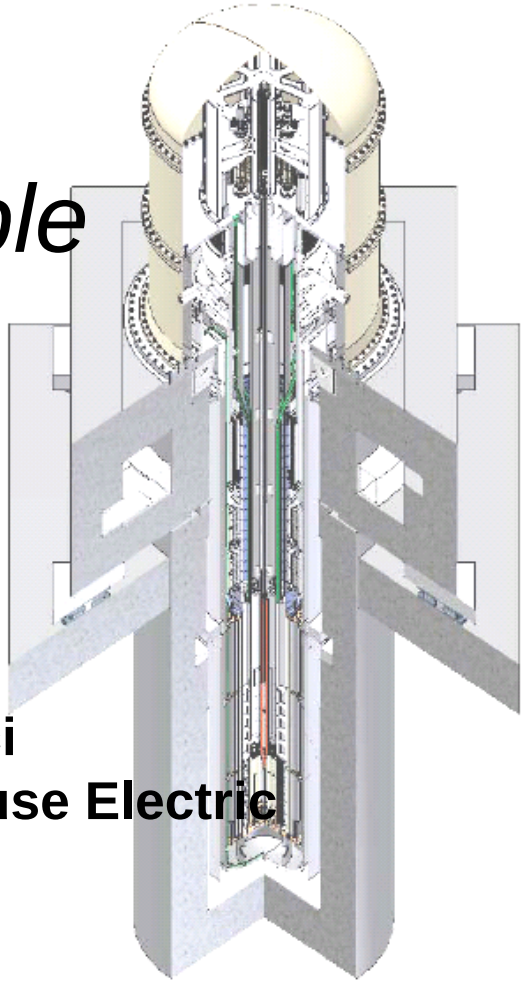
TOSHIBA
Leading Innovation

AS-2009-000036 Rev.1
PSN-2009-0563

4S Reactor

Super-Safe, Small and Simple



June 2009

Kazuo Arie
Toshiba Corporation

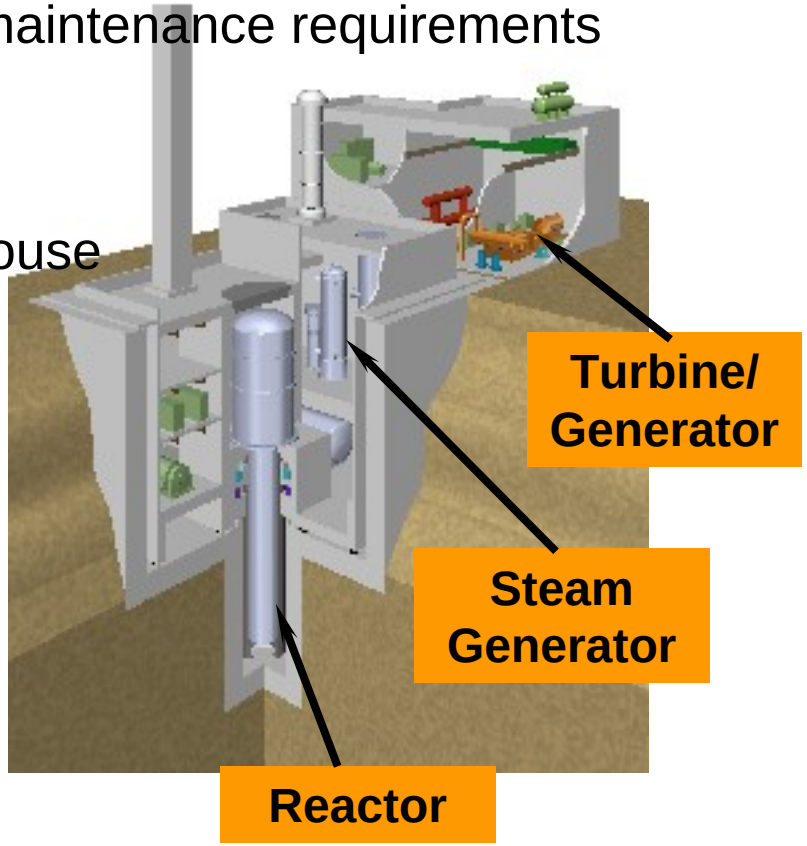
Tony Grenci
Westinghouse Electric Company

4S Presentation

- Introduction – Marvin Yoder
- 4S Overview – Kazuo Arie, Toshiba
- 4S Design - Tony Grenci, Westinghouse
- Licensing Status – Tony Grenci, Westinghouse
- Questions

Overview

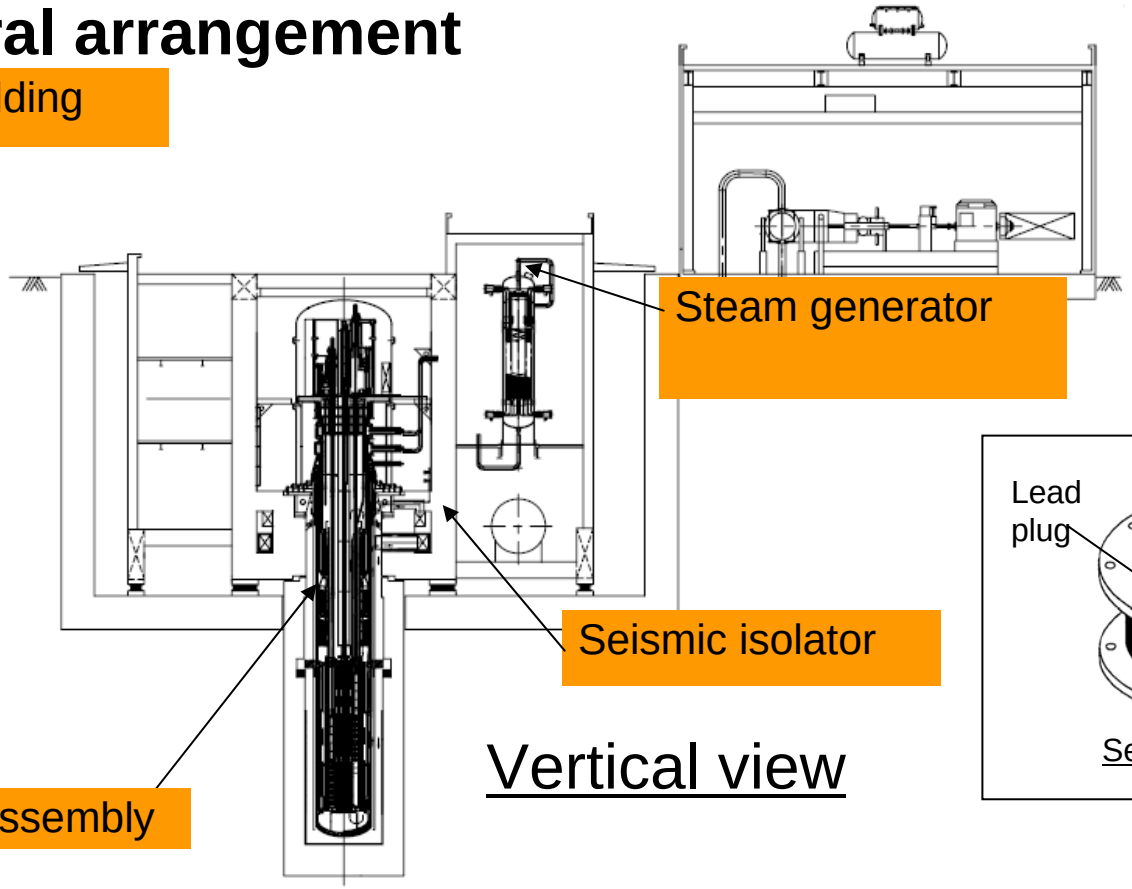
- **Goals**
  - Provide safe, clean, reliable, grid-appropriate power
  - Minimize security and proliferation risks
  - Minimize infrastructure, operation & maintenance requirements
- **Sodium cooled fast reactor**
  - Co-developer: CRIEPI
  - Developing Partners: ANL, Westinghouse
- **30 MWt (10MWe)**
  - (Initial Configuration)
- **Main features**
  - Passive safety
  - No onsite refueling for 30 years
  - Low maintenance requirements
  - High inherent security



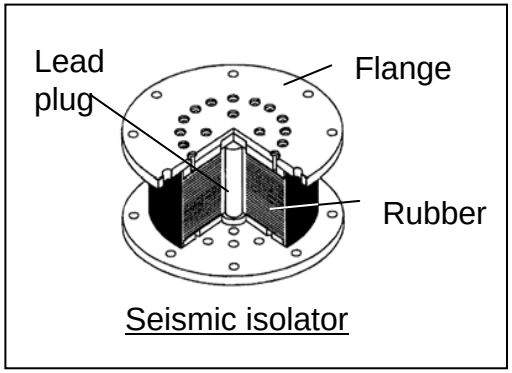
Plant Description

General arrangement

Reactor building



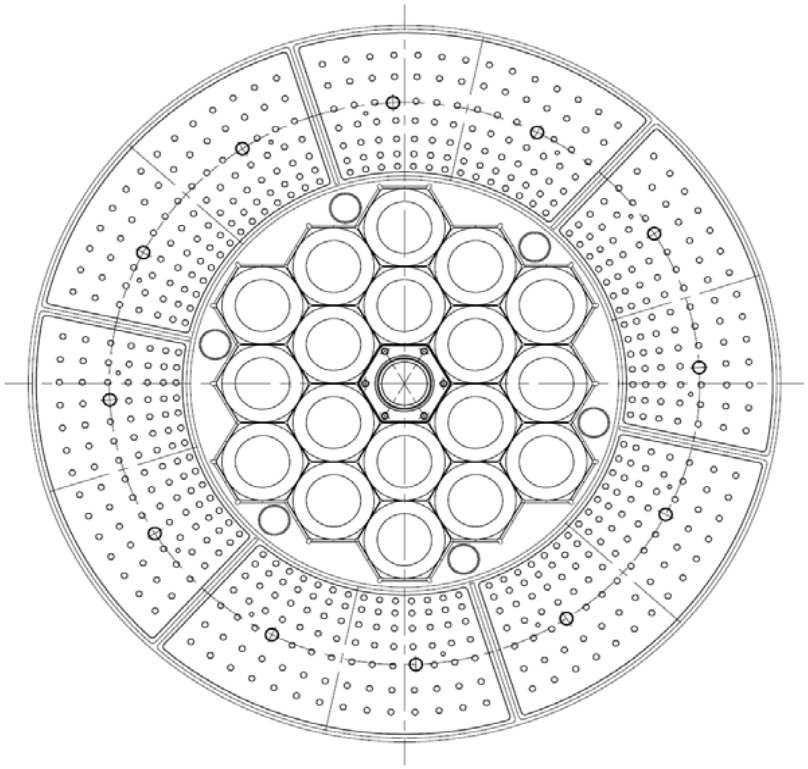
Vertical view



- Seismic isolation is provided for the reactor building.
- Reactor building is below grade.

4S Advantages - Economy

- Diesel fuel prices are high and unpredictable.
- Long refueling interval (10-30 years) front-loads the fuel costs.

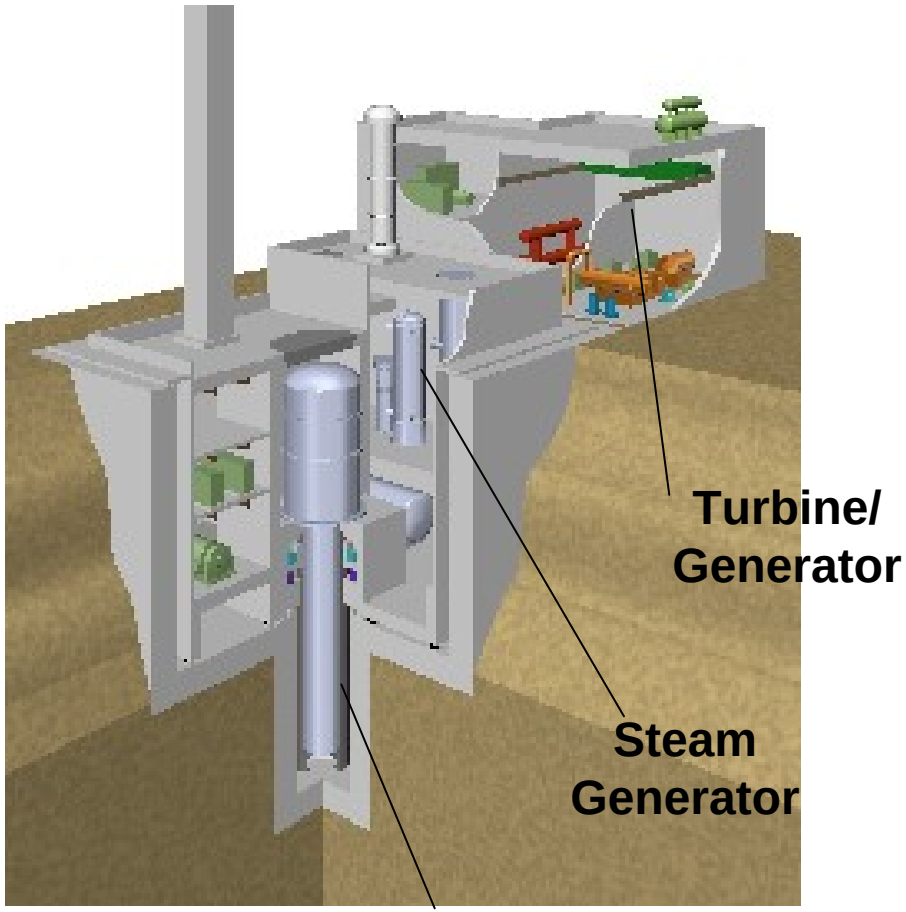


4S Advantages - Operations

- Small operations and security force
  - Simplified operations, load changes accomplished using turbine bypass
  - Automatic burnup compensation
  - Passive safety systems
  - Small plant footprint

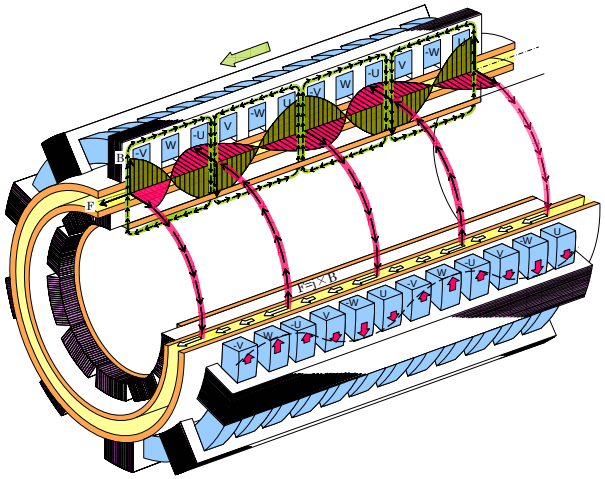
4S Advantages- High Inherent Security

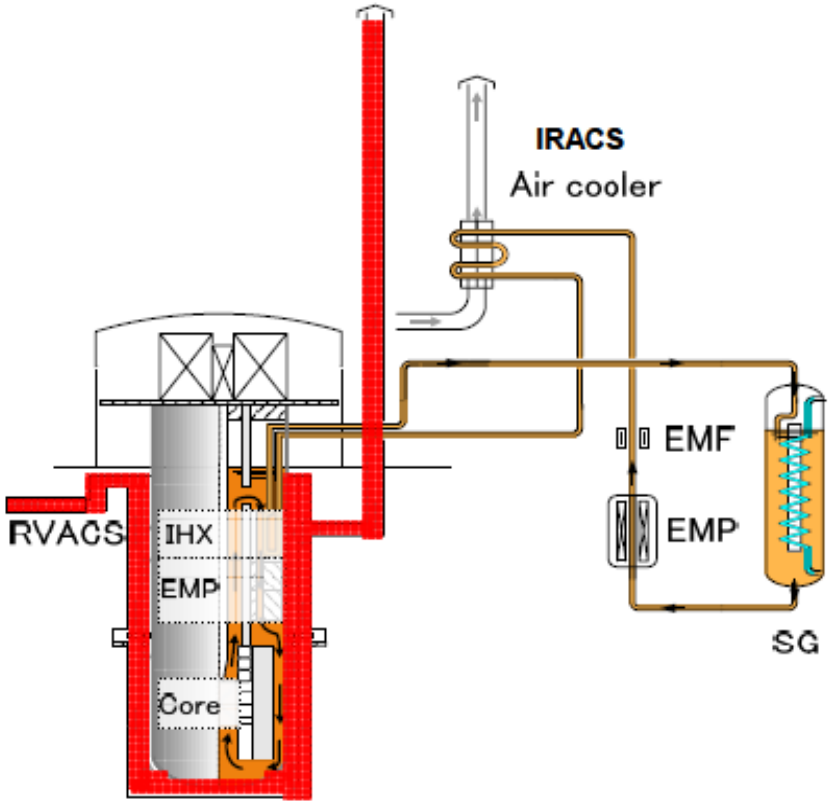
- Below-grade siting to protect from missile or airplane impact.
- No onsite fuel storage (10 MWe).
- Sealed Reactor Vessel.
- Heavy Lifting and Fuel Handling Equipment removed from site.
- Fuel enrichment below proliferation grade.



4S Advantages - Maintenance

- Passive systems
- Materials compatibility
- Minimal moving parts
  - EM Pumps

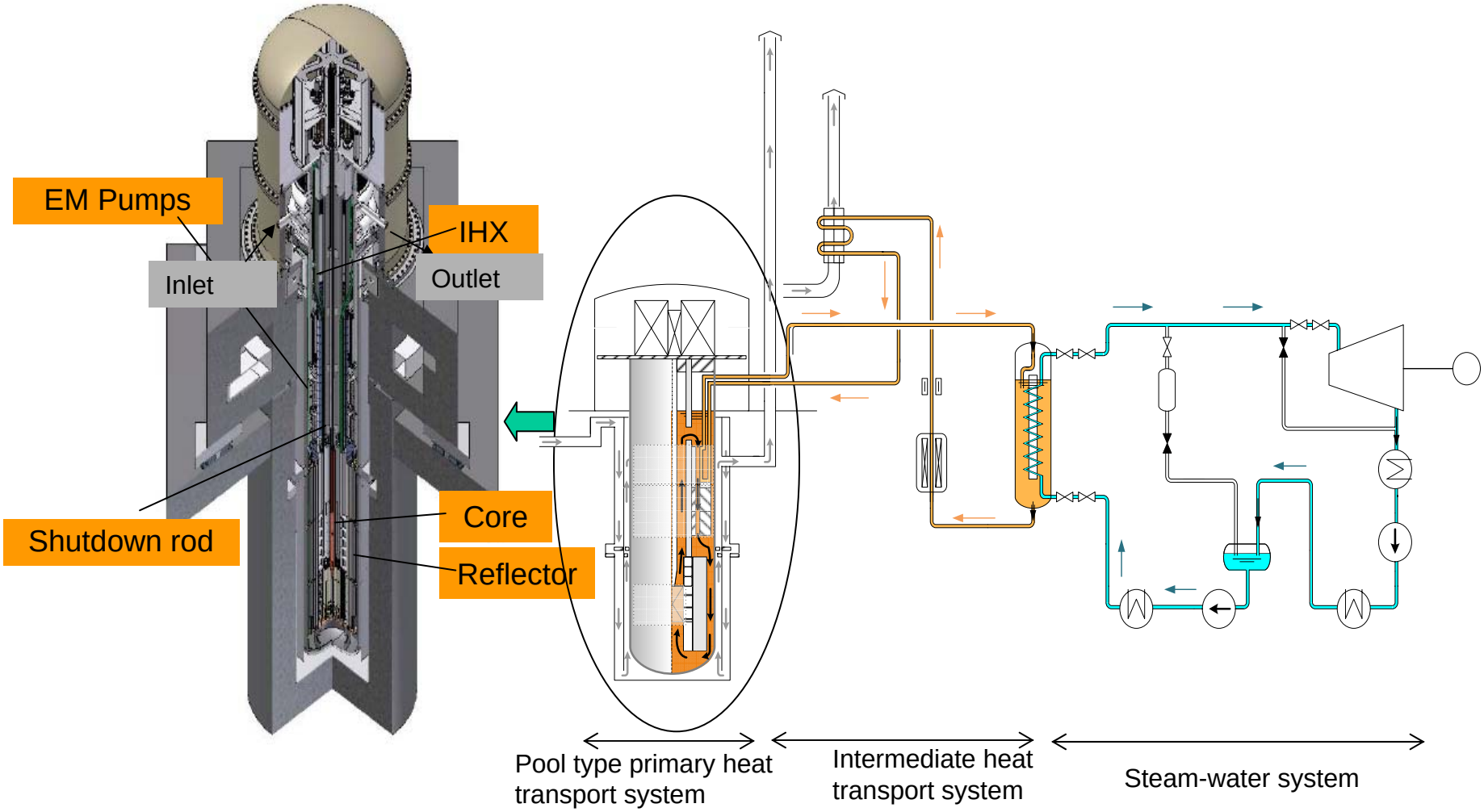




4S Versions

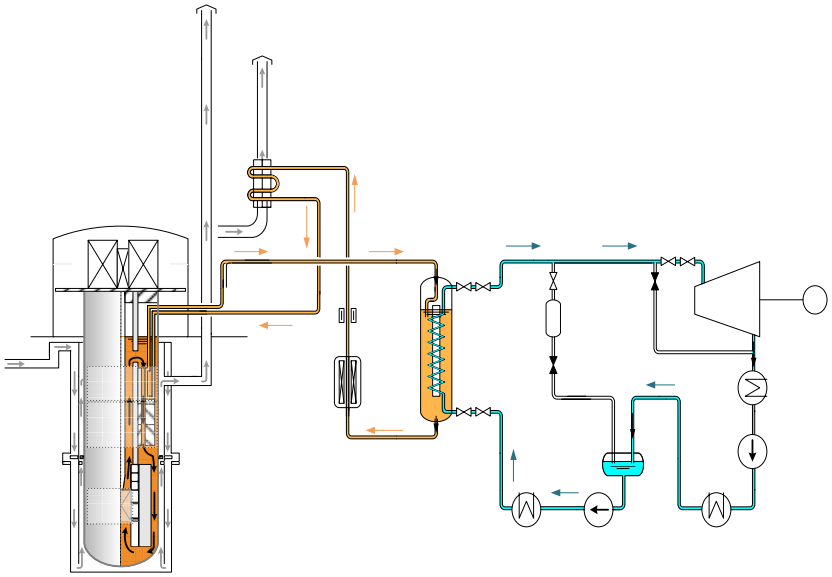
- Two versions being designed simultaneously.
  - 10 MWe version
  - 50 MWe Version
- Rx Vessel, Rx Building identical for both versions.

4S System Configuration

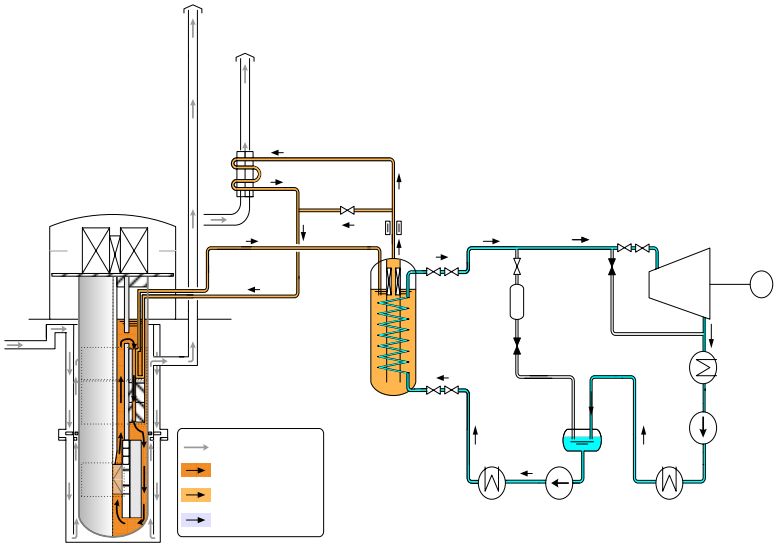


4S Versions

- Steam Generator, IHX, Air Cooler sizing
- IRACS operation



10MWe



50MWe

Plant Design Parameters

Reactor Core

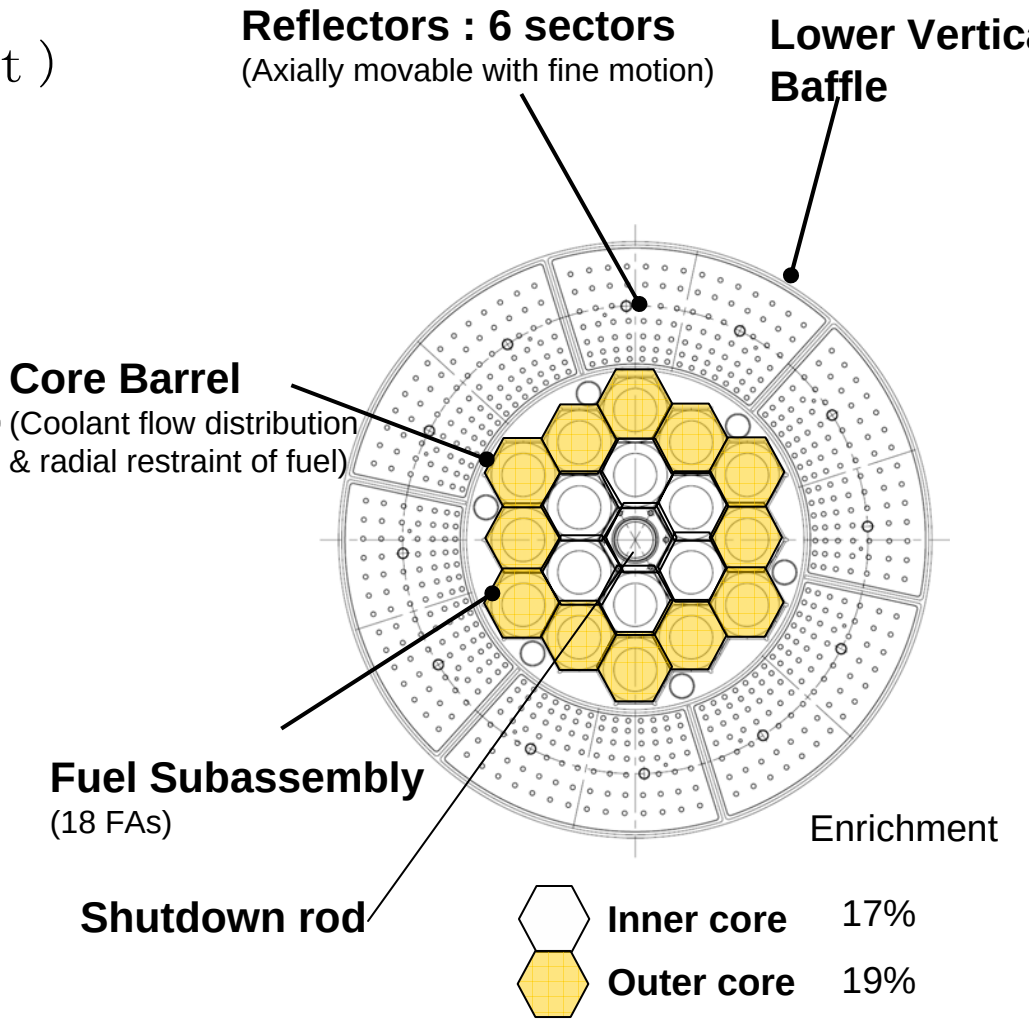
Core Height	2.50 m	**(8.2 ft)**
Equivalent Core Diameter	0.95 m	**(3.1 ft)**
Fuel / Clad Material	U-10%Zr / HT-9 steel	
235U Enrichment (inner / outer)	**17 / 19 %**	
Average Burn-up	34,000 MWd/t	

Reactor Vessel

Design Pressure	0.3 MPa	**(44 psi)**
Design Temperature	550 deg.C	(1022 deg.F)
Inner Diameter / Thickness	3.5 m / 25 mm	(12 ft / 1.0 inch)
Total Height	24 m	(79 ft)
Material	Type 304 stainless steel	

Core Design

- Core
  - Core height 2.5m (8.2ｆｔ)
  - Equivalent core diameter 0.95m (3.1ft)
  - Fuel subassembly number 18
  - Enrichment (Inner/outer) 17/19%
- Reflector control
  - Movable annular reflector
  - Material: Mod9Cr1Mo
  - Size Thickness 38cm (1.2ft)
  - Height 2.7m (8.8ft)

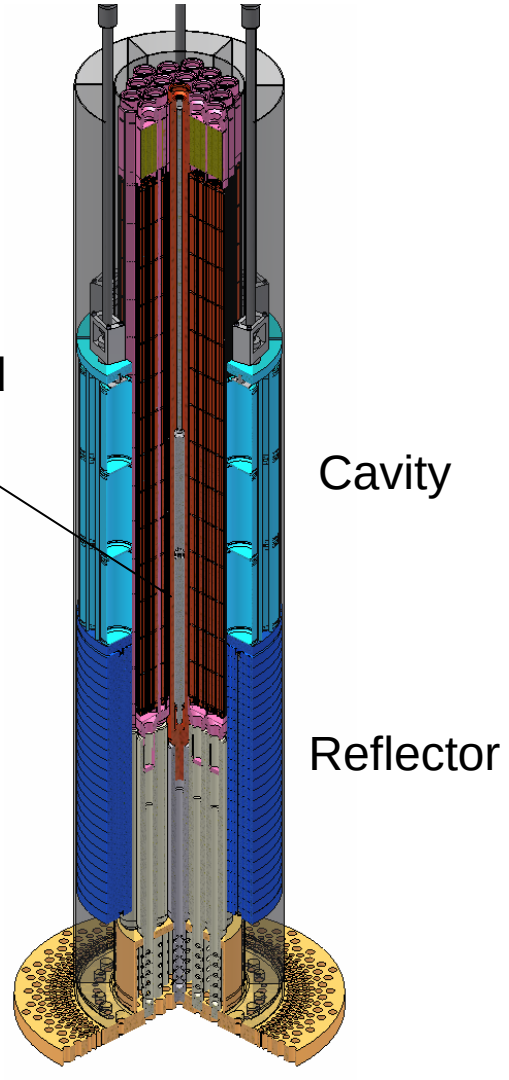


Reactivity Control System

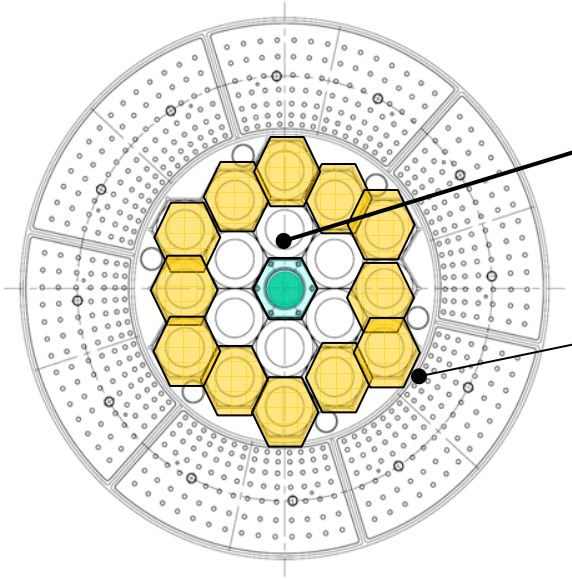
Reflector	
Number	6
Reflector stroke	2.7m (8.8ft)
Scram	gravity

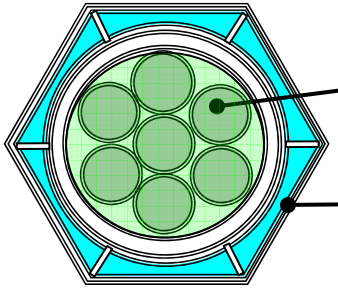
Shutdown rod	
Number	1
Rod stroke	2.5m (8.2ft)
Absorber material	B4C
Scram	gravity Insertion

Fixed absorber	
Number	6
Absorber stroke	2.7m (8.8ft)
Absorber material	Hf



Reactivity Control





Shutdown Rod
(B_4C neutron absorber)

Fixed Absorber
(Hf: 6 segment)

Reflectors : 6 sectors
(Axially movable with fine motion,drop down for scram)

Inner core

Outer core

Available Systems	Reflector	Shutdown Rod	Fixed Absorber
Start up & normal shutdown	0	0	-
Burn-up compensation	0	–	0
Scram	Δ*	Δ	-

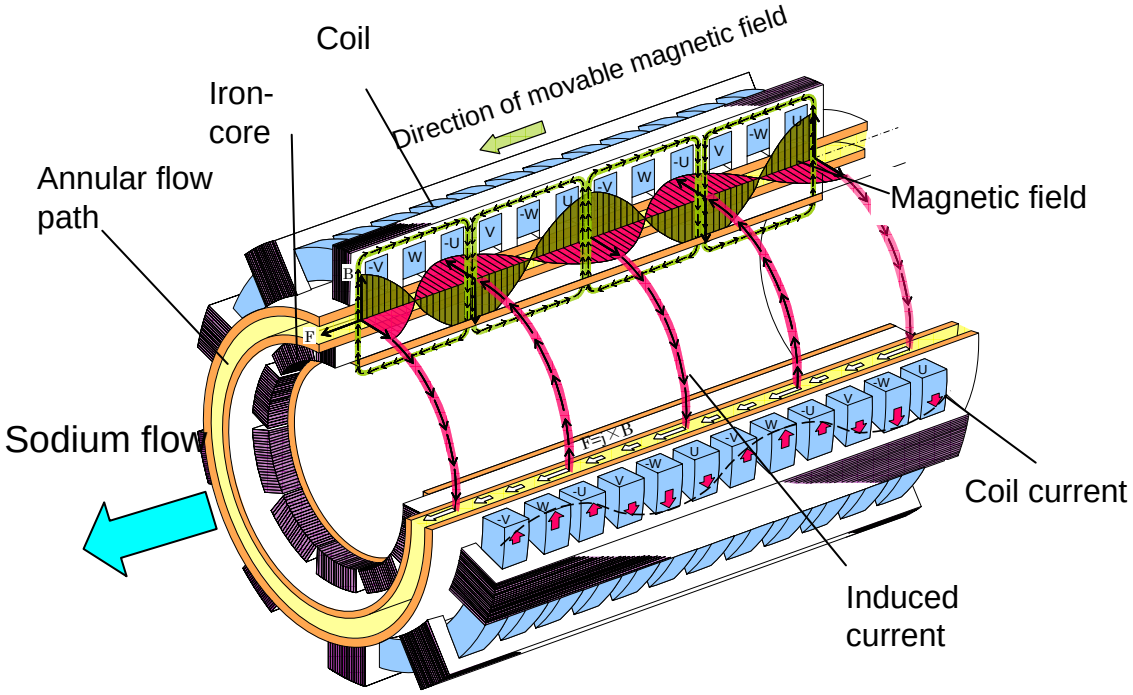
O – Needed

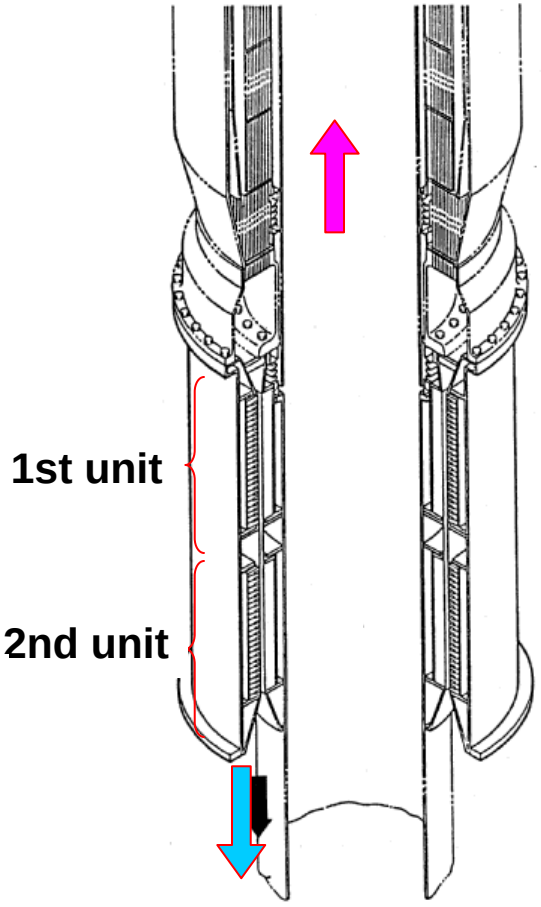
Δ – Redundant and diverse

* - Provides one reflector stuck margin

Primary EM pumps

- **Two pumps in series**
- **No moving parts**

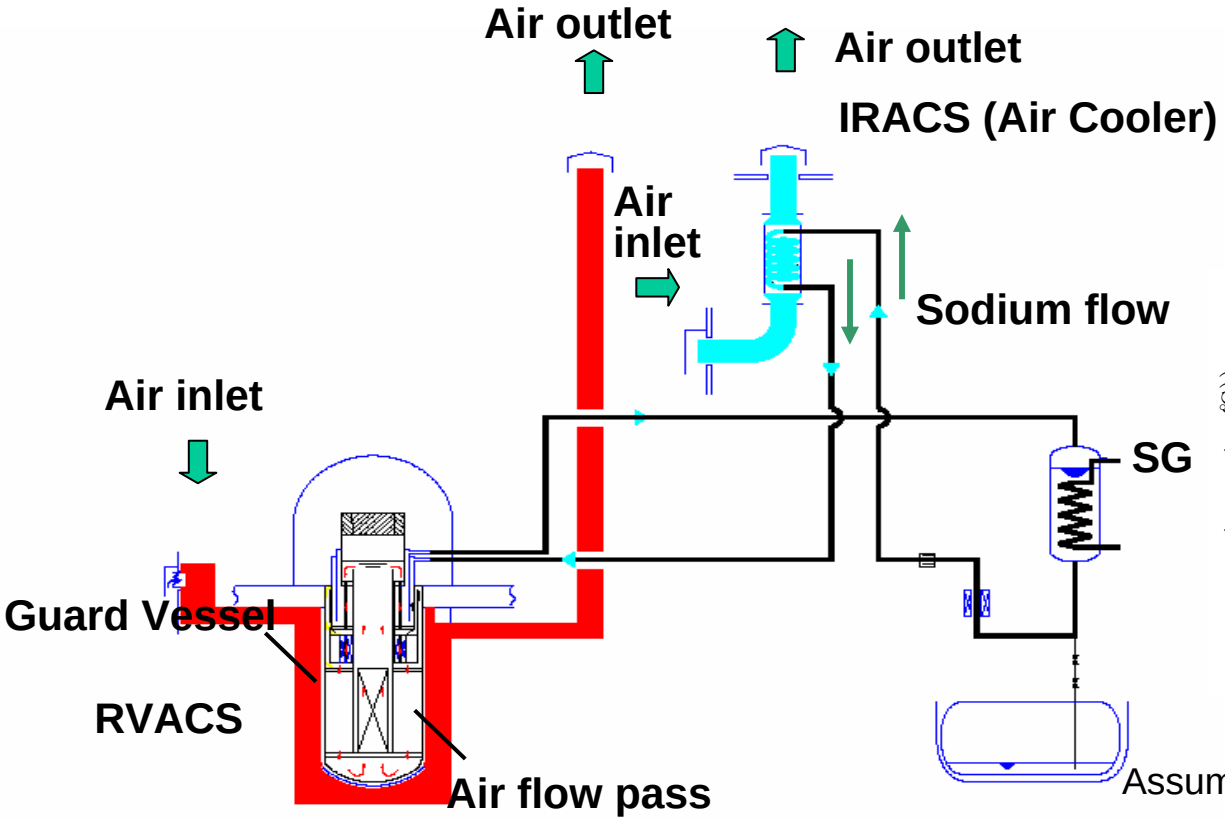


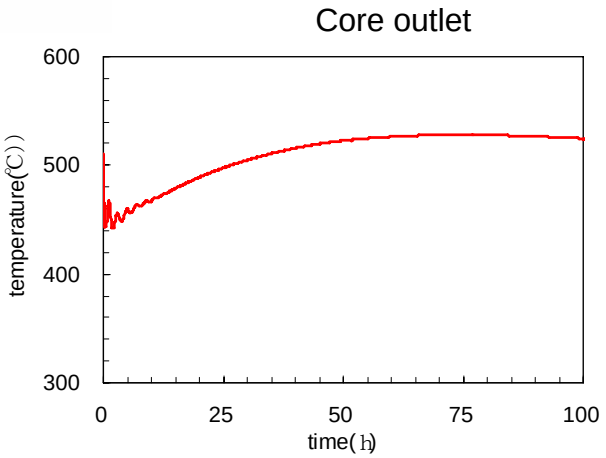


EM pumps in series

Passive Decay Heat Removal

- **Heat removal by natural circulation & natural air draft**
  - Redundant and diverse residual heat removal
  - RVACS: Natural air draft outside the guard vessel
    - Sufficient cooling capacity by only RVACS
  - IRACS: Natural circulation of sodium and air draft of air cooler

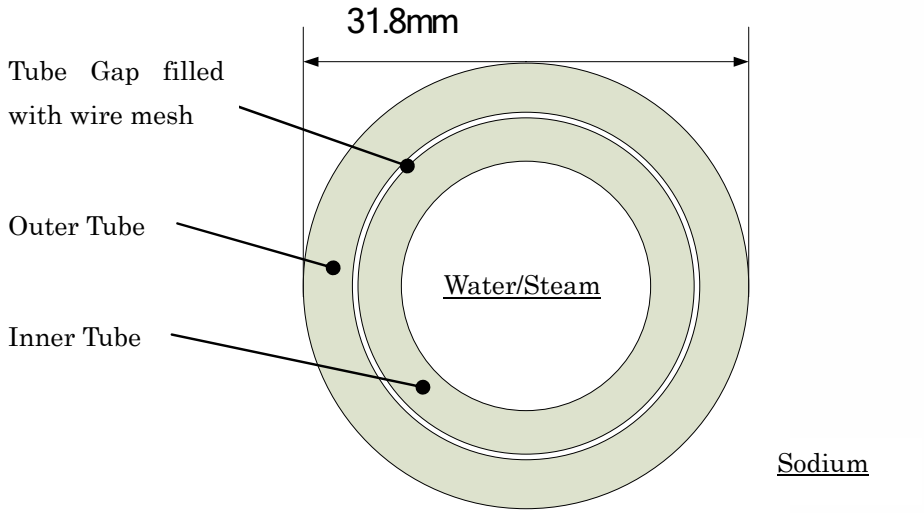


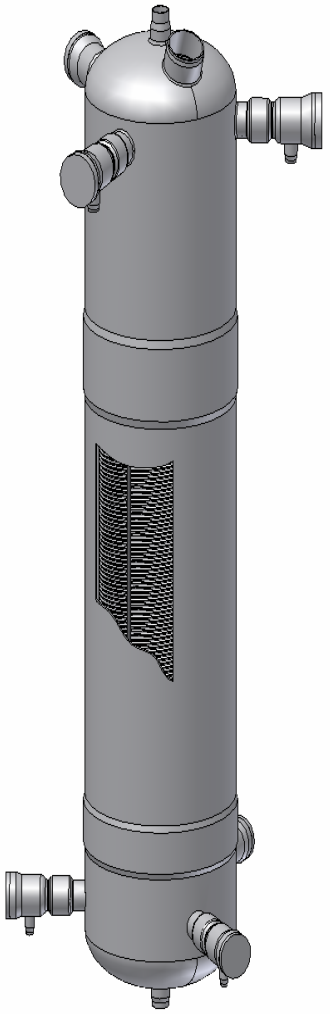


Loss of offsite power
Assumption : Heat removal by only RVACS

Steam Generator

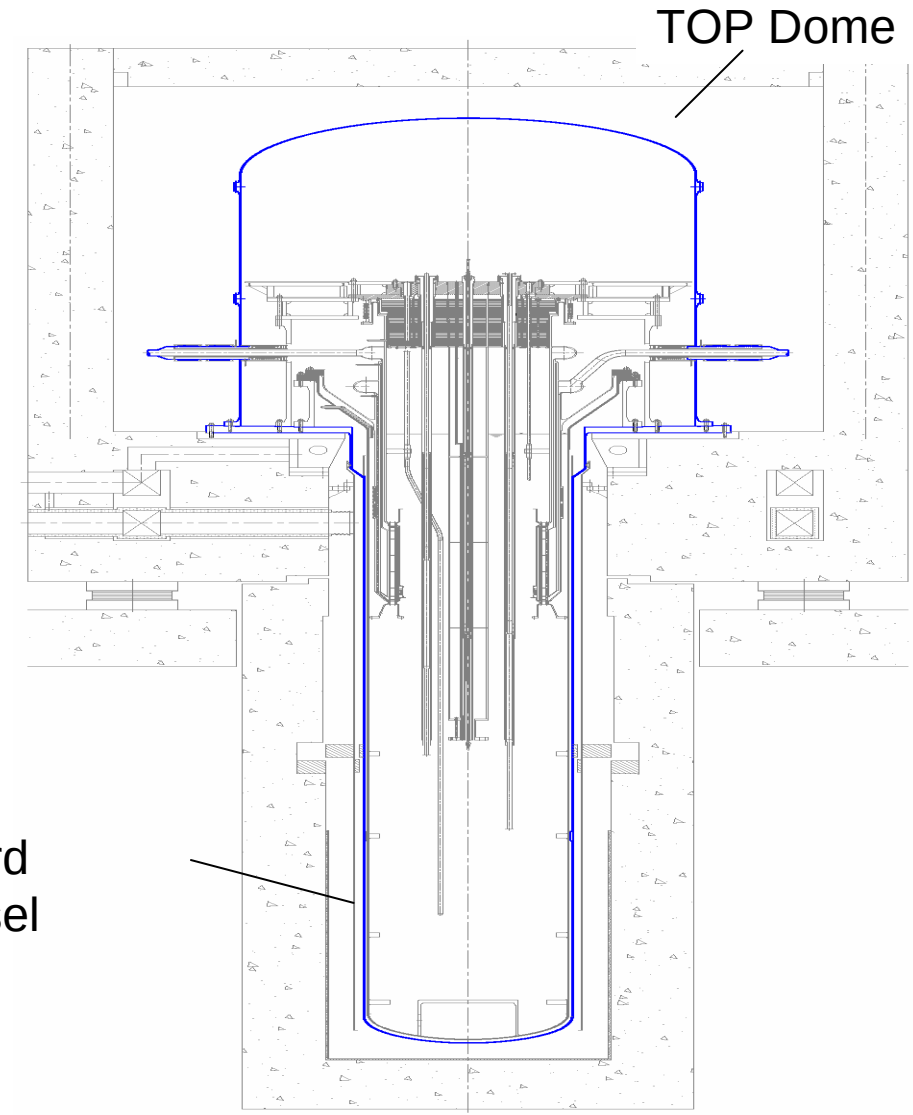
- **Double wall tube steam generator**
  - Minimizes potential for sodium-water reaction





Containment

- **Guard vessel**
  - **Material: 2 1/4Cr-1Mo**
  - **Diameter: 3.65m**
- **Top dome**
  - **Material: 2 1/4Cr-1Mo**
  - **Diameter: 8m**
- **Passive heat removal system**



Safety Features of 4S

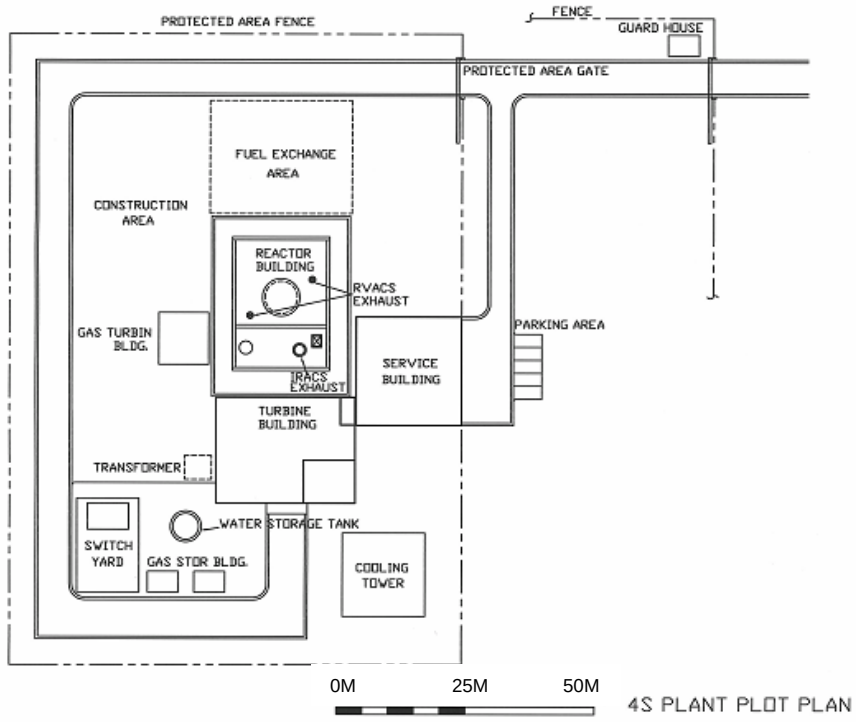
- **Source term reduction**
  - Low power results in low fission product inventory
  - Sodium affinity for fission products minimizes release
  - No significant release to containment due to absence of energetic and pressurization events
- **Radioactive release reduction**
  - Sealed reactor vessel and containment
  - Minimize penetrations and isolation valves
  - Threat to containment integrity is minimal due to absence of damaging phenomena (direct containment heating, steam explosion, hydrogen burning or detonation, missiles)

Safety Analysis Results

- **Large margin to acceptance criteria for site suitability and emergency planning**

Distance (m)	50
EAB (rem)	0.004
LPZ (rem)	0.2
Acceptance dose criteria (rem)	25

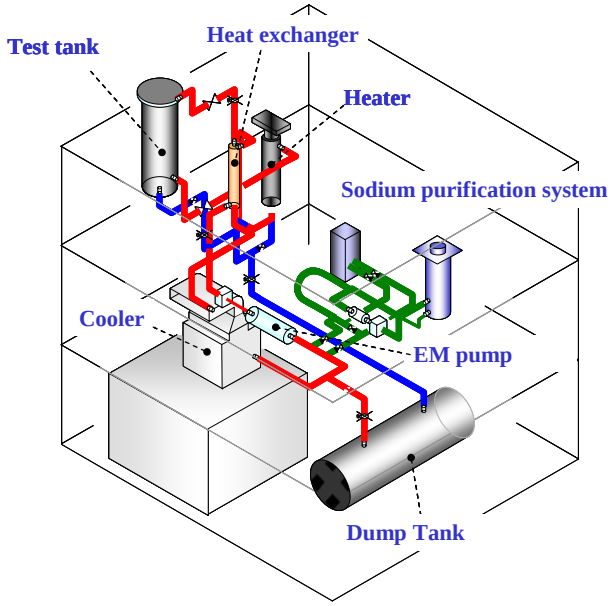
TEDE: Total equivalent dose
EAB: Exclusion area boundary
LPZ: Low population zone



Test Facility for Further Tests

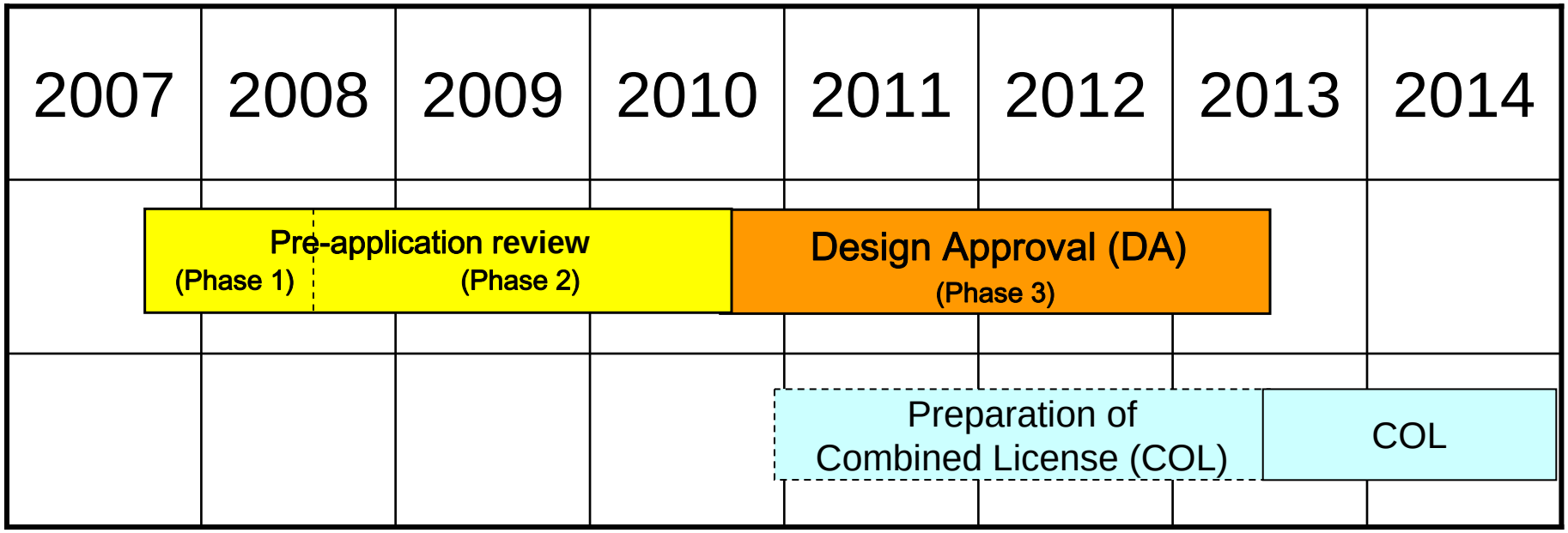
- **TOSHIBA Sodium Component Test Facility**

  - Facility completed December 2008.
  - Functional testing begun January 2009.
  - Planned tests
    - Demonstration of large-scale EM pump.
    - Verification of leak detection system for a steam generator outer tube failure.



Current Licensing Schedule

- **Submit Design Approval application on October, 2010**
  - **Phase 1:** Complete a series of meetings with NRC to identify issues to be addressed before Design Approval application
  - **Phase 2:** Submit technical reports and obtain NRC feedback to address the issues identified in Phase 1
  - **Phase 3:** Submit Design Approval application and obtain SER



The licensing activity is been conducted in cooperation with CRIEPI, ANL and WEC.

Conclusions

- **4S is a mature technology that is ready for regulatory review and commercialization.**
  - Preliminary systems design complete and detailed design in progress
  - Significant body of test data to support key components
  - Proven and tested fuel experience to support the 30-year core lifetime
- **4S U.S. licensing process has begun.**
  - Pre-application review meetings & technical reports
  - Target for FDA - 2013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