BEST AVAILABLE TECHNIQUE (BAT) ASSESSMENT APPLIED TO ACR-1000® WASTE AND HEAVY WATER MANAGEMENT SYSTEMS

M. Sachar, S. Julien, and K. Hau
Atomic Energy of Canada Limited, Mississauga, Ontario, Canada

Abstract

The ACR-1000®design is the next evolution of the proven CANDU® reactor design. One of the key objectives for this project was to systematically apply the As Low As Reasonably Achievable (ALARA) principle to the reactor design. The ACR design team selected the Best Available Technique (BAT) assessment for this purpose to document decisions made during the design of each ACR-1000 waste and heavy water management systems. This paper describes the steps in the BAT assessment that has been applied to the ACR-1000 design.

1. Introduction

Atomic Energy of Canada Limited (AECL) has established a successful, internationally recognized line of CANDU[1] pressurised heavy water reactors that use a heavy water moderator, in particular, the medium-sized CANDU 6 reactor. AECL has consistently adopted an evolutionary approach to the enhancement of CANDU nuclear power plant designs over the last 30 years. The current CANDU 6 reactor design has been developed further in the market-ready Advanced CANDU Reactor (ACR) design.

The ACR-1000[2] design has evolved from AECL's in-depth knowledge of CANDU structures, systems, components, and materials, as well as from the experience and feedback received from owners and operators of CANDU plants. The ACR-1000 design features modern waste and heavy water management systems, based on the application of the As Low As Reasonably Achievable (ALARA)[3] principle [1].

To systematically apply the ALARA principal to the ACR-1000 design, the Best Available Technique (BAT) assessment process, as documented in this paper, was selected. The systems included in the ACR-1000 BAT assessment included:

- The radioactive liquid, solid, and gaseous waste management systems;
- The non-radioactive and mixed waste management systems; and
- The heavy water management and vapour recovery systems.

The Vapour Recovery System, an ACR-1000 heavy water management system, has been selected as an example to illustrate the BAT process and will be described in this paper.

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1 CANDU® (CANadian Deuterium Uranium®) is a registered trademark of Atomic Energy of Canada Limited (AECL), 2010.

2 ACR-1000® (Advanced CANDU Reactor®) is a registered trademark of Atomic Energy of Canada Limited (AECL), 2010.

3 ALARA: As Low As Reasonably Achievable, social and economic factors taken into account.

2. The ALARA principle

The ALARA principle is a guiding principle used during the design of a nuclear reactor to ensure radiation exposure for workers, the public, and the environment is As Low As Reasonably Achievable, social and economic factors taken into account. Application of the ALARA principle during design ensures that the nuclear power plant includes design provisions that suitably consider and emphasize environmental performance and radiation protection for workers, the public, and the environment.

3. Best Available Technique assessment

The concept of the Best Available Technique assessment is that, for a given waste management project, either radioactive or non-radioactive, the design should consider the selection of techniques to protect the environment and achieve an appropriate balance between the environmental benefits and the costs to implement them.

BAT stands for [2]:

“Best” – The most effective technique for achieving a high level of protection of the environment.

“Available” – Techniques developed on a commercial scale that allows them to be used in the relevant industrial sector, under economically and technically viable conditions, taking into account the costs and benefits.

“Technique” – Includes both the technology and the way that the installation is designed, built, maintained, operated, and decommissioned.

The BAT assessment strategy is based on the United Kingdom Environment Agency guidance document “IPPC H1 Horizontal Guidance Note for Environmental Assessment and Appraisal of BAT” [2] and has been customized to meet the ACR-1000 project-specific requirements.

The assessment process is consistent with the regulatory expectations in Canada (e.g., reference [3]) to include ALARA provisions in the design.

3.2 Assessment timing

The greatest opportunity for the selection and implementation of a best available technique design option arises during the early stages of pre-project planning and project definition. As the project progresses through to the development stages of selection, design, and build, there is a reduction in the design options available to the project.

Once the best available technique has been identified, the assessment and options can be revised or refined as necessary throughout the approvals process as new or evolving information or requirements become available.

4. Best Available Technique assessment methodology

The assessment methodology consists of two basic components:

1. The assessment of environmental impacts, and
2. The balancing of environmental impacts against costs.

The process of applying the methodology encompasses six steps:

1. Define the project scope and describe the options,
2. Calculate the waste inventory and potential emissions from the project,
3. Quantify environmental impacts and project-specific environmental criteria,
4. Compare the performance of the options,
5. Evaluate the costs to implement each option, and
6. Identify the best available technique.

The activities associated with each of these six steps, and the example of the assessment methodology applied to the Vapour Recovery System, are described in the following sections.

4.1 Step #1 – Define the scope and describe the options

To apply the Best Available Technique methodology to the ACR-1000 reference design, an assessment team was established and the ACR-1000 project was consulted to define the project objectives and the reason for the assessment in terms of the main environmental impacts and emissions to be controlled.

Once the project objectives were defined, the assessment team consulted with system and technique experts to assemble an expert panel to identify a range of possible candidate options, including consideration of the existing reference design, which could meet the project objectives for each waste and heavy water management system. The expert panel was also consulted periodically throughout the BAT assessment process to ensure that appropriate evaluation methods were implemented.

When identifying the candidate options for the best available technique, the expert panel looked at:

- The use of low-waste technology;
- Choice of less hazardous substances;
- Recovery or recycling of substances generated and used in the process or project;
- Comparable processes, facilities, methods of operation which have been successfully implemented on an industrial scale;
- Technological advances and changes in the scientific knowledge and understanding;
- The nature, effects, and volumes of emissions;
- Commissioning dates and timescales for introducing the technology;
- Consumption and nature of raw materials (including water);
- Need to prevent or reduce the overall impact of the emissions on the environment;
- Need to prevent accidents and minimize the consequences of accidents;
- The project requirements and priorities;
- Regulatory requirements and public acceptance; etc.

A brief description was provided for each of the techniques or configurations selected for the options. The descriptions were sufficient to allow a determination to be made of the feasibility of each option based on the stated project objectives.

A more detailed description of the feasible options was assembled to provide information on the source of the waste, collection, processing, storage, and eventual disposal and monitoring of the waste and discharges produced. The existing system reference design was considered to be a feasible option and was selected as the baseline position for the assessment for each system.

Example: Vapour Recovery System

A component of the ACR-1000 heavy water management program includes the Vapour Recovery System, which is used here to illustrate the application of the assessment process to the ACR-1000 design process. The Vapour Recover System is used in radioactive controlled areas (RCA) of the reactor building (RB) and maintenance building (MB) where there is a potential for heavy water vapour to be present.

The Vapour Recovery System reference design consists of desiccant dehumidifiers that remove heavy water from the air in the RB and MB and collect it on a desiccant. The desiccant is continuously regenerated and the collected heavy water is recovered and re-used. By drying the air in RCA's of the RB and MB, the system controls internal tritium intake in the station and also prevents the potentially costly escape of heavy water from the station. Overall, these functions allow the system to significantly lower the station emissions associated with heavy water.

The objective of this component of the BAT assessment was to improve the heavy water collection efficiency of the reference design ACR-1000 Vapour Recovery System and determine if any further improvements could be made to the system based on the ALARA principle. An expert panel with expertise in heavy water management was consulted to brainstorm the candidate options that could meet the assessment objectives. In total, eight options including the reference design, were determined to be feasible.

4.2 Step #2 – Calculate the waste inventory and potential emissions from the project

The aim of this step was to produce an inventory of sources and releases of waste from each option relative to the reference design. This step was used as a basis for the subsequent evaluation of environmental impacts. The inventory described the nature and quantities of waste, and media into which each waste source was released.

Example: Vapour Recovery System

An inventory of sources and releases of waste from each option including the baseline options was documented based on operating experience from existing CANDU stations and feedback from suppliers and designers.

4.3 Step #3 – Quantify environmental impacts and project-specific environmental criteria

The aim of this step was to quantify the environmental impact of each option such that the impacts could be compared. This included:

- Local effects of emissions to air and water,
- Local and long range effects from deposition,
- Risk of impacts from accidents, and
- Indirect effects of waste hazards, waste generation, and final disposal.

The assessment team worked with the expert panel to establish the relevant environmental impacts from each system. The impacts were then summarised and together were used as a basis to select the overall project-specific evaluation criteria.

The evaluation criteria focused on ALARA and included:

- Minimization of radioactivity at source,
- Minimization of liquid and gaseous wastes,
- Minimization of solid wastes for disposal,
- Process technology,
- Operational and maintenance complexity,
- Administrative and management controls, and
- Identified risks and hazards.

Different weightings were used for application of the criteria to each system based on the types of wastes primarily produced and the specific risks and hazards associated with the system.

Example: Vapour Recovery System

As illustrated in the "Weightings" column in Table 1, the evaluation criteria were assigned weightings emphasising the system objective of improving the heavy water collection efficiency of the reference design. Specifically, minimizing gaseous wastes discharged was assigned the highest weighting of 10.

4.4 Step #4 – Compare the performance of the candidate options

The aim of this step was to evaluate the overall performance of each option according to the criteria determined in Step #3 in order to identify the option that represented the lowest impact on the environment, and therefore the possible best available technique. The evaluation process relied on the professional judgement of the expert panel to balance diverse environmental considerations.

A scoring system was established to evaluate the options:

+ 10 significantly improved compared to baseline option

+ 5 improved position compared to baseline option

0 equivalent to baseline option

-5 worse position compared to baseline option

-10 significantly worse position compared to baseline option

The overall score was calculated by multiplying the weighting factor selected in Step #3 by the assigned score and then adding the results together across all of the evaluation criteria.

Example: Vapour Recovery System

The project-specific evaluation criteria were applied systematically to the Vapour Recovery System using the scoring system as illustrated in Table 1. Each option was scored relative to the baseline option, which was the reference design.

Assessment Criteria	Weighting	Op 2	Op 3	Op 4	Op 5	Op 6	Op 7	Op 8
Minimise radioactivity at source	9	0	0	0	0	0	0	0
Minimise gaseous waste discharged	10	-10	-10	0	+10	-5	0	+5
Minimise liquid waste discharged	8	0	0	0	0	0	+5	0
Minimise solid waste for disposal	7	0	-5	0	0	0	0	-5
Process technology	7	0	0	0	0	0	0	-5
Operational and maintenance complexity	7	0	-5	+5	0	0	0	-5
Administrative / management controls	8	0	0	0	0	0	0	0
Risk to the public	8	-10	-10	-5	+10	-5	+5	+10
Risk of accidents	6	0	0	-5	0	0	0	-5
Cost	6	+5	-5	0	-5	-5	-5	-10
Overall Score		-150	-280	-35	150	-120	50	-30

Table 1 Vapour Recovery System Evaluation Table

4.5 Step #5 – Evaluate the costs to implement each option

After evaluating the options in Step #4, according to [2], the cost of implementing each of the feasible options would have to be estimated in order to balance the environmental impacts of each option against the costs. However, since engineering estimates of the relative costs for each option were available, this information was sufficient to be used to compare each of the techniques.

Example: Vapour Recovery System

For the Vapour Recovery System, when costs were considered as an evaluation criteria, it was determined that the feasible options for the system were not all mutually exclusive (See Table 1). The assessment indicated that the design could be improved from an ALARA perspective by incorporating a combination of the options that scored as overall improvements compared to the baseline option. This combination of options was established as the best available technique for improving the efficiency of the ACR-1000 Vapour Recovery System.

4.6 Step #6 – Identify the best available technique

Based on the evaluation of costs, a well-documented, objective, and justifiable judgement of the best available technique was made by the assessment team for each waste and heavy water management system.

A Best Available Technique assessment document was produced to summarise the teams' findings and a justification was included to support the design decision for each system based on the assessment results.

Example: Vapour Recovery System

The assessment of the Vapour Recovery System, as outlined in this paper, was provided as a component of the overall Best Available Technique assessment document for the ACR-1000 design. Based on the assessment results, a recommendation was made to the ACR-1000 project to incorporate the ALARA design improvements in the Vapour Recovery System design and the changes were incorporated in the design through the appropriate change management process.

6. Conclusions

The process of systematically applying the ALARA principle to the design of the ACR-1000 waste and heavy water management systems has been effectively demonstrated using the Best Available Technique assessment. The assessment established that alternative design options had been considered in each systems' design, and that the best approach overall was selected.

5. References

[1] Canadian Nuclear Safety Commission "Keeping Radiation Exposures and Doses "As Low as Reasonably Achievable (ALARA)"", G-129, Revision 1, October 2004.

[2] UK Environment Agency Horizontal Guidance Note "Integrated Pollution Prevention and Control (IPPC) – Environmental Assessment and Appraisal of the BAT", IPPC H1, July 2003.

[3] Canadian Nuclear Safety Commission "Design of New Nuclear Power Plants", RD-337, September 2008.