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Design Features, Construction and Operating Experiences of ABWR

Improvement of Safety, Economics and Reliability

March 2007

Hitachi, Ltd.

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1. *HITACHI'S BWR EXPERIENCE*

2. *GENERAL FEATURES OF BWR*

3. *DESIGN FEATURES OF ABWR*

4. *CONSTRUCTION AND OPERATING EXPERIENCES OF ABWR IN JAPAN*

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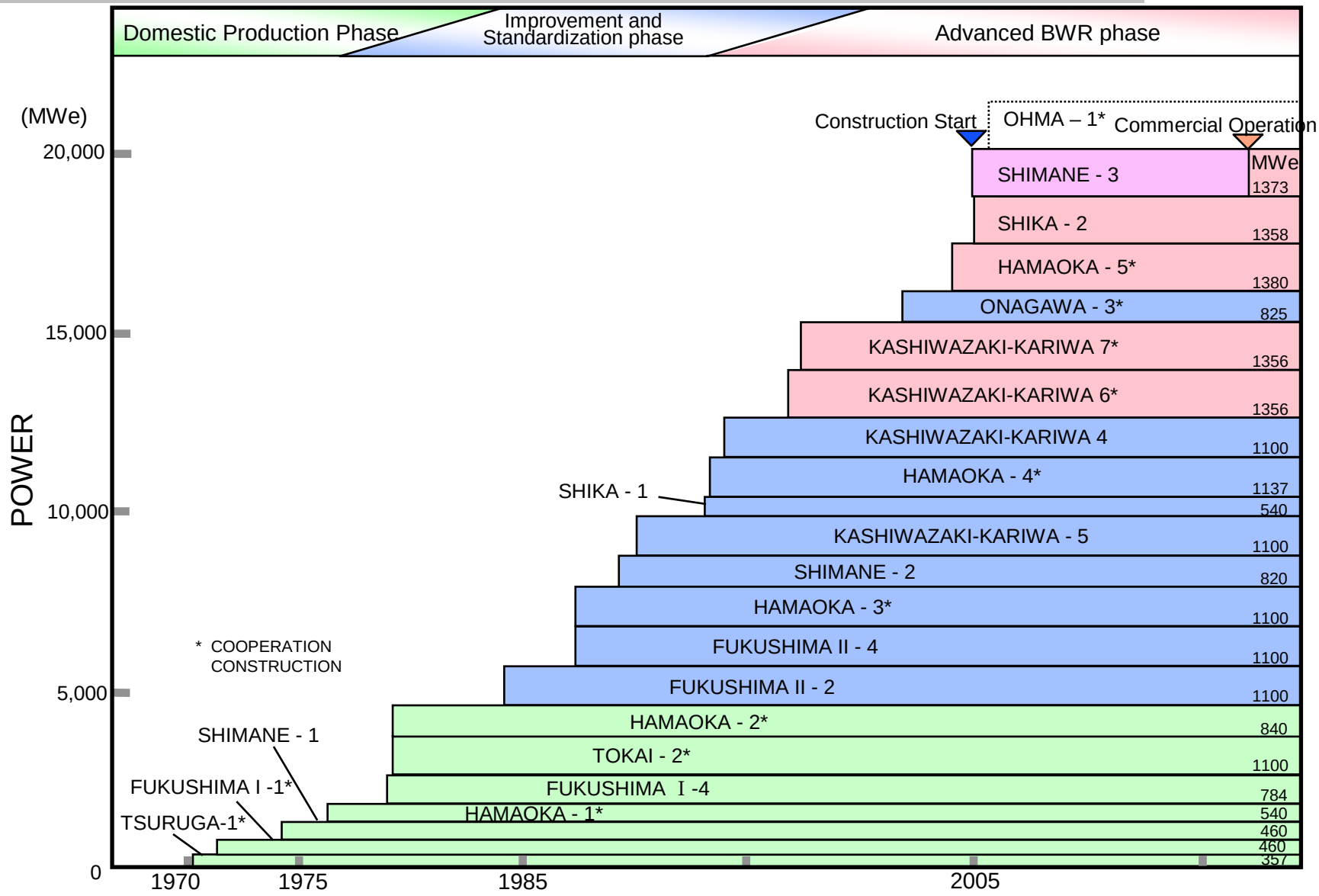
   STRATEGY OF NEXT GENERATION BWR

Nuclear Plant Construction Experiences



BWR/ABWR Plant in Japan

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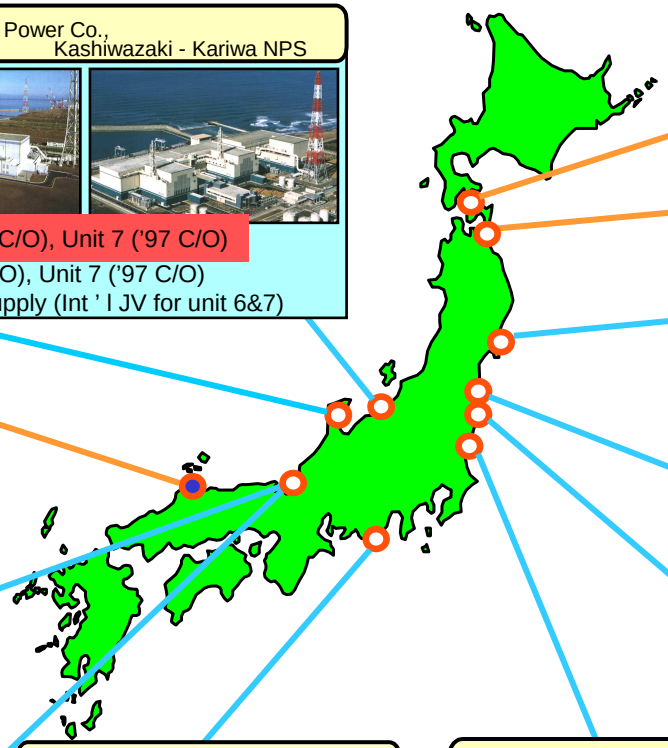
55 plants in operation (32 BWRs, 23 PWRs) and
2 plants under const. (1 BWR, 1 PWR) in Japan

	Full/NSSS		BOP
Hitachi: 20 plants in operation	[12	+	8]
1 plant under construction	[1	+	0]
2 plant planning			

ABWR plant



Hokuriku EPCo.Shika NPS

Unit 1 (1993 C/O),
Unit 2 (2006 C/O):
Total plant supply

Tokyo Electric Power Co., Kashiwazaki - Kariwa NPS

Unit 6 ('96 C/O), Unit 7 ('97 C/O)
Unit 6 ('96 C/O), Unit 7 ('97 C/O)
Total plant supply (Int ' l JV for unit 6&7)

Electric Power Development Co., Ohma

Unit 1:Under Planning

Tokyo Electric Power Co., Higashidouri

Unit 1:Under Planning

Tohoku Electric Power Co. Onagawa NPS

Unit 3 ('02 C/O):
Total Turbine Plant Supply

Chugoku Electric Power Co.,Shimane NPS

Unit 1 ('74 C/O) :
Total plant supply
Unit 2 ('89 C/O):
Total plant supply
Unit 3:Under Construction

Tokyo Electric Power Co. Fukushima No.1 NPS

Unit 1 ('71 C/O)
PCV, Turbine plant
Unit 4 ('78 C/O)
Total plant supply

Japan Atomic Power Co., Tsuruga NPS

Unit 1 ('70 C/O):
Reactor System component

Chubu EPCo.Hamaoka NPS

Unit 1 ('76 C/O), Unit 2 ('78 C/O)
Unit 3 ('87 C/O), Unit 4 ('93 C/O)
Unit 5 ('05 C/O)
Total Turbine Plant Supply

Japan Atomic Power Co.,Tokai NPS

Unit 2 (78 C/O):
Reactor System Component (part)
& Total Turbine Plant Supply

Tokyo Electric Power Co. Fukushima No.2 NPS

Unit 2 ('84 C/O): Unit 4 (87 C/O):
Total plant supply

Japan Nuclear Cycle Development Ins., Monju FBR

Unit 1 (''94 O/T):
Reactor System component

Worldwide Experiences

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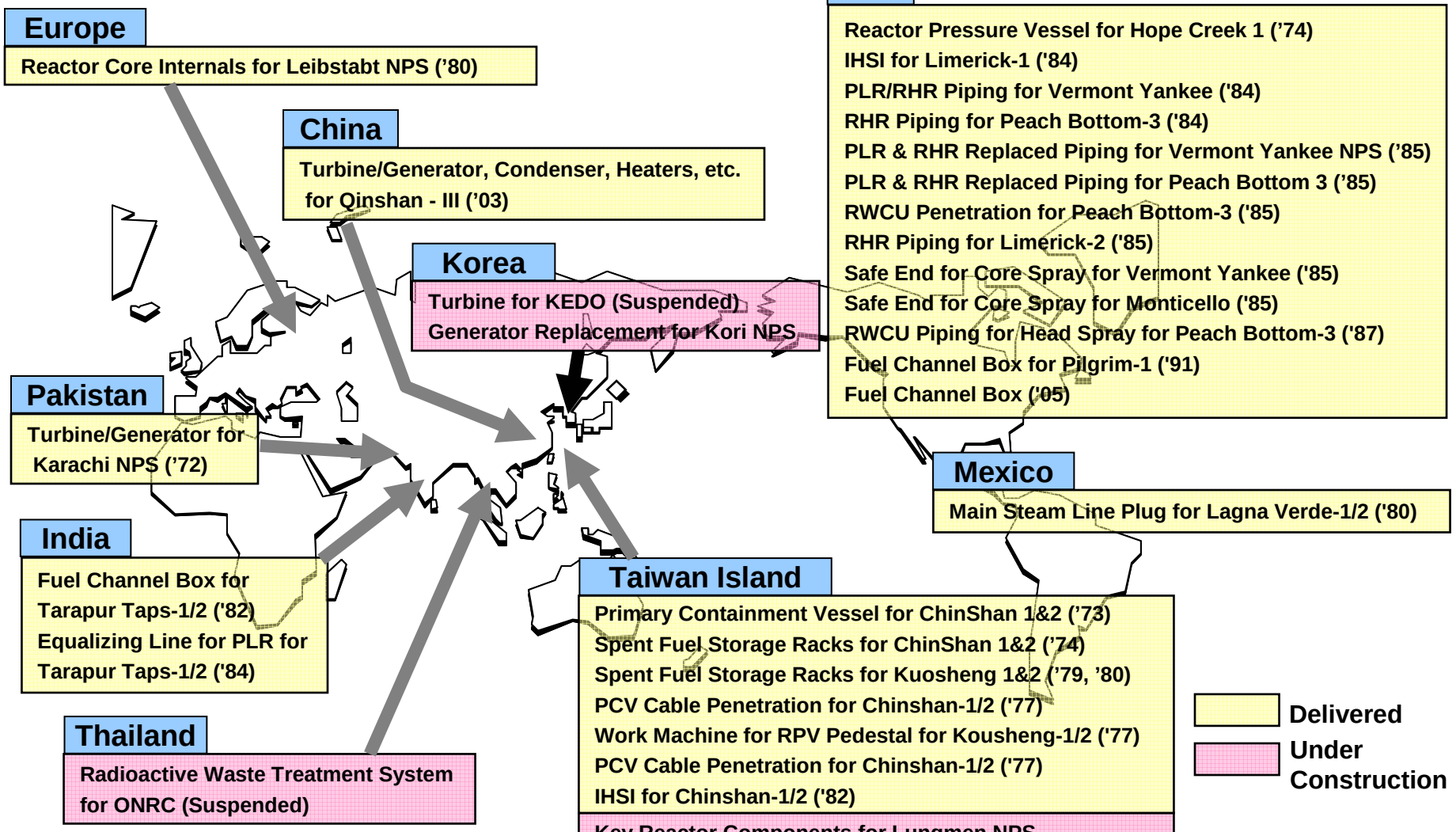

Globalization of Hitachi ABWR

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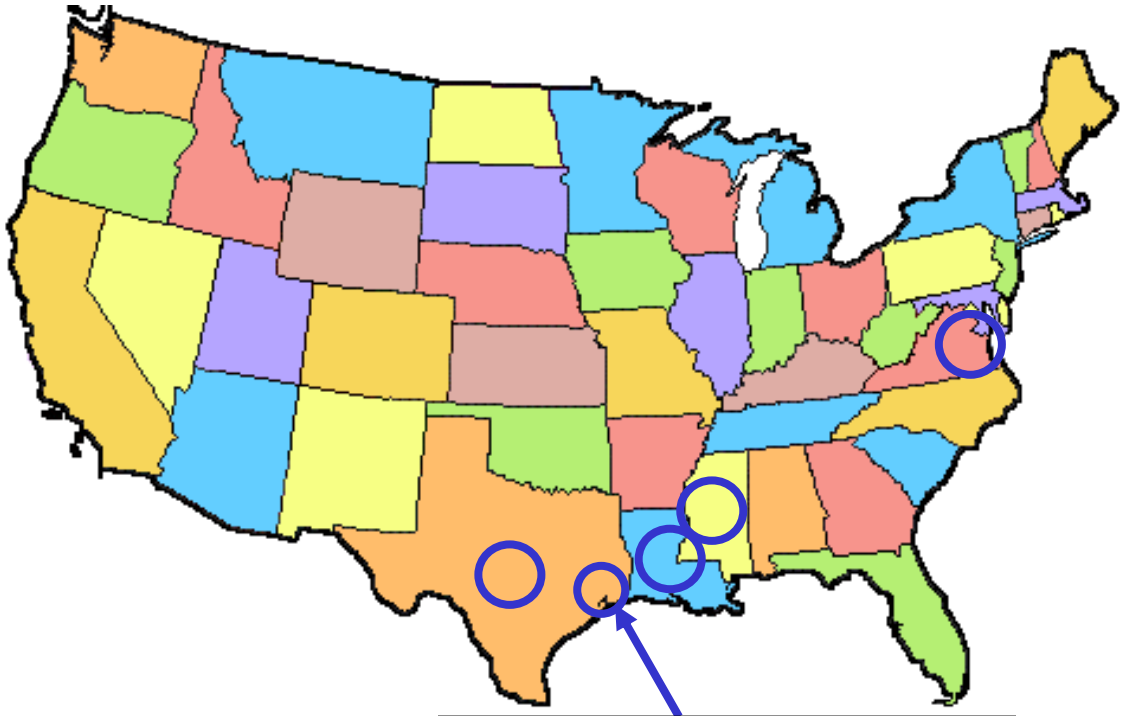
***Hitachi constructs two units of ABWR on STP site together with GE.**

***There are several potential sites for BWR construction marked by ○**



South Texas Project Site

Two Units of ABWR
under Planning (C/O : 2015)

Major Facilities and Product Lines

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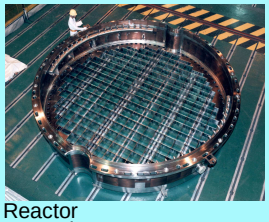
Nuclear Systems Div.
Tokyo Headquater Office

Hitachi Works

Power & Industrial Systems
R&D Laboratory

Hitachi Research
Laboratory

Mechanical Engineering
Research Laboratory



Reactor
Internals

Turbine

Generator

Power & Industrial Systems Div.

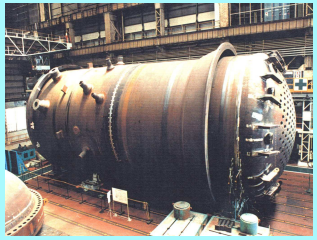
Information & Control Systems Div.

BHK Kure Division

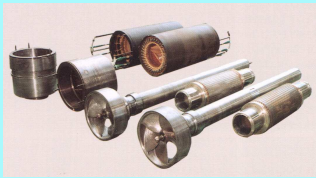
Hitachi Industries Co., Ltd.

Transformer

Main Control System



Reactor Pressure Vessel



Reactor Internal Pump

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GENERAL FEATURES OF BWR

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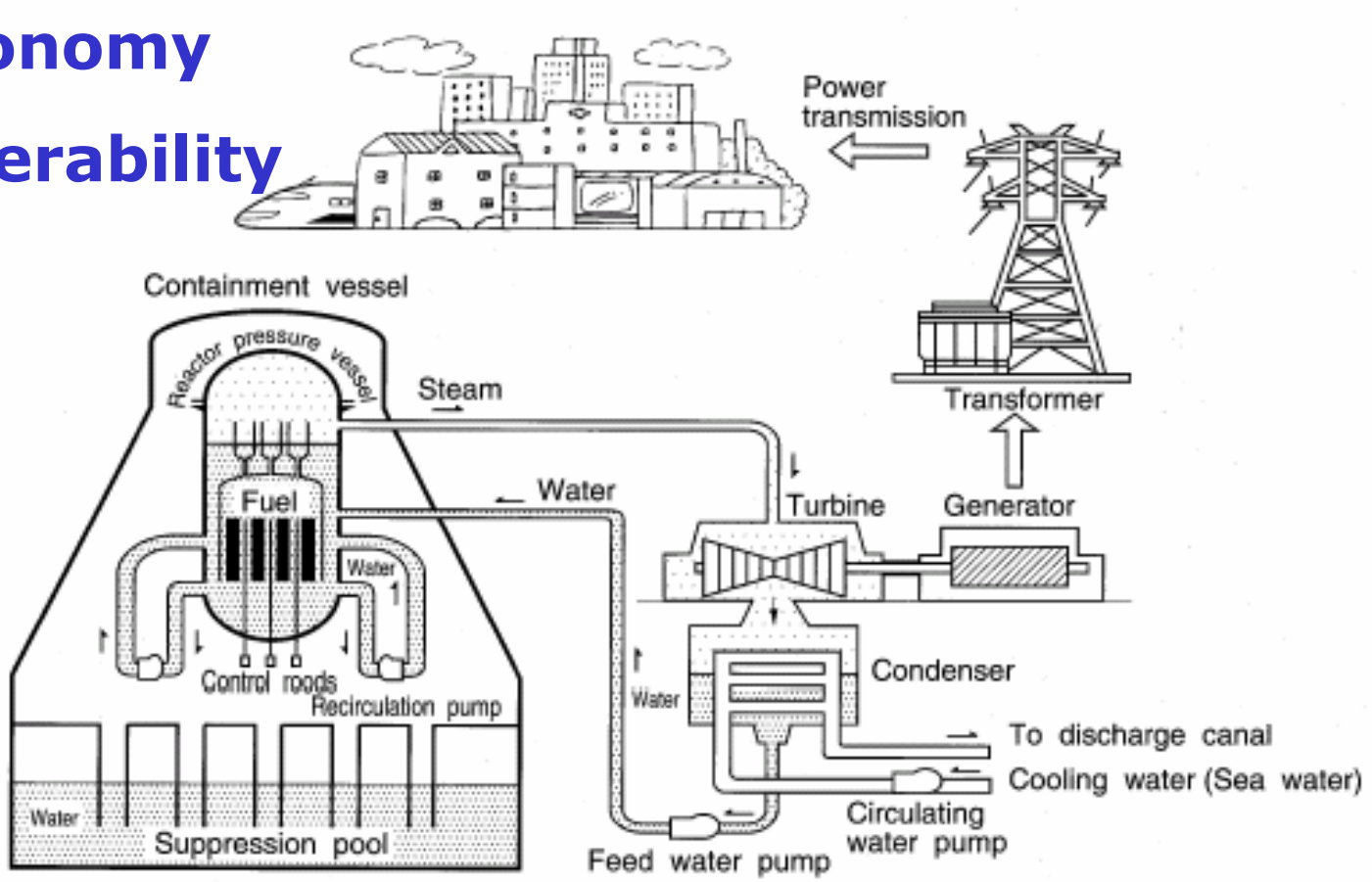
- **High Safety**
- **High Economy**
- **High Operability**



High Safety Features of BWR

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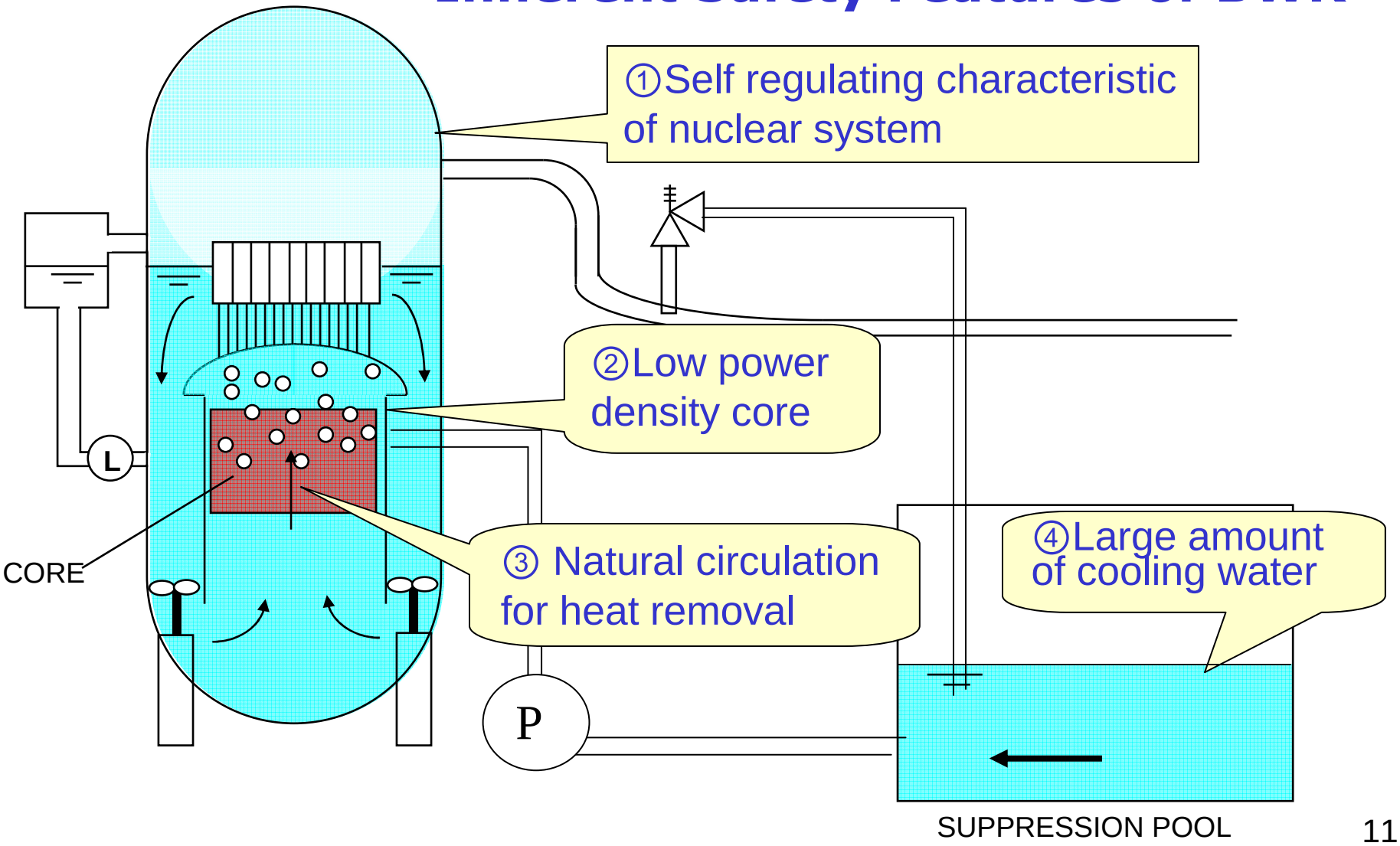
Inherent Safety Features of BWR



High Safety Features of BWR

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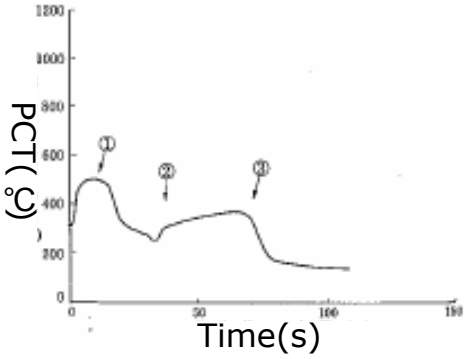
- Large safety margin of RPV integrity due to low core power density

	Power Density	Estimated RPV Neutron Irradiation
BWR	**~ 50 (kW/l)**	**~8.5 × 10^{17} (@40 years)**
PWR	**~100 (kW/l)**	**~3 × 10^{19} (@30years)**

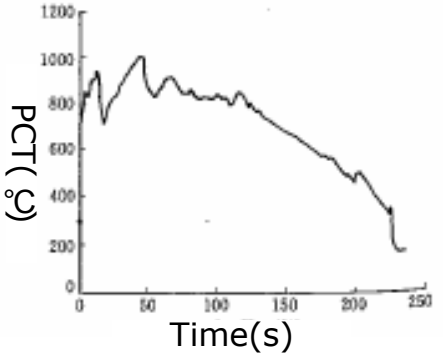
- Large safety margin of PCT(Peak Clad Temp.) in LOCA due to low core power density

	PCT(℃)
BWR	**~500**
PWR	**~1000**

Note:1000MWe-class



BWR



PWR

High Safety Features of BWR

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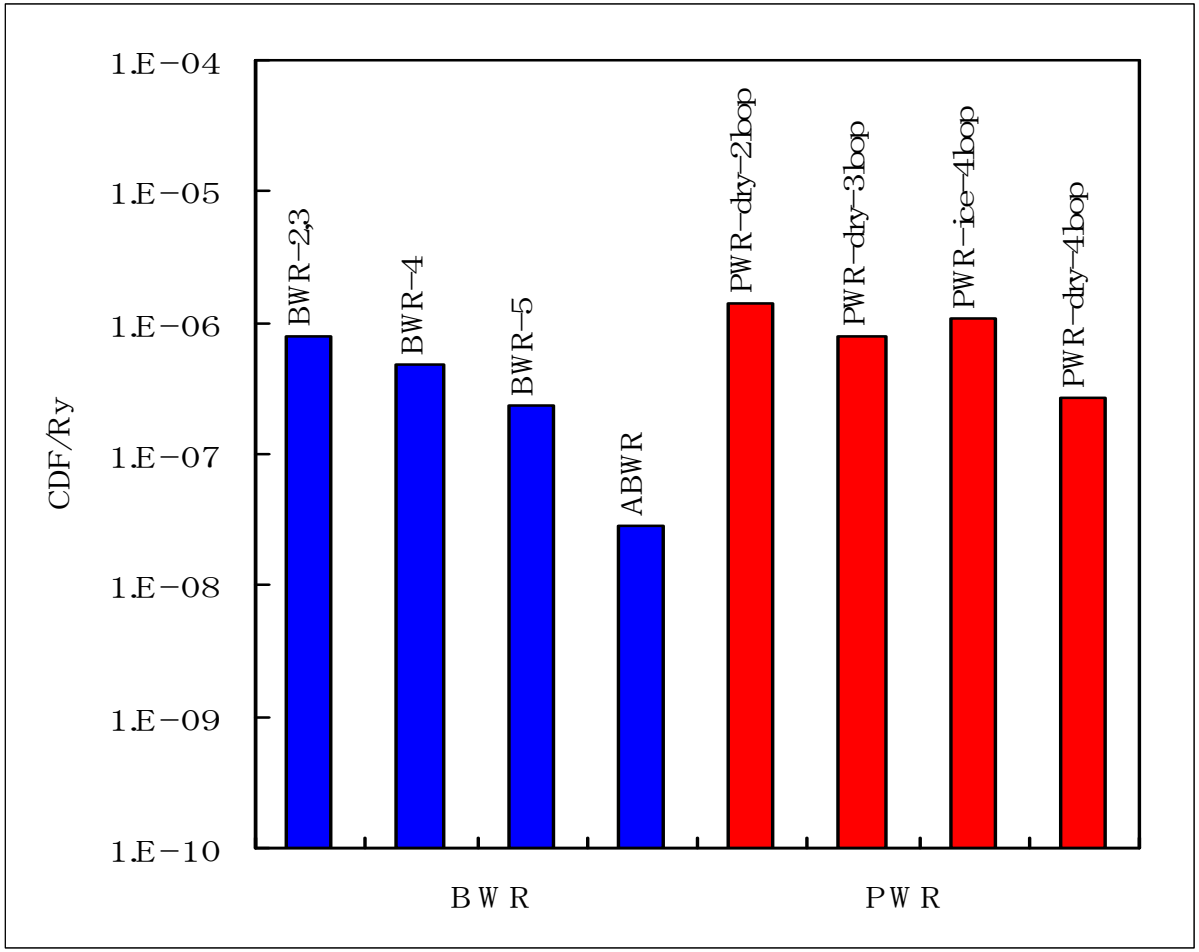
- Extremely Low Core Damage Frequency
- No Actual Experience of Accident such asTMI-2(PWR), Chelnobyl(RBMK)



High Economic Features of BWR

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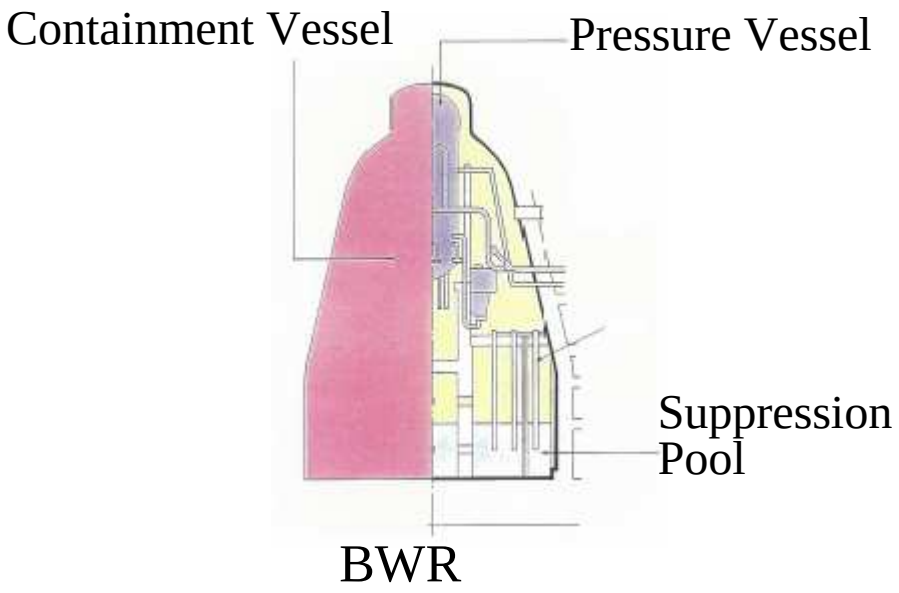
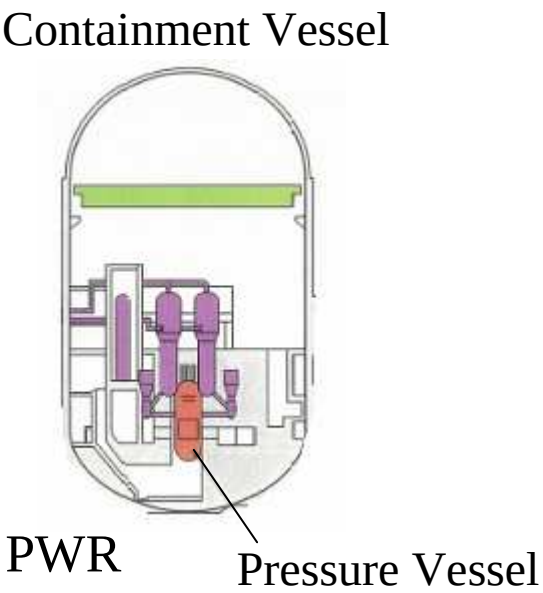
Small Containment Vessel

	BWR (100MWe)	PWR (1000MWe)	ABWR (1300MWe reference)
Volume	**8700 m³**	**73,700 m³**	7400m³
Height	48 m	65 m	36m
Diameter	29 m	43 m	29m





High Economic Features of BWR

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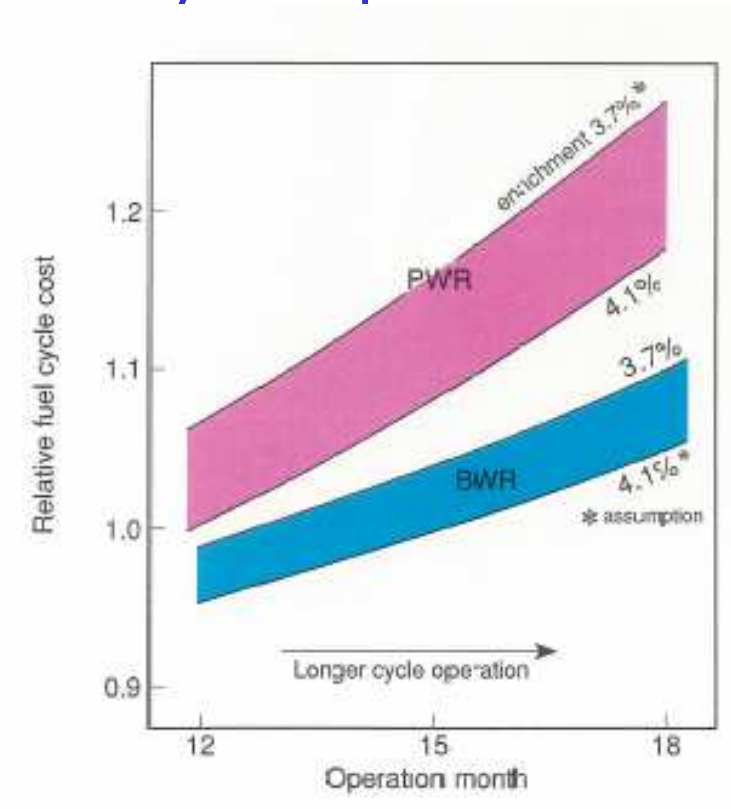
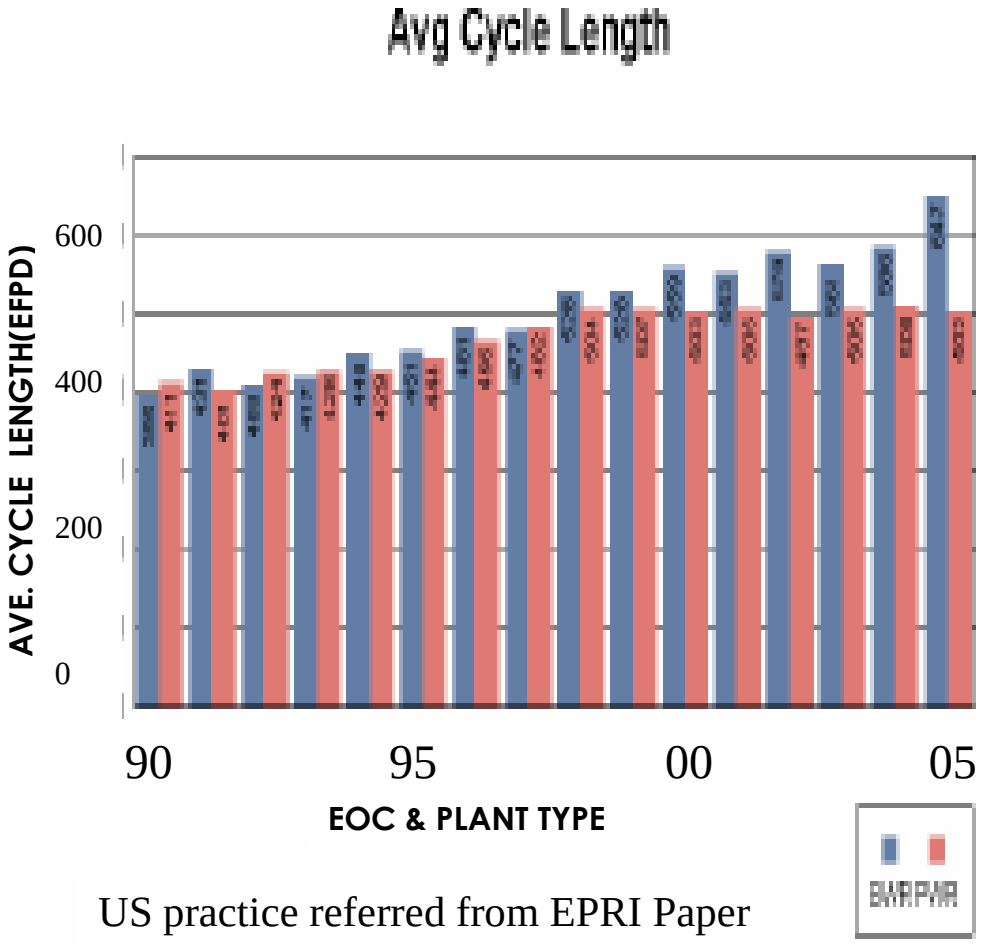
- BWR achieves less fuel cycle cost than PWR
- BWR is more advantageous for the coming longer cycle operation





US practice referred from EPRI Paper

High Operability -Power Control-

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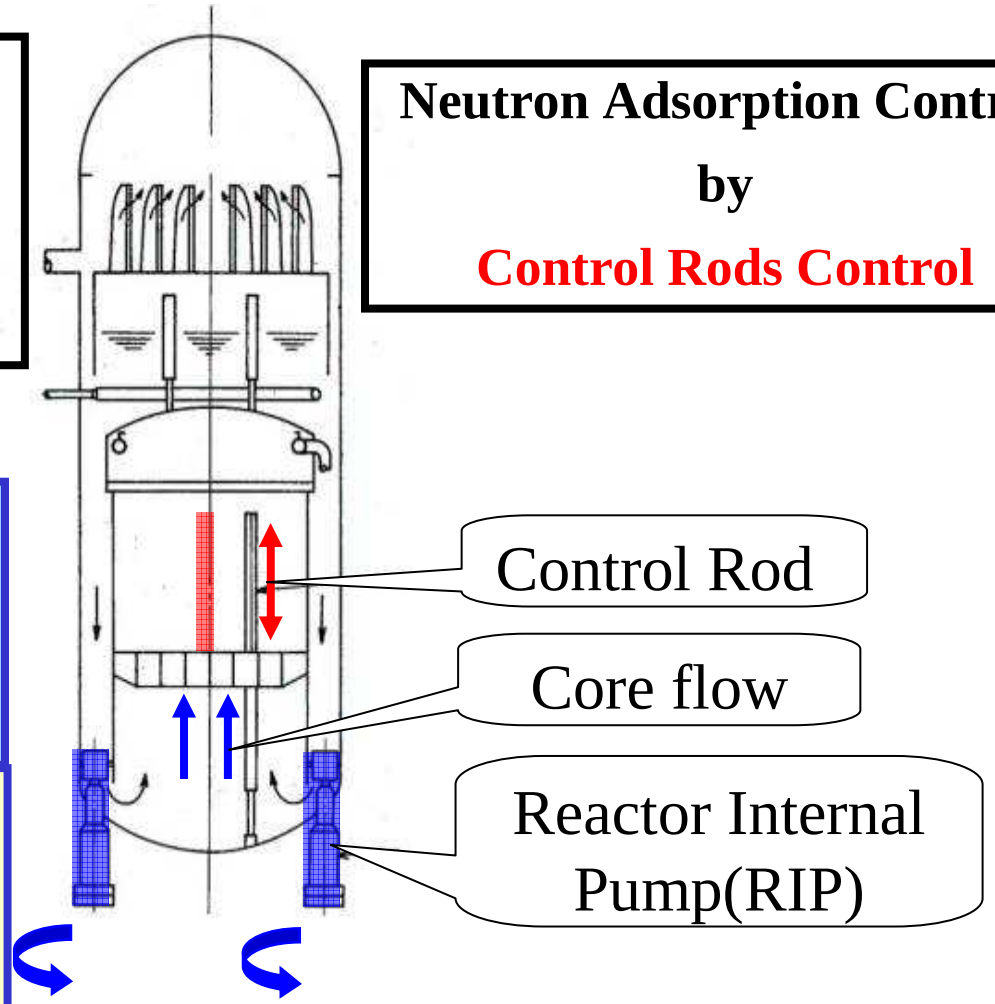
Delayed Neutron Control
(Void Volume Control)
by
Core Flow Control by RIP

Neutron Adsorption Control
by
Control Rods Control

Fundamental concept:

Core flow increase by RIP
Void volume
Moderator effect & Power

Core flow decrease by RIP
Void volume
Moderator effect & Power



High Operabilitu -Power Flow Map-

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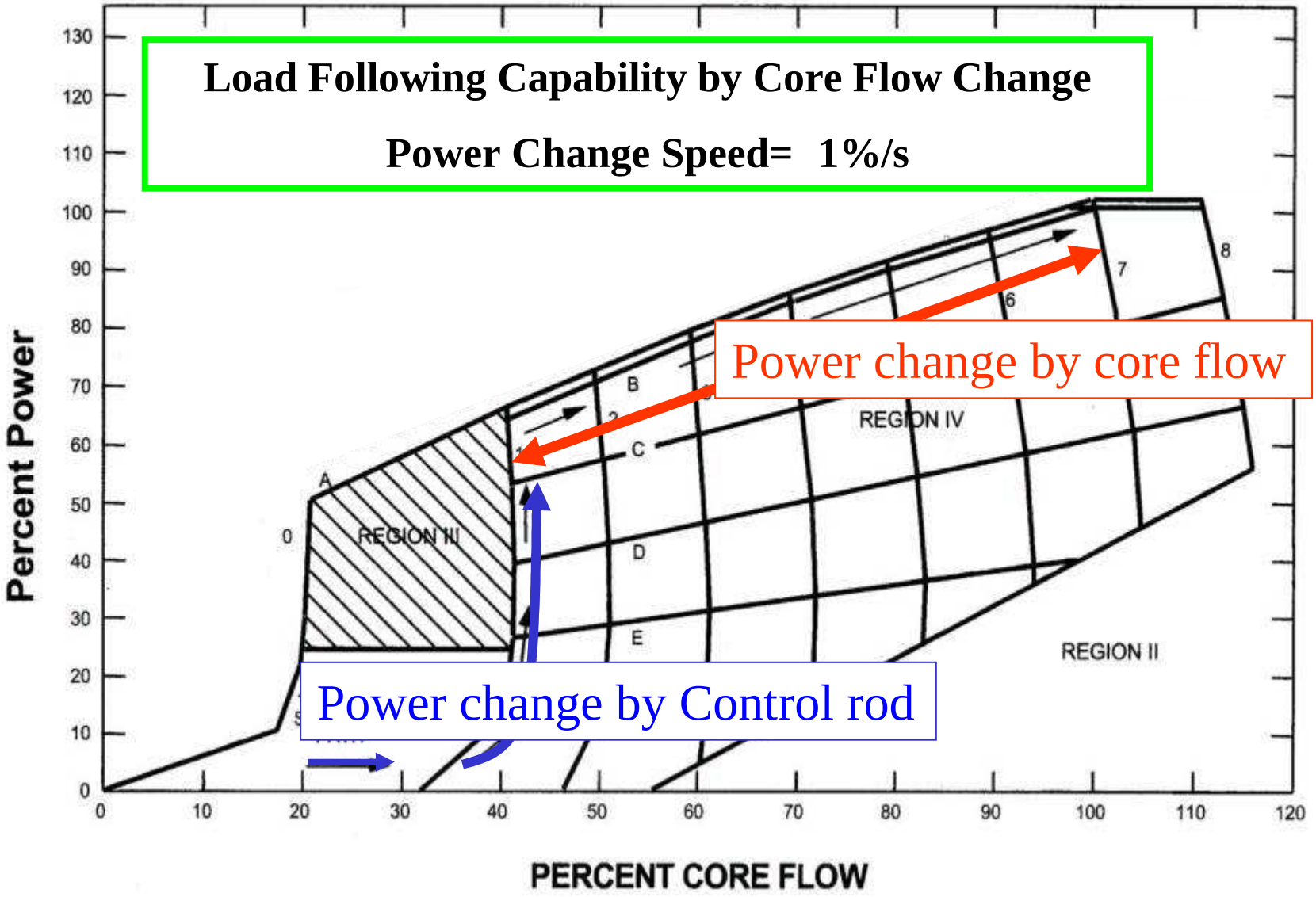

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Background and Purpose of ABWR development

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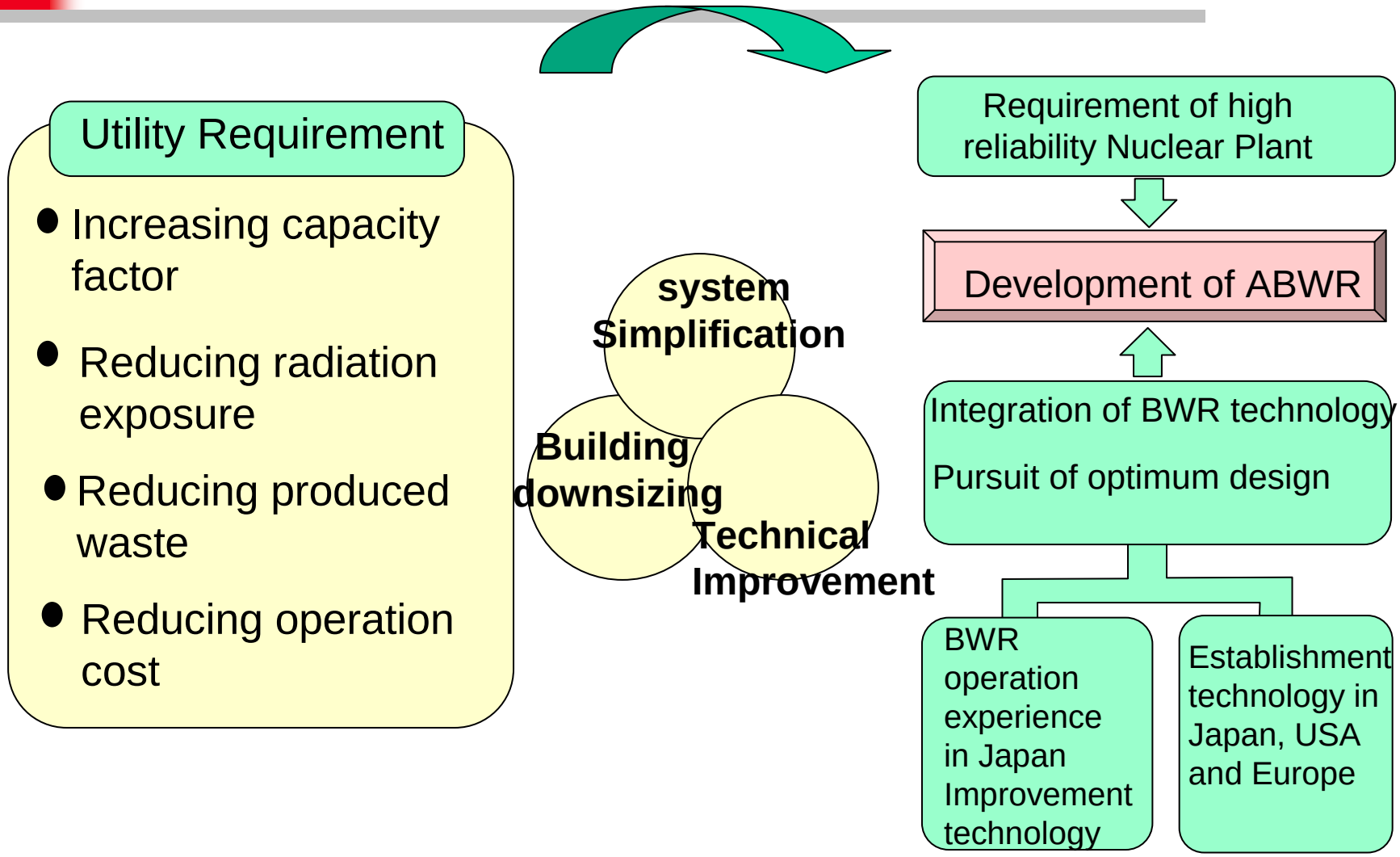

Development of BWRs

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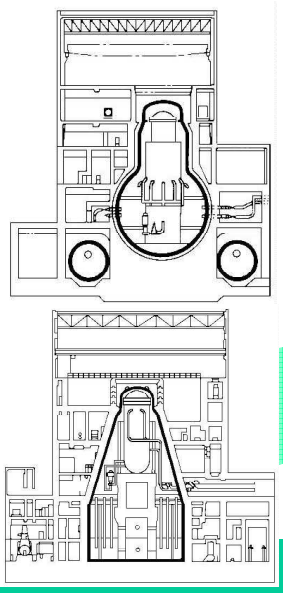
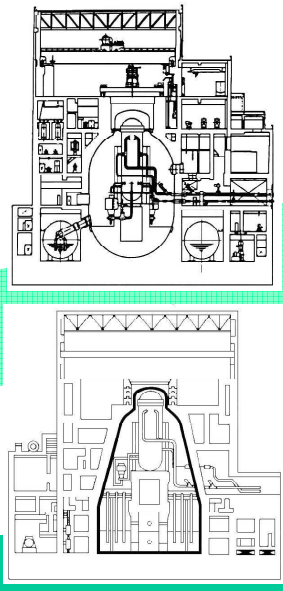
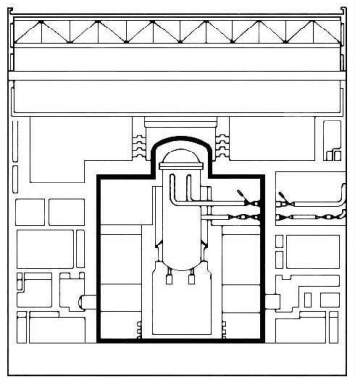
1970 1980 1990 2000 2010

Domestic Production | **Improvement & Standardization** | **ABWR**







SHIMANE-1

FUKUSHIMA1-4

TOKAI-2

SHIMANE-2

SHIKA-1

FUKUSHIMA2-2

FUKUSHIMA2-4

KASHIWAZAKI-KARIWA-5

KASHIWAZAKI-KARIWA-4

KASHIWAZAKI-KARIWA-7

SHIKA-2

SHIMANE-3

OHMA-1

HIGASHIDORI-1

Key Specification of ABWR

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Item		ABWR	BWR-5
Plant Output		Approx. 1,356MW(34.5%)	Approx. 1,100MW(33.4%)
Reactor Thermal Output		3,926MW	3,293MW
Reactor Pressure		Approx. 7.17MPa	Approx. 7.03MPa
Fuel Assemblies		872	764
Control Rods		205 rods	185 rods
Reactor Pressure Vessel	Inner Diameter	Approx. 7.1m	Approx. 6.4m
	Height	Approx. 21m	Approx. 22m
Recirculation System		Internal pump method (10)	External recirculation pumps (2) Jet pumps (20)
Control Rod drive	Normal	Motor drive	Hydraulic drive
	Scram	Hydraulic drive	Hydraulic drive
Emergency Core Cooling System		LPFL (3)	LPCI (3)
		HPCF (2)	HPCS
		RCIC	LPCS
		ADS	ADS
Residual Heat Removal System		3 Systems	2 Systems
Reactor Containment Vessel		Reinforced concrete with built-in liner	Free-standing vessel
Turbine	Type	TC6F－52	TC6F－43
	Thermal Cycle	Two-stage reheat	Non-reheat

ABWR Features

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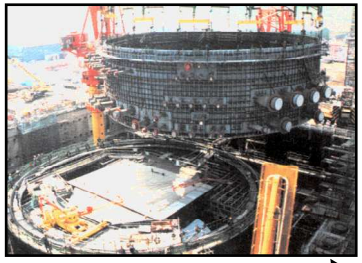
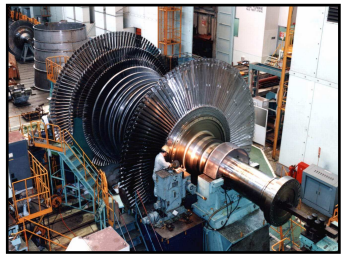
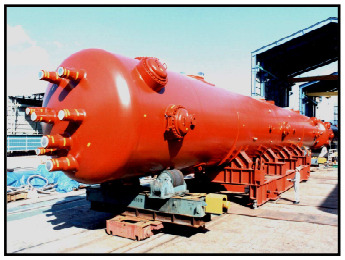


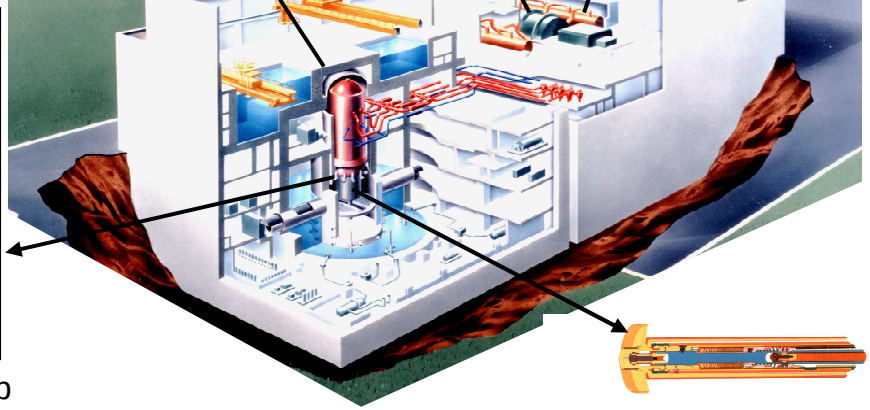
Reinforced concrete containment vessel (RCCV)

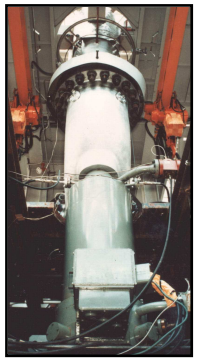


52 inches Turbine blade



Moisture separator Re-heater





Internal Pump

Advanced control rod drive mechanism
(FMCRD)

Enhanced Safety

- Internal Pump
- Advanced control rod drive mechanism
- Reinforced concrete containment vessel

Easy - to - operate

- Internal Pump
- Advanced control rod drive mechanism
- Advanced Man-machine

Economic Improvement

- Internal pump
- Reinforced concrete containment vessel
- 52 inches turbine blade
- Moisture separator Re-Heater
- Advanced control rod drive mechanism

Schematic Diagram of ABWR

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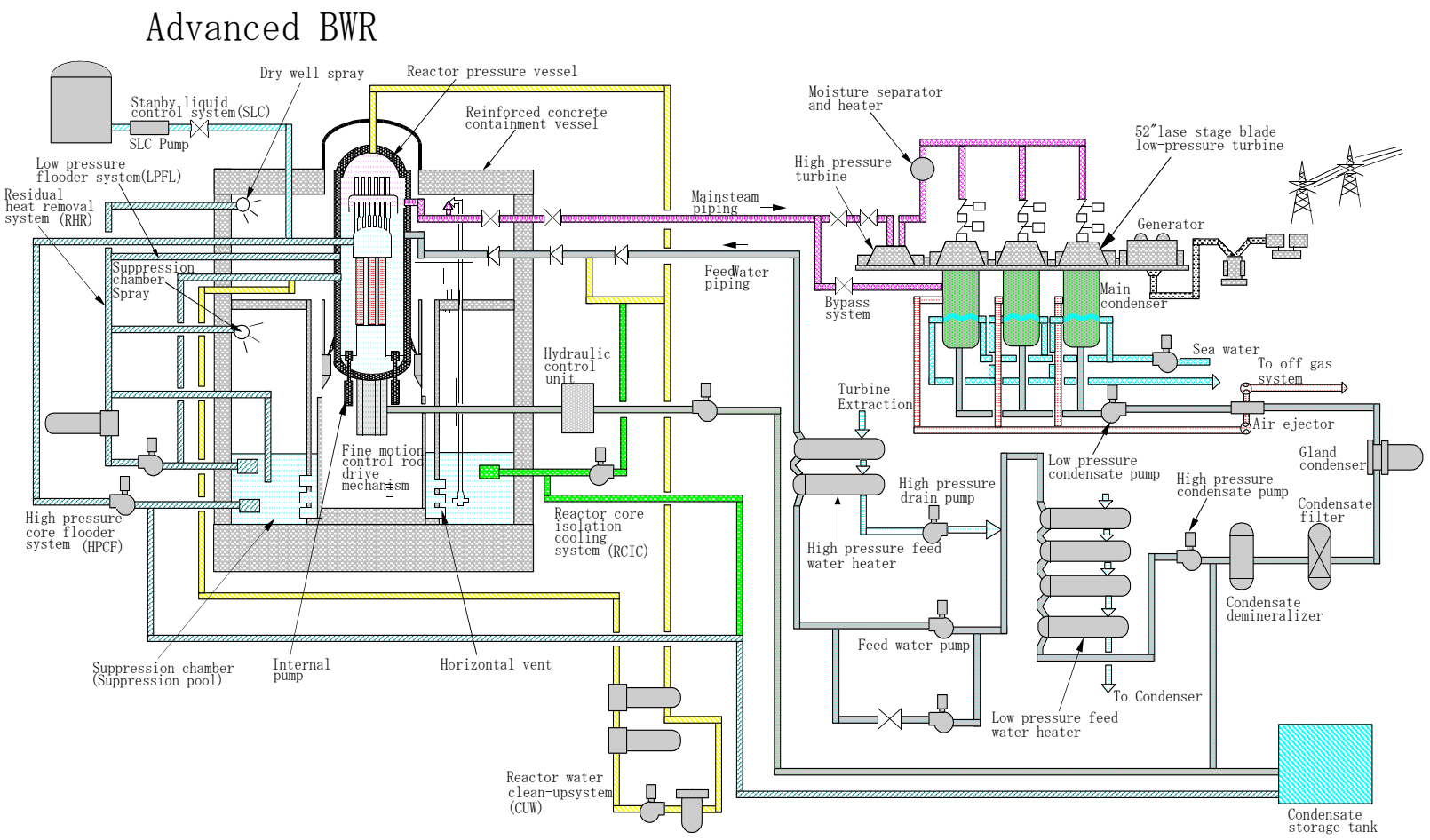

History of Reactor Pressure Vessel in BWR pla

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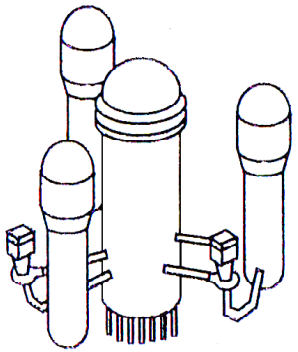
Improvement Safety
(Reduce accidental breaking area)

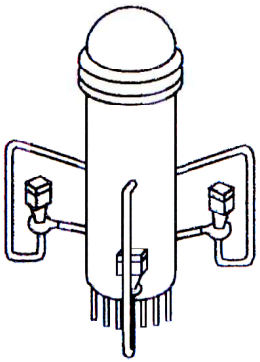
Improvement Economy
(Large Capacity)

BWR-1 (GE)



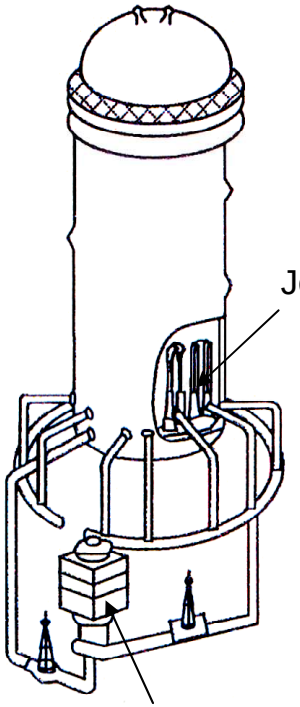
Dual cycle
(with separator)

BWR-2 (GE)

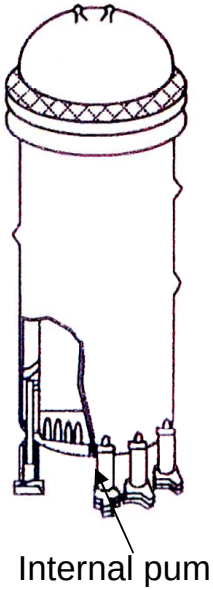


External Recirculation pump
With built-in separator

Improvement &
Standardization BWR
(1100MWe)



ABWR
(1350MWe)



	BWR-5	ABWR
LOCA break area	0.29m^3	0.013m^3
PCV volume	7900 m^3/kWe	5500 m^3/kWe

Reduced Radiation Exposure

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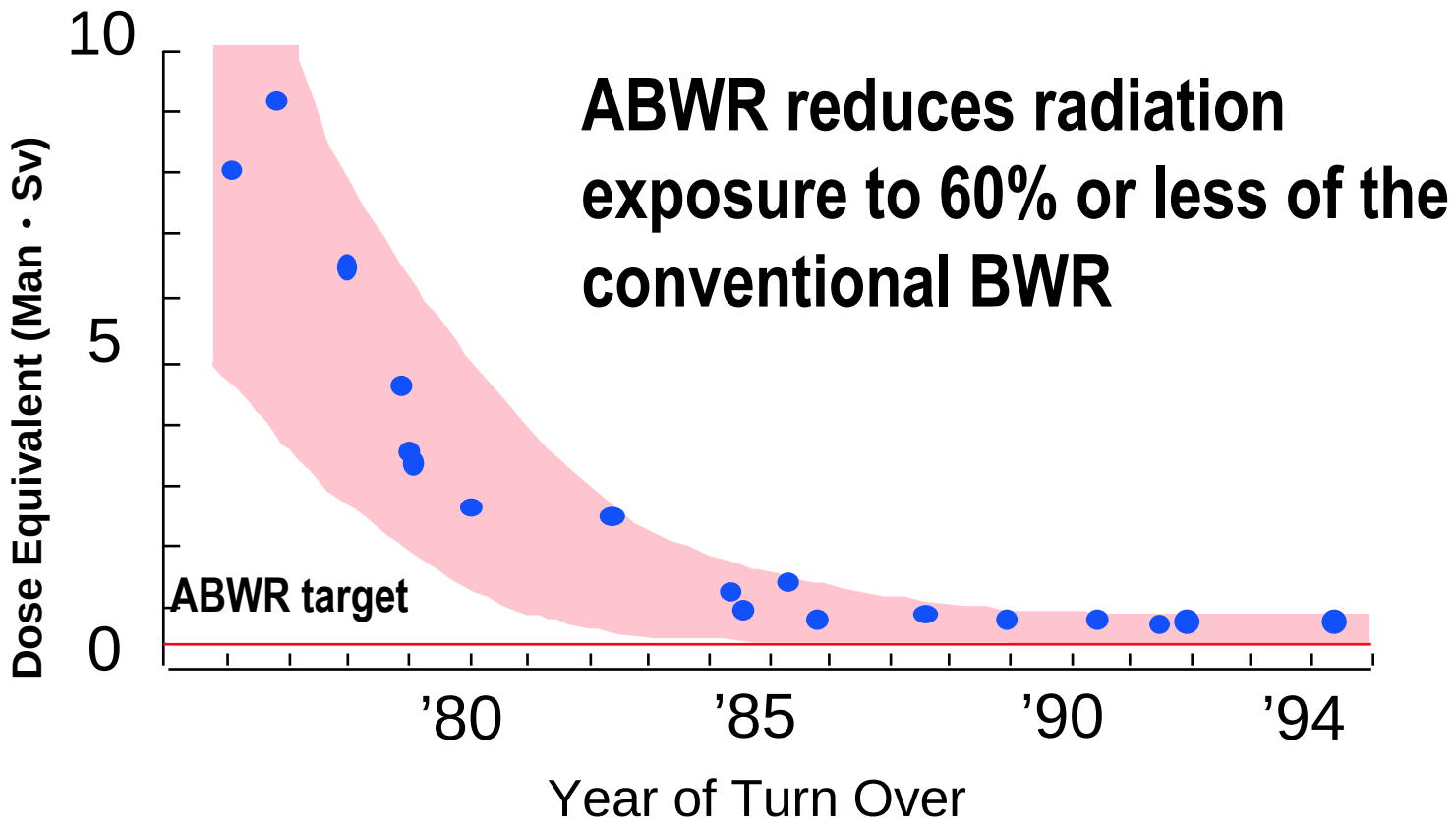
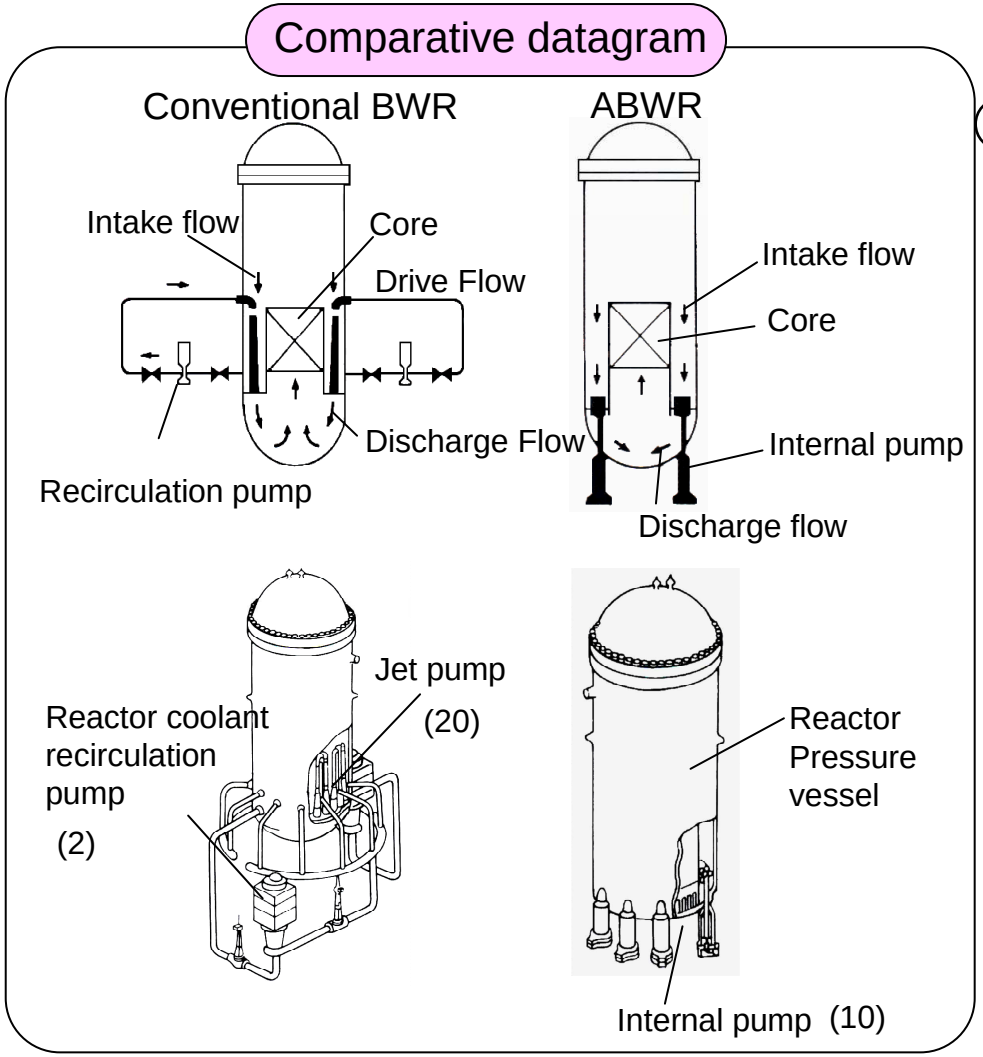


ABWR reduces radiation exposure to 60% or less of the conventional BWR

Internal Pump



◎ **Elimination of external recirculation pump & large size piping and Adoption of internal pump**

- Elimination of large LOCA
- Downsizing of primary containment vessel
- Reduction of radiation dose rate
- Operation cost reduction of pump

Reactor Pressure Vessel and Internals

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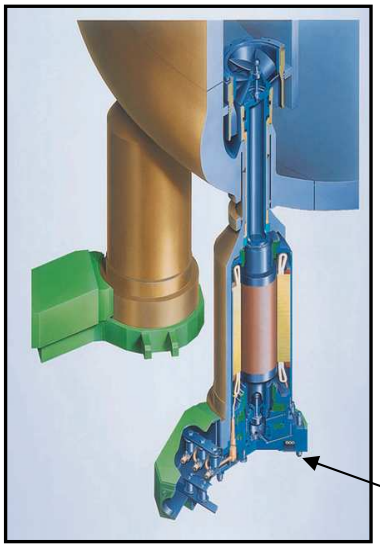
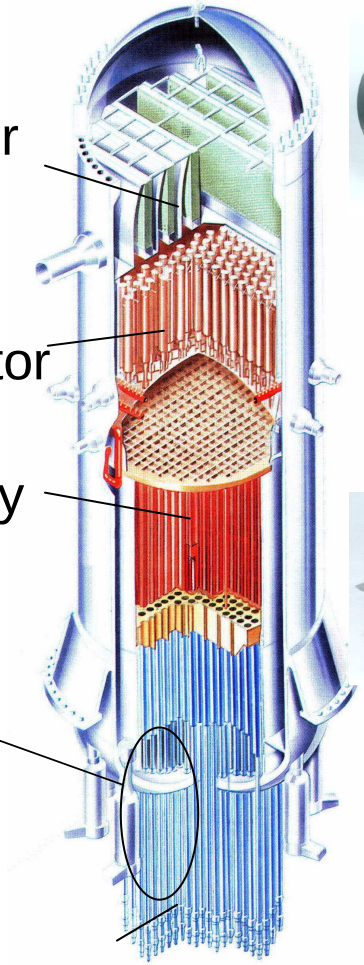


Internal Pump

Steam Dryer

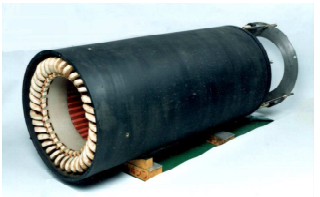
Steam Separator

Fuel assembly



Advanced Control Drive Mechanism

Diffuser/Impeller



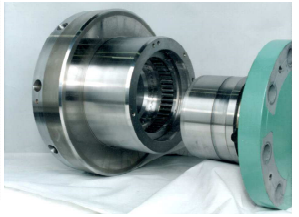
Motor stator

Shaft

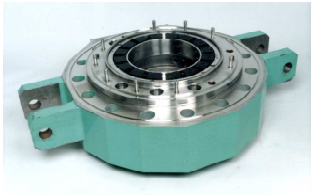
Rotor

Stretch tube

Journal Bearing

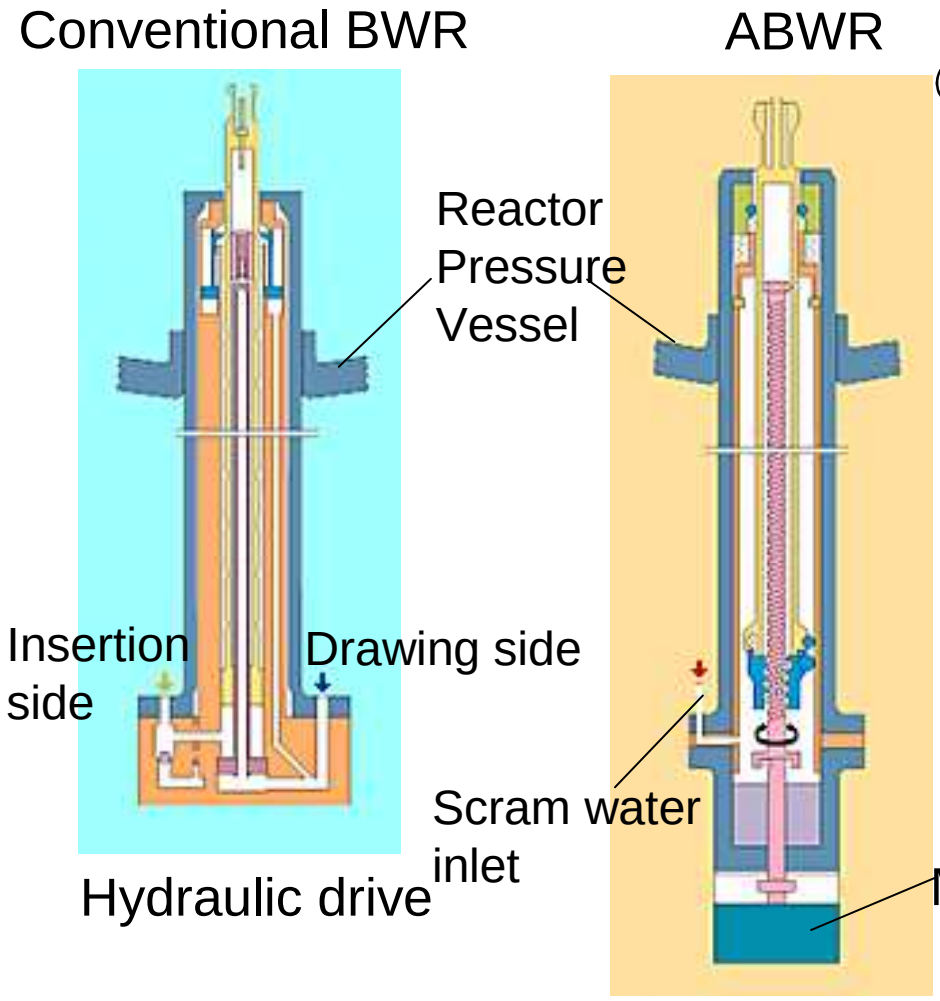


Thrust disc



Motor cover

Advanced Control Rod Drive mechanism



◎Two different drive mechanisms
- Motor drive
  - ● Fine motion
  - ● Backup scram
- Hydraulic drive
  - ● Scram

◎Fine Motion Control rod drive
- Improvement of fuel integrity

Manufacturing - Control Rod Drive Mechanism -

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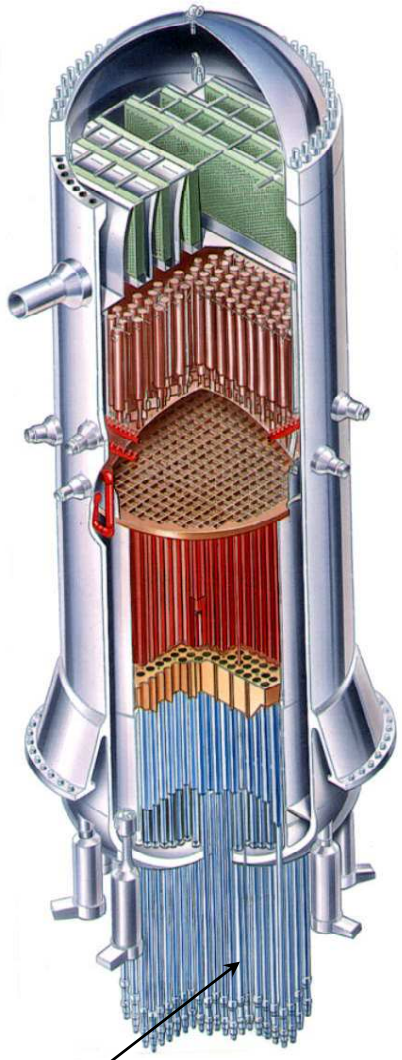
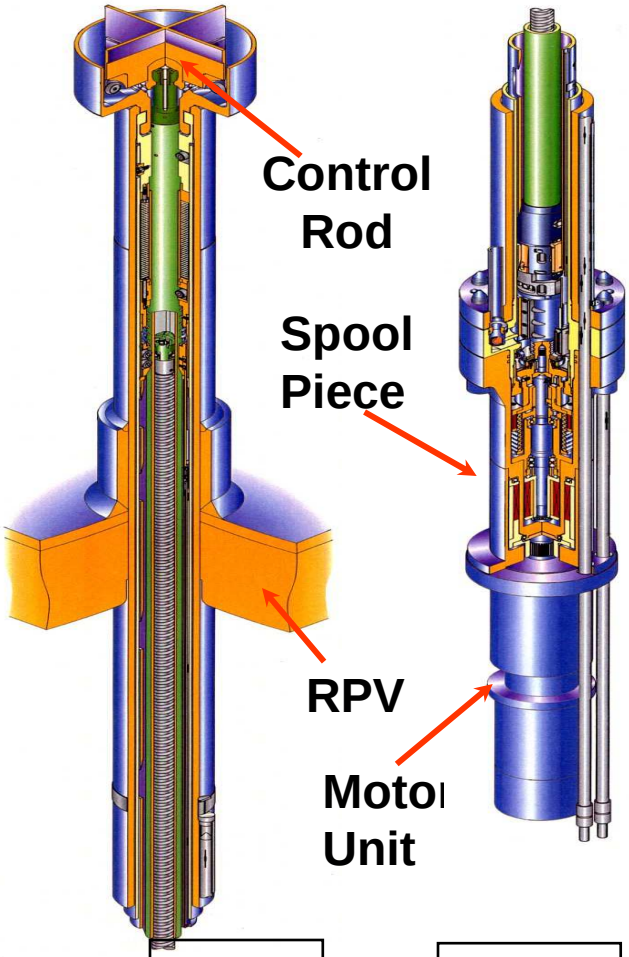


Control Rod Drive Mechanism



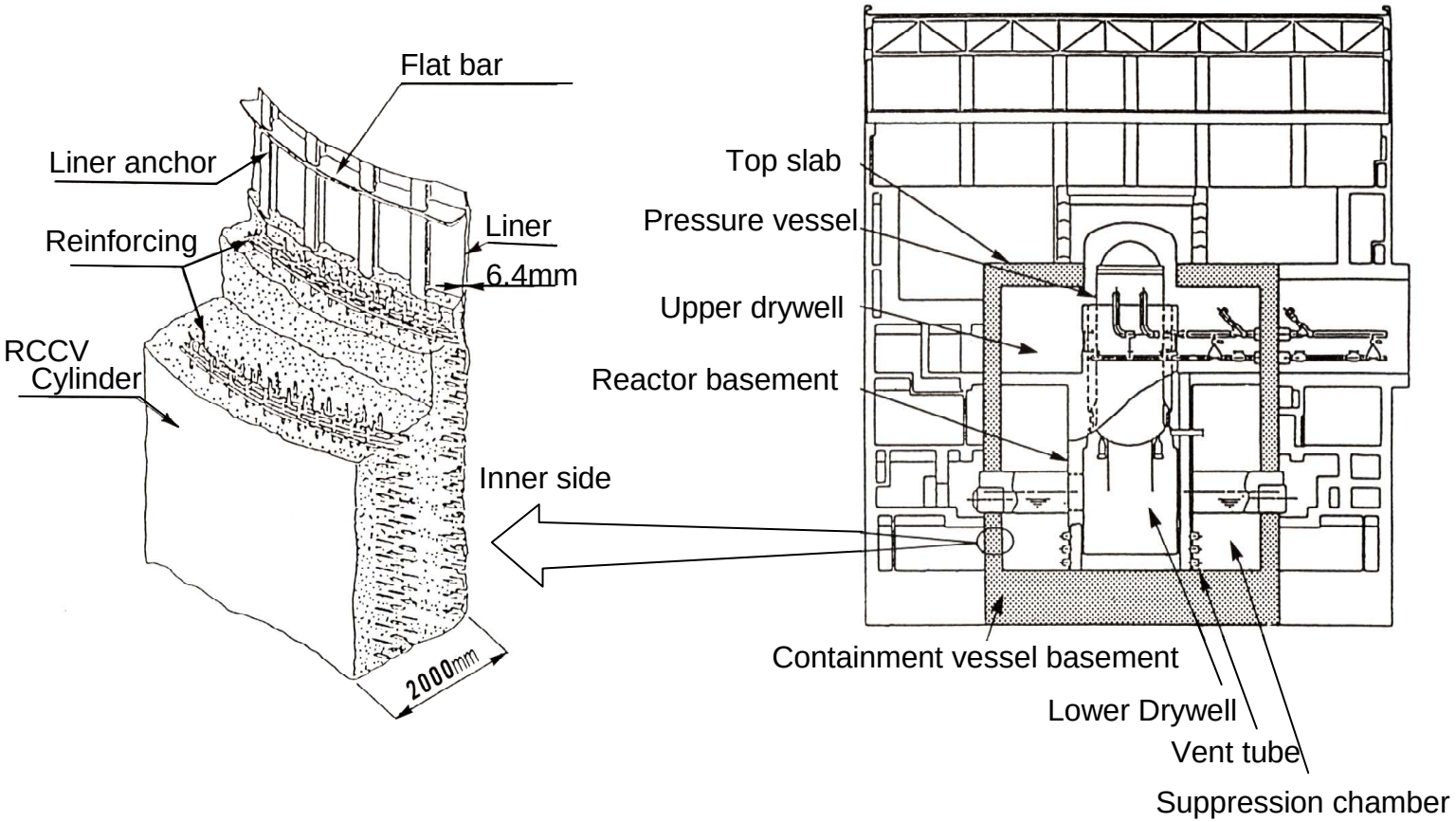
Upper Part

Lower Part

Inner Coupling

Outer Coupling

Reinforced Concrete Containment Vessel (RCCV)



Compactness of Building Volume

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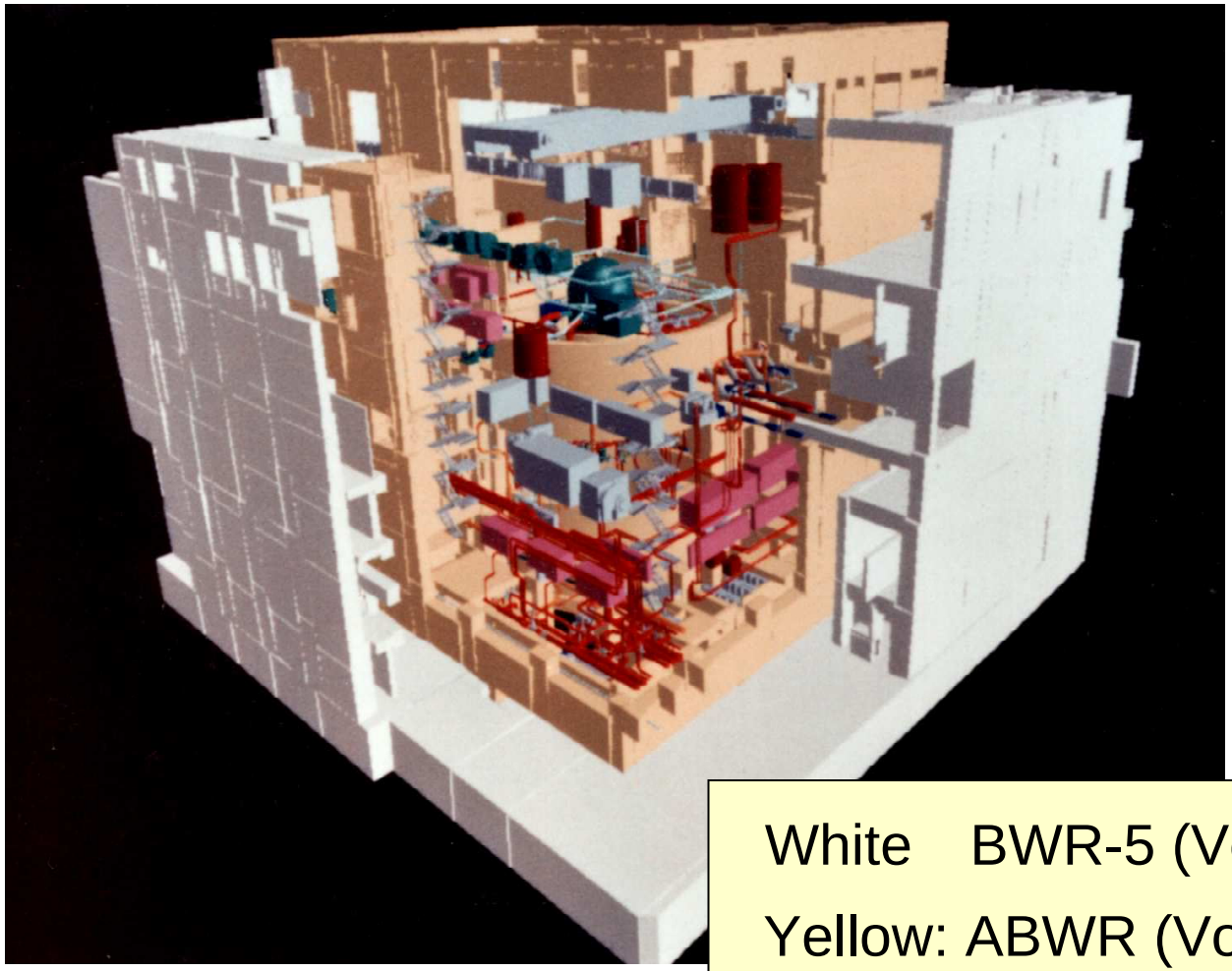

White BWR-5 (Volume 100%)

Yellow: ABWR (Volume 76%)

52 inches Turbine Blade

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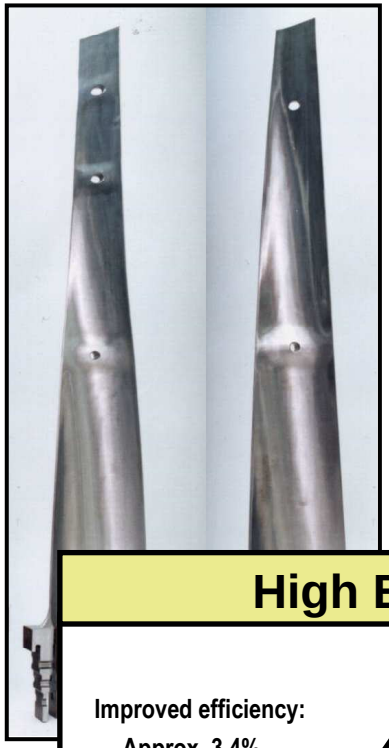
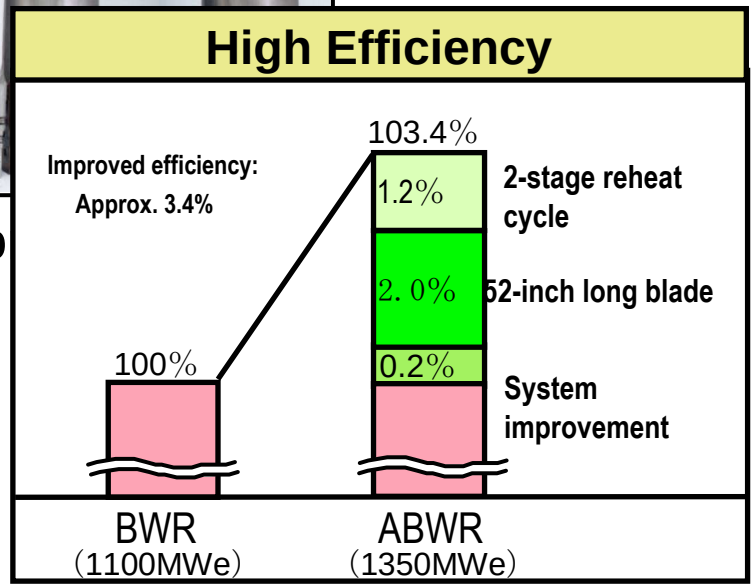
For 60Hz



For 50Hz

Fo



Moisture Separator Re-heater

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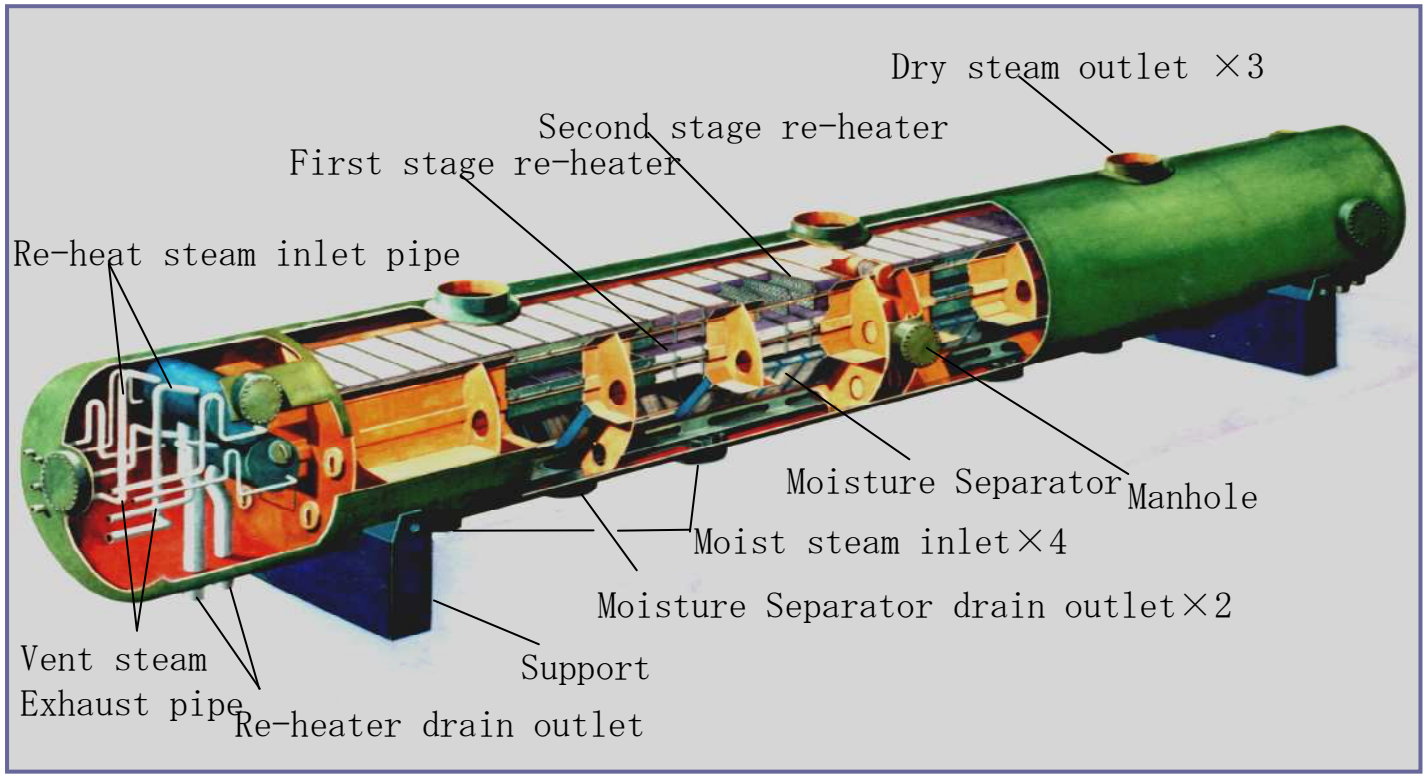

Control and Instrumentation (NUCAMM-90)

HITACHI
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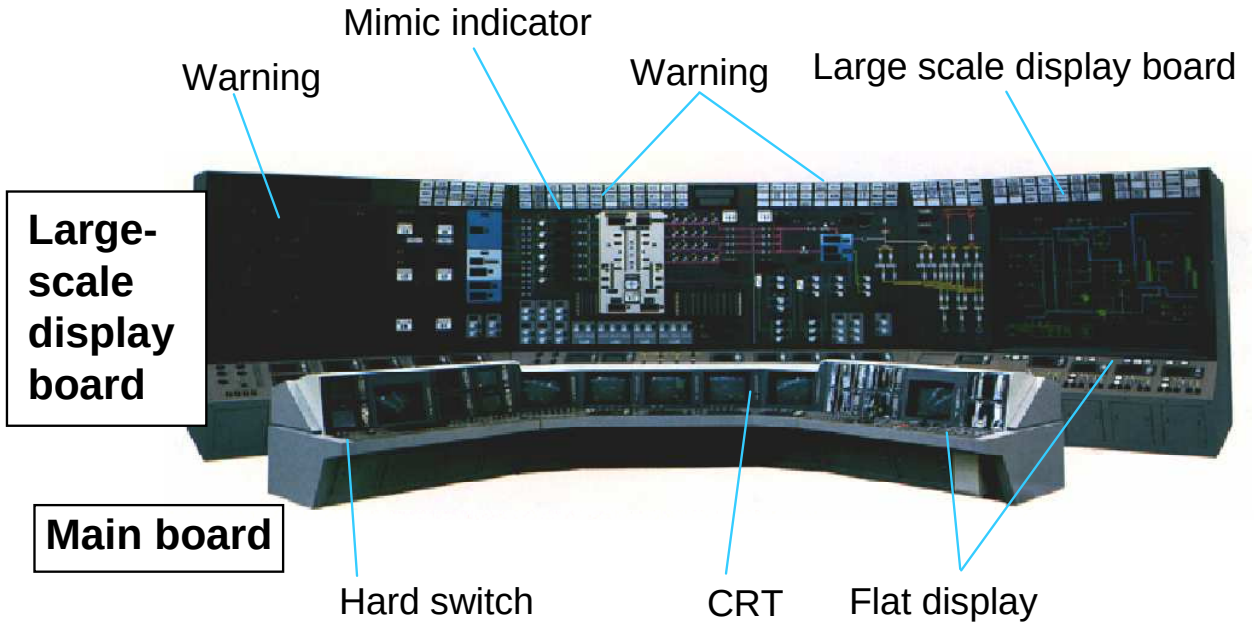


◎ Purposes of Advanced Control Complex

-Improve Operation Reliability
-Reduce Operation Burden
-Information Share among the Operation Crew
-Expansion of digital application

◎Main board/Large scale display board
Length :19m

◎Color CRT and flat display with Touch operation
- Monitoring and Operation consolidation

◎Application of New Technology

-Expanded automation
-Digital System
-Optical Transmission & Multiplexing
-Software Safety System Logic

NUCAMM：Nuclear Power Plant Control Complex with Advanced Human－Machine Interfaces

Manufacturing - Reactor Pressure Vessel -

HITACHI
Inspire the Next

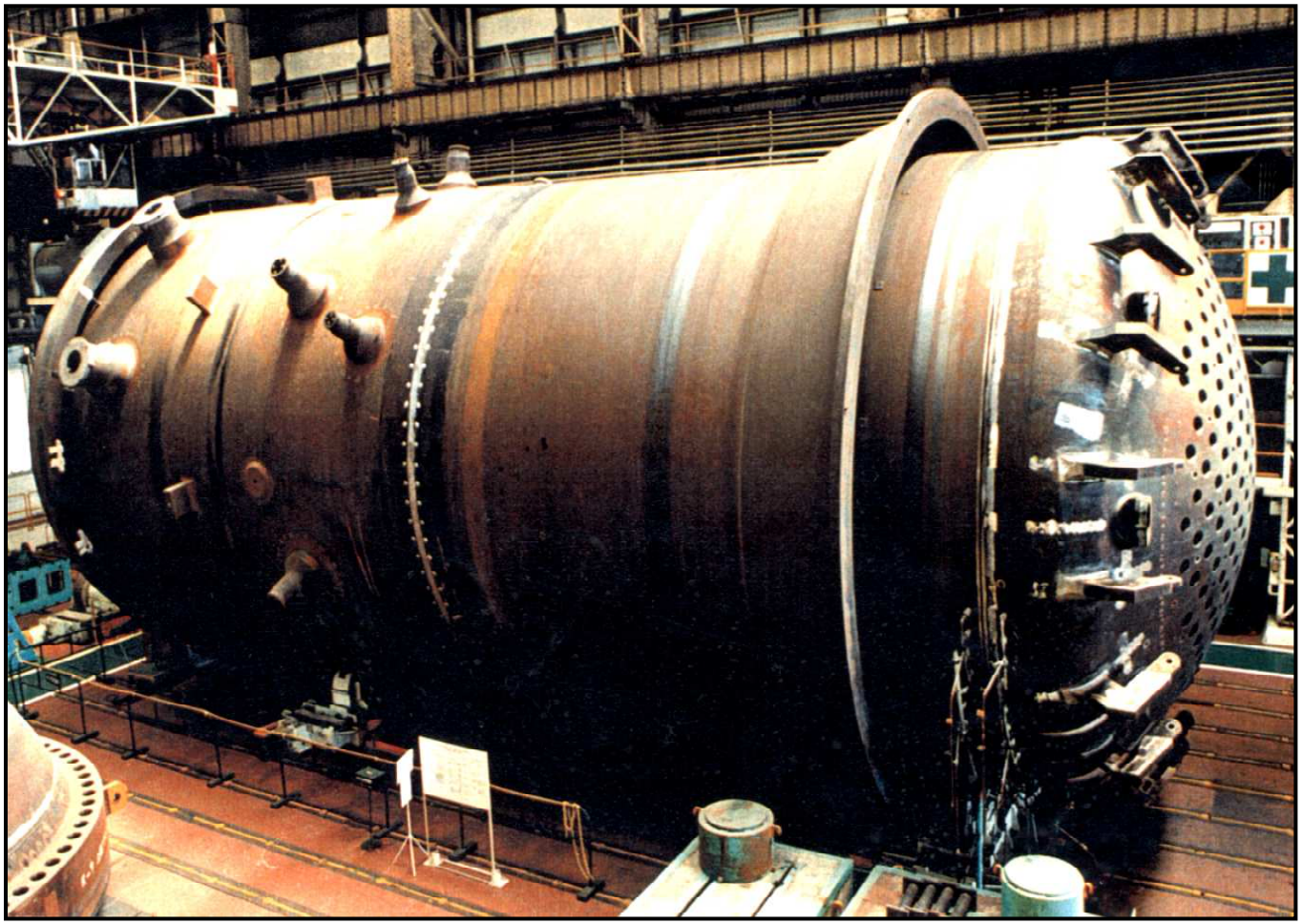
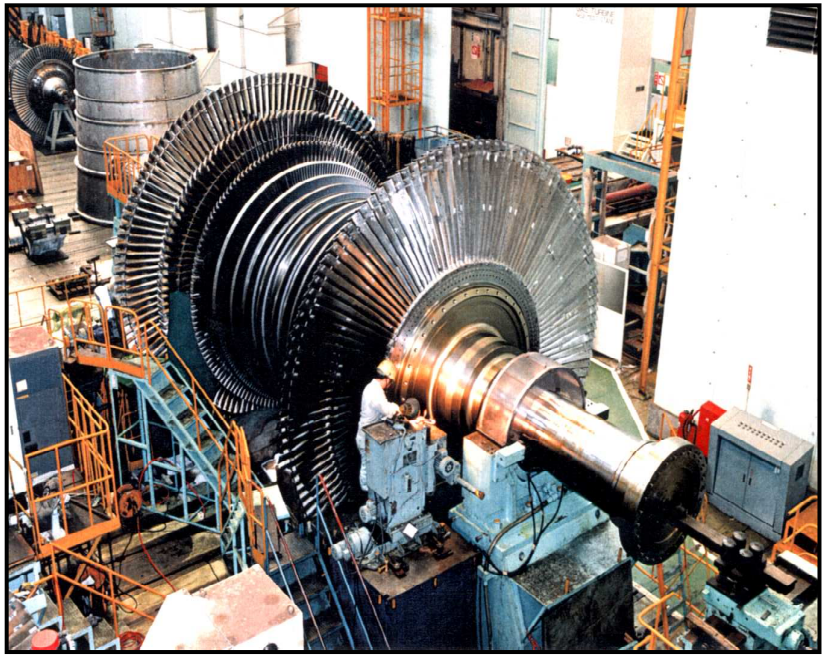


Photo : 1994.9
Shipping : 1995.5

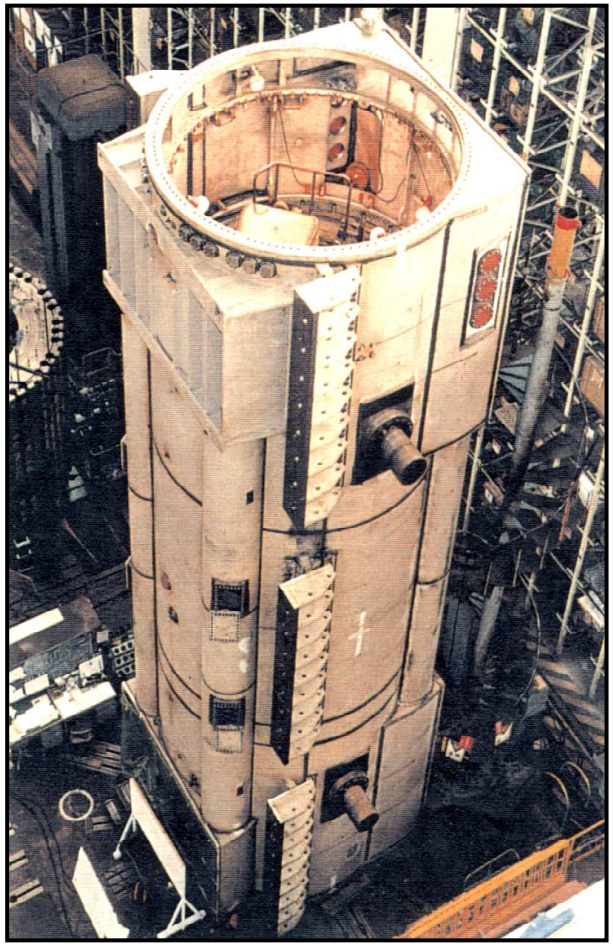
Manufacturing - Rotor and Generator -

HITACHI
Inspire the Next



LP Rotor

Photo : 1994.8
Shipping: 1994.12

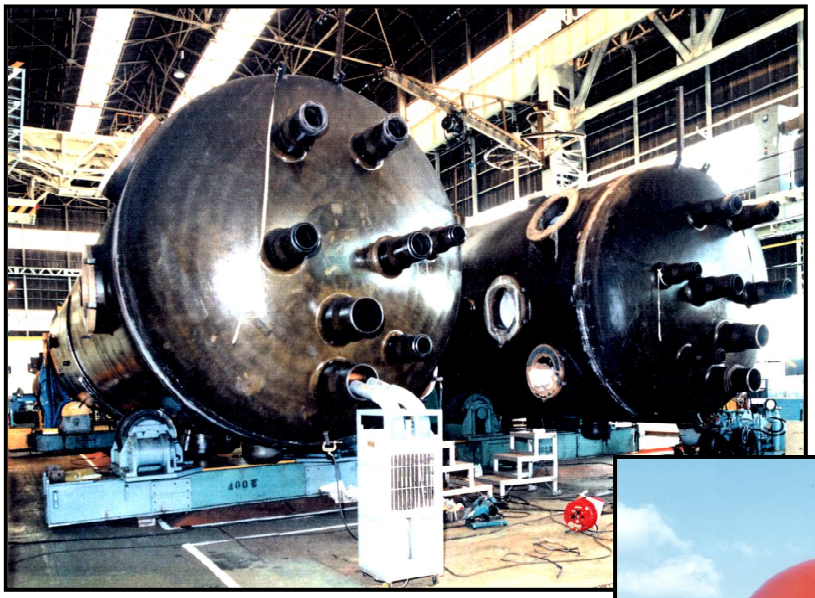


Generator

Photo : 1993.1
Shipping: 1993.1

Manufacturing - Moisture separator Re-heater -

HITACHI
Inspire the Next



Welding Photo : 1993.5

Preparing for shipping Photo : 1994.3
Shipping : 1994.3

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1. *HITACHI'S BWR EXPERIENCE*

2. *GENERAL FEATURES OF BWR*

3. *DESIGN FEATURES OF ABWR*

4. ***CONSTRUCTION AND OPERATING EXPERIENCES OF ABWR IN JAPAN STRATEGY OF NEXT GENERATION BWR***

Advanced Construction Technologies

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1975

・1st Generation

Introduction of
Open-top method
by Tower Crane

1980

・2nd Generation

Introduction of
Large Crawler Crane for
Modularization

1985

・3rd Generation

Expanded Open-top Method
& Parallel construction

1990

・4th Generation

Advanced Construction
Technologies

2000

Development of Construction Technology

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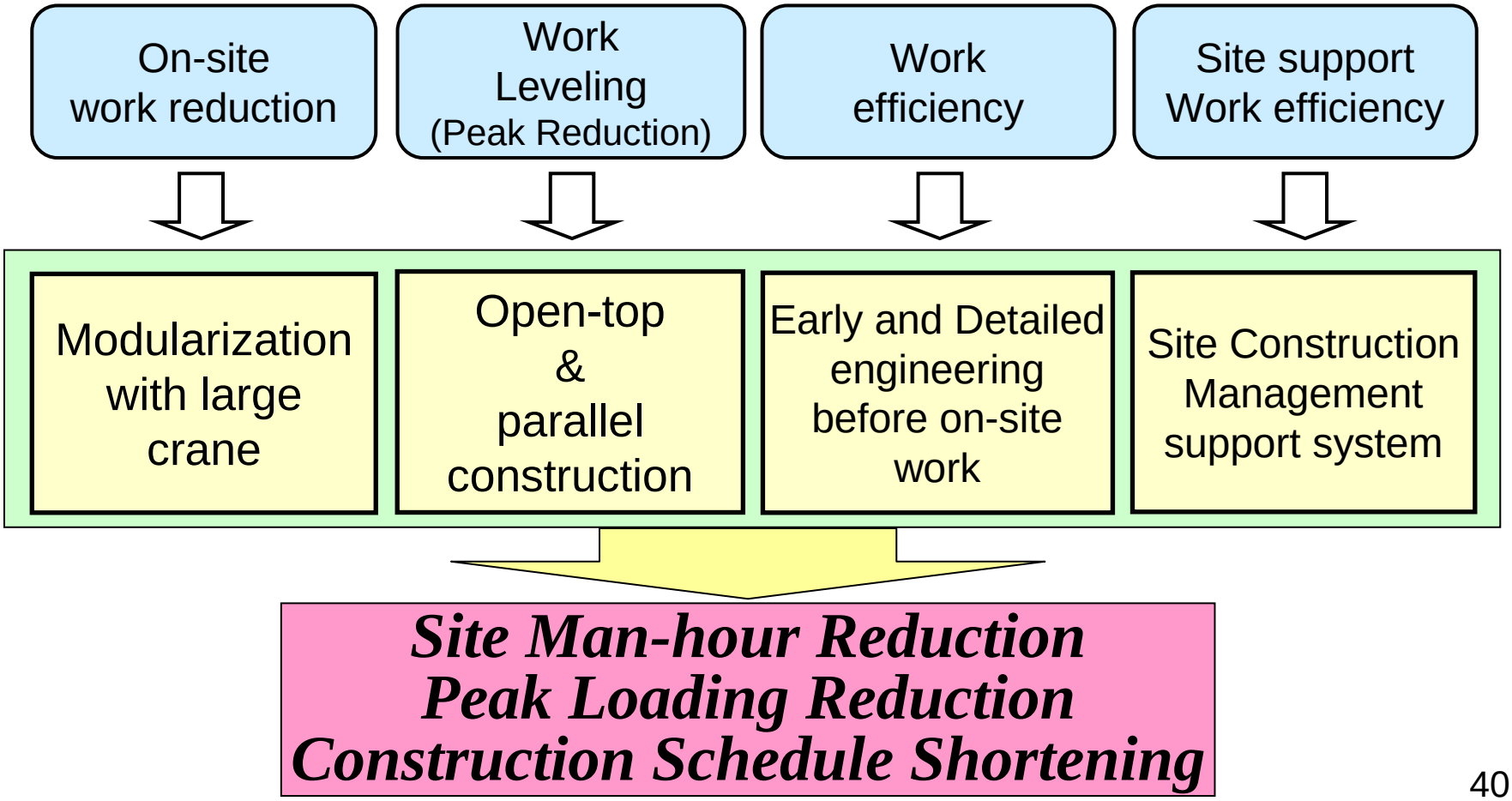
- Based on the following strategies, Hitachi has developed various advanced construction technologies.



Reduction of Construction man-hour & Period

HITACHI
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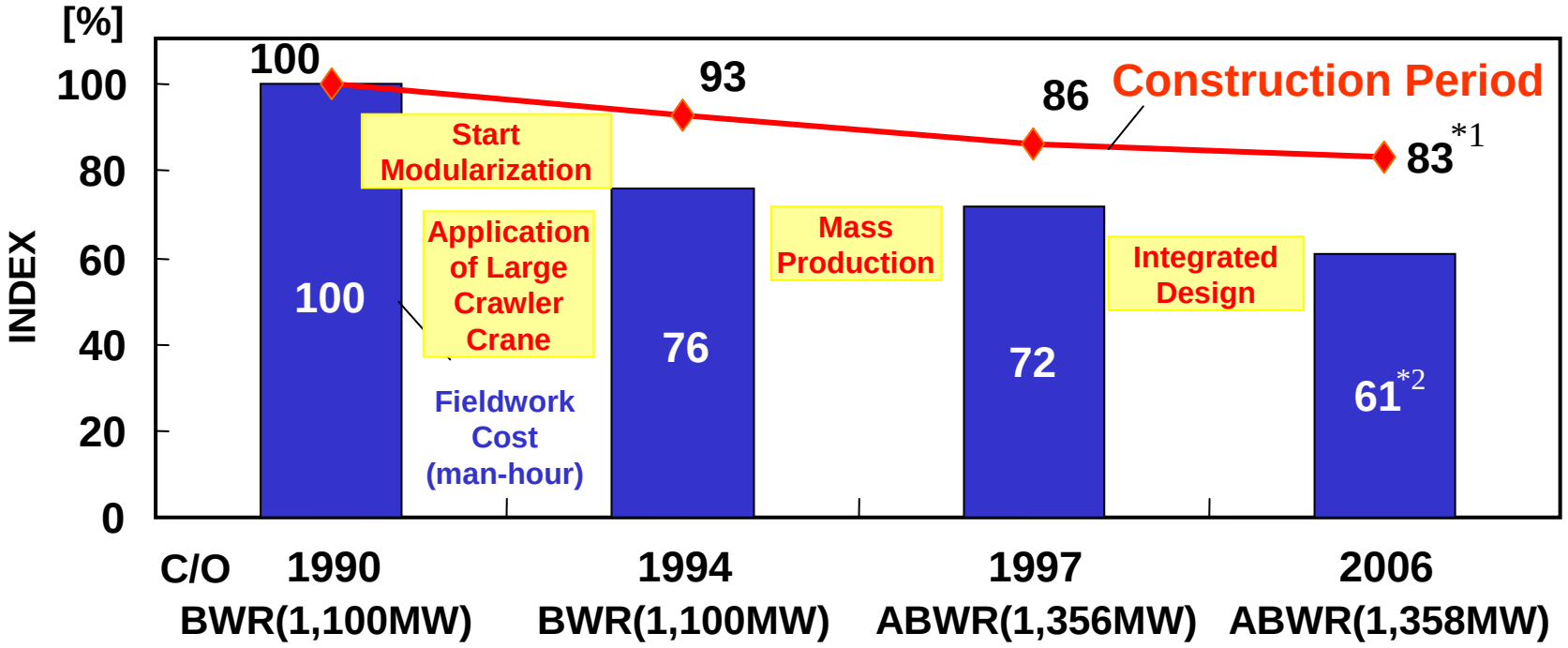

Past 15 years:
*1 Construction period is reduced by nearly 20 %
*2 Construction man-hour is reduced by nearly 40% **(same as Plant Cost)**

Advanced Construction Technology will bring big advantages for schedule shortening and cost reduction.

Construction Schedule Comparison

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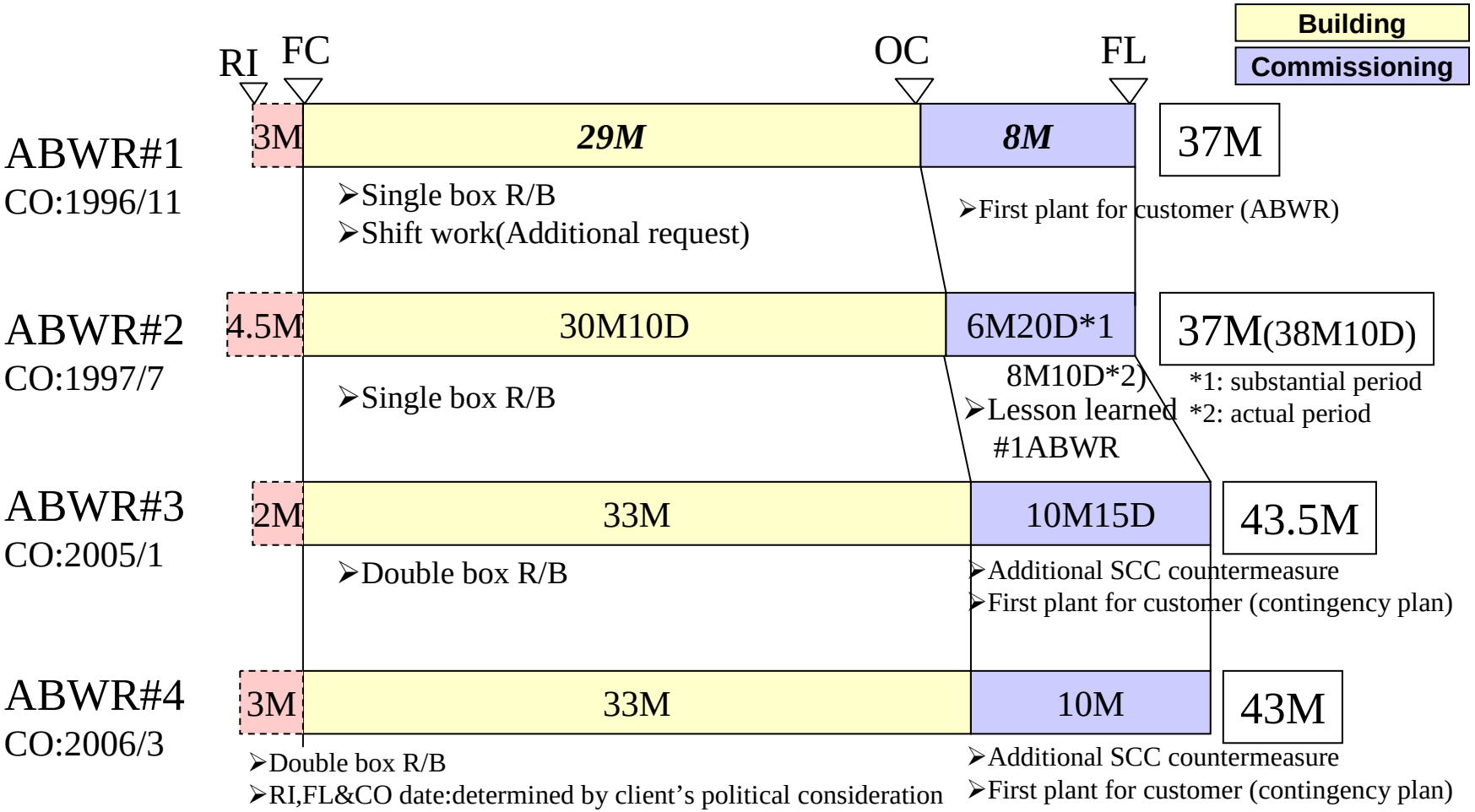

RI : Rock Inspection FC : First Concrete
OC : Overhead Crane Operation FL : Fuel Loading

Modular Construction Standardization to shorten Schedule

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With Modularization Method

Milestones S/C R/I F/C M/C O/C P/S RPV H/T F/L C/O

Construction Period = 38M (actual First ABWR)

Excavation

MMR

Base Mat

Mat Module

RCCV Liner Blocks

Lower

Upper Liner

Top Slab

R/B Building Work

RCCV Installation

Upper Drywell

Roof Frame Work

EOTC

RPV ON

RIN Installation

Commissioning

ECCS/CRD Pre-Operation

Base Mat (460tons)

Mechanical module

Upper Drywell (650tons)

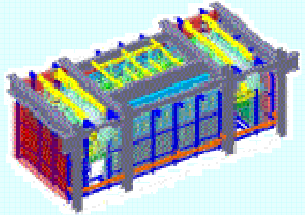
S/C: Start Construction
R/I: Rock Inspection
F/C: First Concrete
M/C: Mat Completion
O/C: Operating Floor Completion
P/S: Power Supply
RPV P/T: RPV Hydro Test Completion
F/L: Fuel Loading
C/O: Commercial Operation
EOTC: Electric Overhead Traveling Crane

Critical Module

RCCV Lower Liner (630t, Composite

Mechanical & Electrical Work In R/B

Mechanical module



HCU Module (250t, Composite)

Mechanical module

CUW HX (40tons)

Mechanical module

Off Gas (27tons)

:Civil/Building Work :Critical Path
:Mechanical Installation

Large Module Applications in R/B

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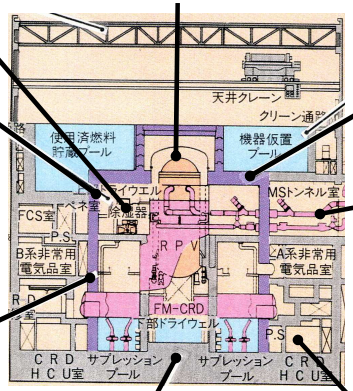
Upper Drywell Module:650ton

RPV:900ton

Top Slab Module:550ton

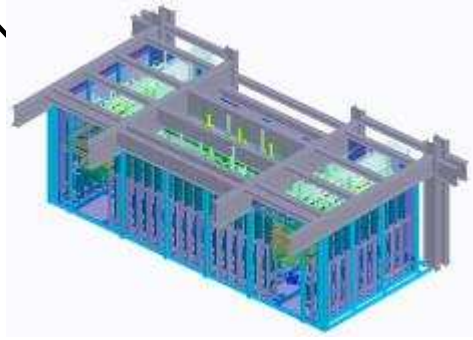
RCCV Upper Liner Module:170ton



Piping Module:120ton

RCCV Lower Liner Module:630ton

Base Mat Module:460ton



Room Module:250ton

Large Module Applications in T/B

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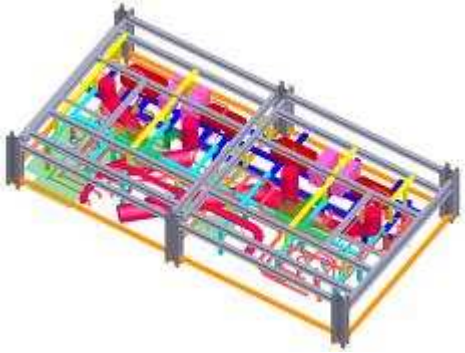
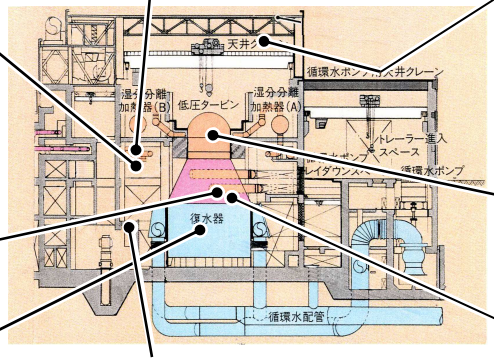
Lower Condenser Module



MSH Drain Tank Area Module

Roof Truss Module

Off Gas Module



MSV/CV Module

Hitachi's Module Application Experience

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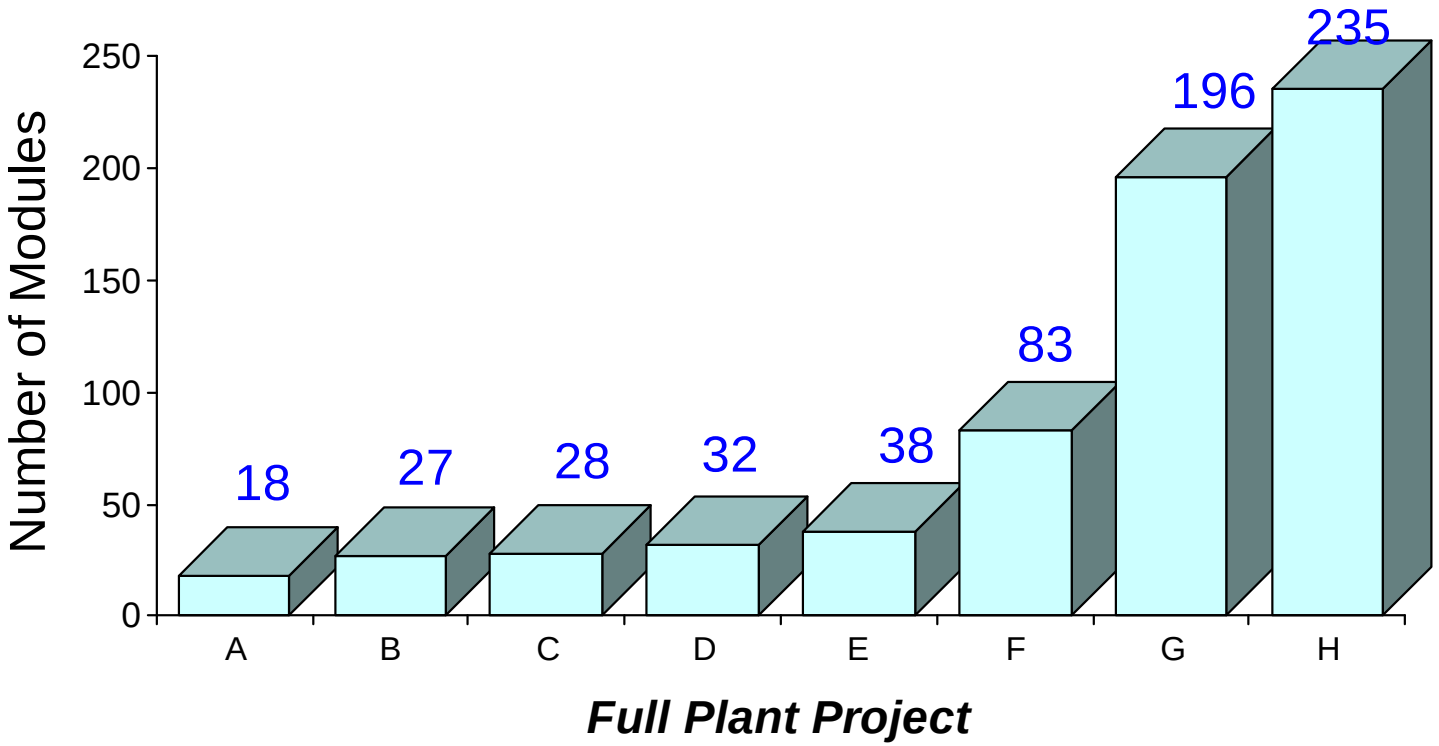

Through over 900 modules and blocks(prefabricated piping and valves) experience, the technology has been being sophisticated in this 25 years.

Tokyo Electric Power Co., Kashiwazaki-Kariwa NPS

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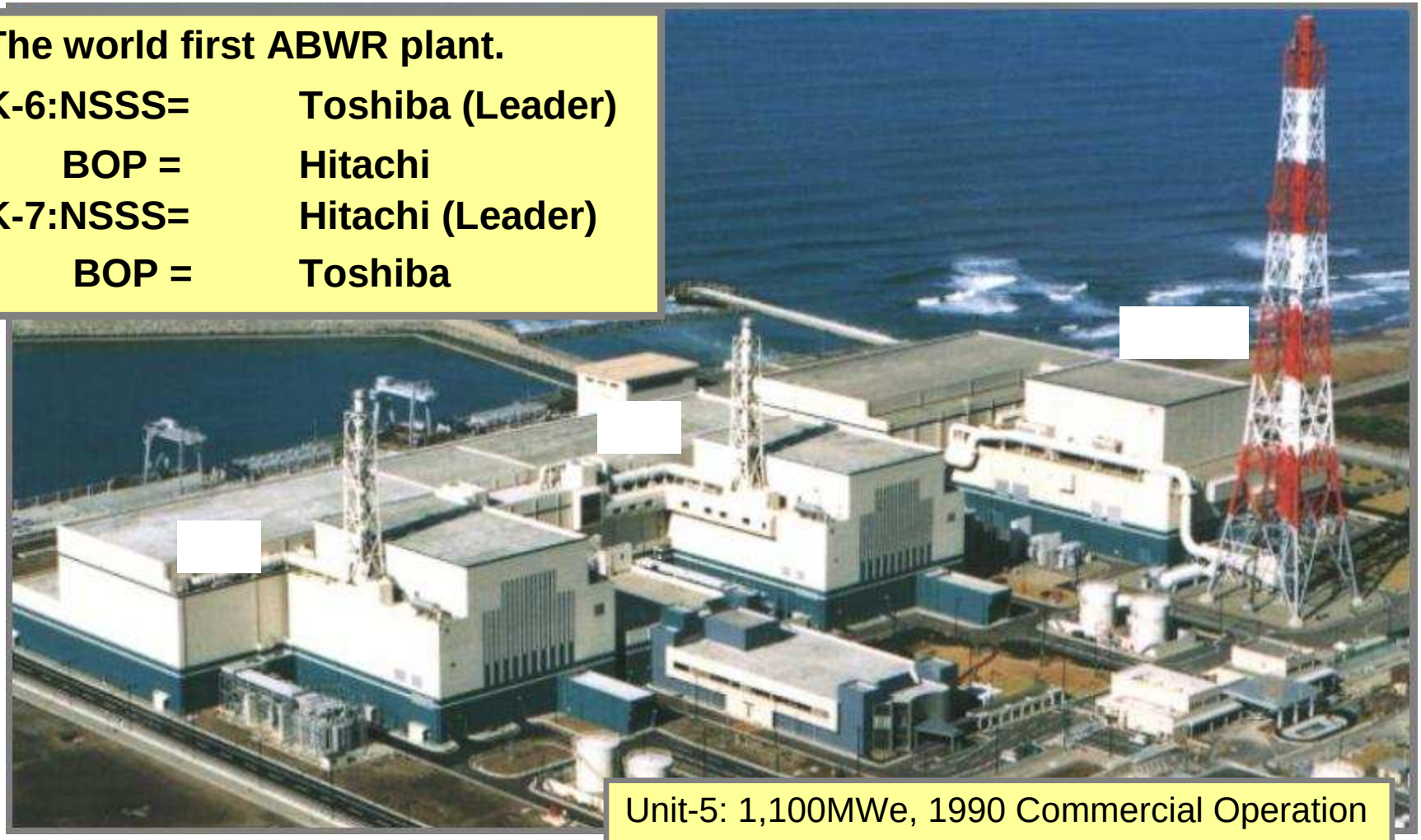
The world first ABWR plant.

K-6:NSSS= Toshiba (Leader)
BOP = Hitachi
K-7:NSSS= Hitachi (Leader)
BOP = Toshiba



Unit-5: 1,100MWe, 1990 Commercial Operation
Unit-6: 1,356MWe, 1996 C/O
Unit-7: 1,356MWe, 1997 C/O

Hokuriku Electric Co. Shika NPS

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Main Control Room

Hitachi's 1st Total Plant Supply of ABWR

Unit-2: 1,358MWe, 2006.3 C/O

Operating Experience of ABWR

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Excellent Reliable Operation

Number of Automatic/Unplanned Scrams

	K-6	K-7
1996	0	N/A
1997	0	0
1998	1	0
1999	1	0
2000	0	0
2001	0	0
2002	0	0
2003	0	0
2004	0	1
2005	0	0

Good Availability/Capacity Factor

	K-6	K-7
Availability	86%	86%
Capacity	81%	81%

Note:

Operation Limitation by Japanese Regulation & Guideline

*Maximum continuous operation period:

less than 13 months

*Longer outage by wider inspection

*Deliberate judgment for start-up

Key Features of ABWR-II Design

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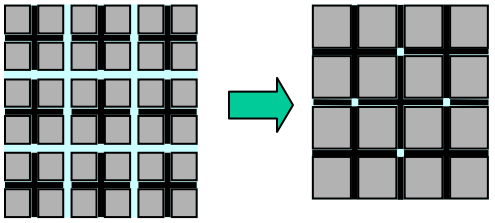
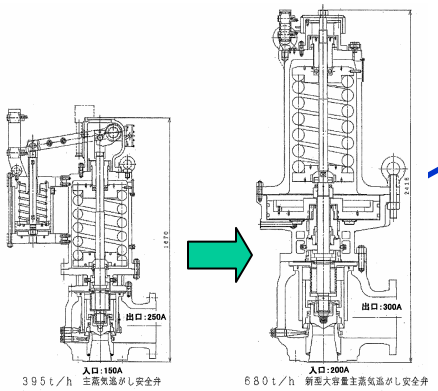
C-lattice

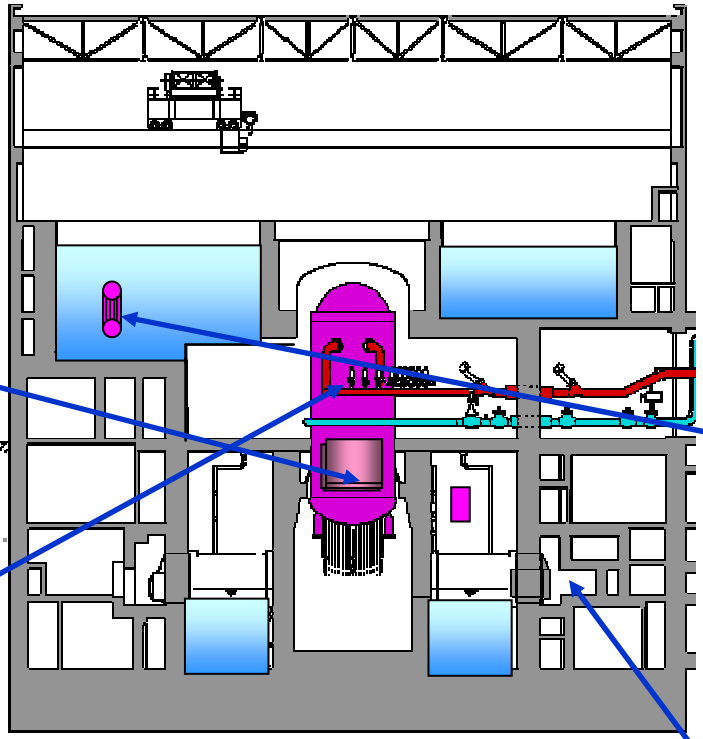
1.5K-lattice



1.5K-Large Fuel Assembly

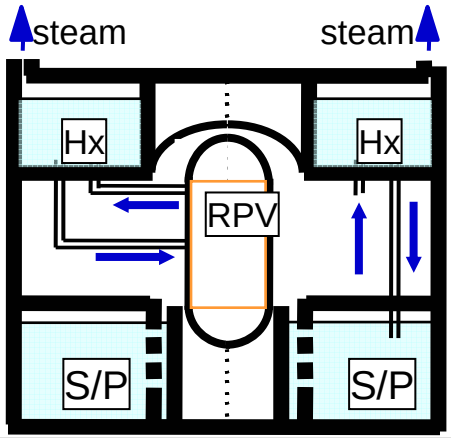


Large-size SRV

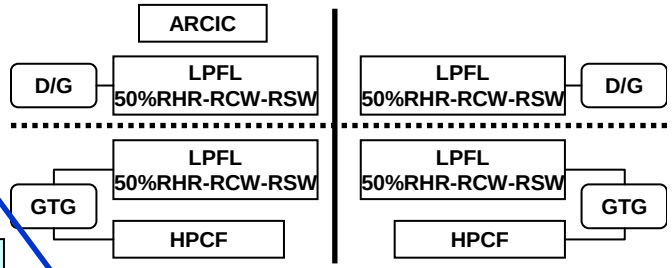


Electrical output : 1700MWe

Construction cost : reduced by 20%



Passive Heat Removal System



Modified ECCS Configuration

Summary

HITACHI
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HITACHI, one of the Largest Full Turn Nuclear Suppliers in JAPAN,

- ***Has enough Experience of BWR Engineering & Construction and Latest ABWR Construction.***
- ***Has three Planning Constructions of ABWR in Japan and two in U.S.***

ABWR is a Latest Model of BWR being High Safety, High Economy and High Reliability.