ABSTRACT

One of the main activities to be undertaken by CNEA will be to provide technological assistance to NASA in problems concerning NPP operation. Works on life extensions of NPP are included in these activities.

To fulfill these requirements the Atomic Energy National Commission (CNEA) has constituted a technical committee for Nuclear Power Plants Support (CAPCEN).

CAPCEN should be the knowledge reservoir of those issues concerning the performance, safety and life extension of Nuclear Power Plants.

One of CAPCEN's most important activities is to promote research work connected with such issues.

The main technical areas are: Pressure Vessel and Piping, Heat Exchangers and Fuel Channels and Reactor Inner Components.

Efforts are focused on the identification of the main components susceptible of ageing, the study of their ageing mechanisms, the follow-up of their behaviour during operation, and the measures taken to extend their life.

1. INTRODUCTION

Since September 1994 the organisation of the Argentine nuclear activities, confirmed in April 1997, is the following:

- "Nucleoelectrica Argentina Sociedad Anónima" (NASA), which operates the two NPP (Atucha 1 and Embalse).

- "Autoridad Regulatoria Nuclear" (ARN)- National Regulatory Board of Nuclear Activities.
Within this scheme, one of the main activities to be undertaken by CNEA will be to provide technological assistance to NASA in problems concerning NPP operation. Works on life extension of NPP are included in these activities.

To fulfill these requirements the Atomic Energy National Commission (CNEA) has constituted a technical committee for Nuclear Power Plants Support (CAPCEN).

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The main technical areas are: Pressure Vessel and Piping, Heat Exchangers and Fuel Channels and Reactor Inner Components.

Pressure Vessel and Piping: at this first stage the main objective is to reduce the uncertainty with respect to the results obtained so far in the Atucha 1 pressure vessel Surveillance Programme. Such uncertainty is due to the different irradiation conditions received by the vessel walls, and that received by the specimens integrating the Surveillance Programme. The aim of this activity is to carry out studies and provide the necessary guidance concerning the pressure vessel integrity. If necessary, a life extension programme based on the above objective will be carried out.

Steam Generators and Heat Exchangers: the main objective is support for operating stations as well as for inspection and life prediction. The main activities are monitoring of cooling system chemistry, and studies of feasibility of cleaning of equipment during programmed outages. This project also includes the study and resolution of problems concerning steam generators and moderator circuit heat exchangers.

Fuel Channels and Core Internals: the aim of this activity is to perform studies in order to provide advice and guidance directed to the optimum behaviour of the reactors' internal components. At this stage the main objective is to increase the knowledge of in-service behaviour of fuel channels and other core internals of Atucha I and Embalse Nuclear Plants.

2. PRESSURE VESSEL AND PIPING

In order to monitor the Atucha 1 RPV radiation embrittlement, as a key parameter in NPP life management, a Surveillance Program is being carried out. Due to the special RPV design, surveillance capsules, containing radiation and temperature monitors, Charpy impact, fracture mechanics and tensile specimens cannot be placed as usual in the LWRs, close to the RPV inner wall. Instead the Atucha 1 capsules are placed at the bottom of the coolant channels with negative consequences regarding leading factor, irradiation flux and spectrum. Consequently, two actions were taken:
1 - Ex-vessel dosimetry was implemented: placement and removal of neutron dosimeters at the outer wall of pressure vessel was done during the programmed outages [1]. A schematic drawing of the reactor cavity, indicating the location of the neutron dosimeters, is shown in Fig. 1. All capsules-holders were placed at the same mid-core level at three different azimuthal positions. Each capsule contained 6 neutron dosimeters, i.e. Co/Al, Ti, Fe, Nb, Cu, Ag, wrapped into a batch with an aluminium foil holder. In total 36 monitors were furnished by the surveillance programme. A new dosimetry is being implemented to confirm the results obtained.

2 - Tests of samples of the reference materials irradiated at the same place of the surveillance ones are being performed. In 1980, SET-3 containing 10 capsules with specimens of IAEA reference steel 20 MnMoNi 5 5 (IAEA Code JF) including Charpy, was installed at CNA-1. The surveillance programme foresees the outages of SET-3 in 1995. From the analysis of the results of SET-1, SET-2 and VAK, together with those further expected to be found after the outage of SET-3 and the evaluation of the IAEA-specimens irradiated at Atucha 1, an experimental correction function for spectral differences may be derived.

3. STEAM GENERATORS AND HEAT EXCHANGERS

Steam generators are among the other key components of the NPPs that can lead to a derating of the station due to a reduction of the heat transfer capability. There are also some heat exchangers in the Argentine stations which, because of the particular plant design, are relevant to the proper operation, safety and economy [2,3]. Then they have to be considered key components and included in the scope of the present programme.

The strategy adopted for the surveillance of steam generators and heat exchangers in Argentina by the Technical Committee in Support of Nuclear Power Plants is based on the following four aspects:

1 - The performance, in regard to the heat exchange capability, has to be set up on the accuracy of the calculation of the power exchanged by the equipment. This is done through accurate measurements of the variables involved, temperature, flow rates and pressure drops. Then the magnitudes obtained are verified by cross-checking balances and represented in a way that at a first sight they depict the current performance. A thorough comprehension of the behaviour of each critical component was stated in our programme of surveillance. Steam generators and some heat exchangers must be considered as unique, and they should be used to foresee not only the effects of fouling but also failures in the instrumentation and/or corrections in the chemistry control.

2 - As it was stated in the item 1, it has been noticed that in an ageing station some modifications can be introduced into the chemistry in response to several reasons of which some examples follow:
   i) If copper alloys were removed, then the secondary side chemistry could be shifted to high AVT with the benefits in the reduction of the iron transport and the balance of plant.
   ii) More stringent specifications for the elimination of potentially damaging species have been introduced along the years and/or new oxygen scavengers concentration and alkaline agents are currently in use.
iii) More sensitive devices together with data acquisition and predictive software are available. Their implementation in the plants is expected.

3 - Non-destructive tests, as well as those performed on tubes pulled out from steam generators and heat exchangers are, despite the cost and effort they represent, a source of invaluable data to prevent corrosion problems. They also provide a direct idea of magnitude and composition of the deposits and the presence of unexpected species in them. In addition, an extensive program of corrosion surveillance on alloy samples located in online autoclaves provide information on corrosion, corrosion products transport and activity transport.

4 - Finally, we consider that the advances on modelling and the power offered by nowadays computer three-dimensional codes that simulate the equipment's behaviour are useful. In connection to them, validation of the results is performed by new devices. A good example are ultrasonic flowmeters for the detection of deviations in the downcomer flow rate.

4. FUEL CHANNELS AND CORE INTERNALS

This area is dedicated to the surveillance of fuel channels and core internals behaviour, optimisation of their performance, and planning of repair and replacement of these components. The Technical Committee also supports R&D work related to these activities, mainly in the fields of deformation under irradiation, corrosion and hydriding, fracture mechanics and non-destructive testing. We shall describe separately the activities concerning both operating Argentine NPPs, Embalse and Atucha 1.

4.1 EMBALSE NUCLEAR POWER PLANT

Embalse is a CANDU 600 PHWR, started in 1983. As it has been done with other CANDU reactors, the operator is presently performing during yearly programmed outages, the repositioning of garter springs that prevent the contact between pressure tubes and calandria tubes. This contact could lead to the failure of the pressure tube through the "delayed hydride cracking" (DHC) mechanism. The pressure tubes are made of cold-worked zirconium-2.5% niobium alloy (CW Zr-2.5%Nb), while the calandria tubes are made of Zircaloy-2. CNEA participates regularly in the repositioning activities in the following areas:
- Pre- and post-repositioning inspection of the fuel channels through non-destructive ultrasonic testing.
- Analysis of fuel channel deformation through the specially developed MACACO code.
- Fracture mechanics assessment of pressure tubes during the repositioning.

Moreover, CNEA has participated in the planning of strategies of pressure tube life evaluation. As it is known, the fitness for service of operating pressure tubes depends on the fulfillment of the "leak before break" criterion, that guarantees that any leaking crack in a tube will be detected before it reaches the critical size. The properties of the pressure tube suffer degradation during operation through corrosion and hydrogen (deuterium) uptake, irradiation embrittlement and irradiation creep and growth.

In Embalse, two pressure tubes, those placed in the A-14 and L-12 lattice positions, were replaced in 1995. Our Technical Committee has prepared a programme for the
evaluation of the condition of these pressure tubes. This programme includes the following activities:

- **Visual inspection.**
- **Metallographic evaluation** (oxide thickness, hydride distribution).
- **Measurement of hydrogen isotope concentration.**
- **Measurement of in-service deformation.**
- **Testing of tensile and fracture properties.**
- **Determination of delayed hydride cracking velocity.**

Hydrogen concentration measurements have already been carried out and the results are being used by NASA to support the repositioning strategies. Other tasks are to be performed in the next future in hot cell facilities at CNEA's Centro Atomico Ezeiza. The main objective of this programme is to fulfill the requirements of the new Canadian Standard, "Periodic Inspection of CANDU Nuclear Power Plant Components", CAN/CSA-N285.4-94 related to replaced fuel channels.

### 4.2 ATUCHA I NUCLEAR POWER PLANT

Atucha I is a pressure vessel-type PHWR, started in 1974. Inside the pressure vessel there is a moderator tank, filled with heavy water, across which 253 vertical coolant channels are placed, as well as control rod and instrumentation lance guide tubes. The fuel elements are placed inside the coolant channels, through which the coolant heavy water flows. The coolant channels are made of Zircaloy-4 and they have two foils, also made of Zircaloy, which act as a thermal insulator between the coolant and the moderator.

The coolant channels and the other core internals suffer several types of degradation during operation: oxidation and hydrogen (deuterium) absorption; irradiation (and hydrogen) embrittlement, and irradiation creep and growth. The oxidation rate of the coolant channels has shown signs of acceleration (breakaway) after 10 full power years, and consequently the deuterium uptake rate has also reached very high values. This phenomenon has led to embrittlement and loss of integrity of the thin insulating coolant channel foils. The irradiation growth of the coolant channels has also shown a breakaway behaviour. As a consequence, the decision to replace the coolant channels was taken some years ago. The replacement was initiated in 1990 and continued in the following years during the programmed plant shutdowns, and it will be completed next year.

The coolant channel replacement strategy and other core internals life management activities were planned when CNEA owned the plant, before August 1994. Presently, our Technical Committee participates in the inspections of the state of the core internals, and frequently issues recommendations about remedial actions.

### 4.3 RESEARCH AND DEVELOPMENT ACTIVITIES

In addition to the described activities, directly related to the technical support for both power plants operation and life management, our Technical Committee collaborates actively in the following R&D areas:

* Changes of mechanical properties under irradiation
* Enhanced irradiation growth
* Post-irradiation inspection of components
* Phase transformations and microstructure of zirconium alloys
* Diffusion at interfaces in Zr-Nb alloys
* Mossbauer spectroscopy
* Zr oxides:
  - in single crystals and alloys
  - precipitates type Zr(CrFe)_2 in the oxide
* Corrosion and hydriding; hydrogen effects on performance; hydrogen embrittlement
* Zirconium hydride blister measurements
* Oxide cover: depth, properties and measurements
* Hydrogen and deuterium content measurement by neutron diffraction
* Fracture and Delayed Hydride Cracking of Zr alloys
* Texture and residual stresses.

5. LIFE MANAGEMENT PROGRAMME

In the past, NPP life management in Argentina was mainly based on the corrective maintenance concept based on the replacement of damaged parts detected during the periodical outages [4]. In recent times, as a consequence of an increasing concern about ageing and life extension, a Programme was created to take care of these subjects.

The Programme (Fig. 2), now in its first steps, comprises several tasks: The first task involves the identification of components, ageing mechanisms and materials likely to age. In this area we are starting with a matrix involving major components (Fig. 3) as Reactor Pressure Vessel, Reactor Internals, Steam Generators, Pressure Tubes, Piping, etc.

6. CONCLUSIONS

As Argentine Nuclear Power Plants are getting older, specially Atucha I with twenty-four years of operation by now, life management programmes are becoming increasingly important.

Efforts are focused on the identification of the main components susceptible of ageing, the study of their ageing mechanisms, the follow-up of their behaviour during operation, and the measures taken to extend their life.
REFERENCES


FIG. 1
NPP COMPONENTS

DATA BASE
- Plant Records
- Mater.Properties
- P8I/ISI
- Internal.Data

SELECTION

AGEING MECHANISMS
SAFETY ANALYSIS

Critical

Non Critical

Monitoring
R & D

Residual Life ?

NO

UNSAFE
- SHUT DOWN

YES

Mitigation
- Repair
- Replace

TARGET LIFE

APPROACH TO NPP LIFE MANAGEMENT

FIG. 2
1 Reactor
2 Steam generator
3 Main coolant pump
4 Moderator cooler
5 Pressurizer
6 Moderator pump
7 Coolant channel
8 Moderator
9 Control rods
10 Main coolant loop (D2O)
11 Moderator loop (D2O)
12 Feedwater
13 Live steam loop H2O