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IAEA EXPERT MISSIONS IN THE RECOMMISSIONING OF THE IAN-R1 TRIGA RESEARCH REACTOR

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ABSTRACT

This paper describes the works that were done by three experts of the International Atomic Energy Agency, from Latin American, during the re-activation of the IAN-R1 Reactor in Bogotá in the year 2005. The main aim of this mission was to assisting the Colombian staff in the safe operation of the reactor, provide lectures for the operating group, review the operational procedures, training the maintenance personnel in the verification, test, adjust, repair, calibration of the nuclear channels and participate in the Ad-hoc committee. The duties of the mission were successfully completed and showed the importance in the cooperation among Latin American countries in solving their own nuclear problems.

1. INTRODUCTION

The researchers Dr. Rose Mary Gomes do Prado Souza and Dr. Amir Zacarias Mesquita from the Nuclear Technology Development Center (CDTN), Brazil, and the engineer Mr. Tonatiuh Rivero from the National Institute of Nuclear Investigations, Mexico, worked during two weeks as experts of the International Atomic Energy Agency (IAEA), in the activities of hot commissioning of IAN-R1 Nuclear Reactor of Investigation (Fig. 1), in the city of Bogotá, Colombia. The operation of this reactor, the only one in this country, started the recover of the Colombian nuclear program.

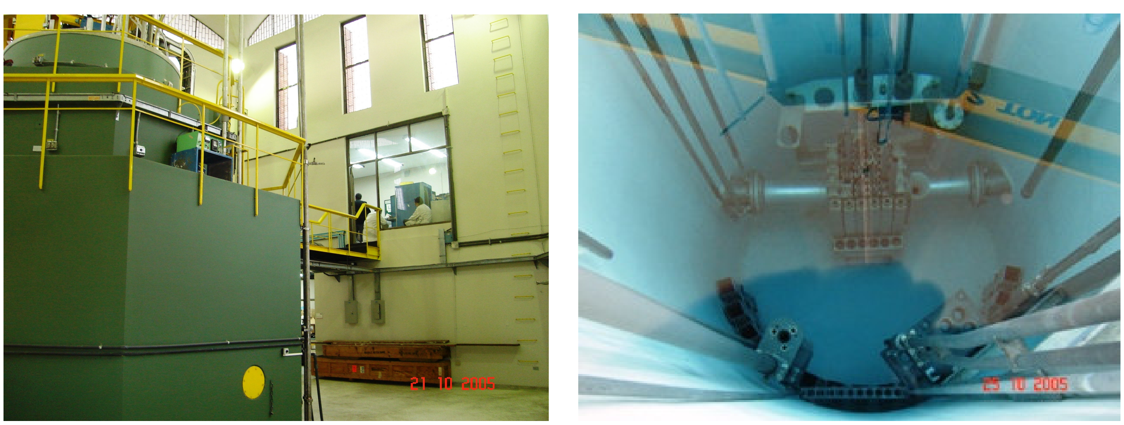

Figure 1. The IAN-R1 TRIGA Research Reactor

The reactor was originally designed and built by Lockheed Nuclear Products in 1965 as a small, 10 kW facility using aluminum plate-type, highly enriched fuel (MTR), under the United State's Atoms for Peace Program. General Atomic has been involved in a gradual upgrading of the facility since 1988, and in late 1994, a tripartite contract was signed with the IAEA, Colombian Authority and General Atomic to manufacture, install and commission the reactor with TRIGA-type, conversion to TRIGA low-enriched fuel [1], and increasing the power of this reactor to 100 kW.

The nuclear activities in Colombia were interrupted in 1998 with the extinction of the Institute of Nuclear Affairs (IAN). In this year, eight fuels elements were removed from the reactor core to kept TRIGA IAN-R1 Reactor in a secure subcritical condition. It was brought into an extended shutdown condition in 1998 after the core conversion, which included the commissioning conducted by the supplier (General Atomic) with "very limited participation of local experts and limited supporting documentation" [2]. The nuclear reactor and its facilities were incorporate to the Colombian Institute of Geology and Mineralogy – "INGEOMINAS" of the Ministry of Mine and Energy. 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 Colombian Authorities decided to reactivate the nuclear activities in the country with IAEA support. The Brazilian researchers were invited due to their experience in the operation of the CDTN's IPR-R1 TRIGA Reactor, and the Mexican electronic engineer due to his experience in nuclear reactor instrumentation (in Mexico, he and his group, exchanged the control console with a new renewal computerized based control console of the Mexican TRIGA Mark III nuclear reactor at the National Institute of Nuclear Investigations).

We stayed in Bogota from 18 to 28 October 2005, and provided lectures and training for the operating team, and reviewed the operational procedures. We assisted the reactor staff in the start up and in the safe operation of the reactor, in the core loading and approach to criticality process, in the control rods calibration, in the determination of excess reactivity and shutdown margin, and also in power determination by thermal method. We participated in the operational activities and also assisted the Ad Hoc committee in the results evaluation during the commissioning process.

All the three neutronic channels were tested, adjusted and calibrated using a recent acquired equipment to do it; the response of the channels (linearity and trip levels) was verified previously to the reactor operation, using test signals. One of the two wide range chambers was repaired because a low signal response due to inner humidity, at the end the chamber position was adjust to check with the power level calculated with calorimetric method. The maintenance personnel were trained into the preparation of the test, verification and calibrating procedures, with the object to assure that the instrumentation was into specifications, and at the same time having evidence for the authorities of the good instrumentation conditions.

2. DESCRIPTION OF THE ACTIVITIES

On the first week (18th to 21st October) the reactor staff, the facilities of the IAN-R1 reactor, and the schedule of the reactor recommissioning [3] were presented to us. We gave some Brazilian TRIGA reactor documents to the operation group, such as: norms for operators training and qualification, requirements of health, operation handbook, safety analysis report and emergency procedures, operators formation course, and some papers and thesis developed in the Brazilian TRIGA reactor. We also received some papers and technical documents about the Reactor IAN-R1, and the report with the tests results that were accomplished by General Atomic [4], when the MTR fuels were substituted by TRIGA type fuels.

We gave some theoretical training to the reactor team. The training subjects were: TRIGA reactor operating characteristics, fuel rods, control rods, cooling system, natural circulation, water temperature, heat transfer, characteristics of the IPR-R1 TRIGA Mark I Reactor in Brazil, operator's formation and methods on thermal power calibration, as calorimetric technique and thermal balance in the heat exchanger [5]. We expounded on reactor instrumentation and control system, power and neutron flux measure, uncompensated ion chamber, fission counter, etc. We also gave lectures about subjects related to the experiments that would be done such as: approach to criticality, period, doubling time, reactivity, Inhour equation, control rods calibration using the positive period and rod drop methods, intercalibration of rods, reactivity excess and shutdown margin determination.

We participated in the Regulatory and Safety Committee of INGEOMINAS meetings. We emphasized the need of permanent training of the operator, according to the international standards, and that Mr. Castiblanco, the reactor supervisor, has a great knowledge in experimental reactor physics and reactor operation, so that he could teach the other operators. The Colombian reactor operators have a good technical formation, all of them have university degree (two electronic engineers and two physicists). It was communicated that the Ad-hoc committee had got a temporary license for reactor operation at 30 kW.

The two clusters (8 fuels rods) removed from the core in 1998 were replaced (Figure 2). The reactor was critical at 100 W during one hour. The Ad-Hoc committee was present during these experiments. When the reactor was critical, it could be observed that the reactivity values of each control rod are almost the same. Each one of the control rod has the capacity of shutting down the reactor and there isn't any rod for fine position adjustment. It was observed that the rod drive mechanisms have high-speed and that the Regulating Control Rod has high reactivity value. Both together make difficult the power adjustment. Figure 3 shows the core configuration after the fuel element loading [6] [7].

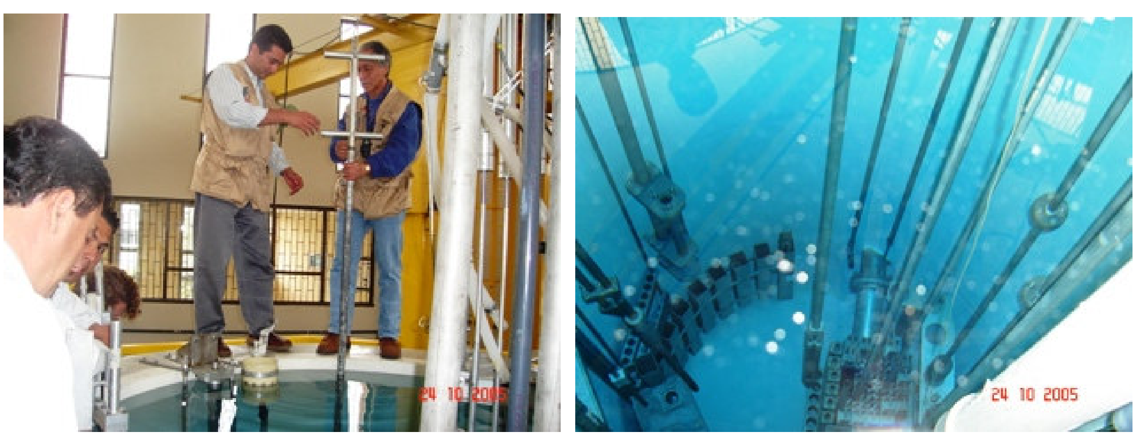

Figure 2. Loading the core with two fuel clusters.

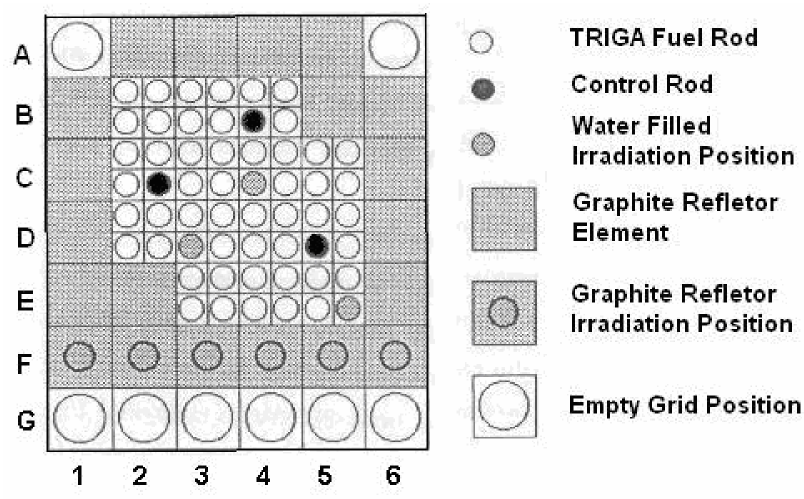

Figure 3. Core configuration after the fuel loading.

2.1. Regulating Control Rod Calibration

The Regulating control rod and the Shim control rods calibrations were performed with the positive period method. In the control console of the IAN–R1 reactor there isn't any reactimeter to measure the core reactivity, so we used the doubling time (DT) procedure to find the period (T). It was obtained the period (T=1.44 DT), and the reactivity was found using the Inhour curve.

There is a very large uncertainty in the visual reading of the time at the moment of doubling power. It was tried to monitor the power by using a Fluke digital oscilloscope, with output for computer video monitor, but there was not enough time to familiarize with the oscilloscope software. So the reactor operators made the measurement of the time with digital chronometers.

One of the fission counter failed during the rods calibrations. So, one of the power measuring channels could not be used. We decided to continue the calibrations because the reactor would be operated at low power level (10 W) and the other two power measuring channels still worked (uncompensated ion chamber and the other fission counter).

The initial operation check-list was accomplished and it was observed that all protection devices were available. Besides the manual scram button on the operator's control panel and close to the reactor pool, there are many automatic shutdown circuits (scram circuits). Some of them are:

- Seismic;
- Air monitor; radiation level of the air in the control room and in the reactor room;
- Period (3 s);
- Voltage failure in the ion chamber or fission counter;
- Overpower in the measure channels;
- Water high temperature.

It was recommended that the fission counter should be repaired before the reactor power calibration. It was also recommended that for routine operations all the fission counters and the ion chamber should be available. In the end, the fission chamber was cleaned and repaired, the connectors and the container was replaced. The cause of the fault was the water condensated into the signal and high voltage connectors; this operation was previously verified using a high resistance meter to measurement the isolated resistance of the electrodes. Mr. Tonatiuh assisted the fission counter repair.

2.2. Thermal Power Estimate by Calorimetric Procedure

On the second week (24^{th} to 28^{th} October*),* some thermocouples were put along the pool, and the top of the pool was thermally isolated (Fig. 4a). The reactor operated at a constant power with primary cooling system switched off, and the rate of temperature rise was determined. With the specific heat of the system and water volume of the pool, the core power was then determined from the measured rate of temperature rise from operation of the reactor. During the calorimetric experiment, all the pool temperatures were collected manually in intervals of 30 minutes. With the power indication of 8 kW in the control console (Fig. 4b), there was a SCRAM for high radiation in the reactor room, indicating that the actual power was larger than the console indication. The Cerenkov radiation could already be visualized in the reactor core. Therefore the reactor was maintaining critical with this power indication in the console.

The control rod initial positions were: Shim 1 (655), Shim 2 (661) and Regulating (674). The reactor stayed critical for about 3 hours with manual power corrections because the automatic control system failed. The power obtained by the calorimetric method was 30 kW. In the next day, the reactor was turned on in critical conditions with the control console indicating 8 kW. The positions of the ion chamber, and the two fission counters were adjusted until the console indications became 30 kW.

Figure 4. a) Thermal isolation of the pool before the thermal power estimation.
b) The IAN TRIGA control room.

3. CONCLUSIONS

The IAN reactor team together with IAEA experts have successfully completed the recommissioning of the TRIGA research reactor. The technological interchange and cooperation among the American Latin countries were a very positive fact of this mission. There is enough technical capacity in our region to solve nuclear problems.

The three control rods worth were almost the same. Excess reactivity and one stuck margin were calculated from control rod worth. It was confirmed that safety margin of control rod worth was enough. The neutronic and thermal-hydraulic parameters obtained were close to those found by General Atomic in 1997 [4]. All these experimental results are shown in reference [8].

The good formation of the IAN-R1 reactor operators, two physicists and two electronic engineers, one of them is studying Master of Science, is a very positive point. The IAN-R1 Reactor supervisor has great theoretical and practical experience in operation procedures.

There are good computer equipments, good electronic instrumentation, a data acquisition system already implemented [9], a good communication and physical protection systems [10]. The control bar graph display of the console screen is very friendly. There is a No-Break that feeds the control console and the control rods electromagnets. So, in the event of electrical energy failure the operator has time to make decisions.

ACKNOWLEDGMENTS

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REFERENCES

1. Castiblanco, L.A; Sarta, J.A. *Calculos y Seleccion de un Nucleo TRIGA para el Reactor IAN-R1*. (1993).
2. International Atomic Energy Agency. *Job Description, IAEA Technical Co-operation Expert Mission*, Project and Task Number: COL1010 03, Vienna, 2005.
3. INGEOMINAS. *Manual de Puesta en Marcha del Reactor Nuclear de Investigación IAN-R1*. Documento RN – MPM – 001. Bogotá D.C, Septiembre, (2005).
4. General Atomics. *Reactor Startup and Acceptance Tests Summary of Results.* Instituto de Ciencias Nucleares y Energias Alternativas. Santafe de Bogota, Colombia, September 5, (1997).
5. Mesquita A. Z., *Experimental Investigation on Temperatures Distributions in a Research Nuclear Reactor TRIGA IPR-R1*, Ph.D thesis, Universidade Estadual de Campinas, São Paulo, (in Portuguese), (2005).
6. Sarta, J.A.; Castiblanco, L.A; Razvi, J. *Conversion of the IAN-R1 Reactor from MTR HEU Fuel to TRIGA LEU Fuel. Proceeding of 1997 International Meeting on Reduced Enrichment for Research and Test Reactors (RERTR)*. Jackson Hole, Wyoming, USA, (1997).
7. Sarta, J.A.; Castiblanco, L.A. *Neutronic Calculations in Core Conversion of the IAN-R1 Research Reactor from MTR HEU to TRIGA LEU Fuel*. In: The 25th International Meeting on Reduced Enrichment for Research and Test Reactors (RERTR). *Proceedings…* Chicago, Illinois, USA, (2003).
8. Souza, R.M.G.P; Mesquita, A.Z.; Castiblanco, L.A. *Hot Commissioning Tests and Technical Results of the IAN-R1 TRIGA Reactor. Proceeding of WORLD TRIGA USERS CONFERENCE*, 3. Belo Horizonte, Brazil, August 21-25, (2006).
9. INGEOMINAS. *Soporte Logico del Sistema de Control del Reactor Nuclear IAN-R1*. RNDR-001, Bogota, (2005).
10. Castiblanco, L.A; Sarta, J.A. *Enhancement of Physical Security at the IAN_R1 Research Reactor*. In: Conference on Physical Protection of Nuclear Materials. Proceedings… IAEA Vienna, (1998).