Southern African Pyrometallurgy 2011, Edited by R.T. Jones & P. den Hoed,
Southern African Institute of Mining and Metallurgy, Johannesburg, 6–9 March 2011

Co-generation: A challenge for furnace off-gas cleaning systems

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Keywords: co-generation, furnace CO-gas cleaning, disintegrator scrubber, Theisen

Abstract – In a closed, electric, reduction furnace, no oxygen enters the furnace from the surrounding environment. The off-gases are thus not "burnt" and therefore contain a considerable amount of CO and H_2. Traditionally these gases have been captured and burnt in a flare stack. Recent developments have led operators of such furnaces to revise this strategy and to consider utilising these gases as a fuel for gas-fired generator sets to produce electricity, thus becoming more energy efficient.

On 31 March 2010 the new emission standards, in accordance with the Air Quality Act, Act 39 of 2004, were promulgated. The *minimum* emission standards according to the act require that the particulate matter emissions from the primary fume-capture systems on closed furnaces for "new plants" in ferroalloy and calcium carbide production not exceed 50 mg/Nm^3 and 25 mg/Nm^3, respectively.

By implementing co-generation, the producer automatically complies with the new environmental emission standards for an off-gas. As much as 30% of the electrical power cost, which is set to double in the near future, can be saved by partly generating one's own electrical power.

In December 2010, the National Treasury published a discussion paper for public comment, one entitled "Reducing greenhouse gas emissions: The carbon tax option". Irrespective of how the tax is finally implemented, it will result in an increase of production costs in affected industries.

This paper focuses on the characteristics of a furnace-off-gas cleaning system for closed ferroalloy smelters, characteristics that meet the requirements of both reducing solid-matter emissions and operating a safe and reliable gas plant.

INTRODUCTION

In a good, sealed, electric, reduction furnace no oxygen enters the furnace and the furnace off-gas system from the surrounding environment. The off-gases are thus not "burnt" and therefore contain CO and H_2. The volume and composition of the gas depends on variables such as the feed material, their pre-treatment methods, and the type and construction of the smelter. The solid matter content in the gas off-take of a furnace varies with the design and dimensions of the furnace, electrode arrangement, material feed details, and operational conditions.

In closed AC and DC furnaces wet scrubber systems are mostly used to cool and clean the gas extracted from the furnace. Currently some of the CO-rich off-gas is used for sintering and pre-heating, but the majority of it is flared to convert the poisonous CO gas to CO_2. The percentage of gas in the total gas volume created in the smelter currently being used for heating purposes is negligible compared with the available potential of energy recovery. Recent developments have led operators of such furnaces to revise this strategy and to consider utilising these gases as a source of fuel for producing electric energy, thus becoming more energy efficient by operating a so-called co-generation installation.

DEFINITION OF CO-GENERATION (CoGen)

Co-generation is a term loosely used to describe a variety of applications. Typical uses include the generation of electricity in a power station and then using the thermal heat for heating of buildings. It is also widely used where various thermodynamic processes are combined to become more energy efficient.

For the purpose of this discussion co-generation is the use of CO- and H_2-rich off-gases from a closed electric-arc furnace to produce electricity by internal combustion engines.

WHY CO-GENERATION?

Environmental Emissions

On 31 March 2010 the new emission standards, in accordance with the Air Quality Act, Act 39 of 2004, were promulgated.[1] The emission standards are classified into two groups, *viz*., "existing plant" and "new plant" (see Table I). New installations being built must immediately comply with the new-plant standard. Existing plants must comply with the existing-plant standard within five years and to the new-plant standard within ten years.

The new emission standards are generally much stricter than old standard they replaced. Many, if not most, of the existing installations do not comply with the new standards. This means that producers must either replace their existing gas-cleaning plant (GCP) or add additional equipment to the back-end of the existing GCP to comply with the new standards.

Emission standards in other countries require lower solid-matter emission limits than applicable in South Africa. In the German "TA-Luft", which came into force in 2002, solid-matter emissions not exceeding 20 mg/Nm^3 is the common *minimum* standard.[2] Much more restrictive figures are valid for specific production processes,[2] and local authorities in Germany mostly require solid-matter emissions not to exceed 10 mg/Nm^3 for foundries or even 5 mg/Nm^3 or less for certain industries.

Table I: A summary of listed activities and associated minimum emission standards identified in terms of Section 21 of the National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004). Subcategory 4.9: Ferro-alloy production[1]

Description:	Production of alloys of iron with chromium, manganese, silicon or vanadium, the separation of titanium slag from iron-containing minerals using heat		
Application	All installations		
Substance or mixture of substances		**Plant status**	**mg/Nm³ under normal conditions of 273 Kelvin and 101.3 kPa**
Common name	**Chemical symbol**		
Sulphur dioxide	SO_2	New	500
		Existing	500
Oxides of nitrogen	NO_x expressed as NO_2	New	400
		Existing	750
Particulate matter from primary capture system, open and semi-closed furnaces			
Particulate matter	N/A	New	30
		Existing	100
Particulate matter from primary capture system, closed furnaces			
Particulate matter	N/A	New	50
		Existing	100
Particulate matter from secondary capture system, all furnaces			
Particulate matter	N/A	New	50
		Existing	100

The gas quality requirements for co-generation far exceed the emission standards of even the more stringent new-plant standard in South Africa, valid for closed ferroalloy smelters:1

New-plant emission standard ..... < 50 mg/Nm³
Gas Motor Standard .... < 15 mg/Nm³
Gas Turbine Standard .... < 5 mg/Nm³

The preceding solid-matter concentrations for gas motors and gas turbines are rule-of-thumb figures only, depending on the equipment supplier's fuel-gas specification.

Whilst being forced to utilise capital to comply with legislation, one can nevertheless use the opportunity to install equipment that will condition the gas to be suitable for co-generation.

Cost of electricity

In February 2010 Eskom received approval from NERSA to increase the national electricity tariff in South Africa by a nominal 25% for three years in a row.[3] This effectively doubles the cost for consumers over a three-year period. Such a cost increase has a significant impact on the producers of ferroalloys, where electricity consumption is one of the major cost drivers.

A closed, electric, reduction furnace will typically have an off-gas composition of 60–90% CO and 5–30% H_2 by volume (v/v). This gas, after having been suitably conditioned, can be used as a fuel source in internal combustion engines, which in turn drive alternators to produce electrical power. In this way as much as 25% (or even more) of the power requirements of a furnace can be self generated. This own generation can either be utilised to reduce the power cost or it can be used for additional production which was previously not possible owing to a capped power allocation.

Carbon tax

In December 2010 the National Treasury published a discussion paper for public comment, one entitled "Reducing greenhouse gas emissions: The carbon tax option". Submissions of comments closed on 28 February 2011.[4] Although it is only a discussion paper for public comment at this stage, it does give some indication of the current thinking by the government and what to expect. A few key issues are highlighted.

- The question of green house gases (GHG) and their impact on climate is accepted and not subject to debate.
- A form of taxation on the use of carbon fuels and the associated release of CO_2 is imminent. Factors supporting this opinion are—
    - The South Africa government's announcement that it was committed to decreasing local GHG emissions by 34% by 2020 and by 42% by 2025 (South Africa is not bound by the Kyoto Protocol).
    - Expectations of an announcement by South Africa at the 17th UN Climate Change Conference to be hosted in Durban, South Africa, in December 2011
    - The electricity levy implemented in September 2009
    - The excise duty to be levied on new passenger vehicles from September 2010
- A carbon tax is preferred to an emissions trading scheme
- Although a tax based on actual measured emissions is preferred, a proxy tax, based on the producer of carbon fuels (upstream) or the consumer of carbon fuels (downstream) is much easier to implement
- The tax will be phased in gradually
- R70 to R200 per tonne of CO_2 equivalent is being suggested (20.0 c/kWh)[5]
- Questions of international competitiveness and the impact on low-income households must be addressed

Irrespective of how the tax is finally implemented, it will find its way into the price of electricity, with the consumer bearing the final cost. Indications are that this could result in another 20 c/kWh on top of the existing electricity tariff.

Clean Development Mechanism (CDM)
According to the Kyoto Protocol a CoGen project implemented in South Africa could qualify as "Clean Development Mechanism" (CDM).[6] This is possible as South Africa is not an Annex 1 country (mainly European and industrialised countries). Under the protocol, such a project could then earn Certified Emission Reduction (CER) credits for each tonne of CO_2 equivalent saleable to Annex 1 countries.

The result
Thus, by implementing co-generation for electric-power generation, a ferroalloy producer automatically complies with the new environmental emission standards for off-gas. Also, up to 25% of the cost of electrical power, which is set to double in the near future, can be saved by the producer's partly generating its own electrical power. Furthermore, the carbon credits earned result in a positive inflow of funds, making the project more economical by shortening the payback period and improving the IRR.

ENERGY RECOVERY POTENTIAL WITH CO-GENERATION

Theoretical Considerations
Smelting is a very energy-intensive process and a number of by-products are produced. The primary by-product of interest is the carbon monoxide (CO) rich off-gas. It also contains significant amounts of hydrogen (H_2), depending on the furnace operating conditions. The potential use of the off-gas as a primary fuel source in a power-generation facility to reduce dependency on the national electric grid is becoming more and more important.

The volume and composition of the off-gas generated by a closed furnace depend on the feed material, the furnace-feed pre-treatment methods (e.g., pre-reduced feed generates less gas than other feed materials), the design of the furnace, furnace controls, and the metallurgical condition of the process. Gas volumes generated by closed FeCr furnaces have been reported to be 220–250 $Nm^3/h/MW$, or 650–750 Nm^3/t FeCr, consisting of 75–90 % CO, 2–15% H_2, 2–10% CO_2 and 2–7% N_2.[7] The solid content of the uncleaned furnace off-gas is reported to be typically 35–45 g/Nm^3. These figures can vary, depending on the operational conditions and the production technology employed.

Consider CoGen. We calculate conditions from theory using the nominal design figures for a FeCr DC-arc furnace recently commissioned at Middelburg (see Table II).

Details of the process and the equipment used in this FeCr smelter plant, which was commissioned in 2009 and is being operated successfully by Samancor Chrome at a level of 60 MW, were presented at INFACON XII in Helsinki.[8, 9] The DC furnace operated at a load of 60 MW generates roughly 17,000 Nm^3/h off-gas containing (on average) 63% CO, 3% CO_2, 30% H_2 and 4% N_2. The "burning energy", expressed as the lower heat value (LHV) of this combustible gas, is 3.11 kWh/Nm^3 (under dry conditions), which means that 52.8 MW is available to be supplied as "fuel input" to a gas engine generator set. GE Jenbacher, one of the suppliers of such equipment, indicates an electrical efficiency of at least 35% for such a type of fuel gas.[10] Hence, *about 18.5 MW can be generated by using the off-gas from the 60-MW furnace, which means that approximately 30% of the (electrical) energy supplied to the furnace can be recovered if the total furnace-gas volume generated is used as a fuel source for a gas engine generator set.* In addition the thermal heat energy of the gas engine's exhaust gas, at approximately 500°C, is also available for recovery, to be used in steam generation, material drying, for pre-heating, etc.

Table II: Typical furnace off-gas data of a "modern" DC-arc furnace for the production of FeCr

Specific furnace off-gas volume per MW furnace load	280 Nm^3/h
Crude gas temperature at furnace off-take	1600°C
Crude-gas dust content	150 g/Nm^3
Furnace off-gas analysis:	
CO	58–64% v/v
CO_2	2–6% v/v
H_2	26–34% v/v
N_2	0–5% v/v
O_2	<< 1% v/v

The combustion of the 17,000 Nm^3/h furnace gas generates about 22 t/h CO_2 emissions (approximately 160,000 t/a CO_2), an output that would draw a significant carbon tax such as the one currently under discussion.

The savings in total production costs by providing co-generation for electric power generation (only) can be roughly calculated for each smelter by using the above estimates and the individual annual FeCr production figures with the related furnace off-gas volume and composition generated during the process.

Practical considerations

The gas formed as result of the reduction process in a closed furnace has to be extracted from the furnace by keeping the gas pressure under the furnace roof nearly constant. A highly sensitive furnace pressure control is required to avoid unacceptably pressures in the furnace, which lead to CO gas escaping through any gaps in the furnace and associated plant equipment. On the other hand, unacceptably low pressures in the furnace create the risk of ambient air being sucked into the furnace gas system, which runs the risk of explosions, especially during the start-up and shut-down of the smelting process. In other words,

➔ **Requirement No. 1: Obtain reliable control of furnace pressure**

The off-gas generated in the furnace must be cleaned in order to comply with the solid-matter emission levels in the environmental legislation. Wet scrubber systems are used in closed reduction furnaces in the ferroalloy industry. Apart from cleaning the gas, these also cool down the gas, but for practical reasons the latent heat of the gas is not utilized. Generally there are different types of "low pressure" and "high pressure" scrubber:[11]

- Venturi scrubber
- Jet scrubber
- Disintegrator scrubber

The specific consumption of scrubbing water varies with scrubber type. The gas cleaning efficiency varies scrubber type and the entire gas cleaning system used. Ultimately the scrubber system must comply with the "minimum emission standard" mentioned earlier—i.e., the solid-matter emissions of the off-gas of "new" closed ferroalloy furnaces must not exceed 50 mg/Nm^3. In other words,

> ➔ **Requirement No. 2: Comply with the emission standard: the solid-matter concentration should not exceed 50 mg/Nm^3**

The furnace off-gas to be utilized for the generation of power by means of combustion motors coupled with generators must meet the supplier's specifications for Co-Gen equipment. GE Jenbacher (Austria) is considered to be the preferable supplier for Co-Gen equipment by the bigger part of the South African ferroalloy industry. Their quality requirements for the fuel gas are much stricter than the legal emission requirements. This does not only refer to the solid-matter content of the gas, but also to other engine-specific requirements, as shown in their specifications (see Table III).[12]

Beside other quality requirements the most important requirement to be highlighted is that the "dust particle content" may not exceed 50 mg/10 kWh. This is *not* equal to the solid-matter concentration 50 mg/Nm^3, because Jenbacher's restriction refers to the LHV of the gas supplied to the engine. Taking this into consideration, we find that the solid-matter particle concentration must lie below 15 mg/Nm^3 (to be re-calculated for each individual gas composition). In other words,

> ➔ **Requirement No. 3: Comply with the specification of the gas-engine supplier': the solid-matter concentration should not exceed 5 mg/Nm^3**

For all three units—i.e., the smelter, the associated furnace-gas cleaning plant, and the Co-Gen equipment—consideration should be given to reliability, availability, and safe operation without any adverse or hazardous impact of one of the "packages" on another. In other words,

> ➔ **Requirement No. 4: Comply with the operational requirements of the entire smelter-plant complex**

The four requirements listed should be incorporated into the equipment and control of furnace off-gas cleaning.

Table III: Extract from Jenbacher Technical Instruction No. 1000-0302, Fuel-gas quality—Special gases

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)	

2) The absolute quantity of elements which have entered the engine is decisive when analysing the trace element content. In order to compare different gases, the trace element concentration is compared to a certain level of fuel gas energy and to natural gas (methane, Hu approx. 10 kWh/Nm^3).

3) The micro filter used as standard by GE Jenbacher boasts a filtration efficiency of approx. 99% for particles > 3 µm and is not designed to be a work filter.
The permissible dust or particle content specified for > 3 µm is only indicative of the filter service life if it has not been additionally reduced by moisture.
If the filter service life as stated in the maintenance plan is not achieved or the filter service life is found to be unacceptable or the operation of the gas pressure control system is compromised, measures must be taken by the customer to improve the situation.

THE DISINTEGRATOR GAS-CLEANING SYSTEM

It is reported that the gas-cleaning efficiency of ejector-venturi scrubbers allows only for a residual dust concentration of 50–100 mg/Nm^3 in the cleaned furnace gas. The dust remaining in the gas is very fine. Using a venturi scrubber to remove a fraction finer than 1 µm from the gas is very difficult. Only by filtering the gas with an additional sintered-plate filter after the scrubber can one achieve a residual dust level of 1 mg/Nm^3.[11] Attention to cleaning the off-gas from the 60-MW DC furnace at Samancor Chrome faced similar considerations, a comparison of the performances of the venture scrubber system and the disintegrator scrubbing system:[8]

The 60 MW DC furnace at Samancor Chrome was fitted with a Disintegrator Scrubber, for the following reasons:

- A disintegrator scrubber plant minimizes the explosion hazard caused by the presence of CO gas. In contrast to this, the hazard posed by a conventional scrubber plant in this regard is severe, as previous experience has proved. A conventional scrubber operates with a high negative pressure between venturies and fans, which increases the risk of air ingress and the resulting explosion damage. A disintegrator scrubber system operates with a very low negative pressure.
- The gas cleaning efficiency of a disintegrator scrubber is better than that of a conventional scrubbing system. Although the design specification for a typical disintegrator scrubber is 20 mg/Nm3, it in practice achieves particle levels as low as 10 mg/Nm3 in the cleaned off gas. In contrast to this, the vendor guarantee in a conventional venturi scrubber is only 30 mg/Nm^3, and based on previous experience it is doubtful whether better than this will be achieved.

The use of venturi scrubbers to clean the furnace gases from closed ferroalloy furnaces is wide spread in South Africa. Under the old emission limits of < 100 mg/Nm^3, the technology met its duties most of the times. Multi-stage, high pressure venturi scrubbers will eventually meet the new emissions standards of < 50 mg/Nm^3, but it may well be very difficult to achieve less than 15 mg/Nm^3 solid-matter content in the cleaned CO-gas required to operate a gas engine for co-generation. Some companies operating closed furnaces are considering co-generation installations and are being forced to think about how to comply with the requirements.

To enable a client to evaluate the use of furnace gas as a fuel in an internal combustion machine for electricity generation, one needs first to conduct tests on the present "off-gas". Independent of the requirement to achieve the new emission standards with existing or upgraded installations are the quality standards for the fuel gas of a gas engine, which are stricter; the requirement for additional equipment to purify the CO gas further should be investigated.

As mentioned, designs for disintegrator gas-cleaning systems have for many decades achieved an efficiency as now required for the described purposes. The systems are successfully operated world wide in a variety of applications, especially those of cleaning CO-rich furnace gases.[11] In South Africa, disintegrator scrubbers are in use at Richards Bay Minerals (ilmenite smelters), Exxaro Namakwa Sands (ilmenite smelters), Exxaro KZN Sands (ilmenite smelters), SACC (South African Calcium Carbide—carbide furnace), and Samancor Middelburg Ferrochrome (FeCr Smelter). All these *existing* installations have been designed not to exceed 30 mg/Nm^3 (indeed, they maintain 20 mg/Nm^3) solid-matter concentration in the cleaned gas, even though the permissible emission levels at the time of commissioning were much higher.

The principle of a disintegrator-based gas-cleaning plant (Theisen-GCP)
A disintegrator GCP comprises the following (see Figure 1):[11]

- The *quench cooler* W10, for rapid gas cooling and the elimination of coarse solid-matter particles

- The *safety valve* B11, operating as overpressure valve to protect the GCP from furnace pressure peaks which cannot be compensated by the furnace pressure control installation
- The *rotary hood water seals* B12 and B13, used as isolation valves to switch over from "clean-gas operation" via the GCP and "emergency stack operation" via the *emergency flare stack* A 12
- The counter-current flow *cooling and washing tower* W14, for further gas cooling and pre-cleaning of the furnace gas
- The *disintegrator gas scrubber* V15, for final gas cleaning and also for acting as wet ID fan to compensate for all internal pressure losses
- The *water droplet separator* F16, to separate the cleaned furnace gas from the solid-laden scrubbing water
- The water sealed *overflow valves* B17 and B18, also acting as non-return valves
- The cleaned gas can either be released into the atmosphere via the *clean gas flare stack* A17 or be made available for any consumer system
- The main gas components are monitored online by the use of *clean-gas analysis equipment* X19. The monitored components—CO, CO_2, H_2 and O_2—provide information about the conditions in the furnace and the entire furnace off-gas system. Furthermore the fuel-gas quality is important for the operation and control of an internal combustion engine supplied with the cleaned furnace gas

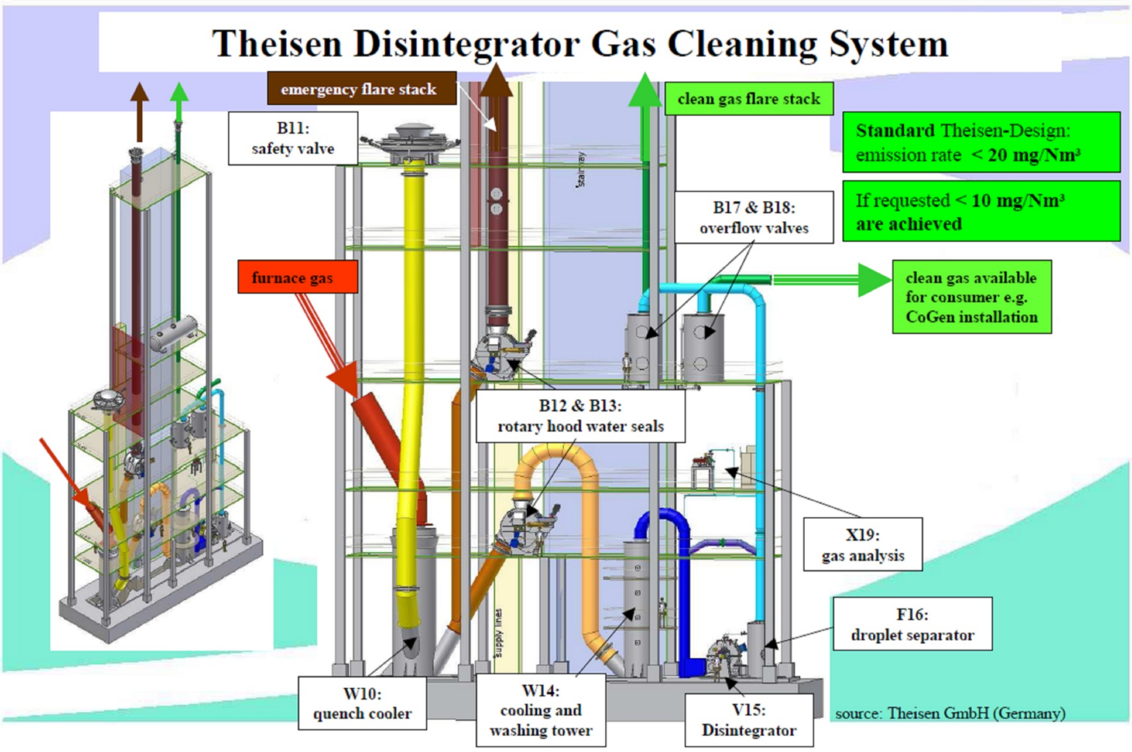

Figure 1: Typical design of a disintegrator gas-cleaning system for closed reduction furnaces

Recent emission test results

Namakwa Sands (Exxaro Sands)—operating Theisen disintegrator gas-cleaning systems since 1994 (a second unit was installed in 1998)—recently contacted a local organisation to test the off-gases from both their ilmenite smelters at the Saldanha plant.[14] The emission tests, which included both physical and chemical characteristics, were required to enable the client to evaluate the use of furnace gas as a fuel in an internal combustion engine for electricity generation. The tests, conducted over the period 20–30 September 2010, used a combination of US EPA reference-isokinetic test methods and other techniques to examine the clean gas stacks from furnaces 1 and 2. The emission flow rates recorded at both furnace stacks were consistent during all sampling runs, which were conducted with the smelters operating under normal conditions. The most important, average results recorded from the tests are presented in Table IV.[14]

The following account summarizes the main conclusions drawn from the assessment:

- Both of the stacks recorded similar average CO and CO_2 concentrations of approximately 78% and 1%, respectively
- Maximum dry standard particulate concentrations of 3 mg/dsm^3 and 1.6 mg/dsm^3 were recorded at Furnace 1 and 2 respectively
- Halides, halogens, sulphur dioxide, prussic acid and total reduced sulphur compounds at both of the furnace stacks were not detected
- The naphthalene concentrations of 0.13 mg/dsm^3 and 0.06 mg/dsm^3 from the two stacks were the highest of all PAH compounds detected
- Volatile organic compounds (VOCs) were determined by means of canister sampling. Most of the VOCs targeted were below the laboratory detection limit (< 1mg/m^3)

The test results from the GCPs installed at Namakwa Sands demonstrated that emissions complied with the new plant emission standards as set out in the Air Quality Act *and* complied with the fuel-gas quality required by internal combustion engine suppliers.

Table IV: Particulate levels in furnace off-gas in the stacks, Namakwa Sands

Determinand (Furnace 1)	**US EPA M8**	**US EPA M26A**	**US EPA M0010**
Stack temperature (°C)	31	29	30
Dry standard particulate concentration [mg/Nm^3)	3,0	<0.4	<1.4

Determinand (Furnace 2)	**US EPA M8**	**US EPA M26A**	**US EPA M0010**
Stack temperature (°C)	32	34	33
Dry standard particulate concentration (mg/Nm^3)	< 1.4	< 1.3	1.6

South African Calcium Carbide (SACC) also contacted a local organisation to test the furnace gas at its Newcastle plant.[15] (The disintegrator GCP had been commissioned in 1981.) These emission tests were conducted under two different scrubber-condition scenarios:

- The dirty-scrubber scenario, where the disintegrator plant had already been in operation for a certain time and accretions on the internals could possibly have adversely affected the gas cleaning efficiency
- The clean-scrubber scenario shortly after having cleaned up the installation

The emission tests were conducted with a combination of US EPA reference-isokinetic test methods and other techniques over one-hour durations for each of the scenarios tested.

The following account summarizes the main conclusions drawn from the assessment:[16]

- The average emission flow rates recorded during the clean-scrubber scenario were approximately 10% higher than those recorded during the dirty-scrubber scenario
- The average off-gas temperature recorded during the clean-scrubber scenario was 8°C lower than recorded during the dirty-scrubber scenario
- The individual particulate (dust) concentrations ranged from 3 to 9 mg/dsm^3 between the four sampling runs, with an overall average concentration of 5.4 mg/dsm^3 being recorded
- The particle-size distributions recorded that 90% of dust particles collected on the sample filters were less than 3 μm in diameter, and all the dust particles were less than 10 μm

Although the GCP was designed and commissioned more than 30 years ago, the test results from the Theisen GCP installed at SACC demonstrated that emissions complied with the new plant emission standards set out in the Air Quality Act *and* complied with the fuel-gas quality required by internal combustion engine suppliers.

Exxaro KZN Sands[18] investigated the characteristics of the dust particles[19] removed from the off-gas of their ilmenite smelters, off-gas that is cleaned by a Theisen disintegrator GCP. The dust (slurry) is settled in a gravity separator (clarifier), returning clean water back to the plant process-water system. The thickened sludge, also known as thickener underflow, was sampled and characterized. Two samples were taken at the underflow position:

- *Sample DB533,* dust collected from the thickener underflow, in the form of slurry directly from the underflow valve
- *Sample DB543,* dust collected from the thickener underflow, in the form of wet solid that had been accumulated on the floor below the underflow valve

Of interest is the particle-size distributions of the two samples (see Figure 2), which (nearly) represent the PSDs of the solid-matter particles removed from the off-gas with the disintegrator GCP.

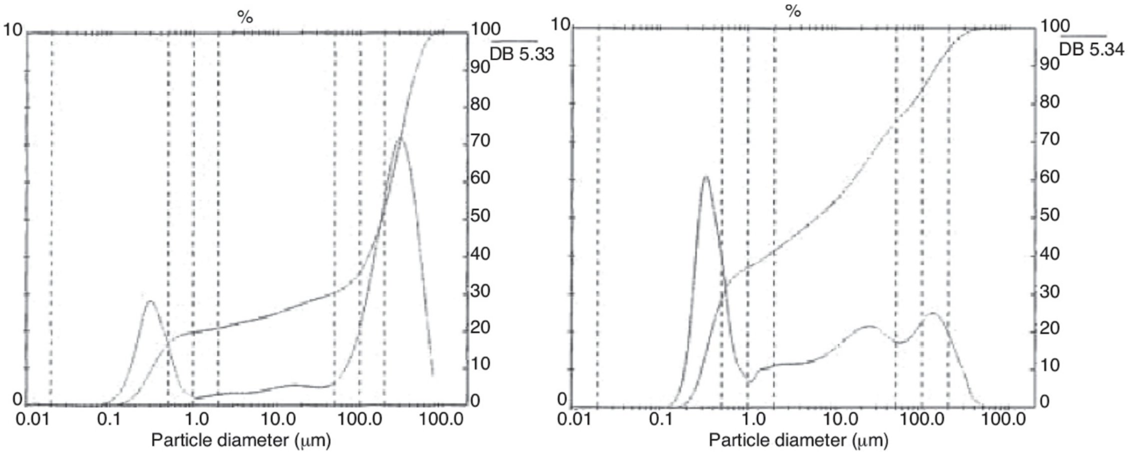

Figure 2: Particle-size distributions of the dust samples.
Both differential and cumulative analyses are shown[19]

A clear bimodal distribution is observed. For the first sample (DB533) the first peak is situated at a particle diameter of between 0.1 μm and 1μm, while the maximum of the second peak is situated at approximately 300 μm. The second sample (DB534) also has a major peak below 1 μm. For this sample approximately 37% of the material is finer than 1 μm and it is believed that the peaks situated below 1 μm are mainly due to fume condensates, whereas the larger particles are the carry over of particulate material into the off-gas system. Although these samples are not necessarily representative of the smelter dust, the particle-size analysis of the solids does demonstrate that the disintegrator GCP has captured and removed very fine material (< 0.5 μm) from the furnace gas with significant efficiency.

Other disintegrator GCPs, in operation for various applications and different types of furnaces supplied in the last decade, have been designed for a clean gas dust content < 20 mg/Nm^3 and < 10 mg/Nm^3, respectively. Emission tests conducted by the clients and relevant authorities show that installations satisfied the contractual requirements and the concept of furnace off-gas cleaning presented is a reliable and safe one.

As for CoGen all the tests conducted have shown that the disintegrator gas scrubber satisfied the related requirements without needing to provide additional filtration equipment to purify the fuel gas supplied to an internal combustion engine.

CONCLUSIONS

By installing a disintegrator-based, state-of-the-art, off-gas-cleaning system, the ferroalloy producers in South Africa can achieve stable and safe furnace and gas-plant operations. Furthermore, as we have demonstrated with the reference plants, the off-gas conditioned by the disintegrator GCP complies with the most stringent environmental legislation and is suitable for use as a fuel in a gas engine generating electrical power. Generating their own power in this way, producers will be able to offset some of their power costs, which will double because of the approved electricity tariff and anticipated carbon tax. Lastly under the CDM programme carbon credits can generate an income for a co-generation project.

ACKNOWLEDGMENTS

This paper is published by permission of Theisen GmbH (Munich, Germany) and Theisen Engineering (Pty) Ltd (Johannesburg, South Africa). We should like to thank both South African Calcium Carbide (Pty) Ltd and Exxaro Namakwa Sands for allowing us to use the results of their emission tests that were recently conducted.

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