Project Number: 51-ETB-9803

99D278I

Web Based Training for the WPI Nuclear Reactor

An Interactive Qualifying Project Report
Submitted to the Faculty of
Worcester Polytechnic Institute
In partial fulfillment of the requirements for the
Degree of Bachelor of Science

By

John P. Koser

Michael A. Shear

Richard V. Tino III

Date: April 28, 1999

Approved:

Professor E. Thomas Boulette, Advisor

Abstract

Computer-based employee training is being increasingly utilized. For an employer, the benefit is lower training costs in terms of instructor-hours. For the student, there is the pedagogical benefit of self-paced learning. However, students may lose the potential benefit of personal contact with an instructor associated in "hands-on" learning or in the classroom experience. How effective is computer-based training in reducing instructor time and cost, and how effective is this type of training in assuring students' learning comprehension and retention? This IQP will approach these questions in the context of training operators for nuclear reactors. The training of operators for the WPI Nuclear Reactor Facility will be used as a test example by the creation of a Web-based training system to augment the existing training program. This Web-based system will have all the features of traditional computer-based training with the additional advantages of hyperlinks to additional resources, such as the NRC Web site for 10CFR, located in the appropriate locations throughout the training program.

Preface

The Worcester Polytechnic Institute Nuclear Reactor Facility is constantly training students to be Reactor Operators (RO) and Senior Reactor Operators (SRO). This provides the facility with staff to operate for the following year, and gives the student valuable experience. The training culminates in an NRC examiner administering a three (3) hour written exam and a three (3) hour oral or practical exam. The web site that is the product of this IQP, is designed to aid in the training course that undergraduates take in order to receive their Operators Licenses. The web site is located at www.wpi.edu/~ans, the WPI chapter of the American Nuclear Societies page. The name of the site is N.U.T.S. or Nuclear University Training System. Nuclear University is the fictional source of many project requests in the nuclear engineering classes at WPI.

Table of Contents

1.0 Background

The Worcester Polytechnic Institute Nuclear Reactor is a 10-kW (thermal) rated General Electric Open Pool Training Reactor located in Worcester, MA. The reactor first achieved criticality in December, 1959 and was at that time rated for 1kW. The license was upgraded to 10kW in 1967 and the license was renewed for twenty years in 1983. In 1988 the reactor underwent an NRC-mandated shift from High-Enriched Uranium (HEU; approximately 90% enriched U-235) to Low-Enriched Uranium (LEU; 19.75% enriched). The reactor core sits in an 8' x 8' x 15' pool of demineralized water sourounded by an aluminum-lined 5' thick concrete wall. The reactor is cooled by natural convection. Control mechanisms consist of three boron-carbide control blades and a single stainless steel regulating blade. Reactor-related experimental facilities include an in-core experiment holder, a beam port, and a thermal column.[i]

The WPI Nuclear Reactor Facility (NRF), consisting of the WPI Nuclear Reactor itself and several other experimental facilities, is used by students and faculty from many departments to support various research activities. The NRF has a full-time director, who is a member of the WPI staff and a licensed Senior Reactor Operator; however, many of the research activities and most reactor operations are run by several student assistants. These students are both graduate and undergraduate students in Nuclear Engineering who have been licensed by the United States Nuclear Regulatory Commission (NRC) as Reactor Operators (RO) or Senior Reactor Operators (SRO) for the WPI Nuclear Reactor. Typically, interested sophomores and juniors in the Nuclear Engineering department are offered the opportunity to undergo a semester-long training process culminatting in the licensing exam. This exam is administered by an NRC representative, and consists of a practical exam and a written exam. The written exam covers three sections: Reactor Physics, WPI NRF facilities, and WPI NRF operating procedures. The practical exam is given in the reactor facility, and involves the candidate performing a reactor startup and answering questions about any of the sections which are covered in the written exam.

An analysis of similar computer-based training programs in the nuclear industry is attached as Appendix 1, and the typical training program of a commercial power reactor is, documented in Appendix 2, compared and contrasted with the non-power reactor training program in place at WPI. The actual training programs are attached as Appendices 3-4 for Limerick Atomic Power Station (PECO Energy) and Pilgrim Station (Boston Edison) respectively.

2.0 Purpose

The former training process was based around a weekly one-hour group lecture by Mr. Leo Bobek, the former NRF Director, and a weekly two-hour individual practice session with one of the student members of the NRF staff. The lectures currently cover a wide array of physics, facilities, and operating procedures; the practice sessions are opportunities for the operator candidate to practice reactor operations by actually performing a startup, critical operations, and a shutdown under an SRO. The physics portion of the lectures are typically focused towards reactor kinetics, radiation transport, instrument design, and other nuclear physics topics included on the NRC exams. There is no formal outline for the operations portion of the lectures but it tends to include going through all of the Operational Procedures, included as Appendix 5, step by step. It is thus obvious that much more time is spent on the skills needed for the practical exam than those directly relevant to the written portion; however, those candidates who fail the exam almost always fail the written portion. Specifically, the Reactor Physics section is failed most often, followed by the Operating Procedures section and then the Physical Facilities section. Accordingly, it is desired to change the training program to add more time spent on these sections.

Adding more lecture time is not an option, since the training program is not an academic course and must be scheduled around the availability of all of the trainees and the instructor. Even though only four or five trainees are accepted each year, it is usually difficult to find a common time for one lecture a week in addition to the individual practice times. Reducing practice time to focus more on written exam preparation is also not an option. Legally, an operator candidate must perform five "significant reactivity manipulations" before being eligible for the NRC exam. A "significant reactivity manipulation" is defined as a change in the reactor power level of a factor of two or more. However, a trainee is usually not fully capable of operating the reactor safely and effectively until they have operated for much more than this NRC-defined minimum. For example, many experimental procedures require reactor power to be held steady to within $\pm$ 0.2% of full power. The trainee's ability to supply this amount of precision is the result of much more practice than the five manipulations required. Additionally, the trainees generally do not have the intimate familiarity with both the physical facility and the operating procedures that is required for safe and successful reactor operation until well after the required five criticality manipulations.

Since more instructional time is needed, but not readily available, what has been done to the present time has been to provide trainees with copies of material such as the operating procedures (Appendix 5) and the Final Safety Regulatory Analysis (FSAR) documentation in plain text format on a disk with instructions to study independently. This is difficult, however, because these documents reference the physical facilities of the NRF and are difficult to understand in plain text with no way to visually see the relationships between various pieces of equipment. It is the hope of the authors that this project will provide such a visual link using the capabilities of the World Wide Web (WWW). An additional advantage of the Web-based nature of these documents on the N.U.T.S. site is that when the FSAR is revised within the next two to three years for relicensing, the revised version can be placed on the Web site for the use of both prospective and current reactor operators.

The purpose of this IQP is to create a computer-aided training program utilizing the potential of the WWW to link many different types of media together. The major problem with the current method of reactor operator training is that the trainees are required to memorize textual descriptions of equipment and procedures, following which they are expected to be able to perform the procedures and identify and operate the equipment. They usually are not able to do this without being walked through the procedure several times during either the lecture portion or the practice portion of the training program. Hopefully, by using the hypertext-linked format of this project to connect the textual descriptions and pictures of the actual equipment involved, along with links to the regulatory reasons for procedures, these procedures and equipment can be learned more effectively on the student's own time. Although the student would still be walked through the procedures in a hands-on manner once or twice, the amount of time needed in the practice sessions and lectures could be greatly reduced. The ultimate goal is for the lectures to focus primarily on reactor physics, while the practice sessions could maintain their current focus on actual reactor operation and facilities. This would be made possible because the trainees would already be familiarized with the physical facilities and the operating procedures before the training sessions, so no time need be wasted in the lectures doing this initial familiarization. This would save at least two or three lectures, which is a significant fraction of the eight to ten lectures given. Additionally, the practice sessions would flow more smoothly because the trainees would already be somewhat familiar with the equipment and procedures before arriving for practice. It is also hoped that the hyperlinked format of the Web will provide the potential for learning material in more depth than the traditional, necessarily linear, format of the lectures.

3.0 Methodology

A scientific study to determine the effectiveness of this project in improving operator training is difficult, due to the very small number of trainees each year. Last year, for example, there were only four trainees; of these four, three are the authors of this project. As a result, the effectiveness of this project will be measured subjectively since no means exist to obtain an objective measurement. It is realized that this is relatively poor scientific practice, but there does not appear to be any way to avoid this solely subjective measurement.

4.0 Similar Programs

An attempt was made to find similar programs elsewhere to compare "N.U.T.S." with, but the authors could not find any Web based training systems currently in use. Several organizations are using traditional computer-based training(CBT) to some extent, which has many of the same advantages but lacks the ability to hyperlink outside of the training program itself. A list of all programs contacted and the information gathered is included in Appendix 1. One of the best examples is the CBT used by the National Institute for Standards and Technology (NIST) for the initial radiation user training for experimenters, but not for reactor operations training[2]. Programs such as this do not have the universal availability of the "N.U.T.S." system due to the Web presence of the latter, and are less capable of cross-referencing. For instance, in the Documentation section of "N.U.T.S." there is a link to the Nuclear Regulatory Commission (NRC) Web site. This link is to the 10CFR section, which is the official version of 10CFR according to the NRC and will be updated constantly by the NRC as stated by a note on the Web site: "Important Note: We keep this collection up to date on a weekly basis. Various files in this collection are updated frequently as changes to rules are noticed in the Federal Register."[3] This linkage capability is one of the major advantages of Web-based materials.

5.0 Web Site Construction

The goal of the web site is to present the technical documentation, reactor systems, and related information relating to the operation of the WPI nuclear reactor in a format that is easily assessable and navigable. The information presented is not very easy or interesting reading, however a thorough understanding of the information presented is necessary to successfully complete the Reactor Operator (or Senior Reactor Operator) exam. The web site consists of 6 sections: "How to get started", Documentation, Reactor Systems, Online Tour, Useful Links, and "Why this was created."

Documentation:

The documentation section contains all the documentation for the WPI Nuclear Reactor Facility. Including: Final Safety Analysis Report (FSAR), Technical Specifications (Tech Specs), Operating Procedures, Emergency Operating Procedures, Maintenance Procedures, and Miscellaneous Procedures. Also included is a glossary of abbreviations enabling a student to understand all the acronyms used in the various documents.

Reactor Systems:

The Reactor Systems section contains information on each of the Mechanical and Control & Instrumentation systems as they relate to reactor operation. Each system is defined in the FSAR and has Technical Specifications that relate to limits, set-points and other control data.

Online Tour:

The Online Tour section takes the trainee step-by-step through the Pre-Critical Check-Out section of the Operating Procedure (OP01). Each step includes all the relevant information (Tech Specs & FSAR data) concerning the piece of equipment in each step.

Exam Section

Exams from previous years are in interactive form; while the student will have to keep score for himself the test will allow him to take the tests online and correct his answers on a question-by-question basis. A reference (usually a hyperlink) to the material forming the basis for the correct answer is attached to most questions. The picture section is what most clearly takes advantage of the hyperlinked nature of the Web; each picture is linked to a description of whatever the picture is showing which is, in turn, linked to any regulatory references and/or operations procedures references.

Secondary Sections:

The sections: "How to get started", Useful Links and "Why this was created" are all much smaller and simpler. They are designed to inform the user about the site and what types of resources are available from the web site. The "How to get Started" section is essentially a collection of frequently asked questions (FAQ), giving information on how to use the site most effectively. The "Why this was created" sections discuss the purpose and theory of this IQP. It also contains a copy of this paper. Finally the Useful Links section, is a compilation of links that were useful in construction this web site, as well as many links to nuclear related technologies and regulatory agencies.

The FSAR on the Web site is the current SAR as of October, 1998. This SAR is currently undergoing extensive modifications to prepare for relicensing of the reactor in the year 2001. Once the modifications are completed, which is scheduled to occur by the end of 1999, the SAR on the Web site will be updated. Alternatively, the SAR may be placed on the Reactor Facility Web site ("http://nucleus.wpi.edu/") and the SAR on the N.U.T.S. site may be replaced by a link to the Reactor Facility site to take advantages of the constant updating which would not otherwise occur.

Appendix A: Other CBT In Use In The Nuclear Industry

The authors emailed the Test, Research, and Training Reactor mailing list (trtr@wpi.edu) with a request for anybody currently using any form of computer-based or Web-based training to reply and correspond with us. The only responses received from reactors were from organizations which do not use computer-based or Web-based training for reactor operators. Specifically, reactor staff members from Purdue University, the University of Texas, the University of California at Irvine, and Penn State stated that they are not currently using computer-based training at all. Also, PECO Energy uses only a very small amount of computer-based training in their reactor operator training course due to the prohibitive expense of creating such a training program.

The only organization that we received a response from that uses a significant amount of CBT was the National Institute of Standards and Technology (NIST). NIST does not use CBT in their reactor operator training course, but they do have an established CBT program for experimenters who will be using the reactor or other radiation experimentation facilities. This program focuses mainly on radiation, radiation effects, and radiation protection. It also addresses many procedural issues that are specific to NIST. The program (NSBR) utilizes some limited hyperlinking, but instead of linking to other locations the links lead to short one- or two- paragraph descriptions of the linked word or phrase. The program also uses limited multimedia material, in the form of recorded sounds and pictures as well as some simple animations. More information on NSBR can be found at its Web site at "http://rrdjazz.nist.gov/".

Appendix B: Comparing And Contrasting WPI Reactor Operator Training to Typical Power Reactor Operator Training

A typical power reactor training program consists of approximately two months of classroom study, followed by a year of mixed classroom, simulator, and actual in-plant work. The two months of classroom "pre-training" are roughly comparable to the entire WPI training program. WPI has the advantage that all trainees have successfully completed at least two introductory nuclear engineering classes, and most have completed four or more; this allows the use of a once-weekly lecture for eight to ten weeks to complete the physics education necessary to pass the NRC exam. This same material is taught by a typical commercial plant in their two months of full-time "pre-training." The material that a commercial plant teaches operators during the year of regular training is for the most part unneeded by WPI RO's since most of it is focused on plant systems and procedures; since the WPI reactor is so simple, the number of systems and procedures to be learned is much lower. Also, since WPI does not have a simulator, all training is done on the actual reactor itself instead of the commercial plant approach of practice on a simulator before manipulating the controls of the actual plant.

WPI's SRO license program is practically nonexistent; the requirements to upgrade from an RO to an SRO license are primarily experience and knowledge of a very limited set of Emergency Response Procedures (ERP's). As a result, the "SRO Upgrade Training" consists of perhaps a few hours of self-study. For a commercial plant it is much more involved, mostly accident mitigation and monitoring as well as general supervisory skills. As a result, the typical commercial SRO upgrade program is approximately another year of training after the candidate obtains his RO license.

In sum, the training requirements for the WPI reactor are very significantly less than those for a commercial plant. This makes it possible to have undergraduates obtain their RO licenses while studying on their own time and attending an occasional lecture; it also makes it possible for a relatively simple online training program to be very effective in supplementing those lectures and practice sessions.

Appendix C: The Training Program at PECO Limerick Station

The training program for Reactor Operators at PECO Energy's Limerick Station, one of two reactor sites owned by PECO Energy along with Peach Bottom Atomic Power Station, is approximately a year long of full-time class. The Limerick pre-training program consists of eight to nine weeks of theoretical study, reduced for degreed nuclear engineers to the last week of the general RO pre-training program. The purpose of the pre-training program for Limerick is to provide the theoretical physics background for the RO program. The training department is looking into the possibility of converting this pre-training program in part or entirely into CBT. This conversion would ultimately streamline the process since each trainee could proceed at his or her own rate and fewer instructors would be required, but the cost involved in the initial creation of the program is too high to implement it in the near future.

Throughout the one-year training program, time spent in training is divided evenly among three phases. The first phase is classroom training which consists of lectures and demonstrations. The second phase involves having the trainee perform the skills which were taught in the lecture portion on the simulator. The third and final phase of training at Limerick is when the trainee performs the skill "for real" on the actual reactor. Each phase is completed in sequence for each skill being taught.

The major problem faced by the Limerick training program is that the NRC requires five reactivity manipulations on the actual reactor before the candidate may sit for a licensing exam. A reactivity manipulation is defined as an adjustment of reactivity that results in a power change equal to or greater than 5%. Since both reactors at Limerick have capacity factors over the last several years of 90% or more, reactivity manipulations are scarce. Most, if not all, of Limerick's scheduled reactivity manipulations are in fact carried out by trainees under the supervision of a licensed operator.
Limerick's program for Senior Reactor Operators is also about a year long, and is similar in format to the Reactor Operator program.

Appendix D: The Training Program Outline at Boston Edison Pilgrim Station

1. INTRODUCTION

Tasks performed by Reactor Operators (RO) and Senior Reactor Operators (SRO) were identified and verified by subject-matter experts, and provide the basis for the NRC License Training Program (RO/SRO). The resultant task lists were used to design and develop the training curriculum. Upon successful completion of this training program, the operator will be able to perform the required tasks safely and efficiently.

Academic training will provide the theoretical knowledge base required to enable the operator to understand and respond to plant conditions. Since all plant conditions cannot be accurately predicted, the operator must have a sufficient theoretical knowledge base to recognize and respond to abnormal or emergency conditions, and take steps necessary to mitigate the event.

This program is one in a series of programs developed by the Operations Training Department. Program completion enables the trainee to qualify as a Reactor Operator or Senior Reactor Operator.

2. GOALS/OBJECTIVES

The goals of this program are to develop:

a. confidence in the ability to conduct plant operations from the control room in a safe, reliable and professional manner

b. the ability to coordinate unit-related activities from the control room

c. the ability to function as an effective member of a control room team

d. the ability to analyze available information and diagnose problems

e. the ability to think and respond to integrated plant operating conditions

f. the proper attitude and professional demeanor for operating positions

g. the ability to recognize symptoms and mitigate the consequences of off-normal and emergency conditions

h. an awareness of events that have occurred at nuclear stations and an appreciation for the lessons learned from those events

i. an understanding of the importance of vigilance and awareness of plant conditions and trends in operations

j. an appreciation for the importance of the critical safety functions

k. understanding of specific Pilgrim procedures and technical specifications and how to use them

l. the concept of alternative action paths in conditions for which no procedures exist

The objective of this program is to qualify participants to perform the tasks identified for the licensed operator (RO/SRO) positions.

3. PREREQUISITES, ENTRY SKILLS, AND RETENTION REQUIREMENTS

a. All NRC license candidates shall have completed Plant Access Training, Basic Radiation Worker training and have unescorted access to Pilgrim Nuclear Power Station.

b. All license candidates shall satisfy the program enrollment eligibility requirements as set forth in:

   1) Boston Edison's Nuclear Training Manual.

Completion of NRC License training and successful NRC licensing examination completion is required for qualification as a RO or SRO. Program completion is documented by completion of the appropriate Nuclear Training Manual Qualification Card. Continued participation in the Operator Requalification program (O-RQ) is required to retain status as a licensed RO or SRO.

Retention in the program is dependent upon the trainee's attainment of the stated learning objectives, consistent with the criteria established in Boston Edison's Nuclear Training Department Procedures, and Nuclear Organization Policy # C.2.03..

4. LISTING OF COURSES

The NRC License Training Program (RO/SRO) consists of seven courses. Course titles and approximate course time requirements are listed below. These estimates are based on the assumption that the trainee completes the structured presentations and does not "test-through" any material.

Course	Title	Approximate Time (in weeks)
O-RO-01	Academics Training	6
O-RO-02	Systems Training	13
O-RO-07	Emergency Preparedness	1
O-RO-03	Simulator Training	10
O-RO-04	On-Shift Training	20
O-RO-05	Needs Assessment	6
O-RO-06	Administration	2
TOTAL		58
	Testing, Vacations, Review	9
	TOTAL (SRO)	67 weeks
	TOTAL (RO)	65 weeks

NOTES

1) The program duration and sequence shown above reflects a typical student population and availability of facilities.

2) The duration and sequence of the program and/or any of the courses may be altered as necessary to allow efficient instruction and use of facilities.

3) A student may not be exempted from any part of the program based solely upon his background or previous training. To be exempted from a part of the program, a student must score $\geq$ 80% on a "test-out exam", which should be administered to the student prior to the course being taught. If the student scores below 80% on the "test-out exam", he/she will be required to attend the scheduled training.

4) A customized training schedule is to be developed and maintained for each class of N.R.C. license candidates.

5. TRAINING PROGRAM IMPLEMENTATION "LESSONS LEARNED"

See Attachment A

6. CONTACT PERSON

Operations Training Department Manager
Chiltonville Training Center
(508) 830-7600

ATTACHMENT A

TRAINING PROGRAM IMPLEMENTATION "LESSONS LEARNED"

Experience gained through the implementation of previous NRC License Training Programs, has led to the finding of practices and policies which have proven to be effective. These practices and policies are listed below, and should be reviewed and factored into the implementation of future NRC License Training Programs:

a. Pre-screen all proposed NRC license candidates against the program enrollment criteria.

b. All NRC license candidates should complete the following during the two weeks prior to program implementation:

   1) Plant Access Training, Basic Radiation Worker Training

   2) Annual company physical (to NRC Licensing standards)

   3) Whole Body Counts

   4) Face Mask Fits

   5) "Instant" SRO License Candidates should:

      · Familiarize themselves thoroughly with the station/plant tour.

      · Notify the Emergency Planning Staff that they are being enrolled in N.R.C. License Training

c. The Program Schedule should have two weeks of vacation availability factored into it.

d. The Program Schedule should account for company holidays whenever possible, especially:

   1) Thanksgiving

   2) Christmas

   3) New Year's Day

e. The Program Schedule should provide for three weeks between the "Program Audit Examination" and the "NRC Licensing Examination".

f. All NRC License Candidates are to receive "Plant Status Update Training" and participate in a "Program Critique", following the NRC Licensing Examination.

   1) SRO License Candidates should remain in training two additional weeks to receive "Control Room Management and Problem Solving Skills" and SCRE training as appropriate.

g. The Training Program Coordinator should forward a schedule of the class' projected work hours to the Operations Department Manager every 3-4 weeks. This allows the ODM to post a work schedule which accurately reflects the work hours of the students; minimizing "off-schedule" work, and clearly identifying foreseen overtime needs.

   1) The Training Program Coordinator should contact the ODM if any significant deviations occur from the class' projected work schedule, or if additional overtime needs are identified.

h. The students are required to take regular written quizzes and examinations throughout the training program, and require a score of $\geq$ 80% to "pass" these quizzes/examinations. When a student scores < 80%, a detailed review of his quiz/exam is to be conducted and a remedial plan developed per procedure T.16. The student is to be provided counseling and/or remedial training on failed areas, and should be re-examined on these areas (as delineated in T.16) along with his next regularly scheduled quiz/exam. Remedial training sessions are to be clearly documented.

i. The Training Program Coordinator is required to closely track the performance and progress of all license candidates, complete with substantiating documentation.

j. Academics refresher training sessions should be conducted once per week until the GFE section of the written license examination is completed.

k. The "On-Shift " course is most effective if the license candidates are evenly split into separate training groups, which rotate through the following schedule weekly, with weekends off:

   1) 0715-1515 shift
   2) 1515-2315 shift
   3) 2315-0715 shift
   4) Training Center, 1515-2315 shift

l. The "On-Shift " course is most effective if SRO Certified or SRO Licensed Instructors are assigned to a rotating shift schedule to coordinate, implement and document the on-shift training.

m. The below listed courses/topics are typically taught or revisited with the License Candidates during the "On-Shift " course when the students are in the classroom at the Training Center:

   1) Administrative Procedures and Controls

   2) Technical Specifications

   3) Emergency Organization Overview and EALs

   4) Problem Diagnostics

   5) Transient and Accident Analysis

6) Mitigating Reactor Core Damage

7) Overview of 10CFR20, 10CFR55, 10CFR50 and 10CFR100

n. The program schedule should provide for the license candidates to be administered complete NRC-style written examinations, between the "Systems Course" and the "Program Audit Examination".

o. Each license candidate should be administered NRC-style oral/walk-through examinations between the "Systems Course" and the "Program Audit Examination."

p. The "Program Audit Examination" should be developed and administered to the class by a team of personnel which have had no involvement with the training program. The personnel selected to be on the Audit Examination Team should have extensive backgrounds/experience in the area of NRC License Training and/or administration of NRC License Examinations.

1) Once the Audit Examination Team is selected, they should be provided with a copy of the same Pilgrim Station procedures and training materials which have been provided to the NRC Region 1 Staff.

q. The license candidates should be scheduled to take the Generic Fundamentals Examination after the completion of the Academics Course and prior to the Program Audit Examination.

1) At least 2 NRC-Style "practice" GFE section exams should be administered to the class prior to taking the NRC exam.

r. Operations and Operations Training Management should remain continuously and conspicuously involved in progress of the class. Weekly "question and answer" sessions is an effective method of maintaining these lines of communication open.

s. Training/Study materials should be distributed to the class at least one week prior to the instruction on that topic. This will allow students to review subjects in advance of formalized instruction should they choose to do so.

Appendix E: WPI Nuclear Reactor Facility Operation Procedures (OP's)

WORCESTER POLYTECHNIC INSTITUTE OPEN POOL TRAINING REACTOR
OPERATION PROCEDURE OP-1
PRE-CRITICAL CHECK-OUT AND OPERATING PROCEDURES
I. PRE-CRITICAL CHECK-OUT

1. PREFACE:

The purpose of the start-up check list is to verify that the reactor is in a normal and safe operating condition prior to criticality, and that proper security precautions have been taken relative to all restricted areas. It is important that all items on the list be verified and checked off. The order is not mandatory. The completed check-out list must be approved by a licensed operator. This procedure has been written in detail both to aid the operator and to facilitate the role of the reactor as an educational tool.

2. PERSONNEL REQUIREMENT:

one liscensed operator

3. PROCEDURE:

3.1 Visual Check of Core and Facilities

3.1.1 Pool Level

A normal pool water level is considered to be from the overflow pipe to not more than six inches below it.

3.1.2 B-10 Counter

The B-10 counter should be in its lowest position. This can be verified by observing that the plastic roller is in the guide slot on the B-10 column. The steel suspension cable should be threaded in the slotted steel plate at the bridge and the uppermost stop on the cable should be resting on the plate.

3.1.3 Fuel Loading

Note the number of fuel elements loaded in the core.

3.1.4 In-Core Experiments

Note any in-core experiments. In-core experiements should also be noted in the operation log book for the day.

3.1.5 Neutron Source

Verify the neutron source is in core position D-2.

3.1.6 Experimental Facilities

The beam port shield, beam port shutter, and thermal column door should be verified closed or logged open if they are in use.

3.1.7 Pool Resistivity:

A demineralizer reading is taken using the electronic device at the console. The minimum acceptable reading is 5 X 105 ohm-cm.

3.2 Area Radiation Monitors

There are three area radiation monitors under surveillance located in the reactor facility. One is on the upper level on the reactor bridge on the south side. This reads the radiation level at about 1 foot above the surface of the water. The second unit is located downstairs between the beam port and the demineralizer on the reactor wall. The third monitor is also on the lower level and is located close to the thermal column door.

3.2.1 Source Check:

The three area monitor readouts are located at the console. Perform a source check of each monitor by activating the check source control.

3.2.2 Setpoints:

Perform a check of each monitor's high alarm setpoint by activating the high alarm check control. The pool monitor alarm setpoint must be 50 mR/hr or less and the beam port and thermal column monitors' setpoints must be 20 mR/hr or less.

3.3 Instrument and Control Power

3.3.1 Verify the instrument and control power switches are on.

3.3.2 Verify the CIC HV supply indicates HV reading of 600 +/- 10 on both the (+) and (-) sides.

3.3.3 Verify the B-10 HV supply indicates a HV reading of 750 +/- 10.

3.4 Reactor Check

The two recorders located on the console are powered by the small switch located on the front of the recorder. Lower the chart pens via the pen lever to the right of the chart. Verify chart motion and that the recorder pens are inking. Date and initial the charts prominently.

3.5 Startup Channel Gain and Discriminator Settings

Verify that the discriminator and gain settings on the startup channel single channel analyzer are at the posted values.

3.6 The Master Switch to Test

Place the master switch to the test position. When the switch is placed in the test position, a horn will sound which can be acknowledged (silenced) by either of the alarm acknowledge buttons on the console or the panel alarm. Reset the scram by pushing the Scram Reset button.

3.7 Log-N Amplifier Calibration Check

3.7.1 Period Calibration:

Depress the 3 sec pushbutton on the keypad of the amplifier and verify that the reactor scram functions and that bistable trips 1, 2, and 3 are indicated. Observe that the period meter settles on 3 seconds.

3.7.2 Log-N Calibration:

Depress the 0.1A pushbutton on the keypad and observe that the Log-N indicator settles at approximately 10% power.

3.7.3 Meter and Recorder Response:

Verify the recorder has recorded approximately 10% power. Reset the scram.

3.8 Blade Drive Test

It is the purpose of the blade drive test to check the operation of the drive motors on the regulator and safety blade drives, to verify that the positional indicatorsof the safety and regulating blades are operating properly, and to verify that the lights on the console board are operating properly.

3.8.1 Withdrawal, Display Response, and Coast

Select a blade and withdraw it at least an inch but not more than three inches. It should be noted that when the blade is withdrawn approximately 3/4 " the "in" light will go out. The blade must be withdrawn past the "in" light interlock. During the withdrawal procedure watch the digital display and verify proper response. When the withdrawal switch is released note the amount of coast of the blade. It should not exceed 0.1". Insert the blade to less than one inch and verify that it drives properly.

3.8.2 Repeat procedures 3.8.1 with the two other drives and the regulating blade drive. If there is any abnormal behavior in any of these tests note this fact on the check-out list.

3.8.3 Manual Rundown:

Actuate the manual run-down switch. This should drive down all the safety blade drives and the regulating rod. The drive motors will shut itself off automatically when all blades are in. Verify that this has operated properly and then return the manual rundown switch to its normal "off" position.

3.9 Master Switch to Run

Turn the master switch to "Run" position. A horn will sound and will continue to sound for several seconds to warn individuals in the facility of an impending start up. In turning the key to "Run", a scram will have been initiated. By holding the alarm acknowledge button, the alarm will silence after the several second duration.

3.9.1 Magnet Current:

Press the scram reset button and verify that all three magnet current meters show magnet current.

3.10 Source Checks

It is the purpose of the source checks to verify that the detectors (CICs) are operating properly, that the amplifiers in the console are operating properly, that the scram circuits are operating properly and that the blades will actually scram; that is, that there is no mechanical binding anywhere in the system. The procedure is as follows:

3.10.1 Linear Percent Power Channel 1:

a. Adjust the range selector switches for Percent Power Channel No. 1 and No. 2 to at least 100 watts.

b. Withdraw blade No. 1 about 4 inches.

c. Remove the source from the source holder (grid position D-2)

d. Place the Linear recorder selector switch to record channel 2 so that the test will not be recorded.

e. Move the range selector switch for Percent Power Channel No. 1 to the 0.1 watt scale.

f. While the operator observes the scale, an authorized helper on the reactor bridge should swing the source bottle up against the column containing the CIC for channel No. 1. The bottle should be placed against the column at least a couple of feet above the top of the core box.. It should then be allowed to slide down the column very slowly until a reading is seen on the safety channel meter. The reading should be called out by the person at the console to guide the person on the bridge as s/he lowers the bottle downward, very slowly. When the meter reading reaches the scram point the reactor will scram, dropping the blades, and the alarm will sound.

g. The alarm horn may be acknowledged immediately by the reactor operator.

h. The scram point should be entered on the check-out sheet.

i. The source should then be maintained outside its holder so that the operator may perform the first rod inhibit check.

3.10.2 First Rod Inhibit Check:

It is the purpose of the first rod inhibit check to verify that the B-10 counter is in proper operation, that the source is in its proper location, and that the instruments on the console are reading the source neutrons in the reactor shut-down condition. Unless there is a reading on the Start-Up count rate meter of greater than 50 counts per second an interlock should prevent the withdrawal of the safety blades.

a. Reset the scram from the previous source check.

b. Turn the drive selector switch to blades 1, 2, and 3 and attempt to raise each of these blades. (They should not move).

c. With the drive selector switch set to blade No. 2, attempt to raise blade No. 2

d. While the raise switch is in the out position, have the assistant lower the source bottle into the reactor. If you have been making a rod inhibit check properly, as the source bottle goes into the source holder the reading on the Start-Up meter will go up above the 50 mark and blade No. 2 should start to withdraw from the core.

3.10.3 Linear Percent Power Channel 2:

a. Withdraw blade No. 2 to about 4 inches.

b. Set the Linear recorder selector switch to record power channel No. 1, so that the test will not be recorded.

c. Remove the source from the source bottle.

d. Move the range selector switch for Percent Power Channel No. 1 to the 0.1 watt scale.

e. Repeat the source check procedure for blade 2 and Percent Power channel 2 the same way it was performed for blade 1 and Percent Power Channel 1 (3.10.1.f, g, h,).

f. Return the source to the source holder, and reset the scram.

3.10.4 Log and Linear Channel:

a. Select blade No. 3 with the drive selector switch and withdraw it about four inches. This check is to verify the period scram is in proper operating order.

b. Verify that the range selector switches are at 100 watts.

c. Remove the source bottle from the source holder.

d. Slide the source bottle down the Log N chamber column at a velocity such that a period of about 6 seconds is obtained. (Too rapid motion will be unreadable and too slow will fail to produce a scram).

e. Verify a reactor scram at about a 8 second period.

f. Replace the source in the source holder.

g. Reset the scram.

3.11 Log N Linear Power Scram

Depress the 1mA switch on the calibration keypad of the Log-N Amplifier and verify the scram function. Note the scram setpoint on the right hand linear bar-graph. Reset the scram.

3.12 Second Rod Inhibit Check

The purpose of the second rod inhibit check is to assure that the reactor can only be taken critical using the regulating blade.

a. Select one of the three safety blades and withdraw it approximately one inch.

b. Simultaneously begin to withdraw the regulating blade. Note the control blade will no longer withdraw. Continue to withdraw the regulating blade beyond its in limit.

c. Stop driving out the regulating blade and verify that no control blade can be withdrawn.

3.13 Manual Scram

You have one blade now partially withdrawn from the core. Press the manual scram button. The reactor should scram and the withdrawn blade should drop in the core. Both the safety blade drive and the regulation blade should automatically drive in. When all drives are in, reset the scram.

3.14 Source Readings

Source readings should be taken and compared with the readings obtained on the previous operation.

3.14.1 Record:

Read and record the Start-Up meter reading for a one minute count on the scaler.

3.14.2 Compare:

Go to the start-up check list binder and record on your check list the readings obtained before the last critical run. These can then be compared to the readings that you have just taken and the agreement should be reasonably good or explainable (some variation with the previous readings is normal). For variations greater than a factor of two, note the cause or inform the SRO prior to start-up.

3.14.3 Reset:

Turn the scaler to the continuously operating condition.

3.14.4 B-10 Audible Signal:

Verify that the neutron count audible signal is functioning.

** Verify that all items on the check list have been filled in and sign the check list. **

II. OPERATING PROCEDURES

1. PERSONNEL REQUIRED:

One licensed reactor operator at the console and one other person present in the reactor facility. A licensed senior reactor operator shall be readily available on call.

2. REACTOR START-UP:

2.1 If the check out was performed earlier in the day verify the checkout was completed and signed. Turn the console key lock to the operate ("Run") position and visually note that all console conditions are normal.

2.2 Open the log and note the names of the operator at the panel, senior operator, and others who are directly involved in the reactor operation. Record that the check out has been completed and note the condition of the Ar-41 monitor system and the security condition of the 2nd and 3rd floor rooms above the reactor. Note the pool temperature and any in-core experiments. If operation above 1 kW is expected, refer to Part 3 of this procedure.

2.3 Withdraw the control blades observing the status and proper operation of all instruments on the control panel. During withdrawal of the third blade provide due caution in observing the status of the reactor.

2.4 Continuously monitor the Log Count Rate meter and the scaler. As the count rate meter builds up to near full scale on the meter, raise the proportional counter assembly to an elevated portion such that it still reads on scale.

2.5 Begin withdrawal of the regulating blade after all the control blades are out. As criticality is approached, monitor the period meter and power indications closely.

2.6 When the linear Percent Power channels and Log N indications are on scale, the

B10 may then be fully removed from the neutron flux if desired.

2.7 Observe the safety channels, switching to the next higher range as required.

2.8 Establish criticality with the source "in" or "out" at the option of the operator in charge and at the desired power level.

3. OPERATIONS ABOVE 1 KW:

3.1 Secure the 2nd and 3rd floor rooms above the reactor by verifying the rooms are evacuated and locked.

3.2 Follow the posted procedure to energize and check the AR-41 monitor.

3.3 Energize the thermal column and beamport exhaust fans by plugging them into the appropriate outlet.

4. REACTOR SHUTDOWN:

Shutdown may be by scram or manual rundown of the blades. Complete the reactor Shutdown Checklist and attach it to the Pre-Critical Checklist.

4.1 Turn the "Manual Run Down" switch to the right (run down) position. Lower the start-up detector into the core as necessary to maintain adequate neutron counts. When all three "in" lights of the control blades are illuminated, return the switch to the left (off) position. If manual scram is used for shutdown, be sure all magnets are driven all the way down before shutting down the console unless maintenance is planned.

4.2 Turn the key switch to "OFF", remove the key and give it to the SRO.

4.3 Leave the reactor panel circuit breakers closed. Turn the recorders off and lift up the pens.

4.4 For operations above 1 Kw, de-energize Ar-41 monitor and exhaust fans. Unsecure the upstairs rooms.

5. FORMS AND RECORDS:

5.1 Records should be kept of all checkouts, major maintenance, and tests performed on the reactor instrumentation. Completed Pre-Critical Checklists, signed by the licensed operator responsible for the checkout, should be kept on file. Upon termination of the day's operations, the method of shutdown should be noted and the operator and supervisor should both sign the log.

5.2 The operating log should be a detailed record of the critical operation. In addition to the items in 2.2 of this procedure, important changes in operating level and/or major adjustments to instrumentation should be noted as they are made.

5.3 All records shall be maintained in accordance with NRC regulations.

6. MAINTENANCE:

Major maintenance work must be supervised by the Reactor Facility Director or a senior operator and follow the provision the Worcester Polytechnic Institute Technical Specification 3.2 and 5.1 of this procedure. Whenever applicable, WPI Reactor Maintenance Procedures should be used.

END RHSC - Nov. 1983

WORCESTER POLYTECHNIC INSTITUTE OPEN POOL TRAINING
OPERATION PROCEDURE OP-2
EVACUATION PROCEDURES

The Nuclear Reactor Facility operates under a federal license issued by the United States Nuclear Regulatory Commission. As a condition of this license all persons routinely using the Washburn Laboratory must be apprised of the evacuation procedures for the reactor facility.

Copies of the evacuation procedures and authorized personnel who are called in case of emergency are posted in key locations through Washburn Laboratories. When the warning horns sound the primary function of staff members in the building is to leave the building immediately and to evacuate other persons hey may see in the building as they are leaving. In particular, visitors, workmen, service people, and other transients should be evacuated immediately along with the students. It is the function of authorized members of the Radiation, Health, and Safeguards Committee to determine the reason for evacuation and corrective measures needed. All other personnel are simply to leave the building and encourage others to do so. Faculty members are also requested to review the evacuation procedures with each new student class using Washburn and to stress to the students the necessity for prompt evacuation if a warning is sounded.

As a condition of our license we must hold an occasional evacuation drill. These drills are customarily witnessed by members of the Radiation, Health, and Safeguards Committee and a complete report on the effectiveness of the drill and the response of all personnel to it must be maintained in our files for the inspection of the Nuclear Regulatory Commission. Your cooperation during these drills will be appreciated.

Although the WPI reactor is designed with tremendous safety factors, it is worth noting that the 10 Kw max power level is a legal not a physical limitation. The reactor's capacity for disaster, either physical or public relations-wise is considerable.

Your cooperation in complying with our safety regulations and in observing the reactor evacuation procedures is very much appreciated.

RHSC - Nov. 1983

WORCESTER POLYTECHNIC INSTITUTE OPEN POOL TRAINING
OPERATING PROCEDURE OP-3
FUEL UNLOADING PROCEDURES

1. PREFACE:

This procedure pertains to the unloading of the individual reactor core fuel elements to the non-critical geomentry racks.
Instances for unloading include:

- annual bade and control drive inspections
- laboratory excercises.

2. PERSONNEL REQUIREMENT:

At least three persons shall be present for fuel unloading. One licensed operator must be at the console and one must be in the bridge area before fuel removal may begin. A third person must also be present. A senior operator must be present during the unloading operations.

3. PROCEDURE:

3.1 Perform a reactor check-out in the normal fashion using the Pre-Critical Checklist.

3.2 Pull two control blades (usually 1 and 3) to 15 inches.

3.3 Using the hook grapple, remove the fuel elements one by one and place them in the fuel racks. The location of each element at the time of its removal and indication of its respective location on the non-critical geometry rack shall be recorded in the log book.

3.4 When all fuel has been properly deposited in non-critical geometry racks the blades may be dropped and maintenance and inspection procedures for the rod drives may begin.

RHSC April 1992

1.PREFACE:

This procedure pertains to the reloading of the reactor core to a standard configuration. A standard configuration is one which has been previously loaded and for which an excess reactivity measurement has been previously made.
Instances for reloading to standard configuration include:

- Reloading following annual control blade inspections
- Laboratory exercises involving determination of critical size (standard configuration)

2. SCOPE:

This procedure does not apply to the loading of a reactor core configuration whose nuclear properties have not been determined from prior measurements. Procedures for loading a new configuration are delineated in Technical Specification 5.10.

3. PERSONNEL REQUIREMENTS:

At least 3 persons shall be present for fuel loading. A licensed operator shall be at the console and a licensed operator shall be at the bridge. A senior operator shall either perform or supervise the entire loading procedure.

4. PROCEDURE:

4.1 Perform a rector safety system checkout.

4.2 In accordance with Table 4.1 of the Technical Specifications, adjust the neutron count rate set point as necessary to bypass safety blade withdrawal interlock.

4.3 Pull two control blades(usually 1 and 3) to 15 inches.

4.4 Fuel elements shall be moved one at a time with the fuel grappling tool.

4.5 The console operator shall be informed by the operator at the bridge as each fuel element is moved.

4.6 Each fuel element number shall be verified before the element is replaced in the core. The fuel element number and placement within the core grid shall agree with that of a standard core configuration. A diagram of the most recent standard configuration shall be located at the back of the Log Book. A copy of each previous standard configuration, along with its excess reactivity measurement, shall be kept on file.

4.7 The location of each element at the time of its removal and indication of its respective location on the grid plate be recorded in the log book.

4.8 The loading of the last half of the core shall proceed with fuel being loaded nearest the grid box center first and then proceeding outward.

4.9 A criticality check shall be performed after each loading of the last three fuel elements. For a discrepancy of the critical configuration or large discrepancy in the critical control blade height, the reactor shall be shutdown and an investigation performed and cause determined before operations continue.

4.10 Following fuel load completion and determination of critical blade heights, an excess reactivity measurement shall be made and compared to previous operations.

4.11 In the case where fuel elements are removed and reloaded one at a time (i.e. flux plots, etc.) steps 8, 9, and 10 may be omitted. A critical blade height check shall be performed at the completion of all movements.

RHSC - July 1989

1. PREFACE:

In performing these experiments, the core must be free of experiments. The total blade worth is the sum of subcritical worth, corrected for source worth, and excess reactivity. All data are to be recorded and the final result of excess reactivity and total blade worth is listed in the back of the reactor log book.

2. SUBCRITICAL BLADE WORTH MEASUREMENT:

2.1 Starting with all of the safety blades out and the regulating blade fully in, take an initial count on the startup channel with the source in and the B-10 detector raised one notch. Because of delayed neutrons, an average of five counts should be taken and compared with previous counts to verify that the count rate has stabilized.

2.2 Move the reg. blade to a position approximately two inches below the estimated critical position and take a second stable count.

2.3 Bring the reactor critical at a low power level, remove the source and reestablish criticality, then insert the source without any blade movement. Allow about thirty seconds for the period to stabilize and then record the power level and time. Approximately one minute later, record the new power level and elapsed time.

2.4 Withdraw the blade the same amount above the critical position as the last subcritical position was below criticality. Allow 30 seconds for stabilization and record time and power level. Approximately one minute later record the elapsed time and power level.

2.5 The supercritical worth is calculated for both the source measurement (step 3) and blade measurement (step 4) by the use of the Inhour equation. The supercritical worth is then taken to be equal to the last increment subcritical worth, and a C0 calculated using the equation:

$$C0/C = 1 - K_{eff}$$

Where C is the count at the interval. The new C0 is taken used with the first count in this equation to determine reactivity worth.

3. EXCESS REACTIVITY MEASUREMENT:

3.1 Bring the reactor critical at a low power level, preferably below 5 watts, with the B-10 detector withdrawn to its highest position and the source out.

3.2 Raise the regulating blade a small amount, less than 5 inches.

3.3 When a stable period is established, a time and corresponding power level are recorded. After at least one minute a new time and power level are recorded.

3.4 Then insert a safety blade just sufficiently to bring the reactor back to critical.

3.5 Repeat steps 3.2 through 3.4 until the regulating blade is fully withdrawn. The power level should be kept below 800 watts during the measurements, and may be reduced periodically by driving in the regulating blade until power is reduced and then returned to its previous position.

3.6 The reactivity worth of each portion of blade removed may be calculated from the Inhour equation either by hand or by computer program. The sum of the reactivity increments represents the loaded excess reactivity of the core.

RHSC -July 1989

WORCESTER POLYTECHNIC INSTITUTE OPEN POOL TRAINING
OPERATING PROCEDURE OP-6
POWER LEVEL CALIBRATION PROCEDURES

1. The reactor power level is calibrated by irradiating a gold foil in the sample holder position for a predetermined time (Ti) and counted using a Ge detector mated with a multichannel analyzer). The detector should be calibrated using a multi-element standard at the same geometry as the gold foil to determine the efficiency (n) at thee gold photopeak energy (411 Kev). The dead time of the MCA should be kept below 10% during all measurements.
2. The power level is determined using the equation:

$$\text{Power (W)} = \frac{\text{cpsAu } (3.57E\text{-}7)\exp(0.257 \text{ Td})}{\text{mAu } [1-\exp(-1.79E\text{-}4 \text{ Ti})]n}$$

3. Where cpsAu is the net counts per second under the photopeak at 411 Kev, Td is the time of decay of the gold from irradiation to count in days, mAu is the mass of the Au foil in grams, and Ti is in minutes.
4. The number 3.57E-7 is derived from flux distribution and cadmium ratio measurements based on the loading of the 21 1/3 element core, and may be updated as more measurements are made or if the core configuration changes.
5. After the power level is determined, the position of the compensated ion chambers are adjusted as needed to give a proper indication.

The results of the calibration will be recorded and reported semiannually to the RHSC in the april and october meetings.

RHSC - Nov. 1983

WORCESTER POLYTECHNIC INSTITUTE OPEN POOL TRAINING
OPERATING PROCEDURE OP-7
ROD DROP MEASUREMENT PROCEDURE

1. PREFACE:

Magnet release and rod drop measurements are made by feeding a standard repetitive signal into two scalers simultaneously.

2. PROCEDURE:

2.1 A blade is withdrawn to a predetermined height and a microswitch is set to be triggered at that position. The rod is then withdrawn an additional amount (delta h) to its highest position.

2.2 The "blade engaged" switch in the magnet head is connected to the signal generator circuit.

2.3 A scram signal is generated by using the neutron source placed close to a detector such as CIC 1 in safety channel 1.

2.4 The scram output signal from the appropriate pico ammeter goes to the signal generator circuit.

2.5 When a scram signal occurs both scalers begin to count. When the magnet engaged switch in the magnet opens, one scaler stops counting. When the blade has fallen a predetermined distance the second scaler shuts off.

2.6 Dividing the recorded count on each scaler by the appropriate constant gives the counting time for that scaler. For example, if the signal frequency is 75,000 cpm, dividing the scaler reading by 12.5 gives the time elapsed in milliseconds.

2.7 The difference between the overall time to be released and drop delta h, minus the release time, is the time to drop the distance set (delta h). RHSC - July 1985

WORCESTER POLYTECHNIC INSTITUTE OPEN POOL TRAINING
OPERATING PROCEDURE OP-8
ROD WITHDRAWAL MEASUREMENT PROCEDURE

The amount of time required for the withdrawal of a control blade or regulating blade a certain distance should be measured at least annually. In measuring control blade withdrawal, each blade is timed for a withdrawal of 7.5 inches. Any time recorded of less than one minute requires adjustment of the blade withdrawal system. Regulating blade withdrawal is similarly tested for a withdrawal of 4 inches.

RHSC - July 1989

WORCESTER POLYTECHNIC INSTITUTE OPEN POOL TRAINING
OPERATING PROCEDURE OP-9
SHUTDOWN MARGIN MEASUREMENT PROCEDURE

1. PREFACE:

The worth of each safety blade is well over 1% DK/K, so that the removal of any safety blade in addition to the highest worth blade with the reactor remaining subcritical will verify that the shutdown margin is greater than 1%. The highest worth blade as well as the worths of the other blades will be determined upon initial loading of the fuel in the configuration to be measured.

2. PROCEDURE:

The shutdown margin is to be determined by verification that the reactor is subcritical with the highest worth blade, the regulating blade and one other safety blade out. When this blade configuration is reached, the source is removed and a decreasing count rate on the startup channel is verified.

The results of the shutdown margin measurement will be recorded and semiannually reported to the RHSC during the April and October meetings.
RHSC - Nov. 1983

WORCESTER POLYTECHNIC INSTITUTE OPEN POOL TRAINING
OPERATING PROCEDURE OP-10
FUEL INVENTORY
Fuel inventory forms are to be submitted to the NRC twice a year confirming the WPI fuel and Pu holdings as of March 31 and September 30. In addition, the facility director, the radiological safety officer, or an appointed representative of the RHSC shall annually verify all fuel element locations by visually establishing the fuel element number engraved on each element both in the core and in storage. Confirmation that this inspection has been carried out will be made on report from 13 submitted annually at the July meeting of the RHSC.
RHSC - OCT. 1992

WORCESTER POLYTECHNIC INSTITUTE OPEN POOL TRAINING
OPERATING PROCEDURE OP-11
LOG BOOK ENTRY PROCEDURES
For clarity and consistency, it is requested that log book entries be made in the following way.

1. REACTOR CHECK-OUT:

1.1 Log the date and time when the key goes into the console and when the master switch is placed to test.

1.2 Log your name and license type. For ROs, note who the SRO is. If the SRO is not the second person in the facility, log who is.

1.3 Log when the key goes to on.

1.4 Log when the checkout is complete. If a startup is not proceeding, note when the switch is placed to off and that the key is removed.

2. PRIOR TO REACTOR STARTUP:

2.1 If the startup is not preceded by the checkout (ie. for a checkout performed earlier in the day), re-do step 1.2.

2.2 Log the status of the following:

2.2.1 Upstairs rooms.

2.2.2 Argon-41 monitor.

2.2.3 Pool temperature.

2.3 Note if experiments are already in the core or changes to the beam tube or thermal column status.

2.4 Log any changes to equipment or core status or temporary changes to procedures in accordance with T.S. 5.5.

2.5 Log the purpose of the operation and the expected power level.

3. REACTOR STARTUP:

3.1 Log time of initiating blade withdrawal and blade number.

3.2 Log time when blade is fully withdrawn and height.

3.3 Repeat (a) and (b) for all blades. For blade #3, note time and height at which the B-10 detector is moved up.

3.4 Log when the reactor is critical (supercritical) and when the B-10 detector and startup source are removed.

4.REACTOR OPERATION:

4.1 Log the steady state power level indicated on all channels.

4.2 Log the critical regulating blade height. Note any changes to this height during steady state operation.

4.3 Log manual changes in power. Include: method of change, new power level, and new critical blade heights.

4.4 For sample insertions, log the following:

4.4.1 Time of insertion and sample facility.

4.4.2 Material description.

4.4.3 Sample mass.

4.4.4 Expected irradiation time.

4.4.5 Approximate reactivity effect (see NOTES below). State if there is no noticeable reactivity change.

4.4.6 Time of removal.

5. NOTES:

5.1 Samples

5.1.1 For the maximum sample worth of $0.25 (0.193%dk/k) the resultant prompt drop/jump power factor will be 1.33. The resultant stable positive period would be ~30 seconds.

5.1.2 For a sample worth of $0.10 (0.077%dk/k) the resultant prompt drop/jump power factor will be ~1.10. The resultant stable positive period would be ~100 seconds.

5.1.3 LOG ALL IRRADIATIONS IN THE ACTIVATION LOG BOOK USING THE ACTIVATION LOG GUIDELINES.

5.2 Log changes in operator status (ie. console operator, SRO location, etc.).

5.3 Reactor Scram

5.3.1 Place an * next to the entry and log time, cause, and corrective actions if any.

5.3.2 Complete scram listings in back of log book.

5.4 Reactor Shutdown

5.4.1 Log time and mode of shutdown.

5.4.2 Log when all blade drives are full in.

5.4.3 Log when master switch placed to off and key is removed.

5.4.4 Sign the log book after the last entry.

6. EXAMPLE ENTRIES:

4/5/
92

0800 Key in. Master switch to test. C. Brown RO on console. A. Einstein SRO at HL101. L. VanPelt, student is in facility.
0808 Master switch to on.
0823 Checkout is complete. Upstairs unsecured. Ar-41 monitor is off. Pool temperature is 73 F. No experiments in core. Operation for NAA of zeolite samples. Power level to be 750 watts.
0825 Pulling blade # 1.
0829 Blade # 1 is full out at 30.34". Pulling blade # 2.
0834 Blade # 2 is full out at 30.41". Pulling blade # 3.
0837 Blade # 3 stopped at 20.12". B-10 up one notch. Resumed pulling blade.
0839 Blade # 3 full out at 30.37". Pulling reg. blade.
0843 Reg blade stopped at 12.51". Reactor supercritical. B-10 removed and source removed.
0844 Raising power to 750 watts.
0849 Reactor critical at 750 w Ch 1, 740 w Ch 2, 700 w Log. Reg blade at 12.63".
0853 Reg blade adjusted to 12.68".
0854 Cu zeolite, 0.432 g placed in core pos. F-3 for 5 min. No reactivity effect observed.
0859 Sample out.
0901 Raising reg blade to increase power to 1 kw for student demonstration.
0909 Reactor critical at 1 kw Ch 1, 970 w Ch 2, 1 kw Log. Reg. blade at 12.71".
0915 Starting reactor shutdown via manual rundown.
0920 All blades full in. Master sw. to off. Key removed.

---

[i] All information about the WPI Nuclear Reactor and the WPI Nuclear Reactor Facility is taken from the WPI Nuclear Reactor Facility Final Safety Analysis Report as submitted to the USNRC in 1979 and revised in 1988 due to the HEU to LEU switch.

[2] http://rrdjazz.nist.gov/

[3] http://www.nrc.gov/NRC/CFR/index.html