# NUCLEAR ENGINEERING EDUCATION AT THE RPI WALTHOUSEN REACTOR CRITICAL FACILITY

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## ABSTRACT

The Walthousen Reactor Critical Facility (RCF) at Rensselaer Polytechnic Institute (RPI) is a low power (100W) research reactor, used primarily for education. Commissioned in 1956, the facility was originally built by the American Locomotive Company (ALCO) as an experimental facility for designing the prototype of the Army Package Power Reactor [1]. In 1964 ALCO donatedthe reactor to RPI, where it has been in use as a research, education, and training reactor for over 50 years [2]. It is currently fueled with SPERT (F-1) fuel pins having 4.81 wt% enriched $UO_2$ pellets, similar to most commercial light water reactors except the fuel cladding is made of stainless steel and the fuel pins have an active length of 36 inches [3]. The RCF is used as a tool in education through a combination of experiments, operations training, and classroom instruction. Two examples of this are the Critical Reactor Laboratory and training students for their Senior Reactor Operator licenses. Critical Reactor Laboratory is a senior level undergraduate class in which the students get valuable hands-on experience operating the RCF and performing experiments with it. During the class, some of the labs students will perform include an approach to critical, power calibration,measurements of fuel pin worth, control rod worth, and moderatortemperature coefficient of reactivity. Students can also train to get their NRC Senior Reactor Operator license, which includes receiving extensive operational experience as well as training in surveillances, regulations, and maintenance. Several Masters theses and PhD theses [4] have been completed as a result of research conducted at the facility as well. This paper will detail the various ways the reactor is and has been used in education, and some potential new applications for education, including online and distance learning, nonproliferation, safeguards, and detection.

## INTRODUCTION

In 1954, the American Locomotive Company (ALCO) won a bid to build a prototype reactor for the Army Package Power Reactor (APPR) project [5]. This test reactor was built in Schenectady, NY, for a cost of $300,000 [1]. The research and testing done at this reactor was to be in support of designing the APPR-1 reactor, which would be later known as SM-1. The purpose of the APPR project was to build small, low power reactors which would be able to power and heat small military installations. The reactor's first startup was on August 26, 1956, less than 20 years after the discovery of fission. In 1963, ALCO transferred ownership of the facility to RPI.

Originally fueled with highly enriched uranium (HEU) plate fuel, the RCF was the second university reactor in the US to convert from HEU to low enriched uranium (LEU), completing the HEU/LEU conversion in 1987 [6]. The HEU was replaced with fuel pins from the SPERT (F-1) program [7]. As described above, the fuel pins have an active length of 36 inches and an enrichment of 4.81 wt% and a stainless steel cladding. These fuel pins are arranged in a square lattice, with four Boron "flux trap" control rods surrounding the core. Figure 1 is a photograph of the fuel pins in the core, with the for control rods surrounding the core. The RCF is currently licensed to operate at a power of 100 Watts, and has an administrative limit of 15 Watts. The average neutron flux in the core is $2.215*10^8$ $n/cm^2sec$ at a power of 10 Watts.

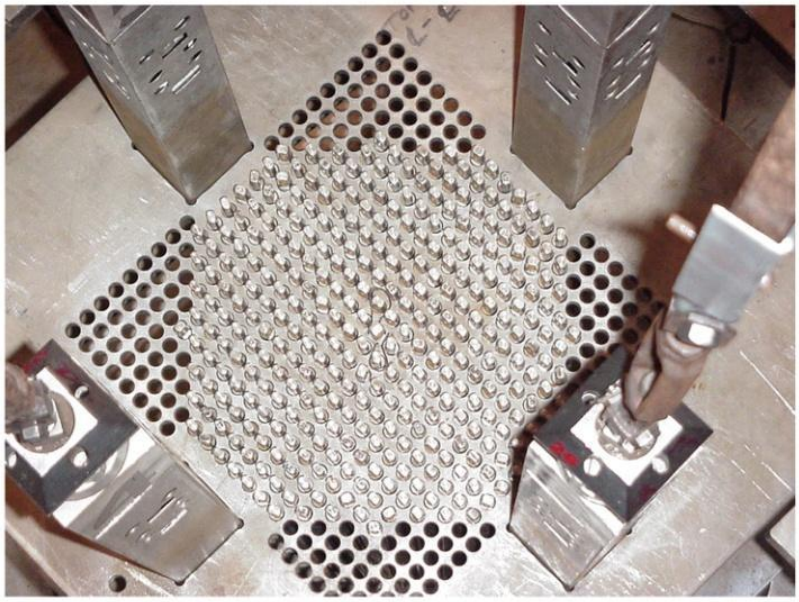

**Figure 1:** ***RCF Core***

Since 1964, RPI has used the reactor as a research, training, and teaching tool. Because of the unusually low power at which the reactor is operated (even for a research reactor), experiments can be performed quickly, and with minimal dose to staff, operators, students, faculty, and the public. Just a few minutes after operation, fuel pins can be removed from the core by hand and replaced with experiments to see the effects of changes to the core.

## EDUCATION AND RESEARCH

Education has been a key focus of the facility. One of the most popular classes in the nuclear engineering program at RPI is the Critical Reactor Laboratory (MANE-4440). During this class, students get hands-on experience operating the reactor. The labs students perform were designed to mirror a commercial reactor startup, starting with "Source Range Detector Calibration" and "Core Loading by Subcritical Multiplication" to "Differential and Integral Control Rod Worth" and "Fuel Pin Worth". Many of the experiments at the RCF are performed by measuring the doubling time of the reactor to calculate the reactivity; this is done by raising the control rods completely out of the core, and measuring the doubling time with a stopwatch. With this method, fuel pin worth, moderator temperature coefficient of reactivity, void coefficient of reactivity, and boron coefficient of reactivity can be measured. Axial and radial power mapping of the reactor

can also be performed by irradiating the fuel, and then taking fuel pins out of the core and measuring their activity with a gamma spectrometer.

A considerable amount of research has also been performed at the RCF. In the future, experiments will be performed as part of the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program to design and perform a number of benchmark experiments which will be used to validate multiphysics codes [8].

The RCF has also been incorporated into many nuclear engineering senior design (capstone) projects. For example, this year, a senior design team designed a system for measuring the flux of the reactor in real time, with the ability to move the detector axially and radially through the reactor. This system allows for the measurement of flux measurements in transient conditions, such as while the reactor is being scrammed.

## TRAINING

Since RPI began operating the RCF, students have trained to operate the reactor and become licensed Senior Reactor Operators (SRO). This training consists of at least one year of operating experience, combined with maintenance and testing of equipment and classroom training on safety, regulations, procedures, and technical specifications. This mixture of hands-on experience and conventional classroom training ensures that trainees have a thorough understanding of the reactor and all its components by the time for their SRO exam. Each trainee also performs at least one safety drill. This opportunity is open to both undergraduate and graduate students at RPI. Figure 2 is a photograph of trainees in the RCF Control Room in 2013, and the same Control Room in 1958. In addition to training of RPI students, other groups visit the RCF periodically for training and education, including college classes from other universities, Army Cadets from West Point, and other local groups (eg. Boy Scout and Girl Scout Troops).

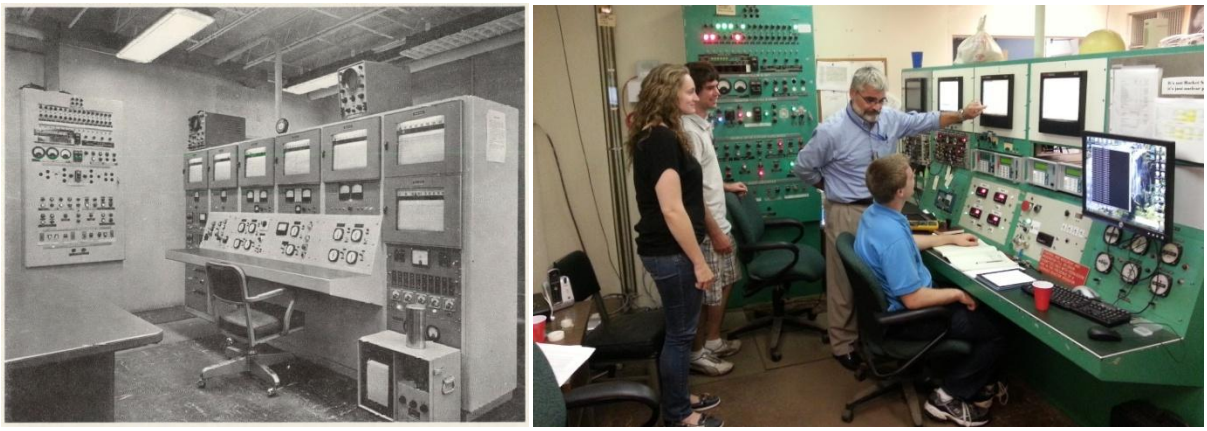

**Figure 2:** *The RCF Control Room in 1958 and in 2013*

## FUTURE EDUCATION APPLICATIONS

As discussed in a previous paper [9], the RCF has the ability to record and stream video, and this ability has been used as part of the class. Video can be recorded in the classroom, reactor room, and control room, which can give students who are not physically at the facility a chance to "virtually" take part in the experiments.

The International Atomic Energy Agency (IAEA) implements nuclear safeguards in various ways, including verifying that safeguards-relevant nuclear facility design and operating information that a country is required to provide. This includes regular and short-notice inspections of declared equipment detail, material inventory, processes and material flow paths among many other items. At the RPI RCF, students can perform a laboratory where they learn about these inspections by actually doing them. For example they can perform a Physical Inventory Verification (PIV) inspection [10], where the students would receive a list of all the inventoried nuclear materials from the RCF director, and walk around and actually verify the consistency and correctness of the provided accounting records. The RCF is inherently suitable for such an activity since students are allowed to handle the fuel directly (both in the reactor and in storage). In conjunction with the PIV inspections, the students can also conduct a Design Information Verification inspection to verify whether the pre-declared RCF facility details are consistent with what is physically observed.

## CONCLUSION

RPI's Reactor Critical Facility has been used as a research, training, and teaching reactor for the last 50 years. The RCF is currently actively used in each of these areas, with students training for their Senior Reactor Operator licenses, new research grants recently awarded, and the Critical Reactor Laboratory class being offered every spring. Since the maximum power that the reactor can be operated at is low, even compared to other research reactors, the reactor geometry can be changed very quickly with minimal exposure to personnel, and experiments can be performed very easily.

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