AUTORIDAD REGULATORIA NUCLEAR
Nuclear Regulatory Authority

CAREM-25 Prototype, regulatory and design aspects

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PROTOTYPES LICENSING FOR NEW NUCLEAR REACTOR DESIGNS

Stages of the licensing process:

- Authorization for siting and construction
- Authorization for fuel load
- Authorization to perform subcritical core tests
- Authorization for first criticality
- Authorization for Zero Power Tests
- Authorization for increasing power
- Authorization for full power tests

To pass from one stage to another the approval of the Regulatory Authority is required

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AUTHORIZATION FOR SITING AND CONSTRUCTION

- Radiological impact to the environment
- Design Information (site, impact on adjacent facilities)
- Feasibility of the Emergency Plan
- Schedule (Research, Construction and Testing)
- Radioactive Waste Management
- Management System

AUTHORIZATION FOR FUEL LOAD

- Complete detailed engineering
- Approve eventual design changes
- Results and test analysis
- Testing and systems release authorization
- Pressure test with dummies
- Complete the relevant safety-issues (see next slides)
- Information for eventual decommissioning

AUTHORIZATION FOR FUEL LOAD (cont.)

Relevant Safety Issues:
List of relevant safety issues:

- Information about the safety of the facility containing:
  - Qualification of the fuel fabrication process
  - Verification of neutronic and thermo-hydraulic design
  - Accident Analysis
  - Verification of the integrity of the containment in accident conditions
  - Analysis of radionuclide transport mechanisms
  - Nuclear and radiological safety during core replacement
  - Technology of the steam generator
  - Technology and reliability of the safety systems
  - Control and safety logic
  - Instrumentation and Control Systems

AUTHORIZATION FOR FUEL LOAD (Cont.)

- Design Authority
- V&V of calculation tools
- Probabilistic Safety Analysis
- Training of operator and other safety-related positions
- Commissioning and power tests programs
- Management System
- Radioactive Waste Management, etc.

AUTHORIZATION TO PERFORM SUBCRITICAL CORE TESTS

- Detailed program of tests
- Conditions and success criteria

AUTHORIZATION FOR REACHING CRITICAL CONDITIONS

- Ad-hoc Committee agreement
- Procedures and Test Plans

AUTHORIZATION FOR ZERO POWER TESTS

- Ad-hoc Committee agreement
- Procedures and Test Plans

AUTHORIZATION FOR FIRST CRITICALITY

- Ad-hoc Committee agreement
- Procedures and Test Plans

AUTHORIZATION FOR FULL POWER TESTS

Power limitation
Maximum burn-up
Additional tests
Inspections

- Complete and current mandatory documentation
- Radiological aspects during operation
- In-service inspections programs
- RPV surveillance program
- Maintenance, testing and inspections of the safety systems

INTRODUCTION

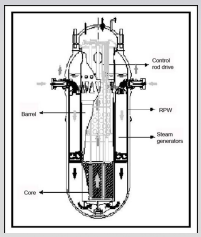
CAREM reactor prototype (**CAREM-25**) has an indirect cycle reactor with some distinctive and characteristic features that greatly simplify the design, and contributes to a higher safety level:

- Integrated primary cooling system
- Natural circulation
- Self-pressurized primary system, and
- Safety systems relying on passive features

PRIMARY CIRCUIT AND ITS MAIN CHARACTERISTICS

CAREM-25 NPP is based on a light water integrated reactor.

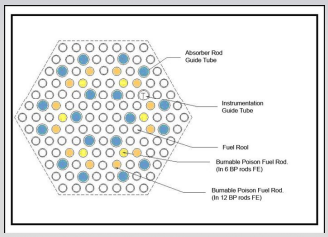
- The whole high-energy primary system, core, steam generators, primary coolant and steam dome, is contained inside a single pressure vessel



Reactor Pressure Vessel

REACTOR CORE AND FUEL DESIGN

- The core has Fuel Assemblies of hexagonal cross section.
- Each fuel assembly contains:



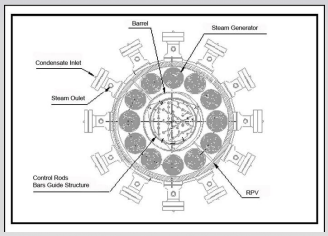
- 108 fuel rods of 9mm outer diameter, some with Gd_2O_3 as burnable poison
- 18 guide thimbles
- 1 instrumentation thimble

- Chemical poisons are not used for reactivity control during normal operation

Fuel Assembly Diagram. Fuel rods, guide thimbles and instrumentation thimble distribution

STEAM GENERATORS

- Twelve identical 'Mini-helical' vertical steam generators, of the "once-through" type equally distant from each other along the inner surface of the RPV
- They produce superheated dry steam at 47 bar



Steam Generation Layout

INSTRUMENTATION AND CONTROL SYSTEMS

- "Real time" computerized system for the control and supervision of the plant operation
- The system has four hierarchic levels and three communication levels

REACTOR PROTECTION SYSTEM

- Design according with advanced technology, the "defense in depth" principle and the early failure detection
- Two independent subsystems one for each of the two shutdown systems
- Four independent and redundant channels with voting and protective logic of dynamic type

PLANT LAYOUT

- **CAREM** nuclear island is placed inside a pressure suppression containment system
- The building surrounding the containment is placed in a single reinforced concrete foundation mat
- The plant layout is divided in three main areas: Nuclear Module, Turbine Module and Control Module
- The Nuclear Module acts as a Secondary Containment

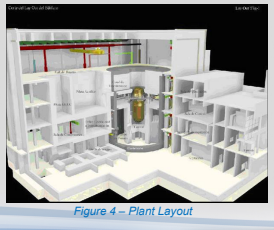


Figure 4 – Plant Layout

NUCLEAR SAFETY

- Prevention of core degradation accidents by means of passive safety features
- No need of active systems or operator actions for a period of two days:
  - LOFA is precluded due to eliminating primary pumps
  - The rod ejection accident is precluded due to control rods hydraulic mechanism located inside the RPV
  - Large thermal inertia and long response time in case of accidents due to large coolant inventory in the primary system
  - Very low fast neutron dose over the RPV wall due to large water volume between the core and the wall
  - Shielding requirements are reduced by the elimination of gamma sources of dispersed primary piping and parts
  - The ergonomic design and layout make the maintenance easier
  - The use of passive components increases plant availability and load factor, and reduces frequency and kind of initiating events

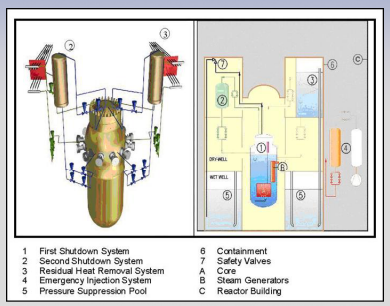
CONTAINMENT AND SAFETY SYSTEMS

The following Table and Figure summarize principal safety functions and safety systems:

Table.I **SAFETY FUNCTIONS AND SAFETY SYSTEMS**

Safety Function	Safety Function
Reactivity Control	First Shutdown System: Safety control rods Second Shutdown System: Boron Injection
Primary Pressure Limitation	Safety Relief valves Residual Heat Removal System
Primary Depressurisation	Residual Heat Removal System
Primary Water Injection	Low pressure: Emergency Injection System Second Shutdown System
Secondary Pressure Limitation	Relief valves
Residual Heat Removal	Residual Heat Removal System

CONTAINMENT AND SAFETY SYSTEMS (Cont.)



1 First Shutdown System
2 Second Shutdown System
3 Residual Heat Removal System
4 Emergency Injection System
5 Pressure Suppression Pool
6 Containment
7 Safety Valves
A Core
B Steam Generators
C Reactor Building

Containment and Safety Systems

ACCIDENT ANALYSIS

For **CAREM-25** accident analysis, several initiating events were considered. Adequate safety system are designed for. For example:

- *Reactivity insertion accident*
- *Loss of heat sink*
- *LOFA*
- *LOCA*
- *Steam generator tube rupture*
- *Steam line break accident*
- *Blackout*

ACCIDENT MANAGEMENT

- Several features are considered to protect the confinement and to manage hypothetical severe accidents:
  - The possibility of a fast core melt and early containment pressurization are limited due to the absence of large LOCA together with the impossibility of a high reactivity insertion
  - Prevention of high-pressure core melt situation is ensured by means of the Residual Heat Removal System, complemented by relief valves opening
  - The suppression pool cooling and purification system cools and refills an other systems are adequate to depressurize the containment. In the event of a LOCA, this system is capable of feeding pure water into the RPV
  - The hydrogen-concentration in the containment is reduced by recombiners
  - The suppression pool type containment provides a good physical mechanism for fission products retention by water

Thank you very much for your attention…

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