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Meeting New Market Requirements with Large Maerz PFR Kilns

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1. Introduction

In recent years the significant increase in steel demand resulted in many expansion projects in steel plants worldwide, mainly in Asia and South America. These projects necessarily generate a higher demand for burnt lime and dolomite – hence new large scale calcining facilities have to be erected.

When planning large capacity lime plants one has to consider making the best use of limestone as high quality limestone deposits become scarce and also raw material costs and environmental concerns demand for an optimised quarry yield.

Until recently rotary kilns were considered to be first choice whenever high lime production capacity was an issue despite the comparatively high fuel consumption. The higher fuel consumption was widely accepted as the respective high production rates could only be realised by installing two or more PFR shaft kilns. Therefore, at high capacities PFR kilns had a disadvantage because of higher overall investment costs. This situation has completely changed due to the sharp increase of fuel costs and the recent development in PFR kiln technology regarding the maximum capacity per kiln unit.

To meet today's requirements for large capacity lime plants two options reflect the state of the art of technology:

1. shaft preheater rotary kilns equipped with a controllable sulphur bypass system to allow for low cost (high sulphur) fuels satisfying highest quality demands for low sulphur lime, or
2. high capacity PFR kilns operating at the lowest fuel consumption of all modern lime kilns and consequently producing significantly lower CO_2 emissions. Furthermore, due to the PFR technology, lean gases with a calorific value as low as 6'000 kJ/m_n^3 can be used to even further reduce operating costs.

Maerz Ofenbau AG, being a member of the Polysius group, can now offer both kiln types. This paper concentrates mainly on the most recent development of large capacity PFR Kilns.

2. Quarry Yield and Lime Kiln Types

An important factor for the economic viability of a lime plant is an optimal use of the limestone resources. Especially in densely populated areas it is extremely difficult to expand existing quarries and virtually impossible to develop new limestone deposits.

Although smaller size limestone may be sold as gravel for various applications, the added value for a lime plant is maximised by producing quicklime.

To avoid excess generation of fines during limestone crushing and to generally reduce crushing costs the maximum stone size should be as large as possible.

Fig. 1a and b show the fields of application of various kiln systems with special consideration to their production capacities and the usable limestone grain size range.

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The range of Maerz PFR Kilns covers production capacities from 100 to 800 tpd using limestone grain sizes from 40 to 160 mm. A special design – the Maerz Finelime Kiln – is able to calcine stone sizes from 15 mm upwards. In cases where a kiln exhaust gas with high CO_2-content is required the Maerz Annular Shaft Kiln is the kiln of choice.

Stone sizes between 15 and 50 mm can be calcined in Maerz Preheater Rotary Kilns preferably if large production capacities are requested. For small capacities Maerz has recently developed a single shaft kiln, the Maerz-RCE Kiln with capacities up to 200 tpd, for calcining this stone size range.

Maerz can even offer a solution to calcine very fine limestone (0.03 – 2 mm) which is the cyclone preheater and suspension calciner technology POLCAL.

As you can see Maerz as part of the Polysius group offers kilns to satisfy virtually all requirements of the industry.

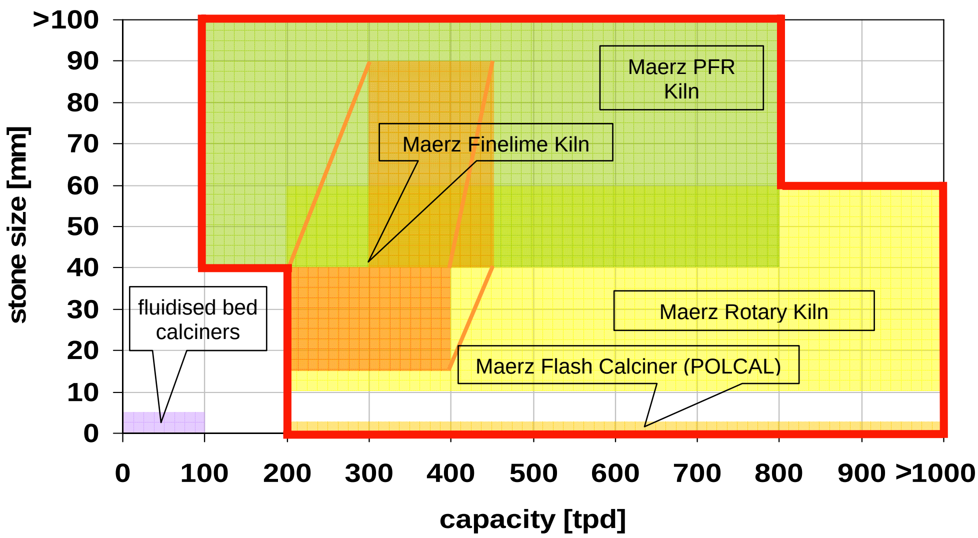

Fig. 1a: Applicability of Various Types of Lime Kilns regarding Raw Material Size and Production Capacity for Very High Reactive Lime

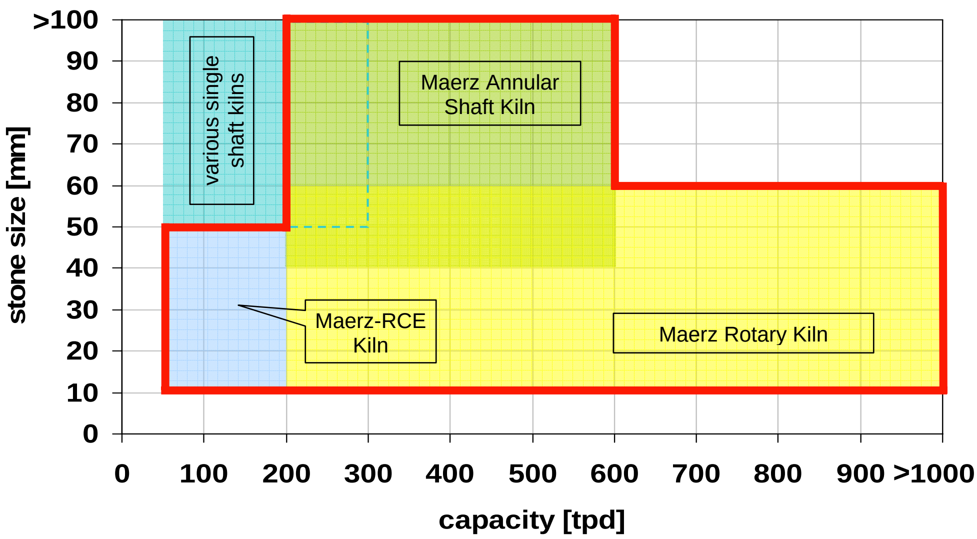

Fig. 1b: Applicability of Various Types of Lime Kilns regarding Raw Material Size and Production Capacity for Medium and Low Reactive Lime

To make use of a stone size range of e.g. 15 - 150 mm to optimise quarry yield the following kiln concepts may be applied depending on the required production capacity:

a) For capacities up to 300/400 tpd a PFR Kiln may be charged in "sandwich mode" where smaller and larger fractions are charged in layers allowing stone size ratios of up to 1:6.

b) For medium to large capacities of several hundred tons of burnt lime per day one could install a combination of the Maerz Finelime Kiln and the classic Maerz PFR Kiln.

c) For very large capacities of several thousand tons per day preheater rotary kilns with sulphur bypass systems could process the smaller fraction and large capacity Maerz PFR Kilns could calcine the larger stone size with optimum heat efficiency.

3. Principle of Maerz PFR Lime Kilns

The "PFR - Parallel Flow Regenerative Lime Kiln" has the lowest heat consumption of all modern shaft kilns which is explained by its mode of operation, see Fig. 2.

The PFR Kiln is characterised by its parallel flow heating system, i.e. the parallel flow of limestone and combustion gases in the kiln, and the regenerative preheating of combustion air.

Fig. 2 shows the basic principle of the kiln and illustrates two phases of the flow. 1 and 2 are the two shafts containing the material to be calcined which are connected to each other by a crossover channel at the bottom end of the burning zone. The stone charging equipment, the reversal devices for air and off-gases as well as the lime discharging arrangement have been omitted from this diagram.

Both shafts are charged alternately with limestone, and lime is discharged continuously at the bottom of each shaft. Fuel is supplied to only one of the two shafts, in the phase shown in Fig. 2 to shaft 1. Fuel is introduced and evenly distributed over the cross section of the shaft at the bottom end of the preheating zone.

Combustion air is introduced under pressure at the top end of the preheating zone above the stone charge and the system is pressurised throughout. Combustion air is preheated in the regenerator (preheating zone) before it mixes with the fuel. The flame passes through the burning zone from top to bottom (parallel flow heating).

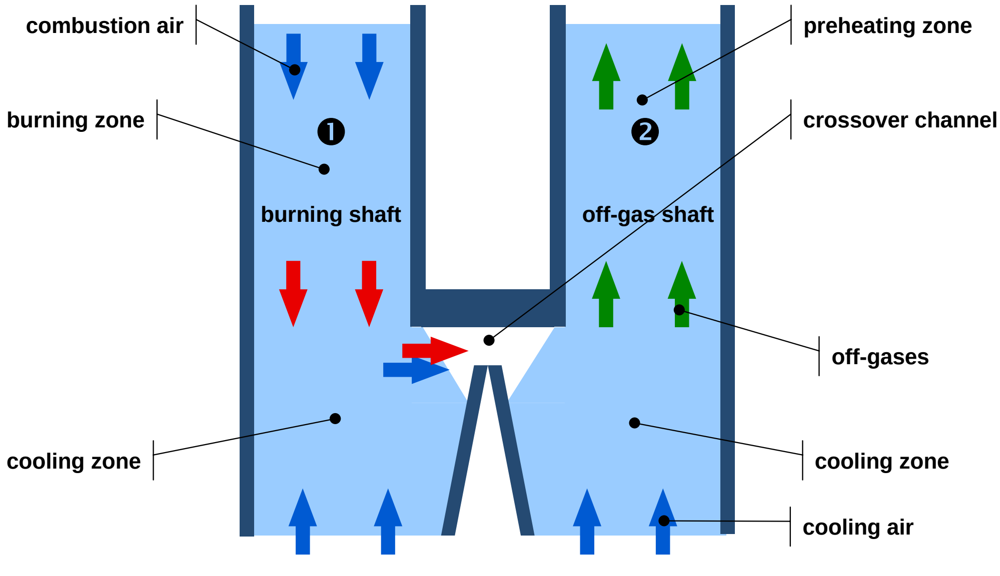

Fig. 2: Principal Function of the Maerz PFR-Kiln

The off-gases leave the fired shaft (primary shaft) via a bank of material and enter the secondary shaft, passing upwards in opposite direction to the charge. They calcine, even if to a small degree, the limestone in the secondary shaft and heat up its regenerator (preheating zone).

The supply of fuel and air for combustion is switched from one shaft to the other at approx. 12 minute intervals (at nominal output). Cooling air is continuously introduced under pressure at the bottom end of both shafts.

Uniform fuel distribution over the entire shaft cross section is absolutely essential to produce a high and uniform quality product, i.e. quicklime or burnt dolomite, required in most application fields. This is achieved by installing burner lances vertically suspended in the stone charge in the preheating zone as shown in Fig. 3.

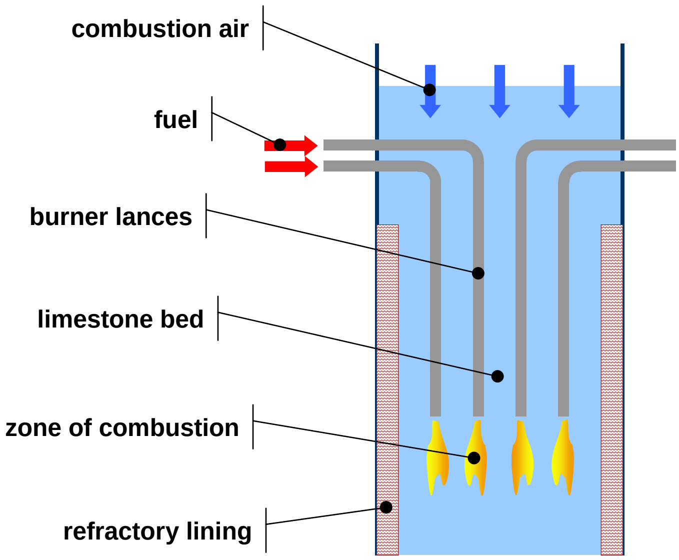

Fig. 3: Burner Lance System in Maerz PFR Kilns

The first PFR Kilns were built at Wopfinger Stein- und Kalkwerke in Austria in the late nineteen-fifties. They had a capacity of approx. 150 tons per day and were equipped with a firing system for natural gas and heavy fuel oil.

4. Comparison of Large PFR Kilns and Rotary Kilns

An increasing demand for larger production capacities mainly from the steel industry, as well as the industry's quest to optimise lime production costs has motivated Maerz to investigate the feasibility of PFR kilns larger than the well known 600 tpd kilns which have been proven over many years.

Looking at Fig. 4 the advantages of the different kiln types become obvious:

	Maerz PFR Kiln	**Preheater Rotary Kiln[1]**	**Long Rotary Kiln[1]**
Stone size	15 – 150 mm	3 – 60 mm	1 – 60 mm
Max. stone size ratio	6:1 (sandwich)	5:1	3:1
Heat consumption based on a gas fired kiln	3'550 kJ/kg	5'000 kJ/kg	6'700 kJ/kg
Electric power consumption based on a gas fired kiln	25 – 40 kWh/to	35 kWh/to	25 kWh/to
Refractory consumption	Low	Low	High
Capital costs based on a 500 tpd gas or oil fired kiln	80%	100%	100%
CO_2 in lime based on a gas fired kiln	< 2%	< 1%	< 1%
Reactivity of lime (t_{60}-value)	< 1 min	1 min	3-5 min
Dust emission (percentage of production)	1-2%	2-5%	5-10%

Fig. 4: Comparison of Large PFR Kilns and Rotary Kilns

4.1 Stone Size and Quarry Yield

To avoid excess generation of fines during limestone crushing and to generally reduce crushing costs the maximum stone size shall be as large as possible – an advantage only a shaft kiln can offer. The maximum usable stone size increases with bigger kiln size.

To also make use of the smaller stone size fractions Maerz developed the "sandwich charging method" where smaller and larger fractions are charged in layers allowing stone size ratios of up to 1:6.

Rotary kilns are generally limited to small and medium sized limestone and cannot process such wide stone size ratios.

[1] Source: Daniel Sauers, Neal Biege Sr., and Diana Smith: Comparing Lime Kilns; National Lime Association Operators Meeting, 1992

4.2 Heat Consumption and Fuel Usability

The decisive factor in operating costs of a lime kiln is its heat consumption. In some countries and for some applications thermal energy is comparatively cheap (e.g. coal in USA and China or blast furnace gas in steel plants). Nevertheless fuel costs contribute between 40 and 60% to the overall production costs.

Although elaborate heat recovery technologies such as preheaters are also applied to rotary kilns, the simple Parallel Flow Regenerative principle of the Maerz PFR Kiln remains unbeaten regarding fuel efficiency.

When looking at very low calorific value gases such as mixed gases in steel plants, the PFR kiln may use gases with net calorific values as low as 6'000 kJ/m^3_n whereas the rotary kiln is generally limited to gases with a calorific value above 10'000 kJ/m^3_n.

4.3 Dust and NO_x Emissions

Due to the intense movement of the limestone in a rotary kiln, particularly when compared to the relatively slow and gentle handling of the material bed in a shaft kiln, generation of dust in the exhaust gases is 2 to 5 times higher than in shaft kilns. In many cases the dust, a mixture of limestone and lime, is difficult to use or sell.

PFR Shaft Kilns generally emit significantly less NO_x than rotary kilns[2]. The reason is that temperatures in shaft kilns are usually below 1'200 °C, so that the formation of thermal NO_x (by reaction of nitrogen with oxygen) is comparatively lower. Additionally, the combustion processes usually produce relatively lower flame temperatures and low-intensity mixing conditions, resulting in lower levels of fuel NO_x. However, in rotary kilns the flame is better defined and flame temperatures are higher than in shaft kilns, which results in higher levels of fuel NO_x. Moreover, because of the different heat transfer processes in rotary kilns, the maximum temperature of the kiln gases is also higher, resulting in increased thermal NO_x levels.

4.4 Capital Costs

In the past two or more PFR kilns were required to produce a large quantity of lime which required considerable investment, particularly when compared to one single rotary kiln. With the development of an 800 tpd PFR Kiln the disadvantage of high capital costs has been eliminated – and the 1’000 tpd PFR Kiln is already in the planning phase!

5. Technical Features of Large PFR Kilns

5.1 Design Principles of Large PFR Kilns

Heat distribution and an even flow of hot gases through the material bed are a prerequisite for a uniformly high quicklime quality across the entire shaft section.

The circular design of the Maerz PFR kiln with its ring channel collecting the hot gases from the entire circumference of the shafts is ideally suited for this purpose. An even fuel distribution can be achieved with the number of burner lances adjusted to the cross section and the desired limestone size – the 800 tpd kiln with an inner diameter of the burning zone of 4.8 m has 33 burner lances.

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[2] Source: European Commission, Integrated Pollution Prevention and Control (IPPC): Reference Document on best Available Techniques in the Cement and Lime Manufacturing Industries, December 2001; Chapter 2.3.3 Emissions, pp 97 ff

To guarantee a uniform gas distribution in the burning zone experience shows that the burning zone should be approx. twice as high as its diameter. For large kilns this rule of thumb means that the overall kiln height increases and with it the pressure drop in the material bed. To compensate this effect and to keep the operating pressure of the large kiln within reasonable limits the stone size has to be increased accordingly – in case of the 800 tpd kiln up to 140 mm.

Further technological details are discussed in the following chapters:

5.2 Suspended Inner Cylinder

Kilns with large diameters would need many refractory pillars to support the inner cylinder dividing the burning zone from the ring channel. Besides the high volume of refractories necessary for the pillars (resulting in high refractory costs) they also form an obstacle in the flow of lime and gases.

Maerz now offers the “suspended cylinder” kiln as solution. Not only does this design provide an unobstructed flow of lime but it also increases the surface for the hot gas passage into the ring channel thereby reducing the speed and dust load of the gases.

Fig. 5 shows the principle of the air-cooled and refractory lined suspended cylinder. The cooling air, leaving the cylinder at a temperature of approx. 200°C, keeps the steel structure in a safe temperature range. To recover this heat the cylinder cooling air is then used as combustion air.

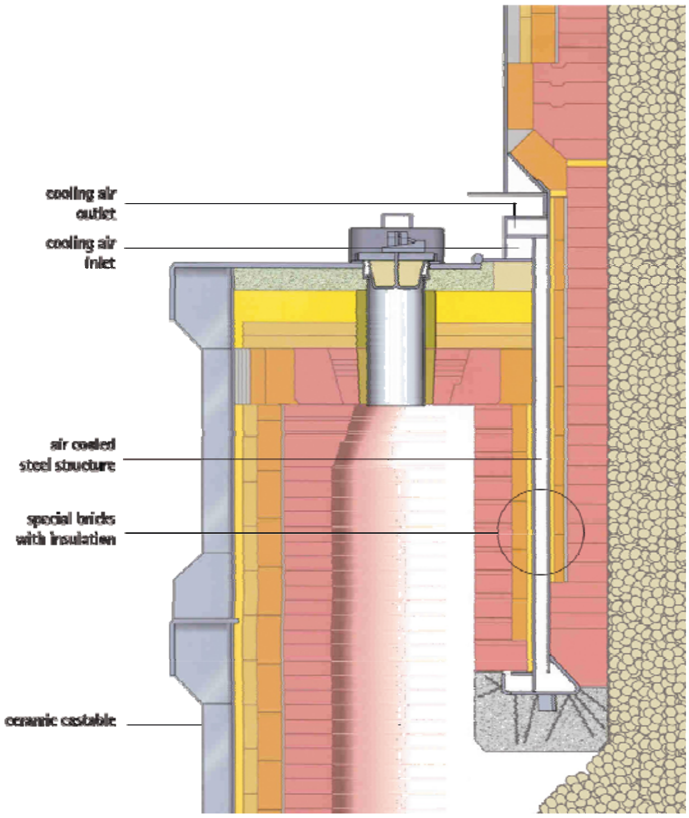


Fig. 5: Principle of the Suspended Cylinder for Maerz PFR Kilns

5.3 Cooling Zone

One of the significant cost factors in a PFR kiln is the diameter of the cooling zone, which has an effect on the steel weight, the refractory lining, the size of the discharge tables and the kiln foundation.

Aiming for an optimal ratio between cost and return Maerz designed the refractory wall of the cooling zone at an angle of 8° which allows an even flow of the material bed and a uniform discharge of the burnt product.

5.4 Discharge Tables

The large diameter of the discharge tables for these big kilns requires a more sophisticated distribution of the lime cooling air. Whereas in smaller kilns the cooling air is fed only from the circumference of the discharge tables, in an 800 tpd kiln the air would never reach the centre axis of the shaft resulting in an insufficient cooling of the lime in the centre.

Hence Maerz developed a system introducing a part of the cooling air via the centre cone as shown in Fig. 6. The cooling air flow can thus be individually adjusted between the central and the peripheral sections of the discharge tables.

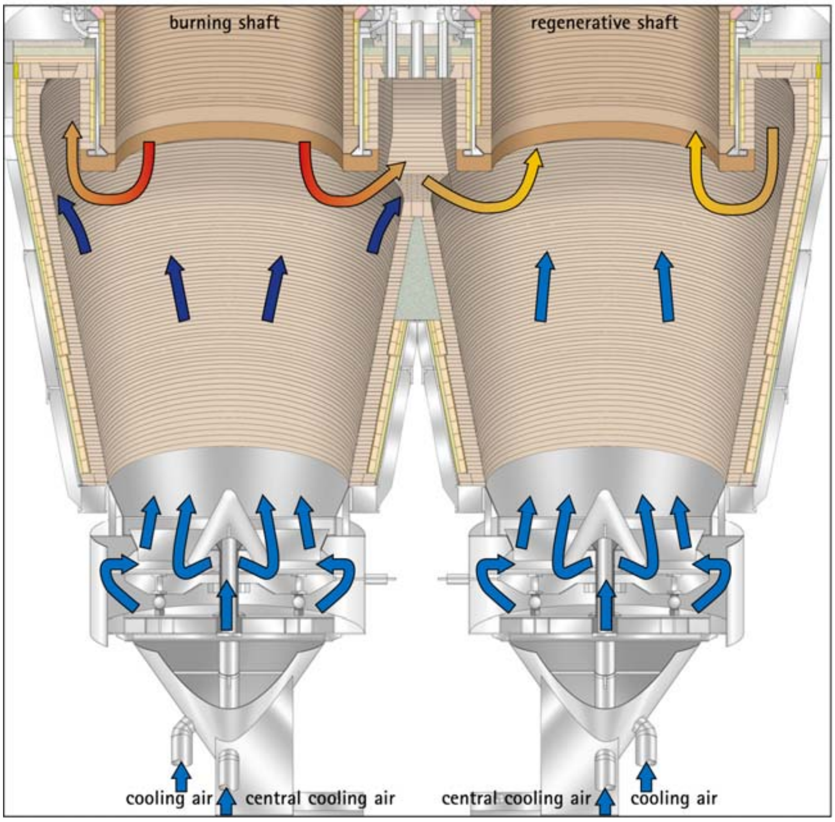


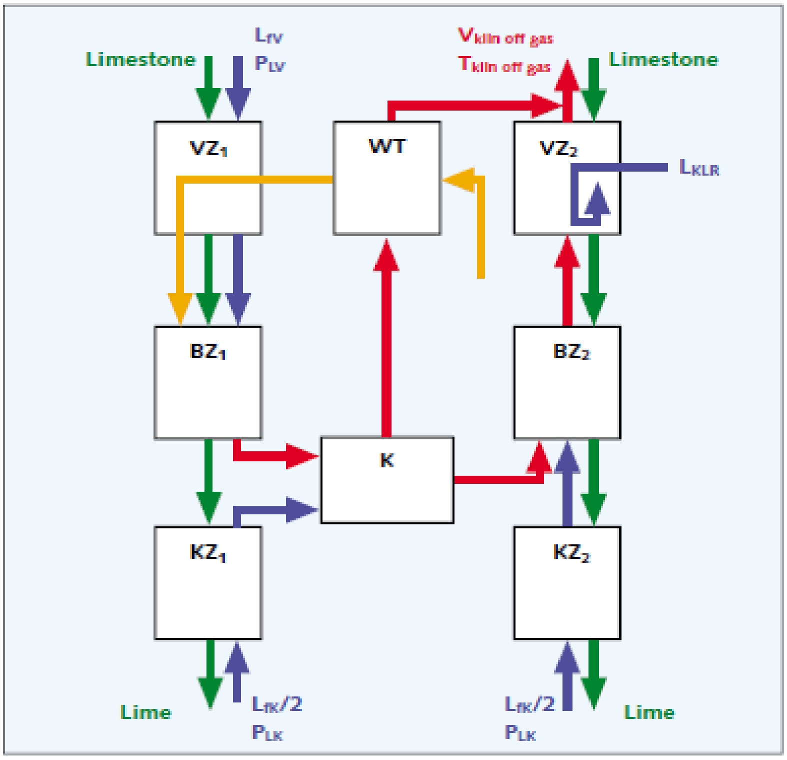
Fig. 6: Cooling Zone of Large Maerz PFR Kilns with Additional Central Cooling Air

6. Outlook

With large capacity units it could be economically interesting to study solutions involving some investment into the peripheral devices of a kiln to be able to use an even wider range of fuels.

As an example blast furnace gas with a net calorific value of only 3'500 kJ/m^3_n could be used without any further enrichment when preheated to 250°C, a temperature at which the gas can still be handled with standard industrial valves and instruments.

Fig. 7 introduces a concept where the hot kiln gases from the cross-over channel are used to preheat a lean gas (for details please refer to Hannes Piringer's publication in ZKG International[3]).



Legend:

VZ_1 … Preheating zone shaft 1
BZ_1 … Burning zone shaft 1
KZ_1 … Cooling zone shaft 1

WT … Heat exchanger lean gas / kiln gases
K … Cross over channel

VZ_2 … Preheating zone shaft 2
BZ_2 … Burning zone shaft 2
KZ_2 … Cooling zone shaft 2

L_{fV} … Combustion air mass flow
P_{LV} … Pressure combustion air

L_{fK} … Cooling air mass flow
P_{LK} … Cooling air pressure

$V_{kiln\ off\ gas}$ … Kiln off gas mass flow
$T_{kiln\ off\ gas}$ … Kiln off gas temperature

Fig. 7: Block Diagram of a PFR Kiln with Fuel Gas Preheating

Maerz is confident to successfully start up the first 800 tpd PFR Kiln this year.

Based on Maerz' many years of experience with lime shaft kilns and the specific operating results of the first 800 tpd kiln, the 1'000 tpd kiln is just a few steps away as Maerz is sure to meet market demands for large capacity PFR shaft kilns.

Literature:

H. Piringer: Fuel gases with low calorific value for firing PFR lime shaft kilns – borderline case studies and realisation; ZKG International (56) No.6, 2003, pp.66-72

Daniel Sauers, Neal Biege Sr., and Diana Smith: Comparing Lime Kilns; National Lime Association Operators Meeting, 1992

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[3] H. Piringer: Fuel gases with low calorific value for firing PFR lime shaft kilns – borderline case studies and realisation; ZKG International (56) No.6, 2003, pp.66-72