

# OSART Good Practices

## CHEMISTRY

### Chemistry programme

#### Ignalina, Lithuania

Mission Date; 5-21 Jun., 2006

#### Desaerated start-up of unit

Usually when choosing water chemistry method for specific reactor, special attention is paid to the normal operation parameters - basic operation mode. In such a case the facilities are designed for the achievement and the maintenance of the necessary parameters. The norms and means of achievement of the specific parameters are not always provided for transients due to their short duration. One of such parameters affecting the Inter Granular Stress Corrosion Cracking (IGSCC) is the oxygen concentration in the primary circuit water during hot hydraulic tests and during start-up phase after a continuous shutdown. After the welded joint defects of IGSCC type had been detected in the downcomers between separator drums and main circulation pump (MCP) the plant developed the programme of primary circuit water desaeration prior to start-up.

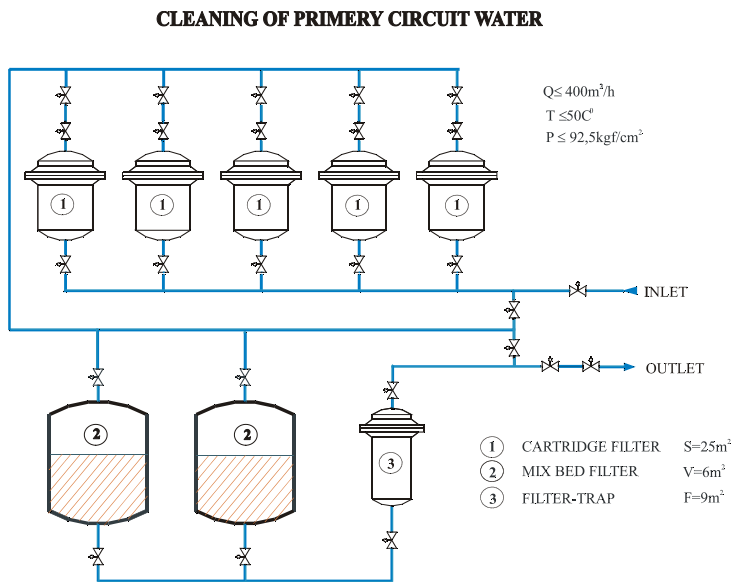
Desaeration procedure includes the following stages:

1. At temperature 70°C the non-nuclear heating of the reactor coolant is started by running the main primary pumps. Initial contents of dissolved oxygen is around 6 ppm.
2. When temperature in the primary circuit reaches 100°C the circulation is started in through the desaerator. The steam generated in the separator drums is convoyed together with the oxygen to the desaerator where the feed water for primary circuit is warmed up.
3. At temperature 110°C the reactor heating is maintained till oxygen concentration decreases lower 200ppb.
4. Simultaneously with the removal of dissolved oxygen from the primary circuit water the feed water of the primary circuit is desaerated. Therefore the primary circuit make-up from the desaerators results only in minor increase of oxygen concentration in primary circuit water (which is less than 100 ppb)
5. During further heating till the nominal parameters the oxygen concentration decrease until 20-30 ppb.

Actually no additional equipment is required for this procedure. Its performance causes extension of start-up activities by 5 to 6 hours, however it ensures to avoid the cracking effect in sensitive zone.

Powdex process on the cartridge filter for primary coolant purification system.

Primary Coolant Purification System (PCPS) is used for maintaining the water chemistry parameters. It operates under the same pressure as the reactor, however the temperature shall not exceed 50°C. The system comprises 5 cartridge filters, 2 mix bed filters and a filter-trap.



In 10 years of operation the defects were identified on the valves caused by the abrasive qualities of the applied inorganic absorbent PERLITE. Only 20% of radioactivity of corrosion products were present in the primary circuit as particles with the size more than 45µm. Others radioactive pollutions were present in ion or colloid forms for which the efficiency of the cartridge filters with PERLITE was very low.

In 1993 of the usage of the powdered ion-resin was tested and held at PCPS. Since 1994 the ion exchange powdered resin has been in use at INPP. Taking into consideration the composition of impurities in the primary circuit water, as well as economical factor, the mixture of cationite and anionite of Microlite type was chosen with the ratio 2:1 and size of particles 20-80µm.

The following advantages were achieved using powdered resins:

- Powdered resins ensure an efficient purification not only for particulate impurities but also for the ion impurities and charged particles of minor size.
- Total exchange capacity of the powdered resins is used in a more complete way. The ion exchange kinetics has been improved which causes the increase of purification coefficient. As a result, after system installation the specific conductivity has decreased from 0.09 to 0.07 µSm/cm.
- In accordance with the practical experience during purification of water with specific activity. equal to  $2.5\text{E}-5\text{Ci/l}$  performed in real conditions the cartridge filter with powdered resin makes the activity 5 times lower while the cartridge filter with PERLITE reduces it only for one third.
- It reduces the dose rate of the resin in the mix bed filters, decreases its destruction and the aforementioned resin can be used much longer (the life time of the resin in the mix bed filters is twice longer at about 2 years)

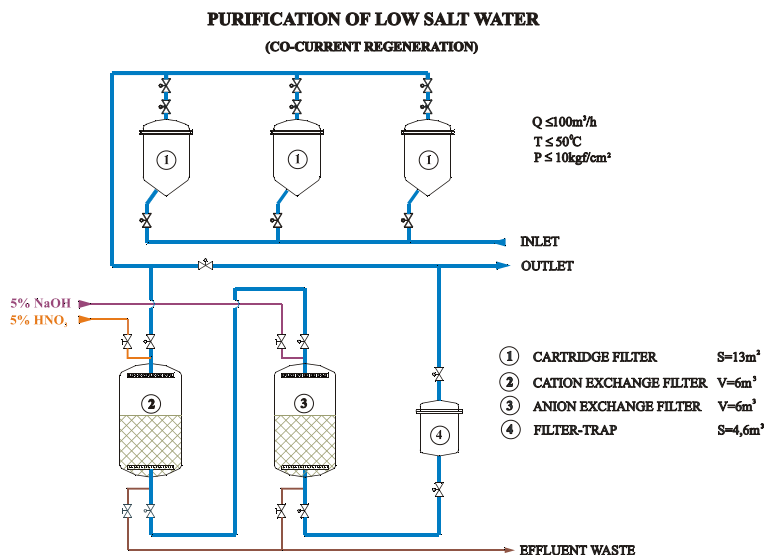
- When using the ion-exchange powder resin the lifetime extension of the cartridge filters with the powdered resin and reduction of pressure drops were identified.
- Due to the lifetime extension of the cartridge filter with the powdered resin and mix bed filter the capacity of the spent resin from the by-pass purification facility of the primary circuit has been decreased 2-3 times.
- Due to the exclusion of the abrasive absorbent PERLITE from the process the operation of equipment of the absorbent preparation unit and filter material retrieval has improved.

Modification of purification facility of low salt water (LSW).

Special purification facility of low salt water was installed at INPP to purify water from impurities coming from the following equipment and systems:

- Blowdown of cooling circuit of control and protection system,
- Condensate with lubricant of turbine equipment,
- Spent fuel pool,

It consisted of three cartridge filters, H+filter(strong acid cation)and OH-filter(strong base anion).



The facility had a lot of operation deficiencies:

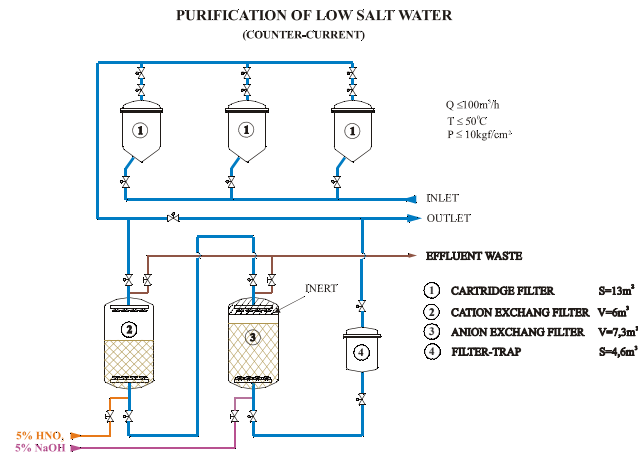
- Often cationite resin got oily due to the high concentration of oil (lubricant) in the water of turbine equipment
- Non-conformance between the exchange capacity of H+filter and OH-filter, which caused overrun of regeneration solutions
- Unsatisfactory quality of regeneration due to the tunnel effect.

As a result the filter lifetime stopped at  $\sim 50\,000\text{m}^3$  and conductivity at the outlet was equal to  $0.6\text{-}0.8\mu\text{Sm/cm}$ .

After implementation of the Fast Acting Scram system where 24 channels were cooled in a film mode and the channel cavity was blown by the gaseous nitrogen the load to the LSW purification facility increased due to the necessity to retrieve nitric acid obtained as a result of irradiation. In order to improve the operation of facility and to prevent occurrence of tunnel effect, the plant developed the organisational and technical measures on reduction of oil capacity getting from the turbine equipment. The plant started modification of LSW purification facility for counter-current regeneration. As a result filter lifetime extended till  $\sim 80\,000 - 100\,000\text{m}^3$  with conductivity at the outlet at about  $0.3\text{-}0.5\mu\text{Sm/cm}$ .

Although the significant improvement was evident the non-conformance between exchange capacity of H+filters and OH-filters still remained. In order to correct this last deficiency the plant decided to implement a modification on the OH-filter.

- Specialists performed calculation of the top and bottom distributor system. The special filter nozzles with the gap 0.25mm were installed on the bottom distributor system and with the gap 0.5mm - on the top distributor system.
- Protective device was developed and installed on the ventilated pipe.
- Floating inert material IN42 was loaded.
- Type of loaded anionite was changed.
- The capacity of loaded anionite was changed from 6 m<sup>3</sup> to 7.8 m<sup>3</sup>.



Thus, the "compacted bed" concept was implemented on the OH- filter which resulted in the following changes:

- Filter lifetime extended till 160 000-220 000 m<sup>3</sup>
- Water quality improved from 0.3-0.5μSm/cm to 0.12-0.18μSm/cm
- Capacity of drain water decreased of one third
- Regeneration time reduced for 30% and therefore specific amount of reagents for chemical regeneration and, respectively, the amount of radioactive wastes reduced
- Resin removal from the filter during backwashing was eliminated
- Stream is distributed along the filter cross-section in a more equal manner

All costs on this modification will be paid off within 1.5 -2 years.

In conclusions the modifications implemented at INPP are not expensive, however their performance resulted in great advantage as described in the following:

1. Improvement of coolant quality
2. Cost reduction for reagents and ion-exchange resin
3. Significant decrease of the amount of liquid radioactive wastes (more than twice)
4. Improvement of equipment reliability and reduction of water chemistry impact to the IGSCC in downcomers.

Monitoring and evaluation of active corrosion products in the primary coolant system in order to reduce dose rate.

When in the previous years an adverse trend was noticed in dose rate at the main circulation loops of the reactors, the Mochovce NPP management created a working group in order to analyze the situation and decrease dose rates.

NPP has implemented a system for the monitoring of creation, migration and deposition of active corrosive products in the coolant in the primary circuit. By mutual comparison of activity and the radiation situation among the units of NPP Mochovce and the other units of VVER 440 type, the power plant creates good database of information for understanding the causes of current radiation situations in the primary circuit.

Power plant personnel monitor the concentration and activity of soluble and insoluble forms of corrosive products in the primary coolant, and on the inner surfaces of selected locations on primary circuit equipment. In addition, NPP monitors efficiency of purifying stations for the capture of corrosive products in the individual modes of the unit, especially during plant shutdowns.

Further indicator is dose rate at 54 defined positions in the six loops of the primary circuit. Median of the data is a good indicator of radiation field and serves for comparison with previous cycles or with other NPPs.

There is also cooperation with several experts from external organizations. The team regularly evaluates the state of the radiation situation and submits proposals of measures for further improvement to management of NPP. Operation procedures are revised in order to minimize deposit creation and release.

In the 2006, a new specific way of „soft“ decontamination of the reactor coolant during reactor shut-down stage was introduced for the first unit outage. Chemical parameters of coolant are characterized by higher oxygen concentration and this oxidizing environment supports re-suspension of corrosion products from inner surfaces of the primary circuit. As result of the procedure, the primary circuit dose rate median decreased by 25 percent in comparison to the previous year and the collective dose for the outage was the smallest one in the history of operation of the Mochovce NPP Unit 1.

The NPP has clear goals. These issues are defined in its main tasks and aims, employees are appropriately motivated for fulfillment of the given tasks. NPP has elaborated the action plan for corrective measures and defined criteria for monitoring of the radiation situation development trends of primary circuit coolant on the units.

### Analysis of ion exchange resins

The plant has a very good system for the control of qualitative parameters of ionex materials used at the power plant. Samples are regularly taken from systems, including the primary and secondary systems, for evaluation and identification of degrading ionex material performance.

Ionex materials in the primary circuit are analysed following a problem with the quality of the output medium or some other problem (increase of pressure difference, shortening the working cycle, etc.)

The power plant performs the following analyses:

1. - optical aspects (under microscope) in the first place in the condition "as is", subsequently after washing and subsequently after regeneration, possibly after specially prepared cleaning procedure (sediments, oils, greases, corrosion products, etc.)
2. - total exchange capacity - volume and mass (in eq/l, or eq/ kg)
3. - content of water - MHC (moisture holding capacity) (in mass %)
4. - the content of dry solids (in mass %)

This analyses enables the plant to determine what happened with a particular ionex based on a comparison of this data with the same parameters of a new ionex (stored samples are used in this time).

This practice enables the power plant to evaluate the real time current condition of an ionex and identify possible violations of operational conditions under which ion resins were working. The power plant closely cooperates in solving of problems in the area of cleaning abilities of ionex materials with producers of ionex materials. This practice also enables NPP management to monitor the current state, predict the real lifetime of ion exchange resins, and facilitates better planning of exchange cycles of these ion exchange resins for individual purification stations on the primary and secondary circuit. Based on this program, the NPP was able to extend the cycle of the primary circuit coolant ionex resin from one to two years.

## South Ukraine3, Ukraine

Mission Date; 9-25 Oct., 2006

Steam generator hide out return effect programme.

Application of the programme that is coming from the evaluation of hide out return effect of steam generators allows a decrease in corrosion to the secondary circuit and deposits in SG.

According to this programme, with morpholine dosing or LiOH, the plant can ensure the setting of a neutral high temperature pH in the feed water and steam generator crevices to decrease corrosion (Evaluation of optimized chemistry values is based on the relation between cation conductivity and sodium concentration).

Iron and copper concentrations were reduced about three times.

The amount of deposits on SG tube surfaces were reduced five times. Deposits are not fixed very often and are removed easily during the phase of shut down with steam generator blow down.



## South Ukraine3, Ukraine

Mission Date; 9-25 Oct., 2006

### On-line chemistry data processing system

The plant installed an effective on-line Chemistry Data Processing System (DAPS) that ensures automatic correction of key parameters in the primary circuit as molar concentration alkaline metals in dependence of boric acid.

The functions of the system for data acquisition and processing are as follows:

- acquisition of important chemistry and process parameters, their processing, storage and display under all operation modes;
- comparison of the measured parameters with standard values;
- generation of alarms when the set-points are exceeded;
- diagnosis analysis by identifying causes of deviations in the chemistry control parameters; and
- suggestion of generation to the plant operators for chemistry process optimization on base chemistry algorithms.

This system enables maintaining the equilibrium alkaline metals related to the boric acid that contributes to stabilizing chemistry regimes of water reactor and controlling of corrosion products transport in the primary circuit. For example:

- corrosion products in the primary circuit decreased about 15% and
- the surface dose rates of steam generator collectors decreased about 20%.

## St. Laurent, France

Mission Date; 27 Nov.-14 Dec., 2006

There is an applied management system to project liquid RW effluent releases together with close monitoring of effluent production in nuclear areas. The effluent control laboratory has on-line river flow data available, as well as analysis results in electronic form to be able to project concentrations in the river. As soon as the flow rate of the Loire falls below  $60\text{m}^3/\text{s}$ , the site of Saint Laurent takes charge of the coordination of tritium releases from the tanks of the four NPP sites located over a distance of about 200 km along the Loire, that is altogether 18 liquid radwaste monitoring and discharge system tanks. Saint Laurent collects the relevant information from the other sites and draws up an overall weekly schedule for releases to come, taking account of transit time. This schedule is submitted to the other sites for approval, then sent to the regulator, every week. The sensitive environment of a natural Loire reserve remains protected respecting regulatory limit for the concentration.

## St. Laurent, France

Mission Date; 27 Nov.-14 Dec., 2006

Using the sample hatch system to transport samples out of the nuclear auxiliary building from one radio-chemical laboratory inside to the other which is outside the RCA.

The sampling system of the radioactive samples is located in the nuclear auxiliary building. The analysis of the samples takes place in the radiochemical laboratory outside of the auxiliary building. What is usually found in other French NPPs, is that the person taking the sample had to leave the auxiliary building using the necessary exiting requirements (removing protective clothing etc) and leaving the RCA.

Using a sample hatch to get samples out of the nuclear auxiliary building: Samples from the radiological controlled area for analysis in the hot laboratory pass through a hatch. They are stored in a sealed container which will serve to transport them from the hatch to the laboratory.

- the laboratory works in line with the requirements of the corporate DI82 guidelines while ensuring sample integrity
- samples are secured in the container and placed in the hatch while waiting to be taken to the hot laboratory
- time saving in case of quick analysis (some samples must be analysed precisely one hour after sampling).
- hatch and container contamination is checked on a monthly basis

The laboratory no longer depends on a contractor to get the samples out. During shutdown phases when sample flow is very high (up to one sampling every thirty minutes) a person no longer needs to wait at the exit door of the RCA.

## Loviisa, Finland

Mission Date; 5-21 Mar., 2007

Actuation of control room alarm in case of safety showers usage.

If a person is affected by hydrazine on him, he must rinse abundantly the chemical residue out of his skin and eyes using the closest emergency shower and eye washing equipment as soon as possible. There comes a collected alarm from the hydrazine station to the control room when someone is using the emergency shower. There are two such emergency showers in the room for hydrazine dilution and these will trigger an alarm.

If an alarm comes to the control room, an operator must promptly leave from the control room to reach the hydrazine station to check what the reason for the alarm is and help the potential injured person.

Shift supervisor alarms fire brigade to the scene of accident. The fire brigade takes care of the first aid and the transportation of the injured person to the medical care if the injuries require that.

## Yonggwang, Korea, Rep. of

Mission Date; 16 Apr.-3 May, 2007

There is an online monitoring system of chemistry of the secondary side. The results are displayed on a PC and include a radio alarm system and a detailed flowchart for troubleshooting.

All systems and components of the secondary side of YGN 5&6 are monitored online. The parameters include pH, cation conductivity, sodium, hydrazine etc. These data are visualized in a schematic flow chart of the circuit and displayed on real time in the main control room and several other computers. If an alarm occurs, the shift chemist and the responsible person are informed of the abnormal condition by cell phone (responsible person) and PDA (shift chemist). An integrated flow chart on the diagnosis of water quality problems, by categorizing various sources of water contamination in the secondary water system, supports the chemist to allow location localize and identification of the problem.

## Tihange, Belgium

Mission Date; 7-23 May, 2007

Incompatibility matrix for storing chemical products in chemical laboratories.

The displaying of the matrix in all storage areas of the chemistry laboratories has brought about quick and seamless improvements in industrial safety and the storage of chemical and/or dangerous products.

The incompatibility matrix for storing chemical products is included in the Memento booklet, nuclear safety and quality expectations. It is also found on each storage cupboard for dangerous products in the chemistry laboratories.

The principles for storing dangerous substances are described in detail in the CHIRAD/00/028 procedure. The incompatibility matrix summarizes in a schematic way the elementary rules for storing chemical products. It is a quick and simple visual tool to know where a chemical product should be stored in relation to the risks pictogram(s) found on its label:

- Chemical products are classified in 6 risk categories:
  - Oxidant
  - Corrosive- acid
  - Flammable
  - Toxic
  - Corrosive- base
  - Harmful / irritant
- Flammable products should be stored separately from others.
- The acids should be kept separately from the bases.
- Harmful / irritant products and toxic products can be stored together.
- If a product has several risk factors at the same time, the following priority must be taken in terms of classification: oxidizing > flammable > corrosive > toxic > harmful/irritant.

### Calibration of micro-pipettes.

The micro-pipette calibration has been implemented after operating experience feedback from Tihange 3. Deviation in the tritium activity readings was noticed when the analysis showed that the reading error was due to a deviation in the volume dispensed by the micro-pipette.

The use of poorly calibrated micro-pipettes can have a significant impact on the quality and accuracy of certain readings which require small sampling volume such as  $\beta$ ,  $\gamma$  and tritium metering.

The testing of pipettes is done according to the ISO 8655 standard, by following the CH123 procedure (Pipette calibration instrument: Sartorius 235P-SD scales and Picasso software).

The management of micro-pipettes is described in the CHIRAD/00/039 procedure:

- The micro-pipettes are stored and managed in the common laboratory.
- The unit laboratories have to contact the common laboratory in order to obtain a micro-pipette.
- Each micro-pipette is checked before being released.
- Those micro-pipettes which are in use are checked every 6 months by the common laboratory. In the case of any non-conformity, they are recalibrated according to the manufacturer's instructions.
- The calibration certificates are put in records in the common laboratory.
- The micro-pipettes which are validated are (re)sent to the laboratories and a label is affixed:
  - L1-Valid >"Expiry date" for Unit 1's laboratory,
  - L2-Valid >"Expiry date" for Unit 2's laboratory,
  - L3-Valid >"Expiry date" for Unit 3's laboratory,
  - L0-Valid >"Expiry date" for the common laboratory.

In conclusion, the implementation of this micro-pipette calibration control system provides quality monitoring of the micro-pipettes and supports the quality of analyses.

## Neckarwestheim, Germany

Mission Date; 8-24 Oct., 2007

The use of an ammonia destruction unit on liquid waste provides a significant benefit in reducing the environmental impact of the plant.

The secondary circuits of the two pressurized water reactors (PWR) of Neckarwestheim NPP unit I and II operate on high ammonia chemistry. Ammonia is removed from these circuits by the steam generator blowdown ion exchange resins, which operate in the hydrogen form. The ammonia enters the waste stream each time the steam generator blowdown ion exchange resins are regenerated. The purpose of the ammonia destruction unit, which was not part of the original plant design, is to remove ammonia from the waste water stream prior to discharge into the river.

The ammonia destruction unit comprises a two part stripping column, a chemical reactor, a fan, an air reheater, two heat exchangers and two feed pumps. The strippers remove the ammonia from the waste water, where it is heated in air to about 300°C and the ammonia is converted into nitrogen and water. The process reduces ammonia concentrations from around 1400 ppm to less than 12 ppm.

The system runs for around seven days in feedback mode with one of the collection tanks containing the waste liquid to be treated. The water from the stripping column is fed back to this collection tank to effectively lower the ammonia load of the collection tank. After about seven days, the ammonia concentration in the collection tank is about 10 ppm, and the waste water is then processed for discharge.

This unit provides a significant reduction in the environmental impact of the plant, as ammonia can have an adverse impact on natural waters.

The use of formalized, detailed and signed-off check sheets for the preparation and implementation of all chemistry related outage activities is an effective tool for managing increased workloads during outages.

The Chemistry section has a detailed checklist for chemical monitoring of plant shutdown and start-up. The checklist covers both the primary and the secondary loops and is broken down into a series of check sheets which cover the following time periods relating to the outage steps:

- Preparatory actions and measurements taken prior to the outage, for example including: checking the condition of the mixed bed filters, checking the levels in the concentrate tanks, operation of the coolant degasification system, stopping zinc injection.
- The measurement programme running from start-up of the degasification system to the time that the Chemistry section switches into 24 hour cover.
- The measurement programme running from the start of chemistry shift covers in the laboratory until clearance is received in order to open the reactor pressure vessel head. This period includes hideout return measurements.
- The measurement programme runs from clearance to open the reactor pressure vessel head to pond flooding including preparatory work for sipping.
- The measurement programme runs from flooding to start-up including all measurements needed for compliance with the safety specifications.
- The measurement programme runs during the period of the outage when oxygen is removed from the circuit.
- The measurement programme runs after clearance to reheat the primary circuit to operational levels including start-up of the cleaning filter systems.
- The measurement programme and the close-out activities during the first two days of operation after full load conditions have been achieved.

The checklist contains useful additional information, for example measuring parameters, measurement frequency, limits, waiting periods that need to be met, reference to relevant documents, procedures and regulations, and explanatory background information. The chemistry staff on duty sign off each action after completion. After the outage, the check sheets are retained as formal records from the outage within the Chemistry section for reference and in order to ensure lessons learnt are retained in the preparations for future outages.

This approach ensures that all the required actions are taken and that activities carried out are properly communicated among staff.

The operating strategy and resin selection on the steam generation cleanup process (SVO-5) has eliminated out-of-service time for resin regeneration during power operation.

At Khmelnitsky NPP, SVO-5 system operates without regeneration during power operation thereby eliminating the possibility of regenerating solutions from entering the steam generators (SGs).

According to the original design, SVO-5 consists of a D2500 mechanical filter loaded with 5 m<sup>3</sup> of cation exchanger; a D1000 cation filter loaded with 1.2 m<sup>3</sup> of cation, and a D1000 anion exchanger filter loaded with 1.2 m<sup>3</sup> of anion. The operating experience showed that this configuration was ineffective, and the available resin was insufficient to support continuous operation between outages. This resulted in the need to perform regeneration while on-line, leaving the possibility of regenerating solutions intrusion into the SGs potentially due to valve leaks or personnel error related to system line-up during regeneration.

Design system configuration was changed to optimize impurity removal. At present, SVO-5 consists of a D2500 mechanical filter loaded with 5m<sup>3</sup> of cation exchanger, and of two D1000 anion filters loaded with 1.8 m<sup>3</sup> of anion exchanger each. This modification of the SVO-5 design configuration extends the filtering cycles of SVO-5 trains between outages to 320,000 m<sup>3</sup>. There is no need anymore to perform regeneration of SVO-5 train while on-power. SVO-5 regeneration is conducted only during outages with a shutdown reactor, thereby excluding a possibility of regenerating solutions intrusion in the SGs.

Through three cross-functional committees - As Low As Reasonably Achievable / Effluents and Waste Committee / Waste Reduction Group and through adherence to the radiochemical and chemical specifications, with strong management commitment, the plant is capable of controlling, reducing, and maintaining as low as possible the source term (dose), liquid and gaseous effluent releases (volume, activity, quantity of chemicals) and process-generated waste.

Over the years since 1990, the plant has progressively implemented a specific organisation structure which, in 2001, gave rise to the creation of three cross-functional committees to which Operations, Chemistry, Waste, Radiation Protection, among others, make their contribution.

These three committees make it possible to control and minimise the source term and its effect on the dose rate and releases into the environment, whilst controlling the production of process solid waste. To do so, within the committees:

- the origin of the dose rate, effluents and waste is closely monitored
- leakages are timely identified and eliminated
- objectives are defined, followed and reprioritised if necessary
- an action plan is implemented and its efficiency is measured
- regular reporting to Plant Management takes place

Plant results demonstrate:

- Extremely low levels of activity in the primary circuit (oxygenation peaks, et.....)
- Actions to improve the source term: replacement of rod clusters, pump bearings
- In terms of liquid waste, released activity has continually diminished over the last 10 years to reach very low asymptotic conditions
- The volume of process waste is controlled



## Forsmark, Sweden

Mission Date; 12-28 Feb., 2008

The sulphate content in the coolant increased after the power upgrade (100% to 108%). The new thermo hydraulic conditions caused a more oxidizing environment at the condensate clean up filters, and the strong cation exchange resins containing sulphuric functional groups were decomposed. Weak cation exchanger with carboxyl groups were tested and fulfilled all requirements for coating, waste handling, clean up function etc. This Low Sulphur Resin (LSR) was tested in a test rig and later on a real filter during operational conditions. It was concluded that the differential pressure increase was slower compared to normal resins and the particle separation was excellent. A draw-back of this type of resin is leakage of trimethyl amine from the anion resin, which is not captured in the weak cation resin bed, but leaks to the reactor coolant resulting in increased nitrate content. However, nitrate ions are less harmful with respect to stress corrosion cracking as compared to sulphate ions.

In addition, the chemistry department has developed a test rig for simulating the coating of candle filters from the condensate clean up system. The test rig consists of sampling holder of Plexiglas, mixture vessel for resin, stirrer, coating pump, pump for sufficient flow for adhesion of the resins, flow meter, differential pressure meter, regulation valves and tubes for connection of air and water. The sampling holder has sufficient space for mounting filters of different sizes from the condensate cleanup system (CCS). The construction is built to simulate the real CCS. Mixture time, coating flow, amount of resins, flocking size and temperature are parameters that can be varied. The result of the coating is visually determined as the filter inside is seen through the Plexiglas. Observation of the size of the flock, sedimentation rate, adhesion of the resin and the distribution over the surface can be carefully evaluated. The coating of the filter can be optimized by pressure variations. Even small variations of the parameters strongly affect the result of the coating.

## Forsmark, Sweden

Mission Date; 12-28 Feb., 2008

The Plant has optimized the oxygen content in the drain of the pre-heaters by changing the ventilation from the pre-heaters to the condenser together with installation of a bypass flow through some pre-heaters. Thus the formation of protective Haematite layers was favoured. The mass of transported iron was significantly reduced, as was the power loss due to pressure drop. This modification is even more important as power up rates will change the oxygen content in the systems.

### 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 three stages,:

- 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 oxidizing agent, is supplied for solution mixing. The time dedicated to this operation should be about 5 to 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 steam generators.

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

### Standards for laboratory management

In order to improve the quality of measurements, Rivne NPP has implemented a procedure for 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 scale of 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 "Methodology for standard sample preparation" #171-09-MVI-VRKhL-KhC;

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

Using chemical salts, the Group dedicated for the preparation of chemical solutions in the Water 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 Chemistry Laboratory.

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

### Implementation of All-Plant Water Treatment Facility (SODV)

Rivne NPP has implemented an All-Plant Water Treatment Facility (SODV) in order to improve the 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 for carbonate 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 ATEP USSR;

**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 by recirculation of lime milk and amelioration of its quality.

The productivity of the Facility (SODV) is 8350 m<sup>3</sup>/h.

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

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

2nd stage: stabilizing treatment by oxyethylenediphosphonic acid (OEDFK) and acidification by sulfuric acid (H<sub>2</sub>SO<sub>4</sub>).

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 3 and 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 per year in 2007);
- The admissible limit of sulphate effluents to the environment has been reduced from 425 mg/dm<sup>3</sup> to 380 mg/dm<sup>3</sup> (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<sup>3</sup> in 2005 to 11399,6 thousand m<sup>3</sup> 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<sup>3</sup> in 2005 to 48855 thousand m<sup>3</sup> in 2007);
- The specific coefficient of water consumption per kilowatt-hour has been reduced from 3,3 m<sup>3</sup>/mln kW/h to 2,9 m<sup>3</sup>/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 demineralizer in the subsequent operating cycle.

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

As a result, the concentration of impurities at the outlet of the condensate demineralizer can be 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 been installed 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 has been released for continuous monitoring of cation conductivity of the above mentioned secondary 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-up system. 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 minor extent 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 high ion 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 is approximately 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 power level 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 during operation.

To get reliable results on the build up of activation products on pipelines, a nuclide specific gamma 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 nitrogen for 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 and one behind a concrete wall.

The on-line dose rate measurement technique, Concrete-OLA, was first introduced at unit 2 in 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 controlling the 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 bleed practice for achieving of satisfactory quality of the condensate:

- o This mobile facility consists of 2 m<sup>3</sup> of mixed bed resin and mechanical filters and it is used for both units.
- o 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 is reached.
- o This technology assures good quality of condensate, saves about 1000 m<sup>3</sup> 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 and facilitates 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:

- o A sampling procedure has been drawn up where sampling activities are evaluated and categorized with regard to overall safety risks;
- o 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;
- o These sheets are plastic-coated in order to assure damage proof and easy decontaminability if required;
- o 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 the potential 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 a factor 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 international standards 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 measures which 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 role in implementation of the above listed measures.

Further improvement in this field is still being achieved through established corporate Radwaste 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<sup>3</sup> of concentrate in 2000 to 28 m<sup>3</sup> in 2009, with expected final value < 20 m<sup>3</sup> 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 towers by 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 to their 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 of alpha 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 potentially leaking 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 and adjust 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 days without any valve left in the wrong position (free Plant Status Control event).

Comprehensive and detailed Chemistry Specification document.

The document is comprehensive, detailed and formatted in a way which makes it easy to use. 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, and includes 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 timely identification 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 chemistry parameters;
12. Procedure of chemical parameters monitoring, obligatory specification of chemical parameters monitoring for all operating modes;
13. Requirements for filtering materials of water chemistry control systems, procedure of acceptance 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 certified instrumentation 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 of radiological 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 reactor modes.

During each planned reactor shutdown the plant provides extensive sampling and analysis of 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 bound compounds 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 blowdown during operation.
- Estimation of the chemistry characteristics of the liquid contained in crevices, and deposits on 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 to evaluate 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 of test 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 the chemistry, 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 specified level.

## Rajasthan, India

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

To improve the efficiency of initial training, Pre Job and Post Job Briefings and to reduce collective 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 identification of potential industrial, radiological and environmental hazards.

The precautions to be taken by workers before and after work execution have been highlighted 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 exchange column.

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 and consequently increased collective doses during and after shutdown.

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

Reactor coolant high temperature pH control in real time.

Description:

High-temperature pH of the reactor coolant ( $\text{pH}_{300}$ ) 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 the collective 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  $\text{NH}_3$ . The data are used to calculate the real-time  $\text{pH}_{300}$ . The calculation is performed by appropriately verified and validated software.

This unique approach has made it possible for the main control room to use  $\text{pH}_{300}$  as a control parameter of the reactor coolant water chemistry. Similarly as for the other parameters, action levels are specified for  $\text{pH}_{300}$ . This method of chemical regime control has 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 the ALARA principle.
5. The updated  $\text{pH}_{300}$  and its real-time control enables respond to fluctuations during the "load-follow" mode and thus to reduce the collective dose.
6. The optimized  $\text{pH}_{300}$  value can be reached within 24 hours after an outage.
7. The approach allows for a highly responsive control of the primary circuit chemistry even 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 worldwide according to the WANO indicator.
2. The  $\text{pH}_{300}$  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 the plant operation, i.e. for 10 years.

Combined use of use of ethanolamine (ETA) and ammonia ( $\text{NH}_3$ ) for secondary side chemistry control, called AMETA, significantly reduces the corrosion rate in the secondary circuit.

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 and biphasic streams.

As a result of AMETA chemistry implementation mass transport of corrosion products to the steam 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 the units 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 in contact with biphasic media, etc.)

AMETA is a good method for equipment layup during shutdown, outages and startup. In the very 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 proportion between ammonia and ethanolamine.

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

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

Cooling tower scaling levels are monitored by calculating and monitoring the Ryznar stability index 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 Ryznar 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 tower scaling levels.
- The matrix and action statements prevent interpretations by stipulating the required actions, 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).



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 in meeting 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 (5 different 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 chemistry department 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 basis regarding questions on handling, storing and labelling the chemicals.
- The station chemical control coordinator has a clear contact point in the other departments.

**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 exhaust system, which reduces the likelihood of contaminating the samples and equipment. Better working 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 is also 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 background checks have been within specification.

## Flamanville, France

Mission Date; 6-23 Oct., 2014

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

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

A phased approach using a delay enables automatic start-up of the suction pump after a certain 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, clogged or damaged filter or an issue with the leak tightness of the sampling system.



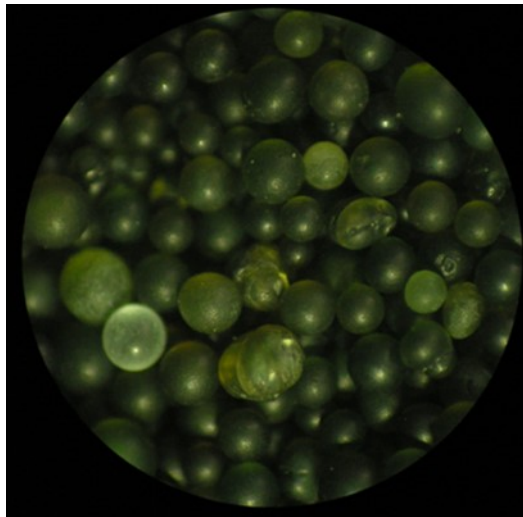
**Advantages/Benefits:** Filters are replaced inside the laboratory in an appropriate working environment. This removes the problems caused by changing the filters in the open air (e.g. wind, rain, etc.). This reduces the risk of compromising the analysis results. The alarm system ensures more easy and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

Additional removal of radio nuclides traces from discharged water.

When discharging distillate from the level monitoring tanks in the environment, radio nuclides are 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 radio nuclides 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 environmental waters.



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<sup>3</sup> (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<sup>3</sup>.

## 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 substances discharged to the environment and at environmental safety assurance when preparing and dosing work solutions of hydrazine.

Each catalyst filter is filled with natron calc to absorb carbon dioxide from the air when the tank "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 ultraviolet light.

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 used for 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 into carbon acids and fall on lighter organic compounds with generation of CO<sub>2</sub> molecules and water H<sub>2</sub>O.

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

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

## Golfech, France

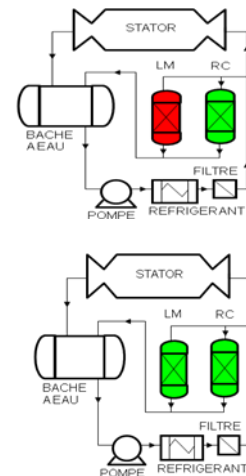
Mission Date; 10-27 Oct., 2016

On-line stator cooling system purification and cleaning

The Unit 1 stator cooling water system (GST) cools the stator bars using demineralised water in hollow copper conductors. Corrosion and blockage of these hollow conductors may decrease the stator cooling flow rate and increase generator stator temperature. International industry operating experience has shown that this has resulted in plant temporary 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 the need for adding chemicals.

1. Acidification : a cationic resin is used on its own.  $\text{Cu}^{2+}$  ions are retained and exchanged with  $\text{H}_3\text{O}^+$  ions, which decrease pH (acid pH). Acid pH makes the  $\text{CuO}$  copper oxides soluble.
2. Purification : a mixed-bed resin is used joint with the cationic resin in order to clean the stator cooling fluid.



## Golfech, France

Mission Date; 10-27 Oct., 2016

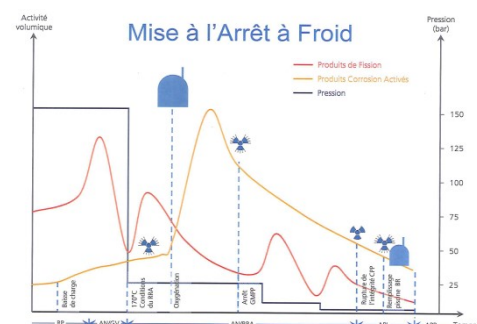
Comprehensive actions for controlling radiation source term during plant shutdown are effective in reducing work area dose rates.

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 ( $325^\circ\text{C}$ ) reducing ( $\text{H}_2$ ) 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 and radiochemical 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 optimize and 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 the environment



Results: The plant has one of the lowest operating source terms in the utility fleet and in the industry 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.

Anti-corrosion management program for equipment and buildings implemented during the project 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 has implemented this in the construction and commissioning phases as follows:

- Main processes included establishing documentation, reviewing design files, on site checking, corrective action and re-checking and closure of action from design to the commissioning period.
- Internal preservation inspection for the main thermal equipment in the primary and secondary 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 should the project be delayed or postponed

C5-M (corrosive category 5, very high marine - ISO 12944-2-1998) of corrosion environment in 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 identified based 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 as design, 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.

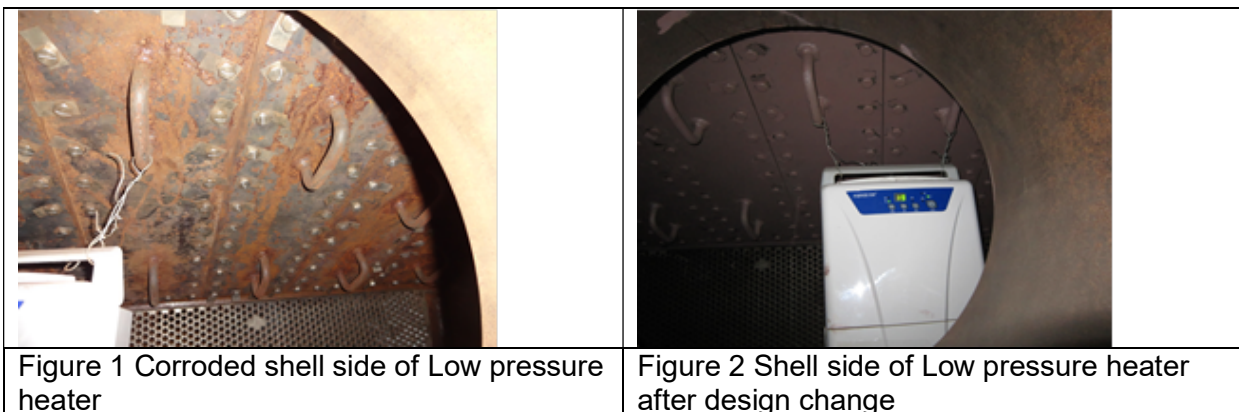


Figure 1 shows the shell side of low pressure heater as found in 2013. Specific internal

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, as shown in Figure 2.

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



## Bugey, France

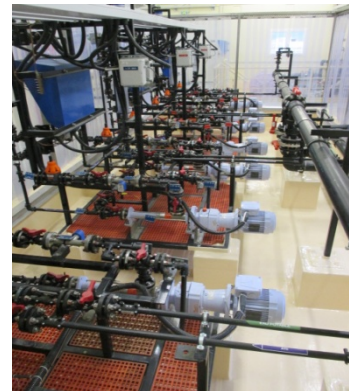
Mission Date; 2 -19 Oct., 2017

Circulation water system treatment for scale and sludge removal using an environmentally friendly 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 sludge deposits in the condenser and circulating water systems. The product used is organic, harmless for the environment and contains neither phosphate nor nitrogen.

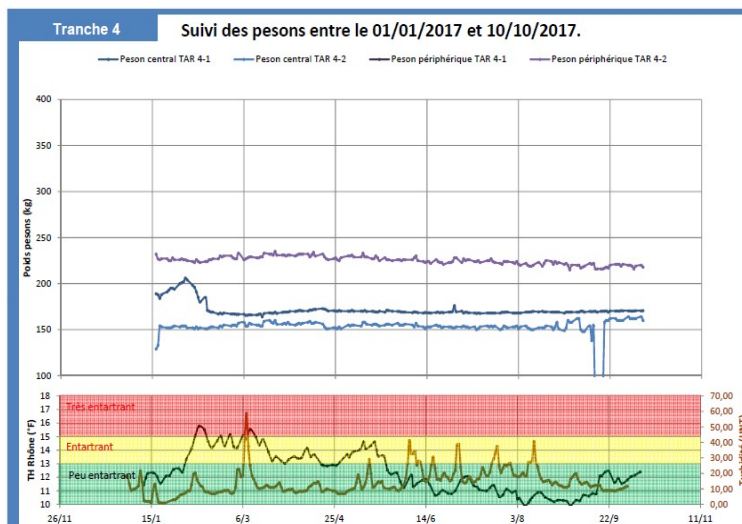


ATO injection pumps



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 gain since ATO injection.



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

A process totally devoid of environmental impact.