**THEISEN** Gas Cleaning Systems

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**THEISEN** Gas Cleaning Systems

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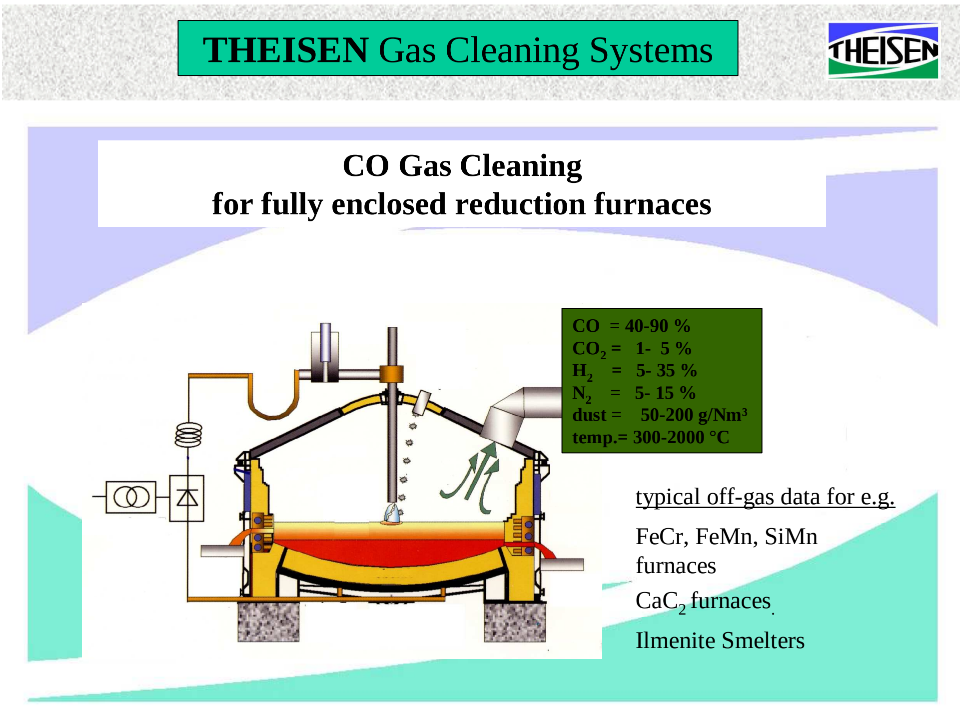
# CO Gas Cleaning Technologies for Fully Enclosed Reduction Furnaces



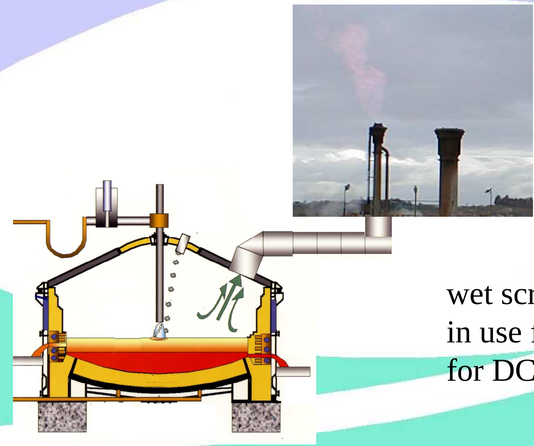

Reduction furnaces generate an off-gas rich in CO and H2, with high dust content and temperatures up to 2000 °C at the furnace gas off-take.

This seminar refers to CO gas cleaning for fully enclosed DC and AC reduction furnaces/smelters, informing the attendees of the different types of CO gas technology in use for this application.

At a typical Disintegrator Gas Cleaning System example the function of the main gas plant elements is explained and plant safety aspects as well as environmental aspects are discussed. The requirements, for power generation (CoGen) using a gas engine driven generator are presented.

Plant engineers are provided with the requirements which should be included in a specification of an enquiry for a Gas Cleaning Plant.

**CO Gas Cleaning**
**for fully enclosed reduction furnaces**

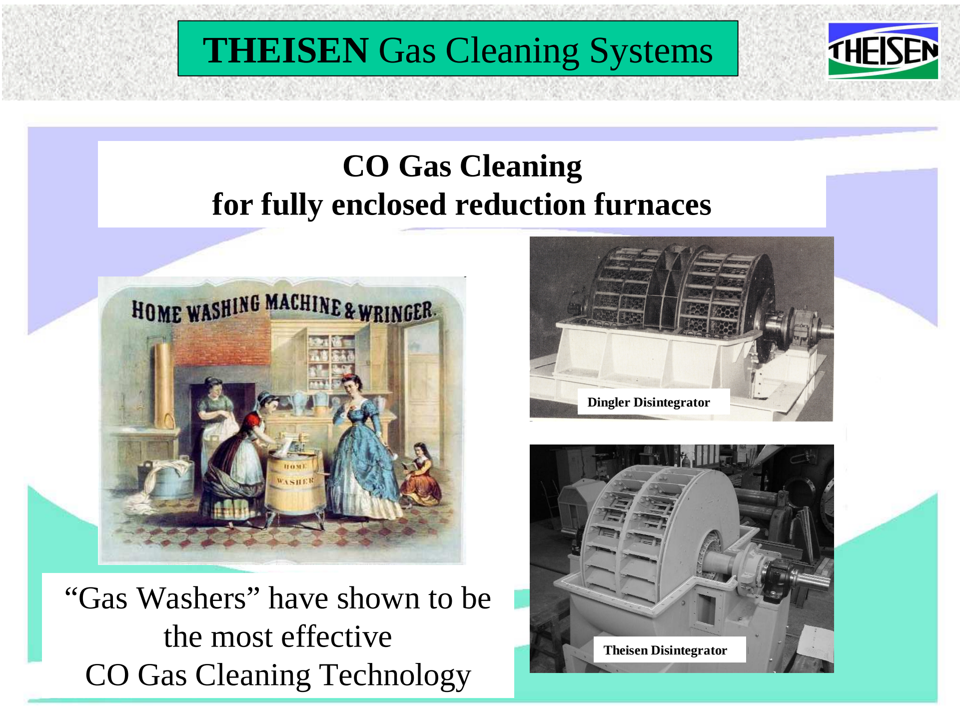


wet scrubbers wide spread
in use for CO gas cleaning
for DC and AC furnaces

Mostly **wet scrubber systems** are in use for the CO Gas Cleaning on fully enclosed reduction furnaces if a non combusted cleaned off-gas is requested to be available at the gas plant off-take and surplus gas to be flared, meeting with the legal emission restrictions without any further treatment.

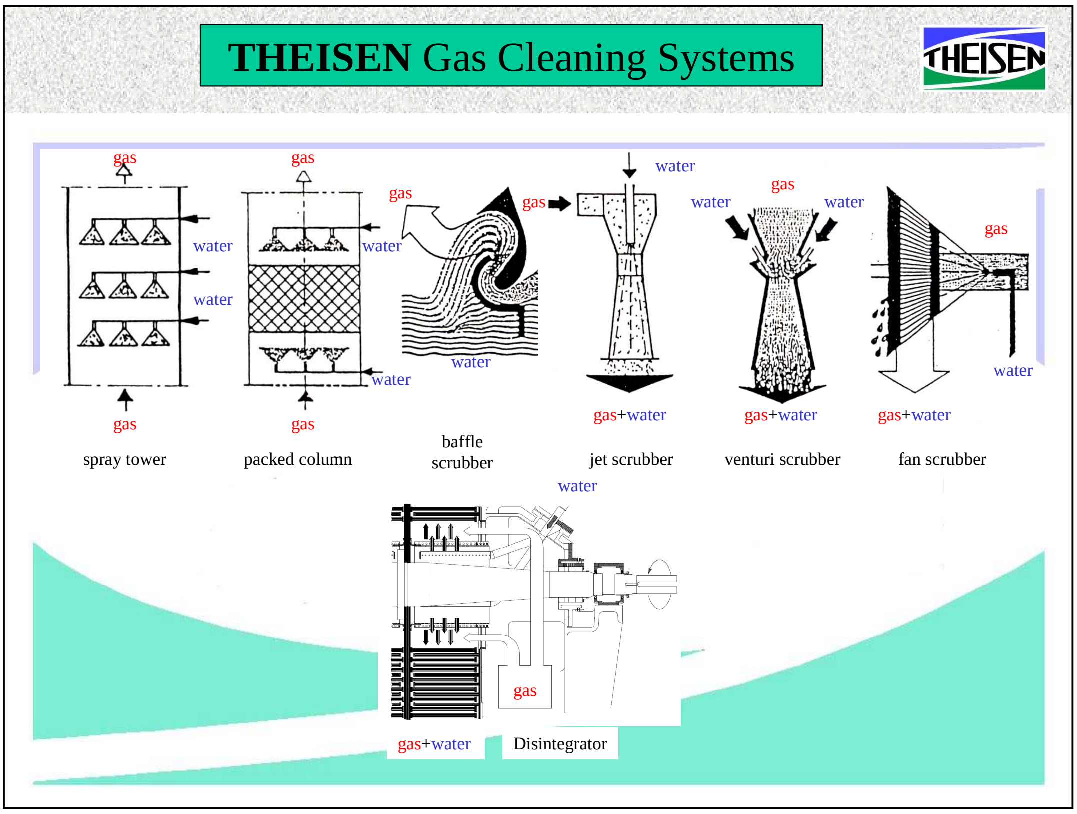
The gas volumes treated are kept as small as possible resulting in compact overall plant dimensions and space requirements.

**Dry filter systems** like bag filters and ESPs are only used if the furnace gas is combusted before being cleaned either within the furnace or in a combustion chamber like installation situated close to the furnace gas off-take.



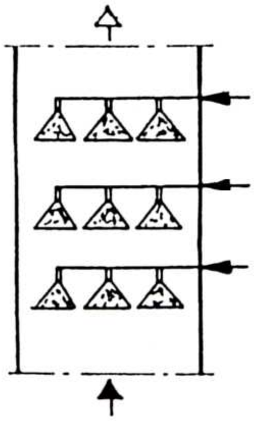

“Washing Machines” like e.g. Disintegrators have shown to be the most effective installation for CO gas cleaning. In South Africa Disintegrators “Dingler-Design” and “Theisen Design” are in use.

Venturi Scrubbers and Jet Scrubbers are installed at various South African smelter plants.



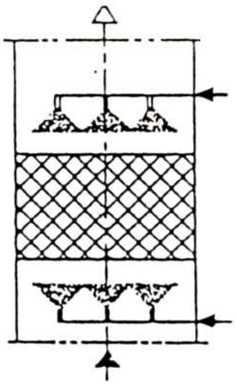

The functional principle of wet separators is based on the transfer of particles from a flowing particle-laden gas stream to a liquid. This requires suitable gas/liquid interfaces and a relative motion between the gas and the liquid phase. There are numerous configurations of scrubbers and scrubbing systems due to the great variety of methods used for generating gas/liquid interfaces and the relative motion between the gas and the liquid, which is water in most of the applications.

**Wet scrubbers can be classified according to design features of the method of liquid induction into 7 basic types:**



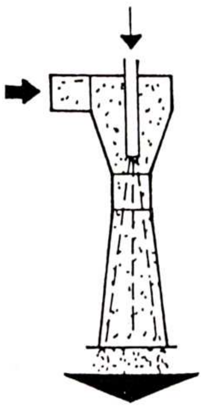
**1.Spray Towers** are widely in use to accomplish heat and/or mass transfer between gases and liquids and to remove solid and gaseous pollutants from gas streams.

They serve as QUENCH to provide rapid cooling of hot gases, as SATURATORS to saturate gases with the vapour of the contact liquid, as COOLING TOWERS to cool water or process gas and as SCRUBBERS for the simultaneous gas cooling and removal of solid particles or gaseous components by ABSORPTION. Water sprays are arranged at several levels and distributed over the entire cross-section to produce a continuous water spray curtain. Co-current and counter-current flow principles are used at different applications. Although long retention times and low pressure losses are provided in spray towers their collection efficiency is relatively poor.



**2. Packed Columns** use packed beds of e.g Raschig Rings, wire mesh, lamella-like internals etc. providing an enlarged wetted contact surface for the heat transfer, mass transfer or collection of particles by inertial impaction. On furnace gas plants packed beds are used as water droplet separators (demisters) but not as "dust washing towers" due to their sensitivity regarding sticking and blocking. In some applications packed bed columns are used as 2nd or 3rd gas cleaning equipment to remove gaseous pollutants like $SO_x$ and $Cl_2$ from the dedusted off-gas – so called ABSORBERS.

**3. Baffle Scrubbers** or “impingement and entrainment scrubbers use a powerful motion in curved channels mixing the scrubbing liquid drops with the particle-laden gas. Those scrubbers are frequently used for the collection of explosive metal dusts but not at furnace gas cleaning plants.



**4. Jet Scrubbers or Injector Scrubbers** are based on the operating principle of the water jet pumps. The injection of the scrubbing liquid via nozzles at gauge pressures between 1 – 3 MPa causes the raw gas to be sucked into the inlet chamber in co-current flow resulting in gas velocities of about 5 – 15 m/s in the contacting zone. As the collection efficiency of jet scrubbers is only slightly greater than that of spray scrubbers, several spray scrubbers are frequently operated in series.

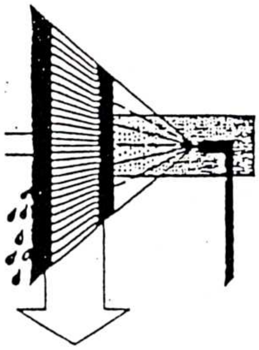
Jet scrubbers do not cause an additional pressure loss. A properly designed jet scrubber can be operated without additional fans. Due to the rather high water supply pressure which requested to be generated with the high pressure pumps, the scrubbing liquid shall be free of abrasive solid particles. A major problem in the operation of jet scrubbers is their high sensitivity to foaming.

**5. Venturi Scrubbers** are the most widely used high-efficiency scrubbers and available in various design, e.g. ring-gap scrubber, tube-gap scrubber, radial flow scrubber. The characteristic feature of Venturi Scrubbers is the convergent-divergent cross-sectional profile of the “venturi”. The highest velocity is reached in the narrowest cross-section, the so-called “throat”. The scrubbing liquid introduced just before the throat is broken up by the gas stream.
As a result of the extremely high relative velocity in the throat (80 – 150 m/s) the particles are instantly mixed with the liquid drops. Advantages are the simple and cost-effective design. Because of the high pressure loss required for an effective dust removal the energy requirements of the ID-fans are substantial. Venturi scrubbers are highly sensitive to gas-load variations and adjustments to varying load conditions can be accomplished by alternating the throat cross-section or by circulation gas. The separation of the particle laden drops from the gas is normally accomplished by centrifugal forces in a downstream arranged cyclone mist eliminator. To increase the efficiency two or more Venturis are installed in series also increasing the pressure losses over the installation resulting in the provision of high pressure ID-fans – some times 2 off in series are required.

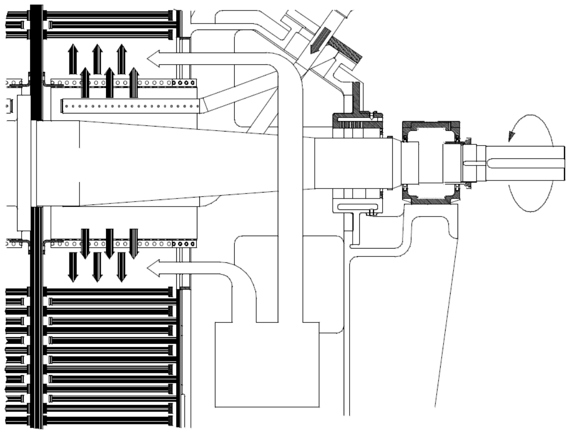
High pressure ID fans with narrow impellers and high circumferential speed operated with water vapour saturated gas installed downstream of the cyclone water separator have to be shown sensitive regarding :

- water droplets generated by condensation or poor separation efficiency of the water droplet separator causing water hammer wear
- residual dust sticking on the impeller causing unbalance and vibration

That’s the reason why you often find stand-by fans installed in parallel to allow for cleaning after having switched over to the stand-by installation.



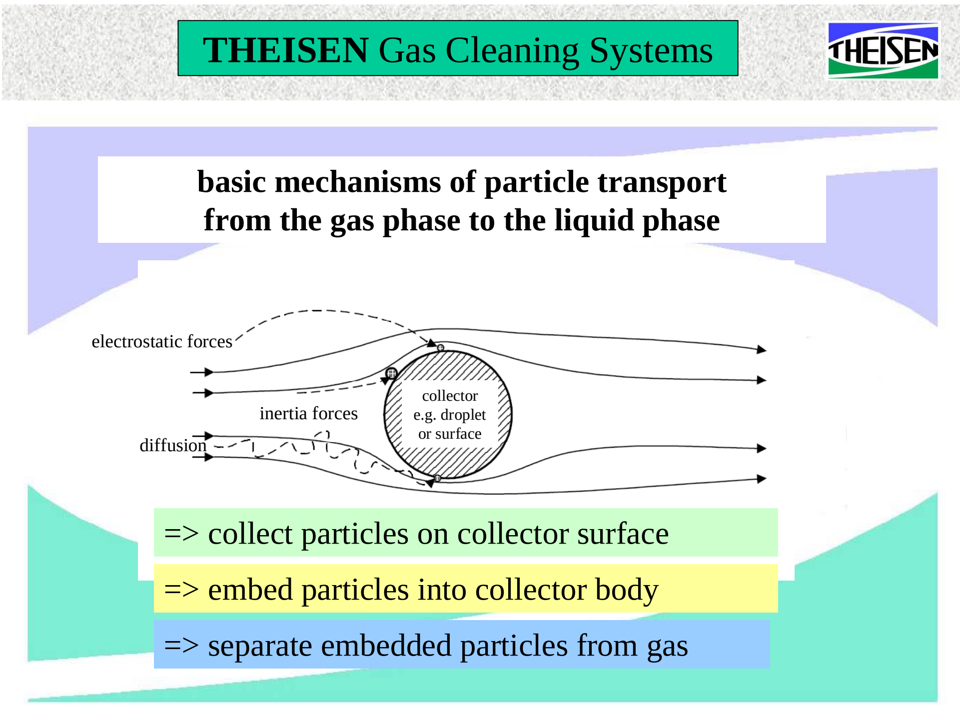
**6. Fan Scrubbers** are more or less fans where water is sprayed in to cool the gas inlet and herewith to saturate the gas with the liquid as well as to wet the impeller. This type of scrubber is not used to clean furnace gas but is provided sometimes on ID-fans of Venturi Scrubbers to extend the operational time of the impellers.



**7. Disintegrators** provide a combination of gas scrubbing and fan in one single machine. They consist of a rotor and stators, which are fitted in a spiral casing similar to a radial fan. The rotating spray cylinders for central scrubbing water feeding and distribution as well as the aerofoil shaped concentrically arranged “rotor cages” are mounted on the rotor shaft. The stators, which are fixed on the housing, also consist of concentrically arranged “stator cages”. Crude gas, charged with particles and atomized washing liquid, undergoes constant and intensive "mixing" whilst passing through the static and rotating cages and embedding the particles into the fine water droplets created. Cleaned gas and solid laden water exits via the tangential gas outlet flange. Cleaned gas and washing liquid are separated in a subsequent water droplet separator. Disintegrators are high-efficiency scrubbers and due to the fan-function of the internals no additional ID fan is required to compensate the pressure losses within the entire gas cleaning system, i.e. from the furnace gas off-take, up to the clean gas discharge of the gas plant.

Free water is always available within the Disintegrator providing the "self-cleaning" of the internals and herewith allowing for long operation time without any cleaning requirement. The permanent presence of free water and the utilization of non-sparking material is one of the reasons why Disintegrators are ideally suited whenever waste gases with high water vapour contents or combustible and/or explosive gases have to be cleaned. Typical applications of Disintegrator based gas cleaning systems are for example:

- top gas cleaning of shaft furnaces like cupola furnaces in the casting industry
- top-gas cleaning of low-pressure blast furnaces in the steel industry
- generator gas cleaning in the base-chemical industry
- CO-gas cleaning of fully enclosed reduction furnaces




The functional principle of wet separators is based on the transfer of solid particles from the gas to a liquid – mostly water.

Beside other aspects the particle transport to the scrubbing liquid in an important step in the collection process.

Particles follow a streamline around a liquid or wetted collection body, e.g. a drop or a wetted solid surface. Part of the particles cannot follow the streamline as they are being diverted around the collection body and hit the surface of the collection body.
This effect is characterized by the target efficiency. The key influencing parameters are the diameter of the collecting body, the particle diameter, the relative velocity between particle and collector, the viscosity of the gas as well as the specific weight of the particles and the gas. No need to say that a lot of other effects also have an influence on the target efficiency, e.g. electrostatic forces and diffusion forces.

For large and heavy particles and low flow velocities, sedimentation also plays a role in particle transport.

Above mechanisms are the driving forces for particle transport to the liquid interface. On impinging on the liquid interface, the particles have to be retained there.

A wet separator always consists of two zones irrespective of whether these are united in one vessel or not: In the first zone, the particles are collected on the drops – in the second zone, the particle-laden drops are separated from the gas.

**factors influencing the collection efficiency**

=> retention time of particle/gas mixture in scrubbing zone

=> relative velocities of particle/gas mixture in scrubbing zone

=> liquid distribution created in scrubbing zone

=> contact surface provided in scrubbing zone

=> particle grain size and characteristics

=> scrubbing liquid characteristics

=> scrubbing liquid/gas ratio

=> and a lot of other influencing factors......

The criteria to be taken into account have been explained presenting the basic mechanisms of the particle transport to the liquid surface.

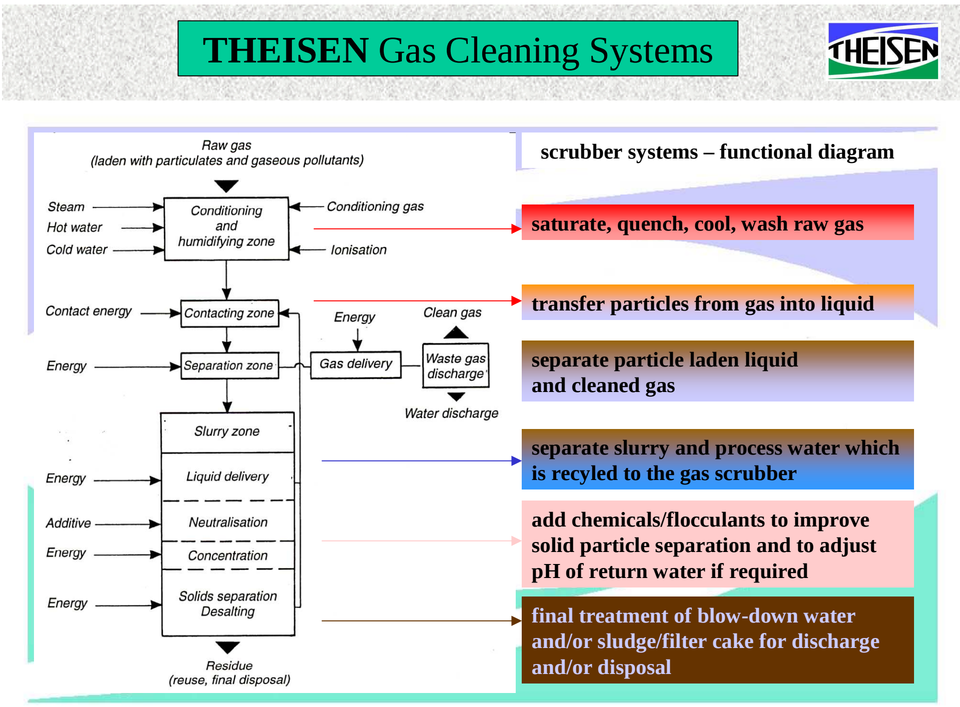
Accordingly, the main factors influencing the collection efficiency are shown in the table above.

A lot of theoretical investigations have been made to describe the collection efficiency, mathematic equations and empirical curves have been established to predict what is happening in a wet scrubber system.

Nevertheless the design of a wet scrubber system for a certain application request a lot of experience from the engineer.

Everybody involved in wet scrubbers knows:

**Dust is not equal to dust and theory can never substitute experience**




Wet separator systems basically consist of “functional zones”, which will not necessarily be realized as separate units.

The process water treatment forms an integral part of a wet scrubber system, not only with respect to environmental reasons but also to treat and prepare the scrubber water to be recycled to the scrubber.

Typical equipment required for the slurry water treatment includes solid matter removal by sedimentation, sludge treatment e.g. by the use of filter presses, clear water cooling and dosing stations for flocculants, pH adjustment and others.

Blow-down water has to meet with the requirements valid for discharge water.

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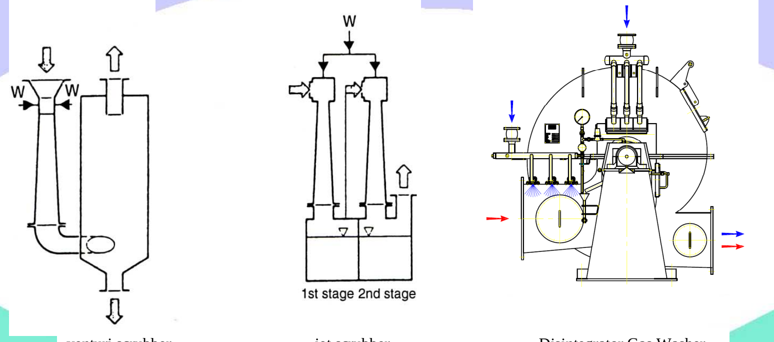
**most common scrubber systems in use at reduction furnaces**




venturi scrubber | jet scrubber | Disintegrator Gas Washer

=> most of the time the Furnace Off-Gas Cleaning System forms part of the “furnace package” of new smelter plants and the furnace supplier provides the system he prefers !

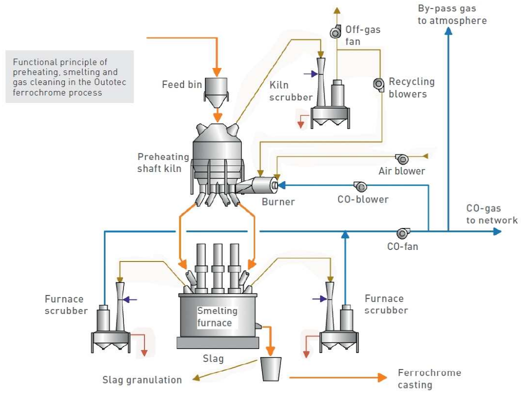
=> when upgrading or substituting an existing system consider practical experiences and future requirements as well. The Furnace Gas Cleaning System is an **INVESTMENT FOR THE NEXT DECADES**

CO gas cleaning systems for fully enclosed reduction furnaces operated in South Africa are equipped with either Venturi Scrubbers, Jet Scrubbers or Disintegrators.

On new smelter plants, mostly the furnace supplier decides, which type of scrubber forms part of his “furnace package”.

At the end of the day it remains the client’s decision which system he decides for, after having investigated the advantages and disadvantages of the alternatives, referring to his specific requirements.

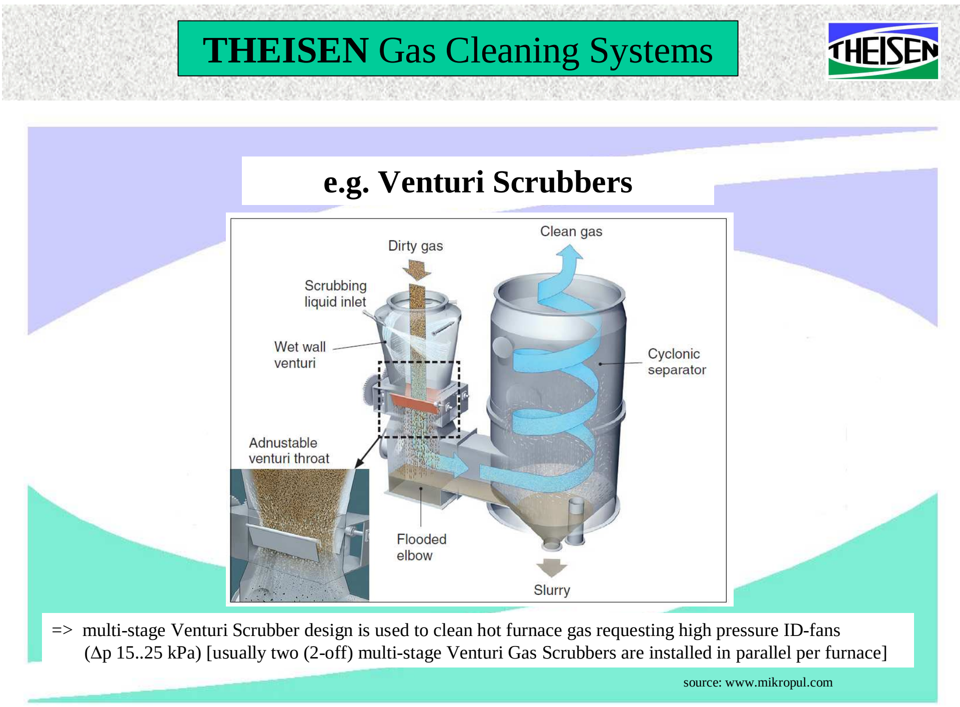
## e.g. Jet Scrubbers




=> furnace off-gases are scrubbed with high-pressure water jets (1-3 MPa)
[usually two (2-off) Outokumpu Gas Scrubbers are installed per furnace]

source: www.outokumpu.com

E.g. Outokumpo uses an own design of Jet Scrubbers within the Outotec Ferrochrome Process to extract and to clean the off-gas from smelting furnaces and associated pre-heaters. As a standard 2 off furnace scrubbers are installed at one furnace.




Others, like e.g. Tenova Pyromet uses their own design of a two stage Venturi Scrubber System to clean hot furnace gas. On those furnaces you also find mostly 2 off Venturi Scrubber Installations connected with one furnace.

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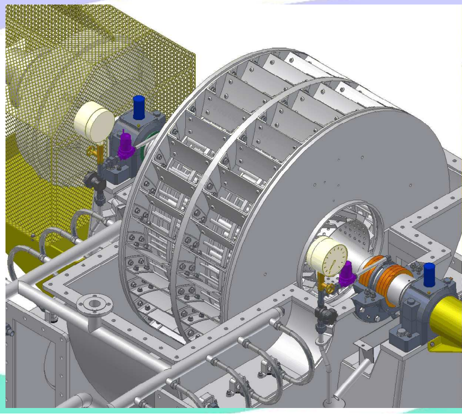
**Disintegrator Gas Scrubber**



=> Disintegrator based Scrubbers are used extract CO gas created in a furnace <u>and</u> to clean the gas.
Due to the "integrated fan-function" no additional ID fan is required at Disintegrator Gas Cleaning Systems.
[in general only **one** (1-off) Disintegrator Gas Scrubber is installed **per furnace**]

source: Theisen GmbH (Germany)

Others like e.g. SMS-Siemag prefer the Disintegrator System to clean the CO gas generated in their fully enclosed AC or DC furnaces.

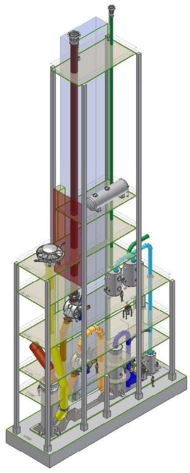
The significant difference between Disintegrator based Gas Cleaning Systems and the other two just presented is the fact, that only 1 off Disintegrator Scrubber has to be provided on one furnace and any back-up scrubber is not required.

Please allow us to explain in detail the Disintegrator based Theisen Gas Cleaning System.

When talking from "Systems" we wish to point out that a gas cleaning plant not only consists in the scrubber itself but a combination of several components joining together and herewith being responsible for the reliable function and operation of the entire smelter plant.

**THEISEN** Gas Cleaning Systems

**Theisen Disintegrator Gas Cleaning System**



example: KZN Sands

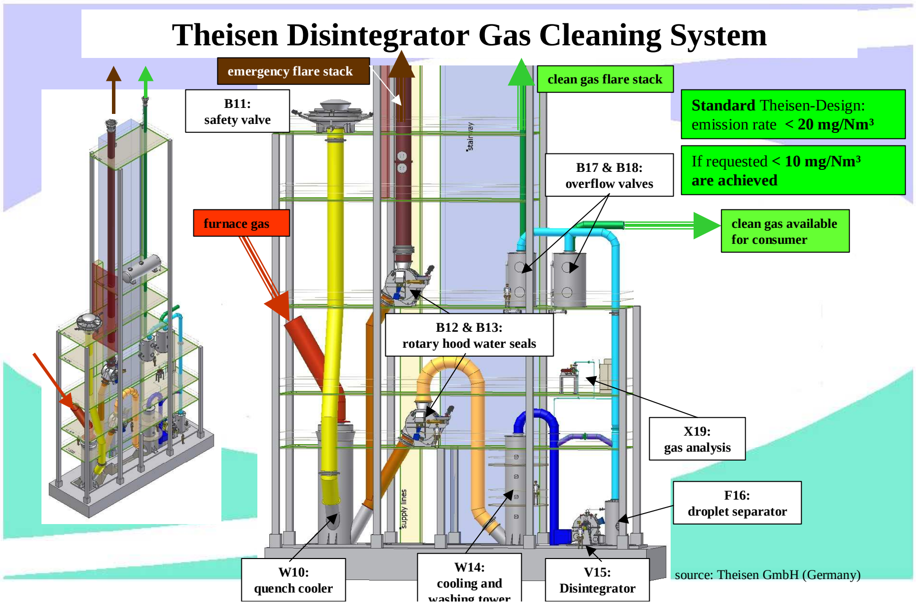
source: Theisen GmbH (Germany)

Gas Cleaning Systems designed and supplied by Theisen are operated in South Africa e.g. at the Exxaro Ilmenite Smelters.

CO-gas generated in Ilmenite Smelters is much hotter than gases from FeCr or FeMn smelters, the dust contains much more fines and the Hydrogen concentration is much higher as well.

Here after we will go through the entire Gas Cleaning System explaining the function and the features of the main equipment.

**THEISEN** Gas Cleaning Systems




Hot furnace gas enters the first stage of the Gas Cleaning System via a water cooled off-gas duct.
In the co-current flow **W10 Quench Cooler** the hot CO gas is cooled down to < 100°C using process water sprayed into the gas allowing to use "normal" material for the downstream ducting and vessels.

If the furnace off-gas temperature does not exceed 350°C – 400 °C, a W10 Quench Cooler is not necessary and the "raw gas" can be directly supplied to one of the two **Rotary Hood Water Seals B12 & B13** installed.

The features of this special type of shut-off valves will be described later. It is essential that both valves are mutually interlocked. This interlock allows only one of the two Rotary Hood Water Seals to be open and due to plant safety reasons a "double" interlock is provided: A pneumatic interlock using pneumatic limit position valves AND an electronic interlock using the limit position switches and the DCS.

During normal operation of the Gas Cleaning Plant the B12 Rotary Hood Water Seal is kept closed where as the raw gas passing the opened B13 Rotary Hood Water Seal is cooled and pre-cleaned in the counter-current flow **W14 Cooling and Washing Tower**.

Coarse particles are already removed and the slurry water is drained to the common sump basin. Depending on the scrubber water supply temperature the gas is also cooled to approx. 40°C entering the inlet legs of the spiral housing of the **V15 Disintegrator Gas Scrubber**.

Scrubbing water supplied to the Disintegrator is atomized passing the static and rotating internals, creating high relative velocities of the water/gas/particle mixture, creating permanently renewed contact surfaces and herewith embedding the fine solid particles into the liquid phase. Due to the design of the Disintegrator Gas Scrubber it also acts as ID fan and compensates all pressure losses within the entire CO gas system starting from the furnace gas off-take up to the stack or a potential “clean gas consumer discharge”.

Water is supplied permanently to the Disintegrator and due to the very high turbulences created in this “washing machine” the self cleaning effect resulting allows long operational time without solid and mud accretions which are known at ID fans operated in a moisture saturated atmosphere.

In other words: the dust particles are removed from the gas phase by being captured and embedded into the liquid phase. Cleaned gas and slurry water leaving the Disintegrator Gas Scrubber in common are separated from each other in the downstream arranged **F16 Droplet Separator,** which is also drained to the common sump basin.

The **B17 & B18 Overflow Valves** act as water seals and flush-back arrestor for the cleaned CO gas, which will either be flared in the **A17 Clean Gas Flare Stack** or will be supplied to a “clean gas consumer system”.

Today Theisen Standard Design allows for residual dust concentrations in the cleaned CO gas before being combusted of max. 20 mg/Nm³. On request the Theisen Disintegrator is designed to achieve < 10 mg/Nm³ - often required if a CoGen installation is planned to be provided for energy recovery purposes.

The furnace pressure control is maintained by a butterfly damper valve installed in the clean gas duct between the F16 Droplet Separator and the B17B18 Overflow Valves allowing to control the furnace pressure within a range of 0 – 100 % of the design gas flow volume.

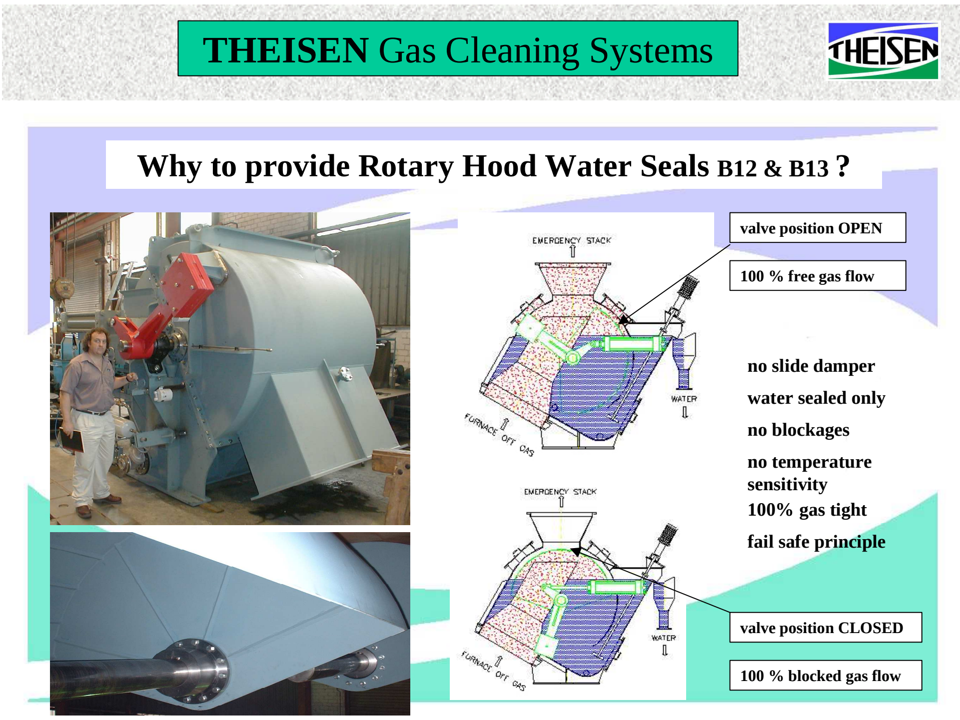
The efficiency of a Disintegrator Scrubber is independent of the deviation from the design gas flow volume – on the contrary the residual dust load in the cleaned gas will further decrease if the plant is operated below the design gas flow volume !

The **X19 Gas Analysis** allows for monitoring the furnace gas composition indicating the concentration of CO, $CO_2$, $H_2$ and $O_2$ during gas plant operation.

In emergency situation, e.g. power failure, scrubbing water supply failure or other safety relevant failures, the Gas Cleaning System is isolated by closing the B13 Rotary Hood Water Seal and opening the B12 Rotary Hood Water Seal – the CO gas will now be flared-off in the **A12 Emergency Flare Stack.** The furnace pressure will still be controlled now switching the furnace pressure control from the damper valve installed in the clean gas duct to the damper valve installed in the emergency system.

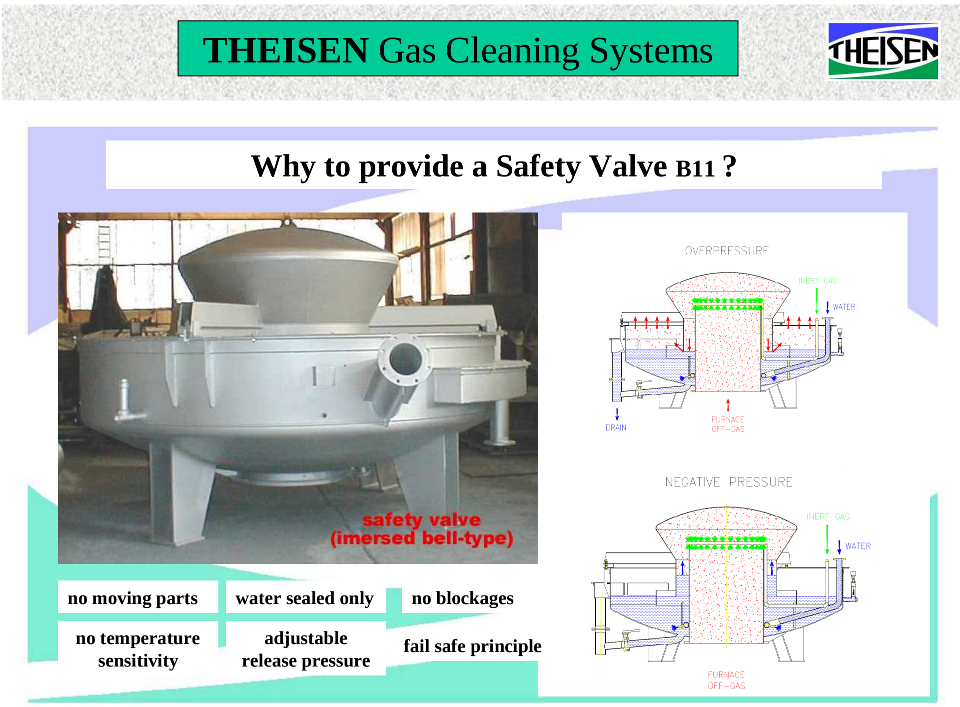
Nevertheless an additional **B11 Safety Valve** is connected with the furnace gas system to protect the entire furnace system from overpressure in case of any failures.

The safety relevant equipment will be explained in detail later.




Gas tight shut-off valves installed in the raw gas ducting have shown to be a critical part of a gas cleaning system. The Rotary Hood Water Seals use the seal function of water only, without any sliding internals and sensitive static mechanical gaskets. The rotary hood movement from open to close position and back is performed by the use of pneumatic cylinders assisted by counter weights, which allow for bringing the shut-off valves into the “fail-safe position” (B12 opened and B13 closed) also during extreme failure situations, e.g. if no pressurized air or no electric power is available anymore.

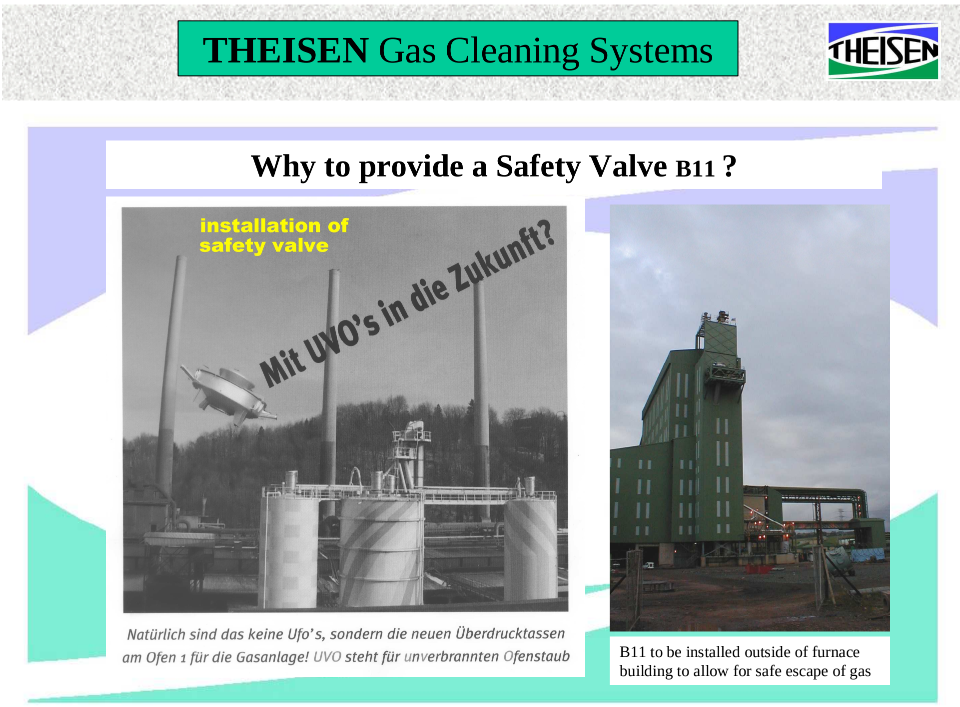
An agitator installed prevents solids to settle in the water seal section and all slurry water is also drained to the common sump basin.



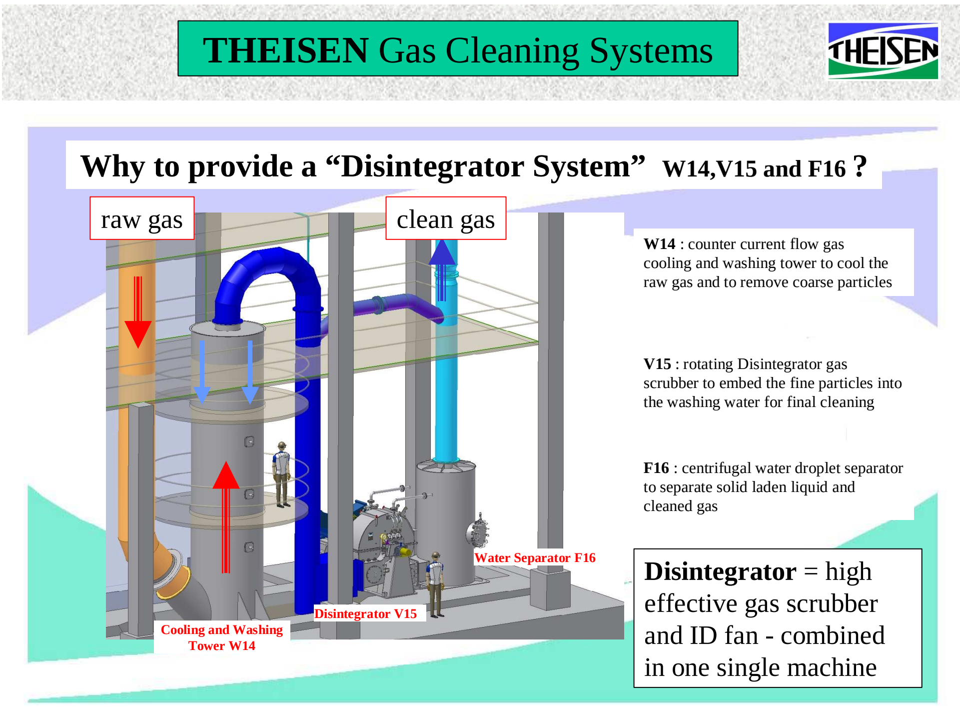

At present a "fully enclosed" reduction furnace can be built more or less gas-tight. The furnace pressure shall always be kept slightly positive. "Slightly" means some "mm WC" only but rather constant within e.g. a range of +/- 10 mm WC.

Although a rather sensitive furnace pressure control allows for a "smooth" furnace operation, sudden "pressure peaks" caused e.g. by eruptions, collapsing material bridges or "wet batch feed" cannot be compensated by the pressure control loop.

Provision has to be made for an overpressure relieve valve designed according the requirements to be reliable for hot and dusty gases, e.g. the **B11 Safety Valve**. This bell-type valve is a water seal with adjustable release pressure but also ensuring that no ambient air can be sucked into the CO gas system at under-pressure situations.




The location of installation should be outside of the furnace building not to risk any CO gas penetrating into the building or flames to cause any damages on the structure.




Let us explain now the key component of a Disintegrator based wet scrubber system – the **V15 Disintegrator** itself :

**The Disintegrator V15 (example)**

Disintegrator Size 2300 kHv

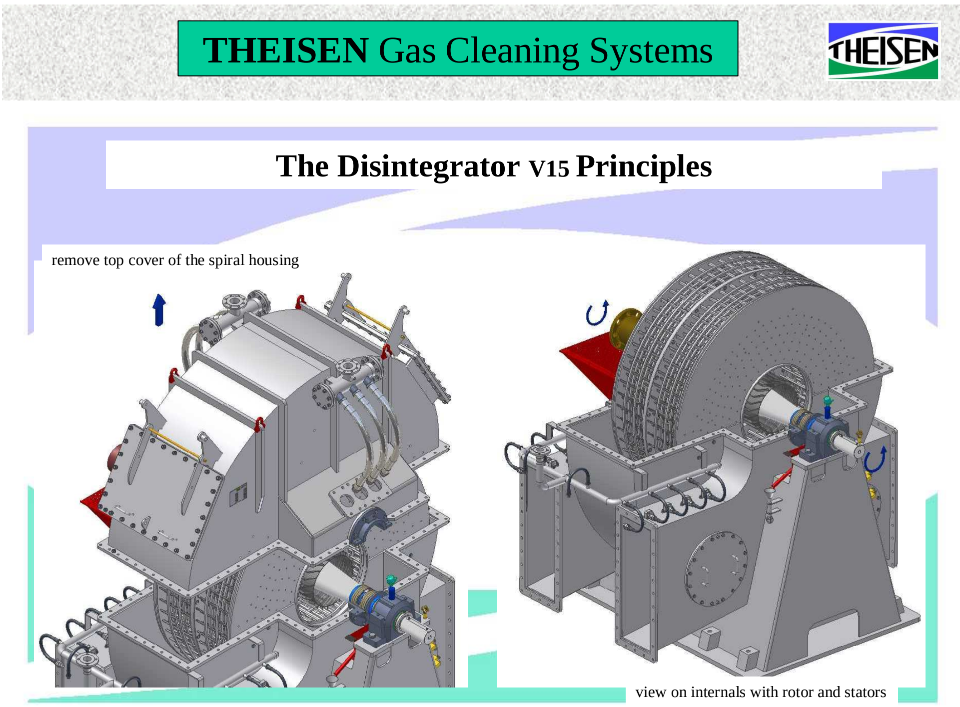
view on spiral housing

The **Disintegrator Gas Scrubber** is individually designed according the process requirements, e.g. the Volumetric Gas Flow, the Pressure Generation required, the Dust Removal Efficiency and the behaviour of the dust itself.

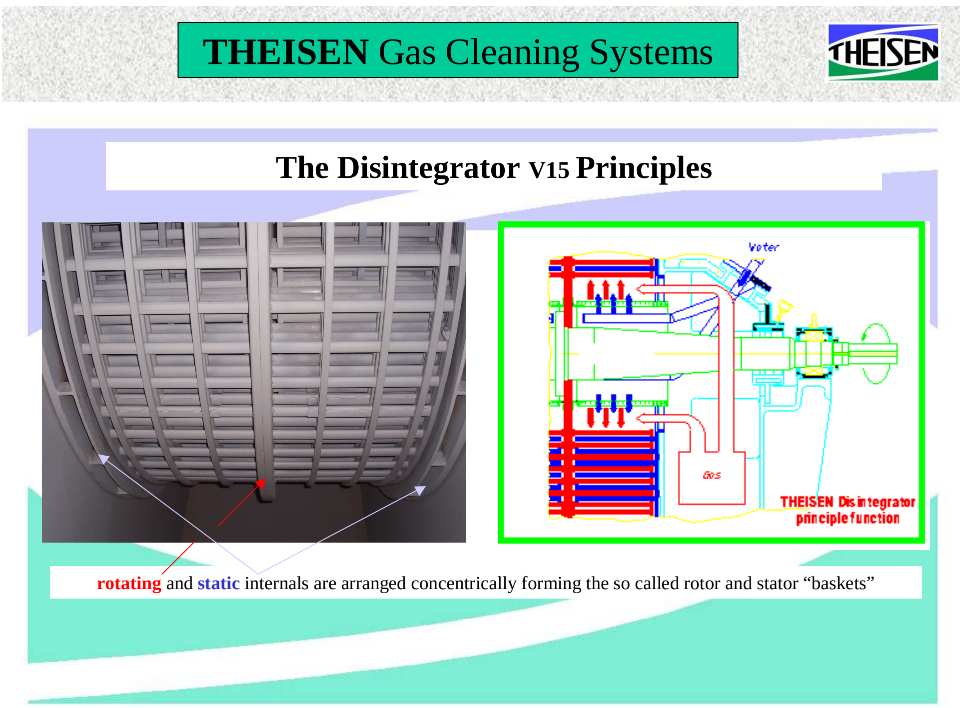
**Theisen** supplies Disintegrators for flow volumes in the range of 15 – 150,000 m³/h, requesting for main drive motors from 3 kW up to 1.4 MW, depending on the application and the process.

All Disintegrators have in common:

- a spiral housing, similar to a radial fan
- a shaft with gas tight shaft seals and outside bearings
- the Rotor, similar to the impeller of a fan
- the static internals fixed on the side-wall of the housing, the so called Stator



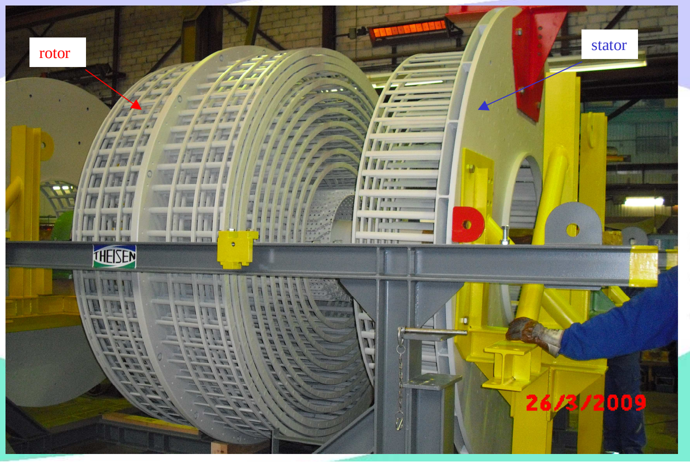

Removing the top cover of the spiral housing the Rotor/Stator unit can be clearly recognized. The so-called Stator-Disks are bolted on the housing herewith forming the static internals. The Rotor with its spray cylinders is fixed on the shaft, supported in its roller bearings.




The rotating and static internals are arranged concentrically – both consisting of aerofoil profile bars welded in the support disks and rings, forming the so-called rotor baskets and stator baskets fitting ”comb-like” together.

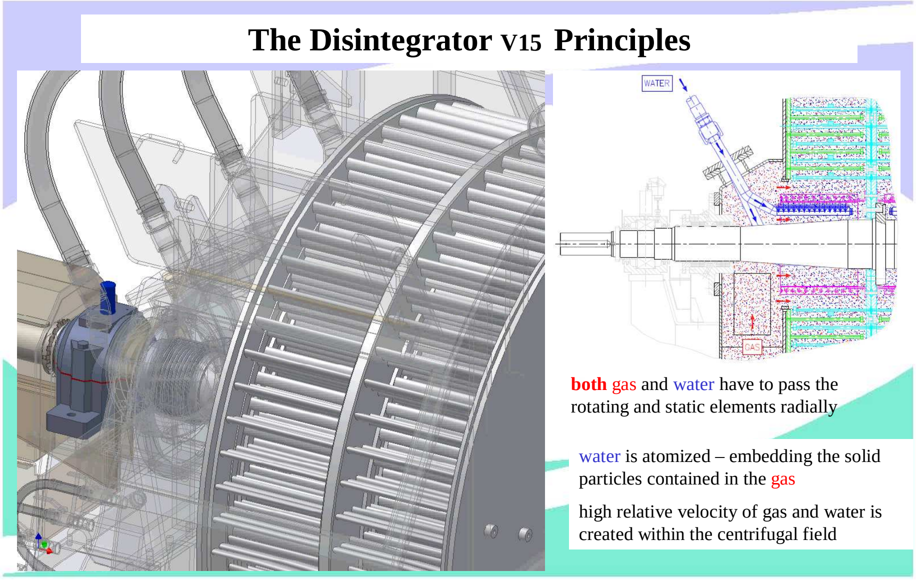
**THEISEN** Gas Cleaning Systems

## The Disintegrator V15 Principles




**rotating** and **static** internals fit together “comb-like”

The comb-like fitting of Rotor and Stator and the arrangement of the droplet shaped bars can be seen clearly when dismantling Rotor and Stator.

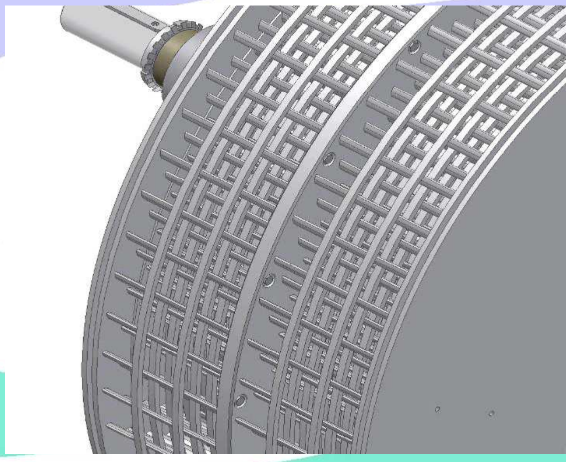



Solid laden gas and scrubbing water enter the spiral housing nearby the shaft, the water supplied by injection tubes is distributed passing the perforated spray cylinders over the entire width of the internals.

Gas and water have to pass the rotating and static “baskets” following the radial field generated within the Disintegrator and hereby the solid particles are embedded in the mist droplets. Passing the rotating and static droplet bar baskets alternating, new contact surfaces are generated permanently – not only the contact surface of the droplets itself but also the collecting surface of the bars allowing for a high efficient dust collection. Gaps between the bars open and close creating high turbulences between gas and water and high relative velocity of gas within the centrifugal field.

Cleaned gas and solid laden water leave the spiral housing via the tangential discharge flange and are separated from each other in the droplet separator arranged downstream.

## The Disintegrator V15 Principles

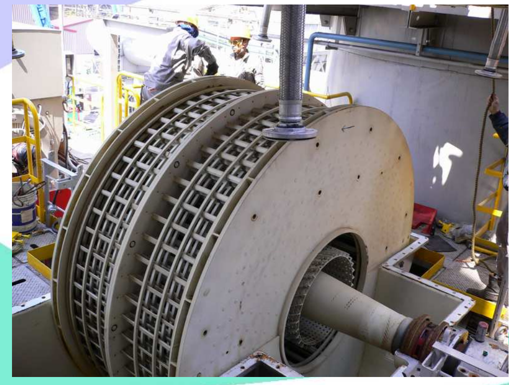


**gas and water passing the rotating** and **static** internals create high turbulences
and constantly renew contact surfaces to enable the water to “catch” fine dust particles.

The movie explains the relative movement of static and rotating parts of the Disintegrator’s internals.

**THEISEN** Gas Cleaning Systems

## The Disintegrator V15 Example



<u>Disintegrator</u> Size: 2300 kHv
volumetric capacity: 60,000 $am^3/h$
clean gas dust: < 10 $mg/Nm^3$
motor power: 1,400 kW
rotor speed: 880 rpm
total weight: 32 t

<u>Rotor including shaft (only)</u>
weight: 6.7 t
diameter: 2.6 m
shaft length: 4.4 m

<u>related to outer row:</u>
circumferencial speed: 111 m/s
i.e. 400 km/h
G-force: 1,050 g

**Disintegrators are supplied within a name-plate capacity 30 $Nm^3/h$.......140,000 $Nm^3/h$ for various applications**

The example of a Disintegrator Unit supplied for a client in Japan allows for getting a “feeling” about the forces within such a structure. The Disintegrator is used to extract and to clean the top gas of a special type of “Reduction Shaft Furnace” to process all iron containing residuals and extreme fine dust from e.g. bag-houses of a steel plant, recovering the metal as liquid iron and the cleaned CO gas to be supplied to the existing CO gas network of the steel mill used for power generation.

If, for example, you are “sitting” on one of the bars of the outer rotating baskets you move with approx. 400 km/h in a curve of 1.3 m radius,
”feeling” your own weight 1,000 times !



Disintegrator Gas Cleaning Systems are operated for special applications all around the globe and of course in South Africa as well.

**THEISEN** Gas Cleaning Systems

**Disintegrator Gas Cleaning Systems installed in South Africa**


commissioned 2009

requirements to be fulfilled:

- availibility > 99 %
- emissions < 20 mg/Nm³
- low maintenance
- high reliability
- long lifetime of Disintegrator

- **Gas Plant Safety**

**other applications: SAF, blast furnace, shaft furnace, slag smelter, CO generator, pyrolysis kiln, etc.........**

All the installations supplied including the above examples have to fulfil their contractual requirements and represent the today standards for efficiency, reliability and – as a mayor aspect – **Gas Plant Safety**

To operate furnaces and associated equipment with high contents of explosive gases like CO and $H_2$ request high standards of safety relevant equipment, minimizing the risk of explosions and dangers for the environment and personal.

Safety relevant installations form an integral part of Gas Cleaning Plant Equipment and Operation.

**The general plant philosophy shall be Safety First**


Operating a Gas Cleaning Plant on Fully Enclosed Reduction Furnaces request a permanent and reliable monitoring of the furnace gas composition, especially the Oxygen content of the CO gas to ensure that the equipment is operated below the “explosion limit”.

The simultaneous monitoring of CO, $H_2$ and $CO_2$ allows for getting information about the entire furnace process, e.g.

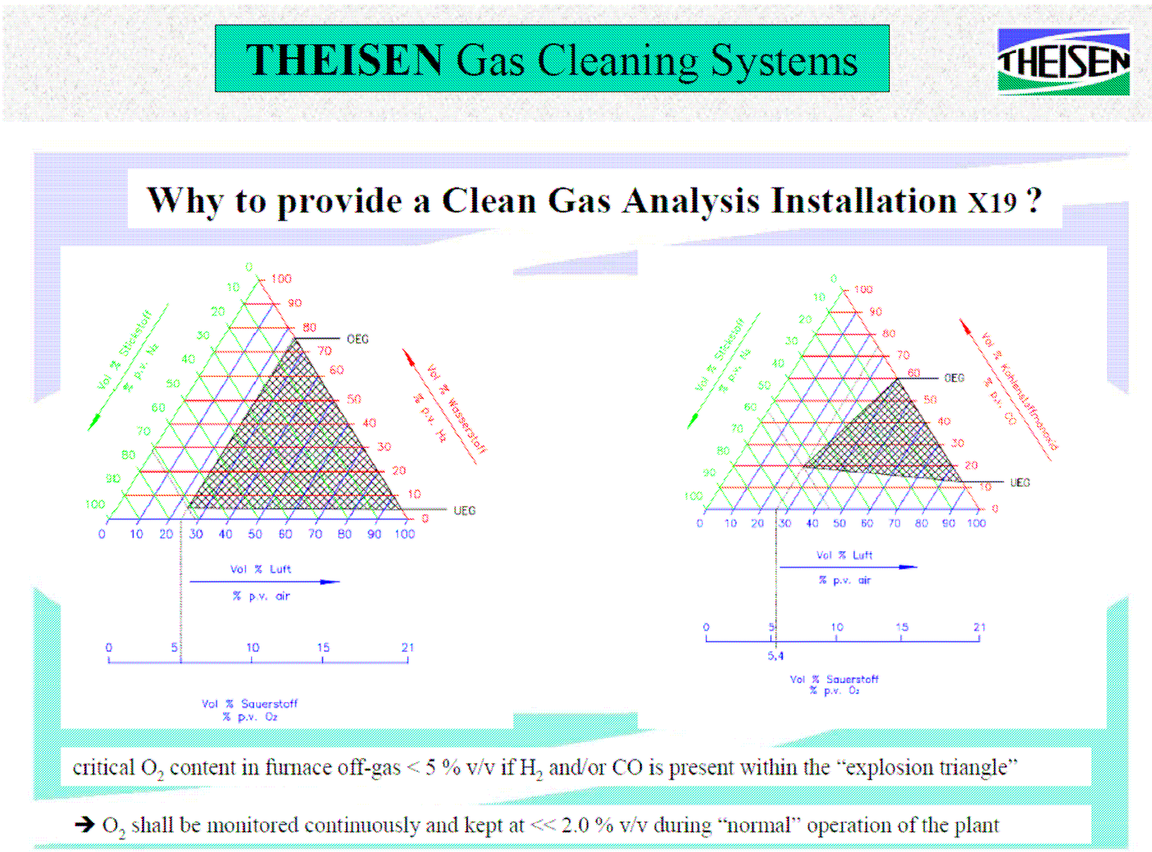
**$H_2$** allows to get an information about the moisture of the furnace feed and possible leakages of e.g. the water-cooled furnace roof

**$CO_2$** indicates possible leakages in the “hot section” of the system

**CO** in relation to above is interesting for the metallurgy and the furnace reduction process itself

**$O_2$** indicates possible leakages in the “cold section” of the system and forms part of the safety interlocks shutting down the plant when exceeding a maximum allowed concentration.

In case of the cleaned CO gas to be used for power generation with e.g. gas engines the gas composition will become relevant for the gas motor control installations.




Explosive gas mixtures are described using "explosion triangles" which have been established for "pure" mixtures of combustible gases and air at 25°C and 101.3 kPa. The corresponding figures for the Oxygen limit concentration can be calculated but other effects have an safety relevant influence on the limit concentration, e.g. the gas temperature, the presence of other gaseous components and the presence of solid matter particles acting like catalysts.

**The monitoring of $O_2$ is essential for a safe plant operation !**

**THEISEN** Gas Cleaning Systems

## Why to provide a Clean Gas Analysis Installation X19 ?

Furnace Gas Cleaning Plant venting during Emergency Situation, e.g.:
-power failure
-srubber water failure
-unacceptable $O_2$ concentration level

Furnace Gas Cleaning Plant during normal operation :
-no visible flame
-emissions far below legal requirements
-safe furnace and gas plant operation
-furnace pressure controlled CO gas extraction

➔ provide measurements to be prepared for all situations which might effect plant safety and availability of installations

In Emergency situations installations shall be provided to allow for a safe shut down of the system to avoid hazardous operation conditions.

This also refers to utility supply failures and sudden interruption of power supply.

The provision of measurements to be prepared for all situations is a “must” and shall form part of each Hazop Study established.

### Decision for a Gas Cleaning Systems shall be based on references

If you pass a smelter plant in operation and neither smoke or a flame is visible on top of the clean gas flare stack you should try to get knowlege about the experience of your collegues operating such an efficient Furnace Gas Cleaning Plant

**THEISEN** Gas Cleaning Systems

### Decision for a Gas Cleaning Systems shall be based on references

**Rudi Gottschling**

**Von:** "Stalberg, Tony" <TonyS@sacarbide.com>
**An:** "Rudi Gottschling" <R.Gottschling@Theisen-MUC.de>
**Cc:** "Sabio, Juan Manuel" <Juans@sacarbide.com>
**Gesendet:** Freitag, 3. April 2009 13:16
**Betreff:** Theisen Gas Plant - SA Calcium Carbide

Hello Rudi,

It is nice to hear from you!

**Question 1** – Yes the Theisen plant continues to operate and serves the furnace as originally designed. We have installed a third compressor / blower which helps the two original blowers to draw the gas through the gas scrubbing equipment. This modification has enabled the smelter to run at a slightly higher load and to handle the extra gas volumes that are generated than design because of the increased amount of volatile material in our feedstock. We have not increased the output of the furnace since we last talked however. The unit continues to perform extremely well with regard to final dust emissions and is indeed still around the 10mg/m3 – 20mg/m3 mark, this figure you can mention in the seminar. During the day time the flare is so clean you cannot always see if the furnace is on! We have made significant progress in on line time of the system as well by introducing anti scaling chemicals on the rotor.

**Question 2** – you are welcome to mention our unit at the seminar as well as the application and the final levels. Either Juan and I or one of us hopes to attend.

Regards,

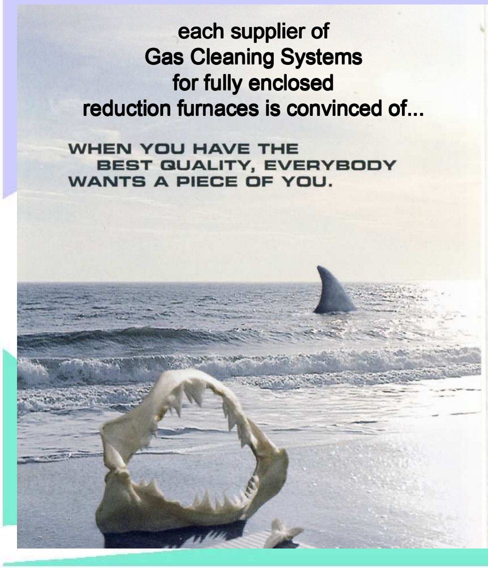
*Tony Stalberg*

SA Calcium Carbide
Technical Manager
27 (0) 083-635-1932
27 (0) 034-370-1101

Note: The Theisen Disintegrator Gas Cleaning System at SACC is in operation since 1981, i.e. meanwhile for 28 years

When investigating to improve an existing installation or looking for a new CO gas cleaning plant for a new production facility the decision shall be based on references and experiences with existing concepts.
- Time goes by and the technology is improving constantly as well. Consider the progress of the "state of the art" and the legal requirements and restrictions.

**THEISEN** Gas Cleaning Systems




To supply best quality the client's engineer has to take care to fix all relevant basic design figures in his enquiry sent out.

Commercial Conditions and Contract Specifications might form an integral part of an enquiry but are of minor importance for the design engineer to decide for the technology to be proposed and to be specified in the quotation the client asks for.

Assist the potential supplier in doing his job by submitting detailed information regarding the Scope of Services and Supply to be quoted.

We are engineers and are looking for the best technical solution for the existing problem. – Not looking for the cheapest price.

Technology shall have priority – but it shall be affordable as well

When establishing specifications the technical requirements shall be defined as clear and complete as possible.

This also refers to the basic input data you have to establish when going out for an enquiry.

## **THEISEN** Gas Cleaning Systems

### Basic Input Data requested by the client to investigate a suitable Wet Scrubber System

<u>Volumetric Gas Flow:</u>

| | |
|---|---|
| normal as per metallurgical calculations | **?** $Nm^3/h$ (ntp) |
| maximum design gas flow | **?** $Nm^3/h$ (ntp, dry) |
| volumetric design capacity of GCP | **?** $Nm^3/h$ (ntp, wet) |

<u>Raw Gas</u>

| | |
|---|---|
| temperature at furnace gas off-take | **?** degC |
| furnace gas dust load max. | **?** kg/h |
| resp. based on max. design gas flow max. | **?** $g/Nm^3$ |

<u>Clean Gas</u>

| | |
|---|---|
| Dust content of cleaned gas | < **?** $mg/Nm^3$ |
| Wash water temperature inlet normal | **?** degC |
| design. | < **?** degC |

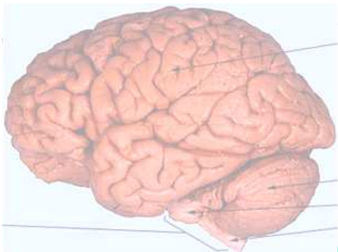
**If you intent to use the cleaned gas for any purposes (e.g. CoGen) indicate requirements !**

## **THEISEN** Gas Cleaning Systems

### Basic Input Data requested by the client to investigate a suitable Wet Scrubber System

<u>Furnace Gas Composition (design)</u>

CO = ? % unit % = mole/mole
$CO_2$ = ? %
$H_2$ = ? % indicate max. value !
$O_2$ = ? %
$H_2O$ = ? %
$N_2$ = balance
volatiles ? tar etc. ?



<u>Furnace Dust Composition (design)</u>
including particle size distribution

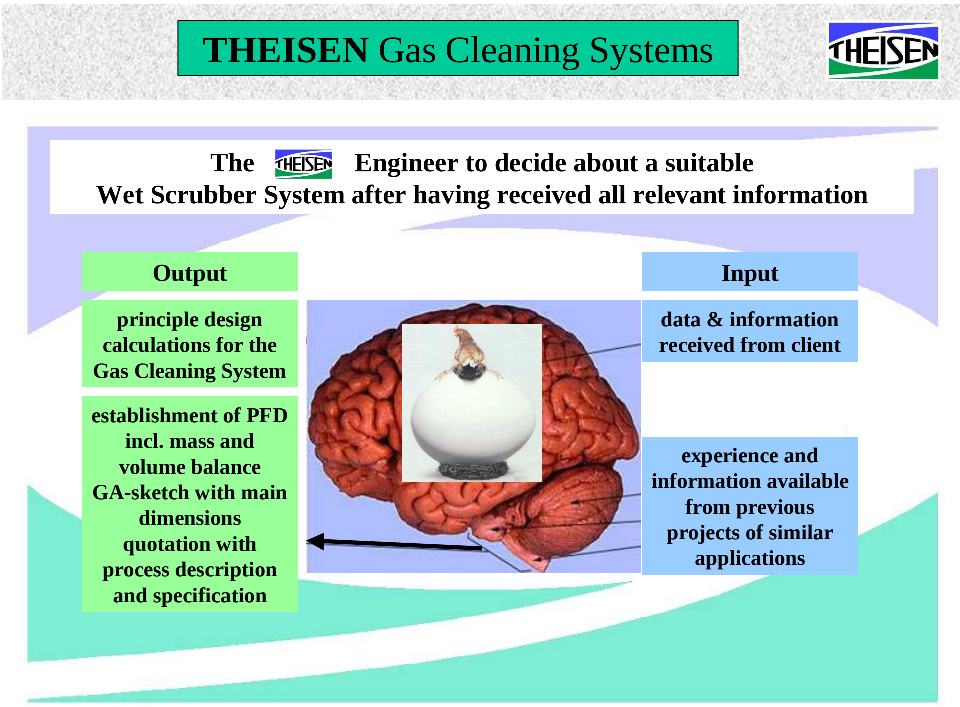
<u>Furnace Operation (design)</u>
AC or DC (MW)
product e.g. FeMn, FeCr etc.
feeding system e.g. batch

<u>Site Data (design)</u>
including barometric pressure

**Do not forget to think about the future requirements to be considered in the planning**

Assist the potential supplier in providing all relevant aspects.

The more details you are able to supply the more professional the quotation can be established.

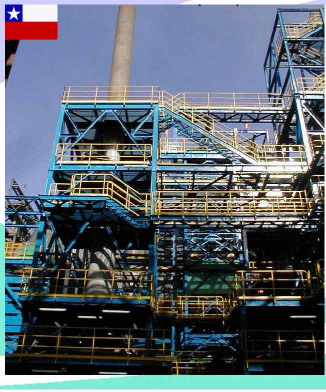



The engineer's brain requests feeding of detailed information before he is able to breed out a proposal for the Wet Scrubber System.

At the end of the day both **partners** want to be happy about the plant supplied, erected, commissioned and operated – and this for decades!

## **THEISEN** Gas Cleaning Systems

**At the end of the day the Gas Cleaning Plant will be commissioned and operated successfully over decades , like the installations in:**



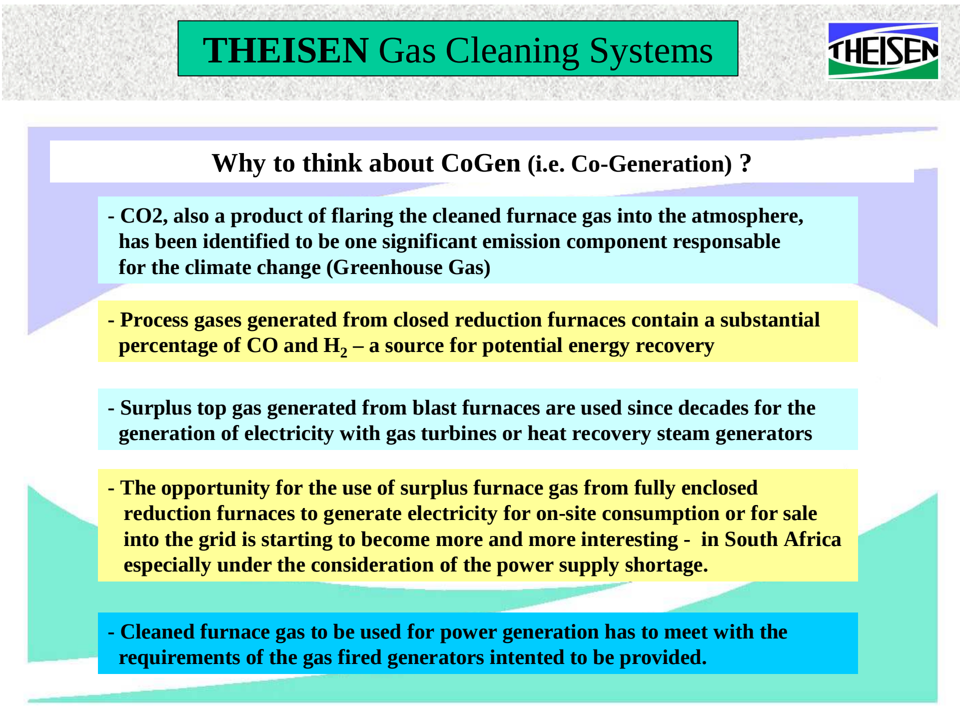
## **THEISEN** Gas Cleaning Systems

**At the end of the day the Gas Cleaning Plant will be commissioned and operated successfully over decades , like the installations in:**

## **THEISEN** Gas Cleaning Systems

**At the end of the day the Gas Cleaning Plant will be commissioned and operated successfully over decades , like the installations in:**

and other Disintegrator Systems operated world-wide



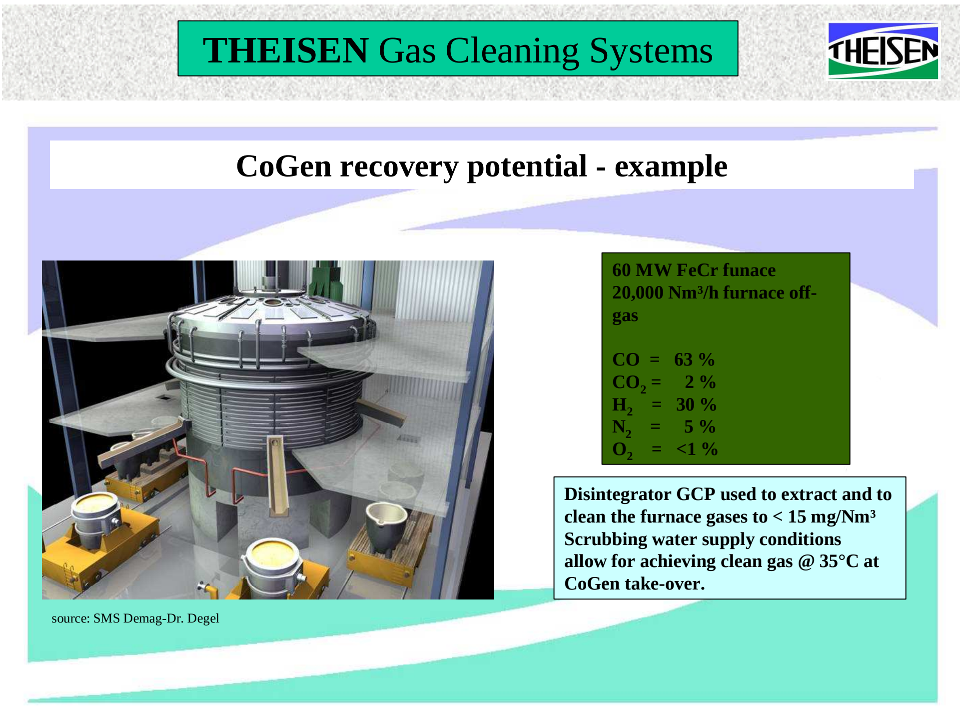

## What is Cogeneration?

Cogeneration (Combined Heat and Power or CHP) is defined to be the simultaneous production of electricity and heat.

Fully enclosed reduction furnaces generate, more or less as a by-product of the smelter process, an off-gas rich in CO and $H_2$.

Today some of the cleaned furnace gas is used for heating processes e.g. ladle heating or pre-heating of feed material. Currently an enormous amount of gas is flared to the atmosphere which is interesting to be used for power generation. Although the overall costs for generating electric power using the CO gas as fuel source are higher than the costs for electricity taken from the grid, some aspects shall be taken into account for in-house generation of electric power.

To allow for investigating this possibility a practical example shall be presented:




E.g. a FeCr furnace creating 20,000 Nm³/h furnace gas with 63% CO + 30 % H2 will be available at 35°C and 15 mg/Nm³ solid matter (dust) after having been cooled and cleaned in a today standard Gas Cleaning System. The dust emissions are far below the legal limits if this gas is flared to the atmosphere and the conditions of the gas are also suitable to be used in e.g. a Gas Engine to generate electrical power.

**THEISEN** Gas Cleaning Systems

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## CoGen recovery potential - example

**60 MW FeCr Funace**
**20,000 Nm³/h off-gas**
**CO = 63 %**
**$CO_2$ = 2 %**
**$H_2$ = 30 %**
**$N_2$ = 5 %**
**$O_2$ = <1 %**

**Cleaned Furnace Off-Gas**
**20,000 Nm³/h @ 35°C**
**LHV = 3,1 kWh/Nm³**
**rel. moisture < 60%**
**total solid particle concentration < 15 mg/Nm³**

**GE-Jenbacher spark ignition Gas Engine Generating Sets used to generate electrical power from cleaned furnace gas will generate approx. 23 MW electrical output. If requested steam can be generated additionally using the exhaust gases as energy source.**

source: GE-Jenbacher

In our example spark ignition gas engine generator sets from the company GE-Jenbacher shall be provided.

The electrical efficiency of those Gas Engine Generator sets for above "example gas" is approx. 37 % allowing for generating approx. 23 MW electrical power using the CO gas of this 60 MW furnace.

The exhaust gas of the gas engines can be used additionally for pre-heating purposes, e.g. to assist drying and/or preheating the furnace feed in a rotary kiln or to generate steam in a boiler.

These Gas Engine Generator Sets can also be used –with some restrictions- as emergency power generators fired with e.g. SASOL gas.

# THEISEN Gas Cleaning Systems

THEISEN

Jenbacher
Documentation

Technical Instruction No.: 1000-0302
**Fuel gas quality**
**Special gases**

**3.2 Physical, chemical and thermodynamic requirements for gas:**

To guarantee faultless engine operation and the specified maintenance intervals, the following gas conditions must be **permanently** maintained at the GE Jenbacher interface.

| Description | Supplement | Limitation | Unit | Note |
|---|---|---|---|---|
| Gas pressure | Min./max. | - | mbar(o) | In accordance with project specification |
| | Fluctuation | 10 | mbar/s | |
| Gas temperature | Min. | 10 | °C | |
| | Max. | 40 | °C | Higher temperatures should be checked in all cases! |
| Relative gas moisture | Max. | 80 | % | Must be guaranteed at any temperature! |
| Lower calorific value | Min. | 1.5 | $kWh/Nm^3$ | Lower values should be checked in all cases! |
| | Fluctuation | 2 | %/30sec | |
| Dust or particle content | Size | > 3 | µm | The filter in the gas pressure control system is not used as a work filter [3)] |
| | Quantity | < 50 | mg/10kWh [2)] | |

source: GE-Jenbacher

using a Disintegrator System:

cleaned furnace gas can be boosted to any requested and constant pressure without problems

Theisen CoGen-Kit guarantees cleaned furnace gas to be available at T<40°C and φ<80 % at take over

LHV of Reduction Furnace Gas > 2.5 kWh/Nm³ under "normal" conditions. CO and H2 are monitored on-line using X19

Theisen GCPs guarantee cleaned furnace gas to be available with << 50 mg/10 kWh > 3 µm dust

source: Theisen GmbH

# THEISEN Gas Cleaning Systems

THEISEN

Jenbacher
Documentation

Technical Instruction No.: 1000-0302
**Fuel gas quality**
**Special gases**

| Description | Supplement | Limitation | Unit | Note |
|---|---|---|---|---|
| Total sulphur [4)] | With catalytic converter | ≤ 200 | mg/10kWh | CO catalytic converter [5)] |
| | Without catalytic converter | ≤ 700 | mg/10kWh | |
| | Without catalytic converter | ≤ 1200 | mg/10kWh | With limited warranty [6)] |
| Total halogens [4)] Cl + 2 * F | With catalytic converter | ≤ 20 | mg/10kWh | |
| | Without catalytic converter | ≤ 100 | mg/10kWh | |
| | Without catalytic converter | ≤ 400 | mg/10kWh | With limited warranty [6)] |
| Highly flam-mable com-ponents | Acetylene (C2H2) | ≤ 0.2 | %Vol | These substances can cause uncontrolled spontaneous combustion in the system! |
| | Carbonyl sulphide (COS) | ≤ 0.2 | %Vol | |
| Explosivity | Gas must not be potentially explosive (no ATEX rating) | | | |
| Tar [7)] ($C_xH_yR_z$) | Tar dew point | Min. 5°C below gas temperature | °C | Where gases contain tar, the gas pressure control system must be provided with a trace heating system including heat insulation! |
| Condensate or sublimate [8)] | | 0 | | No condensate and no sublimation of water or tars in components that come into contact with gas and/or mixture! |

source: GE-Jenbacher

using a Disintegrator System:

wet scrubber systems allow for removing gaseous sulphur components by absorption into the process water

wet scrubber systems allow for removing gaseous halogen components by absorption into the process water

Theisen Clean Gas Analysis X19 guarantees $O_2$ to be "far away" from critical concentration when supplied to the CoGen installations

Tar in Reduction Furnace Gas is removed as well using special Theisen designed GCPs. Condensate or sublimate will not become a problem.......

source: Theisen GmbH

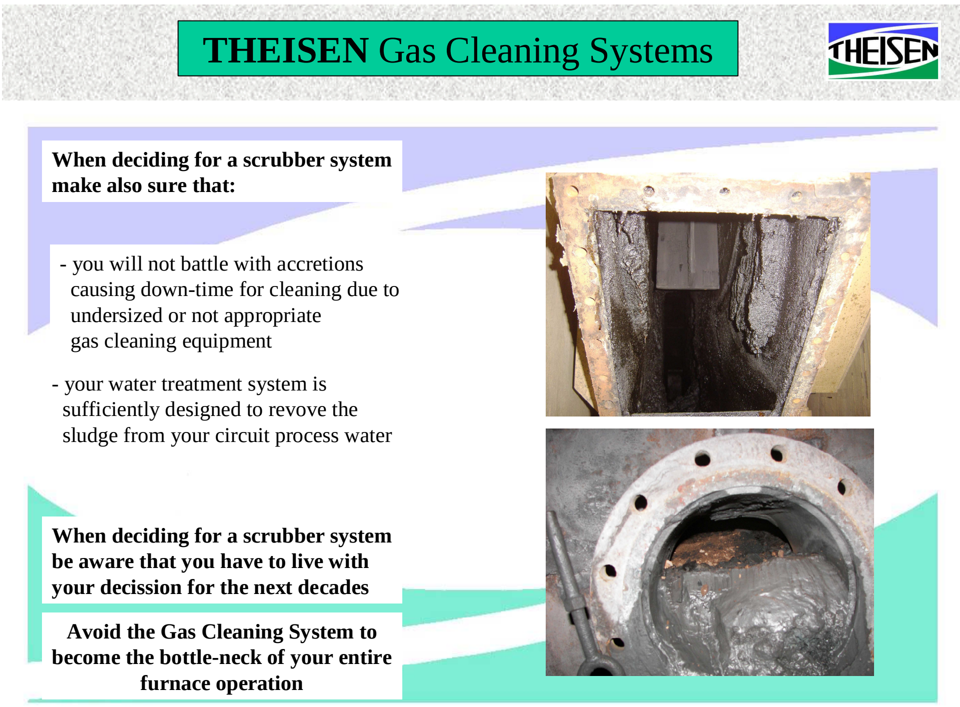
The utilisation of the GE Jenbacher technology request some conditions to be fulfilled for the fuel gas. The requirements defined in GE's specifications must be guaranteed by the furnace gas cleaning system in addition to the furnace process requirements and the environmental aspects.

Having compared these requirements with the Theisen Standard Gas Cleaning Plant Output Data we can ensure that all can be fulfilled if a Theisen CoGen Kit is provided in the clean gas supply in direction to the Gas Engines.

If tar or sublimates have to be considered to be present in the CO gas special solutions exist to solve those problems as well.

An “extreme” example with tar and solid laden furnace gases is the Gas Cleaning Plant operated at SGL Carbon in Austria, were impregnated graphite electrodes are “baked” in enclosed longitudinal furnaces:

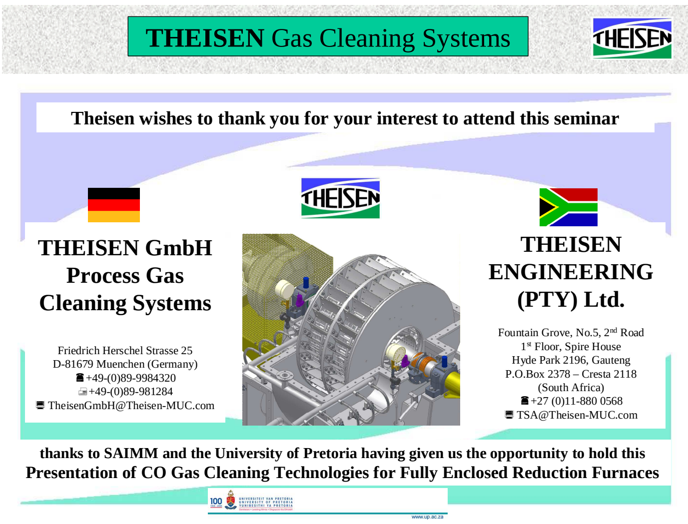

Tar in the furnace gas can become a problem in wet scrubber systems if coal is used as reductant substituting coke which is nearly free of volatiles.




When deciding for a wet scrubber system all aspects shall be considered to allow for a trouble free operation of the Gas Cleaning System without any mayor down-time due to cleaning off accretions and sticking material.

**The scrubber system shall never become the bottle-neck of the entire smelter operation !**

We hope this Seminar will assist you in your investigations for a Furnace Gas Cleaning System for your Fully Enclosed Reduction Furnace.



# HOT, DIRTY & COMBUSTIBLE - SAIMM Seminar 6 May 2009

Posted on 07 May 2009

'If it is hot, dirty and combustible, we like it', remarked Mr Rudi Gottschling towards the end of his presentation on Wednesday, 6 May.

Mr Gottschling gave a presentation on CO-gas cleaning technologies for fully enclosed reduction furnaces at a meeting of the Pretoria branch of the SAIMM.

'We enjoyed the presentation and learned a lot,' said Ms Jacqueline Barnard, process engineer and one of six delegates from SamancorCr's Middelburg Ferrochrome. In typical student fashion Mr Andre la Grange, a fourth year student at the Department of Materials Science and Metallurgical Engineering, remarked 'it was very informative but much too long.' The cocktail party, sponsored by Theisen Engineering Pty Ltd, was enjoyed by all.

The seminar was attended by more than eighty delegates - half of them students and the other half, members from industry. 'This is the most interest Industry expressed in one of our events in years!', said Mrs Sarah Havenga, secretary of the Department of Materials Science and Metallurgical Engineering, co-host of the Pretoria branch of the SAIMM.

'This clearly indicates that we are doing something right', said Mrs Joalet Steenkamp senior lecturer at the department and member of the pyrometallurgy group. 'We addressed a specific educational need and intend to build on this in future', she said.