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Design chemistry implementation experience during the power unit start-up and commissioning

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Abstract

The article covers the results of the design chemistry implementation during the commissioning of the innovative Unit 1 at the Novovoronezh NPP II equipped with a VVER-1200 reactor. The design chemistry is composed of the requirements for the primary and secondary coolant quality, recirculating coolant water (including essential service water), solutions used in safety systems as well as the requirements for technological tools maintaining their quality. Water chemistry setup operations play a significant role at all the stages of commissioning and low power testing. An analysis is made of essential system reactivation and cleansing stages, preliminary treatment technologies, primary and secondary circuit chemical water treatment, and radioactive water treatment. Some design advantages are highlighted, such as the use of reverse osmosis as one of the stages of water treatment and high-pressure filters on the bypass blowdown cleanup system. Consideration is given to some problematic issues that arose in the course of the start-up operations during the equipment depreservation, radioactive drain water treatment and in the recycling water supply system. The authors also analyze the design flaws and issues that may arise during long-lasting operation and the ways to solve them: (1) to provide a reference technology and equipment for processing radioactive drain water; (2) to exclude flushing with chlorinated hydrocarbons from the technology for depreserving the TG internal surfaces; (3) to apply water treatment with inhibitors providing calcium transport with a value close to 100% to the circulating water supply system with a cooling tower or provide liming of all additional water for southern NPPs to minimize the carbonate index.

Keywords: Design chemistry; Water chemistry; Preliminary water treatment; Radioactive water treatment; Flushing; Passivation; Sedimentation; Chemical agents.

Introduction

The design chemistry for commissioning of NPP units with VVER-1200 reactors should include the requirements for the quality of coolants of the main process media:

– Primary coolant.
– Secondary working fluid.
– Circulation cooling water (including essential raw cooling water).
– Solutions used in safety systems,

as well as the requirements for technological tools maintaining their quality. Water chemistry setup operations play a significant role at all stages of commissioning and low power testing [1].

Setting up the main systems and equipment

As part of setting up the main systems and equipment, the equipment surfaces are cleaned of the preserving media (where available) and then flushed to the specified purity criteria.

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1. The purpose of flushing the reactor compartment systems is the final cleaning of the internal surfaces of the primary circuit equipment and pipelines and preparation for the formation of a protective oxide film. Flushing was carried out with chemically purified water (CPW).

Prior to the commissioning of the design water treatment facility (WTF) at the NPP-2, CPW from the operating NPP was used; for that end an underground pipeline was built to connect the WTFs of the operating and constructed NPPs. The decision to combine the WTFs of several power units of the Novovoronezh NPP made it possible not only to provide the unit under construction with chemically demineralized water of specified quality and in sufficient quantity, but also to increase the reliability of the CPW supply system for feeding the existing units.

The high quality of flushing of the reactor compartment systems was confirmed by the low content of impurities in the primary water during the circulation flushing and hot trial of the reactor facility.

During the hot trial, the primary circuit inner surfaces were passivated using a weakly alkaline solution of potassium hydroxide according to the design technology to form a uniform protective oxide film due to long-term interaction of the primary circuit inner surfaces with the alkaline reducing basis.

This technology was developed by the Institute for Nuclear Research and the Institute of Inorganic Chemistry of the Czech Republic and successfully implemented at Units 1 and 2 of the Mochovce NPP and Temelin NPP during the hot trial periods [2–4]. The operational results of the Temelin NPP power units during the subsequent fuel campaigns showed the lowest levels of concentration and activity of corrosion products in the coolant as well as comparatively moderate radiation fields during shutdown periods as compared to other operating VVER units. The average activity levels of typical corrosion products were even lower than those of impurity activation products and fission products. This fact is associated with an abnormally low transfer of corrosion products to the primary coolant due to the creation of a stable protective film on the primary circuit surface [5].

2. The procedure for flushing the secondary circuit equipment is intended for cleaning and washing corrosion products, corrosive-aggressive impurities (chlorides, fluorides), preservative residues and assembling contaminants from the internal surfaces, in-vessel devices and heat exchange surfaces of the steam generators.

Water flushing of the condensate-feed pipeline using chemically demineralized water without chemical agents showed its low efficiency as related to washing free from corrosion products, which negatively affected the operation of the condensate pumps when increasing load due to clogging the screens by corrosion products at their suction.

3. Depreservation of the internal turbine surfaces by means of design methylene chloride-based washings led to the situation when methylene chloride residues, as load increased, entered the steam generators, where they underwent high-temperature hydrolysis to form hydrochloric acid, which caused serious problems in cleaning the boiler water from impurities.

Depreservation of the internal turbine surfaces by means of design washings based on chlorine-containing hydrocarbons is unacceptable due to the lack of thorough cleaning of the depreserved surfaces from the washing residues.

Water treatment facility

According to the design, the water treatment process at the NvNPP II-1 consists of the following stages:

– Water pretreatment using ultrafiltration units.
– Mechanical filtration.
UV disinfection units.
– Reverse osmosis units.
– Counterflow ion-exchange filters (APKORE technology).
– Deep demineralization of water on mixed-bed filters with external regeneration.

The facility capacity for partially demineralized water for spray cooling ponds is 90 m^3/h and for chemically demineralized water is 165 m^3/h.

A fundamentally new solution was the application of a technology for cleaning the Don water from salt solutions using reverse osmosis as one of the stages of water treatment.

Five reverse-osmosis modules (Fig. 1) with a filtrate capacity of 80 m^3/h each provide purification of the Don water to the salt content corresponding to an electrical conductivity of 11 μS/cm; the initial water has an electrical conductivity of 400–550 μS/cm.

Preliminary cleaning of the treated water from dispersed impurities by coagulation with the use of aluminum sulfate (the coagulant was selected experimentally) followed by ultrafiltration makes it possible to reduce the slurry load on the reverse osmosis membranes to acceptable values, and the use of antiscalant eliminates clogging of the reverse osmosis membranes with calcite.

The main filtrate amount is directed to feed the spray ponds of the emergency raw cooling water system to ensure its nonscale forming water chemistry conditions.

To obtain chemically demineralized water of high quality, the filtrate after reverse osmosis undergoes post-treatment on ion-exchange filters according to the classical scheme: a cation-exchange filter—an anion-exchange filter—a mixed-bed filter.

The CPW thus obtained is used for filling and feeding in the turbine and reactor compartment systems. The quality of the CPW in terms of its salt content is close to the quality of theoretically pure water, and the total organic carbon content does not exceed 100 μg/dm^3, which is higher than that obtained without reverse osmosis.

The use of reverse osmosis technology to obtain CPW significantly reduces the use of chemical agents, which increases the environmental safety of CPW production by reducing discharges of highly mineralized waters formed as a result of the performance restoration of the ion-exchange filters [6–11].