BRUCE UNITS 3 AND 4 LIFE EXTENSION INTEGRATED SAFETY REVIEW PROCESS AND LESSONS LEARNED

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Abstract

The refurbishment preparation phase for Bruce A Units 3 and 4 included the performance of an Integrated Safety Review, as called for by CNSC regulatory document RD-360, "Life Extension of Nuclear Power Plants". The Integrated Safety Review is a comprehensive assessment of plant design, condition and operation conducted at the time that plant life extension is being considered. This paper describes the process of preparing the Bruce Units 3 and 4 Life Extension Integrated Safety Review and summarizes lessons learned.

1. Introduction

As part of the *Bruce A Refurbishment for Life Extension and Continued Operations Project*, Bruce Power has chosen to pursue first life extension of Bruce 1&2, followed by announcement in 2007 to follow-up with the life extension for Bruce 3&4. This will require implementing a series of refurbishments, upgrades and enhancements on these units, improving safety while increasing reliability for their extended life. The work to be undertaken either prior to or post-return to service of Units 3&4 is determined in part through the performance of an Integrated Safety Review (ISR).

The ISR is driven by CNSC regulatory document RD-360, "Life Extension of Nuclear Power Plants" [1]. RD-360 requires the licensee to systematically identify and address all environmental and safety concerns and integrate them into an Integrated Implementation Plan (IIP). To prepare the IIP, the licensee must first participate in an Environmental Assessment (EA) and then carry out an Integrated Safety Review.

For the Life Extension Project for Bruce A Units 3&4, the Environmental Assessment, ISR and IIP have been prepared. This paper describes the process for preparing the ISR and summarizes the lessons learned.

Bruce Power is refurbishing Bruce Units 1&2 to return them to service from their temporary lay-up. The B3&4 project is building on the B3&B4 restart and the B1&2 ISR work, extending it as necessary to align with RD-360 [1] and meet evolving regulatory expectations.

It was expected that the B3&4 ISR process would benefit from earlier work done for the B1&2 ISR, thus enabling key project milestones and external stakeholder commitments to be achieved.

2. ISR Objectives

The ISR is a comprehensive self assessment. It is a means of obtaining an overall view of actual plant safety and to determine practicable modifications to improve the safety of older nuclear power plants to a level approaching that of modern plants.

The specific objectives of the ISR are to determine:

1. The extent to which the plant conforms to modern standards and practices;
2. The extent to which the licensing basis will remain valid over the proposed operating life;
3. The adequacy of the arrangements that are in place to maintain plant safety for long-term operation; and
4. The improvements to be implemented to resolve safety issues that have been identified.

Section 3 describes the documents produced in completing the B3&4 ISR process. Section 4 provides the list of Safety Factors encompassed by the ISR and Section 5 describes the process by which gaps were identified and addressed.

3. ISR Documentation

Bruce Power has prepared the following documents to support the ISR for the Bruce A Units 3&4 Life Extension Project:

- B3&4 Life Extension Safety & Licensing Framework

  The Framework document outlined the safety and licensing program for the B3&4 Life Extension Project and was used to engage CNSC staff early in the B3&4 ISR process.

- Bruce A Units 3 and 4 Integrated Safety Review Basis

  The ISR Basis document established the scope and methodology for the conduct of the ISR.

- Safety Factor Reports for each of the first 14 safety factors listed in Table 1 (Security and Safeguards were documented separately).

  Each Safety Factor report documents the review and the findings for the given safety factor. The reports include an assessment of the safety significance of the gaps and the need for any immediate corrective actions.

- Bruce NGS A Units 3 and 4 Global Assessment Report (GAR) and Integrated Implementation Plan (IIP)

  The GAR presents the basis for extended Units 3&4 operation, including the safety improvements embedded in the IIP. The GAR attachments:

  - describe the methodology for assessing gaps identified by ISR/EA;
  - list gaps identified in Section 8 of each Safety Factor report; and
  - provide a comprehensive list of corrective actions and safety improvements addressing the identified gaps

The GAR and IIP are thus combined in a single document, herein called the GAR/IIP.

Each of the above documents has been prepared for submission to the CNSC. The CNSC Staff will review the ISR Basis document, ISR Safety Factor reports, and the GAR/IIP for acceptance. As called for in RD-360, the Commission will either accept the GAR/IIP or require changes. Upon acceptance, the licence will be amended to include licence conditions to be met in the return-to-service of the project.

4. Safety Factors

The ISR encompasses the IAEA Periodic Safety Review (PSR) Safety Factors [2] and, in addition, addresses the CNSC Safety Areas and Programs as identified in RD-360 [1] (see Table 1). The IAEA identifies five Subject Areas which are further broken down into a list of fourteen Safety Factors that are considered to be the basic topics for consideration as part of a comprehensive assessment of overall plant safety. The list of CNSC Safety Areas and Programs in RD-360 corresponds generally to the list of IAEA Safety Factors. The topics of quality management, site security and safeguards required inclusion in the ISR, in addition to the IAEA PSR Safety Factors.

In carrying out the ISR, each Safety Factor was further sub-divided into Review Elements as recommended in the IAEA PSR guide [2]. The concept underlying the ISR is to use these Review Elements to assess each Safety Factor by comparing the current design, operation and licensing basis of the plant, as reflected in the governing programs in use by Bruce Power, with modern regulatory requirements, codes, standards and good practices.

Subject Area	Safety Factor
The Plant	1. Plant Design 2. Actual Condition of Systems, Structures and Components 3. Equipment Qualification 4. Ageing
Safety Analysis	5. Deterministic Safety Analysis 6. Probabilistic Safety Analysis 7. Hazard Analysis
Performance and Feedback from Operating Experience	8. Safety Performance 9. Use of Experience from other Plants and Research Findings
Management	10. Organization and Administration (including Quality Management – CNSC recommended) 11. Procedures 12. The Human Factor 13. Emergency Planning
Environment	14. Radiological Impact on the Environment
Security & Safeguards	15. Security (CNSC recommended – to be documented separately) 16. Safeguards (CNSC recommended – to be documented separately)

Table 1: Safety Factors

5. Process for Identifying and Addressing Gaps

RD-360 requires that the licensee describes its processes for identifying and addressing gaps between current and desired plant state and performance, documenting the significance of any gaps, and prioritizing corrective actions and safety improvements.

The process for identifying and addressing gaps is shown in Figure 1. The first four steps shown in Figure 1 are described in Sections 5.1 through 5.5, below. The fifth step of Figure 1 addresses preparation of the GAR/IIP which integrates the findings of the Safety Factor Reports. The global assessment is briefly discussed in Section 5.3. The sixth item in Figure 1 addresses the process of tracking the resolution of gaps, which occurs subsequent to the ISR process.

5.1 Safety Factor Review

5.1.1 Methodology of the Safety Factor Review

The methodology for the Safety Factor reviews is the process for identifying gaps and evaluating their safety significance. It consists of the activities listed below.

1. Clarify the scope of the Safety Factor review with respect to the IAEA review elements [2] in terms of review tasks.

2. A 'clause-by-clause' review of codes and standards that apply to the safe design of the plant and others that are mandatory regulatory requirements.

3. A 'program' review against codes and standards for each Safety Factor. A program review is a high level review to assure that the scope and intent of the code, standard or good practice is being implemented in the design and operation of the plant.

4. An assessment of the QA programs/processes against the IAEA review elements to determine if the programs/processes meet the objectives of the review elements.

5. An assessment of the effectiveness of the implementation of the station's existing safety management programs for each Safety Factor. The results of internal and external audits, as well as self-assessments and OPEX, are reviewed to identify deficiencies relative to quality standards and performance practices.

6. An assessment of the level of compliance with the codes and standards by assigning the review elements to one of the following categories.

    a. Direct Compliance – compliance has been demonstrated with the applicable requirement.

    b. Indirect Compliance – compliance has been demonstrated with the intent of the applicable requirement.

    c. Shortcoming - gap with respect to modern codes and standards or gap in implementation of the programs that are in place at the station

    d. Discrepancy – gap with respect to the current licensing basis.

5.1.2 Selection of Applicable Codes and Standards

The general philosophy of the codes and standards review is to identify any gaps between the current licensing basis and any additional high-level requirements relating to nuclear safety in modern codes and standards. RD-360 and the IAEA PSR are specific to reactor safety and therefore, the facility is evaluated against a set of modern high-level safety goals and requirements that are particularly relevant to nuclear safety.

The applicable codes and standards fall under the following categories:

1. Acts and Regulations
2. Power Reactor Operating Licence
3. Regulatory Documents
4. CSA Standards
5. International Standards
6. Other Applicable Standards/Practices

The first three categories cover the applicable Canadian regulations and those codes and standards that are referenced in the plant licensing basis, which includes the CNSC regulatory framework, the documents referenced in the station-specific licence, the documents submitted by the licensee in support of the licence application, and the documents referenced therein.

The CSA standards are regularly reviewed by the CSA and are kept up to date, modern and applicable (specifically in the N290 series).

Documents such as IAEA standards were only specified for review if there was no current Canadian standard or accepted process.

An example of the “Other Applicable Standards” category includes the Darlington Design Guides, which are the most current guides applicable to a multi-unit station with shared systems and the Bruce A-type containment. In addition, CNSC Regulatory Document RD-337 was considered to confirm overall alignment with CNSC expectations for new plants.

Clause-by-clause reviews were generally considered necessary for design and analysis related codes and standards, identifying requirements that could directly impact on the installed plant design and may impact on the design scope of the Life Extension Project. Other codes and standards that specify general requirements or that relate largely to process and programmatic issues do not lend themselves to review on a clause-by-clause basis and as such an overall high-level assessment of the respective Safety Factors was undertaken to determine the level of compliance.

5.1.3 Results of the Safety Factor Review

The Safety Factor reviews identified strengths and gaps when assessing the Bruce Units 3&4 design and operation against current safety standards. These gaps fell into three categories in terms of their significance in the ISR.

- Gap between the existing design and the requirements of modern codes and standards. These are referred to as shortcomings.

- Gap in the implementation of the programs that are in place at the station, i.e., there is a misalignment between performance expectations and practice. These are also referred to as shortcomings.

- Gap in the design, equipment, or management programs in meeting the requirements of the codes and standards that were applied to the design and operation of the plant. That is, there is a discrepancy between the existing plant condition and its licensing basis. Gaps against the licensing basis are referred to as discrepancies, and would require immediate corrective action. There were no discrepancies identified in the Bruce 3&4 ISR.

Upon completion of the Safety Factor review, all gaps were evaluated as described in the next Section.

5.2 Safety Factor Evaluation

The safety significance of the gaps was evaluated by applying deterministic safety principles. The purpose of this preliminary evaluation was to identify any gaps that require immediate attention (with respect to the operating reactor) and to give a broad classification of the potential impact of gaps from the application of new codes and standards.

The evaluation criteria for strengths and gaps were based on:

- Defence-in-depth

- Performance assurance

- Safety culture

The gaps were categorized, based on IAEA guidelines ([3], [4]) as Low, Medium or High safety significance.

Corrective actions only need to be taken immediately if there is a gap between the current operating plant state and the licensing basis, although as indicated in Section 5.1.3, no such gaps were found. Corrective actions for the gaps from the comparison with modern codes and standards and gaps found from the assessment of the review elements are addressed in the Integrated Implementation Plan.

5.3 Global Assessment

The Global Assessment is intended to provide a traceable link between gaps identified in the detailed assessment of the ISR Safety Factor reports and their dispositions and in turn provide links with the IIP. The steps followed in the assessment of the collected gaps identified by the ISR are as shown in Figure 2. This also applies to the gaps identified in the EA.

5.4 Resolution of Gaps - Analysis

At the initial stage of resolution, the gaps identified in each of the Safety Factor reports are assessed and corrective actions or safety improvements are developed as far as practicable before detailed evaluation with risk-informed decision making (RIDM), as discussed in Section 5.5.

In terms of the high level safety goals, Bruce A must and has been shown to meet the current radiological dose limits and the risk limits for Core Damage Frequency and Large Release Frequency. In terms of the risk limits for new plants (targets for existing plants) and dose limits for new plants, Bruce Power's objective is to meet these where practicable.

In terms of assessing and reconciling gaps between the existing plant design and codes and standards that apply to a new plant, Bruce Power has implemented the approach outlined below:

1. Rectify gaps between the current plant design and the design basis and licensing basis.

2. Migrate the plant to its design basis aligned to support continued operation for 30 years. This set of improvements should be made for life extension.

3. To the extent practicable, address differences between the current design and licensing basis and the requirements in current codes and standards that are not in the current design or licensing basis.

In all of the above cases it is important for Bruce Power to identify the gaps in order to establish the potential safety implications if the gap is not eliminated. These gaps include shortcomings in processes and programs, as well as shortcomings in the physical plant.

5.5 Resolution of Gaps – Risk-Informed Decision Making

The second stage of the resolution of gaps was undertaken using a Risk-Informed Decision Making (RIDM) process. It incorporated risk reduction analysis, and cost-benefit analysis, as well as deterministic safety principles to evaluate the gaps and proposed improvements. The improvements that merit implementation were prioritized and included in the Integrated Implementation Plan.

RIDM was used as a risk-informed screening framework for evaluating the merits of proposed safety improvements in a consistent and systematic manner. Risk-informed decision making followed the general Industry/CNSC approach incorporating the RIDM Framework. It was originally developed for application to Bruce 1&2, but was updated for Bruce 3&4. The RIDM Framework, supported by probabilistic risk assessment, incorporates deterministic considerations and intangibles which allow proposed design changes to be retained for further consideration even if the quantifiable cost versus benefit on its own would not support retention.

6. Lessons Learned

The lessons learned from the process of completing the ISR for Bruce A Units 3&4 can be divided into regulatory issues and licensee issues.

The main regulatory issue encountered was that the regulatory framework continued to evolve well into the project. This was recognized because OPEX from ISRs already in progress such as

Bruce 1&2 and Pickering B were used as input to the Bruce 3&4 ISR. In addition, regulatory documents were evolving, for example,

1. RD-360 was issued in February 2008, following preparation of the ISR Framework document and in the same month the ISR Basis document was prepared. The ISR Basis was thus prepared using a draft version of the regulatory guidance. As it turned out, the issued version differed little from the draft and so there was no impact on the ISR.

2. A commitment was made to review the design against the requirements of the draft RD-337 document because it was known from Point Lepreau refurbishment experience that CNSC would require RD-337 to be addressed for refurbishment. The compliance review was initially performed with a draft version of RD-337 and had to be updated after issuance of RD-337, Rev. 0. The repercussion of this was that work that was already completed had to be completely reassessed as the issued version of RD-337 was substantially different from the draft version.

   The lesson learned from the need to address an evolving regulatory framework is that to the extent possible, formal reviews against draft requirements should be avoided. Formal reviews should include only those documents issued by a Code Effective Date, mutually agreed with the regulator. Reviews of draft documents should only be performed as pro-active input to planning of improvements, recognizing that the requirements may evolve over time up to the implementation date.

From the licensee perspective, the issues and associated lessons learned included the following.

1. Due to the proprietary nature of information, it was difficult for Utilities to work on establishing a common industry approach to issues affecting all licensees. This lack of co-ordination led to inconsistencies in the ISR assessment, particularly in level of detail and review against current operating licence. For example, there is a need for a common industry approach with respect to issues such as:

   - establishing an appropriate list of codes and standards to be used in the ISR, and

   - developing a common understanding of how the requirements in RD-360 are to be interpreted.

2. There were difficulties obtaining input to the ISR from Subject Matter Experts (SMEs) from the Operations and Engineering line organizations, whose priority is plant operation. To minimize this, at the time that the ISR is committed, there needs to be clear up-front communication to all affected work groups regarding the corporate commitment to the ISR, and work planning needs to account for SME involvement to support requests for information and review of ISR documentation.

3. Given that the Bruce Units 3&4 ISR was prepared by contractor staff, it was essential that a senior management review meeting be held after the review and comment process was completed. The purpose of the meeting was to review the gaps to ensure that there was corporate commitment to the dispositions of the gaps. This worked well because managers had an integrated high-level view of the gaps and the strategies for their resolution and were able to

confirm the status of each issue resolution in progress and commit to a path forward for addressing all the gaps identified in the ISR.

4. Every safety factor report was prepared using boilerplate text, as appropriate, and templates such that there was absolute consistency between reports. Furthermore, a spreadsheet was used to track interfaces between safety factor reports. This was beneficial in meeting the schedule and in providing consistency, in particular with respect to identifying interfaces.

5. Review of the safety factor reports was done in a four-step process which minimized the risk of project delay and enhanced SME buy-in. The review process was as follows:

    a. 50% Scope Review - allowed the client to review the boilerplate information (objective, methodology, etc.), as well as the applicable codes and standards and the program and process documents that would apply for the review.

    b. 80% Gap Review – allowed the client to review the findings and to either provide agreement on the identified gaps or to add additional information to reinforce or remove gaps

    c. 100% Final Review – review of the completed final report

    d. Senior Management Review - see lesson learned, item 3 above

    This review process was found to be very useful. In several cases, additional information regarding internal audits or self-assessments was identified early-on via the 50% and 80% reviews. Identification of this information early in the review process helped ensure that the schedule was met and reduced risk of major changes to the reports later in the process.

7. Conclusion

CNSC regulatory document RD-360 requires the licensee to systematically identify and address all environmental and safety concerns for refurbishment projects, and integrate them into an Integrated Implementation Plan. To prepare the IIP, the licensee must first participate in an Environmental Assessment and then carry out an Integrated Safety Review.

For the Life Extension Project for Bruce A Units 3&4, the EA, ISR and IIP have been prepared. The process followed was successful in that Bruce Power was able to identify and assess the gaps as well as to develop and commit to resolutions of the gaps.

There were a number of lessons learned from the process of completing the first ISR for Bruce Units 3&4 performed in compliance with RD-360, revision 0. These lessons will be taken into account as the ISR is updated to reflect new developments within the U3&U4 Refurbishment program, CNSC feedback and pending new revision of RD-360.

8. References

[1] CNSC, “Life Extension of Nuclear Power Plants”, RD-360, February 2008.

[2] IAEA Safety Standard Series, “Periodic Safety Review of Nuclear Power Plants”, NS-G-2.10, 2003.

[3] IAEA INSAG-8, 1995, “A Common Basis for Judging the Safety of Nuclear Power Plants Built to Earlier Standards”.

[4] IAEA Safety Report Series No. 12, 1998, “Evaluation of the Safety of Operating Nuclear Power Plants Built to Earlier Standards: A Common Basis for Judgement”.

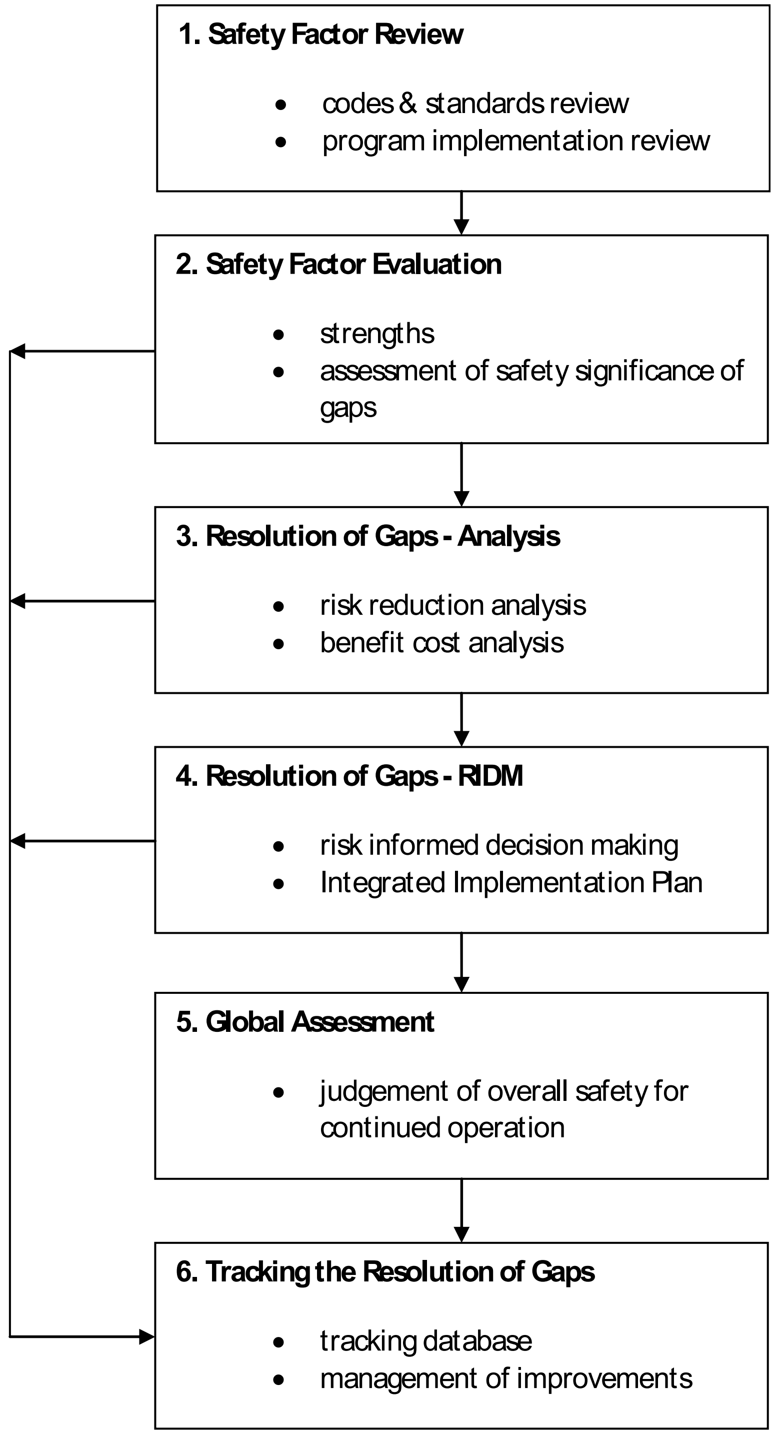

Figure 1: Process for Identifying and Addressing Gaps

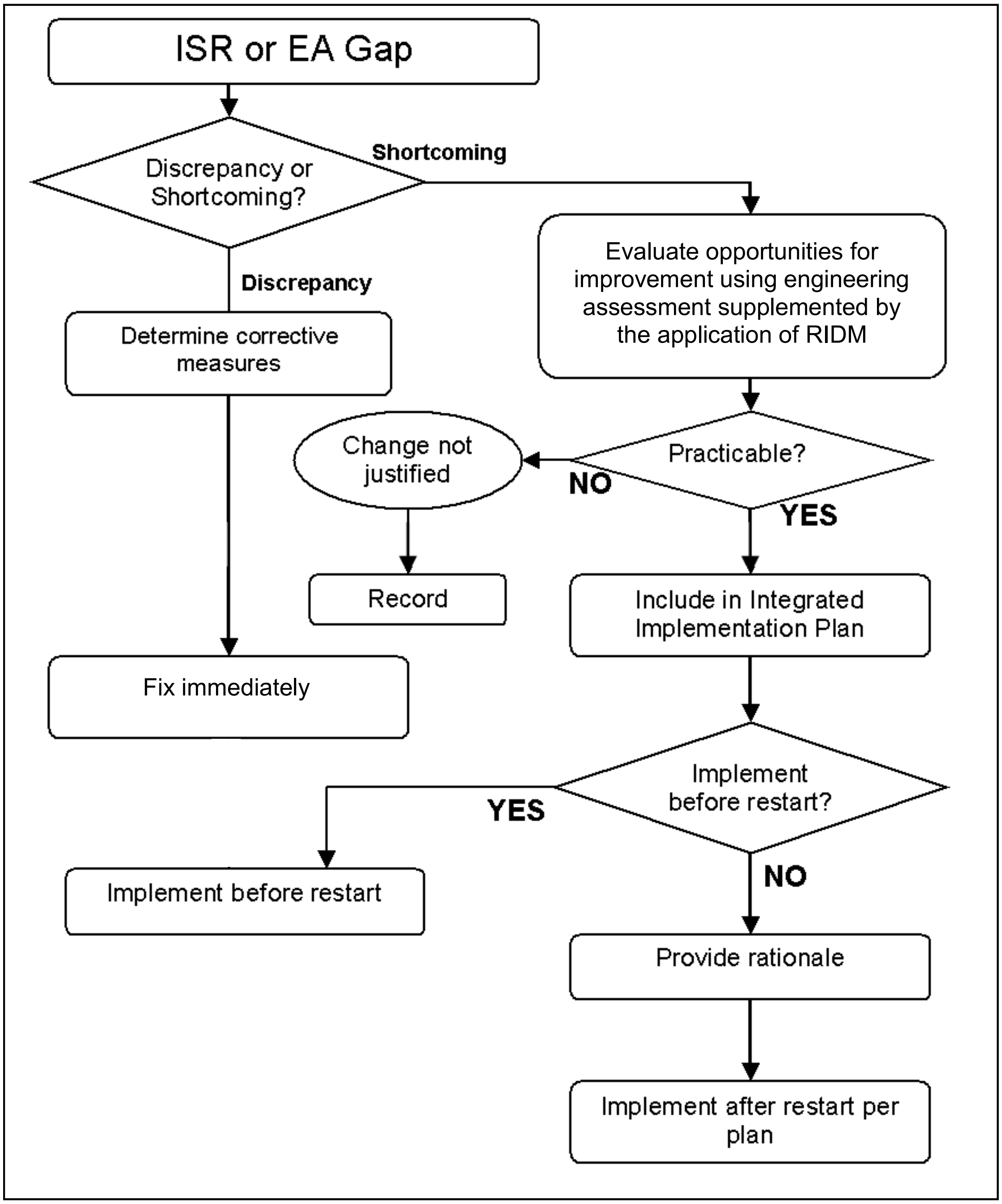

Figure 2: Steps Followed in Assessment of Gaps