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Safety and Radiation Protection at Swedish Nuclear Power Plants 2007

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Summary and conclusions

Overall evaluation of the status of the plants

The safety level of the plants is maintained at an acceptable level. SKI has in its regulatory supervision not found any known deficiencies in the barriers which could result in release of radioactive substances in excess of the permitted levels. SKI considers that improvements have been implemented during the year in the management, control and following up of safety work at the plants. In some cases, however, SKI has imposed requirements that improvements be made. Extensive measures are under way at the nuclear power plants to comply with the safety requirements in SKI's regulations, SKIFS 2004:2 concerning the design and construction of nuclear power reactors, and the stricter requirements regarding physical protection. Concurrently preparations are underway at eight of the ten units for thermal power increases.

At the Forsmark plant considerable efforts have been during the year to correct the deficiencies in the safety culture and quality assurance system that became apparent in 2006. A programme to improve the execution of activities has been established in accordance with SKI's decision. SKI considers that the plant has developed in a positive direction but that there are further possibilities for improvement with regard to internal control. This is amongst other things concerns the areas internal auditing, independent safety review function, and working methods. SKI considers that the improvement programme has the potential to achieve good results for the activities. SKI has had special supervision[1] of the plant since 28 September, 2006.

At the Oskarshamn plant work has been carried out to improve the organisation and routines in several areas. The plant has established routines which provide the basis to ensure that decisions are taken in a stringent manner. The quality assurance system has a clearer structure and there is a better defined division of work. Some measures remain however to be dealt with in 2008.

The Ringhals plant has also worked with attitudes to routines and internal control. SKI considers that the measures have good prerequisites to provide a transparent basis for making decisions in safety matters. During the year it has however become apparent that further improvement measures are necessary. The plant has had a relatively large number of operational disturbances during 2007 which have been analysed in order to implement suitable measures.

Large safety related modernisations and strengthening of physical protection under way

SKI's regulations, SKIFS 2004:2, concerning the design and construction of nuclear power reactors, and SKIFS 2005:1 concerning the physical protection of nuclear plants, mean that extensive measures must be taken by the plants. Modernisation projects follow the time schedules which were decided earlier for implementation in order to comply with the regulations. Some measures are already completed, others are underway, and the programme will continue until 2013. There are some delays in the work related to the strengthening of the physical protection. SKI is supervising the progress of the modernisation and the

[1] Special supervision in this case implies specific requirements concerning regular reporting and special reporting in the event of any incidents as well as more detailed regular supervision of the plant.

improvements to the physical protection of the plants. Considerable regulatory supervision will be needed in the foreseeable future. In addition to the technical measures, it is important to ensure that the aspects concerning man-technique-organisation are taken into account in connection with plant alterations and that competence needs are clear for the different personnel categories.

Thermal power increases

The permitted thermal power for a reactor is stipulated in its license. Any increase requires permission from the government. Forsmark Kraftgrupp AB has applied for permission to increase the thermal power in reactors Forsmark 1 – 3. The government has not as yet granted permission for these power increases. SKI has approved trial operation for Ringhals 1 and Ringhals 3 at the increased power levels during the year. For Ringhals 3 this is the first stage of the planned power increases. Ringhals has also applied to increase the thermal power in Ringhals 4. A prerequisite for this increase is that the unit replaces its steam generators. There are also plans to increase the thermal power of Ringhals 1 to more than the government has already approved. The government has granted permission for the thermal power increase in Oskarshamn 3. SKI is currently performing a safety review of this application. Oskarshamn have made an application to increase the thermal power in Oskarshamn 2.

Nuclear safeguards and waste management

During 2007 SKI, as well as the international atomic energy organisation IAEA and Euratom, has performed inspections to control how nuclear safeguards are managed by the nuclear power stations. In all 80 inspections have been carried out. Nothing has been found during these inspections to indicate that there are any deficiencies in the nuclear safeguard activities.

SKI and SSI consider that the treatment, interim storage and preparations for final deposition of nuclear waste from the nuclear power plants have been carried out during the year in accordance with their regulations.

Radiation protection status

Radiation protection of personnel at the nuclear power stations during 2007 has been carried out so that doses to personnel have been kept at a level which is comparable with international levels for the actual radiation environments and the work performed. No serious incidents or accidents have occurred resulting in abnormal radiation exposure of personnel.

Radioactive releases from the plants have resulted in calculated doses to the most exposed person in the critical group that are well below the environmental impact goal of 10 microsievert.

Forsmark, which in recent years has had recurrent problems with the measurement of airborne radioactivity, has in 2007 made a considerable effort to remedy the problem. SSI’s preliminary assessment is that the measures should be sufficient, but need to be followed up for several years before definite conclusions can be drawn. This will be monitored as part of the normal regulatory supervision.

During 2007 SSI performed inspections at Oskarshamn and Forsmark aimed at assessing how the licensees deal within their own organisations with incidents and accidents with radiation protection implications. SSI considers that there a number of deficiencies which need to be remedied. Oskarshamn needs to improve how new instructions are applied in their own organisation, and Forsmark needs to improve the feedback of experience in the preventative radiation protection work. SSI considers however that both licensees have good ability to react in connection to incidents or accidents with radiation protection implications. SSI is planning to carry out a similar inspection at Ringhals in the spring of 2008.

With the aim of improving the radiation environment at the Barsebäck plant considerable efforts have been made to clean the reactor systems. SSI is positive to this and considers that the decommissioning will be able to be performed under better radiation protection conditions than would otherwise be the case.

In addition to inspections SSI has performed its supervision during 2007 in the form of plant visits and assessment of the reporting from the plants. SSI notes that the nuclear power plants have complied with the requirements concerning reporting in accordance with SSI's regulations. SSI notes further that no significant changes have occurred in the radiation environments at the plants. The radiation doses to personnel during the annual outages have been as expected with the exception of Oskarshamn 2 where the prognosis was exceeded by 0.8 manSv. The reason for this was that there were deficiencies in the planning and running of one of the projects being carried out. At Oskarshamn and Forsmark there is continued attention being paid to the problem of fuel failures in Oskarshamn 3 and Forsmark 3 with the aim at preventing further failures. Unfortunately SSI cannot identify any indications that the problem has been solved. Further effort will therefore be necessary in the future.

SSI also notes that signals are coming from the nuclear power plants that they are having difficulty in finding qualified radiation protection personnel at specific times. The licensees have the responsibility for maintaining an adequate and long term competence and resource assurance for radiation protection at the nuclear power plants and SSI intends to follow up this area as part of its continued regulatory supervision.

Emergency preparedness

SKI and SSI have throughout the year continued to follow and provide the impetus for the development of emergency preparedness at the plants. The questions which have been in focus during the year are the efforts addressing training and the transfer of information to rescue organisations and the authorities that would be involved in the event of an emergency. SSI has also followed up how their new regulations, SSI FS 2005:2 are being complied with. The authorities note that emergency preparedness at the plants has improved but that there is a need for further measures.

1. Premises and evaluation criteria

The Act (1984:3) on Nuclear Activities stipulates that the holder of a license to conduct nuclear activities has the full and undivided responsibility to adopt the necessary measures to maintain safety. The Act also stipulates that safety shall be maintained by adopting the measures required to prevent equipment defects or malfunction, human error or other such events that could result in a radiological accident.

In a corresponding manner, the Act (1998:220) on Radiation Protection stipulates that any person who conducts activities involving radiation shall, according to the nature of the activities and the conditions under which they are conducted, take the measures and precautions necessary to prevent or counteract injury to people, animals and damage to the environment.

Against this background the authorities shall in their regulatory activities clarify the implications of the licensees' responsibility and ensure that they comply with the requirements and rules for these activities and also achieve a high degree of quality in their safety and radiation protection work.

Basic principles for nuclear safety and radiation protection

Safety at Swedish nuclear power plants must be based on the principle of defence in depth in order to protect humans and the environment from the harmful effects of nuclear operations. The defence in depth principle, see *Figure 1*, is internationally accepted and has been ratified in the International Convention on Nuclear Safety and in SKI's regulations, as well as in many other national nuclear safety regulations.

Defence in depth assumes that there are a number of specially adapted physical barriers between the radioactive material and the plant staff and the environment. In the case of nuclear power reactors in operation the barriers comprise the fuel itself (fuel pellet), the fuel cladding, the pressure-bearing primary system of the reactor and the reactor containment.

In addition the defence in depth principle assumes that there is good safety management, control, organisation and safety culture at the plant, as well as sufficient financial and human resources. Personnel who have the necessary expertise and who have the right conditions for their work are also a prerequisite for defence in depth.

Defence in depth also assumes that a number of different types of engineered systems, operational measures and administrative procedures exist to protect the barriers and maintain their effectiveness. This is necessary both during normal operations and under anticipated operational deviations and accidents. If this fails, measures should be in place to limit and mitigate the consequences of a severe accident.

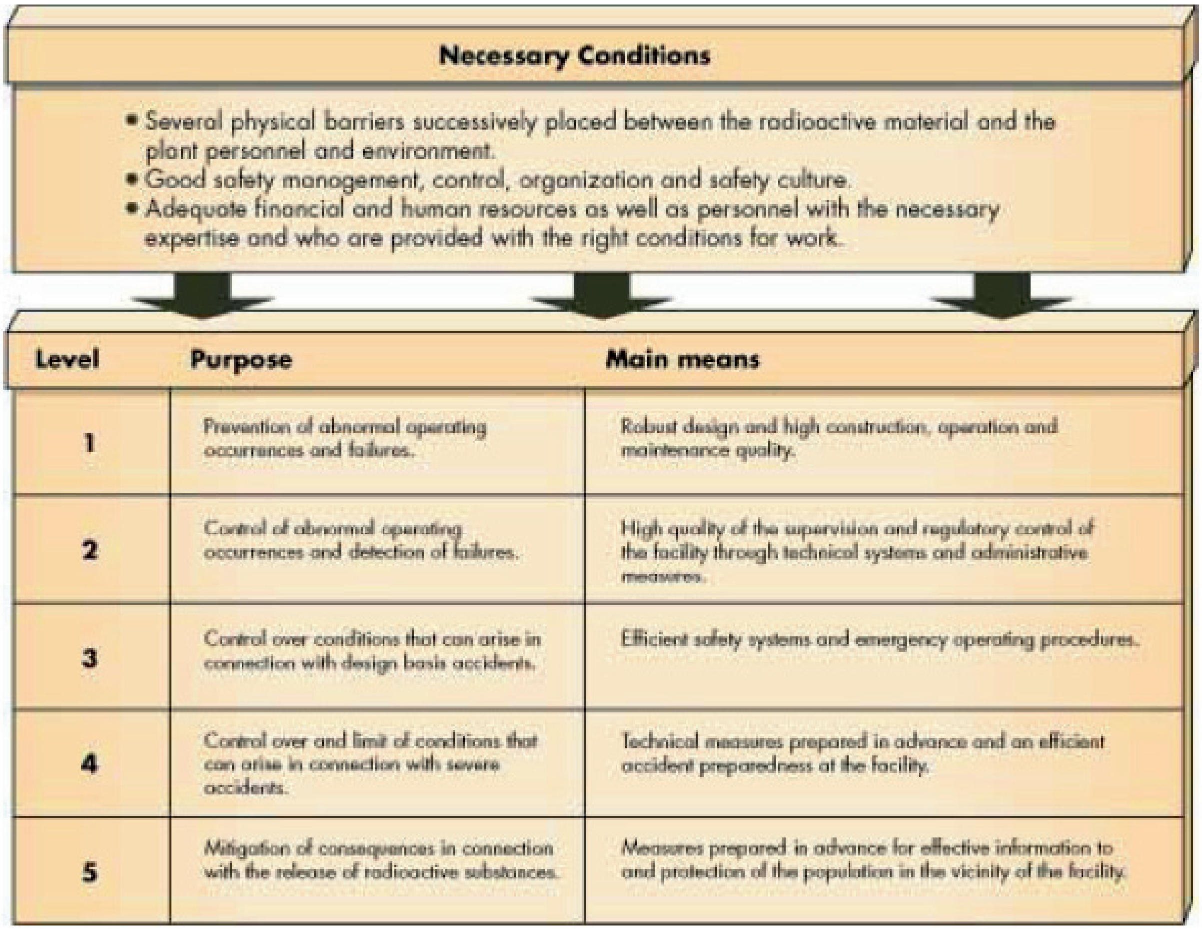
In order for the safety of a facility as a whole to be adequate, an analysis must be performed to identify which barriers must function and which parts of the different levels of the defence in depth system must function during different operational conditions. When a plant is in full operation, all barriers and parts of the defence in depth system must be functional. When the plant is shut down for maintenance, or when a barrier or part of the defence in depth system

has to be taken out of operation for other reasons, this must be compensated by other measures of a technical, operational or administrative nature.
Thus the logic behind the defence in depth principle is that if one level fails, the next level will take over. A failure of equipment or a manoeuvre at one level, or combinations of failures occurring at different levels at the same time, must not be able to jeopardise the performance of subsequent levels. The independence between the different barriers of the defence in depth system is essential in order to achieve this.

In Sweden radiation protection is also organised according to internationally accepted principles. These are based on the balance between usefulness and risk, and are:

– the use of radiation must be necessary, that is to say, no unnecessary applications are permissible
– the use of radiation must be optimised, that is to say, radiation doses must be as low as reasonably possible
– doses to all individuals shall be below the dose levels stipulated by SSI.

The requirements that SKI imposes on the different levels of the defence in depth system are described in SKI's regulations and the associated general recommendations. Correspondingly SSI has also stipulated radiation protection requirements in its regulations. Together these legal documents comprise the essential premises and criteria for the evaluation presented by SKI and SSI in this report.



Necessary Conditions

- Several physical barriers successively placed between the radioactive material and the plant personnel and environment.
- Good safety management, control, organization and safety culture.
- Adequate financial and human resources as well as personnel with the necessary expertise and who are provided with the right conditions for work.

Level	Purpose	Main means
1	Prevention of abnormal operating occurrences and failures.	Robust design and high construction, operation and maintenance quality.
2	Control of abnormal operating occurrences and detection of failures.	High quality of the supervision and regulatory control of the facility through technical systems and administrative measures.
3	Control over conditions that can arise in connection with design basis accidents.	Efficient safety systems and emergency operating procedures.
4	Control over and limit of conditions that can arise in connection with severe accidents.	Technical measures prepared in advance and an efficient accident preparedness at the facility.
5	Mitigation of consequences in connection with the release of radioactive substances.	Measures prepared in advance for effective information to and protection of the population in the vicinity of the facility.

Figure 1. *The necessary conditions for a defence in depth system and the different levels of the system*

2. Operating experience

This chapter describes the operating experience from the Swedish nuclear power plants in 2007. SKI gives information about the major measures which have been carried out during the year and describes the events which occurred and discoveries made at the plants. More details about operations such as availability figures are available from the websites for the nuclear power plants and from their annual reports which in accordance with SKI's regulations are submitted to SKI. Some events and situations are described in more detail in other sections of this report.

During the year two events have be classified as level 1 on the International Nuclear Events Scale (INES). The events occurred in Forsmark 1 and Ringhals 1, and are described in more detail in the following paragraphs concerning the specific plants. Neither of the events resulted in a threat to safety for the surroundings.

Barsebäck

Barsebäck 1
Barsebäck 1 has been closed down since 1999. The main task for the personnel working with Barsebäck 1 is to build up knowledge related to decommissioning and to document the status of the unit prior to its decommissioning.

Barsebäck 2
Barsebäck 2 has been closed down since 2006. The main task for the personnel working with Barsebäck 2 is to build up knowledge related to decommissioning and to document the status of the unit prior to its decommissioning.

Forsmark

Forsmark 1
Forsmark 1 had had undisturbed full power operation until February 2 when it was decided to shut down the plant. This was because the rubber sheet which is part of the diaphragm seal in the containment was found not to comply with specifications regarding elasticity. Forsmark classified this as a Category 1 event and decided to replace the rubber sheet. Category 1 means that the plant may not be restarted without permission from SKI. The event was classified as an INES 1 on the seven-level international scale of events.

The following week SKI carried out an incident related (so-called RASK) investigation at the site aimed at quickly collecting information about the event. The investigation recommended that prior to the restart of Forsmark 1 and Forsmark 2 the plant should determine the status of all rubber sheeting inside the containments. Further the investigation recommended that before restarting Forsmark 2 the plant should demonstrate that the rubber sheeting complied with the relevant specifications. That meant an explanation had to be submitted as to why there were differences in the status of the rubber sheeting compared with that in Forsmark 1. The investigation also considered that, from the safety point of view, the way in which the situation was dealt with by the plant did not deviate from the requirements in SKIFS 2004:1 regarding managing deficiencies in barriers and defence in depth.

Control of the elasticity of the rubber sheeting in question is steered by an administrative system and should be carried out every three years. This control had, because of deficiencies in the administrative system, not been performed.

On March 14 Forsmark applied for permission to restart the plant. Prior to this the rubber sheeting has been replaced and a check has been made of all other testing activities that are steered in the same way. On March 16 SKI granted permission for the plant to resume operation.

Forsmark was subjected to a bomb threat on March 21, which resulted in all work underway being stopped and the plant was evacuated (except for operational staff). One lesson learnt from this bomb threat was that the police responded quickly and cordoned off the area around the site.

On August 5 Forsmark had trouble with the supply from the 70 kV switchyard because of an earthing fault in a transformer. The cause of the earthing fault was an aged cable. The cable was repaired and the instrument transformer was replaced and the 70 kV supply was restored on August 10.

Power reduction for the refuelling outage was started on September 2; the outage lasted until September 20. The annual outage was carried out according to plan. The work which dictated its length was the diesel maintenance.

After the refuelling outage there was undisturbed full power operation until November 27 when the plant was shut down after a short circuit occurred in the interlocking cell of a core emergency cooling pump. About an hour after the short circuit occurred the decision was made to shut down the plant to remedy the problem. SKI carried out a smaller version of an incident related inspection, RASK, the evening after the event, and documented and assessed how Forsmark had dealt with the situation. A subsequent investigation showed that a manufacturing fault in a fuse of the pump was the cause of the problem. The interlocking cell was cleaned and restored before operations were resumed on November 29.

Forsmark 2

Forsmark 2 had had undisturbed full power operation until February 3 when the decision was made to shut down the plant. This was because it was discovered that a rubber sheet which is part of the diaphragm seal in the containment of Forsmark 1 did not comply with specifications regarding elasticity. Forsmark 2 had not tested the effect of ageing on the elasticity of the particular rubber sheeting. Since Forsmark 1 is older Forsmark 2 has relied on the other unit's control of the effects of ageing.

In the light of the deficiencies identified in the administrative steering of testing the rubber sheeting in Forsmark 1 SKI decided that Forsmark 2 should carry out an inventory of all the tests which are steered by such work orders. Forsmark 2 submitted a report showing that they had not missed any tests of relevance for safety prior to restarting. The plant was restarted on February 20 after the rubber sheeting had been demonstrated to comply with the specifications with respect to elasticity.

At the beginning of March with about a week in between temporary automatic disconnections of the turbine occurred. Both incidents were initiated from signals in the seal steam system and had the after-effect of fire sprinkling in the turbine hall.

During the bomb threat to Forsmark all work underway in Forsmark 2 was stopped and the plant was evacuated (except for operational staff).

Early in the morning of May 15 the main recirculation pumps shut down and a partial scram occurred with the result that the power level was reduced to about 30 % of the full reactor power. The event was initiated by a fault in the oil pressure switch on one of the turbines.

Forsmark informed SKI on June 12 that they had identified a fuel bundle that they suspected had not been seated correctly when loading the fuel during the refuelling outage. That meant that it was positioned too high in relation to the other bundles and that some of the coolant flow had not been in contact with that particular fuel bundle. The error was detected when a power measurement signal oscillated in connection with a turbine scram. Control of the "core height film", which is regularly taken before restarting, was therefore repeated. It was discerned that one of the bundles was positioned somewhat higher than the others. After analysis it was concluded that a penalty should be placed on that position in the monitoring program.

On the evening of June 19 a small steam leak was discovered from a drainage line connected to the feedwater piping. The affected turbine was stopped and the following day the reactor was shut down to repair the damage.

The refuelling outage lasted from August 5 to 27. The work which dictated its length was the diesel maintenance.

On December 12 a fault occurred in the safety relief valve to the containment, which meant that it had to be closed with force. In accordance with the technical specifications the thermal power was reduced by 270 MW. The next day the decision was taken to shut down the reactor and repair the safety relief valve. The plant went back into operation on December 14.

Forsmark 3

Forsmark 3 was shut down for a short time in December 2006 because of fuel failures. In January 2007 a new fuel failure was detected. The failure remained stable until the refuelling outage.

In the light of the deficiencies identified in the administrative steering of testing the rubber sheeting in Forsmark 1, SKI decided that Forsmark 3 should make an inventory of all the tests which are steered by such work orders. Forsmark 3 submitted a report to SKI showing that they had not missed any tests of relevance for safety.

At the beginning of February two of the main recirculation pumps stopped because of a fault in the switching yard. The stop resulted in a short reduction in production.

The refuelling outage was started on June 20 and ended on June 30. During the outage apart from refuelling, routine maintenance and inspection and some plant alterations were carried out. Examples of the work are the installation of so-called baffle plates on the steam separators in the reactor to reduce vibrations in the steam line, changing to a new system for measuring the neutron flux in the core, replacement of the rotor, stator and heat exchanger of the main recirculation pumps, and the installation of a diversified source for pumping water into the reactor pressure vessel.

During the refuelling outage it was discovered during a building inspection that a blow down pipe in the diaphragm level of the containment was partially covered by a metal plate. The instructions for readiness for operation have been complemented with an inspection of that specific area.

The restart of the reactor was begun on June 28 but it was interrupted when a steam leak was detected in the reactor containment. The next day the reactor was restarted and reconnected to the grid on the evening of June 30.

Shortly after the restart a new fuel failure was detected. It remained stable for the rest of the year.

Oskarshamn

Oskarshamn 1
Oskarshamn 1 was still shut down at the beginning of the year because of the reconstruction which was undertaken to improve the plant, based on the experience gained after the so-called Forsmark 1 incident of July 25, 2006. Since that had been classified as a category 1 incident SKI had to grant permission for the plant to restart. SKI approved Oskarshamn's application and gave permission for restarting the plant on January 18, and the restart was begun the same day. In connection with the restart a scram occurred whilst the safety relief valves in the steam lines were being tested because of a turbine stop with restrictions on turbine by-pass, TS*D. Appropriate measures were taken and the plant was restarted and the tests performed without any problems. At 60 % thermal power the turbine vibrations were so large that the decision was taken to shut down again. The plant went back into operation on January 23.

A short stop occurred between February 25 and 28 to repair a leak in the drainage system for process water.

On March 8 Oskarshamn was stopped again to adjust the measurement of the main circulation flow rate. This was because it had been detected that there was a non-conservative trip level in the safety systems. The plant went back into operation on March 9.

On March 28 the thermal power level was reduced to 61 % to solve problems with the turbine hydraulic system.

In connection with routine testing of valves in the residual heat removal system it was found that one of the valves did not respond as expected. Shut down of the plant began on April 18. The fault was remedied and Oskarshamn 1 resumed operation during the night between April 21 and 22.

On May 28 a scram occurred because of an unexpected stop in the reactor water clean-up and residual heat removal systems which affected the water level in the scram tanks. Oskarshamn 1 resumed operation on May 29.

On July 30 an oil leak occurred on one of the generators, and the reactor was shut down to find its source. The fault was found to be serious and meant that it was necessary to replace the bearings to a feeder on the generator. The plant went back into operation on August 21.

The refuelling outage started on September 30. Some of the work which was carried out in addition to the annual refuelling was replacement of the control system for the main recirculation pumps and further measures to strengthen the low voltage supply as a result of the incident in Forsmark 1 during the summer of 2006. The planned date for resuming operations was delayed partly because of the turbine bearings and also because a small leak was found from the nitrogen connections to the control rod housings under the reactor pressure vessel. The refuelling outage ended on December 11.

During the start up of the reactor the turbine experienced heavy vibrations which led to a turbine scram. After rebalancing the turbine Oskarshamn 1 went back into operation on December 14.

Oskarshamn 2

Oskarshamn 2 had undisturbed full power operation until July 20 when tests prior to the refuelling outage were started. The plant was shut down for the outage on July 22 which was planned to last until September 12. The most important plant modification carried out during the refuelling outage was changing the steering and monitoring systems for the turbine to a software based system. Major work was also carried out on the feedwater system in which valves and piping inside the containment were replaced. In addition to this the normal maintenance and inspection of a large number of systems and components and refuelling were carried out.

On September 28 the refuelling outage was complete and the plant was reconnected to the grid. Because of the major alterations that had been made, in particular to the turbine system, extensive testing was performed to verify that the plant functioned as it should.

On October 25 a turbine load shedding test was performed. The test means that the plant’s connection to the grid is broken and the plant is instantly converted from production to the consumption of its own power. The test ran according to plan. After the test there was a short planned shut down to carry out some outstanding measures. When resuming production after the test a fire alarm went off in the turbine building and the shut down was started a few hours earlier than planned. The fire alarm is thought to have been set off by thin oil smoke in the turbine hall. The plant went back into operation on October 27.

On November 2 there was another fire alarm and water was sprinkled in the turbine building. The plant was taken to hot stand-by so the cause of the problem could be found. The reason for the fire alarm was oil leaking from a bearing in the high pressure turbine.

Oskarshamn 3

Oskarshamn 3 started the year with undisturbed full power operation until March 31 when the plant was shut down for a short time to replace damaged fuel. Two failed fuel rods had been identified when leak testing the core. Resumption of operations was delayed somewhat because of some problems with the valves in the reactor scram system. On April 6 Oskarshamn 3 was reconnected to the grid.

At the end of May coast down was started. This is the period of the year when the plant's thermal power is reduced because the reactivity of the fuel is insufficient to produce the full thermal power.

Oskarshamn 3 was shut down for the annual refuelling outage over the midsummer weekend. The outage, which was to reload the core was planned to end on July 7. The plant was restarted according to plan on July 7. However on July 8 the start-up was interrupted at 75 % power because of an external leak in the reactor containment. The leak came from a valve in the residual heat removal system. After this had been corrected the plant went back into operation on July 11.

On August 28 a new fuel failure was detected.

On August 30 a steam isolation valve shut because of a short circuit in a pilot valve. This resulted in power reduction and a partial scram. On August 31 power reduction to hot stand-by was begun. After the pilot valve had been fixed Oskarshamn 3 could be reconnected to the grid late on August 31.

On September 14 Oskarshamn 3 began another short shut down to replace damaged fuel. The fuel failure which had been detected earlier had developed a so-called secondary failure. After the replacement, resumption of operation was begun on September 23. At 65 % thermal power a scram occurred because of a defect in the pilot valves of the turbine. After this was fixed the plant was restarted on September 25.

Another fuel failure was detected on October 29.

On December 22 load shedding occurred because of a problem with the turbine. The plant was restarted the same day.

Ringhals

Ringhals 1

Ringhals 1 has had to carry out load balancing on several occasions during the year because of limitations in the transfer capacity to the grid.

A turbine scram occurred on January 23 because a high pressure control valve to the turbine shut.

Ringhals 1 was shut down on January 29 because of changes in the flow rates in a secondary cooling system. In connection with this shut down Ringhals 1 performed a manual scram since there were fluctuations in the levels in the pre-heater chain. The plant was restarted on February 12 after control and remedial actions in the cooling system.

On April 20 Ringhals 1 increased the thermal power to the new level of 111.89 %.

On June 16 a turbine scram occurred caused by a tripped generator protective system on generator 11.

On June 15 Ringhals 1 informed SKI that a leak had been detected through the containment liner plate. Initial investigations showed the leak to be 3.9 ml/day. The amount involved was about 2 ml/day in June, increasing to a little more than 24 ml/day by the end of July. Ringhals 1 applied for and was granted permission to continue operation with a damaged component.

The annual refuelling outage started on August 31. During the outage a damaged divider plate was discovered when inspecting a heat exchanger in the residual heat removal system. There were also deposits found in the heat exchanger. Prior to the restart, SKI carried out an incident related (RASK) inspection concerning these discoveries. Ringhals 1 was restarted on October 12.

On October 14 Ringhals 1 was scrammed manually because the operator was uncertain about the functionality of the neutron flux measurement, since the detector showed almost zero at 20 % thermal power. On October 17 the operator again scrammed the reactor manually because of the same uncertainties. This time there was an alarm that all the channels in this system were not functioning. It is worth noting that the neutron flux measurements were functioning on both occasions, but that the interface to the operator has given them an unclear picture of the status of the system. The system was modified during the annual outage.

On December 13 the generator protection system again caused a turbine scram of generator 11.

During periodic tests on December 18 one of the valves in the lines to the reactor containment system for pressure relief and cleansing to reduce the release of radioactivity in the event of a core accident was found to be shut. The event was classified as level 1 on the seven-level international INES scale.

Ringhals 2

Ringhals 2 has had to carry out load balancing on several occasions during the year because of limitations in the transfer capacity to the grid.

On February 15 the plant was shut down because the unidentified leakage in the reactor containment had increased somewhat. A small bore pipe connected to the primary system had a small crack caused by thermal fatigue. After its replacement Ringhals 2 restarted on February 21.

On March 11 a scram occurred in Ringhals 2 because of problems with a pressure switch on turbine 21. The pressure switch was not functioning properly and this stopped the condensate and feedwater pumps and therefore a turbine scram occurred with by-pass restrictions for turbine 21. The problem also led to problems with turbine 22 which resulted in a turbine scram and a reactor scram. The plant was restarted the same day.

On May 4 there was a short circuit in a turbine which meant that the plant operated at 50 % until May 19 when full thermal power was resumed after the repair work had been completed.

The refuelling outage of Ringhals 2 started on July 31.Amongst other things a new recombiner was installed in the reactor containment. There were some problems unloading the fuel as well as some unplanned work which resulted in the outage being extended by a couple of days. The plant was reconnected to the grid on August 26 but there were problems with vibrations in G21 which resulted in the need to rebalance turbine.

At the end of November a problem with the charging pumps was identified and this meant that the plant was shut down for four days to solve the problem.

On December 3 a leak was found in generator 21 which had to be shut down for repair. After the repair it could be taken back into operation on December 4.

On December 10 the plant was shut down to fix problems with generator 21. Turbine scram had occurred because of a short interruption in the generator cooling. After this there were problems with vibrations in one of the reactor's recirculation pumps. Ringhals 2 had to shut down to resolve these problems on December 11. After the pump was restarted the vibrations returned to normal levels and restart of the reactor was begun the same day.

Ringhals 3
Ringhals 3 has had to carry out load balancing on several occasions during the year because of limitations in the transfer capacity to the grid.

On January 29 the power increase to the higher power level was begun after the approval of trial operations at 3000 MWt had been given by SKI on January 22. On January 30 trial operations were stopped and the reactor was put on hot stand-by. The reason was that there were uncertainties about the measurement of the feedwater flow rate. The flow rate measurement was adjusted as well as the protection system which is affected indirectly by the feedwater flow rate. Restart of the reactor began on February 2.

Ringhals 3 performed a load shedding test on a turbine on February 27. The test is part of the test programme for 3000 MWt.

The refuelling outage started on May 18. The outage was planned to end on June 16. However it was extended because of problems with modifications to the turbine system. The plant was restarted on August 2. The problems were mainly due to piping work in the turbine plant in which Ringhals and the subcontractor did not manage to produce and verify the technical calculations necessary for some of the piping supports for the steam and feedwater piping. During the outage a new generator was installed, amongst other things.

On August 20 at 14:15 generator 32 broke down because of a short circuit. Turbine scram occurred and the reactor thermal power was automatically reduced. Operation continued at about half power until August 22 when the reactor was shut sown for an inspection of generator 31. The basic cause of the break down was considered to be a spanner which had been left in the stator. On September 3 the plant was reconnected to the grid. During September a number of delivery tests were performed on generator 32 including a load shedding test.

At the beginning of October a turbine scram occurred because of reduced vacuum in the turbine condenser.

In November a steam leak was found in the turbine cover. The turbine was shut down for four days and wall thinning was found in several small bore piping in the intermediate heat exchanger.

Ringhals 4
Ringhals 4 had undisturbed full power operation until June 12 when generator 41 was shut down because of high moisture content. The generator was repaired and the restart was begun on June 14. High moisture content then occurred in generator 42 and it had to be shut down. Generator 42 was repaired and restart was begun on June 15.

The refuelling outage was started on June 20 and restart was begun on July 17. During the outage boron deposits were found at a sealing weld in the control rod mechanism on the reactor pressure vessel head. The problem has been observed previously and the replacement of the control rod penetrations is planed for 2008.

During the restart a reactor scram occurred because of exceptionally low levels in the steam generators in connection with a test of the steam driven auxiliary feedwater pump. On August 21and 22 transfer to house turbine operation occurred on two occasions because of an erroneously set switch from the Ringhals switchyard after maintenance carried out by Svenska Kraftnät, SvK.

After the restart moisture penetration in the feeder to generator 41 occurred twice. It was found that the weld repair that had been performed during the first of these two shut downs contained a crack which caused the second shut down. In all four shut downs have been caused by the same problem.

On November Svenska Kraftnät changed the switching in the outer switchyard which resulted in load shedding and house turbine operations for both turbines. Reconnection to the grid was made the same day.

3. Technology and ageing

Continued supervision of ageing management programmes at the nuclear facilities

The Swedish nuclear power plants are getting older. They were constructed in the 1960s and 1970s. The oldest plant, Oskarshamn 1, was taken into operation in 1972 and the youngest, Forsmark 3 and Oskarshamn 3, were taken into operation in 1985. Different aspects of ageing must therefore be taken into account and ageing phenomenon must be taken into consideration in order for the safe operation of the plants. This is particularly important in the current situation where the licensees are planning to operate several of the plants for longer than they were originally technically designed for, which was approximately 40 years.

Normally ageing management refers to components and building structures which form part of the plant barriers or defence in depth concept. This type of ageing involves a continuous process in which the physical properties change in some way as a function with time or use under normal operating conditions. In order to maintain control over the physical ageing it is therefore necessary for the licensee to be well prepared through well planned preventative measures, such as replacement of components that are sensitive to degradation, extensive monitoring and inspection of the plant barriers and its defence in depth systems, and subsequent mitigation and repair measures in the event that damage or degradation is detected. In addition validated models are essential for the analysis and safety assessment of such components that can be kept in service for a limited period of time despite degradation.

Ageing of nuclear power plants has received more and more attention internationally. In many countries better defined requirements have been enforced for the establishment of ageing management programmes and more systematic management and supervision measures necessary to retain control over problems associated with ageing. SKI has introduced corresponding more stringent requirements concerning ageing management in the regulations SKIFS 2004:1 concerning safety in nuclear facilities. According to the transitional regulations, licensees had until the end of 2005 to prepare a complete programme for ageing management.

A programme for the management of ageing related deterioration and degradation is, according to SKI's regulations, a programme that in a coordinated manner demonstrates how these questions are dealt with at the plant. The programme thus coordinates the plant efforts in other already existing programmes such as maintenance, periodic inspection, and environmental qualification. This interpretation, which is presented in SKI's report concerning ageing management programmes[2], has international support, for example in the guidelines from the International Atomic Energy Agency, IAEA[3], and in the European nuclear regulatory authorities organisation, WENRA, in its document on revised reference levels[4]. This means that a programme for the management of ageing related deterioration and degradation must include all the building structures, systems and components of importance for the safety of the plant.

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[2] Ageing management programmes – need and content. SKI report in Swedish. 2006-09-07.
[3] Implementation and review of a nuclear power plant ageing management programme. Safety Reports Series No.15. International Atomic Energy Agency. Vienna 1999.
[4] Harmonization of reactor safety in WENRA countries. Report by WENRA reactor harmonization group. January 2006

In order to obtain sufficient control, management, coordination and following up of the ageing management programme it is necessary that these activities are included in the quality assurance system in a clear manner. This is particularly important since the constituent activities are performed by different parts of the organisation and by different categories of personnel. The overall processes impose specific requirements on coordination, clear lines of authority and responsibility, and so forth. For the same reason it is necessary that the plant safety analysis reports are revised to include information on the organisation and principles for the management and control of the management of ageing related deterioration and degradation. The necessary revisions were completed in 2007 in accordance with a requirement issued by SKI.

Following its assessment SKI has required that the plants make the necessary revisions to both the programmes and the management systems be completed at the latest by December 31, 2008.

Overall development of degradation and the influencing factors

Mechanical components which are part of the barriers and defence in depth

Extensive replacement of components that have been found to be susceptible to degradation has been carried out by the Swedish nuclear power plants. Many of these replacements have been performed preventatively as more knowledge has been acquired about the causes of the damage and the degradation mechanisms. In other cases the components have been replaced when damaged. In 2007 relatively few new cases of degradation and defects have been reported. Previously identified problem areas have been followed up and analysed.

SKI continuously follows the development of degradation in the mechanical components and building structures that form part of the barriers and defence in depth of the plants. SKI also follows up the programmes for monitoring the ageing of electrical cables and instruments. This work includes both evaluation of the development of the damage overall and for the individual plants. The work also covers efforts to follow up under which conditions the various degradation mechanisms occur.

An overall evaluation which covers all the cases of damage in mechanical components since the first plant was commissioned confirms that the preventative and mitigation measures taken have had the intended effect. This conclusion is valid even after the damage that has occurred up to the end of 2007 is included. As shown in Diagram 1 below, there is no tendency to an increase in the number of defects as the plants become older. The overall evaluation also shows that most of the damage to date has been found through periodic in-service inspection before safety has been affected. Only a small proportion of the defects have led to leakage or more serious conditions as a result of the cracks or other types of degradation remaining undetected.

It is mainly different corrosion mechanisms that have given rise to the defects that have occurred, see *Diagram 2*. These account for approximately 60 % of the cases with intergranular stress corrosion cracking as the most frequent degradation mechanism followed by flow accelerated corrosion. Stress corrosion cracking is a degradation mechanism that in nuclear systems occurs for the most part in austenitic stainless steels and nickel base alloys when these are exposed to tensile stresses and corrosive environments. The susceptibility of the material to cracking depends partly on the chemical composition, partly on the heat treatment and the metal working processes used during manufacture and installation in the plants.

Despite the fact that considerable knowledge of the factors which affect degradation has been built up over the past few decades, this is not sufficient to completely avoid problems or always to predict which of the components will be affected.

Whilst stress corrosion cracking has most often occurred in the primary piping and safety systems, flow accelerated corrosion has been more common in secondary systems such as steam and turbine components. Thermal fatigue, which is the third most prevalent cause of damage (and which is responsible for about 10 % of the damage), has largely occurred in primary piping and safety systems. The positive development, with no increase in the number of cases of damage in mechanical components as the plants become older, requires a continued high level of ambition with regard to the preventative maintenance and replacement efforts. SKI will therefore continue to pressure the licensees to maintain this high level of ambition and the preparedness to evaluate and assess damage when it is detected.

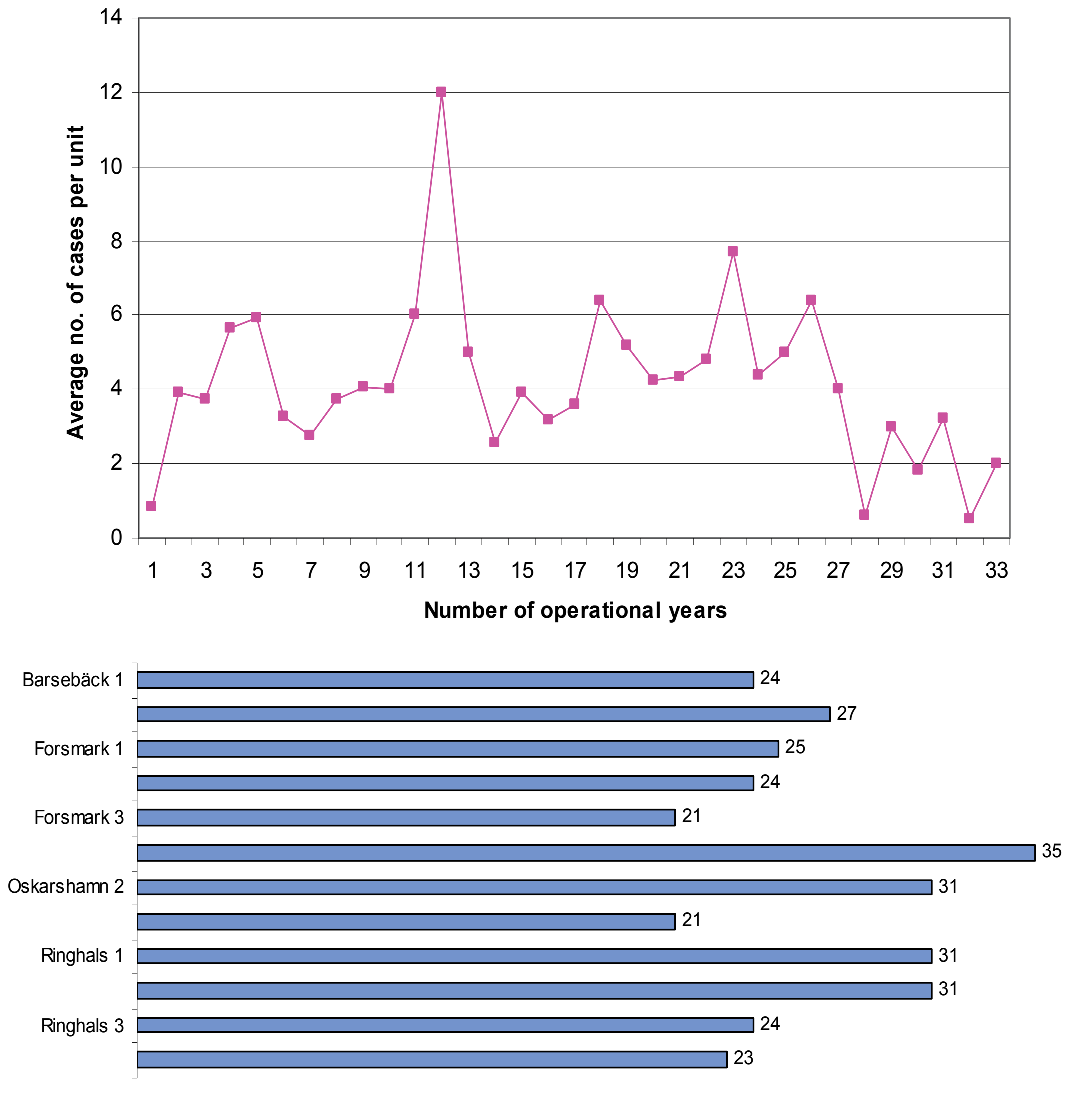

Diagram 1. *The upper diagram shows the average number of reported events per plant and operational year for all the Swedish plants. The diagram includes events in pressure vessels, piping, and other mechanical components except steam generators. The lower diagram shows the operational age of the plants.*

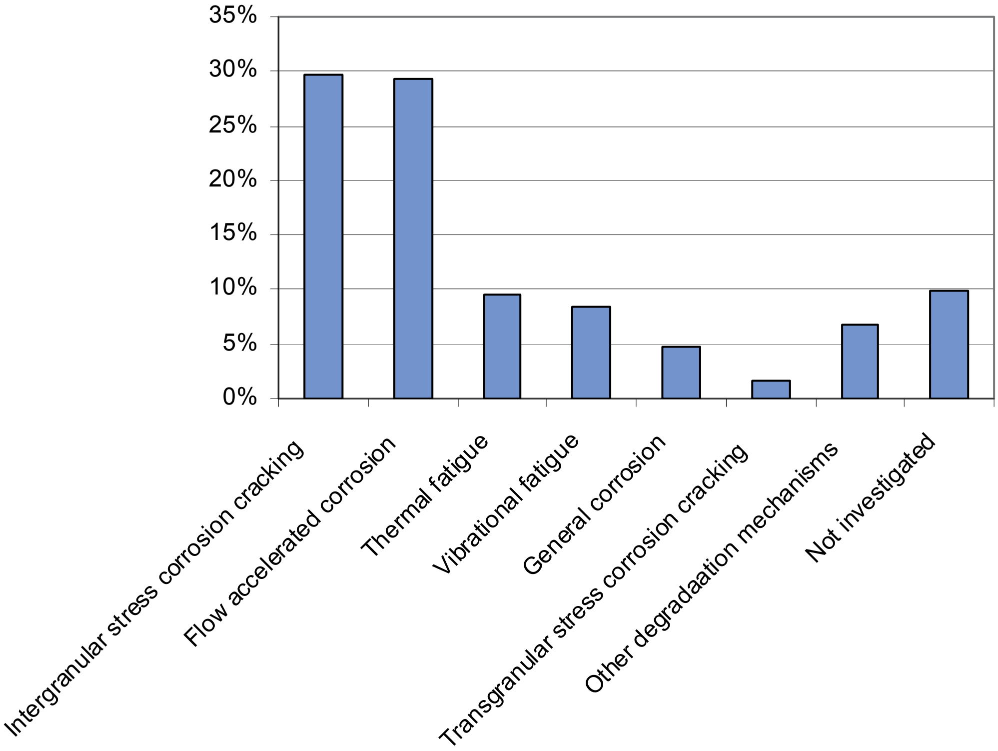

Diagram 2. *Causes of damage according to degradation mechanism.*
(The category "other" includes damage caused by grain boundary attack, corrosion fatigue and mechanical damage.)

Reactor containments

Further studies and development work is still necessary in order to achieve adequate monitoring of the ageing related damage that can decrease the safety of the reactor containment and other building structures. The damage and deterioration which have occurred to date have for the most part been caused by deficiencies in connection with the erection of the structures or their subsequent modifications. This type of damage has been observed in, for example, Barsebäck 2, Forsmark 1, Oskarshamn 1, Ringhals 1 and Ringhals 2. The damage has primarily been the result of corrosion of the metallic parts of the reactor containment, but also degradation of the sealing material. Similar experience has been reported from other countries. Considering the difficulties associated with the reliable control of the reactor containment and other important building structures, SKI considers it important that the licensees continue to study possible ageing and degradation mechanisms that can affect the integrity and safety of these structures.

SKI is continuing with its own study and research concerning the damage and other degradation mechanisms that can affect the reactor containment. Mechanisms that can affect the concrete itself are amongst others chemical reactions, leaching, sulphate attack, cement ballast reactions and carbonation. With regard to these damage mechanisms, SKI's own studies and research to date have shown that the environmental conditions in the Swedish containments are such that the risk for damage caused by the environment is in general considered to be small. On the other hand the damage which has occurred shows that deviations from the construction drawings have led to damage at a later stage. Therefore the risk for the occurrence of different damage mechanisms cannot be assessed entirely on the basis of operational conditions and the nominal design, but must also be based on the reported damage. Further examples of minor damage of this kind have been observed in 2007.

Instrumentation and monitoring equipment

In recent years ageing of instrumentation and control systems has been paid more and more attention both in Sweden and internationally. Ageing phenomena in this type of component differ considerably from the type of ageing of materials and structures which has been discussed above. One reason is that this type of component is often replaceable, and therefore is replaced if defects are detected, without raising the question of ageing. Some of the defects are detected in components shortly after installation, so-called “infant mortality”. The subsequent development depends on the type of component or system in question. Since instrumentation and control systems include sensors, transmitters, displays and systems to present measured data, the conditions, and therefore the possible degradation mechanisms, will vary considerably. Different types of deterioration in the physical properties of a component will depend on the loads to which the component is or has been subjected, and these are to some extent time dependent. Another type of ageing, and for instrumentation and control systems, a very important one, is something that is often called “technological ageing”. This means that systems and components become obsolete because of the technological advances and that they are correspondingly difficult to replace, or that there are problems of compatibility, that is to say it is difficult to replace a limited part. Evolution and the increased use, not least the anticipated increased use, of digital equipment, “clever” sensors and suchlike, obviously affects this situation. Another aspect which can be relevant to note for instrumentation is what can be called “functional ageing”. This means that a measurement or monitoring system has become “irrelevant” as a result of other alterations to the plant. Conditions have simply changed in such a manner that the measurement system no longer gives information in the manner envisaged when it was installed. One example of this is leak detection systems which depend on the measurement of gaseous radioactivity in the containment atmosphere. These systems depend in some cases are on a higher concentration of radioactivity in the coolant than is normal today, and therefore they cannot be attributed their original functionality.

Electrical equipment

In contrast to mechanical components and building structures the condition of electrical cables cannot be followed by in-service inspection and testing. In these cases it is necessary to qualify the cables and equipment in specific testing programmes to ensure that the equipment functions as expected throughout its planned life. The qualification programmes must include both normal operational conditions and also accident conditions, as well as taking into consideration the mechanisms that can affect for example degradation of polymer materials.

The factors which have the most effect are normally high temperature and ionising radiation. High humidity and vibrations can also play a large role in the ageing of electric cables and other electrical equipment. The question as to how these environmental factors should be simulated in the accelerated tests of the qualification programmes has been the subject of considerable discussion for a long time. The different national and international standards for the qualification of electrical equipment vary with regard to which acceleration factors can or should be used. For example, in the case of ageing resulting from ionising radiation the discussion has centred on how high the dose rates can be during accelerated testing, without risking that the degradation will be less than that which will occur in the environments in which the equipment will be used.

With respect to Swedish plants SKI has elucidated the requirements concerning environmental qualification within the scope of the regulations in SKIFS 2004:1. These contain requirements that other equipment associated with reactor safety systems is resistant to the environments to which it can be exposed under those situations when it is credited in the safety analyses. This additional requirement means that to varying degrees the plants must revise their environmental qualification programmes and replace some electrical equipment.

Following up the damage in steam generator tubing

Nickel based alloys have been a relatively common construction material in nuclear facilities around the world, but they have been found to be susceptible to stress corrosion cracking. This is particularly true for Alloy 600 and the corresponding welding alloys known as Alloy 182 and 82. Extensive measures have been taken in the Swedish plants to replace these susceptible materials with other less susceptible materials.

Examples of remaining problems with stress corrosion cracking in nickel based alloys are the steam generator tubes in Ringhals 4. These tubes are manufactured from Alloy 600 and comprise a major portion of the pressure boundary of the primary system in the plant. The damage evolution is therefore followed very carefully through annual inspections and other investigations in accordance with SKI's requirements. The inspections and tests performed during the year have, as previously, included damaged regions of the tube support plate, support plate intersections, preheated parts and the U-bends. A number of tubes were found to contain new stress corrosion cracks in the region of the tube support plate as well as some growth of previously detected cracks. No new defects were found in the U-bend region of the tubes during the inspections and tests performed during the year.

Tubes with such limited damage that there are safe margins to rupture and flaking have been kept in operation in Ringhals 4. Damaged tubes with insufficient margins were fitted with plugs in the ends and thus removed from service and crack propagation was thus halted. During the year a total of 32 tubes were plugged. During the year a number of damaged tubes have been fitted with an inner tube ("sleeving") in order to prevent the propagation of cracks and restore their mechanical integrity. The total number of steam generator tubes which have been taken out of service in Ringhals 4 now corresponds to 3.39 % of all the tubes.

Ringhals has now decided to replace the damaged steam generators in Ringhals 4. In addition to the safety and maintenance advantages of such a replacement the prerequisites will exist for increasing the thermal power in Ringhals 4. Ringhals is planning for such an increase.

Ringhals 2 and 3 have replaced their steam generators with generators of a partially different design and with tubes manufactured from material less susceptible to cracking. During the periodic in-service inspections there have been no signs of environmentally induced degradation. Operating experience gained so far with the new steam generators, installed in 1989 in Ringhals 2 and in 1995 in Ringhals 3, is still good. Some minor wear damage caused by foreign objects has, however, been observed on the secondary side of the steam generators.

In 2007 SKI established new limits for leaks from the primary side to the secondary sides in steam generators. This decision is related to the SKI regulations concerning mechanical components (SKIFS 2005:2) and means a reduction in the permissible leakage by a factor of 5 – 6 as compared with the previous limits. The decision has been based on an extensive evaluation of steam generator tube leakage which was carried out in USA.

Deficiencies in control and maintenance leads to stricter requirements

Early in 2007 SKI decided that Forsmark must carry an extensive control of their documentation in order to clarify if the company follows the approved maintenance and inspection programmes for its reactors. In the case of Forsmark 2 the decision was combined with a prohibition on the restart of the plant before the control had been completed and reported to SKI. The decision was taken because of the deficiencies in the maintenance programme which were discovered in Forsmark 1 when a flexible joint in the diaphragm level of the reactor containment had not been tested according to plan and was later found to have degraded more than was acceptable. After reviewing the Forsmark's control of its documentation from tests and other investigations of components and equipment of relevance for safety as well the implemented repairs, SKI found that there were no hinders to Forsmark returning to operation. The incident led however to SKI requiring all the other Swedish plants to collate information concerning rubber components of importance for the correct functioning of the containment, how they were environmentally qualified, and which subsequent tests and controls have been performed. The review of this information shows that the reactors need to improve the management of their work with environmental qualification and ageing control of these rubber components.

In 2007 SKI has also reviewed the actions taken as a result of the leak which was observed after the modification of the so-called torus in Forsmark 2 during the refuelling outage in 2006. The review was mainly concerned with the conditions which could have given rise to the deficiencies during the installation control which resulted in Forsmark 2 being taken into operation with a leak in the containments tight shell. Based on the review SKI considered that the control of the torus had been carried out in an erroneous manner and that there had been deficiencies in the management of the inspection procedures both by Forsmark and by the accredited control organisation. SKI has therefore told Forsmark that they need to revise their routines, and also informed the other plants of the problems in the management of the control measures. SKI has also pointed out these problems for the Swedish Board for Accreditation and Conformity Assessment (SWEDAC) which has tightened up some of its regulations for accreditation.

Application of the LBB-concept in Ringhals 2

According to SKI's regulations SKIFS 2004:2 concerning the design and construction of nuclear power reactors, there should be resilience to local dynamic effects, in particular in the event that a pipe failure can result in an entire safety function being eliminated, on the first hand this should be achieved by pipe restraints, missile protection or changing the piping layout. In SKI's opinion it is not possible to completely introduce these measures in all the older plants, since the space in the buildings is not always sufficient for such measures. A very thorough safety analysis and verification of measures within the concept of "Leak Before Break", LBB, can provide sufficient safety. The LBB concept means that a piping system has such a design, operational and environmental conditions that the probability for failure is sufficiently small, as well as measures having been taken such that damage, which despite these measures can occur, with large certainty will result in a detectable leak before rupture occurs. Such a solution is in accordance with the requirements in SKIFS 2004:2.

Ringhals applied in 2006 and 2007 for permission to use the LBB-concept for the main recirculation system, pressurizer surge line (with the exception of the dissimilar metal weld at the pressurizer nozzle), residual heat removal system (high pressure parts) and the accumulator line in Ringhals 2. After a comprehensive review SKI is of the overall opinion that, with given specific conditions, the LBB concept is complied with in those systems of Ringhals 2. The conditions are amongst other things that Ringhals 2 revises its safety analysis report and technical specifications with more precise information about the systems and the equipment which is to be used to detect leaks reliably, localise and quantify such leaks from cracks or other damage which, despite the damage mitigating measures, could occur. For some of the piping systems Ringhals is required to install more sensitive equipment to be able to detect, localise and quantify small leak rates.

In connection with its review and decision concerning Ringhals' application to apply the LBB-concept SKI has also informed the other plants of its thoughts regarding leak detection, and has pointed out that both national and international experience shows that successful leak detection and management should be based on several different technical systems and well run control procedures.

Continued follow-up of the mechanical properties of the reactor pressure vessel

During the year SKI has continued to review the programmes for the control of the mechanical properties of reactor pressure vessel material which forms the basis for determining the highest permissible limits for reactor pressure at different temperatures. The specimens sit in special containers (surveillance capsules) which are placed between the core and the walls of the reactor pressure vessel. Based on the results of previous test results SKI has made a decision concerning new dates for the removal of the capsules from Forsmark 1 – 3. SKI has also approved the early removal of samples from Ringhals 3 and 4 since they should not be irradiated to higher fluences than the reactor vessel will receive during the expected operational lifetime. According to the estimates made by Ringhals the samples in Ringhals 3 and 4 have already reached that fluence. SKI's decision means that the capsules have been taken out and stored unopened outside the reactor pressure vessel to await testing.

Deficiencies in ageing management

Early in 2007 SKI decided that Forsmarks Kraftgrupp AB (FKA) must carry out an extensive review of documentation to clarify if the company follows the approved maintenance and control programmes as they should, for Forsmark 2 the decision was combined with a prohibition to restart the reactor before the review had been completed and reported to SKI. The decision was taken because of deficiencies in the company's maintenance programme which became apparent in Forsmark 1 when a flexible joint in the diaphragm level of the reactor containment which had not been testing as planned and it was found later that its condition had deteriorated more than acceptable. After a review of Forsmark's documentation from tests and other examinations of components and equipment of importance for safety, as well as the repair measures taken, SKI found that there was no longer a hinder to resume operation. This event also led to SKI requesting information from the other Swedish plants regarding rubber components of importance for the function of the containment, how the rubber components have been environmentally qualified and which tests and other investigations have been performed to follow their condition. A review of the information which was submitted shows that the plants need to varying degrees to update how they follow up rubber and other sealant material, and also how they manage maintenance and replacement more systematically in the ageing management programmes in accordance with SKI's regulations.

4. Core and fuel issues

Foreign debris in the coolant water continues to cause fuel defects

Leaktight fuel cladding is essential to prevent the release of radioactive substances in and from the plants. Therefore, stringent quality requirements exist for the manufacture of fuel cladding with low acceptable frequencies for defects. The quality requirements have led to the number of manufacturing defects being of the order of one fuel rod in 100,000. Stringent requirements are also imposed on the fuel cladding to, as far as possible and reasonable, withstand the radiation and other environmental conditions to which the fuel can be exposed. Furthermore the design must be well tried and tested and there must be appropriate programmes to follow up and check the behaviour of the nuclear fuel after it has been taken into operation.

During the 1980's and a bit into the 1990's a large number of fuel failures caused by stress corrosion cracking were reported, where the fuel cladding did not meet the requirements concerning tolerance to the environment. Very few of this type of failure have been reported in recent years since operating rules have been introduced and more resistant cladding material has been developed. The long-term trend is that the number of fuel failures in Swedish reactors is decreasing, see *Diagram 3*. All of the reactors have had the odd failure in recent years, but a few reactors (Forsmark 1, Oskarshamn 3 and Forsmark 3) have had more than one fuel failure per annum on several occasions over the last ten years.

The failures that occur nowadays are primarily caused by metal turnings or threads that enter the fuel bundles via the coolant and then wear holes in the cladding. To reduce the number of this sort of failure, fuel assemblies are fitted with filters to prevent the debris from entering the bundles, and cyclone filters are installed in the plants to clean up the coolant. It is however most important that there is a greater awareness of the importance of keeping the coolant free from debris that can wear holes in the fuel cladding. The plants have programmes in place to reduce the risk for damaging debris getting into the systems.

In 2007 a total of seven fuel failures were reported. All of the reactors were free from fuel failures in 2007 except Forsmark 3 which had three fuel failures and Oskarshamn 3 which had four. Over the last five years between three and seven fuel failures resulting from wear have been reported each year. The fuel failure frequency over the past five years has stabilised at a relatively low level. A few reactors (Oskarshamn 3, Forsmark 1 and Forsmark 3) account for most of the failures which means that it should be possible to reduce the failure frequency further if these reactors also manage to employ effective corrective measures to avoid fuel failures.

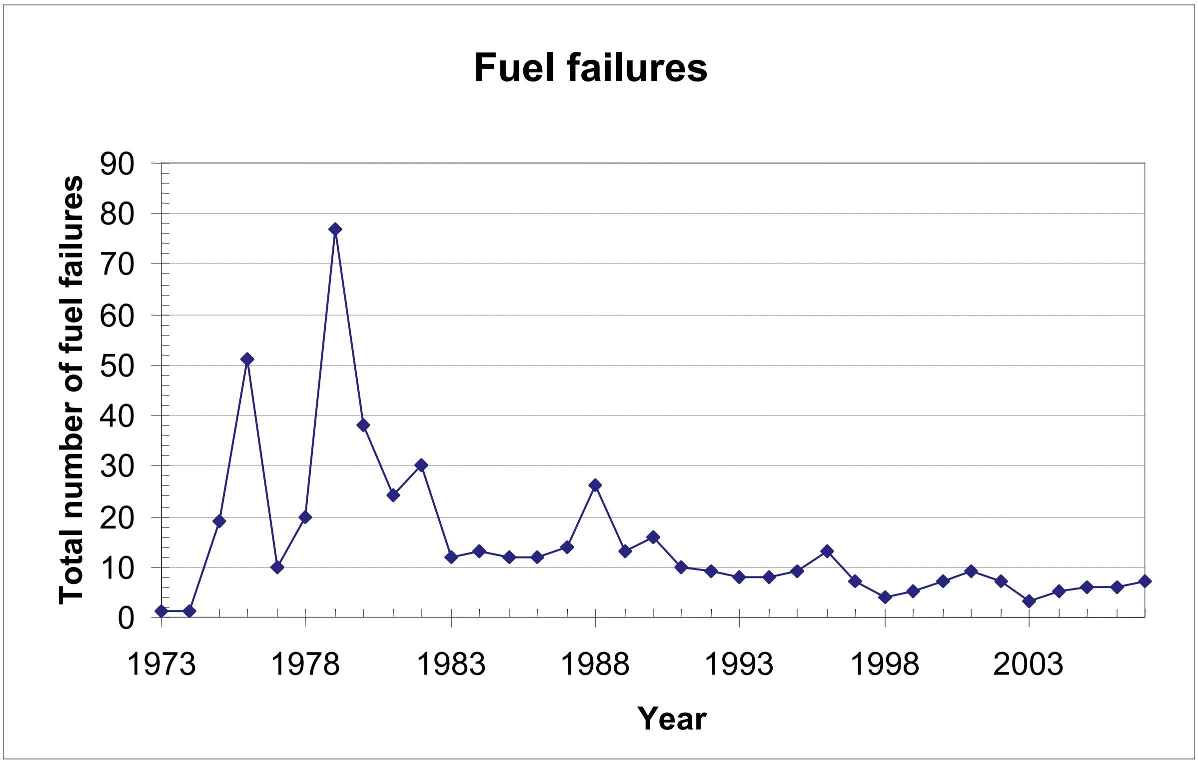

Diagram 3. *Total number of fuel failures reported per annum in Swedish nuclear power plants*

Continued follow-up of bowed fuel

Since the mid-1990's the pressurised water reactors, Ringhals 2, 3 and 4, have had problems with fuel bowing beyond the limit postulated in the safety analysis. The safety related aspects of this must ensure that the control rods can be inserted as necessary and that the thermal limits are not exceeded. Ringhals has implemented measures to restore the straightness of the fuel and to analyse the impact of the bowing on the thermal margins. SKI has evaluated these measures and the methods used to follow-up the bowing and continues to monitor the progress through annual reports in which Ringhals describes the status of the bowing. The direction of the bowing is unchanged in the upper part of the fuel whilst it is more diffuse in the lower part of the assemblies. A number of constructive measures have been taken to improve the situation gradually even if the positive trend has been broken in the past year in Ringhals 2 and 4.

Increased burnup and enrichment

Work has been underway internationally for several years to improve the economic margins through core optimisation, improved fuel utilisation, new fuel designs and increasing operating flexibility. There is an ambition to modernise the core loading strategy so that fewer new fuel assemblies are needed. The maximum fuel burnup is also a factor in the optimisation efforts.

In Sweden there is a general limit of 60 $MWd/kgUO_2$ for the highest local fuel pellet burnup which was introduced through a decision made by SKI in 1995. Previously there was no incentive to go to higher fuel burnup. However the licensees have revised their cost optimisation for fuel and have found that a somewhat higher burnup should be aimed at. Barsebäck and Ringhals were granted permission to increase the local fuel pellet burnup in the reactors Barsebäck 2 and Ringhals 1 from 60 $MWd/kgUO_2$ to 65 $MWd/kgUO_2$. In 2006 applications were submitted by Oskarshamn and Ringhals to increase the burnup for a few specific fuel assemblies in Oskarshamn 3 and Ringhals 2. SKI has evaluated these applications and granted permission for the current burnup limits to be exceeded by a small amount. SKI is of the opinion that this higher local pellet burnup can be allowed with sufficient safety margins. In Oskarshamn 3 the reason for the irradiation is to gain information on a new fuel material (ADOPT-pellet) which is of interest for this reactor. This kind of material is in two of the four assemblies.

Further applications to increase the fuel burnup are expected. SKI is therefore following these discussions in detail and is preparing for future reviews by amongst other things participating in research which will provide a basis for verifying the safety limits for fuel with high burnup. Amongst the issues that are important to follow in this respect is how existing failure mechanisms are affected and if new ones will occur at the higher burnup levels.

As part of the plans to increase the thermal power at several plants (see below) higher enrichment of the fissile material (uranium-235) per fuel assembly is also being discussed. When the thermal power is increased in a reactor the fuel consumption will increase to the same extent, if no other measures are taken. That means that an increase in thermal power of 1 % results in approximately a 1 % increase in fuel consumption. An increase in thermal power can be achieved by consuming more fuel assemblies.

By increasing the enrichment[5] of fissile material the need to consume more fuel bundles can however, be reduced or even eliminated. Modifications to the fuel design can also be expected to reduce the need for more fuel assembles to a limited extent. The licensees will probably use a combination of increased consumption and enrichment to increase the thermal power. The choice of method depends on an economic evaluation in which, amongst other things, the cost for increased enrichment and the larger quantity of uranium and final disposal are influencing factors.

In 2006 preparations were made at two of the reactors in Ringhals to be able to use fuel with a higher burnout by amongst other things modifying the fuel racks in the fuel ponds. SKI did not however permit the plant to carry out these modifications or changes in the safety reports before the authority had reviewed the application and assessed whether the modifications are in compliance with the regulations with regard to criticality. After reviewing the application, and with the additional information that SKI requested, SKI found that the design of the suggested blocked positions had been evaluated sufficiently with consideration to its relevance for safety. SKI considered further that the methods used for the criticality analyses had been tested, and that appropriate events had been analysed, and that the analyses met with the requirements. SKI therefore decided to revoke the earlier prohibition and allowed the suggested blocked positions to be introduced into the fuel ponds.

The fuel designs SVEA Optima 2 and 3 have been found to be more reactive than the reference fuel for the Central Interim Storage Facility (CLAB). Therefore the Swedish Nuclear Fuel and Waste Management Co. (SKB AB) have blocked a central position in the fuel cassettes in CLAB in order to ensure criticality margins for the more reactive fuel. SKI considers that the blocked position has been evaluated sufficiently with regard to its relevance for safety and meets the requirements regarding criticality safety.

[5] The high average enrichment analysed for use in Swedish plants and in the chain handling, storage, and disposal is between 3 – 4 % U^{235}.

Changes in the chemical conditions

Higher burn up of fuel needs higher concentrations of ^{10}Boron (Boric acid) in pressurized water reactors during start up, power operation and shut down to ensure reactivity margins. Boric acid, Lithium and pH are components in a complex chemistry system which balances reactivity control, effects on materials and radiation levels as well as radioactive release. Correct management under different operational states has great importance for ensuring low corrosion and other effects on materials together with a good radiological working environment and low radioactive releases to the surroundings.

In 2007 SKI reviewed a notification from Ringhals of their plans to increase the Lithium concentration in the reactor coolant in Ringhals 2 – 4. In order to obtain the recommended pH in the reactor coolant with increased Boron concentrations the Lithium concentration needs to be increased to $\leq$ 6 ppm. The notified change of Lithium concentration in the reactor coolant changes the environmental conditions for both the fuel and the components of the primary system. Even if the changes are not considered to have a significant negative effect, SKI decided that the plants should follow up the effect of higher Lithium concentrations on the fuel and on the components in the primary system. In its decision SKI has imposed requirements that Ringhals follow up these changes using a specific programme for the purpose and also by following experience of similar applications in foreign plants.

Continued work with thermal power increases

The government license for the operation of a nuclear power reactor includes stipulations for the maximum thermal power which may be taken out of the reactor. The license is thus valid only for that thermal power. In order to increase the thermal power, the government must grant a new license in accordance with the Act (1984:3) on Nuclear Activities.

The thermal power of a reactor can, as described above, be increased by loading more fresh fuel assemblies, or by loading more highly enriched fuel assemblies, or by a combination of these measures. The average heat rating of the fuel assemblies will increase. The power can however be evened out by letting the fuel assemblies that are currently operating at a lower power load take a larger portion of the load increase than the highest rated fuel assemblies.

In a boiling water reactor the higher power in the core is dealt with by increasing the flow rates of the feedwater and steam. It is possible to choose between retaining the recirculation flow rate, which results in a higher steam concentration in the core, or increasing the recirculation flow rate and maintaining the steam concentration. A combination of these measures can also be used.

In a pressurised water reactor the higher power in the core is dealt with either by increasing the water flow through the core, or by increasing the temperature difference over the core. A combination of these measures can also be used. The higher thermal energy generated on the primary side results in more steam being produced on the secondary side. The higher steam flow is then transported to the turbine systems in which increasing the opening of the throttle valves results in the generator producing more electrical power.

Most of the Swedish plants implemented power increases in the 1980's, see Table 1. Most of the previous power increases were achieved by utilising the large safety margins which existed, improved analysis methods, and improved fuel. In several cases these increases in thermal power could be made without major plant modifications. In recent years the licensees have investigated the possibilities of further increases in thermal power. These include both larger and smaller power increases. The incentive is that thermal power increases are a relatively cost-effective means of creating extra electrical production capacity.

Table 1. *Thermal power increases carried out in Swedish plants. The table shows that the total increase in electrical power is 727 MWe.*

Reactor	**Original thermal power (MW_{th})**	**New thermal power (MW_{th})**	**Increase (%)**	**Original electric power (MW_e)**	**New electric power (MW_e)**	**Increase (%)**	**Year for increase**
Forsmark 1	2711	2928	8.0	900	1006	11.8	1986
Forsmark 2	2711	2928	8.0	900	1006	11.8	1986
Forsmark 3	3020	3300	9.3	1100	1200	9.1	1989
Oskarshamn 1	1375	-	-	460	490	6.5	2003
Oskarshamn 2	1700	1800	5.9	580	630	8.6	1982
Oskarshamn 3	3020	3300	9.3	1100	1200	9.1	1989
Ringhals 1	2270	2500	10.1	750	870	16.0	1989
Ringhals 2	2440	2660	9.0	820	910	11.0	1989
Ringhals 3	2783	-	-	-	-	-	-
Ringhals 4	2783	-	-	-	-	-	-

An increase in the thermal power can affect a plant in a number of different ways and to a varying degree depends on the magnitude of the increase. The conditions and parameters which can affect safety must therefore be identified and analysed to determine if the safety requirements are met with the necessary safety margins.

A number of components and systems in a nuclear power plant must be verified as having the capacity corresponding to the higher power rating. The impact on safety is in principle that the core will contain more reactivity. The inventory of radioactive substances in the fuel will increase. The neutron irradiation of components around the reactor core will increase. The residual heat of the reactor is proportional to the operating power and therefore will also increase. The systems that supply coolant to the reactor and remove the residual heat must have increased capacity. Since the total energy production from the core will increase the consumption of fissile material (U-235) will increase. The increase will, at the most, be proportional to the thermal power increase. The increased residual heat will also result in certain sequences during operational disturbances or in the event of a severe accident happening faster.

Permission to operate with increased thermal power can be supported by SKI on condition that it can be shown, through analyses and other measures, that the plant can be operated at the higher power in such a way that the safety requirements are met. In addition any known deficiencies or open issues affecting safety must be dealt with in an acceptable manner. SKI's supervision also includes acting to ensure that possibilities for improving safety are considered when planning different types of changes.

SKI's review of power increase applications is performed in several stages. Initially SKI carries out a broad safety review which forms the basis of the comments submitted to the government prior to their decision concerning the power increase. If the license is granted the subsequent stages are initiated, starting with evaluation of more detailed investigations and analyses submitted by the applicant covering the necessary plant alterations and their operational modes. SKI then follows up the alterations in the plant and makes decisions regarding test operation and routine operation at the higher power level. SKI's process for handling applications for increased power levels is described in "*Regulatory review and other supervision of the thermal power increases in nuclear power plants"*[6].

The following thermal power increases are currently under consideration:

- In 2005 Forsmark submitted an application for permission to increase the thermal power rating from 2,928 MW to 3,253 MW for both Forsmark 1 and Forsmark 2, and from 3,300 MW to 3,775 MW for Forsmark 3. After reviewing the application SKI has concluded that the necessary conditions are met for Forsmark to increase the thermal power in such a way that the safety requirements can be met.
    - SKI has therefore in its comments submitted to the government supported the application and recommended that the government grant permission to operate the reactors with the highest thermal power as specified in their application. In the autumn of 2006 the government asked SKI to supplement its comments. This was because of the incident in Forsmark 1 when several safety systems were non-functional after a reactor scram following a short circuit in a switchyard, as well as the special conditions SKI imposed as a result of the incident.
    - In an additional statement SKI informed the government that SKI's conclusions had not changed with regard to the technical basis for increasing the thermal power in the reactors Forsmark 1, 2 and 3 in such a way that the safety requirements can be met. In this statement SKI also informed the government that it considered that Forsmark has the prerequisites to correct the deficiencies in the management of the company and its safety culture.
    - SKI further informed the government that in the event it were to grant permission and make a decision with regard to the proposed license conditions, SKI does not intend to begin its review of the preliminary safety analyses and thus not grant permission for test operation at a higher thermal power level, as long as the conditions for operation of the plants in accordance with SKI's decision are in force. As has been pointed out in a previous chapter, SKI has in 2007 followed up the measures that the company has taken to correct the deficiencies. Apart from some communication concerning the thermal power increases, SKI has not carried out any reviews during 2007.

- In the autumn of 2005 the government granted permission for Ringhals to increase the thermal power in Ringhals 1 from 2,500 MW to 2,540 MW. A stipulation of this decision is that SKI must approve trial operation and the routine operation of the reactor at the increased thermal power level. In 2006 Ringhals submitted an application for trial operation at a thermal power level of 2,540 MW. As the basis for this application Ringhals has amongst other things performed a number of new safety analyses. SKI completed its review of the application and other documentation supporting the application in April 2007. This was the basis for the decision to approve trial operation at the higher thermal power. After an evaluation of the results of the trail

[6] Regulatory review and other supervision of the thermal power in nuclear power plants. SKI-PM 04:11. Swedish Nuclear Power Inspectorate. 2004-11-01.

operation SKI will assess the question of routine operations at the higher thermal power.

- The government also granted permission for Ringhals to increase the thermal power in Ringhals 3 from 2,783 MW to 3,160 MW. A stipulation of this decision is that SKI must approve trial operation and the routine operation of the reactor at the increased thermal power level. Ringhals is planning to increase the thermal power in two steps. At the end of 2005 Ringhals applied to SKI for the first step. SKI has reviewed the preliminary safety analysis report (PSAR), a revised safety analysis report, associated safety analyses and other related documentation. As a result of the review Ringhals has taken a number of measures to complete and improve the safety analysis. In January 2007 SKI approved the trial operation of Ringhals 3 at a maximum deliverable thermal power of 3000 MW. The decision was coupled with requirements concerning the trial operational programme and also the time for the tests regarding transfer to house turbine operation in the event of loss of the external electrical supply. In September 2007 Ringhals applied for approval of the Preliminary Safety Analysis Report which will be the basis for the plant modifications prior to trial operation of the plant at a thermal power of maximum 3160 MW. The safety review of this is underway.

- On December 17, 2007, Ringhals applied for permission to increase the thermal power of Ringhals 4 from 2783 MW to 3300 MW. Preparations for the safety review, remittance and the preparation of the recommendation to the government have been initiated.

- On June 8, 2006, the government granted permission for OKG to increase the thermal power in Oskarshamn 3 from 3,300 MW to 3,900 MW. A stipulation of this decision is that SKI must approve trial operation and the routine operation of the reactor at the increased thermal power level. In April 2007 Oskarshamn submitted an application to SKI for the approval of the preliminary safety analysis report (PSAR) which forms the basis for plant modifications prior to trial operation at 3,900 MW thermal power. The safety review is underway and additional material has been requested. A decision concerning trial operation at the higher thermal power is planned for the autumn of 2008.

- On September 26, 2007, Oskarshamn applied for permission to increase the thermal power of Oskarshamn 2 from 1800 MW to 2300 MW. Preparations for the safety review, remittance and the preparation of the recommendation to the government have been initiated.

5. Reactor safety improvement

In the summer of 2006 an incident occurred in Forsmark 1 which revealed that there were technical deficiencies in the electrical design. These deficiencies also found in other units. After the licensees had carried out analyses, minor alterations were made to Forsmark 1 and 2 as well as to Oskarshamn 1. The planned modernisation of Oskarshamn 2 was also affected.

The connection with the new regulations (SKIFS 2004:2) is basically the requirement concerning the resistance to common cause failures (CCF), of which the Forsmark 1 incident is a typical example. When these regulations have come in to full effect all the plants will be affected.

As part of its effort to follow up the long term questions arising from the F1-incident SKI organised a Workshop at the beginning of September 2007. Other regulatory authorities and licensees were represented at the meeting. Interest for the resistance of plants to electrical disturbances and connection to the grid was large and resulted in the formation of a working group under CSNI.

After the incident in Forsmark in the summer of 2006, SKI made a decision in September of the same year concerning conditions for continued operation, special supervision and required that a plan be initiated for measures to remedy the situation at the plant. The plant later also chose to request an OSART review of its activities, that is to say a safety review by IAEA. The review was performed over a three week period in February 2008.

New regulations concerning the design and construction of nuclear power plants

Safety improvements at the Swedish nuclear power plants have to date been conducted through successive alterations to the plant and special measures as a result of events which have occurred and problems that have been identified in the plants. An example of a problem that has led to this sort of plant modification is the so-called strainer incident in Barsebäck in 1992, when it was found that the emergency core cooling system in boiling water reactors with external main cooling pumps did not function as postulated in the safety analysis report. The incident led to the refurbishment work in the other Swedish plants and re-evaluation of earlier analyses.

With the new regulations (SKIFS 2004:2), concerning the design and construction of nuclear power plants, the situation has changed somewhat. Safety requirements for nuclear power plants have been developed and made clearer. The requirements have considerable consequences in particular for the older plants, and will result in improved safety.

The regulations came into force on January 1, 2005. Interim requirements will give the licensees sufficient time to plan and implement the necessary measures. SKI has previously issued interim requirements for Forsmark, and the corresponding decisions for Ringhals and Oskarshamn were made in 2007. All of these decisions require that the licensees must meet the regulations in full by 2013 at the latest. During this period the plants are planning extensive modifications in order to carry out thermal power increases.

Modernisation projects

Some time ago the licensees identified the need for extensive modernisation both for reasons of maintenance and safety. Many of the safety improvements will be steered by the regulations in SKIFS 2004:2. There are however other reasons for these measures, for example, operational cost-related considerations such as the increased need for maintenance and testing of older equipment, technical equipment that needs to be replaced because it is outdated, and difficulties in locating spare parts or competence for their maintenance. Control room electronics and equipment are an example of the latter, where older equipment will be replaced by more modern equipment based on digital technology.

The larger modernisation projects of the older Swedish power plants are being carried out in stages and will last several years. Some examples are:

- Oskarshamn 1 was the first Swedish nuclear power plant to undergo very extensive modernisation. The work was completed in 2002 and involved amongst other things a new design of the safety systems, new instrumentation and control equipment, as well as a new control room.
- Oskarshamn 2 is planning to rebuild the safety systems, instrumentation and control equipment and the control room. 2008 is an interim year, and most of the modernisation will be carried out in 2009 and 2011. According to the plans, the modernisation of Oskarshamn 2 will be completed in 2012.
- Preparations are under way in Ringhals 1 to install a new reactor protection system and a new cooling chain. The major part of this work is planned for autumn 2008.
- Modernisation of Ringhals 2 has to date been concerned with the switchyard and waste systems, and is concentrated now to modernisation of the control equipment and the control room. This project has had considerable delays caused by problems connected with the introduction of modern electronics. The introduction is now expected to occur in 2009.
- Ringhals has carried out extensive modernisation of the fire protection systems; the work was completed in 2007. The fire protection systems of all the units have been modernised and made more effective to meet modern design requirements. The project included the installation of new, redundant diesel operated fire fighting pumps, a new ring circuit for the fire fighting water with new risers and distribution piping in all the units.

SKI is supervising the ongoing modernisation work and has identified the need for considerable effort over several years to supervise and regulate future modernisation.

Updating safety analysis reports and technical specifications

As a result of the strainer incident in Barsebäck in 1992 which revealed deficiencies in the design requisites, the utilities started reviewing the original design prerequisites and safety analysis reports in the mid 1990’s. These reviews have identified some deficiencies in both the design and the analyses. SKI’s revised regulations (SKIFS 2004:1) concerning the safety in nuclear facilities the requirements regarding the safety analysis report and the safety analyses have been clarified and made more stringent. During the year new General Recommendations have been developed to clarify what should be included in a safety analysis report. The decision concerning these recommendations is expected to be taken in the spring of 2008.

Ringhals 1 undertook a revision of the safety analysis report (SAR) in the project REDA at the end of the 1990's. Prior to the plant alterations that are planned in both the projects Reactor Protection System (RPS) and Safety Package 2 (SP2), which are mainly aimed at modernising the reactor protection and the residual heat removal systems, a preliminary safety analysis report (PSAR) has been prepared. The PSAR for these projects will be reviewed by SKI in 2008. An approved PSAR is a prerequisite for the alteration work to be started. A revised SAR will also be submitted and reviewed in 2008 as the basis for resumed operation after the alterations have been implemented.

Ringhals 2 has revised its SAR as part of the DART project. Ringhals 2 DART-SAR was submitted to SKI on June 1, 2005. SKI is reviewing DART SAR and will complete its review in 2008 in conjunction with the review of the PSAR for the modernisation project TWICE.

Oskarshamn has worked on safety analyses in accordance with their fixed plans which are in part the result of requirements imposed by SKI. One of the important measures has been the revision of the SAR for all three units, amongst other things for plant operational status other than power operation. For Oskarshamn 3 these are being reviewed in connection with the review for the thermal power increase. For Oskarshamn 2 the review will be carried out in a corresponding manner prior to the modernisation which is planned for 2009. In the case of Oskarshamn 1, SAR will be reviewed in connection with the transfer to routine operation.

SKI's review of SARs is carried in connection to the review of the large projects, modernisation and thermal power increases. Furthermore all the SARs will be reviewed in 2008 and 2009 with respect to the modern requirements in SKIFS 2004:2.

Probabilistic safety assessments

The original reactor design and safety analysis reports have essentially been based on deterministic requirements and analyses. According to SKI's requirements in SKIFS 2004:2, reactor safety development is still based on deterministic requirements and safety analyses. However, there are also requirements to conduct probabilistic safety analyses (PSA) in order to verify and develop safety. The purpose is therefore to obtain a description of risk and safety that is as comprehensive as possible by using both deterministic and probabilistic analyses. PSA is thus an important tool for identifying possible weaknesses and the need for measures to improve safety. This applies to both the design and construction of the plant, the technical specifications as well as the instructions for upset and accident conditions.

PSA methods and areas of application have been the subject of considerable development, both in Sweden and internationally. A complete PSA must cover upset and accident conditions as well as external effects on systems such as the fire protection and flooding systems. It should also cover all operational conditions including start up, shut down and the annual outage.

PSA is being used more extensively, not only for safety development but also for different optimisation measures, such as optimisation of the maintenance, inspection and testing programmes. These applications impose new demands on the scope, coverage, quality and validity of the models and also on the input data and parameters that are used.

Previous PSA models developed for the Swedish plants have some deficiencies in this respect that are being dealt with successively. SKI through its supervision is providing impetus to the work so that the licensees will supplement and complete the PSA in accordance with current regulations. SKI also considers that a comprehensive PSA is an important part of the analysis work to assess the need for measures resulting from the requirements in SKIFS 2004:2.

All of the Swedish plants now have PSA- analyses that cover power operation, start-up and shutdown as well as outage conditions. Localised events such flooding and fire are also covered for all the plants. There are large uncertainties connected with the analyses for localised events and low power operations, which means that it is expected that the licensees will continue to work with these.

It should also be mentioned that SKI has initiated a two year research project aimed at coupling the results from PSA to the different barriers.

6. Organisation, competence and resource assurance and safety culture

The ability to handle a complex interaction between technology, people, organisations and economic aspects is essential to maintain and continuously improve safety. This section deals with how the nuclear power plants, in SKI's view, have worked with questions concerning, amongst other things, organisation, management systems, investigation of incidents, working conditions, competence assurance, MTO and modernisation as well as safety culture in 2007.

Licensees and their management systems

In 2007, SKI has continued to follow the licensees work to develop their management systems.

SKI has found that Forsmark still has a well disposed management system with clearly defined responsibilities. The plant had planned during the year to revise the management system by changing the Managing Director's documentation regarding management's expectations, as well as the documentation concerning the general duties of managers.

Oskarshamn has presented a plan for revising their management system that should be completed in the autumn of 2008. During the year SKI has started its review of Oskarshamn's management system. SKI also notes that RAB has a management system that fulfils its purpose appropriately and is readily accessible. The system is kept up to date and work is underway to further develop its structure and content.

Ringhals has a development plan which stretches until 2011. The plan includes for example development of the portal so that the management system is more user friendly and a revision of the quality assurance handbooks.

During an inspection of Forsmark's system for experience feedback SKI noted that experience feedback is dealt with at a high level in the quality assurance system and the different areas of activity. SKI considered however that the descriptions of how the requirements regarding experience feedback are fulfilled needs to be defined more clearly.

During the year SKI also noted during an inspection that Ringhals has a process for dealing with safety goals and guidelines for safety that provides a reasonable way to work with these issues. However it was noted that the process for dealing with safety goals presented during the inspection is not the same as is presented in the documentation regarding compliance with the regulations. SKI therefore encouraged the plant to revise the documentation regarding compliance with the regulations as part of the next revision so that it contains correct information as to where interpretation of the requirements occurs and that the documents that interpret the regulations and describe compliance with the requirements are used as references in amongst other things quality assurance handbooks.

Internal audit activities

SKI can also report that the nuclear power plants are continuing to develop their operations through the used of internal audits. Once a year SKI meets the different licensees to obtain an impression of how the internal auditing work functions, which audits have been performed and with which results. SKI can report that all of the licensees have a process for carrying out internal audits as part of the management systems, and that there are established routines for the internal auditing work. SKI considers that all the plants maintain high quality in the management and work pertaining to internal audits. SKI had noted that Forsmark did not have permanent employees for its internal auditing work. Recruitment was however underway. At Ringhals SKI noted that internal audits are basically carried out as planned. However SKI is of the opinion that measures to address deviations can be delayed. This situation is a deficiency in the auditing work at the plant which needs to be remedied. SKI considers that there have been improvements in the management and implementation of the internal auditing work in Oskarshamn. SKI is of the opinion however the plant has a somewhat unclear management of how deficiencies can be closed out. Furthermore SKI recommends that the person responsible for the area being audited should be required to attend the final meeting at the end of the audit. This is important to ensure final agreement and to be able to decide which deviations and observations need to be dealt with and the necessary time scale for the implementation.

Organisational changes

Based on inspections which were carried out in 2005 and 2006, and also from following organisational changes notified by the licensees, SKI considers that all the licensees have support in their management systems to manage, steer, carry out, follow up and evaluate, incorporate experience and carry out safety reviews of the proposed changes. Using samples in inspections it has been noted amongst other things that the licensees work in accordance with their routines, and that experience gained from major reorganisations has taken into account and resulted in further development of their processes.

A review of the reorganisation of higher management notified by Oskarshamn in 2007 showed furthermore that the plant had carried out the proposed changes in a steered, controlled and documented manner, inclusive of the primary and independent safety reviews, in accordance with the instructions their management system and with the focus on the necessary safety aspects and safety requirements. SKI considered however that the responsibility and authority for some positions needed to be more clearly defined and that the plant’s planned evaluation needs to include aspects concerning how personnel comprehend the clarity in the responsibility and authority in these positions.

Economy versus safety

One apprehension that SKI has is based on events in recent years that economy and safety, in the event of serious operational disturbances in the daily running of a nuclear power plant, can come into conflict with each other so that production takes precedence over safety. SKI has initiated research that has been carried out in 2006 and 2007 to study the prerequisites that exist at the licensees to make decisions concerning operational readiness that ensure that safety is also in focus. The results show amongst other things that all the licensees have clear policies which put safety first, that there is support in the various management systems, and that established work patterns exist as to how operational readiness decisions should handled from identifying deviations to making the decision, as well as how re-examine decisions at the different management levels in the organisations. How strictly re-examination is carried out varies however between the licensees. Events in recent years have increased the awareness of the licensees as to the importance that for each decision concerning operational readiness they must be able to justify the decision that the plant is in operational readiness, or that if it is not in operational readiness, that the reactor has been taken to an operationally safe state in time.

Safety culture and management for safety

All the licensees work with their safety culture. They have high requirements concerning safety and SKI's role is amongst other things to ensure that the licensees under no circumstances give priority to production at the expense of safety. Therefore it is important to ensure that the organisation has a strong safety culture and a management that has an active safety oriented attitude.

SKI notes that all the licensees work with safety culture and the concept is well known and needs to be given a high status at Swedish nuclear power plants. In order to maintain a good safety culture it is very important and decisive to react quickly to signs of deficiencies, since if deficiencies in the safety culture are not corrected they can jeopardise the organisation's capability to deal with diffuse and difficult situations and maintain safety. SKI's role is, amongst other things, to ensure that licensees mantle the responsibility necessary for active safety leadership, and SKI expects the licensees to develop and maintain a strong safety culture.

Forsmark has been under special supervision in 2007, after the incident on July 25, 2006. During the year SKI has followed the work to improve and strengthen the safety culture amongst other things by following the measures the plant has initiated to remedy the deficiencies identified by SKI and which were the reason for its decision concerning special supervision. Forsmark are working actively with safety awareness and questions regarding safety culture and have carried out a large number of activities in accordance with their remedial programme. The work is progressing well and one challenge that Forsmark has is that this will become well anchored in the organisation and achieve permanency.

For some years the licensees have used a questionnaire to carry out an internal survey of the status of their safety culture. SKI is very positive to the fact that the licensees are working actively with their safety culture and notes that there are a variety of efforts underway in this area, such as seminars and inter-organisational discussions. SKI follows this amongst other things through regular inspections to check the safety culture programmes of the licensees.

SKI considers that all the licensees have activities underway to promote the safety culture and strengthen safety management. The greatest challenge is to maintain safety awareness as a living concept and that this permeates all activities, SKI is going to strengthen its supervision in this area.

Competence and training, suitability and fitness for duty

During 2007 SKI has continued its supervision concerning the competence assurance of contractors at the Oskarshamn plant. Earlier inspections have identified areas in need of improvement and the plant has developed a remedial programme which was followed up in 2007. SKI has found that there are still some things which need improvement with regard to the fixed routines concerning the documentation of experience feedback and registration of the individual competence of contractors. In January 2008 SKI issued a decision requiring the plant to submit a plan to remedy these deficiencies.

SKI's conclusion from the inspection in 2007 of the safety reviewing of purchasing and the resource and competence assurance of contractors and other hired personnel in Forsmark is that the plant complies with the relevant regulations in SKIFS 2004:1, amongst other things through the support in the form of instructions and routines in the quality assurance system and that they work in accordance with their documentation. SKI and the plant have however identified the need for some improvements in this area. With regard to Ringhals, SKI considers that the plant also complies with the relevant regulations in this area, but that measures need to be taken since, amongst other things, it is not clear from the management system which requirements regarding competence should be applied by the purchaser when ordering services. There are deficiencies in the documentation concerning competence at the individual level regarding all the contractors and other hired personnel that are used. The improvement work at both Forsmark and Ringhals will be followed up in 2008.

For a long period of time there have been small margins with regard to the personnel resources in the control rooms of Forsmark 1 and 2. The turn over of personnel has been so large that considerable amounts of overtime and staggering of working times have been necessary. SKI has followed up the continuing work of the plant to remedy this personnel resource problem. During an inspection in the spring of 2007 SKI noted that the plant has considerable need of improvement regarding the personnel resources situation and that there were deficiencies in the working conditions for the personnel. During the year the operational organisation of Forsmark 1 and 2 has taken been changed, and during an inspection in December 2007 SKI noted that the control room personnel now have confidence in their working situation and that it is clear that the situation concerning personnel resources is taken very seriously within the organisation. There was however criticism from some of those interviewed about the remedial plan for personnel resources. In 2008 SKI needs to continue supervision of the work with the personnel resources for the control room.

In December 2007 SKI carried out an inspection of Oskarshamn which was concentrated entirely on the fitness for duty and suitability in other respects. SKI noted that the plant has clear and functioning routines regarding the assessment of the suitability of personnel in general. For operational personnel suitability and fitness for duty is documented in the management system so that continuous assessment can be made. For other personnel there are no requirements concerning suitability and fitness for duty on a daily basis, only in connection with employment and the regular medical examinations.

SKI noted further that the assessments are made but that there is a need to increase the support available to personnel to assess the fitness for duty and the suitability in general. Current requirements regarding responsibility and authority do not specify clearly where the responsibility for determining the suitability and fitness for duty lies for activities other than operational personnel.

Working conditions

During 2007 SKI has started supervision of this area with the goal of establishing the basis to assess how the licensees work in a systematic manner to create the necessary prerequisites for the personnel to work safely. The supervision has been carried out on different levels. On the first hand the focus has been directed to follow up in a general manner and obtain an overall picture of how the licensees have defined the area, how it is organised and how they in a systematic way work with these questions on a daily basis. In addition more limited supervisory efforts have been made in 2007 to follow up how the licensees have taken working conditions into consideration in conjunction with the various modification projects.

During the year SKI has carried out inspections of Oskarshamn and Ringhals with the aim of obtaining the basis for building an overall impression of how they work in a concrete manner with the working conditions in their activities in accordance with SKIFS 2004:1. The overall opinion is that both the licensees live up to these requirements and also that organisational adjustments have been made in order to carry out these efforts in a more concentrated and satisfactory manner. SKI considers even so that the organisational units which have been formed by these two licensees need to be followed up in order to clarify how they develop and function within the two organisations. Furthermore SKI should follow up how Ringhals deals with the problems of stress that they have identified amongst their personnel. In 2008 a similar inspection will be carried out in Forsmark.

During the year a reconstruction project has also been carried out in Forsmark which affected the working conditions of the personnel. The inner ceiling in the control room of Forsmark 1 was rebuilt. SKI carried out supervisory efforts to determine how the working conditions of the personnel were affected during the reconstruction and which preventative measures had been taken. SKI considered that in the specific situation improvements could have been made in the control room with regard to the working conditions and in particular the synergonomic conditions which could have affected the possibility for the operational staff to monitor the plant status. SKI also noted that the two emergency exits to the control room were blocked by scaffolding. After the inspection the plant took quick action to remedy the points raised by SKI.

MTO-aspects of modernisation activities

Extensive modernisation and plant modifications are underway in the Swedish nuclear power plants. For several years SKI held a dialogue with the licensees but since this did not result in sufficient improvements SKI reverted in 2007 to inspecting the licensee’s processes for plant modifications. The focus of the inspections has been the effect of the modifications on the control room from the interaction of the aspects man – technique – organisation (MTO). The results of the inspections showed that there is a need for improvement and such requirements have been imposed on all the nuclear power plants. It is planned to follow this up in 2008 and subsequent years. The most obvious areas in which there are needs for improvement are that the licensees must improve their management systems with instructions and routines to take MTO-aspects into account during the plant modifications and in several cases it is also necessary to make these requirements clearer as well as to carry out analyses of which competence is needed for the different members of staff. Fortunately, examples were found that the practice functioned better than described in the management system.

At the end of 2006 Ringhals had such deficiencies in its management system with regard to the MTO-aspects of its process for plant modifications that SKI considered that an inspection was not appropriate. Following a review of the management system in the spring of 2007 the plant was required to implement improvements. SKI is planning to carry out an inspection of these in the autumn of 2008. The plant has shown examples of better implementation than could be expected from the management system. SKI pointed out, however, that Ringhals risked being too dependent on a specific individual since such a large amount of the MTO-competence concerning plant modifications and the effects on the control room rests on one person.

SKI carried out a similar inspection of the process for plant modifications in Forsmark at the beginning of 2007. The result showed the need for the implementation of several measures. After further dialogue and clarification from the plant SKI required that in the area of plant modification from the perspective of man – technique –organisation the plans for competence and resources, and also the routines for experience feedback, should be revised. The plant has submitted their improvements and a review is underway. In summary SKI noted that there is a problem at the plant concerning the integration of MTO in the process for plant modifications. SKI considered that these problems are for the most part due to the lack of competence in this area within the organisation. SKI plans to follow this up at the beginning of the summer in 2008.

Oskarshamn was inspected at the end of 2007 regarding its process for plant modifications. The need for improvements was also identified at this plant. The plant needs above all to complete its management system to take into account the perspectives of man – technique – organisation in the process for plant modifications. They also need to clarify the responsibility and authority and what competence is necessary to carry out the purchasing function. SKI is preparing a decision requiring the plant to make improvements. It planned that this will be followed up in 2009.

The example used to study the process implementation during the inspection of Oskarshamn was the project Turbic. The inspection provided the basis for the decision regarding the project Turbic that the plant should perform a further integrated validation in which the turbine operators should be subjected to complex scenarios in the autumn of 2008. In connection with this the plant should also discuss which effect the special prerequisites for the base line measurements had on the analyses of the final validation. The base line measurements provide the reference values for the final validation. Unusually, they had not used a simulator which was completely identical to the plant.

Evaluation of incident reporting

SKI has carried out an inspection of the MTO-related reportable events (RO) at Forsmark and Oskarshamn. SKI notes that Forsmark works well with classification and following up the incidents. The plant has made efforts to improve the quality of investigations of incidents, and has identified the need for further improvement. The plant reports that the acceptance of MTO does not seem to be increasing in the company. SKI considers that it is extremely important that these problems are remedied so that neither the area of MTO nor the investigation methodology is discredited due to lack of competence. The fact that Forsmark is working in a broad manner with MTO aspects as a result of the WANO audit can act as a lever for the depth and breadth of MTO permeating the organisation. With regard to Oskarshamn, SKI found that they work with classification and follow up the incidents, but pointed out that they need to work more to evaluate trends over time.

SKI notes that Forsmark works well with classification and following up the incidents. This year the number of RO had increased as had the proportion of MTO-related events. SKI notes that the plant needs to improve its work with investigations of events and change the negative attitude that exists concerning MTO work. SKI shares Forsmark's opinion that the person responsible for questions of a MTO nature should be part of the organisation in order to work in a proactive manner in the daily activities and to be able to influence safety positively. SKI is positive to the fact that the plant has itself identified a number of deficiencies in the activities and is now going to give the work with MTO higher priority. In order to achieve a well thought out organisation for work in this area it is important that an analysis of the organisation is carried out, in the same way as it is with other organisational changes. The plant should also perform a resource and competence analysis for this area of work. Such an analysis should describe which tasks require deeper competence in behavioural science.

SKI notes further that Ringhals works to some extent with classification and following up events, primarily in connection with their annual report. In the follow up that SKI performed in 2004 it could be noted that classification is carried out in different parts of the organisation, but that the plant should systematise the classification and trending to a greater extent in order to learn better from the events. SKI is positive to the fact that the plant has itself identified deficiencies during the preparation of its annual report, amongst other things, trending and being able to work proactively. SKI considers that the plant can improve both the work following events and also include the work which is actually performed in the annual report. With regard to the deeper investigation of events SKI notes that the plant is dealing in a positive manner with the recommendations made previously by SKI and expects that the plant will continue with the improvement work which has been initiated. Further the plant needs, in order to achieve a manner of work and an organisation that suits them for questions concerning man, technique and organisation, to carry out an analysis of the organisation and also perform an analysis resources and competences necessary for this area of work.

Following up the 2005 inspection of Oskarshamn concerning the investigation of incidents and experience feedback, SKI found that several of the areas needing improvement identified in the inspection had not been remedied, and SKI therefore made a decision in 2006 regarding a plan to implement these measures. After a review of the plan, SKI still considers that Oskarshamn needs to improve its work on the investigation of incidents. SKI made a new decision about this and since then the plant has carried out a reorganisation and introduced a new management system. The plant has reported the changes it has made and the other measures in response to the decision and these are currently being reviewed by SKI. During an inspection SKI noted that the plant is working in a purposeful manner for good MTO efforts both for in the investigation of events and activities in general. SKI also noted that the plant works with classification and following up of incidents. There is good agreement between SKI and the plant on classification. SKI is positive that the material is used as the basis for the annual reports, but the plant needs to improve its work with trending over time.

7. Physical protection

SKI considers that all the nuclear power plants have physical protection which meets current requirements. This assessment is based on supervision activities such as inspection, event reports and notification of plant alterations concerning the physical protection of all the plants. SKI's supervision during the year has mostly been concentrated on controlling how the licensees meet the new regulations (SKIFS 2005:1) concerning the physical protection of nuclear facilities which came into force on January 1, 2007. SKI has also followed the work of the licensees to comply with the requirements in SKIFS 2005:1 that come into force on January 1, 2008.

All the licensees have extensive projects underway to implement the measures needed to meet the requirements which will come into force on January 1 and October 1, 2008, respectively. During the year it has become apparent that the assessments of the consequences of the regulations which the licensees made originally were grossly underestimated. The complexity and extent of some of the measures have been accompanied with difficulties to introduce them in time. Because of the delays in the introduction of certain measures the licensees have to varying degrees been granted time limited exceptions until the measures can be completed. In these instances SKI is of the opinion that the objectives of the regulations have been maintained.

SKI has continued the work to complement SKIFS 2005:1 with regulations concerning the protection of so-called vital areas in the nuclear power plants and the licensees have provided valuable contributions that give a broad view of the question.

During the year SKI has continued its dialogue with National Criminal Investigation Department and police authorities in the counties with nuclear power plants, as well as with the licensees for the nuclear power plants, to ensure as far as possible that preparedness is adequate in the event of an attack or serious threat situation.

In conclusion it can be noted that in 2007 SKI has held another staff training course for representatives from police authorities, licensees and county authorities in the counties which have nuclear power plants. The goal was to give the participants improve prerequisites to act in the event of a criminal attack on a nuclear facility and thus contribute to shortening the response times. The course was financed by the Swedish Emergency Management Agency and was the third and final course which has been planned.

8. Nuclear safeguards

The facilities work with nuclear safeguards is satisfactory. In 2007, SKI, IAEA and Euratom have conducted inspections of how nuclear safeguards are handled at the facilities. 80 such inspections have been carried out at the nuclear power plants. The criteria used by IAEA and the Commission require that the inspection interval for facilities with irradiated nuclear fuel does not exceed three months. Furthermore, each facility must perform a physical inventory once a year. For nuclear power plants this is carried out in connection with the annual refuelling outage. The results of this inventory are verified by SKI, IAEA and the Commission. Nothing has emerged during the inspections in 2007 to indicate deficiencies in nuclear safeguard work at the nuclear power plants.

In 2007, the updates of the facility descriptions submitted to SKI by the plants for the supplementary protocol to the safeguard agreement with IAEA, have been forwarded to IAEA in advance of the stipulated date of May 15. The supplementary protocol requires that the signatory must provide IAEA with more information than previously concerning nuclear activities and activities concerned with the nuclear fuel cycle. The supplementary protocol also gives IAEA extended rights of inspection. IAEA did not exercise this right in 2007.

9. Radiation protection

Radiation protection of personnel and its organisation

During 2007 the total collective dose (effective dose to personnel, including contractors) at the Swedish nuclear power plants was 8.8 manSv. The dose is the same order of magnitude as the average for the past five years (8.9 manSv). *Diagrams 4 and 5* show the collective doses at the Swedish facilities in an international comparison for BWR and PWR plants. Countries with comparable reactors to the Swedish plants with respect to design and age have been chosen for the comparison. Diagram 6 shows the dose trend for personnel at the nuclear power plants over the period 1996 – 2007.

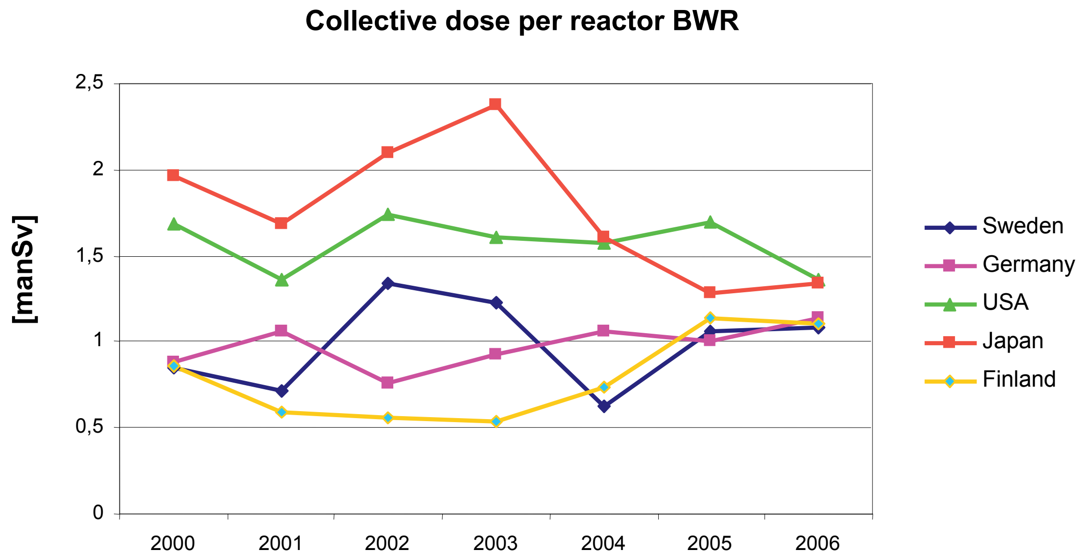

Diagram 4: Swedish collective doses for BWR (boiling water reactors) in an international comparison. Source: OECD/NEA, Information System of Occupational Exposure.

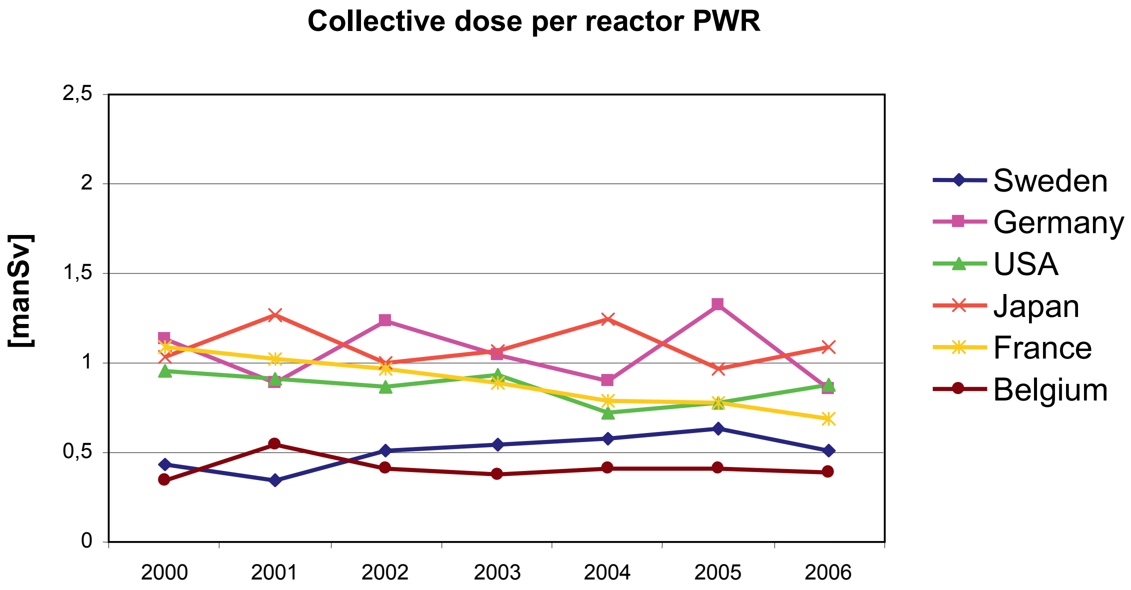

Diagram 5: Swedish collective doses for PWR (pressurized water reactors) in an international comparison. Source: OECD/NEA, Information System of Occupational Exposure.

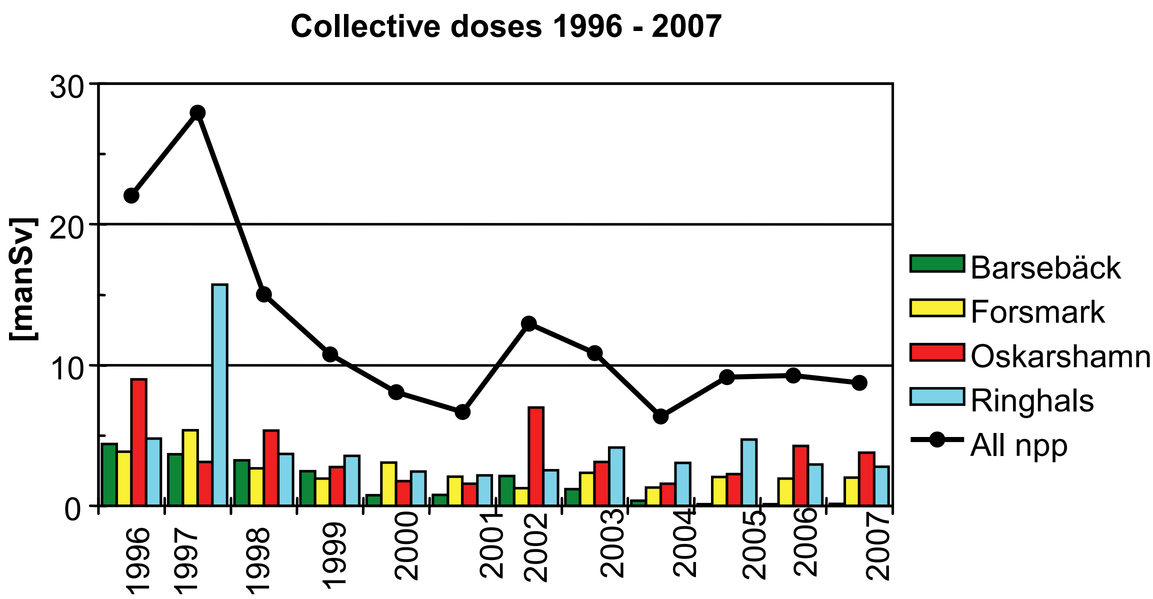

Diagram 6: Annual collective dose (manSv) to personnel at the Swedish nuclear power plants.

During the year 4,348 people have received a registered effective whole body dose (> 0.1 mSv). The average dose for these people was 2.0 mSv, which is a couple of tenths less than the corresponding value in 2006. Nobody has received a dose in excess of the established dose limits. The largest dose, received during work at any of the nuclear power plants, was 18.2 mSv. The largest individual dose received in 2007 was 19.5 mSv. Internal contamination control with respect to intake of radioactive substances has been carried out in accordance with established rules. During the year two people have received internal doses above the reportable level of 0.25 mSv. The doses were small 1.1 and 1.4 mSv respectively. Further information about doses to personnel at the Swedish power plants is shown in *Table 2*

Table 2: Summary of doses to personnel at the Swedish nuclear power plants in 2007

Plant	**Total annual dose** (manSv)	**Average dose** (mSv)	**Largest individual dose** (mSv)	**No. with registrered dose >0.1 mSv**
Barsebäck	0.15	1.33	9.7	116
OKG	3.79	2.36	16.8	1604
Forsmark	2.02	1.56	16.1	1295
Ringhals	2.80	1.50	18.2	1864

The release of radioactive substances to the environment

Nuclear power plants release small amounts of radioactive substances to both the atmosphere and water. These releases are measured continuously. The radiation dose to the public from these releases is calculated using models which are plant-specific, and which take into account, amongst other things, the meteorological conditions and the local land and water environments. The measurement and reporting of releases are to be conducted in accordance with regulations issued by SSI.

Diagram 7 shows the radiation doses calculated from the release of radioactive substances from nuclear power plants in 2007. The radiation doses (quoted in µSv) are for people living close to a nuclear power plant and who are expected to receive the highest doses, the critical group. SSI notes that in all cases the doses are lower than the environmental quality goal of 10 microsievert. The doses also show a decreasing trend in the long term.

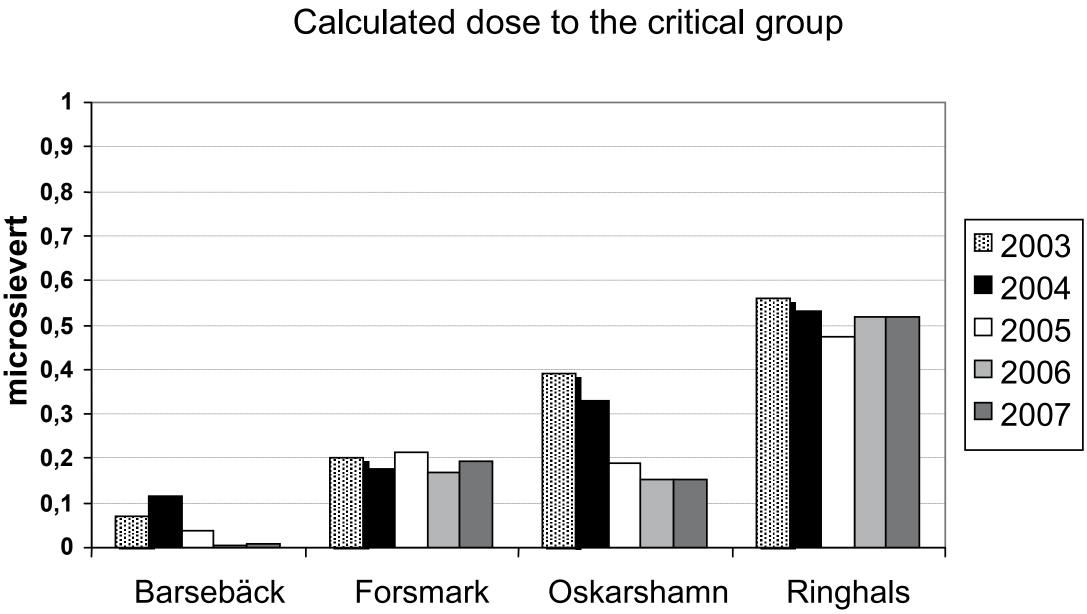

Diagram 7: release of radioactive substances to the atmosphere and water from nuclear power plants.

SSI's regulations contain requirements that the licensees of nuclear power plants report *reference values* for the release of individual or groups of radionuclides. These values are intended to show the normal optimised release level that it is possible to achieve during operations of each unit. The reference value is a measure of the different reactors' ability to limit releases during operation. The decisive factors for determining the reference value is operating experience and knowledge of the magnitude of the release in an historical perspective.

The regulations also contain the requirement to report a *target value*. The target value is the level to which the release of radioactive substances from a reactor can be reduced over a given period of time under normal operating conditions. Work to reduce the releases is thus steered by the established targets. The regulations require that the licensees report their ambitions and strategies for both the short and long term with regard to the reduction of release of radioactive substances.

The reference and target values for the period 2007 – 2011, with partial target values for 2007, have been fixed for Ringhals and Oskarshamn. In Ringhals 30 of the 35 target values for 2007 were achieved. In those cases for which the target values were exceeded it was marginally. In Oskarshamn 15 of the 21 target values have been achieved. The values which have been exceeded have in all instances concerned release to the atmosphere (noble gases and I-131). Amongst other things the repetitive fuel failures in Oskarshamn 3 have been a contributing factor to the somewhat higher releases than were expected. Forsmark has suggested new values, but because of the ongoing environmental impact evaluation of the plant, SSI has not yet made a final decision about these. That the target values have been exceeded in some cases does not mean that the public has received higher doses of significance, or that any dose or release limits have been exceeded.

According to SSI's regulations the plants should also carry out controls and take samples in the surroundings following a programme prescribed by SSI. A limited number of these samples are also measured by SSI. Ceasium-137 from the accident in Tjernobyl in 1986 still dominates the samples taken in the control programme in particular in the soil samples. In the water samples taken from the vicinity of the nuclear power plants a number of other radioactive substances can be detected, e.g. Co-60, amongst other things in samples of algae and the sediment.

Plant specific

Barsebäck
Activities at the Barsebäck facility in 2007 have been concentrated on dealing with issues concerning service operation that has now been established after the final closure of Barsebäck 2 in 2005 and the removal of the last fuel from the site in 2006. SSI considers that the plant has had an organisation and staffing that has been dimensioned for the activities. There is however some uncertainty concerning such a limited organisation, since it is vulnerable to the availability of staff. Therefore the plant must take into account that it must use hired staff if necessary.

The collective dose to the staff during 2007 was 0.16 manSv, with a highest individual dose of 9.7 mSv. In order to improve the radiation environment an extensive decontamination of the reactor systems in Barsebäck 2 was carried out in December 2007. The corresponding work was carried out in Barsebäck 1 in January 2008. The plant is going to evaluate this work in 2008 and present a report of the results. SSI considers that the system decontamination, in addition to the improvements in the radiation environment, also means that the future decommissioning can be performed under much better radiation protection conditions than without this effort.

No incidents of importance for radiation protection have been reported by Barsebäck during the year.

Medium level radioactive waste still remains stored in drums or in the ion exchange resin tanks in the plant, as well as activated components in the fuel ponds. The plant has applied to the safety authorities for permission to cast the resins in bitumen and deposit them in the final repository for radioactive operational waste (SFR). SSI is of the opinion that it is important that the operational waste on site, in the form of solid waste packed in drums and ion exchange resin stored in tanks, is dealt with and that the plant should give this work priority.

Barsebäck is participating in several international collaborative projects concerning decommissioning and SSI also considers that the plant is preparing for the imminent demolition in many ways in an ambitious and commendable manner. There are however some deficiencies in the decommissioning plans that have been submitted to SSI.

During 2007/2008 Barsebäck altered the guard and access functions at the plant and has installed new monitoring equipment for the control of radioactivity of personnel and transport. Plans are underway to establish education activities with radiation protection courses and training in working in controlled areas for personnel from other nuclear power plants.

An inspection has been carried out aimed at controlling the introduction of SSI's regulations concerning emergency preparedness at the plants. SSI considers that Barsebäck lives up to the requirements in the regulations. SSI has however made a number of recommendations for improving some of the activities. Other supervision has been carried out through plant visits and review of the reports that are prepared in accordance with the requirements in SSI's regulations. After reviewing the decommissioning plans submitted by Barsebäck SSI has required submission of additional information.

Forsmark

The environmental impact evaluation of the nuclear power plants in Forsmark as well as the thermal power increases for Forsmark 1, Forsmark 2 and Forsmark 3 is underway and the main hearings were held during the autumn. The environmental court has not yet issued its judgement. During the year SSI has provided comments as part of the preparations and subsequently participated in the hearing in the environmental court has held following the application from Forsmark. SSI suggests that, amongst other things, further measures should be taken to reduce the release of radioactivity.

In February 2008 an international review of reactor safety and radiation protection was carried out by the IAEA at the Forsmark plant. A final report from the IAEA is expected to be presented in the spring. Preliminary indications are that there are no major deficiencies concerning radiation protection.

A new waste store within the production area for interim storage of radioactive material has been tested during the year and SSI considers that there are the prerequisites for the store to comply with the current radiation protection regulations.

The collective dose to the staff during 2007 was 2.0 manSv, with a highest individual dose of 16.1 mSv. No internal doses from the intake of radioactive substances have been registered during the year. The refuelling outages have gone according to plan. The radiation levels in Forsmark 1 and Forsmark 2 have decreased slightly, whilst the levels in Forsmark 3 are basically the same as the previous year. SSI considers that the radiation doses during the refuelling outages are reasonable considering the work load and the radiation levels.

Forsmark has had problems with system 553 (monitoring of airborne activity) during the year with a continued high frequency of erroneous measurements of noble gases and this has resulted in a decision by SSI requiring measures be taken to ensure that the system is reliable. Hopefully the reconstruction of the system, which the plant has undertaken, will result in a more robust system.

SSI has followed the measures taken by Forsmark as a result of the requirements imposed concerning the errors in measurement of the atmospheric release of aerosols and iodine in system 553, and which were detected in Forsmark 1 during the autumn of 2006. Amongst other things the plant has presented a method to correct earlier years' release data, as well as a technical solution which prevents similar measurement errors recurring.

The effect on the surroundings from the release from the plant is small and the levels of the releases to the atmosphere and water are only a fraction of the release limits. Forsmark are currently introducing further measures to reduce the release of radioactive substances to the water in accordance with their declaration in connection with the environmental court hearing concerning the Forsmark plant.

Fuel failures have occurred during recent years in particular in Forsmark 3 and during the current operational period a minor primary failure has developed which has not yet needed attention. In the preventative work to avoid the occurrence of fuel failures an important goal is to prevent foreign debris or objects entering the reactor system and damaging the fuel. SSI considers that the prioritised efforts within the “clean system” programme are good and important.

The intensive sampling programme (extended programme which is carried out every three years) that should have been implemented during the spring of 2007, within the framework for the normal control of the surroundings of the Forsmark site, was not implemented due to a mistake of the person responsible for the programme. The normal programme was however performed and the extended programme was carried out in the autumn instead.

SSI has carried out two inspections during the year. One of them was aimed at controlling how Forsmark complies with SSI’s regulations concerning emergency preparedness at nuclear facilities. SSI considers that the requirements in the regulations are for the most part complied with by the plant. There is one exception concerning the lack of permanent detectors with alarms in the central control rooms of Forsmark 1 and Forsmark 2. The plant has been required to remedy this situation.

The other inspection was aimed at reviewing and assessing the capability of Forsmark to react to and learn from radiation protection related events or incidents. SSI considers that the plant reacts and learns from events in a relevant manner with respect to radiation protection aspects, and that there are routines regarding radiation protection for dealing with situations that can arise. SSI however identified deficiencies regarding how experience from radiation protection work is taken into account in a preventative manner. Problems or situations that have been identified are not always remedied and have thus resulted in incidents occurring. There are also deficiencies in following up how contractors implement the internal instructions of the plant. With regard to the experience feedback, SSI notes that the plant has introduced a new system and is thus giving these questions higher priority in an acceptable manner.

Other supervision has been carried out through plant visits and review of the reports that are prepared in accordance with the requirements in SSI’s regulations, and SSI notes that Forsmark has complied with the regulations concerning reporting.

Oskarshamn
In 2007 Oskarshamn applied for respite from the condition in the judgement of the environmental court concerning the installation of recombiners in Oskarshamn 1 and Oskarshamn 2 in 2007, which SSI opposed in two appeals. The environmental court of appeal then ruled that the recombiners must be installed in Oskarshamn 1 and Oskarshamn 2 not later than June 30, 20008. SSI considers that the inability to fulfil this condition indicates that there are deficiencies in how Oskarshamn has steered the project.

During the year Oskarshamn has applied to the environmental court for permission to increase the thermal power of Oskarshamn 2. The power increase is planned for 2011. In accordance with SSI’s requirements the plant has made a written submission regarding the different aspects of possible consequences for radiation protection in Oskarshamn 2 when it increases the thermal power. This is currently being reviewed by SSI.

During the winter of 2007 tritium was detected in system 733 (demineralised water supply) in the central workshop. SSI decided to forbid the use of the water outside controlled areas until the cause had been found and remedied. After Oskarshamn had taken compensatory measures the decision was in part revoked. No radiation doses have occurred as a result of this incident. One incident occurred in connection with the reverse flushing of a filter to the waste facility when a tank overflowed (dnr 2007/649). The accident was mostly due to human error and better instructions have been introduced to prevent this happening again.

Fuel failure problems continue in Oskarshamn 3. After the refuelling outage in 2007 two failures have occurred which have resulted in the reactor being shut down to deal with the damaged fuel.

The collective dose to personnel at the Oskarshamn facility in 2007 was 3.8 manSv with a highest individual dose of 16.8 mSv. No internal doses from intake of radioactive substances have been registered during the year. The radiation levels in Oskarshamn 2 have increased but are unchanged for Oskarshamn 1 and Oskarshamn 3.

The refuelling outages this year have been carried out with varying results. Oskarshamn 3 had a short refuelling outage without radiation protection problems and with low radiation doses. The outage of Oskarshamn 1 was extended by 42 days, because of a leak in system 754, without the total radiation dose being affected very much. The outage of Oskarshamn 2 was dominated with respect to radiation doses by a project to replace piping and install a cyclone filter in system 312. The work took much longer than expected, and this contributed to the dose being 0.8 manSv higher than estimated. The reasons according to the plant were, amongst other things, deficiencies in the planning and steering of the project. The underestimation of the time needed and the corresponding underestimation of the dose resulted in possibility of a system decontamination not being considered defendable considering the total optimisation of the project. This has in the end led to a higher dose than would have been the case, and emphasises the importance of planning and steering to achieve a good result with respect to radiation doses in large projects. The plant is performing an investigation of how this project was carried out.

SSI considers that the radiation doses during the refuelling outages, with the exception of Oskarshamn 2, are reasonable considering the work load and the radiation levels.

A partial reconstruction of system 553 (air monitoring) was carried out in the autumn. In order to reduce the release new targets and reference values for key radionuclides have been fixed for the period 2007 – 2011. SSI notes that the radiation doses to the public from the release of radioactive substances from Oskarshamn during normal operations continue to be insignificant. None the less, the best possible techniques should as far as possible be used to limit the release of radioactive substances to the surroundings.

During the year SSI has followed up the requirements which were imposed after the incidents in 2006 when a control rod guide tube was dropped and a person was exposed to radiation during radiography. SSI considers that the plant has implemented the necessary improvements such as the introduction of a new instruction for radiography and training of transport personnel.

SSI has performed two inspections in 2007. One inspection was aimed at reviewing and assessing the capability of the organisation to react and learn from radiation protection related events or incidents. SSI considers that Oskarshamn can react and take reasonable radiation protection measures in the event of an incident or accident. SSI has however identified some deficiencies and possibilities of improvement in a number of areas. Amongst other things SSI has noted that the plant lacks a common and uniform system to ensure that information about, for example new instructions, reaches the user and that they are actually implemented (internal control system). Nor is there a clear system to incorporate experience from contractors concerning radiation protection. The plant has at the request of SSI submitted measures to correct these deficiencies.

The other inspection was aimed at controlling how Oskarshamn complies with SSI's regulations concerning emergency preparedness at nuclear facilities. SSI considers that Oskarshamn lives up to the requirements in the regulations, but has also made a number of recommendations for improvements. The plant should revise its training planning with regard to the frequency of the training of the staff coordination between the plant (KC) and the authorities' control centres.

Other supervision has been carried out through plant visits and review of the reports that are prepared in accordance with the requirements in SSI's regulations. SSI has nothing to criticise in the reports submitted.

Ringhals
During the year Ringhals has increased the thermal power of two of its reactors, Ringhals 1 and Ringhals 3. No unexpected consequences regarding radiation protection have been observed yet. A further thermal power increase is planned for Ringhals 3 and an application has also been made to the government for an increase in the thermal power of Ringhals 4.

SSI has changed the radiation protection conditions for shallow ground disposal of low level nuclear waste and Ringhals has now applied to SSI for permission to make a new deposit.

The radiation doses to personnel were lower than expected in all the units. The collective dose to personnel was 2.8 manSv with a highest individual dose of 18.2 mSv. Two cases of internal contamination just above the reporting level have been reported. These occurred in connection with an incident in the active workshop. The radioactive levels in the plant are stable or continuing to decrease. During the refuelling outages in the summer large inspection and plant modification work was undertaken, amongst other things the replacement of the high pressure turbine and intermediate heat exchanger in Ringhals 3, and the low pressure turbines in Ringhals 4, inspection of the steam generators, and work with the reactor coolant pumps in Ringhals 4 and Ringhals 2. One observation that the plant has made after the summer outages is that the proportion of personnel with limited experience from work in the nuclear industry has increased, which has led to the need for more effort to enforce the safety rules. The plant also considers that there is a shortage of experienced radiation protection staff.

SSI considers that the radiation doses during the refuelling outages are reasonable considering the work load and the radiation levels.

In Ringhals 3 the feedwater flow rates were determined using trace element measurement of Na-24 in order to verify the calculations of the thermal power. The work was carried out in a satisfactory manner with regard to the radiation protection aspects.

A number of radiography incidents have occurred during the summer outages, amongst other things due to insufficient cordoning off of the relevant areas. None of the incidents have resulted in radiation doses to personnel that are worthy of note. Ringhals has performed an internal investigation of the radiography incidents and has suggested measures to prevent a repetition, including clearer routines. Another incident occurred in the active workshop in Ringhals in connection with the balancing of a pump axel from Forsmark. Due to faulty handling and insufficient information the active workshop was contaminated during the work. The incident did not result in any significant doses to people involved. Ringhals has investigated the incident and has suggested measures which, amongst other things, will improve the cooperation with the other nuclear power plants in connection with handling radioactive components that are transported from one plant to another. SSI considers that the suggested measures are relevant and will result in a reduction in the risk for repetition.

During the year Ringhals has submitted waste plans for the replaced steam generators. The plans are to continue to send the old steam generators to Studsvik for treatment. SSI has no objections to the waste plans which were submitted, and is positive to the work in Ringhals to deal with the old steam generators.

SSI has performed inspections on four occasions in 2007. The first inspection was directed to the work with ALARA in Ringhals. SSI noted amongst other things that there have been changes in the goals, formulation and implementation of the ALARA work, to a certain extent as a result of the comments SSI has made after an earlier inspection of Ringhals 1 in 2006. SSI considers that the plant complies with the requirements in the regulations concerning work with ALARA.

In the second inspection the system for airborne release in Ringhals was reviewed. SSI considers that there are no deficiencies in the organisation, division of responsibilities or documentation of routines. In connection with the inspection four air filters from system 553 were taken for analysis and SSI's measurements were in good agreement with those made by Ringhals. SSI also considers that the plant works ambitiously with its programme to reduce the release which was agreed in connection with the environmental evaluation. This can also be seen from the fact that target release levels of almost all the key nuclides have been achieved during the year.

Prior to the transportation of old steam generators from Ringhals for treatment in Studsvik SSI carried an inspection to control that Ringhals had complied with the specific requirements for the transport. SSI noted that the transport was carried out in an efficient and competent manner and within the specific regulations.

An inspection was carried out aimed at controlling how Ringhals complies with SSI's regulations concerning emergency preparedness at nuclear facilities. SSI considers that Ringhals complies with the regulations with the exception for the transfer of metrological data. The plant has started to work with measures which are planned for completion in the spring of 2008. SSI also made a number of recommendations including a revision of the documentation system for training personnel with respect to the radiation environment in the event of a serious accident.

In addition to inspections SSI's supervision has been carried out through plant visits and review of the reports that are prepared in accordance with the requirements in SSI's regulations. SSI has not anything to criticise in the reports submitted.

10. Waste management

Treatment, interim storage and disposal of nuclear waste

Different forms of treatment of radioactive operational waste are conducted at the nuclear power plants so that the waste can be disposed of or placed in interim storage pending disposal. Low level waste is deposited in shallow landfills on site at Forsmark, Oskarshamn and Ringhals, or is sent to Studsvik for treatment. More radioactive waste is deposited in the repository for operational waste, SFR-1, which is located near the Forsmark nuclear power plant. Very low level waste can be exempted from the regulations (free-classed) of the Radiation Protection Act and the Act on Nuclear Activities and can then be used without restriction, incinerated or deposited in municipal dumps. Waste containing long-lived radioactivity is placed in interim storage at the nuclear power plants or in CLAB, Central interim storage facility for spent nuclear fuel, pending a suitable repository.

SKI and SSI consider that the treatment, interim storage and disposal of nuclear waste at the nuclear facilities has been carried in a satisfactory manner during the year. In addition to the treatment of normal operational waste, the following can be reported for 2007:

- At Barsebäck work is underway to handle the waste from the operational period. During 2007 a successful system decontamination of reactor two has been carried out. In 2006 an error was found in the database of waste at the plant. This has been corrected during the year. An application has been submitted to the authorities to begin casting waste from ion exchange resins in cement and the review is expected to be completed in the first quarter of 2008. Most of the remaining operational waste from the reactor clean-up systems can, after approval by the authorities, be deposited in SFR-1.
- At Forsmark work has been started to build three new storage facilities amongst other things for the interim storage of medium level and long-lived waste until the final repository for long-lived waste is available (2045). According to industry’s plans, after a short period of storage in Forsmark the waste will moved to the underground storage facility, BFA in Oskarshamn. SSI has given Forsmark permission for shallow ground deposition of waste. Evaporator concentrate is still being stored whilst a method is developed to increase the capacity for its treatment.
- In the underground storage facility (BFA) at Oskarshamn preparations are underway for the interim storage of long-lived waste such as reactor vessel internals from the Swedish nuclear power plants. The aim is to use the underground storage facility until the final repository for long-lived waste is available, which is expected to be in 2045. In January 2008 the government granted permission for the interim storage of waste in BFA until 2045. Permission was also granted for the interim storage of reactor vessel internal components from the other Swedish nuclear power plants.
- At Ringhals waste handling is affected by the prohibition for the deposition of certain PWR waste in SFR-1. The prohibition has been in force since 2003. The waste is being stored at Ringhals until SKB (Swedish Nuclear Fuel and Waste Management Co) submits the statement that the authorities required in 2003 as a result of the review of the safety report for SFR-1. Extensive efforts have been made to study the possibility of treating liquid waste by evaporation. The waste has previously been released to the

environment. In 2007 SSI decided on revised radiation protection conditions for the operation of shallow landfill disposal in Ringhals.

- In 2007, the treatment of more steam generators from Ringhals is almost finished with good results, in addition to those which were sent to Studsvik in 2005. Some analyses remain before the final report can be submitted to the SKI and SSI. If the result is positive the residual waste can be sent to SFR for deposition. Then all the steam generators from Ringhals can be treated in a satisfactory manner.
- As in previous years scrapped components have been sent from the nuclear power plants to Studsvik for treatment in the melting facility
- In 2006 waste packages corresponding to 518 m^3 have been deposited in SFR-1. Since SFR-1 became operational a total of 31,767 m^3 has been deposited. During the latter part of 2007 deposition of waste in SFR was stopped because a renewed estimate indicated that the inventory had been exceeded, and that the reporting from SKB was insufficient or deficient. After clarifying reports from SKB the deposition prohibition was lifted in part in March 2008. There remains a prohibition from 2003 for the disposal of certain waste from Ringhals. In addition a prohibition is in force for certain waste from Forsmark.

Spent nuclear fuel

Spent nuclear fuel and remains of reactor vessel internals that are classified as long-lived waste are placed in interim storage in Clab which is located close to the Oskarshamn nuclear power plants. OKG conducted the day-to-day operations under contract to SKB up to 2006-12-31. From 2007 SKB has taken over the operation of Clab, which has meant considerable adjustment for SKB. During the year SKB has made considerable efforts aimed at continuing to adapt SKB to the responsibility for operating its own nuclear facilities. SKI has followed these aspects SKB's safety work closely.

During the year 44 fuel transport containers with uranium in the form of spent fuel from the nuclear power plants have been received at Clab. At the end of the year there were 4,675 tons of uranium distributed between 23,874 fuel elements.

11. Emergency preparedness

There were no comprehensive exercises executed during the year. According to the Swedish training regime comprehensive exercises are only carried out in “even years”. However attention has been concentrated to the smaller exercises that have been carried out at the nuclear power plants, and the inspections during which the emergency preparedness organisations and preparations at all the nuclear power plants have been discussed. The authorities also took part in the annual meeting at which all the people responsible for emergency preparedness from all the nuclear power plants and representatives from SKI and SSI participate.

SSI has also carried out inspections in 2007 concerning emergency preparedness at the nuclear power plants. SSI considers that all the plants, after a number of deficiencies have been remedied, comply with the requirements in the regulations. More details can be found in chapter 9 “Radiation protection”.

In 2005, SKI performed reviews and inspections of all the nuclear power plants to determine to what extent the licensees meet the requirements in SKI’s regulations, SKIFS 2004:1 concerning safety at nuclear facilities, with regard to the planning of emergency preparedness and information transfer to SKI. The supervisory effort showed that there is a need for improvement of both the planning and the transfer of information. SKI therefore issued a decision that required the plants to carry out improvements. The measures have been reviewed and it had been intended be follow them up in 2007 but this has been delayed until 2008.

SSI, in cooperation with the plants, has strengthened the communication possibilities for SSI personnel in the control centres at the nuclear power plants. SSI personnel at the plant can now communicate in a secure manner with SSI via the internet and get access to the information and analysis systems in the internal network at the authority. This improvement has been implemented at Forsmark and Ringhals. The upgrade is planned for 2008 in Oskarshamn. Corresponding measures have been implemented in the protected control centres of the relevant counties.

SKI, in consultation with SSI, has started a research project concerning the technical alarm criteria at the nuclear power plants. The alarm criteria form the basis for setting the alarm levels, which in turn form the basis for the initial measures for organisations outside the plant to take in the event of an accident. The project is also to investigate the possibility of further improvements in harmonisation of the scope of the alarm criteria at the different nuclear power plants. At the beginning of 2007 SKI managed to get agreement between all the participants and the project was started at the beginning of March.

Experience has shown the importance of well defined criteria and routines for when and how a plant should contact the authorities in the occurrence of incidents, which for some incidents confirms the importance of the project on alarming criteria described above. In particular this applies to incidents resulting from criminal acts, but also other events which lie somewhat under the alarm level in their seriousness.

SKI and SSI have participated in a project group which has investigated the requirements concerning special emergency preparedness for the county administrative board of Skåne after all the nuclear fuel has been removed form Barsebäck. Since all the fuel has been removed the plant has been classified as category 3 in accordance with SSI’s regulations (SSI FS 2005:2) concerning emergency preparedness at certain nuclear facilities. As a result of this SSI has commented to the Ministry of Defence on the need to change the regulations (2003:789) concerning protection against accidents in connection with the decommissioning of the nuclear power plant in Barsebäck. SSI suggests in its comment that the requirement for special emergency preparedness in the county of Skåne is revoked. SSI also suggests that in the future Skåne could support other counties in questions concerning the emergency services in the event of the release of radioactive substances and sanitation (FSO 4 ch. 29 §) in the same way as Västerbotten does.

SKI and SSI have participated in a number of exercises of varying size and complexity, ranging from liaison tests to exercises at units of the nuclear power plants.

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