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by Oliver Arndt

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Oliver Arndt

Lime kiln conversion from coke to natural gas operation – an option in direction of sustainable energy*

Kalkofenumbau vom Koks- zum Erdgasbetrieb – eine Option für nachhaltige Energieversorgung

This paper deals with the conversion of coke fired lime kilns to gas and the conclusions drawn from the completed projects. The paper presents (1) the decision process associated with the adoption of the new technology, (2) the necessary steps of the conversion, (3) the experiences and issues which occurred during the first campaign, (4) the impacts on the beet sugar factory (i.e. on the CO_2 balance and exhaust gas temperature), (5) the long term impressions and capabilities of several campaigns of operation, (6) the details of available technologies and (7) additional benefits that would justify a conversion from coke to natural gas operation on existing lime kilns. (8) Forecast view to develop systems usable for alternative gaseous fuels (e.g. biogas).

Key words: lime kiln, conversion, gas firing system

Diese Arbeit befasst sich mit der Umstellung von koksgefeuerten Kalköfen auf Gasfeuerung sowie den Schlussfolgerungen, die aus abgeschlossenen Projekten gezogen wurden. Dargestellt werden (1) der Entscheidungsprozess im Zusammenhang mit der Einführung der neuen Technologie, (2) die notwendigen Schritte der Umstellung, (3) die Erfahrungen und Probleme, die während der ersten Kampagne aufgetreten sind, (4) die Auswirkungen auf die Rübenzuckerfabrik (d.h. auf die CO_2-Bilanz und die Abgastemperatur), (5) die langfristigen Auswirkungen und Tauglichkeit während mehrerer Kampagnen, (6) die Details der verfügbaren Technologien, (7) die zusätzlichen Vorteile, die eine Umstellung von Koks auf Erdgasbetrieb an bestehenden Kalköfen rechtfertigt und (8) Betrachtungen zur Entwicklung möglicher Systeme für alternative gasförmige Brennstoffe (z.B. Biogas).

Schlagwörter: Kalkofen, Umbau, Erdgasbetrieb

1 Introduction

The European Sugar Industry is facing the challenges to improve its energy efficiency and to use sustainable energy. In Europe, nearly all lime kilns are fired with coke or anthracite obtained from different sources with a large bandwidth of properties, like fixed -carbon, volatiles and ash content. In the past, the availability, price level and high CO_2 content of the lime kiln gas made the solid fuel mixed feed lime kiln the number one choice for the sugar industry. In case of lime kilns, the switch from coke/anthracite to natural gas is an option used to reduce CO_2 emissions.

In North Africa and North America the situation has already changed and natural gas as lime kiln fuel is gaining more and more importance. This development is mainly economically driven, but, especially in the US, it is also forced by environmental laws. Yet, mixed-feed lime kilns are still present in the US.

In 2012, two existing vertical shaft lime kilns were converted from coke to natural gas operations in Germany. The initiative was triggered by observations on emission values made by German environmental authorities, and the conversion of the existing lime kilns from coke to natural gas promised to be a very effective option. The technology used for the conversion is called GDS, Gas Distribution System. The working principle was invented by *John B. Jones* in the US.

The GDS technology had to be adapted not only to the dimensions of the existing lime kilns but also to the strict European safety and operation standards for gas firing systems. The adapted technology now features an automated start-up procedure using pilot burners for ignition and an online kiln gas analysis system to observe and control the combustion process.

2 Types of coke fired lime kilns

The main coke fired kiln models are the older induced draught – or suction type kilns – with internal working shaft diameters from 3.0 m to 3.5 m and nominal capacities of up to 100 t/d CaO or 200 t/d limestone.

In case of more modern, bigger units a forced air system – or pressurized kiln – is common. It has inner diameters of 3.7 m up to 6.7 m with capacities from 125 t/d to more than 400 t/d.

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Both kiln types use limestone grain sizes ranging from 80 to maximum 150 mm. CO_2 concentrations of 32 to 40% are obtained, depending on the kiln type and the amount of excess air. The energy input is 1.9–2.4 GJ/t of processed limestone.

3 Gas fired lime kilns

There are two types gas fired kilns used in the sugar industry:
- The Eberhardt G type kiln, as operated in Egypt, Iran and Uzbekistan, is an induced draft kiln with external combustion chambers. It has a capacity limit of 130 t/d CaO, as it is necessary to bring the heat into the center of the kiln. The max diameter is approx. 3 m. Here the same limestone sizes are used as in coke fired kilns.
- The Eberhardt GDS type kiln is based on a two level burner beam setup which has its origin in the design of John B. Jones. The remaining equipment and layout of this pressurized kiln follow's the Eberhardt model. Here, the necessary limestone size is of the order of 45 to 60 mm, i.e. smaller than the other types.

Both kilns produce kiln gases with a volumetric CO_2 content of 26–32%, which is lower than the kiln gases of their coke-fired counterparts. The fuel, mainly methane, creates less CO_2 than solid fuels. In general, the main volume flow in gas fired kilns is higher, which also reduces the CO_2 concentration in the kiln gas.

The energy consumption of 2.2–2.7 GJ/t limestone is higher than for solid fuel kilns due to higher exhaust gas temperature and cooling losses.

4 Reasons and prerequisites for conversion

The GDS kiln system with its burner beams has been proven as adequate setup for converting coke fired kilns to natural gas. Possible reasons for a conversion are:
- Environmental protection requires lower CO_2 and dust emissions as well as the minimization of toxic and carcinogenic residues.
- Limited availability and storage capacity for solid fuels at the factory.
- Plans to increase capacity without increasing the kiln diameter.

For a conversion instead of a completely new kiln, several requirements need to be fulfilled:
- The combustion system must be fitted to the existing lime kiln.
- Easy maintenance and suitability for campaign operation.
- Burnt lime must have at least the same quality as produced in a conventional lime kiln. The reactivity of the lime must be maintained in the medium to hard-burned range, because it has to be safely processed in the slaking drum.
- All safety standards and regulations of local authorities need to be met.

5 Conversion of a coal-fired lime kiln

According to the abovementioned requirements, a gas-firing system has been developed as an adaptation of the proven burner beam system. It features two combustion levels with double walled pipes with an integrated cooling water chan-

Fig. 1: Eberhardt G type gas-fired kiln

Fig. 2: Eberhardt GDS lime kiln

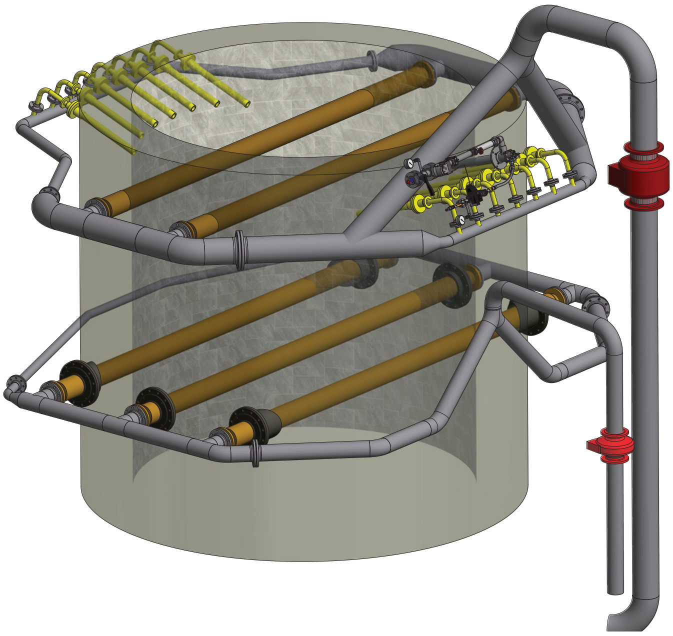

Fig. 3: Gas firing system

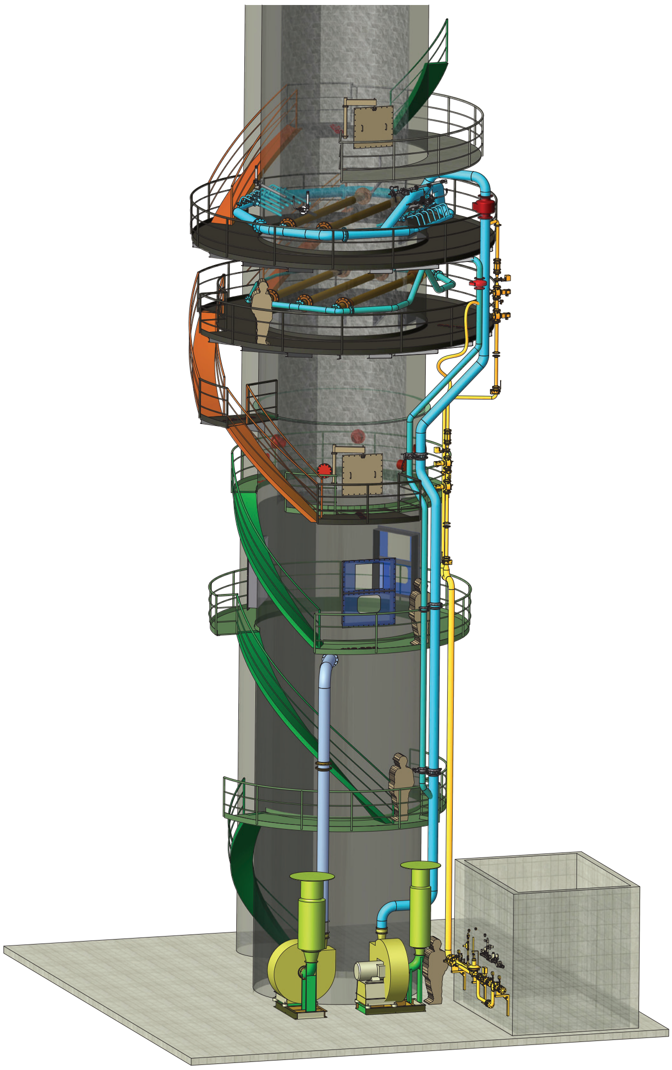

Fig. 4: From coal to gas firing converted lime kiln

nel (Fig. 3). The pre-mixed air-natural gas fuel is injected into the working shaft through multiple nozzles in the beams. In the upper part of the kiln the gas distribution is supported by additional auxiliary lances. The air/gas ratio and quantity can be set independently for the upper and lower parts of the kiln. The upper combustion is stoichiometric for a direct energy treatment of fresh limestone. For a safe start-up of the system, pilot burners are located near the upper level of beams and lances. In the second, lower beam area a rich air/gas mixture is injected in a larger area with air cooling the lime from below. This helps to achieve the complete calcination of the lime without overheating the stone. In addition to the pilot burners, flame arrestors, temperature sensors and an online gas analyzer are used for start-up and operation of the system under safe conditions.

In order to realize the conversion of a coal-fired lime, the followings conditions have to be met:

- The kiln must be a pressure type kiln. In case of a suction type kiln, the discharge area needs to be closed and a suitable airlock must be installed.
- The beams and lances must be mounted and the refractory in this area must be adapted. Consoles above and below this area must minimize the thermal expansion.
- Depending on the type of lime kiln, the beams must be altered for better access.
- Two fans, one for primary air and one for secondary or lime cooling air, are needed.
- The gas and air piping and the corresponding control trains have to be installed.
- The equipment and lines for the cooling loop must be installed to the beam system.
- The control and safety system can be realized as a standalone black box solution or as an extension of the existing control system.

Figure 4 shows a lime kiln that has been converted from coal to gas. The kiln had an internal diameter of 3.46 m and had to be converted from suction to pressure mode.

Figure 5 shows the setup of lances with the small flexible cooling connections and the pilot burner in the center. Figure 6 shows two beams and another pilot burner which is situated above.

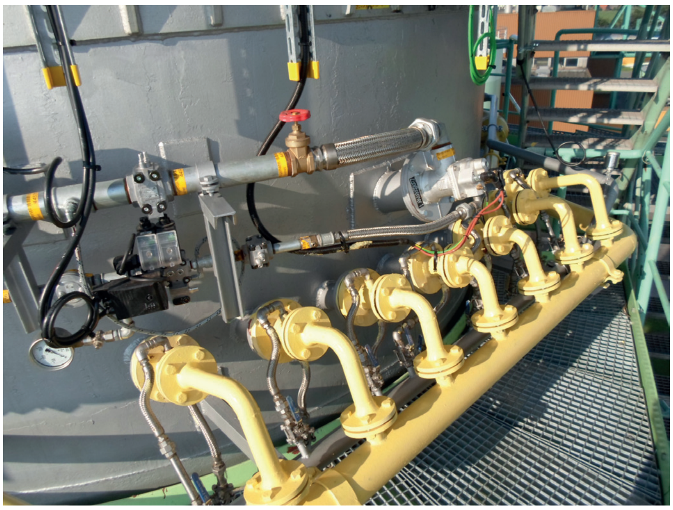

Fig. 5: Lances of gas fired lime kiln

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Fig. 6: Two beams plus pilot burner attached to the lime kiln

6 Results and outlook

The lime kilns at Fort Morgan and Greeley were already converted to the gas firing system, followed by the successful conversion to natural gas combustion in Euskirchen by Eberhardt. A complete new gas fired kiln with the GDS system is under construction in Drayton, North Dakota, with a capacity of more than 200 t of CaO per day for the 2020 campaign with a another conversion coming next year in Croswell, Michigan. 19 gas-fired lime kilns of the G-type have been commissioned in Egypt, Iran, and Uzbekistan, including four conversions from heavy fuel oil to natural gas.

The smaller limestone size used with the GDS system allows to reduce the retention time in the kiln. In addition, the fraction 45 to 60 mm is typically on a lower price level than larger limestones.

The gas combustion system with its ability of fast changes in parameters allows an easier and more predictable operation. Unlike coke fired kilns, the operator does not have to wait two days to see results. Together with the higher flow rate and temperature measurements it is possible to create a higher level of automation with better control loops. The refractory can be optimized for the small fixed combustion zone, which is minimizing the refractory wear of the whole kiln.

The gas firing provides a lower CO_2 concentration in the kiln gas, but the amount is sufficient for juice purification. Theoretically, only the CO_2 from the calcination reaction of the limestone is necessary in the carbonation. Natural gas fired kilns emit 60 kg CO_2/GJ compared to 90 to 100 kg CO_2/GJ for coke or anthracite, i.e. 25–30% lower CO_2 emissions. With the additional uses of lime for example for flume water liming, the overall CO_2 footprint of the plant improves compared to the traditional solid fuels. The amount of gas is much closer to the process demands.

Users reported lower wear of refractory, lower retention time, with lower CO_2 emissions.

As a result, it is possible to process more lime in the same shaft diameter, meaning that the kiln has a much higher specific capacity. With upgraded transport equipment, a 100% performance increase is possible maintaining the existing kiln shaft.

Regarding the future of lime kilns, especially of gas-fired kilns: Eberhardt is pushing the development to lower the energy consumption by improving insulation, distribution and cooling. Additionally, the conversion to natural gas is a chance to use alternative fuel gases like biogas in the future.

Industry 4.0 is a topic everywhere and also the lime kiln should be part of it. An automated process analysis is being developed to predict and optimize the process.

Author's address: *Oliver Arndt*, Eberhardt Schwab GmbH, Am Bauhof 21, 32657 Lemgo, Germany;
e-mail: oliver.arndt@the-M-Group.com