천연가스 복합사이클 플랜트의 시뮬레이션 연구

Simulation Study on the Natural Gas Fired Combined Cycle Power Plants

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조병화*, 이진욱, 이찬, 강승종

(고등기술연구원, 전력에너지연구실)

BOUNG WHA CHO*, JIN WOOK LEE, CHAN LEE, SEUNG JONK KANG

(Electrical Power System Laboratory, Institute for Advanced Engineering)

I. INTRODUCTION

GAS TURBINE POWER GENERATION SYSTEM

ADVANTAGES

1. Short Construction Schedule
2. Low Capital Cost
3. Low Environmental Emission

DISADVANTAGES

1. Low Electric Rating Per Unit
2. Relatively Low Thermal Efficiency
3. Higher Fuel Cost : Natural Gas or Distillate Oil

COMBINED CYCLE POWER GENERATION SYSTEM

Add HRSG and Steam Turbine System to Gas Turbine System
to Overcome Disadvantages of Gas Turbine System

■ ADVANTAGES

1. Higher Electric Rating Per Unit
2. Higher Thermal Efficiency
3. Possibility of Phase Construction

■ DISADVANTAGE

1. Still Has Restriction on Fuel
   Future : IGCC, PFBC, Coal Fired G/T

■ Natural Gas Fired Combined Cycle in Present Study

II. SYSTEM MODELING

GAS TURBINE SYSTEM

■ Key Components of Gas Turbine

Compressor, Turbine, Combustor and Turbine Blade Cooling Circuit

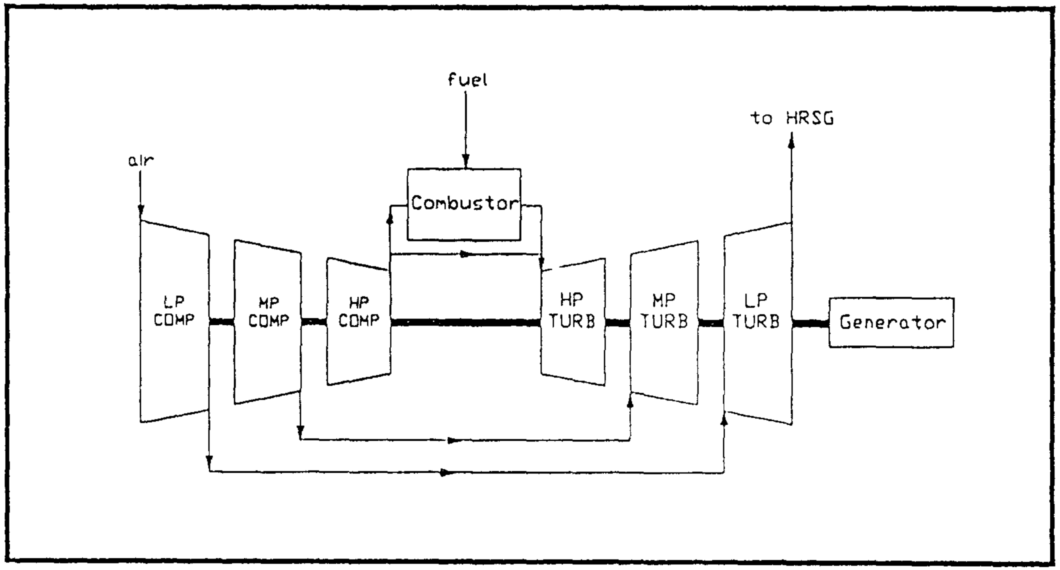


Fig. 1 Schematic Diagram of Gas Turbine System

■ Compressor and Turbine

Isentropic Operation

■ Gas Turbine Combustor

< Combustion Zone >

Stoichiometry Reactor Model

$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$

$C_2H_6 + 3.5O_2 \rightarrow 3H_2O + 2CO_2$

4% Heat loss and 4% Pressure loss assumed

< Dilution Zone >

Quenching of product gas by bypassed air from compressor interstage

Turbine Blade Cooling

< Used Bleeding Scheme >

$m_{C1} = m_{air}[(TIT/10^4) - 0.15]$, at $P_1 = (PR)^{1/2} \times P_{atm}$

$m_{C2} = m_{air}[(TIT/10^4) - 0.13]$, at $P_2 = (PR)^{2/3} \times P_{atm}$

$m_{C3} = m_{air}[(TIT/2x10^4) - 0.07]$, at $P_3 = (PR) \times P_{atm}$

TIT = 1,100K ~ 1,600K

< EPRI's Correlation of Turbine Cooling Method >

$$(\eta_T)_{COOLED} = (\eta_T)_{UNCOOLED}(1 - C_N(m_C/m_G)_N - C_B(m_C/m_G)_B)$$

Table 1 Effect of turbine cooling method to turbine efficiency

Method of Turbine Blade Cooling	Injection Fraction at Trailing Edge, %	CN	CB
Convection	100	0.00	0.00
Film/Convection Combination	75 50 25	0.12 0.15 0.18	0.24 0.30 0.36
Full Coverage Film	0	0.35	0.60
Transpiration/Convection Combination	25	0.50	1.00
Transpiration	0	1.00	1.50

II. SYSTEM MODELING (Cont'd)

STEAM TURBINE SYSTEM

- **HRSG (Heat Recovery Steam Generator)**

  A Series of Heat Exchangers
  Economizer(s), Evaporator(s), Superheater(s) and Reheater

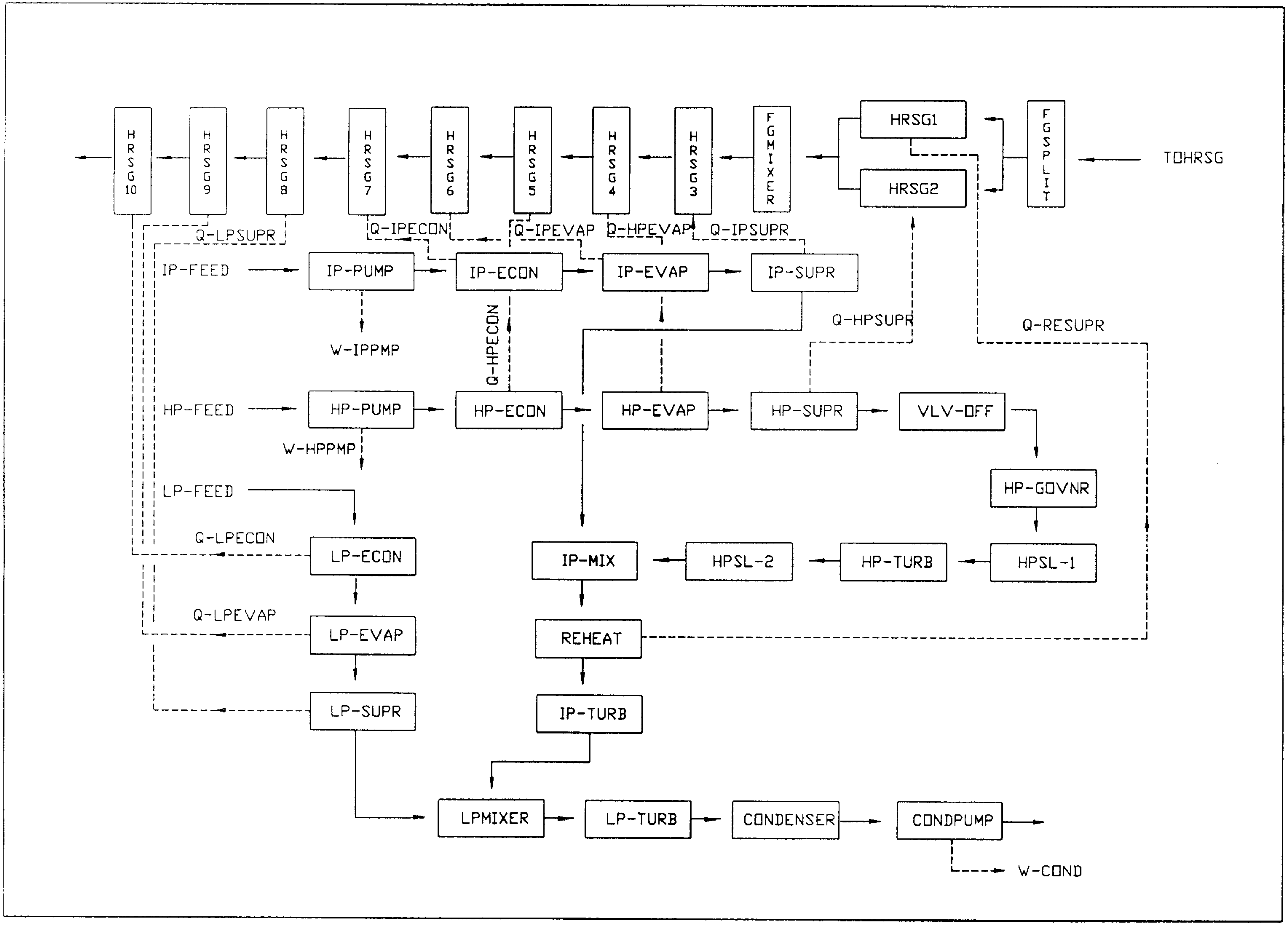
  1% Heat Loss at Each Section assumed

- **Steam Turbines**

  High Pressure Turbine
  Intermediate Pressure Turbine
  Low Pressure Turbine

- **Condensing Unit**

  Condenser, Feedwater Pump and auxiliary equipments


TOHRSG
FGSPLIT
HRSG1
HRSG2
FGMIXER
HRSG3
HRSG4
HRSG5
HRSG6
HRSG7
HRSG8
HRSG9
HRSG10
Q-LPSUPR
Q-IPECON
Q-IPEVAP
Q-HPEVAP
Q-IPSUPR
IP-FEED
IP-PUMP
IP-ECON
IP-EVAP
IP-SUPR
Q-HPSUPR
Q-RESUPR
W-IPPMP
Q-HPECON
HP-FEED
HP-PUMP
HP-ECON
HP-EVAP
HP-SUPR
VLV-OFF
W-HPPMP
HP-GOVNR
LP-FEED
Q-LPECON
LP-ECON
IP-MIX
HPSL-2
HP-TURB
HPSL-1
Q-LPEVAP
LP-EVAP
REHEAT
LP-SUPR
IP-TURB
LPMIXER
LP-TURB
CONDENSER
CONDPUMP
W-COND

Case Study

Case 1 Single Pressure Steam Cycle
Case 2 Dual Pressure Steam Cycle
Case 3 Dual Pressure Steam Cycle with Advanced HRSG Design Concept
Case 4 Triple Pressure Steam Cycle
Case 5 Triple Pressure Steam Cycle with Advanced HRSG Design Concept

Case 5 : Based on Design Concept of Korea Seo-Incheon
Combined Cycle Power Plant

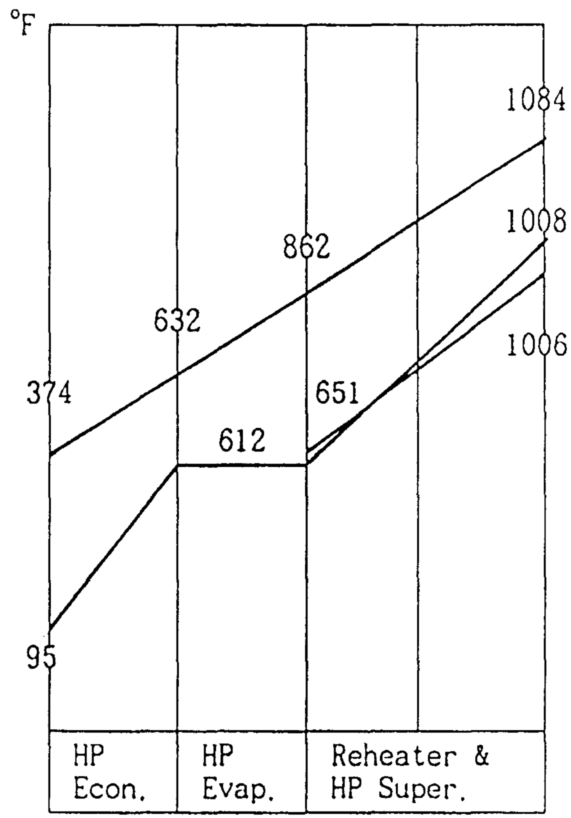


Fig. 2 Temperature of flue gas and feedwater/steam at each section of HRSG for case 1.

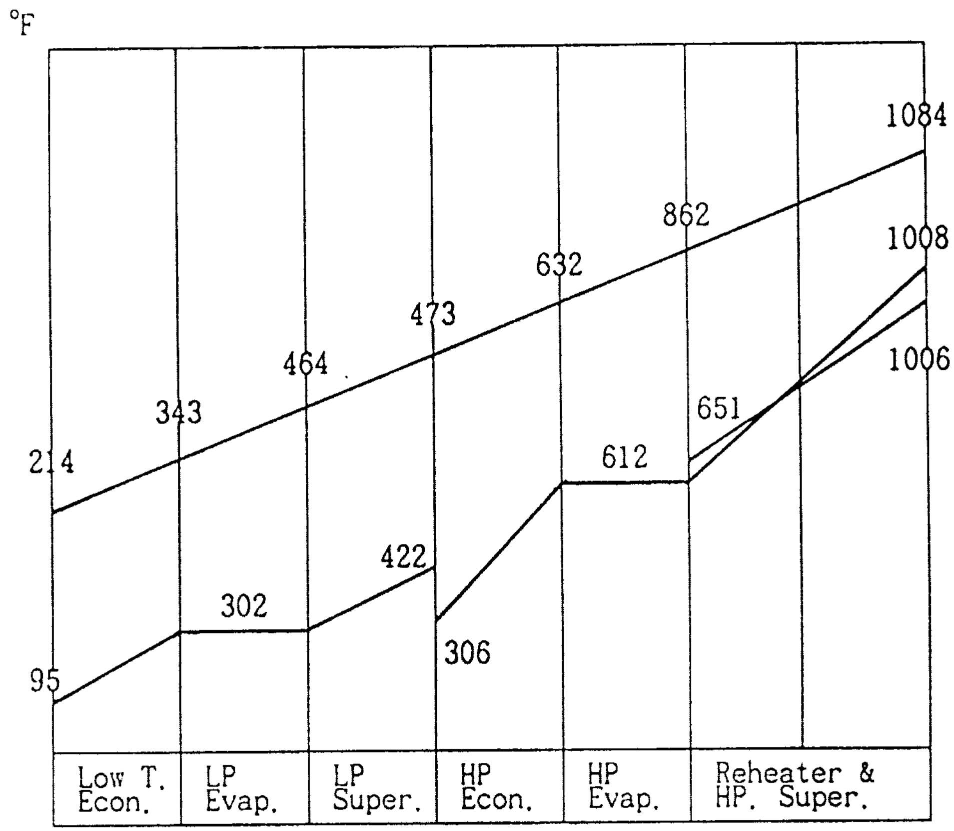


Fig. 3 Temperature of flue gas and feedwater/steam at each section of HRSG for case 2.

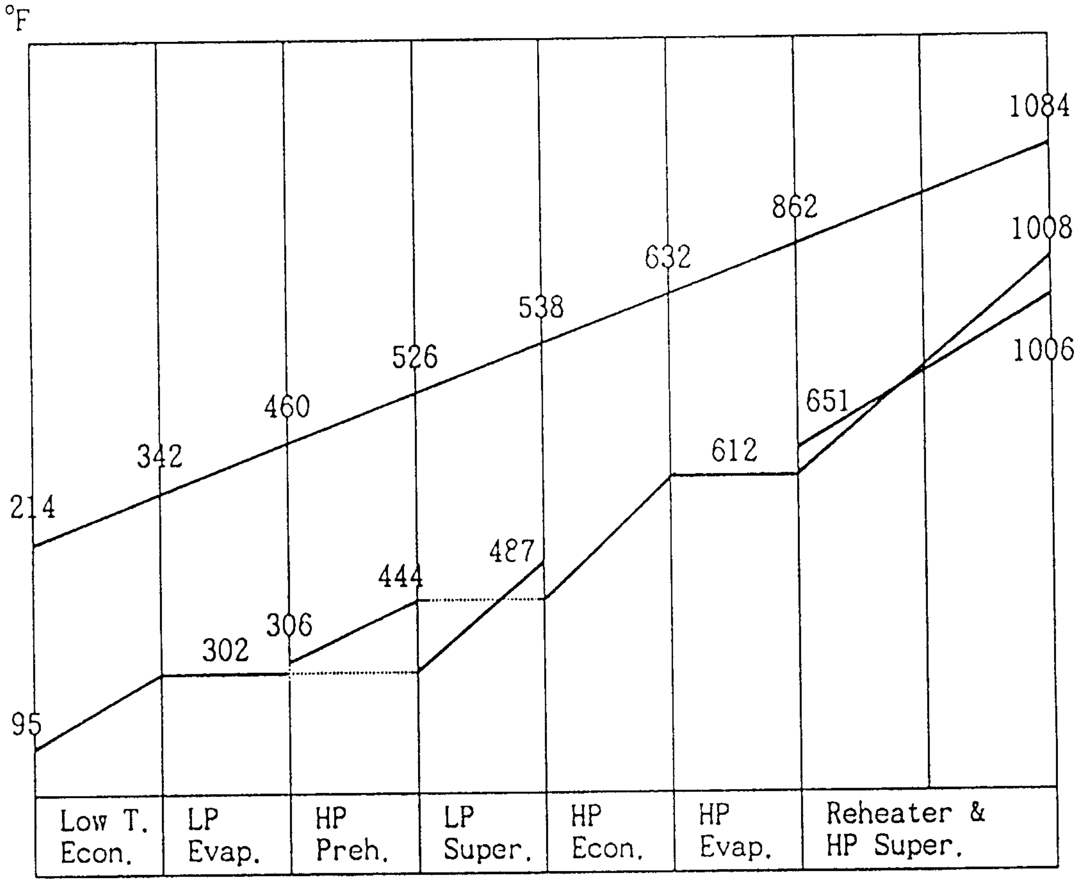


Fig. 4 Temperature of flue gas and feedwater/steam at each section of HRSG for case 3.

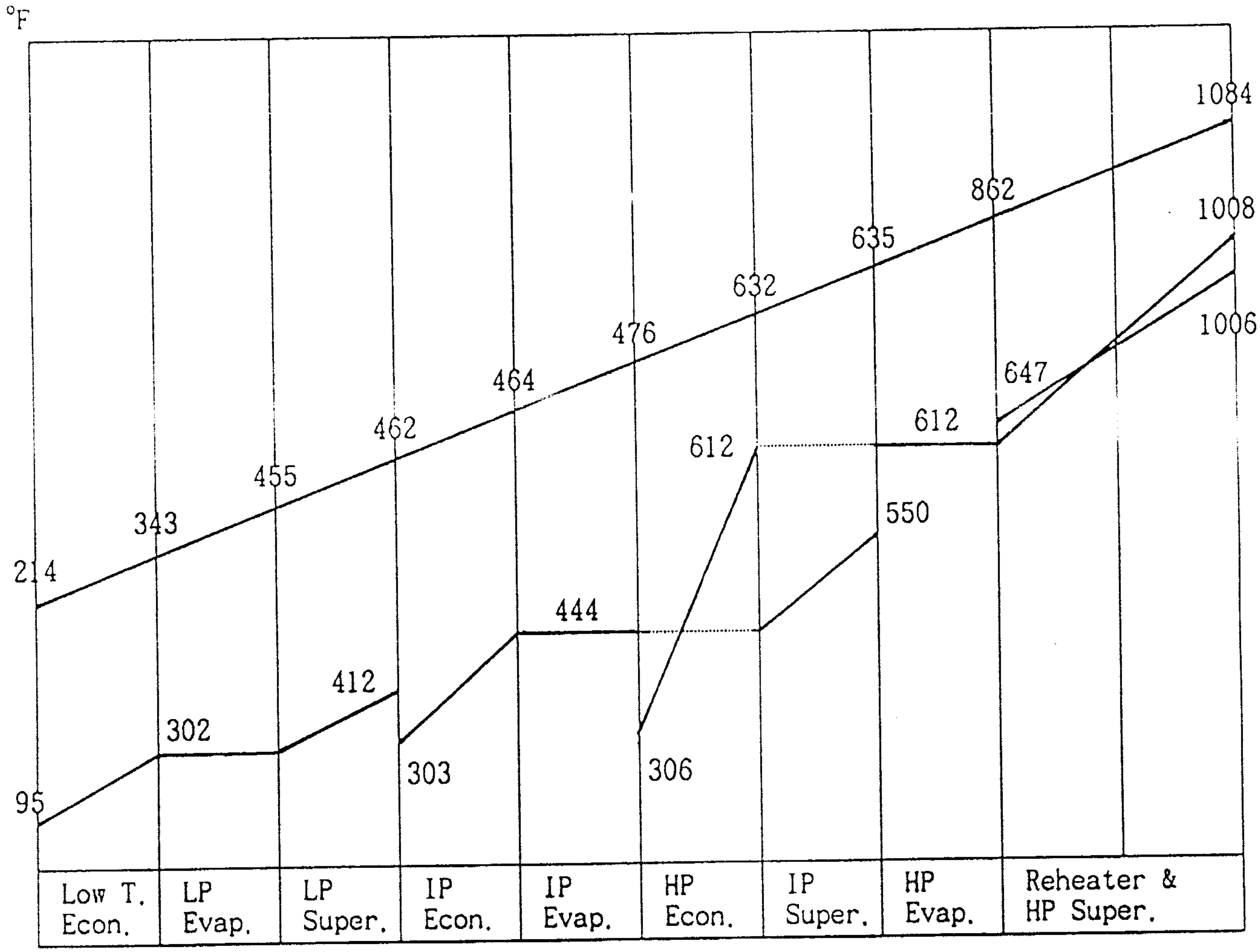


Fig. 5 Temperature of flue gas and feedwater/steam at each section of HRSG for case 4.

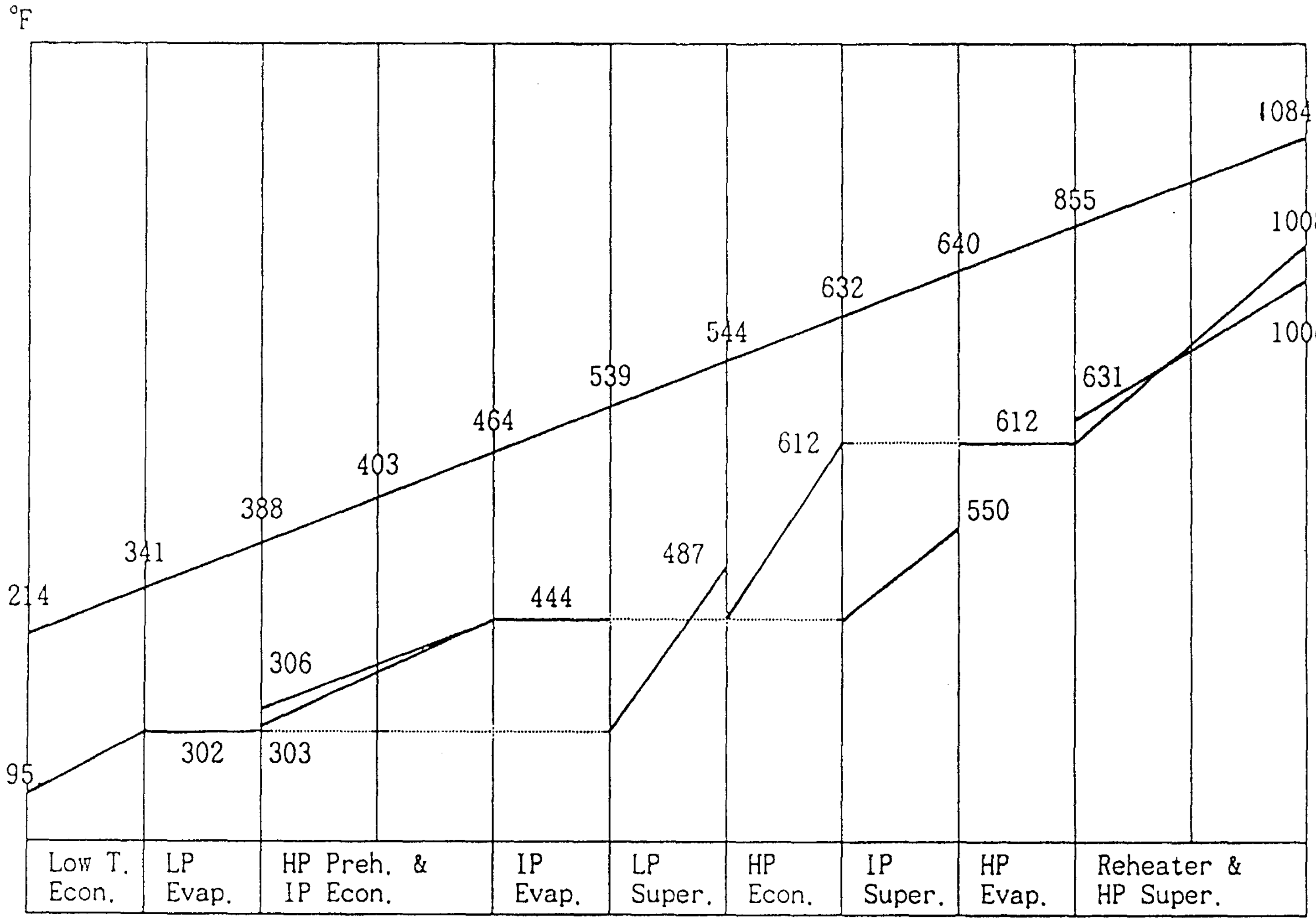


Fig. 6 Temperature of flue gas and feedwater/steam at each section of HRSG for case 5.

III. RESULTS & DISCUSSION

■ PERFORMANCE PREDICTION RESULT

Table 2 Performance prediction result for Seo-Incheon combined cycle power plant

Performance Variables	Present Study	Plant Data [5]	Relative Error
Gas Turbine Power (MW)	151.2	152.8	- 1.04 %
Steam Turbine Power (MW)	82.9	82.9	0.01 %
Combined Cycle Power (MW)	234.1	235.8	- 0.72 %
Heat Input (Gcal/Hr, LHV)	363.5	370.1	- 1.82 %
Turbine Exit Temperature (F)	1054.5	1059.3	- 0.45 %
Combined Cycle Efficiency (%)	55.4	53.9	2.78 %

■ CASE STUDY FOR STEAM TURBINE CYCLE

Table 3 Results of Performance analysis for steam turbine cycle

Variables		Case 1	Case 2	Case 3	Case 4	Case 5	Plant Data[5]
HRSG Inlet Temp. (F) Flue-Gas Flow Rate (Klb/Hr)		1054.5 3380.1					1059.3 3367.1
Steam Flow Rate (Klb/Hr)	HP steam IP steam LP steam	394.05 - -	394.05 - 114.66	394.05 - 111.64	388.63 13.45 105.93	368.19 83.73 44.22	378.53 78.93 40.12
HRSG Exit Temp. (F)		374.4	213.8	213.8	213.8	213.8	213.8
Turbine Power (MW)		72.62	80.82	81.03	81.00	82.89	82.90

IV. CONCLUSION

■ PERFORMANCE PREDICTION RESULT

Qualitatively and Quantitatively Well Consistent with Real Plant Data

■ CASE STUDY

Higher Performance by Dual or Triple Pressure Cycle

Higher Performance by Proper Arrangement of Heat Exchangers in HRSG