OSART Good Practices
CHEMISTRY
Chemistry programme

Balakovo 4, Russia

Mission Date; 19 May-5 Jun., 2008

Chemical cleaning for steam generator

From 2000 Balakovo NPP started implementation of chemical cleaning technology with application of acetate ammonia and EDTA solutions for Steam Generator cleaning from dense crud consisting of iron and copper oxides. Chemical cleaning is implemented in threestages,:.

- During the first stage («cold») copper compounds are removed by means of acetate ammonia solution and ammonia solution with pH=10,2 at 40 C. Compressed air, as oxidizingagent, is supplied for solution mixing. The time dedicated to this operation should be about 5to 6 hours.
- During the second stage («hot») EDTA solution and acetate ammonia solution at 95-98 C with pH=5,0-5,5 are used for removal of crud, consisting of iron oxides. Solution is mixed by steam. The time dedicated to this operation should be about 5 to 6 hours.
- During the third stage («cold») ammonia acetate and ammonia solution with pH=10,0 and at temperature 40-50 C are used for post treatment against copper residue and passivation of cleaned surface. The time dedicated to this operation should be about 5 to 6 hours.

The results of chemical cleaning based on this technology demonstrated high efficiency enabling at the first stage of chemical cleaning to transform copper compound as well as metal copper in the form of copper ammonium complex, to loosen crud and at the second stage to transform iron oxides into the soluble complex with EDTA and remove it from steamgenerators.

This method of cleaning steam generators has been performed thirty six (36) times atBalakovo NPP from 2000 to 2008 using this technology.

Rovno 3/4, Ukraine

Mission Date; 24 Nov.-11 Dec, 2008

Standards for laboratory management

In order to improve the quality of measurements, Rivne NPP has implemented a procedurefor the preparation of reference samples (standard specimen) that are produced by the personnel of the Group dedicated for the preparation of chemical solutions in the Water Chemistry Laboratory.

Implementation milestones:

2005 - Purchase of analytical equipment - water purification facilities of 1st class, the scaleof 1st class with accuracy AX-205 type;

2006-2007 - Refinement of the procedure for sample preparation and establishment of true values of the reference samples according to the document "State Measuring System (GIS)Certified mixtures. General requirements to the development" RMG-60-2003;

2008 - Development of "Provisions on laboratory control of the quality of measurements in the Water Chemistry Laboratory of Chemistry Department" #171-7-P-KhC and "Methodologyfor standard sample preparation" #171-09-MVI-VRKhL-KhC;

2008 - Regular training sessions on the topic "Technology of preparation of referencesolutions and standard specimen" for dedicated staff.

Using chemical salts, the Group dedicated for the preparation of chemical solutions in theWater Chemistry Laboratory prepares standards for other Chemistry Department laboratories.

The nomenclature of standard reference samples for solutions and parameters are controlled and developed based on the norms of the Water Chemistry Laboratory, i.e.laboratory control, calibration of measuring instruments, etc.

The personnel of the Group preparing chemical solutions have the required knowledge, skills and abilities for the preparation of high quality reference samples (standard specimen).

The required accuracy, correctness and effectiveness of the measurement quality system are achieved and standards are distributed for all analytical groups of the Water ChemistryLaboratory.

Timely calibration of all measuring instruments of the Water Chemistry Laboratory is ensured.

Rovno 3/4, Ukraine

Mission Date; 24 Nov.-11 Dec, 2008

Implementation of All-Plant Water Treatment Facility (SODV)

Rivne NPP has implemented an All-Plant Water Treatment Facility (SODV) in order to improvethe safety and economic efficiency of NPP operation by ensuring scale-free water chemistry of plant water supply systems and essential service water systems.Implementation milestones:
1983 - Examination of hydraulic engineering structures and safety system components forcarbonate deposits and recommendations for ensuring scale-free mode of the service water supply system;

1984 - 1986 - design of make-up water treatment facility (SODV) by Ural Division of ATEPUSSR;

1989 - Start of SODV construction;

1993 - Finalization of the design by Designing Institute;

2000 - 2005 - Equipment installation;

2006 - Trial operations;

2007 - Development of process charts and power ascension;

2007 - 2008 - Upgrading of the lime blowdown unit to decrease lime consumption byrecirculation of lime milk and amelioration of its quality.

The productivity of the Facility (SODV) is 8350 m^3/h.

To ensure proper water chemistry with scale-control in service water supply, watertreatment is done in two stages:

1st stage: water clarification (decanting) with the help of liming and flocculation process indecanters with a capacity of 1000 m^3/h (total of 12 tanks);

2nd stage: stabilizing treatment by oxyethylenediphosphonic acid (OEDFK) and acidificationby sulfuric acid (H_2SO_4).

Upon the implementation of SODV, Rivne NPP has achieved the following results:

- Scale-free water chemistry mode for essential service water supply system of Reactor Department components (1, 2, 3 safety trains) due to the make-up of spray-ponds (units 3and 4) after treatment at SODV.
- The consumption of sulfuric acid used for water chemistry correction of circulating water has been reduced by 80% (6267,986 tons per year in 2004 vs. 789,261 tons peryear in 2007);
- The admissible limit of sulphate effluents to the environment has been reduced from 425 mg/dm^3 to 380 mg/dm^3 (Permit for special water use by Rivne NPP UKR#1/Rvn);
- The amount of effluents to the River Styr has been reduced by 38% (from 18286

- thousand m^3 in 2005 to 11399,6 thousand m^3 in 2007);
- The amount of water intake for service water system of power units 1-4 has been reduced by 8% (from 53149 thousand m^3 in 2005 to 48855 thousand m^3 in 2007);
- The specific coefficient of water consumption per kilowatt-hour has been reduced from3,3 m^3/mln kW/h to 2,9 m^3/mln kW/h;
- Corrosion and scale formation processes have been decelerated; that has lead to the improvement of water chemistry parameters in circulating water of units 1-4.

The inspection of condenser surfaces of Turbine Generator-5 (Unit 3) during the Outage-2007 showed significant reduction of carbonate deposits. This is the evidence of the amelioration of quality of circulating water of Units 1-3.

Mihama 3, Japan

Mission Date; 20 Jan.-5 Feb., 2009

Automatic resin separation by use of the colour tone charge coupled device camera (CCD)in demineralizer resins regeneration process.

To regenerate condensate demineralizer resins, it is necessary to separate cation resin and anion resin and immerse them separately in regenerative chemicals. Back washing often varies depending on the water temperature, requiring operators to perform adjustments manually. As a result, impurities could increase at the outlet of the condensate demineralizerin the subsequent operating cycle.

The CCD camera detects the separation boundary and automatically command theadjustment if required for a proper separation of the two resins.

As a result, the concentration of impurities at the outlet of the condensate demineralizer canbe prevented from rising in the subsequent cycle and the operators labour for resin separation can be reduced.

Mihama 3, Japan

Mission Date; 20 Jan.-5 Feb., 2009

Use of cation selective membrane in cation conductivity measurement loop.

To detect sea water in-leakage from condenser, cation conductivity meters have beeninstalled in the condenser hot well, condensate pump outlet and steam generators blowdown. Cations were removed by cation resin in the past but currently the resin columns were replaced by a cation selective membrane.

Based on satisfactory results obtained from one year tests, the method application hasbeen released for continuous monitoring of cation conductivity of the above mentionedsecondary side water system. The advantage of this method consists on continuous operation and reduced work for the chemistry personnel in respect of maintenance activities.

Oskarshamn, Sweden

Mission Date; 16 Feb.-5 Mar., 2009

Recycling of condensate clean-up system resins

The plant has developed and implemented recycling of resin from condensate clean-upsystem. Resins from the condensate clean-up system (CCU) are reused in the waste building.

The ion exchange capacity of the resin in the CCU is during normal operation used to a minorextent only. Even in cases of small condenser leakage there is still a substantial amount of cation capacity left. The filters are normally back-washed as a pressure difference defined for precoat filters is achieved.

In order to reduce the amount of radioactive waste, the resin from the CCU system is reused in the handling system of liquid wastes. Water from floor drainage, usually with highion content, can be cleaned with the resin from the CCU system.

The radioactive releases to water using this technique have decreased and kept at a constant level. The amount of powder resin saved since the introduction of the technique isapproximately 25 tons.

Oskarshamn, Sweden

Mission Date; 16 Feb.-5 Mar., 2009

On line dose rate measurement on primary piping during operation (Concrete- OLA)

During operation the dose rate on the primary piping is strongly dependent on the powerlevel dominated by short lived nuclides such as N-16 and O-19 in the reactor water. Therefore it is difficult to track the dose rate from the oxide layer on primary piping duringoperation.

To get reliable results on the build up of activation products on pipelines, a nuclide specificgamma detector would be needed. A nuclide specific gamma detector in the vicinity of primary piping in the reactor building is problematic because of the need for liquid nitrogenfor the detector cooling as the surrounding temperature should not be too high.

In order to get reliable data with conventional dose rates probes, a special technique has been developed by using two dose rate probes, one in contact with the primary piping andone behind a concrete wall.

The on-line dose rate measurement technique, Concrete-OLA, was first introduced at unit 2in late 2001 to track the build up of activated corrosion products on primary piping. After starting zinc addition both at unit 1 and unit 2 in 2003 the technique was found to be applicable for follow-up of the effects of zinc addition on the oxide layer. The Concrete-OLA -technique is simple, reliable and inexpensive tool for water chemistry control and track dose rate development during operation. The plant has found it to be valuable in controllingthe addition of depleted zinc to the final feedwater line.

Fessenheim, France

Mission Date; 23 Mar.-8 Apr., 2009

Use of mobile demineraliser facility during unit restarts after outages.

Plant has implemented use of mobile demineraliser during restarts instead of feed and bleedpractice for achieving of satisfactory quality of the condensate:
This mobile facility consists of 2 m^3 of mixed bed resin and mechanical filters and it isused for both units.
The facility is used when vacuum in the condenser is created and uses condensate pump to recirculate condensate. When satisfactory water quality is reached, water is supplied to the feed train. The facility remains in operation until 20% of reactor power isreached.
This technology assures good quality of condensate, saves about 1000 m^3 of demineralised water per restart and reduces associated releases of morpholine and make-up water plant regenerant solutions to the environment.

Fessenheim, France

Mission Date; 23 Mar.-8 Apr., 2009

Effective human performance error reduction policy reduces multiple safety risks andfacilitates performance in non standard sampling operations.

The plant has implemented a policy for the reduction of human performance errors in low-periodicity or occasional sampling in non standard sampling circumstances:

- A sampling procedure has been drawn up where sampling activities are evaluated and categorized with regard to overall safety risks;
- Simple highly illustrative single page instruction sheets were developed containing information on safety risks, defining sequence of all associated activities involving communication, checks and manipulations and picture of particular field conditions for easy orientation;
- These sheets are plastic-coated in order to assure damage proof and easy decontaminability if required;
- For safety-related sampling activities, a single set of these instruction sheets is
- available in the supervisory room. In the event of a sampling request, a pre-job briefing with chemistry section supervisory staff is inherently initiated as technicians are expected to collect the relevant sampling sheet from the supervisor before going to the field.

Ringhals 3/4, Sweden

Mission Date; 1-18 Mar., 2010

Argon 41 emission reduction.

Degassing of primary make-up water in storage tanks using a gas transfer membrane system has led to significant reductions of dissolved argon gases (Ar-40) entering the primary circuit, thereby reducing the source term for the activation of Ar-40 and hence thepotential for Ar-41 emissions from the plant.

Supporting facts and effects:

- Production of Ar-41 concentration in the reactor coolant has been reduced by about afactor of 10.
- Airborne emissions of Ar-41 through the main stack have been reduced by a factor of 10.

St. Alban, France

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

The effective quality assurance system of laboratories is established based on internationalstandards organisation (ISO) 17025.

The chemistry laboratories have established and maintained a quality assurance system appropriate to the scope of their activities. Laboratories document their policies, systems, programs and procedures to the extent necessary to ensure the quality of the results which includes validation of analytical methods, the internal quality and the external quality system.

Moreover, the environmental laboratory has established a quality assurance system that is officially authorized. Measurements can thus be shared and can be compared in an objective way; any measurement being made uses the same approved techniques according to the same quality assurance system. Their results are published on the Internet.

The benefit of the comprehensive quality assurance system of laboratories includes a high level of laboratory analysis and published measurement results of the environmental laboratory are irrefutable. The transparency and quality of results give the public confidence.

Bohunice 3/4, Slovakia

Mission Date; 1-18 Nov., 2010

The plant has implemented a comprehensive set of technical and organizational measureswhich resulted in significant reduction of liquid radwaste production. Those measures involve:

- Modification of drain system and operation practices to maximize boron recycling and segregate liquid radwaste collection
- Aggressive leak reduction, level gauges, quality check and prompt waste water source identification program mandatory part of daily meetings agenda
- Detailed daily radwaste production reporting, evaluation and tracking
- Detailed outage planning/optimization of boron solution transfers
- Optimization of regeneration processes for ion-exchange purification systems
- Use of low waste generating decontamination technologies

Maintenance Engineering, Operations Departments and the Chemistry Unit played a key rolein implementation of the above listed measures.

Further improvement in this field is still being achieved through established corporateRadwaste minimization project team initiatives.

Implemented measures resulted in significant overall plant reduction of radwaste concentrate production. This reduction brings benefits in the environmental burden reduction(less waste to be solidified and disposed of) together with significant budgetary (economical) savings.

Plant liquid radwaste generation was reduced from 136 m^3 of concentrate in 2000 to 28 m^3in 2009, with expected final value < 20 m^3 in 2010.

Dukovany, Czech

Mission Date; 6-23 Jun., 2011

Growth control of fibrous algae in cooling towers.

The plant applies algaecide to eliminate the growth of long-fibrous algae in cooling towersby direct sprinkling of it on cooling tower supports. The benefits of this method, as compared with the original method of algaecide application by injecting into the water of cooling towers bays, are as follows:

- Extended interval for the cleaning of inlet screens for the cooling water pumping station.
- A significant reduction in the environmental discharge from the plant related to algaecide.
- Significant economic benefit through reduction of applied algaecide from 100 tons/year to 4 tons/year.

Dukovany, Czech

Mission Date; 6-23 Jun., 2011

Fuel leaker identification using alpha-spectrometry of reactor coolant.

The analysis of alpha-transuraniums in the reactor coolant during reactor operation at power makes it possible to determine a group of potentially leaking assemblies according totheir age in the reactor. The identified fuel assemblies can be scheduled for sipping tests during a subsequent outage.

The monitoring of alpha-transuraniums is carried out after separation by using the method ofalpha spectrometry (americium, curium and plutonium) and the method of gamma- spectrometry (neptunium).

Supporting facts and advantages:

- Shortened time required for the check of assemblies because the group of potentiallyleaking assemblies has been detected in advance
- Reduced dose for operating staff during sipping.

Koeberg, South Africa

Mission Date; 22 Aug.-8 Sep., 2011

The laboratory information and management system (LIMS) is a powerful tool to define andadjust sampling plans. Managers and supervisors can easily control and assess the progress of sampling plans and the results of the analysis. Out of specification situations are clearly indicated. To achieve the goal of “effective pre-emptive chemistry control” (EPCC) flags are defined that are far below any limits of operating technical or operating chemical specification and indicate very early trends in chemical parameters.

Koeberg, South Africa

Mission Date; 22 Aug.-8 Sep., 2011

Sample bottles are equipped with a blank label that has to be filled in. The label contains a tick off field to confirm that the sample valve has been closed after sampling and thus provides an easy way of self-checking. Chemistry performs 3000 valve operations a month and with this innovative idea it is currently holding the plant record with more than 300 dayswithout any valve left in the wrong position (free Plant Status Control event).

Smolensk, Russia

Mission Date; 5-22 Sep., 2011

Comprehensive and detailed Chemistry Specification document.
The document is comprehensive, detailed and formatted in a way which makes it easy touse. The document establishes all management expectations on chemistry control. The document is developed on the basis of the Utility and Supervisory body normative documentation, with additional requirements established for the plant, aimed at water chemistry improvement.

It contains requirements for all modes of operation, containing detailed information and guidance to Chemistry staff on actions in case of deviations from normal chemical values. This information and guidance is based on internal and external operating experience, andincludes possible root causes for deviations. This allows the plant to respond promptly to deviations, as adequate information on mitigation is immediately available.

The document includes:

1. The list of valid normative and technical documents on chemistry technology at the plant;
2. Water chemistry objectives;
3. Main tools and methods of water chemistry control;
4. Main principles of water chemistry parameters rating. Rated and diagnostic quality parameters, operational margins, control levels (valid for the plant and established for timelyidentification and elimination of degrading trends), expected values, main definitions;
5. Procedure of water chemistry control and monitoring of media quality;
6. Requirements to control chemistry data record-keeping;
7. Procedure of water chemistry efficiency measurement and evaluation;
8. Procedure of water chemistry control of the primary circuit and auxiliary systems in all operating modes such as: start-up preparation, primary circuit pre-heating; reactor power increase to the minimum controlled level; normal power mode; unit shut-down and cooling;outage;
9. Requirements for the quality of water chemistry control equipment;
10. Deviation levels and preventive actions;
11. Charts and algorithms of actions to identify and eliminate deviations of water chemistryparameters;
12. Procedure of chemical parameters monitoring, obligatory specification of chemicalparameters monitoring for all operating modes;
13. Requirements for filtering materials of water chemistry control systems, procedure ofacceptance testing and in-service inspection;
14. Requirements for the quality of chemical agents used in water chemistry control,acceptance and operation inspection of chemical agents;
15. Methodology of on-line and manual laboratory measurement results comparison;
16. Lists of certified methodologies of laboratory monitoring and list of certifiedinstrumentation of on-line and laboratory monitoring.

The document establishes clear and precise requirements important for effective water chemistry control, ensuring integrity of safety barriers, reliability of power units operation, minimum deposition on fuel assemblies and heated equipment surfaces, and improvement ofradiological safety, which are all significant to safe plant operation.

Cattenom, France

Mission Date; 14 Nov.-1 Dec., 2011

Chemistry control of the secondary side of the steam generators during shut down reactormodes.

During each planned reactor shutdown the plant provides extensive sampling and analysisof the steam generator blowdown system. The results of the analysis are evaluated to decrease corrosion of the secondary circuit and deposits in the steam generators (SGs).
Evaluation of the quantity and identity is focused on freely bound and fixed boundcompounds of the deposits.

The benefits of this control are as follows:

- Determination of the efficiency of eliminated sludge during shutdown.
- Study of the relationship between chemistry measures and steam generator blowdownduring operation.
- Estimation of the chemistry characteristics of the liquid contained in crevices, and depositson the steam generator tubes during operation.
- Support preventive maintenance of the SGs by removing freely bound deposits by high pressure water, thus extending the period before chemical recleaning of the SGs, is required.
- Knowledge of the chemical compound structure in the crevices of the SGs helps toevaluate the life of the SGs for long term operation.
- Ensuring a stoichiometric balance of impurities that concentrate into the crevice thus minimizing the likelihood of formation of highly alkaline or acidic environment in the SGs.Plant personnel are encouraged to pursue a plant-specific approach, such as cation-to- anion ratio control, to minimize the bulk water impurities on the crevice environment.

Cattenom, France

Mission Date; 14 Nov.-1 Dec., 2011

The validation system for laboratory analysis methods.

The validation process of the analytical methods, including sampling, allows evaluation of the measurement method of chemical, radiochemical and eco-toxicological parameters in real time. Extensive tests are performed independently by five technicians for statistical evaluation of linearity, repeatability, reliability, reproducibility and accuracy, detection limit oftest method and limit of determination of methods used. This allows them to calculate an uncertainty of determination including the sampling and the so-called Z-score (tool used for inter comparison). These tests are carried out every year.

The benefits of this control are as follows:

- The validation of laboratory analysis ensures reproducibility of results irrespective of who performs the analysis and thus enhances the confidence in the laboratory results.
- Published measurement results from the laboratories are therefore irrefutable in thechemistry, radiochemistry and eco-toxicological areas.
- Maintenance of technical skills is a part of the validation method.
- The efficient evaluation of the instability in the analysis and its timely correction.
- The validation method ensures and proves that the measuring devices in the chemical laboratory consistently achieves the precision necessary to carry out tests to a specifiedlevel.

Rajasthan, India

Mission Date; 29 Oct.-15 Nov., 2012

To improve the efficiency of initial training, Pre Job and Post Job Briefings and to reducecollective dose and human errors, the Chemistry Section has developed user friendly procedures with useful photographs, pictorial symbols and red colour highlighted text.

The sampling procedures contain photographs of sampling points with valve identifications,proper connection for sampling and air mask stations which is required to be used during emergency conditions.

The analytical procedures contain photographs of instruments with schematic diagram and photographs with proper connections to be done.

The sampling and analytical procedures have colour pictorial symbols for quick identificationof potential industrial, radiological and environmental hazards.

The precautions to be taken by workers before and after work execution have beenhighlighted in red colours.

Rajasthan, India

Mission Date; 29 Oct.-15 Nov., 2012

To minimize the radiation exposure caused by antimony-124 in Primary Heat Transport system, the Chemistry Section developed 6 years ago a way to avoid antimony release during long outages, by controlling hydrazine addition and adapted purification ion exchangecolumn.

Antimony-124 activity was observed in Primary Heat Transport System heavy water during shutdowns when there was ingress of atmospheric air into the system during maintenance jobs. Presence of this strong gamma-emitting radioisotope (gamma energy of 603 keV and 1691 keV; half time of 60.2 days) causes high radiation fields from piping and equipment andconsequently increased collective doses during and after shutdown.

The Chemistry Section has carried out studies and established the root cause and for themechanism of release of antimony-124, then implemented an innovative and simple chemistry measure to maintain reducing chemistry in primary coolant during shutdown byway of hydrazine addition and using anion exchange columns for primary coolant purification.

Temelin, Czech

Mission Date; 5-22 Nov., 2012

Reactor coolant high temperature pH control in real time.Description:
High-temperature pH of the reactor coolant (pH_{300}) is the most important parameter for development and transport of activated corrosion products and also deposits of the radioactive corrosion products at different locations of reactor coolant system and connected systems. More than 90 % of the dose received by the personnel, as well as thecollective dose, is caused by active corrosion products (ACP).

The plant performs on-line measurement and monitoring of all relevant parameters for high-temperature pH, i.e. concentrations of boric acid, Li, K and NH_3. The data are used to calculate the real-time pH_{300}. The calculation is performed by appropriately verified and validated software.

This unique approach has made it possible for the main control room to use pH_{300} as a control parameter of the reactor coolant water chemistry. Similarly as for the other parameters, action levels are specified for pH_{300}. This method of chemical regime controlhas been reviewed and approved by the fuel manufacturers.

Advantages:

1. Immediate response by operating personnel to potential deviations.
2. The stable chemical regime minimizes ACP formation and transport.
3. Low deposit of ACP on primary circuit surfaces results a low collective dose.
4. The approach minimizes manual analyses of reactor coolant samples to comply with theALARA principle.
5. The updated pH_{300} and its real-time control enables respond to fluctuations during the“load-follow” mode and thus to reduce the collective dose.
6. The optimized pH_{300} value can be reached within 24 hours after an outage.
7. The approach allows for a highly responsive control of the primary circuit chemistryeven at full power when the boric acid concentration is close to zero.

Operating results:

1. The collective dose at the plant has been the lowest among VVER and PWR worldwideaccording to the WANO indicator.
2. The pH_{300} value has been maintained within 7.0 – 7.2 range at all times.
3. The method has been used to for chemical regime controls since the beginning of theplant operation, i.e. for 10 years.

Kozloduy, Bulgaria

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

Combined use of use of ethanolamine (ETA) and ammonia (NH_3) for secondary side chemistry control, called AMETA, significantly reduces the corrosion rate in the secondarycircuit.

The team identifies as a good practice the combined secondary chemistry (AMETA) program. This program combines the benefits of ETA and high ammonia regimes to significantly reduce corrosion-erosion processes and provides uniform pH in mono andbiphasic streams.

As a result of AMETA chemistry implementation mass transport of corrosion products to thesteam generators is reduced up to the trace concentrations and the buildup of corrosion products on the heat exchanging surfaces is significantly reduced.
The actual amount of corrosion products inside the steam generators is so low that it is not representative for the instrumentation methods of analyses. The cleanliness of heat exchanging surfaces of the steam generators is confirmed by filming and photos.

The SG inventory pH value is increased to more alkaline area. As a result from this change,the corrosion products convert from hematite to magnetite form. Therefore the corrosion products are easily removed from steam generator inventory. No sludge accumulation is observed on the bottom part of steam generators and low rows of tubes. The new chemistry regime also provides increase of pH values in SG header crevices.

The number of SG plugged tubes is as low as 84 (15 at Unit 6 and 69 at Unit 5) since theunits were commissioned.

The scope of maintenance works to be performed during outage of the secondary side equipment is significantly reduced. (maintenance of pipes, turbine blades, equipment incontact with biphasic media, etc.)

AMETA is a good method for equipment layup during shutdown, outages and startup. In thevery first day of operation the concentration of corrosion products in SG feedwater already corresponds with the values specified for the fifth day of plant operation.

In AMETA conditions all chemicals are injected in automatic mode in strict proportionbetween ammonia and ethanolamine.

No hide-out return phenomena is observed during the plant shutdown.

Chooz, France

Mission Date; 17 Jun.-4 Jul., 2013

Use of the Ryznar stability index to monitor cooling tower scaling levels.

Cooling tower scaling levels are monitored by calculating and monitoring the Ryznar stabilityindex which measures the susceptibility to scaling and corrosion.

The Ryznar stability index is calculated on a daily basis in order to establish the scaling potential of water flowing through the tertiary circuit. Measurements are transposed onto the Riznar correlation matrix and onto the schematic representing the concentration factor,divided into 4 zones. Actions and operational limits are defined for each zone.

Benefits:

- The Ryznar stability index gives a rapid and clear indication of potential cooling towerscaling levels.
- The matrix and action statements prevent interpretations by stipulating the requiredactions, which could go as far as taking the unit into controlled shutdown mode.
- Reduction of scaling levels on cooling tower plates.
- Reduction of sulfuric acid amount and harmful waste needing to be processed (all scaling waste from cooling towers is considered to be harmful due to potential presence of amoeba).

Clinton, USA

Mission Date; 11-28 Aug., 2014

The station has a department chemical control representative (DCCR) in all its departments. DCCR acts as a point of contact for the station chemical control coordinator when problems involving chemical product use, storage, labelling, or disposal arise and assists in resolving these problems. DCCR is also required to take corrective actions when gaps are identified inmeeting chemical control requirements. DCCR coordinates the monthly chemical control locker inspections and assists personnel in the department with the purchasing process for chemical products. In addition, the following factors contribute to the successful chemical control programme at the station:

- Each storage area has a designated person whose responsibility is to assure that the handling, labelling and storing of chemicals is done in a proper manner. Ownership creates responsibility.
- The station chemical control coordinator does quarterly walk-downs together with the department chemical control representative to inspect storage areas for unauthorized or improper use of chemicals.
- The station has strictly followed the policy in labelling all the chemicals at the site (5different types of labels).
- If chemicals have to be transferred to smaller containers, the secondary containers are available in various storage locations. These secondary containers are pre-labelled but also plant specific labels must be attached to the containers.

The benefit of this approach, as compared to the arrangement whereby the chemistrydepartment is the only responsible organization for chemical control, is as follows:

- The responsibility for the chemical control and labelling is distributed throughout the departments using the chemicals.
- Departments have their own contact point to help personnel on a day-to-day basisregarding questions on handling, storing and labelling the chemicals.
- The station chemical control coordinator has a clear contact point in the other departments.

Borssele, Netherlands

Mission Date; 1-18 Sep., 2014

Environmentally controlled room in the nuclear laboratory

Chemistry instruments used for analysis of samples related to plant safety are located in an environmentally controlled room. This produces more accurate and consistent results for analysed parameters on the RCS and boron storage tanks.

This room also functions as a cleanroom, because there is a continuous ventilation exhaustsystem, which reduces the likelihood of contaminating the samples and equipment. Betterworking conditions are also guaranteed, because temperature and humidity are stable and comfortable. Heat produced by the equipment in the room is removed efficiently.

The plant implemented this room in 2013 as a part of laboratory renovation. In this room the measurements that are the most sensitive to variations in temperature and humidity are undertaken. The most important measurement is for B-10 in nuclear systems, which is performed on the Inductive Coupled Plasma- Mass Spectrometer (ICP-MS). The ICP-MS isalso used to measure metals in both nuclear and conventional systems. Another device in this room is the Milli-Q, which produces pure water from tap water, and is used for preparation of standard solutions used for QA checks of the ICP-MS and other equipment.
Ever since operation with the ICP-MS in this room, all of the standard and backgroundchecks have been within specification.

Flamanville, France

Mission Date; 6-23 Oct., 2014

A new aerosol sampling system providing alarm, which reports deviations to on callchemist.

New sampling heads on external aerosol sampling stations were installed so that chemistscan easily exchange filters in the laboratory.

A phased approach using a delay enables automatic start-up of the suction pump after acertain length of time.

A local alarm system (a warning light) has been installed, which is transmitted by mobile telephone, to identify certain faults such as: the presence of two filters, a missing, cloggedor damaged filter or an issue with the leak tightness of the sampling system.

Advantages/Benefits: Filters are replaced inside the laboratory in an appropriate working environment. This removes the problems caused by changing the filters in the open air (e.g.wind, rain, etc.). This reduces the risk of compromising the analysis results. The alarm system ensures more easy and efficient operation of atmospheric dust sampling due to the fact that faults are identified and communicated immediately.

Novovoronezh, Russia

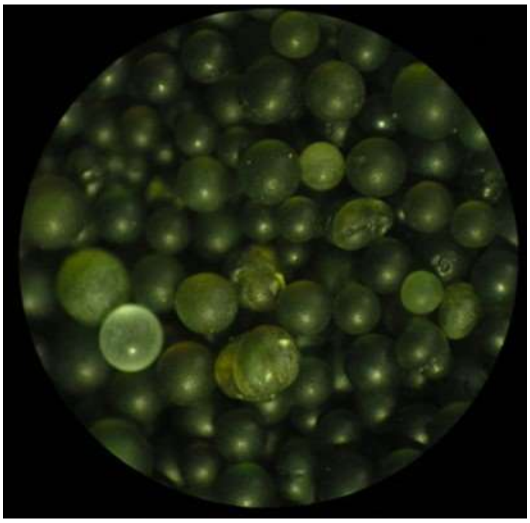
Mission Date; 9-26 Nov., 2015

Additional removal of radio nuclides traces from discharged water.

When discharging distillate from the level monitoring tanks in the environment, radio nuclidesare also discharged though the amount of radio nuclides in the discharged residual water does not exceed the reference levels.

To perform additional purification of the discharged distillate and reduce discharge of radionuclides to the environment an additional radionuclide filter for discharged water with ion- selective sorbent “Termoxide-35” was installed on distillate discharge line from the level monitoring tanks.

When flowing through the barrier filter filled with ion-selective sorbent “Termoxide-35” the concentration of Caesium radio nuclides is reduced to natural levels in the environmentalwaters.



Operating experience with using barrier filters filled with ion-selective sorbent “Termoxide-35” shows that if the filtration speed is 30 volumes of purified water per hour per one volume of sorbent, then 1 m^3 (1.2 tons) is sufficient for purification of residual water from radioactive Caesium isotopes at least within 8 years with the annual discharge of residual water 10 000 m^3.

Novovoronezh, Russia

Mission Date; 9-26 Nov., 2015

Reduction of hazardous substances fumes discharge in the environment.

The plant's atmospheric vents from hydrazine equipment are equipped with hydrazine oxidation catalyst filters. Use of those filters is aimed at reduction of hazardous substancesdischarged to the environment and at environmental safety assurance when preparing anddosing work solutions of hydrazine.

Each catalyst filter is filled with natron calc to absorb carbon dioxide from the air when thetank "is breathing" and also filled with activated carbon for catalytic oxidation of hydrazine by the oxygen from the air when blowing down fumes from the tank.

Novovoronezh, Russia

Mission Date; 9-26 Nov., 2015

Cleaning organic carbon from condensate by usage of OH radicals generated by ultravioletlight.

Concentration of organic carbon (TOC) is limited in the coolant to prevent creation of a carbon layer on the fuel cladding. Sources of TOC are make-up water and solutions usedfor decontamination. Cleaning organic carbon from condensate is effective way how to reduce TOC content in all solutions used at the plant including coolant.

For cleaning organic impurities from condensate the Advanced Oxidation Technology is applied. It is based on destruction of organic compounds in water by intense oxidizing processes activated by hydroxyl radicals. Generation of hydroxyl radicals in water (OH- radicals) initiates chain reactions of organic compounds oxidation in oxygen media. As a result of the chain reactions generated aldehydes and ketones are oxidized and turned intocarbon acids and fall on lighter organic compounds with generation of CO_2 molecules and water H_2O.

Experience of this technology operation shows high reliability and efficiency of organic impurities reduction to a level of 0,3 mg/dm^3 with the flow-rate of the processed solution upto 20 m^3/h.

Current technology is simple for use in plant conditions, it is environmentally-friendly as itdoes not require additional agents which increase the volumes of radioactive waste. Thistechnology significantly reduces the formation of a carbon layer on high burn up fuel.

Golfech, France

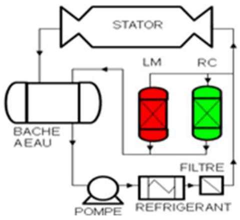
Mission Date; 10-27 Oct., 2016

On-line stator cooling system purification and cleaning

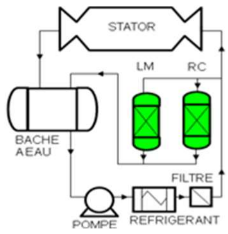
The Unit 1 stator cooling water system (GST) cools the stator bars using demineralisedwater in hollow copper conductors. Corrosion and blockage of these hollow conductorsmay decrease the stator cooling flow rate and increase generator stator temperature.
International industry operating experience has shown that this has resulted in planttemporary power de-rates or shutdown to perform cleaning.

In contrast, station chemists and operators use a two-stage process using existing plant equipment, air and pH adjustments that supports a controlled on-line cleaning without theneed for adding chemicals.

1. Acidification : a cationic resin is used on its own. Cu^{2+} ions areretained and exchanged with H_3O^+ ions, which decrease pH (acid pH). Acid pH makes the CuO copper oxides soluble.



2. Purification : a mixed-bed resin is used joint with the cationic resinin order to clean the stator cooling fluid.



Golfech, France

Mission Date; 10-27 Oct., 2016

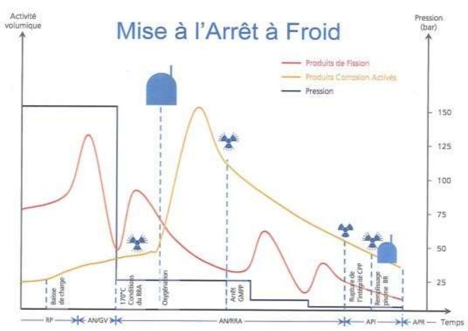
Comprehensive actions for controlling radiation source term during plant shutdown areeffective in reducing work area dose rates.

International operating experience has shown that chemistry impact on source term can be significant. This is especially important when shutting the plant down to perform equipment maintenance and refueling operations. There are operating conditions when station conditions transition from a high temperature (325°C) reducing (H_2) environment to an oxygen rich environment (air) at ambient temperature to support defueling. These stages results in various physical and chemical changes. The station chemists and operations' personnel have developed and implement a detailed procedure with rigorous chemical andradiochemical criteria for controlling these stages. Incorporation of operating experience from each outage is also incorporated for continuous improvement of operating practices.

Advantages/Benefits

Compliance with set criteria is essential to optimizeand limit the following as low as practical:

- Risks for equipment and materials
- Impact of operation on work area dose rates
- Impact on the release of effluents to theenvironment



Results: The plant has one of the lowest operating source terms in the utility fleet and in theindustry for plants of similar design and capacity. Also, contaminated areas are few supporting the ability for operators and other workers to perform work without frequent donning of protective clothing.

Taishan, China

Mission Date; 8-26 Jan, 2017

Anti-corrosion management program for equipment and buildings implemented during theproject phase.

It was an initiative in the nuclear energy industry to set up a systematic anti-corrosion management program for equipment and buildings in the whole project phase. The plant hasimplemented this in the construction and commissioning phases as follows:

- Main processes included establishing documentation, reviewing design files, on sitechecking, corrective action and re-checking and closure of action from design to thecommissioning period.
- Internal preservation inspection for the main thermal equipment in the primary andsecondary loop is performed, and equipment is in good condition.
- Contamination analysis on the stainless steel surface in the nuclear island is performed.
- Anti-corrosion for the equipment and buildings can become even more important shouldthe project be delayed or postponed

C5-M (corrosive category 5, very high marine - ISO 12944-2-1998) of corrosion environmentin the Taishan site is defined. Corrosion issues of equipment and buildings are of great importance due to the high salinity and high relative humidity content in the atmosphere for the site.

The anti-corrosion management procedure and anti-corrosion implementation procedures are established. Especially a list of key anti-corrosive equipment and buildings is identifiedbased on the three main factors i.e. characteristics of equipment material corrosion resistance, atmosphere environment corrosivity and safety level of equipment.
Then a corrosion inspection plan is set up which runs through all periods of project, such asdesign, manufacture, storage, installation and commissioning.

Based on the plan of the anti-corrosion program, the work is performed, including field corrosion inspection, defect feedback using corrosion condition inspections, and solutions are provided. Corrosion issues can then be followed-up, so as to ensure the key anti- corrosive equipment is in good condition. Since 2010, 509 inspections on-site have been carried out, including 126 arrival inspections, 199 site tours, and 163 take-over inspections.1513 corrosion issues have been found. 98% of the problems have been well resolved, such as issues about pressurizer paint damage and SG nitrogen pressure lower than expected.

	
Figure 1 Corroded shell side of Low pressure heater	Figure 2 Shell side of Low pressure heater after design change

Figure 1 shows the shell side of low pressure heater as found in 2013. Specific internal coatings were required by the design to meet the anti-corrosion requirements and this design conforms to the requirement, hence, the corrosion issue is effectively controlled, asshown in Figure 2.

The benefit of this practice is that corrosion is more effectively monitored and can beprevented from an early stage.

Bugey, France

Mission Date; 2 -19 Oct., 2017

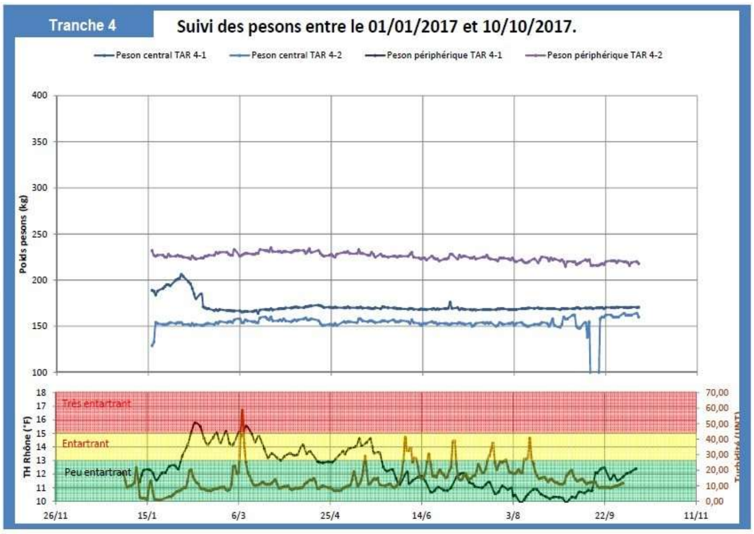
Circulation water system treatment for scale and sludge removal using an environmentallyfriendly product

At the plant, an injection facility injects on an ongoing basis an organic scale removal product (ATO) into the circulating water system. The idea is to prevent scale and sludgedeposits in the condenser and circulating water systems. The product used is organic, harmless for the environment and contains neither phosphate nor nitrogen.

ATO injection pumps

The advantage of this process is to protect cooling water baffles against excessive weight, resulting in a significant decrease in maintenance needs (cleaning and flushing) and in number of replacements, thus avoiding possible unit shutdowns for corrective maintenance.

Load cell curve indicating absence of weight gainsince ATO injection.



ATO is a heavy acrylic polymer which has an effect on scale witha dispersing factor against suspending matter coming from the river and present in the circulating system.

A process totally devoid ofenvironmental impact.

Olkiluoto 3, Finland

Mission Date; 5-22 Mar., 2018

Visual suspended solids analysis

Suspended solids (SS) analysis is performed on multiple systems, especially duringcommissioning, to monitor system cleanliness.

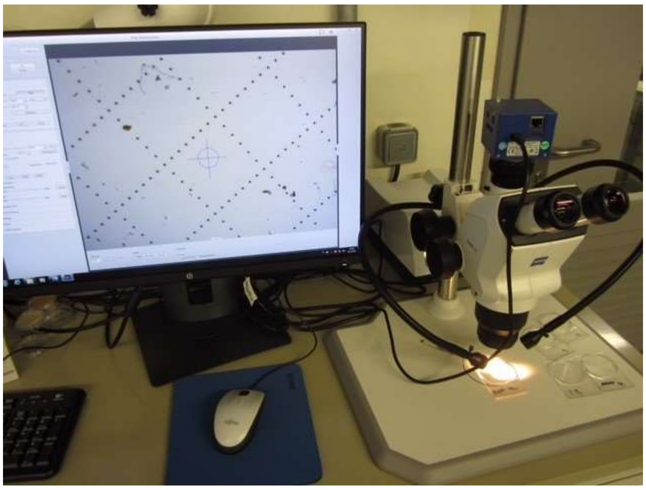
Suspended solids (SS) are analysed after a known sample volume is filtered through a 0.45µm laboratory filter.

The primary method used in the industry for SS analyses is the gravimetric method.
This method involves filtering one litre of sample through a pre-weighed filter. The filter andfiltrate are dried for 1 hour in an oven and cooled to room temperature in a desiccator.
The dried filter and filtrate are re-weighed and the total solids calculated. This analysis takes approximately 2 hours to complete.

A second method for performing the SS analysis is the stain method. Plants can quantify SSvalues by comparing samples after filtering to coloured stain charts obtained from a vendor. This method takes about 15 minutes to perform and is less accurate than the gravimetric method.

The plant has developed and validated a unique method for performing a visual SS analysesusing a microscope and camera combination. It is based on internally created standards, which are prepared with known weights of magnetite/hematite crystal mixture filtrates. A set of these filters with known suspended solids concentrations are prepared and stored in filter planchets in the lab for reference. Analysts are trained to evaluate unknown samples againstthese preparations. This method takes about the same amount of time as the stain method.

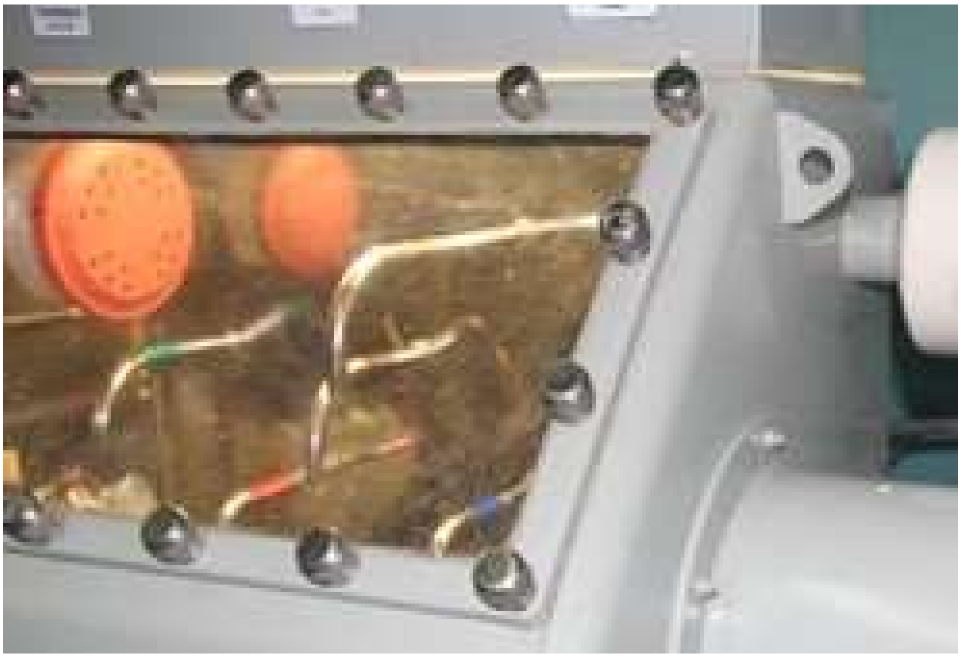
Benefit: The plant-developed SS method makes it possible to quickly detect wear, foreign material and many other kinds of failures from process samples. Particles can be counted, measured, and photographed from the microscope ocular camera. All digital photos can bestored in the Laboratory Information Management System database. This method is accurate, efficient and provides the added benefit of photographic storage of the sample results. This has been a very positive factor during the plant commissioning phase because thousands of samples are sent to laboratory for suspended solids analyses.



Bushehr, Iran

Mission Date; 29 Sep. -17 Oct., 2018

Sampling of primary circuit water is performed once a day by the shift laboratory using a sampling glove-box to analyze oxygen and hydrogen concentration. A feed through line has been designed and manufactured to connect the inside of the sampling glove box with a portable gas analyzer located outside the glove-box. This modification allows a more preciseand fast analysis which minimizes the operator's dose intake provides effective support for the adjustment of the water-chemical regime (ammonia injection).



Sampling box (before modification by the plant): O_2/H_2 manual measurement

Sampling box (after modification by the plant): O_2/H_2 measurement with portable equipment

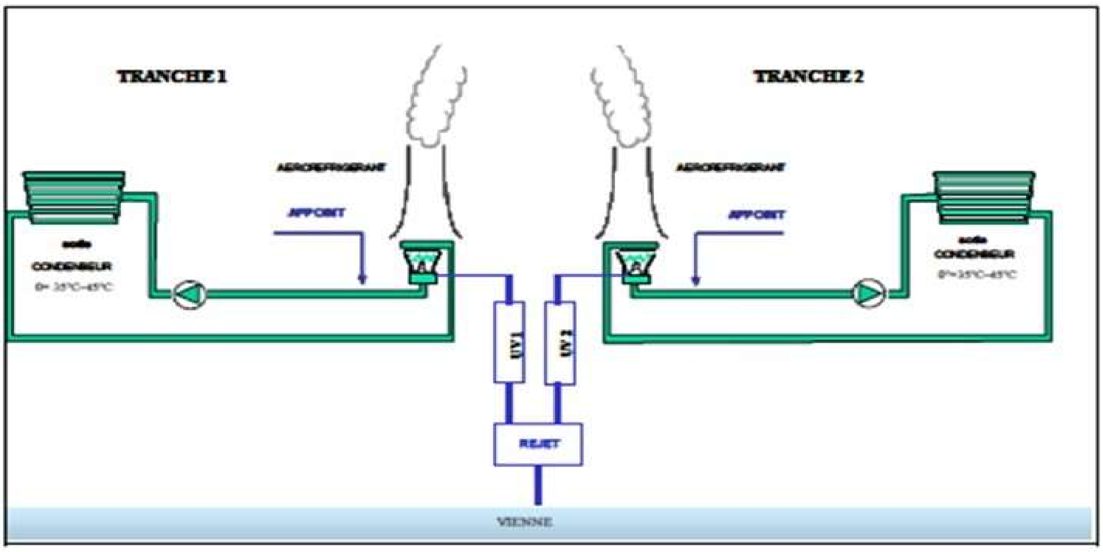
Civaux, France

Mission Date; 30 Sep. -17 Oct., 2019

UV treatment of cooling tower drain water

The plant has implemented physical (ultraviolet) treatment of cooling tower drain water with the purpose of limiting releases of amoeba.

The treatment uses mercury-vapour lamps which emit quasi-monochromatic UV-C light at 254nm, in the optimum band for the germicidal effect. The treatment is physical and has no impact in terms of releases of chemicals into the environment.



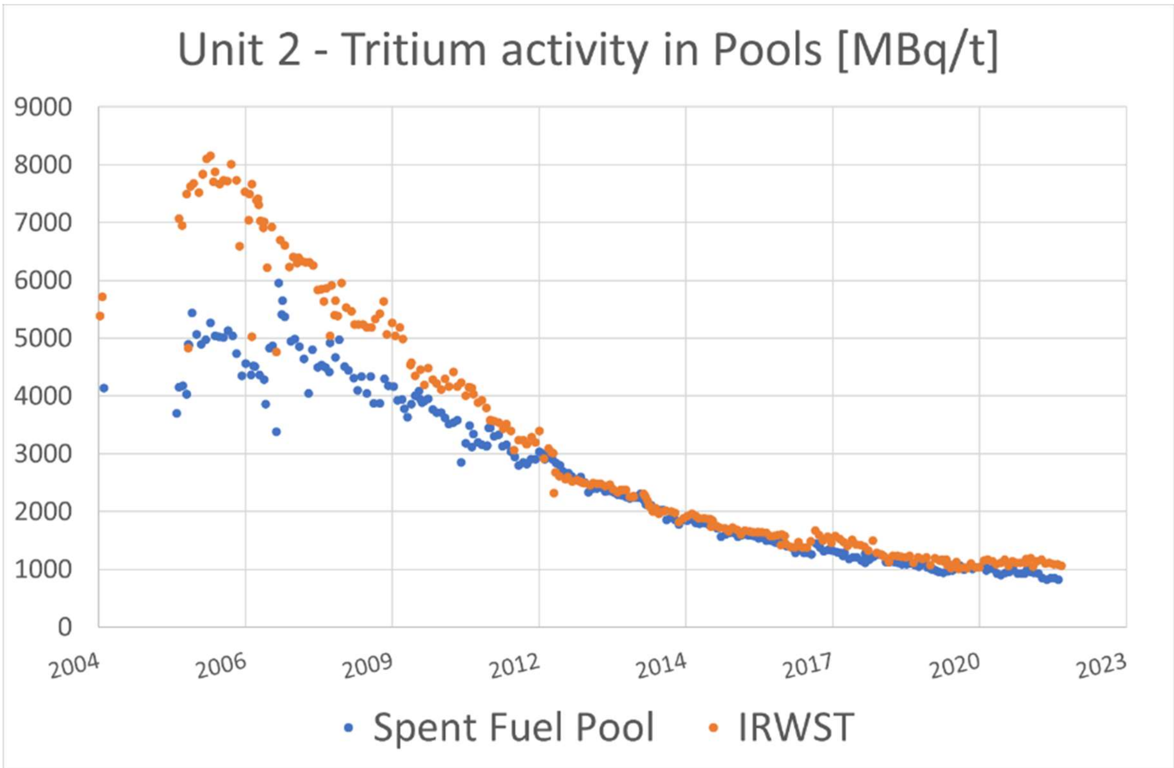
The UV stations enable the amoeba population to be killed off, particularly Naegleria fowleri, an amoeba that is pathogenic in humans. The UV stations also allow the plant to comply with health protection thresholds.

Penly, France

Mission Date; 4 - 21 Sep., 2023

Specific tritium management to minimise tritium activity in the pools, i.e. In-Refueling Water Storage Tank (IRWST) and Spent Fuel Pool (SFP).
This good practice limits tritium in gas releases with a beneficial impact on radiation protection and the environment.
Tritium (^3H) is a radionuclide produced in the reactor. It is a pure-beta emitter with low energy for external radiation. Therefore, the radiotoxicity of this element is relevant to internal exposure situations.
Over a cycle, tritium spreads and accumulates in the different systems connected to the Reactor Coolant System (RCS). During shutdowns, the opening of the reactor vessel causes tritium to spread to the Reactor Building Pool. The tritium activity in the IRWST and in the SFP will therefore increase from cycle to cycle if the tritium activity in the reactor cooling circuit is not reduced beforehand.
Currently, there are no treatment processes for tritium enriched water and, due to its long radioactive half-life (12.3 yrs), interim storage for decay prior to environmental releases is not feasible.
Accordingly, the good practice applied by the plant is to progressively release as much produced tritium as possible in liquid effluents over a cycle:

- Yearly objectives are to achieve a 100% release of the yearly tritium source term into the liquid effluents.
- During the cycle, chemists define and apply the overall strategy by regularly requesting RCS feed and bleed operations, for the specific purpose of eliminating tritium.
  The distillates which are produced from the treatment of primary effluents are not recycled.
- Tritium activity is also monitored in boron tanks prior to shutdowns: the tank with the lowest tritium activity will be used in priority during shutdown boration.
  Since the implementation of this strategy, the tritium activity in the pools has decreased by a factor of 4 to 6.



Decrease in tritium concentration in the IRWST and in the SFP over the years 2004 to 2022