Commissioning and Start-Up of RA-8 Critical Assembly

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Abstract

The RA-8 critical assembly was designed as one of the experimental facilities for the CAREM Reactor Project. This paper describes the activities developed during the cold and hot commissioning, pointing out the difficulties and the solutions applied (some of them original ones). Moreover, this paper will show the main features of the newest nuclear installation of CNEA making a brief description of its characteristics.

Among the special circumstances related to the commissioning that are described in the paper we can mention the following:

1. The facility shares the building with the Thermohydraulic Assay Laboratory (L.E.T.), another experimental facility of CAREM, and thus some shared systems have already been working for many years before this start up. Special procedures for these systems were designed to verify the proper functioning under the new requirements.
2. A new driving mechanism, based in hydraulic cylinders, was used to move the control rods. The criteria for acceptance and a validation of the procedure completeness have been carried out.
3. The implementation of a power measurement system based in neutron noise.
4. Measurement of Power Distribution using direct gamma counting from the fuel elements.
5. The commissioning was interrupted for a ten-month period because the personnel involved had to carry out the commissioning of the Egyptian Research Reactor 2.

Also, the common activities during a commissioning are described, pointing out the major steps carried out and the results obtained. The following are examples of these activities:

1. Environmental dose survey (before fuel loading and during other stages).
2. Test of equipment and systems isolated from the rest of the plant.
3. Integrated system test (two or more systems working at the same time).
4. Start-up and power operation simulations before fuel loading.
5. Fuel loading strategy during the approximation to criticality by mass.
6. Modification of systems' components to improve the performance of the installation (e.g. hydraulic system pressure, control rod's length, nuclear instrumentation, core grid, etc). In the paper, the reasons to perform the modification and the results obtained are described.

This paper shows how these particularities and other tasks made the RA-8 commissioning very hard and had required very high skills in the crew involved (CNEA-INVAP) to succeed. The lessons learned have been recorded and we hope they will be useful in the design stage of facilities of this kind or more complex.

Finally, criticality was achieved on July 16, 1997 at 9:00 PM with a core configuration of 1300 rods (fuel elements), configuration very close to the calculated value of 1320.

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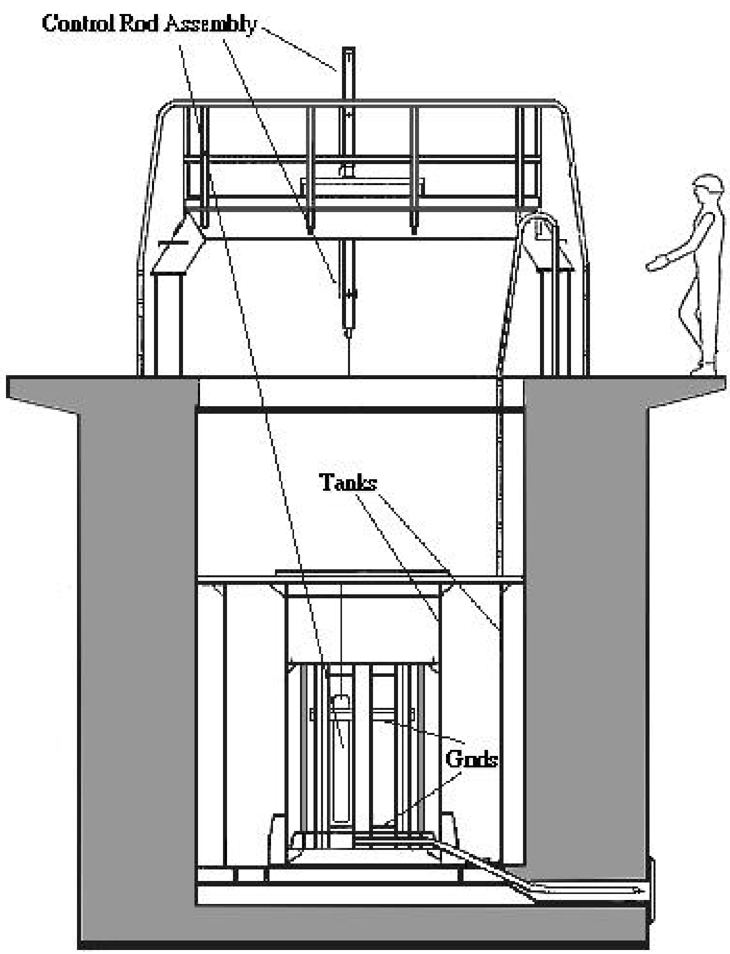
Facility Description

RA-8 is a critical assembly fueled with enriched uranium (1.8%) and moderated with light water. It is located in Pilcaniyeu Technological Research Centre at 60 km from San Carlos de Bariloche city, Rio Negro, Argentina.

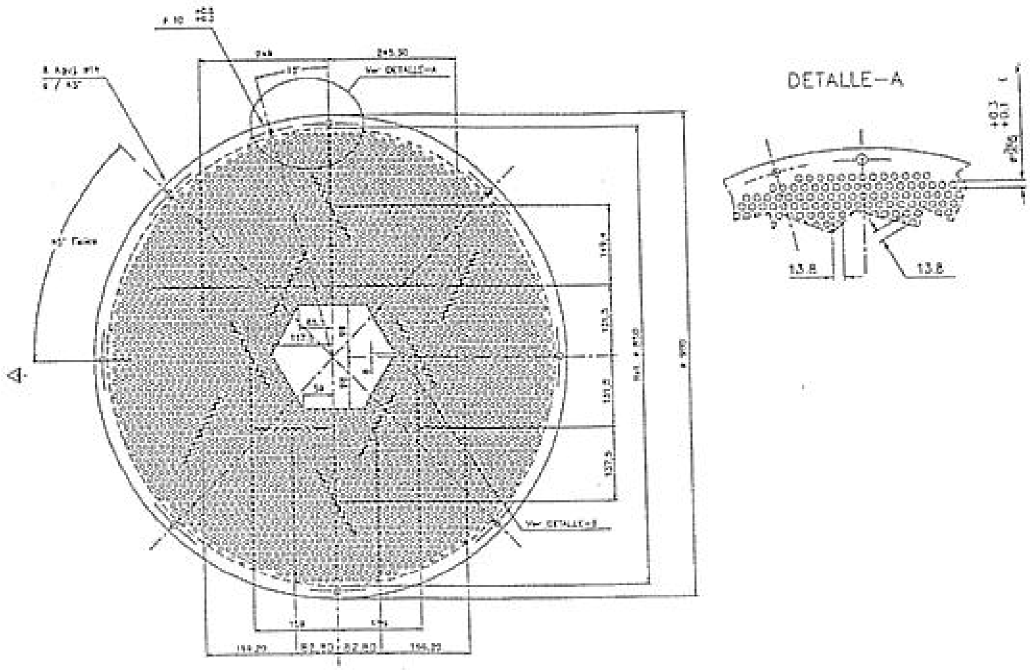
The pools, shields, core grids and associated systems are located inside an appropriate building (the Reactor's Hall). The core is an assembly of fuel elements that are located within two grids inside two coaxial tanks surrounded by a heavy concrete shield. The mechanism bridge, which can house up to 13 control rod driver mechanisms, is located over the grids. Bellow the tanks, there is a pool where the moderator is located during shutdown. This pool receives the moderator after its drainage through two 12" flapper valves (second shutdown system) located in the bottom of tanks.

The moderator can be moved to/from the reactor pool using a couple of pumps (for low and intermediate flow rates), one electrovalve and the two mentioned flapper valves.

The pool is an arrangement of two coaxial tanks communicated at the bottom in order to have the same level in both during the operation and leaving the possibility to drain first the internal one through the flapper valves.



The present grids allow configurations up to 3500 fuel elements in an hexagonal geometry. Also serve as support for neutron detectors and thermocouples to measure the moderator temperature. The grids can be easily replaced by new ones changing, for example, geometry and pitch and keeping the other components unaltered.



REACTIVITY CONTROL

There are two operation modes:

- OMB: in which the reactivity is changed moving the control rods.
- OAM: in which the reactivity is controlled varying the level of the moderator inside the pool.

In OMB mode the core is covered with water whilst the control rods are in their lowest position. After that, the selected safety rods are withdrawn from the core followed by the compensation rods moving one at time.

In OAM mode the control rods are withdraw keeping the flapper valves open (and the pool empty). Once they reach the upper level, the flapper valves are closed and the moderator is pumped at intermediate rate until certain interlock level, continuing the addition with a low flow rate pump. The level of water is controlled, in this operation mode, using the low flow pump and the electrovalve.
The safety logic triggers two different scram options, one by the fast dropping of the control rods and the other by opening the flapper valves.

MAIN CHARACTERISTICS

The nuclear instrumentation has three low counting range (start up) channels based in He^3 detectors and three high range (power range) supported in CIC (compensated ionization chambers), all connected to the interlocking and safety logics. A fourth CIC will be implemented to be used as power reference.

There are fixed Geiger-Müller detectors to supervise the radiation dose in several areas of the facility, some of them have local warning alarms. This system is complemented by portable detectors to determine gamma and neutron dose rate in special circumstances (experiments, fuel unload, etc). To check contamination a suitable detector is located in the exit of the Reactor Hall and can be moved to a suspected area to perform a surface surveillance.

Experiments can be performed by poisoning the moderator with different boron concentrations and heating it up using electrical heaters up to 70 ºC.

The control room is located outside the Reactor Hall and has a computer based data acquisition and display system to monitor the operational status and follow up the evolution of different parameters. Hardware instruments are also available to operators and allow the full control of the facility.

Commissioning

Special circumstances appear during the RA-8 cold and hot commissioning. These are described below together with normal commissioning activities developed.

SHARED COMPONENTS COMMISIONED PREVIOUSLY
The facility shares the building with the Thermohydraulic Assay Laboratory (L.E.T.), another experimental facility of CAREM, and thus some shared systems have been working for many years before this start up. Special procedures for these systems were designed to verify the proper functioning under the new requirements. In these procedures new requirements and set up values have been introduced, remarking these changes to the operators that were familiar with the pervious systems status.

Examples are the crane-bridge and the water treatment plant. In the first case, the bridge had been working several years moving heavy components, but during the commissioning the main requirement was precision to locate components (central section of core grid). For this reason the speed of motion and the travel length produced by every pressed button had to be decreased to accomplish new goals. Additionally the button command was replaced to obtain more confidence in the response.

The water treatment plant was upgraded because the reactor has different requirements than the LET, specially in the control of turbidity and algae. Carbon, very fine filters and UV lamps had been added to the system to accomplish the new requirements.

NEW DRIVING MECHANISM DESIGN
A new driving mechanism, based in hydraulic cylinders, was used to move the control rods. The previous experience of commissioning staff was related with mechanical assemblies powered by step-motors, obviously the acceptance criteria are different. For the new system, the most important parameters were:

1. up-direction speed: not greater than a certain value (fixed by reactivity considerations). Independent of the numbers of rods moving at the same time. Constant during all the travel length.
2. down direction speed: almost equal to up-direction speed. Constant during all the travel length.
3. minimum step in up direction: fixed by reactivity considerations.
4. positional stability: maximum change in position over the time (to prevent constant corrections). Capability to retain “upper or lower limit” indication.

The staff also performed neutron activation test of hydraulic fluid in order to determine the kind of radionuclide that can be produced by a big leakage over the fuel elements.

POWER CALIBRATION USING NEUTRON NOISE TECHNIQUES
Special devices with very narrow ionization chambers have been mounted between the core grids to measure the power (lower that 1 W) using a noise amplifier. Three of these chambers were located in positions surrounding the fuel elements at one half of active length. A correlation between their readings allows the physics group to determine neutronic parameters which resulted to be close to the calculated ones. The first point measured at low power and the others obtained in the “start-up range” during the power raise stage were used to calibrate the reactor’s nuclear instrumentation for power level and confirm the trigger value of this range.

DIRECT GAMMA COUNTING TO POWER DISTRUBUTION DETERMINATIONS
The power distribution (one of the first experimental activities developed) was done measuring the gamma field produced by small portions of selected fuel elements.

Using a collimator, a detector and a multichannel analyzer, the physics group made a follow-up of the gamma activity of various fission products as a function of post-irradiation time. In this way they selected an “energy window” suitable to determine the energy produced by a portion of a fuel element after being irradiated[1] and measure, mapping the axial and radial power distribution.

MIXED COMMISSIONING ACTIVITIES.

The commissioning was interrupted for a ten-month period because the personnel involved had to carry out the commissioning of the Egyptian Research Reactor 2. Regarding the fact that both installations are totally different (a critical assembly on one side and a 22 MW reactor on the other), the staff had to overcome such problems as:

1. different languages
2. different instrumentation, “logics” and system performance
3. relevant parameters to be supervised and different set-up values

ENVIRONMENTAL DOSE SURVEY

Before the arrival of fuel elements to the site, a radiological survey was performed. A check that values didn’t change outside the reactor building after the fuel arrival was also performed with identical results. At that time a specific procedure to establish fixed monitoring points, sampling and measuring of soil, air and water was developed in order to systematize the collection of samples. This procedure was repeated at different power levels demonstrating that the impact in the environment was negligible.

During the hot commissioning the dose in normal operation places was measured in order to check the proper working conditions in the facility. Normal values, coincident with readings from fixed area monitors were found.

EQUIPMENT AND SYSTEM TEST

The plant equipment was tested individually checking their capability to carry out the functions they were designed for. The interrelation with the LET systems was checked for every equipment, mainly taking into account the electronic noise produced by the electrical heather power supply.

Certain equipment was modified to take into consideration the recommendations of the Ad-Hoc Committee (a group of experts designated to supervise the commissioning). One example was the fire fighting system in which we introduced warnings of low and high levels in the water reservoir. Other systems tested were:

1. Loading/unloading of the moderator
2. Neutron source driving mechanism and positioning.
3. Control rod driving mechanism and hydraulic pressure supply
4. Nuclear and conventional instrumentation.
5. Safety and interlocking logics.

INTEGRATION TEST

After the individual test an integrated analysis was carried out with several system working at the same time.

The main problems solved during this stage were the electrical noise produced by different equipment (for example moderator pumps) on the neutronic channels. The general solution was to introduce filters in different “modules” or to improve the isolation (and grounding) of equipment.

START UP AND POWER SIMULATIONS

Previous to fuel loading, simulations of both operation modes were performed using pulse and current generators to provide “counting” to start-up and power channels. Small problems appeared mainly due to “early failures” in different modules. The weight of the control rods was simulated using a lead counterweight.

FUEL LOADING STRATEGY

The first elements loaded in the core allow the staff to assemble the control rods, which need to have two rows of fuel elements surrounding each one to prevent contact with the grid. Once the seven control rods were assembled, a dropping time test was performed to set up proper values to the rod stoppers.
After this stage, the first configuration was assembled in such a way as to allow a direct view of the fuel element’s position. Further addition of fuel elements was done using a TV camera to check the right positioning in both grids.

Another important factor taken into consideration for the addition of fuel elements during the approximation to criticality was the relative position of the neutron source and the detectors. More fuel elements increase the size of the core and then the detectors must be farther away changing their efficiency. The chosen strategy was to keep one detector fixed (close to the calculated critical radius) and use it to rescale the others that move with the increase of core's size.

The approximation to criticality was made operating the RA-8 in OMB mode and increasing the amount of fuel elements (keeping always the cylindrical geometry) in agreement with the extrapolation of "1/n versus # of fuel elements curve". In every configuration a "1/n versus position of control rod" was measured.

Finally the RA-8 went critical by first time the July 16th, 1997 at 21:00 hrs. with a core configuration containing 1300 fuel rods (close to the previously calculated value).
The next stage (power increase) 20 more fuel elements were loaded keeping the cylindrical geometry. With this configuration the neutronic parameters were measure to check the compliance with the limits specified by the National Regulatory Authority.

SYSTEMS MODIFICATION
After the first stage was finished, modifications were introduced to the reactor to solve small problems or increase its capability.

System or equipment	Purpose
Start up and power neutronic chains	Increase the noise rejection. Tidy-up
Control rods enlarging arms	Cropped to allow better positioning.
Central section of grid	Small changes to ease the insertion/extraction maneuver.
Pool water chemical control	Keep the water quality for longer time

SECOND STAGE OF COMMISSIONING.

After the modifications were carried out, the staff had to perform again several procedures to test the effectiveness of these changes and the proper functioning of all the systems.

The OAM operation mode was tested and used to commission the experimental procedure to be used during the first irradiation. The core configuration chosen was a cylindrical array of 1300 fuel elements which had (after the modification in control rod) enough reactivity to allow the operation at 1 W. During this stage, the National Regulatory Authority allowed and supervised the power increase up to 10 W.

Conclusions

After the success in the previously mentioned commissioning tasks, criticality was achieved on July 16th, 1997 at 9:00 PM with a core configuration of 1300 rods (fuel elements), configuration very close to the calculated value of 1320.

The first irradiations made in the commissioning stage also were used to test the capability to perform experiments, for example determine the power distribution measuring gamma activity from the fuel rods. The RA-8 has shown that it is a flexible installation that allows the execution of a broad range of experiments and its applications can be greatly improved with small changes.

Available instrumentation and data acquisition system are interesting points for the researchers to carry out new kind of experiments.

The possibility to perform experiments to demonstrate basic neutronic principles, make the RA-8 an interesting option to be used for training and teaching. As an example, the RA-8 was used for the "Workshop of Electronics in Research Reactors" sponsored by IAEA during 1998.

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[1] Desarrollo y puesta en operación de un sistema experimento-cálculo para determinaciones de Distribución de potencia en el RA-8, Daniel Hergenreder, Instituto Balseiro, julio 1999.