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Copper 2010

Design Considerations for Sulphuric Acid Plants

Short Course
Sulphuric Acid Production Technologies

Presented by

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Additional Resources

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Course Objective

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Provide an overview of design considerations for the sulphuric acid plant equipment and systems.

Create an awareness of available options

Discussion on plant energy consumption

Options for treating gases from batch smelting processes

Course Outline

Gas Cleaning
- Quench System
- Gas Scrubbing
- Gas Cooling
- WESP's

Contact Section
- Blowers
- Converters
- Gas-to-Gas Heat Exchangers

Strong Acid System
- Towers
- Packing Supports
- Packing
- Distributors
- Acid Coolers

Electrical Power Consumption

Batch Processing

Gas Cleaning

Waste gases from the metallurgical processes must be treated to reduce the sulphur dioxide emissions to the atmosphere. To achieve this the sulphur dioxide in the gas is converted to sulphur trioxide for the production of sulphuric acid in the sulphuric acid plant.

The metallurgical off-gases must be cleaned prior to entering the contact section of the acid plant to enable the plant to produce a product acid of acceptable quality for use and sale.

Clean gas is also required for the proper operation of the plant.

- Prevent plugging of catalyst and subsequent increase in pressure drop
- Prevent poisoning of the catalyst
- Prevent corrosion of acid plant equipment

Primary contaminants in the gas are: SO_3, dust, metals, mercury, selenium, arsenic and fluorides, etc.

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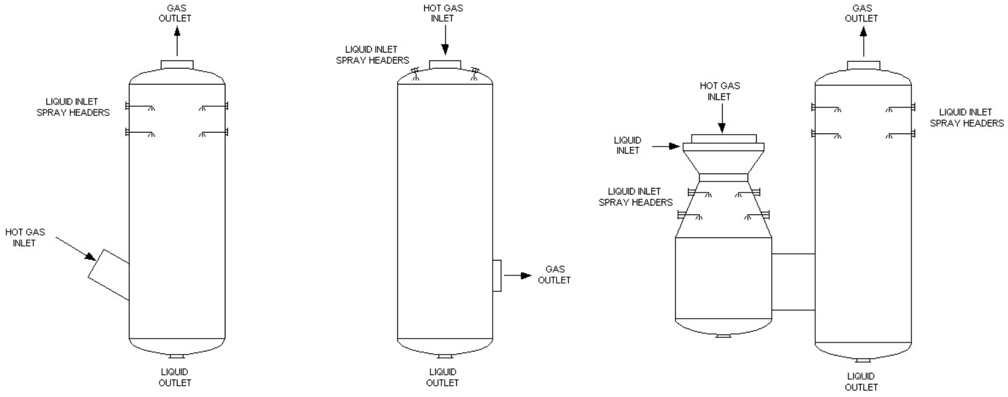
Quench System

The function of the Quench System is to:

- Adiabatic saturation and cooling of the incoming gas
- Partial cleaning of the gas
- Provide residence for the condensation of metallic vapours and growth of the particles to facilitate their subsequent removal in downstream equipment
- Reduce gas temperature sufficiently such that materials of construction can be changed to Fibreglass Reinforced Plastics (FRP) and thermoplastics

Quench System

Different types of quench systems.



Also, radial flow scrubbers, venturi scrubbers and DynaWave systems can be used to quench the gas.

The gas inlet of the quench tower is a high maintenance area if it is not designed properly and materials have not been specified properly. The process conditions in the gas inlet area vary from hot dry gas to wet cold conditions. Materials can be specified for hot dry gas conditions but these materials are not suitable for wet cold conditions and vice versa. In most quench tower designs, there is no clear interface between the two conditions so the area is subject to brick failure and corrosion.

If the interface between hot/dry and cold/wet can be clearly delineated through proper design of the gas inlet, maintenance in this area will be greatly reduced.

Quench System

Design Considerations/Parameters

Superficial Velocity: 10 to 15 ft/s (3 to 4.6 m/s) (open quench tower design)

Liquid to Gas Ratio: 15 to 20 USGPM/1000 ACFM (2 to 2.7 m^3/1000 m^3)

Residence Time: If the off-gas contains large amounts of metallic fumes a minimum residence time of 3 seconds is recommended to allow for condensation of the fume and growth of the particle that will allow the impurities to be removed in downstream scrubbing equipment.
If the off-gas does not contain metallic fumes, then any gas-liquid contact device can be used.

Emergency Water: In the event of a failure in the quench circulating system, emergency water is required to reduce the gas temperature and protect downstream equipment until the plant can be safely shutdown. Emergency water must come from an uninterruptible supply.

Metallic Fumes: Arsenic, Selenium

Emergency Water: Usually an elevated head tank with sufficient capacity to supply water for the time it takes to safely shutdown the plant. The tank needs to be high enough to provide sufficient head/pressure to the spray nozzles. A possible alternative is a firewater system which typically is equipped with emergency back pumps/systems to ensure water is always available.

Reference: Gleason, T., "Scrubbing of Volatile Compounds in Wet Gas Metallurgical Systems", Symposium on Trace Metals in Non-ferrous Metallurgy, The Metallurgical Society of CIM.

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Gas Scrubbing

Many devices are available for scrubbing and cleaning the gas. The choice will depend on the amount and nature of the impurities.

- Fixed or variable throat venturi scrubber
- Radial flow scrubber
- Peabody scrubber
- Packed tower
- DynaWave reverse jet scrubber

Many devices are available for scrubbing and cleaning the gas. The choice will depend on the amount and nature of the impurities.

The selection of a scrubber will depend on dust loads and the particle size.

If gas flow varies a lot a variable pressure drop device is recommended so that gas cleaning efficiency can be maintain throughout the range of gas flows.

Materials of construction will depend on the gas temperature and composition of the weak acid. Generally, FRP and thermoplastics are specified. In some cases, rubber lined steel or stainless steel can be used.

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Gas Scrubbing

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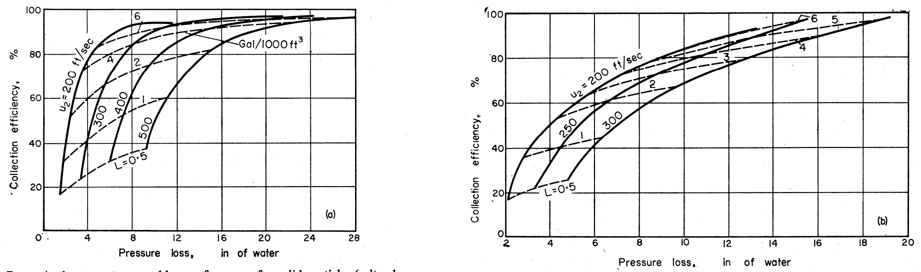
In general, there is an operating cost/penalty for achieving higher scrubbing efficiencies in terms of the pressure drop across the device.



(a) Pease–Anthony ventury scrubber performance for solid particles (salt cake fume from Kraft Mill).[241]

(b) Pease–Anthony venturi scrubber performance for mist droplets (sulphuric acid mist).[241]

FIG. 9.28. Liquid consumption and pressure losses for venturi scrubbers.

Other considerations:

- Plugging
- Turndown

DynaWave Characteristics

- Turndown: 2:1 with no loss in efficiency

- Energy consumption of system is split between gas side pressure drop and liquid pumping energy

- No moving parts

- Large diameter nozzles are not easily plugged

Venturi Scrubber Characteristics

- With variable throat, efficiency can be maintained through a wide turndown

- Energy consumption is primarily in gas side pressure drop

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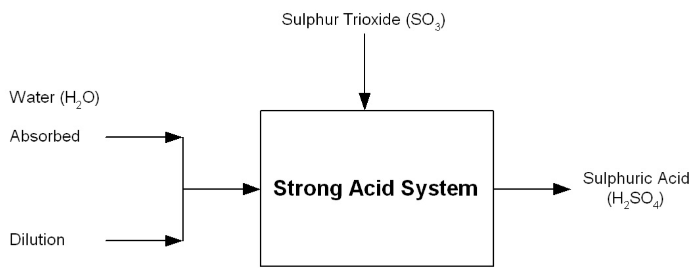
Gas Cooling

Purpose

Cool the process gas to condense sufficient moisture from the gas to meet the plant water balance.

Plant Water Balance

The amount of SO_2 and water entering the sulphuric acid plant must be in the correct proportions or balance in order to produce sulphuric acid of the desired concentration.



Plant Water Balance

Acid is made up of SO_3 and water. In a sulphur burning plant, a small amount of water comes in with the atmospheric air required for sulphur combustion. The majority of water is added as dilution water in the absorber system. In a metallurgical or regeneration acid plant, considerably more water enters the contact section of the acid plant with the gas exiting the gas cleaning system. If there is too much water in the gas or the SO_2 concentration is low, the proportion of water to SO_3 that is produced may be too high to produce the acid at the desired concentration.

The plant water balance is the point at which the incoming water meets the exact requirements for producing acid at the desired strength. If the plant is not in water balance, the desired product acid concentration cannot be maintained and will decrease.

Gas Cooling

Two basic ways to cool the gas

Direct Cooling

Direct cooling of the gas involves contacting the gas directly with the cooling medium. This is generally done in a packed or tray tower with weak acid as the cooling medium.

Indirect Cooling

Indirect gas cooling is generally done in some type of heat exchanger, the most common being vertical shell and tube condensers cooled by cooling water.

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Gas Cooling

Direct Cooling

- Packed Cooling Tower
- Tray Scrubber
- Open Spray Tower
- Cyclone Cooler

Direct cooling systems require a weak acid circulation system and weak acid coolers (typically plate and frame heat exchangers).

Direct cooling involves two temperature approaches.

1. Cooling water and weak acid temperature approach in the weak acid cooler.
2. Weak acid and gas outlet temperature approach in the cooling tower/device.

Typical approach temperature at the top of the cooling tower is 1.7ºC (3ºF).

Gas Cooling

Indirect Cooling

- Vertical shell and tube heat exchanger
- Star cooler
- Graphite coolers
- Calorplast heat exchanger

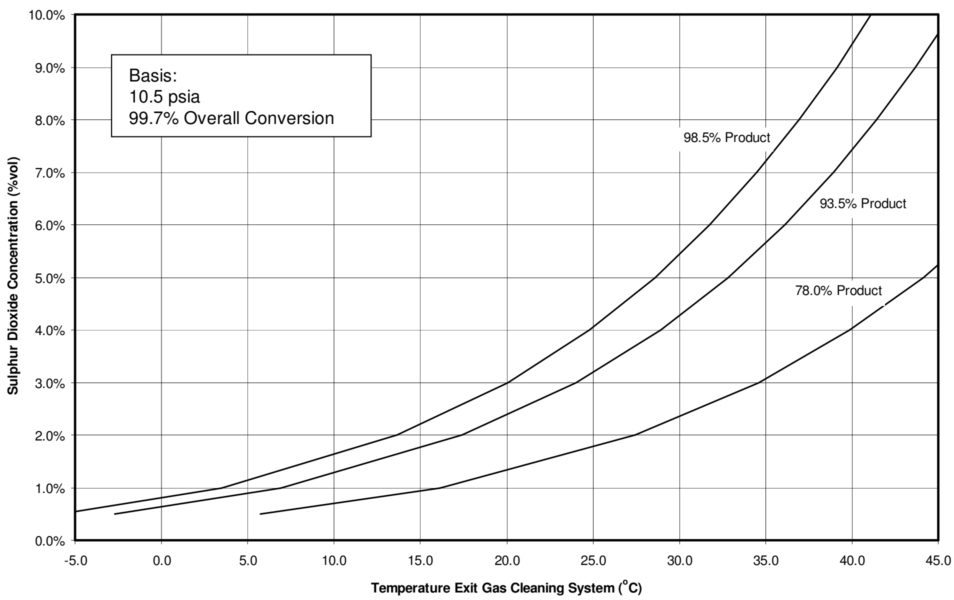
Indirect cooling systems avoid the need for a weak acid circulating system.

Indirect cooling involves only one temperature approach.

1. Cooling water and process gas temperature approach in the heat exchanger.

The closer the temperature approach, the larger the heat exchanger.

Gas Cooling



The barometric pressure has an impact on the partial pressure of water in the gas and the operation of the gas cooling system.

At the same temperature, gas at a lower absolute pressure will contain proportionally more water than gas at a higher absolute pressure.

It will be more difficult for a plant located at high elevation to meet the plant water balance than a plant located at sea level.

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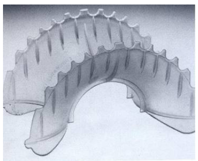
Gas Cooling

Packed Cooling Tower Sizing and Design



Packing: 75 mm (3”) Polypropylene saddles
Tripaks

Sizing: Based on pressure drop and flooding considerations
Typically superficial gas velocity in the range of 1.55 to 1.9 m/s

Liquid Flow: 15 to 45 m^3/h per m^2 cross-sectional area
Subject to pressure drop and flooding considerations and the tower heat load

Materials of Construction: Typically fibreglass reinforced plastic (FRP)
Dual Laminate

Some plants will use mechanical chillers to obtain colder water temperatures for cooling so the plant water balance can be maintained.

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Wet Electrostatic Precipitators

To produce a clean gas that will be fed to the acid plant for the production of sulphuric acid.

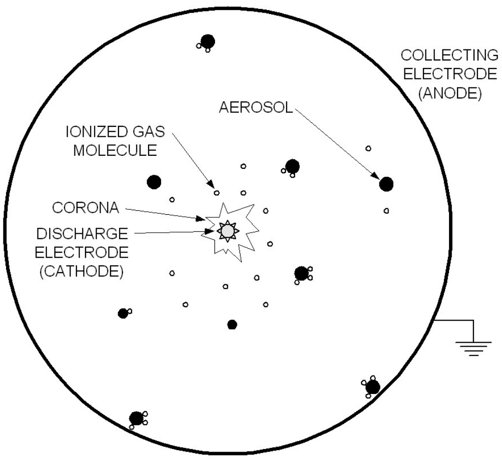
- Removing dust
- Removing condensed metal fumes
- Removing acid mist

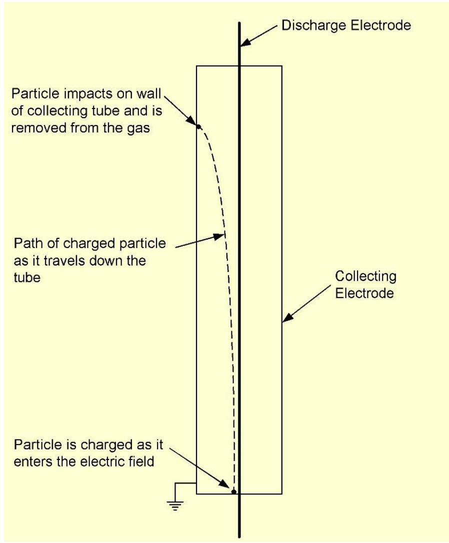
Mist precipitators are the final line of defense against admission of impurities to the acid plant and must always be kept operating at peak efficiency.

Vendors

- GEA Bischoff
- Outotec/Boliden
- Beltran
- Hugo Petersen
- FLSmidth Airtech
- Southern Environmental
- Others

Wet Electrostatic Precipitators





Collection Efficiency = $1 - \varepsilon^{(-\omega A/V)}$

Deutsch Equation: Collection Efficiency = $1 - \varepsilon^{(-\omega A/V)}$

ω - Migration Velocity

A - Collecting Area

V - Gas Flow

The migration velocity is the average velocity at which the charged particle travels to the collecting electrode. The amount of electrical charge that can be placed onto a particle is a function of the size of the particle, gas properties, electrical, chemical and physical properties of the particle as well as the design of the discharge electrode. The migration velocity is generally based on experimental and actual operating data determined from years of experience. Each vendor will have their own database of design velocities that they use when sizing their units.

The magnitude of the migration velocity indicates the difficulty of removal for a particular contaminate. In general, acid mist, copper, iron and nickel are easy to collect. Zinc, lead, arsenic and antimony are more difficult to collect. For a given gas velocity through the ESP the desired collection efficiency and migration velocity will set the collection area required.

Wet Electrostatic Precipitators

Design Considerations/Parameters

Acid Mist Outlet Loading: <30 mg/Nm^3 (optically clear gas)

Dust Outlet Loading: <1.2 mg/Nm^3

Other Impurities: Collection efficiency as required to meet product acid quality requirements and operating parameters

Gas Distribution: Design of inlet and outlet ducting should provide even gas distribution into parallel WESP's. Design of WESP's should also provide for even gas distribution across collecting tubes.

Latest development is the membrane/fabric WESP's offered by Southern Environmental. Collecting surface is a fabric that is hung from the water distribution pipes to form square collecting tubes. The fabric is continuously irrigated to wash the collected particles and make the collecting surface electrically conductive.

References available in other industries and currently one in an metallurgical sulphuric acid plant in the USA.

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Blowers

The acid plant blower compresses the gas to a sufficient pressure to overcome the pressure drop through the plant. The blower also draws the gas through the upstream gas cleaning system in a metallurgical acid plant.

Most acid plant blowers are single stage centrifugal machines driven by electric motors or steam turbines.

Blowers are typically single stage centrifugal blowers with overhung impellers. Parallel blowers can be used when gas flows are high.

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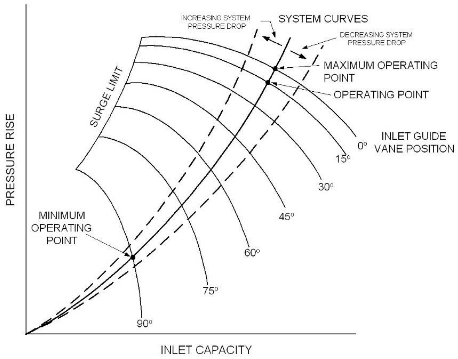
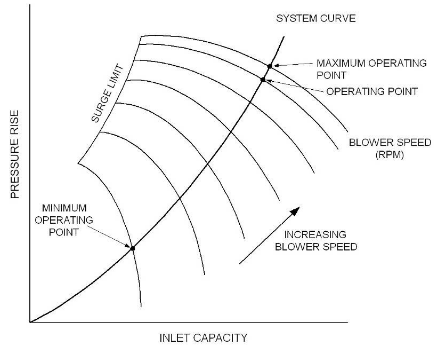
Blowers

The capacity of the blower is control primarily in one of two ways: Inlet Guide Vanes (IGV) or speed variation using a Steam Turbine or Variable Frequency Drive (VFD) electric motor.

IGV



VFD or Steam Turbine



IGV's are most common and the least expensive.

VFC can be justified if gas flow through the plant varies a lot and the power savings is great enough to justify the higher costs.

Steam turbines are typically used in sulphur burning plants where large amounts of steam are generated. If co-generation is part of the plant, then it is usually better to send all the steam to the turbo-generator (T/G) and run the blower using an electric motor. A T/G generally will have higher efficiency than the blower steam turbine so overall efficiencies will be higher with an electric motor.

Blowers

Design Considerations/Parameters

Dirt Allowance: 635 to 762 mm WC (25 to 30 in. WC)

Over Capacity: 5 to 10% of volumetric flow

Minimum Flow: typically preheat requirements ~30 to 35% of design flow

A recycle line from the blower discharge to the drying tower inlet will allow for additional turndown capability.

Five operating points are usually defined when specifying a blower:

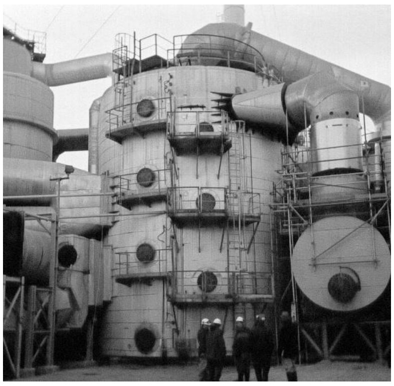
- Design (clean)
- Design (dirty) – incorporates dirt allowance
- Overdesign – incorporates volumetric overcapacity
- Minimum (clean)
- Minimum (dirty)

Others

- Preheat – usually accommodated in the minimum flow cases
- As dictated by operation of upstream metallurgical operations

The result is an operating envelop of where the blower is expected to operate.

Converters



The purpose of the converter is to:

- Contain and support the catalyst which is used to speed up the reaction whereby sulphur dioxide and oxygen are combined to form sulphur trioxide and heat. The catalyst is generally divided into three to five separate layers or beds.
- Minimize heat loss to maintain an essentially adiabatic reaction.
- Provide for the uniform flow of process gas to and from the catalyst beds.

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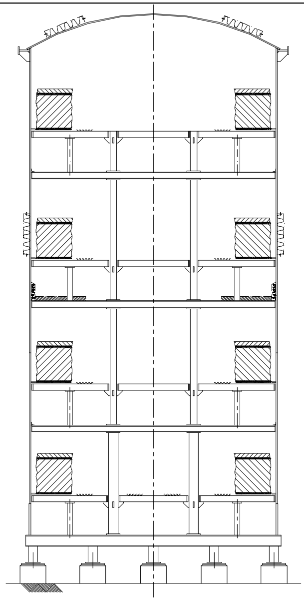
Converters

Staid Converter Design

- Based on the 'old' cast iron grid and post converters
- Available from MECS only and licensees
- Column and grid design
- No provision for internal heat exchanger
- All gas connections on the side of the converter
- Bed occupies full cross-section of converter
- Columns do partially block movement inside converter



Column Spacing

Above the catalyst support: 8 ft between main columns

Below the catalyst support: 4 ft between main and stub columns

Catalyst Support Grid

Welded stainless steel grid with wire mesh screen

Roof Design

Dished roof typical for smaller converters. On large converters a flat sloping roof can be done.

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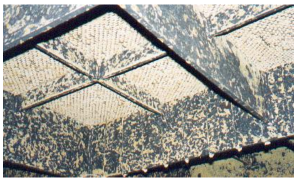
Converters



Picture 1 – Section of converter shell being lifted into position

Picture 2 – Converter base plate being fabricated

Picture 3 – Catalyst support grid

Picture 4 – Converter base being positioned on foundation

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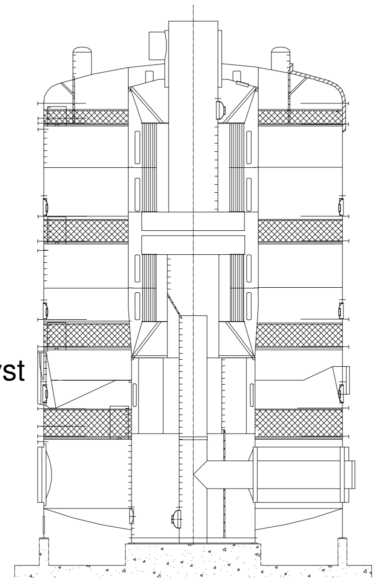
Converters

Converter with Central Cores

- Central cores supports catalyst beds
- Internal heat exchanger(s) – up to 3
- Provides for radial distribution of gas
- Core occupies part of converter cross-section so converter is slightly bigger in diameter
- All welded stainless steel construction
- Can be designed to accommodate 5 catalyst beds



Converters with central cores are available from most technology suppliers including the following:

•Chemetics

•Outotec

•Fleck

•SNC-Lavalin (FENCO) – Although a long time licensee of MECS, FENCO developed and patented their own converter design with a central core. US Patent No. 7497998 - March 3, 2009

•Noram (The central core does not extend the full height of the converter. Usually located at the top of the converter)

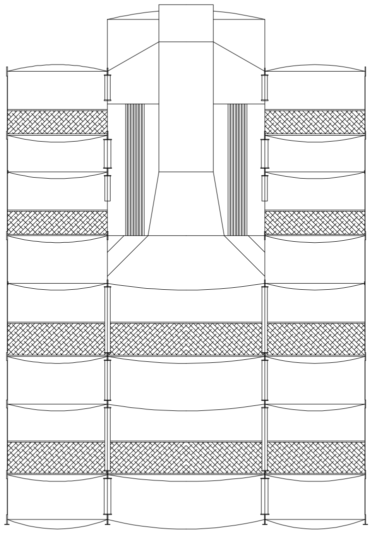
Converters

Photos of stainless steel converter with core tube under construction. The core section rises at the same time as the outer shell courses. Installation of the division and catalyst support plates is done progressively as the converter is erected. These plates provide a working surface for the next section of shell being erected.

Converters

Noram/Cecebe Converter

- Columns support central 'core'
- Internal heat exchanger
- Provides for radial distribution of gas in some beds
- Some beds occupy full cross-section of converter



The converter was designed and patented by Mr. Gordon Cameron. US Patent No. 5,232,670 - August 3, 1993.

Trivia: Cecebe is the name of the lake that Mr. Cameron lived near.

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Converters

Ambatovy Project
Madagascar

Two 2750 MTPD sulphur burning sulphuric acid plants

Technology Supplier: NORAM Engineers and Constructors Inc.
Contractor: Bateman (Africa) Pty Limited
Converter Fabricator: Metso ND (South Africa)

Picture 1 – Two NORAM converters under construction dockside at in South Africa

Picture 2 – Internal view showing the catalyst support plate and support posts

Picture 3 – Converter being offloaded from ship

Picture 4 – Converters erected on site

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Converters

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Design Considerations/Parameters

Materials of Construction: 304 SS (0.04 to 0.08% C) (primary)

321 SS, 347 SS, 348 SS (alternate)

Design Temperatures: up to 650°C

Design Pressure: < 100 kPa (not a pressure vessel)

Flow through Catalyst Bed: 60 to 100 SCFM/ft^2

Catalyst Loadings: By catalyst suppliers

Design should allow for additional catalyst for future expansion

Gas Distribution: Design should provide for the best gas distribution

Catalyst Bed Pressure Drop: Bed 1 - Design + 1270 mm WC

Others - Design + 635 mm WC

Materials of Construction

- 304H SS is equivalent to 304 SS (0.04 to 0.08% C)

- 321 SS is essentially 304 SS that has been stabilized with titanium so it is less sensitive to intergranular corrosion after heating within the carbide precipitation range of 425-850°C. Typically used in the hotter areas of the converter (i.e. Bed 1 outlet).

- 347 SS and 348 SS are stabilized against chromium carbide formation by the presence of columbium and tantalum.

Catalyst Bed Pressure Drop

The catalyst bed support must be designed for the weight of catalyst as well as the load imposed by the pressure drop across the bed. All catalyst pressure drops will increase due to the accumulation of dust in the bed. Bed 1 has the highest design allowance because most pressure build up occurs in this bed.

Design Considerations/Parameters

Location/Order of Catalyst Beds

The location/order of the catalyst beds in the converter is optimized in the design phase to accommodate the flow of gas from internal and external heat exchangers, minimize ducting runs and optimize mechanical design, operation and maintenance.

A lot of designs have Bed 1 located at the bottom of the converter since this bed is screened the most often. Unfortunately, Bed 1 also operates at the highest temperature so its location at the bottom means that it must carry the weight of the entire converter. The mechanical design must be more robust than if Bed 1 was located at the top of the converter.

In the days of the cast iron grid and post carbon steel converters, Bed 1 was always located at the top of the converter.

Considering that Bed 1 is typically screened every shutdown (12 to 24 months) is having Bed 1 at the top of the converter really a disadvantage?

Design features that will improve catalyst screening:

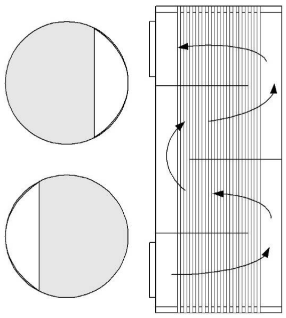
- Stair access tower to each bed rather than ladders
- Two manways for personnel access (located 180º apart)
- Separate nozzle for screening equipment (hoses, conveyors, etc.)
- Adequate headroom

Heat Exchangers

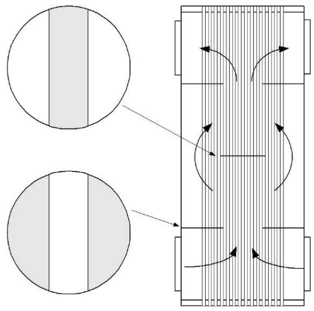
The function of a gas-to-gas heat exchanger is to cool/heat the process gas to achieve the desired temperature for maintaining the process conditions. The heat exchangers are required to operate over a wide range of conditions so they are equipped with gas bypasses to enable the process temperature to be controlled.

Heat Exchangers

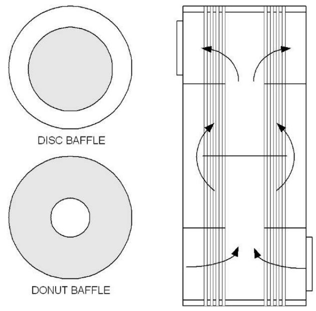
Single Segmental



Double Segmental



Disc and Donut



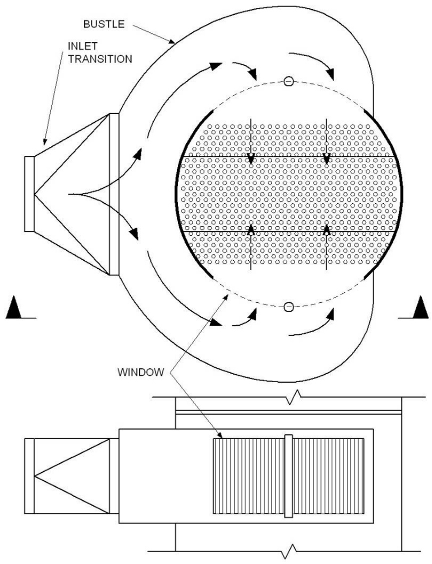
<u>Others</u>

- Crossflow heat exchanger
- Plate heat exchanger – MECS Monplex

No-Tube-In-Window designs ensures that all gas flows across the tubes which provides higher heat transfer coefficients than longitudinal flow (parallel with tube).

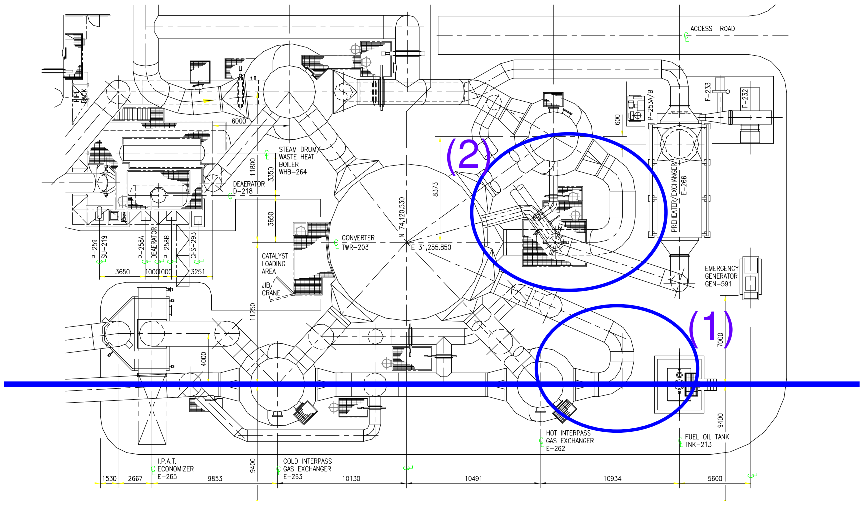
Single and Double Segmental Baffles

- Shell side nozzles are either on the same side or 180º apart
- Layout of heat exchangers and converter is limited due to the restricted placement of the shell side nozzles.
- Single segmental baffles have lowest heat transfer coefficients
- Double segmental baffles can achieve heat transfer coefficient as high as disc and donut designs



Single and Double Segmental Baffles

- Impact on Layout



The use of single and double segmental baffles places limitations on the location of the heat exchangers and on the routing of interconnecting ducting.

The flow through the shell side of the heat exchangers in the lower part of the layout is in series so the heat exchangers must be located in line with each other. The result is an awkward ~180° (1) bend to connect to the converter. A similar ~180° bend (2) is required for the heat exchanger located directly above.

The routing of gas ducting is restricted by the positioning of the nozzles on the heat exchangers. The 180° bends add more costs and pressure drop to the system.

Heat Exchangers

Disc and Donut Heat Exchangers

- Freedom to place shell side nozzle in any orientation 360º around shell
- Result is improved ducting arrangement between heat exchangers and converter
- Generally higher heat transfer coefficients and lower pressure drops

US Patent No. 4357991 – Heat Exchanger Having Improved Tube Layout

US Patent No. 5044431 – Tube Layout for Heat Exchanger

US Patent No. 5277247 – Heat Exchanger Having Improved Tube Layout

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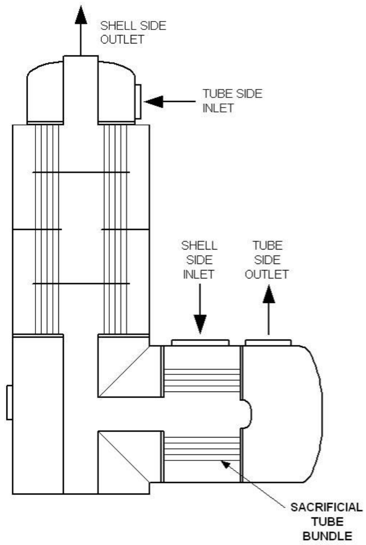
Heat Exchangers

Sacrificial Heat Exchanger Design

- The Cold and/or Cold Reheat exchangers are most prone to corrosion and plugging due to acid condensation in the cold parts of the exchanger. A small portion of the tube bundle fails but the majority of the heat exchanger is still good.
- The sacrificial bundle can be constructed of SS for better corrosion resistance without having to make the entire exchanger out of SS.
- The sacrificial bundle can be easier and less expensive to replace.



Conventional Heat Exchanger Design

If condensation cannot be avoided, the operating life of the unit will be shortened. The entire unit must be replaced or re-tubed when too many leaking tubes have been plugged and the unit can no longer meet the required heat transfer. When a heat exchanger is inspected, what is often found is that tube failure occurs only in the region where condensation occurs and the majority of the tube is still in good condition. However, due to the design of the heat exchanger, the entire tube must be replaced.

Sacrificial Heat Exchanger Design

If the corroded section of the tube bundle were a completely separate bundle with its own tube sheets, then only this section of the heat exchanger would need to be replaced. This smaller tube bundle is referred to as the sacrificial tube bundle. When the inevitable acid condensation, tube corrosion and failure occur, the small sacrificial bundle is the only section that needs to be replaced and not the entire unit

A heat exchanger designed with a sacrificial bundle will be more expensive because there will be four tube sheets instead of the normal two. Carbon steel can be used as a material of construction for both the main and sacrificial tube bundles. In this case, the cost of replacing the sacrificial tube bundle will be relatively inexpensive particularly if the tube sheets have not been damaged. If the sacrificial bundle is constructed of stainless steel, it will further increase the life of the equipment and reliability of the plant but the cost of replacement will be higher due to the higher material costs.

A cold exchanger with a sacrificial tube bundle can be designed with either single segmental, double segmental or disc and donut baffles. The best designs are achieved if a disc and donut baffle arrangement is used since the designer can keep all the shell side gas passages internal to the shell.

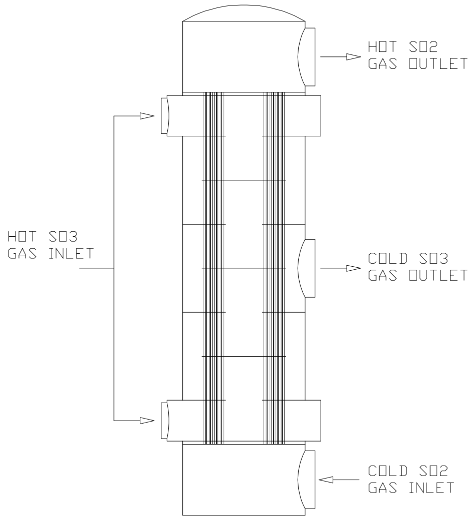
Sacrificial Heat Exchanger

Freeport McMoran (Phelps Dodge), Miami, Arizona, USA

Cold and Cold Reheat Exchangers

Split Flow SF™ Exchanger

- Hot gas is directed to the cold end of the heat exchanger to raise the tube wall temperature which prevents condensation of acid and formation of sulphates
- Condensing gas is on the shell side which goes against conventional design of having condensing gas on tube side for ease of cleaning
- Ideal for use as a Cold or Cold Reheat exchanger
- Essentially a co-current and counter-current HX combined



US Patent No. 6080369 – Gas-to-Gas Heat Exchanger for Use in Sulphuric Acid Plants

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Heat Exchangers

Design Considerations/Parameters

Materials of Construction:

- Hot Exchangers: 304 SS (0.04 to 0.08% C)
- Cold Exchangers: Carbon Steel, Stainless Steel

Overdesign:

- Hot Exchangers: 5 to 10% (typical)
- Cold Exchangers: 15 to 20% (typical)

Design Basis (typical):

- Hot/Hot Reheat Exchangers: Maximum SO_2 gas strength
- Cold/Cold Reheat Exchangers: Minimum SO_2 gas strength
  Autothermal limit

Calorized heat exchanger tubes were common before the introduction of stainless steel as a material of construction. Calorizing is a process whereby aluminium is diffused into the surface of a base metal to form a material that resists high temperature scaling. Calorizing should be considered if scaling is a problem that increases heat exchanger pressure drop and reduces heat transfer. Calorizing can be applied to both carbon and stainless steels.

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Towers

The drying acid absorbs the water vapor remaining in the gas after it leaves the Gas Cleaning Section of the plant. Drying of the gas is necessary:

- To avoid corrosion caused by wet SO_2 gas before the converter and by wet SO_3 after conversion,
- To avoid loss of production due to the formation of acid mist in the absorption tower,
- To keep a clear stack,
- To avoid acid condensation during shut-downs and thus protect the catalyst from degradation.

The absorber acid absorbs the SO_3 formed in the converter. Absorption of SO_3 from the gas is necessary to:

- Remove all SO_3 and acid mist from the gas stream before it exits the tower.
- Produce 98.5% acid in the absorption tower

Exception is the Wet-gas Sulphuric Acid (WSA) process that does not require a drying tower.

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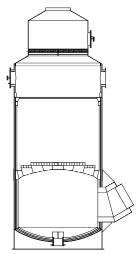
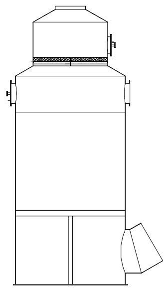
Towers



Brick Lined

- Proven traditional technology
- Tolerant of wide variations in temperature and acid concentration
- Highly dependent on the quality of the brick and installation



Alloy

- Sensitive to variations in acid concentration
- Easily repaired by patching and welding
- Light weight
- Not recommended for Dry Tower application

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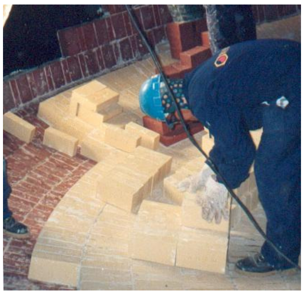
Towers – Acid Brick

Two basic types: Red Shale and Fireclay

Red Shale	Fireclay
• 6.5% iron content	• 2.5% iron • Higher resistance to thermal shock

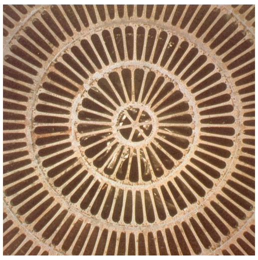


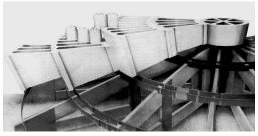
- Less expensive red shale brick is used against the steel shell.
- Fireclay brick is used in contact with the hot process gas because of its better thermal shock resistance.

Regardless of the type of brick used, the most important aspect of an acid resistant lining is the installation. Many of the failures associated acid resistant linings can be traced back to problems with the installation.

Towers – Packing Support

Self-Supporting Dome

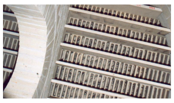
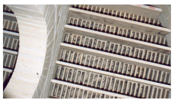
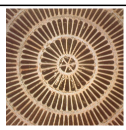




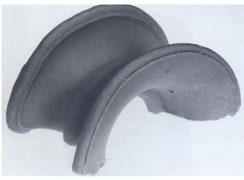
Brick Arch and Beam

Alloy Packing Support

Towers – Packing Support

Packing Support Type		Open Area at Primary Support	Open Area at Secondary Support
Arch and Beam 6” centres		77%	48%
Arch and Beam 8” centres		83%	59%
Self-Supporting Dome		60%	37%
Alloy Grid		80%	80%

Towers - Packing

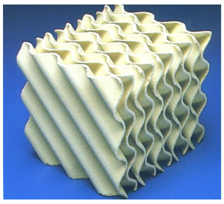


Saddle

HP+

WavePak

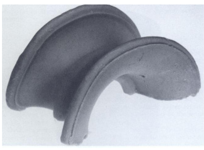
Cecebe HP



Structured

Flexisaddle
LPD

Towers - Packing



- Ceramic saddles are the standard packing for drying and absorber towers.
- Designing using saddles results in a conservatively sized tower.
- Replacing saddles in the future with one of the high efficiency/capacity packings provides for expansion of the plant without needing to replace the tower.

- Designing a tower starting with high efficiency/capacity packings will result in the smallest possible tower.
- However, there will be no opportunity to improve tower performance or increase capacity.
- Packing costs are higher than standard saddles.

Towers - Distributors

- Old technology
- < 1.1 distribution points per square foot
- Corrosion results in large amounts of sulphate

- Pipe distributor must be buried to avoid excessive droplet entrainment.
- Buried distributor can result in localized flooding.
- Orifices can plug easily.

- Supplied and designed by Noram.
- PTFE downcomers are fragile.

- Orifices are located on top of pipe so are more difficult to plug.
- Deflector plate produces a gentle spray. Distributor does not need to be buried.

- State of the art trough distributor.
- Up to 4 distribution points per square foot.

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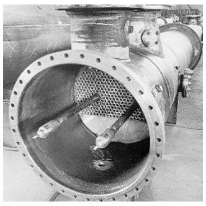
Acid Coolers



Anodically Protected Shell and Tube
- Proven technology
- High water velocities are required to minimize tube side fouling

Plate and Frame Heat Exchanger
- High heat transfer coefficients
- Less expensive
- Limits on maximum temperature

Alloy Shell and Tube Heat Exchanger
- Similar to anodically protected without the anodic protection

Acid Plant Electric Power Consumption

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Power Consumption

Type of Plant	Power Consumption kWh/tonne acid (100% basis)
Classic figure from literature	38.6
Metallurgical plant, continuous steady gas flow	111.0
Metallurgical plant, variable Pierce-Smith converter gas flow	177.0
Metallurgical plant, combined continuous and variable gas stream	133.0
Sulphur burning acid plant with turbo generator, no cooling water system	51.0
Zinc roaster	112.0
Wet gas cleaning and double absorption plant on a zinc roaster	104.0
Evaporative cooling water system	13.5
Sulphur burning acid plant with turbo generator, HRS system	24.8
Sulphur burning acid plant, steam turbine driven blower, including turbo generator and utilities	19.2
Sulphur burning acid plant, conventional, including utilities	63.5
Acid Regeneration Plant, alkylation spent acid (100 MTPD)	95.0
Haldor Topsøe – WSA (6% SO_2, 0 barg at battery limits)	45-50

There is a wide range of power consumptions depending on the type and configuration of the plant. The lowest power consumptions are obtained when the main blower is driven by a steam turbine that uses steam generated in the plant.

Power Consumption

Acid Plant Blower

The acid plant blower is the single largest consumer of power in the plant. Any reduction in plant flow or pressure drop will result in lower power consumption and reduced operating costs.

The cost of electrical power continues to increase.

Reducing plant pressure drop usually means an increase in the size of the equipment which means higher initial capital cost for the equipment.

Example

Blower flow = 230100 m^3/h
25 mmWC (1" WC) change in pressure drop results in a change in power consumption of 75775 kWh/year

Use of high efficiency motors throughout the plant will help to reduce overall electrical power consumption.

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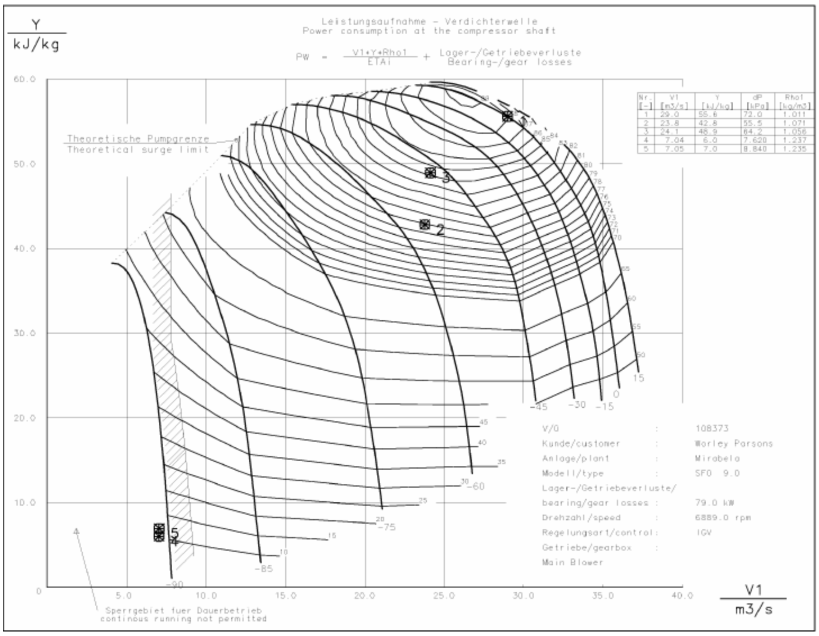
Power Consumption



Nr. [-]	V1 [m3/s]	Y [kJ/kg]	dP [kPa]	Rho1 [kg/m3]
1	29.0	55.6	72.0	1.011
2	23.8	42.8	55.5	1.071
3	24.1	48.9	64.2	1.056
4	7.04	6.0	7.620	1.237
5	7.05	7.0	8.840	1.235

Typical curve for a motor driven blower with inlet guide vanes for flow control.

The power consumption depends on the operating point (flow and pressure rise). As well, the efficiency of the blower also changes with flow and pressure rise. Operating close to the design point will provide the highest efficiency and the minimum power consumption on a unit basis.

When designing a new plant you want the blower to operate at the highest efficiency point for the majority of the time. Excessively oversizing the blower results in operating inefficiencies and higher power consumptions.

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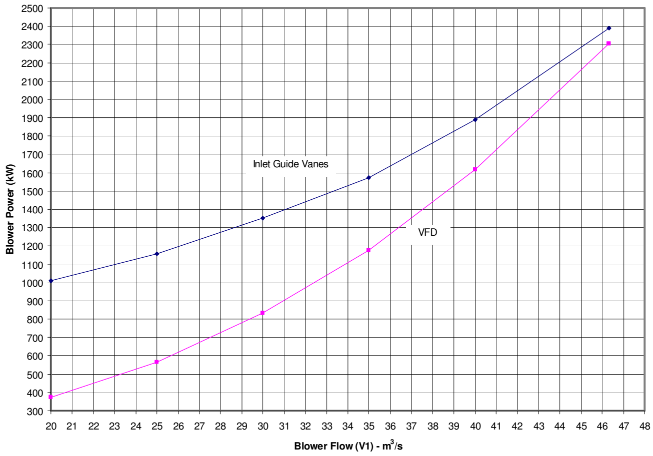
Power Consumption

Inlet Guides Vanes (IGV) versus Variable Frequency Drive (VFD)

At the maximum flow, VFD's have a slight advantage over IGV's in terms of power consumption. If the plant operates most of the time at the design flow, IGV's are preferred because of their lower initial cost.

At lower flows, VFD's offer significantly reduced power consumptions over a blower operating with IGV's. VFD's will provide the most benefit when the flow to the plant varies a lot or operates below the design point.



An analysis of the plant operation is required to determine if a VFD has any advantage over an IGV. The fraction of time that the plant operates at the design and reduced capacities is used with the corresponding power difference to determine the annual power savings. The power savings can be set against the additional cost of the VFD to see if the payback period is reasonable.

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Power Consumption

Copper 2010

Reducing Plant Pressure Drop

- Screen catalyst regularly
- Use low pressure drop catalyst
- Change packing in towers to lower pressure drop/high efficiency packing
- Perform regular pressure/temperature surveys of the plant
- Clean gas-to-gas heat exchangers if tubes are blocked or fouled
- Consider oversizing ducting and nozzles
- Consider efficient plant layouts and ducting runs.
- Operate at highest possible SO_2 concentration to minimize total gas flow

Ducting

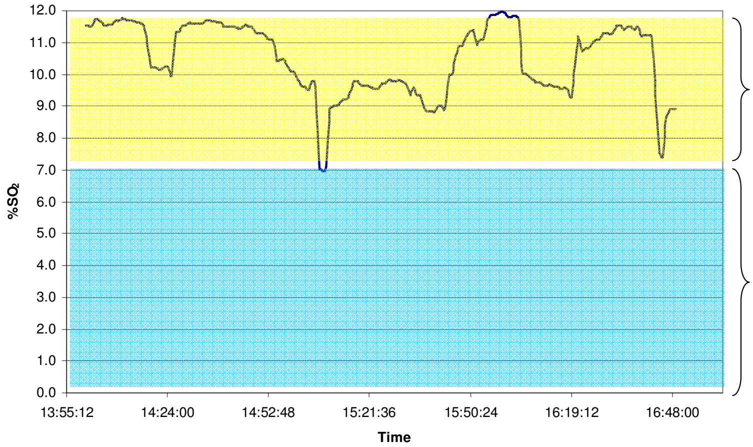
The pressure drop for individual ducts is small compared to the overall plant pressure drop so it is difficult to see the impact of increasing its size on the overall plant pressure drop. However, when the pressure drop across all ducts are considered, the fraction of the total pressure drop becomes significant.

Pressure drops across individual ducts are seldom measured during pressure/temperature surveys. Ducting losses end up as part of the equipment pressure drops so it is easy to ignore the impact of duct and nozzles sizes on the plant pressure drop.

Design Considerations for Acid Plants Operating in Conjunction with Batch Smelting Processes

Batch Processing

Feed from Flash Furnace and P-S Converters

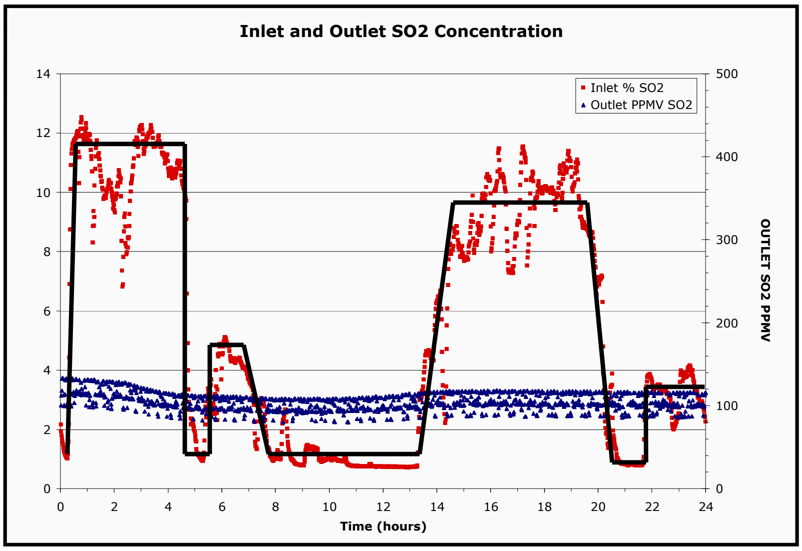


SO_2 concentration and flow fluctuates within an acceptable range. Acid plants can be designed and operated successfully for these conditions.

During normal operation SO_2 concentration and gas flow do not fall into this range of operation.

High strength SO_2 gas from the flash furnace provides a lot of flexibility for the acid plant to take P-S converter gases which vary in flow and SO_2 concentration. SO_2 concentrations are high enough that the amount of dilution air can be varied to provide some degree of control of the SO_2 concentration feeding the acid plant. Variations in SO_2 concentration seen above are a function of the control system to adequately control SO_2 concentration. Improvements in the control system are possible level out the variations in SO_2 concentration.

Batch Processing



HZL Inlet & Outlet SO_2 Concentrations

Courtesy of Cansolv Technologies

- Highly variable conditions
- Unsteady state operation
- Basically on-off operation

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Batch Processing

Top Submerged Lance (TSL) Technology

- Flexible technology
- Can be used to process a wide variety of materials
- Scalable (small to very large)
- Low capital cost
- Good environmental performance
- Can be operated in continuous or batch modes

TSL Technology Suppliers

Ausmelt Limited

www.ausmelt.com.au

ISASMELT – Xstrata Technology

www.isasmelt.com

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Batch Processing

- Converter temperatures are continuously changing.
- Plant never operates at a steady state.
- More difficult to maintain SO_2 emissions when conditions are varying all the time.
- Temperatures fluctuate throughout the plant. Condensation of acid in cold areas.
- Wear and tear on mechanical equipment. Blower operating conditions are constantly changing.
- Stress on equipment due to changing temperatures.
- Higher level of operator attention and training required.

Sulphuric acid plants are robust plants capable of handling a variety of conditions. However, over the long term, this type of operation will begin to show up in increased maintenance and equipment failures. Consideration should be given to upgraded materials of construction, installed spares, upgraded equipment, etc. A preventative maintenance program is highly recommended which will increase the reliability of the equipment and minimize interruptions due to equipment failures.

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Batch Processing

Lead Smelter Example

Stage		Smelting	Reduction	Standby Burner	Lance Hold
Duration	Hours	7.5	1.5	Intermittent	Intermittent
Gas Temperature	^oC	335	345	315	295
Gas Flow	Nm^3/h	41,000	35,000	12,400	6,300
SO_2	%	4.72	0.2	0	0
O_2	%	7.65	7.62	10.6	13.2
H_2O	%	21.93	12.32	11.2	8.8

Smelting is 83% of the batch cycle time
Reduction is 17% of the batch cycle time

Low SO_2 concentration
~6.0% SO_2 dry basis

Virtually no SO_2 for 17% of the batch time

Small plant!!
~ 200 MTPD (nominal)

Batch Processing

Lead Smelter Example

Design Approach and Considerations

- Sulphur burner to supply SO_2 during periods of low SO_2
- Total acid production to be minimized because of local market conditions
- During the smelting stage, sulphur burner to be operated at minimum capacity

- Plant essentially switches from a metallurgical to a sulphur burning plant during the smelter batch cycle
- High level of instrumentation and control is required

The specific requirements of the client has introduced additional complexity to the design and operation of the acid plant as well as cost. When the design criteria for the plant are being developed, the implications of each criteria should be examined to see what impact it will have on the design, operation and cost of the plant.

Batch Processing

Lead Smelter Example

Design Approach and Considerations

If there was no requirement to minimize acid production, the preference would be to operate the sulphur burner at a continuous minimum rate to maintain the operation of the plant during the reduction stage. The smelting gas would be added to the sulphur burner gas without changing the sulphur burning rate.

The result would be a feed gas that fluctuates but is manageable.

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Batch Processing

Copper 2010

Hindustan Zinc Limited

- 2005 – expanded lead production by 50,000
- Ausmelt TSL technology used
- Single furnace operation
- Two-stage process (smelting and slag reduction) in a single vessel

Stage		Smelting	Reduction	Clean	Lance Hold
Duration	Hours	6.38	2.0	2.0	0.5
Gas Temperature	ºC	350	350	350	350
Gas Flow	Nm^3/h	21936	22410	24016	2808
SO_2	%	11.64	0.22	0.09	0.10
O_2	%	4.22	3.15	4.35	1.51
H_2O	%	21.91	12.21	11.11	10.87

Smelting is 76% of the batch cycle time
Reduction is 24% of the batch cycle time

High SO_2 concentration
~14.9% SO_2 dry basis

Batch Processing

Hindustan Zinc Limited

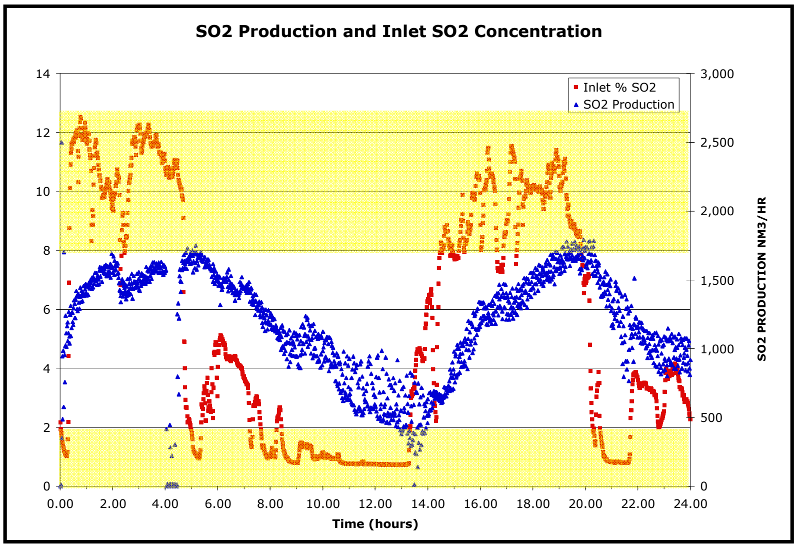
- During the smelting stage the SO_2 in the off-gas is equivalent to an additional 270 MTPD acid production
- Existing acid plant could not cope with this additional production and the high SO_2 concentration
- Over the entire batch cycle, the equivalent acid production is 160 MTPD which the existing acid plant was capable of handling

Solution

Use a regenerative SO_2 scrubbing system and store a part of the SO_2 produced during the smelting stage in the solvent and release it in a controlled manner to create a steady feed to the acid plant.

Batch Processing

Hindustan Zinc Limited



Conversion of an unacceptable feed stream to one that is acceptable to the existing acid plant.

WorleyParsons
resources & energy

Batch Processing

Votorantim Metais

- New lead smelter with a capacity of 75,000
- Ausmelt TSL technology selected
- Single furnace operation
- Two-stage process (smelting and slag reduction) in a single vessel

Stage		**Smelting**	**Reduction**	**Slag Tapping**
Duration	Hours	6.0	1.0	0.5
Gas Flow	Nm^3/h	18000	21000	7600
SO_2	%	12.6	0.23	0.5

Smelting is 86% of the batch cycle time
Reduction is 14% of the batch cycle time

Votorantim Metais

Three options were evaluated:

- Conventional double absorption sulphuric acid plant
- Haldor Topsøe WSA technology
- Regenerative SO_2 scrubbing with a conventional acid plant

Results of the evaluation was the selection of Haldor Topsøe WSA technology. Some additional features of the plant are:

- Tail gas hydrogen peroxide scrubber
- Use of liquid SO_2 to increase and control the SO_2 concentration going to the plant

Batch Processing

Process Design Issues

Plant Water Balance	• Burn sulphur or liquid SO_2 injection • Use of chilled water to cool the gas • Produce lower acid concentration
Autothermal Limit	• Burn sulphur or liquid SO_2 injection • Operate preheat system • Single absorption plant
Variations in SO_2 Concentration	• Burn sulphur or liquid SO_2 injection • Regenerative SO_2 scrubbing

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resources & energy

Batch Processing

Copper 2010

Equipment Design/Selection

- Variable pressure drop venturi scrubber – gas cleaning efficiency can be maintained as flow varies
- Blower flow control – Inlet guide vanes vs. variable frequency drives (VFD)
- Upgrade materials of construction where corrosion concerns are likely
- Upgrade equipment thermal insulation – well insulated equipment will allow plant to better handle the fluctuations in temperatures

Batch Processing

Control System

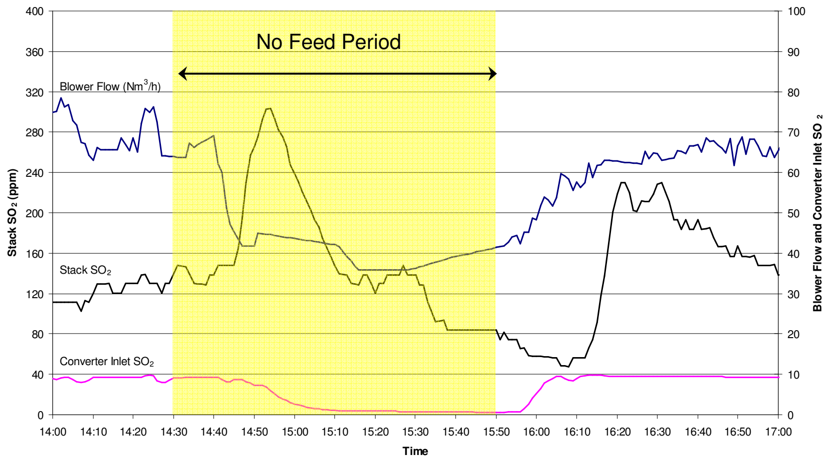
- Use of SO_2 and O_2 analysers to provide information on what is coming into the plant and to control the amount of air dilution and SO_2 going to the converter.
- Use of feed forward control techniques to anticipate and prepare the plant for changes in process conditions.
  - ramp up of a sulphur burner
  - raise converter bed temperatures
  - increase SO_2 addition

Operator training is also an important factor in the successful operation of an acid plant on a batch smelter.

The operation of the smelter will not always be as per design. Problems may arise such as extension of the time with low SO_2 that will have an impact on the acid plant. The operators will need good judgement to decide when actions such as starting/stopping the preheater should be done.

Good communication is required between the smelter and acid plant operators. The smelter and acid plant are intimately linked together and dependent on each other. Communication of intent and problems is required so each plant can take the necessary action to minimize disruption in the operation.

Batch Processing



Periodic stoppage in feed to the flash furnace. Acid plant blower is required to continue operating to provide draft at the furnace. Acid plant is able to take gas containing no SO_2 for short periods of time without the need to operate the preheater.

Stoppage is required once a day for removal of accretions at the furnace outlet. Acid plant must stay on-line to provide sufficient draft for the cleaning to be done safely.

During the cleaning period there is no requirement to start the preheater.

Problems can arise if the 'no feed period' is extended beyond normal time. If the catalyst beds cool too much, the preheat system may be required.

It takes 1 to 2 hours for the operation of the plant to return to normal. If feed to the acid plant is interrupted during this period the recovery of the plant to normal operation is more difficult. Again, the plant has the option to start the preheater to raise catalyst temperatures.

Oleum is also produced at this plant which can be used to fortify the circulating acid when there are water balance problems.

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Batch Processing

What approach would I recommend?

Single absorption plant with a tail gas scrubber

Bypass gas direct to tail gas scrubber during extended periods of low or no SO_2

Why?

- *Single absorption plants are better able to handle varying operating conditions than double absorption plants*
- *Lower autothermal limit than double absorption plants*
- *During short periods of no SO_2, send gas through acid plant*
- *Tail gas scrubbers are able to handle varying inlet SO_2 levels and still provide low SO_2 emissions. Tail gas scrubbers are also a back up during start ups and upset conditions.*
- *Acid plants can tolerate short periods of no gas and still retain sufficient heat in the catalyst to restart without using the preheater. Bypassing gas direct to tail gas scrubber avoids having to use the preheater to maintain catalyst temperatures.*

Many options have been presented which can be applied to the issue of designing and operating a sulphuric acid plant on a batch smelting process. The design of the acid plant will require a detailed analysis and understanding of the smelter operation and the specific requirements of the plant operator and site conditions.

The simpler the solution, the lower the cost and the easier the operation of the plant.