



Design and Technology Development of CAREM for Near-term deployment, and the Status of the construction of CAREM25 prototype

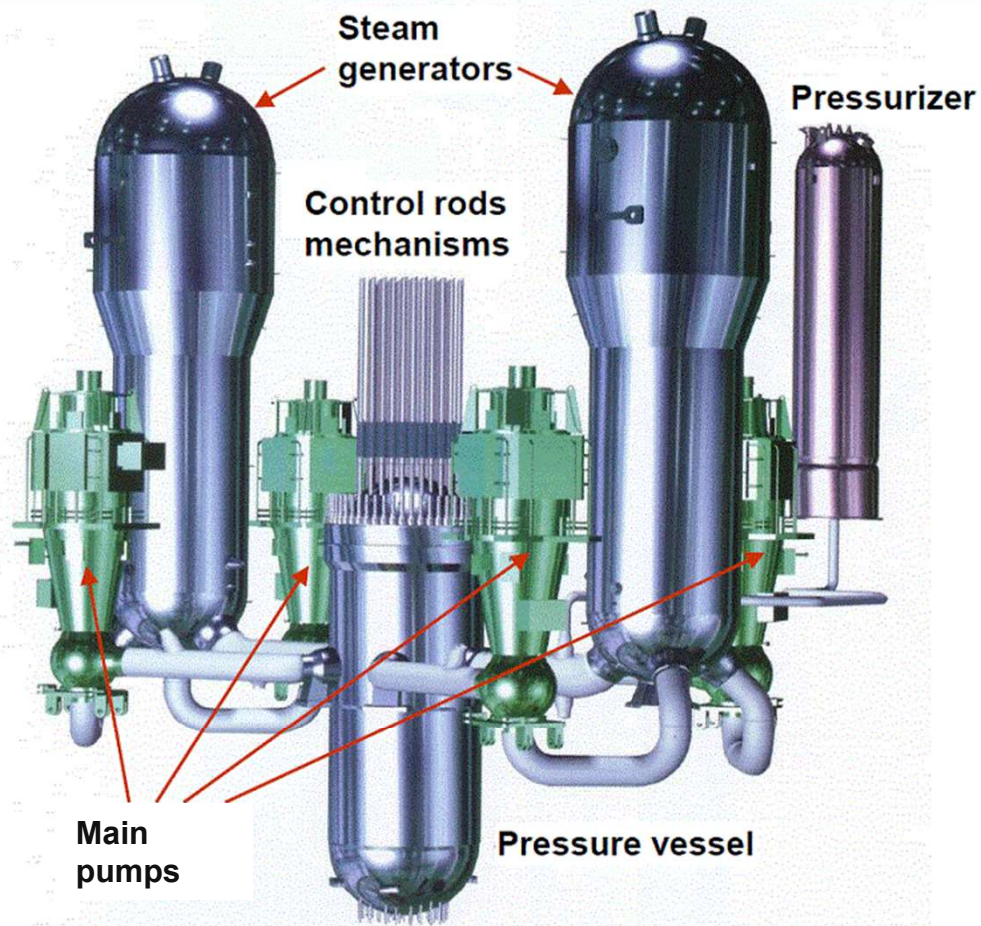
Darío F. Delmastro

Gerencia de Ingeniería - Gerencia de Área CAREM | Comisión Nacional de Energía Atómica

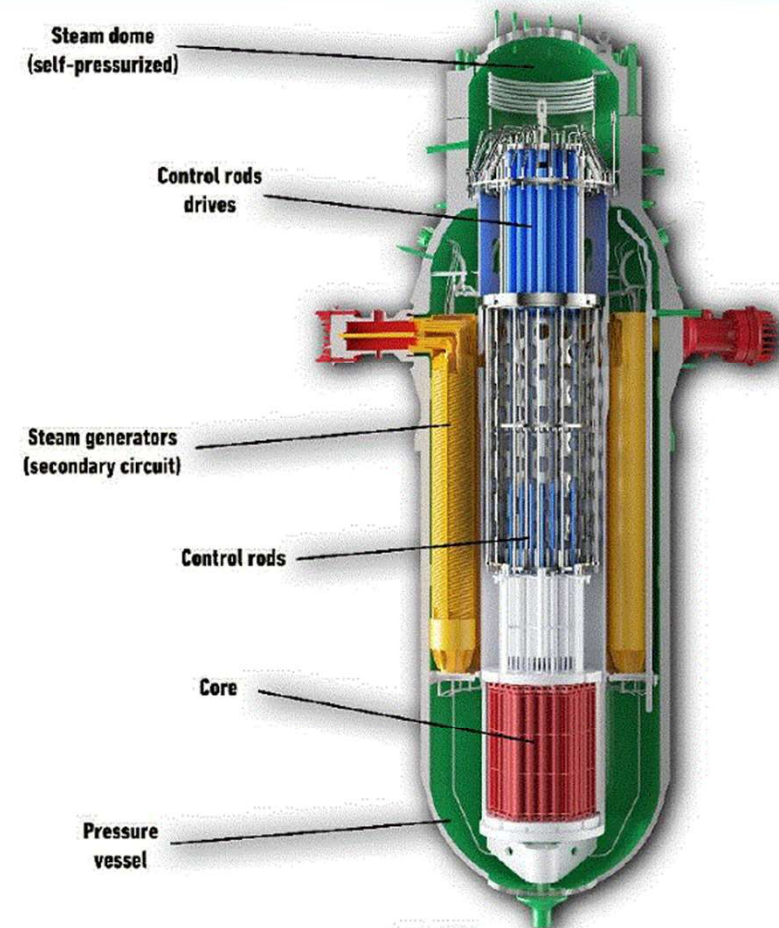
First Meeting of the Technical Working Group for Small Modular Reactor (TWG-SMR),

Vienna, April 2018

COMPARISON: CLASSIC PWR / CAREM

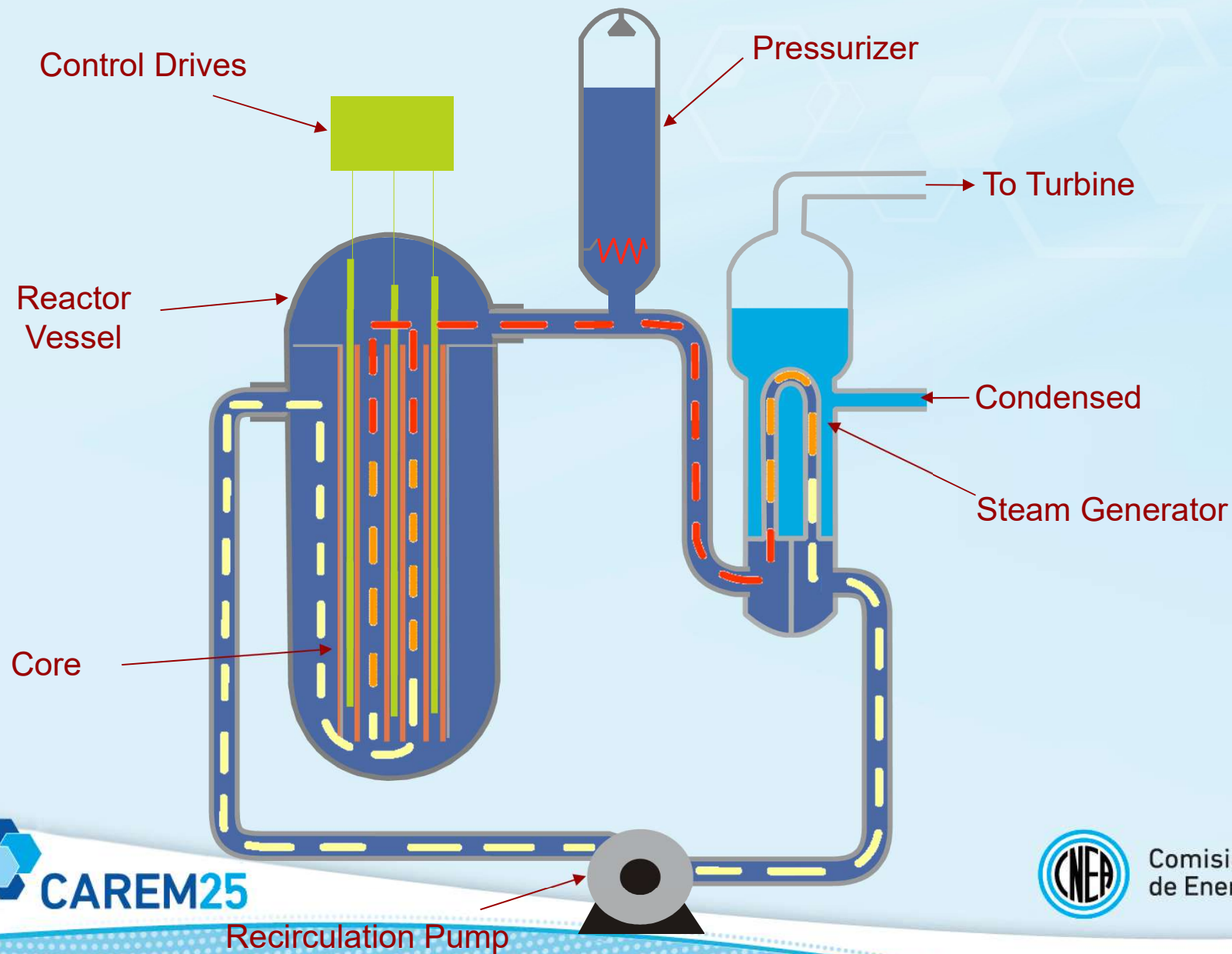


CLASSIC PWR

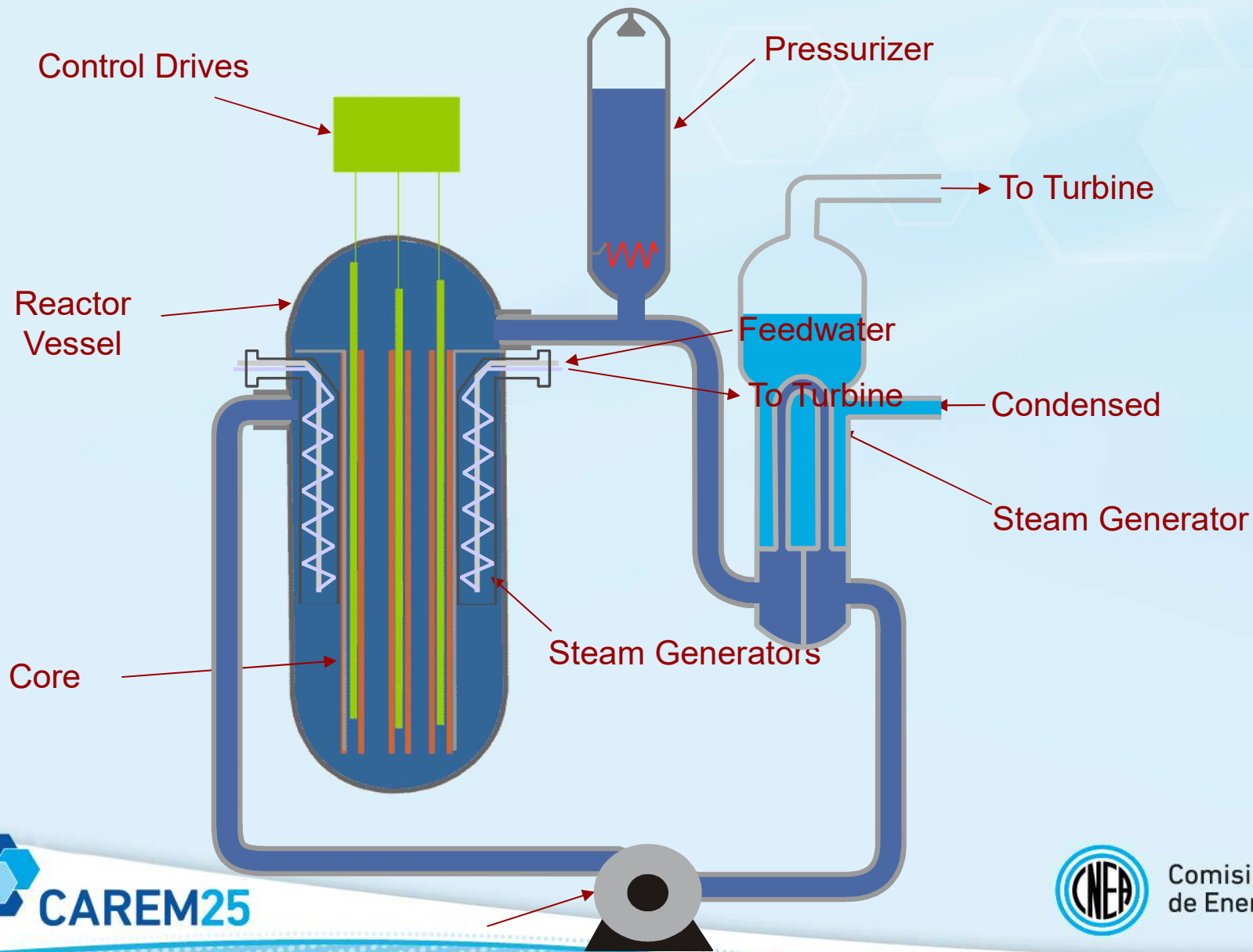


CAREM

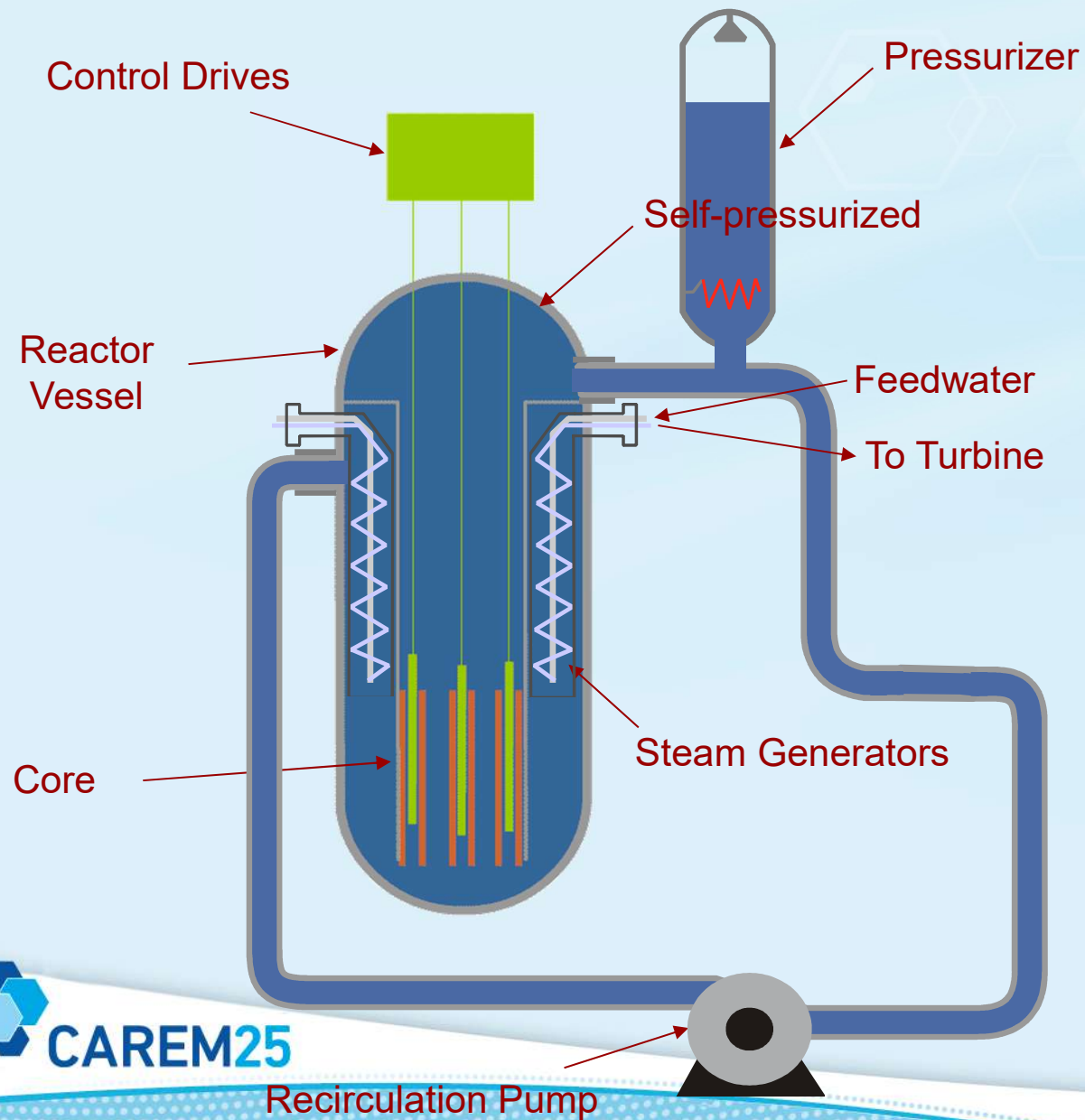
OPERATION OF A CLASSIC PWR



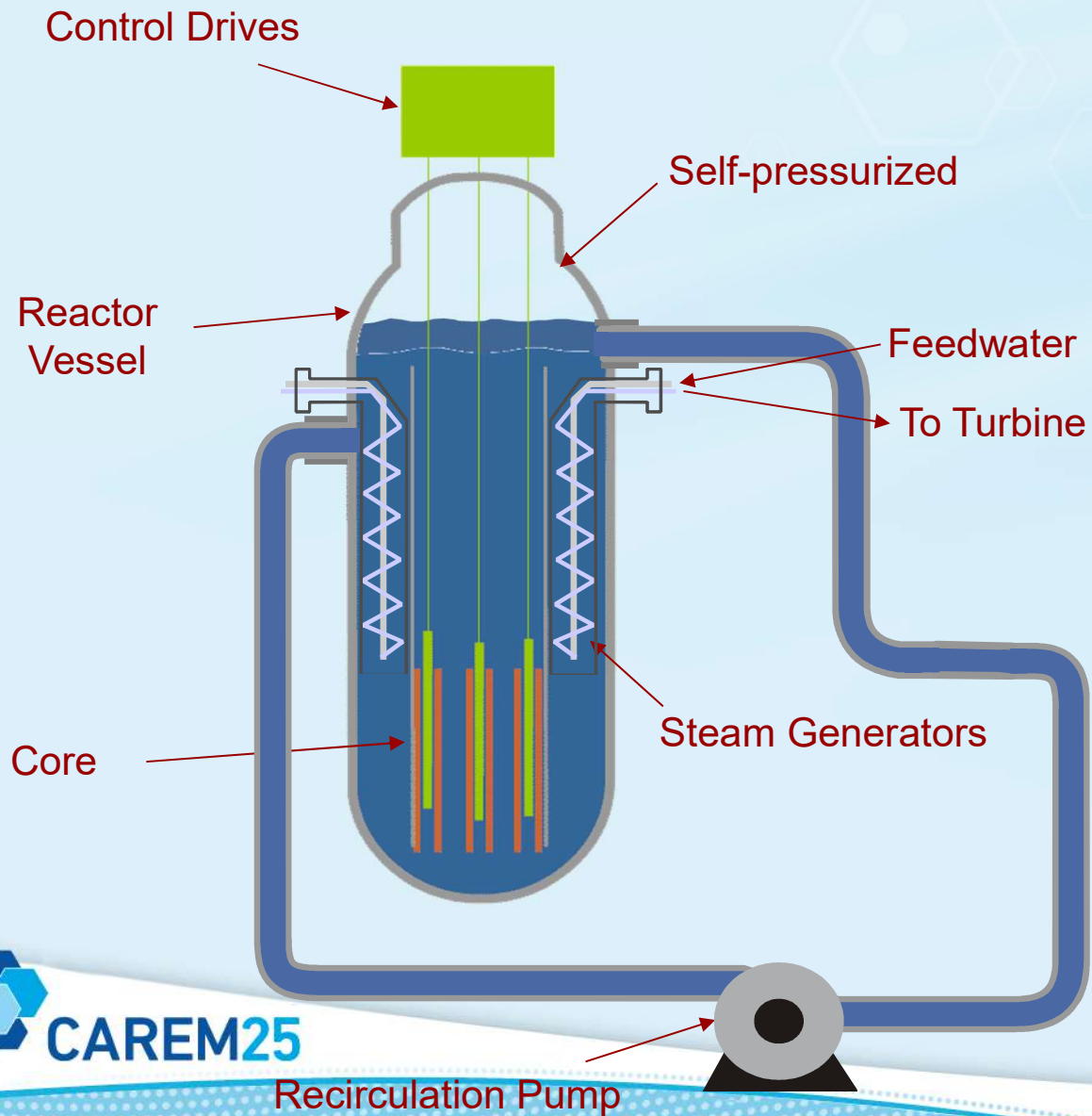
TRANSFORMATION: INTEGRATION OF THE SGs



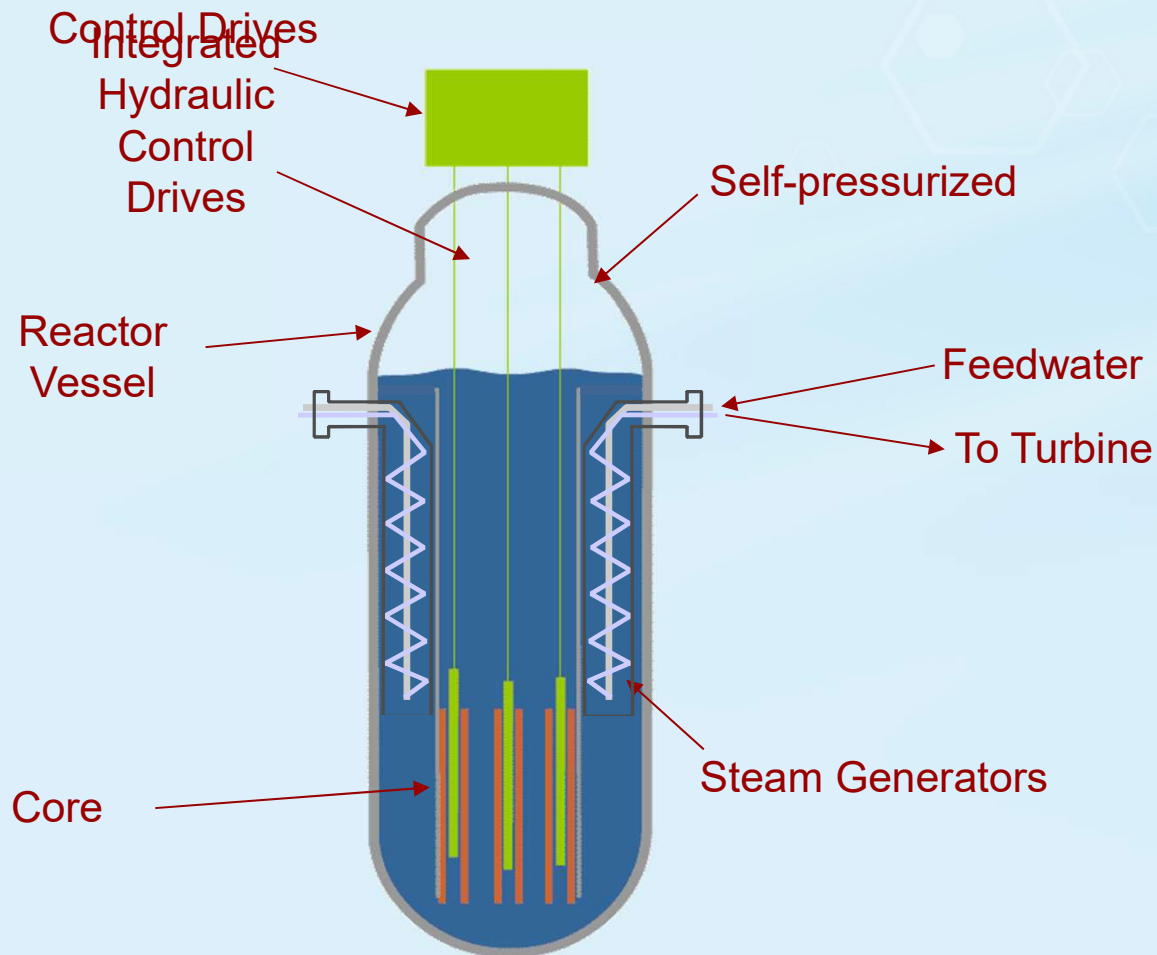
PRESSURIZER ELIMINATION



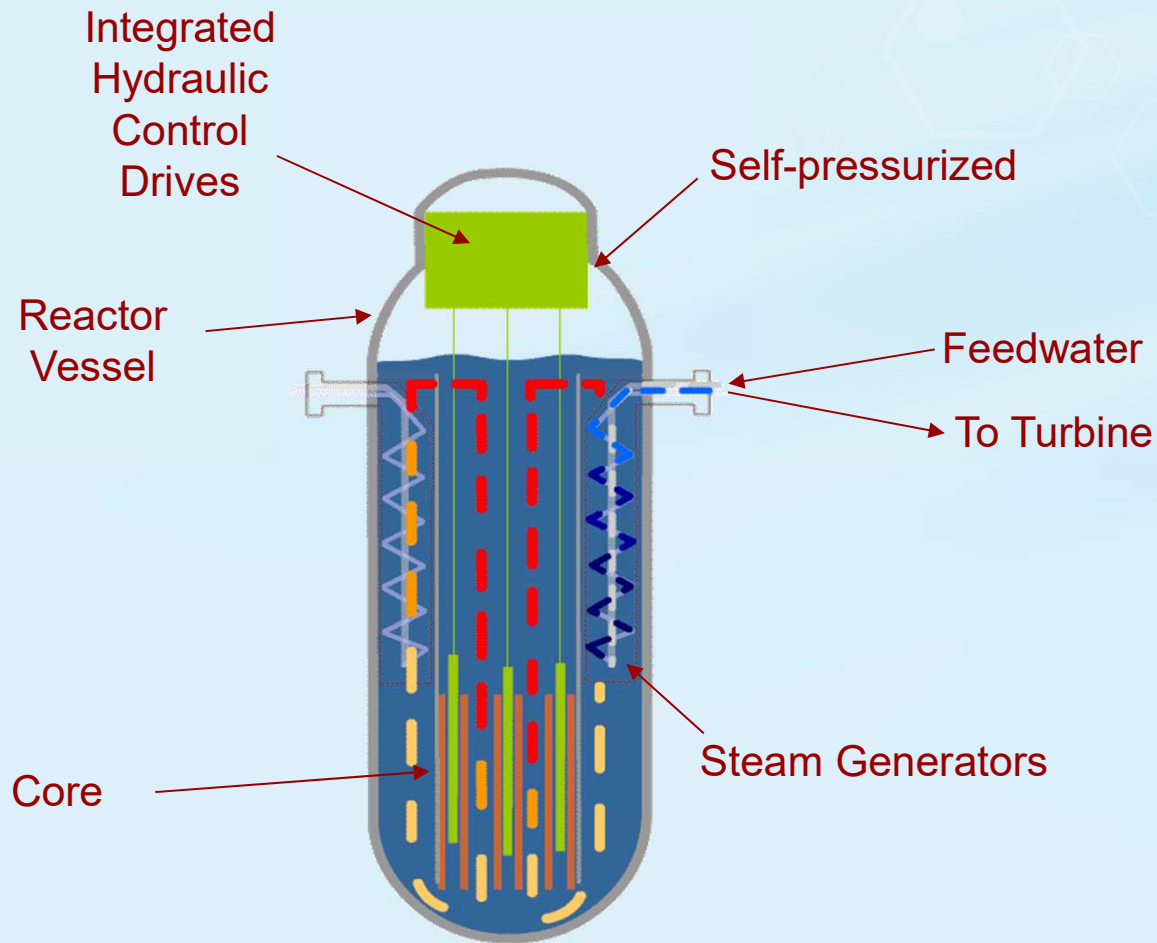
PUMPS ELIMINATION



CONTROL DRIVES INTEGRATION



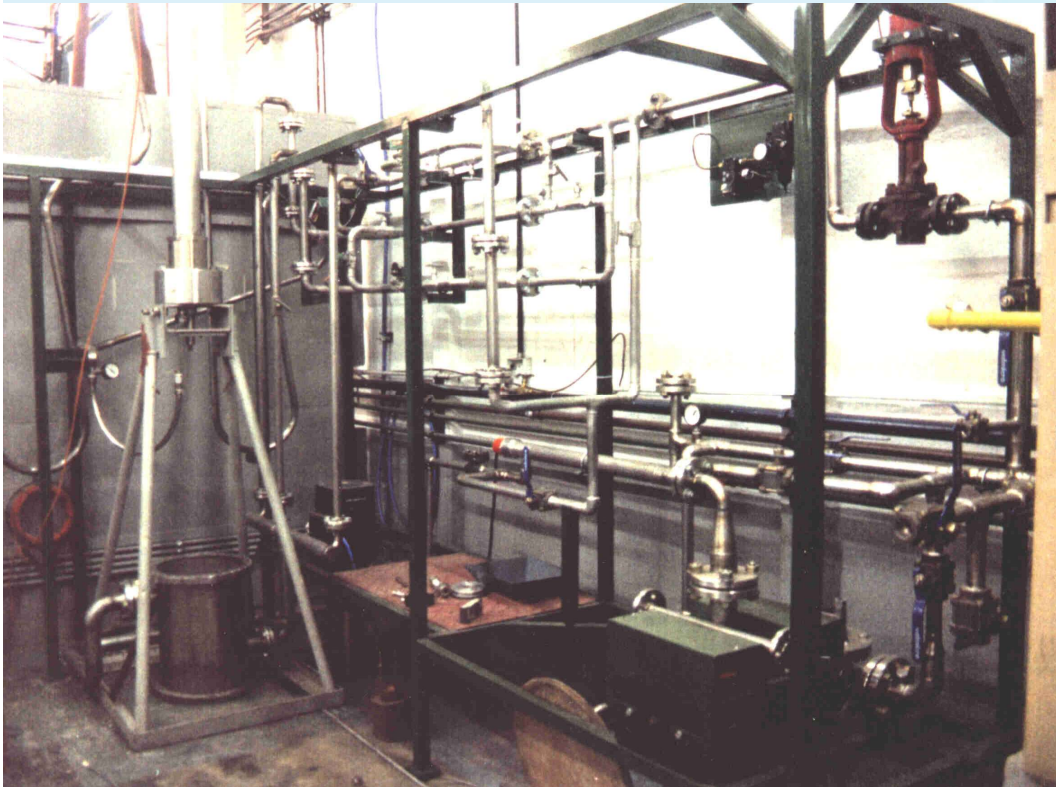
CAREM OPERATION



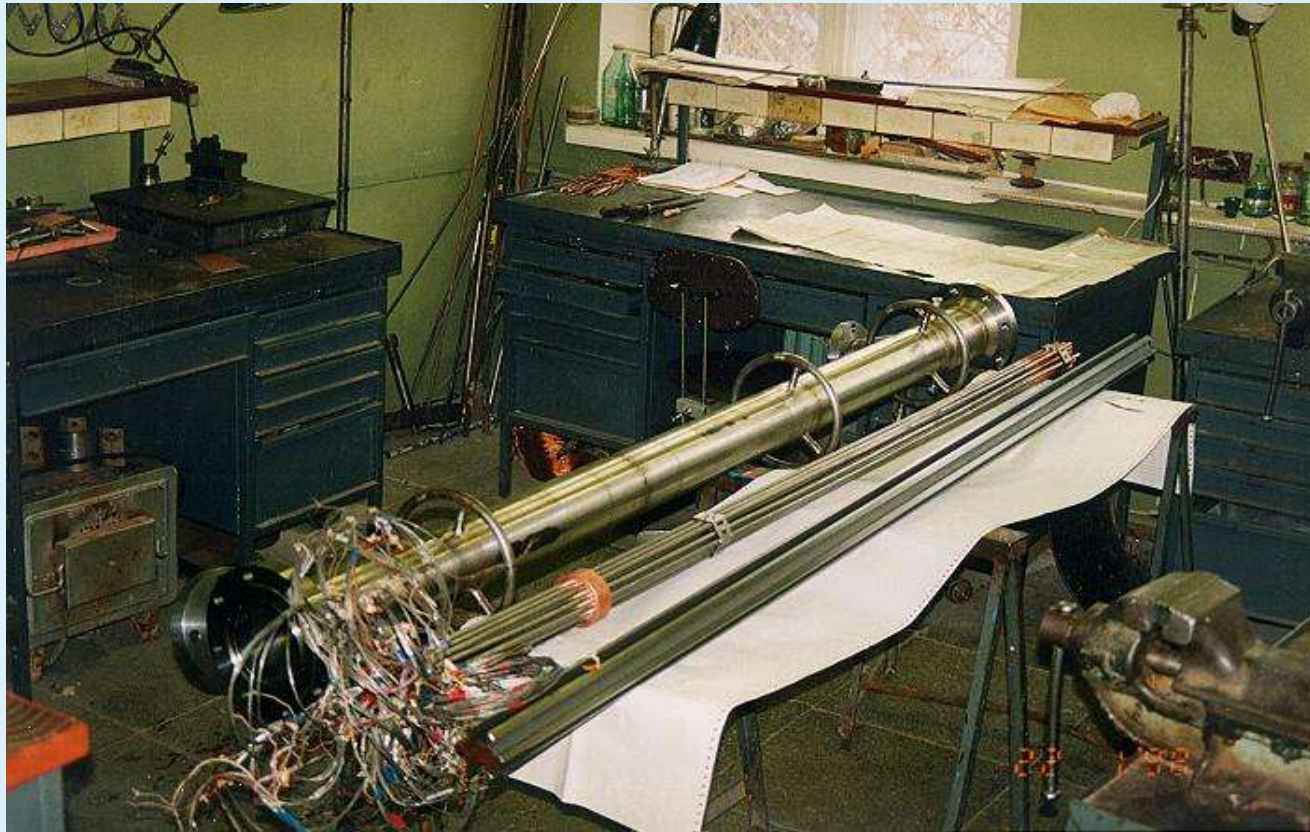
CAREM Distinctive Features

- Integrated primary cooling system
- Primary cooling by natural circulation
- Self-pressurized
- Safety systems relying on passive features

Developments - Hydraulic CRD Tests

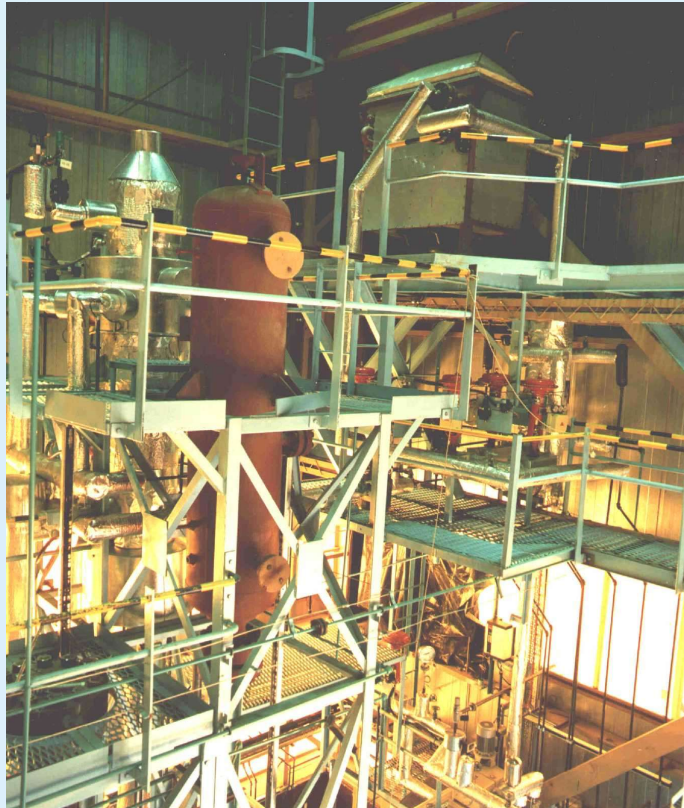


Developments - Thermal Limits and CHF Tests



LP Freon Loop Test (+250)
HP Water Loop Test (25)
TH LAB IPPE (Obninsk-Russia)

Developments - Natural Circulation and Self-pressurization Assessment



A High Pressure Natural Convection Loop (CAPCN) was constructed and operated to produce data in order to verify the thermal hydraulic tools used to design CAREM reactor, mainly its dynamical response.

This is accomplished by the validation of the calculation procedures and codes for the rig working in states that are very close to the operating states of CAREM reactor.

Developments - Fuel Element



LOW Pressure Test Rig

Others Developments

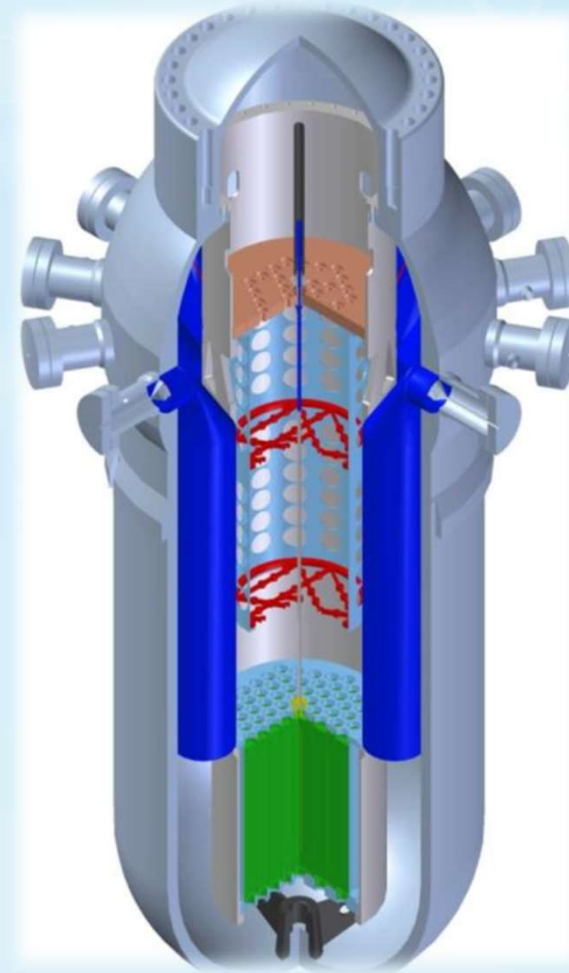
- Critical Facility
- Manufacturing Processes
- Fuel Maneuvering Device (Refueling)
- Use of Product Lifecycle Management and Collaborative Software (3D CAD Design, Integrated Digital Mock-up, 3D Simulation Software, FEA, etc.)

AIMS OF THE PROTOTYPE

- To provide the design basis for the commercial CAREM NPP
- To facilitate the licensing process of the commercial CAREM NPP
- To generate developing abilities within the CNEA, its associate companies and the private industry in Argentina (supplier development)
- To export NPPs in a competitive market, like previous experience with Research Reactors.

CAREM25 – BASIC PARAMETERS

- PWR type
- 32 MWe gross
- 100 MW core thermal power
- Integrated Primary System
- Natural circulation
- Self-pressurized
- Enriched UO_2 fuel
- Passive safety systems
- Operating cycle length of 14 months



CAREM Prototype site



CAREM Prototype construction



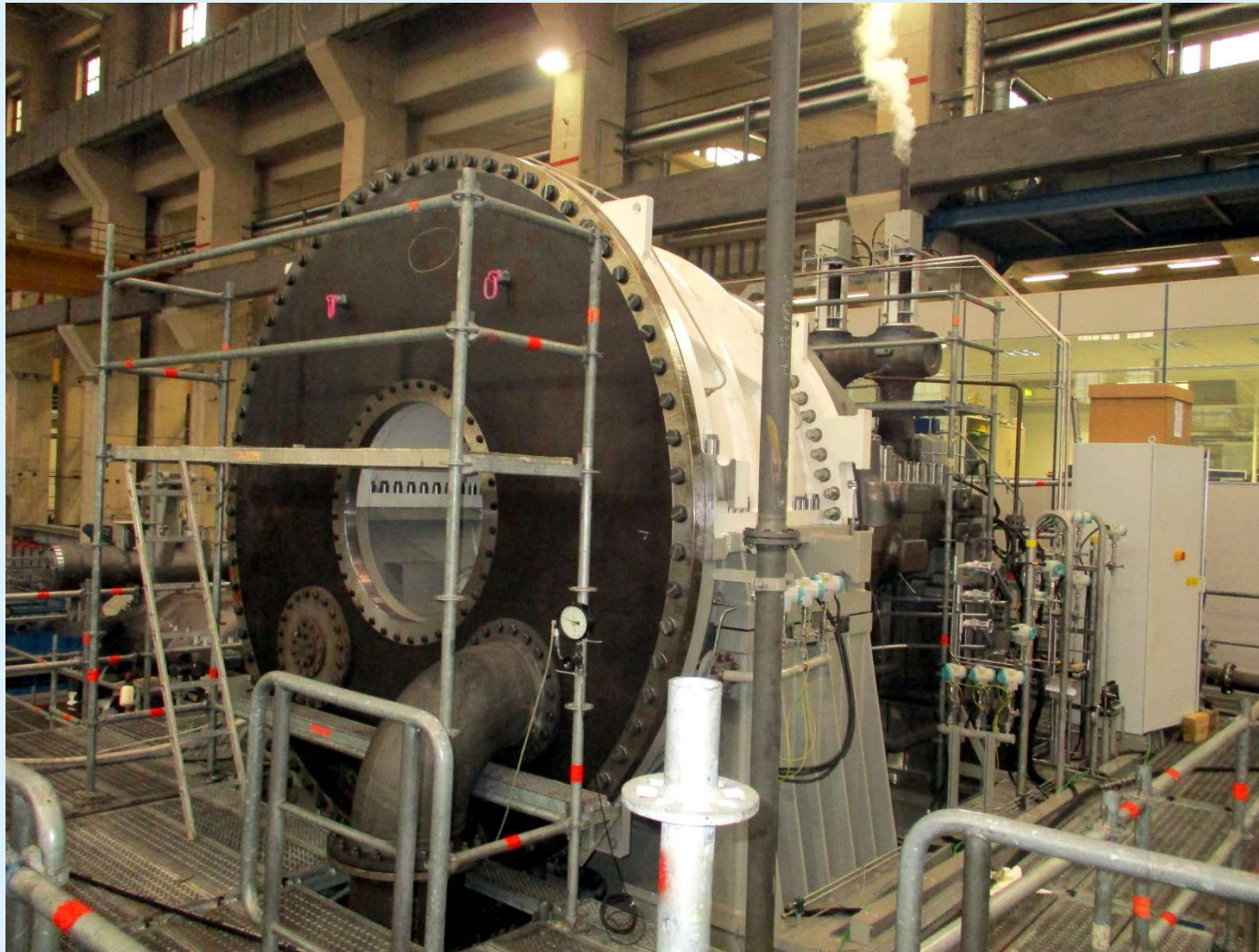
CAREM Prototype construction



CAREM Prototype construction



CAREM Prototype turbine



CAREM Prototype RPV



CAREM commercial units

- Based on the prototype CAREM 25.
- Lessons learned.
- Economies of Scale (the power of each reactor can be increased up to approximately 400 MWt each).
- Economies of multiple units (learning curve, costs reduction in owner's cost, engineering, equipment and construction).
- Construction and commissioning in stages.

CAREM commercial units

- Early revenues due to electricity sales as the first unit starts
- Easier to meet the growing energy demand
- More flexibility to complement renewables energy sources.
- More flexibility to be adapted to site requirements
- Systems and components sharing.

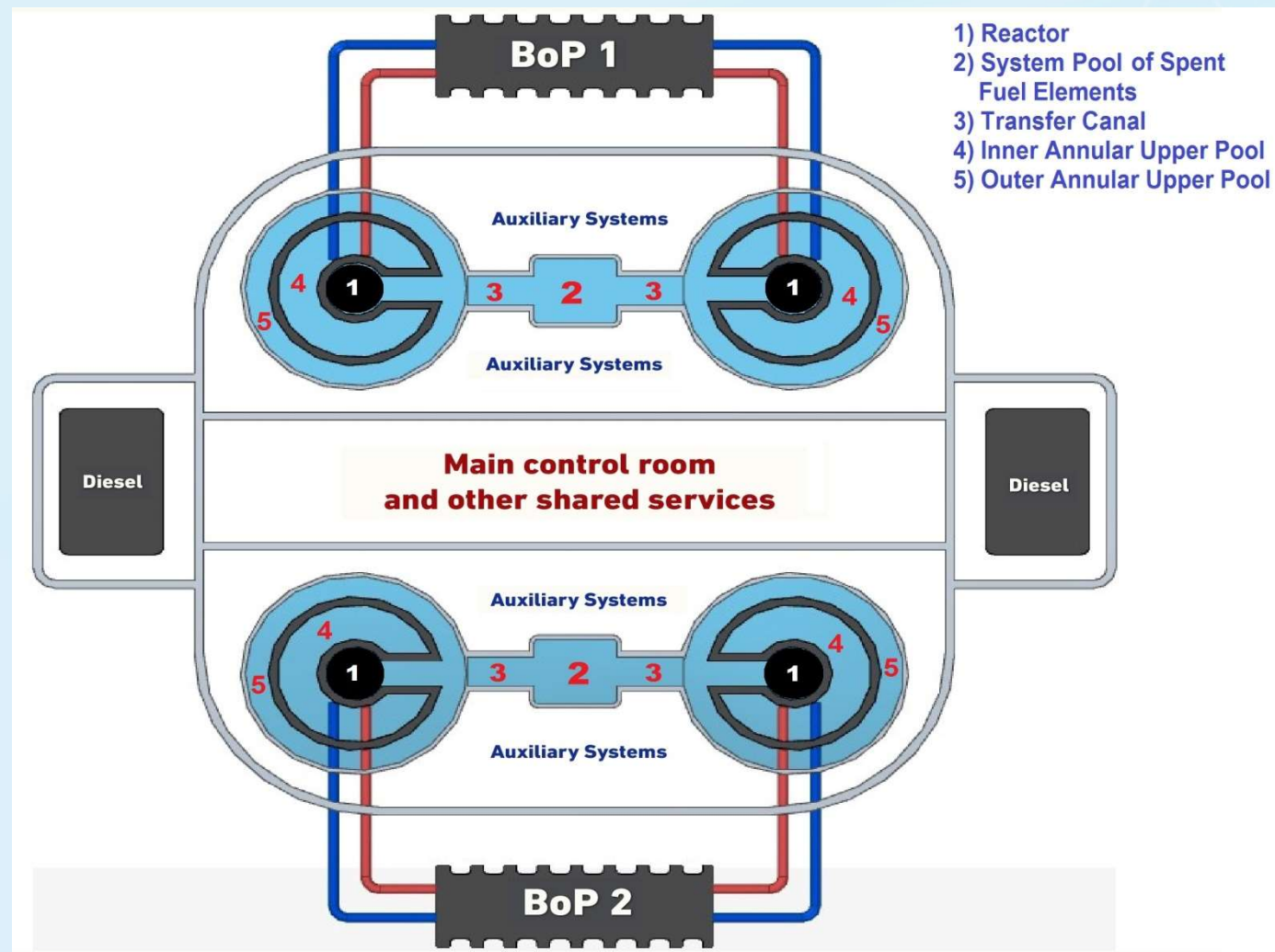
CAREM 480 NPP

- Based on the prototype CAREM 25.
- Multi-reactor NPP.
- It is comprised of 4 reactors of about 400 MWt each.
- Each reactor has its own containment.
- The lay-out for each containment will be based on the CAREM 25 but it will have some differences due to improvements in the design of systems related to nuclear safety.
- Increased power of each reactor (economy of size).
- Shared systems and components.
- Construction and commissioning in stages.
- Optimization of the safety design.

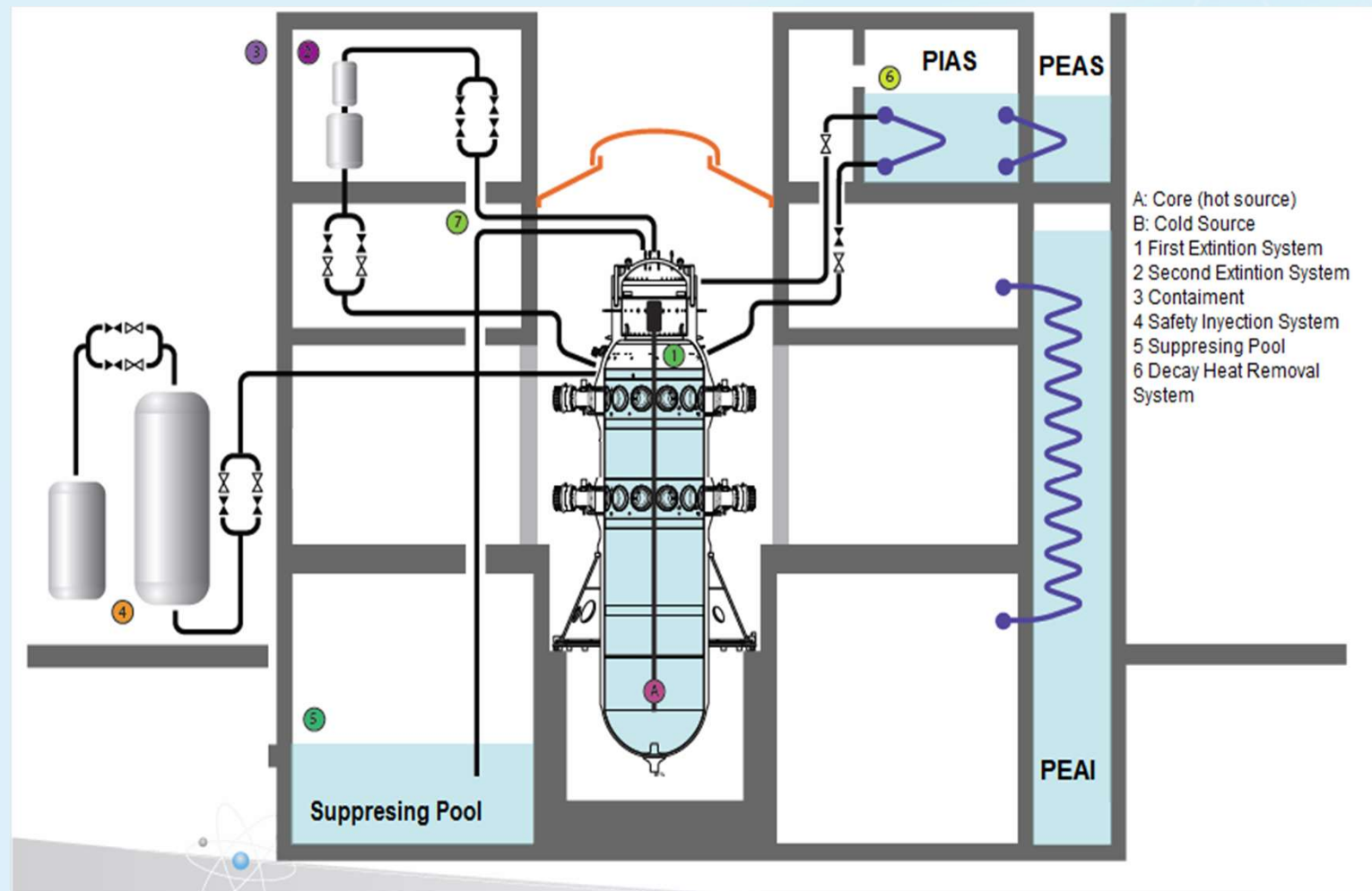
CAREM 480 NPP

- There will be two parallel nuclear buildings.
- Each of them will house two reactors with their corresponding containments, a spent fuel pool between them and the nuclear systems of both reactors.
- The auxiliary building will be located between both nuclear buildings. It will house shared systems and services, the main control room, the auxiliary control room and the administrative offices.
- Two BOPs, each with the capability of processing the steam coming from two reactors. This arrangement will enable the power generation on a staggered approach plant construction to meet the growing energy demand.
- More flexibility to complement renewables energy sources.

CAREM 480 NPP- Conceptual LAY OUT



NUCLEAR SAFETY SYSTEMS IN CROSS SECTIONAL VIEW



MAIN SAFETY SYSTEMS/COMPONENTS

- **First Extinction System (FES):** The rods drop by gravity on the core to stop the fission chain reaction.
- **Second Extinction System (SES):** It acts as a back-up system for the FES. It injects a borated solution into the RPV by gravity.
- **Decay Heat Removal System (SECR):** En the event of LOHS, this system removes passively the decay heat. The steam flow that comes from the RPV dome is condensed in heat exchangers inmersed in the PIAS. The condensate returns to the RPV.
- **Safety Injection System (SIS):** In a LOCA event, injects water coming from N2 pressurized tanks.
- **Suppression Pool:** During a LOCA event it limits the containment pressure. Through bubbling it lowers the concentration of the non-condesable gases, reducing the steam condensation resistance against the walls.

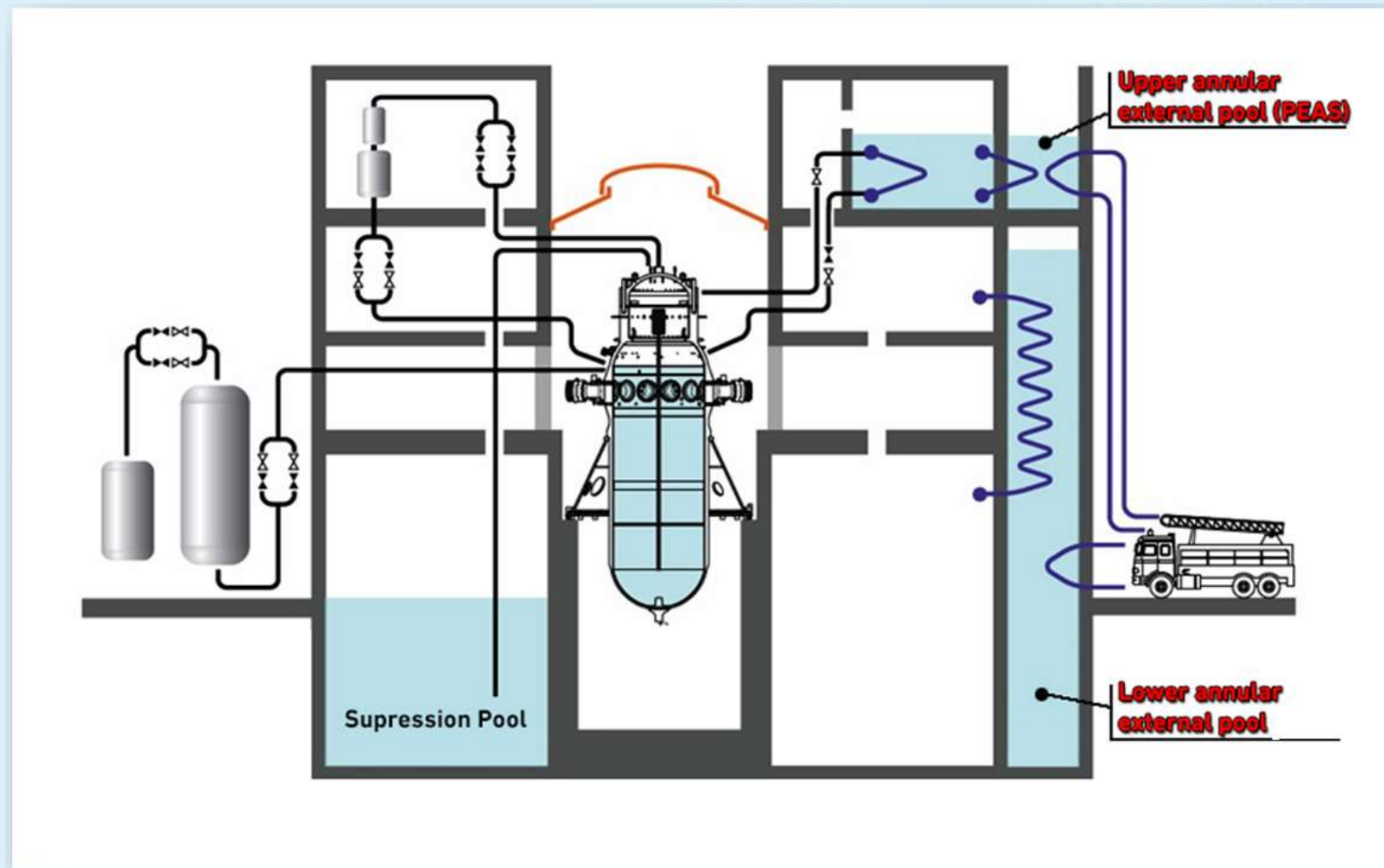
MAIN SAFETY SYSTEMS/COMPONENTS

- **Inner Annular Upper Pool(PIAS):** Its main function is to absorb the decay heat from the primary circuit. It is part of the SECR. The absorbed power is transferred radially through metallic structures to the
- **Outer Annular Upper Pool (PEAS).** Together with the atmosphere above it comprises the ultimate heat sink.
- **Outer Annular Lower Pool (PEAL):** Removes the heat released in a LOCA
- **RPV Safety and Relief valves:** Reduce the pressure through venting. Discharge into the PIAS. It depressurizes the RPV in case that the SECR fails.

OTHERS SYSTEMS/COMPONENTS

- **Grace Period Extension System:** . It allows to cool down or replace the water contained in the external pools by autonomous means (fire fighter trucks for instance) that can get water from several reservoirs. It also allows to inject water in the RPV. This configuration extends the grace period almost indefinitely until the power is restored.
- **RPV Cavity Flooding System:** In the event of severe accident The RPV cavity that is surrounded by the RPV shield can be flooded by autonomous means to cool down the RPV.
- **Hydrogen Control System in the Containment:** Passive Autocatalytic Hydrogen recombiners will be placed inside the containment to reduce the hydrogen concentration.
- **Supression Pool Venting System:** Reduces the containment pressure.

GRACE PERIOD EXTENSION



Financial aspects of CAREM 480 NPP

Fuel Cycle Cost from 7 to 10 U\$/MWh

LCOE from 70 to 90 U\$/MWh

The cost per installed kW shall not be higher than USD 5000, approximately like a PWR.

The above mentioned values in the table correspond to an IRR of 10% during a period of 30 years.

We are currently working on the calculations models to analyze the financial benefits of some changes based on the experience gained from the prototype.

Simultaneously, the financial database is being updated by gathering the prototype construction real values and optimized construction costs.

THANK YOU FOR YOUR ATTENTION



Comisión Nacional
de Energía Atómica

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