Repowering of Thermal Power Plants as Fully-Fired Combined Cycle Generating Plants

Takao Koike

Chubu Electric Power Co., Inc. Nagoya, Japan

Yoshiki Noguchi

HITACHI, Ltd. Tokyo, Japan

1. INTRODUCTION OF EXISTING POWER PLANT REPOWERING

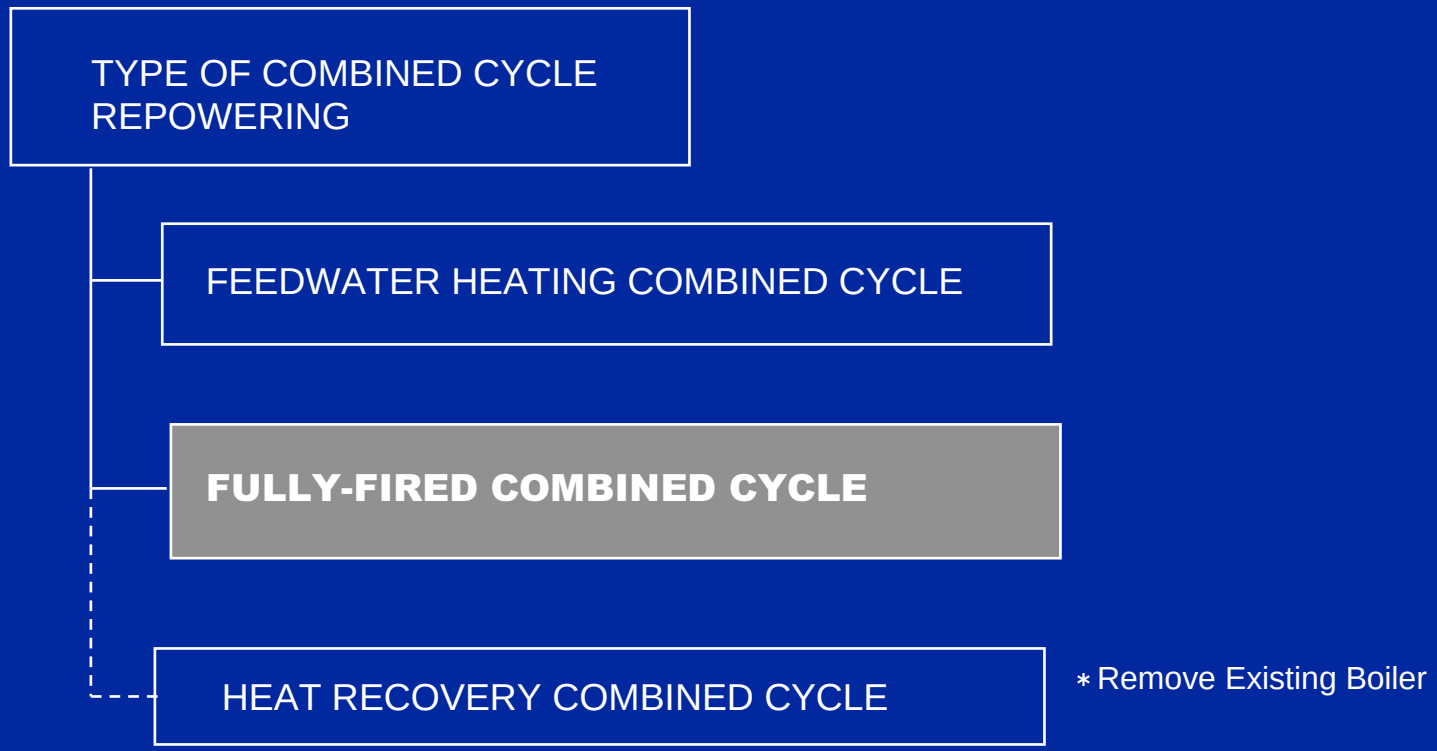
· REQUIREMENTS

A) REDUCTION OF POWER GENERATING COST ····· **Economy**

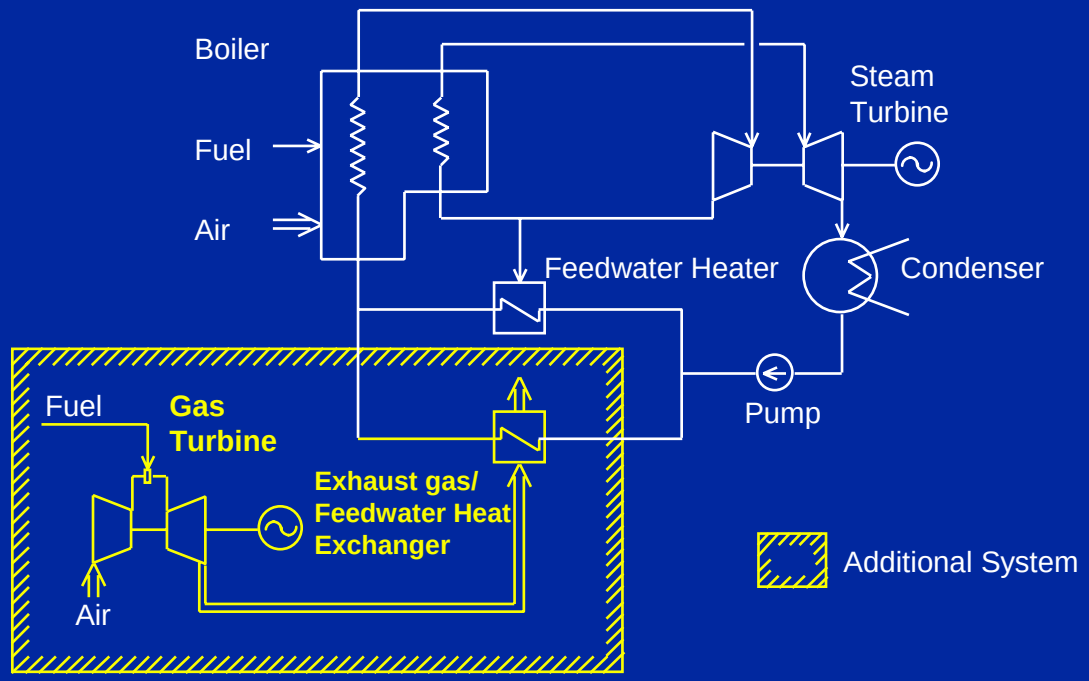
B) REDUCTION OF CARBON DIOXIDE EMISSIONS ····· **Environment**

C) IMPROVEMENT OF EFFICIENCY OF EXISTING POWER PLANTS ····· **Energy**

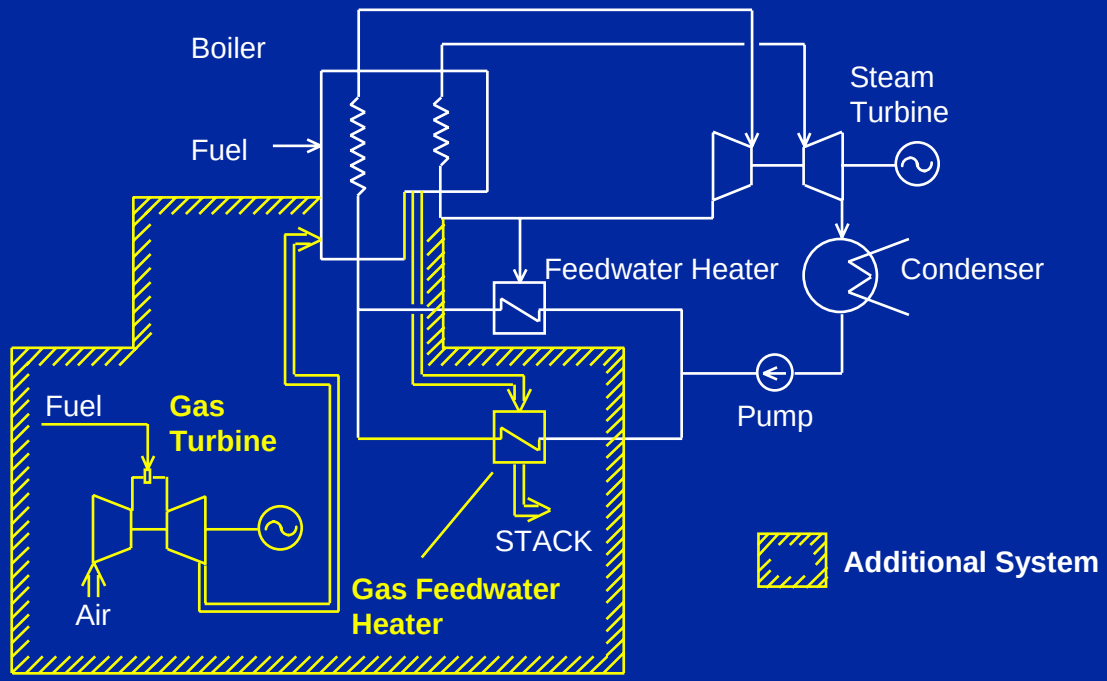
· SOLUTIONS



1.1 FEEDWATER HEATING COMBINED CYCLE

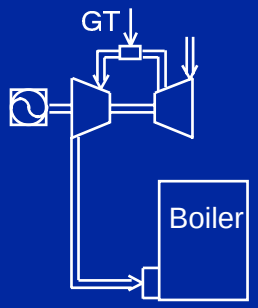
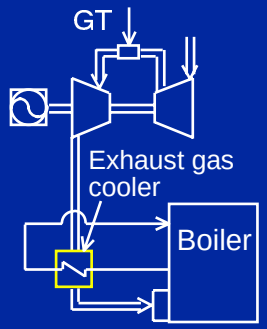
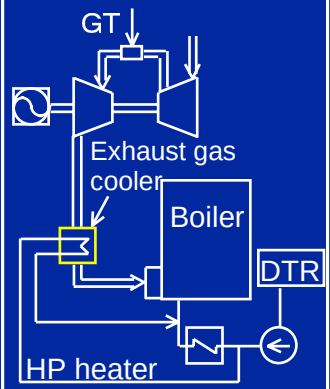
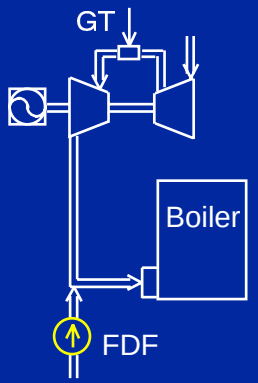
SYSTEM CONFIGURATION	
IMPROVEMENT IN PLANT EFFICIENCY	**Approx. 2 %** (Relatively)
MODIFICATION AND NEW INSTALLATION EQUIPMENT	**Modification Items** **Nil** **New Installation Equipments** **· GT generating equipment** **· GT exhaust gas duct** **· GT exhaust gas stack** **· Exhaust gas/feedwater heat exchanger**
REMARKS	1.New equipments can be installed while the existing power plant in operation. 2.Interconnection can be completed in less than eight weeks.

1.2 FULLY-FIRED COMBINED CYCLE

SYSTEM CONFIGURATION	
IMPROVEMENT IN PLANT EFFICIENCY	**Approx. 5～10%** * (Relatively)
MODIFICATION AND NEW INSTALLATION EQUIPMENT	**Modification** Items **・Boiler** **New Installation Equipments** **・GT generating equipment** **・GT exhaust gas duct** **・Gas feedwater heater**
REMARKS	Modification of the existing plant can be completed in less than six months.

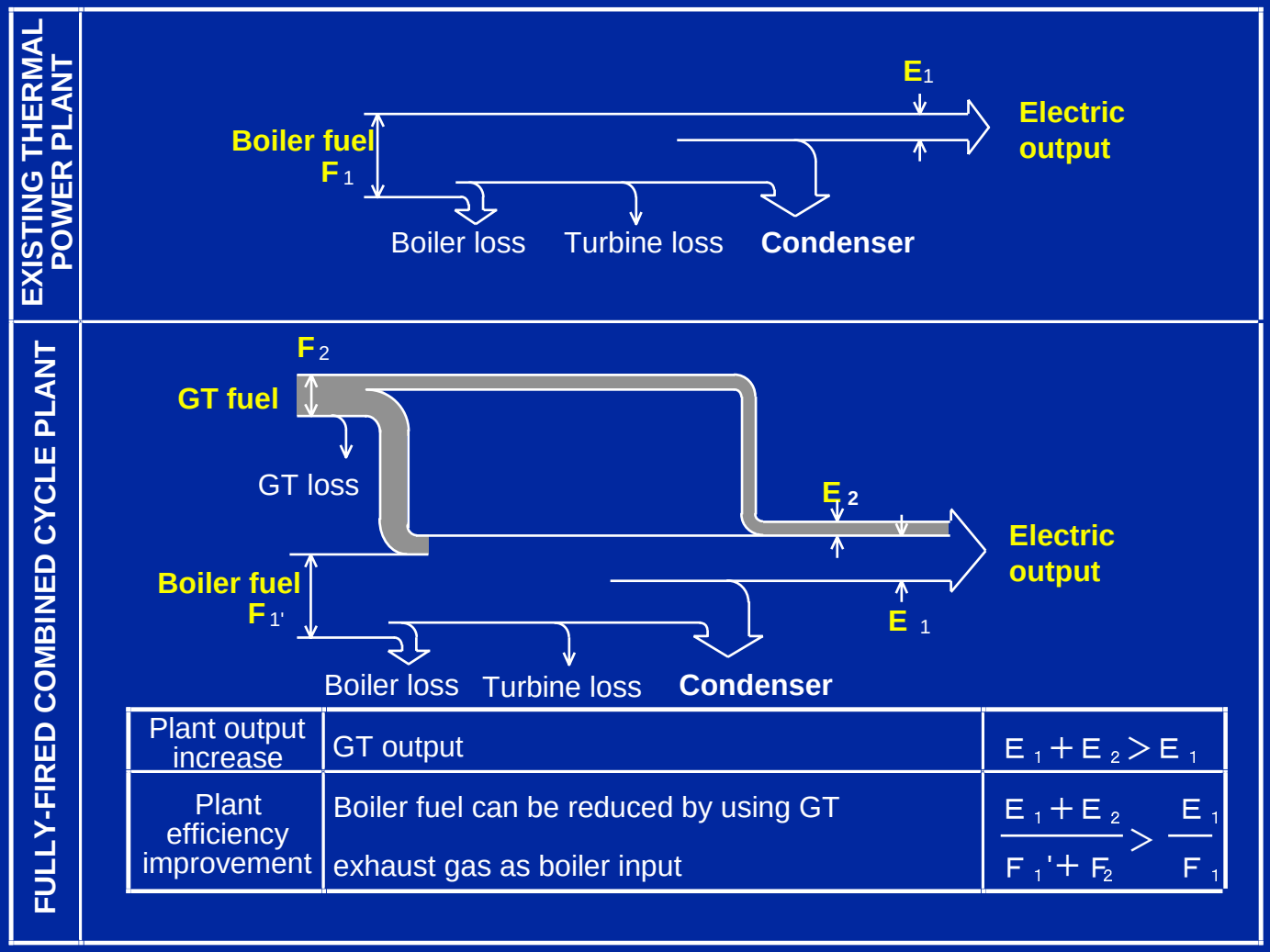
* It depends on system configuration around the GT and Boiler show in the table of Item No.1.4 (Next page)

1.3 SYSTEM CONFIGURATION AROUND THE GT AND BOILER

Item	High temperature wind box	GT exhaust gas cooler		FD fan mixing-injection
Heat recovery equipment of GT exhaust gas	Boiler	Boiler evaporator	Feed water heater	Boiler
Configuration				
Improvement of the thermal efficiency(relatively)	⊕ 8～10% *1)	⊕ 8～10% *1)	⊕ 5～6% *1)	⊕ 3～4 %
Modification of the boiler	Largest	Larger	Smaller	Smallest
Remarks	・Thermal analysis for the interface between the boiler and wind box is required. ・The wind box shall be made of materials such as low alloy steel or stainless steel.	・Exhaust gas cooler is designed as a boiler evaporator. ・Bypass system around the boiler evaporator is required.	・Bypass system around the feed water system is required.	・A gas mixing device is required for the mixing point of GT exhaust gas and FDF air.
Period of modification work	Longer	Longer	**Shorter**	**Shorter**

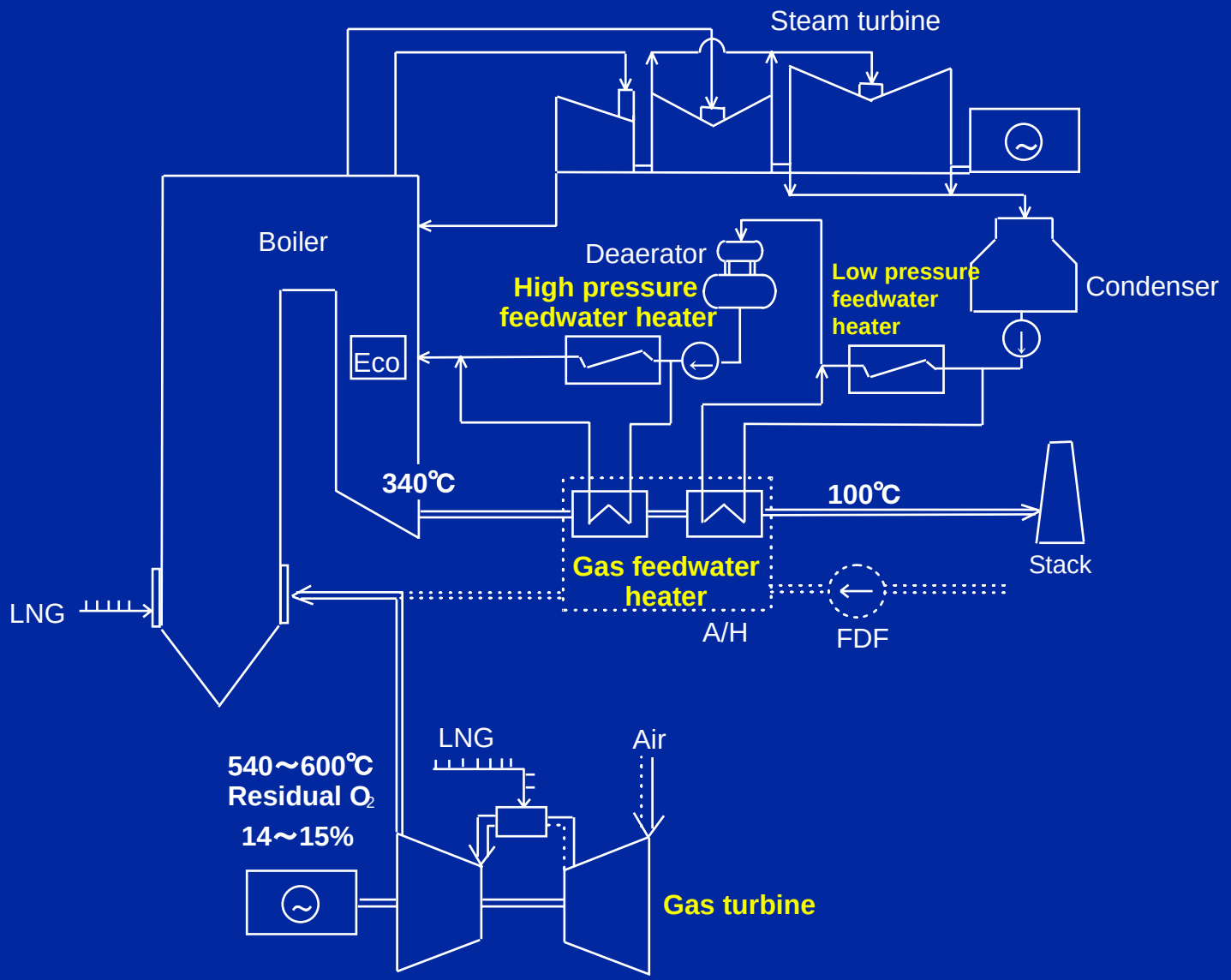
*1)In case that gas turbine exhaust gas flow is Just matched to boiler combustion air required.

1.4 PLANT EFFICIENCY IMPROVEMENT BY CONVERTING TO FULLY-FIRED COMBINED CYCLE PLANT



Plant output increase	GT output	$E_1 + E_2 > E_1$
Plant efficiency improvement	Boiler fuel can be reduced by using GT exhaust gas as boiler input	$\frac{E_1 + E_2}{F_1' + F_2} > \frac{E_1}{F_1}$

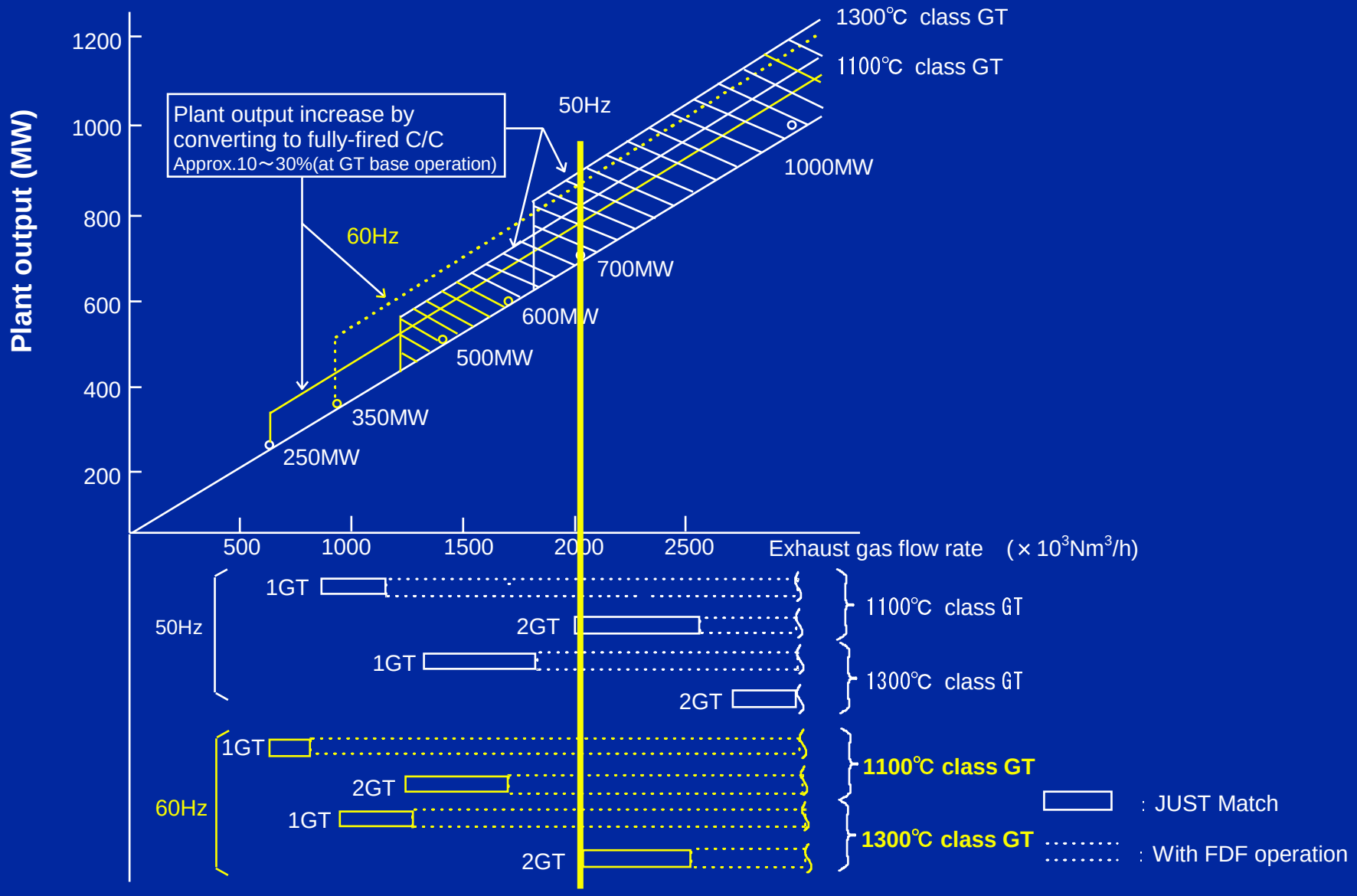
1.5 BASIC CONFIGURATION OF FULLY-FIRED COMBINED CYCLE PLANT



1.6 BASIC ENGINEERING FOR FULLY-FIRED COMBINED CYCLE PLANT

Item		Basic engineering	Consideration
Performance	**・ Increase of output** **・ Improvement of efficiency**	・ Adoption of high **efficiency** gas turbine ・ Selection of heat recovery type ・ Selection of gas turbine to match the existing boiler	・ Utilization of gas turbine exhaust gas as a combustion air ・ Effective utilization of exhaust heat of gas turbine and boiler ・ Increase of plant output is equal to gas turbine output ・ Plant efficiency improvement (depend on cycle configuration)
Environment	**・ Boiler exhaust gas** **・ Cooling water for condenser**	・ Study on **environmental** regulation or requirements	・ Exhaust gas flow rate from boiler will be increased ・ NOx from stack shall be less than the limitation ・ Increase of cooling water flow rate for condenser, or Increase of temperature rise of cooling water for condenser
Arrange-ment	**・ Site area**	・ **Compact** arrangement	・ Installation of gas turbine beside the existing thermal power plant
Schedule	**・ Modification schedule** **・ Shut-down period**	・ **Shorten** the modification period ・ **Shorten** the shut-down period	・ Construction work while the existing thermal power plant in operation ・ Effective utilization of inspection period ・ Shorten shut-down period
Operation	**・ Gas turbine**	・ Gas turbine simple cycle operation	・ Gas turbine simple cycle operation -Low efficiency -Environmental issue
	・ Steam turbine	・ Steam turbine independent operation is required or not	・ Depend on steam turbine output and plant operation
	・ Plant operation	・ Same operation flexibility as existing thermal power plant	・ Combined cycle operation by using high load change rate of gas turbine
Modification	**・ Existing equipment**	・ Utilization of existing equipment	・ Utilization of equipment for boiler exhaust gas ・ Utilization of existing stack
	・ Additional equipment	・ Removal of existing equipment ・ Additional equipments with gas turbine installation	・ Removal of FDF, A/H etc. ・ Addition of IDF, gas feedwater heater, gas duct, damper etc.

1.7 EXAMPLE OF SELECTION FOR GAS TURBINE TYPE

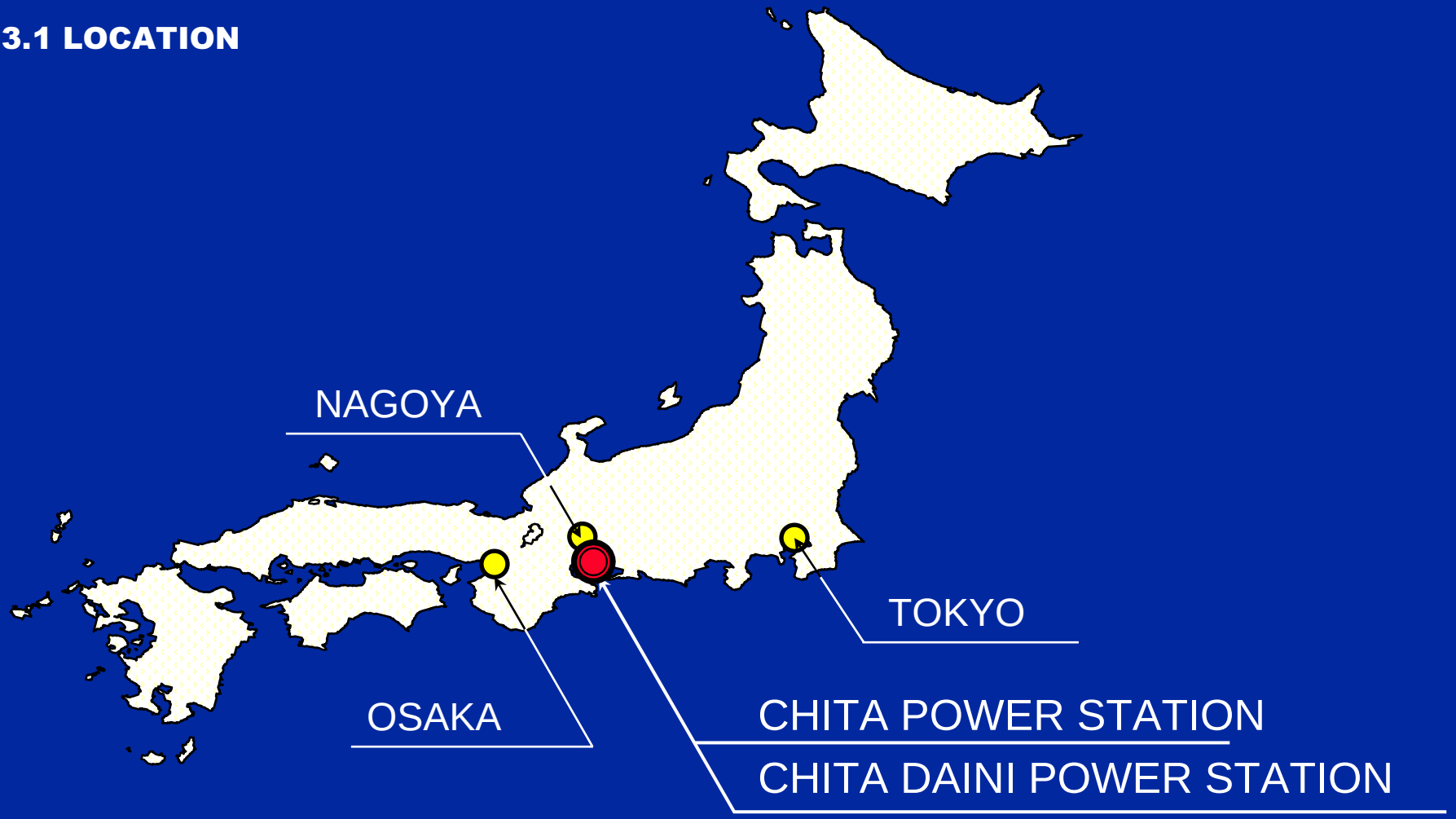


2. EXPERIENCES IN JAPAN

No.	Utility	Plant name	C/O	Output (MW)			Supplier			Remarks
				GT	**ST**	Plant	GT	Boiler	ST	
1	Tokyo Electric Power Co., Inc.	Goi Unit No.6	‘94/7	126	350	476	Hitachi	Hitachi	Hitachi	Repowering (Hitachi)
2	Chubu Electric Power Co., Inc.	**Chita Unit No.6**	‘94/9	**154**	**700**	**854**	Hitachi	Hitachi	Toshiba	Repowering (Hitachi)
3	Chubu Electric Power Co., Inc.	**Chita Daini Unit No.1**	‘94/9	**154**	**700**	**854**	Hitachi	Hitachi	Toshiba	Repowering (Hitachi)
4	Chubu Electric Power Co., Inc.	**Chita Unit No.5**	‘95/6	**154**	**700**	**854**	Hitachi	Hitachi	Toshiba	Repowering (Hitachi)
5	Chubu Electric Power Co., Inc.	Chita Unit No.2	‘95/8	154	375	529	Mitsubishi	Mitsubishi	Toshiba	Repowering (Mitsubishi)
6	Chubu Electric Power Co., Inc.	Chita Daini Unit No.2	‘96/7	154	700	854	Toshiba	IHI	Toshiba	Repowering (Toshiba)
7	Chubu Electric Power Co., Inc.	Chita Unit No.1	‘96/8	154	375	529	Mitsubishi	Mitsubishi	Toshiba	Repowering (Mitsubishi)

3. REPOWERING FOR CHITA POWER PLANT AND CHITA SECOND POWER PLANT OF CHUBU ELECTRIC POWER Co., Inc.

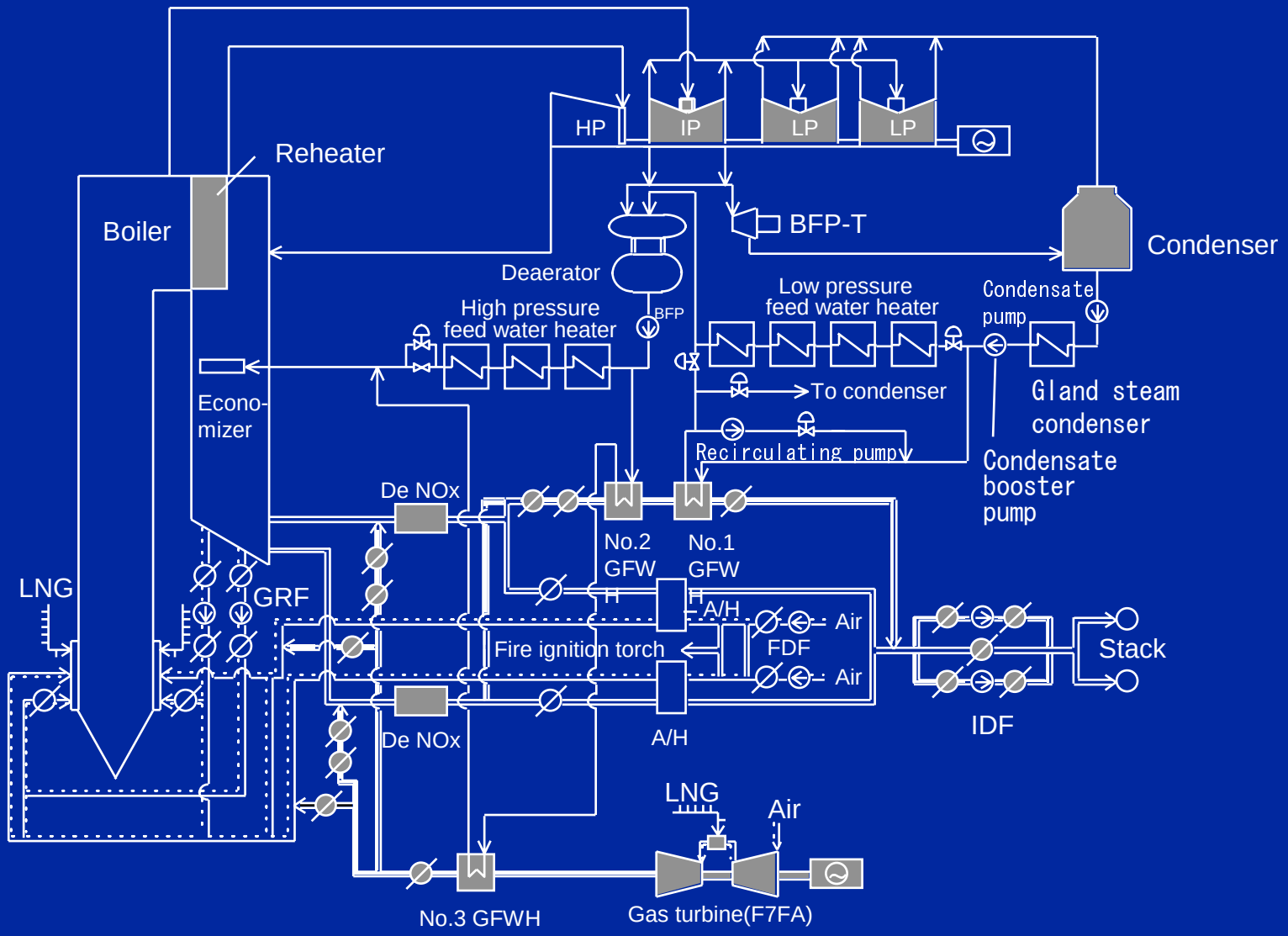
3.1 LOCATION



3.2 MAIN SPECIFICATION

Item	Before repowering		After repowering	
	Chita Unit No.5,6	Chita Daini Unit No.1	Chita Unit No.5,6	Chita Daini Unit No.1
Plant output	700MW		854MW	
Steam turbine output	700MW		700MW	
Gas turbine output	–		154MW	
Boiler	–		(Modification)	
Type	Supercritical, constant pressure once-through reheat system	Supercritical, sliding pressure once-through reheat system	Supercritical, constant pressure once-through reheat system	Supercritical, sliding pressure once-through reheat system
MCR	2300t/h		2150t/h	2050t/h
Air supply system	Forced	Forced	induced	induced
Fuel	LNG		LNG	
Steam turbine	–		(Modification)	
Type	TC4F-33.5		TC4F-33.5	
Vacuum of Condenser	722mmHg		717mmHg	
Gas turbine	–		(Newly installed)	
Type			Single-shaft type	
Model			F7FA	
firing Temperature			1288℃	
Fuel			LNG	
Commercial operation	#5:1978.5 #6:1978.4	1983.9	#5:1995.6 #6:1994.9	1994.9

3.3 SYSTEM CONFIGURATION



Gray areas indicate newly installed or modified sections.

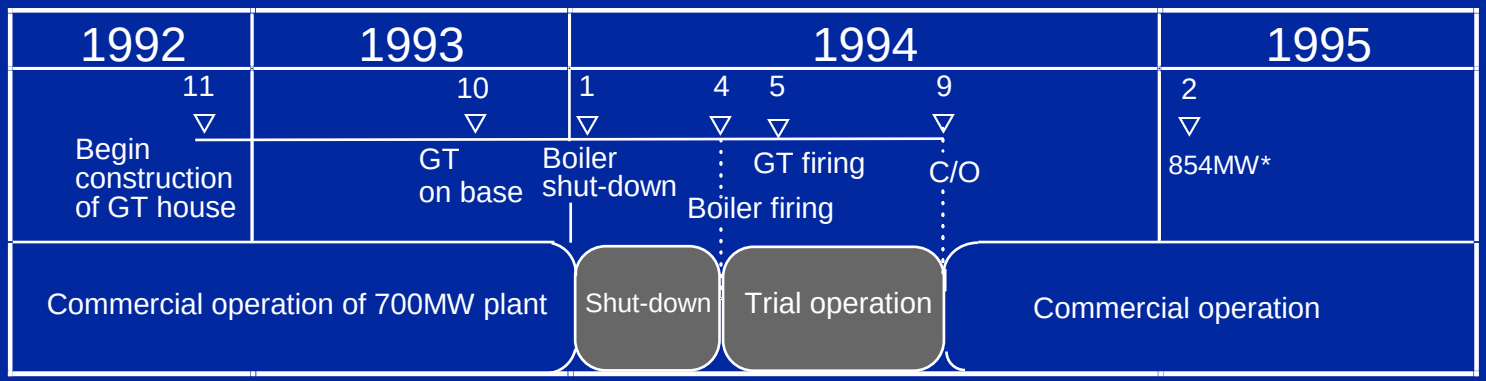
3.4 SYSTEM FEATURE

Item	Feature
Gas turbine exhaust gas heat recovery system	Feed water heating system No.3 gas feed water heater (newly installed) (Gas turbine exhaust temp. : about 600℃→350℃)
Boiler exhaust gas heat recovery system	No.2 gas feed water heater (newly installed) No.1 gas feed water heater (newly installed) Boiler exhaust gas temp. (about 350℃) →Stack inlet gas temp. (about 100℃)
Boiler bypass duct	Newly installed (For plant start-up and partial load operation)
Forced draft fan/ air heater	Existing equipment (Gas turbine exhaust gas flow ＜ Boiler required air flow) (Steam turbine independent operation possible)
Induced draft fan	Newly installed (For adjustment of gas turbine exhaust draft)

3.5 INSTALLATION AND TRIAL OPERATION SCHEDULE

- Add F7FA gas turbine to existing 700MW thermal power plant
- Repowering to 854MW fully-fired combined cycle plant
- Modification of repowering is completed with shut-down period of three(3) months

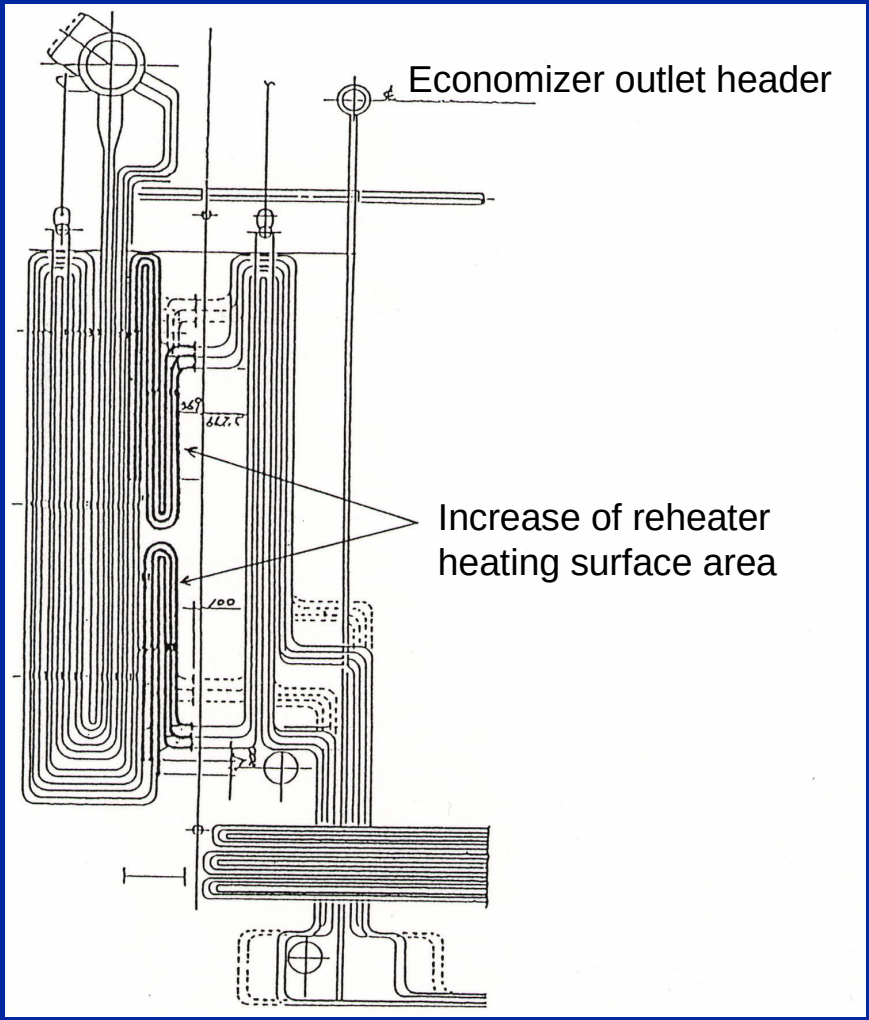
Construction schedule of repowering



*) Authorized output

(Example of Chita Unit No.6)

3.6 MODIFICATION OF BOILER



Example of Chita Unit No.6

Heating surface area of reheater is increased because steam flow rate and heat load of reheater is increased by converting to fully-fired combined cycle plant.

The modification of combustion facility is necessary to introduce fresh air to ignition torch because low O2 gas turbine exhaust gas is used as boiler combustion air source.

Catalyst and plate type catalyst are increased because exhaust gas flow and NOx concentration is increased by adding gas turbine.

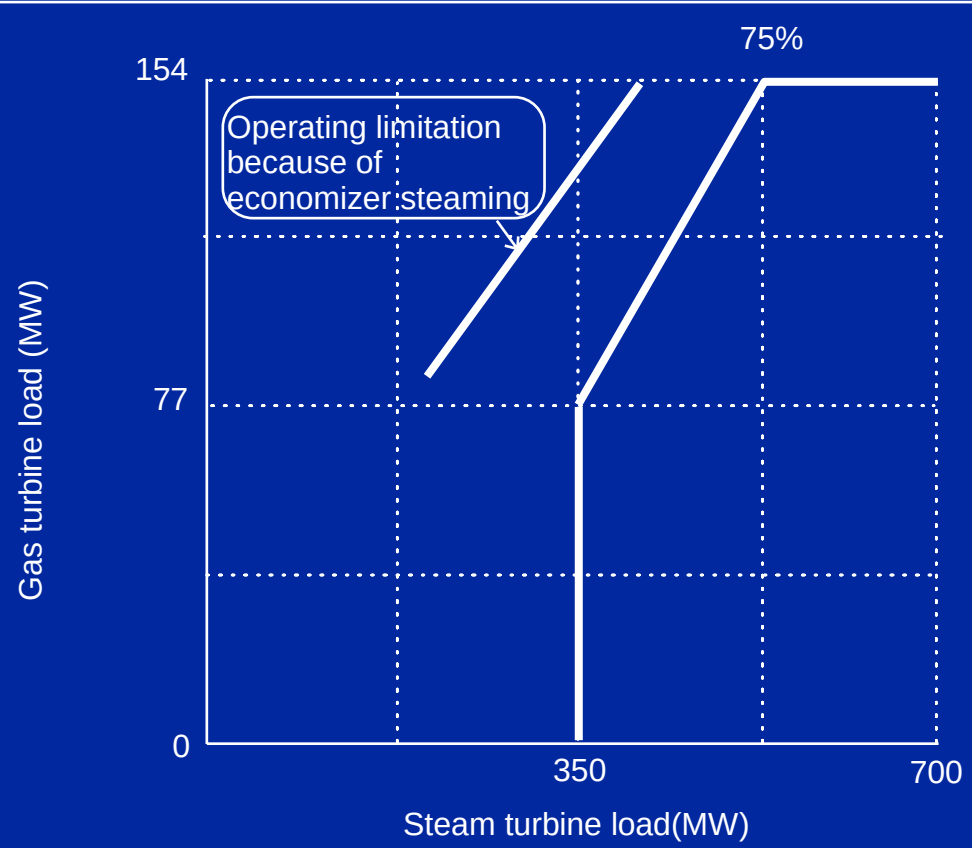
3.7 MODIFICATION OF STEAM TURBINE PLANT

Further investigation for the modification of the condenser and circulating water system is required because the heat load of the condenser is increased due to the addition of a gas turbine

Item	Chita Unit No.6	Chita Daini Unit No.1
Steam turbine	IP and LP nozzle(newly exchanged)	LP nozzle (newly exchanged)
	(because of the increasing the IP/LP section steam flow)	
Gas turbine auxiliary cooling water facility	Dry type radiator (for gas turbine plant)	Dry type radiator (for gas turbine plant)
Condenser	Re -used (cooling water flow not changed)	Re -used (cooling water flow not change)
Circulating water system	Re -used	Re -used
Condensate water system	Re -used (operate stand-by equipment)	Re -used (operate stand-by equipment)
Boiler feed water pump (driven by steam turbine)	Re -used	Re -used

3.8 PLANT OPERATION
GAS TURBINE AND STEAM TURBINE LOAD

- Gas turbine is started at 50% steam turbine load from the view point of high efficiency operation
- Gas turbine is operated as high load as possible



3.9 PLANT PERFORMANCE TEST RESULT

Item		Chita Unit No.5	Chita Unit No.6	Chita Daini Unit No.1
Gas turbine output		154MW	154MW	154MW
Plant efficiency improvement *1)	Result	5.8%	5.0%	5.7%
	Target	3.7%	3.7%	3.5%
Plant efficiency (HHV) (Combined cycle operation)		40.0%	40.1%	40.7%
Plant efficiency (HHV) (Steam turbine independent operation)		37.8%	38.2%	38.5%

*1) Plant efficiency improvement shows the relative improved efficiency between steam turbine independent operation and combined cycle operation.

4. REDUCTION VALUE OF CARBON DIOXIDE EMISSIONS

Type of Power Plant	Conventional	Conventional	Fully-Fired Combined Cycle (After Repowering)	Advanced Combined Cycle
Fuel	Coal Fired	LNG Fired	LNG Fired	LNG Fired
Unit Gross Output	700MW	700MW	845MW	235MW
CO2 emission *1)2) per gross output (kg-CO2/kWh)	0.80 (kg-CO2/kWh)	0.58 (kg-CO2/kWh)	0.54 (kg-CO2/kWh)	0.45 (kg-CO2/kWh)
	[Base]	**[- 28%]**	**[- 32 %]**	**[- 44 %]**

Assumption : Type of Power plant units are selected as typical examples.

*1) CO2 emission = Energy Consumption x Carbon emission factor
x Fraction of Carbon Oxidised x 44/12

*2) Operating hour is 6100 hr/year (70% Capacity Factor)