at the plants including radiation protection, safety philosophy and rules, emergency preparedness, etc.

- The implementation of modifications in equipment, systems and technical specifications are carried out according to established procedures. The tool to ensure that all safety requirements are adequately met is a system for internal and independent safety review at each plant (see section 14.2.2).

- Initiatives to safety culture promotion programmes have, on a national level, been forwarded by a group with representatives from SKI, SSI and the utilities. A Swedish version of the IAEA INSAG-4 document ”Safety Culture”[35] has been issued and distributed as a booklet to all NPPs. Other initiatives include safety culture seminars for all staff, implementation of the STAR or STARK-paradigm,[36] safety culture assessments performed in association with the ASAR projects (see section 14.2), and research initiated to develop tools for safety culture assessments.

10.3 Regulatory control

SKI is engaged in many inspection and assessment activities to make sure that safety is prioritized by the licensees. Examples are the following:

- Regular top management meetings with the licensees to discuss recent issues and safety priorities in general.

- Periodic reviews of the licensee safety policies, management systems and organizational measures to prioritize safety.

- Regular reviews of the organization, competence, methods and results of the licensees internal and independent safety reviews and quality audits.

- Analysis and trending of LERs in order to identify degraded performance.

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[35] Safety Culture. IAEA Report Safety Series No 75-INSAG-4. Vienna, 1991.
[36] Stop, Think, Act, Reflect, Communicate

- Reviews of event investigations of the licensees to check the quality of the investigations and follow up on the implementation of corrective measures.

- Reviews of safety analyses and follow up on the measures taken as a result of the analyses.

- Regular inspections and assessments of the planning for and the conduct of refuelling outages including the work of contractors. These assessments also include work conditions for the personnel and the use of overtime.

10.4 Measures taken by the regulatory body

In the Quality Strategy of SKI issued 1996-05-10 it is stated as the first priority:

”We shall focus on our primary tasks- on what is most important to safety, to national non-proliferation obligations and to the measures needed in order to meet public needs for information about nuclear risk and safety”.

The most important instrument for implementation of this policy is the annual Activity Plan in which priorities are clearly stated. As an example, the prioritiy of regulatory activities for the Office of Reactor Safety will consider the following factors during 1998:

- events (e.g. the phase-out of Barsebäck 1),

- identified generic safety issues (e.g. review of procedures and implementation of operability control),

- SKIs basic tasks (safety assessments, reviews and topical inspections),

- SKIs internal QA-work (development of regulatory acceptance criteria), and

- governmental directives (issuing general safety regulations and the Swedish report to the Convention on Nuclear Safety).

The new SKI regulatory supervision philosophy, which means more focus on processes and activities (see section 9.3), has been adopted in order to use resources in the most cost-efficient way in the supervision of safety at the NPPs.

Safety priorities can also be seen in the selection of plant modifications to be reviewed by SKI and in the planning of inspections. Recent developments include making more use of risk informed priorities.

10.5 Conclusion

The Swedish Party complies with the obligations of Article 10.

11. Article 11: FINANCIAL AND HUMAN RESOURCES

1. *Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.*

2. *Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with approproate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life.*

11.1 Regulatory requirements

The basic legal provision on resources is indirect in stating that the holder of a licence shall be responsible for ensuring that all measures are taken which are needed to maintain safety, with reference to the nature of the activities and the conditions in which they are conducted[37]. It follows from this provision that the necessary financial resources to maintain safety must be provided by the licensees.

With regard to human resources there are three sets of regulatory requirements issued by SKI, from a general quality assurance provision on necessary competence to detailed provisions in the technical specifications on minimum staffing of the reactor unit control rooms in different operational states.

1. The SKI ”regulations” on Quality Assurance include a requirement that the quality system of the installations shall ensure that the necessary competence is available and is maintained for the personnel who are involved in quality affecting activities. For in-house personnel education, experience and tasks shall be documented. Contractors shall be approved by quality audits according to documented routines.

2. The SKI licence conditions on ”Competence control of certain personnel at the NPPs” apply to control room operators, field operators, operational managers, certain maintenance personnel with responsibility for the maintenance of safety systems, and full time instructors and trainers at the NPPs. For these categories the following applies:

   (a) responsibilities and authorities shall be defined,
   (b) competence requirements shall be analysed and documented,
   (c) training programmes shall be defined and documented,
   (d) annual competence assessment shall be executed and documented,
   (e) all training activities shall be documented.

[37] The Act On Nuclear Activities 10 §.

For control room personnel (turbine operator, reactor operator, shift supervisor) there are additional provisions on basic technical education, detailed requirements on basic plant training, annual retraining for two weeks (one week in a full scale simulator) based on a specified training inventory, detailed requirements on training schedule, service time and annual competence assessment needed for authorization. There are also requirements on joint competence level for the whole shift team and certain provisions about authorization for more than one control room position. Finally the regulations contain provisions about the annual reporting of training and competence assessment documentation to SKI.

There is no formal licensing of control room operators in Sweden, but the system just decribed is a kind of utility administered licensing system. SKI will in the near future revise and further clarify the requirements on competence control in order to make it even more in line with a utility administered licensing system.

3. The technical specifications (STF) of every reactor unit contain priovisions about minimum control room staffing required during full power operation and refuelling outage. During full power operation the minimum allowed competent staff for a BWR is five persons:
   - one shift supervisor,
   - one reactor operator,
   - one turbine operator,
   - two field operators.

   For PWRs the same applies with the addition of an assisting reactor operator. These provisons are regarded as licensing conditions.

The new general safety regulations of SKI (see section 7.2) are specific about the staffing. A long term planning is required of the licensees in order to ensure enough staff with sufficient competence for the safety related tasks. A systematic approach should be used for the planning and evaluation of all safety related training. It is also required that there is a careful balance between the use of in-house personnel and contractors for safety related tasks. The competence necessary for the ordering, manageing and evaluation of the result of contractors work, should always be at disposition in the organization of a nuclear installation.

The new regulations also contain provisions that the staff must be fit for their tasks. This implies medical requirements and tests for drugs, etc. Such provisions have not been issued to date by SKI, but the licensee handling of the fitness for duty issues have been inspected at the NPPs.

11.2 Financial resources of the licence holders for operations and safety improvements

The majority owners of the Swedish nuclear power plants are Vattenfall AB and Sydkraft AB with ownership shares as shown in figure 1 of chapter 2. They are the two largest electric power producers in Sweden generating about 52 and 18 percent respectively of the total electricity production. Besides the nuclear power plants both companies have substantial assets in hydro power and thermal power.

Both the Vattenfall Group and the Sydkraft Group are financially very stable and have excellent financial records. Some key figures from 1997 are given in the following table:

	Earnings MSEK[38]	Total assets MSEK	Electricity sales TWH	Equity/Assets Ratio %	Investments MSEK
Vattenfall Group	5 439	78 872	78.7	40	4 877
Sydkraft Group	5 181	47 495	32,0	40	8.957

Table 10: Financial records of the utility groups in Sweden

The costs for operation and investment in the nuclear power generation are well covered by sales revenues and accounted for using normal accounting principles. So far all safety investments in the NPPs have been financed by corporate funds, as decided by the utility boards, on commercial conditions for the license holders. This means that realistic plans for write-offs have to be made. Costs for safety improvements are thus considered to be an integrated part of the total operating costs. A high safety level, demonstrated by a good safety trend, is considered essential for the total business concept.

11.3 Financial and human resources for waste management at the sites and decommissioning

The waste management on site is, and has always been, regarded as an integrated part of the operation of the nuclear power plant. This is the case at all Swedish sites, and consequently the provision of financial and human resources is equivalent with operations in general as described above. More details about the waste handling process on site, type of waste and packages etc. are provided in section 19.2.8.

Typically, 10-20 persons per site are directly involved in the waste management. These figures include individuals working with the practical handling of the waste, such as separating, compressing and packaging low level waste, de-watering, processing and cutting of intermediate-level waste, and transporting and storing of waste on site. Also included are resources for measuring and documentation of the different types of waste. However, resources for the operation of the intermediate storage, CLAB, and the final repository, SFR, situated at Oskarshamn and Forsmark respectively, are not included.

The decommissioning and dismantling of a reactor is a costly and extensive undertaking. For the entire Swedish nuclear programme, the costs for handling of all nuclear waste and for dismantling of the 12 units are calculated to between 46 and 53 billion SEK (in 1997 money value) provided that the units are operated

[38] Before taxes and minority share. The Sydkraft extraordinary figure includes sales of shares during 1997. The prediction for 1998 is 3 000 MSEK.

for the minimum of 25 years and for the maximum of 40 years. In addition to these costs about 10 billion SEK has already been invested in the CLAB facility, in the transportation system, the Hard Rock Laboratory (see chapter 2) and in different R&D projects[39].

According to the Act on Nuclear Activities it is the responsibility of the licence holders to take all necesssary measures for the safe handling and final disposal of spent fuel and nuclear waste, for decommissioning and dismantling of installations. It is also the responsibility of the licence holders to pursue the necessary R&D efforts needed for these activities. In order to ensure the financing of these activities, a waste and decommissioning fee is paid by all twelve operating units, according to a special act: the Act on the Financing of Future Expenditures for Spent Fuel etc (1992:1537). The fee is calculated on every produced kWh and varies a little from year to year. Based on calculations made by SKB and additional estimations, the fee is annually calculated and proposed by SKI, decided by the Government and since 1982 paid to a special state fund "The Nuclear Waste Fund" in order to secure the value and the future access when required. During 1998 the fee varies between 0,4 and 1,6 öre/kWh (1 SEK = 100 öre) for the different nuclear power units. The amount is calculated on an operating time of 25 years. In case of a longer operating time, fees for the handling of additional nuclear waste will have to be paid, but all the fixed costs are included in the cost estimate for 25 operating years. In case of an earlier shut down, the licence holders must provide a financial security to the Nuclear Waste Fund.

11.4 Staffing and training for safety-related activities at the nuclear installations

Utility principles for staffing

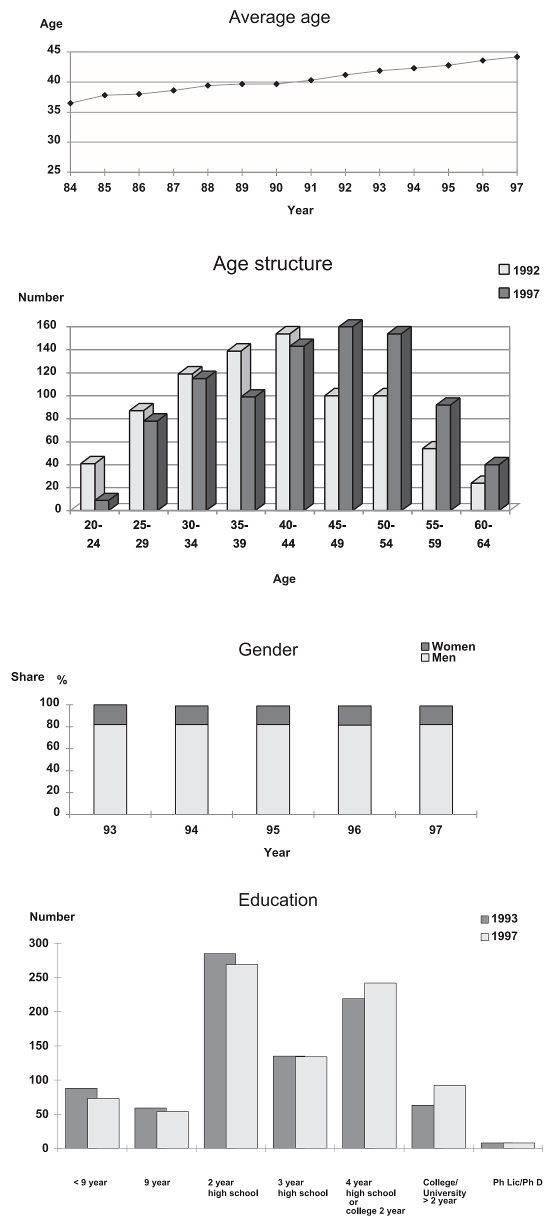
The operating organizations of the Swedish NPPs are relatively small when compared with most other NPPs around the world. The quantatively low number of staff is compensated for by the access and use of a fairly large number of consultants and contractors in the nuclear area, both within the utility and externally, among these are the original main suppliers. Many of these consultants and contractors have been utilised by the NPPs for many years. This goes not only for the organizations but also for the individuals, which in most cases assures continuity and good quality work.

Contractors are in the first instance used during annual refuelling and maintenance outages, while consultants are utilised to varying extent by the NPPs all around the year, in practically all fields including safety analysis tasks. As mentioned in chapter 2, the number of contractors used is between 500-1000 during a unit refuelling outage, normally lasting for 3-5 weeks. Throughout the year 20-50 consultants are used per site for specific technical support tasks. The number is dependent on the actual work load situation at the NPP, and the need for specific competence not normally available within the NPP organization.

To ensure a sufficient number of qualified staff for all safety-related activities, the NPP organizations are dimensioned for coping with all normal operational activities and emergency activities within the design basis. For less frequent tasks contractors and consultants are used as needed, some on long term contract. To an increasing extent the licence holders have realized the needs for long-term personnel planning. This has to do with the limited supply of qualified nuclear engineers, and the long training and qualification time needed

[39] Financing. This is how the costs for the nuclear waste are paid. SKI Brochure. June, 1998. (in Swedish)

Figure 9.



before newly recruted staff can be given full reponsibility for safety tasks. During recent years a large number of experienced engineers have retired from the utilities and the main supplies. Many of these engineers are veterans from the beginning of the Swedish nuclear power programme, and have personal experience from the commissioning of the units. Thus it is a dubble challenge for the licence holders to find new staff and to reproduce the fundamental knowledge base which lay behind the Final Safety Analysis Reports.

One strategy applied to accomplish this is to involve both the main supplier and the operators in the current design basis reconstitution projects (see section 6.2). This serves the purpose not only of verifying the safety level of the plants, but also to preserve and pass on the knowledge and experience of those who participated in the original design work and building of the plants before they retire. This includes transfer of knowledge to a new generation of engineers.

The use of staff from the operating organizations in modernization programmes has also proved to be an exellent way, not only to transfer the operating experience into the projects, but also to assure that the plant people will be familiar with the renewed and upgraded reactor prior to the restart of it. Participation in modernization projects is also a way to stimulate the development of the personnel and increase the competence and knowledge about new technology.

The retirement of experienced staff from the NPPs will continue at an accelerated pace over the next 10 years as the average age of the staff increases. In Figure 9 some figures are shown from the Forsmark NPP which are representative of all the Swedish NPPs.

It can be noticed today that the interest in nuclear engineering among students has declined. Consequently the number of professors in nuclear branches at the universities of technology has also decreased. This will probably make it even more difficult to recruit new qualified engineers to the nuclear power plants in the future, if no actions are taken, although only limited effects have been seen so far. The industry is fully aware of this situation, several investigations and analyses have been made and a number of steps have been taken to deal with the situation.

The industry parties have realized that they must take a greater responsibility for the basic and advanced nuclear education. One important step, to stimulate the interest in nuclear topics and improve the cooperation between the nuclear industry and the universities, was to establish the Nuclear Technology Centre at the Royal Institute of Technology in Stockholm. The Centre, which is supported by the Swedish utilities, SKI and ABB Atom, also supports research projects across the faculties and in other Swedish universities.

Other types of research projects and advanced education in the nuclear area are also encouraged, such as the support by the utilities and the SKI of the research on Severe Accidents, and the financing of professorships in Nuclear Safety and in Human Factors science by SKI.

Participation in international R&D projects is another important means to generate and develop the competence in nuclear specialities. In order to learn about requirements for new reactors, with the possibilities of using new knowledge to improve the present reactors, but also to increase knowledge and competence in this area, Swedish utilities have joined the EUR-project with the objective to participate in the development of a set of modern requirements for BWRs.

Organization and structure of training at the NPPs

Personnel recruited to qualified positions at the NPPs comply with a specified educational level, most often a technical university degree or a high school technical diploma. The distribution of the educational level at the Forsmark NPP is shown as an example in Figure 9. In addition often other industrial - or preferrably nuclear experience is needed. For most technical positions additional in-house training and experience is required by the utility and SKI before the employee is given the full responsibility. For control room personnel and operational managers plant specific training and experience are mandatory.

For control room personnel an internal promotion schedule is applied in which all operators begin as field operators. The qualification time to become a reactor operator is about 5 years, and to become a shift supervisor about 7 years, if a strict promotion schedule is applied.

The Swedish NPPs have in general relatively small training organizations, typically one training manager and 5-10 training engineers with some functional specialization. The training organizations are reinforced as needed by instructors from the operational, maintenance or safety departments. The training organization varies from plant to plant, but all these organizations work as internal consultants for the line organizations. This means that the responsible line managers, e.g. for operations and maintenance, define and order training efforts from the training manager. The training organization at the plant training centre makes the detailed plans, produces course descriptions, training material, summons the selected students, conducts the training, sometimes with resources from outside, and arranges evaluation of the training efforts. The line managers are responsible for the annual competence assessment according to SKI regulations, but the training organizations provide support in preparing the annual inventory of training needs.

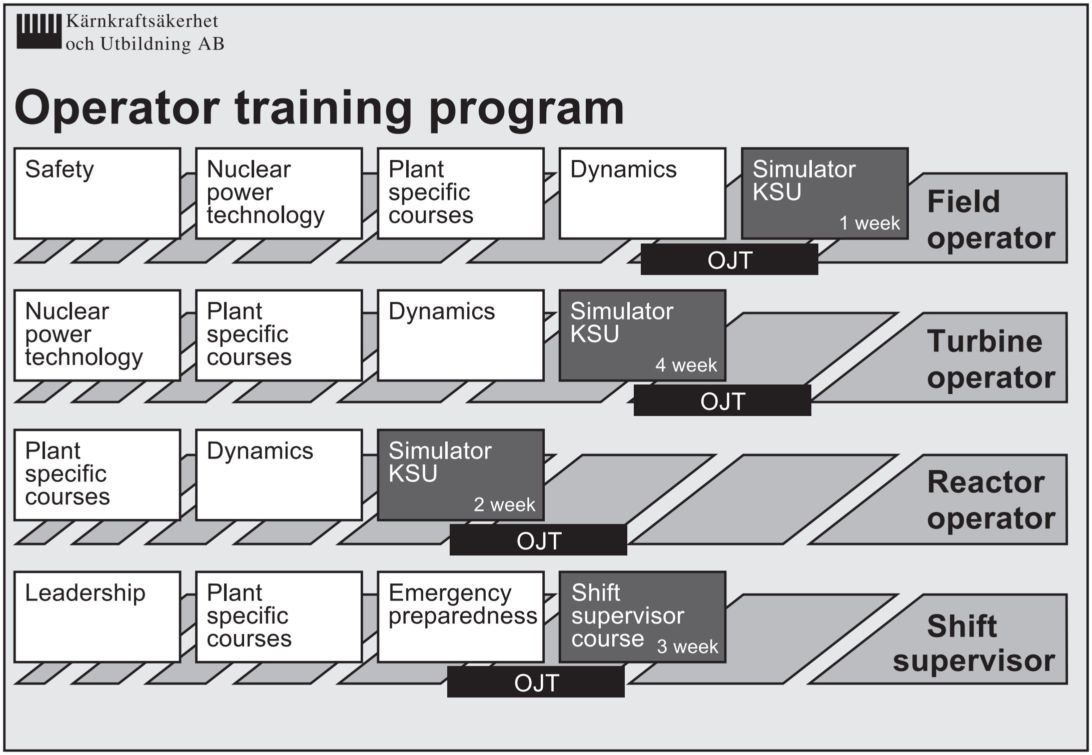
At every NPP there are defined and documented training programmes for newly employed and promoted personnel. These programmes are required in order to work in a specific position with full responsibility. The training programmes contain theoretical courses, simulator training (for some positions), practical training and work in parallel with an experienced colleague. All new courses of the mandatory programmes have, since a few years ago, been developed with the application of a systematic approach. The structure of the training programmes is quite similar for all the Swedish NPPs. A general overview of the operator training structure is given in Figure 10. For a number of positions annual retraining is also required. In addition to these in-house training programmes, necessary for holding a position, there are also a number of specific courses offered for a general personnel development purposes.

The mandatory training programmes typically include basic courses in nuclear technology and safety, plant knowledge including systems, processes and dynamics, technical specifications (STF), radiation protection, plant organization and work routines. Operational personnel are given extended courses on systems, processes and dynamics, transients and accident scenarios, operational procedures and STF.

General authorization is needed for entering the controlled areas of the Swedish NPPs according to SSI regulations. A requirement for this authorization is an introductory course on nuclear safety and radiation protection as well as a medical examination, both have to be renewed every three years. All contractors must pass this course and additional training on plant safety and work routines.

On average the Swedish NPPs spend 7-15 days on every employee and year on organized training of safety related tasks, the largest numbers of days are spent on operational training. Training of new employees and for new positions are not included in these figures.

Figure 10.



OJ = On the Job Training.

Organization and structure of simulator training at KSU

As mentioned in chapter 2 the full scale simulator training is provided at a centralized Training Centre, KSU, located in Studsvik and owned jointly by the utilities. The KSU Training Centre includes seven full scale simulators, as shown in table 11, providing training of all Swedish control room operators in control room environments almost identical with the real plants. As can be seen in the table the simulators correspond to the seven design generations of the Swedish plants.

All modifications of the real control rooms or of plant parameters are installed in the respective simulator. The utilities have stated as an objective that all major modifications shall be installed in the simulator, before being implemented in the plant, in order to be validated, provide training and be evaluated.

KSU collects extensive operational experience in order to keep the simulators updated, and they have many international contacts to this end. During the 1990´s the older simulators have been upgraded, and all the simulators can now simulate accident sequences up to core melt. For severe accident simulations, work stations are available.

The KSU staff of 160 employees includes 45 simulator instructors, many of whom have been recruited from the NPPs, and are experienced operators.

The simulator training is planned in close cooperation with the respective NPP. Preparatory training is given at the home plant. The home plant training centres use compact simulators for main process simulations. Instructors from the home plants are present at KSU on a regular basis as well as representatives from the operational management in order to evaluate their students.

The basic training programmes for turbine operators and reactor operators include 6-9 weeks long simulator courses for the training of control room tasks. Prospective shift supervisors are given a one week course on team management, and field operators are given an orientation course of a week. Entire ordinary shift teams are retrained annually for 2 weeks in the simulator in order to maintain and increase their skills. About half of the training time is used for emergency operations training. An important part of the training is communication and coordination of the team. The retraining also plays an important role in the introduction of plant modifications and other new features. The simulators are also being used in the regular unit emergency exercises to an increasing extent.

Simulator	Target unit	Taken into operation
B1	Barsebäck 1 and 2, Oskarshamn 2	1975
R3	Ringhals 3 and 4	1978
FO3	Forsmark 3 and Oskarshamn 3	1984
F1	Forsmark 1 and 2	1990
R1	Ringhals 1	1991
O1	Oskarshamn 1	1993
R2	Ringhals 2	1995

Table 11: Swedish full scale simulators.

11.5 Regulatory control

As mentioned earlier, Sweden does not apply an official licensing system for NPP operators. The Swedish system is based on a regulatory review and assessment of the quality of the training systems, and the competence assessment applied by the NPPs, rather than on individual licensing. Except for the issuing of regulations, this means that SKI exercises regulatory control in the following way:

- Financing. This is how the costs for the nuclear waste are paid. SKI Brochure. June, 1998. (in Swedish) Topical inspections. During the 1990´s there have been several major topical inspections of the NPP training systems. The following fields have been covered: oprational training, training and use of STF, maintenance training, annual retraining of control room operators. During these inspections the organization, resources and planning of the training have been assessed, as well as the content, conduct and evaluation of it.

- Review of annual training reports from the NPPs. SKI regulations are specific on the contents of these reports. They are reviewed by SKI inspectors and specialists.

- Annual meetings with the training managers and line managers in operations and maintenance. During these meetings SKIs regulations and the results from the regulatory inspections and reviews are discussed. Generic issues are identified and action plans developed. Experience at the different NPPs regarding the solution of some specific training issue are also discussed at these meetings.

11.6 Conclusion

The Swedish Party complies with the obligations of Article 11.

However, there are some concerns, as reported earlier, whether the Swedish NPPs today have sufficient numbers of qualified staff for all engineering tasks. There are also some concerns as to whether the supply of qualified nuclear engineers and other specialists will be sufficient for all demands for qualified staff during the remaining nuclear operating time in Sweden. These concerns have to do with the limited supply in Sweden of nuclear specialists and are related to the following circumstances:

- SKI has reported to the Government (see section 6.1) that there are indications on work overloading of the NPP organizations and keen competition to recruit qualified specialists. This situation has to do with the extensive analysis and modernization programmes now going on at all the Swedish NPPs with implementation of new technology. At the same time there is increased retirement of experienced staff.

- SKI will in the new safety regulations increase the requirements on safety analysis, on updating of safety reports, and extend the scope of internal and independent safety review. This is estimated to require 5-12 additional qualified engineers per reactor site in the long run.

- SKI and SSI have been given more resources in order to carry out new regulatory tasks (see section 8.2). This will further increase the demand for qualified nuclear engineers and other specialists.

- The governmental decision to start the phase-out of nuclear power will possibly affect the interest of students to engage in nuclear engineering courses and especially in nuclear research training. It has already been observed that university courses in nuclear topics have been cancelled.

The situation is being somewhat balanced by the use of international contractors in the ongoing or planned modernization programmes and the possibilities, within the safety requirements, to extend these programmes over time. However, this situation needs to be followed closely and SKI has announced its intention to take the initiative for a new official investigation about how Sweden could safeguard the competence needed to operate nuclear power in a longer perspective (see section 19.3). An international initiative has also been taken by NEA to update an earlier investigation of the nuclear competence demand and supply situation in the OECD countries.

12. Article 12: HUMAN FACTORS

Each Contracting Party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

12.1 Regulatory requirements and initiatives

Early efforts

Before the TMI-2 accident, regulatory efforts in the human factors area were not very extensive in Sweden. However some good practices had been introduced in dialogue with the industry, such as the so called ”30- minutes rule”, requiring automatic safety systems response for the first 30 minutes of design basis transients, in order to give the operators time to think before acting in a situation of high workload and stress. Some initiatives were also taken to regulate the training of control room operators in connection with the use of the first new full scale simulators.

The Reactor Safety Committee set up by the Government after the TMI-accident in 1979 (see section 1.3) recommended a substantially reinforced and more coordinated programme on human factors, both with regard to formal regulatory and research avtivities. The recommendations of the Committee formed the basis for development of SKI activities in the human factors area in the 1980´s. Resources were allocated to SKI to build up its own group of human factors specialists.

As the programme developed, the term ”human factors”, or the term ”man-machine” which was used in Sweden, was found somewhat inadequate to describe the programme and the issues it addressed. Thus the programme was renamed as addressing the interaction between Man, Technology and Organization, ”MTO” for short, and this is now the accepted name within the Swedish nuclear industry.

Implementation of the SKI MTO Programme

Despite these firm initiatives taken to improve the work within the human factors area it became evident that additional efforts were needed before the MTO programme could be implemented[40]. Firstly there had to be people familiar, both at SKI, the utilities and the research institutions, with the human factors issues and methods in the nuclear context. Thus, the MTO specialists of SKI served in an educational role both within SKI and towards the industry in the first years. University based research and training of MTO specialists were strengthened by SKI financing of a special chair for a professor of MTO and nuclear safety in the Department of Psychology at the University of Stockholm.

In order to promote plant mangement involvement in, and understanding of the MTO programme issues, SKI invited the four plant directors to join a high-level coordinating group on MTO activities. The group also included the SKI office directors of inspection and research. The group was chaired by a very experienced retired plant

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[40] Dahlgren K & Högberg L. The Swedish regulatory approach to human factors. Paper presented to OECD-NEA-CNRA Special Meeting in June 19-20, 1990.

director acting as a consultant to SKI. The group worked for about two years, and its work contributed to the mutual understanding of MTO issues and the coordination of efforts in the MTO area. All plants appointed special MTO functions, some organized in multi-disciplinary groups including expertise in the behaviourial sciences.

The SKI MTO programme

The objectives of the MTO Programme are defined as

- to ensure that proper consideration is given to human factors issues in the design, operation and maintenance of nuclear facilities,
- to ensure that operating experience, incidents, etc are reported and analysed with regard to human factors and that relevant methodology is developed for these purposes,
- to contribute to an increased knowledge and application of human factors considerations.

These objectives have been implemented in dialogue with the utilities and have in that way also served as regulatory requirements. In the new safety regulations (see section 7.2) these objectives are included as requirements together with some additional requirements.

Specified areas within the MTO Programme include

- organizational issues and safety culture,
- quality assurance (see chaper 13),
- competence and training (see chapter 11),
- control room work and design,
- procedures,
- maintenance,
- incident- and risk analysis,
- decommissioning.

As SKI has moved towards more activity and process oriented supervision, MTO aspects have increasingly been integrated into all SKI regulatory activities. This is also reflected in the new general safety regulations.

The development of the programme has been supported by research. The more extensive research acitivities that have been performed include participation in the OECD Halden Reactor Programme, studies of factors affecting performance in non-destructive testing, methods for assessing shift team performance, and the development of methods and tools for inspection of organizational learning[41], maintenenance programmes[42] and quality systems. Recently research activities has been initiated to support the assessment of MTO-related aspects during different phases of decommissioning.

12.2 Measures taken by the licence holders

The MTO-concept

As mentioned above the concept of Human Factors has in the Swedish practice been substituted by the more general term MTO (Man-Technology-Organization) as a broader safety domain than traditionally has been associated with the Human Factor concept. Today the MTO-concept comprises a variety of areas of knowledge, research and methods including root-cause analysis, man-machine, safety culture analysis and organizational assessment.

Organization of MTO/Human Factors activities

The organization of MTO activities varies somewhat between the Swedish NPPs and depends on different subject areas considered within the field. A common organizational principle is, however, that the plants have developed policies, responsibilities and organizational structures to support the focus on MTO activities. For example all plants have so called ”MTO-groups”, two of the plants have groups in each production unit as well as a joint group hosted by the safety and quality departments. The main tasks of the groups are to examine LERs from the MTO perspective, to perform trend analysis and to recommend, review and encourage the implementation of root-cause analysis.

MTO activities in Swedish NPPs are supported by specialists in MTO from their own organization, associated organizations and consultants.

MTO in design

Due to modernization of the control rooms in Swedish NPPs there has recently been an increased focus on MTO in the design process. All Swedish NPPs have completed projects to develop ”control room philosophies” and guidelines to support the modernization projects of the control rooms. In these documents current principles, codes and standards, as well as assessments of the current control rooms from an MTO and ergonomic perspective, are taken into account. In 1997 a joint project among all the NPPs was conducted with the goal of developing strategies for the validation of changes in the control rooms.

Event analysis and trending

Programmes, training, and organizational structures for performing analysis of events associated with organizational and human factors are implemented at all Swedish NPPs. The most common method has

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[41] Dahlgren K & Olson J. Organizational factors and nuclear power plant safety: A process oriented approach. Paper presented at PSAM II, San Diego, USA, March 20-25, 1994.

[42] Chockie A & Sandén P-O. Managing maintenance for improvement: an international perspective. Paper presented at International Maintenance Conference, Toronto Canada, November 3, 1993.

been to use a modified HPES technique (in Sweden named MTO-analysis) but recently more attention has also been given to ASSET as a tool for root-cause analysis. Some development in methodology has also been accomplished in which HPES and ASSET are combined.

On a national level trend analysis of MTO-related events has been conducted until recently for many years by KSU (see chapter 19). The same organization also supports training in event analysis. The amount of trend analysis (i.e. MTO-focused) conducted by the utilities themselves varies, but NORDSÄK decided in 1996 that all Swedish NPPs should use the same classification system. Along with this, the plants also have their own methods and classification systems. There are for example programmes for the trending of industrial safety events and for trending of MTO-related events.

Several dedicated projects have also been implemented over the years, in order to find common determinations behind events, such as an self-evaluation of LERs reviewed by IAEA (ASSET) in Forsmark.

MTO in operator training

Operator training involves training in human factor issues as well as systematic team training given by MTO-specialists. A special instrument for the assessment of team performance has been developed by Vattenfall and Ringhals NPP in cooperation with SKI.

Safety culture initiatives

See section 10.2.

Special projects

Within the frame of the MTO/Human Factors concept various projects have been conducted or are currently in the planning stage with the aim to promote safety in Swedish NPPs.

A few examples are the following

- Evaluation of control room function during outages. Such projects have been performed at several utilities and further projects are planned.

- A project to identify good practices in the control room was conducted by Forsmark in 1990 and integrated into the current control room philosophies.

- Development of methods for barrier analysis in association with modernization of fuel handling has been performed by both Forsmark and Barsebäck.

- A project to identify risks associated with organizational and human factors in non-destructive testing was completed in 1994, and further projects are planed in collaboration with the University of Stockholm (Human Factors department).

- Several research projects dealing with HRA.

The future of MTO initiatives in Sweden

The Human Factors/MTO disciplines are expected to grow further in the future. The Swedish NPPs have taken a rather pragmatic stance to MTO focusing on cost-effective and practical methods to support human performance. At the same time more emphasis has been focused gradually upon management and organizational issues as an important ingredient associated with the MTO-concept. In particular, it seems that the MTO concept can be used more extensively in the future in order to promote a ”system thinking” of nuclear safety, in which knowledge of man, technology and organization are regarded as a unified system rather than analysed as separate components.

12.3 Regulatory control

For several years, SKI has worked on developing inspections, methods and strategies focusing on the quality of safety related activities performed by the licensees. In 1996 SKI conducted an extensive process-oriented inspection project in one plant focusing on a number of areas of importance to safety; organization and safety culture, quality assurance, competence development programmes, including management training programmes, control room work, plant modifications, internal safety assessment, feedback of operational experience, and in-service testing. One purpose of the inspection project was to perform an independent assessment of the effects of an improvement programme introduced by the plant in response to a decision by SKI to introduce special supervision of the plant. Further improvements were also to be promoted where found appropriate. The inspections on- site were carried out by mixed teams of inspectors and specialists including the MTO-experts of SKI[43].

The need for review of the Swedish control rooms was emphasized by the 1979 Reactor Safety Committee. The approach taken by SKI was to initiate a research project where the oldest and the newest control room were compared using the experience and assessments of the control room crews. The results of the study were fed back to and discussed with all crews, operations and plant management. The actions taken by the plant were followed-up together with the inspectors. Improved cooperative patterns were created between crews, plant management and technical specialists, resulting in successive improvements in the working conditions and development plans of the control rooms. SKI then asked the other plants to demonstrate plans for control room reviews, and followed their implementation.

In the 1990´s several plants started programmes for modernizing the I & C equipment and the control rooms. In a regulatory letter to the utilities SKI announced its decision to review these programmes including the plans for modifying the control rooms. The need to include MTO experts and end user experience throughout the programmes was stressed for accomplishing the necessary input to the specifications, analysis, design and evaluation. Plans for human factors verification and validation were explicitly asked for as were analyses of the need for competence and training of the staff and organizational support. Analyses of the implementation strategy were also called for. In order to promote further development of knowledge and tools, seminars have

[43] Högberg L, Svensson G & Viktorsson C. Regulation for continuous improvements - the new regulatory strategy of SKI. Paper prepared for presentation at IAEA International Conference on Topical Issues in Nuclear, Radiation and Radioactive Waste Safety, 31 August- 4 September, 1998.

been arranged with the participation of representatives from SKI, the utilities and research institutions. The programmes will be reviewed by SKI and supplemented with inspections and detailed reviews of single modifications.

Members of the MTO department have participated in the investigation teams appointed by SKI for analyzing some incidents with application of the MTO perspective. However, the main approach has been to require incident analyses to be performed by the utility using systematic methods analyzing the interaction of man technology and organization. This has now been incorporated in the new safety regulations. Selected investigations performed by the plants are reviewed by SKI in a team of engineering and MTO experts in order to determine the more urgent further actions to be taken by SKI. Regular inspections are made of the system and practices of the plants for identifying events as MTO-related incidents, their analyses, trends identified and actions taken. In recent years the inspections have focused more on the MTO- functions of the plants, its organization, programmes and activities, resources, training, procedures and tools. Plans and activities for proactive analyses and assessments of working conditions are being stressed in accordance with the proposed new regulations.

SKI has concluded that the licensees have increased their competence and made good progress in the handling of MTO-issues during the last years. A more systematic approach to these issues has been implemented at all the NPPs, and the importance of the MTO aspects of design, operations and maintenance have been fully recognized by the plant managements. Assessments of the efficiency of the MTO programmemes have also been made at all NPPs and further needs of improvements have been identified.

12.4 Conclusion

The Swedish Party complies with the obligations of Article 12.

13. Article 13: QUALITY ASSURANCE

Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all acitivties important to nuclear safety are satisfied throughout the life of a nuclear installation.

13.1 Regulatory requirements

The present SKI ”regulations”on Quality Assurance entered into force on 1 January, 1991 as a licence condition for nuclear installations and transport of nuclear material or nuclear waste. The regulations are quite general and apply to systems, equipment, devices and associated activities which directly or indirectely can affect the protection and safety of the environment and the personnel. The licensees are required to use a quality system, according to the definition in ISO 8402, for continuous planning, management, control, evaluation and documentation of all activities affecting quality. The quality system shall be well adapted to the activities, based on an approved quality policy which is well anchored in the organization. The rest of the regulations include specified requirements on the scope of the quality system. The following areas shall be covered:

- ensure that the activities comply with acts, ordinances and regulations,
- ensure that the organization is functional and documented,
- ensure that an organization and documented routines exist for safety review,
- ensure that safety related activities are carried out in accordance with documented routines,
- ensure that necessary competence exists and is maintained for personnel in activities affecting quality,
- ensure that equipment and activities have the necessary quality and that this is verified by documented routines,
- ensure that all systems, equipment and devices are regularly tested and maintained according to documented routines,
- ensure that purchases are only made from suppliers which are approved by audits or other means to show the fulfilment of necessary quality. Documented routines for audits shall exist as well as an updated list of approved suppliers,

- ensure that all plant modifications are carried out according to documented routines and with due regard to design basis and operational conditions. Such modifications and their background shall be documented,

- ensure that the final safety report FSAR, or similar document, is continuously updated and accessable,

- ensure that experience feed-back is performed continuously in a systematic manner according to documented routines and including experience from the own and similar activities.

The quality system shall be systematically and periodically audited by a special function with an organizational position to ensure integrity. Every functional area affected by the regulations shall be audited at least every fourth year. Quality audits and corrective measures shall be documented. All deficiences, damage and non-conformities important for safety shall be documented. The licensee shall take such corrective measures so that the root causes to deficiences are eliminated.

The new general safety regulations (see section 7.2) will replace the above regulations in the application on the nuclear power plants. The new regulations will include and expand the above provisions on many points. One important modernization is the requirement for continuous development of the safety of the nuclear installation. The new regulations focus on nuclear safety and not quality in general, even if the two concepts are strongly related. As a general recommendation, the IAEA code and safety guides on the "Quality Assurance for Safety in Nuclear Power Plants and other Nuclear Installations"[44] are mentioned as an approved reference in deciding on the scope of the quality assurance needed with respect to safety.

13.2 Measures taken by the licence holders

Quality programme

Development of quality assurance programmes at the Swedish NPPs began during the late 1970's. These programmes have since been developed continuously over the years, and have, of course, been affected by regulations and expectations from the regulatory body and business associates. In the beginning the quality manuals of the NPPs were limited to descriptions of routines in a number of functional areas, but lacked clear statements of the objectives and requirements. In the 1990´s there has been a considerable development of the concept, and the quality assurance programmes of the Swedish NPPs have today been integrated in the total management system of every plant.

The quality and management systems of the Swedish NPPs are somewhat different in structure and content but the main principles are the same, with documents on three levels. The first level documents are issued by the plant director. Included in these are typically a vision to strive for, a business idea which outlines the mission of the NPP, objectives for different areas and strategies to accomplish the objectives. Objectives typically exist for

[44] Latest issue: IAEA Safety Series No 50-C/SG-Q. Vienna, 1996.

- nuclear safety,
- occupational safety,
- power output availability,
- economic results,
- confidence from society,
- environmental impact, and
- personnel absence.

In the level 1 documents a comprehensive description of the organization with responsibilities for functions and processes, division of authority and management principles are also included. Further there are policies, conditions and directives for the main activity processes at the plant. In the conditions are included all the legal requirements as well as the plant owners´ requirements and additions. As an example, from the Barsebäck NPP the following processes are regulated in this way:

- Quality assurance
- Nuclear safety
- Leadership
- Personnel
- Competence
- Communication
- Nuclear installation
- Experience feedback
- Environment
- Emergency preparedness

- Economy control
- Procurement
- Insurance
- IT
- Documentation

Finally the level 1 documents include directives to all departments and staff units at the power plant.

The second level documents of the management system contain ”answers” from the responsible managers on how to work with the tasks given by the plant director in the level 1 documents. These ”answers” are given as objectives, directives, process descriptions and instructions for the different areas of responsibility. The third level of documents includes instructions for specific activities and tasks included in the different areas of responsibility as defined by the second level documents.

In addition to the three levels of documents, there can also be administrative handbooks of various types. In the Barsebäck case such handbooks regulate the routines for quality audits, information service, nuclear safety assessments, MTO-investigations, experience feed-back, electrical safety, emergency preparedness and industrial safety. There are also handbooks for personnel issues, environmental issues and Technical Speficications (STF). At other NPPs these areas are controlled in other ways within the frame of their quality and management systems.

The purpose with the quality and management system is to achieve a unified and consistent control system for all plant activities based on clear policies and measurable objectives. There should be a traceability from policy to work instruction.

In Sweden the general description of the quality and management system is normally regarded as the most important document of the plant as it gives an overview of the demands and the way the organization is supposed to work in order to meet these demands. The documents are kept available for everyone in the plant organization, and also for others who are affected by the information in the documents, for instance contractors, consultants and the regulatory authorities. All documents in the quality and management system are under controlled revision, regularly or when needed, in order always to reflect the actual situation at the plant

Quality system implementation and quality audit programmes

Every Swedish NPP has developed a quality audit programme, which is utilised to monitor how well the quality system is implemented and applied in the organization on different levels, as well as the efficiency of the system to ensure quality and safety. Such quality audits are performed on a regular basis, so that all areas are covered during a four year period. Quality audits are performed by audit teams consisting of 3-4 individuals, experienced in the reviewed area, and an audit team leader. For obvious reasons, the team members are not supposed to be responsible for or working in the reviewed area of the unit being audited.

The quality audits result in audit reports, which after review by the audited personnel are presented for the plant management, which must decide upon the measures to be taken based on the deviations identified, and the observations and recommendations made by the review team. The plant management normally also decides when actions to correct the revealed deviations should be completed. Follow-up of actions arising from the quality audits are carried out by the plant's Quality and Safety group. See also 14.2.2.

Quality audits of suppliers

According to the SKI requirements on quality assurance, all purchases of goods and services which might have an affect, directly or indirectly, on the protection and safety of the environment or the personnel, shall be made from suppliers that through quality audits or in other ways, have shown they can comply with quality requirements. The ambition of the NPPs is not limited to these demands, but also includes suppliers of goods and services, where malfunctioning might cause considerable consequences for the NPPs.

A review of a supplier includes not only a quality audit, but also a technical and commercial evaluation of the equipment or services offered. From 1998 a review of the supplier's environmental management system will be included in the review. These aspects will, however, not be covered in this report.

The purpose of a quality audit of a potential supplier is not only to evaluate whether the supplier has implemented and uses a documented quality system, but also to evaluate the supplier's capability of providing correct and expected quality.

Quality audits are typically accomplished by audit teams consisting of 1-4 auditors. The audit shall be led by an audit team leader with documented knowledge and experience in the QA area and with the quality norms. The team leader shall have experience from participation in several quality audits. The team shall comprise one or more persons with competence or experience from the product or service to be reviewed. Thus, there is no formal licensing of audit team leaders and team members for Swedish NPPs.

A quality audit results in an audit report, that is accepted by the reviewed company, before being presented for the purchasing organization. If deficiencies are revealed during the audit, the reviewed organization is requested to describe what measures will be taken to correct the deficiencies, in order to be accepted as a supplier of products or services to the NPP. In certain cases a follow-up visit of the audited company is required to verify the actions have been taken by the company.

Approved quality audits accomplished by any of the other Swedish NPPs are normally considered comparable with a plant´s own quality audits and, consequently, audit duplications at the same supplier can be avoided. Simplified quality audits or evaluation of previous experience of a supplier are sometimes acceptable, when purchasing of goods and services dedicated for use in the lower quality classes.

An approved quality audit is normally valid for three years, but can under certain circumstances be extended to four or five years.

Close cooperation exists between the four NPPs in the area of quality auditing of suppliers, for instance by sharing lists of approved suppliers and audit results.

As an operator of Westinghouse designed reactors, the Ringhals NPP is also a member of the Nuclear Procurement Issues Committee (NUPIC). Through this membership Ringhals is provided with quality audits of US suppliers, and also contributes its own audits of European suppliers to the NUPIC register of approved suppliers.

13.3 Regulatory control

Based on the current Quality Assurance licence requirements a Quality Systems Evaluation Method[45] has been developed and an inspection handbook is in use at SKI.

The method is used during both regular and topical inspections. Ususally the quality system itself is not the only target for these inspections. Appropriate aspects of the application of quality assurance are included in all SKI regulatory inspections. Thus during inspections, routines and instructions are studied, as well as how they are enforced in actual practice in order to control safety-related activities. One example is the large inspection of one NPP made 1996 (se section 12.3), which also included an assessment of the implementation of a new quality system.

SKI also makes assessments of quality assurance processes while reviewing large modification plans, for example the renovation of Oskarshamn 1, and the earlier mentioned modernization of control rooms (see chapter 12). In these cases the quality assurance plans for the projects and the implementation of the plans were assessed.

The lisencees´s plans for quality audits and the reports of the audits performed are also subject to reviewing by the SKI.

In general SKI is satisfied with the implementation of quality assurance at the NPPs. The development of the integrated quality and management systems approach has taken several years and considerable effort at the NPPs. In some cases implementation has not been well prepared, and has been slowed down due to insufficient staff resources, or lack of support from all organizational levels. Organizational changes have also affected the implementation work and made revisions necessary. Events at the NPPs have now and then revealed deficiences in the routines used, for instance for operability control after an outage. Some of these events have received considerable attention by the media. The regulatory experience shows the necessity of having a vital quality audit programme at the plants and using the audits to develop quality and safety. This means that the audits should not only investigate the compliance with the documented routines, but also the suitability and the efficiency of the routines in line with the concept of a learning organization.

13.4 Conclusion

The Swedish party complies with the obligations of Article 13.

[45] Melber B, Durbin N, Lach D. & Blom, I. Quality Systems Evaluation Method: Development and Implementation. Volume 1. SKI Report 95:62.

14. Article 14: ASSESSMENT AND VERIFICATION OF SAFETY

Each Contracting Party shall take the appropriate steps to ensure that :

(i) comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of operating experience and significant new safety information, and reviewed under the authority of the regulatory body.

(ii) verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.

14.1 Regulatory requirements

14.1.1 Safety assessment and safety review

The requirements in Sweden on safety assessment before the construction and commissioning and throughout the life of a nuclear installation go back to a provision in the Act on Nuclear Activities

(8 §): ”When a licence is issued, or during the period of validity of a licence, conditions required with reference to safety may be imposed”. In section 7.2 it is further described how licensing of the Swedish NPPs was conducted and which requirements applied. A preliminary safety analysis report (PSAR) was required to be approved by the regulatory body before construction, and a final safety analysis report (FSAR) with technical specifications (STF) added was required to be approved before the start of commercial operation. The licence conditions issued by SKI on quality assurance further require that the FSARs are continuously updated and accessable. In the individual licences it is further stated that all major plant modifications shall be reviewed from a safety point of view by an independent licensee safety committee, and approved by SKI before implementation.

One requirement in these safety reports was demonstration using deterministic analysis that the installation fulfilled all the design requirements and that it could cope with normal operation, as well as all probable events and transients which could affect the safety function. All the requirements on safety assessment are valid also for backfitting measures.

As mentioned in sections 1.3 and 6.2, Parliament decided in 1981, after the TMI-accident, in accordance with a Government bill (1980/81:90), to require a periodic safety review programme with the use of PSA in Sweden. In this programme every reactor should undergo at least three reviews during its operating life. This has been interpreted as one review every 10 years. SKI was authorized to issue directives for the reviews. As is reported in section 6.2, the regulatory requirements on periodic safety review (ASAR) and PSA have been devloped from the first cycle of reviews in the 1980´s and are more extensive in the second cycle of 1990´s. The present directives include the following major components

- A comprehensive analysis of how safety work at the plant is organized and implemented, including the training of personnel.

- A comprehensive report on operational experience, the more important technical improvements, and other measures taken to improve safety both in the plant and in the organization since the previous ASAR.

- A detailed, plant-specific level 2 probabilistic safety analysis (PSA).

- A comprehensive report on current safety improvement programmes, as well as a proposed future programme, based on the findings and conclusions from the periodic safety review.

In connection with the SKI decision to approve the restart of Oskarshamn 1 after the long repair period (see section 6.1), it was stated in a regulatory letter to all licensees that an up to date PSA is necessary for the systematic safety assessment of reactors built to earlier standards. This applies to the evaluation of deviations from the original design requirements, as well as the evaluation of deviations from modern safety standards. For the safety evaluation of the plants the guidelines in the IAEA documents INSAG-8[46] and CB-5[47] should be used. It was also stated that Swedish judgement scales should be developed and used as references .

In the Government bill 1980/81:90, filtered venting systems of the Swedish reactor containments were also proposed (se section 18.1). The proposal was based on a joint safety study FILTRA conducted by SKI, ASEA-ATOM, Studsvik and the utilities. This study was the start of another joint extensive research and safety analysis programme on severe accidents (RAMA), which finally resulted in criteria and guidelines on release mitigation, established in a Government decision 1986.

In the new general safety regulations of SKI (see section 7.2), the requirements on safety assessment, safety reporting and safety review have a central position. Basically all the earlier regulatory requirements and directives are included in the new regulations, which also specify the information to be included in a safety report. Some earlier requirements are expanded, and one completely new provision is added:

”The safety of a nuclear installation shall, after being taken into operation, continuously be assessed in a systematic way. The needs for safety enhancement measures, technical as well as organizational, which are called upon by such safety assessments shall be documented in a safety programme. This programme shall be revised annually”. In line with this provision a living PSA will be required by SKI.

The requirements regarding safety reviews by the licensees are extended both in scope and with regard to the need for one complete primary safety review in connection with a proposed safety decision, for instance on a plant modification, and a second independent safety review by a special safety review unit, basically to check the quality of the analysis made behind the decision, in particular if all safety aspects have been considered and if the relevant safety requirements are fulfilled in the proposed design and installation.

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[46] A common basis for judging the safety of Nuclear Power Plants built to earlier standards. IAEA Report INSAG-8. Vienna, 1995.
[47] Safety evaluation of operating Nuclear Power Plants built to earlier standards. IAEA Guide CB-5. Vienna, 1996.

14.1.2 Verification

Surveillance

Regulatory requirments concerning surveillance are included in the technical specifications (STF) of each unit (see chapter 19). Compliance with STF is a licensing condition and changes in STF are subject to SKI approval. According to the new general safety regulations (see section 7.2) it will be sufficient to notify SKI about changes after the internal twofold safety review.

The purpose with the surveillance is to verify on a regular basis that those systems which are credited in the safety report (FSAR) have such a status that they will fulfil all their safety tasks until the next functional test occasion. The requirements comprise the following:

- functional tests of central active components in systems of direct safety importance (every month),
- capacity tests of pumps in the emergency core cooling system and residual heat removal system (every 3 months),
- integrated tests of the inter-function between systems participating in emergency core cooling and residual heat removal, often in connection with tests of the automatic diesel sequence (every year),
- functional tests and calibration of switches and instrumentation with a central importance for the function and monitoring of operability in systems of safety importance (every year),
- tests and inspection of central passive components in the core cooling system and the residual heat removal system (every year).

The intervals of the functional tests shall be determined by standards, manufacturers recommen-dations, PSA and earlier test results.

Inspection of structural components in nuclear installations

As mentioned in section 7.2, the first general regulations issued by SKI in 1994 concerned the structural integrity of mechanical components in nuclear installations (SKIFS 1994:1). They cover pressure and load bearing components and other structural components necessary to ensure

- containment and cooling of nuclear fuel,
- containment of radioactive material formed during the nuclear process,
- core geometry and reactivity control.

The regulations contain general requirements on design, construction, material fabrication, examination, testing and in-service inspection (ISI) of items such as

- pressure vessels,
- reactor pressure vessels internals and steam generator tubing,
- piping systems,
- pumps and valves.

The basic regulations require that structural components must be designed, manufactured and installed so that they are able to fulfil all their safety functions reliably during both normal and accident conditions. After being taken into operation a component must be regularly checked, monitored and inspected and also maintained to ensure safety during use. Structural components may only be used within the limitations given in the regulations. The regulations also include basic requirements that structural components must be inspected to the necessary degree and with acceptable results in accordance with the regulations, and that a certificate of conformity with the requirements has been issued by an accredited inspection body with third party status. Before an inspection company can become an accredited inspection body with third party status, it has to fulfil the regulations issued by the Swedish Board for Accreditation and Conformity Assessment (SWEDAC).

It is required that components and other system parts are divided int three control groups (A-C) to identify in-service inspection needs, scope and objective. Assignment must take into account the probabilities of cracking or other degradation, as well as the possible consequences. Group A includes the structural parts for which the resulting risks are assessed to be the highest. All non-destructive testing (NDT) of the reactor pressure vesssel and other components in control groups A and B must be performed using NDT-systems which have been qualified to reliably detect and characterize, and correctly determine the size of the degradation which can occur. Such qualification must be supervised and assessed by an independent qualification body, which has been approved for the purpose by SKI. To be approved the body must have an independent and impartial position, a suitable organization and the necessary technical competence for the purpose.

To ensure that the qualified NDT-systems are only used within the limits which have been demonstrated during the qualification process, SKIFS 1994:1 also requires that the inspections have to be performed by accredited testing laboratories. Before an inspection company can become an accredited testing laboratory working with qualified NDT-systems in the Swedish NPPs it has to fulfil the regulations issued by SWEDAC.

14.2 Measures taken by the licence holders

14.2.1 Safety assessment

Before constructing and commissioning the Swedish nuclear installations, comprehensive and systematic analyses and assessments of safety were performed. The analyses and assessments were documented in a final safety analysis report, FSAR, for each unit and submitted to the SKI for review and approval.

The different units in the Swedish nuclear power programme were built over a time period of about 20 years up to 1985. This period was characterized by extensive development which is reflected in the scope and comprehensiveness of the FSAR documents of the units, from the first rather limited one for Oskarshamn 1, up to the very comprehensive FSARs for Forsmark 3 and Oskarshamn 3. As an example the list of contents, regarding the general and system parts, of the Forsmark 3 FSAR is given in Figure 11.

One of the major aims of the ongoing design reconstitution projects, discussed in chapter 2.2, is therefore to update all design safety analyses, for each unit, and produce a new FSAR which fulfills modern standards. The new FSARs will also be stored by data media in such a way to make it most accessable for the users.

The safety analyses of the Swedish plants in the FSARs were from the beginning essentially structured according to the US rules. The events to be analysed were divided into different classes depending on expected frequency and severeness of the event. The highest class contains the design basis accidents (DBA), typically a large loss of coolant accident: double ended guilliotine break of the largest pipe. Design criteria to be fulfilled comprise limited fuel cladding damage and no zirconium-water reaction (maximum cladding temperature 2200 deg F). Although the DBA did not include core melt, a large part of the fission products was postulated to be released to the containment. It was then proven that the containment would contain the radioactive material, so that the radiation dose to the critical group in the environment was acceptably low.

The introduction of the severe accident mitigation requirements in 1986 meant that a new class of accidents, including severe fuel damage (core melt), had to be introduced, and the FSAR analyses needed to be extended to show that the criteria for this case (see chapter 18.1) were satisfied.

Modifications in safety related systems and equipment as well as new safety-related analyses initiated by operational experiences or new knowledge from research or development, have to be documented, as updates of the FSAR, as necessary. The systematic approach to this updating has differed depending on the condition and status of the FSAR at the particular plant. The design reconstitution will provide the prerequisites for systematic and comprehensive successive updating of the safety assessments in the FSAR.

As a complement to the deterministic analyses contained in the FSAR, probabilistic safety analysis (PSA) is used as the main tool for periodic safety assessments (ASAR). An overview of the PSA programme is given in section 6.2. The PSA programme was started in the late 1970's with limited assessments of Oskarshamn 1, Forsmark 3 and somewhat later of Ringhals 1. When the ASAR-programme was initiated a basic PSA study (level 1, internal events) was required to be included in the first cycle of ASAR to be conducted (ASAR-80). In the second cycle of ASAR (ASAR-90) a more comprehensive PSA was required.

The basic PSA methodology was adopted from the WASH-1400 analyses, but extensive development of the methods and tools for PSA has been undertaken over the years. As a result, up-to-date software and considerable expertise is at hand both within the Swedish utilities, authorities and consultants/vendors. One item of particular importance is the reliability data base accumulated from operational experience since 1977. This data base is systemized in the so-called reliability handbook (the T-book), which provides specific reliability data of high quality for a large number of components.

As mentioned all nuclear reactors in Sweden shall be subjected to individual systematic safety reviews utilizing PSA. The original objective of PSA, as part of the ASAR programme (ASAR-80), was to periodically assess the safety of the operating nuclear power plants. However, experience has shown that the most important aspect of the programme is its continuous contribution to safety work promotion and the development of safety.

PSAs results are also used to support backfit decisions, risk reduction measures, emergency operation procedure changes and future design modifications.

The main value of a PSA study is therefore considered to be the systematic analysis and identification of weaknessess in the design and in the maintenance and operation procedures and practices. The outcome in the form of risk figures for individual units has to be used with great care, particularly when making comparisons with other studies.

As a rule an explicit cost benefit analysis is not performed on PSA results, but several cost effective safety improvements have been identified by such results. Incompleteness, lack of realism and its qualitative nature are considered to be the major limitations of PSA. This also makes the analyses quite sensitive to changes in the presumptions. Current advanced PSA tools are also not particulaly user friendly.

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FORSMARK UNIT 3

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Figure 11.

The number of safety improvements based on PSA is large. Generally, they cover measures to protect against common cause failures, other design changes, improvements of operator support and improvements in maintenance and testing.

Risk informed applications have been implemented on several occasions, as these examples from the Vattenfall group show

- modification of test intervals, eg checking valves of the residual heat removal system in Ringhals 2,
- prioritizing inspection work, eg isolation valves and pipelines inside the containment in Forsmark and Ringhals,
- permitting preventive maintenance during power operation, eg Forsmark 1 and 2,
- changing repair time requirements of the Technical Specifications, eg high pressure injection systems in Ringhals 1,
- application of exemptions from technical specifications (STF).

At Vattenfall the PSA models are used on annual basis to calculate retrospective curves of the relative instantaneous core damage frequency resulting from system unavailability during the year. Initiating events during the year are also evaluated and included. The results for each unit have been used to give an overview of the probabilistic safety level, and have provided insight into the severety of the occurred events, which have sometimes deviated from the operator's perception.

The most extensive use of PSA in the evaluation of plant modifications has taken place in conjunction with the uppgrading of the Oskarshamn 1 unit, which was not built according to modern licensing requirements. A two-step approach was adopted: (1) the plant is required to fulfill modern deterministic licensing requirements, (2) all deviations from modern licensing requirements are evaluated using PSA. The modifications were concerned with e.g., separation of electrical systems, reactor water level measurement, protection against floding and fire initiating events, as well as improvements in the reactor scram system (see further section 6.1).

Similar modifications, but on a smaller scale, have been made in the other older BWR plants. The findings from PSA for these plants have been along the same lines as for Oskarshamn 1. In the PWR plants, results from PSA have led to modifications, for instance in the protection and separation of safety systems against fire.

The documentation of BWR PSAs is basically structured as in the following list of contents

1. Summary
2. Summary of the analyses and results
3. Analysis of initiating events
4. Event tree analyses

5. Systems analyses
6. Analysis of dependencies
7. Appendices
7.1 Description of the methods
7.2 Plant description
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7.4 Coding of event trees, fault trees and basic events
7.5 Failure data
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7.7 Uncertainty analysis

The documentation of PWR PSAs is basically structured as in the following list of contents:

1. Summary
2. Description of the methods
3. Plant description
4. Analysis of initiating events
5. Plant disturbances and success criteria
6. Event tree analyses
7. Systems analyses
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14.2.2 Verification

A number of different verification programmes are used in order to ensure that the physical state and the operation of the nuclear installation continue to be in accordance with its design, safety requirements, and its operational limits and conditions. These can be gathered in the groups: surveillance, in-service inspection, preventive maintenance and safety reviews.

Surveillance

The operational limits and conditions are described in the technical specifications document (STF). The document is described in more detail in chapter 19. The technical specifications document also clarifies what types and with what frequency functional tests are to be carried out in order to verify that components and systems are ready for operation. These tests are carried out in accordance with procedures and all test results are reviewed and documented.

Verification of the operability of safety systems when going from shut-down to a power operating mode has been paid specific attention, and is ensured by a great number of other parameters, as well as functional tests, such as control room equipment, use and design of procedures, etc. This is described further in chapter 19.

In-service inspection

Regulations on in-service inspection programmes have existed since the very beginning of the Swedish nuclear reactor programme. An evolution of the regulations has taken place over the years from the early demands on quality systems via detailed requirements during the 1980's to today's very general regulations (SKIFS 1994:1), which became effective in 1995. The current regulations and guidelines for mechanical equipment cover all areas from how to deal with modifications and repair work, to in-service inspection programmes, and qualification of inspection systems. In order to document the industry's interpretation of the regulations, the Swedish NPPs started a project for assessing the regulation requirements and producing a document that could serve as an industry standard. This document was divided into general, technical, quality control and in-service inspection requirements, and has served as an aid for the development of plant specific documents in these areas.

The new regulations also require the in-service inspections to be performed by qualified and accredited inspection bodies, laboratories and personnel, and in accordance with approved NDT-techniques. As a consequence, new organizations have been established for the qualification of NDT-systems and techniques as well as for carrying out and evaluating such inspections.

Based on previous experience within this area, the regulations require a grouping of the components and inspection areas in an inspection matrix based on the likelihood that the component be damaged, and the consequences of such damage. This results in three inspection groups, which determine the volume of the inspections, inspection frequency, etc, depending on the type of component and inspection area. Supporting documents, inspection methods and qualification of inspection systems are directed by the matrix. Directives are also given on the type of reports required and on certification.

The assignment of components to specific inspection groups is documented together with relevant information concerning the inspection area. The assignment is reviewed and approved by the plant organization, but the objectives and the volume of the total inspection programme are to be reviewed by the accredited inspection organization. The information concerning inspection group assignments and inspection areas is maintained in a database, and forms the basis for the creation of inspection plans that are part of the inspection programmes to be performed at given inspection times.

The inspection group assignment is reviewed annually, and modified if deemed necessary, depending on plant modifications, damage which has been found in Swedish or foreign installations, or new research information with relevance to the safety of mechanical equipment in the NPPs.

Preventive maintenance

Maintenance in systems important for reactor safety, and for other systems and structures as well, is optimised with regard to the relation between corrective and preventive maintenance. The preventive maintenance implemented at the Swedish NPPs includes predictive (condition-based), periodic and planned maintenance and serves the purpose of maintaining a piece of equipment within design and operating conditions and extending its life, thereby eliminating or at least minimizing the risk for failures that can limit safe and reliable plant operation or result in forced outages. A well balanced preventive maintenance programme is the result based on engineering analysis in which safety as well as economical aspects are considered. The programme is well defined and periodically revised as additional operational experience is gained.

Predictive maintenance results are used to trend and monitor equipment performance so that planned maintenance can be performed prior to equipment failure. Examples include the following:

- Vibration monitoring and diagnostics
- Acoustic analysis
- Lubrication oil and grease analysis
- Non-destructive examination
- Bearing temperature analysis
- Insulation analysis (megging)
- Monitoring and trending of equipment

Periodic maintenance consists of activities performed on a routine basis, and may include any combination of external/internal inspection, alignment or calibration, overhaul, and component or equipment replacement. Typically, any deficiencies found by predictive or periodic maintenance are addressed by corrective or planned maintenance.

Planned maintenance includes activities performed prior to equipment failure and is typically carried out during outages, or on spare or redundant equipment that is available during plant operation.

Optimization is also carried out in order to find the right balance between maintenance measures and equipment modification. This is regarded as a different type of maintenance, as it considers radical changes or recently developed installations or work methods. Equipment modification is a planned upgrading operation which improves the equipment reliability. It is an operation combining correction and prevention of its recurrence but as the implementation tasks usually take a long time, modification has to be seen mainly as a preventive action.

The present Swedish operational limits and conditions (STF) do not allow the maintenance people to take components out of operation in order to perform preventive maintenance measures using the service and maintenance criteria. These are solely for corrective maintenance actions. The only exemptions are the units designed with four subs, where one of the subs may be out of operation without any limitations. The new general safety regulations (see section 7.2) make it generally possible to perform preventive maintenance during operation, if this is specified in STF and within the conditions analysed and described in the basic safety report (FSAR).

Modification activities are carried out based on strategies, not only for short-term purposes, that assure the safe operation of the units during the next operational cycle, but also as part of the Plant Life Management (PLM) programme, that deals with the life expectancy of components compared to the plant life expectancy. Various PLM-programmes exist at all the NPPs. They are part of the long-term plans and strategies, that the plants apply in order to reach the company goals, when considering safety, production, economy and environmental impact. In the maintenance area these strategies say that the units shall be maintained so that they can be operated safely, economically and environmentally soundly during their technical life.

Safety review

In order to verify that the operation of the nuclear reactors is in accordance with the applicable national safety requirements and with international guidelines and good practices, different types of safety reviews are performed regularly at the NPPs. The primary safety reviews of events, changes in STF and plant modifications etc. are carried out by the operations department, which is responsible for reactor safety. If needed, resources from other departments are utilized.

In addition important safety issues are reviewed a second time by a quality and safety department within the plant organization, but which is not involved in the preparation or execution of the issues under review. The prime objective of the secondary review is to assess whether the primary review has included the relevant types of analyses and investigations, and that it is of sufficient quality, rather than to repeat the primary review. The results of the reviews are documented and points of view clearly marked. The quality and safety department also engages in different forms of continuous observation and following up on the daily operations of the plant.

When performing QA-audits and MTO-examinations the same type of manning is used as for the independent safety reviews, but on these occasions peers from other plants are often used. In the case of MTO-investigations the objective is to analyse the issue in detail.

A third type of review is performed by safety review committees and councils at different levels of the utility organizations. They exist in some cases at the unit level, normally on the site, and also at the utility level. They are manned by individuals representing different disciplines in order to achieve a broad view of the discussed subjects. The members are appointed on the basis of their personal qualifications and knowledge. On some committees and councils there is also one or more external member. Committees working at the unit level deal with daily operational matters of safety character, such as event and scram-reports, operational experience from other plants, and safety issues linked to STF and to modifications. Committees working on the site or on the utility level focus on principal issues such as safety policy and strategy, the plants' adherence to the authorities' general regulations, and general reviews of the safety and quality activities. As an illustration the organization for safety review at Forsmark NPP is shown in Figure 12.

Issues of special safety significance, for instance major plant modifications, are handled according to a detailed documented procedure. An example is the following:

- Prestudy and initiation of the plant modification project.

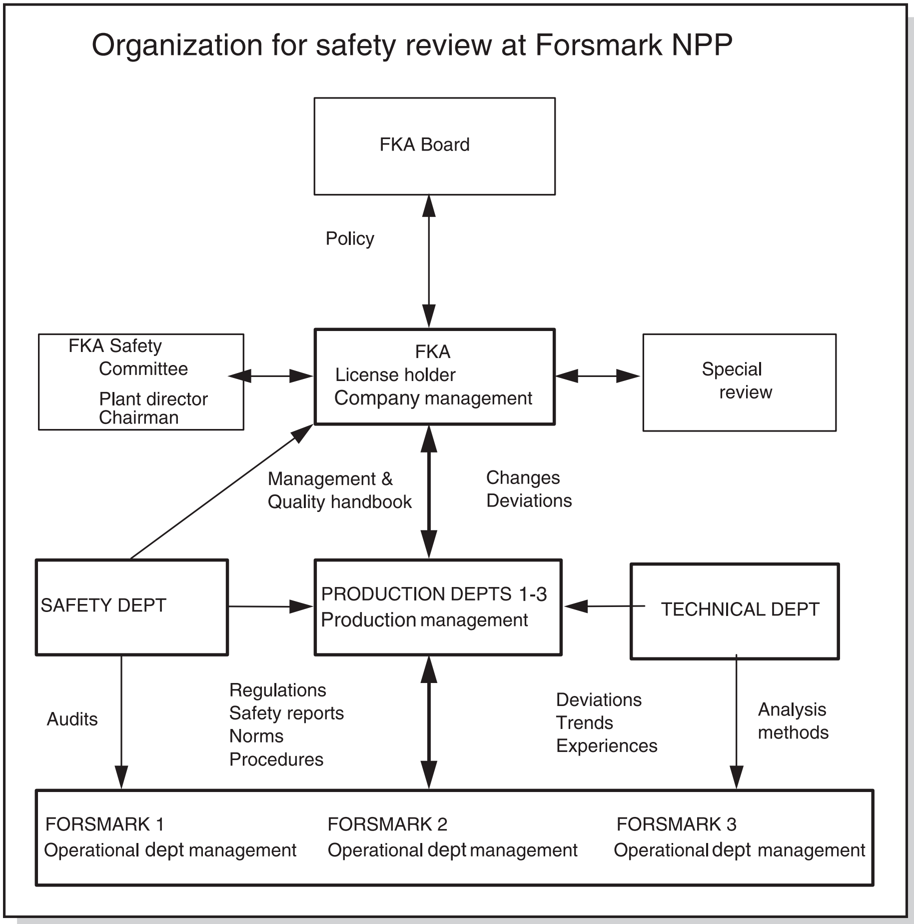
- Design, analyses and reviews from all relevant aspects by the operations and design departments. The comments given are analysed at a review meeting, and a conclusion is made as to whether or not the project can be accepted. A project report is issued.

- Safety review by the safety department, including reactor safety, quality, radiation protection and environmental aspects. Plant modifications in safety related systems are at some sites also reviewed by the on-site safety committee.

- Decision to realize the project.
- Final design and construction, functional tests.
- Documentation including updating of the FSAR and technical specifications (STF), according to a special checklist.

International peer reviews are also performed at the Swedish NPPs with a certain frequency. OSART missions have been conducted at all four sites (see below) and, so far, one plant has hosted an ASSET mission. The WANO Peer Review (PR) Programme is fairly new and so far only Ringhals 1 has been the

Figure 12.



subject of a PR. However, all four sites have volunteered to host a PR during the next couple of years. Though PRs and IAEA OSARTs differ in a number of ways, they serve in a complementary way a common purpose of enhancing nuclear plant safety and reliability by comparing the reviewed plant with the best international standard.

The KSU membership in INPO has resulted in Technical Visits by smaller INPO-teams to the Swedish sites. A technical visit could be described as a very short and simple alternative to the evaluations practised by INPO towards US plants. The reports of the WANO PRs and the INPO Technical Visits, are the property of the host plant, and are normally not distributed outside the plant organization.

14.3 Regulatory control

Safety assessments

Safety assessments made by the licensees in accordance with regulatory requirements are reviewed by SKI and comments are provided in a review report. Periodic safety review reports (SKI-ASAR) are submitted to the Government. If the licensees are required to take any further measures to improve the analysis or the conclusions drawn this is specified in a regulatory letter. This letter has in all major backfitting cases been sent after meetings between the licensee experts and the SKI specialists to discuss the issues in-depth.

Review of safety analyses is most often performed by special review groups consisting of specialists representing the different departments in the Office of Reactor Safety and other offices as needed. As these review tasks most often require considerable resources, the review group is sometimes augmented by consultants. For instance the SKI review of a utility ASAR is estimated to require about one manyear (the utilitity effort is about 4-5 manyears).

SKI has concluded that the FSARs of the older reactors have not been maintained in a proper manner mainly due to limited resources and old documentation systems. This will now be corrected in the reconstitution projects (see section 6.2). The regulatory reviews of the ASARs have basically confirmed the conclusions drawn by the licensees, but regarding some issues the regulatory authorities have been more critical. These remarks have mainly focused on organizational and quality assurance issues, such as lack of human resources and planning for long-term safety work, lack of upgrading and missing parts of the PSA, deficiences in experience feedback work, insufficient analyses of operational events, and implementation of organizational change without the necessary preparations. None of these remarks have, in itself or in combination, been serious enough to question the operational permits. In the reports to the Goverment SKI has summarized its observations and recommendations. These are followed up in the ordinary inspection work.

The regulatory reviews of the PSAs during the 1990´s have shown a need for continued development of the modelling and input data in order to make the analyses more precise. The PSAs must also be completed with more events being analysed in order to fulfil the directives for ASAR 90. The most complete PSAs level-1 are Oskarshamn 1 and 2. The most complete PSAs level 2 are Ringhals 1 and 2 and Barsebäck 1 and 2. The reviews also confirmed the need for further modification of the older plants in order to meet the safety goals for new reactors.

Safety review conducted at the NPPs

The organization, competence and procedures for safety review at the NPPs are assessed by SKI in connection with specific issues, for instance major plant modification projects. In these cases the project routines are reviewed as one issue to be included in the later regulatory decision on the restart of the reactor. Topical inspctions have also been carried out with a special focus on the activities of the safety departments of the NPPs. Special reviews have also been made on the plant modification procedures of the licensees and their project handbooks.

Structural integrity inspections

The detailed technical inspections and associated structural integrity assessments were, until 1 January 1995, performed by a Government-owned company, the Swedish Plant Inspectorate, authorized to perform such tasks under a special act, and with supporting authorization given in earlier SKI regulations issued as common licence conditions. Today, the inspections and associated assessments are carried out in accordance with the above mentioned SKI general regulations SKIFS 1994:1, by third party inspection companies accredited by the Swedish Accreditation Board (SWEDAC). In contrast to the previous mandate of the Swedish Plant Inspectorate, now SAQ AB, the mandate of the accredited inspection companies will be limited to verifying compliance with the regulations. To date the Swedish Plant Inspectorate has continued to provide this service, pending accreditation of the first inspection company.

A separate company, SQC (see chapter 2), has been formed for independent qualification of non-destructive testing and inspection techniques performed by the licensees and their suppliers of inspection and testing services. The company and its activities are subject to SKI regulations to ensure independence and expertise.

The intention is that there shall be a ”clean table” with no remaining issues after each maintenance outage, before start up of the reactor. All inspections shall be carried out using inspection and testing procedures which have been duly approved by the qualification company, and all remaining indications of defects or degradation shall be evaluated and shown to be acceptable as verified by the inspection company. All repairs shall be carried out using qualified procedures supervised by and carried out to the satisfaction of the inspection company. The guidelines attached to the SKI regulations define the acceptable level of safety.

The normal supervision of SKI is mainly concerned with the inspection and qualification companies as well as dealing with exemption applications from the licensees. However, as the competence of the licensees is considered vital, SKI also inspects the licensees´ competence, resources and organization in the field of structural integrity by means of topical inspections.

Maintenance

Maintenance programmes and selected maintenance activities are inspected using the Maintenance Inspection Guidebook (see section 7.4). The guidebook is designed to be a tool in determining whether or not the maintenance programmes are improving. Programmes are seen as consisting of people, material, tools, information and coordination resource functions, all interrelated. The licensees are encouraged to develop a base report on maintenace along these lines. Licensee event reports of relevance for maintenance are reviewed by SKI and discussions are initiated on maintenance experience feed-back.

OSART

A special form of regulatory assessment of the licensees activities is international peer reviews requested by the Government, in this case as a member of IAEA. The following OSART missions have been conducted in Sweden:

Unit	Year
Barsebäck 1-2	1986
Forsmark 3	1988
Oskarshamn 1	1989
Ringhals 3-4	1991

Table 12. OSART missions to Sweden.

The OSART reports are valuable as a calibration of the national regulatory assessments of the NPPs. In general SKI concluded that the OSART missions did not identify any issues not known before by the national regulatory bodies. However the reports and the licensees activities to prepare for the follow-up missions provided valuable information for the ordinary regulatory work. In addition to OSART an IAEA ASSET peer review mission was conducted in Forsmark in 1996.

14.4 Conclusion

The Swedish party complies with the obligations of Article 14.

15. Article 15 RADIATION PROTECTION

Each Contracting Party shall take the appropriate steps to ensure that in all operational states the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonable achievable and that no individual shall be exposed to radiation doses which exceed prescribed national dose limits.

15.1 Regulatory requirements

As mentioned earlier the Radiation Protection Ordinance (1988:293) states that SSI may, in so far as it does not conflict with the purpose of the Radiation Protection Act (1988:22), issue regulations concerning the provisions in the Act. SSI has had this possibility since 1976 and the first regulation in SSI's Code of Regulations was issued in 1977. The decision to issue a regulation is always taken by SSI's Board, but the initiative usually comes from one of the Departments. Several of the regulations currently in force are revisions or amendments to regulations issued previously. As a result of the Swedish association to the European Union, some of them have to be adjusted in order to be in accordance with the European Basic Safety Standards Directive. The regulations are in some aspects quite detailed, but the main purpose is to define a framework within which the licence holder has a large degree of freedom for different actions and measures, as long as certain basic demands such as dose limits are fulfilled.

Only 13 of the 39 regulations in all issued by the SSI are applicable to nuclear installations. Of these the most important are:

- **SSI FS 1981:3** Regulations about medical examination for radiological work.
- **SSI FS 1989:1** and **1994:5** Regulations about dose limits in activities with ionising radiation etc.
- **SSI FS 1996:2** Regulations with regard to the removal of goods and oil from nuclear installations.
- **SSI FS 1991:5** Regulations concerning limitations of releases of radioactive substances from nuclear power plants.
- **SSI FS 1994:1** Regulations about radiation protection advisers at nuclear plants.
- **SSI FS 1994:2** Regulations for personnel radiation protection for work with ionising radiation at nuclear plants.

15.1.1 Regulatory requirements on occupational radiation protection

These requirements are listed in SSI FS 1994:2 and are only applicable to the nuclear industry. One of the most powerful tools in these regulations to control and decrease occupational radiation, is the requirement for a programme for dose reduction. The programme is to cover short term as well as long term plans and measures. It should be approved by the management and made known at all levels within the organization. The dose reduction programme should be a living document, and thus updated continuously.

Below are listed the demands of most importance in the regulation. It should be mentioned that the regulations are currently under revision.

- **Site specific instruction for radiation protection**
  Each nuclear facility must have instructions that shows how the radiation protection is organized and what measures should be taken to prevent radiation doses.

- **Controlled area**
  Within controlled areas zones should be established if radiation and/or contamination levels vary within certain limits.

- **Training in radiation protection**
  All personnel entering a controlled area should have knowledge of radiation protection. The extent of the training varies depending on the kind of work which is to be performed.

- **Extended radiation protection training**
  This training is aimed at contractors team leaders and operational and maintenance personnel within the site organization.

- **Dose limits and dose limitation**
  Dose limits are the same as recommended by the ICRP that is 100 mSv for any 5-year period, and 50 mSv for a single year. Requirements for a programme on dose reduction (ALARA-programme) are included in the regulations.

- **Dose surveillance**
  Dosimeters should be provided by the licence holder and should be worn on the chest. They should be of a type approved by the competent authority.

- **Dose register**
  Results of the evaluation of individual radiation doses should be available in a common central dose register.

- **Medical examination**
  Medical examination is regulated in special regulations. These regulations are at present under revision in order to comply with the European BSS.

- **Area monitoring**
  The purpose with this paragraph is to ensure that the extent of a controlled area is correct. Measurements are to be made by smear samples at certain intervals and places.

- **Calibration of instrumentation for radiation protection**
  All instruments used for radiation protection and the control of radiation doses should be calibrated to a calibration source approved by the competent authority

- **Internal transports**
  Any transportation within the industrial area should, if possible, be in accordance with international regulations.

- **Juveniles**
  Individuals under the age of 18 are not permitted to work inside a controlled area. Some exceptions may occur, e.g. persons performing some kinds of activity in connection with their education. In such a case more restrictive dose limits are applied. Persons under 14 years of age may not enter controlled area.

- **Reporting to SSI**
  All data concerning individual monitoring of external radiation and internal contamination are to be reported on an annual basis. Events and incidents that have, or might have, led to a radiation dose exceeding 50 mSv should be reported promptly. In advance of each outage, a description of major work to be carried out and a dose prognosis should be submitted, and after the outage a special report should be produced where a comparison between the prognosis and the actual outcome is discussed.

- **Filing**
  All records concerning individual doses, effluents, etc, should be kept in accordance to Swedish archive regulations.

15.1.2 Regulatory requirements on environmental radiation protection

The regulatory requirements for the protection of the environment are given in SSI FS 1991:5. The basic idea is that when the general population has proper protection against the harmful effects of radiation the environment also has sufficient protection. The regulations apply to all releases of radioactive substances to air and water during normal operations. The regulations are based on the ALARA principle and ICRP's definition of the critical group. Average individual effective doses to persons in the critical group, due to all releases, should be below 0.1 mSv/year. A release of any mixture of nuclides resulting in a dose of 0.1 mSv to the critical group is called a "norm release". In addition a reference value of 5 manSv annual effective collective dose per GW installed electrical output is used. This will ensure that world wide individual doses will not exceed 0.1 mSv per year in the far future, assuming a production of 10 kW per capita.

The regulations also state how releases are to be monitored and how environmental surveys, reporting and dose assessments are to be made. Measurement to be performed in the event of increased release rates are also specified. For example, in the case of a release rate exceeding 1/200 of a norm release per hour, the reactor causing the release must be shut down before a total release corresponding to 1 norm release is reached.

Following instructions given by SSI, the operator determines site-specific dose factors (dose per quantity of activity released) for every nuclide. The dose factors for each nuclear power plant are subject to approval by SSI and given in reference documents. The term 'norm release' refers to any combination of released radionuclides which, multiplied by the respective dose factors, sums up to a dose of 0.1 mSv to the critical group. As the contribution of all the relevant nuclides are included in the comparison with the 'norm release', no separate nuclide-specific release limits are used.

The SSI regulation 1991:5 also states that equipment for monitoring releases and for environmental monitoring shall be approved by SSI, and shall be tested regularly and whenever a malfunction is suspected.

15.2 Measures taken by the licence holders

The organization of radiation protection at the nuclear power plants

The operative radiation protection at a power plant is usually organized within the operational organization of each reactor unit at the site. In most cases they are also responsible for the surveillance of industrial safety. Typically the staff consists of 5-10 persons during normal operation. As an example, the radiation protection organization of Ringhals NPP is shown in Figure 13. During the outage period, the staff will be considerably reinforced by contractors in order to maintain surveillance as required.

To ensure that radiation protection work is maintained at a high level of quality, and also to fulfil all the requirements set by company instructions and quality rulesas well as the authority regulations, the radiation protection work at the power plant is supervised by a radiation protection advisor. This person reports directly to the plant director, or to the manager of the safety and quality department.

General power plant radiation protection services, not allocated to any particular reactor unit, such as dosimetry, plant waste handling and storage, and decontamination, are usually organized under the radiation protection or service departments.

Internal procedures for radiation protection

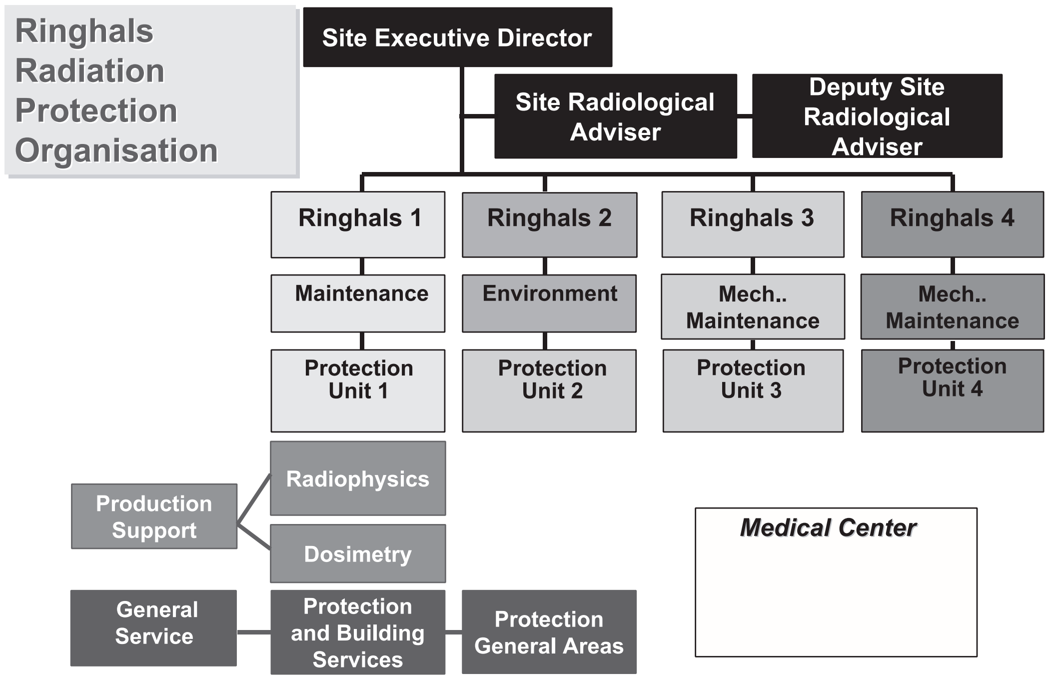
All radiation protection activities at the power plant are performed according to internal instructions. These instructions give rules and guidance on such items as

- classification of radiological zones,
- radiological education (to all personal as well as radiation protection staff),
- medical examination,

- monitoring of external and internal personal doses,
- monitoring of contamination,
- control of waste and materials taken out from the NPP,
- calibration of instruments,
- rules for transportation of radioactive goods,
- reports to the radiation protection advisor.

A very important practice when planning the outage work is to involve the radiation protection staff at a very early stage. This ensures that the radiological aspects of the work will be fully covered in the planning process.

Figure 13.



Dose registration and system radioactivity control

Individual doses to persons working in controlled areas in the NPPs are measured with TL-dosimeters which is the legal instrument for registration of occupational doses. These doses have been reported many years to the Central Dose register in Sweden (CDIS), owned mutually by the Swedish NPPs, ABB Atom and Studsvik. CDIS is operated by an IT-company on behalf of the owners under the supervision of SSI, that also has access to the database. The information in CDIS covers all personnel working in the Swedish nuclear facilities and constitutes a good basis for statistical examination and trend-graphing. Besides, it is an aid for the control of doses to contractors moving between the different NPPs. The CDIS-information is archived for thirty years. Persons entering controlled areas also wear an electronic dosimeter, which allow the RP staff to perform quick checks of individual as well as job-related doses. The TL-dosimeters are examined monthly and the electronic dosimeter system is used as a registration system during the month. The electronic dosimeters also allow the workers to closely follow their own doses and to get an alarm if they are working in an area with a dose-rate higher than that set on the dosimeter.

In order to have a good view of activity build-up and dose-rates in the various reactor systems, most of the units make qualified measurements annually or biennially. The information is used for the production of trend-graphs and serves as a basis for long-term decisions on measures to decrease the continued build-up of activity, but also for actions to reduce dose-rates.

Dose reduction and implementation of ALARA programmes

The ALARA principle is implemented in all radiological work. In daily operations optimization is usually performed by the radiation protection staff, based on experience. A very important tool is the personal electronic dosimeter system, which enables the staff to monitor the doses received by each person and during each activity. Since the doses can be read directly by the user this will also make every person aware of their dose build-up and the effect of different protective actions. To bring ALARA home to every person working at the power plant is one of the most effective dose reduction measures.

During recent years special projects at the NPP´s have been performed in order to identify the potential for reducing the dose rates in the plants. Different areas have been investigated, such as water chemistry, material composition in systems, fuel integrity, and working methods. Several possibilities have been identified, specific for each reactor, and those deemed to be feasible (both from economical and practical standpoints) are usually incorporated in the programmes for renewal and service of the reactor systems. For the PWRs the water chemistry was modified as early as in 1983, which has had a positive effect on doses. For large projects a so called a-value of 4000 kSEK/manSv is used when evaluating if the measure will be undertaken. When deciding on minor dose reduction measures this value may be overruled since the measures are very often beneficial to industrial safety and sometimes also for reactor safety and operations.

A more formal approach to ALARA is the specific ALARA programme issued at each NPP. In these programmes annual goals are set up, for example in terms of collective dose or dose rate in certain systems, as well as the means to reach the goals.

Besides concentrating on lowering the collective doses and system dose rates, special attention is of course paid to dose reduction for the groups of individuals receiving the highest doses.

Environmental radiological surveillance
All release points at the NPPs are monitored. The main ventilation stack is monitored continuously (in most plants nuclide specific), and water tanks are checked before the content is released and they are also sampled during the release.

On the site and in the near vicinity there are TL dosimeters set out, which are evaluated regularly. At most NPPs radiation monitors around the power plant also give the dose rate on-line. The monitor readings can immediately be made available to the authority upon request. At further distances from the plant a large number of TL dosimeters have been set out by the County Administrative Board. These dosimeters are evaluated by the power plant once a year.

In order to check the impact on the environment, extensive sampling of fish, grass and other vegetation is taken each spring and autumn. These samples are taken, and for one site also evaluated, by an independent organization approved by SSI. For three of the sites the samples with SSIs permission are processed and measured by the power plant and the result is reported to SSI. In addition, SSI with its own resources occasionally takes and evaluates environmental samples.

Reporting
Regular reporting to SSI in the radiation protection area includes annual dose budgets, as well as budgets for planned outages, accompanied by descriptions of major jobs that will contribute to the occupational doses. The outcome is reported annually and after the completion of the outages respectively and comprises comments and experience gained. Individual internal contamination above certain levels, or other unexpected radiological events are reported promptly.

Other information that is reported regularly is for instance

- activity releases through the ventilation stack and to the water recipient,
- activity in the reactor water and in samples taken around the plant,
- doses measured by TL-dosimeters in the near vicinity of the plant as mentioned above.

15.3 Regulatory control

As a rule regulatory control is performed by inspections and examination of reports, plans and other written material requested by SSI. The major inspection efforts are performed in connection the planning, conduct and evaluation of the annual outages at the plants. In general SSI is satisfied with the status of the radiation protection work of the licensees.

15.4 Conclusion

The Swedish Party complies with the obligations of Article 15.

16. Article 16: Emergency Preparedness

1. *Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installations, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.*

2. *Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the states in the vicinity of the nuclear installation are provided with appropriate information for emergency planning and response.*

3. *Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear insatllation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.*

16.1 Regulatory requirements

On-site

In the Government bill 1980/81:90, issued after the TMI-accident, the emergency preparedness issues received considerable attention. It was proposed by the Government, and decided by Parliament, that the emergency planning must consider all types of accidents, from those with very small environmental consequences to the most serious accidents. Further, systematic training of decision makers must be arranged as well as organization of personnel on duty and arranging of verified telecommunication between the responsible organizations. Finally it was required that technical support centres to the control rooms of the NPPs be established.

The development and practice of an on-site emergency preparedness plan is a licensing condition. In the new general safety regulations of SKI (see section 7.2) this requirement is specified. It is required of the licensees, in case of incidents which could lead to a radiological accident, that there are plans for:

- alerting the emergency preparedness personnel without delay,
- bringing the plant to a safe and stable state,
- informing about the technical situation at the plant.

The plan shall be kept up to date and tested in regular exercises.

It is further required that assigned personnel, suitable emergency operating centres, technical systems, tools and protective equipment exist to the extent needed to carry out the above tasks. Further details are given in the general recommendations to the regulations.

Besides SKI other authorities pose requirements on the licensees concerning emergency preparedness. SSI has issued requirements on radiation protection and monitoring (see chapter 15). The Swedish Rescue Services Agency has issued requirements on alarms and information of the public.

In Sweden two alarm levels are applied in the notification of the off-site emergency organizations. These levels have been defined by SSI in a regulatory letter to all licensees.

1. Alert

This level means that an event has occurred that may degrade the reactor safety functions, but no releases have occurred or are expected at the moment. The NPP emergency organization must be called in and the authorities must be notified promptly. The public is to be informed on the situation through radio messages.

2. General emergency

This level means that an event has occurred that may necessitate protective measures outside the NPP. Releases have occurred or are expected within the next 12 hours. The NPP emergency organization is to be called in and the authorities shall be notified promptly. The public are to be warned by sirens and the Radio Data System, and informed about the situation through radio messages.

Symptom based Accident Management Procedures exist at all the NPPs according to the Government decision of 1986 on accident mitigation measures. These procedures are coordinated with the technical criteria for issuing of an alarm. These criteria are based on the status of critical safety functions as well as dose rates within the containment, main ventilation stack and the site area.

Off-site

In accordance with the Government bill 1980/81:90 Parliament has decided that the land area around the Swedish nuclear power plants shall be divided into an Inner Emergency Planning Zone, with a radius of 12-15 km, and a Radiation Monitoring Zone extending to a radius of 50 km. The Rescue Services Act (see section 7.1.3) states that within these zones it is the responsibility of the County Administrative Board to establish a radiological emergency plan. The County Administrative Board is according to the Act also operationally responsible for all rescue and other public protection activities needed in a radiological accident situation. The Rescue Services Act requires that all the 21 counties have a radiological emergency planning, which should be more developed in those counties where an operating nuclear power plant is located. Danish authorities take an active part in the Skåne County Administrative Board emergency planning for Barsebäck NPP.

In the national emergency preparedness organization SSI, SKI and the Swedish Meterological and Hyrological Institute (SMHI) serve as expert authorities, in accordance with their instructions, and are required to set up their own emergency organizations. The prime task for SSI is to provide the administrative authority of the county and other relevent authorities with advice on countermeasures to limit the radiological consequences in the event of a release to the environment. To perform this task the SSI emergency organization includes an administrative reference group consisting of representatives of authorities: SKI, the Swedish Rescue Services Agency, the National Board of Health and Welfare, the National Food Administration and the Board of Agriculture.

These representatives serve as a liaison between the central emergency organization at SSI and the authorities responsible to decide upon countermeasures within their respective spheres of responsibility. Within the central emergency organization SSI and SKI have a joint information division with the main task to analyse and provide information to the mass media and to the general public.

The emergency preparedness role of SKI is to analyse and advise the County Administrative Board on the development of a nuclear accident, and to estimate the time scale and the source term of a potential or real release from the plant.

The role of SMHI is to act as the Official National Point of Contact with responsibility for relaying accident notifications from abroad to SSI and SKI. This task should be performed in addition to their responsibility for weather forecasts and calculations concerning atmospheric transport and deposition of radioactive substances in connection with a nuclear accident.

An overview of the responsibilities and information routes of the main actors is provided in Figure 14.

16.2 Measures taken on-site by the licence holders

Emergency response organization

The on-site emergency response organizations at the four sites are clearly structured and defined and are, as far as possible, built on the normal operating organizations. This means that people work in their ordinary functions, with, in some cases extended responsibilities. Line mangers and supervisors participate actively in the planning and emergency preparedness activities. The line managers are responsible for the readiness of emergency response equipment and personnel. Planning and preparedness also include assuring that staffing and resources are sufficient to accomplish assigned tasks, and that if required the work can continue in shifts for several days.

The shift supervisor and the engineer on-duty are very important positions, especially during the early stages of an emergency, before the emergency organization has been notified and gathered. Engineer on-duty is a function that is shared between 15-20 well experienced persons on each site. The engineer on-duty stays on site, or is always available on the site within 30 minutes. He has the full authority, in absence of the plant director, concerning emergency response activities. This comprises among other things alerting and notifying of the on-site and off-site response organizations. Besides this, he should assist the shift supervisor in evaluating the emergency situation and estimates of releases from the plant.

Emergency plans and procedures

Documents describing policies and objectives of the plant's emergency planning and preparedness programme are normally included in the quality system of the NPP. In addition each NPP has its own emergency plan which consist of two parts, one operative part giving guidelines for effective response to emergency situations, and a descriptive part giving an overview of the planned measures. The emergency plan is supported by

Figure 14.

Spheres of responsibility

- The twenty-four County Administrations Boards in Sweden are responsible for leading emergency relief and rescue operations in connection with nuclear accidents. They are also responsible for clean-up after accidents involving radioactive material.

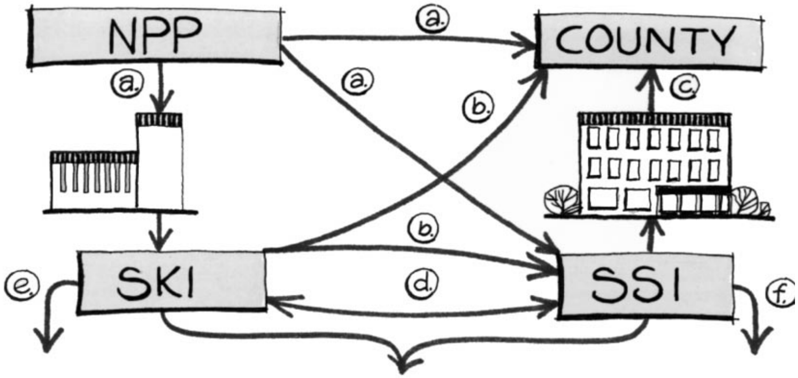
- The Swedish Rescue Services Agency supervises regional planning and coordinates contingency planning for rescue services and clean-up.

- The nuclear power company is responsible for preparedness on its own property and must promptly report any malfunction or unplanned release of radioactive material to the County Administration as well as to SKI and SSI.

- SSI leads and coordinates measurements of radiation on the national level and advises both county administrations and pertinent central authorities such as the National Food Administration, the Swedish Board of Agriculture, and the National Board of Health and Welfare concerning measures to minimize the radiation dose received by the population.

- SKI analyzes the accident causes and estimates the source term of a possible radioactive release.

- SMHI is responsible for relaying alarms from abroad and for weather forecasts to indicate the likely pattern of dispersion of radioactive material after an accident.



a) Report on the event.
b) Technical information.
c) Advice on radiological consequenses and protection activities.
d) Status report/interchange of information.
e) Technical information on international basis.
f) Radiological information on international basis (early warning).

From: In case of a nuclear accident – Sweden is prepared. A brochure by SSI, SKI and SRV.

procedures, in which detailed actions required to carry out the emergency plan are specified. Specific checklists and manuals exist to a varying extent for all key functions.

The descriptive part of the emergency plan describes the emergency response organization, authorities and responsibilities of key functions and emergency response personnel not covered by established procedures. The operative part deals with emergency event classification, notification and activation of the emergency response organization, assessment and monitoring of radioactive material release, and in-plant personnel protective actions including accountability and evacuation.

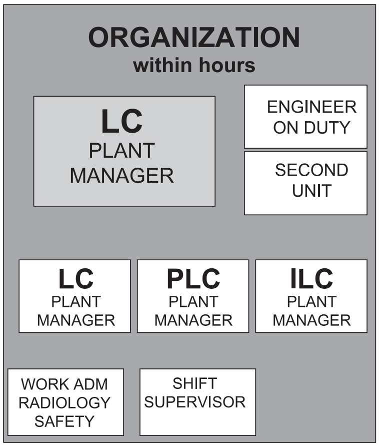
The co-ordination of plant activities with those of off-site organizations and authorities are also described, as well as communication with public and media.

Facilities, equipment and resources

Provisions are made for adequate response facilities and appropriate equipment and resources that can be brought into operation without delay in the event of an emergency. These include centres from which emergency response can be directed, and to which information can be chanelled. The main principle is that the plant top management gathers in a centre to deal with strategy issues, communicates with external organizations like the utility headquarters, the County Administrative Board representatives and the authorities, gives directives to and receives information from the decentralized operative centres. These centres are dedicated for taking care of the affected reactor unit, for handling personnel matters like gathering, accounting for and protecting the staff, and for supplying information about the event to the plant staff and to the media. As an example the different centres at the Barsebäck NPP is shown in Figure 15. In Figure 16 is shown an overview of the on-site and main off-site organizations after notification of a general emergency.

For communications various independent systems are available. As well as the ordinary telephone system with independent connections, national defence lines, mobile telephones, radio communication equipment, and systems for communication on the power grid, faxes and computerized information systems are used.

Figure 15.



LC = Plant Emergency Management Centre
TLC = Technical Management Centre (affected unit)
PLC = Personnel Management Centre
ILC = Information Management Centre

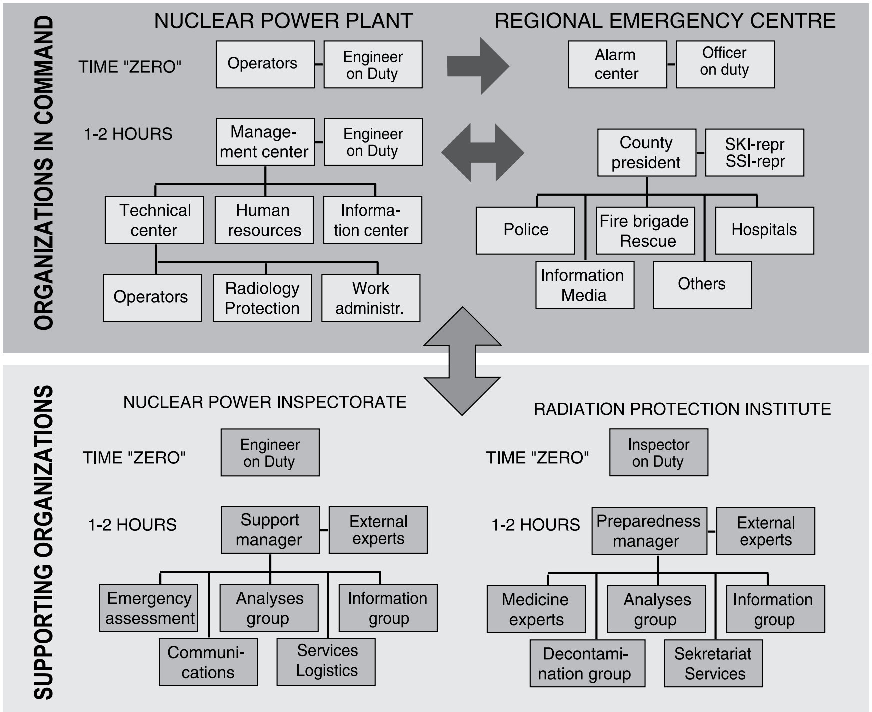
The plants have installations for monitoring and sampling radioactive material in the primary system, within the station buildings and measuring devices for the release of radioactive materials through the ventilation stack. At some sites on-line radiation monitoring equipment is installed in circle around the plant. At other plants radiation monitoring is carried out by monitoring patrols, which also perform outdoor sampling. Meteorological information is obtained from the on-site weather masts measuring at different altitudes.

Training, drills and exercises

Emergency training programmes exist for all plant personnel according to their specified emergency duties. Initial training of personnel assigned to various functional areas of emergency activity is followed by drills to further develop skills in specific disciplines such as:

- accident management,
- communication,
- radiation monitoring and sampling,

Figure 16.



- fire fighting,
- emergency repairs,
- first aid,
- accident consequence assessment (radiological dose projections in emergencies).

A programme is provided for general employee training of on-site personnel, apart from those having emergency duties, in order to familiarise them with procedures for alerting personnel of emergency conditions and evacuating the affected area of the site. Similar training is also given to contractors and consultants working on the site.

On-site exercises affecting all plant personnel are carried out regularly, at least once a year. Off-site emergency organizations and other external resources serve as counterparts during these exercises. Similarly, specific representatives of the plant emergency organization act as counterpart, when the County Administrative Board performs its exercises.

As mentioned below, every Swedish NPP in addition participates every fourth year in an integrated on-site and off-site full scale exercise conducted and evaluated by the Swedish Rescue Services Agency.

Review and experience feed-back is an essential part of the on-going process for improving the emergency preparedness and capability at the plants, and is applied by the plants in conjunction with drills and exercises.

Emergency assessment and notification

Classification of emergency events is performed in accordance with the regulatory requirements. The classification is carried out based on the emergency plan, and the accident management procedures and the parameter information from and diagnostics of the affected reactor unit.

The decision for alerting and notifying the off-site organizations and authorities is based on the classification of the emergency event. Subsequent messages to off-site authorities are forwarded regularly to inform of the assessments concerning radiological consequences. Radiological emergency assessments include methods for determining the source term, measuring the release rates, measuring radiation levels in the environment, and estimating projected doses for potential releases.

Off-site radiological field data are logged, compared with source term data, and used in the protective action recommendation process.

Public and media information

The responsibility of the plant´s public information group is in the event of an emergency limited to news releases to the media concerning the event and the conditions on-site. However, in an emergency situation this group is enlarged and provides the public information staff at the utility, and the regional and national authorities with basic information for dissemination to the public and media. Different methods have been developed to monitor news broadcasts, bulletins and news reports for misinformation and to respond quickly to rumours and misinformation.

The plant public information people work continuously during normal operation in developing a good network among and a good relationship to media people, which is one requisite for success in the public information sector in an emergency situation.

16.3 Measures taken off-site

Within the above-mentioned zones several precautionary actions have been taken. A number of predefined points for radiation monitoring have been identified, and a strategy developed for monitoring teams to take action. The monitoring teams are personnel from the local rescue forces (fire brigades). The emergency organization of the county also includes the police, medical personnel, the coast guard, municipal authorities, etc.

Communication means have been installed which make it possible for the County Administrative Board, the NPP and the expert authorities at a central level, such as SSI and SKI, to communicate reliably in the case of an incident/accident.

Within the inner emergency planning zone iodine pills are distributed to all households together with two leaflets, one with advice as to what to do in the event of an accident, and the other on basic facts about ionisation radiation and radiation risks.

Indoor and partly outdoor warning systems are also installed to alert the public within the inner emergency zone. There are also plans for evacuation of the public from the inner zone if needed.

Each year a number of exercises are performed at various levels. Once a year a large exercise takes place involving one of the four nuclear power sites and the entire national emergency organization, including the central authorities and the emergency field organization of the county in which the nuclear power plant is situated, such as the rescue forces, the police, the municipality administrations and the emergency departments of hospitals within the county. These exercises are rotated so that all four counties and nuclear power sites are fully exercised over a four year period. In addition there are smaller exercises each year in all four counties which have nuclear power reactors in operation.

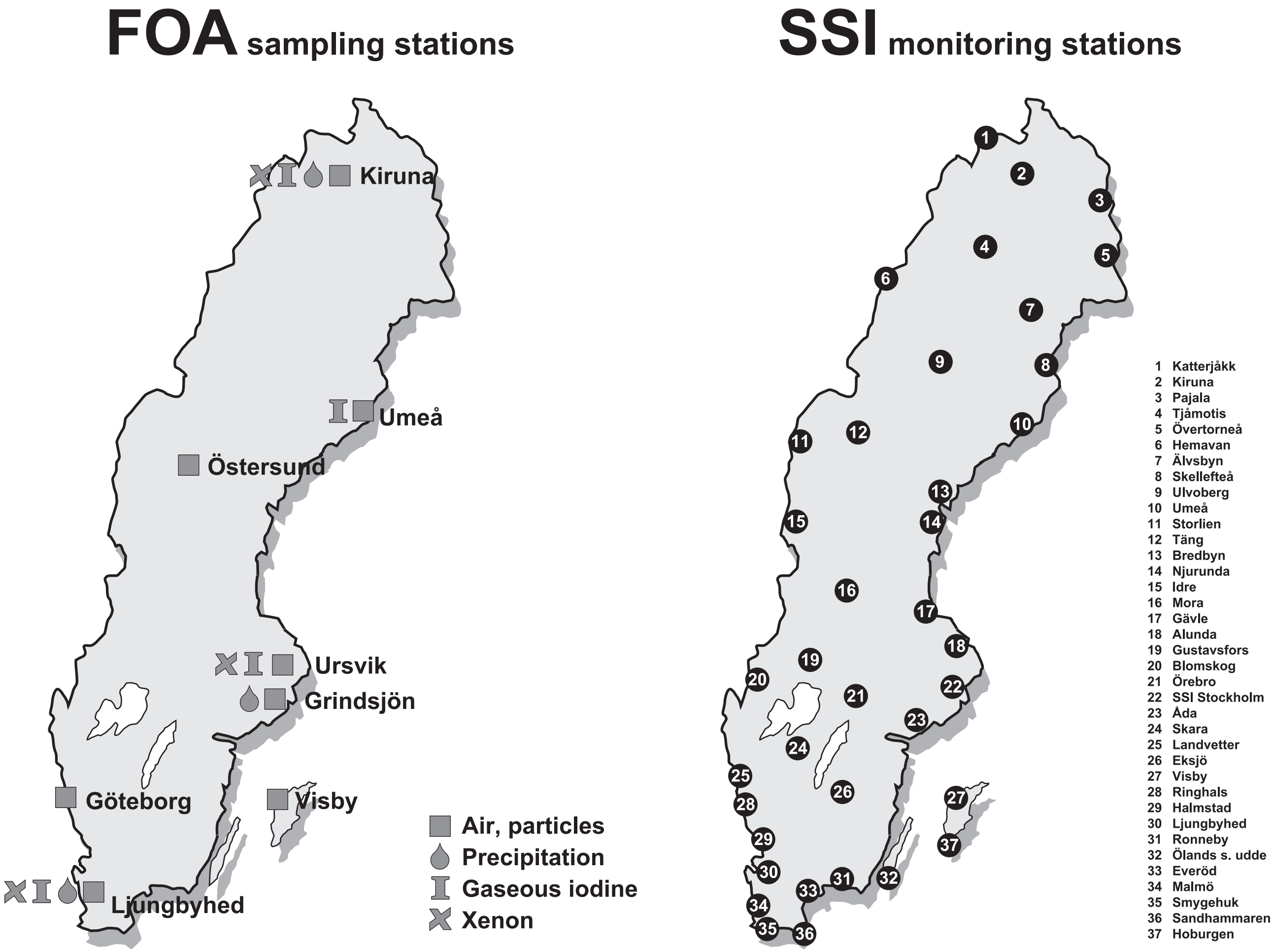
Counties without nuclear power installations are encouraged to participate in international or the large national exercises. The main ambition is to train specific functions of their organizations, such as the decision makers or communication and cooperation, with expertise organizations in the national emergency organization. Sweden also participates in international exercises when available, for example the INEX-2 exercises and various Nordic exercises.

Regulatory and planning measures have also been taken to ensure that national preparedness and knowledge is available if needed, and how to perform large scale decontamination actions in the event of a severe radioactive contamination of the environment.

16.4 National monitoring and measuring

In Sweden SSI has been given the task of coordinating national monitoring and measurement resources to be used in the event of a radiological emergency. To provide early warning there are 37 gamma monitoring stations. In case of a dose rate increase above a given level SSI will be notified via a radiation protection officer on duty on a 24 h bases. To provide early information by detecting long distance or low level releases of radioactive substances, air-borne particles are collected on filters at seven high-volume sampling stations. The filters are analysed using high-resolution germanium detectors. The location of the air-sampling and monitoring stations is shown in Figure 17.

Figure 17.



Nine research laboratories throughout Sweden have been contracted by SSI to participate in the national radiation protection organization led by SSI to collect, sample and perform measurements in the event of an emergency. To characterize the different radionuclides on the ground, there are resources available to perform high resolution field gamma spectrometry.

16.5 Measures taken to inform neighbouring States

Sweden has ratified the International Convention on Early Notification and the Convention on Assistance in the Case of a Nuclear Accident. An official national point of contact has been established, available 24h a day.

In addition Sweden has bilateral agreements with Denmark, Norway, Finland, Germany and Russia regarding early notification and exchange of information in the event of an incident or accident at a NPP in Sweden or abroad. An agreement on authority level also exists with Lithuania. There is also planning to fulfil the requirements from the European Union concerning the information exchange within the ECURIE information system. Several exercises are performed each year to test the communications needed.

Between the Nordic authorities involved in the field of radiological emergency planning there exists an agreement to exchange data on a routine basis from the automatic gamma monitoring stations in the respective countries. SKI also has a an agreement with the Danish regulatory authority to provide information about safety analyses and other safety relevant information concerning the Barsebäck NPP.

16.6 Regulatory control

The on-site emergency preparedness planning is inspected jointly by SSI and SKI. In the recent years two major joint topical inspections have been conducted. The first of these inspections focused on the fulfilment of the following requirements

- the emergency response organziation shall be well defined and easy to understand,
- alarms and notifications shall be carried out without unnecessary delay,
- decisions shall be made by the most competent staff,
- regular training and exercising and competence assessments shall be conducted.

In addition the measures for radiation protection, monitoring, sampling, repairs, rescue and evacuation of staff were assessed. The second inspection was a follow up of the first one. In general SKI and SSI were satisfied with the measures planned and implemented by the licensees.

In addition to inspections of the emergency planning, SKI and SSI occasionally inspect the plant actionsduring emergency exercises. For this purpose a special inspection model has been developed in order to assess the most important tasks for safety.

The off-site emergency planning is assessed by the Swedish Rescue Services Agency in cooperation with the relevant authorities. The Rescue Services Agency also organizes evaluations of the national exercises, documents the results and provides feed-back to the organizations involved.

16.7 Conclusion

The Swedish Party complies with the obligations of Article 16.

17. Article 17: SITING

Each Contracting Party shall take the appropriate steps to ensure that approprpriate procedures are established and implemented:

(i) for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;

(ii) for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;

(iii) for re-evaluating as necessary all relevant factors referred to in sub-paragraphs (i) and so as to ensure the continued safety acceptability of the nuclear installation;

(iv) for consulting Contracting Parties in the vicinity of a proposed nuclear in stallation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation.

17.1 Regulatory requirements

All the Swedish nuclear sites are located on the coast with access to sea water for cooling and possibilities for sea transportation. The sites were originally selected taking into account relevant factors such as the above-mentioned, and the population density at various distances. The final acceptance decisions were taken by the Government after investigation by a special committee that all legal requirements were met. In the case of Barsebäck, Danish authorities were provided with full insight into the application for construction. Present legal provisions to maintain the environmental conditions of the sites include restrictions for building activities close to the site[48]. Since construction of new nuclear power plants is precluded by law, siting requirements for new plants are not relevant except for nuclear waste handling and disposal sites.

However, the licensees are required to re-evaluate the relevant factors for the site which could affect the safety functions of the NPP. This is primarily done in the framework of safety analyses. The probability of local external events affecting the safety of the NPP, such as blocking of cooling water inlets, salt deposits on the switch yards, airplane crashes, flooding and earthquakes should be assessed in PSA. Also in connection with new activities in the neigbourhood of a NPP, analyses have to be made to show the possible impact on the NPP safety functions. Only if this impact is acceptable is permission given for the new activity.

[48] Use of land in the neighbourhood of a nuclear power plant. Swedish Plan Agency Report 1977:42 (in Swedish).

17.2 Measures taken by the licence holders

The safety goals defined in the safety policies are also valid for external events. Safety, therefore, has to be evaluated with respect to factors which are specific for the site, like seismicity, weather conditions, etc. Site-specific factors relevant to plant safety have been identified through operating experience and in the probabilistic safety analyses of external events. When needed, measures have been introduced to improve safety as shown in the following examples:

- The first ten plants were designed and constructed without formal qualification with respect to seismic events. They have therefore been analysed after being taken into operation using best estimate probabilistic methods and compared to the goals for core damage frequency and radioactive releases. As a basis for these seismic evaluations the characteristics of a seismic event typical for the Swedish geological conditions was developed and documented in a research project in cooperation between SKI and the utilities[49]. Where appropriate plant modifications have been made to improve resistance to seismic impact. As a rule new equipment and systems installed are verified with respect to seismic events.

- Special precautions have been taken to avoid problems associated with location on the west coast of Sweden. These precautions consist of special means to prevent the clogging of cooling water inlets by sea weed and jellyfish and spray systems to clean the switch-yards from salt deposits during storms from the sea.

- The containments have been designed to withstand an airplane crash of moderate size (sports plane) and the risk of larger crashes has been analyzed and found to be tolerably low based on available air traffic statistics.

Advanced plans existed in the late 1980´s, when decommissioning of two of the nuclear units was proposed by the Government, for building natural gas combined cycle units at two of the sites and a pilot coal-gasification plant at one site. For different reasons these plans were not realized but projecting included comprehensive safety assessments regarding the potential influence on the existing nearby nuclear installations.

The dominating risk from the projected plants was that of explosions and missiles. They would therefore have to be located at a sufficient distance from the nuclear installations. Other aspects analysed were the handling of oil in the harbour, and the potential impact on the switch-yard. The safety issues were all on the agenda of the safety review committees at the sites as long as the projects lasted, and the regulatory authorities were kept informed. Typically the safety review committees set the requirement that the new installations should not be allowed to have any impact whatsoever on the safety level of the nuclear plant.

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[49] Characterization of seismic ground motions for probabilistic safety analyses of nuclear facilities in Sweden. SKI Technical Report 92:3, April 1992.

17.3 Regulatory control

Regulatory assessments of site- specific factors are made as in the regulatory review of safety assessments described in section 14.3. With regard to the seismic qualification of the older plants, SKI has not yet made a decision on the requirements. As mentioned in section 6.1, this is a generic safety concern and a dialogue is underway with the licensees based on results from ongoing assessments. Based on evaluations made so far, measures have been taken in the older plants to safeguard some electrical equipment, such as the installation of seismically qualified battery racks.

17.4 Conclusion

The Swedish Party complies with the obligations of Article 17.

18. Article 18: DESIGN AND CONSTRUCTION

Each Contracting Party shall take the appropriate steps to ensure that:

(i) the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defence in depth) against the release of radioactive materials, with a view to preventing the occurrance of accidents and to mitigating their radiological consequences should they occur;

(ii) the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;

(iii) the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface.

18.1 Regulatory requirements

Defence in depth

As mentioned in section 8.1.2 the Government in the letter of approproation 1997 gave directives for the fundamental reactor safety principles and objectives to be applied by SKI:

- Swedish nuclear installations shall have a satisfactory protection in several barriers to prevent serious accidents and incidents originating from technology, organization or competence, and which also prevent or mitigate releases, should a severe accident occur;

- Swedish reactors shall have sufficient protection against terrorism, sabotage and theft of nuclear materials.

These principles and objectives reflect internationally established safety principles and objectives, such as those published by the IAEA[50].

As reflected in SKIs regulations and the regulatory letters, prevention of core damage has first priority as a safety objective. To achieve this objective, a number of safety principles and practices have to be applied. They can be visualized as a safety chain[51] (Figure 18), which includes both technical and organizational links, the latter being more emphazised in the regulatory letters of the last few years.

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[50] Safety Fundamentals: The Safety of Nuclear Installations. IAEA Safety Series 110. Vienna, 1993.
[51] Högberg L. Nuclear saftey and waste safety aspects of a twelve reactor nuclear programme. The CNS Annual Lecture, 1997.

Key technical safety principles on prevention include

- Design featuring high inherent stability and few sources for operational disturbances;

- Robust defence-in-depth based on physical and functional separation, redundancy, and diversity – basically verified by deterministic assessments, complemented by PSA;

- Reliability targets for safety system performance derived from plant-specific PSAs: $<10^{-5}$ per reactor year core damage frequency and the use of living PSAs in safety management;

- Rigorous in-service inspection and control programmes, including qualification of non-destructive testing programmes to ensure adequate margins against structural failures.

The safety and reliability of any reactor, old or new, however well designed and constructed, will deteriorate in a short time if it is not operated and maintained to very high standards. Therefore, the SKI regulatory strategy fully recognizes that successful achievement of a high level of safety depends as much on safety culture in management and organization as on good design and high-quality construction. As a consequence, SKI is now focusing considerable attention on safety issues related to the interaction between man, technology and organization (se chapter 12). Key MTO-related safety principles to be applied according to the requirments on prevention include:

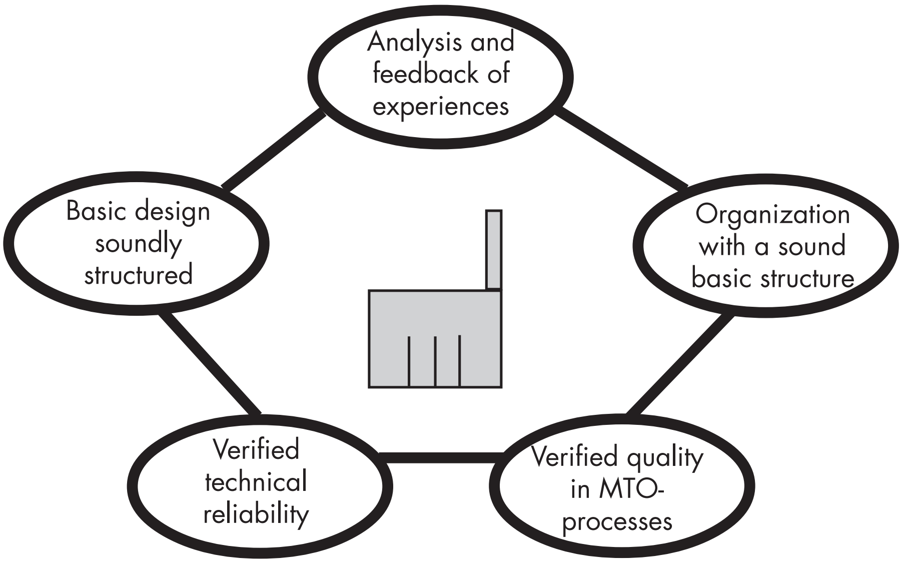

Figure 18: The safety chain.

- Sound organizational structure. Key features of such a structure include clearly defined responsibilities, along organizational lines, as well as for processes run across organizational lines. Competent staff, in adequate strength, is also a prerequisite.

- Verified quality in MTO processes. Key features include well-designed instructions and procedures, an enquiring, learning attitude at all levels, and systematic safety reviews as well as regular QA audits.

As mentioned in section 7.2 the original licensing requirements on defence in depth were detailed and basically conformed to the USNRC General Design Criteria (10 CFR 50, Appendix A), Regulatory Guides (NUREG), other appendices to 10 CFR 50 and codes and standards from ANSI, ANS, IEEE, ASME etc. Specific Swedish requirements, such as the 30-minute rule (se section 12.1 and 18.2) were added. Later the IAEA reports INSAG-3 and INSAG-8 have been used in the regulatory review of plant modifications.

With regard to environmental qualification of structures, systems and components, US codes and standards have also been used in Sweden with SKIs approval. However, methods and standards have been further developed in Sweden. In 1982 SKI required a status inventory of electrical equipment within the containments and of the penetrations. This led to an extensive programme to establish requirements and to qualify the safety related equipment in the containments of all the older reactors. All equipment in the containments not conforming to the requirements has now been replaced. Outside the containment the requirements are to install qualified equipment as old equipment is replaced or changed.

According to the SKI regulations on structural components in nuclear installations (SKIFS 1994:1), structural components shall be divided into quality classes 1-4 for determining the design and quality assurance requirements for repairs and for the manufacture and installation of replacement components or additional components. Assignment to quality classes must take into account the importance of the component for the safety under normal and disturbed operational conditions.

For the design of components which belong to quality class 1 or 2, the specification of the design basis must be approved by SKI. The components must be designed in accordance with well proven industrial standards and codes which have been demonstrated to provide sufficient margins for the components to ensure that they can fulfil their safety functions.

In the new general safety regulations of SKI (see section 7.2), the principle of multiple barriers and defence in depth in several levels is specified for all major nuclear installations. In the general recommendations reference is made to the IAEA report INSAG-10[52]. In order to fulfil the requirements on defence in depth, design requirements are stated which are in compliance with the safety fundamentals of IAEA[53] . In addition to these general regulations SKI plans to specify in more detail the requirements for technical safety systems to be included in the defence in depth of Swedish reactors operating after 2000 (see section 6.4). A prestudy of these requirements was started by SKI in 1997.

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[52] Defence in Depth in Nuclear Safety. IAEA report INSAG-10. Vienna, 1996.
[53] Safety Fundamentals: The Safety of Nuclear Installations. IAEA Safety Series 110. Vienna, 1993.

Severe accident management and release mitigation

Even if prevention of accidents is the first priority, the Swedish regulatory strategy recognizes that accidents involving severe core damage (core melt) may nevertheless occur. Therefore, measures are required to achieve reasonable capability of managing such accidents, and of limiting releases to the environment in such accidents, especially of nuclides causing long-term ground contamination, taking into consideration the social disruption that may be caused by such contamination, as demonstrated by the Chernobyl accident.

Criteria and guidelines for release mitigation in the event of severe accidents were finalized in a government decision in February, 1986[54] as a condition for operation after 31 December 1988. This decision states that, in the case of an accident involving severe core damage, including core melt, releases should be limited to a maximum of 0.1% of the core content of cesium 134 and cesium 137 for a reactor core having a thermal power of 1800 MW, on condition that corresponding fractions of other nuclides that play a significant role in ground contamination also are retained. Severe accident sequences of extremely low likelihood, such as pressure vessel rupture, need not be taken into account. It should be noted in this context that the total radioactive fallout over Sweden after the Chernobyl accident corresponds to more than 1% of the core content of cesium in the Chernobyl reactor.

During the 1980's these release mitigation requirements led to major backfitting of the Swedish reactors, e.g. with filtered containment venting systems[55]. Plant-specific accident management procedures were also required by the government decision and introduced at the NPPs . The objective of these procedures is to enhance the capabilty of bringing a severe accident sequence under control and achieving a stable final state, with a damaged core covered by water and cooled, with the containment depressurized and with preserved integrity.

Requirements concerning protection from intentional damage such as sabotage are posed in special directives as licensing conditions. These requirements include specific design measures.

In addition to the regulatory requirements on design and construction there are quality assurance requirements (see section 13.1) on control and documentation of plant modifications.

18.2 Measures taken by the licence holders

18.2.1 Defence in depth

The safety philosophy applied in the design of all Swedish nuclear power plants is based on the principles of defence in depth and of multiple barriers to prevent the release of radioactive material into the environment. As mentioned these principles originate from the criteria formulated by the USNRC, published in the General Design Criteria (10CFR 50 Appendix A), GDC.

[54] Swedish Government Decree, February, 1986 (in Swedish).

[55] Release-Limiting Measures for Severe Accidents. Swedish Nuclear Power Inspectorate - Swedish Radiation Protection Institute Report to Government, December, 1985 (in Swedish).

The design principle of defence in depth comprises three different levels.

1. The reactor should be designed with inherent stability and sufficient safety margins under normal and abnormal operation. Components and systems to be of high and uniform quality. Quality assurance required in all phases.

2. The reactor shall have separate control and protection systems as well as separate systems for cooling the reactor and the containment. Each safety system shall fulfil the single failure criterion.

3. The reactor and its primary system should have a containment for minimizing the release of radioactive material to the environment in case of an accident. Emergency cooling and containment systems to be designed for double-ended break of the largest primary system pipe.

All Swedish plants were designed to fulfil the requirements of the GDC and analyses are provided in the FSAR of each unit to show how this is accomplished.

The BWRs are all of Swedish design (ASEA, later ABB Atom) and not based on foreign licence. As shown in chapter 2, five design generations can be defined with significant development steps between the generations. The first generations comprising five units have external main recirculation loops, while the last four units have internal recirculation pumps with no large pipes connected to the reactor vessel below core level. All have fine motion control rod drives and hydraulic shutdown systems. In the first two generations diversification was used in the emergency cooling systems, but in the later generations this was replaced by increased reliability in the electrical supply and a higher degree of redundancy.

The BWR containments are all of the pressure suppression (PS) type and have been back-fitted with facilities for venting and (except Barsebäck) diversified containment cooling. These systems were introduced as a result of the requirements on severe accident mitigation decided in 1980 for Barsebäck and in 1986 for the other NPPs. The first filter system installed in Barsebäck is a passive system designed to prevent containment overpressure in a LOCA with a failing PS function. For the other BWRs the filtered venting system was designed, according to another principle with improved PS reliability, to prevent late over pressurization, and a separate unfiltered venting system protects the containment in the event of a LOCA with a failing PS function. Besides the technical modifications the requirements on severe accident mitigations also included accident management procedures.

In some areas specific Swedish requirements have been added, e g. the so-called 30-minute-rule. This rule requires that all measures, which need to be taken within 30 minutes from the initiation of an incident, which involves risk for radioactive release, have to be automated. This rule is implemented in the BWRs, and with some exceptions in the PWRs.

Another area where stricter Swedish rules are applied relates to fire protection and separation of safety related equipment. In the four youngest BWR units the essential safety systems are designed with four independent loops, which are physically separated. In the older units at least two independent and physically separated loops are installed, in one case, Oskarshamn 1, this has been done as a modification of the original design.

In other areas new knowledge or new requirements have also caused modification of the design and construction of the Swedish plants. One example is the mentioned (see section 6.1) improvement of the emergency cooling systems of the five oldest BWRs implemented as a result of an event at Barsebäck NPP in 1992. In this event the strainers to the emergency cooling pumps, after a scram with containment isolation following a valve failure, were clogged with isolation material teared down by steam earlier than calculated in the safety report.

With the objective to provide a systematic and user friendly compilation of the regulations, standards and codes used for the Forsmark and Ringhals plants, Vattenfall has developed a comprehensive, computerized library. This library contains about 8000 standards and codes (from Sweden, USA and other countries), includes advice for the user and is an important tool for use in design modifications, equipment replacement, etc. In the OSART review of Ringhals 3-4 in 1991 it was noted as a commendable practice.

The protection with respect to intentional damage, such as sabotage is accomplished by separate physical protection schemes including hardware protection measures, specific procedures and a security organization.

18.2.2 Proven technology

The principle of proven technology is broadly accepted and implemented in the design and construction procedures for the Swedish nuclear plants.

When the first plants were designed they were mostly based on the light water technology developed, tested and proven in the United States. In those cases where the Swedish designed plants contained unique features careful analysis and test programmes were carried out. In some cases new verification tests had to be performed when the original tests had proved to be inadequate. One example of this is the extensive testing programme leading to new strainer designs in the emergency cooling systems. Resources and laboratory facilities for advanced thermo-hydraulic and mechanical tests are available both at the vendor, ABB Atom, at the Vattenfall laboratories in Älvkarleby and at the Studsvik facilities. In Studsvik advanced equipment for materials and mechanical testing of radioactive material is available in the hot cell laboratory.

In the current modernization programmes use of up-to-date but proven technology is one of the basic criteria.

In order to ensure the function of the safety-related systems, and to obtain correct and reliable information from the process in the event of an emergency, the components inside the reactor containment have been environmentally qualified. This qualification was preceded by detailed inventorying of all equipment in the reactor containment. At the same time requirements concerning function and duration, when the equipment is supposed to work, were specified. These requirements were different in part from those based on the DBA conditions used when the reactors were designed and constructed. Not least the TMI accident has contributed with extended information concerning requirements during emergency situations.

A comprehensive test programme was worked out and components identical to those installed in the containment were tested according to this programme, but in an environment representative for the conditions that can be expected in the containment, if a serious event takes place. The testing included all types of equipment like electromagnetic and motor operated valves, instrumentation, CRD-motors and cables.

Equipment that did not meet the specified requirements was replaced with new equipment that could withstand and work in the expected environment. In particular cables have had to be replaced. In most cases when equipment was replaced, this was due to the fact that equipment is also affected during normal operation in the environment in which it works, leading to its ageing.

In spite of the measures taken by the operators, continued research and development is going on within this area. Attention is paid not only to factors like temperature, humidity, radiation and vibrations, but also to electromagnetic and chemical environments. This work is performed in cooperation between the Swedish NPPs and SKI and in close contact to what is going on abroad.

18.2.3 Reliable, stable and easily manageable operation

The Swedish nuclear plants were all designed and constructed with the goal of high inherent stability and few sources for operational disturbances. The control rooms were designed based on experience and design rules within each owner organization.

In the design as in later backfitting and plant renewal stable manageable operation, good maintainability and feasibility for replacement and modification of equipment have been emphasized and seen as a provision for high availability and safety. Easy physical access and, in the latest BWRs, four train redundancy to allow on-line preventive maintenance, are examples of measures to improve manageability.

For BWRs, the Swedish ones not excluded, the problem of core stability has to be considered. Measures have to be taken to secure stability in the operational region and detect deviations from stable behaviour. Rules have been implemented at each plant for the core design and for detecting and counteracting core instability. The measures taken vary among the plants, but include measurements of margins to instability before start-up and during operation, operator procedures to avoid entering unstable operational regions and partial shut-down in some cases. Development is going on to increase the understanding of dynamics leading to instability and improve the measures to avoid instability in the BWRs.

For the PWRs xenon induced core oscillations may occur. Since these oscillations have very low frequency they are handled by manual control rod manoevrering according to operational procedures.

In the on-going modernization projects the MTO (human factors) and man-machine interface has been given considerable attention. In particular, the modernization of control rooms involves MTO and man-machine expertise, and guidelines have been established based on this expertise and incorporating experience from earlier operation.

18.3 Regulatory control

In major plant modification projects design and construction is controlled by SKI basically through review of the detailed project reports submitted by the licensee after internal and independent safety review. The reports contain safety analyses, design specifications, material specification basis, manufacturing and installation specifications, and specifications of the commissioning tests. In addition the project organization, project routines and quality assurance are reviewed. The design and project review is made by a group of SKI specialists including MTO specialists (see chapter 12). Comments are provided in a review report and additional requirements, if any, are provided in a regulatory letter. Installation work is inspected in connection with regular inspections of the plant. On some occasions SKI also observes the commissioning tests.

The SKI inspectors are regularly informed about current plant modification plans and these are specified in applications to SKI. Sometimes the applications arrive very close to the construction date which makes it difficult to allow the necessary time for regulatory review without delaying the project. According to the licensing conditions SKIs approval is mandatory after internal independent safety review and before a plant modification is implemented. SKIs approval of the design basis is also mandatory concerning equipment of quality class 1 and 2 according to the general regulations SKIFS 1994:1. In practice only a selection of plant modifications is scrutinized more closely by SKI inspectors and specialists due to limited resources. The selection depend on the assessed safety importance of the modification. One criterion on safety importance is if new technology is introduced in the safety systems, such as replacements of old relay instrumentation and control equipment with modern programmable electronic equipment. In these cases SKI has taken an interest in the verification of the software and has actively followed international work on developing relevant methods.

In the new general safety regulations of SKI (see section 7.2), plant modifications will be handled in a more unified way. After internal primary and independent safety review SKI shall be notified of all technical and organizational modifications which affect the conditions specified in the basic safety report (FSAR). SKI will decide in accordance with internal procedures which modifications to select for closer scrutiny and additional regulatory requirements if necessary. General recommendations are given on how to interpret the selection of modifications for notification to SKI and on a reasonable time before start of construction.

18.4 Conclusion

The Swedish Party complies with the obligations of Article 18.

19. Article 19: OPERATION

Each Contracting Party shall take the appropriate steps to ensure that:

(i) the initial authorization to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme demonstrating that the installation, as constructed, is consistent with design and safety requirements;

(ii) operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;

(iii) operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;

(iv) procedures are established for responding to anticipated operational occurrences and to accidents;

(v) necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;

(vi) incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body;

(vii) programmes to collect and analyse operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies;

(viii) the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.

19.1 Regulatory requirements

19.1.1 Initial authorization

As reported in section 14.1 the initial authorization was based on two different safety analyses. One before construction and one before taking the NPP in operation. In connection with all the 12 permits for commercial operation, commissioning programmes were required and assessed by the regulatory body. In connection with permission to increase the power levels, as reported in section 1.2, a safety analysis as well as a commissioning programme was required by SKI. These programmes contained a number of tests and controls to be conducted at various steps in the process to increase the power level. Each step was reviewed by SKI before permission was given for the next step. Finally an operational period of about a year was required with an extended testing programme at the final power level before permission for normal operation was granted.

Subsequently commissioning programmes under an extended supervision from SKI have been applied for the replacement of the steam generators of Ringhals 2. The extended supervision included special inspections and submittance of results to SKI at special times or check-points. At present Ringhals 3 and Oskarshamn 1 are under special supervision following replacement of the steam generators and the major renovation programme respectively (see section 6.1). The length of the commissioning programmes are in these cases dependent on the final assessments made by SKI.

19.1.2 Operational limits and conditions

As a licensing condition operational limits and conditions have to be presented and approved by SKI before commercial operation. These technical specifications (in Sweden named STF) shall safeguard that the conditions stated in the final safety analysis report (FSAR) are implemented in the operation of the NPP. It is further required that the necessary changes to STF shall be made as a result of plant modifications or operational experience. Changes shall be subject of internal independent safety review and submitted to SKI for approval before implementation. In the new safety regulations (see section 7.2) it will be sufficient after a twofold safety review by the licensee, to notify SKI of such changes before implementation.

19.1.3 Approved procedures

In the SKI licence conditions on quality assurance (see section 13.1) there is a general requirement that activities affecting quality (and safety) shall be carried out according to documented and quality audited routines. This is interpreted such that licensee approved procedures must be in place for operation of the NPP and maintenance of safety related systems. In the STF of every unit regulations are also included on procedures for change of operational status and the conduct of tests etc during operation. For inspection and testing there are more detailed requirements given in SKIFS 1994:1 (see section 14.1). No specified requirements are posed by SKI on the structure and contents of operational or maintenance procedures. The new general safety regulations of SKI (see section 7.2) specify that procedures shall exist for dealing with normal operation, incidents and accidents. Procedures for operability control and procedures to be used in case of incidents or accidents shall be subjects to twofold safety review by the licensees before application.

19.1.4 Procedures for anticipated operational occurrences and accidents

As mentioned in section 18.1 the Government requirement that symtom based accident management procedures were developed and implemented before the end of 1988. Together with earlier extisting system based emergency operating procedures, they are to cover the whole spectrum from operational disturbances, to handling all design basis accidents, and core melt sequences with the use of the accident mitigation systems. For accident senarios beyond core melt, handbooks have been developed in accordance with requirements on emergency preparedness planning.

19.1.5 Engineering and technical support

See chapter 11 on human resources.

19.1.6 Incident reporting

Notification of SKI and SSI according to alarm criteria is required as an emergency preparedness measure (see section 16). In addition SKI has specified in a regulatory letter to all licensees the requirments on reporting incidents within an hour to the SKI decisionmaker on duty. Such reports are required in the case of events of such a significance that the engineer on duty is called to the central control room of the NPP, in cases of ”abnormal events” and in cases of other events of a public interest (for instance a harmless fire on the site or a false emergency alarm). Abnormal events are specified in the technical specifications (STF) and are cases such as

- transients threatening the structural integrity of the cladding or the reactor pressure vessel,
- serious degradation of a barrier for inclusion of radioacive material,
- unplanned or uncontrolled major radioactive release from the plant,
- unplanned reactivity or criticity events,
- deficiences in routines and procedures of an extent that seriously threatens the safety of the NPP, and,
- serious deficiences found in the safety report of the plant.

Notification of an abormal event is to be followed by a comprehensive report within 10 days. In the case of an abnormal event, continued operation is subject to SKIs approval.

Other licensee events (reportable occurrences, RO) which are specified in STF shall be reported according to procedures also specified in the STF as a licence condition. A report comprising event description, consequences, safety significance, causes and corrective measures shall be sent to SKI within 7 days. If this is not possible, a confirmed final report shall be sent within 30 days with information and the results of a root cause analysis. The reports are sent on a special form approved by SKI.

Reports according to the INES[56] - manual of events at level 2 or higher according to technical criteria, are to be sent to SKI within 16 hours, in order to be conformed by SKI, and reported to IAEA within 24 hours. Events at level 1 are to be reported within 7 days.

In addition a report about the operational status is required by SKI every day as a routine from all NPPs. This report shall also include notification of events which have occurred during the last 24 hours.

In the new general safety regulations of SKI (see section 7.2) the requirements on reporting incidents will be changed and adapted to partly new criteria for taking actions in cases of deficiences in barriers or the defence in depth. Such deficiences shall be classified in three categories according to their safety significance. Category 1 and 2 corresponds roughly to abnormal events and reportable occurrences. The requirements on reporting times are shortened for the most serious events and extended for less serious events. Category 3 is

[56] International Nuclear Event Scale

temporary deficiences occurring as a consequence of planned measures described in STF to repair a component before it degrades to a more serious situation. SKI is to be notified of such events in the daily report and they are to be summarized in an annual report.

19.1.7 Operating experiences

According to the SKI licence conditions on quality assurance (see section 13.1) the licensees shall apply systematic and continuous experience feed-back in accordance with documented routines including experience from their own activities as well as other similar activities. It is also a licence condition to investigate events and use the results to improve safety. In addition specific experience feed-back measures with regard to material control and maintenance are required in SKIFS 1994:1 (see section 14.1).

The new general safety regulations of SKI (see section 7.2), include the general requirement concerning experience feed-back and the requirement to investigate events and disseminate the results in the organization in order to improve safety. Further there is a general recommendation that in the work with plant safety programmes, technical and organizational experience should be considered, as well as results for continuous safety analysis, experience from similar plants, results of research which could affect the assessemnt of safety, and the development of those codes and standards which were applied in the design and operation of the plant.

19.1.8 Generation of radioactive waste

As mentioned in chapter 8 there is an overlapping responsibility of SKI and SSI to issue regulatory requirements on the handling of radioactive waste. As a general principle SKI poses requirements on the safe containment of the waste with regard to the technical design of the barriers and the handling system. SSI poses requirements on the handling of the waste with regard to radiation protection of the workers and the environment.

As licensing conditions specified in regulatory letters the following requirements apply

An inventory register shall be kept up to date over all spent fuel and radioactive waste on-site.

- Measures for the safe on-site handling, storage or final disposal of waste shall be analysed and described in a safety report to be approved by SKI and SSI before measures are taken. The measures for on-site handling shall consider the requirements on safety posed on the continued handling, transport and final disposal of the waste. The safety report shall also include measures which need to be taken on-site to prepare for the safe transportation, storage or final disposal in a nuclear waste facility.

- If abnormal waste in quantity or quality appear as a result of operations or maintenance, measures for the safe handling of this waste shall be analysed and described in a safety report to be approved by SKI and SSI before measures are taken.

Only by SKI and SSI approved packages may be transported to a final repository. For this approval the waste must comply with the conditions stated in the safety report of the repository. For packages of waste ordinarily produced by the nuclear power plant a type certificate can be issued. Such approved type certificates will be included in the safety report of the waste producing plant, as well as in the safety report of the final repository.

No specific regulatory requirement exist on minimization of radioactive waste, except what follows from the requirements of ALARA (see section 15.1). The Swedish position is that such requirements could be detrimental to safety, for instance through higher burn-up of the fuel. As disposal of spent fuel and nuclear waste are very expensive, the licensees have a powerful economical incentive to keep the volumes, as well as the activity, low.

19.2 Measures taken by the licence holders

19.2.1 Initial authorisation

No nuclear units have been commissioned in Sweden since 1985, when Forsmark 3 and Oskarshamn 3 went into commercial operation and no more units are planned or under construction. Hence, the convention text (i) is not really applicable. Re-commissioning a unit after a long forced shut-down or due to the installation of new and extensive systems has, however, been applied as mentioned above.

All the Swedish units in operation have been analysed and have followed commissioning programmes in order to demonstrate their consistency with the design and safety requirements, specified in laws, regulations and standards, that existed when they were started up, see also chapter 14. The objective of this programme was to develop a PSAR before commencing the design, construction and erection of the unit, and later a FSAR, and through extensive operational tests to verify bothe the function of the different individual systems and their joint function. Permission to start up the units was given in steps by SKI after completion of the different operational tests, and reporting of the results of the start up stages. Permission for commercial operation was given when the operational tests were satisfactory completed and reported, and FSAR and technical specifications were accepted.

19.2.2 Operational limits and conditions

The operational limits and conditions of the reactor units are described in the Technical Specifications (STF), a document, which is considered one of the cornerstones in the governing and regulation of the operation of the Swedish NPPs. Every STF is unit-specific and is approved by SKI as a licensing condition. STF for the older units were produced in close cooperation between the nuclear utilities and, consequently, the structure of the documents is similar for all STFs in the country.

The original STF for each unit is derived from the safety analyses in the FSAR, where the behaviour of the unit, when different transients and abnormal events occurred, was described. However, several revisions have been made in all STFs since the first versions were issued. Corrections and updating takes place, when new and better knowledge is available, either from research and tests or operational experience. Suggestions for changes in STF are reviewed carefully from the safety point of view at different levels in the operating organization and are finally approved by the regulatory body, before they are introduced into the document.

The fact that STF is reviewed and revised regularly has contributed to making it a living document. It is also part of the quality and management system and used frequently in particular by the operations staff.

An essential part of STF is the earlier mentioned (see section 10.1) general clause that says that "…should any doubt appear about the interpretation of the text, the general purpose of STF shall be guiding. This means that the unit in all indefinite situations shall be maintained or brought respectively to a safe state." Other parts of STF, which have been developed at a later stage are the specific chapter concerning the conditions during refuelling outages, and the description of the background to the document. The need of a specific chapter for the outage conditions became obvious at an early stage and such a chapter was implemented at most of the units during the early 1980's. The ordinary STF was written for operational conditions and did not give the operators the kind of support they needed when the unit was being refuelled and maintained, with a great number of the safety systems out of operation. Since the implementation of the "Outage-STF" they have better control of the safety conditions in the unit. The background description is important for preserving and carrying further to new staff the knowledge and experience of those who participated in the original production of STF. The structure and contents of a typical STF are shown in Figure 19.

When introducing modifications and accomplishing in-service inspections according to inspection programmes, these have to be followed up with certificates about conformity issued by an accredited organization. Before being accepted for continuous operation modified and maintained equipment must also pass an operability test, that verifies that the equipment fulfils specified operational requirements.

Due to some recent incidents at the plants, SKI has required the licence holders report how they verify the operability of safety systems after the completion of for instance maintenance work. The incidents also forced the operators to re-consider their routines when leaving the cold shut-down mode and moving into the power operation mode, which is regulated by STF. This analysis included the follow-up of on-going and finalized maintenance work, as well as functional tests, but also rounds in the central control room and verification of the operability of passive safety systems. The analysis led to various improvements at the different plants. Implementation of general operability schemes and improvements of current routines for operating procedures when going from shut-down to power operation have been reported to SKI. The following are examples of measures taken according the later category:

- More strict signing of single actions taken according to procedure sequences.
- Better co-ordination of operating procedures and routines for the start-up phase.
- The operability verification of safety systems is enhanced in procedures.
- Deviations from procedures are handled more formally.
- Computerised planning systems are implemented for the shift changeover.

A preventive MTO-analysis has been performed at Barsebäck in this area in order to reveal weaknesses in the current approach to verification of operability. Communication between the plants has been started with the objective of exchanging experience and strengthening this administrative barrier of safety. In addition, the requirement on verification of operability will be considered during the modernisation processes going on in most units, particularly when it comes to the design of the control rooms.

Figure 19.

Structure and content of Technical Specifications (STF) – Example

1. General
1.1 General regulations
1.2 Definitions

2. Safety limits
2.1 Safety limits with respect to fuel cladding integrity
2.21 Safety limits with respect to primary system integrity

3. Operational limits and conditions
3.1 Core instrumentation, safety chains and information ystems
3.2 Limitation of core power with respect to emergency core cooling
3.3 Reactivity control
3.4 Emergency core cooling
3.5 Primary system integrity
3.7 Reactor containment
3.8 Residual heat removal systems
3.9 Emergency ventilation and closure of reactor and turbine buildings
3.10 Electrical power supply
3.11 Radioactive releases and activity control
3.12 Boron changes
3.13 Fuel pools and fuel management
3.14 Heavy transports in the reactor building
3.15 Fire protection systems
3.16 Plant manning
3.17 Low and intermediate level waste management
3.18 Filtered pressure-relief of the rector containment
3.19 Safety equipment in external buildings

4. Surveillance tests
4.1-19 Same content as chapter 3.

5. Administrative regulations
5.1 Operating organisation and safety reviews
5.2 Principles for operations and maintenance management
5.3 Documentation
5.4 Routine reporting
5.5 None-routine reporting
5.6 Conditions for continued operation after occurred unforeseen event

6. Background to technical specifications, chapter 1 - 3

7. Conditions and limits at rector water temperature < 100 °C

8. Background to technical specifications, chapter 7.

19.2.3 Approved procedures

All activities that directly affect the operation of the plants are governed by procedures of different kinds. Normal operation, emergency operation and functional tests are included in this category. Maintenance activities according to an approved maintenance programme are also to a great extent accomplished according to procedures, however, not always as detailed as operating procedures, where activities are described in sequences step by step. Signing of steps carried out in the procedures is mandatory in most cases, in order to confirm the completion and facilitate verification.

The operations personnel are deeply involved in the production and revision of operating procedures. Normally, the different process systems are ”distributed” among the shift teams and part of the team ownership of the systems is the responsibility to develop, review and revise their operating procedures.

The development of procedures follows specified directives, which include the reviewing of the documents, normally, by more than one person other than the author, before being approved by the operations manager or someone else at the corresponding level. The same applies for revising procedures. Revising procedures is to be carried out continuously, or particularly in the case of maintenance procedures, when new experience is obtained.

The full-scale simulators of the units are used as far as possible when verifying a new or revised operating procedure

19.2.4 Response to anticipated operational occurrences and accidents

Emergency procedures have been developed in order to deal with anticipated operational occurrences, but also with severe events and accidents. Emergency procedures for individual systems are complemented with symtom based accident management procedures for the all units. The latter ones represent a link to the safety panel display system (SPDS) which exist at some Swedish units as part of the accident management system. The accident management procedures are also the link to the emergency planning and its criteria for issuing of alarm. In Figure 20 the common structure of procedures applied in emergency situations is shown. Procedures for extraordinary situations, in the top of the pyramid, include procedures for the engineer-on-duty, the operative emergency response plan, and technical handbooks for dealing with severe accidents beyond the design basis.

19.2.5 Engineering and technical support

The principles for staffing of the NPPs are reported in section 11.4.

Competence that might not be fully available within the own organization at all plants is for instance expertise and resources for:

- PSA,
- core design and calculation,
- accident analysis,

- materials and chemistry assessments,

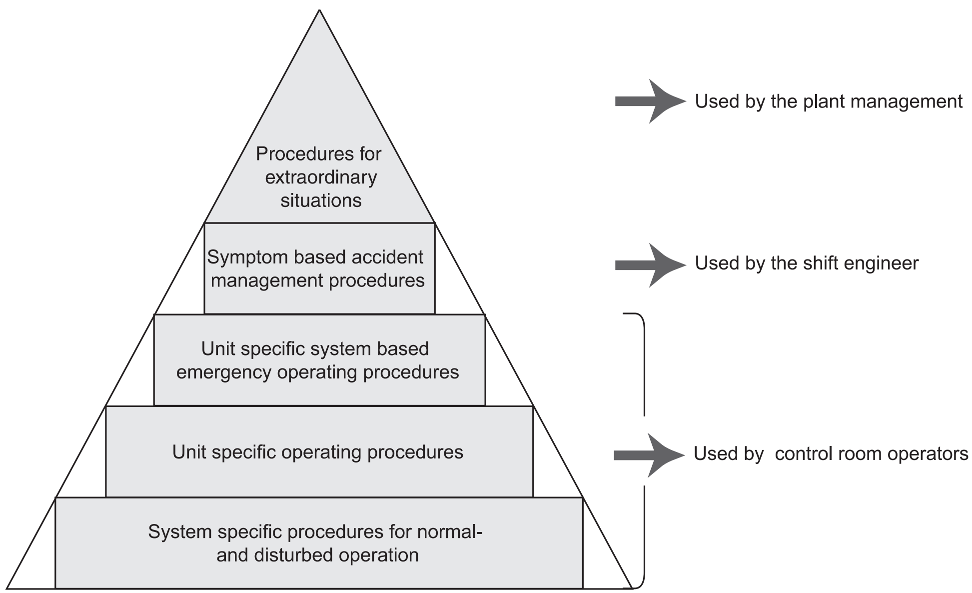
- radiation shielding and environmental consequence calculations.

Although highly qualified expertise is not available in-house in some specific areas, the intention is always to have the ordering competence within the operating organization, and the capability of evaluating the results of analyses, calculations, etc. performed by consultants.

19.2.6 Incident reporting

Incidents significant to safety are reported according to the non-routine reporting requirements in the technical specifications (see section 19.1.6). Two types of licensee event reports (LER) exist. The more severe one, called abnormal event (OH), requires that the plant inform SKI within an hour, and in some cases also SSI. A final report shall be submitted within ten days from the time of the event and the analysis of the event and appropriate measures to prevent recurrence shall be approved by SKI before the re-start of the reactor. Only

Figure 20. Overview of the main procedures applied during emergency situations. Other documents exist as refrences to the main procedures. The level of detail and the number of procedures decreases with the hight of the pyramid.



a very limited number of events of this category have occurred at the Swedish plants over the years. These events are typically also of such a dignity to warrant reporting according to the International Nuclear Event Scale (INES).

The other type of LER, called RO (Reportable Occurrence), is used for less severe events, typically 30-40 per unit and year. This type of event is mentioned in the daily report, which is sent to the regulatory bodies, followed up by a preliminary report within seven days and a final report within 30 days. Events that have resulted in a reactor shut down are analysed by the operations department and reviewed by the safety department, and on some sites by the relevant safety review committee before the re-start of the unit. The reports are reviewed at different levels within the operating organization and approved by the operations or production manger before submittal. As well as a wide distribution within the own organization and to the regulatory bodies, the reports are sent to the other Swedish NPPs.

The front side of the standardized report form describes the event in general: identification number, title, reference to STF, date of discovery and length of time for corrective actions, conditions at the time it occurred, system consequences, a contact person at the plant and activities concerned by the event. On the reverse side of the document a description of the event is given. The following titles are used:

- Event course and operational consequence
- Safety significance
- Direct and root causes
- Planned/decided measures
- Lessons learned by the event

If the description of the event is comprehensive, additional pages are added to the form. As an example the reporting form used by OKG is shown in Figure 21.

Reports are also required in accordance with STF when exceeding the permitted levels of activity release from the plant or in the event of unusually high radiation exposure to individuals at the plant. These types of non-routine reporting are primarily directed towards SSI.

19.2.7 Operating experience analysis and feed-back

The objective of the operating experience analysis and feed-back programme is to learn from their own and others'experience and prevent recurrences of events, particularly those that might affect the safety of the plants. The operating experience process consists of a wide variety of activities within the plant organization as well as externally. A number of activities are described very briefly below.

The major operating experience feed-back comes from the plant itself and consequently the largest plant analysis effort is focused on the events in their own reactor. The RO-reports constitute an essential input into this analysis task, together with specific operating experience reports that are written for events not meeting

Figure 21.

OKG AKTIEBOLAG
– ett företag i Sydkraftkoncernen

Page 1 (2)

Licensee Event Report **Unit No** **Report No**

Title

System **Component**

☐ **Preliminary** ☐ **Final** **Rev**

The report written according to requirements in Technical Specifations, section **Paragraph**

The event is a deviation from operational requirements in TS, sub chapter

Detected Date Time	**LCO**
Back in operation Date Time	**Last verified operable**
Repair time Hour Min	**Unavailability** Hour Min

Reported by **Date**

Checked **Approved**

OPER'NAL STATUS WHEN DISCOVERED	OPERATIONAL CONSEQUENCE	CONSEQUENCES ON SYSTEM LEVEL
☐ Refuelling	☐ Hydraulic scram Auto☐ Man	☐ Total loss
☐ Cold shutdown	☐ Mech. scram Auto☐ Man	☐ Reduced system function
☐ Hot shutdown	☐ Turbine trip Auto☐ Man	☐ Extra reduced redundancy
☐ Nuclear heating	☐ Power reduction %	☐ Reduced redundancy
☐ Hot standby	☐ Recirc. runback Type	☐ No system consequence
☐ Power operation	☐ Reactor isolation Type	☐ Inapplicable
Thermal power % MW	☐ Nuclear island operation	
Generator power MWe	☐ Increased periodical testing	Fault notification, if any
	☐ No operational consequence	
	☐ Other consequences	
☐ Planned operation in progress		
☐	☐	
☐	☐	

Contact for experience feedback: Phone:

Internal special reports/references:

Interesting for: (final LER)	Opera-tion	Core physics	Industrial safety	Mech. mainte-nance	Electr. mainte-nance	I&C mainte-nance	Material Chemis-try	Emer-gency Prep.	QA	Training	Human factor

Distribution:

Report No LER Page 2 (2)

Event description and operational consequences

Safety impact

Root cause(s)

Actions taken

Lessons learned

the RO-criteria, or so called near-events. MTO-analysis is used, when root-causes and analysis in-depth are deemed necessary or desirable.

Analyses of scram- and RO-reports from Swedish, as well as Finnish BWRs, and also certain international information are performed by ERFATOM (see chapter 2), which is a group formed by the Swedish and Finnish BWR-operators and ABB Atom. The analysis work is performed by representatives of the organizations above and the result of the work is reported to the plants in weekly and monthly reports complemented with topical and annual reports. The event reports are classified; and the more severe ones also include recommendations directed towards the Swedish and Finnish operators.

For the PWRs, a process was established in Ringhals after the TMI-2 accident to systematically collect and analyse safety issues relevant for the Swedish units. Sources of information have been various NRC, INPO and WANO documents as well as information from Westinghouse and Framatome Owners Groups. In later years the same process has also been used to evaluate information from international sources, relevant for the Ringhals 1 BWR. In recent years about 600 reports etc. per year have been screened for its relevance by the Ringhals organization.

All Swedish RO-reports are registered in a database operated by KSU. The database is intended for the use by the operators, who have direct access and use it for specific purposes, and for KSU, which uses it for statistics and different types of trend graphs. A newly presented report from KSU showed that 35-40 % of all RO-events and 50 % of all scrams are MTO-related, i.e. the interaction between man, technology and organization is part of the cause in these events. The report also indicates that among the most frequent root-causes are lack of self-checking for prevention of failures, deviations from procedures and deficiencies in the process of verification of operability. The number of MTO-related RO-events at the Swedish NPPs is not alarming from a safety point of view, but there are also economical, as well as public information reasons, why the plants should try to reduce the number, and for some time attention has been directed towards this area. One should, however, be careful when drawing extensive conclusions from this material, because there are uncertainties in the underlying information and the RO-forms were originally made for technical failures, and are not fully adapted for human factors analysis.

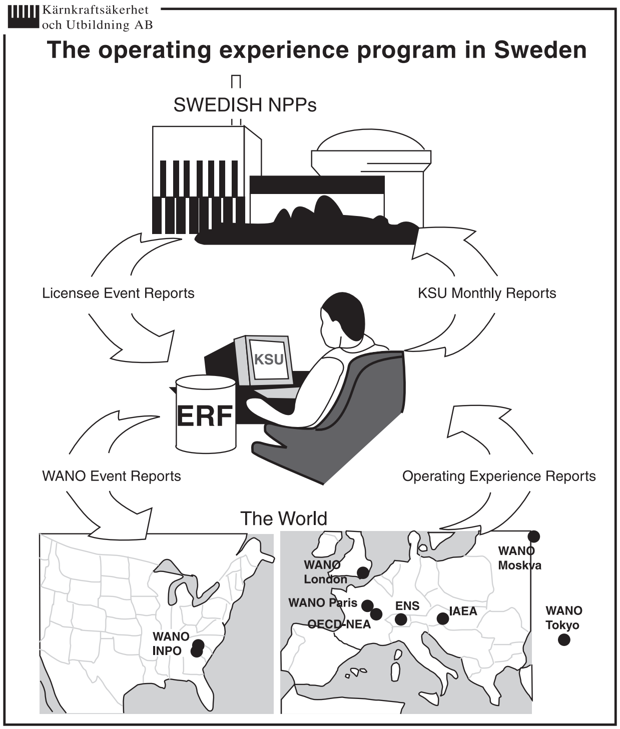
Information about operating experience distributed by organizations like WANO, INPO, IAEA, OECD-NEA and NucNet is collected, reviewed, thinned and sorted by KSU before distribution to the NPPs. The information is distributed as monthly reports, but also as special reports, when this is considered appropriate. KSU also produces an annual report summarising the performance of the Swedish NPPs, unit by unit, but also containing special articles about interesting events. The annual report is issued not only in Swedish but also in English in order to satisfy the interest of foreign operators.

KSU is also the link for reporting events from the Swedish NPPs to the WANO Event Reporting programme. Based on the Swedish LERs KSU chooses the events that meet the WANO-criteria and together with representatives of the affected NPP, KSU produces the WANO event report for world-wide distribution.

Figure 22 gives a brief overview picture of the information flow of operating experiences between Swedish NPPs, KSU and international organizations.

The routines for handling the experience feed-back information varies between the plants. At the Oskarshamn units for instance, experience feed-back co-ordinators and specific meetings on experience feed-back issues are part of the experience feed-back programme. The co-ordinators, belong organizationally to the operations department, make sure that information from KSU and ERFATOM is distributed to relevant personnel in the different departments for information or for comments and analysis if required. The more severe events from the ERFATOM-reports, certain foreign events and MTO-analyses are normally discussed at the experience feed-back meetings. Decisions about changes, based on the information gathered at the experience feed-back meetings, are taken by the operations department. In certain cases, when ERFATOM makes recommendations, information about resultent actions is submitted to ERFATOM. In particularly, trends and conclusions of the experience feed-back work are discussed in the various safety review committees at the plants.

Figure 22.



19.2.8 Generation of radioactive waste

The objectives of the waste management at the sites are to

- minimize the amount of waste

- ensure that all nuclear waste is handled and conditioned for the final deposition according to current laws and authority requirements, and

- accomplish the waste management in a safe and cost-efficient way with the least possible impact on human health and the environment.

Waste minimization is in certain cases substituted by optimising the waste generation, when consideration is taken to radiation doses and costs. Minimization of the amount of waste is, for example, achieved by reducing the amount of different kind of materiel that is brought into radiologically controlled areas, and by separation of waste at source.

Radioactive waste generated at the NPPs is of different kinds, and consequently treated and stored differently, as described briefly below.

Spent fuel

All spent fuel is stored in fuel pools at the NPPs on average for two years while awaiting transportation by m/s Sigyn to the central interim storage facility (CLAB) at Oskarshamn.

Intermediate-level waste

This type of waste is dominated by filter and ion exchange resins, which are mixed with cement or bitumen in concrete, or steel containers, or steel drums, of different sizes. The cement or bitumen immobilises the waste, while the containers and drums contain the waste, and in the case of concrete containers provide some radiation shielding.

Some intermediate-level filter resins with lower activity contents are placed in concrete tanks and dehydrated.

Metal scrap, and different types of garbage above a certain level of activity, also belong to this category and are placed in concrete containers, compacted, if possible, and grouted with concrete.

Low-level waste

After a separation process, with respect to activity content and combustibility, the low-level waste is compacted into bales or packaged in drums or cases, which are placed in standard freight containers. At three of the sites some waste with very low activity level is disposed of in special shallow land burial sites at the NPPs. These deposits are covered with soil and the drainage water is checked regularly.

Some low-level filter and ion-exchange resins are stored in concrete tanks and dewatered. Some combustible low-level waste is shipped to Studsvik, where it is incinerated at a special facility. The ashes are collected in steel containers which are grouted with cement in larger drums.

The intermediate and low-level waste at the NPPs is stored temporarily in rock caverns or storage buildings awaiting transportation to the final repository (SFR) located near the Forsmark NPP. In order to fit into the SFR-programme, both when transported and when finally deposited, all containers and drums must be approved by the authorities.

For all waste management at the sites strict registration and documentation is required. Examples of data concerning the waste that is documented and entered into a database are

- Identity
- Type of package
- Date of production
- Category of waste
- Weight
- Activity content, nuclide composition and dose rate at a distance of 1m
- Position in the intermediate storage facility

The production and storage of radioactive waste at the plants is reported quarterly and annually to SKI, SSI and to the Swedish Nuclear Fuel and Waste Management Company, SKB (see chapter 2).

19.3 Regulatory control

Operational limits and conditions
Applications on changes in STF and on exemptions from STF are reviewed by a special standing goup of inspectors and specialists at SKI. Based on the assessemnts and information provided by the licensees and available safety analysis, assessments are made about how the proposed changes or exemptions contribute to the risk profile of the plant.

A few years ago SKI inspected the training and retraining in STF of operational-, maintenance and technical support personnel at all the NPPs. Included in the inspection was how the document is used and kept up to date. SKI concluded that the use of STF was well understood and the training of operational personnel was well organized. Hovever the training could be improved for other groups coming into contact with the requirements of STF, for instance personnel in the maintenance - and chemical departments. It was also concluded that updating STF was sometimes slow, due to limited staff resources and that consultants were often used for this important task. Finally is was noted by SKI that underlying documents for STF existed or were under production for all units.Underlying documents would be a very helpful tool in training of new operators in STF.

Procedures
Operational and maintenance procedures are normally not reviewed by SKI. Only in connection with event investigations would SKI ask for a procedure to be submitted for review. In the frame of quality assurance inspections or review of quality audits made by the licensees (see section 13.3) SKI have looked into the routines used for updating procedures. The accident management procedures required in the Government decision of 1986 were, however, inspected by SKI in two ways

1. An inspection of the development and implementation status of the procedures in connection with approval of the accident mitigation measures late in 1988. This inspection was followed up by another topical inspection in 1994. The validation, training, use, experience feed-back and updating of the procedures were studied. In general SKI was satisfied with the results but some recommendations were given to improve the feed-back of experience in the use of the procedures.

2. A review of the structure and contents of the procedures in connection with the topical inspection of 1994 on emergency preparedness. The relationship of the procedures with the technical alarm criteria was studied as well as the shift supervisor´s coordination of important technical decisisons with the rest of the emergency management organization. In this case SKI also made some recommendations to the licensees.

Engineering and technical support

SKI has not so far specifically inspected the engineering and techical support available at the NPPs. In connection with other inspections and reviews, the staffing situation has occasionally been commented upon.

However the former Director General and one expert of SKI participated in a government commission appointed in 1988 to review the national demand and supply up to 2010 of qualified staff for nuclear operation, technical support and regulation. The commission was appointed as a result of the decisison at that time to close down two nuclear units, one in Barsebäck and one in Ringhals (see section 1.3). The decision raised concerns about the available nuclear competence in Sweden for the continued operation until shut down of the last unit. The commission report was issued in 1990[57] with a number of suggestions and recommendations. Some of these have been implemented, some are overplayed and others are still valid. SKI has suggested this kind of investigation be repeated (see section 6.2).

Incident reporting

Licensee event reports are reviewed upon arrival by the responsible site inspector, who asks the NPP for clarification if necessary. As a routine all arrived LERs are screened every week by a standing group of inspectors and specialists in order to assess the event, the analysis and the measures taken by the licensees. If there are any regulatory concerns the issue is brought up at the management meeting in the Office of Reactor Saftey and further measures to be taken by SKI are decided.

On average 30-40 LERs per unit and year are sent to SKI and 0-2 scram reports. Less than 10 percent of the LERs cause a regulatory concern. In about 10 cases per year for all units a regulatory letter is sent requiring further measures. Most of these cases are connected with the outage period and with restart of the unit after outage where problems are detected by ordinary tests. A typical SKI requirement is extended tests or further investigation before restart is permitted.

A few individual events have over the years been reported as ”abnormal events” or, events of INES level 2 according to technical criteria.

[57] SOU 1990:40: Nuclear Power phase-out- competence and employment (in Swedish).

Experience feed-back analysis
All LERs and scram reports from the Swedish NPP units have for several years been registered in a database at SKI (STAGBAS). With this data SKI conducts systematic trend analyses. The results are published in ”Incident catagogues” where the trends for different areas included in STF can be compared for a specific unit with the average for the reactor type. The total number of LERs, the proportion of recurrent failures and the causes stated in the LERs are also presented. This material is used in different ways in the regulatory supervision. The ”Incident catalogues” are also distributed to the licensees, but they are not intended to replace the trend analysis to be conducted by the licensees themselves. SKI does not have the detailed knowledge of the plants which should govern the utility work with trend analysis.

In 1995 SKI inspected the organizations and routines for internal and external experience feed-back at the NPPs. In general the situation was satisfactory, but some recommendations were made to improve the analysis of events from other NPPs.

Radioactive waste
Inspection of the on-site technical handling of spent fuel and nuclear waste is occasionally carried out by the SKI site inspectors reinforced with specialists from the Office of Nuclear Waste Safety. Sometimes inspectors from SSI participate in these inspections. In addition SSI also inspects the radiation protection apects of the waste handling. A major effort by the specialists of the SKI Office of Nuclear Waste Safety has been to review and approve the type packages produced at the NPPs for final disposal in SFR, or regarding spent fuel in the intermediate storage CLAB. This review is also made in cooperation with SSI. In 1992 a major topical inspection was conducted of the organization, competence and routines for the on-site waste handling, including waste reduction measures. The inspection resulted in a number of recommendations, but the general situation was found to be satisfactory. Other regulatory measures include review of the quarterly and annual licensee reports on production and storage of nuclear waste on-site.

19.4 Conclusion

The Swedish Party complies with the obligations of Article 19.

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