Causal Factors Guide for the Evaluation of Accidents in Research Reactors

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ABSTRACT

In the field of radiological and nuclear safety, the Nuclear Regulatory Authority (ARN) of Argentina controls three research reactors and three critical assemblies, by means of evaluations, audits and inspections, in order to ensure the fulfilment of the requirements established in the Licenses, in the regulatory standards and in the mandatory documentation in general.

From the Nuclear Regulatory Authority's point of view, within the general process of research reactors safety management, the management of operating experience plays an outstanding role.

In this aspect the ARN has established specific requirements in the Operation Licences in relation to the communication, evaluation, investigation of causes, and adoption of corrective measures, for the events that occurred.

From the experience collected in the analysis of the reports sent by the operators it has been verified some weaknesses in relation to the methodology of analysis of events and in the determination of the causal factors.

In such sense, with the purpose of establishing some help for the appraisers and to homogenize the treatment of the events, two reference guides were designed: a guide for the evaluation of events and the other with a grid of causal factors

This paper describes the main aspects of the operating management system established for research reactors and critical assemblies in Argentina, and the guides developed for the event analysis and determination of causal factors.

INTRODUCTION

The NUCLEAR REGULATORY AUTHORITY (ARN) was established as an autonomous body reporting to the President of Argentina by Act 24,804 known as the Nuclear Activity National Act, which came into force on April 25, 1997, and is empowered to regulate and control the nuclear activity with regard to radiation and nuclear safety, physical protection and nuclear non-proliferation issues. It must also advise the Executive on issues under its purview.

The objective of the ARN is to establish, develop and enforce a regulatory system applicable to all nuclear activities carried out in Argentina.

The goals of this regulatory system are:

· To provide an appropriate standard of protection for individuals against the harmful effects of ionizing radiation.

· To maintain a reasonable degree of radiological and nuclear safety in the nuclear activities performed in Argentina.

· To ensure that nuclear activities are not developed with purposes unauthorized by the law and regulations resulting therefrom, as well as by the international agreements and the non-proliferation policies adopted by Argentina.

· To prevent the commission of intentional actions which may either have severe radiological consequences or lead to the unauthorized removal of nuclear materials or other materials or equipment subject to control.

With the purpose of fulfilling the objectives before mentioned, the ARN has developed and has been provided with three basic capacities:

a- Legal capacity: it is an organization established by means of a law, with missions and functions clearly established and legally recognized.

b- Technical Capacity: it has a staff with a high percentage of professionals; most of them with a post graduated degree and a suitable training.

c- Operational capacity: it has adequate infrastructure, equipment and budget for the fulfilment of its functions.

In Argentina there are two nuclear power plants in operation, one under construction, three critical assemblies, three research and isotope production reactors, one decommissioned critical assembly, 25 major radioactive facilities and more than 1,600 facilities for medical, industrial, research and training purposes which use radioactive materials or sources.

The type of regulatory tasks can be different in three main fields: Radiological Protection and Nuclear Safety, Safeguards and Physical Protection

In the field of Radiological and Nuclear Safety control, applied to Research Reactors and Critical Assemblies, ARN's regulatory activities are directed at controlling 3 research reactors and 3 critical assemblies, analyzing design and operation-related documents, permanently assessing safety during operation, and verifying by means of regulatory inspections and audits the compliance with the provisions of the license concerned.

The principal characteristics of the Argentinean RR and CA are presented below,

RESEARCH REACTORS AND CRITICAL ASSEMBLIES IN ARGENTINA

	CRITICAL ASSEMBLIES			
	RA-0	**RA-2**	**RA-4**	**RA-8**
POWER (W)	1	1	1	10
TYPE	TANK	TANK	HOMOGENEOUS	TANK
UTILIZATION	TEACHING AND TRAINING	RA-3 FACILITY	TEACHING AND TRAINING	CAREM FUEL TEST
FUEL	UO2	UAL	UO2	UO2
FUEL ELEMENT	RODS	MTR	POLIETYLENE PLATES	RODS
ENRICHMENT (%)	20	90	20	1.8 AND 3.4
RECTIV. EXCESS	0.40 $	-------	0.4 $	NOT DEFINED
STATUS	OPERATIONAL	DECOMMISIONED	OPERATIONAL	EXTENDED SHUTDOWN
PLACE	UNIVERSITY - CÒRDOBA	CONSTITUYENTES ATOMIC CENTRE	UNIVERSITY- ROSARIO	PILCANIYEU ATOMIC CENTRE
CRITICALITY	1970		1971	1998

	RESEARCH REACTORS		
	RA-1	**RA-3**	**RA6**
POWER (Kw)	40	10000	500
TYPE	TANK	TANK	TANK
UTILIZATION	RESEARCH, TRAINING, BNCT, MATERIAL TEST	RADIOIS. PRODUCTION, RESEARCH, AxA	RESEARCH, TRAINING, AxA, BNCT
FUEL	UO2	UO2, USI3	UO2
FUEL ELEMENT	RODS	MTR	MTR
ENRICHMENT	20	20	90
RECTIV. EXCESS	1.5 $	8 $	2 $
STATUS	OPERATIONAL	OPERATIONAL	OPERATIONAL
PLACE	CONSTITUYENTES ATOMIC CENTRE	EZEIZA ATOMIC CENTRE	BARILOCHE ATOMIC CENTRE
CRITICALITY	1958	1967	1982

REGULATORY CONTROL

The regulatory control of Research Reactors and Critical Assemblies is carried out by mean of inspections, audits and safety evaluations, all based on the following criteria: Prevention, Process Evaluations, and Management of Operational Experience (ref.1).

With relation to the Prevention criteria, attention must be paid to the evolution of parameters and indicators, in order to early detect precursors that could affect safety. As a result of those activities, when appropriate, the Regulatory Body can use its enforcement capacity with the purpose of avoiding the progress of negative trends or to correct deviations.

The Evaluation of Process means that each topic to be controlled is analyzed taking into account the three basic components, and the interaction between them: Equipment and systems, documents and procedures, and human factors.

The Management of Operative Experience is mainly oriented to the investigation of the events occurred in research reactors: compilation of information related to the event, analysis of the information, determination of causal factors, definition of corrective measures, and control of application of these measures. The primary objective of this task is to determine why the event took place and to adopt suitable measures to avoid the recurrence or the occurrence of similar events.

Management of Operative Experience: Regulatory aspects

With the purpose of management, two types of events have been classified:

- Low Level Events: all those situations that separate from to the normal operation and normal tasks, which could produce an increase in the radiological and/or nuclear risk, but can not be qualified as High Level Event. For example:
    - Personnel irradiation or contamination at levels lower than annual constrains
    - Fall of irradiated samples during transport
    - Early detection of failure or bad performance of the equipment that fulfils safety functions
    - Etc.

In the Operation Licences of Research Reactors it has been established that the Primary Responsible (Reactor Manager) shall send every trimester (among other information) an analytical report with all the LLE that took place in this trimester.

- High Level Event (HLE): all those situations that separate from to the normal operation and normal tasks, which cause important radiological consequences, or produce significant increase in the radiological and/or nuclear risk. For example:
    - Personnel irradiation or contamination at levels higher than annual constrains
    - Radioactive discharges al levels higher than annual constrains
    - Extended contamination
    - Significant degradation of one or more physical barriers of the defence in depth.
    - Failure or bad performance of equipment that fulfils safety functions
    - Etc.

In the Operation Licences of Research Reactors it has been established that, once an event is detected and qualified as HLE, the primary responsible shall: communicate it, in a summarized way, to

the Regulatory Body; within the 24 hours send a detailed description; and within the next 30 days send an analytical report of the event.

Management of Operative Experience: Analytical event report

From the experience gathered in the analysis of the information of events received from the facilities, the following weaknesses were observed:

- Depth of analysis: tendency to identify direct causes but not root causes,
- Scope of analysis: tendency to identify only internal faults,
- Spectrum of analysis: Lack in the identification of contributor factors

In order to solve these problems the following measures were taken:

- The reactors personnel was trained in techniques related to analysis of events,
- A guide was written for the evaluation of events (annex 1), and the reactors personnel was trained in its use,
- A guide was written for the evaluation of causal factors (annex 2), and the reactors personnel was trained in its use,

On the other hand, at present we are working on writing a general procedure for the evaluation and management of events in research reactors.

For the preparation of the causal factors guide, an ample vision was adopted with respect to the causes that contribute to the occurrence of events, including the factors related to institutional management.

Was also included the factor (or block of factors) "Regulatory Control" in the scheme. Although it has not been developed in detail yet, and falls out of the analysis that the Organization of Operation makes.

The writing of these guides is very recent (in fact are under qualification) and we have not enough experience in their application, but during 2006 we carried out a practical exercise for application of the causal factors guide to a well known accident, with very satisfactory results. This exercise was done within the activities of retraining of reactors licensed personnel as well as in a special workshop held in the post degree course of Radiological a Nuclear Safety.

The writing of the guides was based in self criteria and in the documents indicated in References

CONCLUSIONS

We considered that the regulatory criteria of demanding the Operating Organizations to carry out a systematic and documented investigation of abnormal occurrences will produce as a result a substantive improvement in the prevention of occurrence and/or recurrence of events.

The decision of considering the management of events as one of the most important subjects in the regulatory control of research reactors has allowed to develop an effective tool to increase the knowledge of the facilities and their personnel, and to stimulate the continuous improvement in safety.

We estimate that the systematic use of the guides in the process of evaluation of events and in the determination of causal factors will allow a significant improvement in the quality of event analysis and, therefore, in the implementation of appropriate corrective measures.

It should be remarked that the guide is still in its test and validation stage and it will be improved as it is systematically used.

ANNEX 1:

GUIDES OF CONTENT: ANALYTICAL REPORTS OF EVENTS

DESCRIPTION OF EVENT

1. General reactor information.

2. Identification of systems, components and/or devices involved in the incident.

Functional description of involved systems, components and/or devices (Include drawings, descriptions, parameters of operation, etc.)

3. Status of the reactor prior to the incident; tasks under development.

Description of the status of the reactor (in operation, handling of samples, maintenance, experiments, etc.), with special emphasis on the systems involved in the incident, including values of physical parameters.

Description of the all tasks under development with some relation with the incident (identification of applicable procedures, identification and distribution of the personnel, drawings and schemes with the location of components and personnel)

Identification of pertinent situations of context that could have influenced in the incident.

INVESTIGATION OF THE EVENT

1. Collection of data and information

Background: description of events that took place in the past, prior to the event, and related to it. Brief description of previous similar situations.

Detailed description of the site, right after the event (schemes, photos, reconstruction, conditions of equipment and systems, and all data considered significant).

List and description of documentary evidences: mandatory documents related to the activities under developing (standards, guides, procedures, Limits and Conditions, etc.) with remark to relevant aspects related to the event. Copy of records of operation, radioprotection, maintenance, etc

Testimonial evidences: identification of people interviewed, including data of their function in the installation, role during the development of the sequence of events that gave rise to the event. Detail (textually as far as possible) statement of the witnesses.

Description of eventual calculations and results presentation.

2. Analysis of data and information.

2.a. Description of Facts

Sequence of previous events

Presentation of the sequences of events, from the initial event to the accident itself. Identification of the main sequence and secondary sequences.

Presentation of normal sequence of events (ideal sequence without accident).

Presentation of the sequences and hypotheses that could maximize the consequences of the accident.

Identify in each step the physical events (in equipment and systems) and the human actions (decisions, actions and omissions)

Sequence of events after the accident

Presentation of the sequences of events, from the accident itself to the final stable state. Identification of the main sequence and secondary sequences.

Presentation of the sequences of events, from the accident to the final normal state. Identification of the main sequence and secondary sequences.

Identify in each step the physical events (in equipment and systems) and the human actions (diagnosis of the accident, decisions, actions and omissions)

Consequences

Detailed description of the undesirable consequences produced by the accident in the personnel, equipment and systems, including quantification.

2.b. Evaluation of causal factors

Identification of faults, bad functioning, errors and/or violations; determination of direct causes.

Identification of contributor factors

Analysis and determination of root causes. Presentation of the adopted criteria and detail of analyses done

2.c. Presentation of conclusions and summary of root causes.

MANAGEMENT OF CORRECTIVE ACTIONS

1. **Equipment and systems**
   Description of corrective actions adopted in relation to the equipment, components, tools, instruments, etc., including period of time in which these actions are going to be carried out.

2. **Personnel**
   Description of corrective actions adopted in relation to personnel (theoretical or practical training, replacement, etc.) including period of time in which these actions are going to be carried out.

3. **Procedures**
   Description of corrective actions adopted in relation to procedures and work practices, including period of time in which these actions are going to be carried out.

4. **Management and supervision**
   Description of corrective actions adopted in relation to the direct supervision of the tasks, to the supervision on the part of the reactor responsible, and to the independent revision on the part of the responsible organization.
   Description of concrete corrective actions adopted by the organization in relation to the safety policy.
   Period of time in which the actions are going to be established.

ANEX 2:

GUIDE OF CAUSAL FACTORS

LEVEL 1	LEVEL 2	LEVEL 3	CAUSAL FACTORS
EQUIPMENT AND SYSTEMS	EXTERNAL FACTORS	**Natural**	Flooding Lightning strikes Storm, wind loading Earthquake Freezing High ambient temperature/high humidity Heavy rain or snow Heavy sand storms
		Technological	Air planes Explosion Toxic other
	INTERNAL FACTORS	**Design And Specifications**	Failure in specifications
			Designer qualification LTA(*)
			Design process
			Design failure
		Construction manufacture	Constructors qualification LTA
			Quality of materials or components
			Construction specifications
			Failure during const. or manufacture
		Assembly	Assemblers qualification LTA
			Assembly specifications
			Failure during assembly
		Operation	Operation out of limits
			Operation error
		Maintenance	Maintenance program LTA Maintenance program not fulfilled Preventive maintenance badly executed Corrective maintenance badly executed Excess of corrective maintenance

LTA: Less than adequate

LEVEL 1	LEVEL 2	LEVEL 3	CAUSAL FACTORS
HUMAN FACTORS	COMMUNICATION	Verbal	Lack of standard words or phrases
			Noise during communication
			Faults of the emitter (Inhibited Style, Aggressive Style, Confused or vacillating, Laconic, Physical or language problems)
			Faults of the receiver (Lack of attention or active listening, Pre-interpretation, Preconception or Over understanding, Physical or language problems)
			Lack of feedback
			Use of different units
		Written Or Graphical	Document not available
			Document not updated or incomplete
			Lack of standard words or phrases
			Lack of guides or procedures
			Edition errors (Error in writing or syntax, Blurred copies or badly printed, Small letters, Confused or incomplete drawings, Erroneous drawings, etc.)
			Use of different units
		Not Verbal	Lack of standard codes
			Faults of the emitter (Erroneous signals, Confusing signals, Bad communication or with delay)
			Faults of the receiver (Erroneous interpretation, Lack of attention)
			Bad visibility
	WORK ENVIROMENT		Housekeeping
		---	Environment extremely cold
		---	Environment extremely hot
		---	Noisy Environment
		---	Bad visibility
		---	High radiation
		---	Lack of oxygen
		---	Contamination, dust, gases
		---	Unsafe or uncomfortable place
		---	Water spilling
		---	Enclosed area (claustrophobia)

LEVEL 1	LEVEL 2	LEVEL 3	CAUSAL FACTORS
HUMAN FACTORS	INDIVIDUAL FACTORS	---	Knowledge LTA
		---	Error in diagnosis/evaluation
		---	Skills (Communicational, Operational)
		---	Mistake
		---	Excess or lack of confidence
		---	Lack of attention
		---	Tunnel vision
		---	Psychological factors a. Lack of motivation b. Stress c. Tediousness
		---	Physical factors a. Fatigue b. Diminished senses c. Illness d. Physical condition
		---	Intentional attitude
		---	Lack of critical attitude
		---	Hurriedness, anxiety

LEVEL 1	LEVEL 2	LEVEL 3	CAUSAL FACTORS
EQUIPMENTS AND SYSTEMS + HUMAN FACTORS	MAN- MACHINE INTERFACE	**Identifiers (labels, tags, warnings...)**	Lack of identifiers
			Confusing or illegible
			Different conventions
			Labels inadequate
		Ergonomics	Inadequate ergonomics
		Instruments And alarms	Do not exist or LTA
			Bad functioning
		Comunic. Equipment	Failure or bad functioning
		Manual actuators	Failure or bad functioning
			Manual actuators inadequate
		Displays	Erroneous presentation
			Presentation delay
			Inadequate displays

LEVEL 1	LEVEL 2	LEVEL 3	CAUSAL FACTORS
ORGANIZACIONAL MANAGEMENT	ORGANIZACIONAL WEAKNESSES	Policy And Organization	**Policy (safety culture)** LTA Inadequate definition Inadequate implementation
			Organization Inadequate Not formalized Not implemented – not fulfilled Inadequate functions and responsibilities Unbalance responsibility-authority
		Managerial Weaknesses	**Human resources** a. Insufficient b. Qualification LTA c. Unmotivated d. In conflict e. Lack of prizes and punishments
			Other resources a. Inadequate budget b. Burocracy (delay) c. Inadequate infrastructure d. Lack of tools or elements e. Transport
			Controls a. Do not exist or LTA b. Over indulging c. Little strict
		Quality Management	**Quality system** a. QS LTA b. Incomplete c. Not updated
			Implementation of QS a. Not implemented b. Inadequate implementation
			Documentation a. Technical information (manuals, technical specifications, etc.) b. Drawings, schemes, c. Archives and records
			Procedures and instructions a. Incomplete or erroneous b. Not used c. Badly executed

LEVEL 1	LEVEL 2	LEVEL 3	CAUSAL FACTORS
ORGANIZACIONAL MANAGEMENT	REACTOR MANAGEMENT	**Work Planning**	Without previous planning
			Inadequate planning a. Coordination between groups b. Contingencies c. Resources d. Excess of tasks
			Inadequate preparation
		Work Supervision	Lack or insufficient supervision
			Inadequate style
			Self check not used or badly applied
			Independent check not used or badly applied
			Work pressure
			Inadequate control of contractors
		Supervisors Competences	Technical competence LTA Related to human relations Related to management
		Personnel Qualification and training	Personnel qualification LTA Personnel training LTA Personnel retraining LTA

LEVEL 1	LEVEL 2	LEVEL 3	CAUSAL FACTORS
REGULATORY CONTROL	STANDARDS AND REGULATIONS	**Legal background**	Lack of Basic Law
			Faults in the definition of functions of the regulatory body
			Faults in the definition of authority of the regulatory body
		Regulatory standards	Lack of regulatory standards
			Safety aspects not covered
			With errors, not updated
	ORGANIZACIONAL WEAKNESSES	**Policy and organization**	Inadequate HHRR policy
			Inadequate organization
			Inadequate objectives and priorities
		Management	Inadequate HHRR management
			Activities management
			Manager competencies
		Infrastructure	Insufficient or inadequate HHRR
			Inadequate facilities and equipments
			Insufficient budget
	WORKING FAILURES	**Personnel Competence**	Knowledge LTA
			Inadequate profile
			Related to human relations
		Operational Management	Planning
			Preparation
			Execution
			Following
		Support Activities	Lack of specialized support
			Lack of administrative support

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