Monitoring of Primary Circuit and Reactor of NPP A-1

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Nuclear Power Plant A-1 in Jaslovske Bohunice was commissioned in 1972. Heavy water moderated, carbon dioxide cooled channel type reactor was shut down after two accidents in 1977. During more serious second accident, the reduced coolant flow caused local overheating of the fuel and consequent damage/melting of the fuel channel. Both accidents had led to the damage of several fuel assemblies with extensive local damage of fuel claddings. As a consequence, the main cooling circuit was significantly contaminated by fission products and long-life alpha nuclides.

The work is described that has been carried out by the Consortium (AllDeco & Belgoprocess) for the Phare project EUROPEAID/116059/D/SV/SK.

The detailed monitoring of dose rates, smearable contamination and sampling of contamination was performed. Extended monitoring in reactor vessel, primary circuit pipes, turbo-compressors, steam generators, main valves, gas tanks and also heavy water system with collectors, coolers, distilling and purification station, pumps and valves was done. Appropriate devices and procedures for the monitoring and examination of the installations were prepared and applied.

Obtained results will serve for the future planning of the decontamination and decommissioning works.

1. Reactor monitoring

The following activities have been performed within the reactor monitoring:

- Video monitoring of the physical state of technological channels D-04, E-12, F-06, G-03, H-08 and L-12 to ascertain the presence of deposits on internal surface of technological channels
- Video monitoring of the physical state of the hot gas chamber to ascertain the existence of residues of the damaged fuel on the bottom of the hot gas chamber
- Measurement of the vertical distribution of dose rates in the selected technological channels
- Collection of samples of deposits from internal surface of the reactor vessel for chemical and radiochemical analyses (smears, scrapings etc.)
- Neutron dosimetry in the hot gas chamber in order to confirm presence of residues of the damaged fuel and collection of samples
- In situ confirmation of the presence, and determination of the contents of residues of media in the reactor vessel (carbon dioxide, heavy water, tritium, hydrogen) in gas state or indication of presence of liquid state (high concentration of tritium)

On the Fig. 1 it can be seen a drawing of the reactor and also radiation field levels derived from the measurements of dose rates in various channels. The 3-D model of the reactor that had been developed as part of this Project proved invaluable for orientation, visualisation, planning and analysis of results.

Dose rates were measured in the technological channels from the reactor hall floor to the bottom of the hot gas chamber in decrements of 1 m and 0.5 m. The highest absolute values of dose rates were found in channels located in the middle of the reactor (up to 1900 $mGy.h^{-1}$ in the active zone region).

The values obtained with bubble neutron dosimeters in the channels and hot gas chamber were below the sensitivity threshold of the devices, i.e. lower than 1 $\mu Gy.h^{-1}$. The results confirm that there are no significant neutron sources in the reactor.

Samples of radioactive aerosols were taken from the space above the reactor with technological channels open. This was done during the visual survey of the selected channels, inspection of the hot gas chamber and also during sample collection. A tent was made from a pipe structure covered with a polyethylene sheet and erected above the reactor. Measured values of the concentration of radioactive aerosols inside the tent were in the range between 3.04 and 11.05 $Bq.m^{-3}$. These values are relatively low, acceptable and comparable to the values that were obtained during other work in the reactor hall.

Tritium concentration was measured in selected channels by a slow calibrated suction of the air with controlled capture of tritium and subsequent measuring of tritium in a liquid scintillator. In the channel C-05 at the depth of -15 m, i.e. by the bottom of the avial vessel and above the existing channel plug, tritium activity was 267.5 $MBq.m^{-3}$. Over the channel H-08 in the hot gas chamber tritium activity was 245.3 $MBq.m^{-3}$. The obtained values of tritium activity are high and indicate the presence of heavy water in reactor deposits.

Measured humidity in the channels was higher than 90 %. Concentration of CO_2, which was measured at the same time as that of tritium, was at background level (0.1 % content of CO_2).

Concentration of hydrogen (up to 600 ppm) and oxygen (20.7 - 19.1 %) was measured in channels. The values of hydrogen concentration in the monitored gaseous substance are relatively high and are probably caused by radiolysis of water that is present in compounds and radioactive waste in the reactor.

The decrease in the concentration of oxygen in technological channels and hot gas chamber is proportional to the increase in hydrogen at the points where samples were taken. Presence of other simple organic gases (e.g. methane, NO_x, etc.) in the air mixture can also be assumed, given the established facts. The overall concentration of these gas products of radiolysis in the mixture is unlikely to exceed 2 % by mass.

TV inspection of channels, hot gas chamber and avial vessel was accomplished via channels H08, D04 and C05. Fig. 2 and Fig. 3 are typical pictures to illustrate the state and characteristics of radioactive waste in the reactor.

2. Primary circuit

When discussing the results of monitoring it is useful to further categorise this latter group of equipment according to the loop on which it is located, specifically whether the loop in question was in operation during the accident in 1977 (loops 1, 2, 3 and 6) or whether it was in outage (loops 4 and 5).

Internal surface of the equipment in loops 4 and 5 is covered by a compact thin layer of oxides (Fe_3O_4, Fe_2O_4 and Fe_2O_3). Specific gamma activity (Cs-137) is of the order of 200 to 300 $Bq.cm^{-2}$. Surface alpha activity of radionuclides (Am and Pu) reaches the level of about 1 % of gamma activity.

Dose rates in contact with, or in the vicinity of, equipment in loops 4 and 5 reach the level of single figures to tens of $\mu Gy.h^{-1}$. Radiation risk associated with any future decommissioning work is negligible.

Internal surface of equipment in loops 1, 2, 3 and 6 is covered by radionuclides, sediments and deposits that arrived from the reactor during the accident, some of them possibly shortly afterwards. Dose rates on the equipment reach tens to thousands of $\mu Gy.h^{-1}$. The significant differences in the range can be explained by the fact that the gas exited the reactor in two directions. At the time of the accident one side of the reactor was connected to loop 6 and the other to loops 1, 2 and 3. The damaged fuel element and the melted part of the vessel were situated on the loop 6 side of the reactor.

Partial decontamination of steam generators 3 and 4 was undertaken shortly after the accident, using water solutions. Turbo-compressor 1 was also decontaminated by blowing gas through it. Even though the operation was not very successful (decontamination factor $\leq$ 2-3) some reduction in contamination level was achieved.

It is estimated that the total contaminated area of primary circuit equipment (pipework, steam generators and turbo-compressors) is some 48 000 m^2. It follows that the total gamma contamination is of the order of 10^{14} to 10^{15} Bq and total alpha contamination 10^{11} to 10^{13} Bq. The total amount of deposits in the gas circuit is about 14.3 tons.

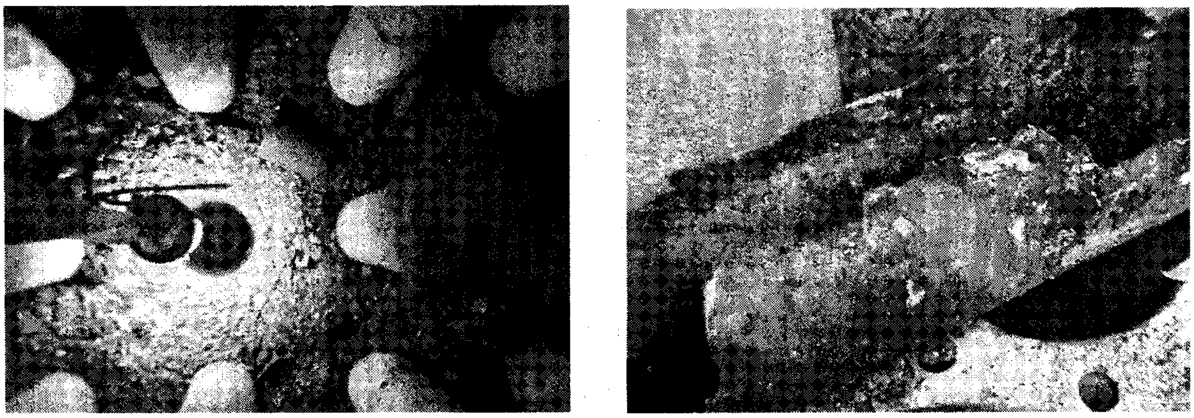

Figure 2: State of the reactor equipment recorded via the technological channel C-05 at the level -12 m showing pipe fragments and deposits at the bottom of the avial vessel

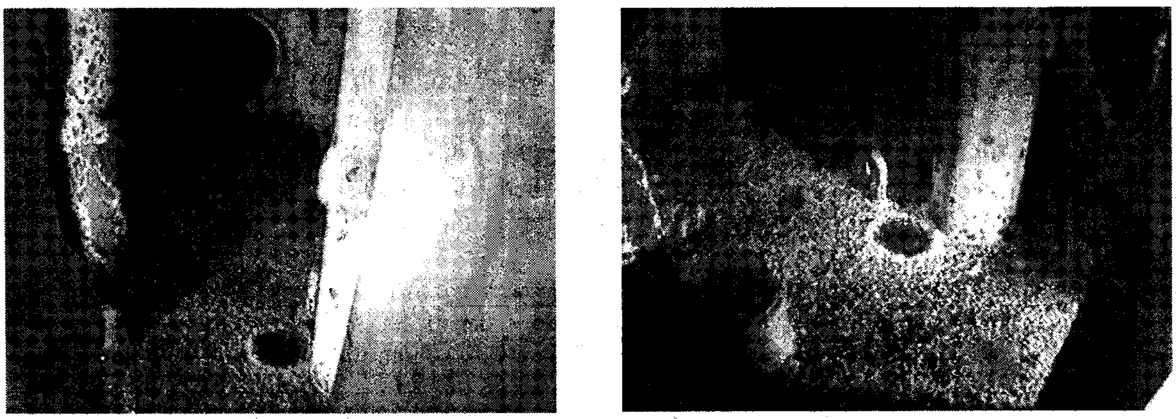

Figure 3: Typical look of sediments and deposits on the pipes and at the bottom of the hot gas chamber in the reactor

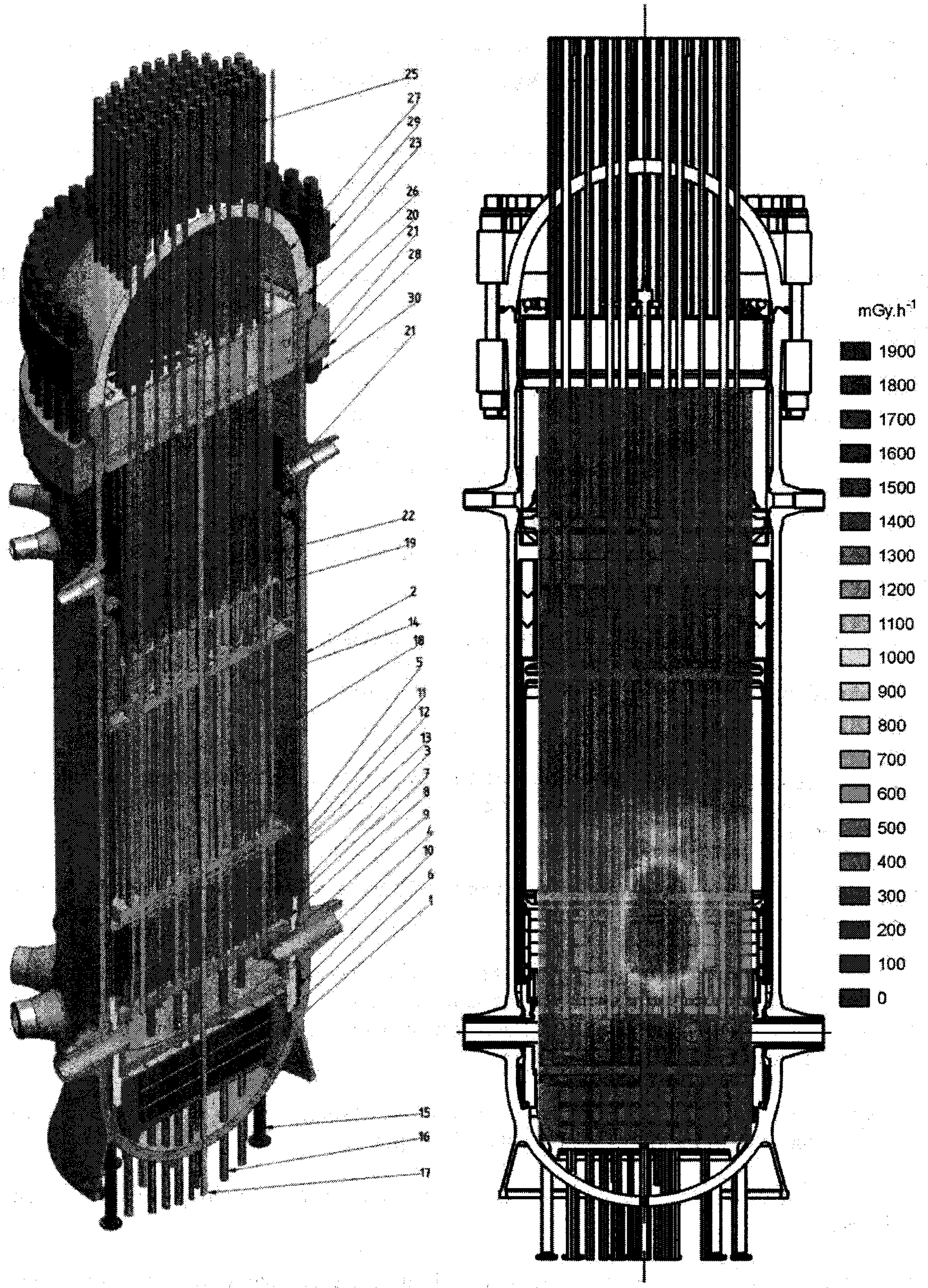

Figure 1: Schematic diagram of the reactor and radiation field intensities