In J. Misumi, B. Wilpert, R. Miller (eds.) (1999): Nuclear Safety: A Human Factors Perspective, Taylor&Francis Ltd. ISBN 0-7484-0818-5.

CHAPTER THREE

Finnish and Swedish practices in nuclear safety

BJÖRN WAHLSTRÖM
Technical Research Centre of Finland
VTT Automation

In the conviction that a consideration of similarities and differences between approaches to safety could be beneficial in the field of nuclear energy, a comparative study was carried out to collect reliable, non-anecdotal information about Finnish and Swedish nuclear safety practices. Observed differences proved to stem mostly from the way in which the respective nuclear power programmes had evolved. The methodology developed in the study was based on a map of safety activities and their relationships, a conceptual overview that has formed part of the project in which the reported study was embedded. Data were collected in interviews with plant personnel and the competent Finnish and Swedish authorities. Results indicated important differences between the nuclear safety practices of Finland and Sweden, despite the two countries' large similarities.

Nuclear power accounts for an important share of the electricity generated in many countries. Nonetheless, there is also opposition to nuclear power in the same countries, a major concern being that nuclear power plants cannot be operated safely over extended periods of time. However, experience from plants that have performed well provides evidence that safe operation is possible. Finding out which characteristics make nuclear power plants operate safely at acceptable levels of output has thus become a key issue in the debate about this form of energy production.

Because operational experience has shown organisation and management to be central to safety and acceptable performance, some research has focused on identifying organisational factors that can affect safety and operation. It has, however, been difficult to make the findings specific enough for application to the daily routines at nuclear power plants. It has also been difficult to assess the extent to which findings are exchangeable between different cultural environments.

The study reported in this chapter was carried out as a part of a project conducted within the Nordic research cooperation on nuclear safety (NKS). The aim of the project, RAK 1: `A survey and an evaluation of safety practices', is to identify possible deficiencies and evaluate the effectiveness of safety practices, especially for activities with a large impact on safety. One part of the project was concerned with mapping a conceptual model of nuclear safety. The map illustrates the path between the requirements for various safety activities and the solutions to the problems they pose. The second part of the project, based on interviews, was intended to validate the map of nuclear safety practices and to provide non-anecdotal information about differences in safety practices. Data for that study were collected in 62 interviews in Finland and Sweden with the personnel at nuclear power plants, the relevant authorities, and one reactor vendor. The total effort spent in the project from 1995 to 1997 has been approximately half a person year per year, not counting the effort of the project reference group and the persons interviewed.

3.1 BENEFITS OF A COMPARISON

The safety of nuclear power depends not only on technically successful plant designs, but also on management and work practices. This understanding has been captured in the concept of safety culture that was introduced by the International Atomic Energy Agency (IAEA) after the Chernobyl accident (INSAG, 1991). Perhaps the most important aspect of the concept is the realisation that the commitment to safety by individuals and society is a major precursor for safety and efficiency, but that this commitment is not enough. Management and work practices also have to be efficient in pursuing the high-quality execution of all tasks. Nuclear power plants have to operate in a commercial environment, which means that it should be possible to perform all necessary tasks competitively.

Studies on the operational performance of nuclear power plants have indicated wide differences (see Beckjord et al., 1987, IAEA, 1989, Marcus et al., 1990). Some plants have been able to achieve high energy availability year after year, whereas other plants have trouble reaching the relatively modest average level of the nuclear power plants in the world. The difference in income from sold electricity gives an immediate impression of the problems poorly performing plants have to struggle with. Typically, they have a large backlog of modifications and improvements to be carried out. Sometimes urgent investments may add up to a major share of the annual turnover. By contrast, well-performing plants typically have their operation in order and can invest in fine-tuning the plant for optimal performance.

Findings from several operational safety review teams (OSART) missions of the IAEA highlight practices of well- and not-so-well performing plants. `At each plant visited there are some practices or ideas which could be adopted by others ... and some areas where improvements could be made have been identified even at the best plants' (IAEA, 1988, p. 4). This observation indicates that an exchange of sound practices between plants could benefit the whole industry. But is an exchange of safety practices possible? A blind exchange may not be feasible, for such practices are anchored in a cultural environment. Suitable interpretation and translation of them, however, should make it possible to transfer the principles rather than exact

scripts. There is also an incentive to transfer sound operational practices: the industry as a whole is judged by its worst performers (Rees, 1994). Only openness and self-regulation will be able to neutralise the political hostility toward the nuclear power industry in many countries and possibly even build support for nuclear power.

Experience from the business world indicates that comparisons and benchmarking are efficient ways for a plant to improve its performance. An in-depth comparison of practices, performance indicators, and company cultures permits an assessment of a plant's strengths and weaknesses. A feasible way to achieve a transfer of sound operating practices is thus to use bench marks for two or more actors in the field. The benefit of the comparison then becomes the awareness of other practices and the necessity of assessing their potential benefits. Awareness of other practices makes it easier to see the advantages and disadvantages of a plant's own practices and can help fine-tune them without major changes.

3.2 THE NUCLEAR POWER PROGRAMMES IN FINLAND AND SWEDEN

'The nuclear era in Sweden began in 1956 when the company AB Atomenergi filed application to build and operate a materials research -reactor in Studsvik (a small village near Nyköping, about 50 miles southeast of Stockholm). AB Atomenergi was also involved in the construction of the first nuclear power reactor in Sweden, the Ågesta, which delivered district heat to a suburb of Stockholm from 1964 to 1974. An upgraded version of this plant, the Marviken reactor, was abandoned when an analysis revealed problems in maintaining core stability.

The first electricity-producing reactor in Sweden, Oskarshamn 1, was ordered in 1965 by Oskarshamnsverkets kraftgrupp AB (now OKG) from Asea Atom (now ABB Atom). That facility was followed by four more Swedish reactor orders to ABB Atom, each one with improved constructions to be built in Ringhals, Barsebäck, and Oskarshamn. The first reactors ordered by the Swedish State Power Board (Vattenfall) were a boiling water reactor (BWR) from ABB Atom and a pressurised water reactor (PWR) from Westinghouse in Ringhals. The Ringhals PWR reactor was followed by two more PWRs. At the fourth nuclear site in Sweden, Forsmark, two BWRs, Forsmark 1 and 2, were built by ABB Atom. These reactors were all improvements on the earlier generations, and another round of improvement was made by ABB Atom in its Oskarshamn 3 and Forsmark 3 reactors.

In Finland serious consideration of nuclear power for generating electricity was initiated in 1963, when the council of IVO (the largest Finnish power utility) authorised its board to ask for tenders for a nuclear power plant. The tenders were opened in 1965, but no order was placed at that time. In 1968 the Finnish government decided to postpone the whole project for building nuclear power plants. In 1969 discussions were opened anew, and one PAIR plant was ordered from the Soviet Union, together with an option on a second installation. Soon after, private industry in Finland formed a new power company, TVO, which ordered one BWR plant from ABB

Atom with an option on an additional one. Orders for the two options were placed soon afterwards.

The situation of nuclear power in Finland and Sweden today is different from that of the early 1970s. In keeping with the decisions after the referendum on nuclear power in 1980, Sweden has decided to phase out nuclear power by the year 2010. In Finland a consortium between IVO and TVO applied for a decision in principle to build a fifth nuclear power unit, but the application was narrowly defeated in parliament in 1993. The discussion in Finland on further reactors has stalled, but at regular intervals voices are heard in favour of reopening the question. The discussion in Sweden has been more concentrated on when, how, and which units are to be shut down ahead of schedule. Both industrial management and labour unions are lobbying for reconsideration of the decision to phase out nuclear power, but so far without result.

3.3 REGULATORY ENVIRONMENTS IN FINLAND AND SWEDEN

Nuclear power in Finland and Sweden is regulated by national laws and regulations. The first Atomic Energy Act in Sweden was passed in 1956 and in Finland 1958. Both Acts stipulated that the operation of nuclear facilities requires an operating license awarded by the authorities. The Acts have been revised in both countries several times. A major amendment of the Nuclear Energy Act in Finland was passed in 1987 after a long discussion dating as far back as 1978. The Act is rather detailed and contains technical safety requirements. A decree in 1988 and a decision by the Finnish government in 1991, laid down further details on how to ensure the safety of nuclear power plants.

Laws and regulations in Finland and Sweden empower a national authority to act as a regulator. In Sweden this authority is split between two bodies, the Swedish Nuclear Power Inspectorate (SKI) and the Swedish Radiation Protection Institute (SSI). In Finland the Finnish Center for Radiation and Nuclear Safety (STUK) regulates both reactor safety and radiation protection. Both in Finland and Sweden the responsibility for safety is placed squarely on the operator of the nuclear facilities. The authorities have the power to require the facilities to shut down if there is any doubt about their_ safety. Operating licenses in Finland have always been issued for a limited period, but in Sweden such restriction is only the exception.

Finland and Sweden differ greatly when it comes to the details of the requirements for operating a nuclear power plant. In Finland STUK has written a comprehensive set of safety manuals, the YVL guides, which take a stand on various issues. Salminen (1997) gives a recent presentation on the use of these guides. Their creation goes back to the Loviisa NPP project, in which the agreement between the utility and the vendor called for the licensing of nuclear power plants to be subject to Finnish requirements. The YVL set presently consists of about 70 guides arranged into eight technical areas. They are updated regularly and go through a detailed

reviewing process before they are adopted. The YVL guides are not mandatory but do represent a strong recommendation. They are relatively general, giving a frame in which the designers of nuclear power plants are granted relative freedom. The YVL guides have a legal status lower than the decisions of STUK. That is, a new guide will not automatically be applied to an old plant, but new guides are known to have been made mandatory after a certain transfer period.

The Swedish licensing and inspection systems are quite different from the Finnish. The system in Finland is to a large extent governed by the YVL guides, whereas this kind of a system does not exist in Sweden, where American regulations are used instead and reference is made to the US Nuclear Regulatory Commission requirements. In Sweden a license to operate a nuclear power plant is awarded on the basis of an application, to which a final safety analysis report (FSAR) is attached. For the most part, the substance of an FSAR is based on a common understanding between SKI and the applicant. When the application is accepted, the FSAR is seen as an integral part of the license and, in a way, as an agreement between the authority and the utility on the construction and operation of the plant. Inspections are performed to ensure that actual practices are in compliance with the requirements of the FSARs. When new requirements are adopted, they are communicated to the licensees in regulatory letters. The situation with regard to more general requirements is going to change in Sweden. In the most recent update of the nuclear energy act in Sweden SKI was given the authority to issue its own regulations, and this process has begun.

3.4 SIMILARITIES AND DIFFERENCES

In this comparison of similarities and differences, it is fair to say that the former outnumber the latter. The differences are easy to trace back to historical variations in the way in which nuclear power was introduced in Finland and Sweden. The largest difference is perhaps the fact that Sweden has its own national vendor for reactors. The idea of developing internal Swedish requirements was considered 'inappropriate, because Sweden hoped to receive export orders for her reactors. The decision to use American licensing guidelines is thus understandable. The rapid development of the BWR concept of ABB Atom has reflected great flexibility in approaches to new solutions, and a willingness to solve problems as they emerge. In retrospect, a problem with this model has been that the documentation of the designs has sometimes lagged behind and has not always been explicit enough.

The other major difference between Finland and Sweden is the present political climate surrounding nuclear power. In Finland the option to build additional nuclear power plants is still open, but Sweden is adhering to the date of 2010 for the phase-out of nuclear power. In Sweden this threat for the whole industry has been part of day-to-day life for more than ten years. Discussions with representatives of the nuclear industry reveal frustration with the situation and a fear that it may become difficult to attract young people to the industry. A similar concern for the age structure of the people employed by the industry is shared in Finland, and the construction of a new plant is considered important for the long-term development of competence in this field.

A major similarity between the plants in Finland and Sweden is their commercial success. All plants have been able to achieve high power-availability figures for many years, and they can be judged as very efficient with respect to all performance indicators. There are several reasons for this success. From the outset, the nuclear industry attracted the best and brightest young engineers, who are the ones most likely to have the innovative outlook upon which a nuclear power plant's design depends. The first important advances in the nuclear industry had already been taken in the major countries of the world, a fact that made it possible to achieve good results with reasonable effort. Both Finland and Sweden have an industrial infrastructure that is able to support large, high-tech projects. The practices associated with fossil fuel power plants had not become deeply entrenched either in Finland or Sweden, so it was possible to consider the needs of nuclear power with an unbiased mind.

Despite the fact that the nuclear power programme in Sweden is three times larger then that in Finland, SKI has fewer resources than the corresponding parts of STUK. This difference in resources is also reflected in working practices in that SKI channels its inspection efforts more to the safety processes of the utility companies than to technical details. This focus is reflected in SKI's continued pursuit of plans for risk-based regulation designed to help direct its attention to the most important activities.

There is efficient communication, both formal and informal, between the authorities and the utilities both in Finland and Sweden. Regular meetings are held at each hierarchical level, and difficult issues are confronted openly in discussions. Scientific societies, committees, steering groups for research projects and similar kinds of contact fora provide the opportunity for representatives of the organisations involved to meet and exchange views on current problems.

Swedish and Finnish procedures for considering human factors and organisational issues differ. In Sweden all nuclear power plants and SKI have their own 'man-technology-organisation' or MTO groups. These groups have been given the responsibility of supplying their respective organisations with expertise in the behavioural sciences. The members of an MTO group analyse events and incidents for human errors and organisational deficiencies, participate in audits and reviews, and advise on major modifications in the plants. These groups also have a large influence and are valued by technically oriented people. In Finland general opinion has been that such specialised groups are not needed, and that the issues they address can be dealt with as a part of technical considerations.

The authorities and the utility companies in both Finland and Sweden have close contact with international bodies. Working groups of the IAEA and OECD's Nuclear Energy Agency (NEA) have proved to be important fora for communication with international experts. The utility companies have engaged in user-group cooperation. The contact network of the World Association of Nuclear Operators

(WANO) provides a significant channel for both international experience and exchange programmes between nuclear power plants.

The training of control room operators in Sweden is centralised in Studsvik, where KSU, a company owned by the Swedish utilities, operates simulators for all the Swedish plants. In Finland simulator training has been decentralised, with simulators being operated by the utility companies themselves at their plant sites.

Education and research are central to maintaining long-term safety in nuclear power plants. In recent years the number of university graduates with a specialisation in nuclear engineering has been decreasing both in Finland and Sweden, but so far it has been possible to meet the nuclear power industry's most urgent needs. ABB Atom and the power companies in Sweden have initiated programmes for young university graduates to be trained in various skills considered important by the industry. In Finland no such programmes are operated, but a pool of skills is maintained by the Technical Research Centre of Finland (VTT). In Finland public research on nuclear power is funded by the Ministry of Trade and Industry, but in Sweden SKI administrates the research directly. Much of the research on nuclear power in Finland is conducted by the VTT, in cooperation with STUK and the utility companies. In Sweden no similar research organisation exists, and the projects are scattered between consultant companies and university groups.

3.5 ONGOING ACTIVITIES

In Finland and Sweden major restructuring of the electricity supply has been initiated. The development follows the path already taken by the United Kingdom and Norway, where an electricity market has been established. This restructuring implies that competition is being brought into electricity production. Electricity utilities are being broken up into production companies and companies responsible for the operation of the electricity grid. Electricity transmission and distribution is considered an infrastructure where a monopoly is acceptable. Upon payment of a connection fee, a producer is allowed to use this infrastructure to deliver power to customers. The restructuring process has influenced the ownership structure of the whole industry, in which many mergers and new contacts have taken place since 1995. Among the nuclear utilities there have been fears that increased competition will make it more difficult to exchange information important to safety.

The nuclear power plants both in Finland and Sweden are going through major modernisations. The projects involved stem partly from a concern to ensure safe and uninterrupted operation for additional decades, and partly by a need to replace solutions that for various reasons are difficult to sustain. In Finland an additional motive for the modernisation projects is to increase the plants' electric power output. In Sweden there have also been political motives, reflecting a willingness to invest in continued operation of the plants.

In Sweden large projects have been initiated to reconstitute the design base of the country's nuclear power plants. This work was prompted partly by the incident in 1992 at Barsebäck where strainers were clogged far more rapidly than expected. This incident pointed to deficiencies in the design of the five older ABB Atom constructions. Two large projects, one for the Ringhals plant and the other for the Barsebäck and Oskarshamn plants, have been contracted to ABB Atom. A similar but smaller project has been launched by Forsmark. A deliberate decision has been to involve young people as much as possible, in order to facilitate the generational change of the nuclear industry in Sweden.

3.6 A MAP OF THE SAFETY PRACTICES

Information for comparing Finnish and Swedish activities in nuclear safety was collected on those activities which were regarded as the most important. However, the original idea of constructing a map of safety practices showing a path between requirements and solutions eventually proved somewhat difficult. A comprehensive picture of the safety activities involved can be achieved only through a combination of many different views.

Perhaps the most important components of all activities are the concepts of goals, planning, and feedback (see Figure 3.1). A goal is defined for all activities, a planning process is used to search for ways to achieve defined goals, and the feedback of actual outcomes provides inputs for improvements in the next round. Safety activities should be described and operational. The description of safety activities should be accurate enough to serve as a kind of procedure for how to do the work. Described safety activities are operational if actual practices match the description. Inspection can therefore be seen as a twofold process: described arrangements of the safety activities are compared with an ideal model, and it is then verified that activities are performed as described.

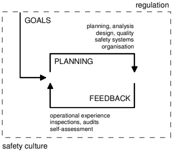

Figure 3.1 The generic components of safety practices.

It is proposed that the model of safety activities should include various angles of view. Systematic planning is an important part of all safety activities. Safety control can be seen as three interacting control systems: technical, administrative, and societal (see Figure 3.2). The administrative and societal controls involved are allocated to certain organisations, which are given the responsibility for their efficiency. The technical and administrative system of a plant can be described as in Figure 3.3, along the two axes of abstraction (e.g. goals, functions, and design) and aggregation (ranging from the system as a whole to its constituent parts), with the design of the plant typically advancing in the direction of the arrows. Three major processes interact in building a plant and its operational practices: design and construction, verification and validation, and licensing. Systematic *quality assurance* is a special aspect to be integrated in other activities, and it involves a description of work practices and regular audits. Safety precautions are structured around *threats and barriers*, an approach that also lays the foundations for the defence-in-depth principle (INSAG, 1997). Lastly, *quantification* of the efficiency of various safety precautions makes it possible to set priorities for possible improvements.

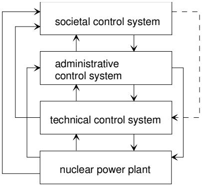

Figure 3.2 Three interacting control systems ensure the safety of a nuclear power plant.

An early version of these views on safety activities was used to structure interviews with various experts within the industry and with the safety authorities. The information collected in those discussions became the basis for refining the model of safety activities. The next step in developing the ideal model will be to formalise the concepts to make them more consistent and more accurately described. The model has been used for an assessment of the modification activities at nuclear power plants in Finland and Sweden. It can also be used to structure inspections and self-assessments at nuclear power plants, and can provide a scheme for a more systematic comparison of different approaches to nuclear safety.

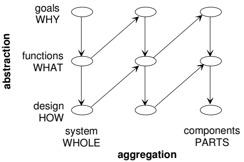

Figure 3.3 Relationship between abstraction and aggregation.

3.7 CONCLUSIONS

This review of Finnish and Swedish practices pertaining to nuclear safety has made several aspects of the topic clear. First, nuclear power has a political dimension that makes it unlike other industries. This fact has to be recognised when administrative and societal control systems are set up. Secondly, it is evident in retrospect that the effort needed to operate and maintain nuclear power plants has been underestimated in that industry. Nonetheless, nuclear power is still economically competitive compared with other methods of generating electric power. Thirdly, two explanations for the success of Finnish and Swedish nuclear power plants were given repeatedly in the interviews with safety authorities and experts. One was that engineers, authorities, and personnel in the Finnish and Swedish nuclear power industry have demonstrated a degree of farsightedness and a proactive approach to dealing with hazards. The other reason is that they have been prepared to learn from experience, to think for themselves, and to remain open-minded. These explanations stress the importance of systematic planning and the involvement of all personnel in the effort to optimise the use of skills and resources. They are also well in line with the safety concepts of feed-forward and feedback control suggested in Rasmussen (1987) (see also Wilpert in this volume). Fourthly, large similarities between Finland and Sweden must not be permitted to obscure the existence of important differences, which have been observed between Finnish and Swedish safety practices. Those differences are mostly of historical origin: that is, they have arisen from the ways in which the respective nuclear power programme developed. Fifthly, the results of the project seem to indicate that the concept of safety culture is immediately understood by people in the

nuclear community. To operationalise the concept, however, it may be necessary to include additional definitions and methods that will enable authorities and experts in the nuclear power industry to use it in their audits and self-assessments. If this concept is embedded in the map of safety practices and combined with appropriate organisational and cultural theory, it can provide insights into this process of redefining safety culture.

A well-designed and efficient plant, a strong economy and well-trained personnel certainly strengthen the likelihood of high performance. Neglecting these factors risks a downward spiral in operating conditions, a vortex of deterioration from which it is difficult to escape. Even for a plant that is performing well it is crucial not to stretch these resources too thinly, since the resulting lack of flexibility may endanger the working spirit of the plant personnel if something unforeseen happens. These reserve resources can in the meantime be put to practical use supporting international activities, such as creating new standards or providing help to countries that are struggling to enhance the performance of their nuclear power plants.

References

BECKJORD, E., GOLAY, M., GYTOPOULOS, E., HANSEN, K., LESTER, R. and WINJE, D. (1987) *International comparison of LWR performance* (MIT Energy Laboratory Report No. MIT-EL 87-004). Cambridge, MA: Massachusetts Institute of Technology.

IAEA (International Atomic Energy Agency) (1988) *OSART results: A summary of the results of operational safety review team missions during the period August 1983 to May 1987* (IAEA-TECDOC-458). Vienna: IAEA.

IAEA (International Atomic Energy Agency) (1989) Good practices for improved nuclear power plant performance (IAEA-TECDOC-498). Vienna: IAEA.

INSAG (International Nuclear Safety Advisory Group) (1991) *Safety culture* (Safety Series No. 75 - INSAG-4). Vienna: IAEA.

INSAG (International Nuclear Safety Advisory Group) (1997) *Defence in depth in nuclear safety* (INSAG-10). (Manuscript in preparation).

MARCUS, A. A., NICHOLS, M. L, BROMILEY, P., OLSON, J., OSBORN, R. N., SCOTT, W., PELTO, P. and THURBER, J. (1990) *Organisation and safety in nuclear power plants* (NUREG/CR-5437). Washington, DC: US Nuclear Regulatory Commission.

RASMUSSEN, J. (1987, *May) Safety control and risk management.* Paper presented at the IAEA/NPPCI Specialists Meeting on The human factor information feedback in nuclear power: Implications of operating experience on system analysis, design and operation, Roskilde, Denmark.

REES, J. V. (1994) *Hostages* of *each other. The transformation of nuclear safety since Three-Mile Island.* Chicago: University of Chicago Press.

SALMINEN, P. (1997) Renewal of operating licences of Finnish nuclear power plants. In International Atomic Energy Agency (IAEA) (ed), Reviewing the safety of existing nuclear power plants (pp. 139-50). Vienna: IAEA.