TOSHIBA
Leading Innovation

Japan-Poland Clean Coal Seminar2014
2nd June, 2014

TOSHIBA's Energy Solution

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Technology Executive

Power Systems Company
Toshiba Corporation

TOSHIBA eco style

Toshiba Group contributes to
the sustainable future of planet Earth.

Today's Contents

1. Toshiba in Thermal Power Energy Sector
2. Enhancement of thermal Power plant
   - Ultra Super Critical (USC)
   - Advanced Ultra Super Critical (A-USC)
3. Carbon Capture Technologies
   - Post Combustion Capture
   - Novel thermal Power System with CCS
4. Conclusions

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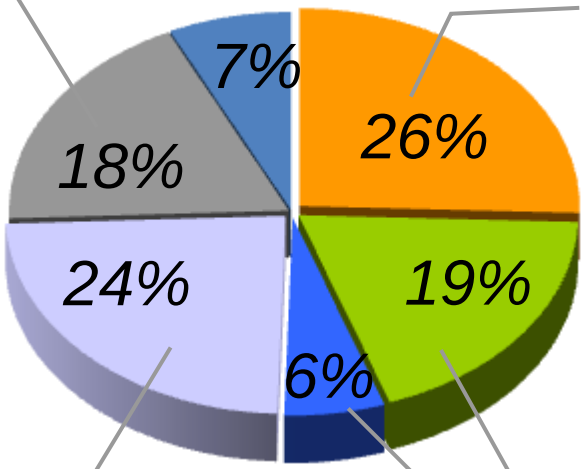
TOSHIBA's Business segments

Total sales: $65B

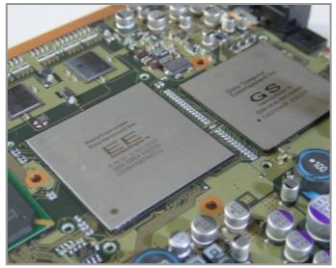
Lifestyle



*FY2013 data

Energy & Infrastructure

Electronic Devices



Healthcare

Community Solutions

Committed to power solutions

- Thermal

- Geothermal

- Wind

- Mega solar

- CCS (CO_2 capture)

TOSHIBA

- Smart grid

- Hydro

- Nuclear

- Fuel cell

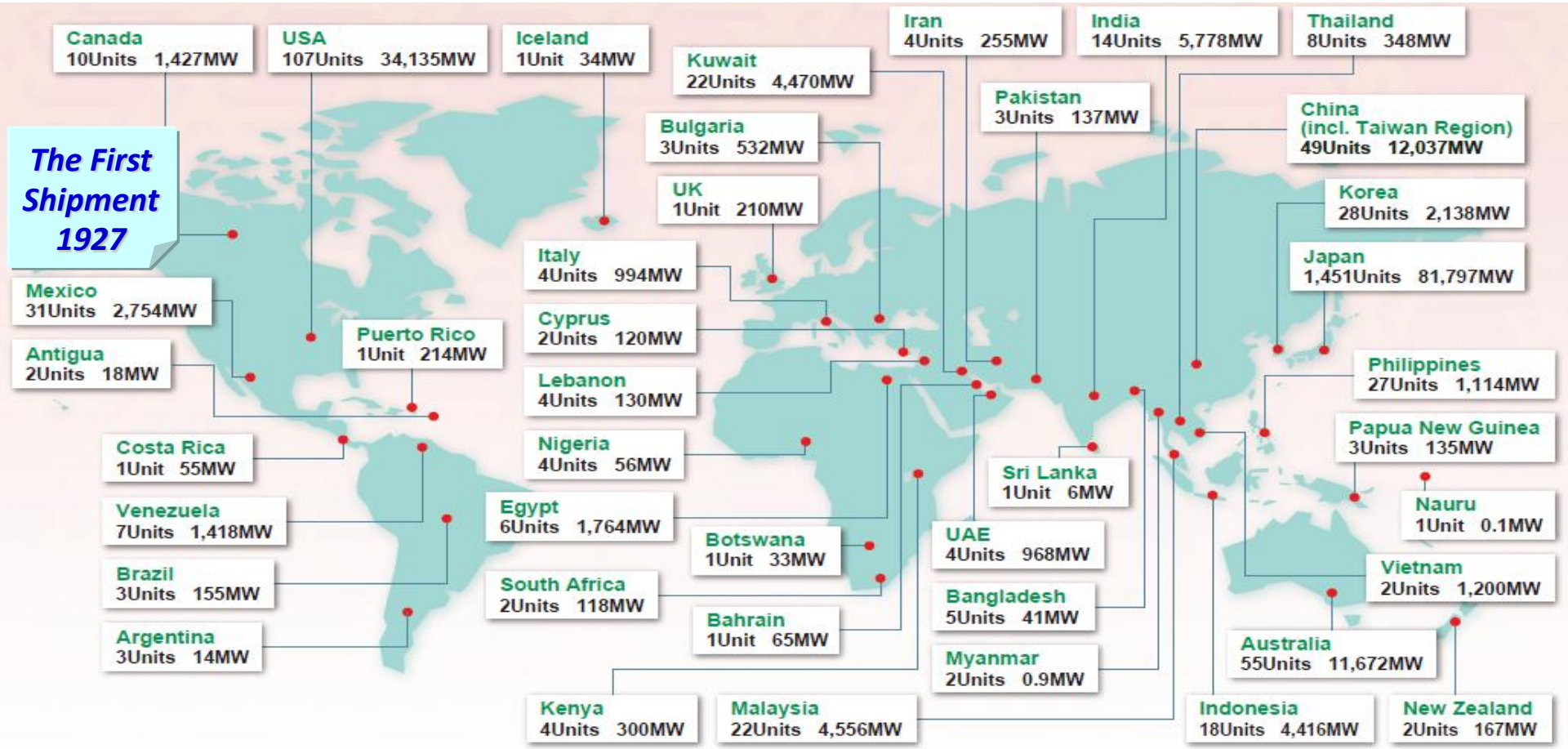
Toshiba: "One-stop solution" provider in power business

Turbine Power Plants Supplied by TOSHIBA

Rich Experiences all over the world from 1927

- No.1 market share in North America in the past decade

1,904 units
171GW



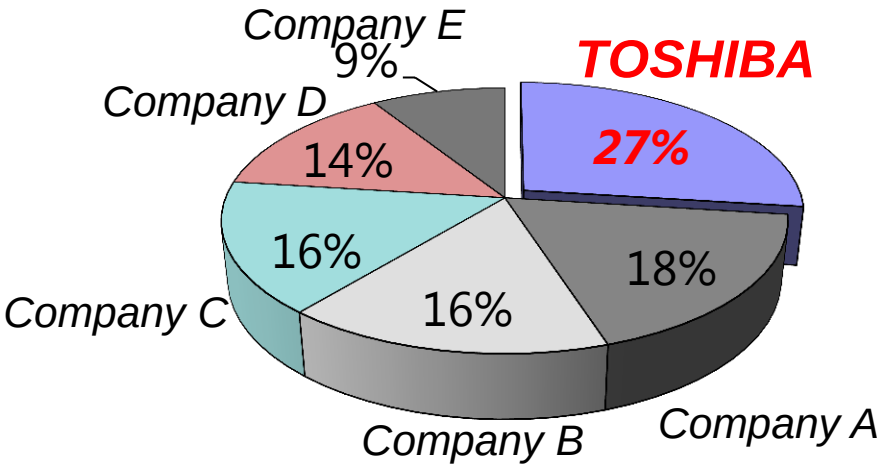
Leader in World Wide Share

World Share of Supercritical Steam Turbine

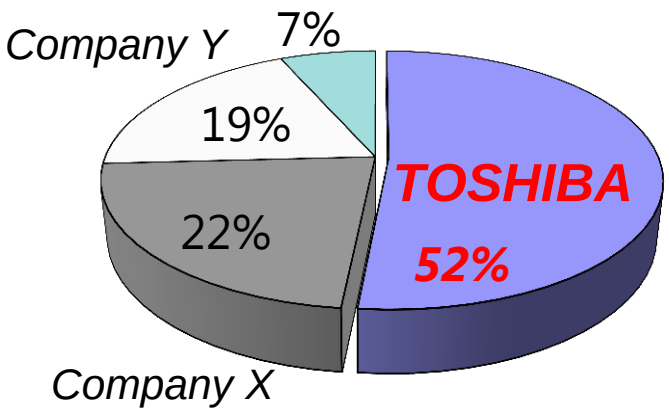
(Among Major Manufacturers during 1988～2008(20yrs))

Toshiba is the Leading Player of Supercritical Steam Turbines
:81 units in the world except China

Wold Wide Share



Share in Japan



Data extracted from McGraw Hill Data

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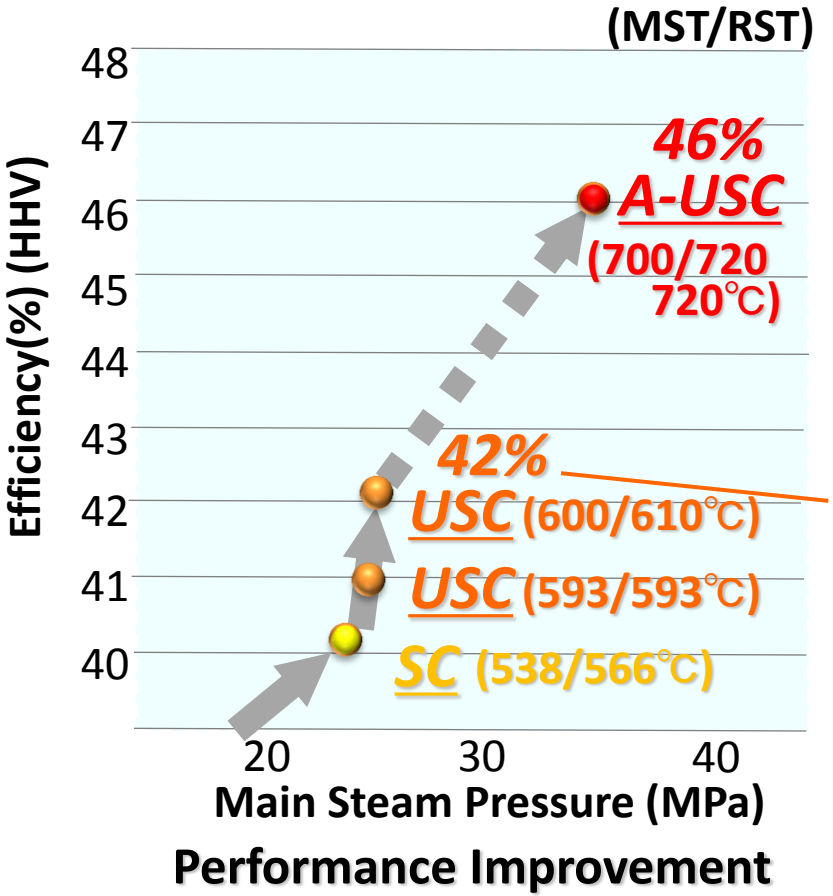
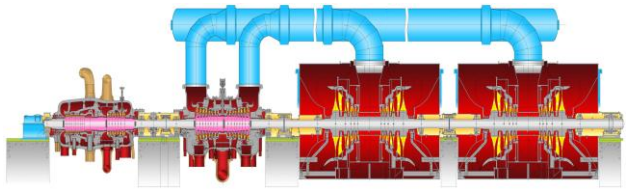
Efficiency Enhancement

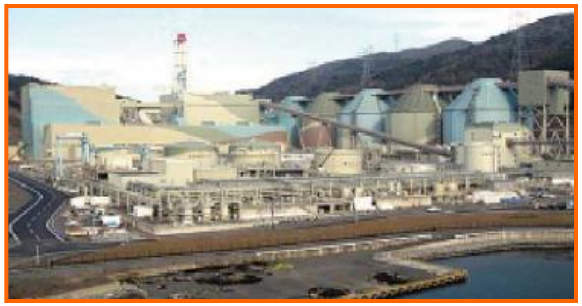
Continuously striving for performance improvement

- Develop higher temperature and higher pressure turbine
- The Highest Efficiency 42% as USC (600 ℃)



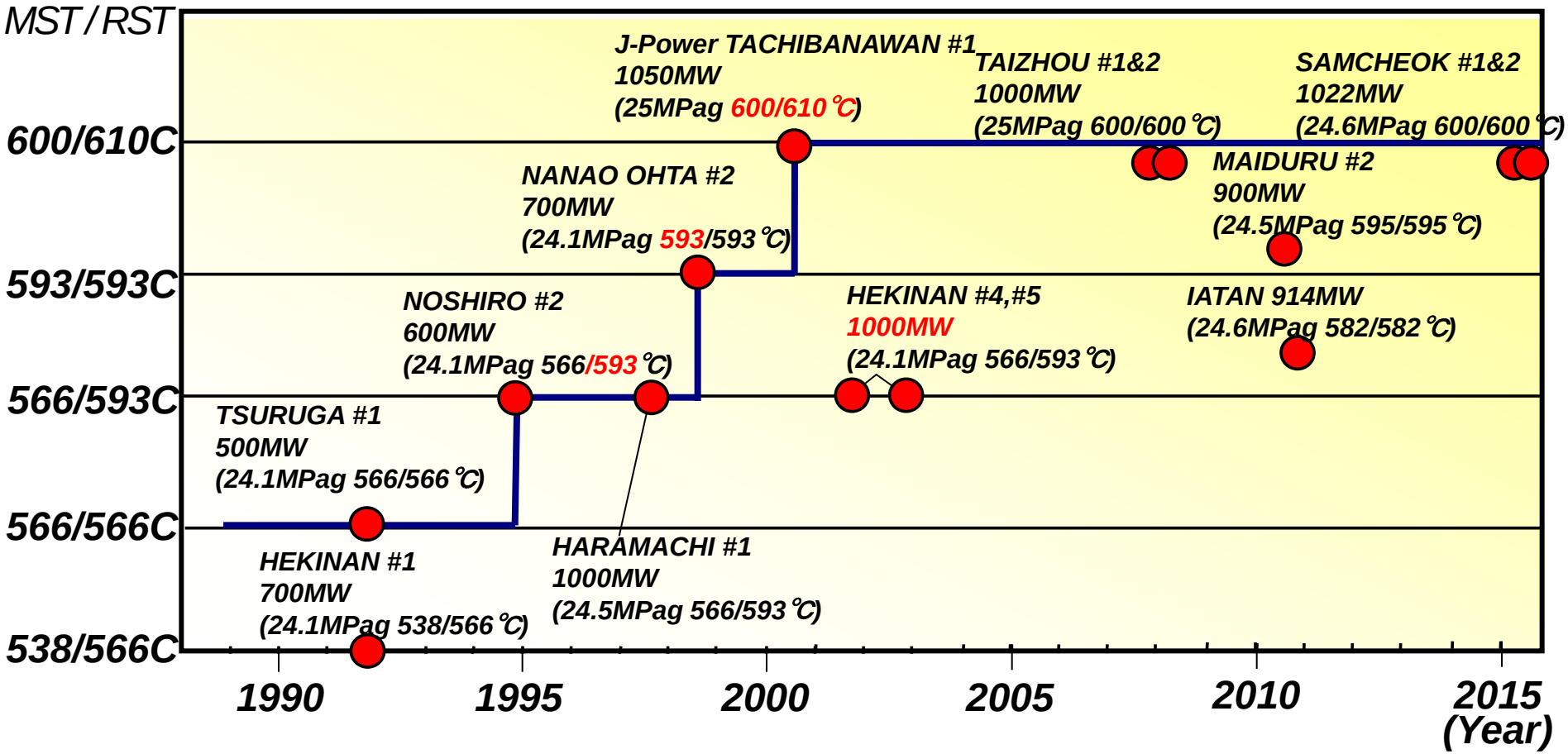


Advanced-Ultra Super Critical



Ultra Super Critical

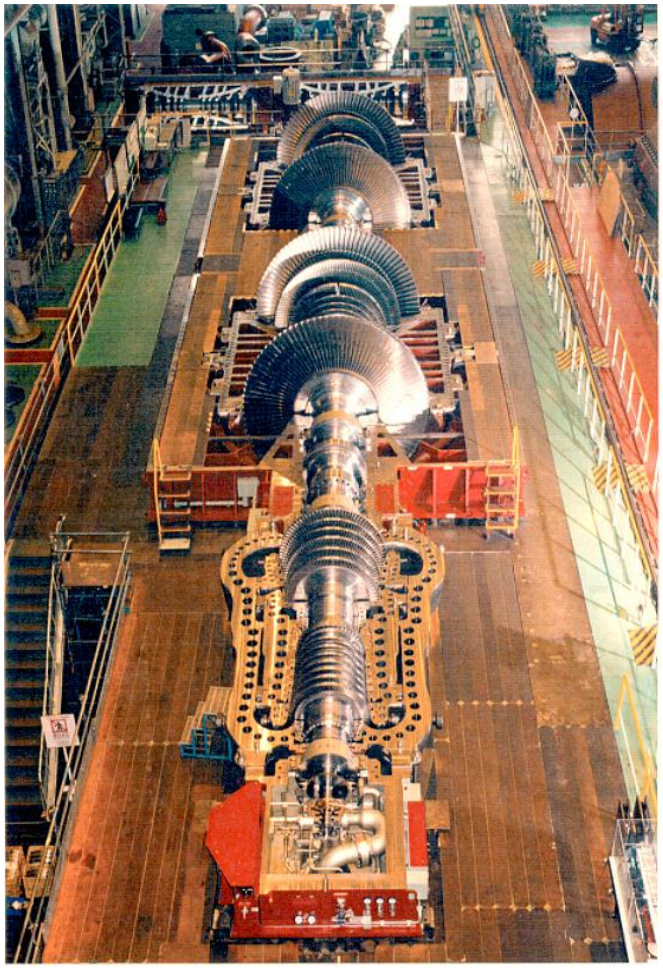
Toshiba USC Development Trend



MST: Main Steam Temperature
RST : Reheat Steam Temperature

Benchmark Power Plants with High Steam Parameters

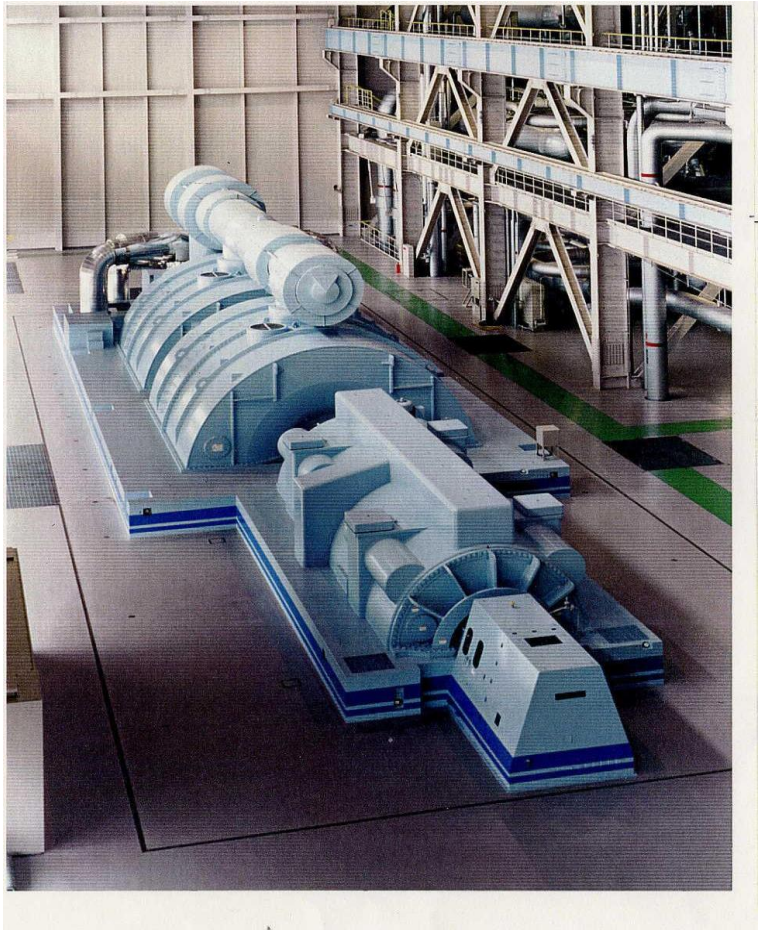
NOSHIRO #2 POWER PLANT(JAPAN)



Customer:	Tohoku Electric Power Co., Japan
Taking Over:	Dec. 1994
Turbine:	Tandem Compound, Four Flow, Reheat Type (TC4F-42”)
Output:	600 MW
Main Steam:	24.1MPag, 566 C
Reheat Steam:	593 C
Rotation Speed:	3000 rpm

Benchmark Power Plants with High Steam Parameters

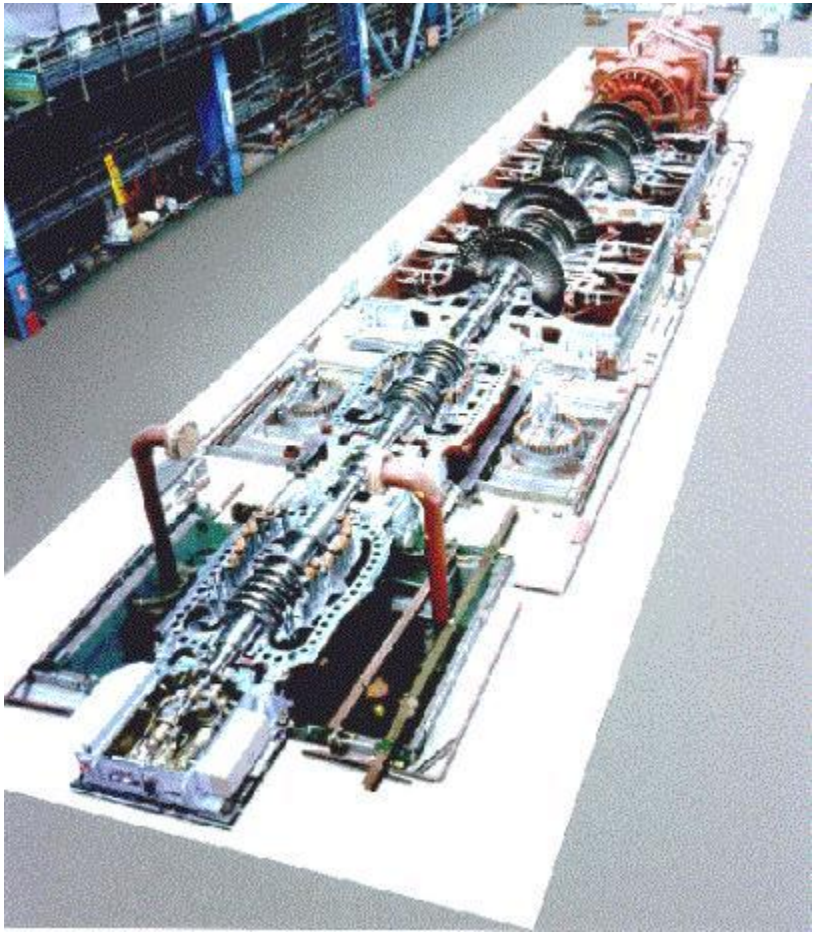
NANAO OHTA #2 POWER PLANT (JAPAN)



Customer:	Hokuriku Electric Power Co., Japan
Taking Over:	July 1998
Turbine:	Tandem Compound Four Flow, Reheat Type (TC4F-40”)
Output:	700 MW
Main Steam:	24.1MPag , 593C
Reheat Steam:	593 C
Rotation Speed:	3600 rpm

Benchmark Power Plants with High Steam Parameters

Hekinan #4,5 POWER PLANT(JAPAN)



Customer:	Chubu Electric Power Co., Japan
Taking Over:	November 2001（#4） November 2002（#5）
Turbine:	Tandem Compound, Four Flow, Reheat Type (TC4F-40”)
Output:	1000 MW
Main Steam:	24.1MPag, 566 C
Reheat Steam:	593 C
Rotation Speed:	3600 rpm

Benchmark Power Plants with High Steam Parameters

TACHIBANA BAY #1 POWER PLANT (JAPAN)

Customer: Electric Power Development Co., (J-Power), Japan

Taking Over: July 2000

Turbine: Cross Compound, Four Flow, Reheat Type (CC4F-48 inch)

Output: 1050 MW

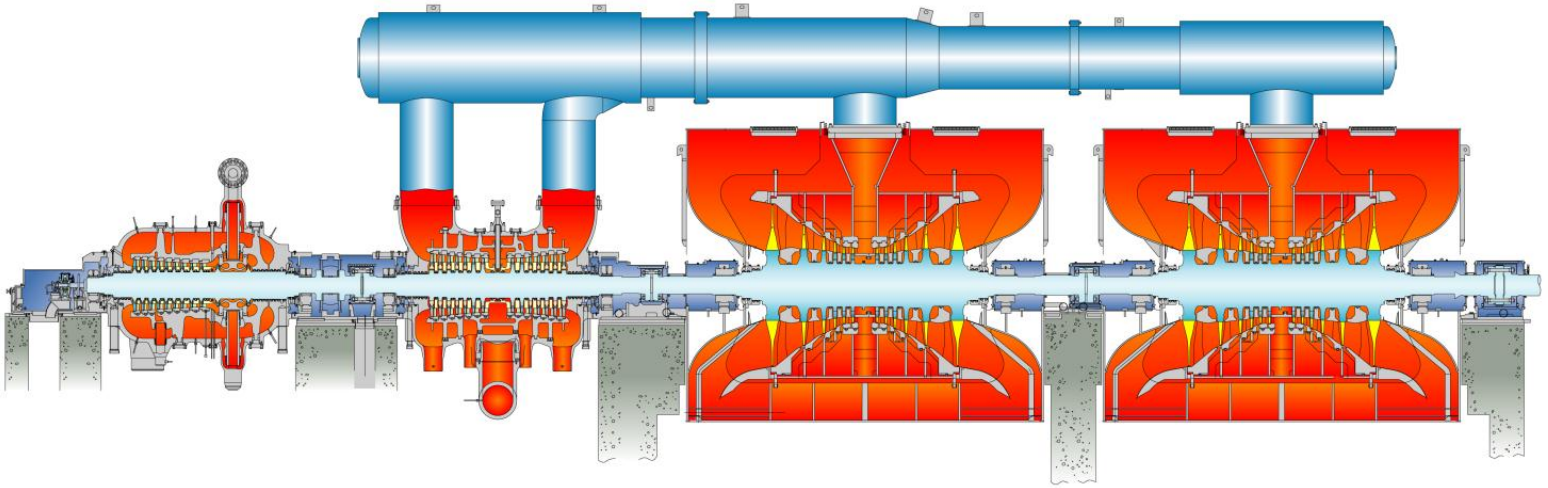
Main Steam: 25MPag, 600 C

Reheat Steam: 610 C

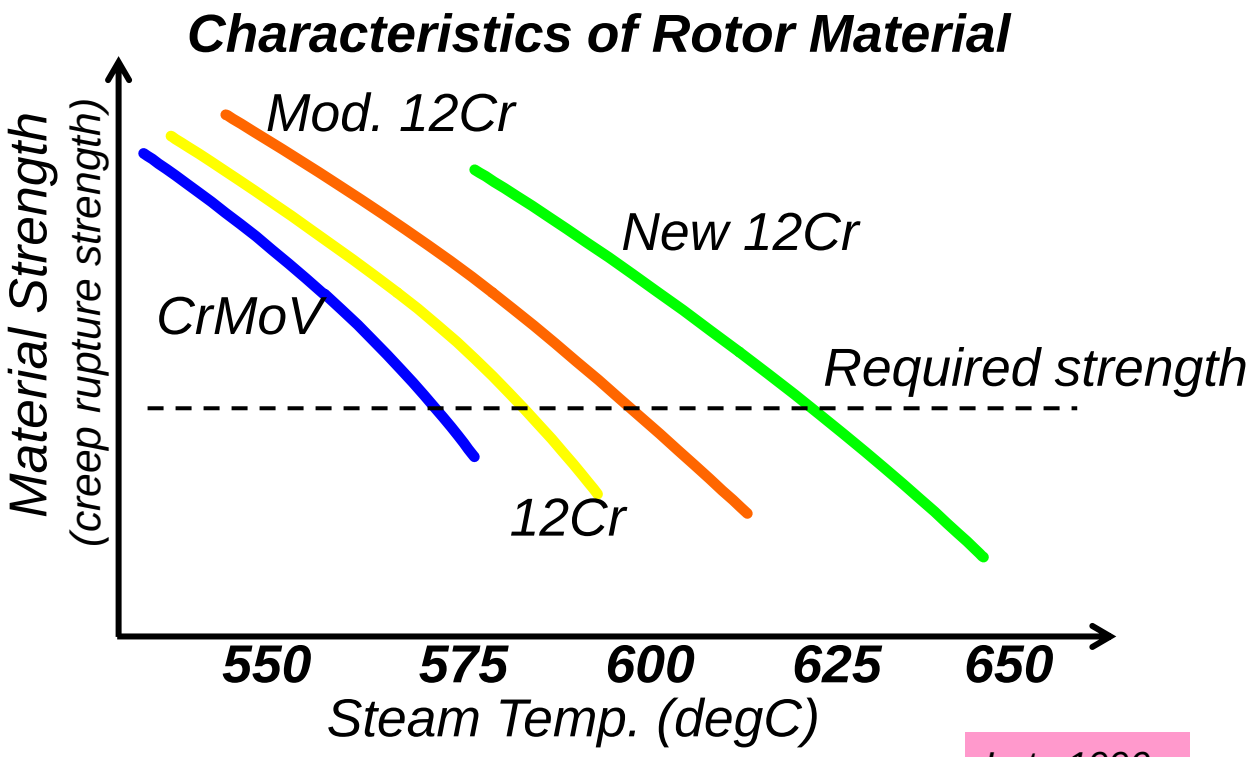
Rotation Speed: 3600 rpm / 1800rpm

Benchmark Power Plants with High Steam Parameters

Customer:	KOREA SOUTHERN POWER
Turbine:	Tandem Compound Four Flow Ti 48inch
Generator:	2 X 1230MVA
Output:	2 X 1022MW
Steam Conditions:	24.6MPag, 600/600 C
Rotational Speed:	3600rpm
Commercial Operation:	2015 (scheduled)



Enhancement of steam temperature



<Sub critical>
CrMoV Steel

1970s

<Super Critical>
12Cr steel

- **High chromium**
- **Nb,N added**

Early 1990s

<Super Critical / Ultra Super Critical>
Mod. 12Cr steel

- **W added**

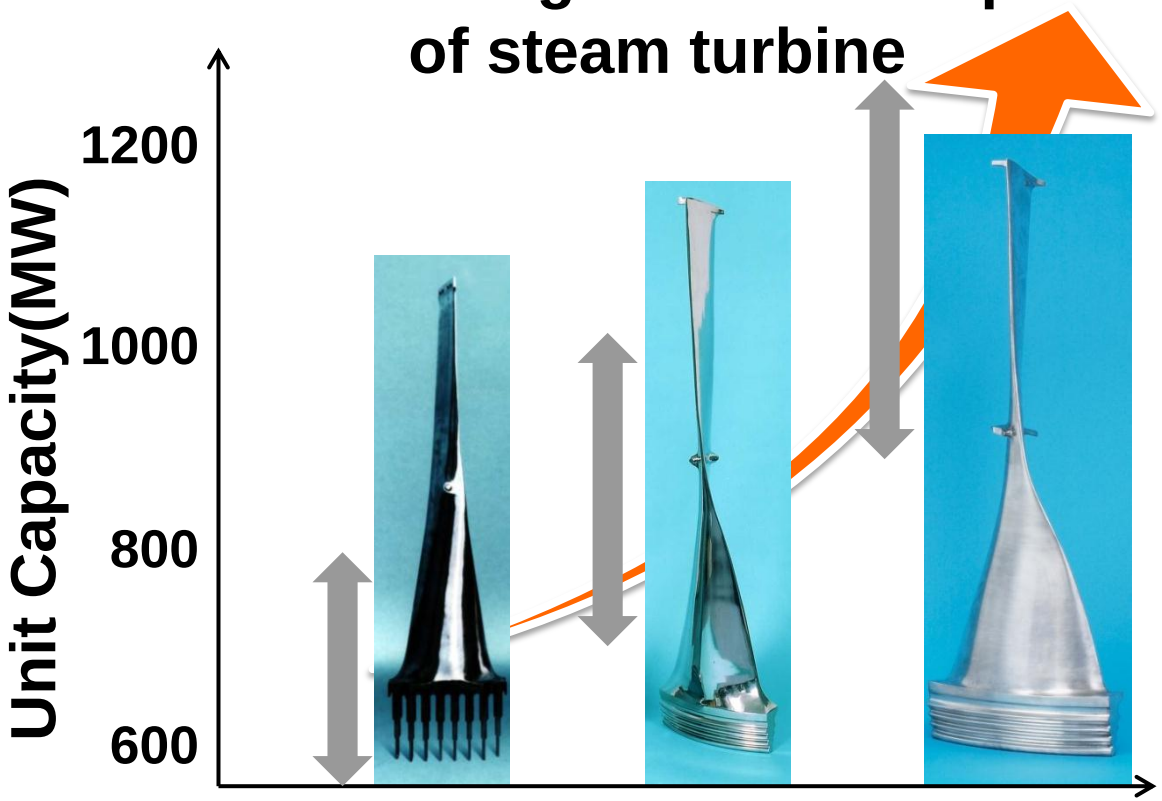
Late 1990s

<Ultra Super Critical>
New 12Cr steel

- **Co,B added**
- **W increase**
- **Mo decrease**

Enhancement of unit capacity

Last stage blade line up of steam turbine

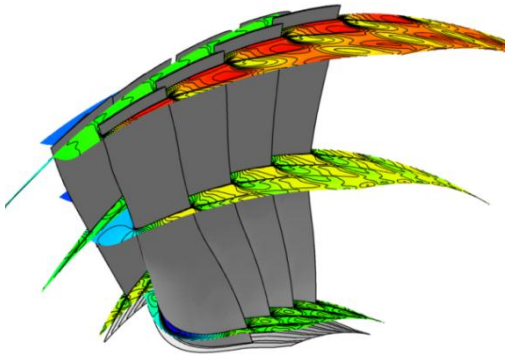


Material	Steel	Steel	Titanium
Blade Length (for 50Hz/60Hz)	42/35inch	48/40inch	58/48inch
First unit Taking over	1994	2005	2010

- **High reliability**

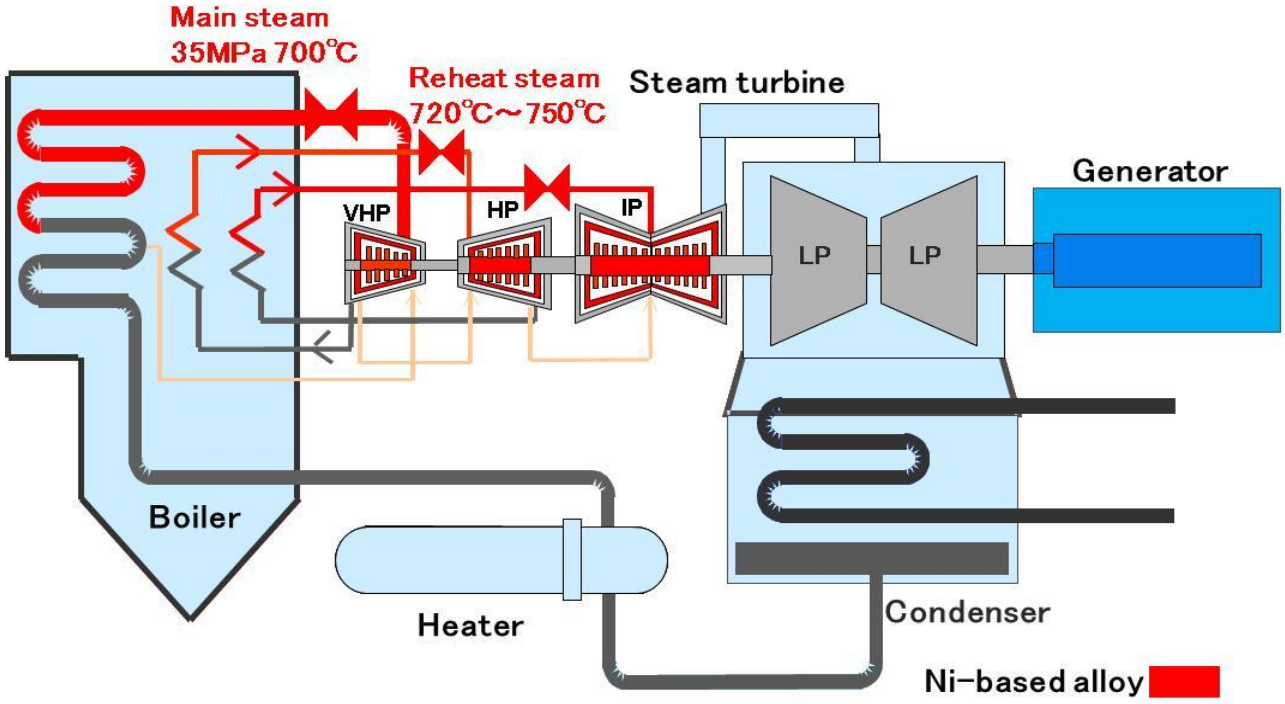
Full Scale Test Facility

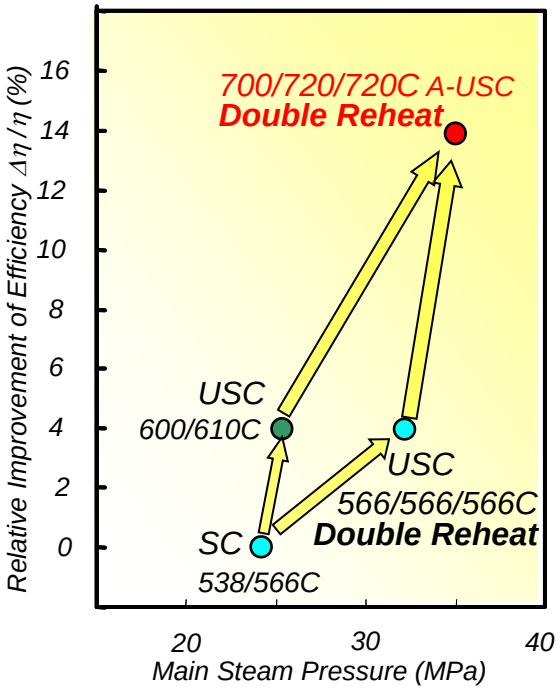
- **High efficiency**



Computed Fluid Dynamics Simulation

A-USC(Advanced Ultra Super Critical) System





■R&D Requirements

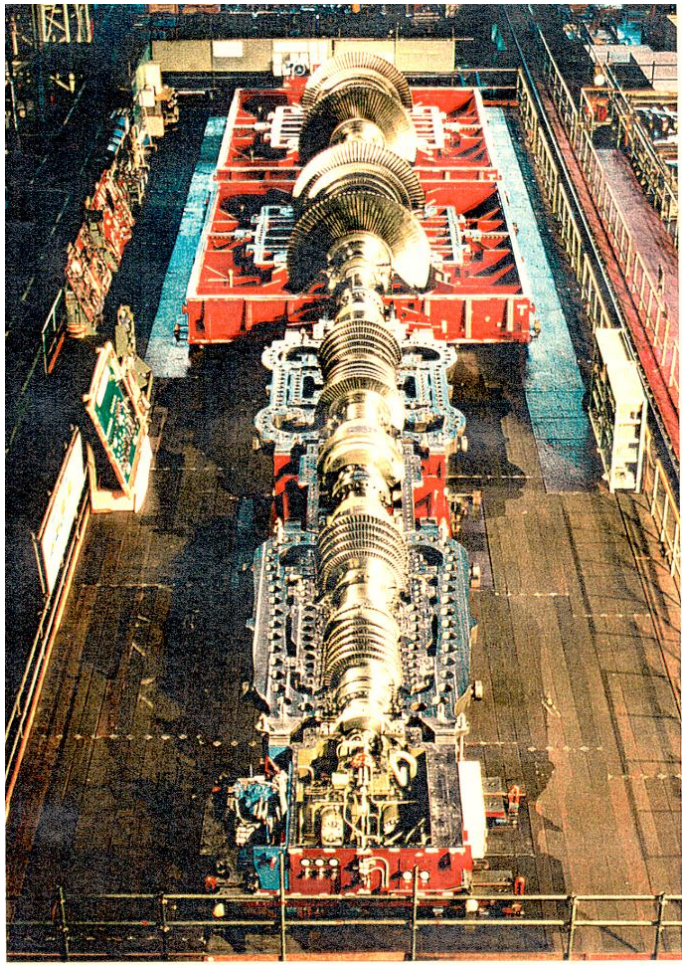
Overall system
- ●Steam condition
- ●Heat balance

Steam Valve
- ●High temperature material

Steam Turbine
- ●High temperature material
- ●Turbine Structure / Flowpath

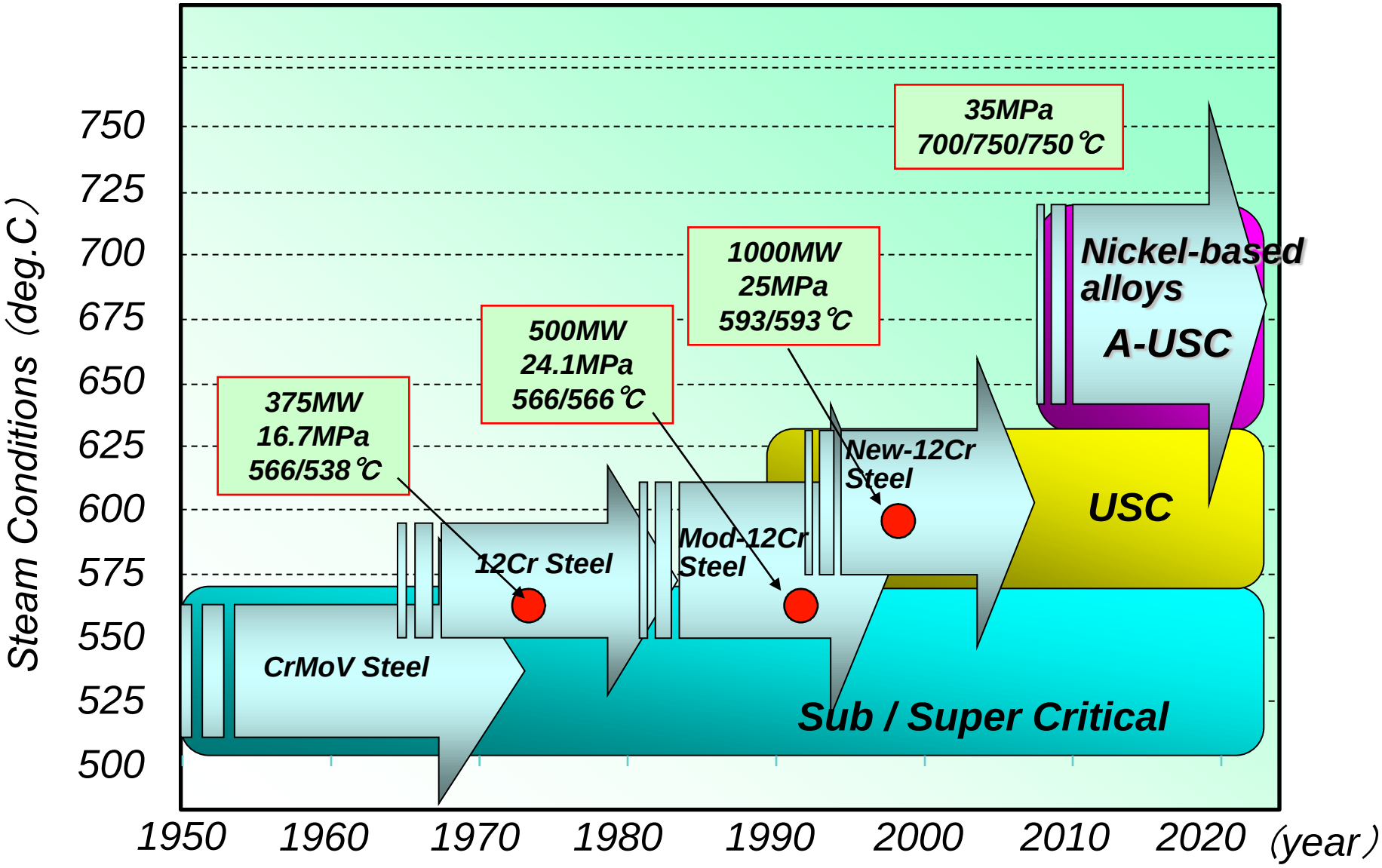
Double Reheat Plant : TOSHIBA's proven technology

Kawagoe #1,2 POWER PLANT(JAPAN)



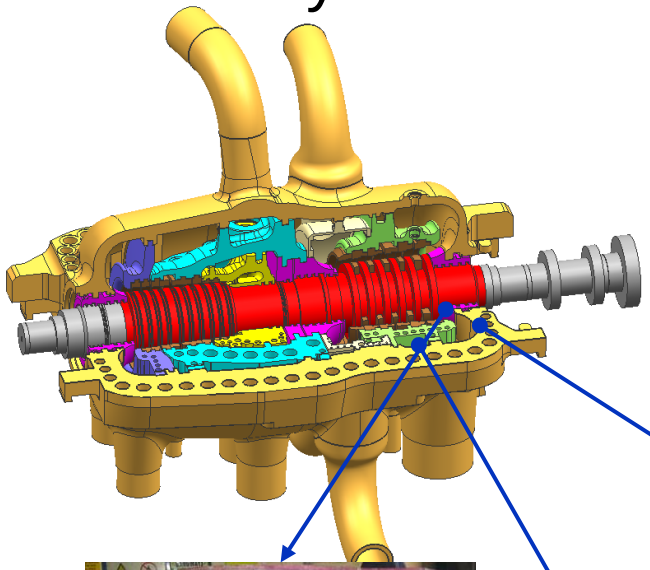
Customer:	Chubu Electric Power Co., Japan
Taking Over:	Unit #1: Jun 1989 Unit #2: Jun 1990
Turbine:	Tandem Compound, Four Flow, Double Reheat Type (TC4F-33.5")
Output:	700 MW
Main Steam:	31.0 MPag , 566 C
Reheat Steam:	566 / 566 C
Rotation Speed:	3600 rpm

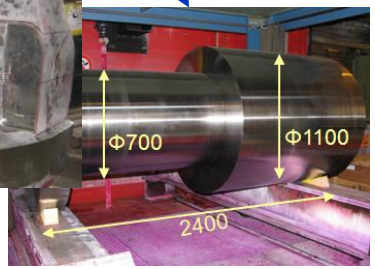
Transition of Steam Turbine Materials in TSB

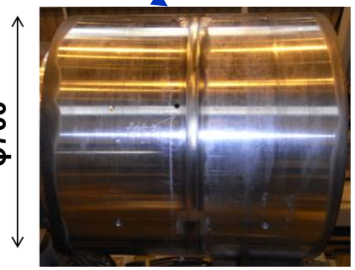


Development of High Temperature Material

Verify manufacturability of
Ni based alloys in **actual size**



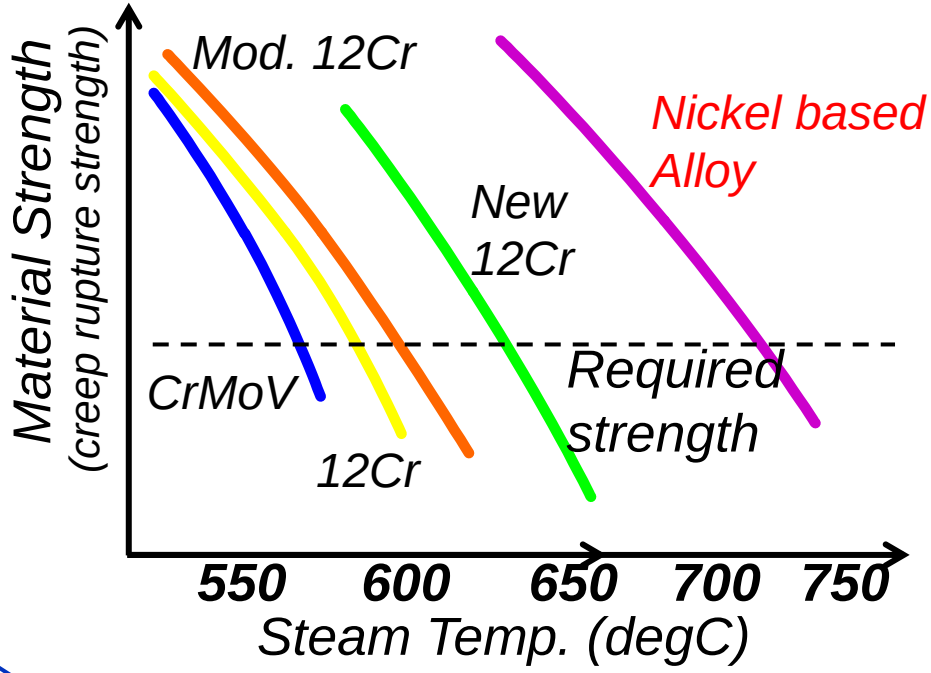


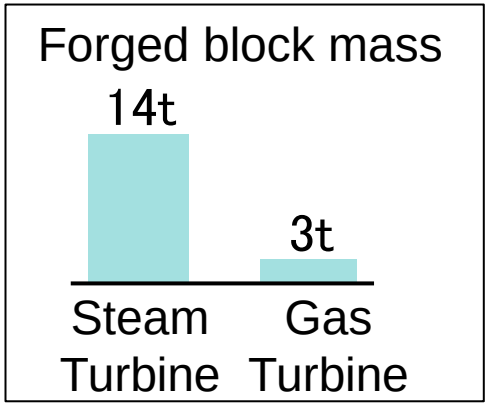


Casing
Weight: 9ton

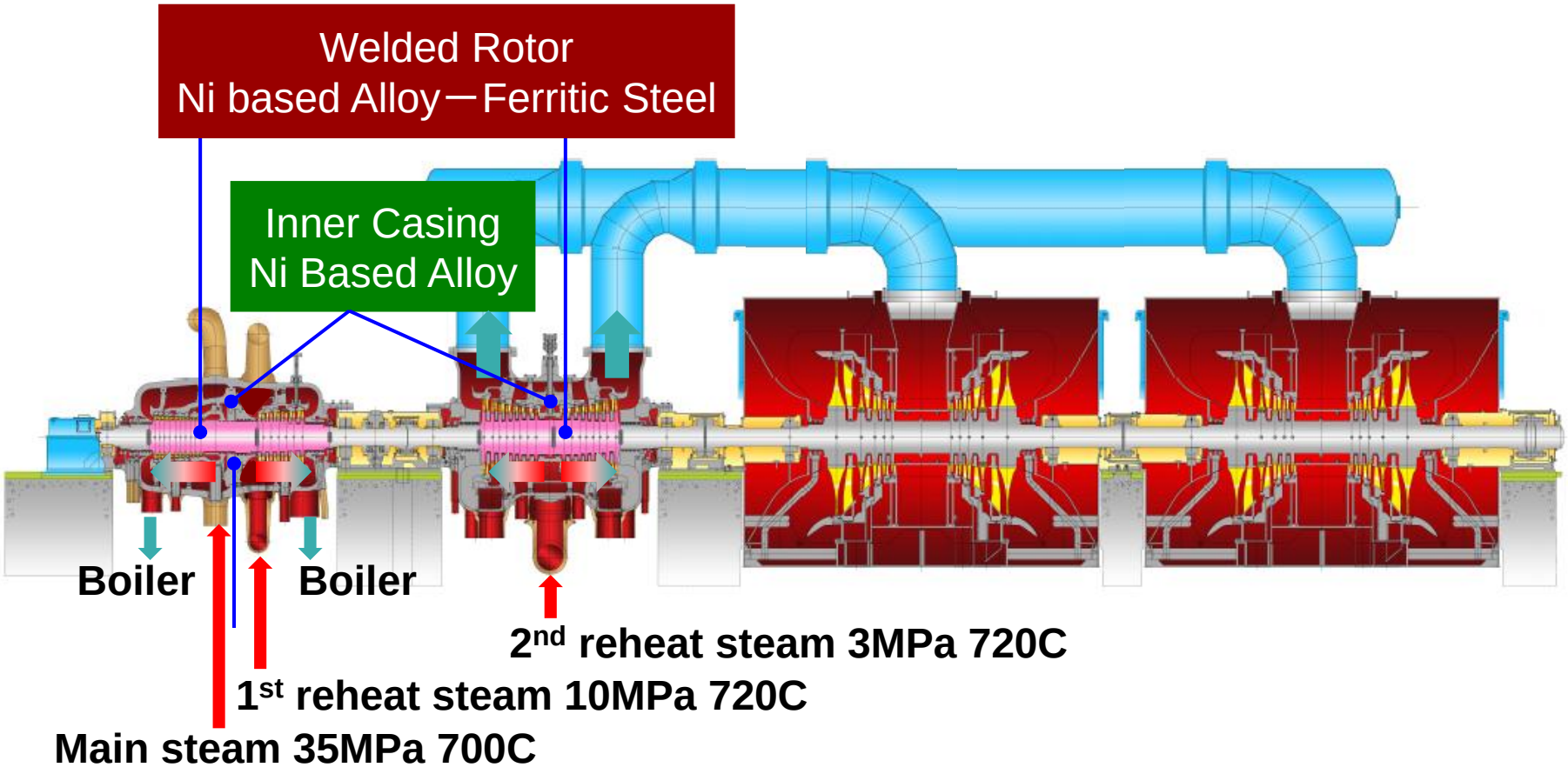
Rotor
Weight: 14ton

Welded rotor





Conceptual design of A-USC Steam Turbine



A-USC (1000MW Class, 35MPa, 700/720/720 C) turbine

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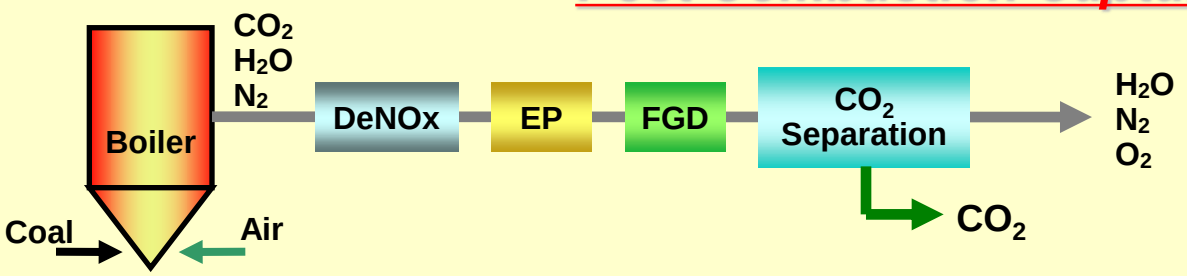
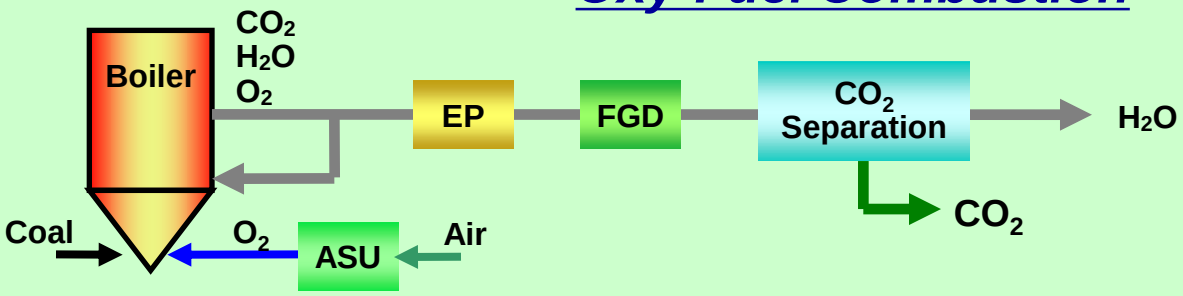
Carbon Capture Technologies

Post Combustion Capture



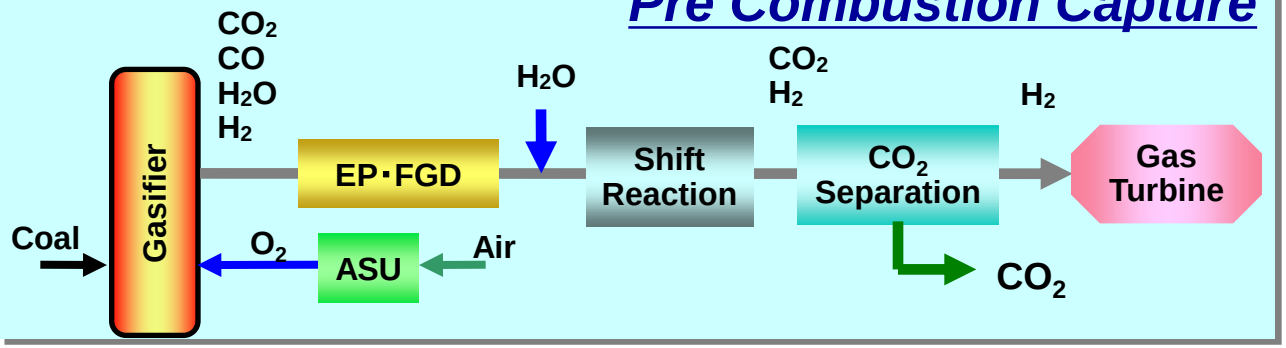
Advantages
- Applies widely to thermal PP (New, Retro, CC, Industrial)
- Proven technology
Challenges
-Energy Required for capture
-Cost of Capture Equipment

Oxy-Fuel Combustion



Advantages
- Size of capture equipment is small (No N_2 to separate)
- Boiler size smaller
Challenges
-Energy Required for ASU
-Cost for ASU
-CO_2 purity

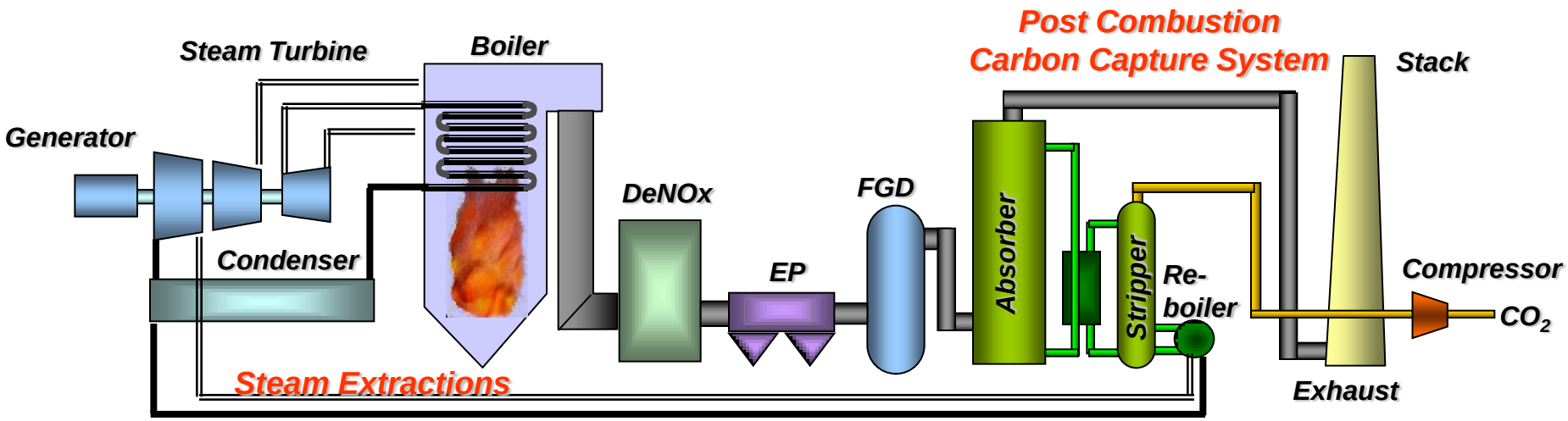
Pre Combustion Capture



Advantages
-Size of capture equipment is small (High pressure syngas)
Challenges
-Energy Required for ASU
-Operational Flexibility
-Cost of overall plant equipment

ASU: Air Separation Unit FGD: Fuel Gas Desulphurization EP: Electrostatic Precipitator

Easy Integration with Existing Plants



Integration with Power System	Integration with Exhaust System	Carbon Capture System
・Heat & Mass Balance ・System Operation	・DeNOx, FGD, EP Requirements ・Pressure Losses, etc.	・Integrated arrangement with Power Island Components

Knowledge of both Efficient Power Plant Cycle and Carbon Capture Technology is required

Mikawa PCC Pilot Plant

Plant Outline

Commenced:	September 29, 2009
Carbon Capture Technology:	Post Combustion Capture Amine-based Chemical Absorption (Toshiba's Solvent System)
Capture Capacity:	10 ton-CO_2 / day
Flue Gas Flow:	2100 Nm^3 / hour

Summary of Results (as of May, 2014)

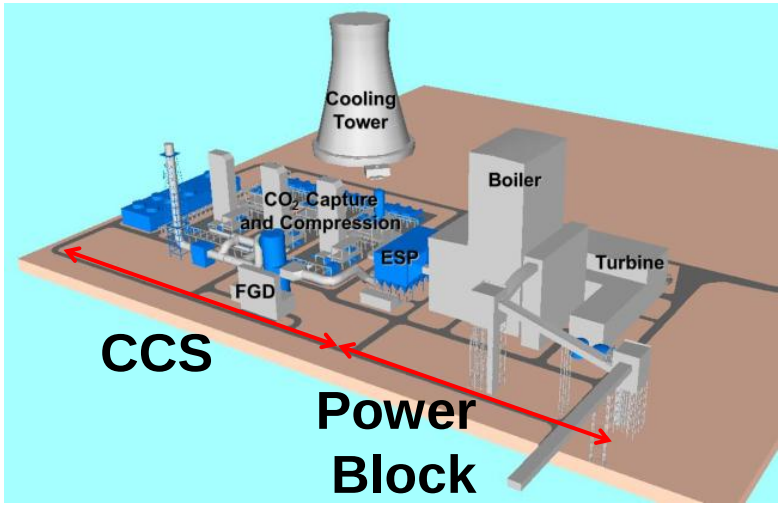
- Cumulative 8125 hours of operation
- CO_2 Recovery Energy: less than 2.4 GJ/ t-CO_2 (@90% CO_2 Capture, CO_2 Conc. approx. 12%)
- Verified system stability over 2800 hours of continuous operation.

CCS Plant Design Examples

Examples for Coal Fired Thermal Power Plants

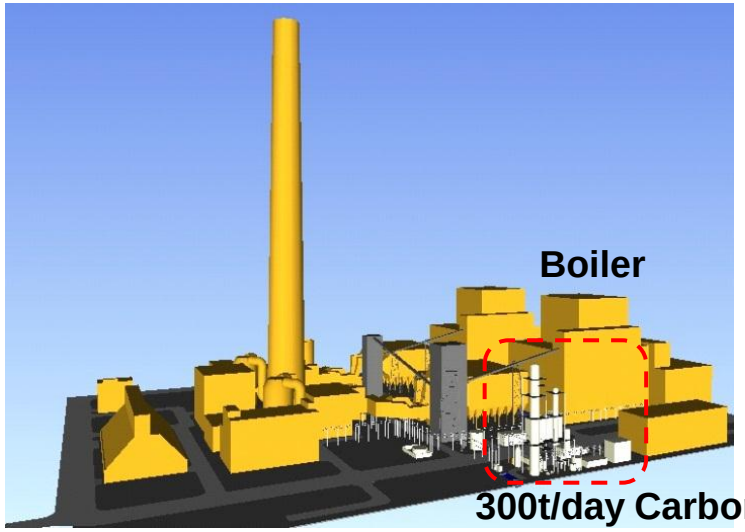
New Build

CCS (Ready) Plant Design for
New Build Power Plants (500MW Class)
・Full CO_2 Capture (90%)
・Space for CCS nearly equal
Space for Power Block



Retrofitting

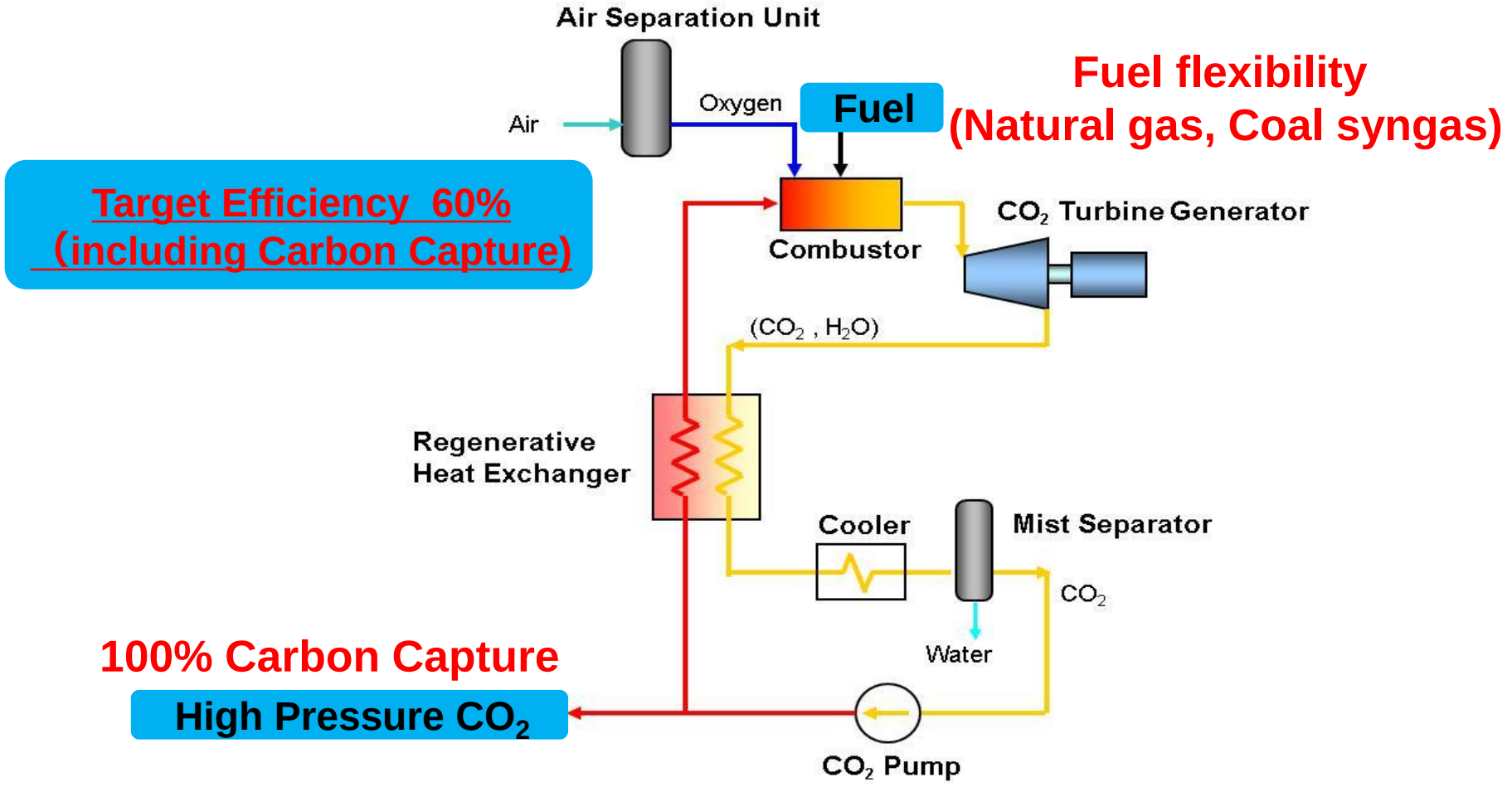
CCS Retrofit Design onto
Existing Power Plants (550MW Class)
・300t/day (3%) CO_2 Capture Planning
Power Output Loss Augmented by
Steam Turbine Uprate / Modification
・3000t/day (30%) CO_2 Capture Planning



300t/day Carbon Capture Plant

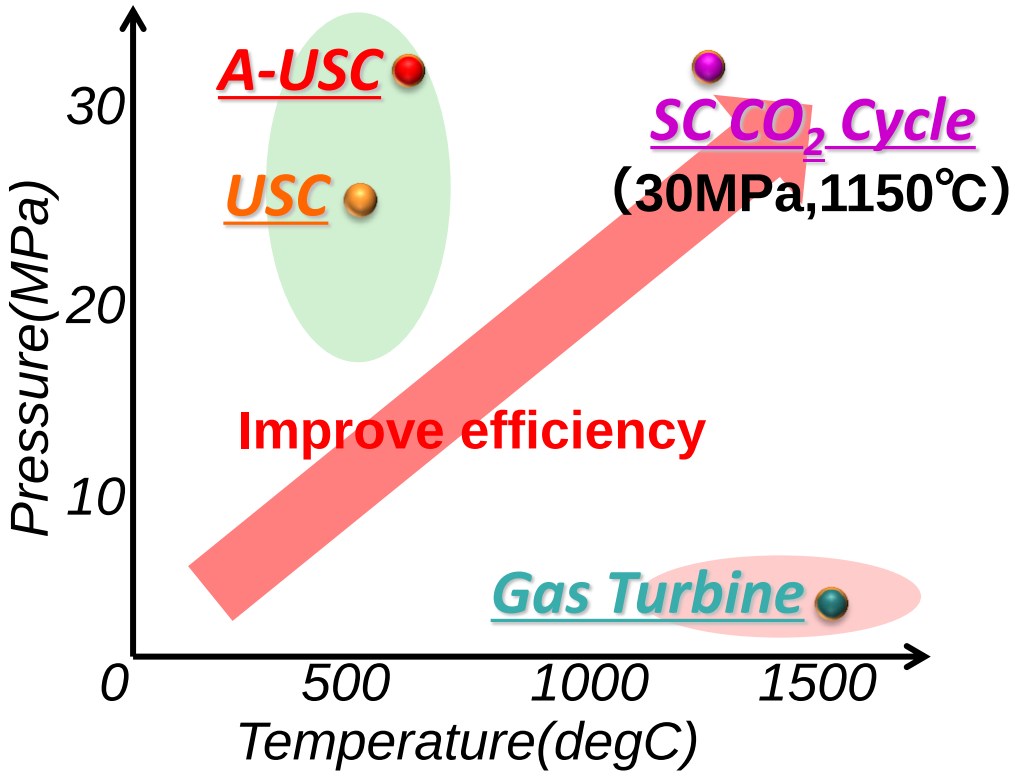
Supercritical CO_2 Circulated Cycle Thermal Power Plant

- ***Novel system for producing cheap, clean electricity from fossil fuels.***
- ***Generates zero atmospheric emissions (100% carbon capture)***
- ***Produces electricity at a lower cost compared to existing technologies.***



Supercritical CO_2 Circulated Cycle Thermal Power Plant

Gas and Steam Conditions

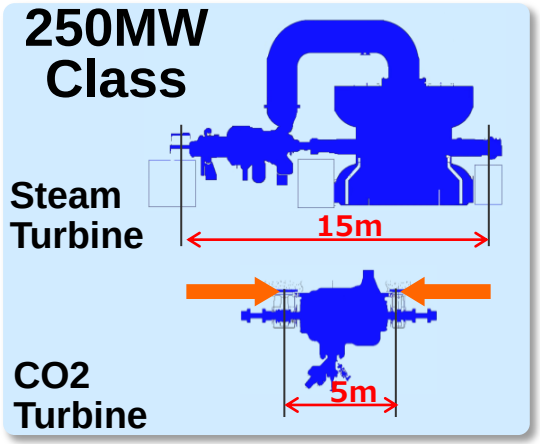


<New technology>

① Combustor
- Oxy-fuel combustion
- High - pressure combustor

② Supercritical CO_2 Cycle
- High pressure & temperature

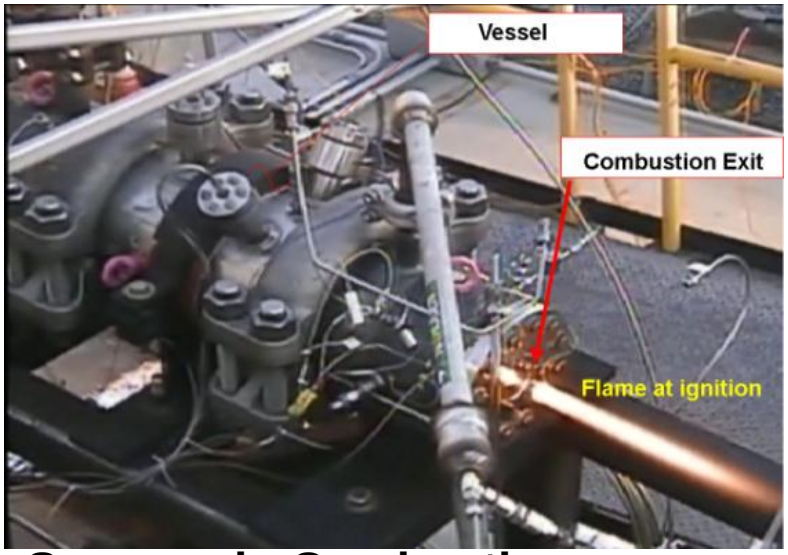
High energy density



Supercritical CO_2 Circulated Cycle Thermal Power Plant

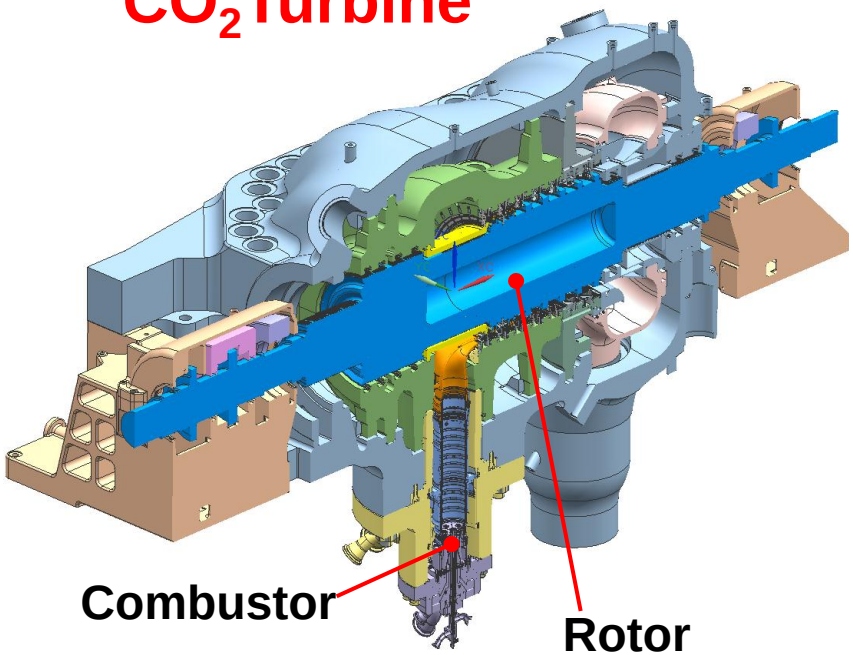
R&D Status

Combustor



Success in Combustion
Aug 2013 in California

CO_2 Turbine



(Nickel based Alloy)

25MW Class Design Complete

- **Blade Cooling system (Gas Flow Balance, Coating)**
- **Rotor System Dynamics**

Summary of Results (as of May, 2014)

Verified stability of combustion

- **Low level vibration**
- **High combustion efficiency**

Conclusion

TOSHIBA contributes to improvement of coal fired thermal power plants

- ✓ **Enhancement of thermal power plant efficiency**
  - ➢ **Broad experiences of USC**
  - ➢ **Advanced Technologies for A-USC**
- ✓ **Reduction in CO_2 emission**
  - ➢ **Post Combustion Capture Technology**
  - ➢ **Super Critical CO_2 Circulated Cycle**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