KRAKÓW S.A.
Grupa Mostostal Warszawa

DRY SCRUBBING
SEMI-DRY FLUE GAS DESULPHURIZATION SYSTEM

A PRESENTATION

CLEAN AIR - WE MAKE IT HAPPEN

Contents

Introduction

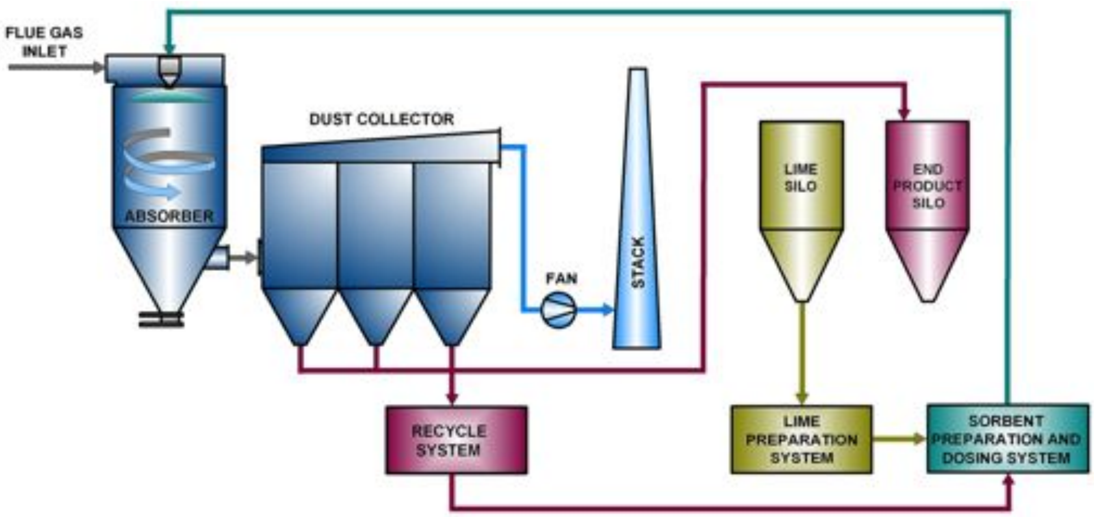
The FGD dry scrubbing process is a well-demonstrated and frequently used alternative for the removal of acidic components from flue gases. It is furthermore the technology that has proven to be the most attractive in various industrial applications.
This fact is reflected in our company's list of successfully completed projects.

AMK Kraków SA, based on years of operating experience of delivered plants, created a database for the process performance which has become foundation for a superior semi-dry FGD process. This database gives us the ability to design systems specially tailored to comprehensive customers' needs, meeting stringent emission regulations in a cost-effective manner.

General

Hot flue gases exiting a coal- or waste-fired boiler or any similar emission source, typically contain significant amounts of SO_2, HCl and other acidic components, as well as entrained fly ash or dust.

The main concept behind the semi-dry FGD process is the contact of the flue gas with atomized slurry containing flesh lime resulting in the efficient absorption of acid gas pollutants.



The chemistry of the process, in a somewhat simplified manner, can be summarized by the following reactions:

$$Ca(OH)_2 + 2HCl = CaCl_2 + 2\,H_2O$$
$$Ca(OH)_2 + 2HF = CaF + 2\,H_2O$$
$$Ca(OH)_2 + SO_2 = CaSO_3 + H_2O$$

While the water contained in the slurry is evaporated, the reaction product of the process is in the form of a dry powder. This dust is further removed from the gas stream in a dust collector.

Details

The primary absorption of the gaseous pollutants takes place in the spray dryer vessel. Raw gas is introduced to the absorber chamber via the inlet roof gas disperser. The rotary atomizer system processes alkaline slurry from sorbent preparation system by generating a cloud of fine droplets. The spray is then, in the upper section of the absorber, intimately mixed with the incoming gas stream. The diffusion of acid gases onto the large surface of the spray droplets subsequently occurs, resulting in the formation of a neutral salt by the reaction with alkaline lime particles contained in the droplets. Simultaneously, the water contained in the sprayed suspension evaporates by the efficient transfer of the heat from the flue gas, which consequently is adiabatically cooled.

The process controls both the total amount of lime entering the chemical reaction and the amount of water evaporated. It ensures that the flue gas temperature at the exit from the absorber is maintained between 15 and 25 °C above the adiabatic saturation point (i.e. the process remains dry!).
The flue gas' acid components are simultaneously reduced to the level that is required by stack emission regulations. The SO_2 removal efficiency may be as high as 97% -98%.

At the outlet of the absorber the flue gas is laden with the process end-product in the form of dry powder, containing no more then 2-3% moisture. This dry particulate matter, consisting of mainly calcium, sulfite/sulfate, excess lime and fly ash, is subsequently removed from the flue gas stream in the downstream-located dust collector, while a smaller, somewhat coarser fraction is also discharged at the bottom of the spray dryer vessel.
In case a fabric filter has been selected as the final dust collector the process performance is further enhanced by the “secondary” acid gas reaction with residual lime in the layer of alkaline dust on the surface of the filter bags.

The dry end product is discharged from the bottom of the fabric filter hoppers, and directed either to the recycle slurry preparation system or to the end-product storage silo for utilization or disposal. Recycling a part of the end-product solids by mixing it with the fresh lime decreases the content of unused lime in the end-product, improving the overall lime utilization.

The reagent feed system for the rotary atomizers combines feed slurry from the lime preparation system and the slurry prepared from recycled end-product. The final regent slurry is pumped it to the top of the spray dryer. It is here atomized into a cloud of fine droplets by the rotary atomizers.

Spray Absorber

The spray absorber ensures proper mixing of the raw gas stream with the atomized reagent (lime) slurry and provides sufficient residence time for the chemical reaction to occur. This is achieved by the proper design of the inlet flow gas disperser and the absorber vessel, which is resulting in optimum SO_2 removal efficiency and lime utilization.

The gas disperser, located at the entry point to the absorber also ensures satisfactory turn-down flexibility for the typical boiler load range. Depending on the application different types of gas dispersers are employed, including adjustable, tangential inlet plenums, as well as fixed, direct/ radial inlet ducts.

FEATURES AND BENEFITS

Single and multiple atomizer options

The removal of one atomizer for service/maintenance is possible without process interruption. This is especially important for large facilities.

Use of direct drive atomizers

Provides smaller, low-weight lighter units that are easier for handling by operators.

Alkaline environment in the entire absorber vessel

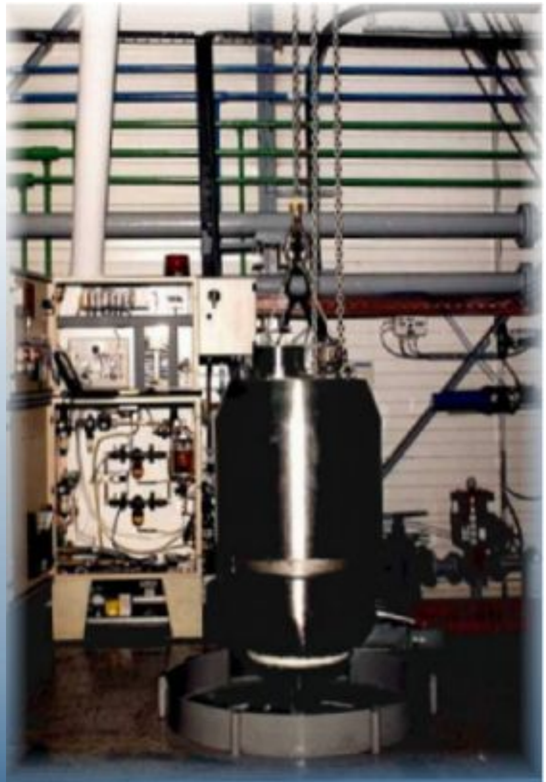
Allows for the use of normal mild steel vessels. No expensive linings, no exotic materials.

Smaller diameter to height ratio of absorber

Allows for easier retrofit in limited-footprint situations.

Rotary Atomizer System

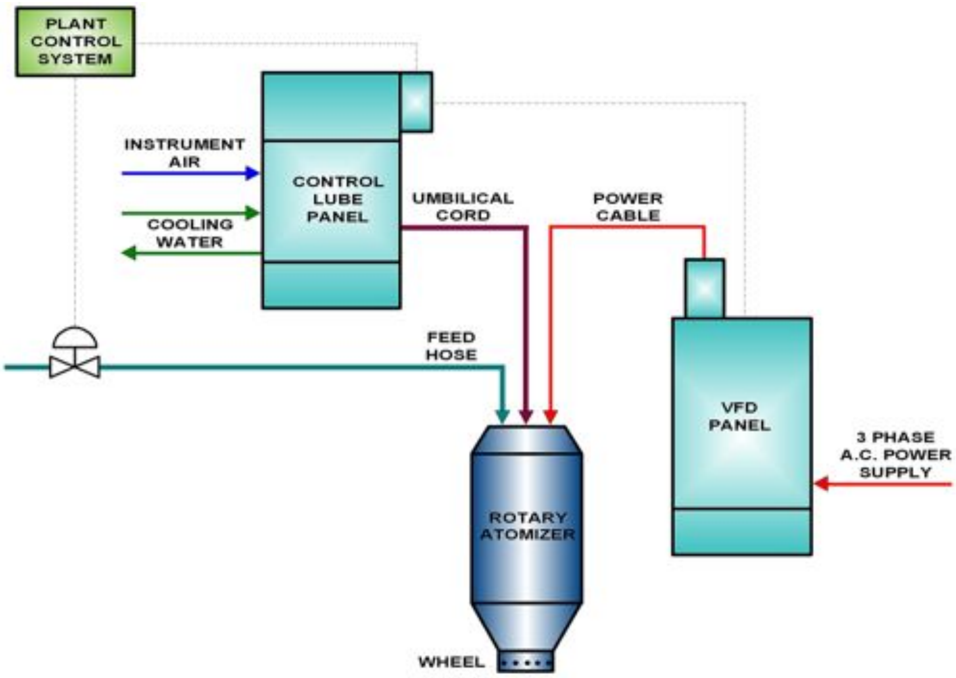
Rotary atomization provides the most energy-efficient and reliable means of generating an atomized spray from a high flow rate of the reagent (lime) slurry. The principle of rotary atomization is based on the acceleration and shear of the lime slurry into uniform droplet size (3-40 micron) for all flow rates (the mean droplet diameter remains unchanged). The specific atomization energy is thereby kept constant, which means that the total energy consumption is maintained at a minimum. These are unique features which cannot easily be achieved by other means of atomization.



The rotary atomizer is a direct-drive, high-frequency, two-pole electrical motor designed for a VFD power supply in the range above 200Hz, thereby creating rotating wheel speeds in excess of 12.000 RPM. The atomizer is further supplied with an integral local control panel, and also may be controlled directly by plant's DCS. Dedicated atomizer software is supplied with the control system.

A typical rotary atomizer system comprises:

- the rotary atomizer ('spray machine') with atomizer wheel
- the control and lubrication panel
- the frequency inverter (variable frequency drive, VFD)
- connecting hoses and cables



FEATURES AND BENEFITS

Simple, reliable construction

The atomizer wheel is mounted directly on a rigid shaft of the high-speed motor, with a minimum of moving parts

Compact size

Low weight allows for easier manual handling by operators during removal, inspection and cleaning

Energetic efficiency

The VFD-driven electrical motor uses the minimum amount of energy necessary for the atomization of the amount of slurry given by the process requirement

Sorbent Preparation System

Quick lime (CaO) is for both process and cost reasons the most common choice for the alkaline sorbent.

The lime is supplied in pebbles or in pulverized form and is first converted to lime milk. This process takes place in a slaker, where CaO reacts with water in a strongly exothermic reaction to form a suspension of calcium hydroxide.

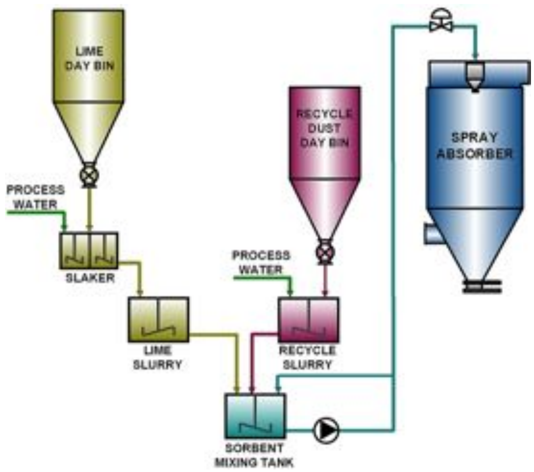
The freshly slaked lime milk has high reactivity towards acidic components. Suspension of hydrated lime in water may be used as an alternative reagent; however, it is typically only used when smaller quantities are required.

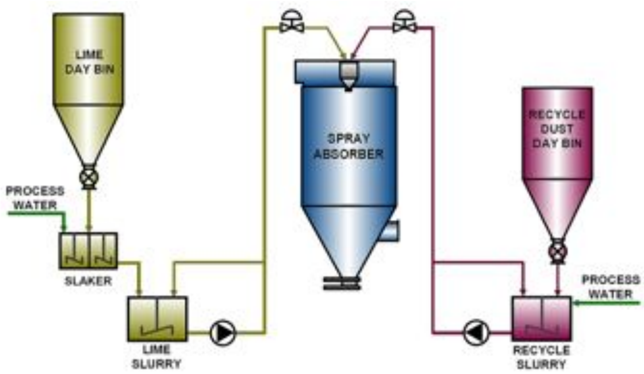
Some dry scrubbing systems use the concept of end-product recycle.
The process uses part of the reaction product for re-slurrying and then combines it with the fresh lime stream.
This recycle process generally improves the lime utilization, which makes it particularly attractive for high lime consumption rates.

Recyle of the end-product also improves the drying characteristics of the lime slurry and generally enhances process flexibility and efficiency.

The required system response time and cost considerations determine whether lime milk is mixed with recycled slurry in the storage tank or in the atomizer's wheel.
The above process options are sometimes referred to as 'slow response' or 'fast response' systems.

SLOW RESPONSE





FAST RESPONSE

Dust Collector

The electrostatic precipitator is in many applications used as the particulate control device for the dry scrubbing process. However, the fabric filter offers process advantages which make it the most common choice for the downstream dust collector.

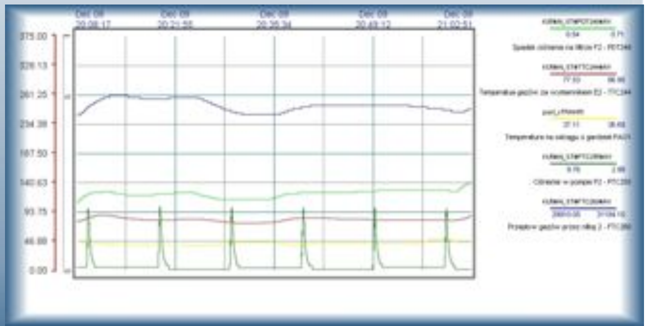
This is primary because the chemical reaction between lime and SO_2 continues inside the porous structure of the dry particles when collected onto the fabric.

An optimum process efficiency calls for a low approach to the saturation temperature. This is obviously in contrast to the safe operation of a baghouse. However, dedicated design and careful fabrication of the dust collector allows for its safe operation at relatively low temperatures without risk of condensation, corrosion or similar problems.

Well-developed control procedures and extensive experience in the proper design of spray dryers has eliminated the need for the use of expensive, temperature resistant filter media. This has in consequence reduced both investment and operating costs of the dust collector.

Process Control

Vital to the FGD system performance, especially in case of the semi dry process, is the quality and reliability of the control system. The basic parameter for the dry-scrubbing process is flue gas temperature at the absorber outlet. This temperature determines the flow rate of the sorbent slurry fed to the atomizer. The removal efficiency and the lime utilization significantly increase with the approach to the adiabatic saturation temperature. However, too low gas temperature is not desired as it may result in wet conditions in the absorber. Therefore approach-to-saturation becomes the most essential process variable.



As the flue gas condition at the absorber inlet may change rapidly, following any changes in the boiler load and variations in the fuel composition, the reliability and accuracy of this process control is crucial to the overall scrubbing process performance. The proper control algorithms required for the immediate and accurate response to the dynamically changing inlet conditions have been developed by AMK Krakow SA process and instrumentation engineers based on many years of operating experience.

The control tasks are carried out by up to date programmable logic controllers working in network connections. A typical system includes an operator workstation, controllers and local control panels for maintenance and checkout.

Control system performs the following functions:

Automated startup

During the startup of the system the verification of a number of process and equipment conditions is done prior to initializing the operation of any equipment. This procedure ensures trouble-free start of the absorber, preventing undesirable upset conditions.

Automatic operation

After the startup procedure has been completed the control system will run the plant with the objective of maintaining a pre-set value of the SO_2 stack concentration or the SO_2 emission while keeping the lime consumption at the lowest possible level. This task is carried out by a digitized PID software controller. The two basic control loops of the process are as follows:

1. Keep the outlet gas temperature at a pre-set level by controlling the total amount of water being fed to the rotary atomizers,
2. Distribute the total amount of water between the lime and recycle slurr to ensure proper response to the variations in composition of the inlet flue gas.

Automated shutdown

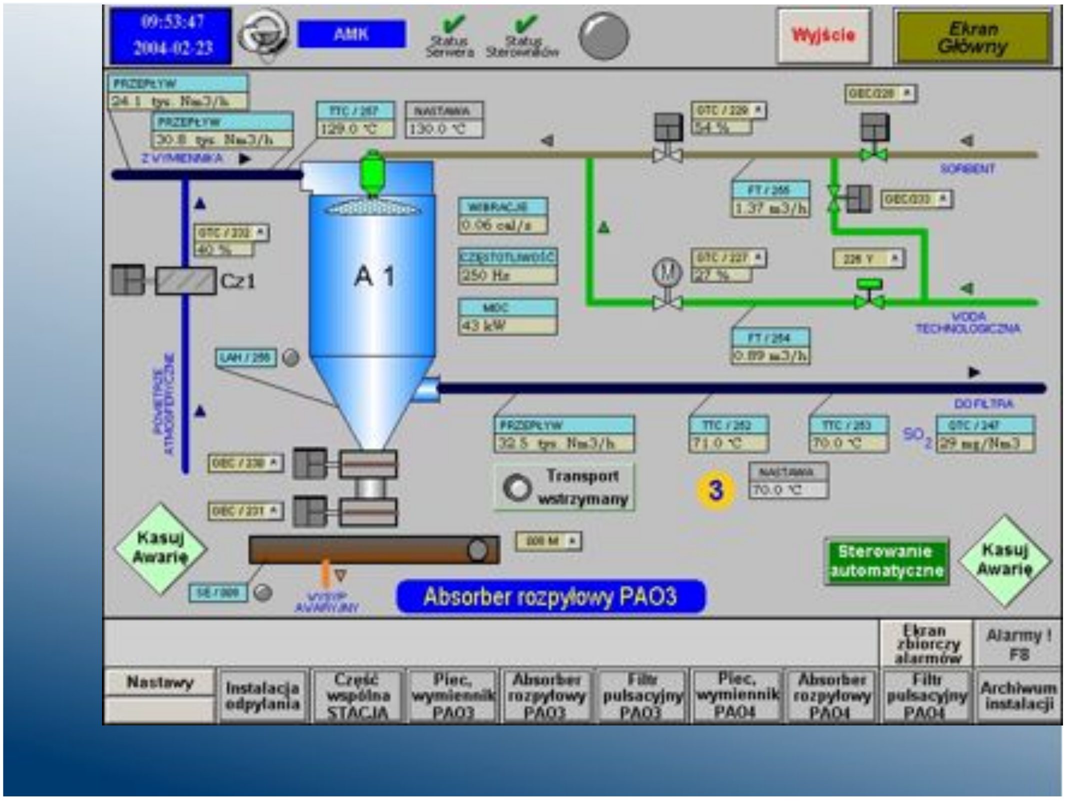
During the scheduled shutdown of the system a sequence of automated steps is carried out to ensure that the plant is brought back to a condition from where it is ready to be started up again.

Remote control by the operator

All motors, valves and other process equipment can be stated and stopped from operator workstation or local control panels (MMI)

Typical set of software components utilized in our system:

- PLC system modules for real-time operation
- PLC application programs
- MMI panels operating system
- MMI panels application programs
- Networking and communication software
- Workstation system modules and firmware
- Workstation application program



FEATURES AND BENEFITS

Precise temperature control based on sophisticated algorithms

Allows narrow approach to saturation, resulting in optimum process efficiency for all flue gas conditions including dynamic changes in gas flow and composition at the absorber inlet.

Fully automated operation of sorbent preparation and pumping as well as solids conveying systems
The number of operators is kept at minimum; their duties are limited to supervision and necessary mechanical maintenance.

Advanced diagnostics

All process variables are constantly monitored and any deviations from the expected values are analysed in the system and instantly signalled as an aggregated warning. This results in regular preventive maintenance rather than coping with consequences of failures.

Use of state-of-the-art PLC hardware, networking connections and operator workstations

Most recent hardware, firmware and application software can be supplied, tailored to the application needs and any specific customer's requirements.

Effective and user-friendly operator interface

Full use of up-to-date software tools, including hierarchical access, process visualisation, current and historical trends, alarms and warnings system.

Range of Application

The dry scrubbing process has over decades successfully competed with other gas cleaning processes in the following applications:

- Desulphurization of flue gas from coal-fired utility or industrial boilers
- Cleaning of waste gases from municipal, industrial or hazardous waste incinerators
- Recently, dry scrubbing processes have also been successfully used in specific applications of the non-ferrous metals industry (e.g.for the simultaneous removal of acid gases and white arsenic vapours).

The size of operating facilities ranges from 20 000 to several million m^3/h of gas flow.

End - product

The end-product of the dry-scrubbing process is mainly composed of calcium sulphates and sulphites. The content of other components is application specific and includes unreacted lime, other salts (e.g. chlorides) and fly ash.

The end-product's physical and chemical properties indicate many potential commercial uses, ranging from soil amendment for reclamation purposes through structural fill and road base construction to retarder in portland cement, bricks and blocks production.

A technology has recently been developed for simple and inexpensive conversion of the end-product into wallboard-grade gypsum.

The product is stable for landfilling purposes and can be disposed along with coal fly ash.

Summary of Process Benefits

economic

- low investment costs for materials and equipment
- low operation and maintenance labour requirements
- relatively low electrical power consumption
- low water consumption

environmental

- high SO_2 removal efficiency
- complete SO_3 removal (plume elimination)
- high removal of other acid gasses (HCL, HF)
- potential removal of mercury and other toxic metals
- very low stack dust emissions

suitability for retrofit applications

- suitability for retrofit applications
- flexibility in terms of general arrangement of equipment
- relatively small space requirements

operational

- computer automation of the process control and monitoring
- multiple atomizer design enhances redundancy

by - product

- potentially marketable, solid end-product
- no liquid waste

Selected Completed Projects

FGD System at a Power Plant

Project name:

Flue Gas Desulphurization System at the Power Plant in the Copper Smelter Głogów I

Customer:

KGHM Polska Miedź SA, Poland

Project schedule:

Signing of the contract:	February 1996
Basic and detailed engineering:	February 1996 November 1996
Erection:	February October 1997
Commissioning:	November 1997

Emission source:

Nine coal-fired boilers used also for incineration of throat gas from shaft furnaces

Inlet flue gas characteristics:

rapid changes of the flow rate, temperature and composition of the raw flue gas depending on the shaft furnaces operation

content of metallic dust, in particular copper, lead, zinc and arsenic, resulting in high acid dew-point

Process gas

flow rate:	211 000 1 086 000 m^3n/h
temperature:	160 - 300 ^0C (after incineration and initial cooling)
dust concentration:	2,5 g/m^3n
SO_2:	18 g/m^3n

Project objective:

To ensure that the stack emission limits of SO_2 and dust meet stipulated limits at possibly lowest cost. The availability of the plant is of utmost importance (minimum 98 %). All end-product of the gas must be utilised in the copper smelter.

Process description:

Copper smelter Głogów I uses shaft furnaces to produce copper matte. The throat gas released in this process contains large amounts of combustible constituents (carbon monoxide, hydrogen, hydrocarbons) and variable, significant concentrations of acidic pollutants (sulphur di- and trioxide, hydrogen chloride, hydrogen fluoride) This gas is incinerated in specially adapted boilers in the power plant. The incineration process eliminates combustible gases and dust, whereas the acidic pollutants contents remain unaffected.

Dust contained in the flue gas from each boiler is pre-collected in cyclones (battery limit of the project). The first part of the system is the inlet manifold duct, from which the raw flue gas is distributed to three process trains, each consisting of one gas-gas heat exchanger, one triple atomizer spray absorber and one pulse-jet dust collector. The treated flue gases are heated up to approx. 120 °C by the raw hot gases in the heat exchanger before entering the concrete stack and being discharged to the atmosphere. The system includes also the quick lime storage, the reagent slurry preparation unit and the end-product storage. These facilities, due to limited space available in the vicinity of the power plant, are situated in remote locations.
The end-product of the process is wholly utilised in other operations of the copper smelter.

Operating experience:

Results of guarantee emission tests:

dust concentration:	< 10 mg/nm3
SO2 removal efficiency :	97,2 %

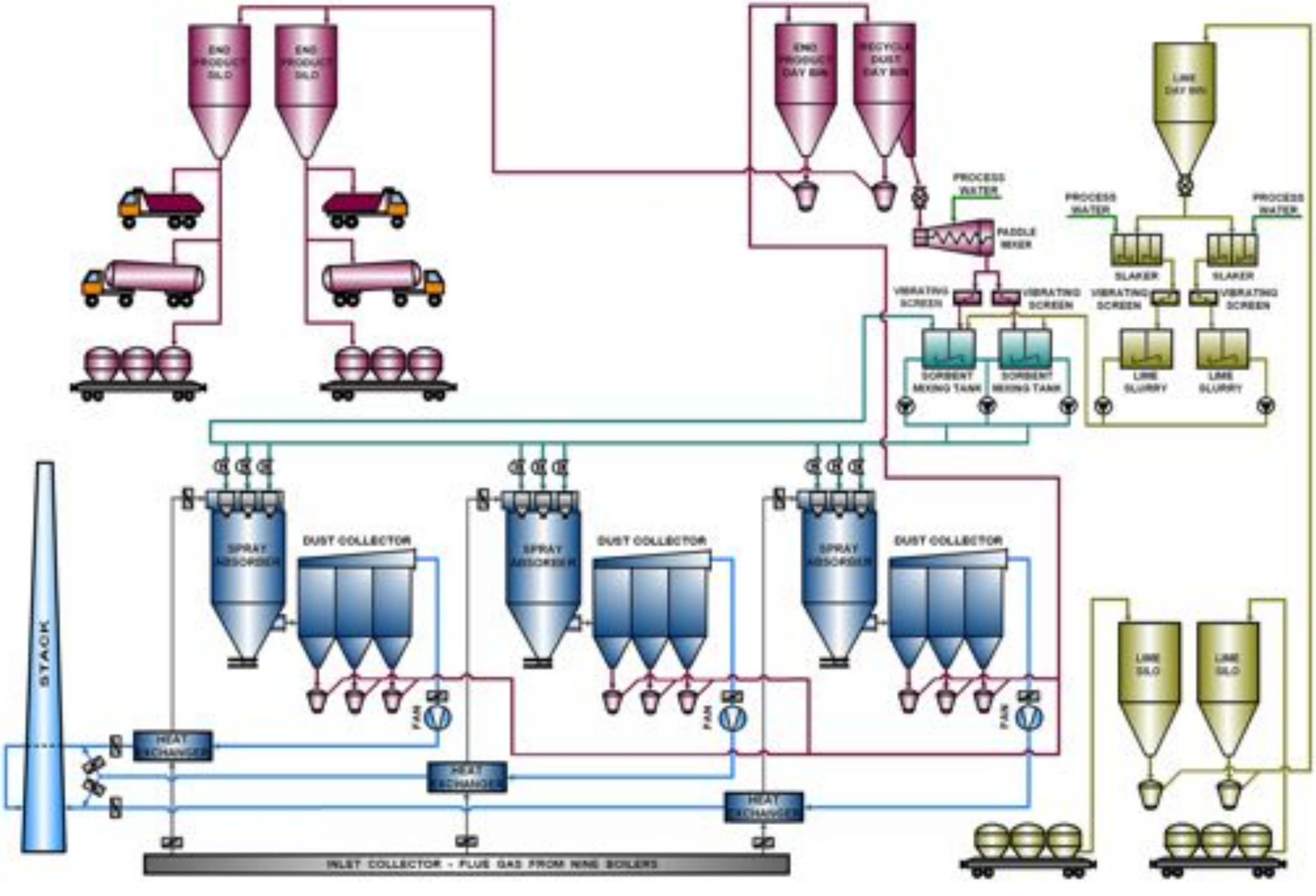
The optimisation of the process parameters during initial years of operation resulted in the current lime consumption at the level of 1.1 kg CaO / kg absorbed SO_2
Availability of the system is well in excess of 99 %.

Summary:

The Dry Scrubbing process was chosen for this application after comprehensive evaluation of offers representing wide variety of technologies, including regenerative , wet lime and limestone and other variations of semi-dry processes. The criteria of this evaluation included reliability, investment and operating costs, removal efficiency and end-product utilisation.

The project successfully demonstrates some of the distinguished features of the Dry Scrubbing process including extremely high availability of the triple atomizer absorber, great flexibility of the arrangement of process devices and ability to achieve SO_2 removal efficiency in excess of 97 % in economically justifiable manner.

The concept incorporating the heat exchanger into the process allowed the customer to continue using the existing concrete stack, which has further contributed to the overall economy of the process.



SELECTED COMPLETED PROJECTS
FGD System at a Power Plant

Waste Gas Clearing System for Liquid Copper Fire-refining Process

Project name:

Gas cleaning facility for copper fired refining furnaces

Customer:

KGHM Polska Miedź SA, Poland

Project schedule:

Signing of the contract:	July 2000
Basic and detailed engineering:	July 2000 - September 2000
Erection:	September 2000 February 2001
Commissioning:	March 2001

Emission source :

Two furnaces for fire refining of liquid copper and casting of copper anodes

Process characteristics in all aspect of the emission of pollutants

- variability of flow rate and the composition of the process gas depending on the process phase
- high content of unburnt hydrocarbons and carbon monoxide
- high peak values of sulphur dioxide concentration during charging and initial refining
- content of metallic, predominantly condensation dust, in particular copper, lead, zinc and arsenic
- high concentration of white arsenic (As_2O_3) in gaseous phase

Process gas parameters

gas flow rate :	max 2 x 35 000 m^3n/h (down stream of incineration chamber)
gas temperature:	200 - 600 ^oC (after incineration and initial cooling)
hydrocarbons :	max 54 mg/m^3n
SO_2 :	max 2 500 mg/m^3n
CO :	max 1 600 mg/m^3n

Project objective:

To ensure that the stack emission of all pollutants meet stipulated limits at possibly low investment and operation costs.

Emission limits:

Dust concentration:	below 1 mg/m3n
SO2 :	below 25 kg/h for each rotary furnace which corresponds to the removal rate of minimum 70%

Process description:

Gasses extracted from each furnace are directed to the incineration chamber where they are mixed with certain amount of ventilation air. Proper residence time, oxygen excess and temperature ensure elimination of combustible constituents (carbon monoxide and hydrocarbon) further on, the rest of the ventilation air is mixed in to cool the gasses down to 6000C. In the next stage further cooling takes place in the tubular air gas heat exchanger down to approx. 1500C. Removal of acid pollutants is performed simultaneously with evaporating cooling in a single atomizer spray absorber. The outlet temp of 700C ensures that all white arsenic is in solid state and may be separated along with other gas in a downstream pulse-jet collector. Solid product of the gas cleaning facility is recycled to the shaft furnaces, whereas the clean gasses are discharged to the stack.

Operating experience:

- Results of guarantee emission tests:

Dust concentration:	max 0.7 mg/nm3
SO2 :	0-17 mg/nm3

- Availability during the first year of operation exceeded 98,5%

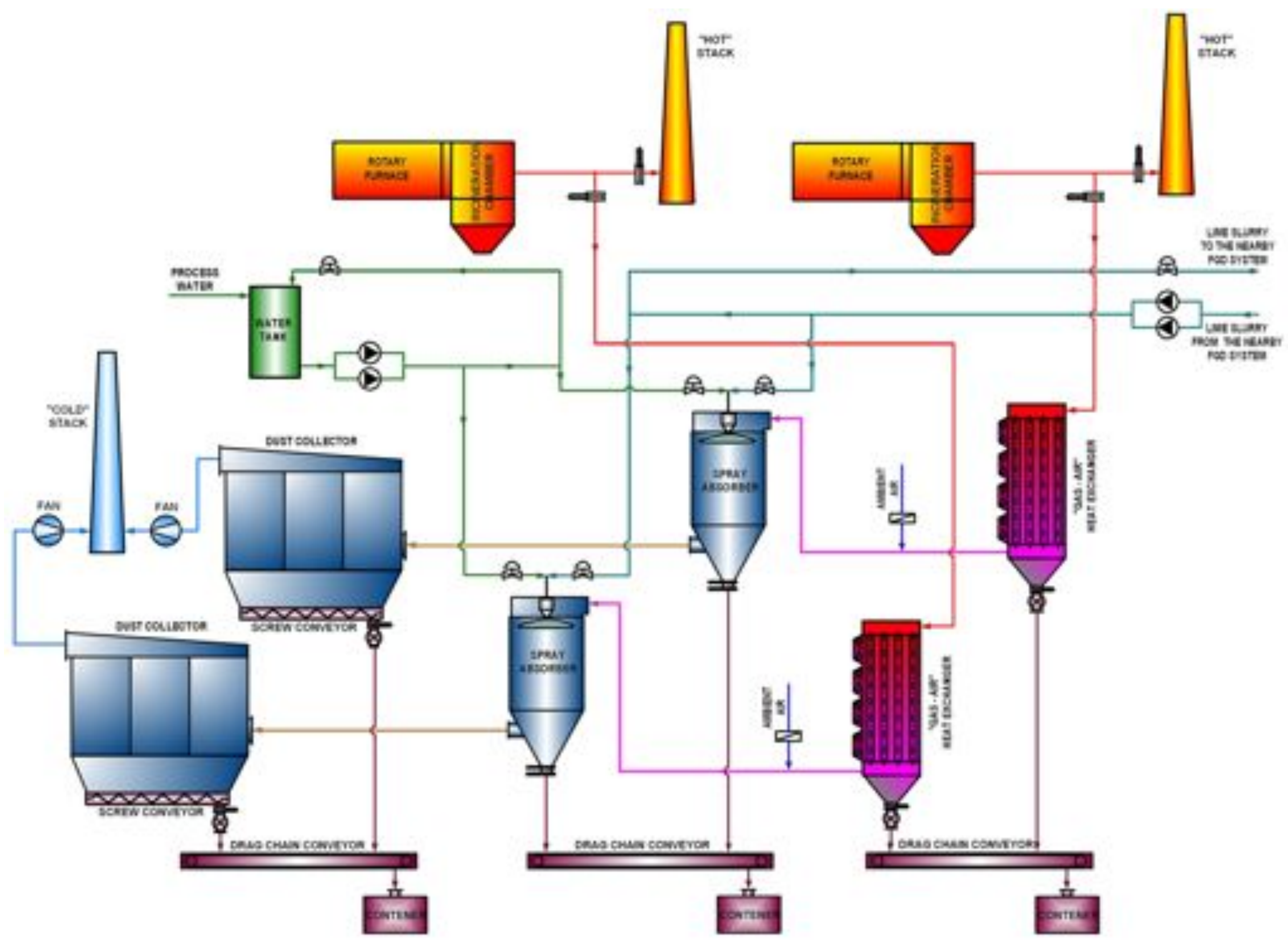
Summary:

- The process applied for the cleaning of off-gases from anode furnaces in Copper Smelter Głogów I is unique in this branch of industry. Other dry systems based on bagfilters include cooling by ambient air intake which results in the dramatic increase in gas volume, equipment size and cost. Typically used wet systems are characterised by much higher costs, both investment and operating.

- Three years of the operating experience fully confirmed the feasibility of the process.

- Due to high efficiency of the system, emission of all pollutants from the anode process was practically eliminated. Results of control measurements of emission proved that the emission of arsenic is much lower than required by the European and US standards. Emission of dust and SO2 became negligible.

- High availability, relatively low investment and operating costs led to signing a contract for similar system for the same customer.



SELECTED COMPLETED PROJECTS

Waste Gas Clearing System for Liquid Copper Fire-refining Process

FOR MORE INFORMATION
REGARDING OUR PRODUCTS AND CAPABILITIES
PLEASE CONTACT US:

AMK Kraków S A

Al. Jana Pawła II 41, 31-864 Kraków, Poland

tel. +48 12 647 66 38, fax +48 12 647 68 97

e-mail: amk@amk.krakow.pl, website: www.amk.krakow.pl

TÜV CERT
ISO 9001
ISO 14001

AMK Kraków S A
Al. Jana Pawła II 41, 31-864 Kraków, Poland
tel. +48 12 647 66 38, fax +48 12 647 68 97
e-mail: amk@amk.krakow.pl, www.amk.krakow.pl