OSART Good Practices

TECHNICAL SUPPORT

Reactor core management (Reactor engineering)

Neckerwestheim, Germany

Mission Date; 8-24 Oct., 2007

Monitoring sub-criticality during fuel handling.

A visual display has been created for fuel loading and unloading in the computerized operation management system to support the shift crew when monitoring sub-criticality. It displays charts (PRISCA) and time graphs.

The purpose of this function is to support the supervision and the communication between the refueling machine operators, shift crew and the reactor physics section during fuel handling. The content of screen image is as follow:

Core cross section:

- Current core loading pattern (core cross section);
- Number of fuel assemblies in core, current step in fuel movement sequence plan;
- Neutron count rate and selectable time curves;
- Neutron count rate limits; and
- Boron concentration and temperature in reactor core.

Graphic content of time curves:

- Evolution of neutron count rates for both chambers of external neutron flux; and
- Associated limits (min./max.).

Sub-criticality of the reactor core is monitored by shift operators and reactor physics during fuel handling with the aid of these two graphs. If limit values are reached, the process computer triggers an optical and acoustic alarm. When a limit signal is given, the Shift Supervisor interrupts fuel loading and initiates the necessary corrective actions according to the operating procedures.

This system provides Control Room Operators with a better method of monitoring refueling status than is generally seen in other NPPs.

Chinon, France

Mission Date; 27 Nov.-14 Dec., 2007

The plant has developed and used a unique integrated computer data base used by many departments for fuel management. This data base is used for:

- Complete fuel management
- Management of extensive core process parameters, such a pellet-clad mechanical interface, fuel integrity, in-core measurements, etc.
- Management of extended fuel cycle
- Fuel movements and criticality monitoring with forecast capability
- Update of ex-core detectors
- Control rod drop time trending for proactive decision to replace guide tube
- Parameter setting for nuclear instrumentation

The plant can predict, in advance, potential deviations of the core parameters from the safety range and archive the necessary data.

In view of its advantages and efficiency since 2003, and this data base will be deployed on the whole French fleet under the name SILLAGE.

Forsmark, Sweden

Mission Date; 12-28 Feb., 2008

MATSTAB (a full 3-dimensional neutron model in combination with thermal hydraulic model) can provide information on core design for stability prediction and stability optimization. This model features fast calculation speed and high prediction accuracy. MATSTAB was developed by the plant in 2001 and subsequently applied to all BWR Swedish plants.

- MATSTAB is developed in the context to prevent core instability incidents mainly due to thermal hydraulic oscillation occurred in reactor vessel.

- MATSTAB takes full advantage of sparse matrix technology and frequency domain methods to meet with the CPU requirements for a full 3-dimensional reactor representation.

- MATSTAB can predict the behaviour of a global oscillation within 3 minutes, using the interface with the online steady state core simulator (POLCA).

- MATSTAB can display the influence to stability of an individual fuel assembly. This allows new insights into the mechanisms behind instabilities and also to optimize the core design or a control rod pattern with respect to stability.

- The predictions of the code are validated against stability measurements obtained at the plant.

Doel, Belgium

Mission Date; 8-25 Mar., 2010

The fuel department has compiled a pocket size book that is easy to use and provides a short and easy to read description of tools, equipment and installations used for handling of fuel and core components. The pocket-size book is called the “Fuel Bible”.

The book is easy to carry and is used by the fuel handling operators and maintenance teams. It is also used as an aid in training. The short descriptions of tools and equipment are complemented with graphics and pictures to support the text. The book is not a substitute for procedures, but provides comprehensive descriptions to help the operators, and gives answers to frequently asked questions.

St. Alban, France

Mission Date; 20 Sep.-6 Oct., 2010

Remote video surveillance of fuel handling, enhancing technical support.

A remote surveillance system for fuel handling and physical inventory activities has been put in place to enhance technical support and improved use of the video system.

The fuel condition recording equipment includes 2 cameras, a video rack and a connected external hard drive providing 8000 hours of continuous recording. The equipment is connected to the plant IT network for real or differed time recording on remote computers.

The system put in place is not expensive and allows for increased and faster use of technical support from reactor engineering, both from site level or corporate level. It allows real time tracking of recordings from a remote office with a view to early detection and analysis of defects, and early transmission of the pictures to corporate entities for further expert appraisal and confirmation of plant analysis. In addition, the system allows immediate strong improvement of the sharpness and the level of details of the fuel assembly pictures. This facilitates the diagnostic to be performed by reactor engineering.

The system can be used for shipment of used fuel, yearly physical inventory, verification of assemblies before refueling (search for foreign materials underneath the debris filter on the bottom end, search for impacts or foreign material on the fuel assemblies) and classification of damaged fuel assemblies (visual examination of the grids, rods and ends, classification of foreign material type).

This device is used each time fuel assemblies are subjected to a camera inspection by plant staff. For example, in May 2010, thanks to this device during the examination of the lower parts of the fuel assemblies inside the spent fuel pool, the plant identified the presence of small-sized foreign materials on 2 fuel assemblies.

Since small defects are hard to interpret on pictures, the fuel building operators can directly transfer the picture to work planning for further analysis.

Direct communication between fuel work planning and fuel building technicians has made it possible to optimize the camera shots and to detect small-size foreign materials.

Smolensk, Russia

Mission Date; 5-22 Sep., 2011

Equipping fuel casks with shock indicators.

Fuel casks are equipped with non-restorable shock indicators with the actuation threshold of 5g. These shock indicators enhance the following safety related aspects:

- To improve quality of fuel casks treatment.
- To increase personnel responsibility while handling them.
- To detect weak points of transport, loading and unloading operations.
- To trace conditions of fuel casks transportation along the whole way from the manufacturer to the user.

A shock indicator comprises of two sensitive elements in the form of two steel balls fixed by two springs in their sockets. The axes led through the centers of the ball couples are perpendicular to each other. If the indicator's load exceeds its actuation threshold (5g), the sensitive elements fall out of their sockets. The elements fallen out are perpendicular to the shock direction (in case of an axial shock, both elements fall out). It allows to register a shock exceeding the actuation threshold in three directions (in vertical, axial and perpendicular). The sensitive elements are placed in the transparent casing that allows visual identification of the indicator state (position of balls).

After indicators have been actuated, a value and direction of loads having affected the fuel casks and elements are analyzed.

Mühleberg, Switzerland

Mission Date; 8-25 Oct., 2012

Support for industry efforts to improve fuel design and monitoring practices has resulted in good fuel performance and fewer fuel assemblies discharged from the reactor.

The plant has supported industry efforts to improve fuel design and monitoring practices.

This practice aids the industry and improves performance at the plant. Examples include:

- The plant installed a limited number of fuel assemblies with an improved design and closely monitored the fuel performance over several years. The fuel assemblies performed well, up to peak pellet exposure of 80 MDT/MT. Many other plants similar to KKM have drawn on this operating experience success and installed the same design in their plants. The improved design allows fewer required fresh fuel assemblies to be loaded into the reactor and correspondingly reduces the number of fuel assemblies discharged from the reactor.
- New inspection tools were developed in close coordination with the vendor and other industry experts to improve the safe inspection of the improved fuel design. Examples include a tool for improved inspections of fuel channels and a special guide block to aid re-insertion of fuel rods back in the fuel bundle after inspection.
- Plant personnel perform reactor core and fuel criticality tests at both the beginning and end of the operating cycle. This practice allows a realistic measurement of the available shutdown margin for the reactor core. It also provides reliable data for computer code verification and more accurate predictions of margin over the operating cycle.

The practice of cooperating with fuel vendors to test improved fuel designs, combined with thorough fuel inspection, monitoring and testing activities, allows for good fuel performance at the plant.

Gravelines, France

Mission Date; 12-29 Nov., 2012

Guide on preparation of power reduction transients and reactivity variation.

The plant has developed a guide on preparation of power reduction transients. The guide, in laminated A4 format, is presented by the plant's core/fuel engineers to operators in a "just-in-time" briefing session in advance of power reduction transients. It uses graphics and text to describe the physical phenomena involved during power reductions, alert the operator to sensitive phases, and provide guidance on all of the different operation actions involved. Information contained in the guide includes: dilution and boration curves; operating envelope graphics; information on control rod operations; requirements for reactivity balances; and relevant operating experience feedback on power reduction transients.

The guide reduces the risk of failure to comply with safety requirements during power reduction transients and reactivity variation.

Kozloduy, Bulgaria

Mission Date; 26 Nov.-13 Dec., 2012

Independent testing of fresh fuel enrichment

Since 2009, 100% of the deliveries of fresh nuclear fuel undergo a gamma-spectrometric control of the 235U enrichment at the plant.

The measurement is performed in Fresh Fuel Storage Facility, for each assembly, immediately after completing the standard incoming inspection. The aim of this additional control is to compare the declared enrichment according to the passport with the actually measured one, which guarantees that the fuel was adequately designed and manufactured in compliance with the design specifications.

The sensitivity of the method allows distinguishing the enrichment of the fuel that is used at the plant with sufficient reliability. Practically, this inspection is the final stage where a difference between the declared and actual enrichment could be detected, before the assembly is placed in the core.

Preventing the insertion of a fuel assembly with the wrong enrichment, i.e. avoiding the possibility of loading a fresh assembly with 4.3% enrichment instead of a fresh assembly with a 3,98% or 3,53% enrichment helps avoid unintentional criticality and flux shape problems and greatly enhances safety.

Although the quality and assurance (Q/A) system for many NPP guarantees that fresh fuel from the manufacturers is within specified requirements with the respect of enrichment levels, the investment cost for this equipment is low and it provides an additional barrier for not inserting fuel with wrong enrichment into the core.

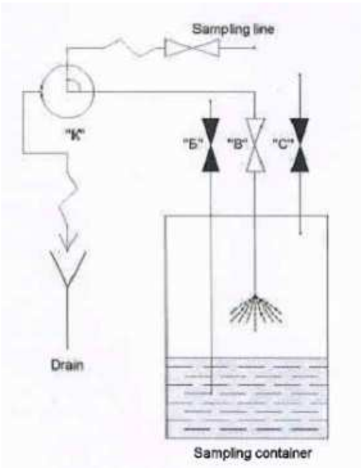
A wrong enrichment level of the fuel is usually detected during start up tests and the fuel has then to be removed. In this case this can be avoided before the refueling starts during the outage which also saves time.

Novovoronezh, Russia

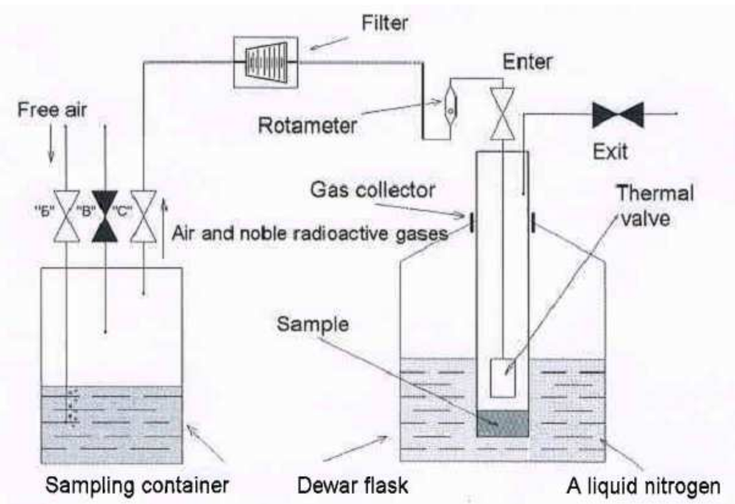
Mission Date; 9-26 Nov., 2015

Use of gamma-spectrometric analysis for inert radioactive gas (IRG) specific activity in the primary circuit coolant for estimating the burnup of leaking fuel assembly during power operation.

The plant has developed, implemented and is presently using the method of inert radioactive gas (IRG) specific activity monitoring in the primary circuit coolant. The method developed provides a possibility to extract IRG from the primary coolant sample and produce a counting sample for gamma-spectrometric measurement, consisting of liquefied gas only, which assures high reliability of the measurement results obtained. The method is based on simple technical solutions, therefore its practical implementation at other NPPs is feasible and economically efficient. The liquid sample of the primary circuit coolant is taken from the normal sampling line to a leaktight sampling vessel by a closed sprayed flow. When the coolant gets into the sampling vessel, the gas is removed from it, and the gases dissolved in the coolant sample are transferred to the gas volume of the sampling vessel.



In order to further collect the gas and produce a counting sample cryogenic condensation is used of the extracted gas to a leak-tight metal counting sample (gas collector), placed in liquid nitrogen.



The measurement results of IRG specific activity in the primary circuit coolant present a reliable indicator for timely identification of microscopic fuel pin defects of "gas leak" type in the operating reactor core, and therefore are used as a valuable tool in fuel pin integrity monitoring during reactor plant operation at power.

In order to implement the IRG monitoring system, the plant has developed, performed qualification and implemented the "Method of inert radioactive gas volume activity monitoring in the primary circuit coolant and in the sipping test rack water at the plant.

MVR 7.2.7-08". The certificates of periodic calibration checks of the gamma-spectrometric systems used for IRG monitoring include certified geometries of IRG monitoring counting samples.

The data on inert radioactive gas specific activity along with the activity data of reference radionuclides of iodine and cesium in the primary circuit coolant are used as input data in the computerized expert system developed for the plant Unit 5, used for monitoring, prediction and analysis of nuclear fuel status trends in the core of the reactor operating at power. The analysis of IRG activity data obtained during operation of the 31-st fuel load using the expert system allowed performing preliminary prediction of the possible year of placing the leaking fuel assembly in the core, which was confirmed by the sipping analysis performed during the annual outage.

From this method the year the leaking fuel assembly was placed in the core can be judged by comparing inert gas ratios. For low burnup, the ratio of Xe-133 vs Kr-85 and Xe-135 vs Kr-88 can predict with accuracy the burnup of the leaking fuel assembly. For higher burnup, the ratio of Cs-134 vs Cs-137 can predict the burnup of the fuel.

This method not only is economical but it provides increased safety as the new core can be designed earlier, instead of waiting for the results of sipping for emergency core design.