SODIUM COOLED SMALL FAST LONG-LIFE REACTOR "4S"

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ELECTRIC POWER PROMISE FOR TOMORROW
Central Research Institute of Electric Power Industry
CRIEPI

4S: Super-Safe, Small and Simple

For dispersed energy sources and multi-purpose reactors

- Enhanced safety
- Improved reliability
- Reduced maintenance work
- Simple operation

realized by small-sized fast reactor

4S Design Requirements

1. All temperature feedback reactivity coefficients including whole core sodium void reactivity are negative.
2. The core integrity is secured against all anticipated transient without reactor scram
3. No emergency power nor active mitigating system is required (passive decay heat removal system).
4. The reactivity core lifetime is more than 10 years.

Core Design Approach

Long-life core

Negative void reactivity

Good internal conversion ⟺ Neutron leakage enhancement

consistency

Large fuel volume fraction

Reflector control

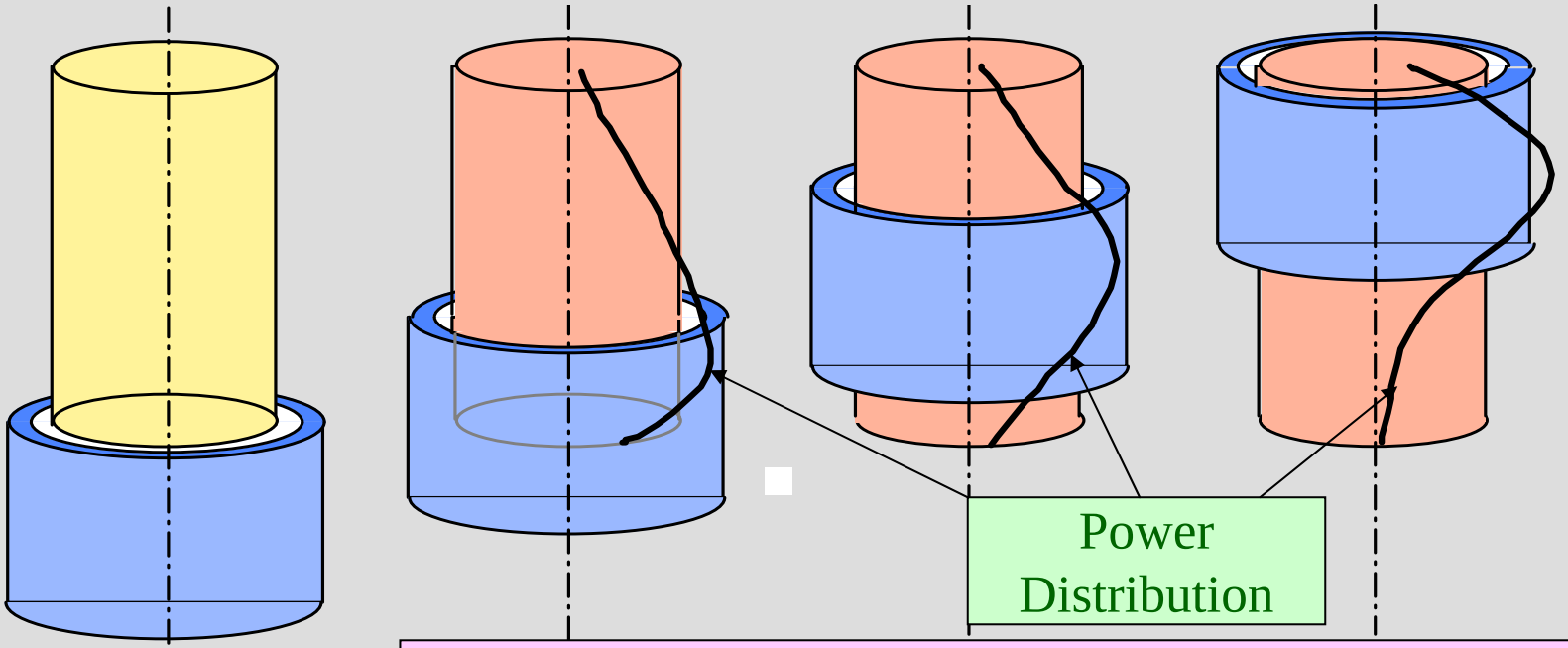
Long & Wider fuel

Slim core

Core height: > 2 m
Fuel dia.: > 10 mm

Basic configuration: slim & long
still another requirements

Reactivity Control by Reflector



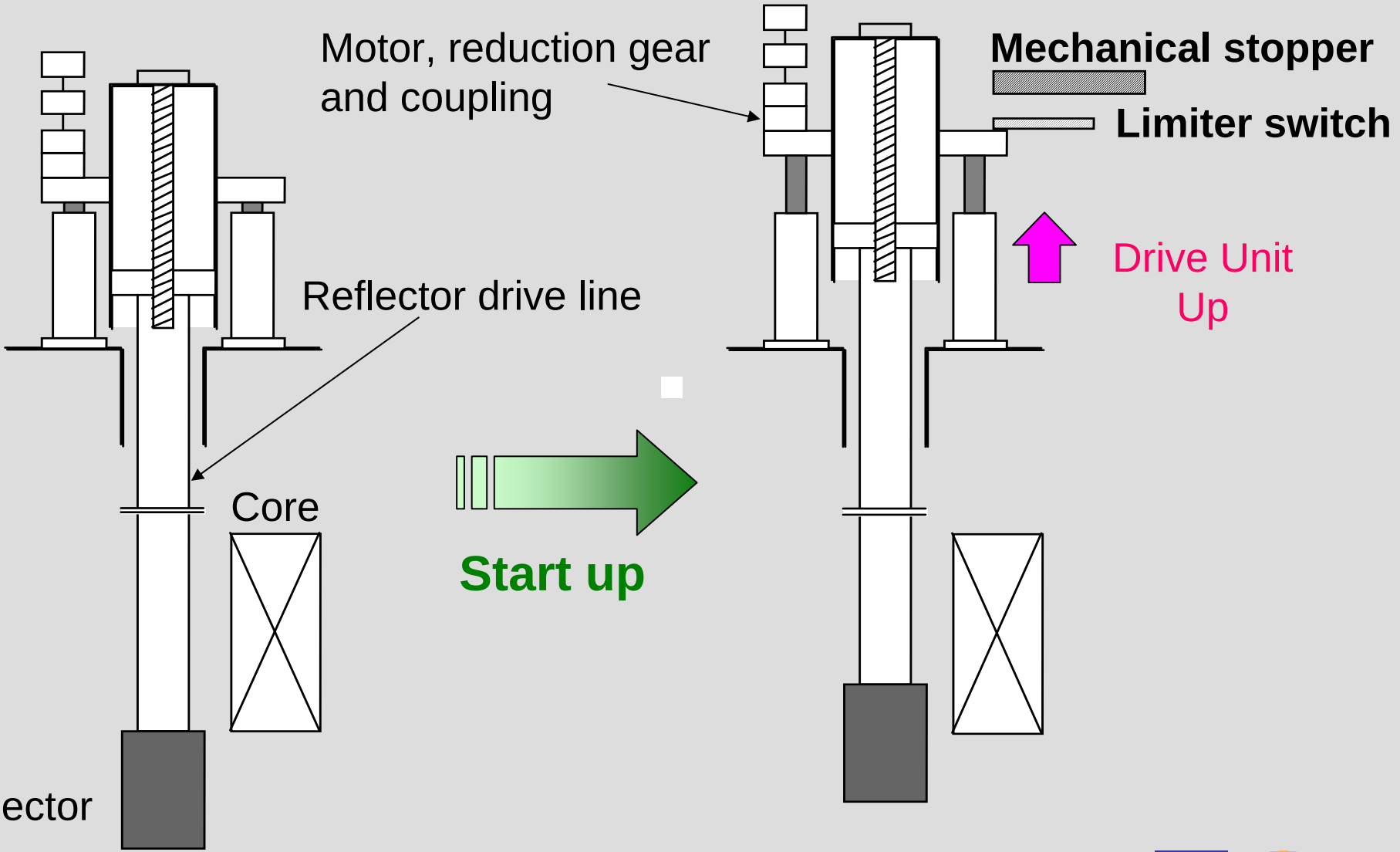
Before Operation

Beginning of Core Lifetime | **Middle of Core Lifetime** | **End of Core Lifetime**

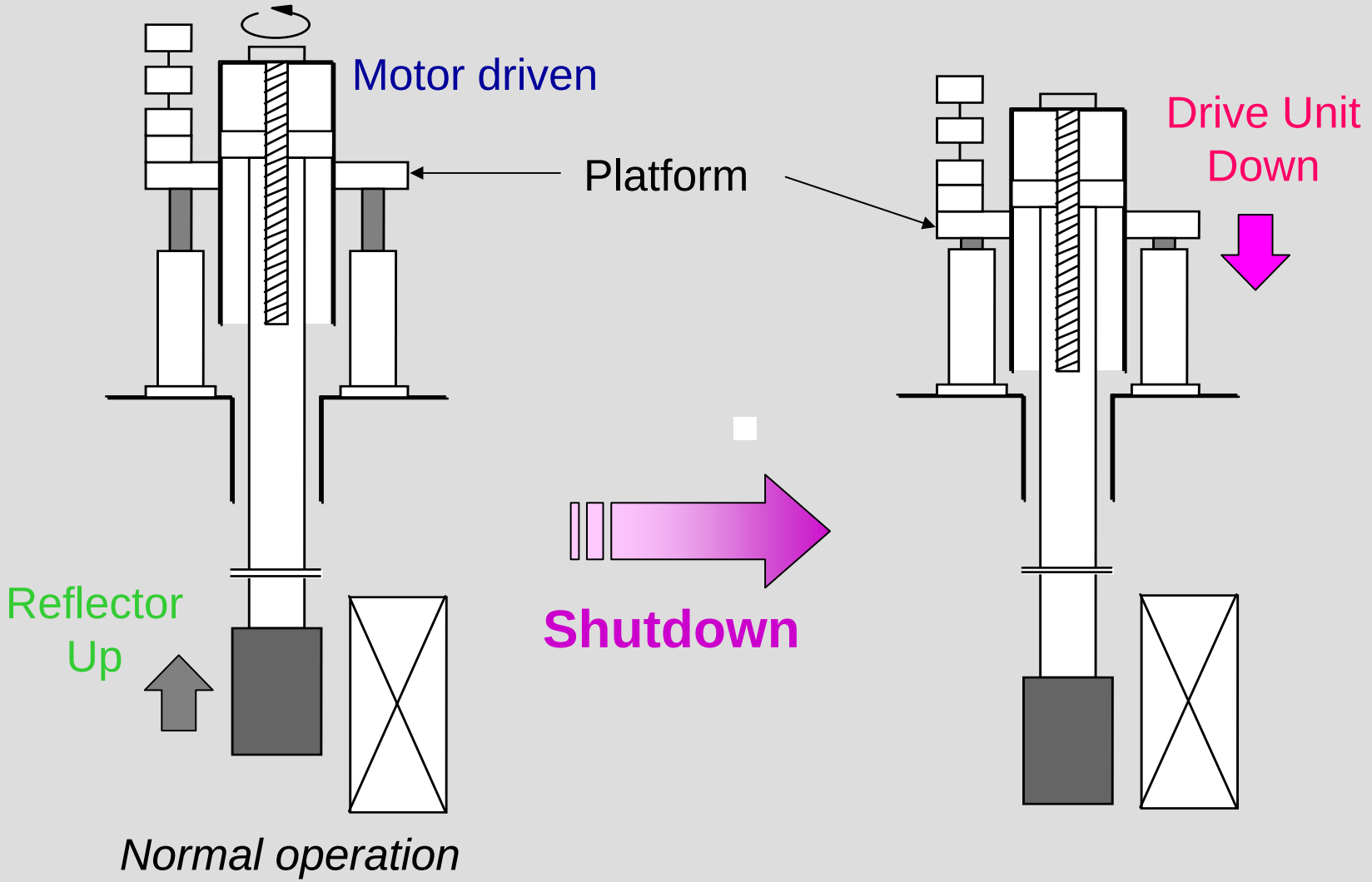
The core is sub-critical under the condition of uncovered with the reflector.

The reflector is moved upward for the start up. Then the reflector is moved upward with very low speed for burn-up control.

Reflector Control Procedure (1)



Reflector Control Procedure (2)



Design Parameters

Core lifetime	> 10 years
Sodium coolant void reactivity	< 0
Core height	< 2.0 m
Core pressure drop	< 0.2 MPa
Max. LHR	< 25 kW/m
Ave. burnup	~100 GWd/ton

Basic requirements

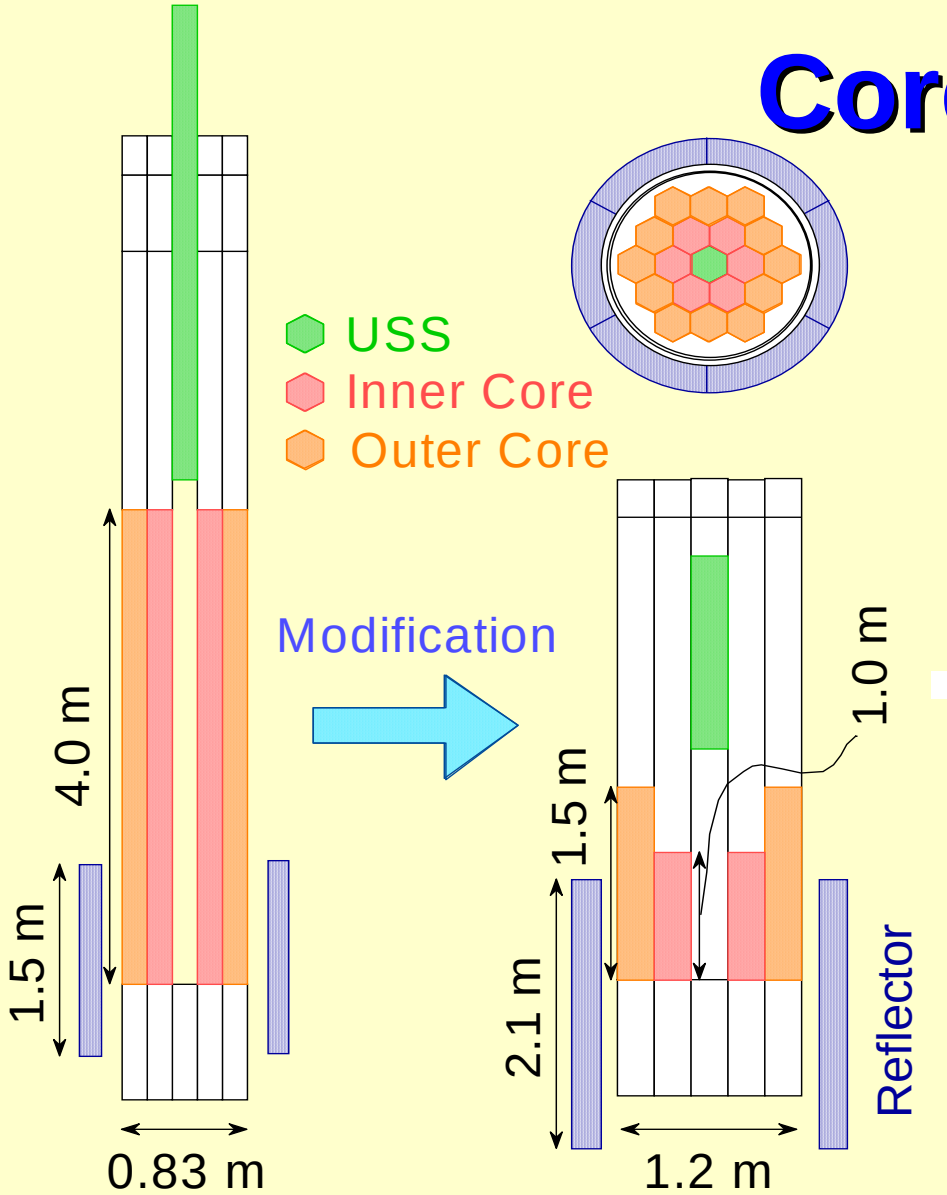
for safety

for economics

System Heat Balance

Primary Temperature [^{o}C]	510 / 355
Secondary Temperature [^{o}C]	475 / 310
Steam Condition [^{o}C/MPa]	453 / 10.8

Core Design (4S-50MP)



4m core height

Irradiation tests ?

To decrease the height

To keep 4S concept

1.2m ϕ x 1.5m

Design restriction

Pu enrichment: 20 wt%
Smear density: 75%

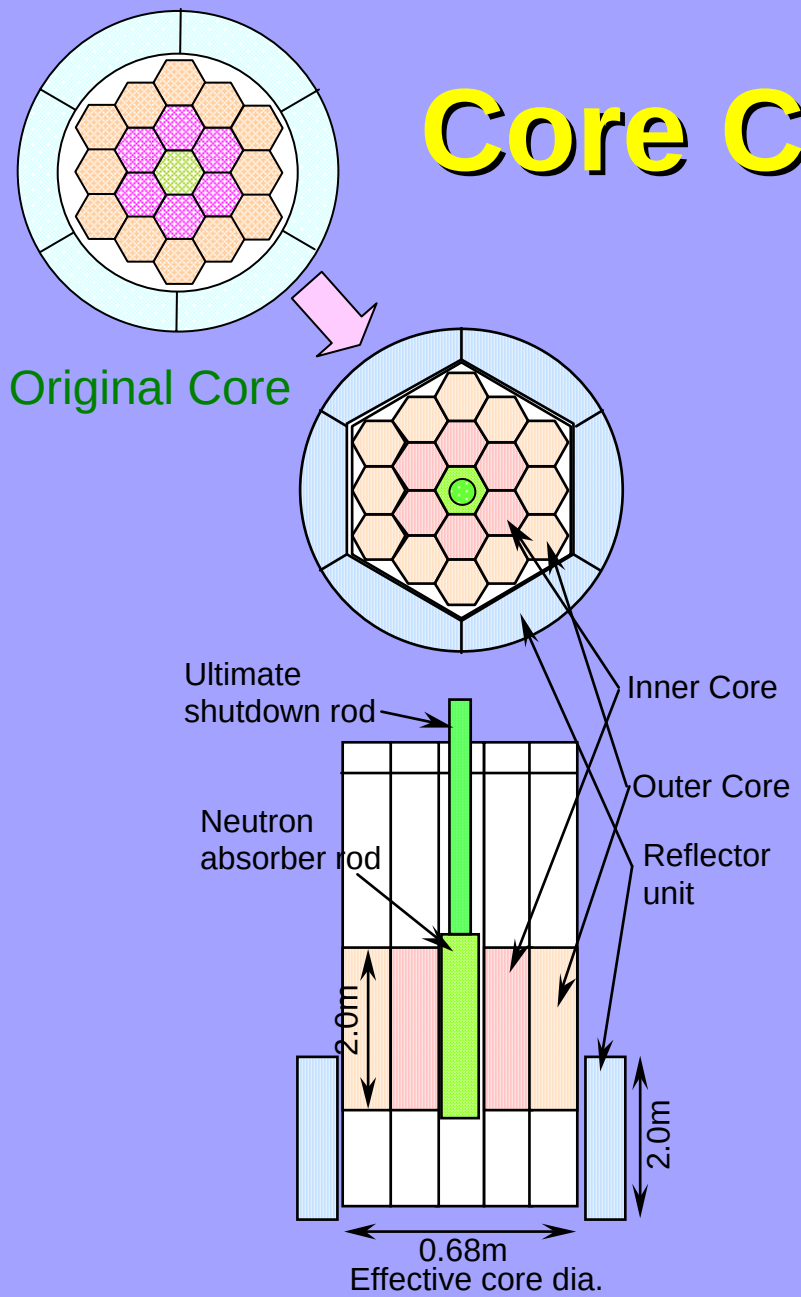
Main core design specification

Thermal output [MW]	30	130	3900
Electrical output [MW]	10	50	1500
Core cycle lifetime [yrs.]	30	10	1.5
Core dia. [m]	0.68	1.2	5.1
Core height [m]	2.0	1.5	0.85
No. of S/As (inner/outer)	6/12	6/12	276/138
No. of fuel pins	169	469	331
Fuel pin dia. [mm]	10.0	10.0	8.5
Cladding thickness [mm]	0.50	0.59	0.50
Pitch/Dia.	1.10	1.15	1.17
Smear density [%TD]	78	75	75
Duct pitch [mm]	151	258	198

Main core design specification

Thermal output [MW]	30	130	3900
Electrical output [MW]	10	50	1500
Pu enrichment [%] (inner/outer)	24.0 / 24.0	17.5 / 20.0	12.2 / 17.1
Ave. burn-up [GWd/t]	76	70	148
Conversion ratio	0.60	0.71	1.25
Coolant void reactivity [$]	~0	~0	~8
Burn-up swing [$\Delta\rho$]	~16	~9	1.11
Reflector reactivity [$\Delta\rho$]	~8	~10	-
Fixed rod reactivity [$\Delta\rho$]	~10	-	-
Max. LHR [kW/m]	11	25	48
Fuel vol. fraction [%]	54.2	49.7	43.2
Coolant vol. fraction [%]	28.0	33.0	35.2

Core Concept (1MWe)

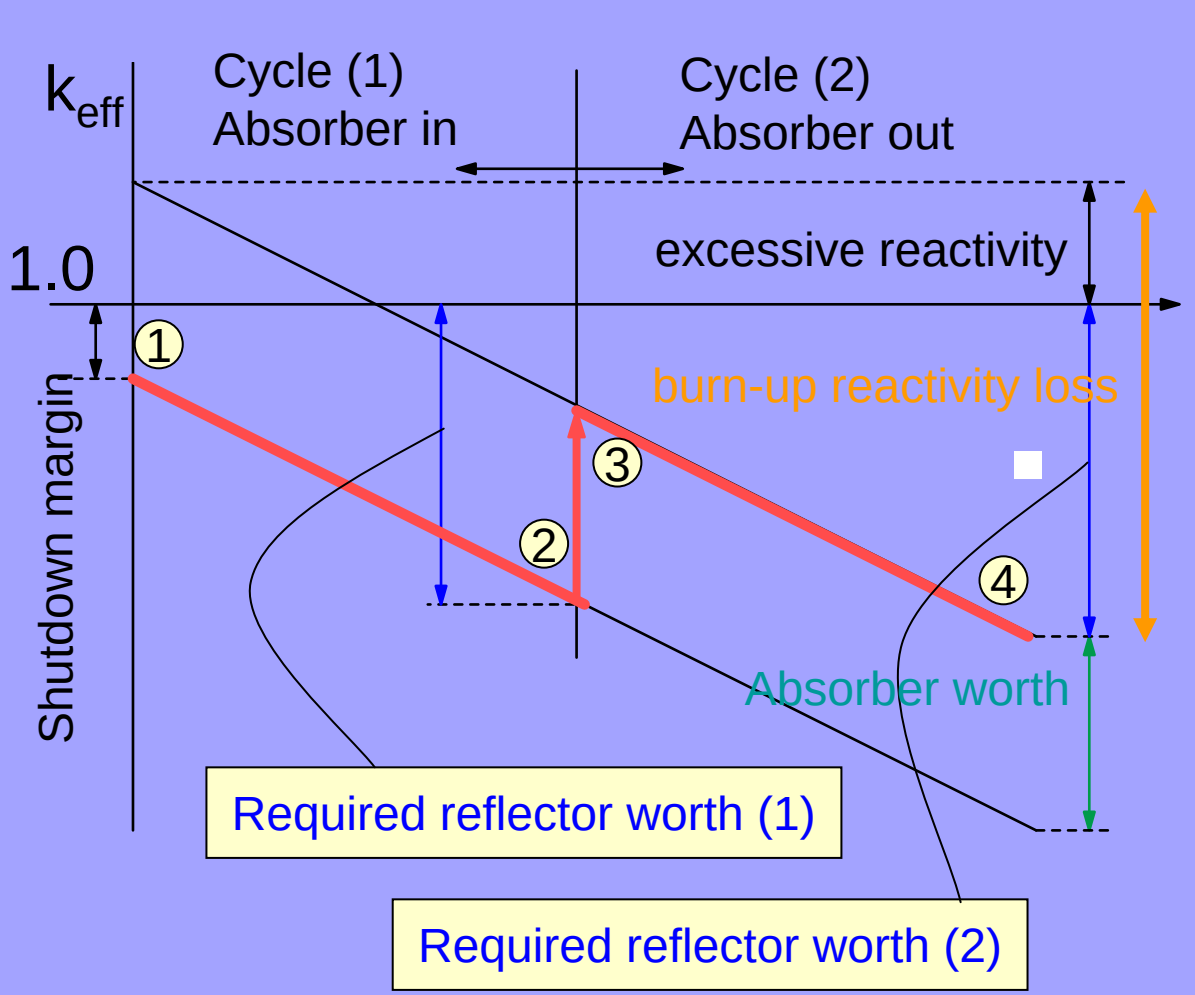


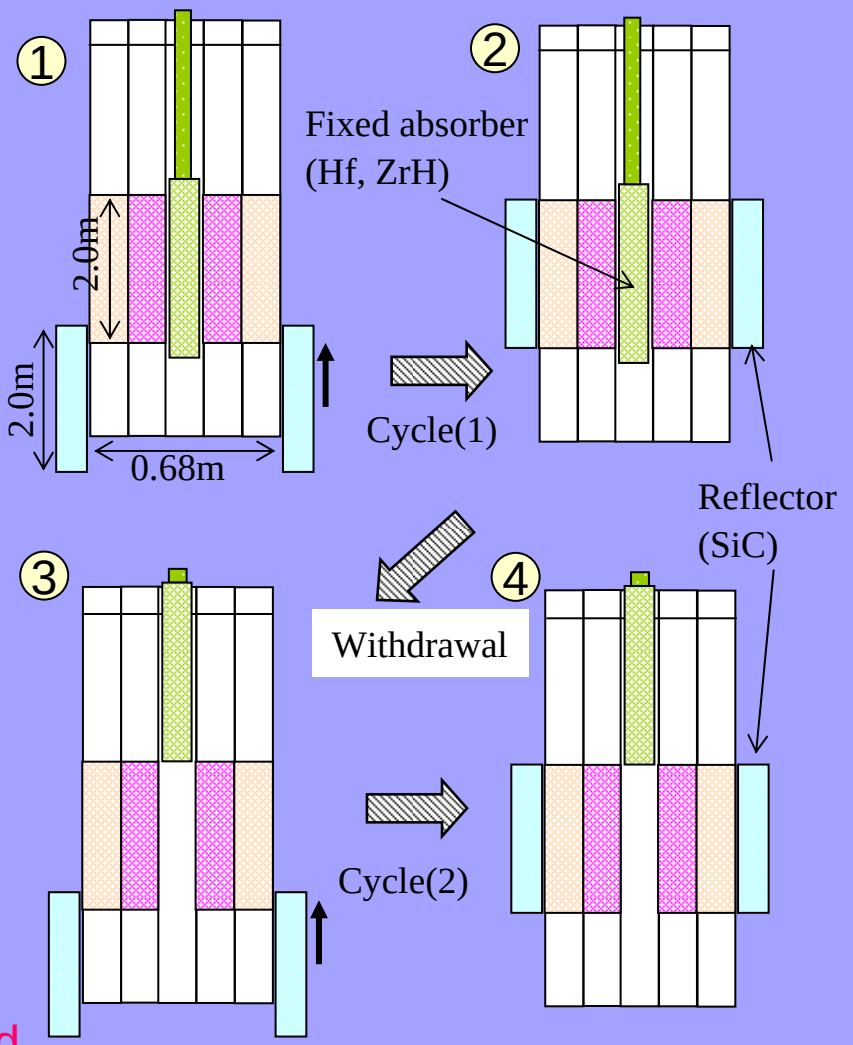
The subject for the lifetime extension…
burn-up reactivity loss is larger than the worth of reflector

- Hexagonal core barrel
- The reflectors are arranged close to the fuel assembly

- Fixed neutron absorber is adopted in the center channel
- The required worth of the reflector is decreased by the absorber

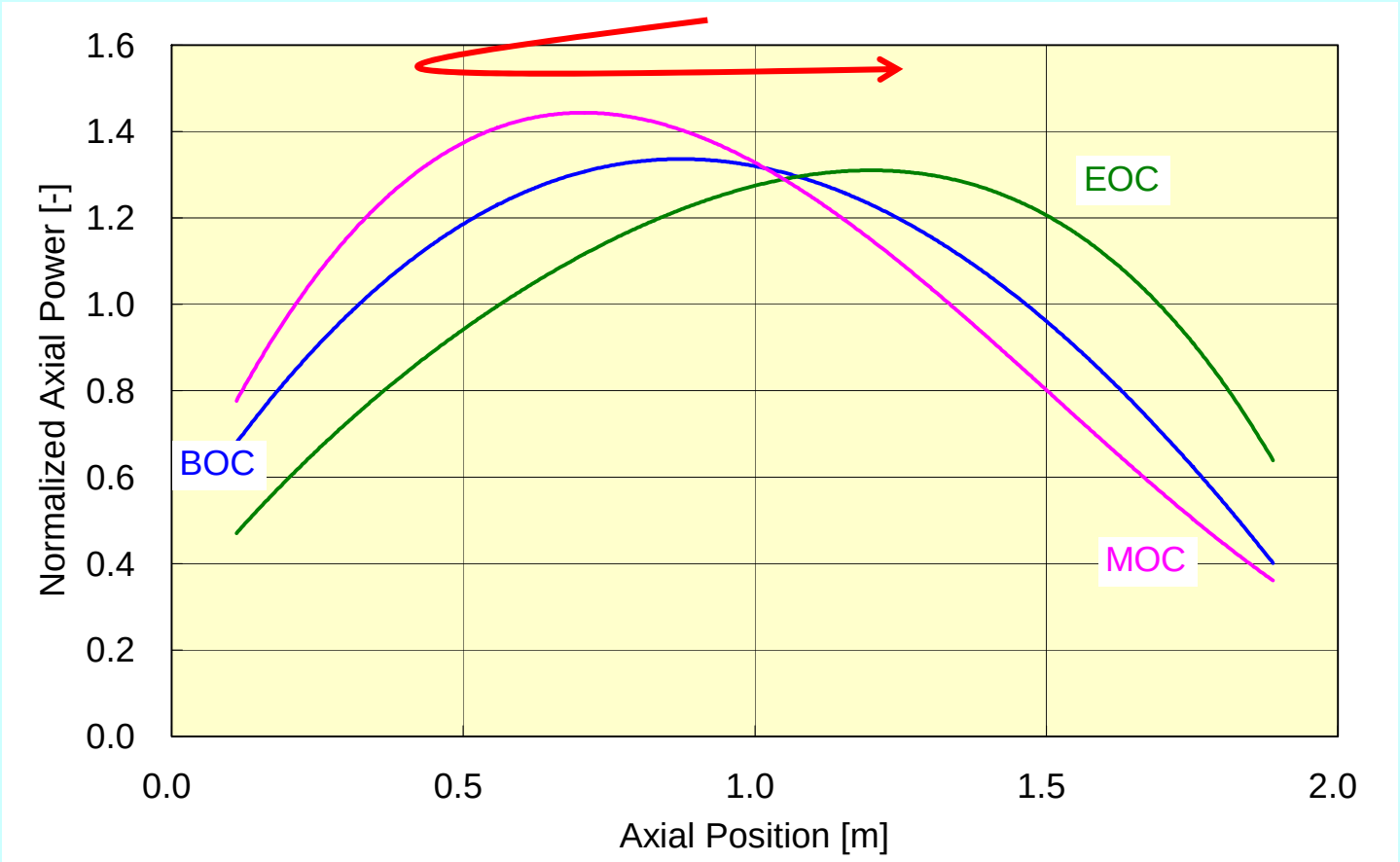
Core Concept (1MWe)

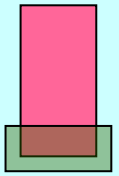




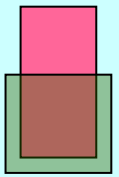
The core concept for 30 years by 10MWe is constituted

Axial Power Profile

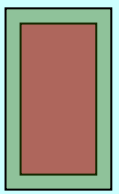




BOC



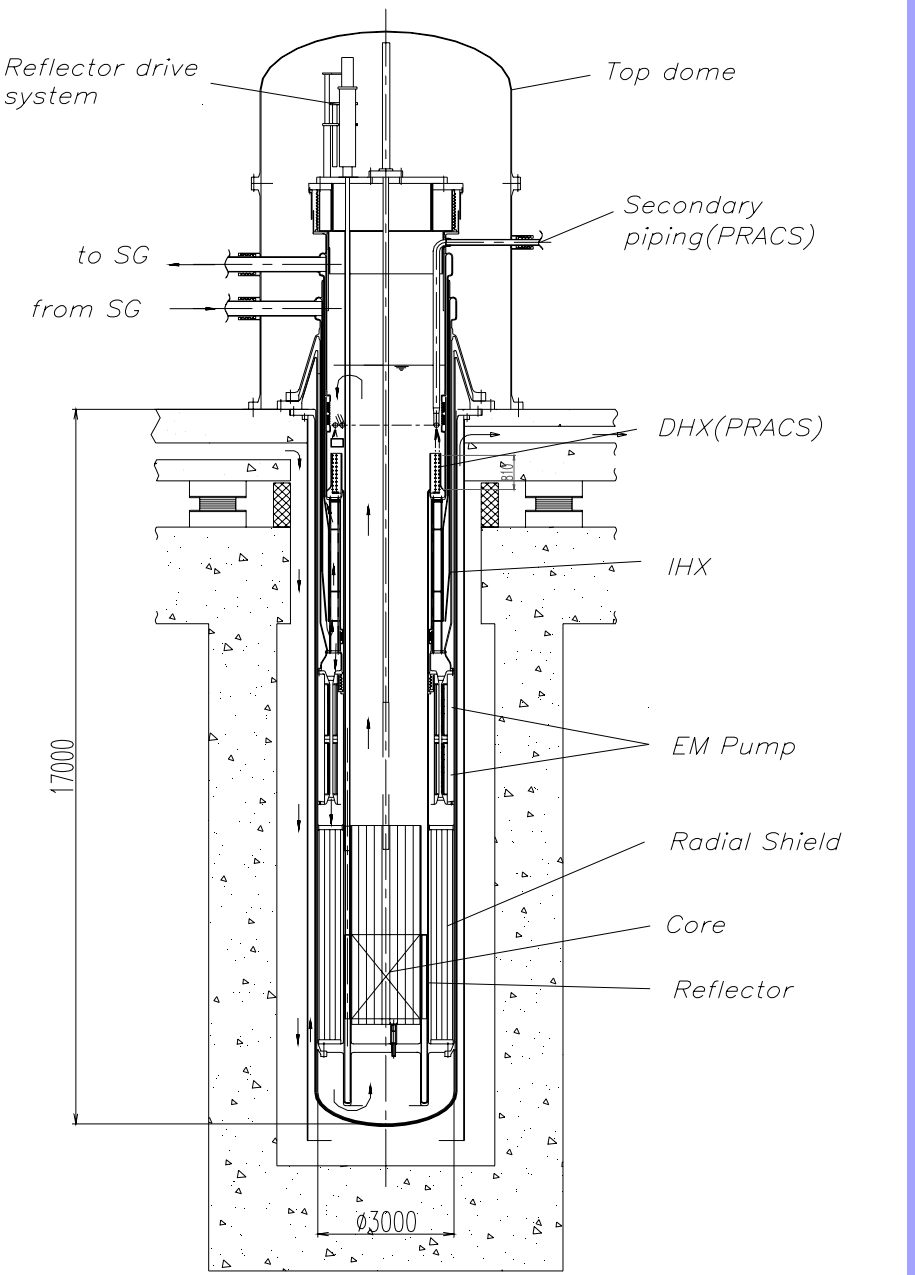
MOC

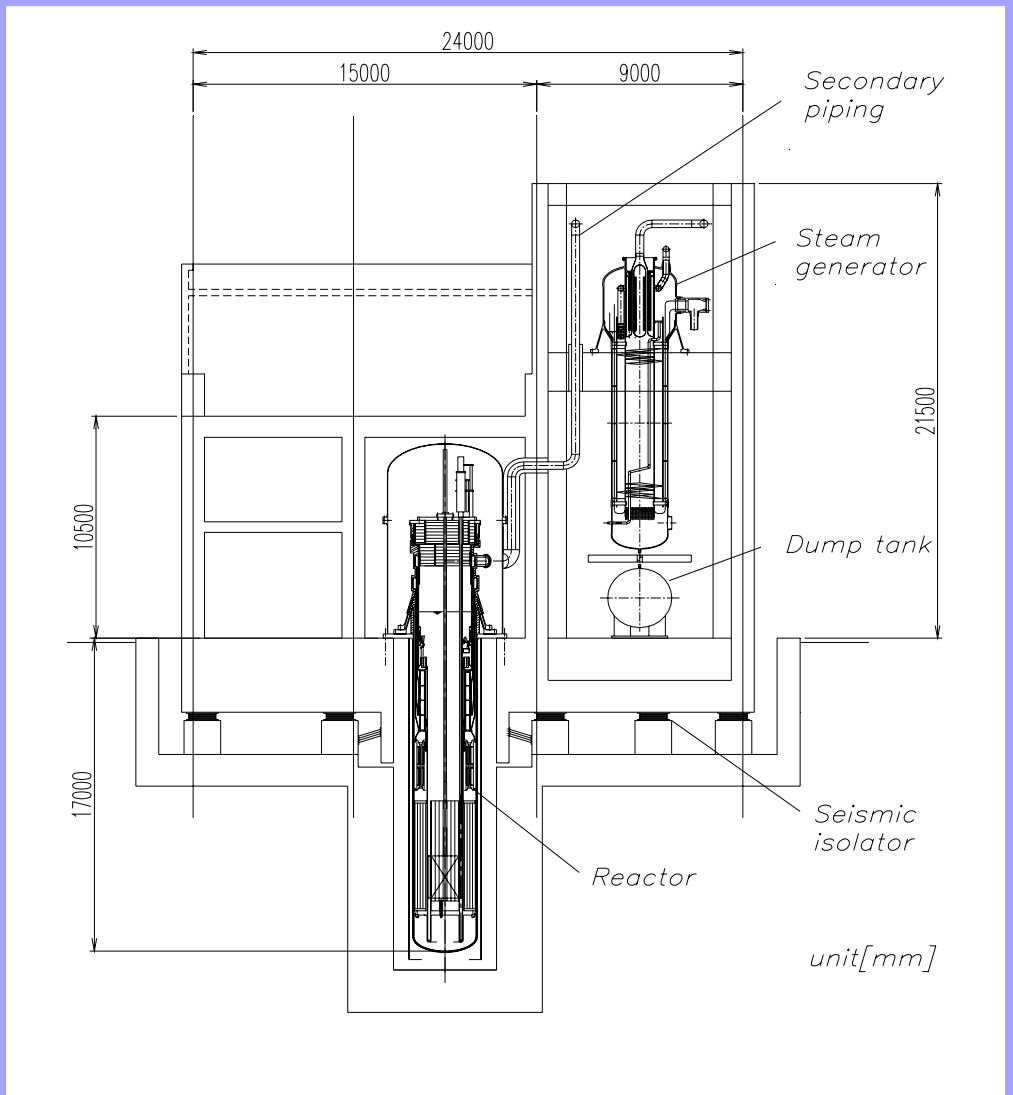


EOC

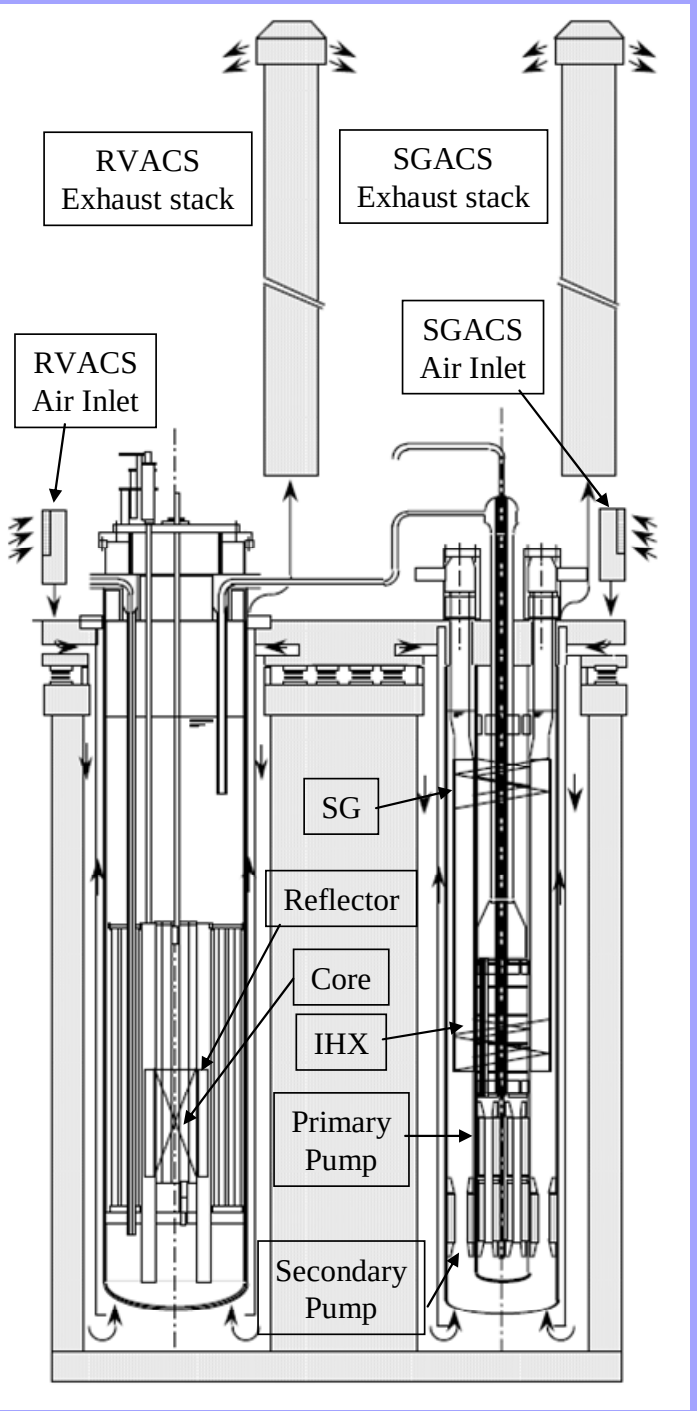
1991 design: monotonically move (core height > reflector height)
4S-10ML/4S-50MP: slightly move (core height = reflector height)

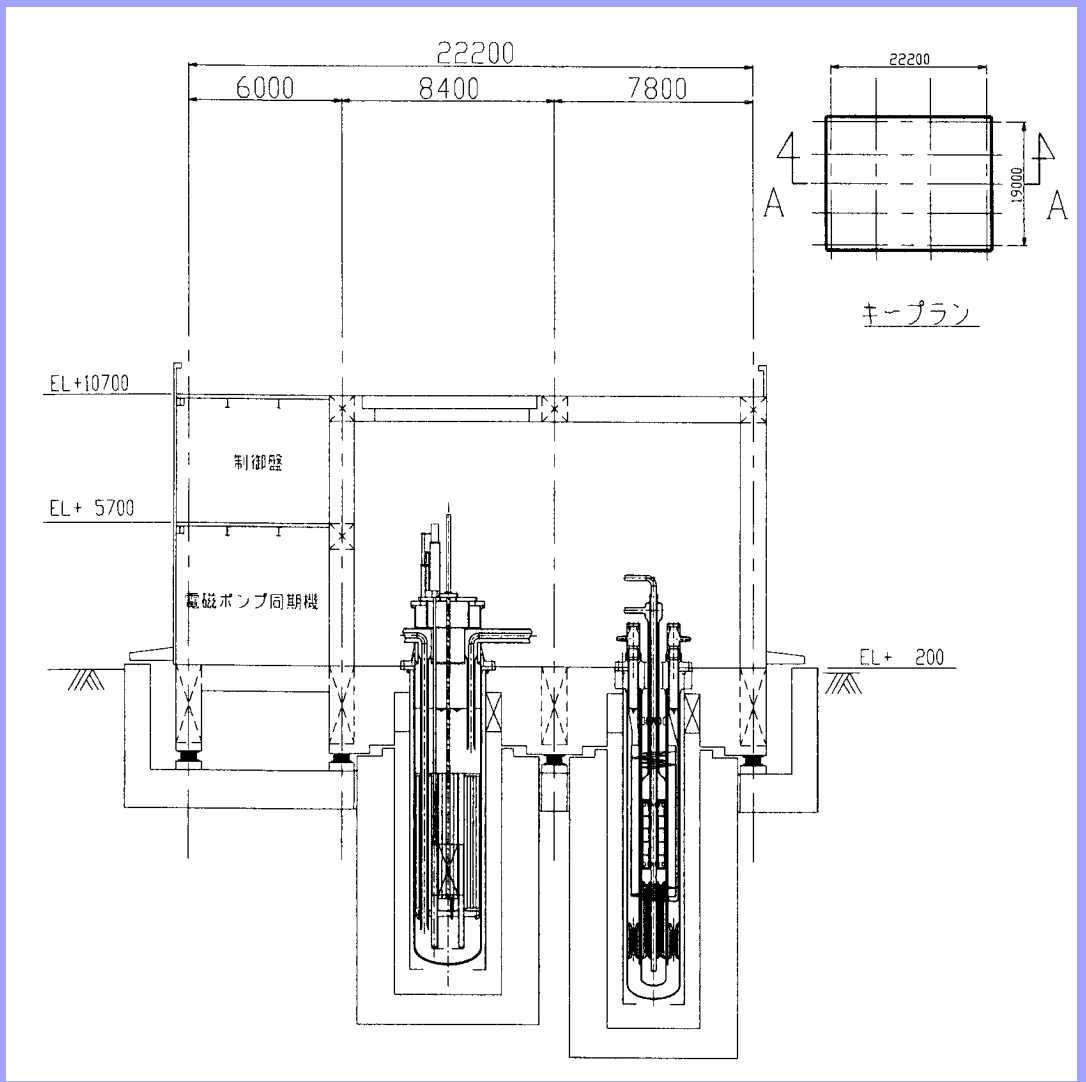
4S-50MP


Reflector drive system
Top dome
Secondary piping(PRACS)
to SG
from SG
DHX(PRACS)
IHX
EM Pump
Radial Shield
Core
Reflector
17000
ø3000


24000
15000
9000
Secondary piping
Steam generator
Dump tank
Seismic isolator
Reactor
10500
17000
21500
unit[mm]

4S-10ML


RVACS
Exhaust stack
SGACS
Exhaust stack
RVACS
Air Inlet
SGACS
Air Inlet
SG
Reflector
Core
IHX
Primary
Pump
Secondary
Pump


22200
6000
8400
7800
22200
19000
A
A
キープラン
EL+10700
制御盤
EL+ 5700
電磁ポンプ同期機
EL+ 200

Conclusion

- The sodium cooled small-sized fast reactors named 4S-50MP and 4S-10ML are designed to meet the global energy source market as dispersed electric power or multi purpose reactor.
- The 4S reactors are designed to have the long lifetime core, which is one of the solutions to satisfy design requirements.
- The negative coolant void reactivity is kept in 4S reactors to enhance safety characteristics.
- The reflector controlled metallic fuel cores are adopted which have tall height and wider fuel pin.
- In the 4S-10ML design, the fixed absorber rod is adopted to supplement the reflector to compensate the burn-up reactivity loss.