

SOFTWARE QUALITY ASSURANCE PROJECT FOR REACTOR PHYSICS CODES AT THE POINT LEPREAU GENERATING STATION

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ABSTRACT

One of the ongoing challenges faced by the Nuclear Industry is Software Quality Assurance (SQA). In this paper, a project to address SQA issues in the Reactor Physics Group at the Point Lepreau Generating Station (PLGS) will be discussed. The work illustrates a process which could be implemented at any facility to achieve code compliance to CSA Standard N286.7 requirements.

1.0 INTRODUCTION

1.1 Background

Many of the activities of the Reactor Physics Group at the Point Lepreau Generating Station are computer-based. Almost all of these activities, should they be performed in error, have the potential to directly infringe, or cause to be infringed, one of the Operating Policies and Principles (OP&P) or compliance limits that the group is charged with managing. Possible errors may arise in any phase of the software life-cycle. Examples include: flaws in the underlying physical models that remain undetected because of insufficient validation; failure to properly implement version control, both of the software, and also the input representations; and failure to properly process input or output data.

In this environment where the software used may be described as “mission critical”, there has been a realization at PLGS consistent with national and international trends, that improvements are necessary in all aspects of the management of the software lifecycle. Guidance in appropriate management measures can be found in a variety of national and international standards. The approach taken at PLGS has been to develop internal procedures that, if followed, will ensure that the requirements of CSA N286.7 - Quality Assurance of Analytical, Scientific, and Design Computer Programs for Nuclear Power Plants^[1] are met. The internal procedures are described in three station instructions:

- *SI-01365-T82, "Quality Program for Analytical, Scientific, and Design Computer Programs"*^[2];
- *SI-01365-T83, "Development of Analytical, Scientific, and Design Computer Programs"*^[3]; and
- *SI-01365-T84, "Acceptance, Version Control and Configuration Management of Analytical, Scientific, and Design Computer Programs"*^[4].

These new procedures were implemented in 2001. At that time, the PLGS Reactor Physics Group with assistance from Atlantic Nuclear Services Ltd. (ANSL) commenced the Software Quality Assurance (SQA) project to ensure code compliance with N286.7. Due to the size of the project, it was planned over a four year time frame.

1.2 Code Usage in the Reactor Physics Group

The main Reactor Physics codes are linked under an interface application called Frontend. Modules of Frontend mirror Reactor Physics procedural routines executed on a scheduled basis. These cover specific processes such as detectors and instrumentation, flow verification, control, power, poison, as well as special cases such as compliance, calibration, outage, and upset.

Frontend acts as a central control panel through which all the routines can be executed semi-automatically and in sequence. The program also acts as a guide presenting current departmental procedures and software documentation via its configuration management database. It is also an information panel, an alarm panel for scheduled runs and an error or data consistency checker. This leads to efficiency, consistent runs, consistent datasets, less random error, and ultimately safety.

2.0 PROJECT METHODOLOGY

The SQA project was divided into two phases. The first phase of the work involved developing an inventory of all the codes used by the Reactor Physics Group and determining the general level of compliance of each code to SQA requirements. This phase was used as a baseline for the second phase which encompassed all work required to bring the codes into compliance.

2.1 PHASE I

2.1.1 Creating an inventory

The first step of Phase I was to inventory all codes used by the Reactor Physics Group. Using existing information and information gathered from Reactor Physics staff, an initial list of 95 codes was tabulated. From the list, a database was created which included the name of each code, the name of the person responsible for the code (Primary Holder), the type of code and the code group or process that it was associated with. An excerpt of the database is shown in Table 1.

Table 1: Excerpt from Reactor Physics Code List.

Code	Primary Holder	Type of Code	Process
AR_VB	René Cusson	VisualBasic 5	RFSP PRODUCTION RUNS
FUELSTAT	Rick Sancton	Spreadsheet	RFSP PRODUCTION RUNS
LOFUDE	Rick Sancton	Fortran77	PROCESS DN SCAN DATA
MARGREP	René Cusson	VisualBasic 4	RFSP PRODUCTION RUNS
ROPDC	Dean Taylor	Fortran77	PRODUCE ROPDC REPORT
SSTATE	Tim Whynot	Fortran77	FLOW VERIFICATION

2.1.2 Determining the level of compliance

The Reactor Physics Group maintained a binder of associated documentation for each code. The available documentation as well as process flow sheets and procedures were reviewed to determine the current level of compliance of each code to Station Instructions, and thus N286.7. The information discovered was added to the inventory database.

It was recognized that the existing information did not necessarily present itself in the style of the discrete documents required. For example, for a given code, those elements that could be considered to be the required content of a User's Manual may well be intertwined with those that may be considered to be the required content of a Programmer's Manual. Judgment was applied in determining whether the mixed documentation was adequate and whether the individual components were sufficiently comprehensive.

If a new code was identified during the review of the code binders, it was added to the inventory. Consideration of all the Reactor Physics Group computational tools that could have a bearing on OP&P and license compliance issues, including numerical/scientific software, data handling routines, scripts and spreadsheets, yielded a final inventory of 132 items. This total does not include simple batch files used to move data to appropriate directories for processing or archiving.

2.1.3 Grouping the codes by process

Having determined the available information for each of the codes, the process of filling in the gaps could be planned. Due to the large number of codes, it was decided to further organize the codes in a more efficient manner. This entailed grouping the codes into logical packages.

With the guidance of the Reactor Physics staff, the codes were divided into a number of code groups. These code groups consisted of meaningful categorizations of codes, that is, codes that are used as part of a sequence of calculations were kept together. The code groups generated are shown in Table 2.

Table 2: Reactor Physics Code Groupings.

Group #	Group Name
1	RFSP Production Runs
2	RFSP Predictive Runs
3	Fuel Channel Selection
4	Determine Bulk Power Limits
5	Produce ROPDC Report
6	Generate Quarterly Report
7	Process DN Scan Data
8	Poison Tracking
9	ROP TSPS/TAP Update
10	Core Decay Power Calculation
11	Produce Irradiated Fuel Properties
12	Produce Station Heat Balance
13	Flow Verification
14	Weekly Flux Calibration
15	Semi-Annually Flux Calibration
16	Tracking HTS Ageing
17	Monthly & Quarterly Report Fuel Management
18	RTD Bias Calculation
19	General Analysis Tools
20	Flux mapping Performance
21	Core Model Development and Maintenance
22	Reactor Transients and Upset Analysis
23	Flux Detector Health Monitoring
24	Outage and Run-up Monitoring

Codes that did not fit into a specific process were combined into Group 19 – General Analysis Tools.

2.1.4 Phase I Results

Upon completion of Phase I, the level of compliance was known for the 132 codes identified in the Reactor Physics Group. For many of the codes, little or no documentation could be located. If current Station Instructions were strictly applied, most codes would not have the required documentation. This was expected as the Station Instructions were recently implemented and most of the codes had been developed and revised internally over the life of the Station. In most cases, the documentation found would fall under what is required for a typical User's Manual. However, even though these documents covered some of the required information, certain elements were often missing.

2.2 PHASE II

Having assessed the status of each of the codes in Phase I, a baseline had been established. The next phase of the project was to bring all of the currently used codes into full compliance with CSA-N286.7.

2.2.1 CSA - N286.7 requirements

The scope of CSA N286.7 is stated as follows:

This Standard specifies requirements for the quality assurance program applicable to the design, development, maintenance, modification, and use of analytical, scientific, and design computer programs that are used in nuclear power plant applications. Such computer programs are used to perform or support:

- (a) design and analysis of safety-related equipment, systems, structures, and components as identified by the owner;*
- (b) deterministic and probabilistic safety analyses and reliability studies;*
- (c) reactor physics and fuel management calculations; and*
- (d) transfer of data between computer programs or pre- or post-processing calculations associated with (a), (b), and (c) above.*

The Standard requires documentation, verification and control throughout the software life-cycle. The previously mentioned Station Instructions^[1,2&3] were written to achieve compliance with N286.7. The Instructions described the process of software development, modification and control on a practical level. The major documents required are: Theory Manual, Programmer's Manual, User's Manual and Validation Report. Other documents include: Change Control Plan, Release Plan and Configuration Management Plan.

2.2.2 Achieving CSA - N286.7 compliance

With assistance from Reactor Physics staff, the codes were prioritized with the most urgent codes being worked on first. The prioritization was by Code Group, although a few important codes were handled individually. Some of the work to achieve code compliance was done in-house by the Reactor Physics Group but most of the work was contracted to ANSL.

It is important to note that some of the codes identified in Phase I were not included in the scope of Phase II of the project. For example, codes such as RFSP and MCNP developed by third parties such as Atomic Energy of Canada Limited (AECL) and Oak Ridge National Laboratory (ORNL) Code Library respectively were not included. These purchased codes represented approximately ten percent of the total number of codes. Any required documentation for these codes was sought from the developer. As well, a few codes were deemed obsolete or no longer required and were removed from use and archived.

Since the codes were already in use, the work was technically considered as code modifications as opposed to new code development. However, modifications to the source code were beyond the scope of the project. In a few cases where code deficiencies were found during verification and validation, SQA work was suspended until the code was revised so that work could continue.

To simplify the documentation process, it was decided that the small scripts and codes (both pre- and post- processors) could be essentially treated as part of or an extension of the parent code. For example, the codes BLIMP and BLIMP Runner were handled as one set of documentation. This approach was used as long as the documentation was comprehensive enough to cover all functionality.

Common sense had to be applied when developing SQA documentation. For example, it may not be necessary to include a Theory Manual for a data-handling script file, nor to provide a Design and Development Plan for a spreadsheet calculation. Each code by its nature and the documentation available was unique. A basic approach was developed which could be customized for each code. The steps described below are typical of a relatively large code with little conforming documentation available.

- i. The first step required was for the Primary Holder to freeze the entire code group until all of the SQA documentation had been completed and issued. For tracking purposes, all codes were simply identified by their name and version number. Due to the time required to perform the work, the codes remained in use.
- ii. All code and related files (source, executable, data files, etc.) and associated code documentation, including departmental procedures were provided to ANSL. For each code group, ANSL assigned a Code Coordinator to act as the principal developer of documentation. This person interacted with the PLGS Primary Holder on technical issues and reported to the ANSL Project Manager. As needed, the Code Coordinator was assisted by other qualified ANSL staff.
- iii. The Code Coordinator reviewed the code group and any existing code documentation or procedures. In some cases, a demonstration of the code at PLGS was required. Even though it was determined in Phase I that documentation existed for a particular code, it did not mean that this documentation actually reflected the current code in use. At this stage, a review of the code itself was also required.
- iv. A work plan was developed for the code group. It consisted of a Computer Program Feedback Form and a Change Control Plan. The deficiencies found in Phase I were sighted as a nonconformance on the Computer Program Feedback Form. Once signed by the Primary Holder, this form initiated SQA documentation development process. The Change Control Plan defined the work necessary to correct the nonconformance described on the Feedback Form. It specifically identified the documents which needed to be developed and/or modified. Typically, the following seven documents were produced for each code:

1. Change Control Plan
 2. Theory Manual
 3. Programmer's Manual
 4. User's Manual
 5. Validation Report
 6. Configuration Management Plan
 7. Release Plan
- v. All documentation created was done following PLGS procedures. For this type of project, PLGS issues Information Reports (IR's) which are electronically available on the Station's intranet. For each document to be developed, a document number and template were issued by PLGS Document Control to the Code Coordinator. In cases where some documents existed for the current version of the code, the information was inserted into a new IR template and the revision numbers of the documents were incremented. This was done to maintain a consistent package of documents for each code.
- vi. Document reviewers and approvers were assigned at this point. Typically, the reviewer was the Primary Holder of the code and the Approver was the Supervisor, Reactor Physics.
- vii. The documentation development process required a significant amount of interaction between the Code Coordinator and the Primary Holder. Interim drafts were exchanged during development to acquire input and comment.
- viii. Many codes required verification and/or validation activities. Verification activities could consist of line-by-line examination of code, the review of critical formulas, parameters, limits, etc. and the use of sample problems. Validation activities could include the use of experimental data other than that used to develop correlations, commissioning data and operating data, hand calculations, bench mark tests, closed mathematical solutions, and results from another validated code. Validation provided sufficient information to permit the determination of uncertainty allowances with respect to the intended application. Validation activities often required plant data and input data/parameters as well as assistance from PLGS staff to act as independent technical reviewers.
- ix. Once final drafts of all code documents were complete, the documentation was sent to the Reviewer with a formal Comment and Disposition Form. Feedback and comments were incorporated as required.
- x. The final step was to gather signatures on the documents and have PLGS Document Control issue the formal documents.

3.0 RESULTS

The SQA project is expected to be completed by the end of March 2005. The most obvious tangible results of the SQA project are the few hundred documents created to support the codes and code users in the Reactor Physics Group. There are also numerous other benefits stemming from this project, such as:

- The Reactor Physics Group's has achieved code compliance to N286.7 and can undergo scrutiny from internal, external and regulatory assessments.
- Deficiencies discovered during the project have been fixed or scheduled for corrective actions. As well, areas for improvement have been identified. This has lead to better codes and processes.
- With the codes having undergone recent verification and validation activities, there is increased confidence in the output.
- Complete documentation is now available for training new staff members.

The SQA project required a great deal of time and resources. To obtain the long-term benefits of this project, the Reactor Physics Group must make a concentrated effort to maintain the codes.

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