Graded Approach Applications in Nuclear Research Reactors

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ABSTRACT. A graded approach is applicable in all stages of the lifetime of a research reactor (site selection, site evaluation, design, construction, commissioning, operation and decommissioning). The IAEA Safety guide no. (SSG-22) presented recommendations on the graded approach to application of the safety requirements for research reactors. In these applications, a graded approach is only used in determining the scope and level of detail of the safety assessment carried out in a particular state for any particular facility or activity. In this document, the graded approach is applied for many applications of ETRR-2 research reactor, such as; the QA level determination during ETRR-2 fabrication and construction stages, and the frequency of Inspection, periodic testing and maintenance. Each application is graded quantitatively, which is considered to be a new trend. Grading was applied based on many factors such as; safety, reliability, design state, complexity, experience, availability, and economic factors. A certain amount of points were assigned to each factor. A formula then is applied to obtain the total amount of points. This total rating may correspond to a general system or to its components.

Key Words: Graded approach, ETRR-2, Maintenance, Quality assurance

1. INTRODUCTION

A graded approach is the process of ensuring that the level of analysis, documentation, and actions required by the regulatory framework to confirm the safety of a research reactor (RR) facility are commensurate with:

(1) The relative importance to safety, safeguards, and security;

(2) The magnitude of any hazard involved;

(3) The life cycle stage of a facility;

(4) The particular characteristics of a facility; and

(5) Any other relevant factors. [1]

1.1. Objective of the Graded Approach

• The objective of the graded approach is to adjust application of the safety requirements for analysis, evaluation and documentation to the potential hazards associated with the reactor facilities.

• The desired effect of applying the graded approach is that resources will be used more efficiently and produce maximum benefit.

• The graded approach should be used to eliminate unproductive or unnecessary features or activities.

• All relevant requirements must be complied with. A graded approach should be used to determine the appropriate manner to comply, not to provide relief from meeting a requirement.

Application of a graded approach may include:

• Determining the significance and complexity of a product or service, the maturity of the technology involved and the experience with its application;

• Evaluation of the impacts of a product or service on health, safety, security, the environment, quality and achieving the organization's objective; and

• Assessing the consequences of failure of a product or incorrect performance of a service.[2,3]

1.2. Basis Criteria for the Establishment of a Graded Approach

The factors to be considered in establishing a basis for the application of a graded approach include but are not limited to:

(1) Reactor power;

(2) The type, amount and enrichment of special nuclear material;

(3) The type of fuel elements (properties of fuel and cladding);

(4) The type and the mass of moderator, reflector and coolant;

(5) Nuclear Design Characteristics - excess reactivity, maximum reactivity addition rate, reactivity coefficients and inherent safety features;

(6) The existence of a containment or confinement structure;

(7) The utilization of the reactor (experimental devices, fuel experiments and reactor physics experiments;

(8) Presence of high-energy sources and other radioactive and hazardous sources.[4,5]

1.3. General considerations regarding the concept of grading

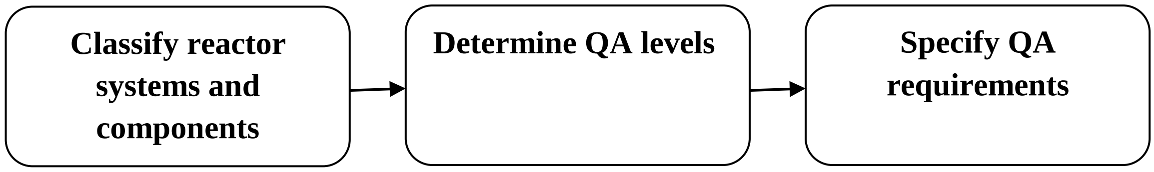
A graded approach is applicable in all stages of the lifetime of a research reactor. During the lifetime of a research reactor, any grading that is performed should be such that safety functions and operational limits and conditions are preserved, and such that there are no undue radiological hazards to workers, the public or the environment. The grading of activities should be based on safety analyses, regulatory requirements and engineering judgment. Engineering judgment implies that account is taken of the safety functions of SSCs and the consequences of failure to perform these functions, and implies that the judgment is documented. Other elements to be considered in grading are the complexity and the maturity of the technology, operating experience associated with the activities and the stage in the lifetime of the facility.

2. GRADED APPROACH APPLICATIONS IN ETRR-2 REACTOR

ETRR-2 is a multipurpose reactor, 22 MW, open pool type reactor with a maximum thermal neutron flux of 3.7x 10^{14} n cm^{-2} s^{-1}. The reactor was designed, provided, constructed, and commissioned through the international cooperation with INVAP- Argentina [8].The following are two typical applications of graded approach;

2.1. Application of Grading to QA during ETRR2 construction

The grading process consists of;



1- Classify each plant system using defined criteria

2- Assign a QA level for the activity to be carried out, or item/service to be procured or used, using defined risk logic tree. Starting at the plant class level, consider enhancement.

3- Apply controls to the activity or item/service appropriate to the QA levels.

Grading was applied to the QA level determination during ETRR-2 fabrication and construction stages based on many factors: safety, reliability, design state, complexity and experience. A Total Quality Rating (TQM) of the structure, systems and components is obtained by assigning the values for each of the factors considered in the formula. The TQM may correspond to a general system or to its components. Quality Assurance levels will be assigned according to ETRR-2 's Quality Level Determination Procedure. Under no circumstance has the catastrophic failure of the item to be classified been considered. A reasonable or conceivably possible failure or a known failure in other installations will be postulated. The item's eventual redundancy will not be considered. It shall be considered, moreover, that all activities undertaken in connection with the design and the installation itself will be carried out by individuals or companies duly qualified according to the requirements imposed by the corresponding System - Subsystem - Component levels. The following factors have been considered in connection with level assignations;

Safety

This factor includes both the radiological aspect, as well as the physical and industrial safety factors.

Reliability

This factor includes consideration of possible loss of profit, e.g. through delay, failed repair work, interruption of service i.e. radioisotope production or the irradiation of an experiment, etc.

Complexity

This factor includes consideration of the complexity of the design, difficulties in replacing parts, accessibility for maintenance and unique structures, systems and components design.

Design state

This factor gives consideration to identifying the maturity of the design, from fully tested structures, systems and components design of proven quality able to be used without modifications, to a new design to be developed from basic principles and data. Whenever a prototype is to be built, this action will be valued by assigning a lower factor to it.

Experience

This factor takes into account the accumulated and objective experience of the structures, systems and components, obtained by the organization, by suppliers, by other organizations or by recognized consultants and/or contractors.[12]

Factors determining total points (or rating) of each component:

Safety (factor "a")

0 – The failure produces no personal injuries.

1 – The failure produces slight injuries to operation personnel.

2 – The failure produces severe injuries to operation personnel.

3 – The failure produces severe injuries or death to operation personnel and slight injuries to general public.

4 – The failure produces severe injuries or death to operation personnel and severe injuries to general public.

5– The failure produces severe injuries, probably resulting in death to general public and the operation personnel.

Reliability (factor "b")

0 – A failure causes slight inconveniences and / or expenses. The service is not affected.

1 – A failure causes certain inconveniences and / or expenses.

2 – A failure results in significant damage to the service of the installation and / or results in high costs.

3 – A failure damages the service of the installation and / or results in high costs.

4 – A failure seriously damages the service of the installation and / or results in serious costs.

5 – A failure results in the total loss of the service of the installation and / or extremely serious costs.

Complexity (factor "c")

0 – The item is quite simple

1 – The item has only certain difficult parts or a few strict characteristics

2 – The item has some difficult parts or strict characteristics

3 – The item has some difficult parts or characteristics that are strictly interrelated

4 – The item has a significant number of difficult parts or strictly- interrelated characteristics

5 – The item has a large number of difficult parts or strictly- interrelated characteristics

Design state (factor "d")

0 – There is a fully proven design that will be used without modifications

1 – A design effort is required to evaluate an existing design with respect to an application tested under difficult conditions

2 – A design effort is required to evaluate an existing design with respect to a new application under difficult conditions

3 – A design effort is required to combine design elements tested so that they function together in a new application and / or under new conditions

4 – A design effort is required to add new design elements (not tested) for a new application under new conditions.

5 – A design effort is required to develop a new design as from basic, physical and chemical data.

Experience (factor "e")

0 – The item has already been produced in accordance with the same requirements and specifications.

1 – The item has already been produced, through under different requirements and specifications

2 – The item's design is new. Hence, it has not been produced before, though the requirements and specifications under which it is made are known.

3 – The item had not been produced before and it is being made under previously unknown requirements and specifications.

4 – The item constitutes a wholly new development. The information on applicable requirements and specifications should be developed.

Quality level determination formula; this formula is applicable to systems, equipment or items as follows:

$$TQR = 2a + b + c + d + e$$

After determination the quality levels of the research reactor systems and items, we can grade all the required QA documents and procedures of each quality level as shown in table 1.

TABLE 1: Quality levels and Procedures matrix

PROCEDURES System functions	“A” Level	“B” Level	“C” Level	“D” Level
Contract review	X			
Design control	X			
Documentation issuing and control	X	X	X	
Procurement	X	X	X	
Measuring and testing equipment	X	X	X	
Incoming inspection	X	X	X	
In-process inspection	X	X		
Final inspection	X	X	X	X
Items supplied by the client	X	X		
Identification and traceability of items	X	X		
Manufacturing and construction	X			
Special processes	X	X	X	
Handling, Storage, packaging, preservation, and shipping	X	X	X	
Non-conformance items	X	X	X	X
Corrective action	X	X		
Quality records	X	X	X	X
Items identification and follow up	X	X	X	
Handling, storage, preservation, packing, and shipping	X	X	X	
Audits	X			
Quality program documents				
Manual	X	X	X	
Manufacturing, construction, start-up, and inspection plan	X			
Inspection and test plan		X		
Verification plan			X	
Provision plan				X
Procedures	X	X	X	
Release certificate issuing	X	X	X	X
Quality records				
Inspection and test (results)	X	X	X	X
Nonconforming items	X	X	X	X
Corrective action	X	X		
Qualification of special processes, personnel, etc.	X	X	X	
Conformance certificate	X	X	X	X

2.2. Application of grading to maintenance, periodic testing, and inspection at ETRR-2

The requirements for maintenance, periodic testing and inspection of research reactors are established in Ref. [7]. Grading can be applied to the frequency of maintenance, periodic testing and inspection of individual safety system components (SSCs), and is required to be adjusted on the basis of experience and the importance to safety of the SSC concerned. In developing the procedures for maintenance, periodic testing and inspection, consideration should be given to the importance to safety of the SSC concerned, to the complexity of the maintenance, testing or inspection activity, and to the experience of the staff and their familiarity with the systems.

ETRR-2 equipment and components classification is needed in order to obtain an increasing reliability of equipment and components. Several factors, depending on the parts utilization, may define the reliability requirements (i.e. safety, availability, economic factors, experience and complexity). The importance of each one of the indicated factors is quantified through a points system ("0","1", "2", "3", "4" and "5").

The value "0", corresponds to the less important case and the value "5" to the situations with bigger importance. The relative importance within the different factors is included by a set of weight coefficients.[9]

Through the below formula the class for each equipment and component can be obtained as follows:

$$X = 2.5a + 2b + 1.5c + 1d + 1e + 0.5f$$

Class A: for $x >= 24$

Class B: for $12 < x < 24$

Class C: for $0 <= x <= 12$

Development of the classification system:

Safety (factor a)

"0": The failure will not produce personnel injuries.

"1": The failure can produce light personnel injuries.

"2": The failure can produce major injuries to the operative personnel.

"3": The failure can produce the death of the operative personnel.

"4": The failure can produce probably the death to the operative personnel and/or injuries to the public

"5": The failure can produce probably damage and death of the public and/or the death of the operative personnel.

Availability (factor b)

"0": The failure produces an insignificant inconvenient and/or a quickly repair of the equipment and/or component.

"1": The failure produces a significant inconvenient and/or a slowly repair of the equipment and/or component.

"2": The failure produces a major and/or irreparable inconvenient in the equipment and/or component.

"3": The failure produces an inconvenient of the equipment and/or component and an insignificantly inconvenient of the system.

"4": The failure produces a major inconvenient of the equipment and/or component and a significant inconvenient of the system.

"5": The failure produces a major inconvenient of the equipment and/or component and a major inconvenient of the system too.

Design state (factor c)

"0": There is a design fully proved that will be used without modifications.

"1": It is necessary a design effort to evaluate an existing design, respect to the application on trial in the same condition.

"2": It is necessary a design effort to evaluate an existing design, respect to a new application under demanding conditions.

"3": It is necessary a design effort to combine different elements of design (already tested), in order that they operate as a whole in a new application and/or new conditions.

"4": It is necessary a design effort to incorporate new design elements (not yet tested) for an application under new conditions.

"5": It is necessary a design effort to develop a new system starting from physical and chemical basic data.

Economic factor (factor d)

"0": A failure produce insignificant expenses (less than 500 U$S)

"1": A failure produce some expenses (less than 5000 U$S)

"2": A failure produce important expenses (less than 20000 U$S)

"3": A failure produce costs of greater range (less than 40000 U$S)

"4": A failure produce major costs (less than 70000 U$S)

"5": A failure produce costs of extreme seriousness (less than 100000 U$S or more)

Experience (factor e)

"0": The item has been produced previously conforming to the same requisites without related problems with the quality assurance.

"1": Important previous experience and little related problems with the quality assurance.

"2": Some previous experience and little related problems with the quality assurance.

"3": Some previous experience and some related problems with the quality assurance.

"4": Little previous experience and large related problems with the quality assurance.

"5": Without previous experience and related problems with the quality assurance.

Complexity (factor f)

"0": The item is simple.

"1": The item has only a few complex parts or a few strict characteristics

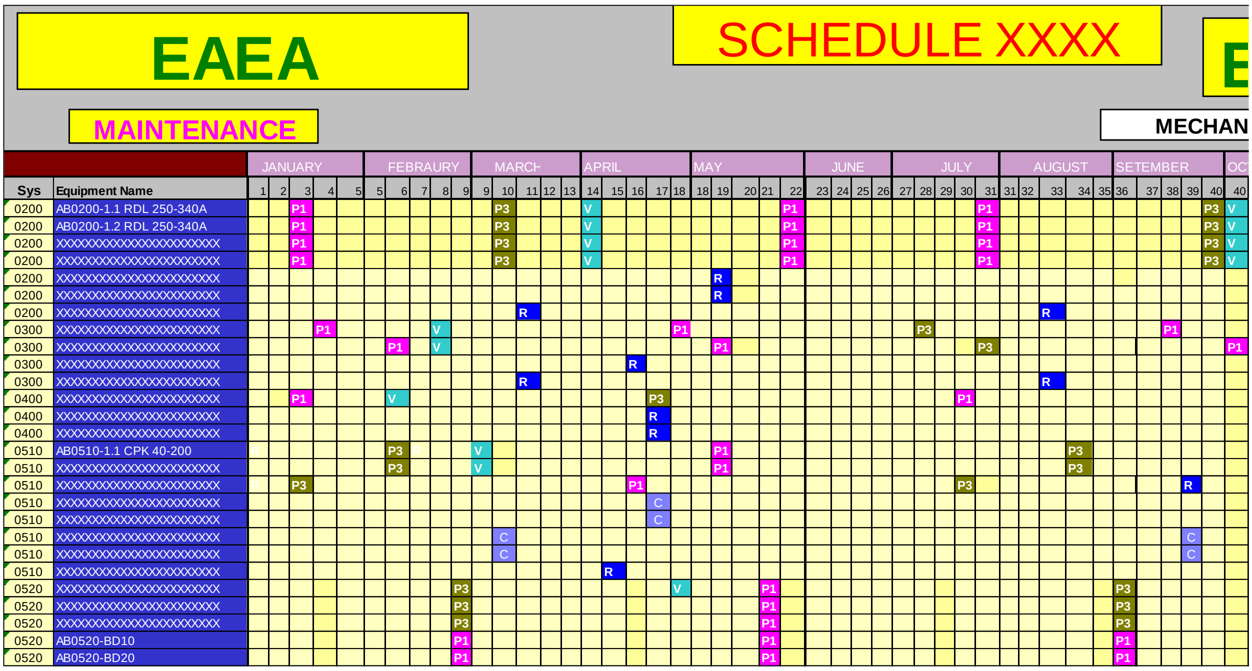
"2": The item has some complex parts or strict characteristics

"3": The item has some complex parts or some interrelated characteristics

"4": The item has a significant quantity of complex parts or a significant number of strict interrelated characteristics

"5": The item has a great number of complex parts or a great number of interrelated characteristics.

The sequence of the preventive maintenance programme for the 52 weeks per year was developed according to this classification. An example of the PM schedule of the mechanical and electrical components is shown in Fig.1.[16]



Key symbols

R=Revision, L=Lubrication, RT= Running test, M= Check & Measure, C= Clean, F= Full maintenance, A= Calibration, V= Alignment & Vibration measurement, D= Drop time measurement, P1= R+RT, P2= R+L, P3= R+L+RT ,P4= C+M , P5= RT+C+M.

FIG.. 1. PM schedule for mechanical and electrical components

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