APPENDIX 2 Safety improvements

Rauno Lehto, Veli Riihiluoma, Päivi Salo, Heimo Tukala, Keijo Valtonen

Loviisa nuclear power plant

Provision for severe accidents
Measures to mitigate the consequences of severe accidents were carried out at both Loviisa plant units during the annual maintenance outages of 2003. The modifications related to hydrogen management and management of containment leaktightness. In addition, measurement installations not completed in the 2002 annual maintenance were completed.

In severe accidents, hydrogen is released inside the containment. Catalytic recombiners were installed inside the containment to burn hydrogen without quick explosive fires. Installation of the recombiners in the containment upper compartment was continued during operation. The entire installation work was completed by the end of the year.

The steam generator room has glow plugs for situations involving especially quick hydrogen releases. The plugs were qualified for severe accident conditions and their placing was changed when more recombiners were installed. In the annual maintenance, 40 glow plugs were installed at both plant units.

The sealing material on the doors of the reactor pit was replaced with material that better withstands severe accident conditions. Additional sealing could not be implemented according to plan. The deviation has STUK’s approval until the 2004 annual maintenance.

In addition to those implemented previously, the option of manual tripping was provided for one more containment isolation signal necessary for the maintenance of containment leaktightness. These manually tripped special functions assure containment leaktightness against system leaks.

Replacement of radiation measurements
Replacement of fixed radiation monitors was continued at Loviisa plant. During the Loviisa 2 annual maintenance outage, 61 monitors were replaced. In addition, the radiation monitors of the ventilation stack were replaced at Loviisa 2 towards the end of the year. Corresponding modifications had been made at Loviisa 1 in 2002, excluding the ventilation stack monitors, which were replaced in 2003.

The fixed measurement system of Loviisa nuclear power plant comprises a total of 140 independently operating monitoring devices that follow dose rates in the plant’s rooms, the radioactivity in processes and the amount of releases. Part of the system is capable of functioning even in severe accidents.

New radiation monitoring technologies yield data more versatile and accurate than before on the radiation levels of measured objects. In addition, measurement data from the new radiation monitors is more efficiently available for use by the plant personnel. Besides the control room and the monitors’ local displays, the data can be directly utilised in the work locations of those responsible to control radioactivity and those working in the I&C unit. Some of the new devices can be easily moved if needed, facilitating an improved focusing of radiation measurements.

Supports of low pressure emergency cooling system pumps were modified
High vibration values had been observed in the low pressure emergency cooling system pumps of both Loviisa plant units. To reduce them, the supports of the pumps were modified in the annual maintenance outages. Deviating vibration values had been detected in one Loviisa 1 and three Loviisa 2
pumps. Each plant unit has four low pressure emergency cooling system pumps.

The deviating vibration values were due to the natural frequency of the entity comprising the pump unit and its supports being ca 100 Hz, which is identical to the frequency of the initiator from the pump unit’s electric motor. Vibration levels can be reduced by changing the natural frequency of the structure and that of the initiator such that they are not the same. A structure’s natural frequency can be increased by making it stiffer and decreased by reducing its stiffness. There have been earlier attempts to reduce vibrations by making the foundation stiffer, but its natural frequency did not improve sufficiently. The foundation’s stiffness was reduced by opening the supports of the upper plate at the corners i.e. the perpendicular walls of the foundation were sawn open around the corners. After this, the natural frequencies of the pump units were measured and found to have decreased by ca. 10–15%. Test runs showed a marked reduction in the pump units’ vibration levels.

Olkiluoto nuclear power plant

Feedwater distributors were replaced at Olkiluoto 2

Old feedwater distributors were replaced in the Olkiluoto 1 annual maintenance outage. The new distributors are capable of handling post power upgrade feedwater flow and their design takes into account heat stresses exerted on ascending pipes of the emergency cooling system located inside the reactor pressure vessel. The pipes are located directly under the feedwater distributors. Heat stress is imminent when cold feedwater mixes with warmer water returning from the steam separators. The new distributors are meant to mix these flows as well as possible and to thus reduce heat stresses exerted on the ascending pipes.

The process interface of process computers was modernised

In the 2003 annual maintenance outage of Olkiluoto 2, the oldest process computers plus their process interface equipment were upgraded and provided with user interfaces. The process interface gathers and transmits measurement and condition data to the process computer system and the process automation system user interface. For analogue data gathering, the upgraded equipment constitute a new “Data gathering and temperature monitoring system”. The power supplies and data buses of its processors have been doubled for enhanced availability. In addition, the new system carries out temperature measurement-related actuations, monitors signal limits, carries out alarm functions and further delivery of signals to the control and alarm panels of the control room, conducts operating time calculations for electric motors, and gathers and calculates trends.

The upgraded alarm computer constitutes a system of its own. It collects binary event data on processes and transmits them to the process computer through the new “Data gathering and temperature monitoring system”.

The Olkiluoto 2 system connects to two new servers of the process computer system. These servers, equipped with next generation software, were commissioned for operation abreast with the process computer system proper. Their two workstations were placed next to the user interfaces of the process computer on the control room main operation board, which was also upgraded.

Similar modifications were implemented at Olkiluoto 1 in the 2002 annual maintenance outage but the control room was not equipped with a new process computer user interface. The system’s upgrading was continued in the annual maintenance by arranging the connections between its process I & C stations.

The safety significance of the process computer system and its data gathering system mainly pertains to the provision of information and they do not contribute to the actuation of safety functions.
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APPENDIX 3 Significant operation events

Jarmo Konsi, Jukka Kupila, Rauno Lehto, Hannu Ollikkala, Pentti Rannila, Rainer Rantala, Veli Riihiluoma

Loviisa nuclear power plant

A delay in the repair of a high pressure safety injection system pump at Loviisa 2

In connection with the periodic testing of a reactor high pressure safety injection system pump at Loviisa 2 on 3 March 2003, excess water was detected in the reactor's high pressure safety injection system. It was attributed to a leaking shaft gasket on the pump's coupling side. The pump was replaced with a reserve pump whose functioning was problematic, too. The utility had to apply for two exemptions from the Technical Specifications from STUK to accomplish the repair and make the pump operational during plant unit operation.

After leak detection, the gasket was tightened without delay, with the pump running. The leak was not reduced, however, and the gasket was retightened, which resulted in smoke coming out of the gasket housing. The gasket was loosened but fuming and heating did not stop. The pump was stopped for inspection on 4 March 2003. Its shaft was found stuck and large cuts were found on the coupling side of the gasket housing. In addition, the shaft's protective sleeve was almost broken and had stuck to the shaft. A decision was made to dismantle the entire pump for repairs.

The pump in question is part of the reactor high pressure safety injection system and it pumps boron water into the primary circuit in the early stages of an accident. The system has two redundancies, two parallel pumps in each. During normal operation the pumps are only operated for ca. two hours for testing. The Technical Specifications allow for a period of three days of subsystem unavailability for repairs during plant unit operation.

This 3-day repair period would not have been sufficient to find out the cause of the pump failure and to repair it, so the utility applied for a 7-day extension, which was granted by STUK.

It was evident from the parts of the dismantled pump that the sleeve of its labyrinth shaft sealing had stuck to the shaft and had to be machined off. After its removal, the shaft was tested by liquid penetrant and long circumferential cracks were detected. A week would not have been enough to repair the original pump and so it was replaced with a corresponding spare pump. The operation of the new pump was found problematic, too. It was repaired and STUK decided on a 10-h trial run more extensive than a regular periodic functional test. The trial run was completed on 14 March 2003.

Although the pump seemed to be in good order during the trial run, the vibration spectrum of the coupling-side bearing of its electric motor indicated an imminent bearing failure. The utility applied for a 3-day extension to the deviation from the Technical Specifications, which was granted by STUK. The new permit was valid until 17 March 2003. The bearing in question was replaced but the vibration spectrum was still found ambiguous. The motor was replaced with a spare motor.

In addition to the motor failure, also the pump was found defective, i.e. it jammed when manually run. The bearing and housing of the spare pump were partially dismantled but the cause of the jamming remained unclear and it was decided to entirely dismantle, inspect and repair the pump. The repaired pump unit was tested on 17 March 2003 with acceptable results.

The utility has purchased spare parts for the pumps and initiated analyses to purchase new pumps.
Inoperability of ventilation stack release measurements at Loviisa 2
During the weekly changing of sampling filters of the sampling lines of the ventilation stack of Loviisa 2 on 16 October 2003, the filter of one sampling line was found to be in an incorrect position. The other line was out of service due to measuring device replacements. The situation was put right without delay by replacing the incorrectly positioned filter with a new one. The observation was reported to the relevant foreman by email. The event’s safety significance was only recognised in December at what time it was re-evaluated and also reported to STUK.

Ventilation outflow from the controlled area of both plant units at the Loviisa facility is channelled to the ventilation stack. The radioactivity of outgoing air is monitored at each plant unit by continuous-operation measurements and once-a-week laboratory analyses. The release measurement systems comprise two independent lines in which the sampling filters and continuous-operation radiation monitors are located. The Technical Specifications require that two out of three monitors be operational. Due to the incorrect position of the sampling filter, a representative sample flow from Loviisa 2 was not obtained for the two sampling line monitors in operation and the release measurement function thus was not operational as required in the Technical Specifications. The plant unit’s radiation measurement system was being upgraded at the same time and thus also the third monitor of the release measurement system was out of service. In addition to this, a representative weekly sample for laboratory analysis did not accumulate in the filter.

According to detailed utility analyses, the release measurements had been simultaneously inoperable for ca. 20 hours. Based on the plant unit’s operating statistics, it has been shown that the unit operated normally during the time period in question and no exceptional releases occurred. A separate stand-by radiation monitor for accident situations was in operation the whole time.

A definite reason for the incorrect filter position has not been found. The old release measurement system has been completely removed already, making reconstruction of the event causes impossible. After equipment upgrading, recurrence of the event is impossible. Owing to the event, the Loviisa utility has paid attention in training to the procedure of reporting exceptional observations.

The event was classified INES Level 0.

Olkiluoto nuclear power plant
Deterioration of the containment isolation function due to the failure to operate of a steam line isolation valve at Olkiluoto 1
Periodic tests of the main steam line isolation valves were carried out at Olkiluoto 1 on 8 February 2003 during which the outer isolation valve of one main steam line failed to operate. These main steam lines penetrating the containment are equipped with isolation valves both within and outside the containment. The quick closure of the valves, if a steam pipe breaks, is an important safety function because it prevents level swelling of the reactor due to a pressure decrease caused by a pipe rupture and the subsequent rising of water to the steam lines and the possible damaging of steam piping. Periodic tests are conducted every two months and they measure i.a. valve closure times, which may not exceed 1.6 s. The valve in question totally failed to close in the test.

The valve’s stem sealing was loosened after the test and lubrication was applied on the stem until the valve’s closure time was acceptable. A total of six close-signals were sent to the valve. It did not close on the first two signals and after the next four signals it was made to close by lubricating the stem and loosening the stem sealing. The valve was considered operational based on the first below-the-approval-limit closure time and no additional tests were performed to ascertain approval. The valve closed in 1.41 secs in the approved test, i.e. closure time was very close to required value. Normal isolation valve closure time is below one second in tests.

The valve that failed to close was previously tested on 22 December 2002, with an acceptable closure time. Its stem sealing had been tightened on 27 December 2002 because it was leaking. The valve had not been tested, and it may have been inoperable, since then. The containment isolation function was thus less effective for ca. six weeks. During this time the containment isolation function for the steam line in question relied on the containment inner isolation valve.
The valve’s internal parts were replaced in the 2003 annual maintenance. Nothing out of the ordinary was detected on examining the removed internal parts and after inspection the valve’s failure to close was attributed to a stem sealing that was probably too tight. In addition, the valves’ maintenance instructions and the procedure for assessing the acceptability of the results of periodic tests have been made more specific.

The event was classified INES Level 1.

**Inoperability of emergency coolant pumps at Olkiluoto 2 during annual maintenance**

During the annual maintenance outage of Olkiluoto 2, the emergency cooling pumps were not in automatic start-up readiness for ca. 14 hours, in non-compliance with the Technical Specifications.

This occurred during the maintenance of control rod actuators during which, according to the Technical Specifications, at least one auxiliary feed water system pump and at least two reactor core spray system pumps must be operational. Maintenance operations started on 12 May 2003 at about 21 hrs. All four parallel pumps in each subsystem were separated about 30 mins earlier. The error went unnoticed during the night and morning shift changes. STUK’s inspectors noticed the situation during inspection in the morning of 13 May. All the four redundant pumps were immediately restored to service.

During the maintenance of a control rod actuator, a leak could occur in the bottom of the reactor pressure vessel, which would, within 60 mins, cause a 14 cm decrease in the reactor pool water level. In the situation prevalent at the time, the systems supplying emergency water would not have actuated automatically. As there is an abundance of water above the reactor core, there would have been a long period of time available for leak detection and restoration of the availability of the pumps before the situation would have become critical to safety. Any leaks would have been easily detected both from the signals received in the main control room and when working in the space beneath the reactor pressure vessel.

The event was preceded by a situation in which the pumps are to be separated in accordance with the plant unit procedures. The plant unit had been shut down for annual maintenance, the reactor water level had been raised up to the reactor pressure vessel flange and the bolts of the reactor pressure vessel head were being unfastened. The pumps are separated from switch-plants to prevent their automatic starting and manual starting from the control room. This prevents their inadvertent starting when work is done on the reactor pressure vessel flange. Should the pumps inadvertently start, reactor cooling water would end up on those detaching the reactor pressure vessel head.

The pumps were separated in the morning of 12 of May. The raising of the level of the reactor pool, which connects to the reactor pressure vessel, was started on the same day, entailing, according to the plant procedures, restoration to operability of three reactor core spray system pumps and of one auxiliary feed water system pump. Once the reactor pool level had reached overflow channel level the pumps were separated again, which was against the plant procedures. The shift manager concluded that the systems are not needed since the reactor pool is full of water. In case the pumps started accidentally, the reactor water level would start to rise and could possibly rise high enough for the water to enter the reactor hall floor. One such near miss -situation had occured once in the operating history of the Olkiluoto plant units. A reactor core spray system pump started and raised the water level close to floor level.

The event was attributed to a deviation from the procedures: the pumps were separated when the reactor pool was full of water. The deviation’s acceptability and appropriateness was not looked into either and it was not reported to the next shift during shift change. The plant’s other monitoring methods failed to indicate the event as well.

The utility will review its procedures and the Technical Specifications to prevent recurrence. The event has been addressed in training given to the operating personnel.

The event was classified INES Level 1.
Flow indication in a welded joint of a feed water nozzle of the Olkiluoto 2 reactor pressure vessel

An indication, 12 mm in length and 9 mm in depth, along the pipe center line was detected in one of four feed water nozzles of the Olkiluoto 2 reactor pressure vessel in a periodic inspection during annual maintenance. The flaw is located in a welded joint between the reactor pressure vessel nozzle and its safe-end. The feed water pipe is welded to one end of the safe-end. New NDT techniques were used in the inspection that was carried out on the pipe inner surface. The examination, by both ultrasound and eddy current methods, was conducted by an independent company specialising in inspection with NDT testing methods commissioned by the utility.

Corresponding Inconel 182 weld metal cracks have been observed quite often also at foreign nuclear power plants. The likely cracking mechanism is Interdendritic Stress Corrosion Cracking (IDSCC). Needle-like dendrites are formed when molten metal reaches solid state in cooling. Crack formation may be connected with a partial hot crack that occurred during welding. A weld joint’s stress level is high due to residual stresses formed during manufacturing. Owing to operating experience from foreign plants, reactor pressure vessel nozzle joints containing the filler material in question are inspected every 3–5 years, whereas normal weld joint inspection interval in the international standard applied here is 10 years.

Wall thickness in the area in question is 34 mm, i.e. over two times design norm minimum thickness. Even if the crack penetrated the wall, it would not lead to total pipe rupture but would be revealed while still a very small leak, i.e. the Leak Before Break (LBB) principle would apply. The crack growth rate has been assessed as low based on measurements made on test specimens and on practical experience. There are less residual stresses deeper into the joint and thus the crack growth driving force is smaller. Crack longitudinal growth is restricted by crack collision with material that better withstands stress corrosion cracking. On reviewing the measurement data on an ultrasonic examination from the external surface of the nozzle area in the year 2000, using an improved interpretive programme, a weak indication of almost equal size was detected. This shows that the flaw has not noticeably grown in three years.

The utility commissioned inspection of corresponding welds in the feed water nozzles of the Olkiluoto 1 reactor pressure vessel in the annual maintenance outage, although they were not included in the 2003 inspection scope. No flaw indications were detected.

The flaw is due for repair in the 2005 refuelling outage, using a filler material that better withstands stress corrosion cracking. In spite of this, the indication will be inspected even in 2004 and will be repaired then in case of substantial crack growth. In addition, the sufficiency of the frequency of reactor pressure vessel nozzle inspection and the appropriateness of examination methods will be re-evaluated. The utility will also investigate the options of preventively repairing Inconel 182 weld joints by cladding using improved filler material.

A strainer clogged up at Olkiluoto 1 during annual maintenance

At Olkiluoto 1 on 1 June, 2003 a reduced flow was detected in one sub-system pump of the shutdown reactor sea water system. The pump's suction inlet was checked and found clean. A strainer in the same line was checked as well. A wealth of mussels and other impurities was found. In addition, a flow control flap essential for strainer flushing was in a wrong position. The strainer thus did not function properly. The flaps of three other sub-systems and corresponding flaps at Olkiluoto 2 were checked without delay and found operational.

The strainer may have become clogged when sea water channels were commissioned during annual maintenance. Impurities may have dislodged then, some ending up in the strainer in question.

All four lines of the shutdown reactor sea water systems of both plant units were equipped with strainers in 1992. They prevent the heat exchangers that cool back-up diesel generators from getting clogged up by mussels and other impurities, which may dislodge from the sea water channels. The diesel generators feed power to components important to safety in a loss-of-grid
situation. The actuator of the flap of the strainer in question was replaced in 2002.

The event’s causes were multiple. Clogging was attributed to the actuator of the flow-controlling flap having been installed 90 degrees incorrectly. The incorrect actuator position was not disclosed in a post-maintenance functional test, which is conducted to assure component functionality and to disclose any mistakes and defects. The clogging of the strainer was not revealed in a pressure difference measurement either.

The position of the control flap’s actuator was corrected. Three other strainers in Olkiluoto 1 and all four Olkiluoto 2 strainers were inspected and their correct installation ascertained. The utility will also review working instructions such that verification and recording markings for ascertaining strainer flap position will be recorded. General instructions will be drawn up for the maintenance of actuator-equipped flap valves. The utility will check the pump’s flow graphs to assure its post-maintenance operability.

Corresponding events relating to the installation of valve actuators have occurred at the Olkiluoto plant. After the events, the procedures were reviewed and training was given to mechanics.

Three out of the system’s four sub-systems were fully operational and thus the plant unit was in a design-basis state; its safety would not have been endangered in an accident. The event was classified INES Level 0.

**The rate-of-change limit for reactor water temperature given in the Technical Specifications was exceeded at Olkiluoto 1**

On 4 July 2003 during the start-up of Olkiluoto 1 from the 2003 annual maintenance outage, a reactor scram from low reactor water level occurred during reactor cool-down to cold shutdown to repair a water leak in the cable penetration of one main circulation pump. The rate of reactor temperature decrease momentarily exceeded the rate-of-change limit in the Technical Specifications.

The reactor was cooled by using a control valve of the pressure reduction system. The valve opened fully during cooling, after which the reactor pressure and level quickly decreased. The reactor water temperature decreased ca. 30 °C in ten minutes, whereas the Technical Specifications allow for a reduction of 15 °C in ten minutes. The reactor feed water pump in operation was on manual drive and was not capable of compensating for the coolant flowing from the reactor through the control valve; the reactor level thus dropped low enough to actuate a scram. All four pumps of the auxiliary feed water system started and restored normal reactor water level.

Since the reactor control rods were inside the reactor at the time of the event, no actual scram occurred but only scram safety systems started. They operated according to design. The maximum limit on the reduction in reactor water temperature protects the reactor pressure vessel from premature fatigue. Component fatigue analyses have postulated a couple of temperature changes quicker than this during the plant service life. The temperature change-of-rate limit was exceeded only briefly and primary circuit integrity was not endangered.

The event was caused by an error that was made in operating the control valve of the pressure reduction system. The operator had not updated the pressure set value for valve control prior to adjusting the reactor pressure. It was 5 bar, which is used for outages, and the valve opened too much. In addition, shortcomings were found in the operating instructions for the control valve, and the operator failed to adequately follow reactor pressure and level behaviour during cooling.

To prevent recurrence, the utility has reviewed the operating instructions for the pressure control system and given the operators plant stimulator training on the matter.

The event was classified INES Level 1.

**Inoperability of a fire damper in the staircase of the Olkiluoto 2 reactor building**

It was found out at Olkiluoto 2 on 25 August 2003 that a fire damper of the reactor building air-conditioning system was not operational in the way required in the Technical Specifications.

On Thursday 21 August 2003, a test in accordance with a preventive maintenance programme had been started at the plant unit to measure pressure differences in the staircases of the reactor building. In the test a blower with an intake direct from outside blows an overpressure into the stairway. The required overpressure was not
reached in the first test. The matter was looked into and it looked like that the fire damper in front of the blower did not open. However, a failure notification was drawn up for the blower for which there are not requirements is the Technical Specifications. Instead, the Technical Specifications require the fire damper to be operational or fixed closed. It was now closed but not fixed closed although it was obviously inoperational.

The blower overpressurises the stairway in the event of a fire, using fresh air taken directly from the outside and facilitating exit in case the stairway is filled with combustion gases. The fire damper must open in case of fire. In an accident involving a release of radioactive substances within the reactor building, an underpressure must be established to prevent radioactive releases into the environment. The fire damper must then be in the closed position and leaktight to prevent outdoor air from entering the reactor building through it, which would prevent underpressurisation. In such a situation the off gas system handles reactor building air conditioning and filtering.

The failure notification was entered in the plant unit work order system and it was not noticed that the Technical Specifications set requirements for the failed damper. The situation prevailed over the weekend. On Monday the failure of the test was attributed to the coil of the motor of the fire damper’s actuator, which was replaced. That the fire damper’s failure was connected to the requirements of the Technical Specifications was disclosed when STUK’s resident inspector paid attention to the matter.

During the time of inoperability of the fire damper, spent nuclear fuel was transferred from the plant unit to the spent fuel storage, using a transport container specifically designed for this purpose. The Technical Specifications require that all fuel handling onsite must be stopped if components important to the operation of the off-gas system are inoperational.

An analysis of the event disclosed that the preventive maintenance task in question, which relates to the measurement of pressure differences in the stairway room, had been inactive in the data systems of both Olkiluoto plant units for about a year. From this followed that the 2002 maintenance had not been carried out. The functioning of the blower and the fire damper had been checked on 23 July 2003 and they were found to function normally.

In 2003 the utility had planned and implemented several measures to prevent corresponding occurrences. The improvements focused, among others, on reviewing the plant data system and on making more effective the monitoring of inactivated preventive maintenance tasks. In addition, all tests and inspections defined in the Technical Specifications will be reviewed to ascertain that they are active tasks in the pre-maintenance and periodic testing system.

The event was classified INES Level 1.

**Inoperability of a fire pump at Olkiluoto nuclear power plant**

One fire pump at Olkiluoto nuclear power plant was inoperational for 42 days due to a maintenance error. A valve on the pump’s pressure side was left closed after preventive maintenance. This was not noticed in functional tests and inspections of fire water valve positions. Two other fire water system pumps were available and the extinguisher system would have operated, if necessary.

The event occurred during the pump’s preventive maintenance during plant operation on 20 to 29 August 2003. The pump and its motor had been isolated for safety for the duration of maintenance operations. The maintenance staff found the separation insufficient, however, and closed two valves outside the safety isolation instructions. The valve closures were not addressed and recorded in accordance with relevant utility instructions. When safety isolations were restored after the work, one valve was left unopened. It would have prevented pumping of water by the pump to the fire extinguisher system piping. After the maintenance operations, the pump was subjected to a functional test, which did not reveal the incorrect valve position.

A fire water system visual inspection is conducted weekly in which the status of the valves should have been checked and the error detected. However, it was only detected on fifth check up on 1 October 2003, after which the correct position was restored without delay.

In connection with the event, shortcomings were detected also in how the periodic inspection
follow-up system was used. Tests had been acknowledged as done, even if that was not the case.

To prevent recurrence, the utility will make instructions more detailed and review how procedures, data systems and the Technical Specifications correlate with one another. In addition, the personnel will be given training on procedures and requirements pertaining to safety engineering components.

There was no imminent danger for plant safety from the event. The fire extinguisher system has three pumps one of which is capable of providing sufficient extinguishing water for the facility. One pump is electrically operated and two are diesel operated. The event compromised the reliability of the fire extinguisher system, however, and indicated significant shortcomings in the organisation’s operation. It was classified INES Level 1.

The floor drainage level measurement function at the Olkiluoto spent fuel storage was not inspected

For several years, four floor drainage level transmitters in the spent fuel storage of the Olkiluoto facility had not been inspected. They are in rooms not easily accessed that are assumed to have a high radiation level. The Technical Specifications require that they are functionally tested once a year. Several rooms have been fitted with them to assure detection of any water leaks from the fuel pool cooling system. No problems relating to their testing have been brought to the attention of the organisation. The inspections were reported as having been completed, however.

Three uninspected level transmitters are in rooms accessed through a concrete hatch lifted open by crane. Due to their high radiation level, the rooms are subject to restrictions as regards time spent working there. The fourth level transmitter is in a room not easily accessed either. In addition, the yearly measurements of the rooms’ radiation level had not been done. These facts have, for their part, contributed to the assumption, prevalent among inspectors, that the rooms are not to be accessed. Inspection of the transmitters has been acknowledged as done in the data system, along with inspections of other corresponding level transmitters. This is why the situation was only detected in October 2003 when the problems were openly reported to the line organisation.

To prevent recurrence, Teollisuuden Voima Oy will ascertain that procedures, data systems and the Technical Specifications correspond to one another. In addition, new instructions on the inspection of level transmitters in the spent fuel storage will be drawn up. Procedures for making room radiation measurements will be reviewed and the personnel will be given additional training on work methods as well as on requirements pertaining to components covered in the Technical Specifications.

The event had no immediate impact on the safety of spent fuel storage. However, it indicated shortcomings in the organisation’s operation and in adherence to guidelines. It was classified INES Level 1.

High vibration levels on emergency coolant pumps at Olkiluoto 1

Periodic condition monitoring measurements in the autumn of 2003 revealed high vibration levels on the reactor core spray system pump units at Olkiluoto 1. These were compared with corresponding Olkiluoto 2 values, which were found to be lower.

Operating together with other systems, the reactor core spray system protects the reactor core against overheating during emergency cooling. The system’s pumps provide the spray water needed. The core spray system is a stand-by safety system for long-time core cooling. One of the system’s four pump units has been evaluated as having been fully available for long-term pumping. Three pump units could have failed in long-term pumping. In the early stages of an accident, two pumps have to be available, and for long-term cooling, one pump suffices. The plant unit’s safety would not have been in immediate danger in an accident, even if the cooling function was significantly reduced.

Elevated vibration levels had been measured on the pump units of the Olkiluoto 1 reactor core spray system for several years already. The motor of one pump unit was replaced in 2002 but it soon reached the elevated, prior-to-replacement vibra-
It was only after the 2003 vibration measurements that Teollisuuden Voima Oy started to look into the causes of the elevated vibration levels. The matter was looked into by subjecting one pump to extensive testing and vibration measurements in early October 2003. During the tests, even the structure of the pump unit’s mounting base was investigated and the steel plate under the motor was found not to be firmly attached to the concrete. In addition, unfilled cavities were found beneath the plate. The motor base’s behaviour was thus flexible. A flexible base can be ascertained to cause vibration levels higher than a stiff base. A component on a flexible base is allowed higher vibration levels than one mounted on a completely stiff base.

The defective bases of pump units at Olkiluoto 1 were repaired in early November 2003 by filling out cavities beneath the steel plates with concrete. In verifying measurements, essentially lower vibration levels have been found. The utility has also taken measures to inspect fastenings and concrete castings of the bases of other systems and pump units at Olkiluoto 2.

The event was classified INES Level 1.
## APPENDIX 4 Periodic inspection programme

*Kaisa Åstrand*

<table>
<thead>
<tr>
<th>Basic programme</th>
<th>Inspections in 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loviisa NPP</td>
</tr>
<tr>
<td><strong>A</strong> Safety management</td>
<td>X</td>
</tr>
<tr>
<td><strong>B</strong> Main functions</td>
<td>X</td>
</tr>
<tr>
<td>B1 Assessment and improvement of safety</td>
<td>X</td>
</tr>
<tr>
<td>B2 Operation</td>
<td>X</td>
</tr>
<tr>
<td>B3 Plant maintenance and ageing management</td>
<td>X</td>
</tr>
</tbody>
</table>

### C Inspections by functional unit and field of competence

| C1 Plant safety functions | X | X |
| C2 Electrical and I&C systems | X | |
| C3 Mechanical engineering | X | X |
| C4 Structures and buildings | X | X |
| C5 PSA and safety management | X | X |
| C6 Document and information management | X | |
| C7 Chemistry | X | X |
| C8 Nuclear waste | X | X |
| C9 Radiation protection | X | X |
| C10 Fire protection | X | X |
| C11 Emergency preparedness | X | X |
| C12 Physical protection | X | X |
| C13 Training / Human resources and training | X | X |
| C14 Quality assurance | X | |
| C15 System line-up procedures | X | X |
APPENDIX 5 Licences and approvals in accordance with the Nuclear Energy Act

Marko Hämäläinen

C214/241, 7 Febr. 2003, Teollisuuden Voima Oy
Licence to export irradiated fuel samples (two from a water channel and three from the corner of a fuel assembly spacer grid, with a combined activity of 380 GBq) from Olkiluoto nuclear power plant Unit 1 to Sweden for hot cell analysis. Valid until 30 April 2003.

C214/244, 20 March 2003, Teollisuuden Voima Oy
Import of control rods (6 pcs) from Sweden. Valid until 31 December 2003.

C214/245, 15 April 2003, Teollisuuden Voima Oy
Import of control rods (8 pcs) from Sweden. Valid until 31 December 2003.

C214/246, 21 May 2003, Teollisuuden Voima Oy
Licence to import from Japan “Licenced Software” – FINELOAD-3, including potential later updates. Valid until 31 December 2018.

A214/40, 23 May 2003,
Fortum Power and Heat Oy (Generation)
Licence to export to Studsvik, Sweden, three irradiated nuclear fuel rods (max. 40 g of plutonium and 3000 g of enriched uranium, max. 30 g of \(^{235}\)U) for fuel tests.

Y214/72, 12 December 2003,
Geological Survey of Finland (GTK)
Retain, use, handle and store nuclear material for analysis at the GTK (a total of max. 1.5 g of enriched uranium, in which the share of \(^{235}\)U is 0.8 g max.).

C214/250, 22 Dec. 2003, Teollisuuden Voima Oy
Import of fresh nuclear fuel from Sweden. A total of max. 17 000 kg of enriched uranium. Provided with the Euratom control stamp “P”. Valid until 31 December 2004.

C214/251, 22.12.2003, Teollisuuden Voima Oy
Import of fresh nuclear fuel from the Federal Republic of Germany. Max. 8 700 kg of enriched uranium. The obligations of an exchange of notes pertaining to the peaceful uses of nuclear materials between the authorities of Finland and the People’s Republic of China apply to the uranium in 18 assemblies. Provided with the Euratom control stamp “N”. Valid until 31 December 2004.

C214/252, 22.12.2003, Teollisuuden Voima Oy
Import of fresh nuclear fuel from the Federal Republic of Germany. Max. 11 500 kg of enriched uranium. Obligations of the Finnish–Russian co-operation agreement on the peaceful uses of nuclear energy apply to the uranium used in the manufacture of above fuel (55 assemblies). Valid until 31 December 2004.

C214/253, 22 Dec. 2003, Teollisuuden Voima Oy
Licence to retain, store and use for training and demonstration, specimen (a total of four specimen manufactured of depleted uranium, with max. 10.3 kg of uranium) of depleted uranium. Valid until 31 December 2013.

C214/254, 22 Dec. 2003, Teollisuuden Voima Oy
Import of fresh nuclear fuel from Spain. A total of max. 1 500 kg of enriched uranium. Provided with the Euratom control stamp “P” or “N”. Valid until 31 December 2004.
APPENDIX 6  STUK’s safety research projects completed in 2003

Esko Eloranta, Harri Heimbürger

Nuclear power plants

Research projects included in FINNUS

FINNUS/AGE; Fuel cladding corrosion mechanism and its modelling, a continuation project; VTT Manufacturing Technology

FINNUS/AGE; Environmentally assisted cracking of NPP materials, a continuation project; VTT Manufacturing Technology

FINNUS/AGE; Modelling of the behaviour of oxide films with regard to their role in activity build-up and different corrosion phenomena in NPPs, a continuation project; VTT Manufacturing Technology

FINNUS/FISRE; Fire safety research, 2001; VTT Building Technology

FINNUS/FISRE; Fire safety research, 2002; VTT Building Technology

FINNUS/FISRE; Effect of smoke and heat on electronics, modelling of fire scenarios for PSA, active fire protection equipment; VTT Building Technology

FINNUS/FISRE; Active fire protection equipment; VTT Building Technology

FINNUS/INSMO; Usage of modelling in ultrasonic testing; VTT Manufacturing Technology

FINNUS/INSMO; Risk-informed periodic inspections; VTT Manufacturing Technology

FINNUS/METRI; Risk informed leakage frequency assessment; VTT Manufacturing Technology

FINNUS/METRI; Development of human error assessment method for low power and plant shutdown risk analysis; VTT Industrial Systems

FINNUS/PASSI; Ageing related failure modes of modern I&C equipment; VTT Automation

FINNUS/PASSI; Reliability assessment and FMEA of programmable automation, a continuation project; VTT Automation

FINNUS/READY; The application of new reactor physics models in criticality safety calculations, a continuation project; VTT Processes

FINNUS/READY; FRAPTRAN-code: Development of FRAPTRAN-GENFLO code, 2002; VTT Processes

FINNUS/READY; FRAPTRAN-code; delivery and validation of FRAPTRAN-GENFLO-code; VTT Processes

FINNUS/READY; FRAPTRAN-code: Application of statistical calculation methods in the FRAPCON 3 and FRAPTRAN-codes; VTT Processes

FINNUS/READY; Application of CDFPLIM-method in dynamic codes; VTT Processes

FINNUS/STIN; Research related to structural integrity of nuclear power plants, 2001; VTT Industrial Systems

FINNUS/STIN; Modelling of loading to structures and equipment, 2002; VTT Industrial Systems

FINNUS/STIN; Development of integrity analysis for structures and equipment; VTT Industrial Systems
FINNUS/STIN; Validation of computational methods, 2002; VTT Industrial Systems

FINNUS/STIN; Development of applicable methods for defining fracture mechanism characteristics of radiated steels; VTT Industrial Systems

**Research projects included in SAFIR**

SAFIR/CULMA; Organizational culture in Finnish NPP maintenance; Development of an assessment method, 2003; VTT Industrial Systems

SAFIR/IDEC; Interaction approach to the development of control rooms; Preliminary development of control room evaluation framework, 2003; VTT Industrial Systems

**Research activities pertaining to regulatory decision-making**

Development of NDT qualification; Provision of QA documents; Serco Assurance Inc.

Numerical evaluation of effects to reactor core caused by steam explosions in the reactor pressure vessel lower plenum; VTT Energy

Fire analysis of Loviisa NPP turbine hall, a continuation project; VTT Energy

Studies in concrete technology for the construction, inspection and repairing of NPP structures, a continuation project, 2002; VTT Building Technology

Ruthenium research; the behaviour of ruthenium in severe reactor accidents, 2002; VTT Processes

FINFLO-code; Development of the code for the analysis of two-phase flow; Finflo Inc.

**Nuclear waste management**

**Research activities pertaining to regulatory decision-making**

IMGS (Investigations and Modelling of Geological Structures) support group; Sven A. Tirén, Geosigma Ab

IMGS (Investigations and Modelling of Geological Structures) support group; Prof. Jaakko Siivola

IMGS (Investigations and Modelling of Geological Structures) support group; Paavo Vuorela, Geological Survey of Finland

The national expert group for the safeguards of final disposal (LOSKA); The use of geophysical methods in the monitoring of final disposal; University of Helsinki, Institute of Seismology.

The national expert group for the safeguards of final disposal (LOSKA); The use of environmental surveillance and the monitoring of spent fuel capsules; VTT Processes

The national expert group for the safeguards of final disposal (LOSKA); The use of satellite surveillance and aerial photography in the safeguards monitoring of final disposal; VTT Information Technology

Review of the reports by Posiva Oy and the evaluation of the progress of Posiva’s R&D concerning geohydrological issues; Prof. Auli Niemi, Uppsala University

Review of Posiva’s development work, 2002; Enterpris Ltd

Review of Posiva’s baseline studies at Olkiluoto; Prof. David Read, Enterpris Ltd

Modeling flow and transport in heterogeneous fractured media; Dr. Tsang, Lawrence Berkeley National Laboratory

Independent verification of radioactive waste packages; VTT Processes
Research pertaining to the development of regulatory control

The geochemical indicators of the last ice age in the bedrock. University of Helsinki, Laboratory of Radiochemistry.

Evaluation of sensors to monitor the effect of bentonite on the corrosion rate of copper in Olkiluoto-type saline groundwater; Helsinki University of Technology, Department of Materials Science and Rock Engineering.

The geochemical behaviour of filled fracture; Helsinki University of Technology, Department of Materials Science and Rock Engineering.

IAEA coordinated research project (CRP). Natural geochemical concentrations and fluxes on the Baltic shields in Finland as indicators of nuclear waste repository safety; year 2002; Geological Survey of Finland

IAEA coordinated research project (CRP). Natural geochemical concentrations and fluxes on the Baltic shields in Finland as indicators of nuclear waste repository safety; year 2003; Geological Survey of Finland

DECOVALEX III; the reporting of rock mechanical simulations for BMT2 in the year 2003. Helsinki University of Technology, Department of Materials Science and Rock Engineering.