Co-generation using calcium carbide plant furnace gas

by Mike Rycroft, editor

It is estimated that South African mineral smelters and chemical processes have the potential to generate more than 2000 MW of electricity from waste gases. In addition to reducing grid energy consumption, projects of this type qualify for clean development mechanism (CDM) funding and are becoming more and more popular as electricity prices rise.

Furnace gas is being used on an increasing scale to generate electricity at smelter and other plants around the world. Installations range from a few MW to tens of MW and even hundreds of MW. Furnace gas has traditionally been used to fire boilers producing steam which is then used to drive turbines producing electricity. The advent of piston engines which are capable of running on furnace gas has changed all this, making co-generation from furnace gas possible on much smaller plants than before.

Internal combustion engines running on natural gas have been in use for many years, and there are numerous machines of this type in use ranging from sub MW to tens of MW in size. The development of modified versions capable of running on other combustible gases in the 1990s paved the way for the use of furnace gas and other waste gases for power generation. Models are now available which can make use of a wide variety of gases from a variety of sources.

Furnace gas

Furnace gas is produced by the carbon reduction process in metal smelters and carbide production plants. This includes iron, manganese, chrome, titanium and other metals. The reduction process uses carbon in some form, such as coke or anthracite. The primary combustible constituents of the gas are carbon monoxide and hydrogen, and other components are generally nitrogen and small quantities of impurities which must be removed from the gas before combustion.

Not all furnace gases are suitable for combustion in internal combustion engines and a certain minimum calorific value and composition is necessary. Gases falling outside these limits may be used for combustion in boiler based systems. Furnace gases may also be used to run gas turbines directly, where sufficient volume of gas is produced.

The SA Calcium Carbide cogeneration project

The project is summarised in Table 1.

The recent increase in electricity tariffs is certain to effect margins for energy intensive companies. South African Calcium Carbide (SACC) opted to develop a co-generation facility using furnace gas from the production process to reduce the impact of higher tariffs and increase production capability.

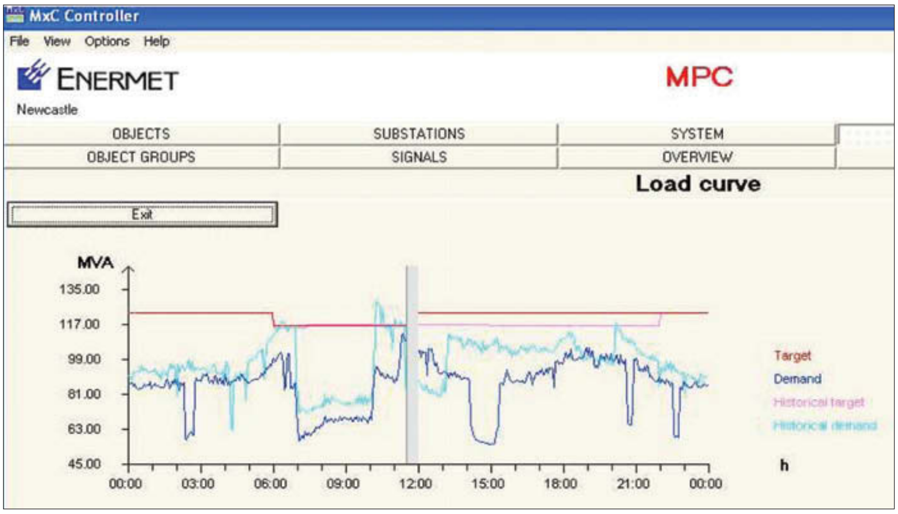

Fig. 1: SACC accounts for 50% of the demand for the Newcastle region.

Fig. 2: Furnace gas was previously flared at the site.

SACC used funding from the IDC to develop an 8 MW co-generation facility, which will serve as both a cost saving initiative and a security of supply measure, the latter being a pre-requisite to maintaining production levels, thus boosting the company's organic growth plans. As a clean development mechanism (CDM) initiative, SACC is to fund the R115-million capital cost requirement for this project over a financing period of 10 years. The principal objectives of the project are:

- Energy security: securing electrical energy for SACC's required growth programme
- Meeting Eskom's PCP requirements
- Development of a "green project" contributing carbon emission reductions

- Development of an economically feasible project for SACC and the Andina Group realising energy cost savings.

Electricity demand

Electricity costs account for the bulk of the company's production costs and without the program SACC would have seen a huge surge in production costs. SACC currently accounts for 50% of the electricity demand of the Newcastle region (Fig. 1), and expansion is restricted by limitations on maximum demand that the company can make on the grid.

Furnace gas

Carbon monoxide gas is produced by the process of manufacturing calcium carbide, and was previously flared at the site (Fig. 2).

Calcium carbide production

Calcium carbide is made by heating calcium carbonate (limestone) to produce lime and subsequently reducing this with carbon. In the first stage of the process limestone, mined in the northern cape, is heated to produce lime:

$CaCO_3 \Rightarrow CaO + CO_2$

Calcium carbide (CaC_2) is manufactured by heating the mixture of lime and carbon (in the form of anthracite) to 2000 to 2100°C in an electric arc furnace. At those temperatures, the lime is reduced by carbon to calcium carbide and carbon monoxide (CO), according to the following reaction:

$CaO + 3C \Rightarrow CaC_2 + CO$

The gas produced has the composition shown in Table 2 [1] and has an LHV of 3,3 kWh/m^3.

The plant

Fig. 3 shows a diagram of the co-generation plant.

The project displays significant technology innovation with the installation of low CV gas-fired spark ignition engines (electrical gen-sets) to provide a total of some 8 MW electrical generation capacity. Project innovation is demonstrated by the use of all exhaust gas heat in the closely located rotary aggregates drying kiln – replacing the current use of LPG. Further innovation of significance is the cleaning and conditioning of the waste gas supplied to the engines to ensure optimum generation operational conditions with no harm to the engines.

Furnace

The furnace is a closed construction of German UHDE design with a nameplate capacity of 50 MW. It is equipped with a hollow electrode system and incorporates in-house modifications and improvements as well as a Mintek designed resistance controller.

The CO was previously piped away and flared into the atmosphere. The furnace has capacity of 100 t of CaC_2 per year and is currently running at about 75% capacity, producing 75 t per year because of restrictions on the power that can be drawn from the grid. The CO currently flared will be used to produce an additional 8 MW of power which will enable the furnace to run at its maximum capacity without increasing the load on the Eskom grid. Furnace overpressure events have been engineered for through use of an innovative system provided by Theisen, the providers of the gas scrubbers. Table 3 shows the projected growth for the SACC plant.

Gas scrubber

The gas leaving the furnace contains impurities in both gaseous and particulate form, and these must be removed before the gas is fed to the engine or flared. The gas quality is a significant challenge and dust levels must be low (<15 mg/Nm^3). This is achieved by the installation of a second Theisen wet scrubber plant which is effective in reducing dust levels to <5 mg/Nm^3. Gas conditioning is a significant barrier which

PROJECT STATISTICS

The SA Calcium Carbide Furnace Waste Gas to Electricity Cogeneration CDM Project			
Type of Project:	Calcium Carbide Furnace Waste Gas Utilisation in reciprocating Internal Combustion Engines		
Project Commissioning Date:	December 2012		
Location:	Newcastle, Kwazulu-Natal, South Africa		
Owner:	SA Calcium Carbide - Andina Group		
Representative:	Mr Roberto Carmona		
Project Managers:	GreenEng (Pty) Ltd / SLR Consulting (Pty) Ltd		
Engineers:	SA Calcium Carbide Environmental & Process Solutions (EPS) B&A Projects GLA Systems Draftline		
Technology Providers: ➢ **Gas Engine Gen-Sets** ➢ **Theisen Engineering**	 GE-Jenbacher (Austria) Scrubber and pressure relief system (Germany)		
Contractors:	Adrian Holtak Construction ROC Global NNC Civils ICON WJ Coetzee (Electrical)		
CDM Registration:	Tuv Nord (Validators) SLR-GreenEng CDM Africa		
Project Status:	Fully Operational from March 2013.		
Project Life:	Est. 20 years		
CARBON FINANCE			
Carbon Reduction Project Type:	Clean Development Mechanism (CDM) Project		
Carbon Advisors:	SLR-GreenEng (Pty) Ltd		
Est. CERs (10 years):	350 000 CO_2eq		
Est. CERs per annum:	35 000 tons CO_2eq		
CDM Methodology:	AMS-III.Q.		
CDM Registration Status:	Submitted for final registration in December 2012 to the United Nations Framework Convention on Climate Change (UNFCCC)		
ENGINEERING			
Installed Capacity	6 060kW to 7 896kW		
Annual Electricity Generation	41,5 to 48,7 million kWh		
FINANCIALS			
Project Financing Period:	10 years		
	ZAR	**Euro (€)**	**US Dollar (US$)**
SA Rand Currency Assumption	1	12.0	9.2
Total Project Capital Cost (ZAR):	R115.1 million	€9.6 million	$12.5 million
Project O&M Costs (over 10 years):	R103.0 million	€8.6 million	$11.2 million

Project Press Release
SA Calcium Carbide Furnace Waste Gas to Electricity CDM Project
March 2013

GreenEng SLR SA CALCIUM CARBIDE

Table 1: Project summary.

Furnace load	**40 MW**			
Furnace gas flow	±7200 Nm^3/h (dry based) approximately 187 Nm^3/furnace MW			
Gas properties	**Gas**	**Proportion (%)**	**Calorific value**	**Energy**
	CO	60,4 average	11,79 MJ/Nm^3	26 607 MJ
	CO_2	±1,3	0	
	H_2	30,2 average	10,02 MJ/Nm^3	45 194 MJ
	H_2O	0		
	O_2	<0,1		
	N_2	±5	0	
	Total	**100**		**71 801 MJ**
Fuel gas LHV	2,67	kWh/Nm^3		19,9 MWh
Efficiency-engine	37%	Energy available for use		7,4 MWh
Other factors	Dust content at ex. flare inlet dry (SGS)		3 – 9 mg/Nm^3	5,4 mg/Nm^3 avg
	Relative gas moisture		100%	26 607
	Temperature at blower outlet		50°C	45 194

Table. 2: Furnace gas composition.

is overcome by the project engineering ensuring the gas relative humidity and pressure levels are maintained within tight limits for the generator-sets. Impurities can damage the engine or affect its performance, as has been experienced on other projects in this country, notably those running on landfill gas, and gas flared to the atmosphere must be free of pollutants. According to the suppliers, the gas coming out of the scrubber has less impurities than the surrounding air.. The scrubber operates on a centrifugal basis, which is very effective for removing particulate matter.

Power generation plant

The plant is housed at the site of an old building close to the furnace and consists of the engine room, control room and transformer room/substation. The choice of this location made the EIA process much easier as there was an existing structure on the site (Fig. 4).

The generator section consists of four E58 version Jenbacher 620 gas engines configured to run on the gas composition existing on site, combined with AVK model DIG 130/i4 alternators (Fig. 5). The engines are a 20 cylinder model, each having a capacity of 124 l, and capable of producing approximately 3 MW of energy at full power. The output is however reduced to 2 MW because of the lower calorific value of the gas produced according to Agaricus who provided the engines. Jenbacher engines were first produced to run on furnace gas in the 1990s and have been developed to run on a wide variety of gases since then. There are a limited number of calcium carbide production plants worldwide and as the machines had to be specially modified to run on the off gas from the production process (see Table 2) there are also a limited number of machines of this version in use worldwide, which may be regarded as a risk factor for the project. Fig. 5 shows one of the installed units.

The engines are managed from the control room where display of the performance of each engine. The number of engines running at any one time will be dependant on the amount of gas produced. The engines run at 1500 rpm and drive alternators producing power at 11 kV. The plant is expected to produce 43 371 MWh/yr of electricity when running at the anticipated capacity. The gas engines are a well established technology used at many site around the country including landfill gas in Durban, smelters at Namakwa sands and Brits.

Control of gas flow

One of the problems facing the operation of such a plant is balancing the amount of gas produced by the furnace with the gas consumed by the engines. The furnace does not produce gas in a steady flow but exhibits slight variations in volume. Some installations make use of a buffer tank to regulate the flow, but in this case the gas is fed directly to the engines. Pressure valves are used to regulate the pressure of the gas entering the engine, and the flow is regulating by diverting surplus gas to the flare. The flare is barely visible at this time, compared to a roaring flame a year ago. When the gas production from the furnace is greater than the amount of gas required by the gensets or when the engine gen-sets are off for any reason i.e. maintenance and the furnace is running, gas will continue to be flared for safety reasons.

Exhaust gas heat recovery

The exhaust gas has an exit temperature of 486°C at full load and is fed to a kiln where heat is extracted and used for drying anthracite before feeding it into the furnace, before being released to the atmosphere. The exhaust gas temperature at the kiln is of the order of 350°C.

Future projects

A predominant project success factor is that SACC have internalised the co-gen project development and maintained project ownership. This approach by SACC displays both technical and financial success ramifications. Technically, the project is developed as an integrated

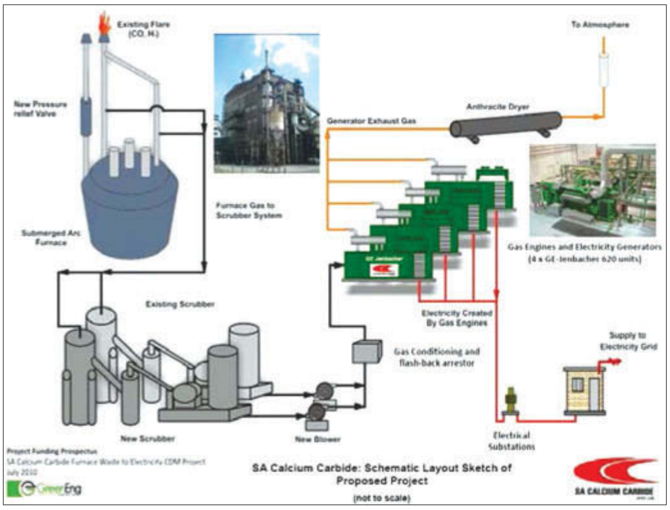

Fig. 3: The final plant configuration. (Photo credit SACC).

Fig. 4: The completed co-generation plant building (photo credit SACC).

SA calcium carbide projected growth

Year No.	Year	Furnace: $mtCaC_2/yr$	Furnace: $mtCaC_2/yr$ (predicted)	Furnace: Gas Flow (Nm^3/hr)	Furnace: Furnace Av (MW)	Engines: Hours	Engines: Capacity (Min)	Engines: engines	Engines: MWh/year
1	2012	67 553	66 202	5 220	29	1789	6.800	4	12 167
2	2013	74 541	73 050	5 760	32	7157	6.800	4	48 667
3	2014	76 871	75 333	5 940	33	7157	6.800	4	48 667
4	2015	76 871	75 333	5 940	33	7157	6.800	4	48 667
5	2016	79 200	77 616	6 120	34	7157	6.800	4	48 667
6	2017	79 200	77 616	6 120	34	7157	6.800	4	48 667
7	2018	81 529	79 899	6 300	35	7157	6.800	4	48 667
8	2019	81 529	79 899	6 300	35	7157	6.800	4	48 667
9	2020	83 859	82 182	6 480	36	7157	6.800	4	48 667
10	2021	83 859	82 182	6 480	36	7157	6.800	4	48 667
11	2022	86 188	84 464	6 660	37	5368	6.800	4	36 500
			769 312			71 569			486 671

Table 3: Projected growth for SACC plant.

enhanced process to SACC's furnace and calcium carbide production process providing electrical energy for own-use and thermal (heat) energy for use in the aggregates drying kiln – and is in no way a "project tag on". Increased furnace production efficiency, for example, produces increased efficiency on waste gas supply volumes for the generation of electrical power by the co-gen project. Indeed, the installation of a 5th engine gen-set is a viable proposition in the future, see Table 3. Financially, the project will realise significant cost savings in the purchase of electricity from the Newcastle municipality – generating some 41,5 to 48,7-million kWh per annum. LPG cost reductions will also be realised from the use of the exhaust heat of the engines in the drying kiln.

A further financial success factor is gained from the generation of carbon credits which are to be registered as Certified Emission Reductions (CERs) and sold on the international market. Lastly, the

Fig. 5: Jenbacher engine installed on site. (photo credit SACC).

internalisation of the project has realised a significant success factor to SACC with their obtaining the DTI's S12i donor funding (tax) grant and more recently, SACC has entered into an IDM Contract with Eskom, supported by Sebenzana, for a required 15% electricity reduction which SACC is set to achieve.

References

[1] SACC CDM project submission to DNA, July 2012.

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Order for tube leak detection systems

Instrotech has secured an order for six new. Inspecta FFT acoustic tube leak detection systems from NTPC Limited, the Indian state-owned electric utilities company which Instrotech was able to supply and ship within six weeks. This locally manufactured technology is able to "listen" to the sound within a combustion chamber and detect leaks of less than 2 mm in diameter in a 600 MW boiler, using an audio sensor. The sensor is a miniature industrial pressure transmitter enclosed in a sealed acid and dust-proof capsule, essential in the harsh environmental conditions where boilers are situated. This early warning leak detection has, on many occasions, saved consequential damage from occurring in a boiler saving millions in repairs or downtime. Whilst governments around the world are trying to reduce their country's domestic coal usage in the hope of using alternate or renewable methods of generation, the demand for coal has actually surged because of high natural-gas costs in Europe, which has increased coal-fired generation by 14% year on year in the Eurozone.

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