Latest developments in dry and wet blast furnace gas cleaning technology

Most of the recent developments in blast furnace gas cleaning technology have been based on dry gas cleaning systems. Based on its proven system for dry cleaning of EAF, DRI, BOF and aluminium smelter gases, Danieli Corus has developed it for use with blast furnaces. This new system consists of a gas conditioning tower, reagent injection system and (pressurised) filter modules with low pressure pulse cleaning and is designed for a residual dust content below 5mg/Nm and for increased topgas recovery turbine (TRT) output and calorific value of the blast furnace gas.

For plants with wet blast furnace gas cleaning systems, Danieli Corus has introduced a new type of demister to replace existing ones. This type is more compact while offering a higher removal efficiency, lower investment and a higher calorific value of the blast furnace gas.

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Blast furnace gas needs to be conditioned and cleaned before it can be used as a combustion gas. Conventional gas cleaning systems consist of a gravimetric dust catcher combined with a wet second stage using a Bischoff scrubber and (axial) demister. Replacing gravimetric dust catchers with cyclones increases the dust removal efficiency in this first stage from 50% to around 85%. Since both these fractions are low in elements that are detrimental for the blast furnace process, such as zinc, this dust can be recycled in the sinter plant without further processing, illustrating a clear benefit of the cyclone over gravimetric dust catchers. The implementation of cyclone technology for the first step of dust removal is now widely accepted in our industry.

In recent years, several technologies for dry dust removal in the second stage of the blast furnace gas cleaning system have been introduced. With dry gas cleaning, a significantly reduced amount of thermal energy is removed with the water/sludge, offering benefits for power generation. With wet gas cleaning systems – either existing or new – droplet removal efficiency remains essential since moisture load on the TRT and gas turbines is detrimental to their operation and condition. Also, moisture load on the hot blast system, as they lack droplet removal, can cause substantial damage through, eg, corrosion of the checker support.

DRY GAS CLEANING

Process The Danieli Corus dry gas cleaning process has several benefits over existing and competing technologies. The dry gas cleaning process consists of four steps (three new plus the existing dust cyclone) which will be described in more detail in the following; the gas conditioning step, absorbent injection step and the dust removal step. A schematic is shown in *Figure 1*.

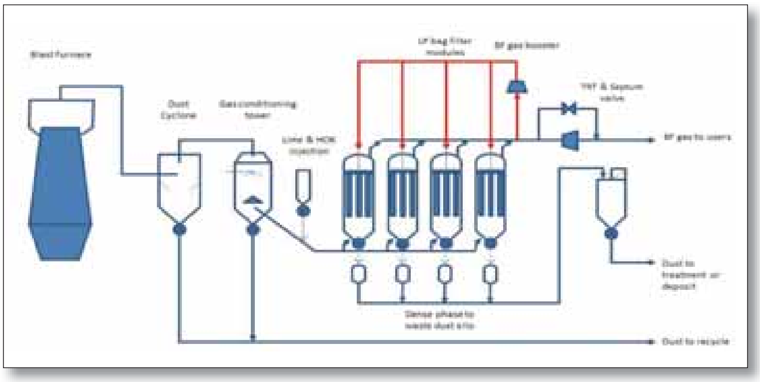

Fig 1 **Process steps**

Conditioning of the blast furnace gas Conditioning of the gas is required in case its temperature is over 250°C. Mostly this high temperature is caused by a process upset or a slip of the BF burden, therefore, the conditioning tower is only in operation during temperature excursions. The blast furnace gas enters at the top of the tower and water is injected in counter current flow (see *Figure 2*). The water is injected together with nitrogen to produce a water mist with droplets of ~150μm diameter. The residence time within the tower is such that all the droplets are fully evaporated at the outlet of the tower. The temperature of the blast gas leaving the conditioning tower is 200°C maximum.

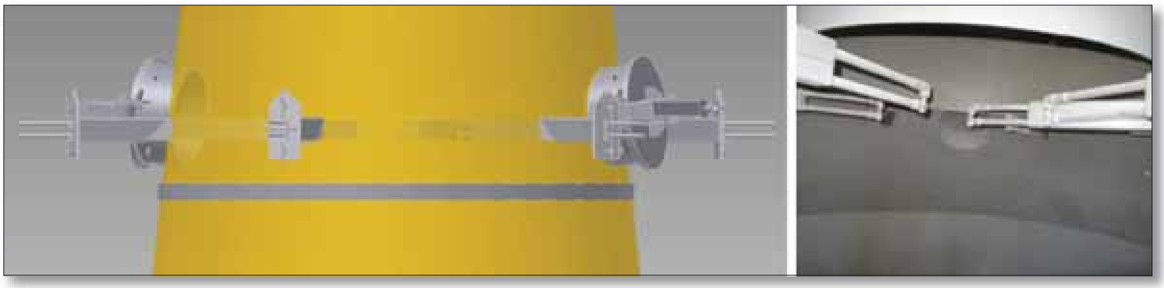

Fig 2 **Water injection in conditioning tower**

Fig 3 **Absorbent injector**

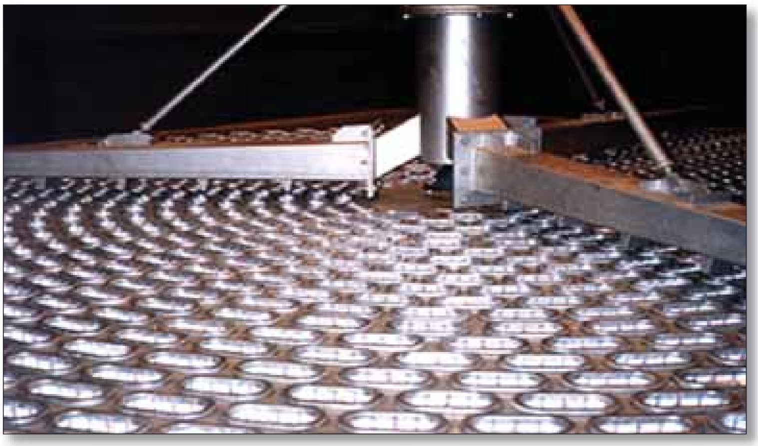

Fig 4 **Filter modules**

The 6° angle of the conical top of the conditioning tower creates a laminar gas flow which prevents droplets from touching the walls and ensures that the walls are dry and dust deposits are minimal. This technology of conditioning the gas is a proven Danieli Corus design incorporated in gas treatment systems for the aluminium industry. The spray nozzles used to atomise the water are configured such that the whole circumference of the inlet duct is covered. The construction material of the spray lances is Hastelloy in order to withstand the harsh conditions of the blast furnace gas. The turndown ratio of the nozzle is 1:6 without compromising the droplet diameter. Furthermore the nozzles can be switched on independently allowing an even larger turndown ratio. The lances can be easily removed from the outside of the tower. A platform and inspection hatches are provided.

Absorbent injection Depending on the raw materials and the use of PCI within the BF it could be necessary to inject absorbent into the BF gas in order to remove gaseous pollutants. The injection of the absorbent is done after the conditioning tower and before the dust removal step (see *Figure 3*). For the removal of sour components, such as hydrochloric acid, the injection of alkali is foreseen whereas the removal of hydrocarbons is achieved with the injection of activated carbon/lignite. The distribution of the absorbent in the gas stream is of the highest importance – the better the distribution, the better the contact with the gas. The best removal efficiency is achieved when the absorbent particles are fluidised in the gas stream. In that way the complete surface area of the particles is available for the reaction with the pollutant.

Once a particle is captured on the filter bag it can still scrub the gas which is passing by, but only a small percentage of the surface area will be available. This is why this injector design is so effective. The absorbent particles are brought into the gas stream radially and cover the whole circumference of the gas duct. This so-called VRI (Vertical Radial Injector) is a standard piece of equipment within the gas cleaning plants that Danieli

	Amount
Higher temperature BF gas	4,000kW
Dilution due to moisture	80kW
Evaporation enthalpy droplets	400kW
Lower power cold blast blower	120kW
Additional output TRT	4,000kW
Water saving	~225m³/h
Saving on water chemicals (2ppm @ 1,200m³/h @ €10/kg)	–
Extra absorbent	100kg/h

Table 1 **Savings with dry gas cleaning**

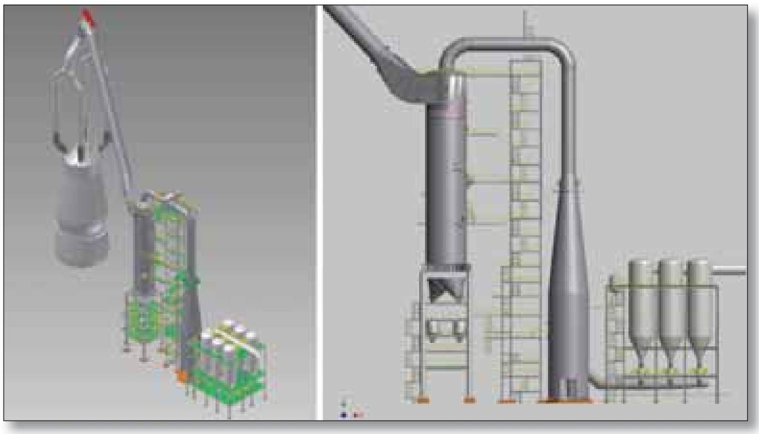

Fig 5 **Small plot plan for dry gas cleaning**

Corus constructs for the aluminium industry. A part of the absorbent (and dust) is recycled to the VRI in order to achieve a lower external stoichiometry and therefore the process requires less absorbent and creates less waste than it would otherwise.

Filter modules for dust removal The conditioned blast furnace gas and the injected absorbent are directed to a number of filter modules in which filter bags take care of the separation of the dust and the clean gas (see *Figure 4*). The configuration of the filter bags is in a circular array to fit as many filter bags as possible in the round pressure vessels. This allows more square meters of filter cloth per module. Due to use of the low pressure (LP) pulse cleaning system, the filter bags can be made longer than standard high pressure (HP) pulse cleaning designs. These longer filter bags also contribute to the surface area within each module, therefore the Danieli Corus design requires much fewer filter modules than competing systems. Each module is equipped with an inlet and outlet goggle valve so that maintenance on the module can be executed during production. The N-1 design allows one module to be taken out of operation for maintenance/bag change without influencing the gas quality or blast furnace operation.

Each module is equipped with a nitrogen flush so that the modules can be opened and vented safely before entering.

Low pressure pulse cleaning system The filter bags within the filter modules need to be cleaned frequently to remove the layer of dust which was deposited over time. With the LP system a large volume of gas is brought into the filter bag which is inflated, causing the dust on the outside of the bags to be ejected. The gas used for the pulsing is clean blast furnace gas, which is boosted in pressure by ~0.8 bar. The use of blast furnace gas does not cause the dilution of the existing blast furnace gas and is therefore not detrimental to the gas quality, unlike in competing technologies. The distribution of the BF pulse gas is done with a slowly rotating device which has three arms on which the gas injection nozzles are placed. The use of these arms allows easy access to the filter bags. If a broken bag is under an arm the arm can be pushed away easily and removal of pulse pipes is therefore not required for this design.

DRY GAS CLEANING: BENEFITS

Dry gas gleaning introduces the benefits of reduced CO_2 emissions due to the higher temperature and quality of blast furnace gas as well as the elimination of water consumption and water chemicals. For a 600,000Nm³/h blast furnace gas cleaning installation the situation is as shown in *Table 1*.

It can be expected that the return on investment for the dry gas cleaning plant is around 1.5 years.

In addition to this benefit, the system offers the clear advantage of a strongly reduced footprint, since the requirement for an effluent treatment plant is eliminated. The area required for a conditioning tower, bag filter modules and storage silos is around 500m², whereas the combined area for a wet gas scrubbing system (two settlers, cooling towers, sludge dewatering, wet scrubber, demister, pump buildings) is around 10,000m² (see *Figure 5*).

NEW MIST ELIMINATOR

In wet gas cleaning systems, a mist eliminator is required downstream of the annular gap scrubber or venturi scrubber to remove the droplet carry-over. The mist eliminator currently in use at most blast furnaces is an axial cyclone type whereby the gas and droplets are brought into a spinning motion with a number of guide vanes, resulting in separation of the droplets from the blast furnace gas. Due to the high pressure drop of the annular gap elements, a large amount of fine droplets are produced. ▷

Droplet concentration conventional mist eliminator	mg/Nm^3	5,000
Droplet concentration new mist eliminator	mg/Nm^3	100
Flow of blast furnace gas	Nm^3/h	600,000
Evaporation enthalpy	kJ/kg	2,500
Net gain thermal energy	kJ/s = kW	2,042
Blast furnace availability	days/year	355
Net gain thermal energy annual	MWh	17,395
CONVERTING TO ELECTRICITY		
Typical electrical efficiency	%	37
Net gain electrical power	MWh/y	6,436

Table 2 **Key process data for new mist eliminator system**

Fig 6 **New mist eliminator developed by Danieli Corus and Sulzer**

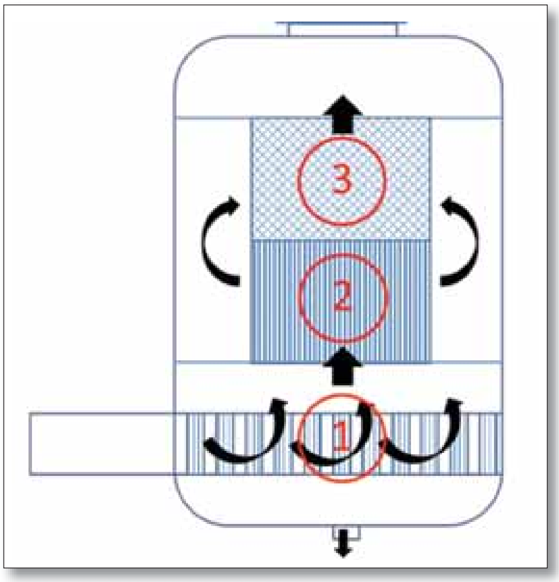

Fig 7 **Three process steps**

It is estimated that the free moisture content could be as high as 250g/Nm^3. This, in respect of the existing type of mist eliminator, does quite well taking into account that the outlet free moisture content is in the range of 4-5gr/Nm^3; an efficiency of 99.6%.

However, the remaining droplets in the cleaned blast furnace gas will be carried towards the stoves, the TRT and the burners of the boilers. The intense contact of dust and water in the annular gap scrubber creates droplets that also contain dust. Within the stoves some of the droplets may collect at the bottom of the burner, creating corrosion and drain issues. When fired in the stoves the droplets evaporate resulting in heat loss/lower stove temperatures. The dust within the droplets may cause dust emission problems during the heating cycle or create dust deposits in the checker work. At the TRT, the dust containing droplets may cause deposits on the turbine blades causing unbalance and blade erosion, resulting in TRT outage and more frequent maintenance. The droplets that are drained through siphons from the blast furnace gas distribution system need to be collected and treated due to the chemical composition of the water. Therefore, removal of droplets from the blast furnace gas is essential for proper operation of the stoves, TRT and boilers.

Within the power and oil & gas industries, a free moisture content of 5g/Nm^3 is considered too high and so in these industries a more efficient mist eliminator has been developed. This more efficient mist eliminator is capable of achieving a free moisture content concentration of < 0.1g/Nm^3. Danieli Corus has teamed up with Sulzer, a large OEM of separation systems for the oil & gas industry to develop a mist eliminator suitable for the removal of droplets from blast furnace gas after an annular gap scrubber (see *Figure 6*).

As a result of this cooperation there is now a patented mist eliminator design that is capable of achieving free moisture concentrations in clean blast furnace gas of <0.1gr/Nm^3 which has a removal efficiency of 99.96%. The following features can be distinguished:

- Smaller footprint
- Similar pressure drop
- Similar CAPEX
- >99.9% efficiency
- Expected ROI <1 year

The newly developed mist eliminator has a three-step approach for the removal of the droplets from the blast furnace (see *Figure 7*). The design is based on three process steps:

1. Shell Schoepentoeter™ at the inlet
2. Sulzer Mellachevron™ mist eliminator
3. Sulzer Knitmesh™ & Mellachevron™

The first step of the design is the diverter inlet, based on the Shell Schoepentoeter™ (see *Figure 8*) which feeds and distributes the blast furnace gas into the column while removing a large part of the coarse droplets.

The droplets from all steps are collected at the bottom of the vessel and returned to the wet scrubber. The second step consists of a vane type chevron mist eliminator, the Sulzer Mellachevron™ (see *Figure 9*), which consists of vertical positioned vanes that separate droplets using the inertia of the droplets.

The finest droplets which pass the chevron mist eliminator need to be coagulated before they can be separated: the third step of the removal process. This coagulation is achieved by the Sulzer Knitmesh™ (see *Figure 10*) which is operated in a flooded mode, creating a horizontal droplet flow. These exiting larger droplets are collected in a Mellachevron™ positioned after the Knitmesh™.

All liquid collected at the first and second chevron mist eliminators is piped towards the bottom of the vessel and evacuated to the wet scrubber.

Based on a large size blast furnace with a gas production of 600,000Nm^3/h, the financial benefits are significant. The heat associated with the evaporation alone represents 17,395MWh in thermal heat loss. It is estimated that the cost for a newly developed demister is slightly higher than for the current axial design and that the ROI for this new type of mist eliminator is less than one year. Key process data are shown in *Table 2*.

Currently a pilot mist eliminator is being developed to assess the design and operating criteria. Special attention is given to the built up and cleanability of dust in the Knitmesh™ section of the new mist eliminator.

CONCLUSIONS

- Blast furnace gas cleaning based on cyclone technology is a proven solution for higher efficiency dust removal in first process step
- Dry gas cleaning technology for the second process step produces clean gas with a higher calorific value for higher TRT output and substantial benefits in power generation
- An additional benefit is the elimination of sludges
- The new mist eliminator design has a smaller footprint than the traditional axial type while operating at a similar pressure drop. **MS**

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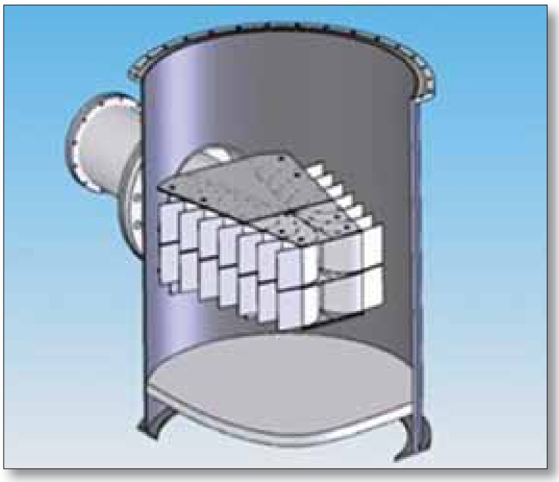

Fig 8 Inlet design based on Shell Schoepentoeter™

Fig 9 Sulzer Mellachevron™

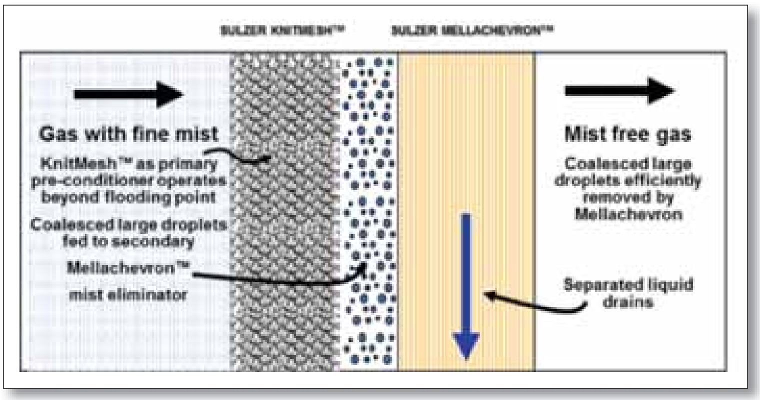

Fig 10 Sulzer Knitmesh™