The new Schwelgern coke plant

Pioneering coke plant technologies are part of our daily business. The efficiency and environmental performance of our plants are renowned worldwide. Tailor made complete coke oven plants from a single source – that's our commitment and your advantage gained from a partnership with us.

500
coking plants worldwide

Engineering Excellence 3

ThyssenKrupp
Industrial Solutions

ThyssenKrupp
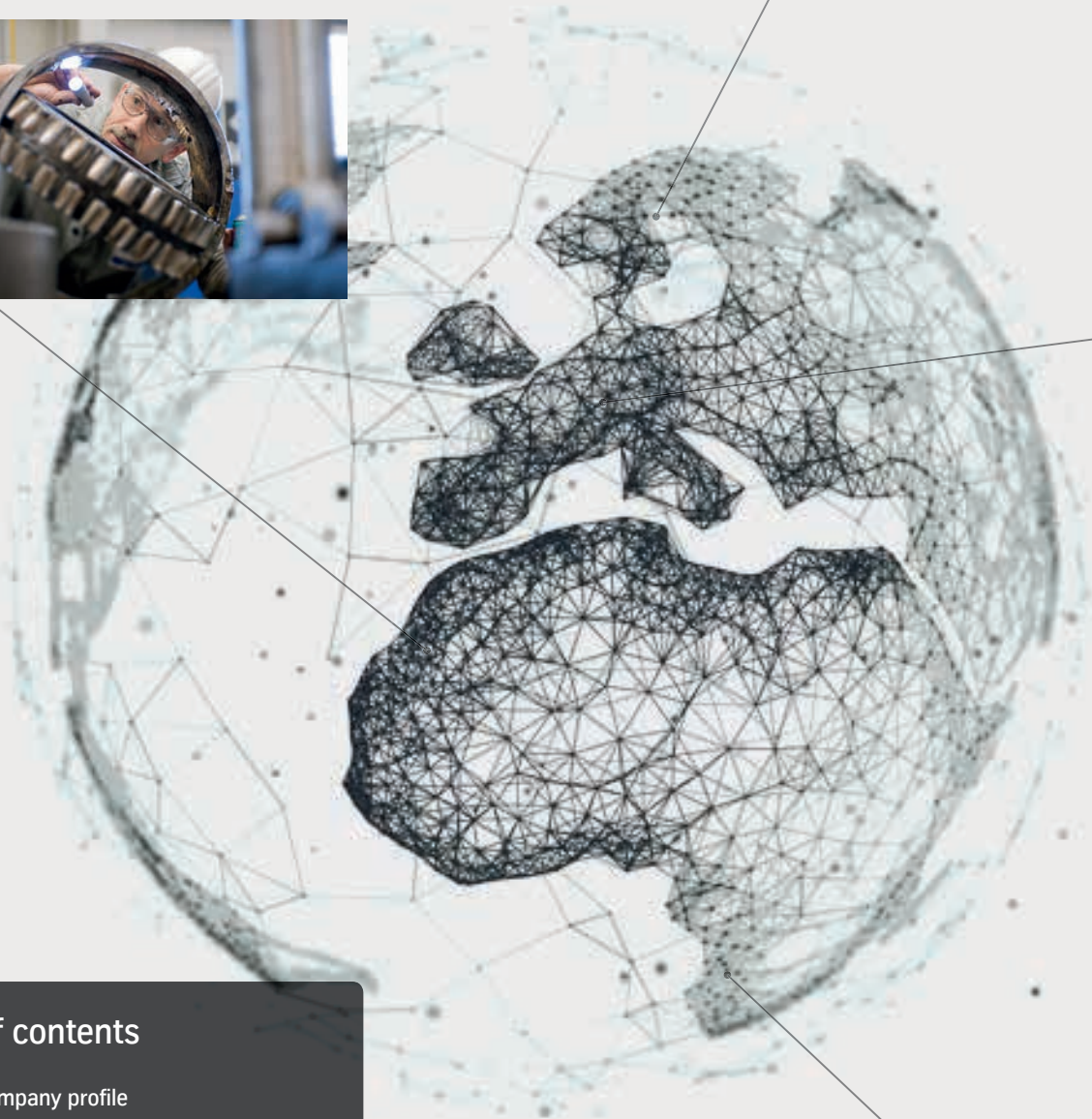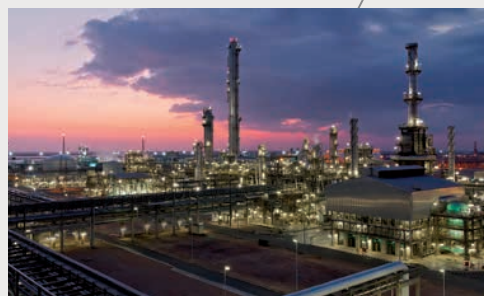
Table of contents

Engineering Excellence[3] – Think globally, act locally

Having erected several thousand plants, ThyssenKrupp Industrial Solutions is one of the world's leading engineering companies. Our Business Unit Process Technologies supplies chemical plants, refineries and coking plants on the basis of tried-and-tested technologies made by Uhde, while the portfolio of the Business Unit Resource Technologies comprises complete cement plants and grinding systems of the Polysius brand, as well as machines, plants and systems for mining, extraction, preparation, processing or transshipment of commodities.

With many years of experience in the EPC business, we offer our customers concepts, market studies, plant layouts, design engineering, supplies, manufacturing services, erection and commissioning – all from a single source. Our employees on all continents use their knowledge and engineering competence to create innovative solutions and to look for ways to conserve natural resources.

Over 40 locations in 25 countries – divided into six regions – form a close-meshed network that allows us to align our services to local conditions consistently. Thanks to this on-site expertise and global networking, we are able to set standards that offer our customers a true competitive edge.

Our comprehensive service concepts take the entire life cycle of a plant into account. We offer OEM spare parts service and complete maintenance management, as well as servicing, modernisation projects and conversions.

Key plant and production data

Number of ovens	2 batteries of 70 ovens each
Oven type	Compound oven designed for heating with lean gas and rich gass
Heating system	Twin-flue oven with air supply in three stages
Coking time	25 h
Chamber dimensions (hot)	- Length 20.80 m - Height 8.34 m - Width 0.59 m
Stack height	150 m
Machine sets	2
Oven cycles per day	135
Coal throughput	10,600 tpd (wet)
Coke production (dry)	2.64 million tpy
Coke oven gas	155,000 m³/h (STP)
Crude tar	78,000 tpy
Crude benzene (BTX)	18,000 tpy
Liquid sulphur	9,000 tpy

The "Schwelgern Story"

Planning of the Schwelgern coke-oven plant at ThyssenKrupp Stahl AG in Duisburg/Germany commenced in the early 1990s.

During the more than 100-year history of the August Thyssen coke-oven plant, housing developments in the Bruckhausen district of Duisburg grew ever nearer to the perimeter of the works site. Over time, residents' complaints about emissions from the works and demands for the coke-oven plant's closure became more and more insistent.

As the old coke-oven plant in Bruckhausen could no longer be revamped to comply with modern-day ecological requirements, plans took shape to replace it with a new facility. Ideally, the new plant should be located outside the densely populated residential areas but still close enough to the steelworks in order to ensure delivery of the 2.5 million tons of coke per annum required by the two large blast-furnaces in Duisburg-Schwelgern and to maintain the gas network between the steelworks' ovens and the power station. A suitable site for the new coke-oven plant

was found on the peninsula between the Schwelgern harbour and the River Rhine.

Engineers of ThyssenKrupp Industrial Solutions were involved in the design of the Schwelgern coke-oven plant from the start. Beginning in 1996, they drew up the technical concepts on the basis of their own modern technologies for coke ovens and gas treatment plants, and compiled the necessary license application documents and the safety analysis.

In November 1998 the license for the project was granted, and the detail engineering commenced immediately afterwards. When the engineering phase was in full swing there were as many as 200 of our engineers engaged in implementing the design concepts. More than 12,000 engineering documents were produced with the aid of state-of-the-art equipment during the 3-year engineering phase.

Within three years of the official groundbreaking in March 2000 and the laying of the foundation stone in July 2000, the

world's most modern, environmentally-friendly and, in terms of its dimensions, unique coke-oven plant took shape on the basis of engineering performed by ThyssenKrupp Industrial Solutions.

Commissioning of the plant started on December 20th 2002 by heating battery 2 under the watchful eyes of our experienced technical crew. As each individual function module and plant section came on stream it justified the technical concepts selected for the plant and confirmed the successful handling of the project by the parties concerned, whose team spirit was exceptional. The first coke was pushed on battery 2 on March 13th 2003, some 6 weeks earlier than planned, and on battery 1 on May 21st 2003, 3 months ahead of schedule.

Using the most modern environmentally-friendly technologies and the highest possible level of automation, the Schwelgern coke-oven plant achieves a production capacity of 2.64 million tons of coke per annum and 155,000 m3 coke-oven gas per hour, setting new standards world-wide.

The main milestones

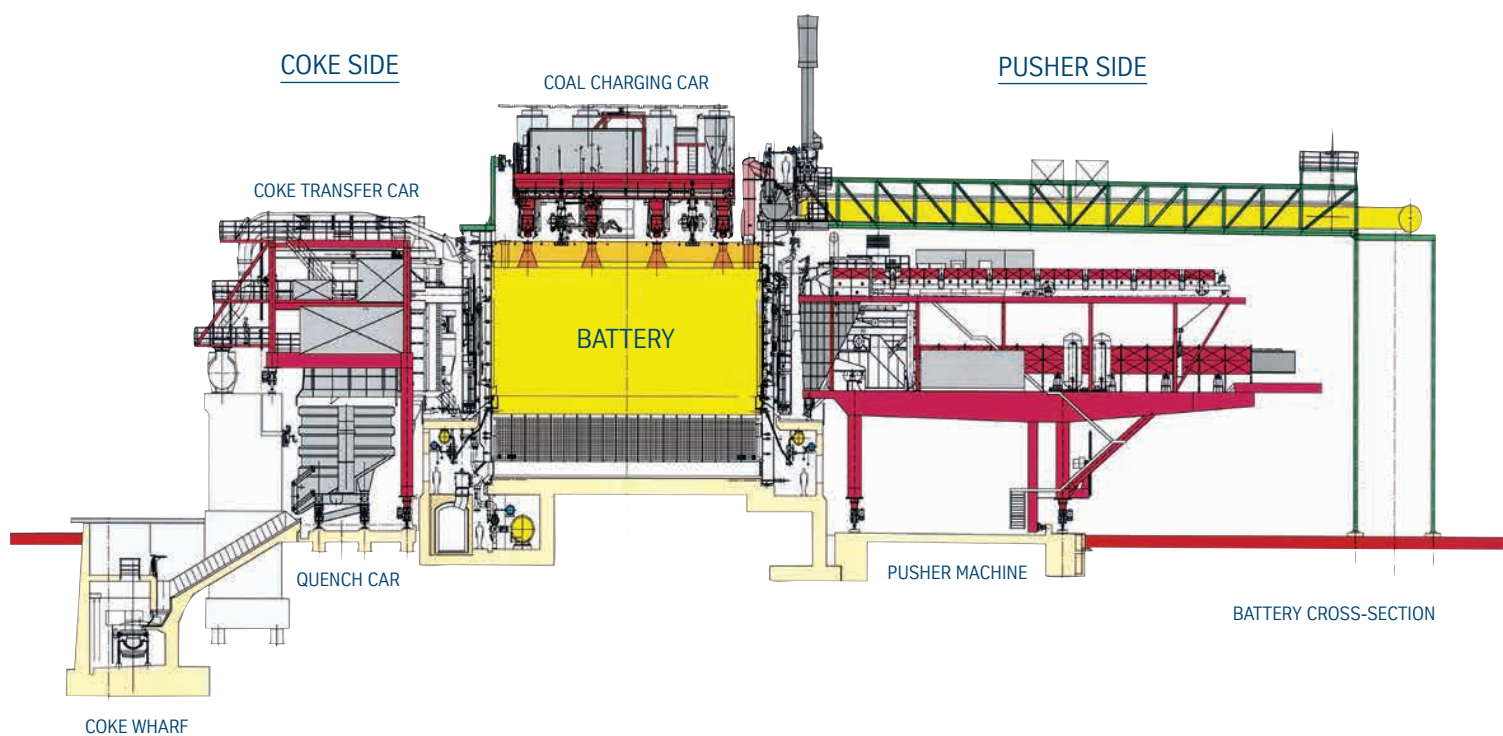|	
09.11.1998	First notice of approval for the construction of the Schwelgern coke-oven plant
30.03.2000	Official groundbreaking
06.07.2000	Laying of the foundation stone
28.05.2001	Start of refractory construction
01.10.2001	Start of mechanical assembly
20.12.2002	Heating start-up
13.03.2003	First coke

The Coke-Oven Batteries

The challenge

The challenge facing the plant design engineers was to rate the coke-oven batteries for a coal throughput of 10,600 t/d - equivalent to a coke output of around 2.6 million t/a - while minimising the operating personnel requirements. At the same time, consideration had to be given to the restrictions imposed by the very limited building space, plus a tight budget and demands for the best possible protection of the environment.

The engineering

The challenge was accepted and the demands were met in full using concepts developed through experience and expertise accumulated in a host of international projects.

COKE SIDE

COAL CHARGING CAR

PUSHER SIDE

COKE TRANSFER CAR

BATTERY

QUENCH CAR

PUSHER MACHINE

BATTERY CROSS-SECTION

COKE WHARF

The results

We are proud that our engineering work has resulted in a major contribution to the successful construction of a coking plant with the world's largest coke oven batteries. The following features are particularly noteworthy:

The large dimensions of the oven chambers allow the specified coal throughput to be achieved by only two batteries of 70 ovens each, for which relatively little space is required. The necessary charging and coke-pushing operations are performed with only one set of oven servicing machines.

The well-proven **CONTROLPRESS®** bracing system guarantees the required pre-stressing and gas-tightness of the refractory walls of the very tall ovens under all operating conditions.

The batteries were heated up using specially designed blower burners which can be operated over a wide control range and which ensure uniform, controlled heating of each battery refractory block.

Careful selection of suitable materials and equipment allowed the project to stay within the budget without detracting from the quality standards required for the safe operation of the plant.

Innovative Environmental Protection at the Battery
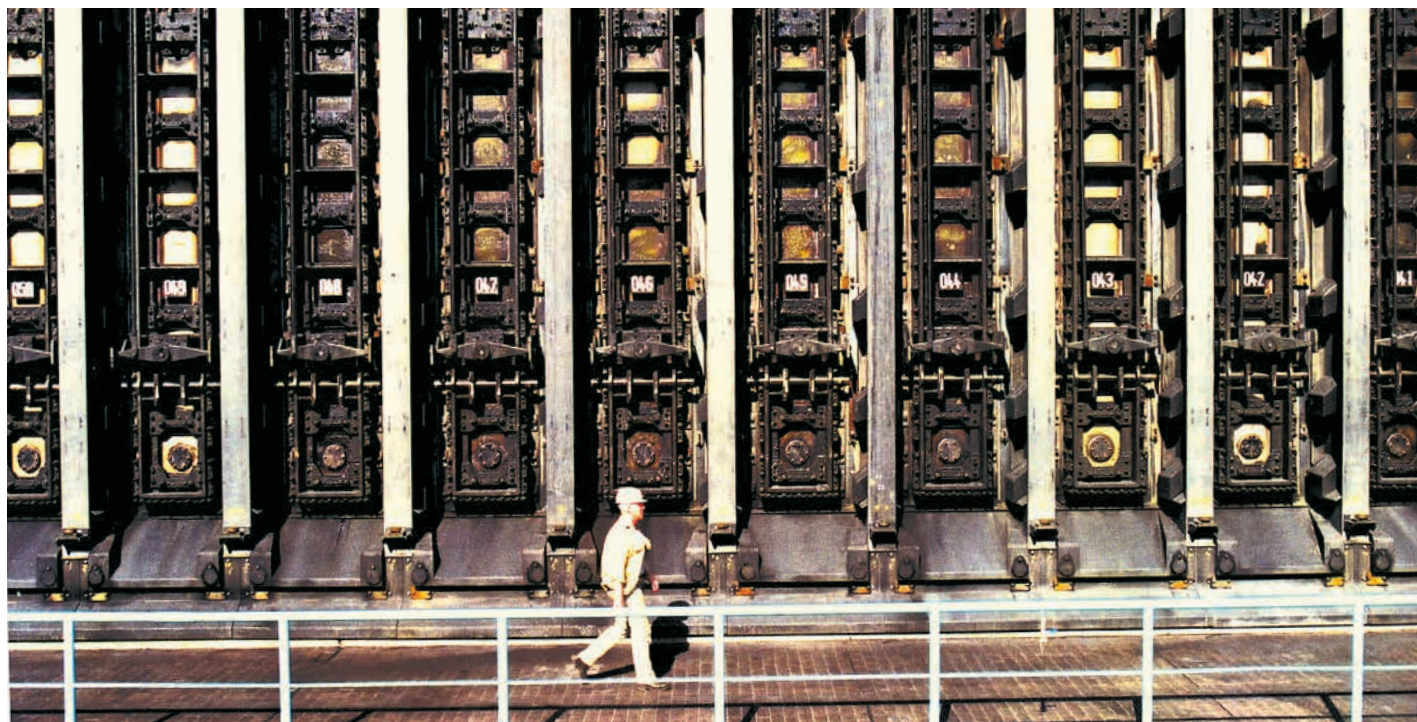
Heating system

The heating system for low-NO_x combustion, which was specially designed for these large ovens, is equipped with a 3-stage air supply system. About half the combustion air enters the bottom of the heating zone through the air duct, while the other half enters the heating zone through two air ports positioned at different levels in the binder wall. The regenerator chambers are divided longitudinally in order to permit individual control of the bottom air and wall air flows. This results in an optimum vertical temperature distribution over the heating walls while reducing the NO_x content of the exhaust gas to a very low level.

Single-chamber pressure control

The innovative EnviBAT™ pressure regulation system, former PROven®*, for single-chamber pressure control allows the pressure in each individual oven chamber to be adjusted as a function of the actual raw gas generation rate, providing the optimum pressure level for the given coking condition. The gas collecting main itself is operated under suction, and the pneumatically actuated EnviBAT™ valve controls the back-pressure in the chamber. The control system is based on the adjustment of the water level inside the EnviBAT™ valve, providing a variation of the valve port area through which the raw gas flows.
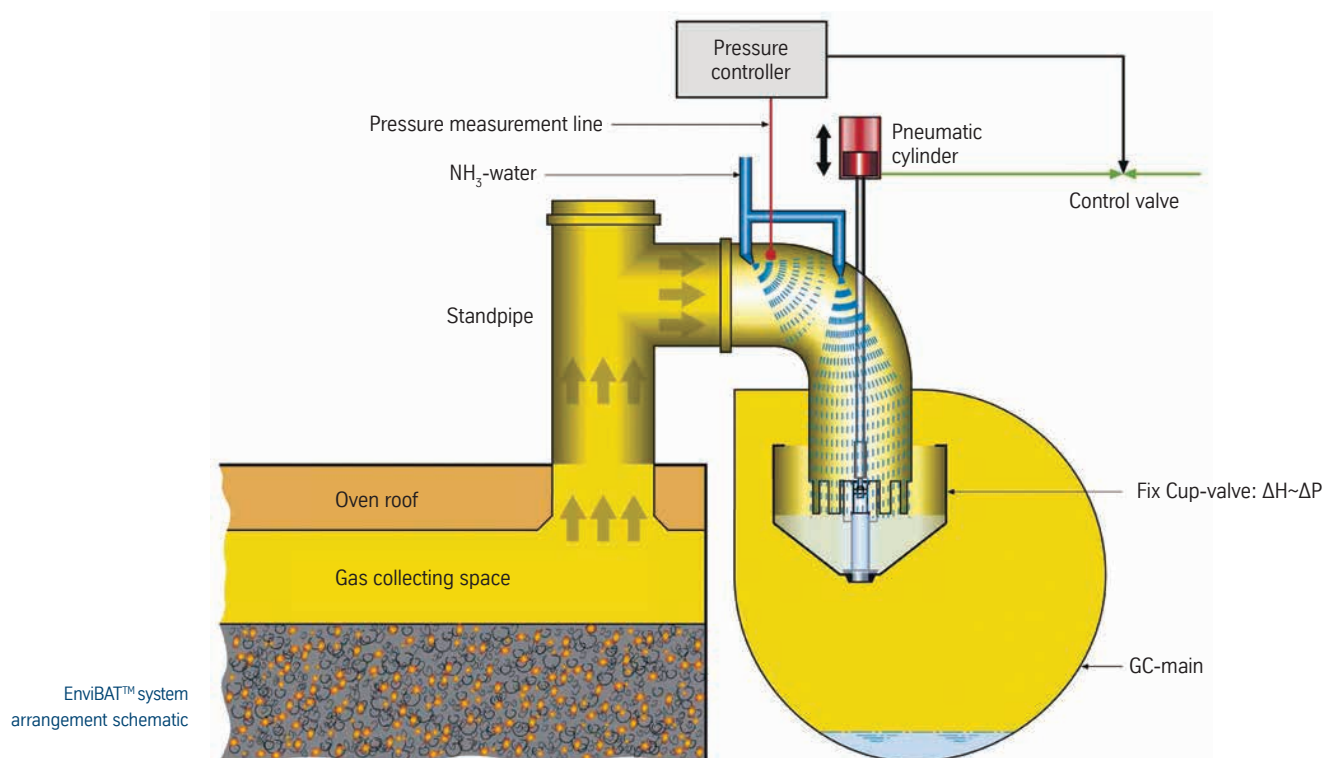
A low chamber pressure is set at the beginning of the coking time so that the large raw gas quantities generated in this phase are discharged without highgas pressures on the oven doors. Door and oven top emissions are thus prevented almost entirely.

*actually is a trademark of TÜV Nord

As coking proceeds, the chamber pressure is gradually increased in step with the reduction in the gas generation rate inside the oven. When the gas output approaches the end of the coking process, the pressure in the oven is raised to the point where no air can be drawn in at the doors. This protects the refractory walls from combustion in the end zone of the chambers, thus prolonging the service life of the ovens.

Charging-gas aspiration

The EnviBAT™ pressure regulation system also ensures that the charging gases are retained within the raw gas system because the standpipes and, consequently, the oven chambers are under suction when charging takes place. Coke oven doors with an efficient sealing system and water-sealed standpipe lids are further safety measures for preventing battery emissions.
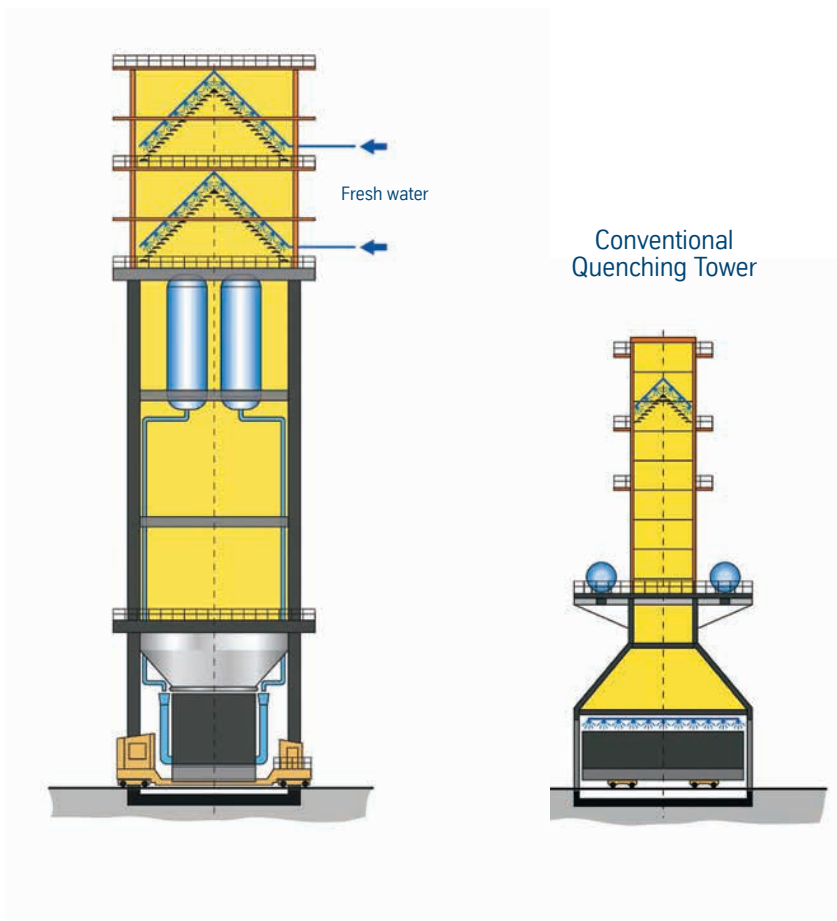
Pressure controller

Pressure measurement line

NH$_3$-water

Pneumatic cylinder

Control valve

Standpipe

Oven roof

Gas collecting space

Fix Cup-valve: $\Delta H \sim \Delta P$

GC-main

EnviBAT™ system arrangement schematic

Coke Stabilisation Quenching / CSQ

CSQ-Quenching Tower

Fresh water

Conventional Quenching Tower

The challenge

Initially it was planned to equip the Schwelgern coke-oven plant with a dry coke-cooling system in order to meet the environmental protection requirements and to recover the energy of the hot coke. However, in view of the fact that energy demands at the Duisburg steelworks site were already largely covered and with a low return on investment from the recovered energy, it was decided to develop an optimized wet quenching system which would satisfy the environmental protection requirements.

The engineering

The engineering-concept was based on the wet quenching system that had been used successfully for a number of years at the coke-oven plant of the Krupp Mannesmann steelworks. This system has environmentally-friendly features that are comparable with dry cooling, is highly reliable and stabilises the coke during the quenching operation.
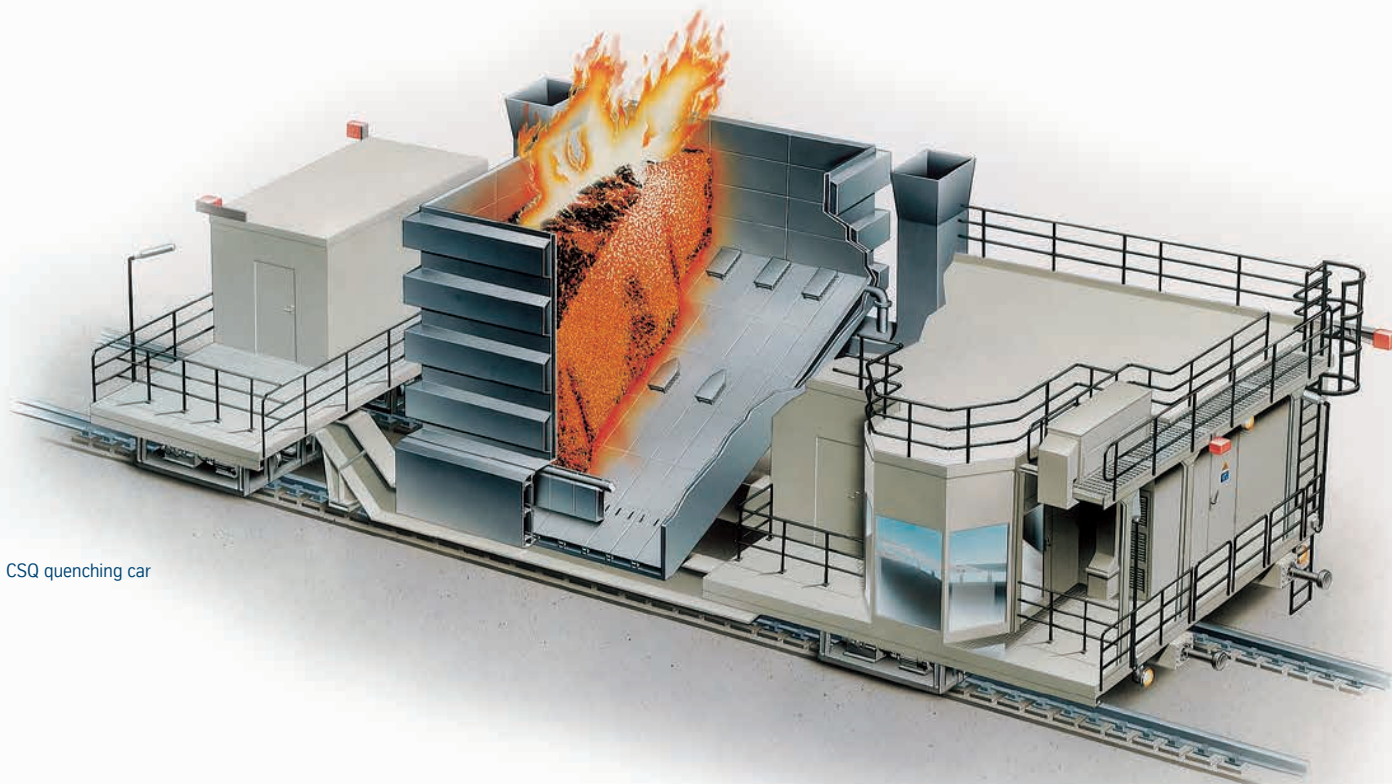
CSQ quenching car

The results

Thus the CSQ wet quenching system was developed, which is accepted as being equivalent to a dry coke-cooling system even in terms of Germany's very strict environmental protection regulations. This system consists of the following functional units:

The major portion of the quenching water is fed into the hot coke bed from below in the CSQ quenching car. The mixture of steam and water that develops in the area of contact quickly cools the coke and propels it upwards. When the coke drops again, the fine particles are separated from the coarse grain and the coke is stabilised. The formation of gaseous emissions is greatly reduced by the high cooling rate. In fact, these emissions are lower in the CSQ process than in a dry cooling system.
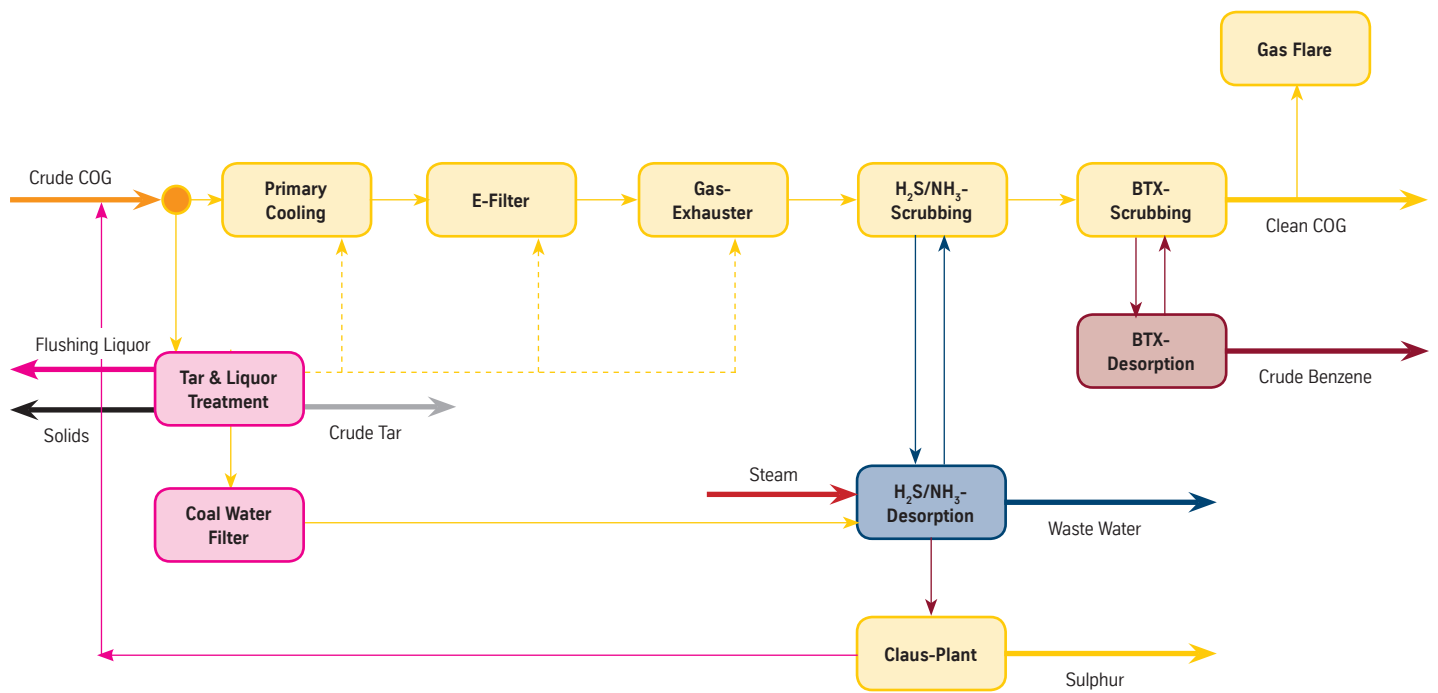
The CSQ quenching tower is approximately 70 m tall and has two levels of specially configured fin-shaped baffle separators for the removal of dust. The ascending vapours are also scrubbed with water and partly condensed. Particulate emissions are thus largely prevented and are lower than with a dry cooling system.

Recycled quenching water is cleaned in the quenching water settling tank. The coke breeze sediment is recycled as sintering coke.

The CSQ system, which was implemented for the first time in its complete form at the Schwelgern coke-oven plant, represents an efficient wet quenching process that provides a high level of environmental performance for a relatively low investment.

Gas Treatment

Process Flow Diagram

Crude COG → Primary Cooling → E-Filter → Gas-Exhauster → H_2S/NH_3-Scrubbing → BTX-Scrubbing → Clean COG

Gas Flare

Flushing Liquor

Tar & Liquor Treatment

Solids

Crude Tar

Coal Water Filter

Steam → H_2S/NH_3-Desorption → Waste Water

BTX-Desorption → Crude Benzene

Claus-Plant → Sulphur

The challenge

A state-of-the-art gas treatment plant was to be installed at the Schwelgern site. The plant had to satisfy the environmental protection regulations in force for water and air while complying with the tight budget. The available building site – situated between the batteries and the bank of the River Rhine – required a compact arrangement of the plant sections and short routes for the gas and utilities.

The engineering

The plant, which was designed by our engineers in close cooperation with experts of the ThyssenKrupp Stahl engineering team, uses state-of-the-art processes and the latest equipment, and represents the optimum solution in terms of both economy and ecology.

To achieve the highest possible reliability, the major items of equipment were rated with 50 % spare capacity. The costs were held within the specified budget in spite of introducing extensive measures for minimising air emissions, water pollution and noise.

Gas Treatment

The major processes

The gas pre-cooling system consists of six horizontal-tube primary coolers, four of which are in operation and two on stand-by. The raw gas from the batteries is cooled in the primary coolers to approximately 24 °C. Hot water is withdrawn from the uppermost cooling stage for heating purposes. The tar content of the gas is reduced to less than 10 g/m³ (STP) by three electrostatic precipitators, two of which are in operation and one on stand-by. The gas is then compressed in the gas exhausters to a pressure of 175 mbar. One exhauster is steam-driven, the second is driven by an electric motor and the third is a standby unit provided with both types of drive.

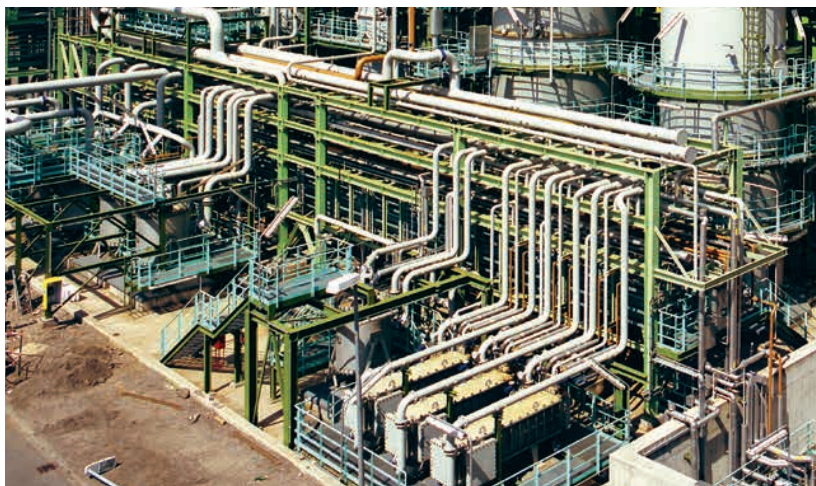In the tar and liquor system the condensate separated from the gas stream before it enters the pre-coolers is processed and decanted into raw tar and water. The raw tar with a water content of less than 3% is a saleable product and is pumped to the tar tanks for intermediate storage. Solids are removed from the tar by centrifuging and are recycled to the coking coal. The surplus ammonia liquor is fed to the H_2S/NH_3 stripping system for further treatment.

The gas compressed in the exhausters is cleaned in the gas scrubbers to the degree necessary for its subsequent use. The gas desulphurising system is based on the **CYCLASULF®** process.
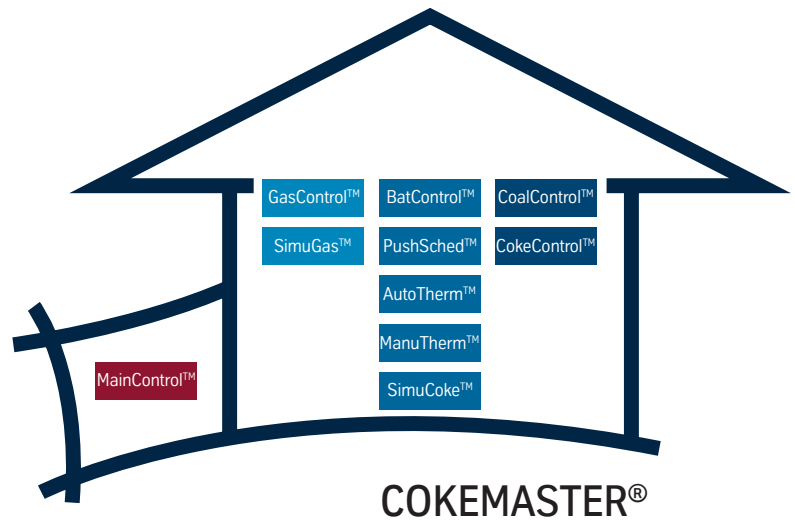
In this process, which was developed by our engineers, the H_2S content is reduced to < 0.5 g/m³ (STP) and the NH_3 content to < 0.02 g/m³ (STP). The vapours stripped in the desorption columns are processed in a **COMBICLAUS®** unit to produce liquid sulphur, with the ammonia being simultaneously decomposed into its constituents N_2 and H_2. The residual gases are recycled to the raw gas mains, resulting in no emissions whatsoever. To fully satisfy environmental protection requirements, a stand-by **COMBICLAUS®** unit is provided.

The final scrubbing stage is the BTX scrubber where the benzene, toluene and xylene are removed from the gas to a residual content of less than 8 g/m³ (STP). At the same time, the naphthalene content is reduced to below 0.1 g/m³ (STP). After treatment in these purification steps, the coke-oven gas is a valuable and environmentally friendly fuel which is exported into the steelworks gas network.

Automation

GasControl™ BatControl™ CoalControl™
SimuGas™ PushSched™ CokeControl™
AutoTherm™
ManuTherm™
SimuCoke™

MainControl™

COKEMASTER®

The challenge

To be able to operate the Schwelgern coke-oven plant at optimum efficiency, it was to be equipped with the latest state-of-the-art automation technology. The aim of automating the process sequences was to facilitate long-term modifications required to meet environmental protection requirements.

The engineering

ThyssenKrupp Industrial Solutions has been successfully engaged in the automation of coke-oven plants since 1980.
The automation systems are always tailored to the customer's specific requirements, and the Schwelgern coke-oven plant is no exception. The modular design of the auto-mation systems favours this approach.
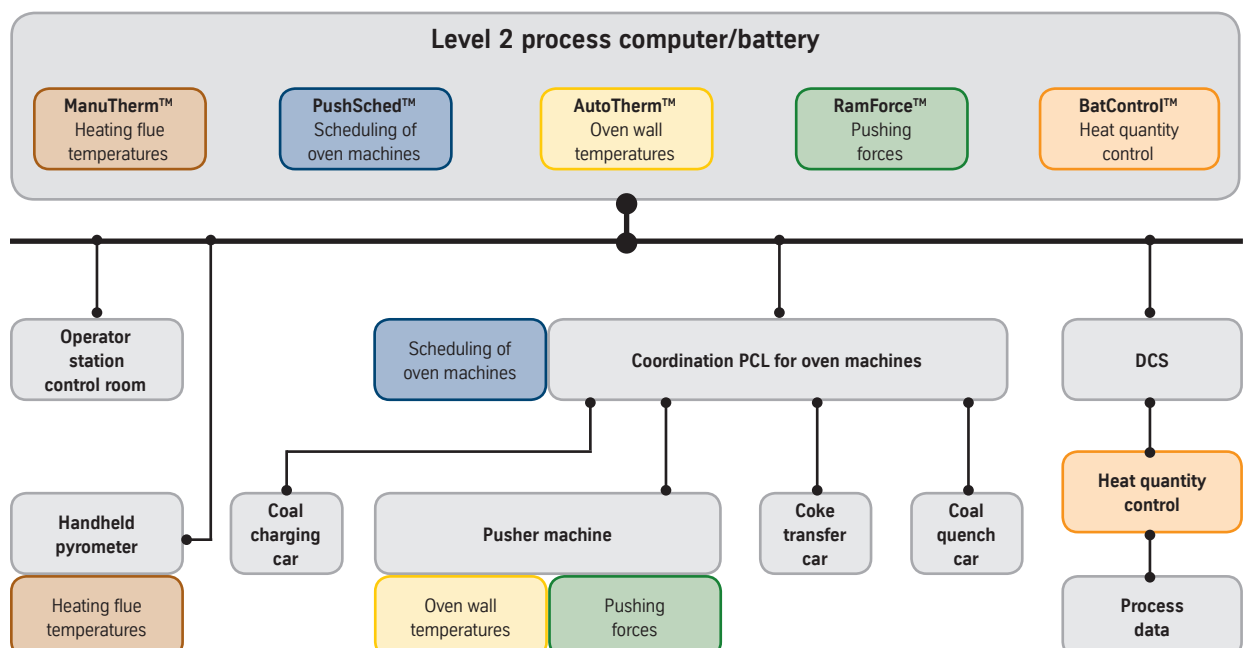
The results

To meet the challenge, the following system structure was evolved under the umbrella of the **COKEMASTER®** automa-tion architecture:

The **AutoTherm™** measuring system uses its six infrared sensor heads to measure the surface temperatures of the two heat-ing walls at three different levels during each coke-pushing operation. In other words, the heating walls are thermally scanned enabling an exact overview to be obtained of the temperature distribution in each heating wall. The aim is to keep the temperature distribution in the heating walls as uniform as possible and to detect any changes.

The **ManuTherm™** system is an infrared pyrometer with integral data memory for taking manual measurements at the heat-ing flues. Its main job is to measure heating flue temperatures when no Autotherm™ measurements are available, for instance when no coke-pushing is taking place for operational reasons. Also, detailed spot measurements can be taken where heating problems have been detected by AutoTherm™. These temperature measure-ments are fed into the computer system and can be used for further calculations and evaluations.

The **BatControl™** system calculates the amount of heat required for the battery, taking into account all relevant operating

Automation system
for battery operation

Level 2 process computer/battery

| **ManuTherm™** Heating flue temperatures | **PushSched™** Scheduling of oven machines | **AutoTherm™** Oven wall temperatures | **RamForce™** Pushing forces | **BatControl™** Heat quantity control |

Operator station control room | Scheduling of oven machines | Coordination PCL for oven machines | DCS

Handheld pyrometer | Coal charging car | Pusher machine | Coke transfer car | Coal quench car | Heat quantity control

Heating flue temperatures | Oven wall temperatures | Pushing forces | Process data

parameters such as coal quality, coal moisture, coke-pushing schedule, etc. The heating situation is automatically controlled and the heat input is immediately corrected upon detecting a fault, such as a delay in production or a change of temperature.

The **PushSched™** system is an automatic pushing and charging schedule calculation program designed to assist operating crews. The production plan is re-calculated continuously after every coke-pushing operation considering special operational situations such as "oven with extended coking time" or "oven shut down". The resulting production schedule is transmitted to the machines. Confirmations received from the oven machines are forwarded to the BatControl™ system in order to make automatic corrections to the heating.

The **GasControl™** system is a process model for gas treatment plants. The process model consists of the commercial simulator CHEMCAD for chemical plants plus extension modules developed by Uhde* for individual coke-oven-specific machinery and equipment. The GasControl™ process model uses chemical and thermodynamic mass equilibria and streams to rate each individual gas treatment unit, determines the input and output streams, and interlinks them in accordance with the plant flowsheet. The model is supplied with the necessary online process variables of the plant instrumentation in real time mode (via the process control system) and the process is calculated dynamically. By varying the control parameters (e.g. steam rate, water rate, etc.) in this virtual plant it is possible to optimise the operating results. The control parameters that deliver the best operating results are re-transmited to the plant instrumentation in order to set the local controllers in the "real" plant. All important data can "be displayed on screens, reports and trend charts.This model is not only a powerful tool for plant optimisation and automation – it can also be used in an off-line simulation mode as a training tool for operators.
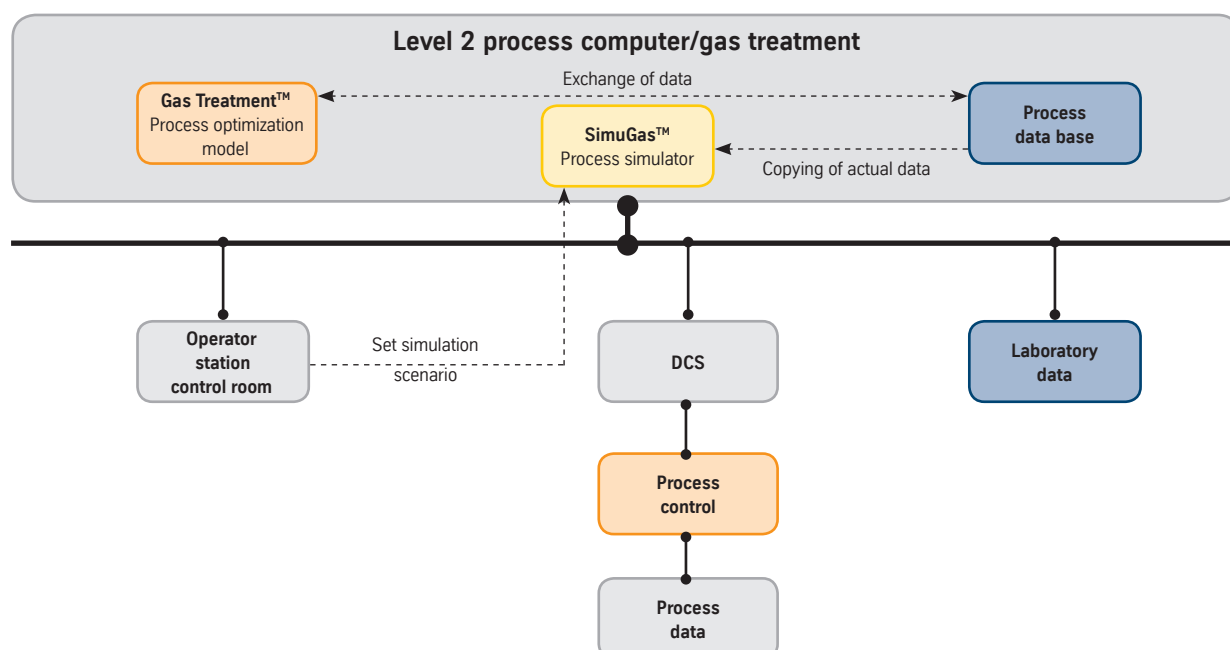
Automation system for gas treatment plant operation

PT 003/0/e/1000/201410/PM/Printed in Germany