RECOMMISSIONING TEST RESULTS OF THE IAN-R1 TRIGA REACTOR

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ABSTRACT

This paper presents the results of the experiments carried out during the re-activation of the IAN-R1 TRIGA Reactor in Bogotá in 2005. The objective of this mission was to participate in the Ad-hoc committee established by INGEOMINAS to follow the recommissioning of the reactor IAN-R1, reviewing the operational procedures, results and records, and assisting the Colombian staff in the safe operation of the reactor. The recommissioning of the reactor IAN-R1 was well performed in safety conditions. The neutronic and thermal-hydraulic parameters obtained in the recommissioning program were close to those found by General Atomics in the tests conducted in 1997.

1. INTRODUCTION

The objective of this mission was to participate in the Ad-hoc committee established by INGEOMINAS in order to follow the recommissioning of the IAN-R1 TRIGA reactor. To provide expert advice on the procedures and results of the approach to criticality, rod calibration, excess reactivity and shutdown margin [1].

The IAN-R1 research reactor in Colombia was initially fueled with MTR-HEU enriched to 93 % U-235, operating since 1965 at 10 kW, and its power was upgraded to 30 kW in 1980. General Atomics achieved in 1997 the conversion of HEU fuel to LEU fuel TRIGA type, and upgraded the reactor power to 100 kW [2, 3]. The reactor was brought into an extended shutdown condition in 1998 after the core conversion that included the commissioning conducted by the supplier “with very limited participation of local experts and limited supporting documentation” [1]. So, it was necessary the development of a recommissioning program that should repeat the results of the commissioning tests conducted in 1997 [4].

The Colombian Institute of Geology and Mineralogy – INGEOMINAS of the Ministry of Mine and Energy incorporated the IAN-R1 research reactor. The operating organization, implemented maintenance and limited periodical tests that allowed the preservation of the reactor systems, with modified operational limits and conditions.

2. THE IAN-R1 REACTOR

The reactor IAN-R1 is a swimming pool type with concrete shield and two beamports. The fuel (U-$ZrH_{1.6}$) is contained in 4-rod clusters. The core configuration is a rectangular grid plate that holds a combination of 4-rod and 3-rod clusters. The 3-rod clusters provide a fourth cluster space to be used either for in-core irradiation or control rod locations. The core contains 50 fuel rods, 3 control rods and 3 in-core water filled experimental locations. The maximum core power level is 100 kW corresponding to a thermal neutron flux level varying from 1.9 x 10^{12} to 4.2 x 10^{12} n/cm^2.s, depending on the core locations. Figure 1 presents the top view of the core. The assembly is located inside an open tank full of light water which acts as biological shielding, partial neutron moderation and core coolant. The reactor core is cooled by natural circulation. The tank water is cooled by the primary and secondary systems.

3. CORE LOADING

The two clusters (8 fuels rods) removed from the core in 1998, in order to guarantee that the system was subcritical, were replaced. Figure 2 shows the core without the two clusters. Since the reactor critical condition was known (equal that one obtained in 1997), the approach to criticality was simplified. All loading steps were proceeded with the three control rods inserted. The reactor was operated at 100 watts, continuously, for one hour.

Figure 1. Schematic top view of the IAN-R1 core.

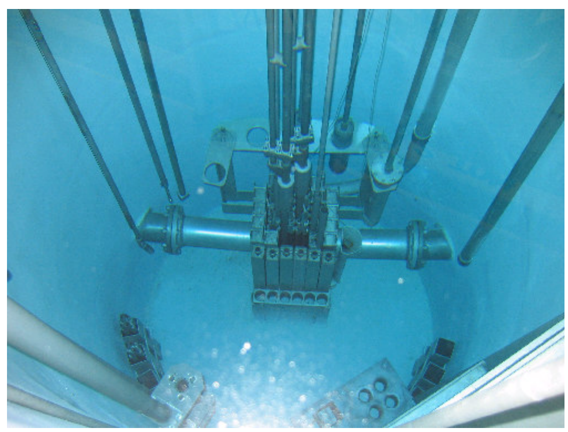

Figure 2. IAN-R1 reactor core without the two clusters.

4. TESTS PERFORMED AFTER REACHING CRITICALITY

4.1. Control Rod Calibration

All three-control rods were calibrated by the positive period method. The method consists of withdrawing the control rod from a known critical position through a small distance. Each successive step is compensated by lowering the other control rod just enough to reestablish criticality. In this process the control rod under calibration proceeds from the most inserted position (maintaining the reactor critical) to fully removed.

The Shim 1 and Shim 2 rods were intercalibrated. The idea was to measure one control rod in presence of another rod, used for compensating the reactivity introduced by step withdrawal of the measure rod. The reactivity measurements were performed at a low power so the temperature increase during the experiment was negligible. The period was obtained using the Doubling Time – DT (T=1.44 DT), that is the time required for the power to increase by a factor of two. It was used DT because in the control console of the reactor does not exist reactimeter to measure the core reactivity inserted in the core. It was tried to monitor the reactor power in a graphic way, using a Fluke digital oscilloscope with output for computer video monitor, but there was not enough time to familiarize with the oscilloscope software. To obtain the DT it is necessary to wait approximately for 2 minutes, after withdrawing the control rod under calibration, to finish the transition region. The doubling time was measured with two digital chronometers, observing the power showed in the digital display in the console. This procedure causes a large DT uncertainty value. The reactivity associated with the measurement was gotten from the graphical form of the Inhour equation. It is important to note that for periods longer than one second, the curve is essentially independent of both ℓ and β.

The integral curve of the Regulating rod as a function of its positions is shown graphically in Figure 3, and the integral curve of the Shim 1 and Shim 2 rods in Figure 4. The worths of the Regulating, Shim 1 and Shim 2 rods presented in Table 2 are 3.25 $, 2.89 $ and 3.39 $, respectively. The three control rods have sufficient reactivity worth to shutdown the reactor, independently. During these calibrations one power measuring channel could not be used because the fission counter associated to it was not functioning (water had entered into the detector). We decided to continue the tests since the reactor was operating at low power, and the other two power measuring channels were still working. The initial operation checklist was accomplished and it was observed that all protection devices were available.

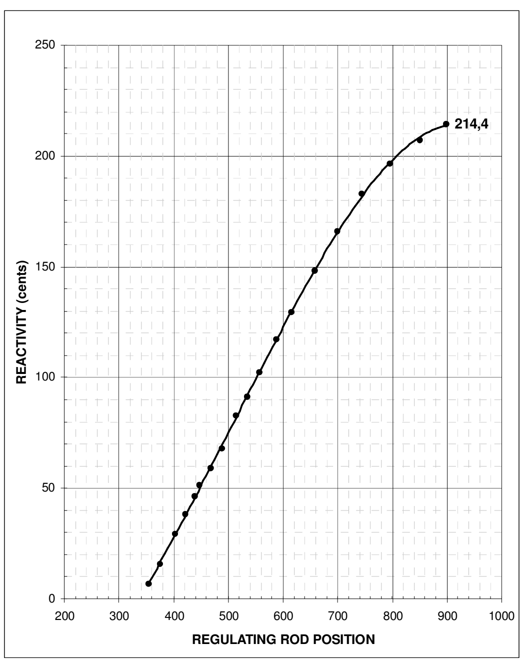

Figure 3. Integral curve of the Regulating control rod.

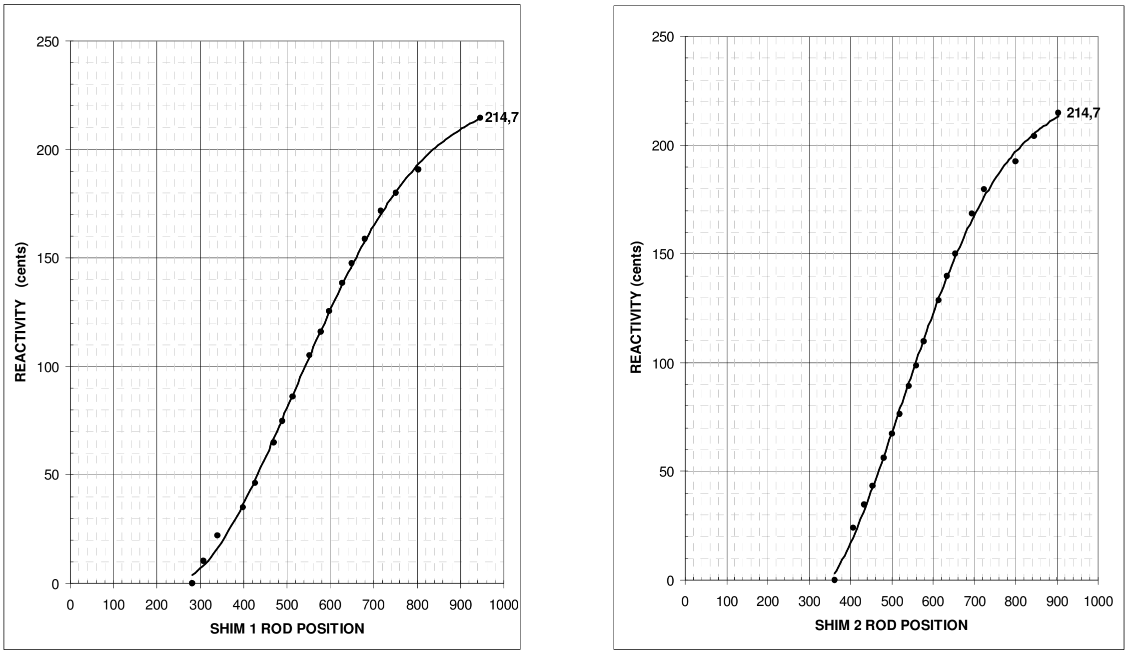

Figure 4. Integral curve of the Shim 1 and Shim 2 control rods.

4.2. Core Excess Reactivity

The excess reactivity (ρ_{exc}) of the core was determined from different control rods critical positions, at low power, and the correspondent calibration curves. The results are shown in Table 1. The average excess reactivity value is (2.18 ± 0.08) $.

Table 1 - Result of core excess reactivity

REGULATING		SHIM 1		SHIM 2		ρ_{exc} (cents)
Position	ρ (cents)	Position	ρ (cents)	Position	ρ (cents)	
646	71.4	946 – UP	0	484	156.2	227.6
569	104.9	946 –UP	0	549	121.2	226.1
608	87.9	659	61.2	656	63.2	212.3
830	10.4	434	162.2	715	39.7	212.3
898 - UP	0	650	64.7	501	147.2	211.9
ρ_{exc} = (2.18 ± 0.08) $						

4.3. Shutdown Margin

Table 2 shows the measured values of the control rods worth, core excess reactivity, and the shutdown margin for IAN-R1 core configuration. The total reactivity worth of the control system is 9.53 $. With a core excess reactivity of 2.18 $, the shutdown margin with the most reactive rod (Shim 2) stuck out of the core is 3.96 $. The shutdown margin is that margin the reactor can be shutdown from a critical condition, and is given by the difference between the reactivity worth of the considered control rods (the most worthy rod is assumed fully withdrawn) and the core excess reactivity.

Table 2 - Results of reactivity

Parameter	ρ ($)
REGULATING Worth	3.25
SHIM 1 Worth	2.89
SHIM 2 Worth	3.39
Excess Reactivity	2.18
Shutdown Margin – SHIM 2 Control Rod Out	3.96

4.4. Thermal Power Estimation

Before starting this test the fission detector had already been repaired, and was operating properly. It was recommended that for routine operations the two fission counters and the ion chamber should be available. The thermal power calibration was performed using the calorimetric method described in the references [5, 6]. Before this calibration, the reactor pool was prepared with thermal isolation. The reactor was operated at approximately 8 kW, indicated in the console, during about 3 hours, with manual power corrections because the automatic control system failed, and with the forced refrigeration off. During the calorimetric experiment, all the pool temperatures were collected manually in intervals of 30 minutes. Figure 5 shows the positions of the thermocouples in the pool, and the average water temperature versus the running time, during the thermal power estimation. At 8 kW the radiation level was approximately of the same order of that one obtained during General Atomics tests [3], indicating that the real power could be greater. It was determined that the real reactor power was 30 kW with an uncertainty of 20 %. With the reactor at 8 kW, the positions of the two fission counters and ionization chamber were adjusted in order to obtain the correct console indication of the power (30 kW).

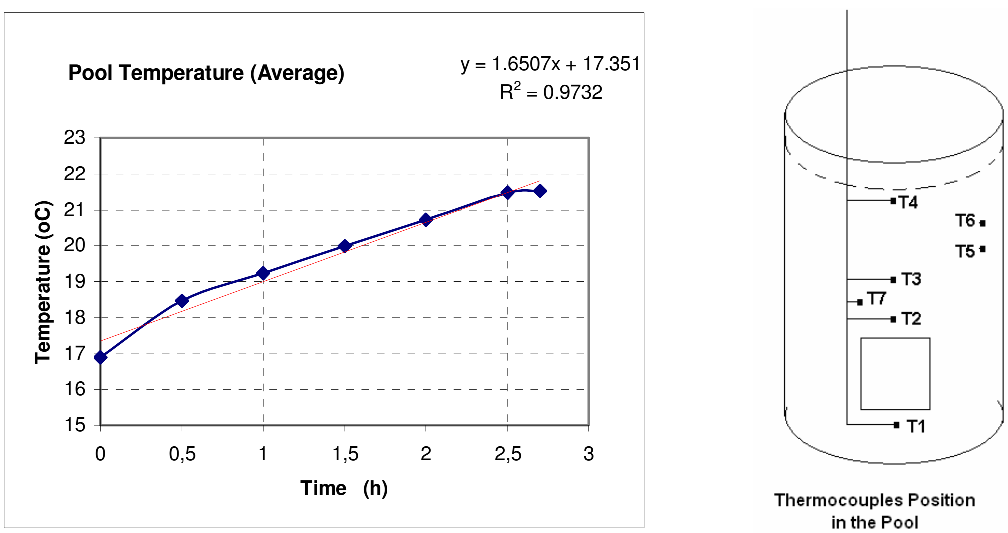

Figure 5. Pool water temperature increase during the thermal power estimation.

5. CONCLUSIONS

The recommissioning of the reactor IAN-R1 was well performed in safety conditions. The neutronic and thermal-hydraulic parameters obtained in the recommissioning program were close to those found by General Atomics in the tests conducted in 1997. The reactor core was loaded with the two clusters (8 fuel elements), the three control rods were calibrated, the excess reactivity and shutdown margin were determined, and the thermal power calibration was performed using the calorimetric method. The worths of the Regulating, Shim 1 and Shim 2 control rods are 3.25 $, 2.89 $ and 3.39 $, respectively, and they have sufficient reactivity worth to shutdown the reactor, independently. The excess reactivity obtained for the proposed core was 2.18 $, and the shutdown margin, with the most reactive rod stuck out of the core, was 3.96 $, hence greater than the minimum safety limit required.

The duties of the mission were successfully completed [6] and were recognized by the Colombian government. We would like to reaffirm the importance in the cooperation among Latin American countries in solving their own nuclear problems.

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