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DOCUMENTATION CONTROL PROCESS OF BRAZILIAN MULTIPURPOSE REACTOR – CONCEPTUAL DESIGN AND BASIC DESIGN

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ABSTRACT

Established in the scope of Plan of Action of the Ministry of Science, Technology and Innovation (PACTI / MCTI) in 2007, the construction of the Brazilian Multipurpose Reactor (RMB) is on the way. This type of reactor has a broad spectrum of applications in the nuclear field and related technologies such as the radioisotopes used as supplies in the production of radiopharmaceuticals, with very much benefit to the Brazilian society being, therefore, the main goal of the Project. RMB Project consists of the following stages: site selection and site evaluation; design (conceptual design, basic design, detailed design and experimental design); construction (procurement, manufacturing; civil construction; electromechanical construction and assembling); commissioning; operation and decommissioning. Each stage requires adaptation of human resources for the stage schedule execution. The implementation of a project of this magnitude requires a complex project management, which covers not only technical, but also administrative areas. Licensing, financial resources, quality and document control systems, engineering are some of the areas involved in project success. The development of the conceptual and basic designs involved the participation of three main engineering companies. INTERTECHNE Consultores S.A. was in charge of conceptual and basic designs for conventional systems of buildings and infrastructure. INVAP S.E. was responsible for preparing the basic design of the reactor core and annexes. MRS Estudos Ambientais Ltda. has prepared documents for environmental licensing. This paper describes the procedures used during conceptual and basic design stages to control design documentation and flow of this documentation, involving the analysis and incorporation of comments from experts, control and storage of a volume of approximately 15,000 documents.

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). RMB Project was established in the scope of Plan of Action of the Ministry of Science, Technology and Innovation (PACTI / MCTI) in 2007. RMB Project aims to conceive, design, license and commission (i.e., put into operation) this reactor. In an optimistic forecast, it will be ready in 2020. RMB will be located in Iperó, a city 130 kilometers far from São Paulo, right next to the Centro Experimental ARAMAR, a unit of Centro Tecnológico da Marinha em São Paulo (CTMSP).

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

- Produce radioisotopes for use in Nuclear Medicine;
- Produce 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.

RMB Project is subdivided in stages, sectors, buildings, and systems.

1.1. RMB Project Stages

RMB Project consists of the following stages: site selection and site evaluation; design (conceptual design, basic design, detailed design and experimental design); construction (including procurement, manufacturing, civil construction, electromechanical construction and assembling); fuel supply; licensing (environmental licensing, nuclear licensing); commissioning; operation and decommissioning.

In this paper, we will focus on documentation prepared for conceptual and basic design stages.

1.2. RMB Sectors and Buildings

Figure 1 illustrates RMB sectors: infrastructure, administrative, and nuclear production and research (NPR). Each sector is formed by the buildings described below:

- Infrastructure sector: consists primarily of Water Catchment, Adduction and Pumping; Water Treatment Station; Solid Waste Treatment; General Site Maintenance Workshops; General Warehouse; Primary Cabins, Drinking and Reuse Water Reservoirs; and Transformer Stations Surface;
- Electrical Substation;
- Administrative Sector: consists primarily of Hotel, Restaurant, Administration/Library, Medical Clinic, Training and Exhibition Center, Garage, Main Gateway, Building Support for Outsourced and Watch Towers;
- Sector of Nuclear Production and Research (NPR): formed primarily by the Reactor Building, Neutron Guides, Storage of Burned Fuels and Handling Items, Radioisotopes Processing and Sources Production, Irradiated Materials Analysis Laboratory – IMAL, Radiochemistry Laboratory – RALA, Operation Support, Researchers, Cooling Tower, Auxiliary Systems, Primary Cabins, Waste Treatment and Storage, Support Workshop and Access Control.

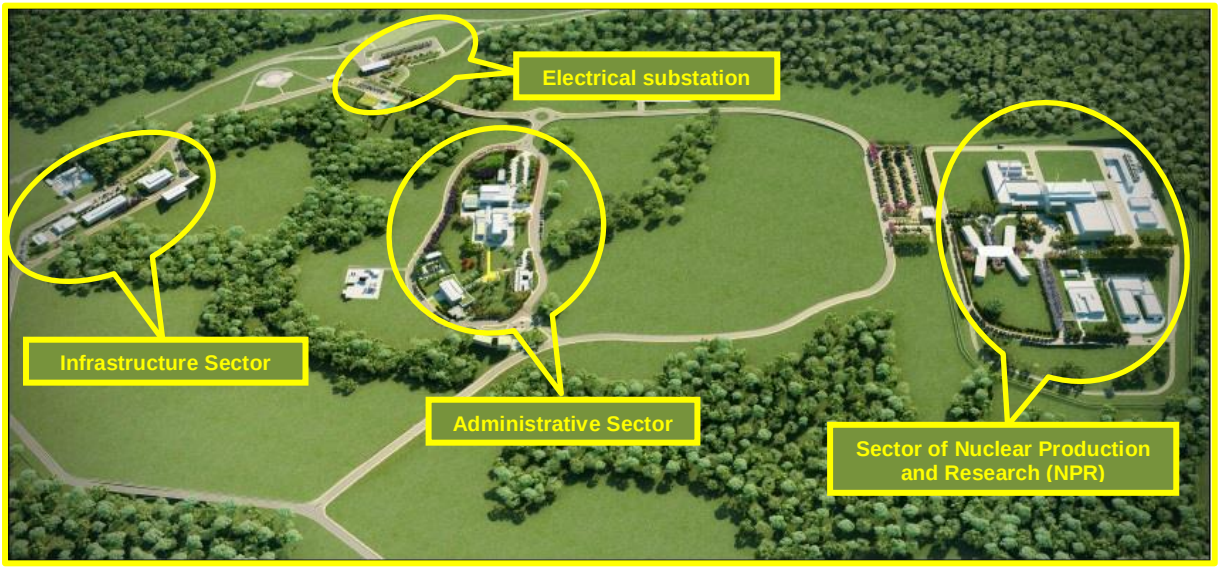

Figure 1: RMB Sectors

1.3. RMB Systems and Subsystems

The construction of nuclear research plants involves integration of various systems.

RMB Project used a meaningful method for systems classification by dividing project management system and the plant into its major systems (e.g.: reactor, steam generator, generator, cooling systems, safety systems, feed water pump, emergency power systems etc.). Further division and subdivision of these systems into basic units followed until each unit was identified as a discrete item or service.

RMB documentation coding was performed based on management and technical systems and subsystems codes, as shown in Tables 1 and 2.

Table 1: RMB Management Systems and Subsystems

Code	Systems (ST)	Code	Subsystems (SS)
00001	Steering Committee		
00010	Executive Committee	00011	Technical Advisory Committee
00100	Planning and Control		
00200	Integrated Management		
00300	Administration		
01000	Site prospecting		
02000	Design	02100	Conceptual Design
		02200	Basic Design
		02300	Executive Design
03000	Manufacturing		
04000	Construction and Assembly		
05000	Fuel supply	05100	UF_6 Supply
		05200	Supply and Fuel Elements
		05300	U Targets Supply
06000	Licensing	06100	Environmental Licensing
		06200	Nuclear Licensing
07000	Commissioning		
08000	Operation	08100	Training
		08200	Operation Manual
		08300	IMS for operation
09000	Decommissioning		

Table 2: RMB Technical Systems and Subsystems

Code	System (ST)	Code	Subsystem (SS)
10000	Reactor	10100	Reactor physics
		10200	Core thermal hydraulics

Code	System (ST)	Code	Subsystem (SS)
		10300	Core engineering
		10400	Structural Mechanics
		10500	Shielding
		10600	Irradiation engineering
		10700	Accident analysis
		10800	Hot cells of handling Items
11000	Cooling systems	11100	Primary
		11200	Pools
		11300	Secondary
		11400	Water purification and replenishment
		11500	Heavy water
		11600	Hot Layer
		11700	Emergency water
12000	Instrumentation and control	12100	Reactor protection
		12200	Reactor monitoring and control
		12300	Control rooms
		12400	Supervision and control
		12500	Radiation monitoring
13000	Electrical Systems	13100	Electrical distribution
		13200	Emergency supply
		13300	Lighting
		13400	Grounding
		13500	Lightning Protection
14000	Auxiliary Systems	14100	Ventilation and Air Conditioning – VAC
		14200	Compressed Air
		14300	Gases
		14400	Fire detection
		14500	Fire fighting
		14600	Communication
		14700	Physical protection
		14800	Pneumatic transport
15000	Reactor use	15100	Radioisotopes production
		15200	Neutron guides use
		15300	Activation analysis
		15400	Transmutation and Doping
		15500	Irradiation testing of materials
		15600	Fuel irradiation testing

Code	System (ST)	Code	Subsystem (SS)
16000	Associated Installations	16100	Mo-99 and I-131 hot processing cell
		16200	Hot cell for radioisotopes and sources handling
		16300	Hot cell for testing post irradiation materials
		16400	Hot cell for testing post irradiation fuel
		16500	Waste treatment and storage system
		16600	Irradiated fuel elements storage system
		16700	Neutron guide systems
		16800	Radiochemical systems
		16900	Support workshops
17000	Infrastructure	17100	Master plan system
		17200	Water systems
		17300	Wastewater and sewage systems
18000	Buildings and structures	18100	Architecture
		18200	Civil engineering
		18300	Loads handling
		18400	Structures
19000	Integration	19100	Design standards
		19200	Security and reliability analysis
		19300	Decommissioning analysis

1.4. Quality Management System

RMB Project operates a quality management program that is either nuclear safety-related or industrial safety compliant. When an item or service is nuclear safety related, RMB Project quality assurance program complies with the standard CNEN-NN-1.16 [4]. When an item or service is not safety related, but is important for utility operation, ABNT NBR ISO 9001 [5] standard is used.

These standards' recommendations are considered by QMS to ensure that all activities performed by RMB Project allow effective implementation of quality assurance actions applicable to the project during its various stages.

QMS program is documented by written implementing procedures. These procedures document the major organizations participating in the program and functions of each organization.

Those standards define, among others, two specific areas for quality assurance: design control and document control.

1.5. Design Control and Associated Documentation Control

Design control program includes provisions to control design inputs, outputs, changes, interfaces, records and organizational interfaces within RMB Project and main vendors for items that are subject to the provisions of the quality assurance program plan. These provisions assure that design inputs (such as design bases and the performance, regulatory, quality, and quality verification requirements) are correctly translated into design outputs (such as analyses, specifications, drawings, procedures, and instructions) so that the final design output can be related to the design input in sufficient detail to permit verification.

Project stages in nuclear plants generate a large number of documents. On average, a project like RMB Project may generate, in its various stages, about 250,000 records, including drawings, drawing reviews, technical specifications, correspondences, minutes-of-meetings, design change notes, commissioning documents, end user manuals etc.

Project records are important because some of these will have to be retained after the life cycle of the asset created - about 25 to 30 years. RMB Project documentation control process assists QMS in planning, tracking and managing these project records over the life-cycle of the project - from conception to commissioning.

In the following sections we will present the methodology used to prepare, analyze and approve RMB documentation for stages of conceptual design and basic design, and amounts of documents issued.

1.6. Work Breakdown Structure

Work Breakdown Structure (WBS) for RMB basic design stage divides RMB Project into Work Packages (WP). As proposed by INVAP S.E, each WP is sorted and grouped by its project stage and main activities (including systems design) as shown in Table 3 below.

Table 3: RMB Basic Design Stage and Main Activities

Project Stage	Main Activity
1 – Basic Design	01 – Core Design
	02 – Pools & internal Components
	03 – Process Systems
	04 – Civil Works
	05 – I&C
	06 – Plant Services & Support
	07 – Reactor Facilities
	08 – Licensing
	09 – Project Management

Table 4 shows a list of Work Packages proposed by INVAP S.E. for RMB Basic Design Stage.

Table 4: Work Packages for RMB Basic Design Stage

WBS	Description
0.01.01	Launching
0.01.02	CNEN/IPEN Interaction
1.01.01	Neutronics
1.01.02	Thermal hydraulics
1.01.03	Radiation Protection
1.01.04	Fuel Assemblies and Control Rods Specifications
1.01.05	Fuel Assemblies and Control Rods Engineering
1.01.06	Beryllium Reflector
1.01.07	First Shutdown System
1.01.08	Second Shutdown System
1.02.01	Reflector Vessel
1.02.02	Reactor and Service Pools (including internal components)
1.02.03	Operations Bridge and Tooling
1.03.01	Reactor Process System
1.03.02	Secondary Cooling System
1.03.03	Facilities Process System
1.03.04	Reactor Ventilation System
1.04.01	Site Characterization
1.04.02	Site, Reactor Building, and Auxiliary Building Architecture
1.04.03	Neutron Guide Building Architecture
1.04.04	Reactor and Auxiliary Building Structures
1.04.05	Neutron Guides Building Structure
1.04.06	Reactor Block and Embedded Component Integration
1.05.01	Reactor Protection System
1.05.02	Control and Monitoring System
1.05.03	CNS Protection, Control, and Monitoring System
1.05.04	Loop Protection, Control, and Monitoring System
1.05.05	Neutronic Instrumentation
1.05.06	Radiation Monitoring System
1.05.07	Control Rooms
1.06.01	Plant Electrical System
1.06.02	Diesel Generators and UPS
1.06.03	Fire System
1.06.04	Cranes and hoisting devices
1.06.05	Site Services
1.06.06	General Services

WBS	Description
1.06.07	Security
1.06.08	Layout
1.06.09	Facility General Guidelines and Criteria
1.07.01	Hot Cells
1.07.02	Radioisotope handling
1.07.03	Cold Neutron Source
1.07.04	Beams and shutters
1.07.06	Irradiation Loops
1.07.07	In-Core Irradiation Devices
1.08.01	Preliminary Safety Analysis Report (INVAP chapters)
1.08.02	Preliminary Safety Analysis Report (RMB/CNEN chapters)
1.08.03	Probabilistic Safety Assessment
1.08.04	CNS Preliminary Safety Analysis Report
1.08.05	Decommissioning Plan
1.09.01	Project Management

2. RMB DOCUMENTATION SYSTEM

Figure 2 shows a flowchart of RMB documentation system. RMB document control process comprises three distinct phases:

- Phase 1: preparation, technical analysis and approval on the system, process or activity interface;
- Phase 2: analysis of conformity to QMS guidelines and backlogs verification;
- Phase 3: Final analysis and document release.

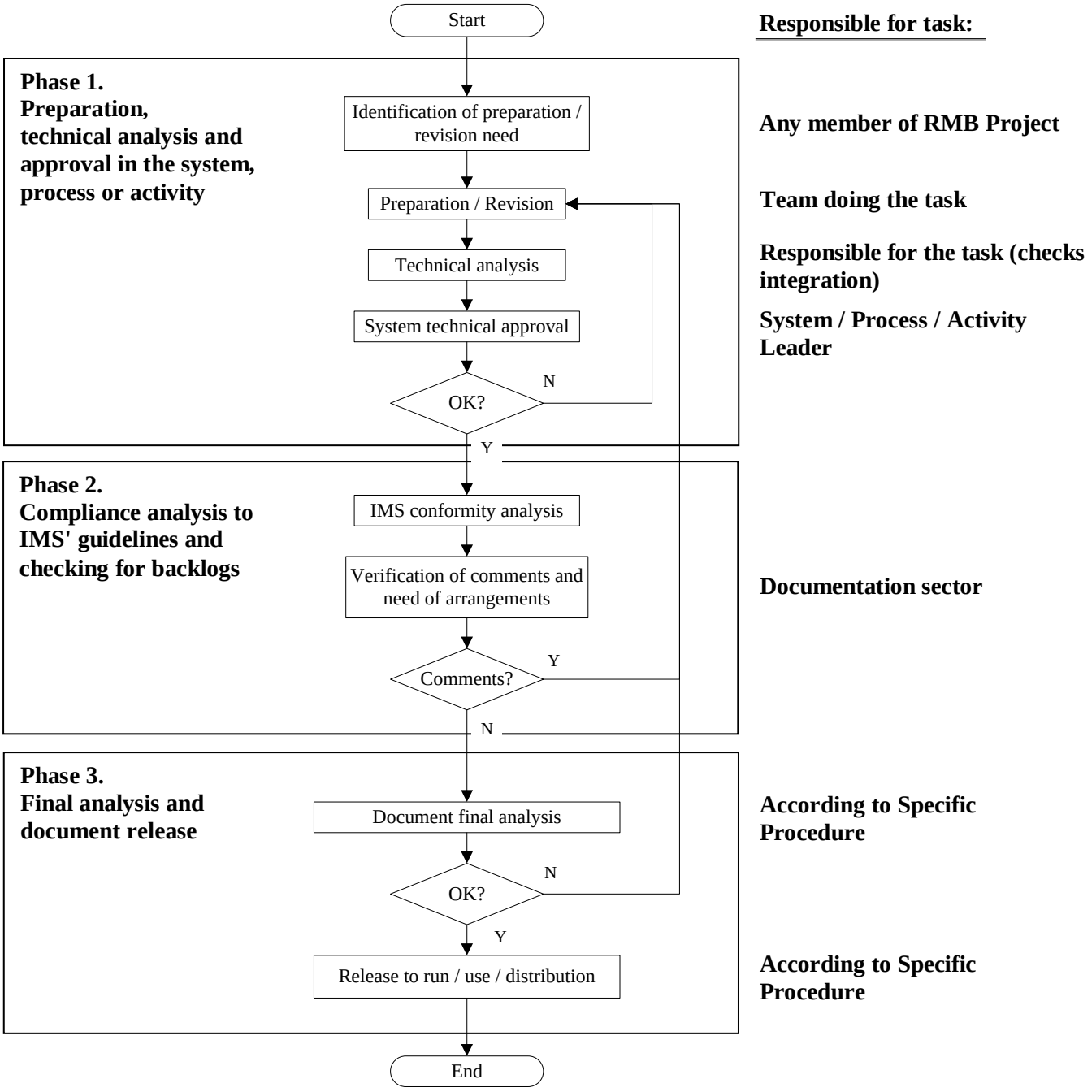

Figure 2: Flowchart of RMB documentation system and responsibilities.

3. EXTERNAL DOCUMENTS ANALYSIS PROCESS

External documents are technical and engineering documents prepared by contracted vendors. Figure 3 shows RMB external documents analysis process.

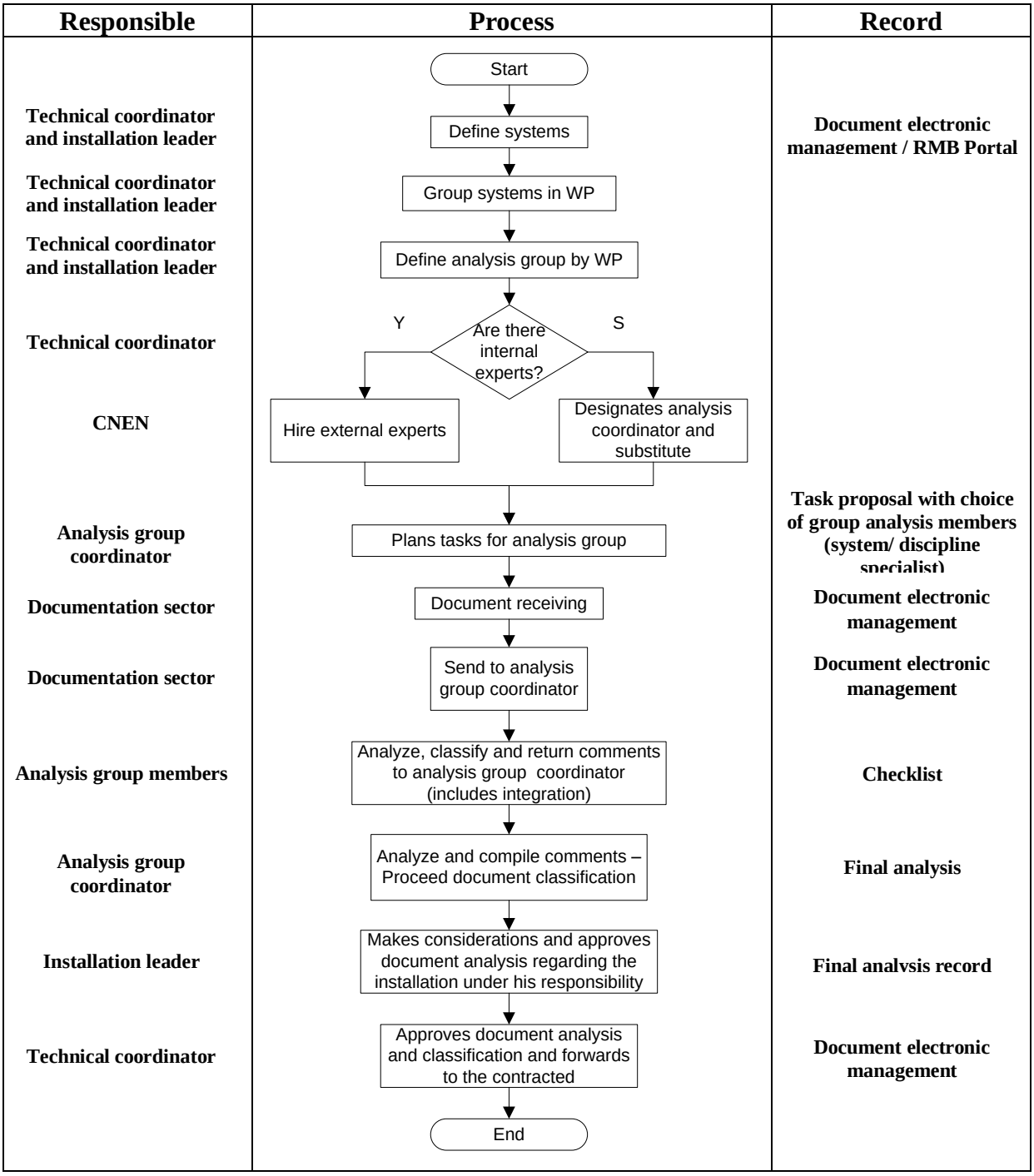

Figure 3: Flowchart of RMB external documents analysis process.

Technical coordinator and facilities leaders define project systems, group these systems in work packages (WP) and define analysis group by WP. In case there are no expert for analyzing external document, CNEN provides hiring of external experts.

Document is received by documentation sector and sent to the analysis group for checking consistency with technical standards and RMB management system. Analysis group coordinator analyzes and compiles comments from the group members and proceeds document classification in a final analysis record: “approved”, “approved with comments” or

"not approved". Installation leader makes considerations and approves the final analysis record regarding the installation under his responsibility. Technical coordinator makes his considerations and approves final analysis record and sends it to contracted vendor.

4. RMB Portal

In order to allow communication among all members of RMB Project in CNEN institutes, a site in CNEN intranet domain was created. Figure 4 shows a snapshot of RMB Portal, which was developed in Microsoft Sharepoint platform. In the snapshot we can see a folder called "GRAFI" that is the acronym for contract analysis and supervision group. In this folder all documents received from contracted vendors are distributed to RMB analysts, according to Project systems and subsystems, as shown in Tables 1 and 2. All records made by RMB analysts are kept in RMB Portal, as well as signed physical copies of records are also kept in physical archives.

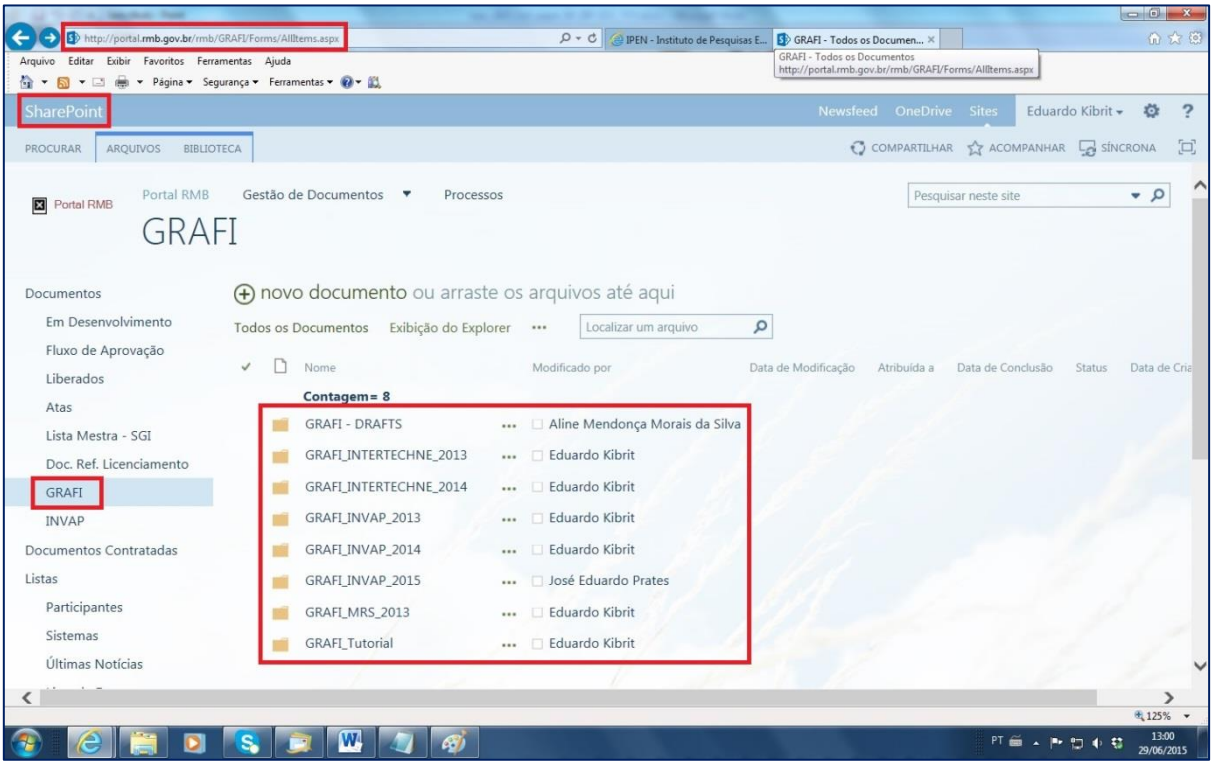

Figure 4: RMB Portal snapshot.

5. RMB EXTERNAL DOCUMENTATION FOR CONCEPTUAL DESIGN AND BASIC DESIGN IN NUMBERS

RMB documentation for conceptual design and basic design were prepared by three different contracted vendors:

- INTERTECHNE Consultores S.A.: Brazilian company located in Curitiba, responsible for preparing conceptual and basic designs for conventional systems of buildings, infrastructure and electrical substation.
- INVAP S.E.: Argentinian company located in Bariloche, responsible for preparing the basic design of the reactor core and annexes.

- MRS Estudos Ambientais Ltda.: Brazilian company located in Porto Alegre, responsible for preparing documents for environmental licensing.

All documents received from contracted vendors were analyzed by groups of RMB specialists, selected according to systems involved, as shown in Tables 1 and 2. The process of analysis is described in Figure 3.

5.1. Intertechne documentation in numbers

Intertechne [1] prepared documents for conceptual design and basic design.

Number of documents received per RMB sector (includes all revisions):
- Administrative: 2602;
- Electrical substation: 190;
- Infrastructure: 2393
- General: 441;
- Nuclear Production and Research: 7817.

⇨ **Total of Intertechne documents received (includes all revisions): 13443**.

A document generally may pass through several revisions until it becomes a valid document. Group analysis meetings are made until all documents are definitely approved. Below, we show the number of group analysis meetings made for Intertechne documents approval per year:
- 2012: 270;
- 2013: 332;
- 2014: 795.

⇨ **Total of group analysis for Intertechne documents: 1397.**

Figure 5 shows the amount of valid documents prepared by Intertechne for conceptual design and basic design of administrative, infrastructure and electrical substation installations.

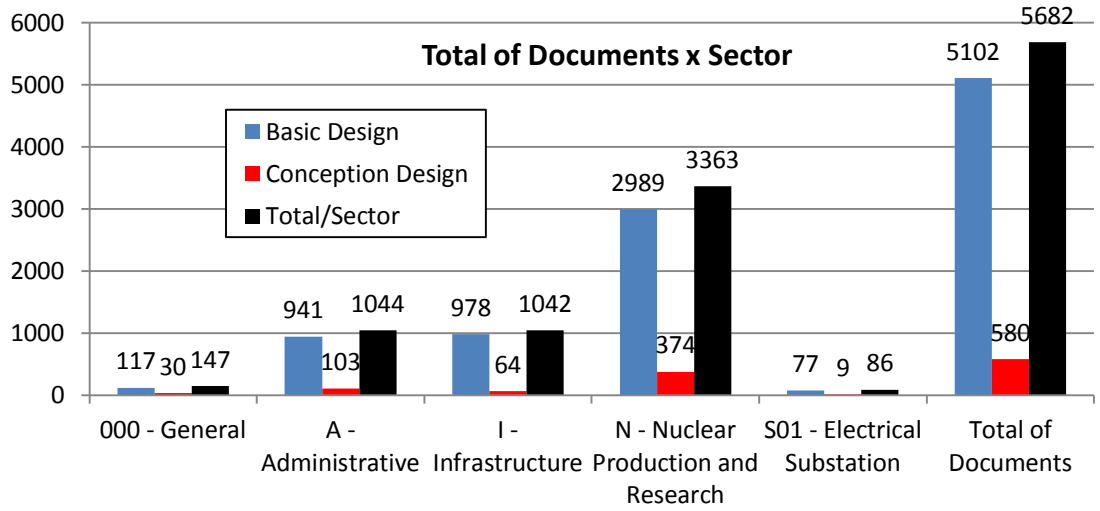

Figure 5: Amount of Intertechne valid documents.

⇨ **Total of Intertechne valid documents (includes final revision only): 5682.**

Considering the numbers shown above, we can estimate contracted vendor Intertechne by an efficacy factor (EF) in producing valid documents:

$$\text{Intertechne (EF)} = \frac{\text{Number of valid documents}}{\text{Number of total documents}} = \frac{5682}{13443} = 42{,}3\ \% \qquad (1)$$

5.2. Invap documentation in numbers

Invap [2] prepared documents only for basic design.

Number of documents received per RMB installation (includes all revisions):
- General documents for Nuclear Production and Research Sector: 12.
- General documents for the whole RMB plant: 10 ;
- Nuclear reactor building: 2262;
- Storage of Burned Fuels and Handling Items Building: 167.

⇨ **Total of Invap documents received (includes all revisions): 2451**.

Below, we show the number of group analysis meetings made for Invap documents approval per year:
- 2013: 161;
- 2014: 319;
- 2015: 02.

⇨ **Total of group analysis for Invap documents: 482.**

The amount of documents prepared by INVAP for basic design is shown below:
- 000 – General: 04;
- N00 – Infrastructure of Nuclear Production and Research Sector: 05;
- N01 – Reactor Building: 981;
- N03 – Storage of Burned Fuels and Handling Items Building: 66.

⇨ **Total of INVAP documents (includes final revision only): 1056.**

Considering the numbers shown above, we can estimate contracted vendor Invap by an efficacy factor (EF) in producing valid documents:

$$\text{Invap (EF)} = \frac{\text{Number of valid documents}}{\text{Number of total documents}} = \frac{1056}{2451} = 43{,}1\ \% \qquad (2)$$

5.3. MRS documentation in numbers

As well as Invap, MRS [3] prepared documents only for basic design. A list of documents produced by MRS is shown below:
- Legal consulting report: 06;
- Assessment of water supply alternatives for RMB: 01;
- Environmental impact study: 01;
- Grant of use of water for human consumption, industrial use and release of effluents by RMB: 01;
- Studies on Developing Anthropogenic Loads: 01;

- Quality assurance program: 01;
- Report of public hearing: 01;
- Environmental impact report: 01.

⇨ **Total of MRS documents (for licensing purposes): 13.**

Because MRS documents were specifically prepared for environmental licensing purposes, no efficacy factor (EF) can be attributed to this contracted vendor.

5.4. Total of External Valid Documents Prepared for RMB Conceptual Design and Basic Design

Adding values shown in 5.1, 5.2 and 5.3 above, the total of valid documents prepared for RMB Conceptual Design and Basic Design is:

Total = Total (5.1) + Total (5.2) + Total (5.3) = 5682 + 1056 + 13

⇨ **Total = 6751 documents.**

6. CONCLUSIONS

The object of this paper was to describe the documentation control process of Brazilian Multipurpose Reactor (RMB) Project for the stages of conceptual design and basic design. RMB stages, sectors, buildings, management and technical systems and subsystems, quality management system, design control and associated documentation control, and work breakdown structure were presented. RMB documentation system flowchart was described as well as the related responsibilities. Document phases from preparation to approval and responsibilities for documentation tasks were shown. A flowchart of external document analysis process was provided with tasks responsibilities and records description. A snapshot of RMB Portal in CNEN intranet was introduced, showing where electronic RMB documentation circulates for analysis. Finally, the amount of documents produced by three contracted vendors was detailed, giving a factor of document production efficacy per company.

Numbers obtained in equations (1) and (2) show that document suppliers for RMB Project face some difficulty in approving documents. On average, approximately more than two documents are prepared so that a valid version is approved. The need for the process improvement becomes evident, and we may infer that better communication between contracted vendors and RMB staff is needed.

Once RMB is a nuclear project, information security, availability of documents approved in its final revision to end user, as well as the control of electronic files and physical documents are essential to the success of the enterprise.

For detailed design stage, subsequent to basic design stage, it is estimated that approximately three times more documents will be issued, namely, approximately 20,000 documents. Within detailed design stage, RMB Steering Committee should plan a structure with human and technological resources suited to the need of detailed design stage. Once detailed design stage precedes construction stage, all documents generated in detailed design stage will be reference to enterprise construction companies. This requires special attention to quality of documents generated in detailed design stage.

ACRONYMS USED IN THIS PAPER

CNEN – Brazilian Commission for Nuclear Energy;
EF – Efficacy Factor;
FINEP – Brazilian Financing Agency for Studies and Projects;
GRAFI – Contract Analysis and Supervision Group;
QMS – Quality Management System;
MCTI – Brazilian Ministry of Science, Technology and Innovation;
PACTI – MCTI Action Plan on Science, Technology & Innovation;
PGA – Brazilian Government Plan for Growth Acceleration;
RMB – Brazilian Multipurpose Reactor (from Portuguese "Reator Multipropósito Brasileiro");
WBS – Work Breakdown Structure;
WP – Work Package.

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