Quality Assurance Implementation and Effectiveness for the CANDU 9 Program

by
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Abstract

This paper describes the Quality Assurance Program, its implementation and effectiveness for the CANDU 9 Program, a major pressurized heavy water reactor engineering effort which accounted for over 450 person-years of work. The paper outlines the CANDU 9 evolution during the 39-month long basic engineering program, and elaborates on the key processes which contributed to CANDU 9 quality: design verification, feedback to design, change control, training, program reviews and audits. How the quality assurance program was organized and documented by the CANDU 9 *Quality Assurance Manual* and procedures, is also described in the paper.

1. Introduction and Background

CANDU® (**CAN**ADA **D**euterium **U**ranium) pressurized heavy water reactors (PHWR), which have the reputation of being one of the world's most successful nuclear reactors, have been operating since the early 1970s. The CANDU 9 reactor is a single-unit, stand-alone version of proven technology, updated with relevant features resulting from ongoing Canadian research and development.

The CANDU 9 design evolved from the multi-unit Bruce and Darlington nuclear generating stations built and operated by Ontario Hydro during the last quarter century. A stand-alone unit of CANDU 9 will have a gross output of 945 MWe. Its basic engineering program (BEP), which started in January of 1995 and concluded in March of 1998, was a major engineering effort, and accounted for over 450 person-years of work. The BEP objectives were to provide assurance that the single unit adaptation from the four unit Ontario Hydro plants was solid and reasonable from the technical and economic standpoints; that CANDU 9 was licensable in Canada; and to develop confidence that a project schedule of 83 months from the contract effective date (CED) to the commercial operations date (COD) was achievable. Upon meeting the basic engineering program objectives in March of 1998, the CANDU 9 Program continued to seek improvements which would enhance product competitiveness and reduce risks for the first CANDU 9 project.

2. CANDU 9 - A Quality Organization

An effective Quality Assurance Program has been in place during the full duration of the CANDU 9 Basic Engineering Program. The Quality Assurance Program evolved over the 39-month period to reflect CANDU 9 changing needs, AECL's corporate restructuring, and technological advancements. The CANDU 9 Program moved quality centre stage (figure 1), from having a quality organization to being a quality organization. Quality improvements and enhancing the CANDU 9 competitiveness became the business of every staff member. In order to enhance its competitiveness, the competence and work processes of the CANDU 9 staff had to be continually assessed and improved, as necessary. It was recognized that competence grows under conditions in which it is required, invited, and nurtured. Competence leads to quality and excellence. The CANDU 9 road to excellence had four major milestones: awareness, understanding, participation, and commitment.

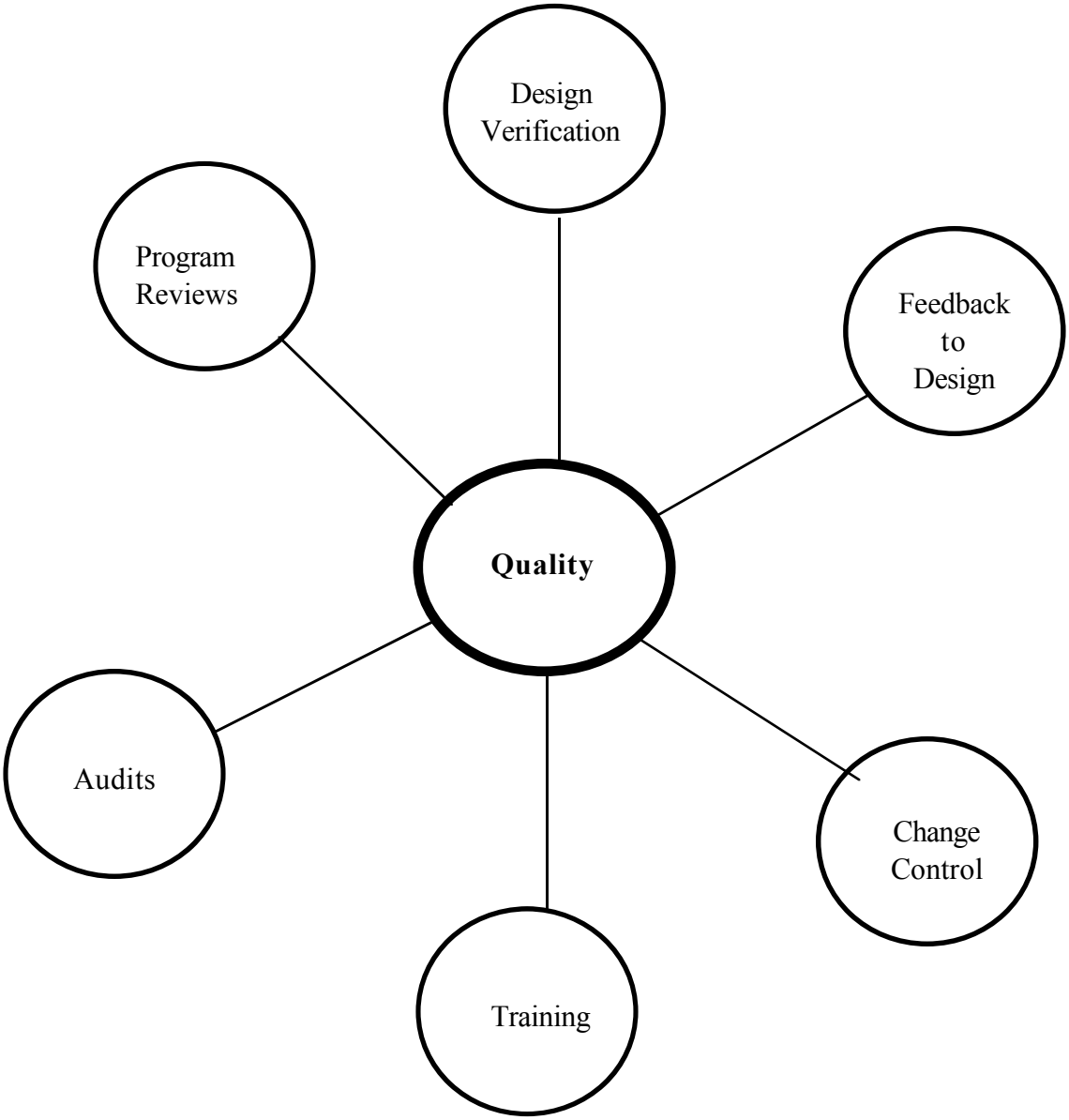

Fig. 1. Quality is at centre stage for the CANDU 9 Program

The CANDU 9 road to excellence was driven by the following business realities and imperatives:

- Supplying the customers with products and services of the highest quality and lasting value to maintain their trust, confidence and loyalty,
- Continuously improving work methods, practices and processes; and developing innovative products and services which meet the customers' requirements and exceed their expectations,
- Motivating all staff members to achieve their full potential by recognizing their individual and team initiatives and creativity, and
- Encouraging all staff to participate in quality improvement initiatives.

3. CANDU 9 Quality Assurance Program

CANDU 9 was committed to conduct all its operations under a well established quality program which was documented in the CANDU 9 *Quality Assurance Manual* and its supporting documents. They meet requirements of the following Canadian standards:

- *Design Quality Assurance for Nuclear Power Plants* (CAN3-N286.2), and
- *Quality Assurance of Analytical, Scientific and Design Computer Programs for Nuclear Power Plants* (CAN/CSA-N286.7).

The CANDU 9 quality assurance manual and supporting documents also comply with the following higher level corporate manuals:

- *AECL Management Manual* (AMM),
- *Research and Product Development, Unit Management Manual* (UMM), and
- *Corporate Quality Assurance Manual*, and
- Generic company quality assurance manuals for
    - Design, and
    - Analytical, scientific and design computer programs.

The CANDU 9 *Quality Assurance Manual* is supported by a specific set of applicable procedures, and identifies links between those procedures, corresponding sections of the manual, and chapters of the standard. The management of the CANDU 9 Program expressed their commitment to implement and maintain the program described in the manual. The CANDU 9 quality assurance manual was also endorsed by AECL's Chief Engineer and the Director of Quality Assurance. The Atomic Energy Control Board (AECB) assessed the CANDU 9 Quality Assurance Program and officially accepted the manual and the referenced procedures.

4. Main Operations and Processes

The CANDU 9 *Quality Assurance Manual* makes reference to over a hundred procedures which provide detail instructions on how to conduct CANDU 9 work activities in an organized and consistent manner. The Manual and the referenced procedures are available in an electronic medium via AECL Intranet, which is accessible to all CANDU 9 staff members. In addition to its convenience, the centrally controlled information repository provides assurance that only the latest and approved versions of the procedures can be accessed and used.

The following subsections describe the work processes and operations most frequently used on the CANDU 9 Program.

4.1 Design Verification

At the onset of the program, a formal document entitled CANDU 9 *Design Verification Plan* was generated with the objective of describing design verification activities, and providing the selection process for verification activities and the criteria for selecting a verification method. Design verification methods employed to ensure the desired quality level include one or more of the following:

- Review of and comment on documents by interfacing disciplines and technical specialists,
- Formal design reviews,
- Formal peer reviews,
- Third party independent reviews,
- Alternate analysis, and
- Qualification testing.

The verification methods most frequently applied were: the review of documents by interfacing disciplines and technical specialists; and the formal design and peer reviews of the major safety related systems.

There were twenty five formal design and peer reviews for the CANDU 9 Program which resulted in 1631 actions assigned by the review teams. All actions were tracked until their completion. Design and peer reviews were officially closed after all actions for the particular reviews had been completed and accepted as such by the review team members. The chairpersons of individual design and peer reviews evaluated the review performance, on a scale of zero to ten, for the following eight categories:

1. Review objective and scope clearly defined.
2. Review package complete and consistent with the scope.
3. Document contents clear and complete.
4. Reviewers given adequate time for review.
5. Reviewers performed an adequate review of the documentation prior to the meeting.
6. Review meeting met the review objective.

7. Designers' ability to justify the proposed design.
8. Reviewers' selection adequate.

Passing marks were five to ten.

5. Feedback to Design

The process, which was developed for the generation, collection, and evaluation of feedback information, was implemented at the CANDU 9 Program. Several company procedures were developed to process feedback from various sources such as: plant operations, commissioning, construction, licensing and regulating, equipment supply and procurement, engineering experience from completed projects, research and development related to CANDU products, and marketing and sales. In addition, a CANDU 9 procedure was written to address specific needs of that program. A project feedback representative was appointed to coordinate collection and evaluation of feedback information for the CANDU 9 Program, and to represent CANDU 9 on the company feedback team.

A feedback monitoring system, comprising a computerized database, was instituted to capture information from a variety of sources, to record and manage that information, and to make it readily available to all staff. Details of the system for generation and evaluation of feedback information were described in the CANDU 9 procedure titled "Feedback to Design".

Generally, any staff member can identify an issue which he/she considers to be of interest to others. The issue is then assessed, reviewed and, if accepted, placed on the feedback monitoring system to be accessible to all staff.

The CANDU 9 Program benefited considerably from the received feedback. Some of this beneficial feedback included the following:

- Constructability input from previous projects,
- Operating plant input from Ontario Hydro,
- Utility expectations and plans for electricity generation, and
- Additional work items (AWI) by the regulator.

In those cases for which feedback was considered beneficial to the CANDU 9 Program, a change was initiated to implement it. The next section describes how changes are processed at CANDU 9.

6. Change Control

From its inception, the CANDU 9 Program was continually changing. The guiding quality principle was that all changes to CANDU 9's accepted items, processes, and practices had to be controlled. Sound innovations and improvements were encouraged and promoted, but detrimental changes were blocked. CANDU 9's change control mechanism was introduced,

documented, and implemented at the CANDU 9 commencement early in 1995 when the procedure entitled "CANDU 9 Change Control" was approved and issued for use.

The procedure describes the CANDU 9 change management process, including the membership and roles and responsibilities of the program management team (PMT) members who are responsible for controlling changes. All proposed changes are categorized as either minor or major as per the criteria specified in the procedure.

Any CANDU 9 staff member can initiate a change. All changes are presented at PMT change control meetings in sufficient detail to establish whether or not they are worth while pursuing. The Chief Engineer, who has the design authority for the company, is given an opportunity to attend PMT meetings which deal with changes. Those changes which are accepted in principle, are substantiated with additional documentation and are presented again. Change requests include, but are not limited to, the following information and data:

- Change impact on engineering, licensing, equipment supply, construction, and commissioning,
- Effects on activities of interfacing disciplines (cascading effects),
- Affected documentation, revisions resulting from the proposed change, and
- Estimates for various cost categories.

Based on the criteria for major or minor changes, all change proposals are categorized accordingly. Minor changes are approved by the PMT and major changes are approved by the AECL's Change Control Board (CCB), which is chaired by the Chief Engineer. The Director of the CANDU 9 Program authorizes implementation of all changes, major and minor.

Most of CANDU 9 changes were due to one of more of the following factors:

- Adaptation from an integrated multi-unit to a single unit nuclear plant,
- Adaptation to local or site conditions,
- Changing customers' needs and expectations,
- Licensing requirements,
- Safety margin improvements,
- Obsolescence of equipment,
- Schedule and cost reduction, and
- Feedback from operating CANDU units.

Documenting and record keeping and in a systematic manner is an important part of the CANDU 9 change control process. Minutes of all change control meetings are recorded by the Secretary, who is from CANDU 9. Official change records are kept; they are filed with the company record management system (RMS). Selected change request documentation is also stored as an electronic medium in the central information repository system in order to be readily accessible to CANDU 9 users.

7. Training

Two basic principles governed the CANDU 9 Training Program: first, the quality principle that personnel will be competent in the work they do; secondly, the guiding principle that AECL will provide employees with the training and development necessary to achieve the company's business plans to prepare adequately to meet future requirements.

A comprehensive training program has been implemented at CANDU 9 from its commencement. The training program is described in the CANDU Training Plan. The document is updated annually to reflect changing needs of the CANDU 9 Program.

The CANDU 9 training objectives are:

- To provide orientation on how to do the work the "AECL way". This orientation is most relevant to those staff members who recently joined the CANDU 9 Program.
- To provide training in technical knowledge, management, business, communication skill, computer software, and other work skills to ensure that all staff are adequately qualified to perform the tasks assigned to them.
- To support improvements in technology and work processes.
- To provide professional development of staff for their career progression in keeping with the future needs of their working unit and the company.
- To ensure sufficient numbers of expert staff remain available in key skill areas to replace those who are retiring, insure against loss of essential skills in key areas, and provide additional qualified expert staff in high demand areas.

The process for identification of qualifications for each position, assessment of the employee qualifications against the required qualification, and definition of training needs, is described in the procedure entitled "Identification and Assessment of Personnel Qualifications". The procedure also contains a sample form which has to be completed for each staff member.

Both the incumbent and his/her manager are responsible for identifying training needs on the form. Usually, the form is initiated by the incumbent and reviewed and modified, as necessary, by the manager. The completed form is approved by the manager, and is updated at least once a year based on the CANDU 9 workplan and changes in the incumbent's roles as the CANDU 9 Program goes through different project cycle stages. Individual training needs are also discussed with staff members as part of the performance review process. The completed forms are used for various purposes which include the following:

- To establish what training courses are needed for each staff member and when to take them. The approved forms constitute a database of training needs for the CANDU 9 Program.
- To determine when various courses are required and to schedule them accordingly.

- To monitor the training progress and related cost.
- To conduct statistical analyses, draw conclusions, and update the Training Plan.
- To draw plans for future projects.

A training coordinator was appointed and given the following responsibilities for the CANDU 9 Program:

1. To guide managers and staff on how to achieve the quality of training which satisfies the governing standards, manuals, and procedures.
2. To guide and facilitate training instructors and managers on how to structure, execute, and document customized training courses.
3. To ensure that the documentation from training courses is properly organized and filed.
4. To respond to queries by CANDU 9 staff members in regard to their individual training needs.
5. To review and approve training requests by CANDU 9 staff members.
6. To record training, and prepare status reports and statistical data. To maintain awareness, through those reports, of CANDU 9's overall progress, and to identify additional needs and priorities.
7. To consolidate training requirements into the CANDU 9 Training Plan.
8. To provide necessary input for the AECL Training Plan.
9. To provide a liaison with the AECL Training Steering Committee.

The CANDU 9 training coordinator is a member of the AECL training steering committee. Participation in the committee gives him/her the opportunity to link the AECL training objectives and programs with CANDU 9 training needs for professional development.

8. Program Reviews and Audits

From its inception, the CANDU 9 Program has been assessed, reviewed, and audited many times.

As required by the national standard, *Design Quality Assurance for Nuclear Power Plants*, reviews of the CANDU 9 design quality assurance program were conducted to assess its adequacy and effectiveness. Reports on quality assurance program reviews were generated using the documentation and statistical data which had been gathered in the course of the CANDU 9 Program.

The CANDU 9 Program was subjected to the following external audits by the Atomic Energy Control Board:

- March 1994 - the audit was on training. The audited staff started CANDU 9 work in January of 1995.
- August 1995 - the audit addressed design processes and verification.
- March 1996 - the focus of this audit was feedback for design, nuclear safety analysis, design processes and verification.

- September 1996 - the audit focused on human factors engineering, production and verification of design description documents, and internal audits.

All external audit observations were addressed, resolved, and closed in a timely manner. Consequently, the "AECB Staff Statement on CANDU 9 Licensability" contained very favorable quality assurance conclusions and summary.

The CANDU 9 Program was further subjected to an audit by the AECL Internal Audit Division during the summer of 1998. The audit scope covered product development planning and engineering processes. In their executive summary, the auditors stated: *"The audit team's opinion is that, in aggregate, the management systems and practices within Product Engineering are operating satisfactorily. Process improvement opportunities have been discussed with management and appropriate action is being taken."*

The CANDU 9 Program was also internally audited six times. The internal audits were, primarily, a management tool to improve performance. It was recognized that, for internal audits to be effective, there must be clearly defined objectives that add value and reflect the interest of the audited parties. Familiarity with the CANDU 9 Program, and interpersonal skills were vital prerequisites for the audit team. Trust between the internal auditor and the auditee, together with the ability to communicate openly and effectively was essential for constructive audit outcome. To be empathetic and efficient, the internal auditor must be both well prepared, and familiar with auditee's working processes. Only with those prerequisites, can the internal audit be part of a working relationship that helps attain continuous improvement.

The following are subject areas which were addressed during the six internal quality audits of the CANDU 9 Program:

- June 1995 - Design (configuration management of engineering layout and documents), and engineering and scientific analyses.
- February 1996 - Personnel qualification and training, non-conformance and corrective action, document production and control, quality records, human factors, and environmental qualification of equipment.
- August 1997 - configuration management (plant layout), implementation of feedback monitoring process, and personnel qualification and training needs.
- February 1998 - Human factors engineering, design and analysis processes, and update of technical description documents.
- September 1998- Records: closure of the CANDU 9 Basic Engineering Program; and Verification: follow-up on design and peer review actions.
- March 1999 - Design Interfaces: CANDU 9 designers - engineering tools developers; and Records: document management practices - implementation of the asset and information management (AIM) system.

9. Conclusions

AECL invested very substantial resources in the CANDU 9 Basic Engineering Program, which commenced in January of 1995 and was successfully completed in March of 1998. Upon meeting all of the objectives, the CANDU 9 Program continued to seek improvements, enhance product competitiveness, and reduce project risks. A comprehensive and auditable quality assurance program was in place during the full duration of the CANDU 9 Basic Engineering Program. The program was described and documented in the *Quality Assurance Manual* and supporting documents, which included over a hundred procedures. The key operations and processes which contributed to CANDU 9 quality were: design verification, feedback to design, change control, training, program reviews and audits. The CANDU 9 Program was subjected to numerous assessments, reviews, and internal and external audits. In summary, the CANDU 9 Program was extremely quality conscious over its full duration. CANDU 9 moved quality centre stage and became a quality organization.

10. Acknowledgments

The CANDU 9 Quality Assurance Program succeeded because of devotion to quality by all staff members. The CANDU 9 Program Management Team is also acknowledged for their understanding, cooperation and support.