V94.2 Buggenum Experience and Improved Concepts for Syngas Applications

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Power Generation

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- Buggenum Plant Concept and Performance Data
- Gas Turbine and Interconnected Syngas Fuel System
- Plant Availability and Measures for Improvement
- V94.2 Syngas Features
- Lessons Learned and New Standardised Concept
- New Developments/ Future Plants

Buggenum IGCC Power Plant Nuon

Location:	Buggenum / Netherlands
Feedstock:	Import Coal
Secondary Fuel:	Natural Gas
Gasifier:	Shell
Air Separation Unit:	Air Products
Gas Cleaning:	Schumacher Candle; Sulfinol Desulfurization, Claus
Combined Cycle:	Siemens Single Shaft Configuration
Gas Turbine:	Siemens V94.2
Steam Turbine:	Siemens KN
Generator:	Siemens (THLR, Hydrogen Cooled)
I&C for IGCC:	Hartmann & Braun
IGCC Configuration:	Fully Integrated
Net Plant Capacity:	253 MW
Net Efficiency:	43 %
Start-up Date:	With Natural Gas 1993 With Syngas 1994/95
Operating Hours:	42,500 h (09/2002)
Syngas Operation:	33,700 h (09/2002)
Operation Mode:	Commercial Operation

Plant Integration

- **Fully Integrated Concept on the Air and Nitrogen Side**
- **W/S integration between Gasifier with Syngas Cooler and Combined Cycle**

Performance Data

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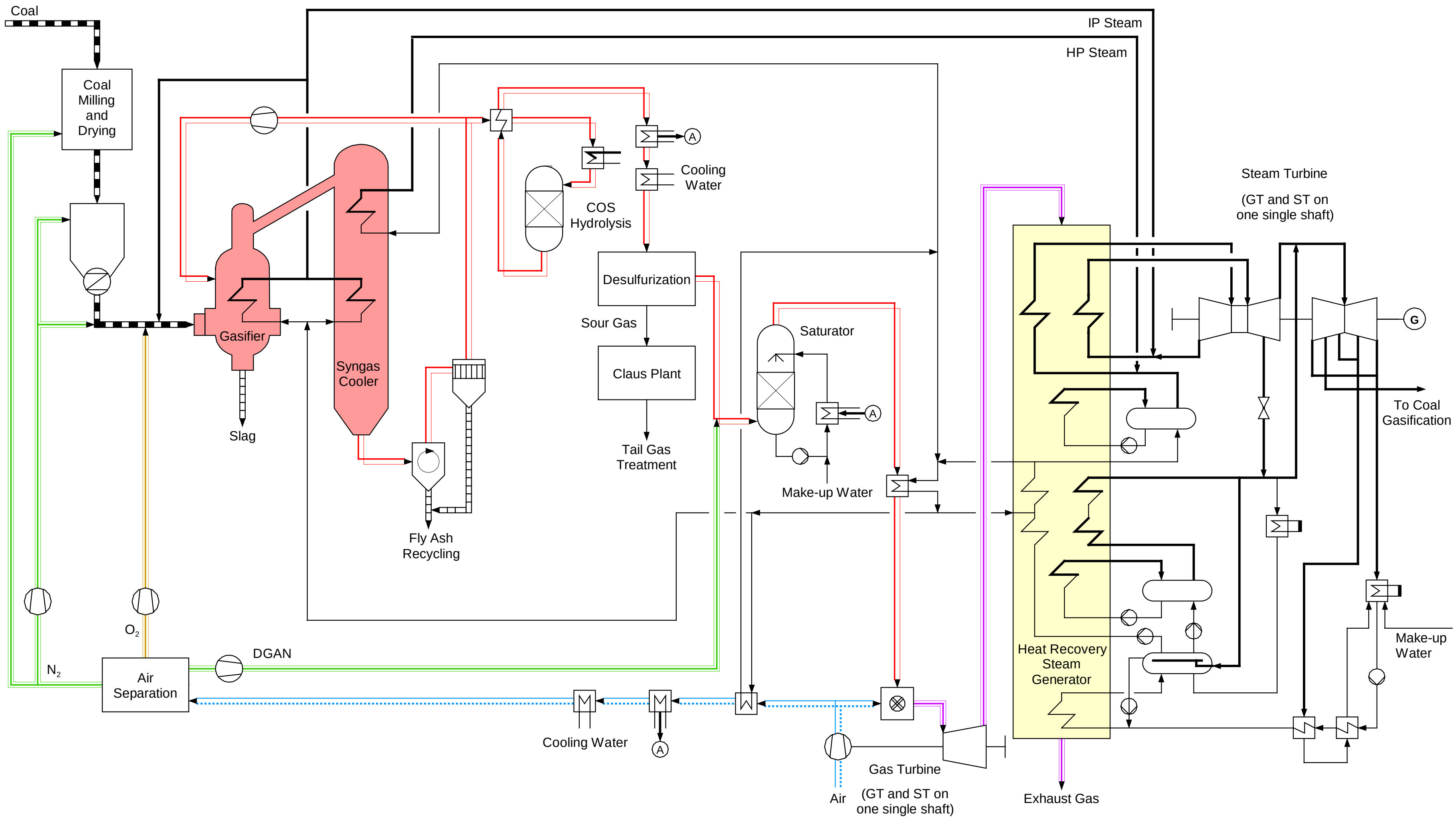
Parameters	Dimension	
Design coal	-	Drayton coal (Australia) [1)]
Cold gas efficiency	%	approx. 80
Composition upstream GT (wet syngas)		
H_2	%vol.	12.3
CO	%vol.	24.8
CO_2	%vol.	0.8
N_2	%vol.	42.0
CH_4	%vol.	-
Ar	%vol.	0.6
H_2O	%vol.	19.1
O_2	%vol.	0.4
H_2/CO ratio	-	0.50
Lower heating value (LHV)	BTU/scf kJ/kg	113 4324
Ambient pressure	bar_a/psia	1.013/14.69
Ambient temperature	°C/°F	15/59
Elevation above sea level	m/ft	0
Condenser pressure	bar_a/psia	0.025/0.36
GT output	MW	156
ST output	MW	128
Gross Power Output	MW	284
Auxilliary power	MW	31
Net power output	MW	253
Net efficiency (LHV)	%	43.2

Process Flow Diagram of Buggenum IGCC Plant



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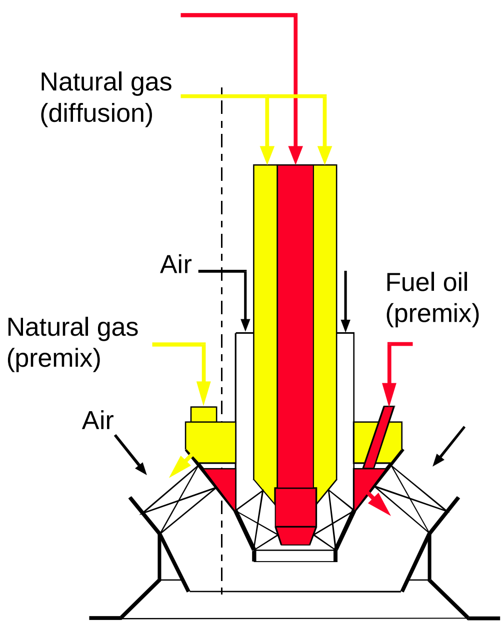
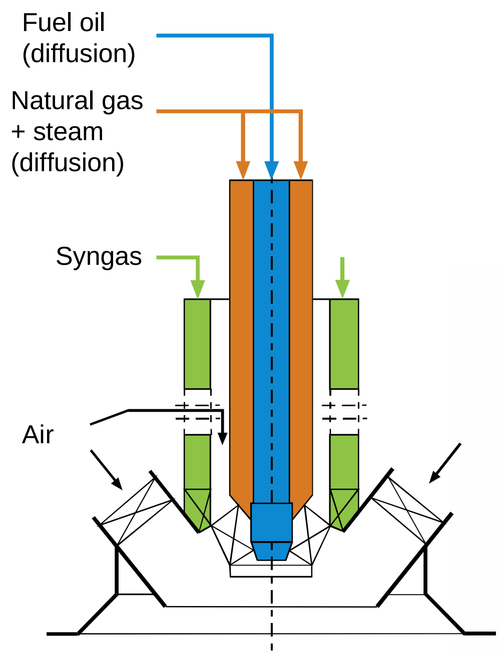
Main Features of V94.2 Gas Turbine

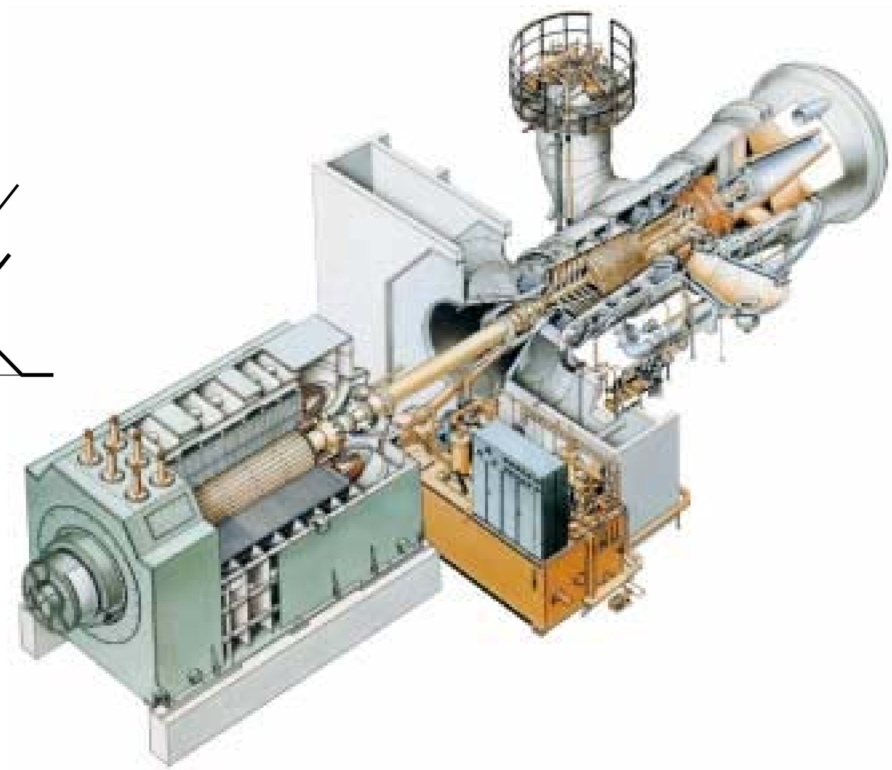


Siemens Hybrid Burner



Siemens Syngas Burner

Diffusion Burner with Swirl Perturbators



Gas Turbine Syngas Supply and Conditioning System of Buggenum IGCC Plant

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Scope and Task:

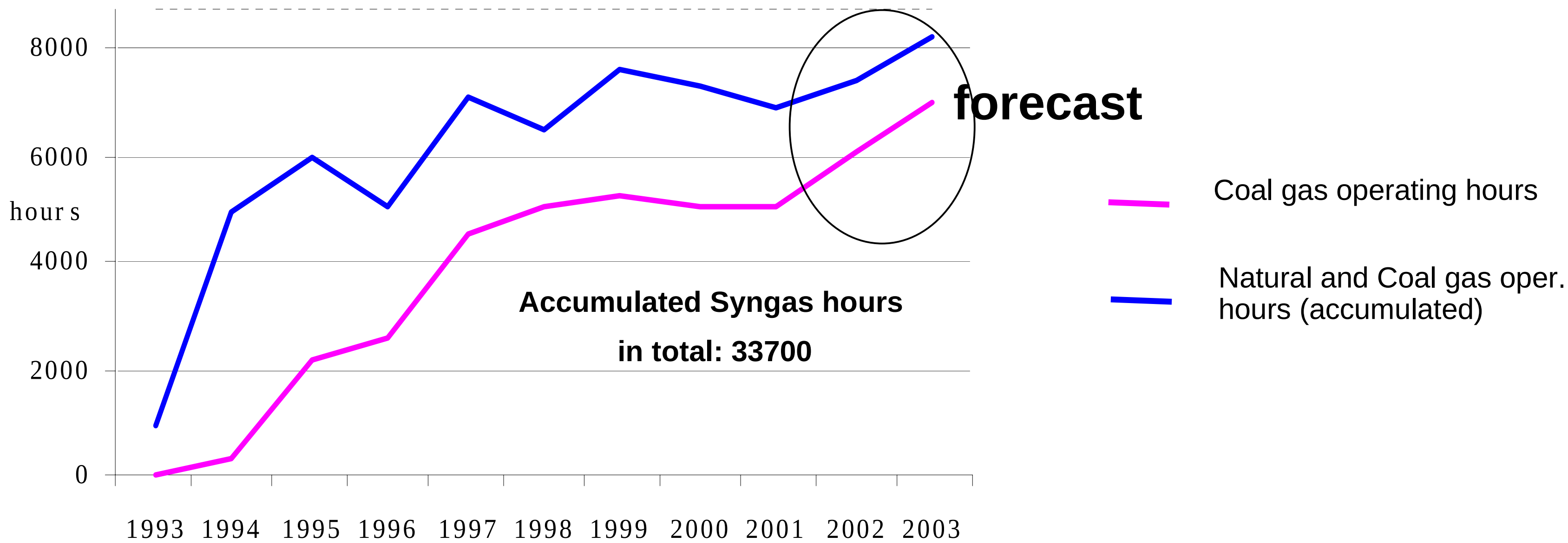
Extracted Air Heat Flow Recovering/ Low Temperature Utilisation for Saturation

Syngas Conditioning with Preheating and Dilution for NO_x Control (Saturation, DGAN and Steam supply)

Heating Value, Flow and Pressure Control on the Coal Gas and Air Extraction Side

Saturator and Heat Exchanger

Operating Hours per Year and per Fuel



Significant Improvement 2002

Availability jan. – aug. 2002 (% time)		
	Syngas operation	syngas and natural gas operation (cum.)
Availability	86.1	96.4
Foreseen unavailability	8.3	3.3
Unforeseen unavailability	5.6	0.3

Important Overall Plant Improvements (Hardware)

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Gas Turbine:

- Modified gas turbine burners (swirl Perturbators added)

ASU:

- Better structure and better material of mol sieves (CO_2 breakthrough at elevated temperatures)

Gasifier and Gas Cleaning:

- Modified construction of hot gas filter
- Modified design of slag bath heat skirt
- Conceptual Change for Slag Fine Separation
- Increased valve diameters for the slag sluicing system
- Modified pulverised coal transport system
- Modified Construction of Syngas Cooler to prevent leakage problems

Process Design Features to Leverage Plant Availability

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Disadvantage of Fully Integrated Concept:

- Extensively Start up time due to Sequential Start Sequence
- High Probability of Overall Plant Trip when one Island fails
- Limited Load Gradients

Measures to Compensate Disadvantages and to Improve Plant Availability

- Oxygen and Nitrogen Buffer (corresponds to 6h Gasifier operation) to maintain Gasifier Operation in case of Gas Turbine or ASU Trip

  → Shortening of potential Coal Gas Break

- Third Coal Mill Train
- Heating Value Control and Capability of DGAN Replacement by steam and vice versa

  → Continues Coal Gas Operation when DGAN trips
  Shortening of Start up Time

- Natural Gas Injection

  → Increase of Load Gradients and Improve Operational Flexibility

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Reduced Start up Time for Coal Gas Operation

- ASU Start up with DGAN compressor independently of GT operation
- ASU operation with air extraction from Gas Turbine when appr. 150MW are achieved
- GT switch over with steam as diluent
- Drying of DGAN compressor
- Diluent change from steam to DGAN and load increase to base load

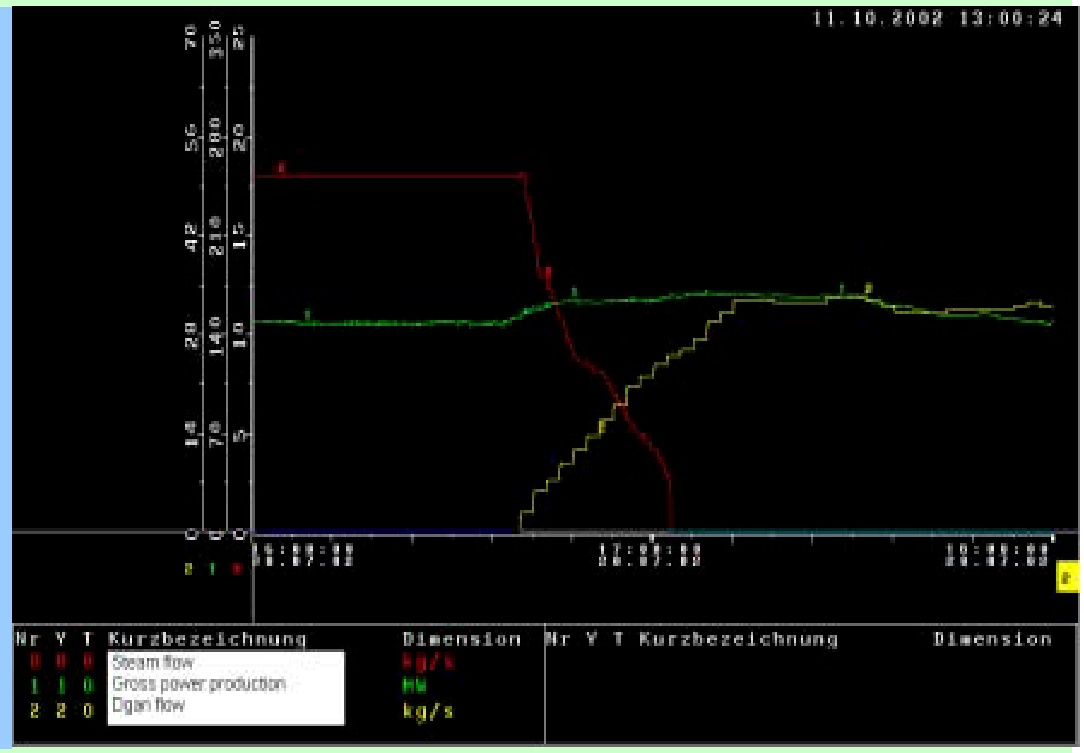
Air Inlet for DGAN Compressor

Special Control Features of GT with Interconnected Syngas Fuel System

Change from Steam to DGAN in Coal Gas Operation

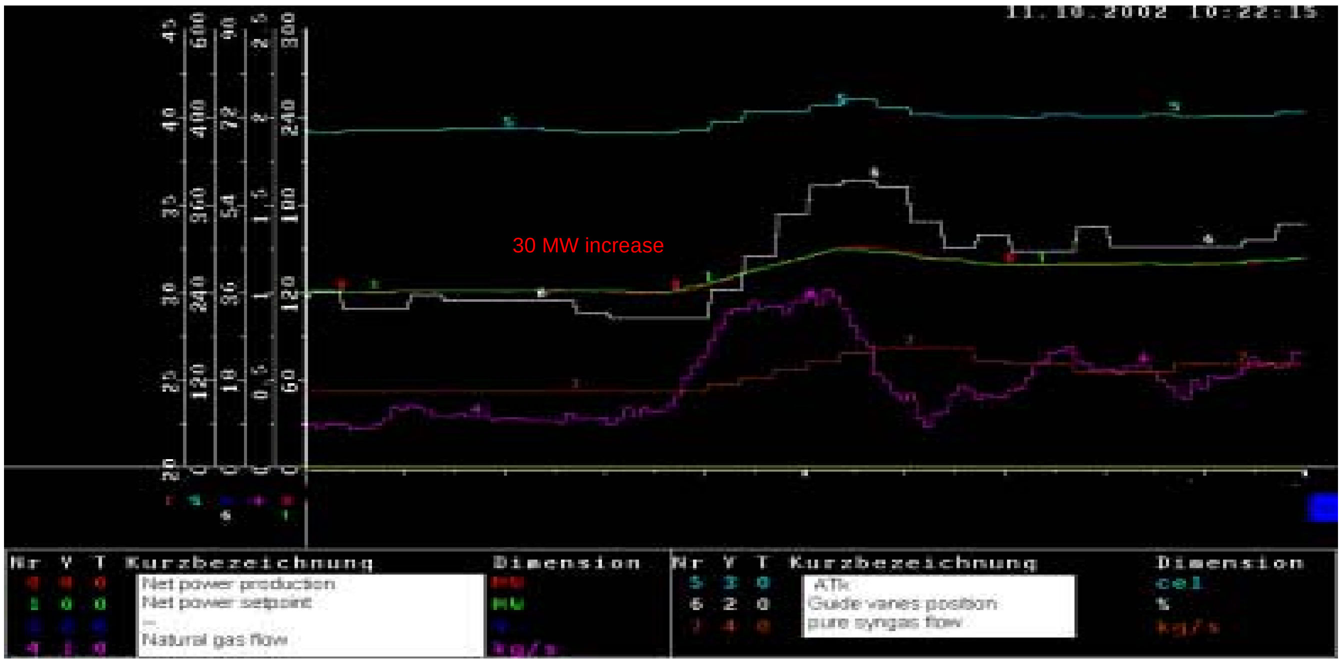
Control Features

- **GT Air Pressure Control Function to support ASU Operation**
- **Change from steam to DGAN**
- **Syngas pressure control**



Increase Load Change Capability by Natural Gas Injection

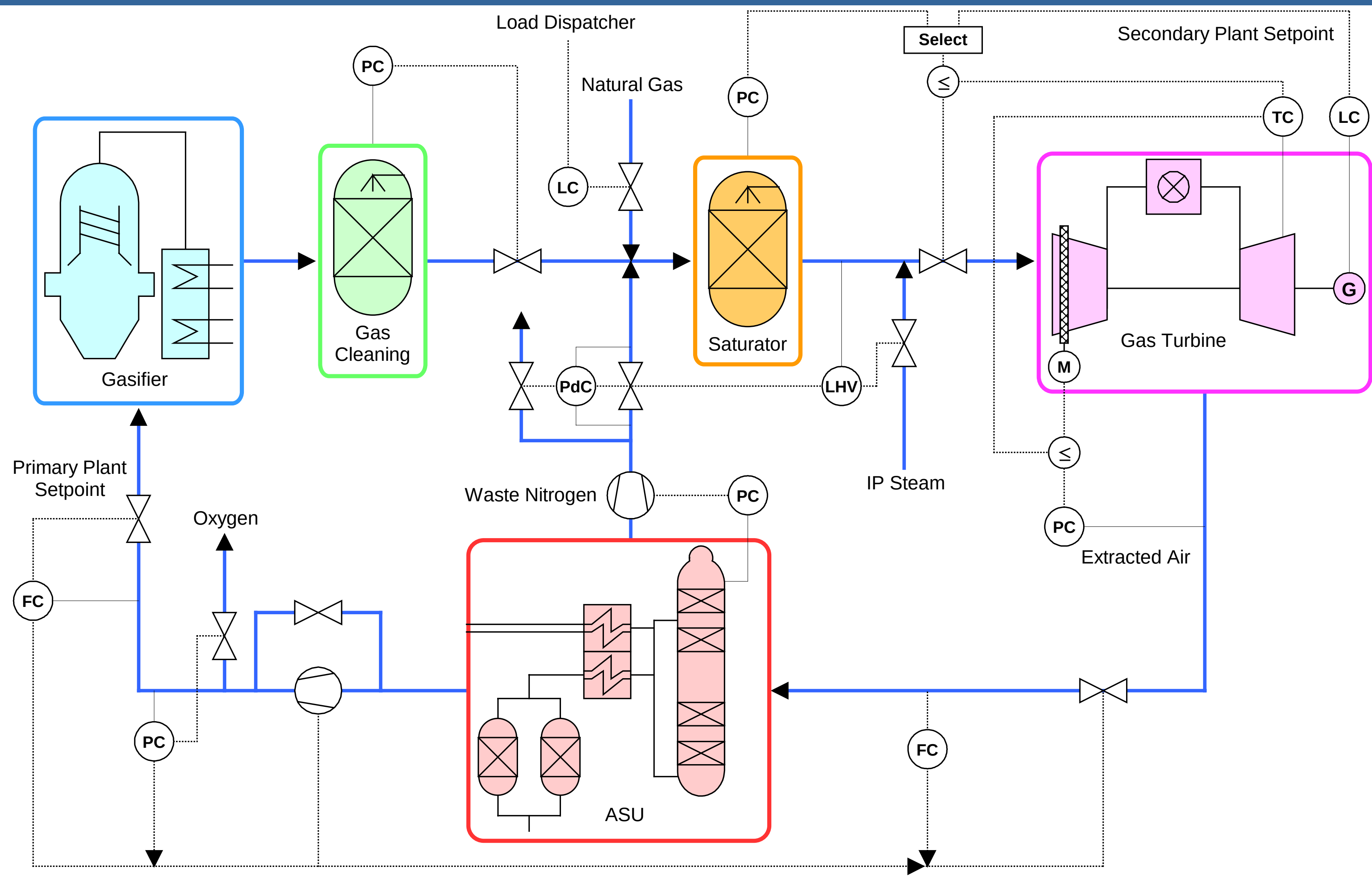
Improving Load Gradients → Peak Shaving Operation



Natural Gas Injection in the Range from 0 to 1,6 kg/s

Increase of Load Gradient from 1,5 to 3,5 MW/min

Overall Control Strategy of Buggenum IGCC Plant



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Syngas Features of V94.2 Gas Turbine

Robust Syngas Operation over a wide operational Range has been proven in Buggenum

Advantages:

Low syngas burner pressure drop	Minimum auxiliary power Consumption
Capability of full air extraction	No additional Air Compressor
Single Digit NO_x Values (< 9ppm)	Meets Future Emission Levels
Major Inspection after 33000 equivalent operating hours (EOH)	Profitable due to reduced Maintenance cost and High Availability

NOx Emission of V94.2 in Syngas Mode

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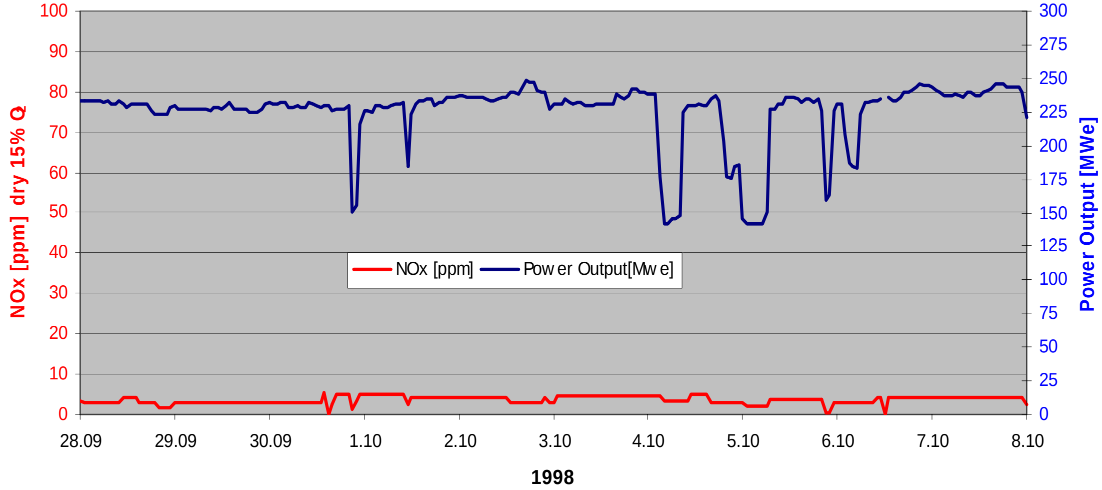

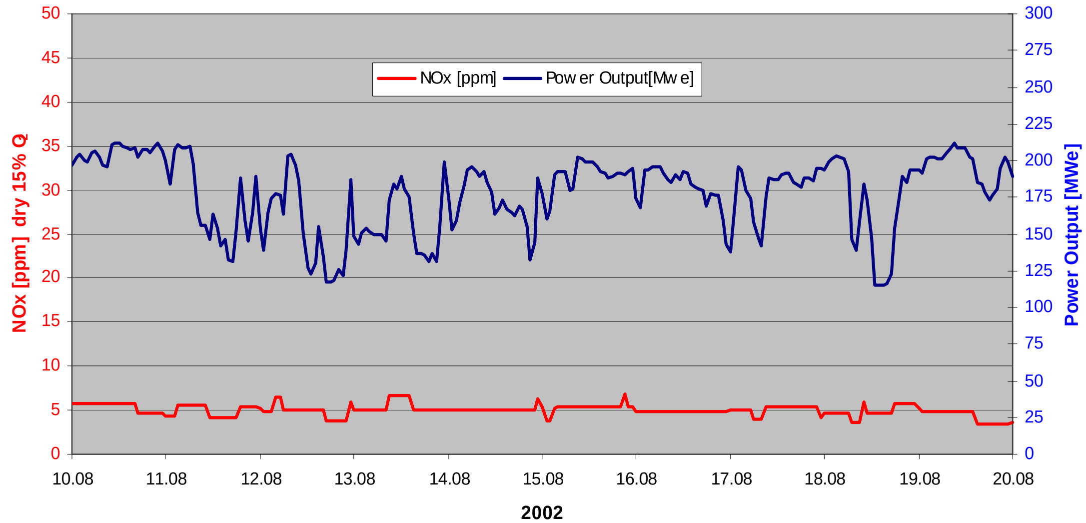

Syngas Experience with Siemens and Siemens Westinghouse Technology

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Plant/Project	Electrical Output (net)	Gas Turbine	Main Features	Start-up
Hörde Steelworks (Germany)	8 MW	VM5	Blast-furnace-gas-fired, gas turbine as mechanical drive	1960
U. S. Steel Corp. (Chicago, USA)	20 MW	CW201	Blast-furnace-gas-fired gas turbine	1960
Kellermann (Lünen,Germany)	163 MW	V93	First CC plant in the world with integrated LURGI coal gasification (hard coal)	1972
Plaquemine (Lousiana, USA)	208 MW [4)]	2 x W501D5	CC plant with integrated DOW coal gasification	1987
Buggenum [1)] (Netherlands)	253 MW	V94.2	CC plant with integrated SHELL coal gasification (hard coal)	1993 [3)] 1994/95
Puertollano [1)] (Spain)	300 MW	V94.3	CC plant with integrated PRENFLO coal gasification (coal and petroleum coke blend)	1996 [3)] 1997/98
ISAB (Priolo, Italy)	521 MW	2 x V94.2K	CC plant with integrated TEXACO heavy-oil gasification (asphalt)	1998 [2)] 1999
Servola (Italy)	180 MW	V94.2K	CC plant with steel-making recovery gas	2000

ISAB and Puertollano Experience

Buggenum Burner design proven in ISAB and Puertollano

Special ISAB Feature:

Load Rejection to Idle Operation in Syngas demonstrated and proven

Burner Design capable to burn Syngas with completely different H2/CO ratio without design modification

Design: H_2/CO ratio =0,85

Operation: H_2/CO ratio =1,06

Syngas Operating hours:

Puertollano > 13000 h

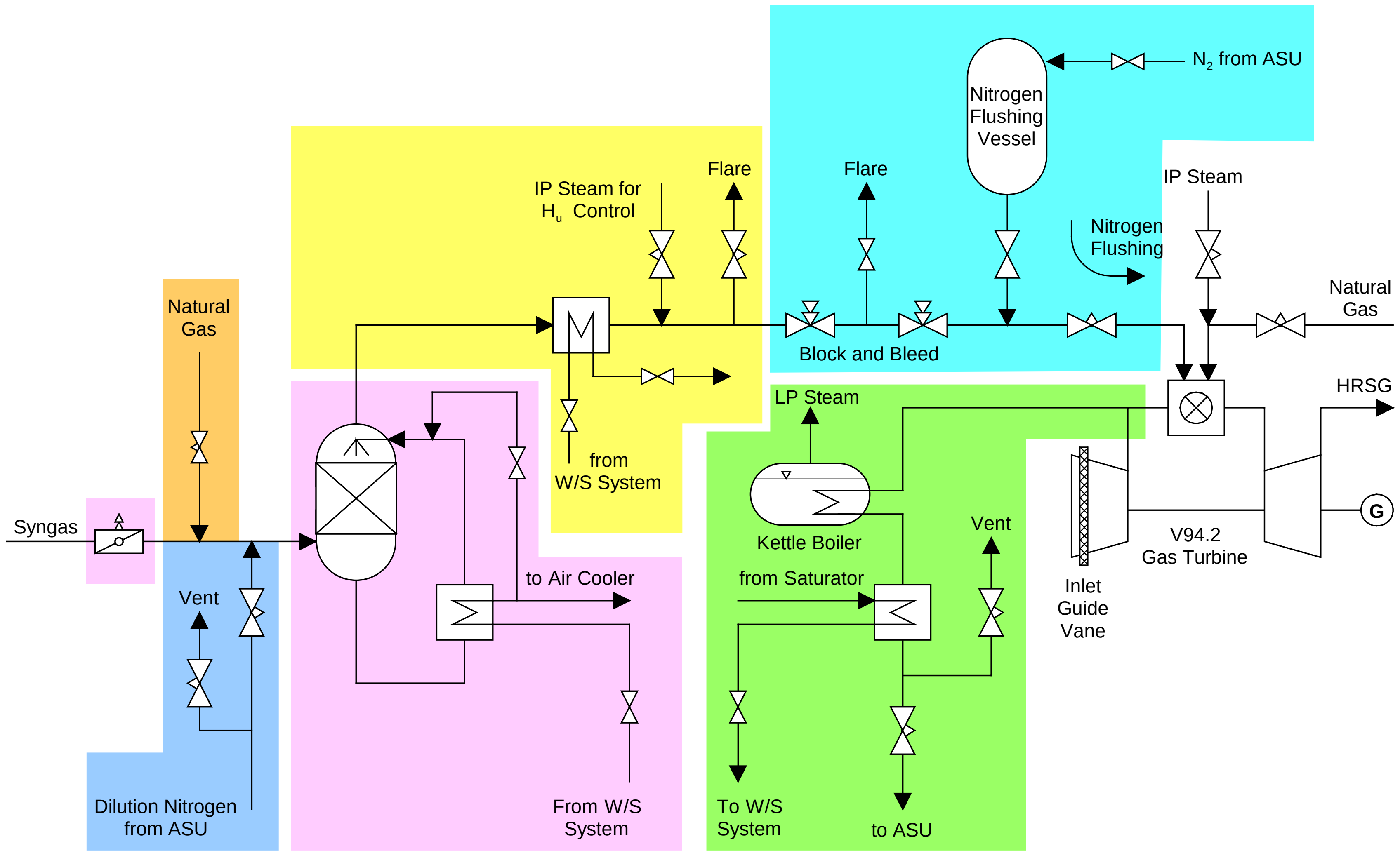
ISAB > 30000 h

IGCC Puertollano

Lessons Learned/ Gas Turbine Syngas Fuel and Conditioning System

System	Experience	Consequences (Lessons learned)
Syngas Burner	• Low pressure loss possible • Swirl perturbator • Stable combustion over a wide heating value range	• Increase of overall plant efficiency • Surpress of flame induced pressure oscillation • Burner and Combustor design proven
Syngas Dilution	• Redundant dilution systems • Capability for diluent replacement	• Providing of IP steam system beyond DGAN system/ heating value control • Location of syngas/nitrogen mixing upstream saturator
GT Syngas Fuel System	• Optimal heat recovery in distinct load cases	• Optimised modular design for simple and reliable operation
Flushing system	• Corrosion of piping/ high temperature gradients	• Nitrogen flushing where IP nitrogen is available
GT Controller	• GT compressor exit pressure control • Syngas pressure Control • Switch over capability at distinct load cases	• Compressor exit pressure control features proven • Additional GT control features depends on selected overall plant concept
Unit Control/ Plant Integration	• Manual operation necessary • Limited load gradients/ operational Flexibility improvable	• higher automated level based on Buggenum and Puertollano experience • Air-side partially integrated, Natural gas or Fuel Oil Admixing

Modular Gas Turbine Syngas Fuel System Design



Standardised IGCC for Refinery Application

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Next Steps for further Economic Improvement

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Buggenum

Peak Shaving Operation

Gasifier and ASU not 100%

→

Feasibility Study to separate Combined Cycle from Gasifier and ASU Operation

Production of Alternative Fuels

Biomass Gasification

(demolition wood, sewage sludge, chicken litter)

→

Phase 1: 30 wt % co-gasification early 2004

Phase 2: 50 wt % co-gasification 2005

Advanced Gas Turbine Combustor

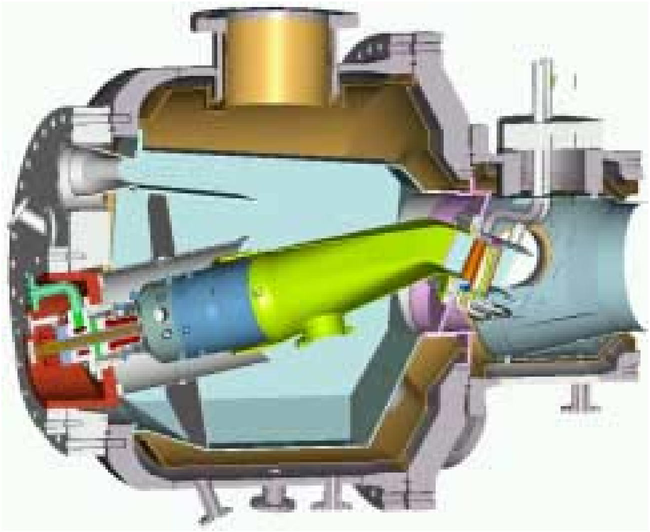
Joint Effort to develop an Advanced Syngas Burner Design for High Efficient Gas Turbine Application (EC funded Program)

Siemens Westinghouse Gas Turbine for 60 Hz Application

Based on Plaquemine Experience Syngas Combustion Tests were performed (intermediate Pressure)

Results:

- Combustor is extremely stable during syngas operation over a wide range of loads and gas compositions
- NO_x target of 25 ppm at base load can be achieved with steam as a diluent
- Carbon monoxide emissions are low (usually below 5 ppm across all loads)



Combustion Test Rig

Conclusion

Buggenum

- Mature Operational Status is reached and the plant operates compatible
- Biomass Gasification gives a high benefit
- Further Economic Improvements are possible

Future Concepts

- Implementation of Lessons learned into future Design Features
- Joint effort from the beginning between client and main suppliers
- As much as possible standardised design to reduce investment and ensure availability