

IMPLEMENTATION OF A MANAGEMENT SYSTEM FOR OPERATING ORGANIZATIONS OF RESEARCH REACTORS

Eduardo Kibrit¹, Afonso Rodrigues de Aquino² and Désirée Moraes Zouain³

¹ Centro Tecnológico da Marinha em São Paulo - CTMSP
Av. Prof. Lineu Prestes, 2468
05508-000 São Paulo, SP
kibrit@ctmsp.mar.mil.br

Instituto de Pesquisas Energéticas e Nucleares, IPEN – CNEN/SP
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
araquino@ipen.br², dmzouain@ipen.br³

ABSTRACT

This paper presents the requirements established by an IAEA draft technical document for the implementation of a management system for operating organisations of research reactors. The following aspects will be discussed: structure of IAEA draft technical document, management system requirements, processes common to all research reactors, aspects for the implementation of the management system, and a formula for grading the management system requirements.

1. INTRODUCTION

The National Commission of Nuclear Energy (CNEN) and its institutes are developing a project for a nuclear research reactor that will serve multiple applications - the Brazilian Multipurpose Reactor (RMB). The project aims to conceive, design, license and commission (i.e., put into operation) this reactor. In an optimistic forecast, it will be ready in 2016. The location of the new reactor has already been chosen: Iperó, 130 kilometres from São Paulo, right next to the Centro Experimental ARAMAR, a unit of Centro Tecnológico da Marinha em São Paulo (CTMSP), where the propulsion system of the Brazilian nuclear submarine is being designed. The increasing use of radioisotopes in health, industry, agriculture, research, among other areas, make nuclear research reactors essential. With the return of Brazilian Nuclear Program, such facilities support several developments in reactor physics, materials and human resources training.

The Brazilian Multipurpose Reactor (RMB) will provide the country a nuclear research reactor for the following applications:

- Produce radioisotopes and radioactive sources for health, industry, agriculture and environment sectors;
- Perform irradiation tests in nuclear material and fuel;
- Perform scientific and technological research with neutron beams.

Currently, there are four research reactors operating in the country:

- IEA-R1: “Pool” type reactor, located in São Paulo, in Instituto de Pesquisas Energéticas e Nucleares (IPEN) of CNEN, built in 1956, with power capacity up to 5,000 kW;
- IPR-RI: “TRIGA MARK I” type reactor, located in Belo Horizonte, in Centro de Desenvolvimento de Tecnologia Nuclear (CDTN) of CNEN, built in 1958, with power capacity up to 100 kW;
- Argonauta: “Argonauta” type reactor, located in Rio de Janeiro, in Instituto de Engenharia Nuclear (IEN) of CNEN, built in 1963, with power capacity up to 200 W;
- IPEN/MB-01: “Critical Assembly” type reactor, located in São Paulo, in IPEN/CNEN, built in 1984, with power capacity up to 100 W.

Research reactors are used for different and special purposes, such as research, training, radioisotope production, neutron radiography and material testing. These objectives require different features of design and different operating systems. These design and operation features can vary significantly, since the use of experimental devices can affect the performance of the reactors. In addition, the need for flexibility in their use requires a different approach to implement and manage safety.

A number of requirements for the safety of nuclear research reactors are the same as or similar to those for nuclear power reactors. In view of the important differences between power reactors and research reactors and among the different types of research reactors, these requirements are to be applied in accordance with the potential hazards associated with the reactor by means of a graded approach, thereby ensuring safety in the design and operation of research reactors.

According to publication IAEA NS-R-4 [2], to ensure safety in an organization operating a research reactor and its associated experiments, a quality assurance program¹ should be established, implemented, managed and evaluated. This quality assurance program should be implemented at each stage of the life cycle of the research reactor, site evaluation, design, construction, commissioning, operation, use, modification and decommissioning. In particular, all operational activities relating to safety, such as management of the reactivity and criticality, core thermal safety, safety of experimental devices, modification of reactors, components and materials handling, safety measures for visitors, and decommissioning, should have their requirements considered adequately in the quality assurance program.

Thus, according to publication IAEA NS-R-4 [2], the quality assurance program shall gradually address items, services or processes according to their importance to safety. This graded approach shall be based upon the reactor or experiment potential risk and shall meet the regulator requirements.

¹ The terms "quality assurance" and "quality management" have been replaced by the term "management" in publication IAEA GS-R-3 [3]. According to this publication, a management system integrates safety, environment, quality, security, health and economic elements into a single management system.

2. OBJECTIVE

The objective of this paper is to present and discuss the management system model for operating organizations of research reactors proposed in an International Atomic Energy Agency (IAEA) draft technical document IAEA TECDOC [1].

3. IAEA TECDOC WORKING DOCUMENT – FINAL DRAFT REQUIREMENTS [1]

3.1 IAEA TECDOC [1] Structure

IAEA TECDOC [1] has the following structure:

1. INTRODUCTION

- 1.1 Background
- 1.2 Objectives
- 1.3 Scope
- 1.4 Structure

2. MANAGEMENT SYSTEM

- 2.1 General / Establishment and implementation of the management system
- 2.2 Safety Culture
- 2.3 Grading the application of management system requirements
- 2.4 Documentation of the management system
 - 2.4.1 General
 - 2.4.2 Information structure

3. MANAGEMENT RESPONSIBILITY

- 3.1 Management commitment
- 3.2 Management processes
 - 3.2.1 General
 - 3.2.2 Planning and Reporting
 - 3.2.3 Management system administration
 - 3.2.4 Organization Structure

4. RESOURCE MANAGEMENT

- 4.1 Recruitment, Selection and Appointment
- 4.2 Performance, Assessment and Training
- 4.3 Employing Temporary Workers or Outsourcing

5. PROCESS IMPLEMENTATION

5.1 GENERIC MANAGEMENT SYSTEM PROCESSES

- 5.1.1. Control of document
- 5.1.2 Control of products
- 5.1.3 Measuring and test equipment
- 5.1.4 Control of records
- 5.1.5 Purchasing
- 5.1.6 Communication
- 5.1.7 Managing organisational change

5.2 PROCESSES COMMON TO ALL RESEARCH REACTORS

- 5.2.1 Project Management
- 5.2.2 Quotation qualification
- 5.2.3 Preparation of Technical Reports
- 5.2.4 Numerical Calculations
- 5.2.5 Incoming and Outgoing Correspondence
- 5.2.6 Archiving
- 5.2.7 Software Administration
- 5.2.8 Administration and Maintenance of Equipment and Installations
- 5.2.9 Operation of Installations and Laboratories
- 5.2.10 Waste Management
- 5.2.11 Health, Safety and Environment of Operations
- 5.2.12 Abnormal events
- 5.2.13 Accident and/or Emergency
- 5.2.14 Reactor Safety Committee (RSC)
- 5.2.15 License, Occupational Health and Safety Assessment
- 6. MEASUREMENT, ASSESSMENT AND IMPROVEMENT
 - 6.1 MONITORING AND MEASUREMENT
 - 6.2. SELF-ASSESSMENT
 - 6.3 INDEPENDENT ASSESSMENT
 - 6.3.1 General
 - 6.3.2 Internal Audits
 - 6.4 MANAGEMENT SYSTEM REVIEW
 - 6.5. NON-CONFORMANCES, CORRECTIVE AND PREVENTIVE ACTIONS
 - 6.5.1 Complaints and product non-conformances
 - 6.5.2 Feedback of Operational Experience
 - 6.6. IMPROVEMENT
 - 6.6.1 Improvement Proposals
- 7. MANAGEMENT SYSTEM IMPLEMENTATION IN A RESEARCH REACTOR
 - 7.1 GENERAL
 - 7.2 INTRODUCTION OF THE MANAGEMENT SYSTEM
 - 7.3 DEFINE OBJECTIVES
 - 7.4 MANAGEMENT COMMITMENT
 - 7.5 IDENTIFY STANDARDS
 - 7.6 ASSIGN PROJECT GROUP
 - 7.7 INVENTORY
 - 7.8 STRATEGY FOR IMPLEMENTATION
 - 7.9 RESOURCES
 - 7.10 SCHEDULE AND MILESTONES
 - 7.11 PHASES IN THE DEVELOPMENT STEPS
 - 7.12 MANAGEMENT SYSTEM MANUAL
 - 7.13 IMPROVEMENT OF THE MANAGEMENT SYSTEM
- REFERENCES
- APPENDIX 1: LEGEND AND ACRONYMS FOR SAMPLE PROCESSES
- ANNEX I: EXAMPLE OF A GRADED APPROACH TO THE APPLICATION OF MANAGEMENT SYSTEM REQUIREMENTS FOR A RESEARCH REACTOR
- ANNEX II: CONFIGURATION MANAGEMENT
- ANNEX III: EXAMPLES OF SYSTEM HEALTH PROCESS

ANNEX IV: EXAMPLE OF AN AGEING MANAGEMENT PROCESS GLOSSARY CONTRIBUTORS TO DRAFTING AND REVIEW

As seen above, IAEA TECDOC [1] has a similar structure to document IAEA GS-R-3 [3]. It has additional requirements to those presented in sections 1-6 of IAEA GS-R-3 [3]. Section 5.2 presents the processes common to all research reactors. Section 7 applies to the implementation of the management system in research reactors. Annex 1 of IAEA TECDOC [1] presents a graded approach to the application of management system requirements for research reactors. Annex II shows an example that describes a process methodology for configuration management. Annex III presents examples of system health process by performance monitoring. Annex IV shows an example of an ageing management process.

The following topics present in detail, the management system requirements, the processes common to all research reactors, aspects to be considered in the effective implementation of the management system and how the grading of the management system requirements should be made for research reactors.

3.2 Management System Requirements

To establish a management system, an operating organisation of research reactors should:

- Review the applicable regulations and standards and the organisation's management and technical practices to determine whether the work activities are adequately addressed;
- Review applicable IAEA requirements to identify shortcomings and assign priorities to those areas requiring improvement or development;
- Establish time-scales within which the required changes are to be implemented;
- Identify plans and document the work activities that have to be carried out.

The management system shall also promote and support a strong safety culture by:

- Ensuring a common understanding of the key aspects of safety culture within the organisation;
- Providing the means by which the organisation supports individuals and teams to carry out their tasks safely and successfully, taking into account the interaction between individuals, technology and the organisation;
- Reinforcing a learning and questioning attitude at all levels of the organisation;
- Providing the means by which the organisation continually seeks to develop and improve its safety culture.

The documentation of the management system shall include the following:

- The policy statements of the organisation;
- A description of the management system;
- A description of the structure of the organisation;
- A description of the functional responsibilities, accountabilities, levels of authority and interactions of those managing, performing and assessing work;
- A description of the processes and supporting information that explain how work is to be prepared, reviewed, carried out, recorded, assessed and improved.

The documentation for the management system shall reflect the characteristics of the organisation and its activities, and the complexities of processes and their interactions.

3.3 Processes Common to all Research Reactors

IAEA TECDOC [1] establishes the following processes common to all research reactors:

- Project management: This process describes the methodology to appoint a project leader, to set up a project including financial, technical and planning aspects, and submission of the results to the customer;
- Quotation qualification: This process describes a methodology used to prepare, authorize, issue and register potential external customers;
- Preparation of technical reports: This process describes a methodology for writing, reviewing and authorization of reports from the operating organisation;
- Numerical calculations: This process describes a methodology to select codes, standards and modelling requirements in case numerical calculations are performed;
- Incoming and outgoing correspondence: This process describes a methodology for receipt, forwarding, distribution and filing of incoming (i.e. receipt from external parties) and outgoing (i.e. sent to external parties) correspondence;
- Archiving: This process describes a methodology to identify and maintain an archive/term list and the expiration date of documents to be archived;
- Software administration: This process describes a methodology used to determine the methods for software administration and the responsibilities of the staff involved;
- Administration and maintenance of equipment and installations: This process describes a methodology used to determine and implement a description of periodic testing and preventive maintenance programmes;
- Operation of installations and laboratories: This process describes a methodology used to safely operate (nuclear) installations and laboratories according to the annual operational plan within the operating limits and conditions of applicable licenses or authorizations;
- Waste management: This process describes a methodology used to handle all waste streams (gaseous, liquid and solid) of an operating organisation;
- Health, safety and environment of operations: This process describes a methodology used to implement health, safety and environmental aspects into daily operation of a (nuclear) facility;
- Abnormal events: This process describes a methodology used to report, handle and solve abnormal events;
- Accident and/or emergency: This process describes a methodology used to manage emergency situations on the site of the operating organisation;
- Reactor Safety Committee (RSC): This process describes a methodology used to seek for advice of the organisation Reactor Safety Committee; and
- License, occupational health and safety assessment: This process describes a methodology to apply, implement or revise the license and/or the occupational health, safety and environmental aspects at the organisational level.

3.4 Management System Implementation

For the effective implementation of the management system, according to IAEA TECDOC [1], we should:

1. Define objectives;
2. Ensure management commitment;
3. Identify applicable standards;
4. Assign a project group;
5. Determine the management system processes that shall exist in order to meet the applicable standards;
6. Establish a strategy for implementing the management system, using P-D-C-A methodology;
7. Identify the resources needed to implement the management system;
8. Establish a schedule with milestones for implementing the management system;
9. Determine the development phases of processes;
10. Develop a Management System Manual;
11. Establish the improvement cycle of the management system.

3.5 Graded Approach for the Application of Management System Requirements

According to IAEA TECDOC [1], the application of management system requirements shall be graded so as to deploy appropriate resources, on the basis of the consideration of:

- The significance and complexity of each product or activity;
- The hazards and the magnitude of the potential impact (risks) associated with the safety, health, environmental, security, quality and economic related elements of each product and activity;
- The possible consequences if a product fails or an activity is carried out incorrectly.

Factors to be considered in the grading of the application of management system requirements for an operating organisation of research reactor include:

- a) The reactor power (for pulsed reactors, energy deposition is typically used, while for accelerator driven subcritical systems, thermal power is typically used);
- b) The radiological source term;
- c) The amount and enrichment of fissile and fissionable material;
- d) Spent fuel storage areas, high pressure systems, heating systems and the storage of flammables, which may affect the safety of the reactor;
- e) The type of fuel and its chemical composition;
- f) The type and mass of moderator, reflector and coolant;
- g) The amount of reactivity that can be introduced and its rate of introduction, reactivity control, and inherent and engineered safety features;
- h) The quality of the containment structure or other means of confinement;
- i) The utilization of the reactor (experimental devices, tests, radioisotope production, reactor physics experiments);

- j) The location of the site, including the potential for external hazards (including those due to the proximity of other nuclear facilities) and the characteristics of airborne and liquid releases of radioactive material;
- k) Proximity to population groups and the feasibility of implementing emergency plans.

3.5.1 Qualification formula

According to IAEA TECDOC [1] the research reactor project is divided into structure systems and components (SSCs), each comprising items, services, and processes. Factors based on significance to nuclear safety, reliability, complexity, design, and experience are determined and a “quality grade” (A, B, C, D) is assigned to each SSCs. The quality grade is obtained applying the results of a “qualification formula” (1) and the criteria in “assignment of quality grades” described below. The management systems define applicable requirements for each quality grade.

Qualification formula, as described in IAEA TECDOC [1]:

$$\text{Total Quality Rating (TQR)} = 2a + b + c + d + e \quad (1)$$

A total quality rating of SSCs is obtained assigning by the values for each of the factors considered in the formula. The criteria applied to obtain the different values for each factor are not discussed here.

The TQR may correspond to a general system or to its components because the components of a system will not necessarily have the same level of the system itself. Here they are referred generically as SSCs.

Brief description of the factors:

Safety (a): This factor includes nuclear, radiation, physical, and the so called industrial safety. It has a weight of 2 and its values can go from 0 to 5.

Reliability (b): This factor includes considerations on the loss of profit, delay or interruption of operation radioisotope production, failed repair work. Its values can go from 0 to 5.

Complexity (c): This factor includes consideration on the design, difficulties in replacing parts, accessibility for maintenance, unique SSCs design. Its values can go from 0 to 5.

Design State (d): This factor gives consideration to identifying the maturity of the design going from a fully tested SSCs design to be used without modifications to a new design to be developed from basic principles and data. Whenever it is assumed that a prototype will be built, this action will be valued by assigning a lower factor to it. Its values can go from 0 to 5.

Experience (e): This factor takes into account the accumulated and objective experience on the SSCs, obtained by the company, by suppliers, by other organisations or by recognized consultants and/or contractors. Its values can go from 0 to 4.

3.5.2 Assignment of quality grades

As described in IAEA TECDOC [1] and shown in Table 1 below, four quality grades are identified: A, B, C, and D. Quality grade A represents the stringent requirements level.

Table 1. Quality grades

Quality Grades	Assignment criteria
A	Items with factor a = 4 or 5
	Items with factor b = 5
	Items with TQR = 25-30
B	Items with factor a = 2 or 3
	Items with factor b = 3 or 4
	Items with TQR = 18-24
C	Items with TQR = 5-17
D	Items with TQR = 0-4

3.5.3 Example

Table 2 below shows an example of the requirements of each of the four quality grades for the procurement process.

Table 2. Example of quality grades requirements for procurement

Procurement	Quality Grade			
	A	B	C	D
1. Supplier evaluation and selection (prior to the awarding of the procurement order or contract)	X	X		
2. Surveillance at the Supplier's facility by the Technical Representative or Quality Officer	X	X	X	
3. Document evidence from the Supplier on that the procured items meet procurement quality requirements, such as codes, standards, or specifications	X	X	X	X
4. Periodic verification of the Supplier's certificates of conformance to assure their meaningfulness	X	X		
5. Evaluation of the performance of the Supplier with the participation of the Technical Representative / Procurement Department / Quality Division	X	X		

4. CONCLUSIONS

To ensure that operating organisations of research reactors operate safely and efficiently a management system that integrates safety, health, environmental, security, quality and economic elements shall be established and implemented, whereas safety shall be paramount upon all elements of the management system.

The management system aims to improve the safety performance of the organization through the planning, control and supervision of safety related activities in normal, transient and emergency situations; and to foster and support a strong safety culture through the development and reinforcement of good safety attitudes and behaviour in individuals and teams so as to allow them to carry out their tasks safely.

In order to operate safely and efficiently, Brazilian operating organisations of research reactors shall establish and implement a management system according to the requirements established by IAEA publications and CNEN regulations.

The purpose of this article was to present IAEA TEC DOC [1] requirements for the effective establishment and implementation of a management system for operating organisation of research reactors.

IAEA TECDOC [1] has a structure similar to document IAEA GS-R-3 [3], but as described in this article, it presents additional requirements for research reactors, such as: processes common to all research reactors, aspects for an effective implementation of the management system and aspects for a graded approach for the application of management system requirements.

Therefore, IAEA TECDOC [1] requirements shall be applicable to any operating organisation of research reactors willing to establish and implement a management system with high performance and high levels of safety.

ACKNOWLEDGMENTS

We would like to thank Centro Tecnológico da Marinha em São Paulo - CTMSP and Instituto de Pesquisas Energéticas e Nucleares, IPEN – CNEN/SP for supporting our participation in this International Conference.

REFERENCES

1. International Atomic Energy Agency (IAEA), *Implementation of a management system for operating organisations of research reactors – A case study*, IAEA TECDOC Working Document – Final Draft, International Atomic Energy Agency, Vienna – Austria (10 July 2011).
2. International Atomic Energy Agency (IAEA), *Research Reactors, Safety Requirements*, IAEA GS-R-4, International Atomic Energy Agency, Vienna – Austria (2005).
3. International Atomic Energy Agency (IAEA), *The management system for facilities and activities: safety requirements*, IAEA GS-R-3, International Atomic Energy Agency, Vienna – Austria (2006).