HUGO PETERSEN - COMPETENCE IN GAS CLEANING SYSTEMS
DOWNSTREAM NONFERROUS METALURGICAL PLANTS

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HUGO PETERSEN

The Company

HUGO PETERSEN has developed from the traditional firm of the same name that was established in 1906 in Berlin and is an engineering company specialising in general plant engineering now based in Wiesbaden. HUGO PETERSEN has many years wide-ranging experience in process plant engineering, primarily in the field of Sulphuric Acid Processes and Gas Cleaning. Together with its main shareholder, Chemieanlagenbau Chemnitz GmbH (CAC), a company with over 40 years experience in the international plant engineering business, HUGO PETERSEN implements turnkey new plants from initial consultancy right through to commissioning. In addition, HUGO PETERSEN can offer its clients improvements and revamps of existing plant systems. Initial consulting, planning and implementation take place within the context of a lean company organisation with experienced engineers and specialists. In all respects, many years of experience guarantee expertise over a wide range of possible applications. For clients from the chemicals and metallurgical industries, as well as those in metals processing, HUGO PETERSEN GmbH’s breadth of experience means not just an efficient introduction to new methods and processes, but also their full implementation.

In addition, along with design and construction for individual components, the company’s range of services also covers supply of complete plants, as well as modernisation projects and revamps in line with local conditions and existing quality requirements. With own technologies and patents in the field of gas cleaning and sulphuric acid, supplemented by licences and cooperation projects, HUGO PETERSEN ensures expertise over a wide range of applications. With specialists and expert knowledge in these fields of application, HUGO PETERSEN is your partner of choice, supporting you and bringing your acid, and project to a successful conclusion.

Gas Cleaning Plant (GCP)

Components and Arrangement of Gas Cleaning Plants downstream Nonferrous Metallurgical Plants mainly depending on the following terms:

- Gas Conditions of the upstream Process
- Sulphuric Acid Quality
- Requirements of Local Authorities
Generally HUGO PETERSEN Design has the following principles:

- **Low Pressure Drop**
  - low operation costs as well as reduced wear and tear

- **Self adaptable Process Operation**
  - reduces manual or control loops impact,
  - means less operational problems and high
efficient operation as no risk of bad control

- **No movable Parts in the Gas Stream**
  - less maintenance

- **High corrosion resistant Material**
  - extended life cycle of the plant

Based on the different requirements the choice of single units and arrangements can be subdivided as follows:

**Conventional Arrangement**

- Pre-quench Tower for Gas Conditioning and Preliminary Cooling
- Post-quench Tower for Gas Conditioning and Secondary Cooling
- Cooling Tower for Gas Condensation and HF-Removal
- Primary and Secondary Wet Electrostatic Precipitator (WESP) for remaining Dust and Mist Removal

**High Dust Arrangement**

- Pre-quench Tower
- Jet Scrubber or Post-quench Tower incl. PETERSEN Spray Separator (PSS)
- Primary WESP
- Cooling Tower
- Secondary WESP

**Additional Mercury and / or Heavy Metal Removal**

- Calomel Process
- Thiosulphate Process
- Activated Coke Filter

**Tail Gas Scrubbing**

- Hydrogen Peroxide Scrubber (SUPER\textsuperscript{OX})
- Ammonium Scrubber
Conventional Arrangement

Diagram 1: Conventional Arrangement incl. SO2-Stripping Tower

The hot gases from the upstream plant are led via hot dust precipitators to the top inlet of the pre-quench tower K1 which is a void tower. At the downward flow the hot gases are cooled down by app. 10 up to 50 weight % sulphuric acid. Due to the special design of the pre-quench tower enabling an internal re-circulation, a safe cooling down is achieved by partial evaporation of the circulation liquid. Due to this spraying the gas temperature is reduced to the equilibrium of the vapour pressure of the circulated sulphuric acid depending on the acid concentration.
Principle scheme of the gas flow on top of the Pre-quench tower

The gases leave the pre-quench tower K1 and enter the post-quench tower K2. In both towers partly dust, HCl and HF are removed as well as Arsenic, Antimony etc. The remaining part of the sprayed liquid is collected in the bottom part of the quench towers and led via the quench liquid pump tank B1 which serves the pumps P1. Two separate lines, each with one pump, serves the sprays at the pre-quench tower and the spray lines of the post-quench tower. The flow rate to the spray nozzles of the pre-quench tower is monitored, and in case of failure of one line the other line serves enough liquid for safe and uniform cooling down of the gases. Due to partial evaporation the circulation system has always a need for liquid which is fed by a cross flow from the fluoride scrubbing tower K3.

Downstream the post-quench tower an optional additional gas stream, coming from the Stripping Tower K4 is mixed with the cooled and pre-cleaned gases. The mixed gases enter the cooling tower K3 wherein the gases pass a packed bed which is irrigated with cooled liquid. Due to the intense contact between the gas and the liquid within the packed bed the gas temperature is reduced down to normally between ranges of 30 – 40 °C.

When cooling down also partial condensation takes place and all liquids are collected in the base part of the tower K3 which is acting as pump tank for the circulation pumps P2. Due to the low temperature the main part of HCl, as well as the remaining part of arsenic, is removed in the scrubbing tower.

The circulation liquid pass a set of acid coolers W1 wherein the heat is transferred to cooling water and the temperature of the circulation liquid is reduced to the required temperature. Downstream the coolers the liquid is evenly distributed by sprays or optional via an acid
irrigation system on the top of the packing of the cooling tower. The condensed water vapour is discharged dependent on the level of the quench-tower pump tank to the pump tank of the quench towers.

The remaining amount of liquid is discharged in dependence of the cooling tower bottom liquid level, either directly to the waste water treatment or via the above mentioned SO$_2$-Stripper K4 to the waste water treatment.

After passing the cooling tower K3 the gases are lead to the two stages wet electrostatic precipitator system.

The wet electrostatic precipitator system in our example consists of totally four precipitators arranged in series consisting of two primary and two secondary WESP’s.

The mist and droplet laden gases enter the shell at the top of the first stage WESP’s (F1/1-F1/2) and passes through guide vanes and two perforated plates which distribute the gas evenly throughout the shell.

The gases then flow downward through the collector tubes and exit centrally through the bottom of the shell of the WESP’s.

The second stage WESP’s (F2/1-F2/2) are connected to the first stage WESP’s by gas ducts, so that the gases flow from the bottom of the first stage WESP’s to the bottom of the second stage WESP’s.

The bottom vestibule of the second stage WESP’s is equipped with guide vanes and two perforated plates as well, to assure that the gas is evenly distributed throughout the collection tubes.

The gases leave the second stage WESP’s through the top vestibule to the downstream drying tower.

In the electrostatic precipitator systems mainly the remaining acid mist and dust are removed to the required emission data.

While it is imperative that the gases flow upward in the second stage to prevent re-entrainment, it is beneficial to have the gas flow downward in the first stage. In effect, the gases at the inlet of the first stage carry a lot of coarse entrained droplets from the cooling system upstream of the WESP-system which will provide a so called "self-cleaning effect" on the collecting surface and reduce the danger of built-up of solids on the collecting surface to a minimum.

As the gas enters the intense electrical field induced between the electrodes and the collector tubes by the high voltage electrode, particles suspended in the gases become charged and migrate under the influence of electrostatic forces towards the collection surfaces.

The accumulated mist particles or droplets form a liquid film on the grounded collector surface and are drained back to the pump tank of the quench towers.

The electrostatic field is established by stepping up low voltage alternating current (AC) in a transformer to a high voltage and then rectifying it to direct current (DC) with a rectifier. The rectified current is then delivered to a system of high voltage electrodes which are suspended
in the centre of each of the uniformly spaced collecting pipes. The high voltage system is electrically insulated from the collecting pipes by special porcelain insulators.

Diagram 2: Conventional Arrangement incl. HF-Removal and separated Quench Tower Circulation

The separation of the liquid circuits of the quench towers allows running the two quench systems with different concentrations of sulphuric acid to increase the concentration of the discharged acid by keeping the outlet temperature of the post-quench tower at low level and to avoid a carry over of concentrated sulphuric acid to the cooling tower.

By adding sodium silicate to the circulation system of the cooling tower fluorides in the off gas can be nearly completely removed.

The main benefits of the HUGO PETERSEN Gas Cleaning Design are:
- Safety Operation due to different independent liquid circuits
- High Availability
- Minimized Control and Operating Efforts
- Minimized Process Water Consumptions
- High Removal Efficiencies
- Space Saving Arrangement
Typical Arrangement of a Pre- / Post-Quench incl. Cooling Tower
High Dust Arrangement

Diagram 3: High Dust Arrangement incl. PPS-System

The post quench-tower is designed as a PETERSEN-Spray Scrubber (PSS) with totally four scrubbing stages, working with high pressure to remove main parts of dust, mist and arsenic components.

The PSS is designed for maximum flow to achieve an efficiency rate of app. 95 % to due big sized particles.

In case of lower gas flow rates, the removal efficiency will increase due to the increasing of the liquid / gas relation.

A further modification is the arrangement of the first wet electrostatic precipitation system F1/1-2 upstream the cooling tower K3 to remove remaining solid contents as it is required to produce a clean weak acid.

The circulation liquids of the quench towers and the flushing liquids of the WESPs are continuously discharged via a sludge precipitator F3 and a redundant filter press system F4/1-2 to keep a constant solid content in the liquids.

The removed sludge can be disposed in the upstream process.
This arrangement should be preferred in case of low or medium gas flow rates. The main benefit of both installations is the low pressure loss as the removal energy is brought in by the liquid. A further benefit is that there is no need for regulation in case of unsteady gas flow rates.

**Mercury / Heavy Metal Removal Systems**

In general the remaining mercury content of the feed occurs partially in vapour form and, depending on the operation temperature of the cooling units, partially as particulates. The particulates are nearly totally separated in the wet electrostatic precipitators, the mercury vapour appear as a contaminant in the product sulphuric acid as it is absorbed by strong acid in the downstream drying and absorption units due to the following reactions:

1. Reaction between dissolved mercury in the acid and elementary mercury in the roaster gas
   \[ \text{HgSO}_4 + \text{Hg}^{0} \rightarrow \text{Hg}_2\text{SO}_4 \]

2. Oxidization of the formed mercurous sulphate by strong acid and oxygen in the gas to mercuric sulphate
   \[ \text{Hg}_2\text{SO}_4 + \text{H}_2\text{SO}_4 + \frac{1}{2} \text{O}_2 \rightarrow 2\text{HgSO}_4 + \text{H}_2\text{O} \]
The Calomel Process

The Calomel Process is based on the oxidation of mercury vapour by mercury chloride to form microbus chloride (calomel) due to the main chemical reactions:

Packed Bed Tower: \( \text{Hg}^0 + \text{HgCl}_2 \rightarrow \text{Hg}_2\text{Cl}_2 \) (calomel)

Regeneration: \( \text{Hg}_2\text{Cl}_2 + \text{Cl}_2 \rightarrow 2 \text{HgCl}_2 \)

The mercury containing cleaned gas downstream the final wet electrostatic precipitation units passes through a packed bed tower K4 where a solution of mercury chloride is circulated via pumps.

A double stage mist eliminator at the top of the tower prevents the carry over of scrubbing solution.

During the reaction between the gas and scrubber solution insoluble Hg chloride (calomel) is precipitated. A part of the calomel containing solution is pumped to the Settler F1.

There the product (calomel) is isolated from the system by decantation as a heavy sludge. A portion of the calomel is then separated from the process.

The remaining calomel is re-oxidized in the chlorinator vessel B1 with the oxidant chlorine (Cl\(_2\)) dosed by an injection mixer R1 and via circulation pumps to Hg chloride (HgCl\(_2\)). A strong solution of Hg chloride (HgCl\(_2\)) is prepared in this manner and stored separately in the strong solution vessel B2 via suction filter F2.

The solution is fed into the circulation system via diaphragm dosing pumps at a rate that corresponds to the consumption according to the calomel process reaction.

![Diagram 5: Typical Arrangement of the Calomel Process](image-url)
Main Benefits:

- Most popular Method for Removing Mercury
- High Efficiency (Sulphuric Acid with less than 0.5 ppm Mercury can be produced from a gas containing 150 ppm mercury)

**Thiosulphate Process**

The absorption efficiency of mercury depends on the acid strength and acid temperature. The lower the acid temperature and the higher the acid concentration, the higher is the absorption efficiency.

To avoid an accumulation of mercury in the product acid it is essential to absorb the mercury vapour in a two stages drying tower unit K1 / K2 running with different acid concentrations whereas the acid concentration in the second drying tower should be higher than the acid concentration of the downstream absorption units.

The mercury containing acid of the drying towers has to be cleaned before discharging into the absorption circuits.

Therefore the acid streams are gathered and treated in reaction units with Sodium-Thiosulphate (Na$_2$S$_2$O$_3$ x 5 H$_2$O).

The total amount of acid of both drying towers is stripped with air in the stripping tower K3 to remove the dissolved sulphur dioxide before being sent to the sampling vessel B1/1.
Afterwards the stripped acid is discharged to the reaction tank B1/2 in which a solution of 40 % sodium thiosulphate and celite as a filter aid medium are added by stirring. Sulphur is formed according to the reaction:

\[
\text{H}_2\text{SO}_4 + \text{Na}_2\text{S}_2\text{O}_3 \rightarrow \text{S} + \text{SO}_2 + \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}
\]

The sulphur reacts with the mercury in the acid to form mercuric sulphide, which is precipitated.

The temperature in this stage is nearly 50 °C and the acid concentration is about 80 weight-percent.

The treated acid overflows to a maturing tank B1/3 also equipped with a stirrer in which the reaction is completed.

As some sulphur dioxide and even some hydrogen sulphide are formed in the purification process, the tanks have to be ventilated.

From the maturing tank the acid is pumped via the acid pumps to the filter press F1/1-2 where the precipitates are removed.

The deposit collected in the filter press contains about 40 % solids and 60 % acid. The deposit could be re-circulated to the pyro-metall-unit.

The cleaned clear acid is finally discharged into a regenerated acid tank B2 and can be discharged to the absorption units.

**Activated Lignite Coke Adsorber**

![Diagram 7: Activated Coke Filter](image-url)
An adsorber working with activated lignite coke or hearth furnace coke located downstream the final wet electrostatic precipitation system is able to reduce emissions of Hg$^0$ and Hg$^{2+}$ to the required values in wet operation.

Furthermore the remaining contents of As, Cu, Fe, Pb, Zn, Sb and Cd, as well as organic solvents or various hydrocarbons are reduced.

Due to its high adsorption capacity a minimum of adsorbent is used. The spent adsorbent can be disposed in the upstream furnace. Depending on the amount of contaminants in the gas the fixed bed has to be moved discontinuously.

Advantages of an activated lignite coke adsorber in comparison to an activated carbon adsorber:

Operating of the activated HOK adsorber below the dew-point of the wet SO$_2$ gas means no developing of so called “hot spots”.

- No fire- and explosion-detections and -protections are required
- No minimum-flow gas necessary
- No inertizing of the adsorbent necessary
- No cost- and energy-intense reheating necessary of the wet SO$_2$ gas above the dew-point
- No Residues for Disposal
- Low operating-costs

**Tail Gas Scrubbing**

Tail gas scrubbing as a means of polishing off-gases from chemical processes, but specially sulphuric acid plants, is a well-known process step, which HUGO PETERSEN has developed to a grade of quality and level, that economically and environmentally the plants will be ready for the future approaches of environmental protection agency acts.

**Hydrogen Peroxide Scrubber (SUPER$^\text{OX}$)**

The SUPER$^\text{OX}$-Process is a treatment technology based on sulphuric acid mixed with H$_2$O$_2$, which guarantees the absorption of SO$_2$ and oxidation to sulphuric acid as follows:

$$\text{H}_2\text{O}_2 + \text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4\cdot\text{H}_2\text{O}$$
The special design guarantees a sulphuric acid concentration of 50-60% by extreme low remaining $\text{H}_2\text{O}_2$ in the product stream.

The produced sulphuric acid can be used as dilution medium in the absorption section of the upstream sulphuric acid plants.

To minimize the $\text{H}_2\text{O}_2$ content of the discharged sulphuric acid, as well as to reach a high acid strength, each scrubbing tower exists of two stages.

The gas from the upstream plant is entering the scrubbing tower K1 in counter current flow to the liquids at the bottom and passing the first packing stage.

At the first stage the process gas is cooled down to its saturation temperature by circulation of 50 - 60% sulphuric acid.

The amount of used process water depends on the SO$_2$-inlet content of the process gas and on the amount of produced sulphuric acid.

At the first stage the remained $\text{H}_2\text{O}_2$ of the upper second stage is reduced by oxidation of sulphuric dioxide as well.

The liquids of the first stage are collected in the scrubbing tower sump, circulated via pumps and distributed above the packing layer via a liquid irrigation system to ensure the distribution of washing acid over the packed bed and to avoid the formation of additional acid mist.
In dependence on the SO\textsubscript{2} content of the process gas an amount of 50 - 60 % sulphuric acid is discharged to the sulphuric acid plant.

Downstream the first stage the process gas is lead and distributed via a droplet separator F1 and an intermediate bottom to the second stage.

In the second stage the main part of sulphuric dioxide is removed by circulation of washing acid with an even higher H\textsubscript{2}O\textsubscript{2}-content than in the first stage.

Due to the lower acid concentration the gas temperature decreases and an additional amount of water is evaporated as well.

The liquid of the second stage is collected in an extra tank B2, circulated via two pumps and distributed in the same way as in the first stage.

The continuous hydrogen peroxide dosing via a dosing pump is controlled by a SO\textsubscript{2}-measurement located downstream the peroxide scrubbers and an external gas-flow-rate signal. The hydrogen peroxide is dosed in the circulation circuit of the second stage at the suction side of the circulation pump to get a better intimate mixing.

The process gas finally enters a wire-mesh droplet separator F2 before it is lead to the stack. Depending on the design of the stack an additional gas-reheating system will be required.

The main benefits of the SUPER\textsuperscript{OX} process are:

- No Waste Products
- High Concentration of Product Acid
- Nearly no remaining Peroxide in the Product Acid
- High Flexibility concerning required Emission Values
- Space Saving Arrangement

**Ammonium Scrubber**

The ammonium sulphate process is based on the following reactions:

\[
2 \text{NH}_3 + \text{SO}_2 + \text{H}_2\text{O} \rightarrow (\text{NH}_4)_2\text{SO}_3
\]

And the oxidation with sulphuric acid:

\[
(\text{NH}_4)_2\text{SO}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4 + \text{SO}_2 + \text{H}_2\text{O}
\]
The gas from the upstream plant is entering the scrubbing tower K1 in counter current flow to the liquids at the bottom and passing the packing.

SO₂ is absorbed by adding ammonium water and formation of ammonium sulphite.
The pre-cleaned gas is led to the second tower K2 where the remaining SO₂ is absorbed in the same way.

The continuous ammonium water dosing in both scrubbing towers is controlled via pH-value of the circulation liquids.

The second scrubbing tower is operating at lower concentrations to minimize the ammonium content in the cleaned gas.

Downstream the second scrubbing unit a final tower K3 is installed for elimination of ammonium sulphite mist.
The mist elimination system consists of two stages, a first wire-mesh stage continuously flushed with process water and a second candle filter stage, flushed with circulation liquid. Alternatively to the final tower K3 a WESP-system can be installed as well.

The ammonium sulphite containing liquids of the towers K2 and K3 are level controlled discharged to the first scrubbing tower K1 where the liquid concentration is increased due to water vaporization.
Depending on the temperature and water content of the incoming gas concentrations more than 40 weight-percent are achievable.

The high concentrated ammonium sulphite liquid is discharged to the reaction vessel B1 where the liquid is oxidized to ammonium sulphate by adding of sulphuric acid of the upstream plant.

In the stripping K4 the due to the reaction formed SO₂ is separated from the liquid with ambient air.

Due to the high vapour pressure of SO₂ above the liquid an outlet concentration of 15 Vol-% of the stripping gas can be reached.

The SO₂ gas is finally led back to the sulphuric acid plant.

Optionally an amount of SO₂ gas can be re-circulated upstream the first scrubbing tower to increase the production of ammonium sulphate, if required.

The produced ammonium sulphate is discharged via overflow from the stripping tower to the storage tank B2.

The main benefits of the ammonium sulphate process are:

- No Waste Products
- Variable Production Rates in case of Recirculation

Let us come to together and develop the optimal solution for you!

The Author

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More than 25 years professional experience in design management, process design, erection supervision, commissioning of gas cleaning and H₂SO₄-plants in Germany and overseas

Sulphuric Acid Plants

- Cinkarna – Celje, Slovenia
  Start-up commissioning and test run sulphuric acid plant of 500 to/day
- Th. Goldschmidt - Mannheim, Germany
  Start up commissioning of sulphuric acid plant of 200 to/day, utilisation of SO₂ and NOₓ containing the Petersen Fattinger process for sulphuric acid and nitric acid included commissioning of pilot plants, start up and test procedures
- Research and development for SO\textsubscript{2} concentration and recovery plants for production of liquid SO\textsubscript{2} and deviates as sulphuric acid ammonia sulphate SO\textsubscript{3} and elemental sulphur
- Sales and presentation of Hugo Petersen’s sulphuric acid technology in Europe and overseas
- UST-Kamenogorsk, Kazakhstan,
  Process design management for gas cleaning plant downwards zinc and lead smelter, responsible for preparation and performing of the final guarantee test of a 928 to/day sulphuric acid plant downwards of a copper smelter incl. heavy metal and effluent treatment plant
- ENAMI – Chile
  Process design manager for complete sulphuric acid plant, including heavy metal removal (Hg, Se, As) and effluent treatment plant, process design management for gas cleaning plant (dry and wet cleaning process), for removal of Hg, As, SO\textsubscript{2}, HCl, NOx, HF, HBr, downwards of burning process for contaminated earth.
- Cinkarna - Slovenia
  Design manager and project manager for the expansion and modification of 240 to/day sulphuric acid plant,
- Outokumpu - Finland
  Preparation of basic design for the tender of sulphuric acid plant R7
- Outokumpu - Finland
  Engineering Management of gas cleaning plant R6 for sulphuric acid plant downwards a copper smelter