SAFETY EVALUATION

OF THE PAKS NUCLEAR POWER PLANT

IN 2002
FOREWORD

Similarly to the practice of previous years the report on annual safety results and activities of the Paks Nuclear Plant Ltd. has been prepared. The safety evaluation provides the most important safety indicators of our units and plant for 2002 as well as the most significant information relating to inspections, utilisation of experience and other safety related activities.

This publication conveys the most important information on safety in the form of safety indicators, inspection results, experience and other safety related data. Safety indicators are presented in an up-to-date structure developed on the basis of international recommendations. This system includes information on safety related events, at the same time.

Evaluation of safety inspections is described separately, in full detail. The safety level after completion of the safety enhancement programme is also summarised in this publication. We hope that this overview will help specialists gain evidence of adequate safety of the Paks Nuclear Power Plant Ltd.

1. EVALUATION OF PLANT OPERATION - SAFETY INDICATORS

The Safety Performance Indicators (SPI) System is based on characteristics related to different activities of the plant and includes the indicators which describe some area or feature of the safe operation by calculated values. The new SPI system established on basis of the recommendation of the International Atomic Energy Agency (IAEA) includes three main groups on top level. The characteristic indicators are divided within each of these groups in categories of general indicators and within the frame of that in categories of strategic indicators. However, from the latter indicators the most important ones are printed in italics.

The significant indicators containing also previous data (arithmetical averages of indicators of the four Paks NPP units) are compared to indicators of some recent years and in certain cases to the international data provided by the World Association of Nuclear Operators (WANO). Due to the different assessment objectives, WANO indicators do not constitute a part of the Paks SPI system in each case, they are presented only in the appropriate field of assessment.

1.1. Normal Operation

1.1.1. Operational Performance - Forced Power Reductions and Outages

*Unit Capability Factor (WANO Indicator)*

This indicator compares the theoretically possible amount of electricity generation to the power generation reduced by planned and unplanned power losses. The unit capability factor (UCF) provides a general characterisation on operation and maintenance level of the plant.

With a very high capability factor, Paks NPP has performed above the world-wide median for years. In 2002 the value of the indicator corresponded to the average of the recent years and showed a slight decrease.

![Unit Capability Factor Chart](chart.png)

It is necessary to mention that in spite of the improving tendency in the world the Paks value is stagnating. Outages organised more effectively could stop decline of factors causing the most significant power losses. However, problems of the last years consequences of which have been effective yet make it impossible.
Unplanned Capability Loss Factor (WANO Indicator)

The unplanned capability loss factor (UCLF) is the ratio of unplanned power losses to the amount of electricity which could have been generated during the given time period. The UCLF value indicates deficiency in maintenance and operating activities or sometimes in design.

In the last year value of this indicator was second best, partly due to change of the WANO calculation methodology, since time period between the planning and the outage is shorter than for weeks shall not be taken into account.

1.1.2. State of SSC (Structures, Systems, Components)

1.1.2.1. Corrective Work Orders Issued

In 2002 the number of corrective work orders for safety systems issued was 4465 (compared to 5675 of the previous year) which can be traced back mainly to the preventive maintenance planned better. The ratio of corrective work orders executed to work orders requested was 95.39 % which shows slight change (96.89 %). The ratio of pending work orders was 25.71 % (after 25.96 %). The ratio of preventive orders vs. preventive and corrective work orders of 82.24 % shows a slight increase (compared to 76.73 %) which is more likely due to the decrease in amount of the mentioned corrective maintenance activities.

Ratio of Unsuccessful Internal Technical Safety (TS) Inspections

In 2002 value of the indicator run close to the previous one, slightly higher. This indicator reflects an improving trend of maintenance quality.

1.1.2.2. Material Condition

The chemistry index calculation observes the concentration of selected impurities in steam generator blowdown and in the incoming water. Although this index is also a WANO indicator the Paks value is calculated in a slightly different way than that for the international comparison. The value of the indicator is 1 if the concentration of impurities does not reach the average value of the recent four years. In 2001 this index was 1.23 which shows a slight deterioration largely due to increase of the sulphate content.

In the field of material condition assessment there are two new indicators: equipment loading cycles accounting and the ratio of tubes plugged in steam generators. Both indexes reflect the status of important equipment as a function of parameter change and equipment age. They show the following year’s usable
amount in comparison to the spare amount calculated originally for one year (taken for a unit). Consequently, a value below 1 is unfavourable while in the opposite case decrease of the spare amount is slow.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>equipment loading cycles accounting</td>
<td>0.4</td>
<td>1.0</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>ratio of tubes plugged in steam generators</td>
<td>2.35</td>
<td>1.56</td>
<td>1.68</td>
<td>1.73</td>
</tr>
</tbody>
</table>

On unit 1 and 3 low value of the indicator can be explained by increased exploitation of loop pressure test cycles on 137 bar. The rate of decrease of spare amount of steam generator tubes is despite the strict plugging criterion acceptable.

1.1.2.3. State of the barriers

**Fuel reliability (WANO indicator)**

This index is defined as the steady-state iodine (I-131 and I-134) activity of the primary coolant, corrected for the tramp uranium contribution and power level and normalised to a constant purification rate, i.e. it reflects the integrity of the fuel.

The values per units in 2002 were as follows: 0.06; 0.2; 4.33 and 0.09 Bq/g. Each of these is (with orders of magnitude) below the specified regulatory limit. Additionally, the indicator improved an order of magnitude on unit 3 and 4. (The higher value of unit 3 can be traced back mainly to the higher iodine activity which has intensified due to shutdown for maintenance in December.) The second best value of the last years was caused by decreasing iodine activity on unit 3.

**Confinement leakage**

This indicator gives the leakage rate measured during the integrated confinement leakage test (ICLT) for each unit following the refuelling outages. (The allowed limit is 14.7 %/day.)

On the basis of the confinement leakage test results up to date, it can be declared that the values for all units are acceptable, similar to values of the previous years. On unit 1 the confinement leakage rate due to reveal and elimination of leak locations is very good as well as on the unit 3 and 4. The indicator for leakage in unit
2 shows a declining trend, therefore after assessment of the leak locations a reveal and elimination programme is expected similar to the successful one carried out by the Slovak contractor on unit 1.

1.1.3. Events

1.1.3.1. Reported events

**Number of events reported immediately to the regulatory body**

In 2002, 45 events qualified as reportable ones were investigated at company level according to the referring directive of the Nuclear Safety Regulation. This number represents about a 20% decrease against the value of previous year.

A relatively uniform distribution is shown among the units (seriatim per units: 9, 8, 16, 10, common: 2). The higher number of events for unit 3 means a deviation from the former status; distribution however by causes and components is relatively uniform. Events that occurred more than once were the failure of additional magnetic load on the control valve of primary circuit safety valves (3 cases), and unavailability of the Auxiliary Emergency Water pumps (2 cases).

The events in part had been analysed by probabilistic methods: We had analysed 6 events that occurred (two reactor protection actuation, turbine shutdowns, water pump shutdowns and actuation of the main steam line fracture protection) as well as four state - type events. According to the results of analyses accomplished with the PSA model, increase of the conditional core damage probability (dCCDP) gets between $10^{-10}$ and $10^{-5}$. The two event overriding the limit of $10^{-6}$ that could be seen as essential ones were the third unjustified reactor protection actuation that occurred at unit 4 (dCCDP = $6.2 \cdot 10^{-5}$) and actuation of the main steam line fracture protection (dCCDP = $2.4 \cdot 10^{-6}$).

Among the affected systems, like in the previous years, the most frequented ones were the Diesel Generators and auxiliary systems (12 events). The reactor protection system was affected seven times in the last year. Distribution of the cause characteristics is similar to those in the previous periods:

<table>
<thead>
<tr>
<th></th>
<th>2002 (2001)</th>
<th>Mechanical</th>
<th>Electrical</th>
<th>I &amp; C</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>26 % (58 %)</td>
<td>3</td>
<td>8</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Personal</td>
<td>14 % (31 %)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Documentation</td>
<td>3 % (6.7 %)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>2 % (4.4 %)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Although we did not indicate among the investigated events, the phenomenon resulting decrease of primary circuit (signal -) traffic at units 1-3 required significant operational and engineering resources. Technical examinations, measurements and analyses stated that a crust of iron oxide content deposited in flow spaces of the fuel assemblies. Appearance of the iron oxide could be attributed to the previously applied steam generator (SG) decontamination procedure. This technology was in use earlier as well, but in last years (2001-2002) it was applied much more frequently during the SG maintenance activities. No one could deduce in advance that this successful cleaning procedure, which helps the radiation protection of the personnel, might lead to such consequences. Thus, its application was terminated and was replaced by solutions of other features.

A new fuel load was set together from the contingency available in the plant that has to operate up to the outage in September 2003. Some other examinations and maintenance are also completed simultaneously.
with the refuelling. Loaded - out fuel assemblies that could be re-utilised are cleaned, than reused. The plant has all the necessary tools and procedures.

The number of events reported regularly to the regulatory body in 2002 amounted to 308. According to the Authority regulations, these events should not be examined, and ought to be reported summarised, quarterly.

1.1.3.2. Other significant events

The number of internal investigations by responsible organisations was 87; a significant increase compared with the 47 of that in 2001. According to the procedure worked out at the end of the year, such investigation is required if it could be related to occurrence of an other essential event. The affected professional area, with contribution of the safety organisation, performs the process.

1.2. Operational Safety

1.2.1. Safety Systems and Equipment

1.2.1.1. Actuations

Number of Reactor Scrams (WANO indicator)

This WANO indicator shows the number of automatic reactor protection actuations per 7000 critical hours periods. It reflects the extent to which the thermo-hydraulic or reactivity transients that lead to automatic protection actuations had been avoided. Our own index gives arithmetical average of such protection actuations per units, for critical state, by taking into account both the automatic and manual actuations. In 2002 however, there was no manual reactor protection actuation.

<table>
<thead>
<tr>
<th>Year</th>
<th>WANO</th>
<th>Paks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>1.02</td>
<td>0.74</td>
</tr>
<tr>
<td>1998</td>
<td>0.74</td>
<td>0.74</td>
</tr>
<tr>
<td>1999</td>
<td>0.74</td>
<td>0.55</td>
</tr>
<tr>
<td>2000</td>
<td>0.55</td>
<td>0.89</td>
</tr>
<tr>
<td>2001</td>
<td>0.90</td>
<td>1.00</td>
</tr>
</tbody>
</table>

From all reactor protection actuations, three had occurred in unit 4 while one in unit 3. Among them, there is one where a previously known phenomenon actuated the protection (i.e. the problem of SG level measurements). By two events, hidden failures were shown up. For the fourth event, a human error had also a significant role. The RP-1 actuations were as follows:

On 2 July 2002, at unit 4, by energising one of the 400 V bus bar, having the circuit breaker switched on, line-to-earth occurred. Resulted by protection actuation, the unit suffered a network reject. Because of the actuated protection, the redundant supply of the 6 kV distributors were switched on. Power supply of the control rods was changed from DC to AC. A strong collapse of voltage occurred also in unit 4 redundant 6 kV power system. Following the protection actuations, state of the unit was successfully stabilised. During the reviews that followed the event, it was stated that voltage inspection relays generating the protection released wantonly.

On 13 July 2002, the “load reduction to household operation power level” transient was tested. Having the 400 kV breaker switched off, an RP-1 actuation occurred due to an unduly “low SG level” signal. Turbine quick valves closed, the household power was supplied by the energy of outrunning turbine, due to which the protection signal of “complete voltage break” for high frequency value had built up. All the three safety system distributors were separated from normal power supply, and the Diesel generators started. The stepwise starting program ran through in order over all the three safety systems. Further to generator switch-off, the 6 kV unit distributors, due to voltage drop, successfully switched over to the redundant power supply.

On 31 July 2002, the unit 4 reactor protection system test was in progress, at nominal output. Having the new test computer installed, its proper operation was checked. During running the program, the protection was
triggered by the signal “steam line fracture at dp>5 bar”, which on turn caused an RP-1 actuation. By getting connected to the Y channel of the central test computer, not the corresponding testing set point was fed in. Because of the unsuccessful X system contacting, during the test that was initiated for checking the operability, the incorrect data base prevailed on the X system that had been earlier erroneously downloaded. Thus the starting signal was generated both on Y and X sets, that - according to the “2 out of 3” logic triggered the protection. All the six SG circuits were closed and the main coolant pumps stopped. As the turbines remained in operation, the pressure in the main steam collector dropped very quickly that initiated the signal of “main steam collector rupture” and actuated the protection.

On 5 December 2002, unit 3 operated at reduced output, and pressure lock of one of the high pressure pre-heater get actuated, thus it was excluded from steam side. During the unit load-up, operation of the steam side began. As idling of protection during setting the pre-heaters was missed, and because of quick pressure change the protection level measurements did not indicate the real values, an RP-1 actuation intervened for limit water level protection, triggered by the “last operating turbine shut down” signal.

Protection was actuated six times during subcritical reactor state. These events have a much less impact on the equipment than those in critical state, however they have the value of warning. This high number is due to the fact that three events of identical cause occurred at unit 1 during shutdown, on the signal of higher neutron flux above the normal shutdown level. For two of the remaining three cases, the human errors dominated.

Other actuations

The number of actuations of the emergency core cooling system (ECCS) and the auxiliary emergency water system pumps was zero in 2002, i.e. no actuations of these systems occurred. The number of actuations of the emergency electric power supply system was 3 and the number of reactor protection level 3 actuations was 6. Both values are low and the intervention was aimed at maintaining the specified power level.

1.2.1.2. Safety Systems Performance

The number of times a safety system was unavailable: 68. Distribution of unavailable states per systems: high pressure ECCS - 5, low pressure ECCS - 5, confinement spray system - 7, auxiliary water and cooling system - 12, diesel generator - 39. These values include both the planned and the unplanned states of unavailability as well as the failures.

Safety System Performance (WANO indicator)

The states of unavailability mentioned above gave the following values of availability (unavailability) for the safety systems performing different functions (equipment unavailability / planned availability time of system / number of trains):

<table>
<thead>
<tr>
<th>System</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
<th>Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>high pressure ECCS</td>
<td>3.57·10⁻⁴</td>
<td>8.12·10⁻³</td>
<td>0</td>
<td>0</td>
<td>2.12·10⁻³</td>
</tr>
<tr>
<td>low pressure ECCS</td>
<td>2.63·10⁻⁴</td>
<td>8.50·10⁻³</td>
<td>0</td>
<td>0</td>
<td>2.19·10⁻³</td>
</tr>
<tr>
<td>confinement spray system</td>
<td>5.27·10⁻²</td>
<td>8.50·10⁻³</td>
<td>3.97·10⁻²</td>
<td>0</td>
<td>1.22·10⁻²</td>
</tr>
<tr>
<td>auxiliary water and cooling system</td>
<td>7.90·10⁻⁵</td>
<td>2.94·10⁻⁴</td>
<td>1.63·10⁻³</td>
<td>5.79·10⁻³</td>
<td>5.16·10⁻⁴</td>
</tr>
</tbody>
</table>

Availability of the safety systems shows an improving tendency in the last few years. Changing the strategy according to which the components were taken out from operation more frequently for disclosing or prevent failures caused deterioration in 2002. The curve below indicates the electrical power supply system inoperability (unavailability).
Reliability of Diesel Starts

The ratio of successful emergency diesel starts was 98 % on units 1-2, while on units 3-4 it was perfect. In case of unit 1-2 the main reason of this value was maintenance of the supporting systems.

The value of reliability of safety systems pump starts (high pressure ECCS - 100 %, low pressure ECCS - 100 %, confinement spray system - 100 %, auxiliary water and cooling system - 97.8 %) is as high as in the previous years. In order to avoid more frequent trip of the auxiliary water pumps measure will be taken.

1.2.2. Preparedness

1.2.2.1. Operational Staff

This group of indicators reflects preparedness of the operating personnel. In 2002 the ratio of failed licensing exams was 1.06 % which is better than the standard value of about 3 %. The ratio of failed internal exams was 1.12 % which shows slight increase. Last year the number of corrective actions related to training was 22 which was twice as high as if the previous value. That indicates high importance of improvement of effectiveness of the trainings.

1.2.2.2. Emergency

The frequency of emergency drills is characterised by the following figures. The number of findings during emergency drills was 19 which was caused probably by higher number of such drills. The effectiveness of the corrective actions (the number of repeating corrective actions) made during emergency drills was zero, the ratio of people receiving training on the emergency plan to the employee total was 91.42 %. Both values reflect an active and conscious participation in drills.

1.2.3. Risk Management

1.2.3.1. Plant Configuration Risk

Number of Events Leading to Limited Operational Conditions

This is a group of events during which certain Technical Specification (TS) limitations are not met but the violation of TS does not take place because the concerned parameter or the prescribed state can be recovered by implementation of the prescribed actions. (A single event could lead to entering of several TS limiting conditions.) In 2002 increase of this value was caused by high number of reach to limit of reserve to boiling due to strict operational procedures set related to deposits on unit 3.
1.2.3.2. Initiating events

The indicators reflect the conditional risk caused by the occurrence of initiating events leading potentially to core damage calculated by probabilistic safety analyses (PSA) or by another concurrent failure.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of initiating events</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>conditional core damage probability</td>
<td>0</td>
<td>0</td>
<td>6.11-10^{-8}</td>
<td>6.49-10^{-5}</td>
<td>6.49-10^{-5}</td>
</tr>
<tr>
<td>caused by initiating events</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The number of the initiating events was low and the value of the core damage risk caused was due to transients mentioned with reactor protection actuation.

1.2.3.3. Core Damage Risk

Core Damage Frequency (at nominal power)

The indicator characterises the plant safety enhancement activity by decrease of the expected annual core damage frequency (CDF) value calculated for the reference period after unit outages in the given year. Due to safety enhancement measures (SEM) implemented the expected CDF on plant units for nominal power, internal, technological initiating events, decreased by more than an order of magnitude. The yearly updated and improved PSA models (so called “living” PSA) consider both the influence of minor modifications and the unit differences.
The core damage frequencies caused by (internal) hazards, i.e. initiating events of fire and flooding at rated power is according to the calculations for the four units are as follow:

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
<th>Unit 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core damage frequency for (internal) fire initiating event</td>
<td>$5.25 \times 10^{-6}$</td>
<td>$8.21 \times 10^{-6}$</td>
<td>$9.02 \times 10^{-6}$</td>
<td>$1.57 \times 10^{-5}$</td>
</tr>
<tr>
<td>Core damage frequency for (internal) flooding initiating event</td>
<td>$9.05 \times 10^{-6}$</td>
<td>$7.09 \times 10^{-6}$</td>
<td>$8.23 \times 10^{-6}$</td>
<td>$1.85 \times 10^{-6}$</td>
</tr>
</tbody>
</table>

The core damage probability during shutdown, outage and refuelling is at magnitude of the rated power value. It currently is slightly higher, $2.81 \times 10^{-5}$ for each unit.

1.3. Attitude Towards Safety

1.3.1. Human Performance

1.3.1.1. Deviation from the planned state

Indexes of this area show the compliance of handling the out-of-design states and that of work scheduling. In 2000 the number of interim modification amounts 128, and 2 exemptions were given from the effect of Technological Procedures. The number of deviations from the designed connection state amounts 229. This means an improvement for all indexes, which is 50% for the second case.

1.3.1.2. Human Factor

Number of Events due to Human Error

The number of events from human errors could be seen as average. Most of the event could be attributed to the mistakes of operators, and at less extent to the maintenance or other personnel.

The ratio of inobservance of the procedures related to the total number of human errors is 77%, according to the investigations. As this is a new indicator, it would be hard to draw any conclusion of the increase.

1.3.1.3. Radiation Protection Program Effectiveness

Not even once had been the radiation protection examination level (6 mSv) attained in 2002. It was the same in the previous year. This represents the observance of radiation protection rules. In the mean time, five
institutional investigations were performed in cases that had to be reported, but did not attain the above-mentioned level.

**Collective Radiation Exposure (WANO Indicator)**

This index is the dose derived from external whole body exposure of all the plant and contractors personnel and the visitors, referred to one Unit. The value is deduced from the measurements of Authority dosimeters.

The collective dose increased by 413.0 man·mSv compared to 2001. A significant contribution was provided by the fact that - because of reactor vessel cleanings - a full core outload was performed in all four units. Above that, repair works of fuel rod control drives and nozzles also meant a significant collective dose. The plant personnel participated got 33\% and those of the contractors 67\% from the collective dose.

**The number of premises brought into higher category** indicates those technological events that require additional radiation protection measures. There had been 3 such cases in 2002 that is a significant improvement against the previous year (5).

**Liquid Radioactive Releases vs. Allowed Limit**

This figure indicates the total beta-activity related to the strontium (Sr-90), tritium (H-3) and corrosive fission product emissions, as a percentage of the Authority limit. The value of the liquid radioactive emission - like to the preceding years - attained a very low level.

Increase in the tritium resulted from beginning the wastewater processing in units 1-2, while that of total beta-activity was caused by higher activity concentration in water discharged from XY tanks during the outage.

**Gaseous Radioactive Emissions vs. Allowed Limit**

These indicators reflect the emission of radioactive noble gases, aerosols and iodine in terms of percentage of the regulatory limits. The values have remained continuously well below the regulatory limits during the whole lifetime of the plant units. In 2001 the indicators decreased further as follows: Release of radioactive noble gases: 0.4\%, radioactive iodine isotopes (normalised to $^{131}$I): <0.1\% and radio-strontium 0.1\%.
Volume of Low- and Medium-level Liquid Radioactive Waste
A total volume of 260 m$^3$ was evaporated in 2002. This means an increase against that of the previous year (165 m$^3$). It was caused by a problem that arose during a storage changing process.

Volume of Low- and Medium-Level Solid Radioactive Waste
This figure indicates the amount of solidified wastes packed in drums (containers included), prepared for disposal in the past year, averaged for one unit. The value remained on the same level with minor fluctuations, and always was kept below the world average.

After an increase in 2001 caused by reconstruction of the shaft No. 1 in unit 2, this index is an average for the last year.

Volume of the High-Level Radioactive Waste
This index provides in volume units the high activity solid radioactive waste stored in the interim storages of the plant. The value of the index was low for 2002, in spite of the increase.
1.3.1.4. Industrial Safety Program Effectiveness

**Industrial Safety Accident Rate (WANO Indicator)**

This figure numerically expresses the disablements longer than one day, occurring for 200,000 working hours (the day of accident not included), or the number of accidents limiting the working ability. This is a clear indication for efficiency of the plant personnel work safety.

While the world average had shown a continuous improvement, this index deteriorated by us up to 1999. In spite of the corrective actions performed and the enhanced attention, its value improved only very slightly in the last year, it is corresponding to the four-year average. In the background, there are mostly the traffic accidents.

![Graph showing industrial safety accident rate](image)

The *industrial safety accident rate* reflects how much working time was lost in the consequence of accidents compared to the full time worked. Last year the value of this indicator was 0.101 % which is at low level, however, not negligible.

The number of *industrial accidents caused disability exceeding 3 days* was 1. This index was 0.074 % in the last year, that is lower by 25 % than that of the preceding year. This is showing a decreasing loss of time beside a stagnant number of accident.

**Number of False Fire Alarms and Number of Real Fire Events**

Although the *number of false fire alarms* and the *number of real fire events* shows the best result of the past years. There was no real fire accident at all, which means the care that was expended to the works of fire risk.

![Graph showing real fire events and false fire alarms](image)

1.3.2. Striving for Improvement

1.3.2.1. Self Assessment

Self evaluations examine the amount and efficiency of our safety and QA inspections. The *ratio of implemented internal audits vs. planned ones* was 107.7 % in 2002. Thus, we succeeded to fulfil the audit plan for each month.
Deviations disclosed by internal audits had risen; the number is 127 (against 51 in 2001). That was a result of the better preparatory work for the audits, and the attention of the management. The increase that could be seen as a significant one is also connected to the higher number of audited organisations.

The ratio of implemented independent internal reviews vs. planned ones amounted 218 %, i.e. a lot of unplanned additional inspections were accomplished. Independent internal safety inspections disclosed 53 cases of deviancies, which is a medium value by knowing the number of total reviews (13.0 % of the total 409).

1.3.2.2. Operation Experience Feedback

The number of repetitive events is 20 among the examined ones. The rise against that of the preceding year is caused partly by new, and partly by recurrent repetitive events, where the number of repetitive personal errors is slightly higher.

Average delay of the investigations was of 10 days in the last year, the ratio of investigations in delay or terminated with delay is 15.6 %. This ratio means less investigations closed with delay, but longer delays for the affected events.

1.3.2.3. Corrective Actions Effectiveness

Results of investigations could be made more effective only by getting the corrective measures performed in time. In 2002 the ratio of delayed corrective measures of investigations was 52.6 %; the average delay of implementation was of 15.2 days. Here the improvement in the ratio is significant, compared with the previous 78.2 %.

The ratio of delayed corrective measures of the internal audits is 45.8 %, and their average delay in implementation is 15.2 days. Here the more important improvement could be seen in the shortening length of delays.

2. SAFETY INSPECTIONS AND SURVEILLANCE ACTIVITIES

2.1. Safety Inspection and Surveillance of Operation

2.1.1. Inspection of Operating Units

2.1.1.1. Inspections

In 2002 the number of internal independent safety inspections was 172. The distribution of inspections by the inspected areas is shown on the chart below.

![Diagram of inspection distribution]

The ratio of inspections of on-power tests within the scope of all inspections was determined by the number of inspections planned by the regulatory body and by type of the tests, while the ratio of inspections of unit conditions was determined by minimum requirement of the pertinent procedure (1 inspection/month/unit). Despite the high proportion of on-power tests their number slightly decreased during the last year under investigation. Six on-power tests were missed due to postponement of the test or change of the test cycle.

The category of overall review covers the types of tests performed during the tests performed quarterly and not observable during other tests.
The ratio of inspection of operational procedures to the total number of reviews shows that the aim decided earlier to increase the number of those was successful. However, just as low as 11.5 % (16) of the total issued procedures were reviewed.

In 2002 inspections of implementation of operational programmes were carried out in a low ratio of 2 % as well. 4.5 % (2) of the 44 operational programmes were checked by the safety organisation.

2.1.1.2. Inspection Results

The inspections are focused on checking how the requirements for the inspected field are met. In 2001 25 inspections ended with findings (14.5 %). Comparing this to the last year value we can see that regulation and implementation were brought in line with each other more successfully in 2001. The majority of anomalies indicates a deviation from the procedures and the smaller proportion of them discloses the procedural deficiencies. The table below shows the percentage of inspections ended with findings.

<table>
<thead>
<tr>
<th>Name of inspected field</th>
<th>Inspections with findings (2001)</th>
<th>Percentage of findings (2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
<td>percentage</td>
</tr>
<tr>
<td>On-Power Tests</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Unit Condition</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Quarterly Comprehensive Inspection</td>
<td>11</td>
<td>44</td>
</tr>
<tr>
<td>Operational procedures</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Unplanned Inspections</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>100</td>
</tr>
</tbody>
</table>

The table above shows that in the case of quarterly comprehensive inspections of units the proportion of inspections ended with findings decreased in comparison to the previous value by 12 % but its number was still high in 2002 which can show importance of these inspections.

If one looks at the trend of quarters there can be recognised more observations at the beginning of the year during the comprehensive reviews, while at the end of the year in case of individual and procedure checking. The last one can be tracked back to the higher number of operational procedures and more strict attention due to deposit problems.

2.1.2. Inspection of Units during Refuelling Outages

A part of the safety inspections performed under outage constitutes an integral part of the activities conducted during refuelling outages. Another part of the inspections (on-power tests) is prescribed by regulation. In 2002 the number of completed inspections was 237 compared to the 148 planned ones.

The plan was exceeded in case of programmes and other reviews. The inspections of on-power tests constituted the majority of performed inspections.

22 of the 237 recorded investigations ended with findings (9 %). The two third of the observations were given during test checking because of not completeness of the test procedures.

2.1.3. Inspection of Training

Contrary to the prescribed one inspection per half a year, 5 inspections of training were held:
- periodic training of operating personnel - 2;
- training on radiation protection;
- basic training course on nuclear power plant;
- communication.

One of these inspections was conducted in each of the first three quarters, and two of them in quarter IV. Thus the distribution of training review can be evaluated as smooth. No one of the inspections ended with a finding.

2.2. Maintenance and Quality Control

This activity covers the review of performance of the different plant organisations according to the plant Quality Assurance Regulation and the inspection of activity of contractor companies as well as the inspection of preparation and performance of maintenance activities and monitoring of fulfilment of housekeeping requirements during maintenance and assembling activities.
2.2.1. Quality Assurance Reviews and Maintenance Control

13 internal audits were scheduled for the past year and 14 were implemented where 127 deviations and 59 proposals of corrective intent had been recorded. 36 tasks arose during these audits that were registered also in the Central Task Tracking System, thus their accomplishment could be followed.

In the Suppliers’ audits, 83 qualifications were completed in 2002. Increase of the Suppliers’ qualification resulted from increase of new qualifications (from 23 to 32) and that of supplementing qualifications (from 9 to 15). Most of the 2002 audits were successful. Results of two periodical audits failed, due to that the qualifications were withdrawn. One of the periodical audits had conditionally succeeded, where the Supplier got the qualification, but his activity has been limited. Altogether 143 deviations were registered in the audits. 70 of them was qualified as minor, 72 as medium and one as serious deviation.

Control of the annual outages covered both the preparations and implementation of the works. Preliminary and final schemes of outages were complying equally from content and formal aspects, so the Authority accepted the submitted schedules and licensed the implementation of the main repair works. According to the referring procedures, we have regularly performed inspections on the units in maintenance, documented in protocols.

As a summary of the inspections and reviews that procedures, requirements referring to the dismantled equipment and clean mounting are met. One can state on the ground of reviews that maintenance processes were accomplished according to the rules in the controlled area, the marking sheets were used for closure on the dismantled components. Area cleanliness and order has to be further improved.

Annual number of inspections for the maintenance works performed during outages amounted 46 cases, and for maintenances apart from the outages 29. We did not find such essential deviation that would influence the quality of the process. Educational and training prescriptions were also checked at the maintenance personnel, altogether at 239 persons. Deviations were found at 3 persons, deficiencies were supplemented up to the deadlines.

2.2.2. Maintenance and Quality Control

Distribution of performed tests is shown by the chart below:

The QC Section implemented altogether 6269 inspections in 2002. Two-thirds of the compliance inspections accomplished by the QC Section were of structural examinations, and control of supplies and pressure tests also formed a great part of them. From all performed examination, 1.5 % was terminated with “unsuccessful” qualification, which is a significant improvement related to last two years (5.7 and 3.3 %, respectively).
In 2002, the QC continued the “super control” reviews. Altogether 61 such reviews were accomplished during the year, from which 8 (13.1 %) got the “unsuccessful” qualification. That is much higher than the ratio of unsuccessful reviews among the normal inspections. By taking into account the results, it could be stated that the level of professional QC control activity has to be improved.

2.3. Labour Safety and Fire Protection Inspections

Within the frame of its surveillance activity the Industrial Safety and Fire Protection Section performs general inspections, specific inspections and follow-up reviews for industrial safety, fire protection and hoist safety. Inspections performed by this section in 2002:

<table>
<thead>
<tr>
<th></th>
<th>Industrial Safety</th>
<th>Fire Protection</th>
<th>Crane Safety</th>
<th>Total number</th>
</tr>
</thead>
<tbody>
<tr>
<td>General inspection</td>
<td>-</td>
<td>40</td>
<td>-</td>
<td>40</td>
</tr>
<tr>
<td>Specific inspection</td>
<td>121</td>
<td>81</td>
<td>286</td>
<td>488</td>
</tr>
<tr>
<td>Risk review</td>
<td>338</td>
<td>-</td>
<td>769</td>
<td>1107</td>
</tr>
<tr>
<td>Fire brigade review</td>
<td>-</td>
<td>422</td>
<td>-</td>
<td>422</td>
</tr>
<tr>
<td>Total number</td>
<td>459</td>
<td>543</td>
<td>1055</td>
<td>2057</td>
</tr>
</tbody>
</table>

General inspections are conducted for individual organisational units, specific inspections cover a relatively limited area or working process while follow-up reviews check the elimination of revealed deficiencies.

Industrial safety inspections check the adequacy of working areas, workplaces, tools and working processes as well as the use and adequacy of personal protective equipment. Fire protection inspections review the adequacy of fire protection procedures, activities involving a fire risk and fire protection equipment. During inspections of hoist safety the status of hoists and trucks as well as the adherence to hoisting procedures are monitored.

In this year, the fire brigade of the facility also performed independent inspections, that covered general activities of the electrical sector, random check of fire hazardous activities and area fire protection. Fire protection and work safety authorities also perform regular reviews. The Company was not amerced in those reviews.

2.4. Radiological inspections

The radiological inspection carried out in the nuclear power plant in 2002 covered two main fields: site radiation protection and nuclear environmental protection.

2.4.1. Site Radiation Protection

The most important tasks of the working site radiation control were bound also in 2002 to the personal exposures, working at areas of radiation hazard and surveillance of radiation and contamination conditions of the controlled zone. The check the exposure from external sources 29882 film-dosimeters, 32019 TL-dosimeters, 2279 working level neutron-dosimeters and 59 local dosimeters were distributed among the employees. In 2002, the highest individual exposure was 19.39 mSv, which is well below of the 50 mSv/y authority dose limit, and did not attain the plant’s own task referring to the individual radiation exposure (< 20 mSv/year) indeed.

Based on the film-dosimeter surveillance, collective dose in 2002 was 2933,4 man·mSv, to which a further 59,8 man·mSv is added from the exposure of personnel controlled only by TL-dosimeters. A further 11.3 man·mSv has to be added due to the neutron radiation exposure. The control the internal exposure, the plant accomplished 5408 whole body counts and the same amount of urinal tritium activity measurements. It has to be emphasised that none of the internal exposure inspections indicated any value above 0.1 mSv effective bound dose.

A wide-scale application of electronic dosimeters was an important tool of the working site radiation protection also in 2002. It is however an essential change from the practice of preceding years that the personnel was completely supplied with operative dosimeters. Operative dosimetry in the last year also provided means for continuous surveillance of exposure and determining the working level exposure.

Radiological work was authorised and inspected generally by the dosimetry staff, shift personnel of the Radiation Protection Section. If the individual radiation exposure from work was presumed to reach 0.2 mSv according to estimation, the performance of activity was allowed only with a radiological work permit. For conduct of work involving a high nuclear risk the use of work program specifying the radiological protection measures was required. In 2002 the dosimetry staff issued 3782 radiological work permits, although in major
part of these cases the individual radiation exposure of workers remained below 0.2 mSv. Local inspection of radiological work covered the full scope of activities involving a high nuclear risk and a significant part of other works authorised by radiological work permit.

Radiological and contamination conditions of the controlled area were checked by continuous remote measurements of the nuclear instrumentation system and by local measurements. The 1000 remote measurement systems installed on the four units maintained continuous radiation monitoring of operation of the important process systems and selected parts of the controlled area. Local measurements were aimed at more precise specification and completion of the received data. The dose maps drawn up on the basis of the local measurements and issued for the workers as well as the awareness of locally higher dose rate areas greatly facilitated to optimise radiation exposure.

2.4.2. Radiological Environmental Protection

Radiological environmental protection was characterised by two-level monitoring last year, too. The data supplied by remote transmitting systems of discharge and environmental monitoring were completed or specified by sampling-based isotope selective measurements which informed also on chemical-physical forms of radioactive isotopes.

Discharge monitoring covered all radioactive isotopes with a postulated release from plant regardless of whether there are regulatory discharge limits specified for them. Liquid effluents and airborne emissions were sampled about 4000 times what supplied approximately 7000 measuring results if considering the different measurements.

In the frame of environmental monitoring - using the same approach as at discharge monitoring - 4000 samples taken in an area of 30 kilometres around the plant were processed and measured.

2.5. Environmental Monitoring

In 2002 the Environmental Monitoring Group performed 39 local site environment protection review and participated on internal audits inspections representing interests of environment control. According to the reviews activities in the field of environment protection were carried out with compliance of the legal and regulatory requirements. During reviews and audits of the regulatory body non-compliance were not observed.

Performance level of the environment protection tasks prescribed in the internal regulations were highly improved during arrangement for the pre-audit of the Environment Control System (ECS) and licensing audit. During the internal and outside audits the following problems aroused for elimination of which certain tasks were specified and performed:

- Not appropriate selected collection of wastes;
- Deficiencies during account of work place wastes;
- Lack or not appropriate labelling of vessels;
- Lack or not appropriate existence of safety data sheet on dangerous materials used at work places;
- Deficiencies in knowledge of ECS and internal regulations;
- Lack of environment jobs and training requirements in the personnel job descriptions.

Task of the Environment Protection Group to test of waters under ground surface from non-nuclear environment protection point-of-view. Samples taken were 367 in 2002. This number does not contain samples taken not by the requirement order of the authority.

3. UTILISATION OF INTERNATIONAL OPERATING EXPERIENCE

3.1. Received Information and Information Source

In 2002, 174 report of events reached the Paks NPP through the WANO Internet Information System. 10 of them was ENR (informative reports) and 66 EAR (report with analyses), and 98 MER (mixed event report). Above that, there had been 4 SER (significant event report) and 2 SOER (reports that summarise essential operational experiences) during the last year. All of these reports were circulated through the plant Intranet network, and the list of content was issued monthly in Hungarian, with a short summary of the events. Altogether 34 reports were completely translated and circulated to the sector organisations. As circulation of 5 of these reports slid to 2003 (because of the time-consuming translation work) and 34 reports from 2001
also was transposed to 2002, altogether 68 WANO reports were transmitted to the professional areas for further processing.

We have got 44 reports through the IRS system of IAEA. 8 of them was completely translated and circulated, and a short translated summary of all events was provided for the professional sectors. Due to the overlapping of the WANO and IRS systems, about 50 % of IRS events received in 2002 had been arrived earlier as WANO events.

During the year, above of the event reports we have got many other documents containing very useful case descriptions that were circulated, mainly for information purposes. The subjects were the maintenance and prevention of recurrent events.

Questions raised by other organisations were responded through the WANO network in 9 cases. Professional sectors were involved if needed. Paks NPP stated questions seven times to exchange experiences, either directly to other NPPs or through the WANO regional centres or the Internet. Altogether 14 responses were received from other plants. Only one question remained unanswered.

Altogether 6 reports were compiled at Paks for international organisations (IAEA, WANO) from three events that arose in 2002:
- Perceiving deformation on the nozzle of control rod drive (of 21-34 co-ordinates). The deformation was perceived during the outage of unit 2.
- Diminishing of the heat removal safety function due to the failure of No. 30RR01D001 Additional Emergency Water Pump.
- Shut-down of unit 2, because of the fire developed in A110/2 cable gallery.

3.2. Utilisation of Operating Experience

In 2002, processing the “non designed exposure” case (WANO SOER 2001 - 1) was completed. The three tasks decided by the Operation Examining Committee (dose mapping and trainings) were implemented in the year in subject. The Committee relegated the tasks related to the two SER events to sector competency, while for four SOER and SER events there was no need to define any measure.

Processing of two earlier WANO SOER and SER events of 1999 and 2000 (network reject, transients, grave storm) also had been completed. 8 of the 9 tasks decided by the Committee had been implemented, while the remaining one could be expected for 2004.

3.3. Enhancement of Efficiency of the Activities

The IAEA OSART review in October 2001 suggested in its notice the enhancement of experience feedback efficiency. Based on this suggestion, the Safety Section made some measures in its OSART schedule to follow the WANO directives and the experiences of other foreign NPPs.

In 2002, the following modifications were implemented in the procedure dealing with utilisation of international experiences:
- Professional sectors shall complete the analysis of screened event reports within 60 days;
- Event Reports are promulgated toward the sectors with response form sheet attached, for the sake of uniform and assessable feedback and registration.

Having the modified procedure agreed, activity of the professional sectors significantly improved.

4. SAFETY ENHANCEMENT MEASURES

4.1. Actualisation of the SEM program

The plant’s program of safety enhancing measures (SEM) was completed in 2002. Implementation of the program significantly improved the safety of the plant, and in the meanwhile provided an opportunity to utilise the operational experience accumulated up to now all over the world. By performing the safety enhancing measures, safety of the Paks NPP is on the world level, attained the safety level of western NPPs of similar age.

The safety enhancing activity that began in 1986 had been transformed into a real program with individual budget. In the first phase of the SEM program about 2,4 billion HUF was spent on investments, and in the second one about 50 billion HUF, at current price levels.
Since 1996, the safety enhancing measures were included into the prescribed tasks of the Nuclear Authority’s Periodical Safety Inspections. Paks NPP accomplished these activities with specific care and by ensuring the proper resources, and regularly reported their status. International forums and organisations have also acknowledged the safety level attained by this program.

Efficiency of the SEM could be characterised either by the probability of core damages occurring during the 330-day fuel cycle from initial event of internal origin, fire, internal flooding, or by that of events during the outage for refuelling following the cycle. This probability value today is $5.3 \times 10^{-5}$, indicating an improvement of more than one order of magnitude, mainly resulted by the implemented safety enhancing measures.

4.2. Main areas of the safety enhancement

Activities accomplished in the area of safety enhancement might be grouped - according to the tasks - as follows:

- Reducing the load on the components (e.g. by diminishing the risk of heat impulse on reactor vessel under pressure);
- Increasing the reliability of the safety equipment (electrical power supply, fire protection, diversification of the protections, emergency water supply of steam generators, etc.);
- Improving the handling of transients (handling the fracture of SG steam collector, terminating the artificial stress relieving);
- Revision of the containment (hydrogen handling, behaviour of the containment in extreme conditions, cabling and instrumentation withstanding the loss of coolant accidents [LOCA], etc.);
- Enhancing the seismic resistance;
- Preparedness for out-of-design damages and emergencies;
- Improvement of fire safety;
- Tools and proceeding for backing the operator, enhancing the operator’s reliability.

4.3. Results of the safety enhancement

It is hard to measure and quantify the safety, the level of safe operation. That is why it was very important to get the Paks units reviewed by independent external experts that were backed by the plant management from the very beginning. Such reviews usually implemented by international organisations indicated the improvement of the safety, development of the operation and maintenance as well the safety culture by examining the features that are mostly immeasurable.

The AGNES project aiming to a comprehensive evaluation of the safety in the mid-nineties - on the ground of deterministic and probabilistic (PSA) analyses - yet had quantified the safety: The expected annual average core damage frequency (CDF) referring to the nominal output, internal technological initial event in that time amounted $5 \times 10^{-4}$/year (calculated for unit 3). Virtually the “AGNES” provided the ground for the just completed SEM program, as it finalised the list safety enhancing measures, and defined its priorities. By PSA assessments became possible to specify those measures that have outstanding contribution to the core damage risks, thus distribution of risk factors could be equalised. The SEM list became part also of Authority tasks arising from the Periodical Safety Inspections.

- The most important SEM was the modification of the Auxiliary Emergency Water System. Having the system relocated into the Reactor Hall, the nominal, internal CDF value diminished by one order of magnitude per units.
- The further most important measures were the termination of artificial de-stressing and emergency cooling arranged by primary circuit feed-and-bleed. By them, the above mentioned risk has been reduced to its half or one-third part.
- We have to emphasise the project aiming to increase the reliability of human activities. Its effect could be hardly expressed by numbers, its impact however on safe and reliable work performance is significant.
- Refurbishment of the reactor protection system through the connected control technological modifications (steam generator protection) improved the nuclear safety. It has an essential effect in improving the operational safety, as a protection system on the world level has been installed on the units.
Through the so-called “living PSA”, i.e. by maintaining the probability models and annually accomplished calculations the core damage risk could be systematically followed. The safety level improving by safety enhancing measures could be followed on the following figure (for one unit):

PSA analyses referring to non-nominal output were valid first for the 1995 reference time. One can see unambiguously from the figure that the risk of core damage during the outage following the cycle for refuelling is significant, compared to the nominal state; it is higher, the analysed initial periods excepted. The effect of the safety enhancement in this state, since 1999, is outstanding. In this period, the measures were implemented in the following areas:

- Safety revision of the heavy load crane operations in the reactor hall, definition of the routing for safe crane movements.
- Measures against erroneous routing in operating states of open reactor vessel, reduction of risk of occurrence for emergencies beginning with loss of coolant in the secondary circuit.
- To reduce the failures remaining from maintenance works, proper design of the tests, utilisation of data from experience.

Risk analyses for fire and flooding were completed first in 1999. Implementation of enhancing measures originating from them since 2000 resulted further safety improvement. Some more important among them:

- Updating of the fire signalisation and extinguishing control.
- Development of fire extinguishing system for the main circulation pump (MCP) motors.
- Refurbishment of the turbine foam fire extinguishing system.
- Installation of emergency oil and hydrogen discharge system for the generators.

The quality of the SEM program and the high safety level that could be attained by its completion was acknowledged at the last stage of the program by international nuclear organisations and the EU.

**SUMMARY**

Based on the information presented we can say that in 2002 the four units of the Paks NPP Ltd. operated generally in compliance with the requirements of the Technical Specifications. Monitoring of reactor core was maintained permanently. Operation and maintenance of the technological systems and equipment was performed according to the procedures, the level of safety was adequate. As analyses show, the indicator reflecting general safety condition of the plant at full power operation - the core damage risk related for internal technological initiating events - continued to decrease in 2002.

Radioactive releases of the plant remained well below the regulatory limit in 2000. The overexposure to critical group of the public from operation of the plant was of the same value that radiation exposure from
background radiation for a few hours. Environmental monitoring was permanent. The integrity of unit 2 shall be improved.

Besides technical questions the evaluation of the human factor, the enhancement of its efficiency and training were highlighted as well. The systematic approach to training and the training of symptom-based emergency operating procedures contributed significantly to achievement of this goal. Utilisation of plant and foreign experience facilitated the identification of corrective actions.

Last year the number of events which had to be reported to the Hungarian nuclear regulatory authority decreased. The number of automatic reactor protection actuations increased by two. Last year no event occurred which would have endangered the health of the public or the personnel or would have been associated with off-normal release of radioactive materials. Further improvement has to be achieved in the area of industrial accidents.

Special team was formed in order to handle the magnetite deposits set on fuel assemblies of unit 1-3. Based on the opinion of that team, the Russian analysis received and economical calculations, the contaminated core fuel was changed and arranged for cleaning on unit 3.

Regarding the statistics and the evaluation presented above we can say that safety of the plant units and the facility as a whole in 2002 was adequate. The safety enhancement programme completed can give a good basis for realisation of power increase and designed lifetime extension.