Dry process kiln systems

- Highly reliable
- Low emission levels
- Efficient energy utilisation
Main features

- Highly reliable systems for any production level
- A wide range of calciner systems to suit specific requirements
- Highly efficient low pressure cyclones
- Effective emission control technology
- Optimized fuel and power consumption
- Suitable for waste fuels
- Compact, space-saving preheater designs
- Matching state-of-the-art technologies for clinkerization, cooling and firing: ROTAX-2 two-support kiln, SF Cross-Bar™ clinker cooler and Duoflex kiln burner

F.L.Smidth offers a range of six standard dry-process kiln systems, each with its unique advantages depending upon the particular application. In this way we are able to provide the industry with the most suitable kiln system configuration for any given set of conditions and requirements.

F.L.Smidth has supplied over 2500 rotary kiln systems and more than 3500 clinker coolers. This experience, coupled with the latest advances in pyroprocessing system design, makes our technology the logical choice for both new installations and modernisation of existing cement making facilities.

In modern cement plants, raw meal is preheated to calcination temperature in a multi-stage cyclone preheater and most of the calcination process takes place in a separately fired calciner. The remaining calcination and clinkerization process takes place in a short length-to-diameter rotary kiln without internals.

Preference is commonly given to the cooling of clinker in the SF Cross-Bar™ cooler in which the two main functions, conveying and cooling of clinker, are completely separated. The introduction of stationary air distribution plates with self-regulating mechanical flow regulators (MFR) has revolutionized cooler operation.

This brochure describes each of the six kiln system configurations in detail and presents general guidelines for their selection depending upon capacity requirements and whether the system is new or an upgrade of an existing installation. System components other than cyclones and calciners are dealt with in separate brochures that describe their mechanical and operational features.
Six standard Dry-process kiln system configurations

SP: Suspension Preheater kiln

ILC: In-Line Calciner

ILC-E: In-Line Calciner using Excess air

SLC-D: Separate Line Calciner - Downdraft

SLC: Separate Line Calciner

SLC-I: Separate Line Calciner with In-line Calciner
**SP: Suspension Preheater kiln**

### Special advantages
- For small capacities
  - the economical solution.
- Very low specific power consumption.
- Simple operation
  - well suited for manual control.
- Accepts higher input of chlorides than precalcining systems with tertiary air duct (without bypass).

### Features
- Normal capacity range: 700-2800 tpd.
- Ratio of firing in riser duct: 0-15%.
- Bypass of kiln gas: 0-30%.
- Planetary cooler can be employed.

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**5-stage SP kiln system and SF Cross-Bar™ cooler**

Typical temperatures in the system are indicated together with the negative pressure in the exhaust gas exit based on a system designed for minimum overall pressure drop. This type of kiln system can be converted to the SLC precalcining system by adding an extra calcining string. If no future capacity increase is to be considered, a planetary cooler may be considered.

1. Raw meal feed
2. Exhaust gas
3. Kiln gas by-pass, if any
4. Clinker
5. Kiln burner
6. Riser duct firing, if any
7. Cooler excess air
Special advantages
• Most economical solution for small and medium capacities.
• Low specific power consumption.
• Easy operation due to high excess air percentage in kiln.
• Low coating tendency in kiln inlet and riser duct.
• Long kiln lining life due to stable kiln coating.
• Less sensitive to chlorides and sulphur than precalcining systems with tertiary air duct (without bypass).
• Smaller kiln dimensions than SP system.

Features
• Normal capacity range: 800-3500 tpd.
• Ratio of firing in calciner: 10-25%.
• Bypass of kiln gas: 0-25%.
• Calcination at kiln inlet: 50-70% (compared to 30-40% for SP operation).
• Planetary cooler can be employed.

ILC-E kiln system with five-stage preheater and SF Cross-Bar™ cooler
Typical temperatures in the system are indicated, together with the negative pressure in the exhaust gas exit, based on a system designed for minimum overall pressure drop. If no future capacity increase is to be considered, a planetary cooler may be considered.
**ILC: In-Line Calciner**

### Special advantages
- High material and gas retention time in calciner due to its large volume and moderate swirl.
- Regulation range of up to 60% bypass of kiln gas using ILC-I version.
- Well suited for low-grade fuels.
- Long refractory life due to low thermal kiln load and stable kiln coating.
- Lowest NOx emission among traditional calciner kiln systems.

### Features
- Normal capacity range: 1500-5000 tpd, with multiple strings > 10,000 tpd.
- Ratio of firing in calciner: 55-65%.
- Normal bypass of kiln gas: 0-30%.
- Maximum bypass of kiln gas: 0-100% using ILC-I version.
- Built-in low-NOx capabilities.
- Calcination at kiln inlet: 90-95%.

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**ILC kiln system with five-stage preheater and SF Cross-Bar™ cooler**

Typical temperatures in the system are indicated, together with the negative pressure in the exhaust gas exit, based on a system designed for minimum overall pressure drop. When designed for bypassing 30% or more of the kiln gases, the layout of the system will be slightly different, as the tertiary air duct is connected to the kiln riser duct at a point below the calciner. This system is called the ILC-I calciner system.
**SLC-D: Separate Line Calciner - Downdraft**

**Special advantages**
- High material and gas retention times in the calciner/combustion chamber whose dimensions are minimal since the kiln gases do not pass through it.
- Very well suited for all fuel types, especially low-volatile fuels, as the combustion in the calciner takes place in hot atmospheric air and the combustion temperature in the calciner can be controlled independently of the temperature of the calcined material fed to the kiln.
- Low NOx operation is possible.
- Smallest possible tower dimensions, as the calciner can be installed separately from the cyclone tower.
- Especially well suited for retrofits of existing SP or ILC preheaters due to very short down time.

**Features**
- Normal capacity range: 1500-5000 tpd, with multiple strings > 10,000 tpd.
- Firing in calciner: 55-60%.
- Bypass of kiln gas: 0-60%.
- Maximum bypass regulation range: 30%.
- Calcination at kiln inlet: 90-95%.

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**SLC-D kiln system with five-stage preheater and SF Cross-Bar™ cooler**

Typical temperatures in the system are indicated, together with the negative pressure in the exhaust gas exit, based on a system designed for minimum overall pressure drop. For production capacities exceeding approximately 5000 tpd, the system is equipped with two or more preheater strings, this also being the case if a particularly low preheater tower is required.
**Special advantages**

- High material and gas retention times in the calciner whose dimensions are minimal since the kiln gases do not pass through it.
- Very well suited for all fuel types, even low-volatile fuels, as the combustion in the calciner takes place in hot atmospheric air, and (as an option) the combustion temperature in the calciner can be controlled independently of the temperature of the calcined material fed to the kiln.
- Long refractory life due to low thermal kiln load and stable kiln coating.
- Independent and accurate draft control for kiln and calciner strings by adjusting speed of individual fans.
- No damper in tertiary air duct.
- Production down to 40% of capacity using kiln string only.
- Production down to 20% of capacity for three-string version.

**Features**

- Normal capacity range: 3000-7500 tpd (one C-string), 7500-12,000 tpd (two C-strings)
- Firing in calciner: 55-60%
- Bypass of kiln gas: 0-100%
- Maximum bypass regulation range: 30%
- Calcination at kiln inlet: 90-95%

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**SLC: Separate Line Calciner**

**Features**

- Normal capacity range: 3000-7500 tpd (one C-string), 7500-12,000 tpd (two C-strings)
- Firing in calciner: 55-60%
- Bypass of kiln gas: 0-100%
- Maximum bypass regulation range: 30%
- Calcination at kiln inlet: 90-95%

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**SLC kiln system with SF Cross-Bar™ cooler and five-stage preheater in the kiln and the calciner strings**

Typical temperatures in the system are indicated, together with the negative pressure in the exhaust gas exits, based on a system designed for minimum overall pressure drop. The system offers the possibility of controlling the temperature level inside the calciner, as part of the raw meal from the second-lowest cyclone stage in the calciner string can be fed directly to the kiln riser and/or the upper portion of the calciner vessel.
**SLC-I: Separate Line Calciner with In-line Calciner**

**Special advantages**
- Very well suited for all fuel types, even low-volatile fuels, as the combustion in the SLC calciner takes place in hot atmospheric air, and (as an option) the combustion temperature in the SLC calciner can be controlled independently of the temperature of the calcined material fed to the kiln.
- Independent and accurate draft control for kiln and calciner strings by adjusting speed of individual fans.
- Production up to 50% of capacity using kiln string only (ILC or ILC-E).
- Same cyclone sizes and feed systems for both strings.

**Features**
- Normal capacity range: 6500-9000 tpd.
- Firing in kiln string ILC: 10-15%.
- Firing in calciner string SLC: 40-50%.
- Bypass of kiln gas: 0-30%.
- Calcination at kiln inlet: 90-95%

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**SLC-I kiln system with SF Cross-Bar™ cooler and five-stage preheaters in both the kiln and calciner strings**

Typical temperatures are indicated, together with the negative pressure in the exhaust gas exits, based on a system designed for minimum overall pressure drop. The system has the added advantages of having equal cyclone sizes in both strings, as well as increased capacity and improved fuel consumption when only the kiln string is in operation.

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1. Raw meal feed
2. Exhaust gas
3. Kiln gas by-pass, if any
4. Clinker
5. Kiln burner
6. Calciner burners
7. Tertiary air duct
8. Cooler excess air
9. Raw meal dividing gate
10. Raw meal change-over gate
Selecting the proper kiln system configuration for a given project is a complicated task that involves a number of considerations. During the initial planning stage it will often be useful to consult F.L.Smidth who has gained a wealth of experience from a large variety of cement projects. As a general guide to choosing the most suitable new kiln system, a number of criteria should be considered, the most important of which are as follows:

Production capacity and investment costs
For any given production capacity, a precalcining system requires considerably smaller rotary kiln dimensions than a simple suspension preheater system.

F.L.Smidth normally recommends a rotary kiln diameter not exceeding 6 metres to ensure reasonably long lining life. For this reason, it is advisable to employ a precalcining system (with tertiary air duct) for kiln productions above 3500 tpd.

On the other hand, the simplicity of the ILC-E kiln system equipped with a planetary cooler makes it the most economical solution for production capacities up to about 3000 tpd. Of course, the lowest-possible heat consumption and clinker temperature are attained by replacing the planetary cooler with a modern SF Cross-Bar™ cooler. For this reason, the grate cooler is the logical choice for most new kiln installations – particularly when taking future expansion into account.

Single-string preheaters are preferred as long as the cyclone diameter remains within reasonable limits. This allows the SP and ILC-E systems to be used as single strings up to a production capacity of 3000-3500 tpd. Similarly, the ILC and SLC-D systems can be used as single strings up to about 5000 tpd. In contrast, the SLC and SLC-I systems always have at least two preheater strings and, therefore, will normally only be considered for throughput capacities above 3500-4500 tpd.

Table 1 shows the six different preheater/ precalciner configurations as a function of production capacity along with standard kiln sizes. The SP kiln system is also shown for comparison, although this would not normally be a preferred solution for a new installation.

Operation and maintenance
These days, precalciner systems are generally preferred to SP-type kiln systems due to the fixed degree of calcination of the material entering the kiln and the shorter material retention time in the system. Longer lining life and lower kiln refractory weight enable precalcining kiln systems to remain in operation for longer periods than SP kilns, thus reducing down time and refractory costs.
Generally, the maintenance costs of a single-string kiln system are lower than those of a double-string kiln system. Consequently, a single-string preheater is always preferable to a double-string preheater for small-to-medium production capacities, provided there are no tower height limitations.

**Fuel types and grades**

All F.L.Smidth kiln systems can be fired with natural gas, heavy fuel oil, standard coal grades or a combination of these fuels. Special fuels, however, require special considerations when selecting the appropriate kiln system configuration:

**Low-volatile fuels**

Fuels such as anthracite, petroleum coke, and other low-reactive fuels pose no problem in the kiln which operates at a high temperature. The kiln burner, however, should be of the modern flame-shaping type, such as the DUOFLEX which has a suitable flow pattern that ensures rapid and stable ignition.

The use of low-volatile fuels in calciners (that usually operate at a temperature around 900°C) can cause problems unless the system is provided with a high-temperature calciner. All our calciner systems are suited for the use of low-volatile fuels as they are designed to allow raising the temperature in the combustion chamber without affecting the rest of the system. This is accomplished by means of a dividing gate that leads a relatively large amount of raw meal to the calciner and/or the kiln riser duct.

**Low-calorific fuels**

Fuels with high ash content rarely cause problems in the calciner because the ash is intimately mixed into the raw meal as a consequence of the turbulence and high material retention time. However, the use of such fuels for kiln firing can cause problems such as (1) the inability to reach sufficiently high flame temperature, and (2) the non-homogeneous mixing of ash into the kiln charge which is already nodulised and partially fused. For this reason, a precalcining system is always preferred when using low-grade coals because the total input ash content to the kiln burning zone is greatly reduced. Each type of fuel should be considered separately.

Typically, the lower limit for net heating value will be 3800 kcal/kg for the calciner and 4000 kcal/kg for the kiln. The separate combustion chamber design of the SLC-D system often allows using alternative fuels of a net heat value as low as 2800 kcal/kg.

**Combustible waste**

Used car tyres, wood, rice shells, etc. may be used as partial substitution for ordinary types of fuel, provided they contain no chemical compounds that might damage clinker quality or hinder smooth kiln operation. Normally, such fuels are fed into the kiln riser for subsequent complete combustion at the kiln inlet. With the ILC precalcining system more than 50% of the fuel can be replaced by combustible waste which is burned in a separate combustion chamber with a HOTDISC. Due to its high temperature and retention time (> 1200°C and > 2 seconds), the kiln is well suited as an incinerator for hazardous wastes which are thus safely disposed of while providing additional heat. However, each type of waste must be considered individually, taking local emission regulations and occupational health and safety issues into account.
Type selection guidelines

Table 2: Heat economy, pressure drop & power consumption

<table>
<thead>
<tr>
<th>SLC</th>
<th>ILC</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-stage</td>
<td>6-stage</td>
</tr>
<tr>
<td>Heat balance in (kcal/kg clinker)</td>
<td>166</td>
</tr>
<tr>
<td>+ radiation loss from preheater</td>
<td>34</td>
</tr>
<tr>
<td>+ radiation loss from kiln</td>
<td>23</td>
</tr>
<tr>
<td>+ heat of reaction</td>
<td>390</td>
</tr>
<tr>
<td>+ free water</td>
<td>2</td>
</tr>
<tr>
<td>+ VDZ cooler loss</td>
<td>103</td>
</tr>
<tr>
<td>+ heat of clinker at amb temp.</td>
<td>4</td>
</tr>
<tr>
<td>- heat in raw meal, air and fuel</td>
<td>32</td>
</tr>
<tr>
<td>- combustibles in raw meal</td>
<td>8</td>
</tr>
<tr>
<td>Net specific heat consumption</td>
<td>682</td>
</tr>
<tr>
<td>Exhaust gas temperature (°C)</td>
<td>352-303</td>
</tr>
<tr>
<td>Pressure loss preheater (mmWG)</td>
<td>328-315</td>
</tr>
<tr>
<td>Pressure loss in rest of system (mmWG)</td>
<td>30-140</td>
</tr>
<tr>
<td>Total pressure loss (mmWG)</td>
<td>358-455</td>
</tr>
<tr>
<td>Power consumption (kWh/t clinker)</td>
<td></td>
</tr>
<tr>
<td>ID fan(s)</td>
<td>4.95</td>
</tr>
<tr>
<td>Cooler (drive + fans + crusher)</td>
<td>5.20</td>
</tr>
<tr>
<td>Kiln drive</td>
<td>2.00</td>
</tr>
<tr>
<td>Primary air fan</td>
<td>1.00</td>
</tr>
<tr>
<td>Cooler vent system</td>
<td>0.80</td>
</tr>
<tr>
<td>Total spec. power consumption</td>
<td>13.95</td>
</tr>
</tbody>
</table>

| EP(1) | FF(2) | FF(2) | EP(1) |

- **Heat efficiency**

The specific heat consumption of the various kiln systems depends mainly on the size of the kiln, the number of preheater stages, the rate of kiln bypass (if any), the raw mix composition, and the fuel type.

Table 2 shows typical heat balances for five-stage and six-stage SLC and ILC kiln systems. As shown, the specific heat consumption of the six-stage preheater system is 10 kcal/kg clinker lower than that of the equivalent five-stage system. By comparison, the specific heat consumption of the five-stage preheater system is 20-25 kcal/kg clinker lower than that of the equivalent four-stage system.

- **Pressure drop and power consumption**

The most power-consuming parts of a kiln system are the exhaust gas fan motor(s), the cooler fan motors and the kiln drive motor.

The power consumption of the exhaust gas fan(s) mainly depends on the total pressure drop in the kiln system. Most of this pressure drop occurs in the preheater. Increasing the preheater cyclone dimensions will reduce the pressure drop, but for any given preheater geometry stable preheater operation (without raw meal falling through the riser ducts) requires a certain minimum pressure drop.

The Low Pressure (LP) cyclone, a standard component in all FLS kiln systems, was developed to ensure a low pressure drop in the preheater while maintaining reasonably small cyclone dimensions.

The table compares the specific power consumption of an SLC and an ILC kiln system, both equipped with LP cyclone preheaters. It also shows a comparison between the two...

Table 2: Typical process values of SLC and ILC kilns with five and six-stage preheaters.

(1) Includes electrostatic precipitator, vent fan and dust conveying system.

(2) Includes fabric filter, heat exchanger, vent fan and dust conveying system.
modern types of cooler venting systems (electrostatic precipitator versus fabric filter and heat exchanger).

For many years, costs have favoured the use of electrostatic precipitators (EP) for this purpose because of the higher running costs of fabric filters (FFs) in terms of power consumption and maintenance (bag replacement). However, with the tightening of emission standards, FFs will tend to be preferred for cooler venting installations, because the EP size increases proportionately with tighter emission standards, while the FF size remains constant.

**Raw materials**

The content of volatile matter in the raw materials is an important factor when choosing the appropriate kiln system.

Volatile matter in connection with kiln operation is usually understood as components containing the elements potassium (K), sodium (Na), sulphur (S), and chloride (Cl). Small quantities of these components will inevitably enter the kiln system with the raw mix and the fuel. On reaching the kiln burning zone, some of the volatile components evaporate and are carried with the kiln gas to the preheater where they condense.

The resulting internal circulation of volatile matter in the kiln system and the concentration of these components in the kiln gases flowing to the preheater eventually reaches such levels that it affects kiln operation. The higher concentration of volatile matter increases dust stickiness which in turn causes coating formation and cyclone blockages.

The type of process selected sets an upper limit to the acceptable content of the various volatile components in the raw mix (and the fuel) used in a preheater kiln system without a bypass. The upper limit tends to be slightly lower with a precalcining system (with tertiary air duct) than with an SP kiln system due to the higher volatile concentration in the gases of a precalcining system which is caused by the lower specific gas flow through the kiln, see table 3.

If the volatile content in the raw mix (and fuel) is higher than these upper limits, the kiln system must be equipped with a bypass that enables extracting some of the kiln gas from the system before it reaches the preheater. In this way, internal circulation of volatile matter is reduced. Bypassing a few per cent of the kiln gases is sufficient to reduce the internal circulation of chloride in the kiln system to an acceptable level. Excessive sulphur circulation requires a somewhat higher degree of kiln gas bypass.

To produce low-alkali cement it may also be desirable to remove large quantities of alkalis through a kiln bypass. This requires a high bypass rate, and a precalcining system with tertiary air duct will be appropriate. For a given amount of kiln gas extracted, higher alkali reduction is obtained in a precalcining system than in a conventional kiln system. A certain reduction of alkali in the clinker can be attained by the lowest-possible increase in the specific fuel consumption.

The ILC-I and SLC kiln systems allow bypassing up to 100% of the kiln gas while the other kiln systems can be equipped with a bypass carrying maximum 25-60% of the kiln gas, which in most cases will suffice to ensure smooth operation, even with low-grade raw materials.

Table 3: The upper limits apply to a raw mix of good burnability and an ideal sulphur/alkali ratio.

<table>
<thead>
<tr>
<th>Volatile Component</th>
<th>Normal limit</th>
<th>High limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine as Cl</td>
<td>0.023%</td>
<td>0.029%</td>
</tr>
<tr>
<td>Sulphur as SO_3</td>
<td>1.25%</td>
<td>1.9%</td>
</tr>
<tr>
<td>0.65 * K_2O + Na_2O</td>
<td>1.0%</td>
<td>1.5%</td>
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</tbody>
</table>
Cyclone preheater

All six kiln systems are supplied with a four-stage, five-stage, or six-stage cyclone preheater equipped with Low Pressure (LP) cyclones.

The unique design of the LP cyclone ensures high thermal efficiency and low pressure drop while enabling moderate preheater tower dimensions.

A four-stage preheater can be designed for a pressure drop down to 210 mm WG across the preheater itself, while a five-stage preheater can be designed for a pressure drop down to 280 mm WG at nominal capacity. Even with these low nominal pressure drops, the preheaters operate smoothly down to 70-80% of rated capacity without increasing the percentage of excess air.

Since the LP cyclones have no horizontal surfaces on the inside, no material will accumulate and this, in turn, ensures smooth operation.

The lowermost cyclone (exposed to gas temperatures of about 900°C) is equipped with a cast, segmented central pipe (thimble) of special alloy which maximises thermal efficiency while ensuring long life.

The central pipe is easy to install and, because it consists of segments, will fit any size of cyclone both in new and existing preheaters.

To prevent the gas from bypassing up through the material chutes between the individual cyclone stages, the chutes are equipped with tipping valves. Distribution boxes with adjustable spreader plates ensure excellent material distribution in the individual riser ducts. Change-over gates and dividing gates are used to efficiently distribute the raw meal.
In the following pages, the three basic types of calciners (In-line, Separate-line, and Downdraft calciners) offered by F.L.Smidth are discussed in detail.

All F.L.Smidth calciners are specifically designed to meet today’s most stringent emissions limits by minimizing NOx and CO emissions among other pollutants. This is best accomplished through the use of a cylindrically-shaped vessel with a conical bottom. The cylindrical design ensures ample internal volume while minimizing calciner weight and surface heat loss.

All F.L.Smidth low NOx calciners are designed for (1) localized reducing conditions and/or (2) high temperature calcination both of which are proven to significantly minimize NOx emissions. The elevated temperature designs are also particularly suited for the use of low volatile fuels.

In fact, many F.L.Smidth calciner designs are specifically tailored for today’s demands for the firing of low-reactive and hard-to-burn fuels. All calciners can be fired with liquid, gaseous or solid fuels. The calciner burners are placed so that the fuel is well distributed across the calciner cross section so that it ignites rapidly in the presence of tertiary air. The downdraft calciner, for example, is equipped with a vertical burner that makes it particularly well suited for low volatile fuels.

All F.L.Smidth calciners (and preheaters) are lined with wear-resistant refractory bricks on all cylindrical and conical surfaces. The irregularly shaped areas are lined with castable. The wear-resistant lining is fitted on a back lining of insulated blocks, which ensures a very low heat loss from the calciner and/or preheater surface. F.L.Smidth calciner types are best classified into the following three groups:

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**In-Line Calciners:**

In-line calciners are generally known to generate lower NOx emissions than separate-line calciners since all of the kiln exhaust gases must pass through the calciner.

F.L.Smidth’s patented Low NOx ILC design is based on dividing the meal from the second lowest preheater cyclone to (1) the kiln riser and (2) the calciner, which are separated by an expanded riser duct that forms a reducing zone. That is, the calcining chamber is built (at least partially) into the kiln riser. In this way, a very simple means of creating low NOx emissions without splitting of tertiary air is attained by firing 100% of the fuel to the kiln riser duct which made possible by means of a single meal split to this “reduction zone”. As a result, it is possible to obtain both reducing conditions and high temperature calcination in one simplistic system (without multiple firing points) for the lowest possible NOx emissions. The combustion air is drawn either through the kiln or through a separate tertiary air duct. Because the kiln combustion gases are drawn through the calciner, the calciner size is necessarily larger to attain the required gas velocity and retension time.

Following the reduction zone, the calciner’s cylindrical section sequentially tapered. The resultant rapid changes in cross-sectional areas create strong vortexes ensuring effective mixing of fuel, raw meal, and gas. The top of the calciner is most often provided with a loop duct to ensure optimum gas retention time, mixing and complete combustion of the fuel.

In the ILC-E configuration, kiln exhaust gas enters the calciner axially through the bottom cone and the calciner exhaust gas leaves the calciner through a side outlet at the top. In the ILC configuration, kiln exhaust gas enters the calciner axially through the bottom cone and leaves through an outlet connected to a central outlet pipe. The mixing of the fuel, raw meal and gas is further enhanced by the tertiary air duct being fitted tangentially on the calciner. This causes a moderate swirl in the calciner which further increases particle retention time. When designed for bypassing 30% or more of the kiln gases, the tertiary air duct is connected to the kiln riser (in an ILC-I configuration) rather than tangentially connected to the calciner.
**Separate-Line**

Separate-line calciners are also known as “air-only” calciners since the calcining chamber is at least partially offset from the kiln riser. The combustion air is always drawn through a separate tertiary air duct. Because the kiln combustion gases do not pass through the calciner, the calciner size can be reduced to attain the required gas velocity and retention time. This often results in a shorter preheater structure (and a shorter erection period for retrofits) since the calciner can be readily situated outside of the preheater structure.

In the SLC configuration, the hot tertiary air from the cooler enters the calciner through the central inlet in the bottom cone and leaves through either a side outlet or in case high temperature operation is planned through an outlet cone connected to a central outlet pipe.

In the SLC-I configuration, a calciner is built parallel to the kiln riser duct as described above and a second calciner is built into the kiln riser duct. This design effectively destroys thermal NOx generated in the burning zone of the kiln. Fuel NOx generated in the calciner is effectively minimized through high temperature operation.

A unique feature of the high temperature calciner system is the fact that the temperature inside the calciner is independently controlled by the position of the gate that divides the raw meal flow to the calciner and to the kiln riser duct, respectively.

So, by feeding a relatively larger amount of raw meal to the kiln riser duct and keeping the fuel input to the calciner constant, the mean temperature in the calciner vessel can be brought up to 950° – 1050°C. The temperature of the exit gas and the degree of calcination of the raw meal leaving the calciner will increase accordingly. However, when mixing with the kiln exhaust gas that contains uncalcined raw meal, the temperature of the gas/particle suspension falls to approximately 900°C. So a normal temperature level is maintained in the calciner cyclone. Similarly, a normal degree of calcination of 90-95% is maintained for the raw meal supplied to the kiln.

The higher temperature in the calciner ensures effective combustion of even low-reactive fuels and helps to greatly minimize fuel NOx formation.

The calciners of the SLC and SLC-I systems are characterized by a strong vortex formation in the bottom cone, ensuring effective mixing of raw meal, fuel and tertiary air for a high particle-to-gas retention time (measured to be approximately 4 in an industrial-scale calciner).
Downdraft types
The downdraft calciner is specifically tailored for low-reactive and hard-to-burn fuels since the combustion air for the downdraft calciner (DDC) is drawn solely from the clinker cooler. The separate-line features of this calciner design minimize the height of the preheater structure since a substantial portion of the total retention time takes place parallel to the kiln riser duct. The placement of the combustion chamber outside the preheater structure makes this calciner design well suited for retrofits since down time is minimized.

The SLC-D configuration combines the advantages of the well-known Separate-line calciners with the low NOx features of the In-line calciner when a portion of the calciner fuel is directed to the kiln riser duct. This effectively destroys thermal NOx formed in the kiln. Most of the fuel is introduced via a multi-channel vertical burner located in the roof of the DDC under high temperature conditions to minimize fuel NOx. In the SLC-D configuration, raw meal entrained in hot tertiary air enters the DDC at the top through a 180 degree involute (similar to an LP cyclone) and exits through a truncated cone which forms a circular duct transition to the kiln riser duct. The 180 degree involute ensures that the majority of the calcined meal is entrained along the walls of the DDC. This effectively protects the refractory lining while promoting hot core conditions for optimum combustion characteristics in the centre of the calciner.

For the same production capacity, the calciner of the SLC-D system has smaller dimensions than the ILC calciner since no kiln exhaust air is led through the calciner. This makes the SLC-D system well suited for retrofit applications even when low reactive fuels are unforeseen.
State-of-the-art systems

Designing equipment and systems for the manufacture of cement has always been a challenging task due to the variations in raw materials, the multitude of cement products required for the marketplace, and the need to minimize investment costs. In addition, integrating high-efficiency concepts with the requirement for reliability has tended to inhibit the development of new machinery and systems. However, widespread acceptance of preheater and precalciner systems has created the opportunity to evolve to the present high level of efficiency and reliability. The figures below clearly reflect the trend towards large single production lines and previously unheard-of levels of fuel consumption for the modern dry processes.

In the case of F.L.Smidth, the evolution of our designs has been driven by the continuing performance evaluation of existing systems, coupled with feedback which has identified the obstacles to achieving optimum performance of every system component. This has been particularly true for kiln system upgrading and modernisation projects. It is commonplace for F.L.Smidth to audit the performance of kiln systems before and after modification. In the process of establishing the potential modification scenarios, each preheater stage, the kiln, cooler and other system auxiliaries are analysed and compared to the standards of performance being achieved by the most modern systems that have been installed by F.L.Smidth worldwide. Some of the more notable achievements of these projects are tabulated below.

By utilising its extensive mechanical and plant design capabilities, F.L.Smidth has been able to implement the necessary modifications with minimum interruption to the plant’s normal operations. In this way, the “state of the art” has been advanced for existing plants as well as greenfield facilities.

### Examples of F.L.Smidth plants operating with low heat consumption

<table>
<thead>
<tr>
<th>Heat balance (kcal/kg clinker)</th>
<th>Plant A Mexico</th>
<th>Plant B Indonesia</th>
<th>Plant C USA</th>
<th>Plant D Thailand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat in exhaust gas and dust</td>
<td>134</td>
<td>184</td>
<td>135</td>
<td>182</td>
</tr>
<tr>
<td>Heat in free water evaporation</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Heat in bypass gas</td>
<td>0</td>
<td>0</td>
<td>39</td>
<td>0</td>
</tr>
<tr>
<td>Radiation loss from preheater</td>
<td>37</td>
<td>22</td>
<td>48</td>
<td>35</td>
</tr>
<tr>
<td>Radiation loss from kiln</td>
<td>28</td>
<td>31</td>
<td>44</td>
<td>25</td>
</tr>
<tr>
<td>Total cooler loss</td>
<td>132</td>
<td>125</td>
<td>113</td>
<td>124</td>
</tr>
<tr>
<td>Heat of reaction</td>
<td>374</td>
<td>384</td>
<td>320</td>
<td>360</td>
</tr>
<tr>
<td>Free heat from air, fuel and feed</td>
<td>-30</td>
<td>-29</td>
<td>-31</td>
<td>-33</td>
</tr>
<tr>
<td>Net specific heat consumption</td>
<td>677</td>
<td>719</td>
<td>673 (651 w/o bypass)</td>
<td>697</td>
</tr>
</tbody>
</table>

Plant A – 6-stage ILC preheater w/2-support kiln and conventional cooler (3000 MTPD)
Plant B – 4-stage SLC-I preheater w/conventional cooler (7800 MTPD)
Plant C – 6-stage ILC preheater w/SF Cross-Bar cooler and 15% operating bypass (3700 MTPD)
Plant D – 5-stage SLC preheater w/ conventional cooler (10,000 MTPD)
Data in this brochure is intended for preliminary project planning only. Manufacturer reserves the right to modify equipment details and/or specifications without notice.