

Cement Seminar

Process Technology

Clinker Coolers

SUMMARY

Clinker coolers reduce the clinker temperature from approx. 1400°C to approx. 100...200°C. The heat of the incoming clinker is recuperated in the secondary air at an efficiency which usually lies within 65.. 70 %.

The different cooler types of major importance are:

GRATE COOLER

- Crossflow heat exchange through clinker bed with cold air.
- Reciprocating grate type: each alternate row consisting of movable (reciprocating) steel plates; grates can either be horizontal or inclined (approx. 3°).
- Occurrence of waste air requires additional equipment for dedusting. Possible alternative: waste air free cooler with air / air heat exchanger and recirculation.
- Capacities of up to 10'000 t/d.
- Alternative forms with two stage cooling and air recirculation are possible.
- Travelling grate type: usually poor clinker distribution and movement on the grate and therefore lower efficiency.

ROTARY COOLER

- Separate tube with separate drive.
- Internal heat transfer equipment (lifters).
- No waste air.
- Capacities of up to 4500 t/d maximum, preferably up to 2000 t/d.

PLANETARY COOLER

- Set of tubes fixed to the kiln, therefore no separate drive required.
- Internal heat transfer equipment (lifters).
- No waste air.
- Not suitable for AS (separate tertiary air duct) precalcining systems.
- Capacities of up to 5000 t/d maximum, preferably up to 3500 t/d.

CLINKER COOLERS

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1. GENERAL CONSIDERATIONS

The clinker cooler has the following main functions:

- Recuperate the clinker heat by heating up the combustion air (secondary and tertiary air),
- Maintain a minimum cooling velocity in order to avoid unfavourable mineralogical clinker phases and crystal size,
- Facilitate clinker handling and storage.

Three groups of coolers can be defined according to their working principle:

- a) On a grate cooler the clinker forms a bed which is transported along the grate by different mechanisms. The cooling air is blown from below the grate by fans and passes through the clinker bed in cross current. Only a part of this air can be used as combustion air, the rest of it has to be dedusted and wasted, unless it can be used for another purpose (e.g. raw material or coal drying, fuel oil preheating, heating of buildings, warm water preparation, etc.).
- b) The operating principle of a tube cooler is quite similar to the one of a rotary kiln: the material and the cooling air are led in counter current through one or more slightly inclined rotating tubes. Special lifters are installed which increase the active heat transfer area between clinker and cooling air.
- c) In the shaft cooler, a nearly ideal counter current heat exchange takes place between the clinker moving down by gravity and the rising cooling air. However, due to various disadvantages, this type of cooler did not find a wide application up to now.

In order to compare different cooler systems, it is usual to define a thermal cooler efficiency as the ratio

$$\eta = \frac{\text{heat content of combustion air}}{\text{heat content of the clinker at the kiln discharge}}$$

with the heat contents relative to ambient temperature. It should however be pointed out that the cooler efficiency depends on the required combustion air of the kiln system. Therefore a cooler comparison only makes sense if done for kiln systems operating with:

- identical heat consumption,
- same excess air factor,
- same primary air ratio.

For a conventional 4st SP kiln system, coolers of type a) and b) have an efficiency in the range of 65 to 70 %.

2. GRATE COOLER

Among all cooler types, the grate cooler offers the highest independence with regard to kiln operation, allowing to keep the combustion air and the clinker outlet temperatures in a normal range even during unstable kiln conditions. This high flexibility in cooler operation mainly results from the adjustable clinker travelling speed and cooling air quantity.

A simplified mathematical model for the clinker cooling in a grate cooler developed by HMC gives the relation between cooling air quantity and clinker temperature as follows:

$$\frac{T_{cli} - T_{amb}}{T_{cli\ in} - T_{amb}} = \exp(-V_{air}/0.77)$$

with

$T_{cli\ in}$ = clinker temperature at cooler inlet ($^{\circ}\text{C}$)
 T_{amb} = ambient temperature ($^{\circ}\text{C}$)
 V_{air} = cooling air quantity ($\text{Nm}^3/\text{kg cli}$)

The curve in Fig. 1 is drawn for the usual figures $T_{cli\ in} = 1400^{\circ}\text{C}$ and $T_{amb} = 20^{\circ}\text{C}$.

Comparisons made with coolers heat balances given by suppliers as well as existing coolers operating data showed that the simple relation above gives for most applications a quite sufficient approximation of the cooling curve, at least for modern designed grate coolers.

clinker inlet temperature : 1400 °C

ambient temperature : 20 °C

clinker temperature

°C

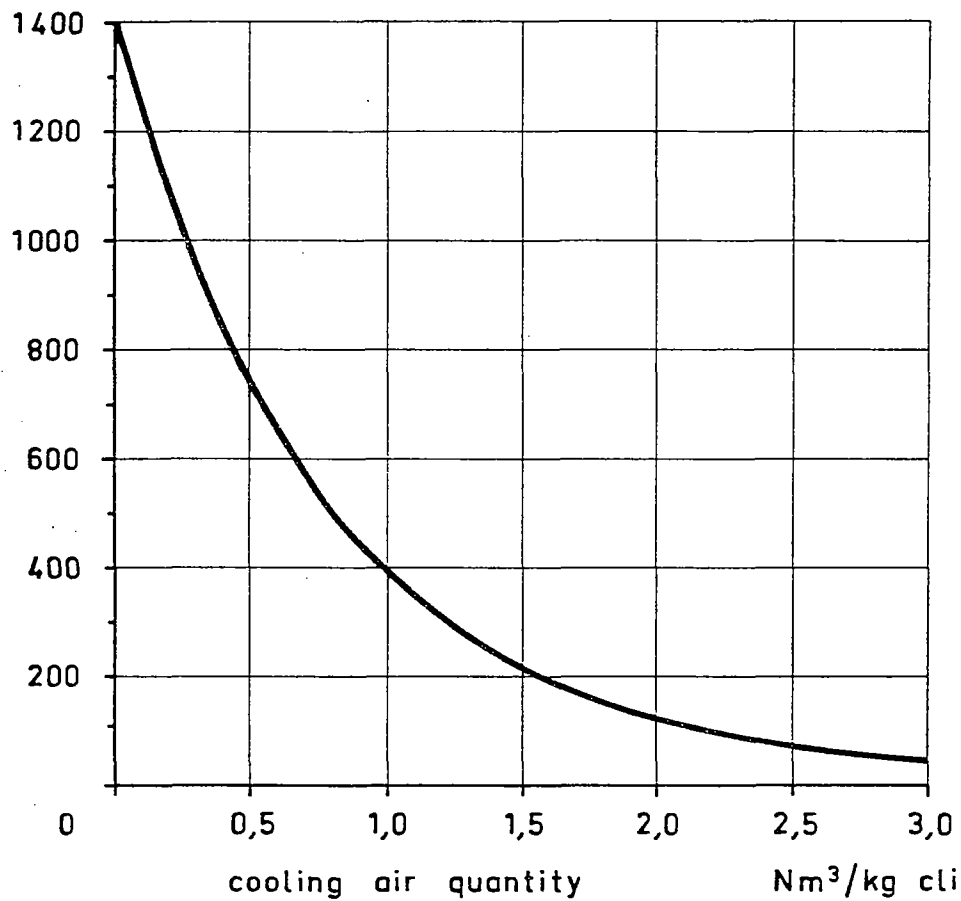


Fig. 1: Cooling of clinker in grate cooler

There exist two main types of grate coolers:

- reciprocating grate cooler
- travelling grate cooler.

They will be described more in detail in the next chapters.

2.1 Reciprocating grate cooler

Nearly all recent large capacity kiln systems with precalcining use this type of cooler. The grate consists of parallel rows of cast steel plates; each alternate row is moved forwards and backwards in order to transport the clinker along the system, as illustrated in Fig. 2.

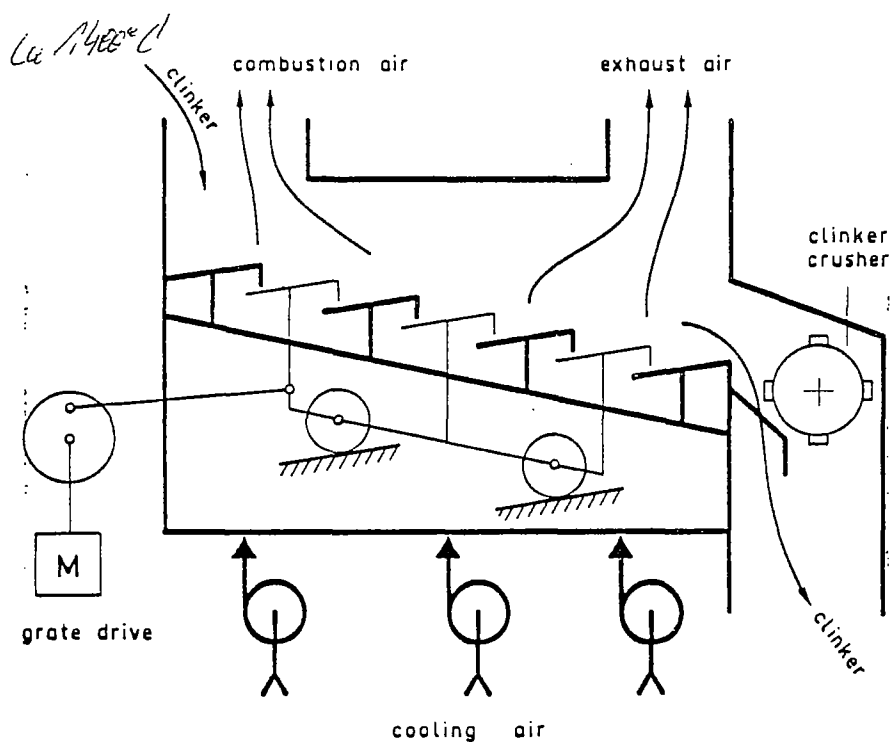


Fig. 2: Working principle of reciprocating grate cooler

Single grate coolers are built for capacities up to about 1000 t/d. For larger units, two or more grates are installed in serie, each one having its own drive. The grates can be inclined or horizontal, with the clinker breaker normally located at the discharge end or exceptionally in an intermediary position (duostage cooler), as shown in Fig. 3.

Capacities up to 10'000 t/d can be realized.

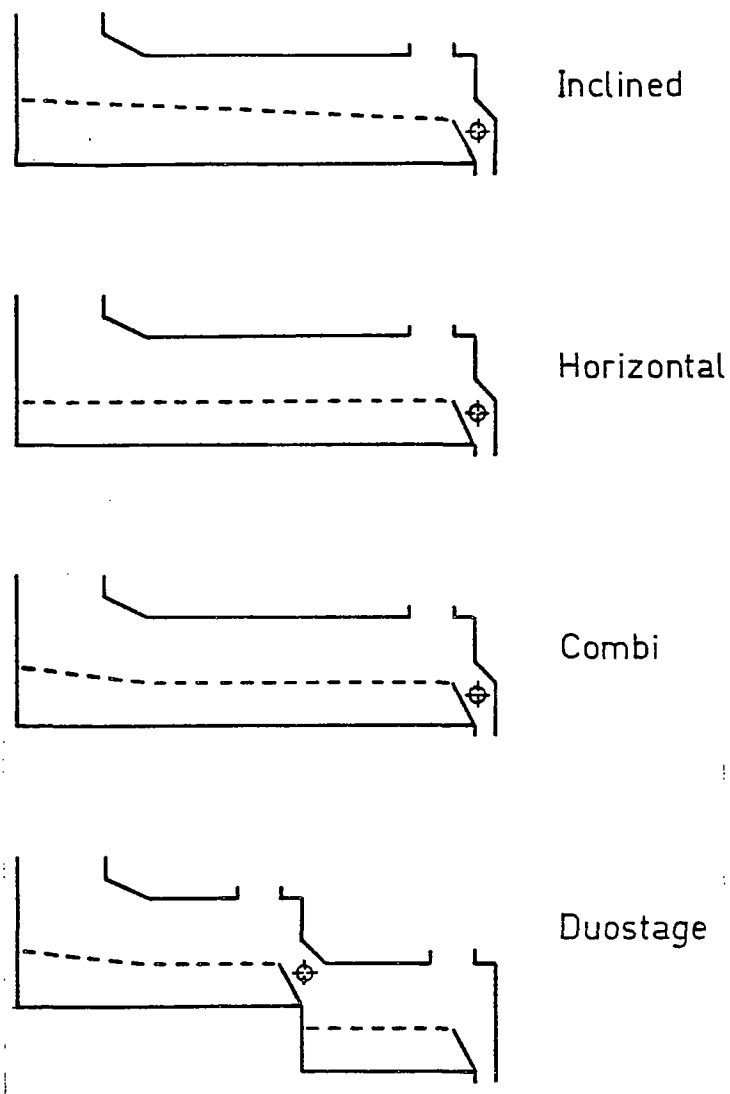


Fig. 3: Various types of reciprocating grate coolers

2.1.1 History

In order to understand better the design of today's grate cooler, a brief review of its history should be given.

The first grate coolers made in the late 1930's by Fuller Company had an inclined grate with 15° slope. This slope proved to be too steep and material fluidized and run off the grate.

The next step was to lessen the grate inclination to 10° . The 10° cooler was used almost exclusively until the mid-1950's. Problems were encountered with these coolers when the clinker was fine and started to fluidize. Wedge grates were used in an attempt to keep material from flowing off the grates. Another problem was the headroom required for the installation of large coolers.

In response to the aforementioned problems with the 10° cooler, the horizontal cooler was introduced. It first appeared in the mid 1950's and was developed simply by laying back a 10° cooler until the grate line became horizontal. Therefore the conveying efficiency was reduced. Some of these coolers were severely damaged by overheating, due to fluidization and accumulation of hot fine clinker at the feed-end.

This drawback of the horizontal cooler led to the development of the so-called combination cooler. It has one or two inclined grates with normally 3° slope, followed by horizontal grates when required for large capacities. Thus a compromise of the advantages of inclined and horizontal coolers has been realized. However, not all suppliers did adopt this solution: some of them are further building successfully pure horizontal or pure inclined grate coolers.

2.1.2 Design features of modern coolers

Fig. 4 to 8 show some aspects of modern coolers.

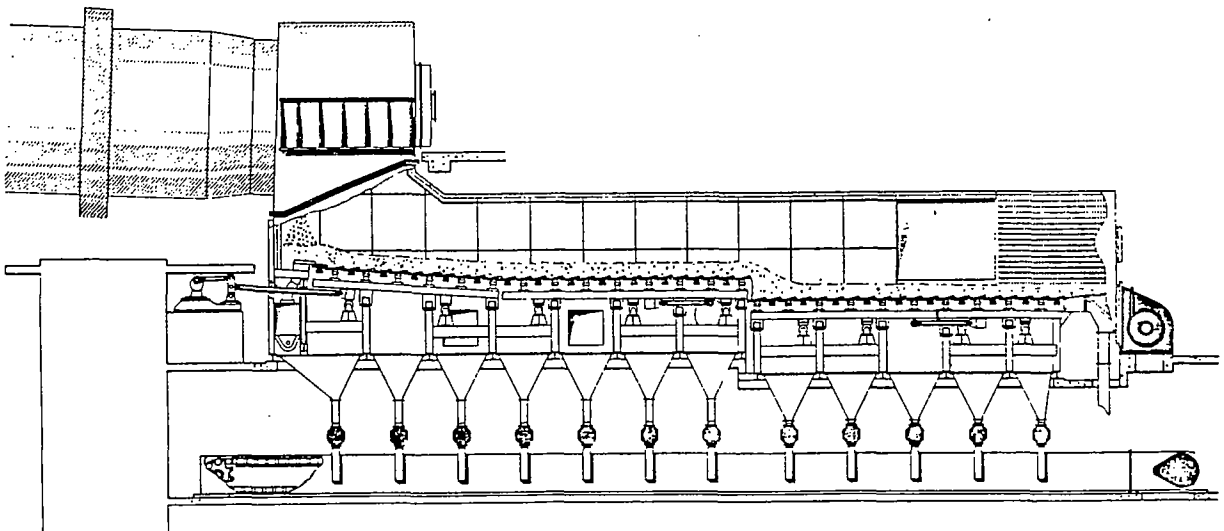


Fig. 4: Combination cooler (F.L. Smidth)

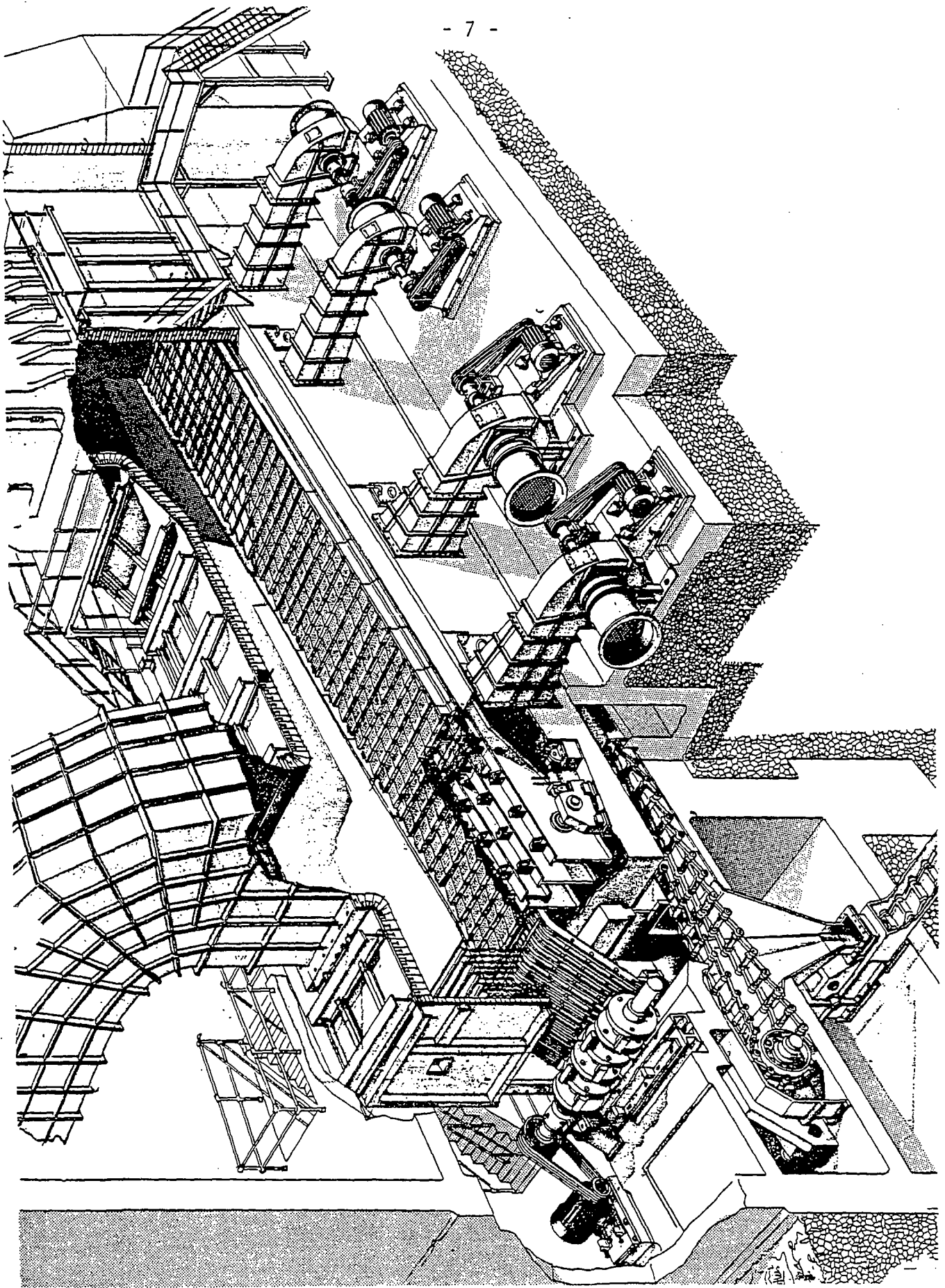


Fig. 5: Inclined cooler (Claudius Peters)

- Fuller Grate Coolers feature:
- Simple, rugged design
 - Dead grates
 - Dual width grates
 - Fingerless supports
 - Internal wheels
 - Spillage removal system

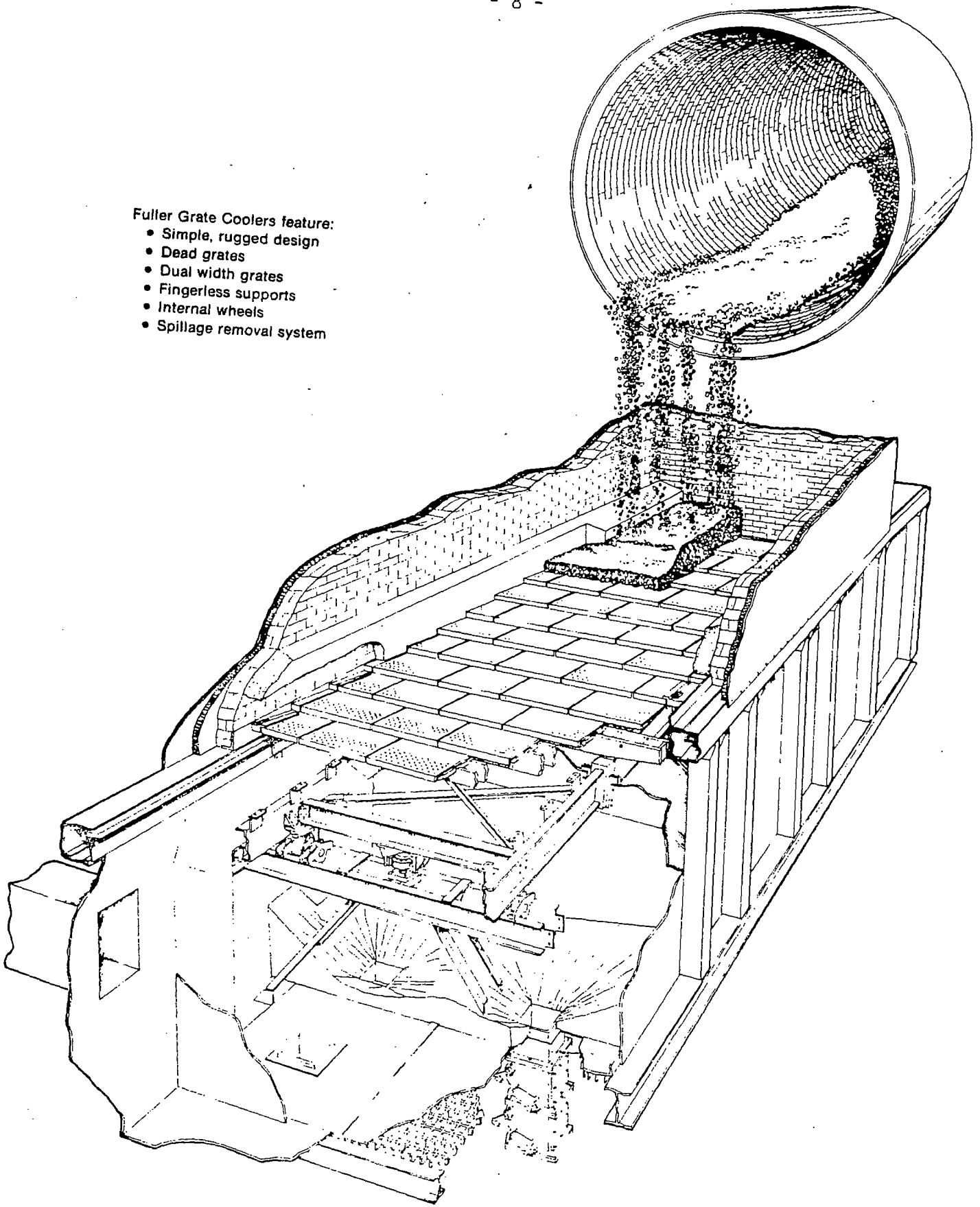


Fig. 6: Inclined cooler (Fuller Company)

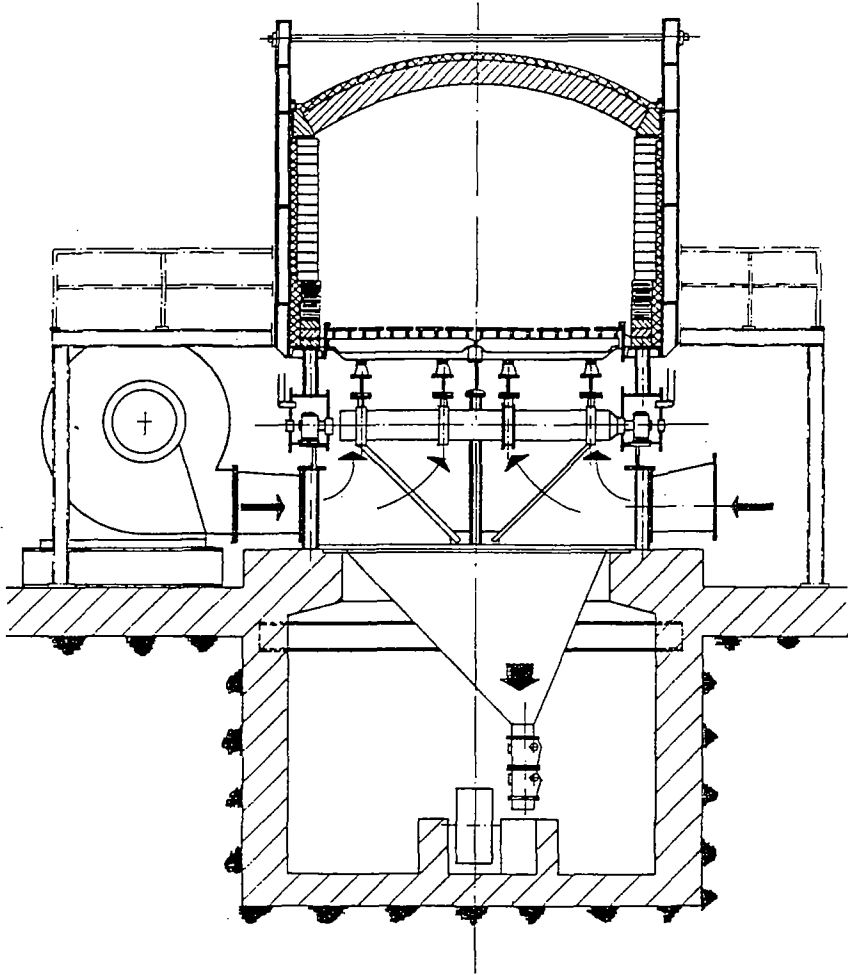


Fig. 7: Cross-section through a cooler (Polysius)

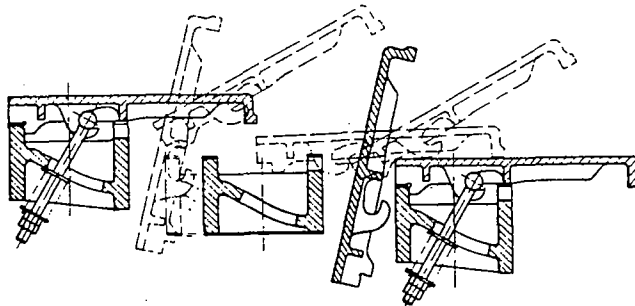


Fig. 8: Replacement of grate plates (Polysius)

The most important design features of modern grate coolers are:

- a) Reduced cooler width, especially at the feed-end ("horseshoe" grate shape), in order to operate the cooler with a thick clinker bed and consequently a good cooling air distribution and a high heat recuperation.

Due to this reduction of the grate area, specific grate loads in the range of 35 to 40 t/m²d are common today.

- b) Good sealing of the cooler compartments, by means of discharge hoppers for grate riddlings, spillage removal through double tipping valves, improved grate shaft seals. A good sealing is essential for a thick clinker bed operation requiring high cooling air pressures (about 60 - 70 mbar in the first compartment).
- c) Good accessibility of the spillage drag chain, located outside of the cooler casing.
- d) Fingerless plates supports, allowing a quick replacement of grate plates from the undergrate chamber (see Fig. 8).
- e) Hydraulic drive for each individual grate, with a speed range of 0 to 25 strokes per minute.
- f) Full width clinker breaker, easily accessible, each hammer replaceable separately.
- g) Total cooling air quantity installed in the range of 3 - 3.5 Nm³/kg cli, with fan pressures decreasing from 60 - 70 mbar in the first compartment to 20 - 30 mbar in the last one. Normally each undergrate compartment is equipped with its own cooling air fan.
- h) Possibility of recirculation of the cooler vent air (after dedusting in cyclones) to the intermediary cooling compartments, in order to increase the temperature of the middle air used for drying or heating purpose.

In parallel to the development of the grate cooler design, its availability could be drastically improved. For instance, grate plates breakages today no more belong to the normal operation and, if they still can happen accidentally, their replacement is much easier than before.

2.1.3 Cooler_control

One of the advantages of the reciprocating grate cooler is its high flexibility, due to operating variables adjustable independently from kiln operation. Usually three main variables are controlled automatically (see Fig. 9).

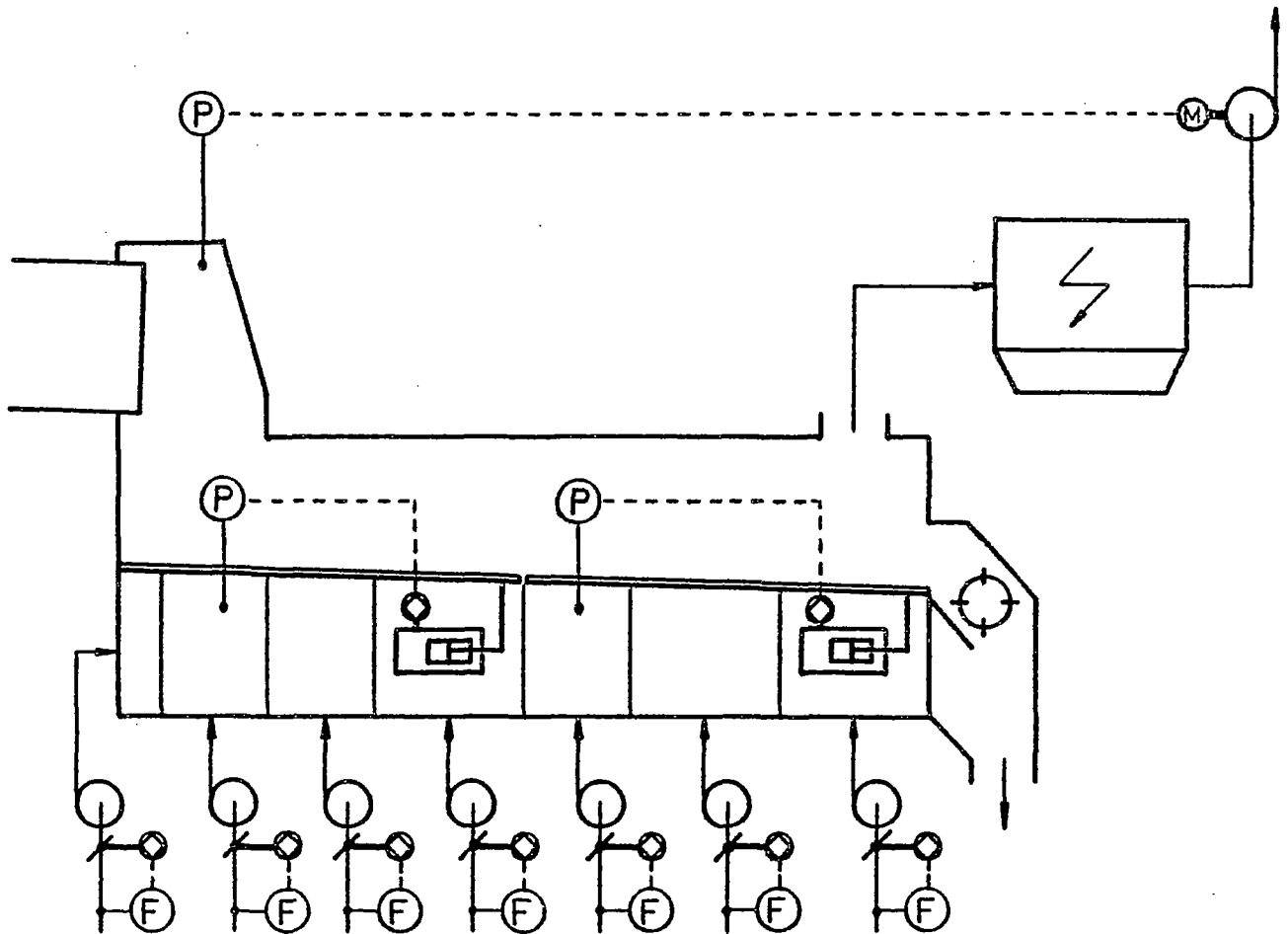


Fig. 9: Basic control loops of a grate cooler

a) Grate speed

In order to prevent the clinker bed resistance from exceeding the pressure capabilities of the cooling fans (which would mean too less cooling air and danger of heat damage), the bed resistance on the grate should be kept constant.

To do this, each grate section drive is controlled by the undergrate pressure of the first or second compartment in each grate section. An increase in pressure indicates an increase in bed resistance (either more material in the cooler or finer material). The reaction is an increase of the grate speed, causing the bed to become thinner. If the undergrate pressure decreases, the drive slows down and the bed becomes thicker.

Another possibility is to control only the first grate by the undergrate pressure, and to keep the speed of the following grates proportional to the speed of the first grate.

b) Air flow

This control is complementary to the grate speed control. It maintains a constant volume of cooling air entering the cooler independently from the grate underpressure.

Each cooling fan is equipped with a piezometer sensor, which will recognize an increase or decrease of the air flow and cause the cooling fan damper to close or open (in case of inlet vane damper control), or the fan motor speed to decrease or increase (in case of variable speed fan drives).

During normal conditions the cooling fans operate at about 2/3 to 3/4 of their maximum performance so that enough spare capacity is left to cope with eventual kiln rushes.

Together, grate speed and air flow control will on one hand ensure a sufficient cooling air supply to the cooler and, on the other hand, tend to provide more uniform combustion air temperature to the kiln.

c) Hood draft

The third component of the cooler control system is the hood draft control.

The kiln hood pressure is used to regulate the cooler vent air fan speed to maintain a constant pre-set draft. As the draft tends to become positive, the cooler vent fan speed is increased. This takes more air from the cooler and maintains the draft setpoint. As with the other controls, reaction in the opposite direction is just as important.

An automatically controlled grate cooler improves the whole kiln operation and allows the operator to concentrate on other problems.

2.1.4 Cooler dedusting

While dedusting of kiln exhaust gas can be commonly solved by using one type of dust collector only (electrostatic precipitator), the choice of the most adequate system for dedusting clinker cooler vent air raises quite often many discussions. This choice problem is basically a result of the special and fluctuating conditions of the vent air to be dedusted:

		normal operation	kiln in upset conditions
air flow (actual volume)	%	100	up to 150
air temperature	°C	200 - 250	up to 450
air dew point	°C	5 - 20	5 - 20
dust load	g/Nm ³	5 - 15	25 - 35

Further the dust particle size distribution can vary in a wide range depending on the burning conditions in the kiln.

Dimensioning of the dedusting equipment must of course take into account the worst conditions, as to be able to meet the required clean gas dust content at any time during kiln operation.

The types of dust collectors normally used to overcome this dedusting problem are summarized in Table 1 with their main advantages and disadvantages. Generally speaking one can say that:

- multiclones will no more be installed in new plants
- use of electrostatic precipitators is now possible without restriction
- gravel bed filters have proved to be very suitable
- bag filters require a preliminary cooling of the vent air.

Type of collector	Advantage	Disadvantage
multiclone	<ul style="list-style-type: none"> - simple - low investment cost - low space requirement - not sensitive to temperature peaks - good experience for many years 	<ul style="list-style-type: none"> - poor efficiency for particles $< 20 \mu\text{m}$ - efficiency sensitive to gas flow fluctuation - comparatively high pressure loss - high operating cost
electrostatic precipitator	<ul style="list-style-type: none"> - high efficiency - low pressure loss - low operating cost - low maintenance cost 	<ul style="list-style-type: none"> - big unit required or use of pulse generator \rightarrow high investment cost - possibly water injection required
gravel bed filter	<ul style="list-style-type: none"> - high efficiency - not sensitive to temperature peaks - experience with many units in operation 	<ul style="list-style-type: none"> - highest investment cost - highest pressure loss - high operating cost
bag filter	<ul style="list-style-type: none"> - high efficiency - relatively low investment cost 	<ul style="list-style-type: none"> - no bags withstanding temp. up to $450^{\circ}\text{C} \rightarrow$ pre-cooling required - high pressure loss - high operating cost - high maintenance cost

Table 1: Comparison of dedusting equipment for clinker cooler

2.1.5 Non-ventilating cooler

A patent has been taken out in 1970 by the "Société des Ciments Français" concerning the recirculation of the vent air after sending it through a heat exchanger (Fig. 10).

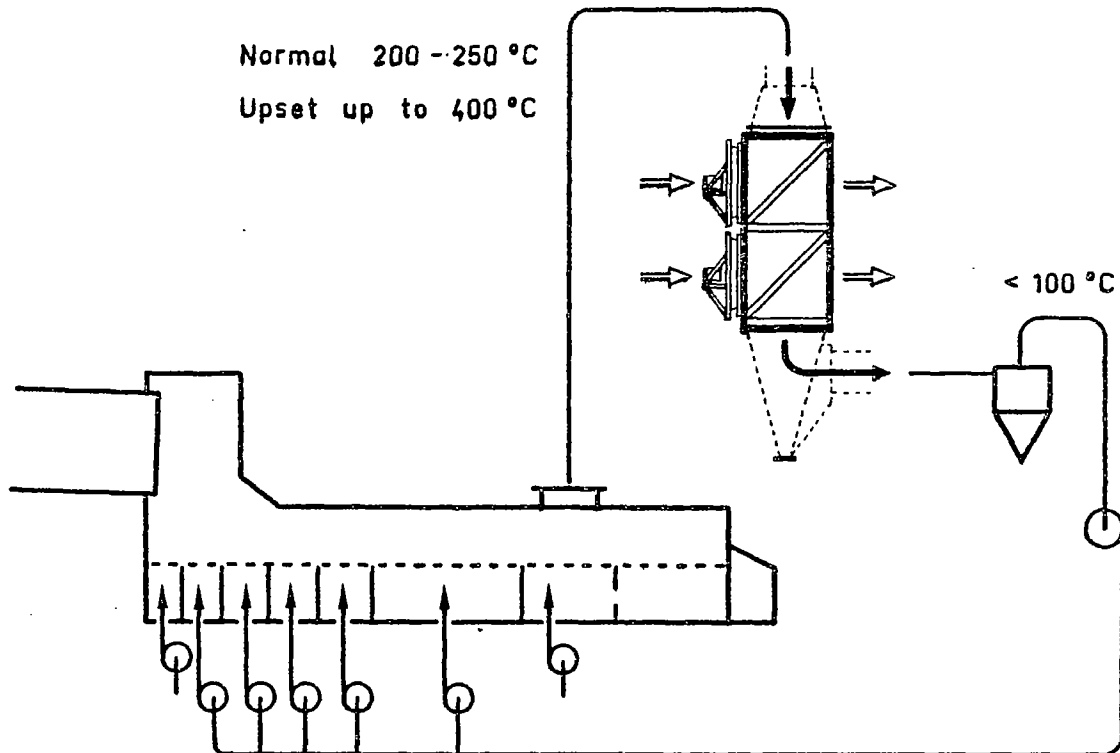


Fig. 10: Principle of non-ventilating clinker cooler

The first application of this unconventional system has been realized in 1970 at the Beaucaire plant of the above mentioned company, on a 1500 t/d Fuller cooler.

The experience gained with this installation was very satisfactory, from a maintenance as well as from a power consumption point of view: no repair at heat exchanger, average lifetime of fan blades about 25000 h, power consumption of 2.1 kWh/t cli for the three fans together.

Up to now, only few installations using this principle have been realized, so that still little experience is available with units in operation. The main advantages and disadvantages of this system are:

Advantages:

- no dust emission at all
- simple
- low investment cost
- moderate maintenance cost
- moderate operating cost
- heat recovery possible (at various temperature levels)
- extension possible by adding further heat exchange units.

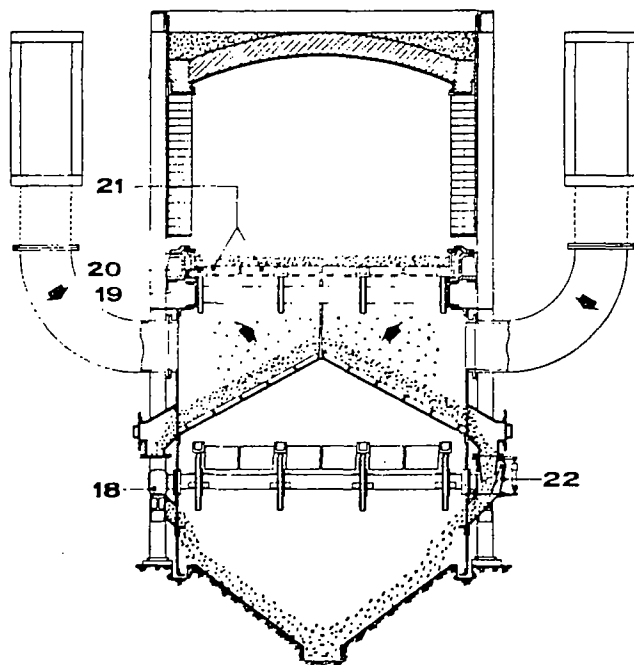
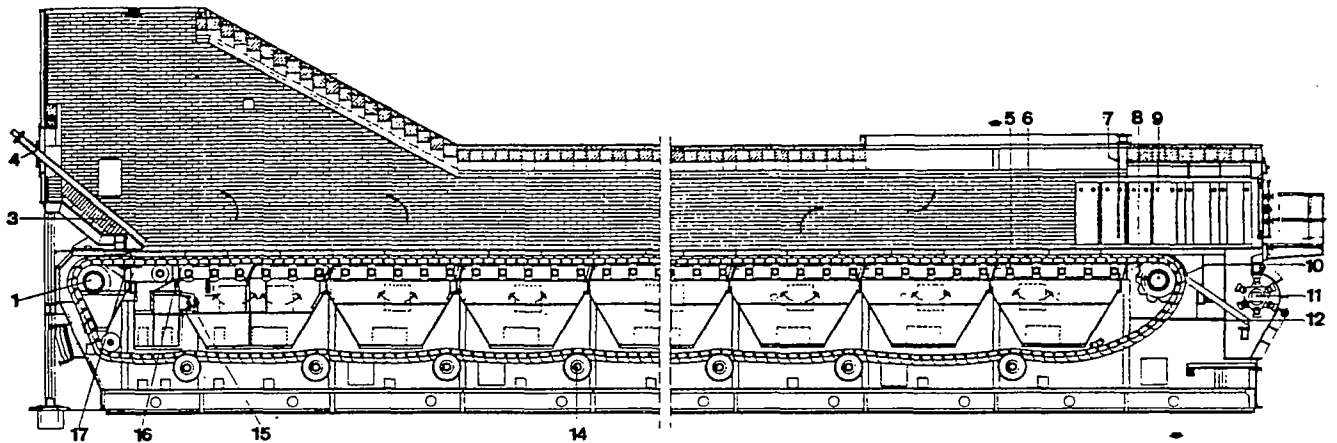
Disadvantages:

- possible wear of fan blades (preventive measures necessary)
- maintenance and operating costs higher than conventional cooler dedusting system with EP.

From a process technological point of view, there is no major objection against this solution. If well designed, it allows a normal cooler operation and a normal clinker outlet temperature without risk of grate overheating.

2.2 Travelling grate cooler

The travelling grate cooler, the so-called "Recupol" cooler (Fig. 11), was mainly developed for use in combination with rotary kilns provided with grate preheaters (Lepol system). Also it looks quite similar to a grate preheater and normally uses the same wear parts.



- 1 Turning shaft
- 3 Supporting girder
- 4 Water cooled steel plate
- 5 Shaft for upper traveling route
- 6 Siding plate
- 7 Chain curtain
- 8 Chain wheel
- 9 Drive shaft
- 10 Strip off grate
- 11 Clinker breaker
- 12 Grate bolt
- 14 Shaft for lower traveling route
- 15 Pulsator
- 16 Blower nozzle
- 17 Drag plate
- 18 Slide bearing
- 19 Sealing elements
- 20 Chain link
- 21 Grate plate
- 22 Flap gate

Fig. 11: Travelling grate cooler (Polysius)

When handling clinker produced by semi-dry kilns, characterized by uniform granulometric composition, the travelling grate cooler can perform very well. However, when dealing with clinker produced in suspension preheater kilns, it is generally slightly inferior to a modern reciprocating grate cooler as regards clinker outlet temperature and thermal efficiency. The main reasons for this poor behaviour are the difficulty to obtain a good clinker distribution at the cooler inlet and the absence of clinker mixing on the grate. The clinker distribution can be improved by using air pulsators at the cooler inlet.

The cooler can, like a reciprocating grate cooler, be equipped with a partial or total air recirculating system and/or middle air extraction for drying purpose.

The specific grate load of travelling grate coolers is usually lower than for modern reciprocating grate coolers, namely in the range of 25 - 30 t/m².d.

Although there are still numerous travelling grate coolers in operation this type of cooler is no more applied for new projects.

3. ROTARY COOLER

3.1 General

The rotary cooler consists mainly of a rotating cylinder (see Fig. 12), similar to a rotary kiln.

The clinker is fed through the inlet chute and is then cooled by air while being transported towards the outlet end. Cooling is performed in countercurrent flow. The tube is equipped with internal lifters which improve the heat transfer. About 2/3 (66 %) of the cooler length is lined with refractory bricks.

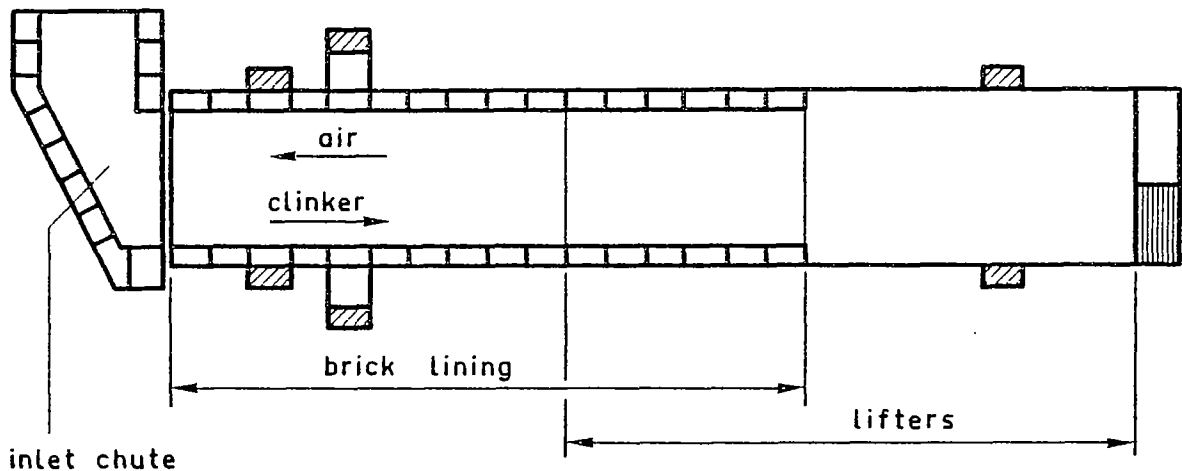


Fig. 12: Rotary cooler

The rotary cooler is of simple design and is the oldest type of clinker coolers. It was seldom used for modern, large kiln systems. Therefore comparatively little design and operating experience is nowadays available for rotary coolers above 2000 t/d. However, the application of rotary coolers still offers certain advantages. Presently units up to 4500 t/d (dimensions dia 6.3/6.0 x 80 m) are in operation. It will be interesting to follow the future development of large rotary coolers.

3.2 Design

The cooler may be arranged in the extension of the kiln axis but often the backflow manner (Fig. 13) is used.

The diameter of the cooler is similar to that of a corresponding suspension preheater kiln. Likewise the rotating speed is in the same range as for the kiln (max. 3 rpm). The length/diameter is approx. 10.

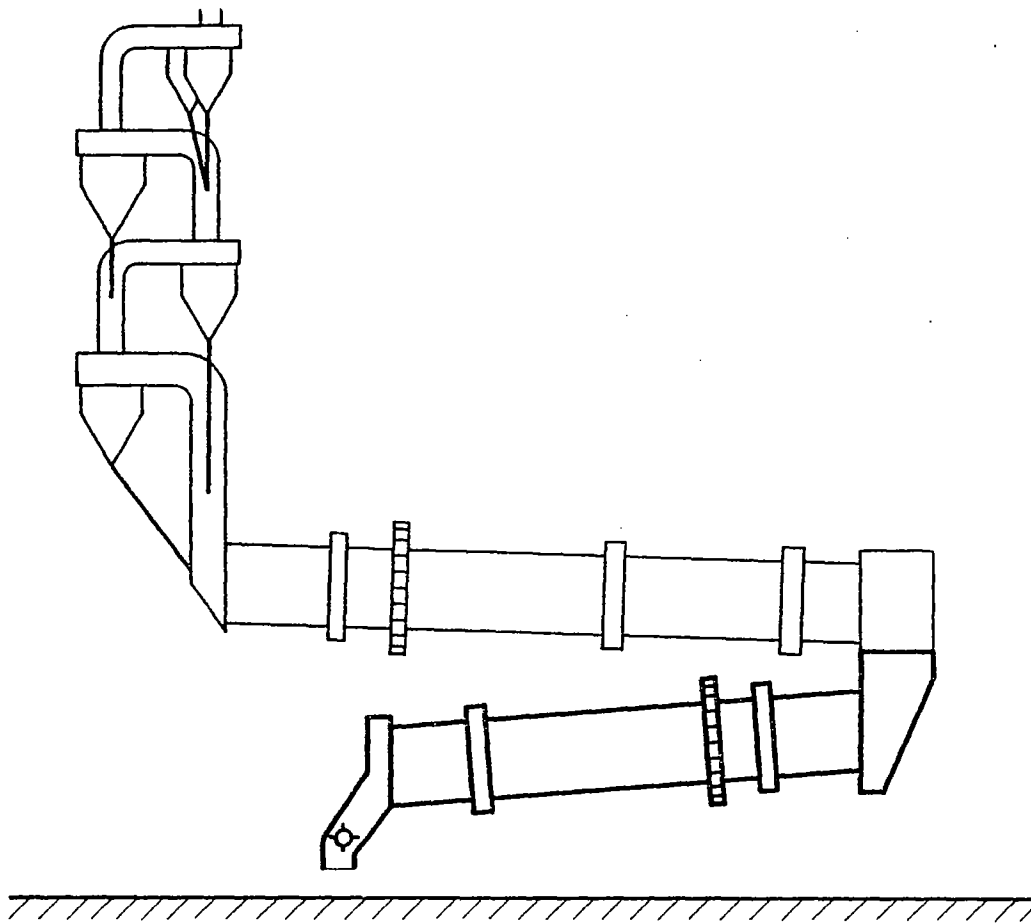


Fig. 13: Rotary cooler layout

The inclination is comparatively high (in the order of 5 %).

The cooler tube is often designed with an extension in diameter but this may not be considered as an absolute necessity.

An important part of the rotary cooler is its internal heat transfer equipment. Its task is to generate additional area by scattering the clinker without generating too much dust. Basically a similar design may be applied as in a planetary cooler tube (see next chapter) however the following differences must be considered:

- The clinker falling heights are larger. Wear protection of shell and lining is essential.
- At a comparative length position the clinker in a rotary cooler is hotter than in a planetary cooler.

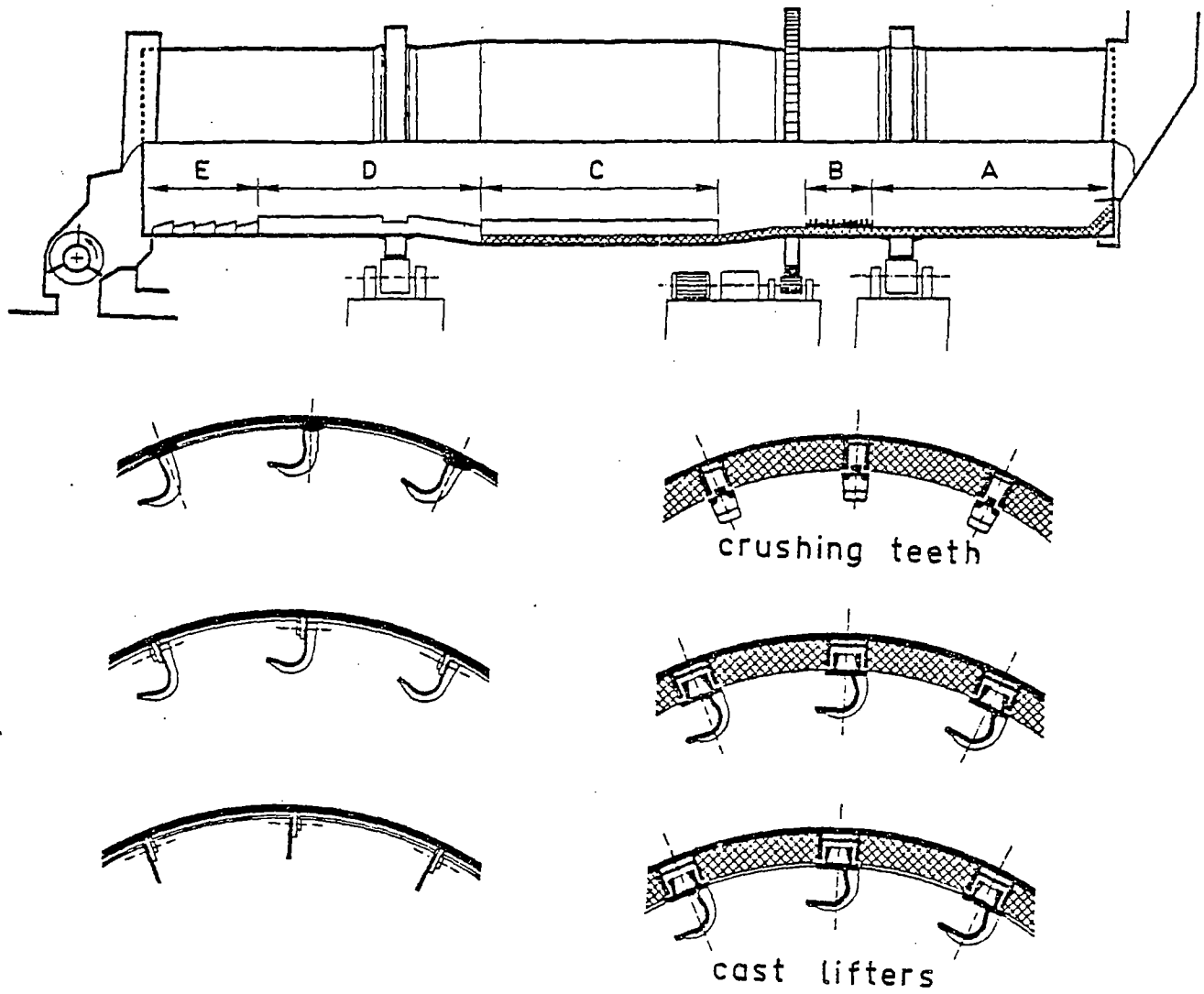


Fig. 14: Rotary cooler

Fig. 14 shows an example of internals. In general the following zones occur in a rotary cooler (simplified):

- A Lined inlet zone
- B Lined crushing teeth zone
(metallic teeth)
- C Lined cast lifter zone, lining protected by wearing plates
(at least in the second half)
- D Cast lifter zone, shell protected by wearing plates
(having air gap, giving also insulating effect)
- E Sheet metal zone with wearing plates

Construction materials have to be selected according to the high temperature and wear requirements.

3.3 Cooling performance

Depending on the design and the shape of the lifters clinker outlet temperature usually tends to be high. In many cases it is necessary to enhance the cooling by injecting water into the tube (up to 60 g/kg clinker) in order to reach reasonably low clinker temperatures of 100 to 150°C.

The cooling efficiency (heat recuperation) is equal or even slightly better than on a planetary cooler.

3.4 Advantages / Disadvantages

ADVANTAGES	DISADVANTAGES
<ol style="list-style-type: none">1. Simplicity of cooler design, robust piece of equipment.2. No special mechanical problems (at least not more problems than on a rotary kiln).3. No control loops.4. Easy commissioning.5. No waste air and therefore no dedusting equipment required.6. Electrical energy consumption is approx. 5 kWh/t lower than for a grate cooler.7. Rotational speed can be adjusted and therefore upset kiln conditions can be handled easier than on a planetary cooler.8. Suitable for precalcining system having a separate tertiary air duct (extraction of hot air is possible).	<ol style="list-style-type: none">1. Little experience available with large coolers (above 2000 t/d).2. Formation of build ups ("snowmen") in the inlet chute. A water cooled chute or a dislodging device is required in such case.3. Clinker outlet temperatures tend to be high and therefore water injection is usually required.4. Due to large falling height wear protection in the tube must be reinforced (compared to a planetary cooler)5. High kiln foundations are required.6. Cooler inlet seal can contribute to additional false air inlet.

4. PLANETARY COOLERS

4.1 General

The planetary coolers are based on the same cooling principle as the rotary coolers in the preceding chapter. However, the essential difference of a planetary cooler is the number of individual cooling tubes. The flow of clinker is subdivided into 9 to 11 (usually 10) cooling tubes which are fixed around the kiln circumference at the kiln outlet (see Fig. 15). Therefore the planetary tubes follow the kiln rotation. Because of their connection to the kiln rotation, planetary coolers do not need a separate drive. This fact already illustrates one main advantage of the planetary cooler: its simplicity in operation.

Strictly speaking the cooling of clinker does not only start in the cooling tubes proper but already in the kiln. In case of a planetary cooler the kiln burner pipe is always inserted into the rotary kiln so that a cooling zone behind the flame of 1.5 to 2.5 kiln diameters is created. This zone is called the "kiln internal cooling" zone and must be considered as an integral part of any planetary cooler. In this zone the temperature of the clinker drops from 1450°C to approx. 1200°C. This temperature reduction is important for the protection of the inlet opening, the elbow and the first section of the cooling tubes.

After this first cooling in the kiln internal cooling zone the clinker falls into the elbows when they reach their lowest point of kiln rotation. The hot clinker is then cooled by air in counterflow. (The amount of air equals the amount of secondary air.) The air is heated up to approx. 700°C. The clinker reaches final temperatures which are typically from 140 to 240°C.

A considerable amount of heat is also transferred to ambient since approx. 3/4 of the cooler shell is not insulated.

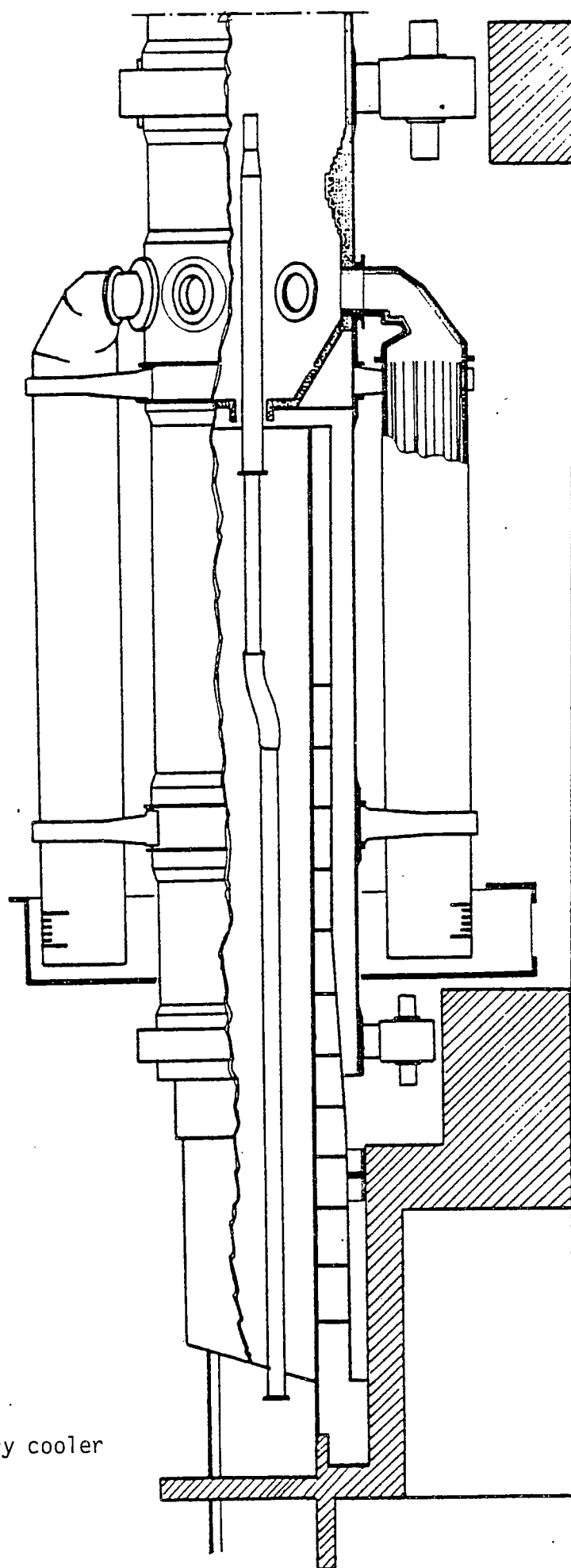


Fig. 15: Planetary cooler

Fig. 16 shows the temperatures which occur in a planetary cooler.

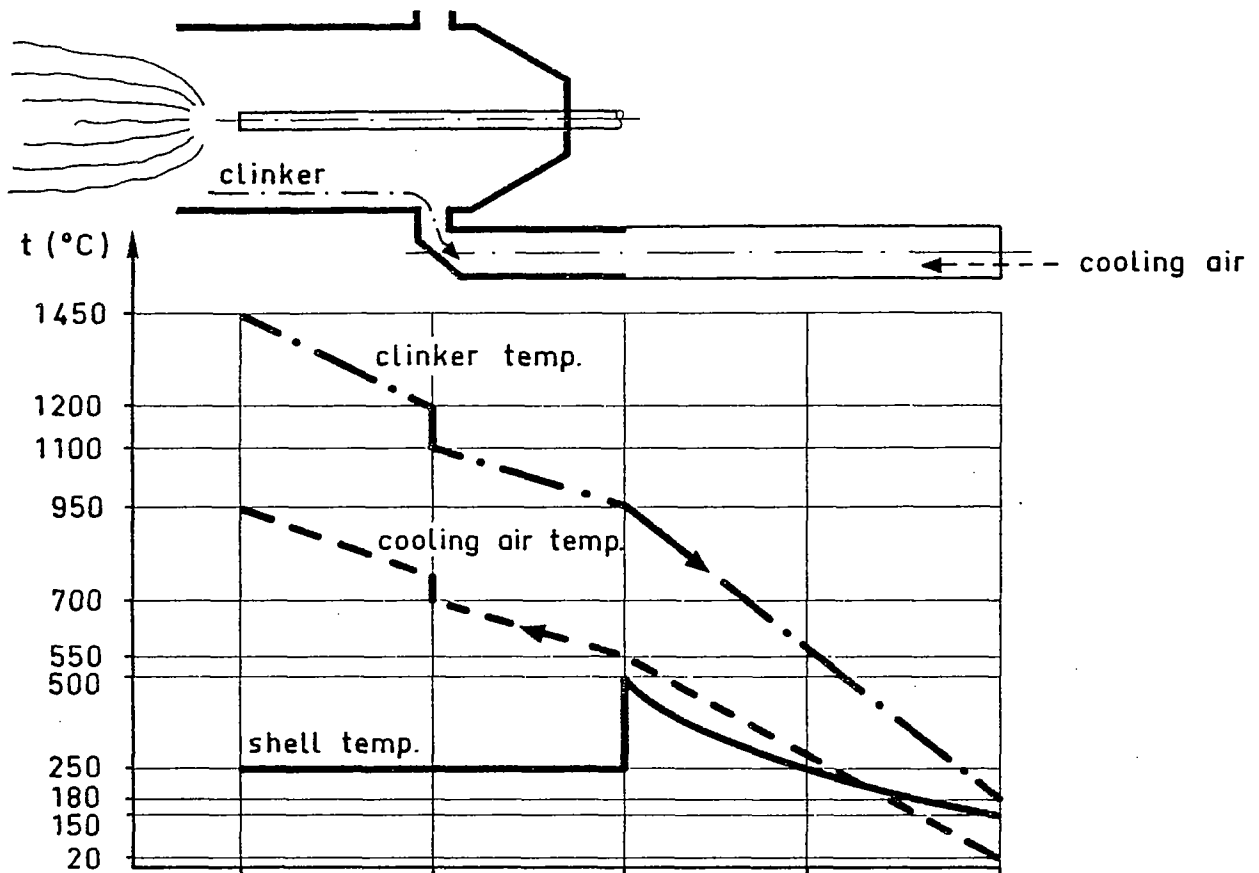


Fig. 16: Temperature profile of planetary cooler

Historical

Planetary coolers have been used since 1920. When large kiln units and grate coolers were developed planetary coolers were abandoned for many years. But about 1966 planetary coolers of large capacities were introduced. At that stage serious mechanical problems occurred on these first large planetary coolers. In consequence lots of work have been done in order to improve the design of planetary cooler. As a result of extensive computer calculations and operating experience the planetary cooler became a reliable equipment.

Nowadays the design has certainly reached a high standard and a considerable level of perfection. Units of up to 5000 t/d are now available. With the development of very large precalciner kilns which require a separate tertiary air duct the significance of the planetary cooler has slightly decreased since it cannot be applied in those cases.

4.2 Design features

Modern planetary cooler show the following design features:

- . Shell extension:

The kiln shell is extended beyond the cooling tube outlets and it is supported by an additional roller station (see also Fig. 15).

- . Fixation of cooling tubes:

Cooling tubes have a fixed support near the inlet and a loose support near the outlet end.

In case of large coolers the cooling tubes may consist of two separate sections and three supports are required. In that case two fixed supports are located near inlet and near outlet and a loose support is located at the interconnection point in the middle.

- . Design of cooler supports:

The kiln shell is reinforced (high thickness) where the cooler support structure for the cooler is welded on. The support structure (base and brackets) itself is of heavy design consisting of reinforcement ribs and box beams.

- . Cooler length:

Length / diameter ratio of tubes is approx. 10 : 1.

- . Inlet openings:

The inlet openings to the cooler elbows weaken the kiln shell and high mechanical and thermal stresses occur in that zone.

The openings are made of oval shape and the kiln shell is considerably reinforced in its thickness (up to 140 mm in large kilns) in order to compensate for the weakening.

In some cases a diagonal retaining bar (made of high heat resistant steel) is incorporated in the opening in order to avoid that large lumps can enter the cooler.

. Kiln-to-elbow joint:

This joint is designed in a manner that no forces due to thermal expansion and deformation are transmitted from elbow to kiln.

. Elbow:

The clinker may not be allowed to fall back into the kiln while the opening is on top position. Therefore the position of the cooling tube is somewhat displaced back against the direction of rotation.

Furthermore the design of the elbow may not create excessive dust backspillage and/or wear.

4.3 Internal heat transfer equipment

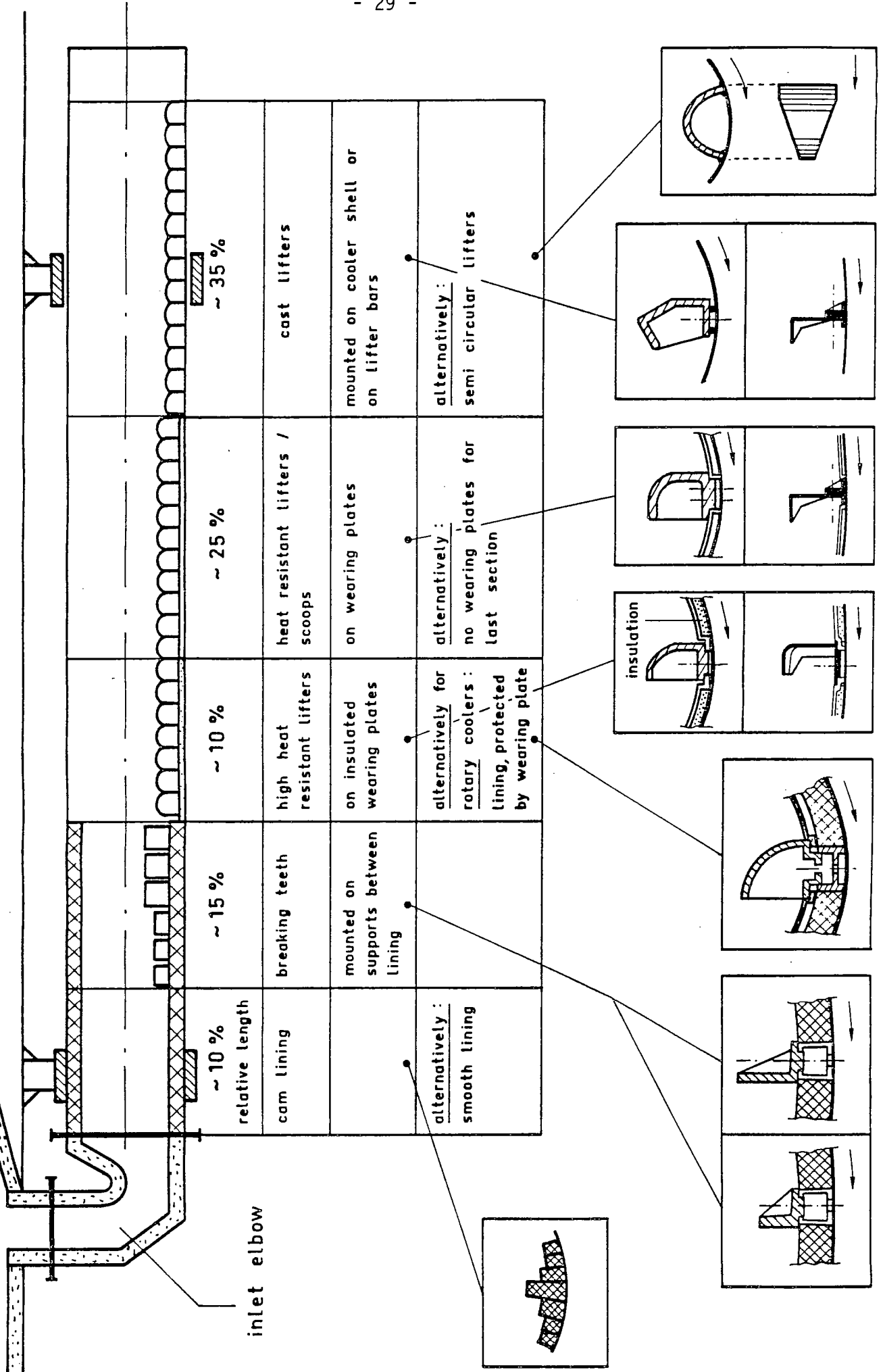
Good operating performance depends strongly on efficient lifters of solid and durable design.

Since high heat resistant metallic lifters are available on the market also the high temperature zones can be adequately equiped. Special high temperature alloys can be used for this purpose. They can withstand maximum temperatures of up to 1150°C. These alloys are usually characterized by a high chromium content of approx. 30 % Cr. Other elements as Ni or Mo can occur in various proportions.

Fig. 17 shows a typical arrangement of heat transfer internals. Breaking teeth are applied in the hottest zone. They are able to crush large lumps of clinker and create also a tumbling effect which improves the heat transfer. They are of heavy design and mounted on separate supports.

The first rows of lifters must be carefully selected from their design and their construction material. Their proper functioning is important since they also protect the following lifters from overheating.

Fig. 17: Planetary cooler internals



After the end of the lined zone the cooler shell must be protected from wear. This is done by wearing plates which also allow for a certain insulation effect by the backfilling with insulating material or just simply by an air gap.

There are numerous other design details which vary from one supplier to the other. The common requirements are to get highly efficient internals giving sufficient lifetime and easy replacement.

4.4 Heat transfer and efficiency

The heat transfer in a planetary cooler is based on a countercurrent heat exchange between clinker and cooling air. Theoretically this principle would allow for high recuperation efficiency. However, several factors act against an ideal heat transfer. The following items influence the efficiency:

- . The clinker must be brought in an intensive contact with the cooling air. The normal contact in a smooth tube would not be sufficient. Therefore the active area must be increased by high efficient lifters. The design and the actual condition of the internal heat transfer equipment are essential for a high recuperation.
- . The quantity of available cooling air affects the efficiency. As long as only one special kiln system is considered the secondary air quantity does not change greatly from one kiln to the other. However, if e.g. a suspension preheater kiln is compared with a wet kiln the air quantity can be more than 50 % higher and thus cooling efficiencies cannot be compared.

Similar to other cooler types the efficiency is not only determined by the machine itself but also by the amount of cooling air i.e. by operating conditions.

- . The granulometry of the clinker affects the cooling efficiency. The smaller the particles are the higher is the specific surface area (m^2/kg). Therefore the heat exchange would theoretically improve. However, this applies only for particle sizes above approx. 1.5 mm. The fine particles (dust) are entrained by the air flow and create an internal dust circulation. By this circulation an unwanted heat transport is induced which deteriorates the countercurrent heat exchange pattern of the cooling tube.

Too much fines are therefore detrimental.

. The lined section of a planetary cooler is typically 1/4 of its total length. Therefore a large proportion of the clinker heat is released through the cooler shell. Approximately 20 % of the clinker heat is lost by this effect. Although this is necessary in order to reach reasonably low clinker temperatures of 140 to 240°C it acts against a high recuperation efficiency.

On a suspension preheater kiln the planetary cooler usually has an efficiency of 65 to 70 % which may drop when the lifters are in bad condition.

The following heat balance may be used as a rough guideline:

Heat input by clinker (1200°C)	100 %
Heat output	
- by secondary air (750°C)	68 %
- by shell losses	22 %
- by clinker outlet (170°C)	10 %

The 68 % in the above example equals the recuperating efficiency.

The preceding explanations have shown that the efficiency depends on two main factors:

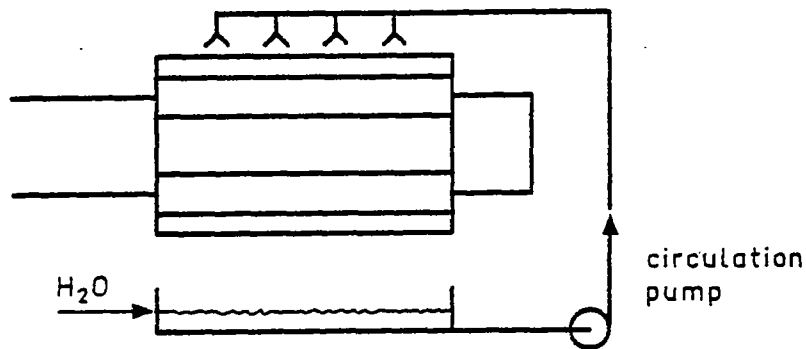
1. Design and condition of the internal heat transfer equipment
2. Operating conditions
(granulometry, air quantity)

4.5 Enhanced cooling

In case of overloaded coolers or poor condition of the internal heat transfer equipment the clinker temperature may become excessively high. In such cases the lifters and the cooler shell may become overheated as well.

If such conditions occur it is possible to enhance the cooling by making use of the water evaporating cooling. There are basically two possibilities of water cooling (Fig. 18).

a) external water spray



b) internal water spray

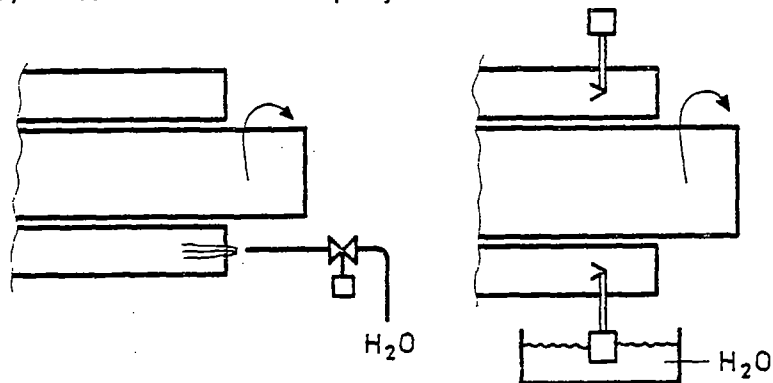


Fig. 18: Enhanced cooling

a) External water spray:

The cooler shell is cooled by spraying water onto the planetary cooler shells.

The water consumption is in the order of 100 g/kg clinker. The recirculation rate is approx. 10 times and the clinker temperature can be reduced by some 110°C.

b) Internal water spray:

A water quantity of approx. 30 to 50 g/kg clinker is sprayed directly into the cooler tube. The possible reduction of the clinker outlet temperature is from 50 to 100°C.

The injection of water can be performed either by spray nozzles which are actuated when the outlet end of the tube passes by or by techniques which are based on the bucket wheel principle.

The injection of water causes also a slight increase of the kiln gas quantity and thus reduces the capacity marginally.

4.6 Advantages / Disadvantages

ADVANTAGES	DISADVANTAGES
<ol style="list-style-type: none"> 1. Extreme simplicity in design and operation. No control loops are required. 2. No exhaust air is produced and therefore no dedusting is required. Considerable investment and operation cost for dedusting can be saved. 3. The specific power consumption is by 6 to 7 kWh/t lower than with grate cooler systems and by approx. 2 kWh/t lower than with rotary cooler. 4. Nearly no unexpected kiln stops occur which are caused by the cooler. 5. Commissioning is easy. 	<ol style="list-style-type: none"> 1. Virtually no control of cooler operation is possible (critical in case of material rushes). There is also no control of the distribution of the clinker to the individual tubes, which may often vary by up to 50 %. 2. Since there is no exhaust air there is no cooler exhaust air utilization possible. In cases where this heat could be used for drying purposes this may become an argument against the planetary cooler. 3. A planetary cooler might become an important source of noise emission (depending on the clinker granulometry). If residential areas are in the vicinity sound protection measures may become necessary. 4. Clinker exit temperatures are comparatively high and call for fully metallic clinker conveying equipment and adequate cooling in the cement mill. 5. Spare capacity is relatively little. Cooler is sensitive to overload.

ADVANTAGES cont.	DISADVANTAGES
	<ol style="list-style-type: none"><li data-bbox="827 517 1346 864">6. The kiln outlet section is a complicated structure which has to resist to high stresses and temperatures. The protective cast refractory mass in this area needs close attention. In case of refractory failure the kiln has to be stopped immediately.<li data-bbox="827 931 1346 1137">7. The kiln downtimes tend to be longer because relining work in the kiln and repair works in the plantes have to be performed simultaneously.<li data-bbox="827 1171 1346 1615">8. The planetary cooler cannot be applied for precalcining kiln systems having a separate tertiary air duct, because there is no possibility to extract hot tertiary air. Therefore the planetary cooler is ruled out for very high kiln capacities (above 4000/5000 t/d). The necessity of a bypass may also act against the planetary cooler.

5. OTHER SYSTEMS

5.1 g-Cooler

The "g-cooler" has been developed by the Claudius Peters Company. The letter "g" stands for gravity since clinker movement is performed by gravity.

This cooler is designed as an after cooler and can therefore only be used in connection with a primary cooler such as a short grate cooler or a planetary cooler. The installation together with a grate cooler is shown in Fig. 19.

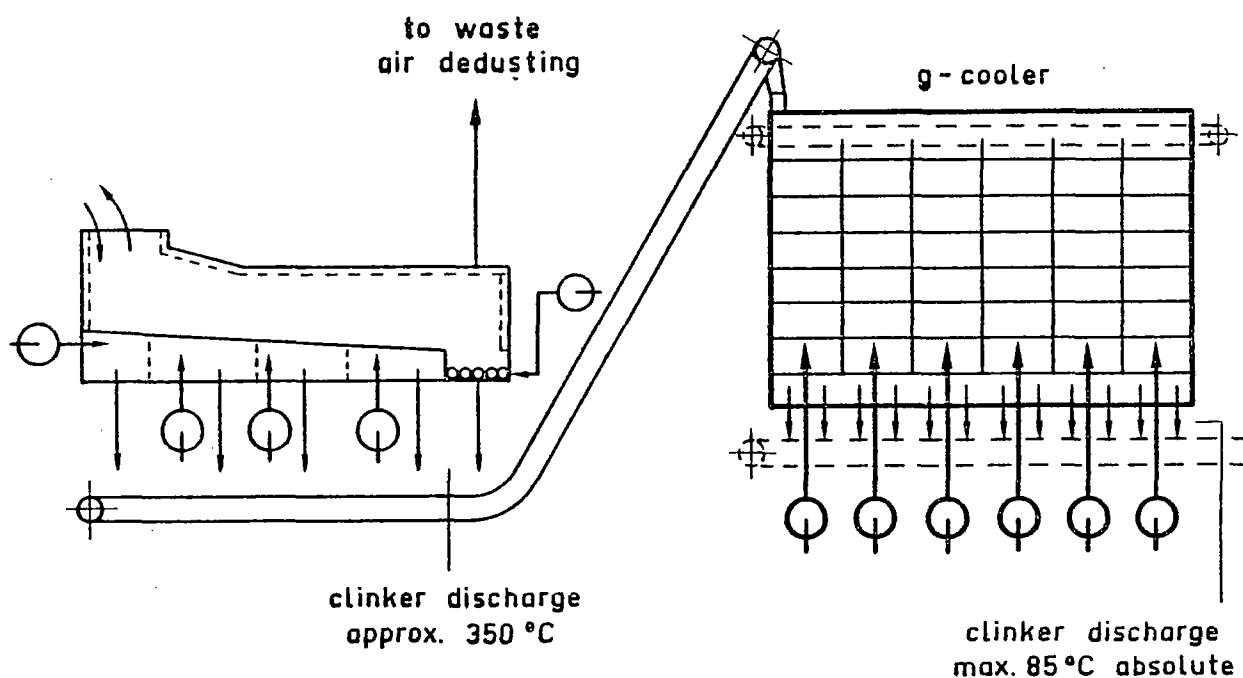


Fig. 19: g-cooler

An intermediary crusher reduces the clinker size to 20 - 30 mm. The material of approx. 400°C is then filled by a drag chain into a vertical shaft. Cooling is performed by horizontal rows of tubes which are cooled by internal air flow. The heat is therefore exchanged indirectly and the air remains dust-free. The clinker slowly drops down (at a speed of 20 - 30 mm/s) and reaches final temperatures of approx. 100°C at the discharge.

There is no dedusting equipment required for the cooling air. However, the system according to Fig. 19 as a whole is usually not free from dusty waste air. In case of a suspension preheater kiln system there is still some waste air required on the grate cooler since the kiln cannot take all the hot air produced during the first cooling step. In addition a marginal amount of dusty air is produced by the g-cooler itself (top and discharge).

The application of this cooler type may be advantageous e.g. in case of kiln extension projects. If an existing grate cooler (or a planetary cooler) has to be operated at higher capacity the new clinker outlet temperature can get too high. In this case the clinker temperature can be kept low by a g-cooler used as an aftercooler.

5.2 Shaft cooler

A shaft cooler can be operated waste-air-free and theoretically offers an ideal countercurrent heat exchange and thus high recuperating efficiency. Based on that idea the first large shaft cooler was designed and constructed on a 3000 t/d kiln in 1973.

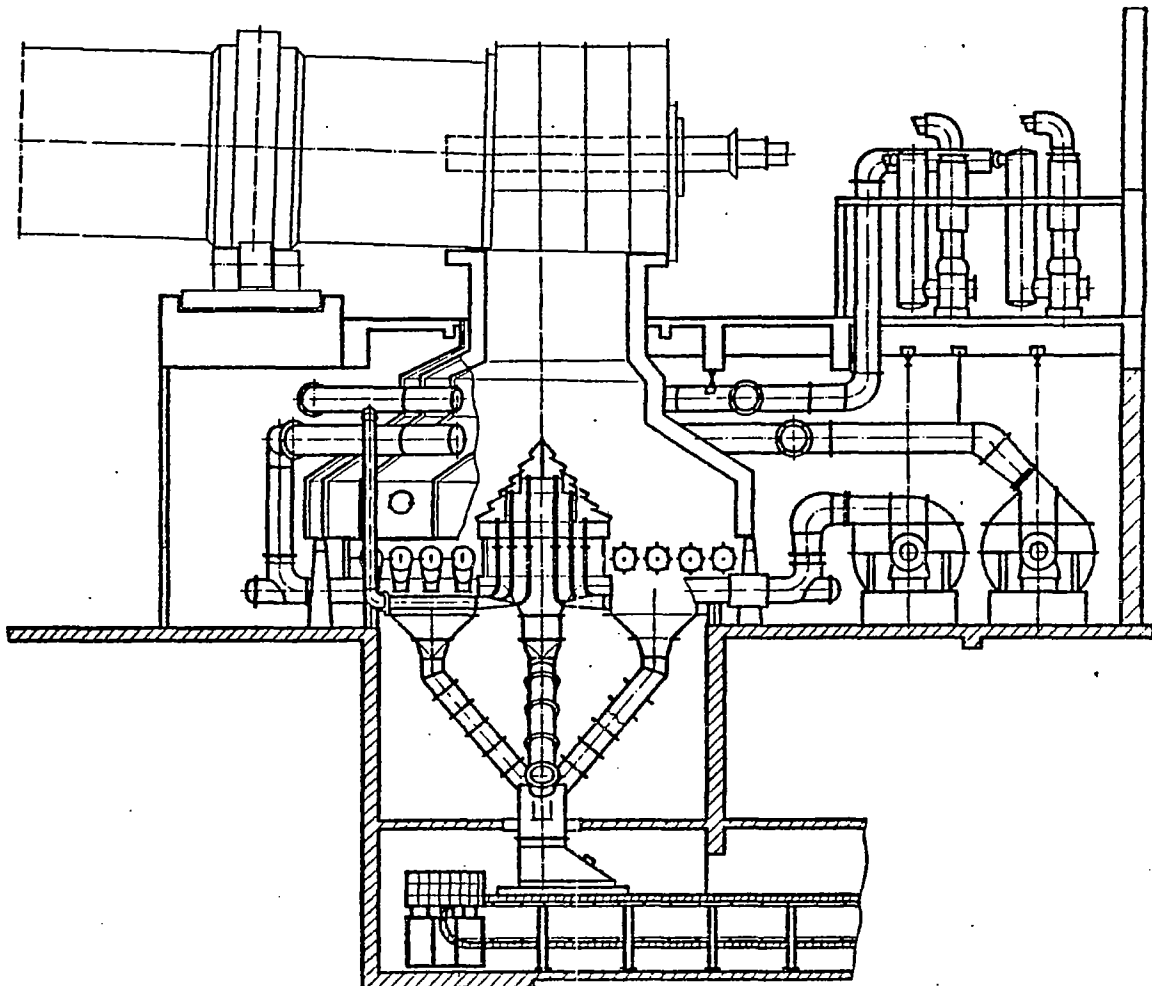


Fig. 20: Shaft cooler

The experience gained in that plant shows that it is possible to operate such an equipment but some serious disadvantages have to be taken into account:

- All depends on the clinker granulometry! Theoretically an extremely uniform clinker granulometry having no fines and no coarse material would be required. This is hardly achievable in a cement kiln. Therefore fluctuations occur.
- High cooling air quantity (= secondary air) of $1.05 \text{ Nm}^3/\text{kg cli}$ is required but even so the clinker exit temperature of 350°C is very high.
- High power consumption (10 kWh/t).

For the above reasons, the technical realisation is not yet solved. The shaft cooler so far is not a reasonable alternative to the conventional clinker coolers.

6. COMPARISON OF COOLERS

6.1 Range of application

The following Table 2 informs about the application range of the individual coolers.

Type of cooler	Optimum capacity range ³⁾ (t/d)	Maximum capacity (t/d)	Suitability for AS ¹⁾ precalcining systems	Dedusting equipment for waste air required	Remarks
Reciprocating grate	1500-5000	10'000	YES	YES ²⁾	
Travelling grate	700-3500		YES	YES	Virtually no more applied for new plants
Rotary cooler	500-2000	4'000	YES	NO	
Planetary cooler	1500-3500	5'000	NO	NO	
Shaft cooler	3000	?	YES	NO	extremely rare application
g-cooler	any		-	NO	only applicable as after-cooler in connection with above cooler types

1) Having separate tertiary air duct

2) In special cases: waste air free operation possible

3) Lower figure means economical limit but not smallest possible capacity

Table 2: Range of application of coolers

The above table only considers the main criteria. It is evident that other criteria may influence the selection of a cooler as well, for example:

- layout possibilities
- old equipment which can be incorporated in a new plant (e.g. an old kiln shell can be converted to a rotary cooler)
- granulometry of clinker (if known)
- noise emission
- possibility to extend capacity in a later stage
- etc.

Nowadays the most common coolers are the planetary coolers and the reciprocating grate coolers.

For large precalcining kiln systems requiring a tertiary air extraction the reciprocating grate is virtually the only type which can be recommended.

6.2 Operating data and heat balance

The operating data and the heat balance of coolers are strongly dependent on the amount of secondary air (plus tertiary air, if any) which is required from the kiln system.

Therefore the data in the following Table 3 are based on a constant amount of secondary air of $0.85 \text{ Nm}^3/\text{kg cli}$. However, one exception has been made in case of the shaft cooler: A shaft cooler cannot be operated with only $0.85 \text{ Nm}^3/\text{kg cli}$ because clinker exit temperature would become much too high. Practical experience shows that $1.05 \text{ Nm}^3/\text{kg}$ are required. This surplus air quantity causes additional exhaust gas losses in the kiln system. Therefore the thermal efficiency of the shaft cooler can by no means be compared with other cooler types!

For the reciprocating grate coolers a desired clinker exit temperature of 100°C has been assumed. That means that the amount of "cooling air" is adapted to the desired cooling effect in all cases.

Table 3: Typical operating data and heat balances of clinker coolers

Type of cooler	GRATE				TUBE		SHAFT
	Reciprocating (all types) ¹⁾	Reciprocating with air recirculation to mid grate section	Reciprocating with air recirculation to first grate section	Traveling ²⁾	Planetary	Rotary	
<u>Air flows (Nm³/kg cli)</u>							
- cooling air	2.20	2.55 ³⁾	2.35 ³⁾	2.20	0.85	0.85	1.05
- secondary air	0.85	0.85	0.85	0.85	0.85	0.85	1.05
- waste air	1.35	0.85	0.65	1.35	none	none	none
- circulation air	none	0.85	0.85	-	none	none	none
<u>Clinker dust in secondary air (kg/kg cli)</u>							
	negl.	negl.	negl.	negl.	0.08	0.08	negl.
<u>Temperatures (°C)</u>							
- cooling air	20	20/145	20/145	20	20	20	20
- secondary air	905	905	945	895	730	825	840
- waste air	230	350	392	215	-	-	-
- circulation air	-	145	145	-	-	-	-
- clinker inlet	1400	1400	1400	1400	1300	1200	1400
- clinker outlet	100	100	100	120	165	210	360
<u>Heat Input (kJ/kg cli)</u>							
- clinker	1505	1505	1505	1505	1220	1355	1505
- clinker dust	-	-	-	-	95	110	-
<u>Heat Output (kJ/kg cli)</u>							
- secondary air	1054	1054	1105	1040	827	950	1194 ⁴⁾
- clinker dust	-	-	-	-	55	65	-
- clinker outlet	63	63	63	80	115	160	300
- waste air	373	373	322	345	-	-	-
- radiation + conv.	15	15	15	15 ⁵⁾	318	265 ⁵⁾	10
- water cooling	-	-	-	25 ⁵⁾	-	25 ⁵⁾	-
<u>Thermal efficiency (%)</u>							
	70	70	73	69	68	70	79 ⁴⁾

- 1) There is no significant difference between inclined, horizontal and combi cooler
- 2) Good clinker distribution (pulsing units) is provided
- 3) "Cooling air" includes amount of hot circulating air, which also contributes to clinker cooling
- 4) Cannot be compared to other cooler types due to different secondary air quantity
- 5) Water cooled chute

6.3 Capital and operating costs

Capital costs

Capital costs for all the discussed systems are of about the same magnitude if a medium size plant (approx. 2000 t/d) is considered. They only may differ within 10 to 15 %. The cost structure of grate coolers, rotary- and planetary coolers may obviously be much different. For example the planetary coolers require a reinforced kiln structure. On the other hand planetary coolers do not required extensive civil works. Comparatively expensive dedusting equipment is required in case of grate coolers.

Operating costs

The electrical power consumption of the different systems can be seen out of the following figures.

Typical electrical power consumptions for several kiln-cooler systems in kWh/t cli based upon a 2000 t/d unit:

	<u>Planetary cooler</u>	<u>Rotary cooler</u>	<u>Grate cooler</u>
Kiln fan	7.3	7.3	7.0
Kiln drive	3.7	1.7	1.7
Cooler drive, fans and dust collection	<u>--</u>	<u>3.7</u>	<u>9.0</u>
Total	11.0	12.7	17.7
Consumption which is caused by cooler alone	2.3 ===	4.0 ===	9.0 ===

Maintenance cost

It may be self-explaining that the maintenance costs for planetary, rotary and grate coolers are each composed of different items. For example planetary coolers require more expensive relining works than grate coolers. However, the total of costs is very similar for all type of coolers. Based on the data which are presently available no significant advantage may be given to one or the other cooler. The maintenance costs are in the order of 0.5 SFr./t or 0.25 US\$/t (per ton of clinker, on price basis 1982).

7. COOLER SUPPLIERS

The most important cooler suppliers are summarised in the following Table 4. Therein the different offered typed are designated by two letters such as:

Grate coolers

TG travelling grate
RG reciprocating grate

Tube coolers

R rotary cooler
P planetary cooler

Shaft coolers

S ordinary shaft cooler
g g-cooler

<u>America</u>	
Fuller Company, Catasauqua, PA, USA	RG
<u>Asia</u>	
Babcock-Hitachi K.K., Tokyo, Japan	RG additionally L (Fuller)
Ishikawajima-Harima H.I. Ltd. Tokyo, Japan	RG
Kawasaki Heavy Industry Ltd., Kobe, Japan	RG
Mitsubishi Heavy Industry, Tokyo, Japan	RG add. L (Polysius)
Nihon Kokan Kabushiki Kaisha, Japan	RG, L (FLS)
<u>Europe</u>	
Claudius Peters AG, Hamburg, BRD	RG, g, L(Fuller, RG)
F.L. Smidth & Co. A/S, Copenhagen, Denmark	RG, P, R
Gatx-Fuller SA, Paris, France	RG, P, L (Fuller)
KHD Industrieanlagen, Humboldt-Wedag, Köln /Bochum BRD	P, RG, R, L(Kawasaki)
Polysius AG, Neubeckum, BRD	TG, RG, P, R
Walter-Beratherm GmbH, Köln, BRD	S

L (.....) = Licensee of

Table 4: List of cooler suppliers

LITERATURE

E. Steinbiss

Stand und Entwicklung der Klinkerkühler
ZKG 1972/11

H. Herchenbach

Verfahren der Zementklinkerkühlung und Auswahlkriterien für die gebräuchlichsten Kühlersysteme
ZKG 1978/1

V. Hansen

Clinker Coolers
World Cement Technology March 1980

N.K. Andersen

Folax-Rostkühler in neuer Bauart
ZKG 1979/5

Th. Lang

Rostkühler mit Zwischenbrecher (Stufenkühler) im Werk Weisenau der Portland Zementwerke Heidelberg AG
VA Bericht 77/4566/D

L.M. Ludera

Dimensionierung von Planetenkühlern
ZKG 1980/9

R. Vogel / B. Winter

Die Beurteilung von Rohrkühlern aus thermischer Sicht
ZKG 1980/11

W. Kühle

Der Rohrkühler, ein optimaler Klinkerkühler
ZKG 1974/9

L. Kwech

Betriebserfahrungen mit einem Rohrkühler und erste Betriebsergebnisse mit einem -Kühler für je 2000 t/d

Th. Lang

Der 2000 t/d Rohrkühler in Rodaun
VA Bericht 77/4558/D

TEST QUESTIONS

1. What are the main functions of a clinker cooler?
2. How is the thermal efficiency defined?
3. Which types of coolers do not produce any waste air?
4. Which types of coolers offer the lowest clinker exit temperature?
5. What are the three basic possibilities to transport clinker within a cooler?
6. Which zones can be distinguished in a rotary (or planetary) cooler?
7. Give typical relative lengths of refractory lined zone for a rotary and a planetary cooler. What are the consequences on individual heat balances of the coolers?
8. Why is a planetary cooler not suitable for certain precalcining systems?
9. Give further advantages and draw-backs of the planetary cooler!
10. Which amount of cooling air ($\text{Nm}^3/\text{kg cli}$) is required for an ordinary grate cooler?
11. Compare a grate cooler combined with a suspension preheater kiln to one combined with a wet kiln. Which one has a better cooling efficiency?
12. Travelling grate coolers practically are not selected any more for new plants. What might be the reasons?
13. Give some typical operating data of a reciprocating grate cooler (including inclined, horizontal and combined types)
 - Clinker outlet temperature
 - Surface load ($\text{t}/\text{m}^2\text{d}$)
 - Max. capacity (t/d)
 - Clinker bed thickness at inlet (mm)
14. What advantages offers the installation of an intermediary clinker crusher on a grate cooler?
15. What are the particular difficulties when shaft cooling is applied?
16. Which cooler type offers the lowest electrical power consumption?

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TYPICAL PROBLEMS OF CONVENTIONAL GRATE COOLERS

- "Red River" = fine clinker, fluidized, rapidly flowing
- Uneven clinker distribution
- "Geyser" = air breaking through clinker bed
- Overheated / burnt plates
- Thin clinker bed
- Poor sealing of undergrate compartments
- Poor recuperation (low thermal efficiency)

MODERN COOLERS: DESIGN FEATURES

- Direct aeration of grate plates
- Individual aeration of sections
- New grate plate designs
- Moveable ducts to moving plate rows *
(telescopic, flexible a.o.)
- Fixed inlet (without moving plates) *
- Higher cooling fan pressure
- Air pulsation systems *
- Lower specific cooling air [Nm³/kg]
- Lower waste air flow [Nm³/kg] -> (smaller filter!)
- Higher specific grate loading [t/(m²d)]
- Smaller cooler dimensions -> space, civil structure
- Intermediate clinker crusher (roller crusher) *
- Pyrometer above cooler grate *

* Depending on design / supplier

The key to successful coolers:

- 1) Correct allocation of air to clinker
- 2) Sustainable gap widths all around
(="Gap Management")

MODERN COOLERS: TECHNICAL DATA

Fan pressure: 45 to 110 mbar

Specific grate loading *1): 45 to > 60 t/m²d

Cooling air *1): (norm) 1.5 a 1.8 Nm³/kg cli
(max) 1.6 a 2.3 Nm³/kg cli

Waste air *2): (norm) 0.7 a 1.0 Nm³/kg cli
220 a 280 °C
(max) 0.8 a 1.5 Nm³/kg cli

Thermal efficiency: >= 75 %

Secondary air: ~1100 °C * 3)

Tertiary air: ~ 920 °C * 3)

Secondary + tertiary air: ~ 1000 °C * 4)

* 1 Depending on clinker temperature

* 2 For modern kiln system (3000 kJ/kg cli)

* 3 Extraction of tertiary air from cooler roof

* 4 Extraction of tertiary air from kiln hood

MODERN COOLERS: ADVANTAGES OF THE NEW TECHNOLOGY

- Improved, smoother cooler operation
- Improved kiln operation
- Higher heat recuperation
-> Reduced system heat consumption
- Elimination / control of the "Red River"
- Clinker fall through (riddlings) significantly reduced
- Reduced power consumption
- Smaller waste air dedusting system -> investment cost
- Smaller cooler -> space, civil structure!

Possible new problems:

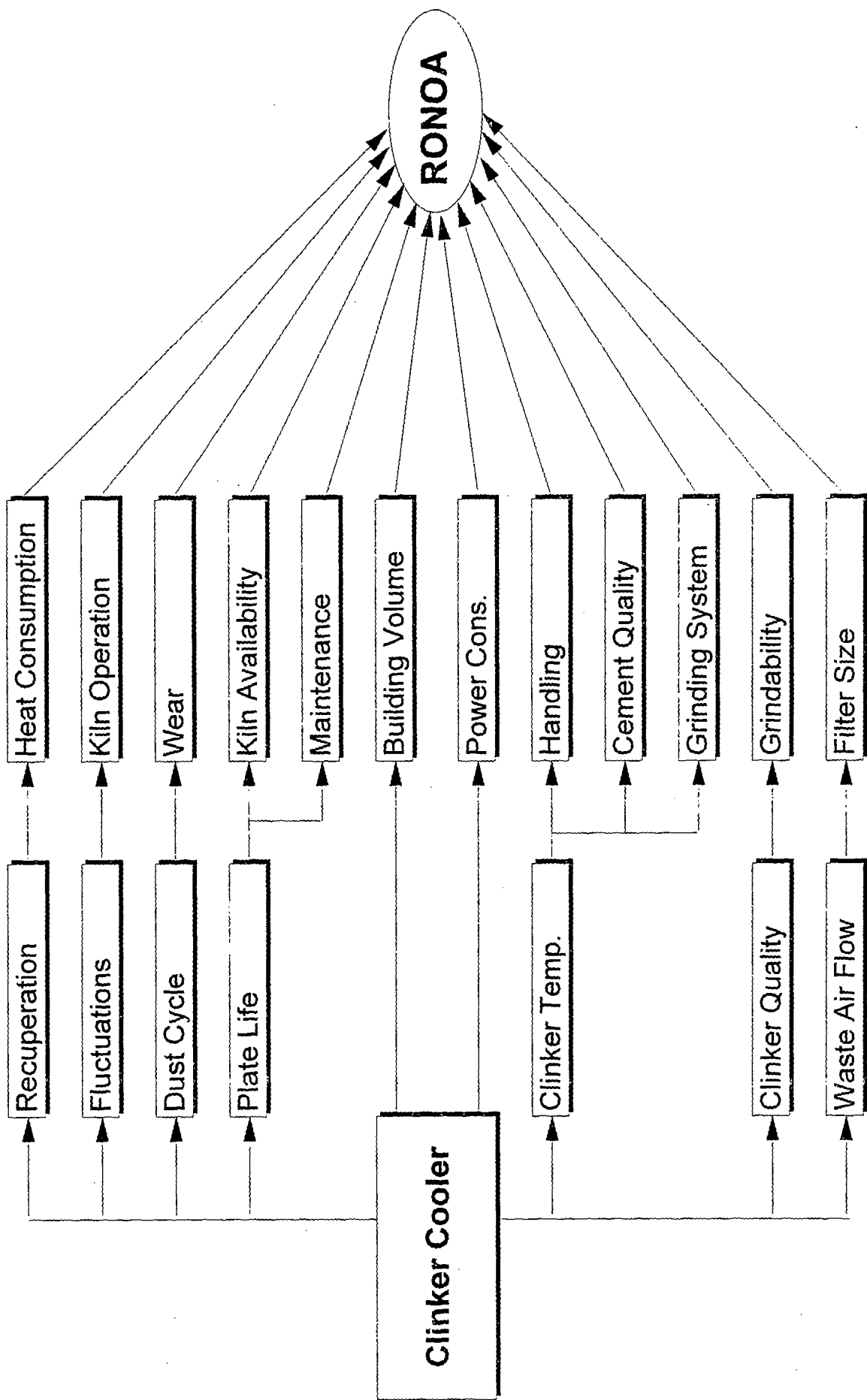
- Problems in the kiln outlet area and burner refractories
(due to higher secondary air temperature)
- Higher tertiary air flow [actual m³/s]
(due to higher tertiary air temperature)

DEVELOPMENT OF GRATE COOLERS

In the years	1950	1970	1990	
Specific grate loading	30	35 a 40	45 ..> 60	t/m ² d
Specific width load	700	1000	>= 2000	t/md
Specific cooling air (operation)	> 2.3	2.3	1.5 a 1.8	Nm ³ /kg cli
Specific cooling air (installed)	~3.0	~3.0	1.6 a 2.3	Nm ³ /kg cli
Undergrate pressure	25 a 30	< 45	n.a.	mbar
Fan pressure (cooler inlet)	<= 50	>= 65	<= 110	mbar
Number of grates	1 or 2	2 to 4	1 to 3	
No. of undergrate compartments	few	max.	direct seal air!	
Internal drag chain for riddlings	yes	no	yes	
Hoppers and gates for riddlings	no	yes	yes	
Grate inclination	> 5	<=3	0-4; 15	degrees
Flow and pressure control	no	yes	yes	
Direct plate aeration	no	no	yes	
Aeration of individual sections	no	no	yes	
Intermediate crusher	no	no	yes *	

* optional

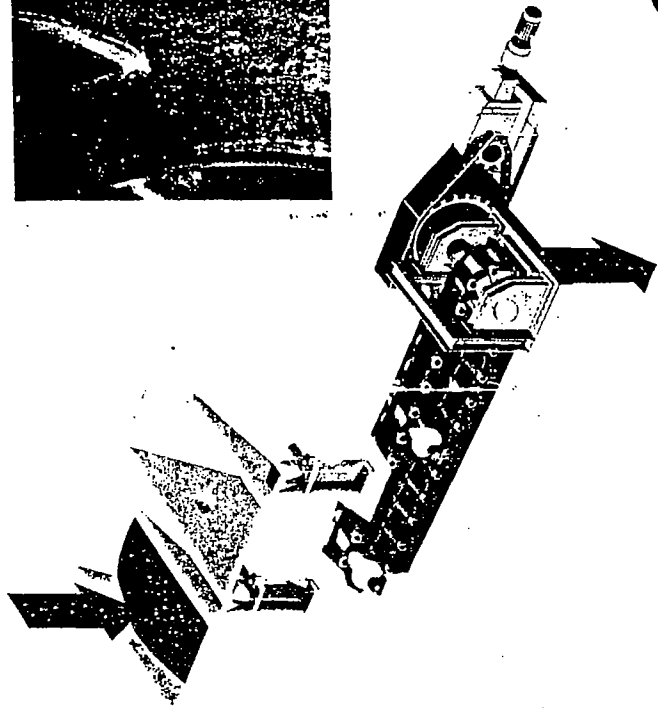
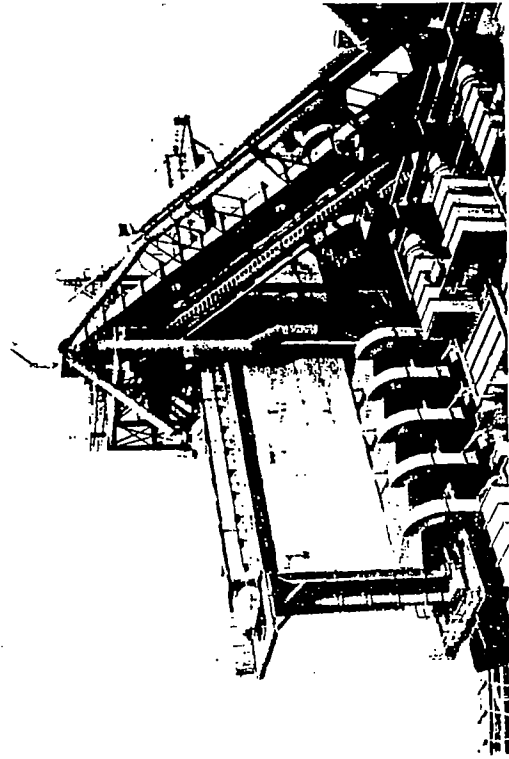
INFLUENCE OF THE GRATE COOLER ON THE PLANT RESULTS



FEATURES OF MODERN COOLERS:
BMH CLAUDIUS PETERS

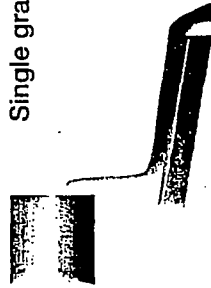
- **PETERS Cooler**
- **"Mulden" plate**
- **First grate or all grates with "Mulden" plates**
- **Inclination of first grate: 3°, all others 0° (Combi Cooler)**
- **2 to 4 grates**
- **Telescopic seal for air to moving rows**
- **Individual aeration of fields**
- **Separate seal air fans**
- **Hydraulic drive**
- **Drive and grate rollers outside of casing**
- **Tertiary air from cooler roof or kiln hood**
- **Hammer crusher or roller crusher (intermediate or at outlet)**
- **Modular concept**
- **Worlds largest coolers (10'000 t/d); conventional design**
- **Gravity aftercooler (G-cooler) available**

Claudius Peters Recuperator / g-Cooler System



The Claudius Peters Cooler Program

Single grate cooler



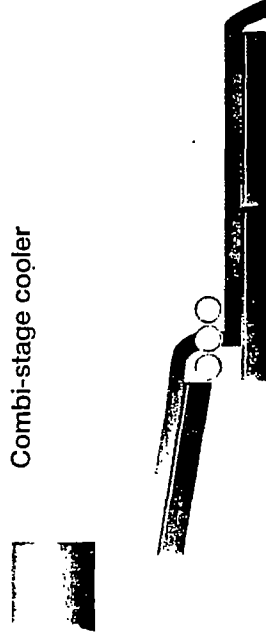
The smallest cooler unit for use with an inclined grate (3°) for capacities up to 1 500 t/d. The single grate is the basic module for the PETERS-cooler program

Combi-cooler



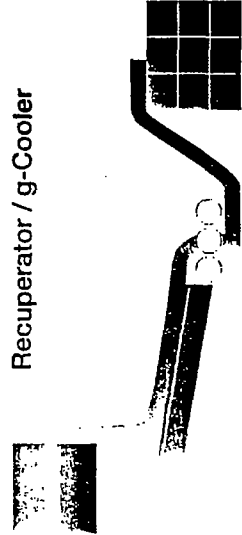
A combination of one inclined grate (3°) and 1-3 horizontal grates for capacities from 1 500 to 10 000 t/d. This design, incorporating a clinker breaker at the end of the cooler, requires the least overall height.

Combi-stage cooler

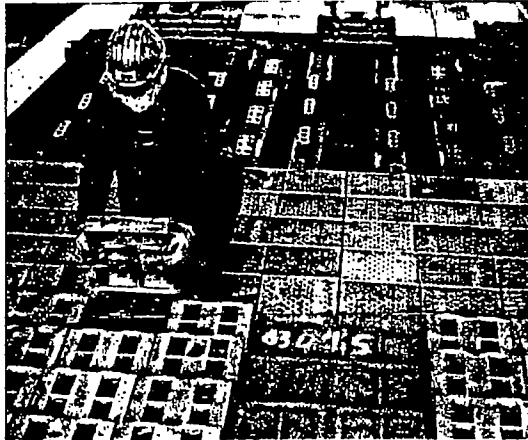
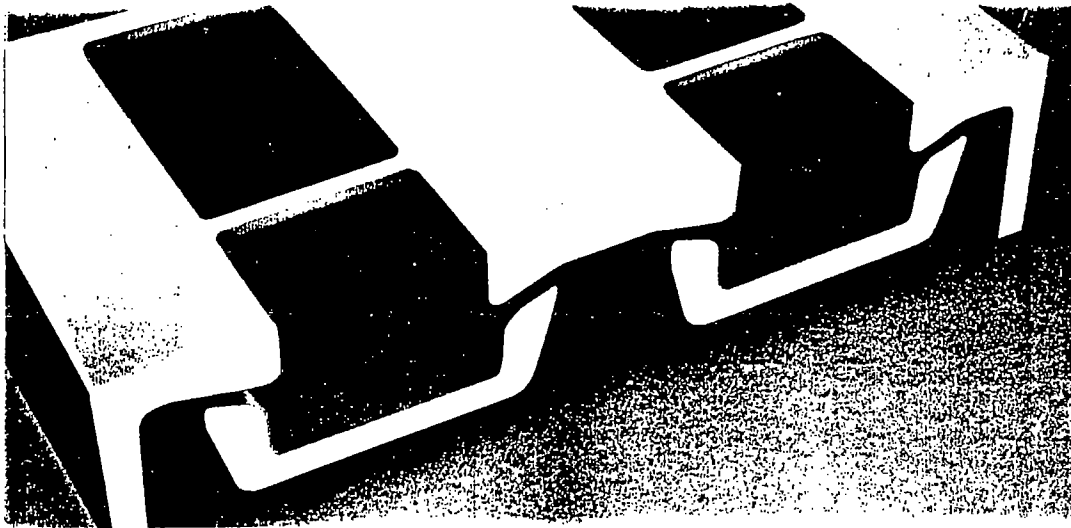


A Combi-cooler with intermediate comminution for capacities from 1 500 to 10 000 t/d. Intermediate clinker crushing is through a PETERS-roller breaker installed behind the inclined or the first horizontal grate. This design results in the smallest grate system possible.

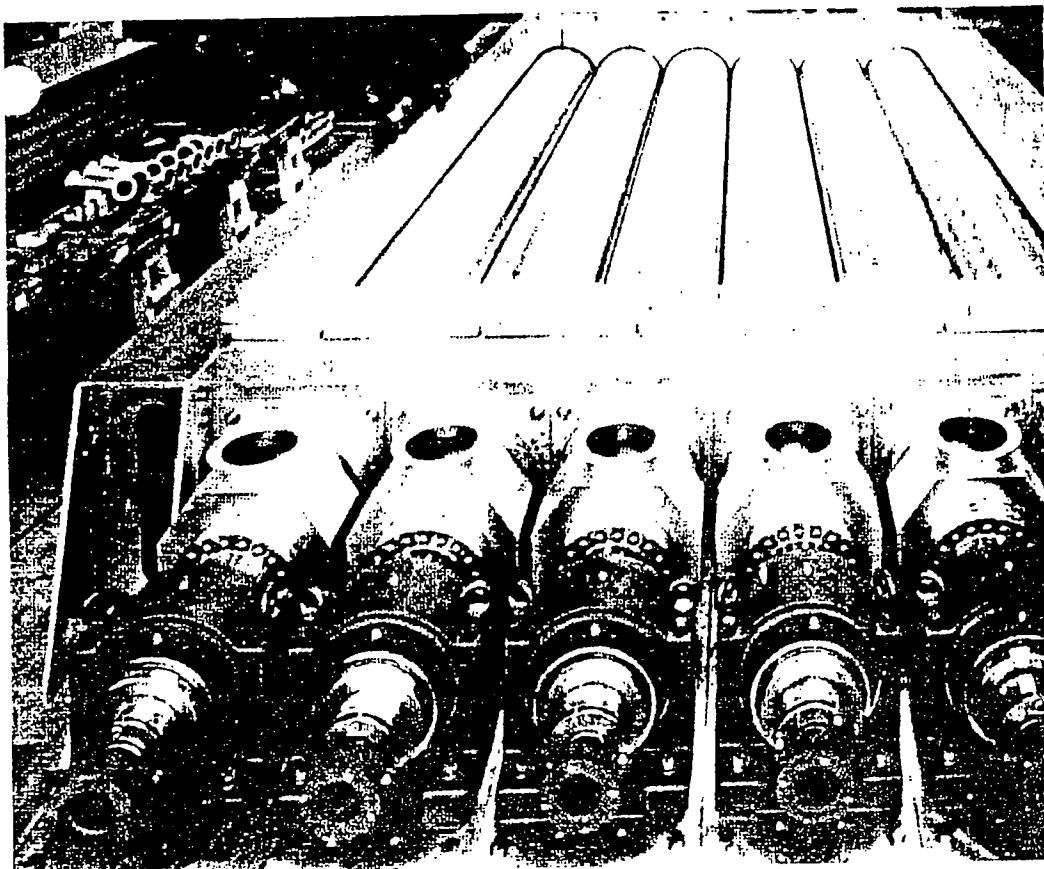
Recuperator / g-Cooler



A combination of an inclined grate (3°) and a PETERS g-Cooler for capacities up to 10 000 t/d. Because of the indirect cooling mode in the g-Cooler the system is nearly free of exhaust air. Especially suitable for capacity increase of existing systems. High installation flexibility.

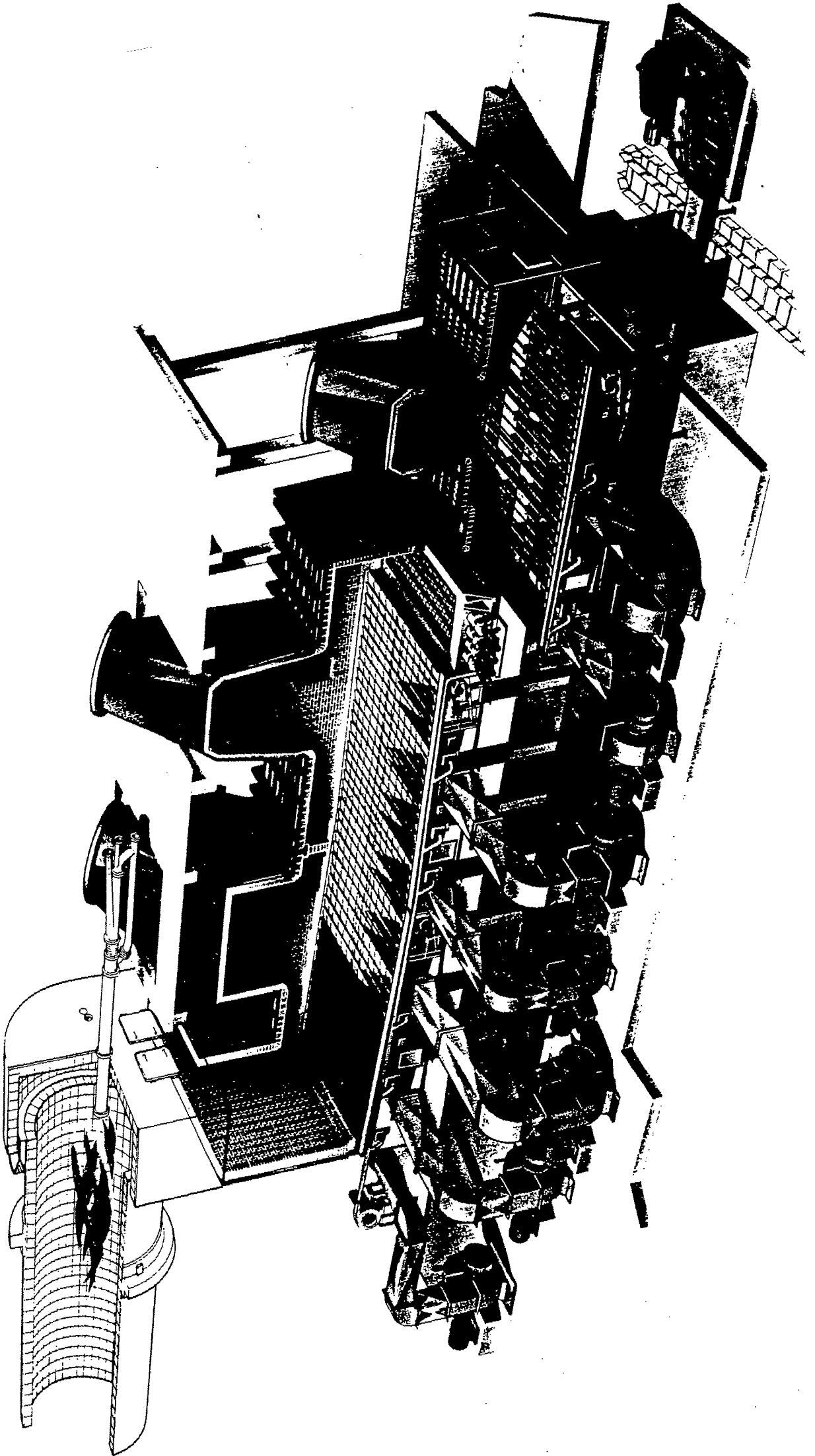


CPG
CLAUDIUS PETERS



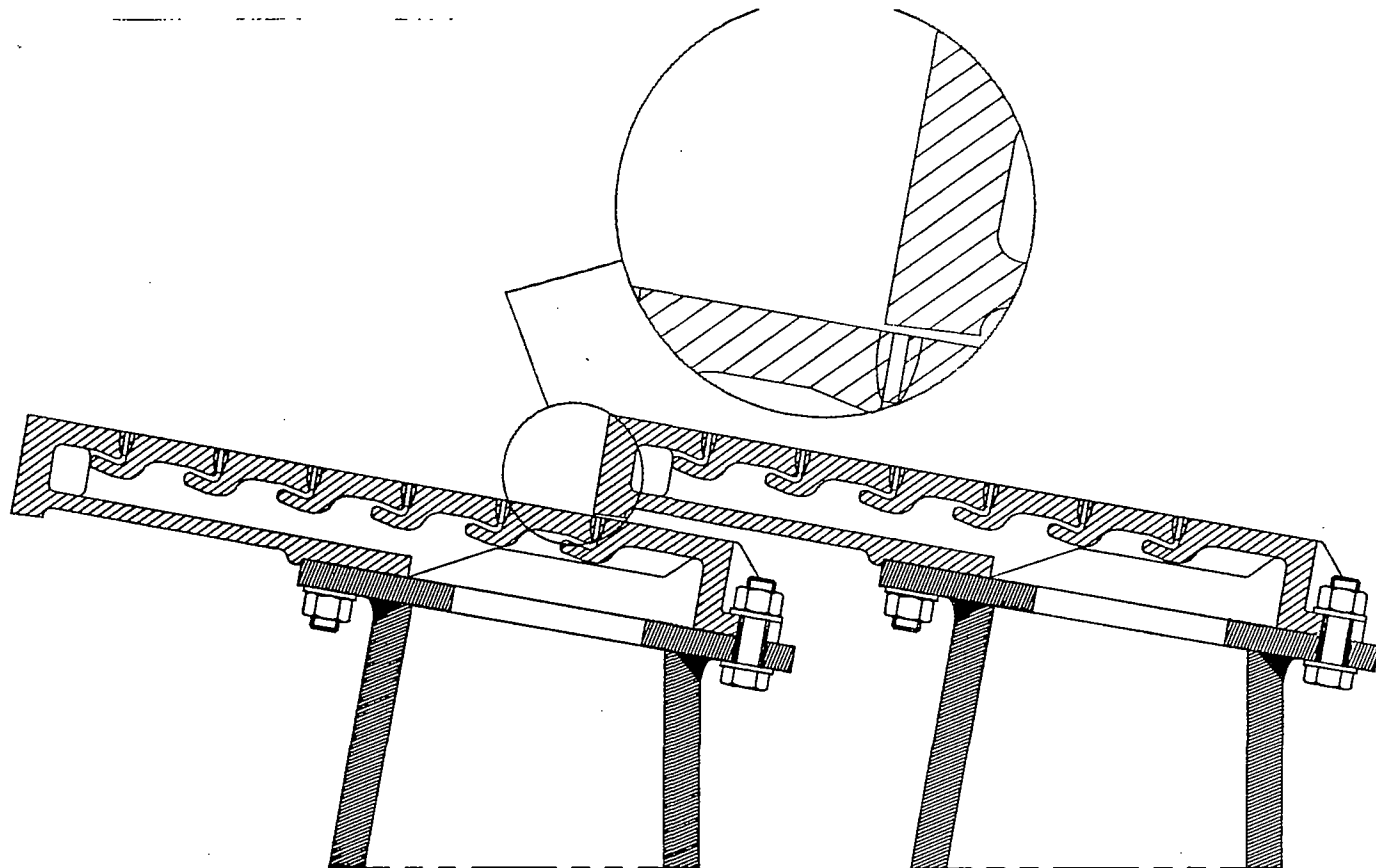
Peters Stage Coupler
Peters

CPAG
CLAUDIUS PETERS



FEATURES OF MODERN COOLERS:**F.L.SMIDTH**

- **COOLAX Cooler**
- **Controlled flow grate plates "FLS-CFG" direct aerated**
Reduced fall through "FLS-RFT" plates chamber aerated
- **First grate with "CFG" plates, rest with "RFT"**
- **All grates horizontal (inclination 0°)**
- **2 or 3 grates**
- **Tilting tube type ducts for air to moving rows**
- **Individual aeration of fields**
- **Separate seal air fans**
- **Hydraulic drive**
- **Tertiary air from cooler roof or kiln hood**
- **Hammer crusher or roller crusher (intermediate or at outlet)**
- **Hoppers or internal drag chain**
- **"Coolscanner" for clinker surface temp.measurement**



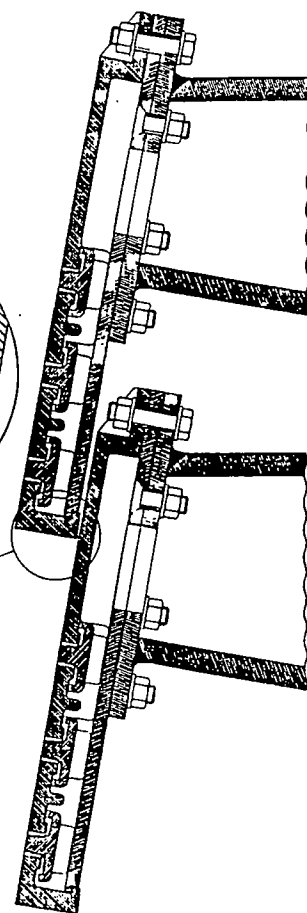
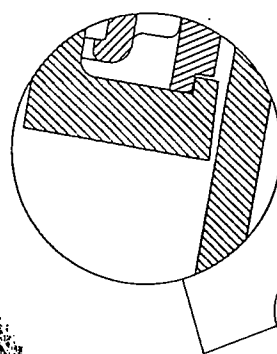
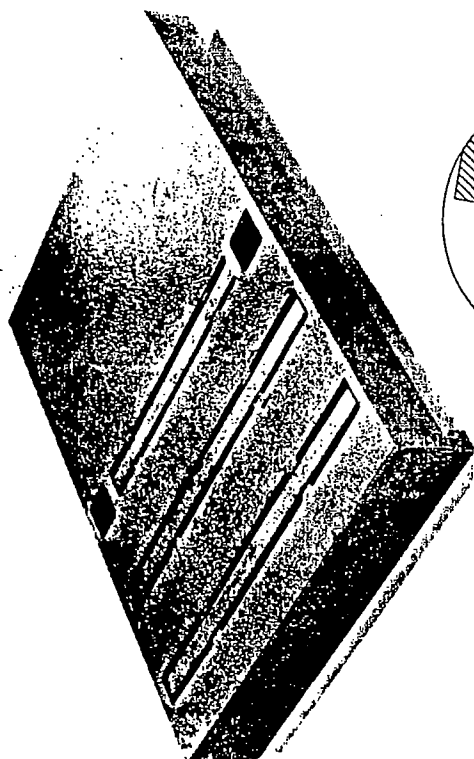
Coolax Grate Cooler

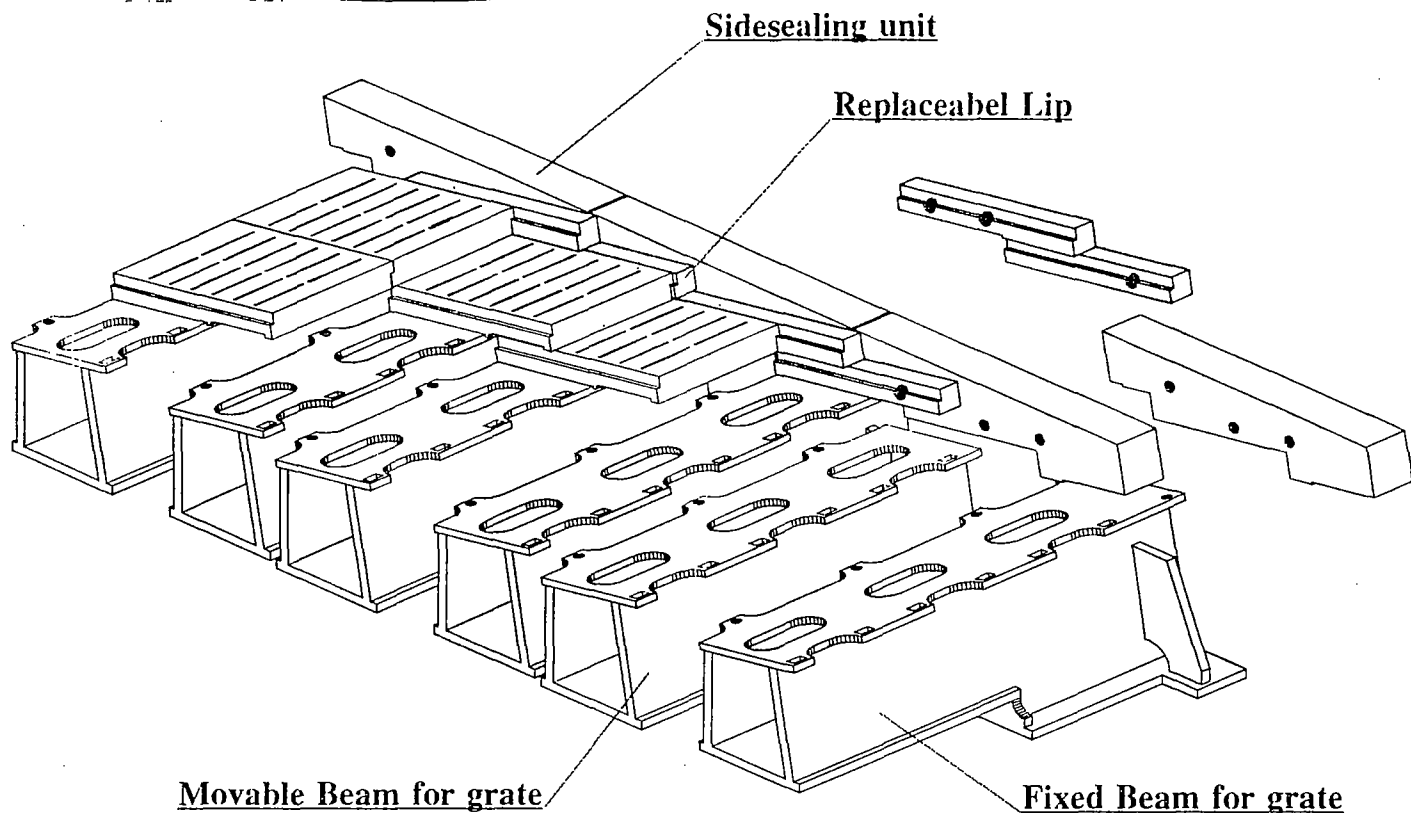
www.klm/WHOCKERHEALING plants

ENCL. 4

CFG grate rows

D.4.1

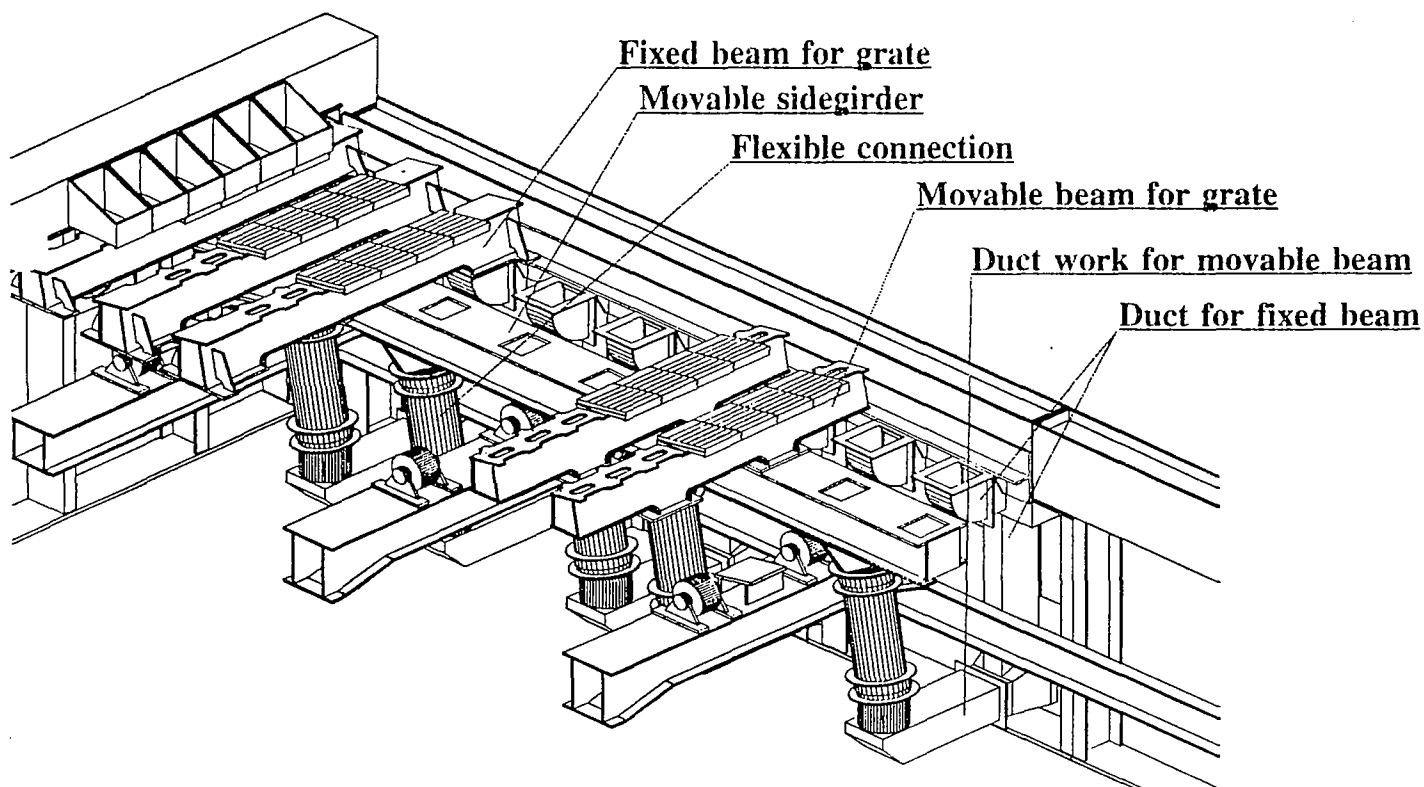




Coolax Grate Cooler

ENCL. 7

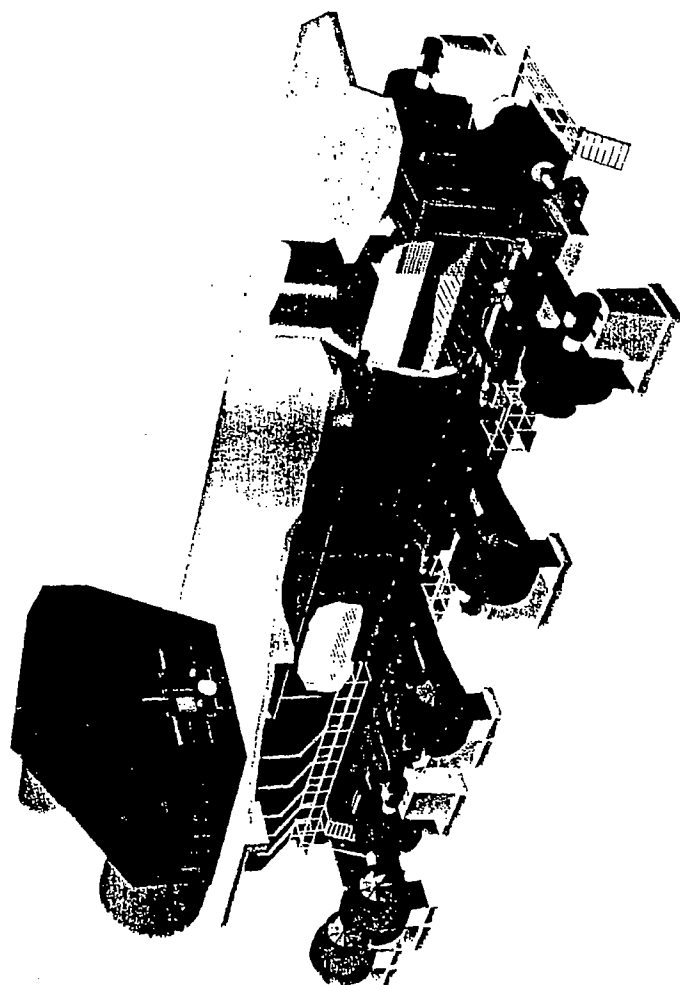
Side Sealing Arrangement



Coolax Grate Cooler

ENCL. 3

CFG-Zone



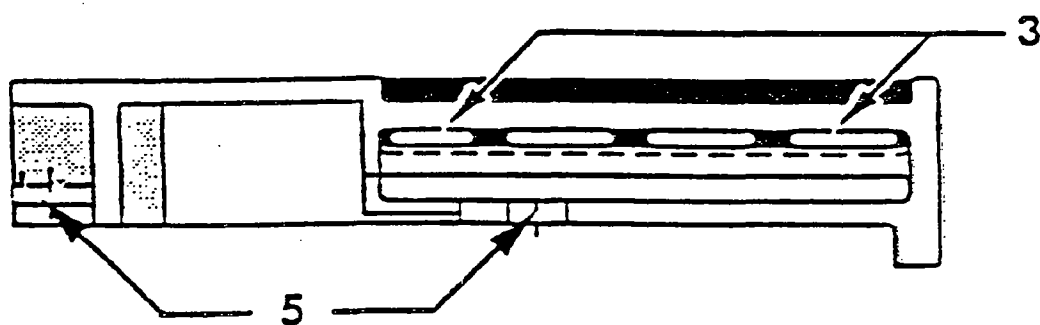
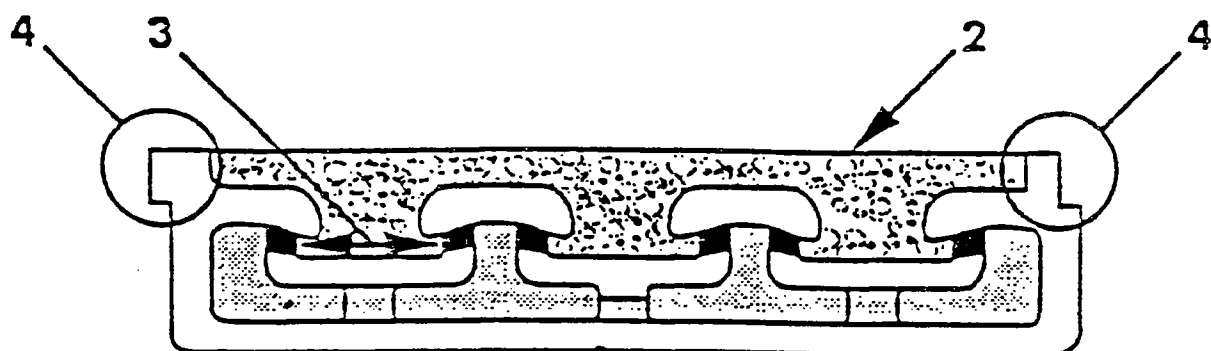
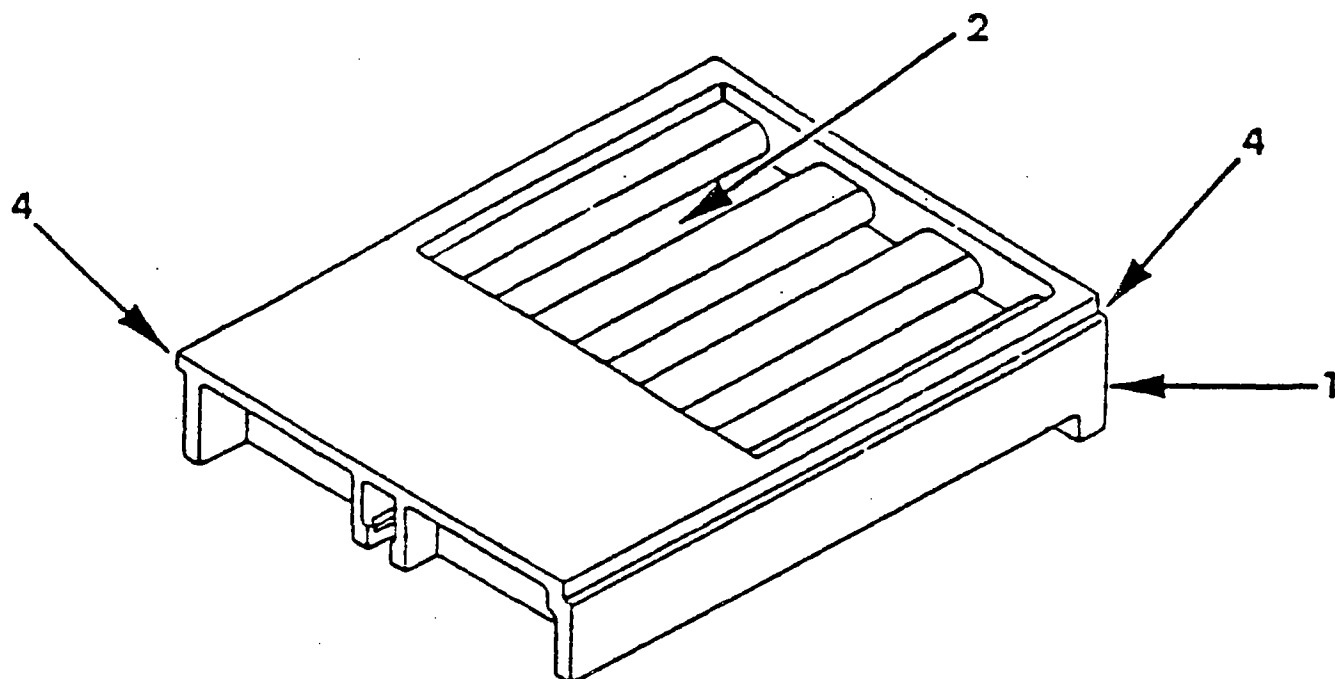
STANDARD COOLAX COOLERS.

Clinker temperature: 65 - 80 + amb.

Prd	size	area	load	Winlet	CFG	No of fans			Drv. length		
T/24h		m2	T/24h/m2	Shoes	Rows	CFG	RFT	Total	I	II	III
1500	842	31.1	48.3	6	17	4+1	3	8	17	25	
2000	1048	42.0	47.6	6	23	4+1	3	8	23	25	
2500	1060	52.7	47.5	6	29	4+1	3	8	29	31	
3000	1072	64.5	46.5	6	35	6+1	3	10	35	37	
3500	1266	71.7	48.8	8	35	6+1	4	11	29	37	
4000	1278	85.9	46.6	8	35	6+1	4	11	35	43	
4500	1284	93.1	48.4	8	35	6+1	5	12	35	24	25
5000	1478	101.4	49.3	10	35	7+1	4	12	35	43	
5500	1490	118.0	46.6	10	41	7+1	4	12	35	30	25
6000	1496	126.3	47.5	10	41	7+1	5	13	35	36	25
6500	14102	136.8	47.5	12	41	7+1	5	13	35	36	31
7000	14108	147.5	47.5	12	41	7+1	6	14	35	36	37
7500	16102	154.8	48.4	12	41	7+1	5	13	35	36	31
8000	16108	168.9	47.4	14	41	7+1	6	14	35	36	37
9000	16120	187.9	47.9	14	47	7+1	6	14	35	42	43
10000	18120	207.1	48.3	14	47	7+1	6	14	35	42	43

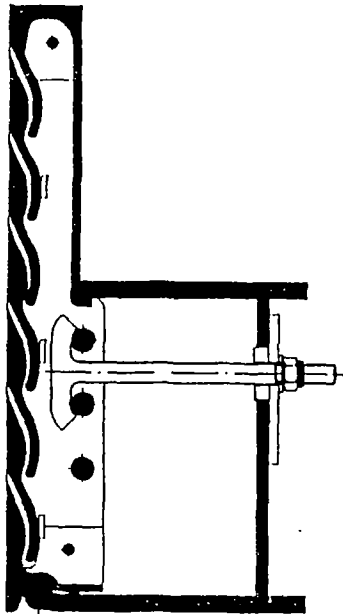
FEATURES OF MODERN COOLERS:**FULLER (a FLS company)**

- Cooler development jointly with FLS
- Controlled flow grate plates "Fuller-CFG" direct aerated
Reduced fall through "Fuller-RFT" plates chamber aerated
- First grate with "CFG" plates, rest with "RFT"
- All grates horizontal (0° inclination)
- 2 or 3 grates
- Flexible hose type ducts for air to moving rows
- Individual aeration of fields
- Separate seal air fans
- Hydraulic drive
- Tertiary air from cooler roof or kiln hood
- Hammer crusher or roller crusher
- Hoppers or internal drag chain

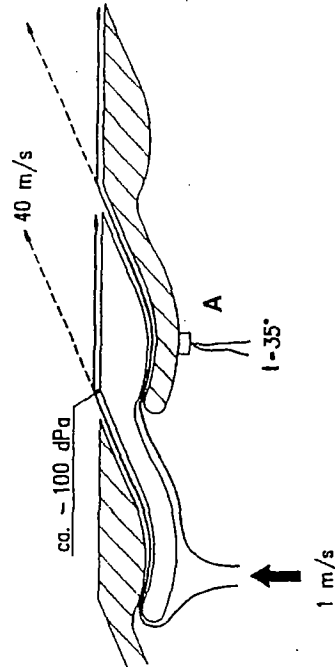


FEATURES OF MODERN COOLERS:**IKN**

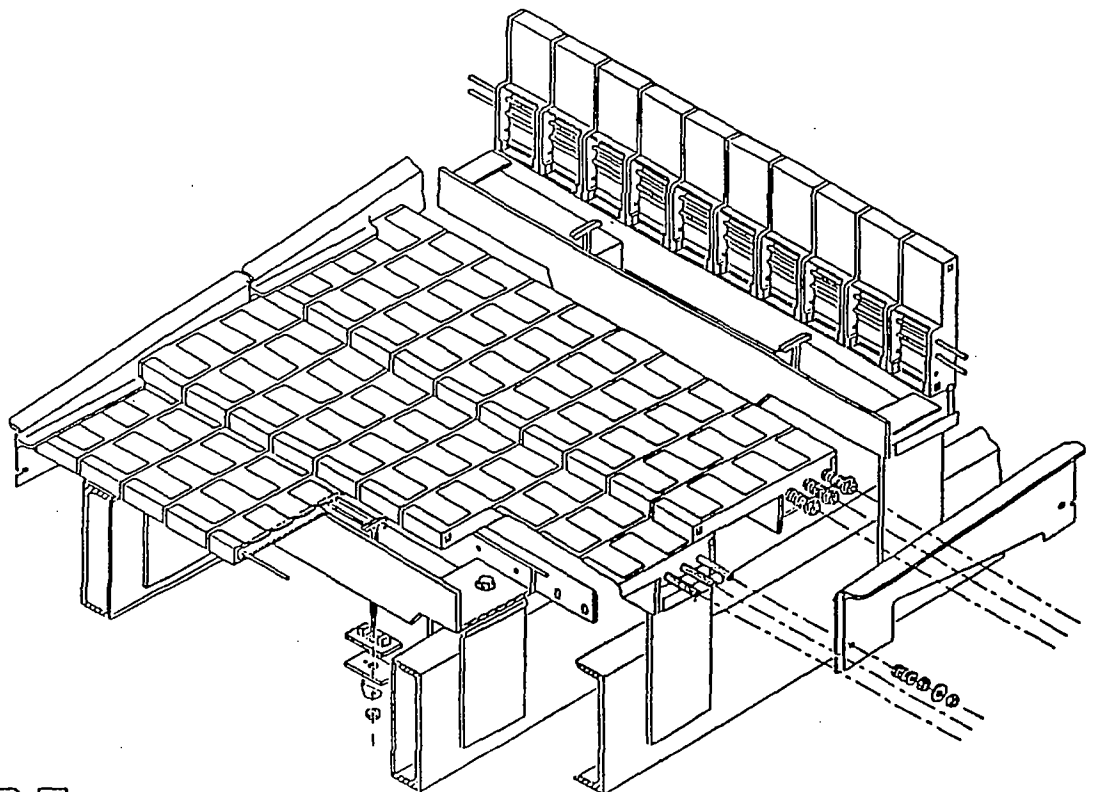
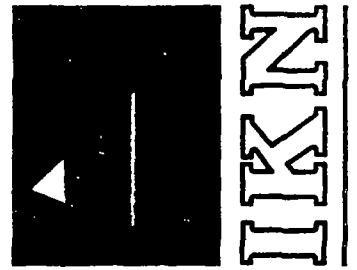
- **Pendulum Cooler**
- **"Coanda" nozzle plate for horizontal aeration (2 types)**
- **100 % equipped with with "Coanda" plates**
- **First grate fixed, inclination 15° for clinker distribution (Klinker Inlet Distribution System = KIDS)**
- **1 grate, inclination 4°**
- **Flexible hoses for aeration to moving rows
new: compartment aeration and open air beams**
- **Differentiation of left / right side aeration**
- **Every third row of grate moving**
- **Central hydraulic drive**
- **Self aligning and centering wear free (Eternal) Pendulum"**
- **Tertiary air from kiln hood (dep. on kiln requirement)**
- **Roller crusher or hammer crusher at the outlet**
- **Retractable radiation shield**



Cross-section through an air beam

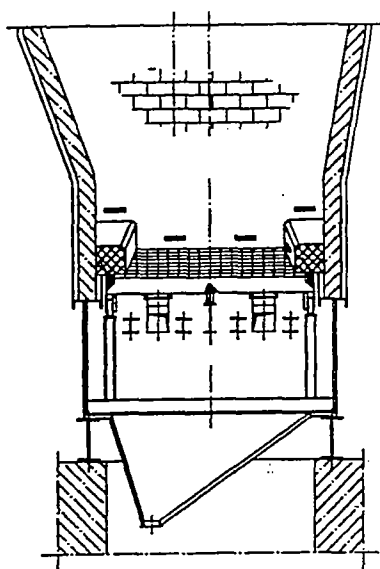


Coanda effect of inclined slots

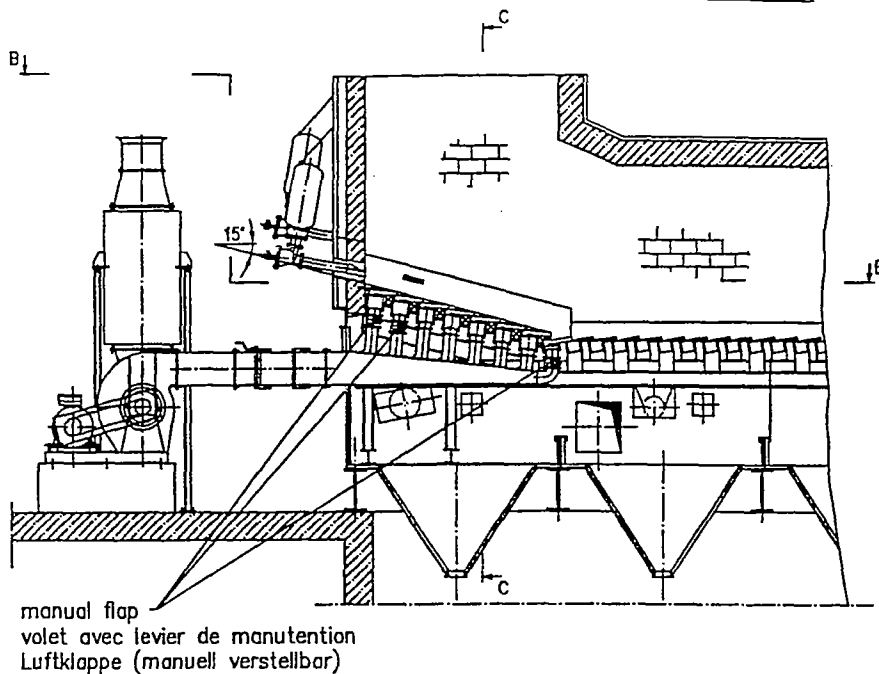


IKN

SECTION C - C

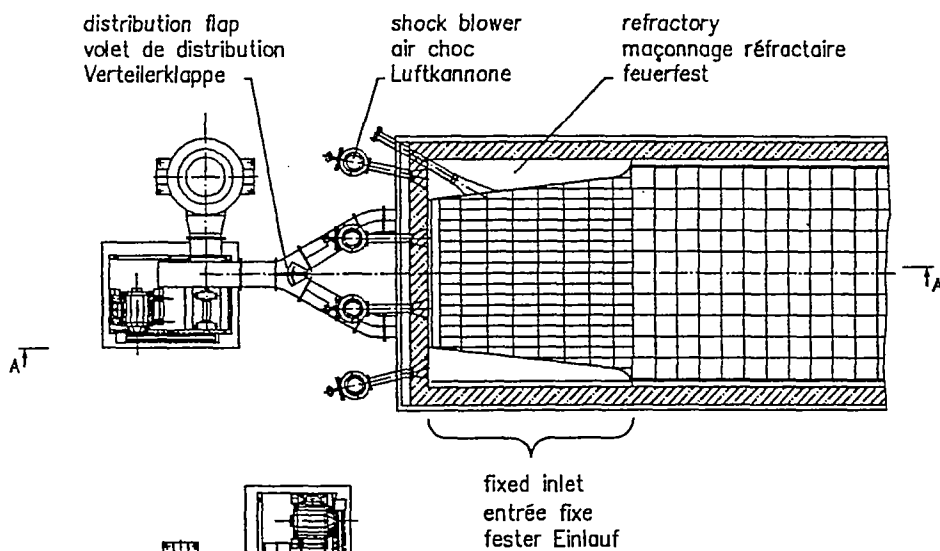


SECTION A - A



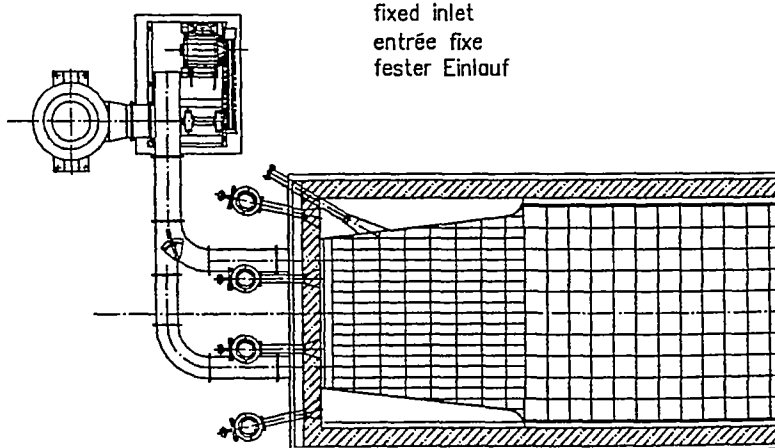
SECTION B - B

FAN FRONTSIDE
VENTILATEUR CÔTÉ FRONT
VENTILATOR STIRNSEITIG



ALTERNATIVE

FAN LEFT-OR RIGHTSIDE
VENTILATEUR GAUCHE OU DROIT
VENTILATOR LINKS-ODER RECHTS



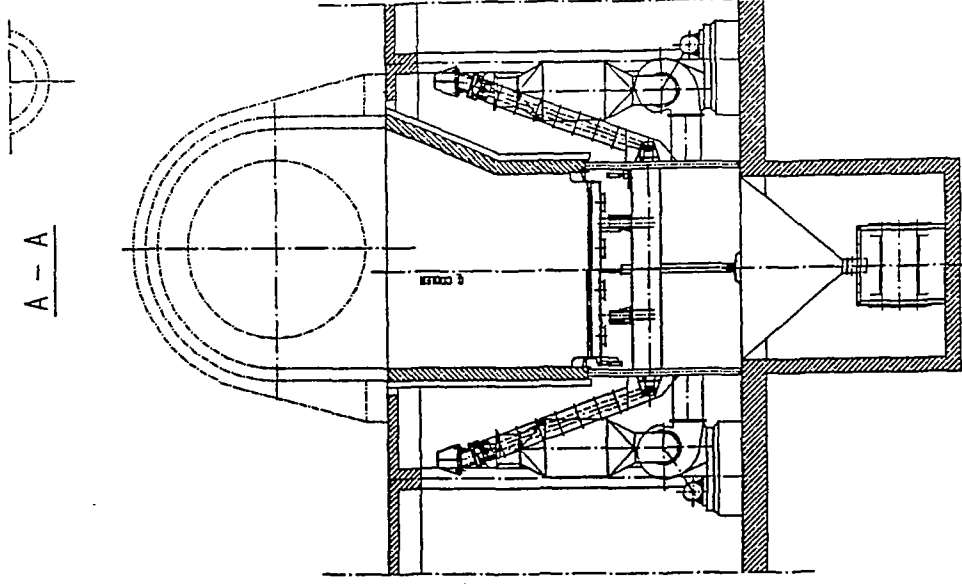
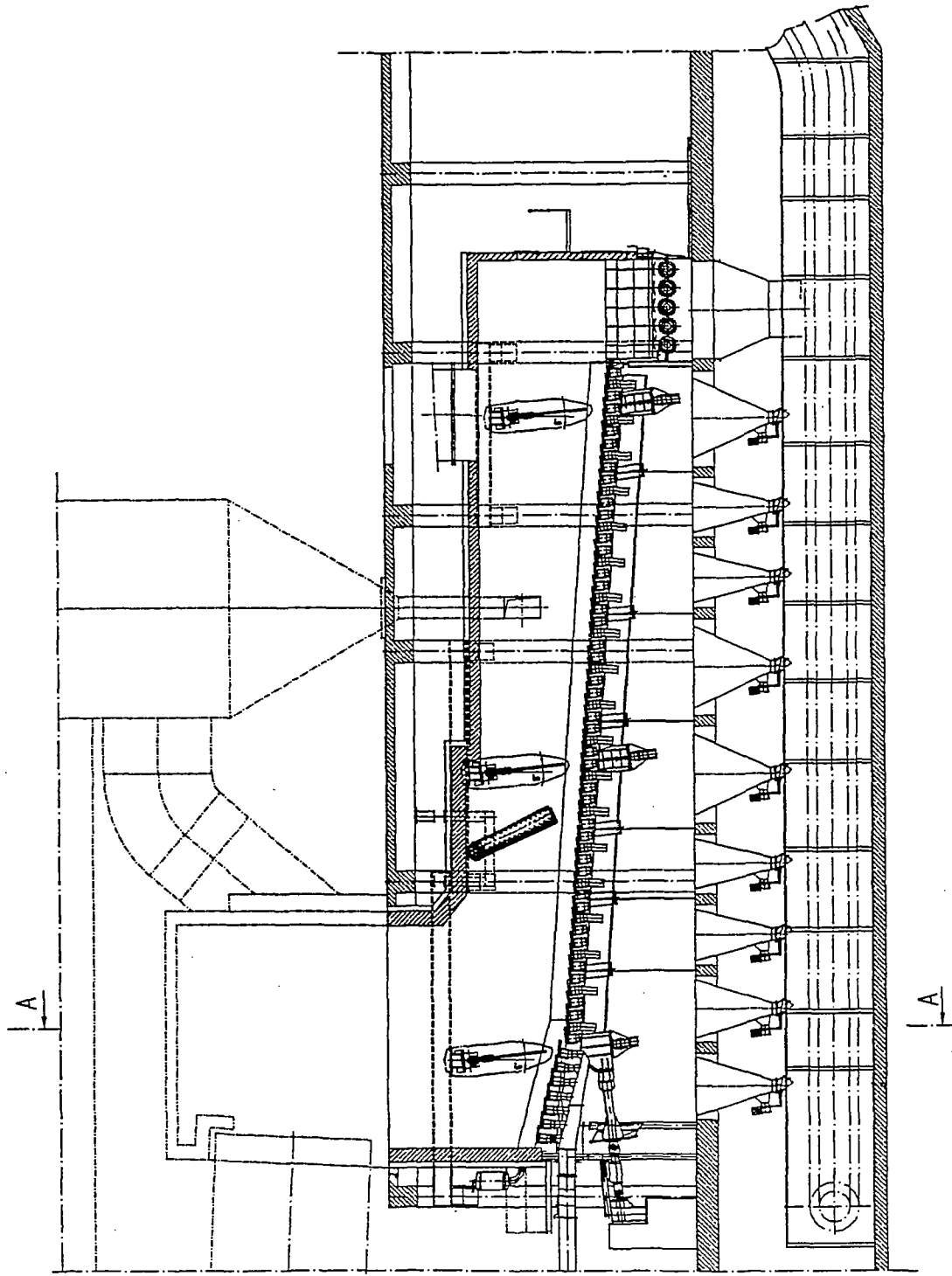
Clinker Inlet Distribution System

Système distribution de clinker

Klinkereinlaufverteilung

IKN-KIDS

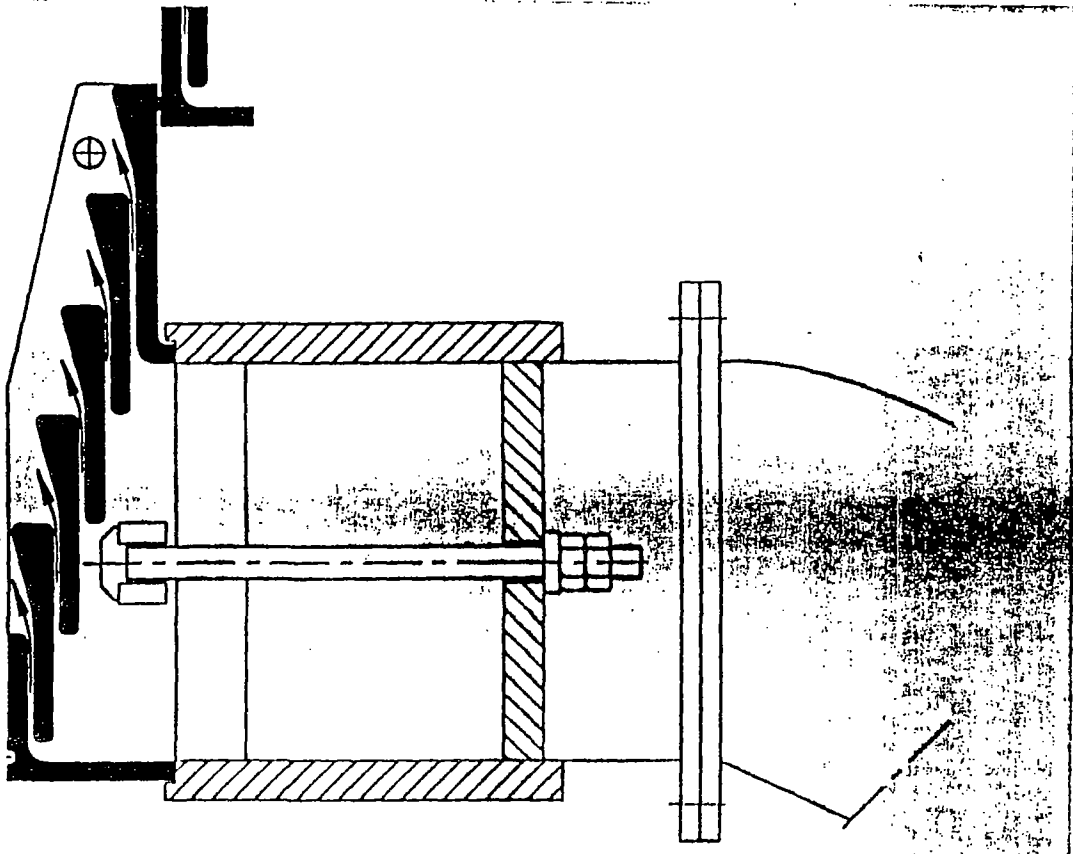
D001.00.19



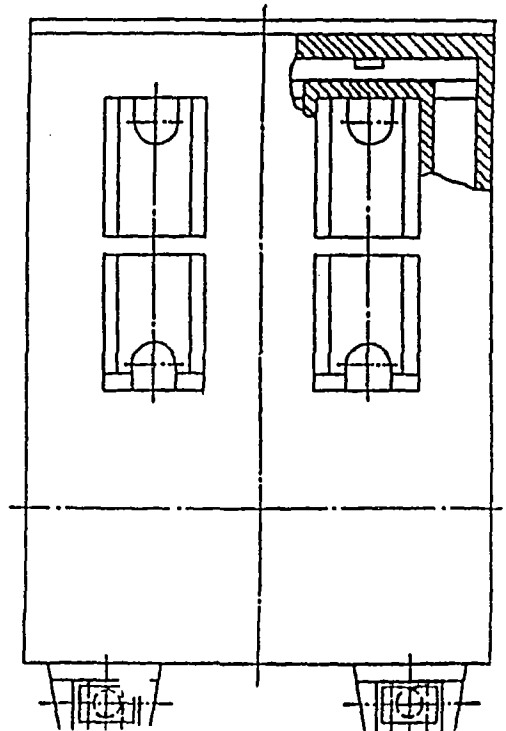
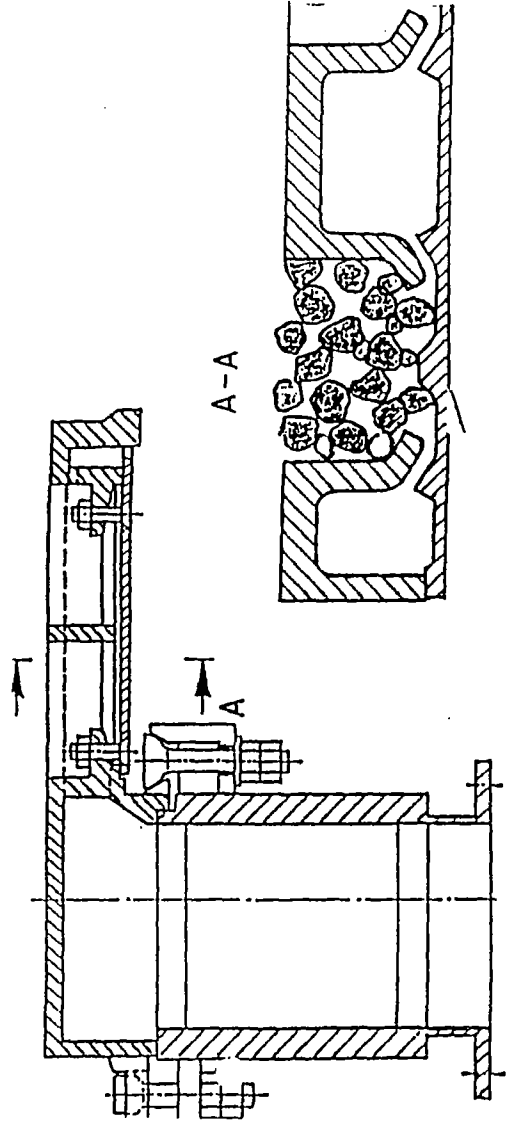
I K N	
PENDULUM COOLER WITH ROLLER CRUSHER AND HEAT SHIELD	
D 001.00.21	21.06.1994

FEATURES OF MODERN COOLERS:**KHD HUMBOLDT WEDAG**

- **PYROSTEP" Cooler**
- **"Step" plates for static chute grate (inclined)**
- **"Omega" plates for intermediate grate (horizontal)**
- **One or two static chutes with "Step" plates**
- **"Omega" plate rows after static grates**
- **Horizontal aftercooling section with conventional plates and chamber aeration**
- **2 telescopic ducts for air to moving "Omega" rows**
- **Direct aeration of "Step" and "Omega" plates**
- **Hydraulic drive**
- **Drive and grate rollers outside of casing**
- **Tertiary air from kiln hood**
- **Hammer crusher or roller crusher (intermediate or at outlet)**
- **Relatively simple solution**



PYROSTEP - Kühler
Stationäre Treppen Rostplatte, direkt belüftet
PYROSTEP - Cooler
Stationary step grate plate, directly aerated

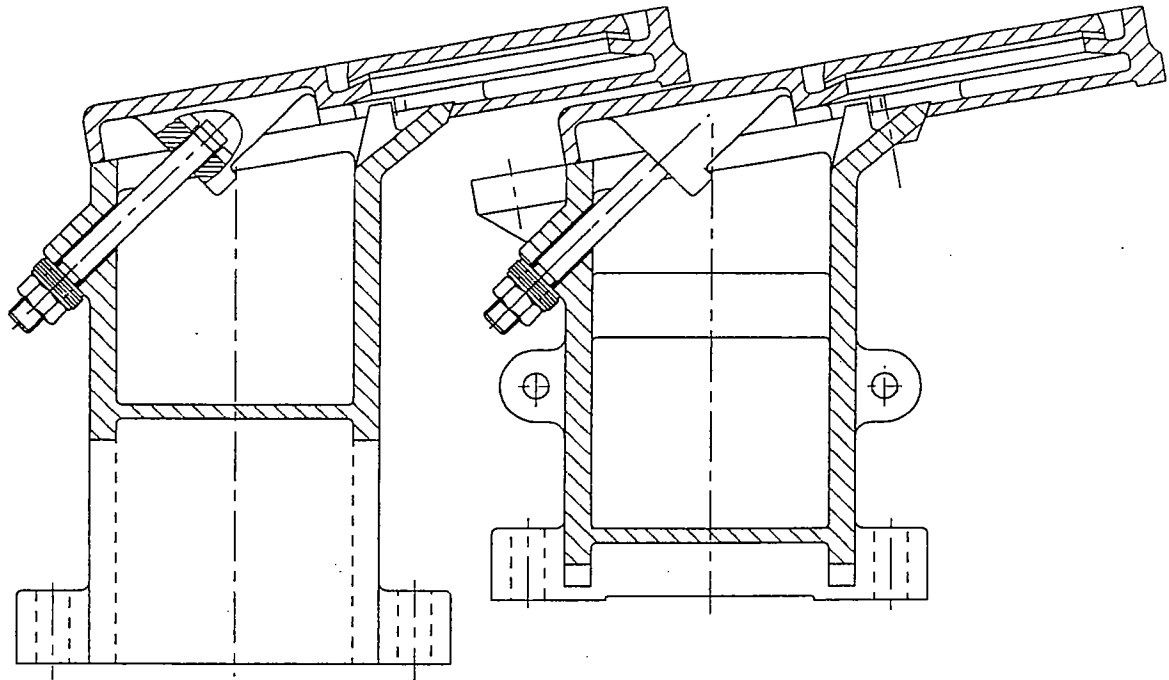


Omega-Rostplatte, direkt belüftet
Omega-Shaped grate plate, directly aerated



FEATURES OF MODERN COOLERS:**POLYSIUS**

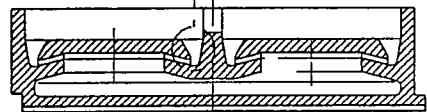
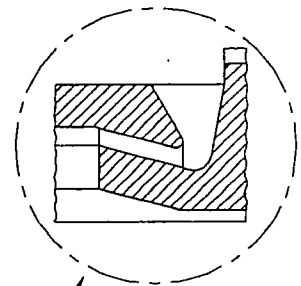
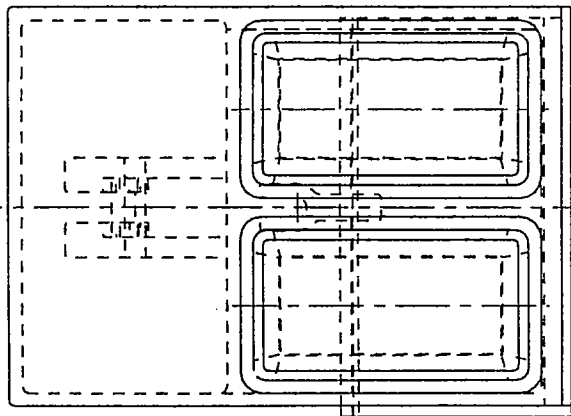
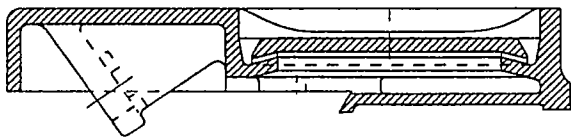
- REPOL S, RS, RS-F
- "Jetring" plate (2 types)
- First grate or all grates with "Jetring" plates
- Inclination of grate 1: 4° and 0°, grate 2 and 3: 0°
- 2 or 3 grates
- Slide seal for air to moving rows
- Individual aeration of fields (stripe pattern)
- Separate seal air fans
- Hydraulic drive
- Sealed compartment for drive and grate rollers
- Central guide roller
- Tertiary air from cooler roof
- Intermediate roller crusher or hammer crusher at the outlet



movable row

fixed row

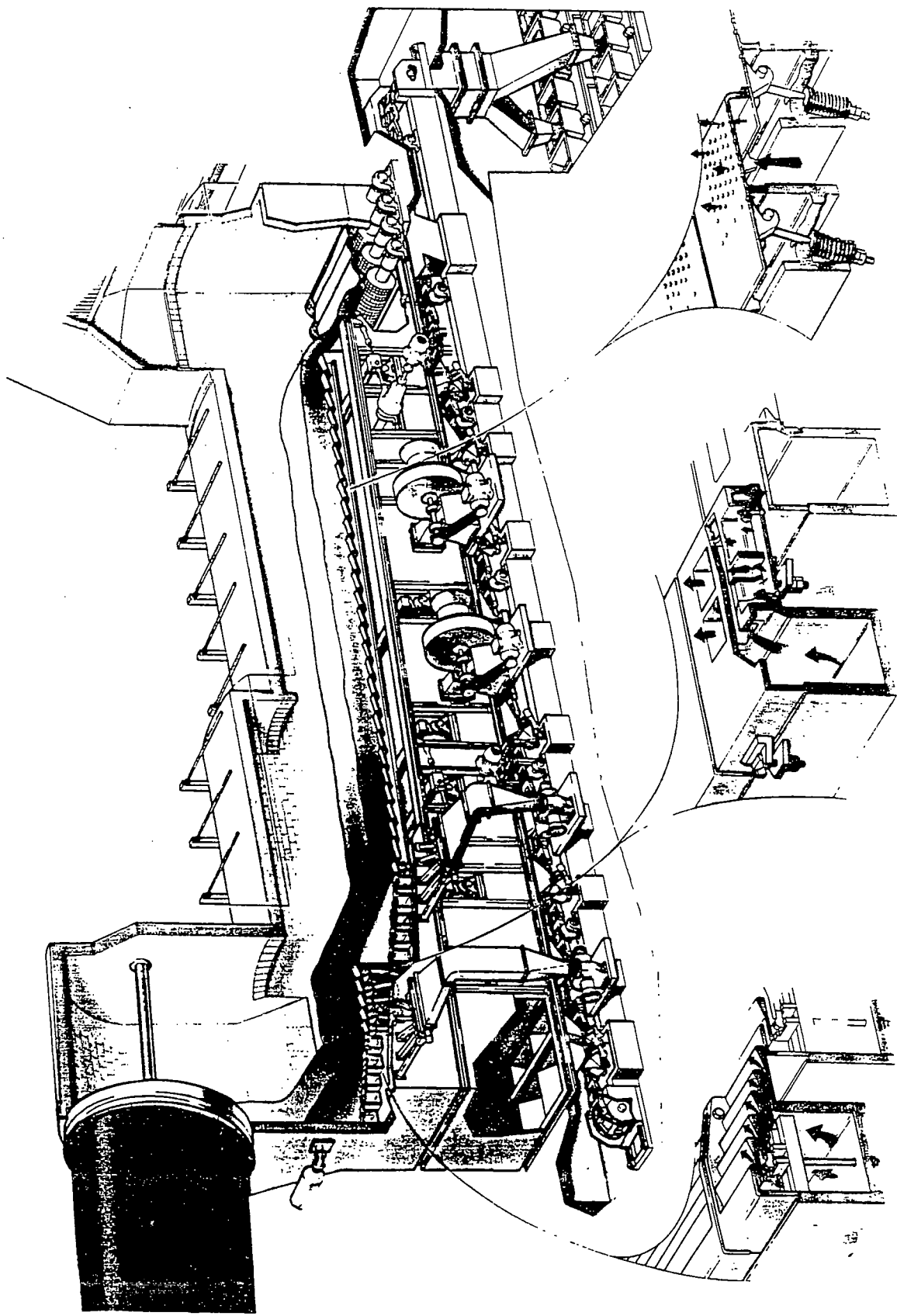
Verschraubung Jet-Ring-Platte Screwing jet-ring-plate



s-pr-1-20

Jet-Ring Platte mit Klinkerkasten Jet-Ring Plate box-type





KHD Humboldt Wedag AG

**Neue Bogen-Einbauten
für Rohr- und Satellitenkühler
New curved internal fittings
for rotary and planetary coolers**

E. Steinbiß, Köln

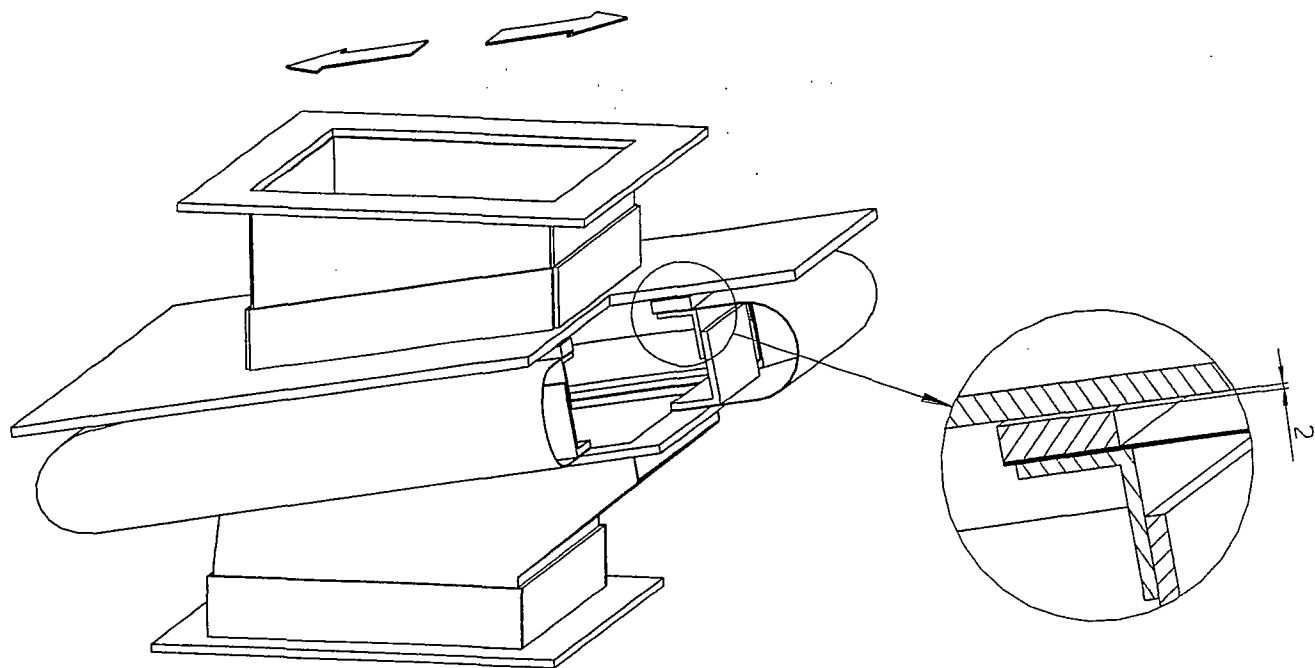
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Sonderdruck aus/Reprint from
ZKG
INTERNATIONAL

**KHD
HUMBOLDT
WEDAG**

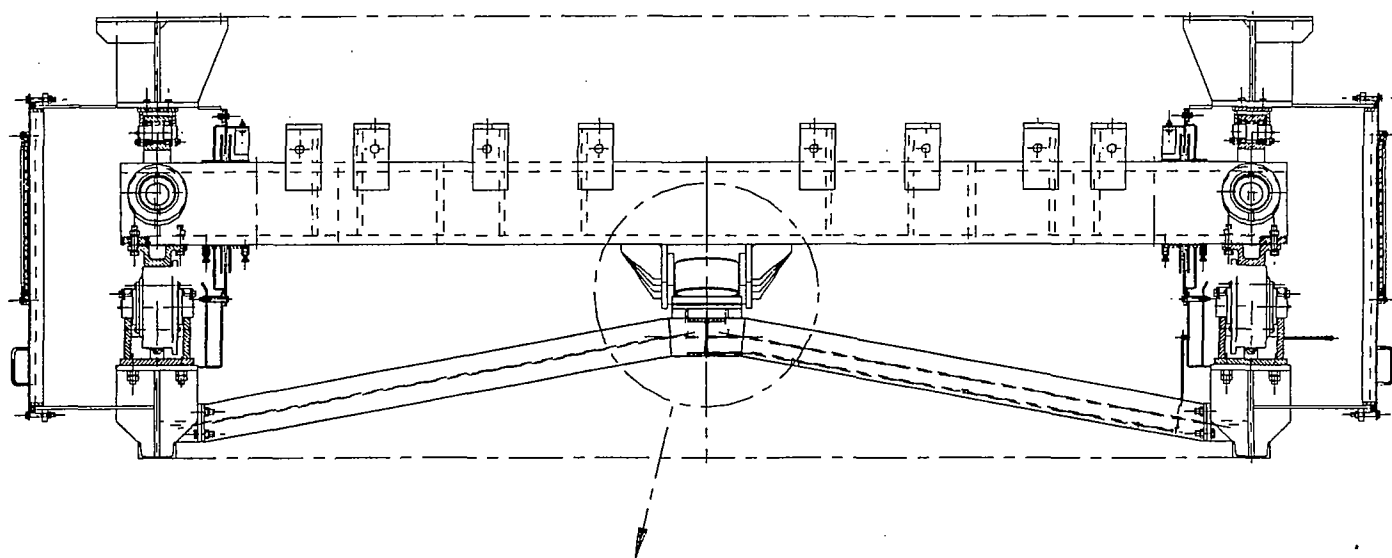
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Schiebedichtung
contactless sealing



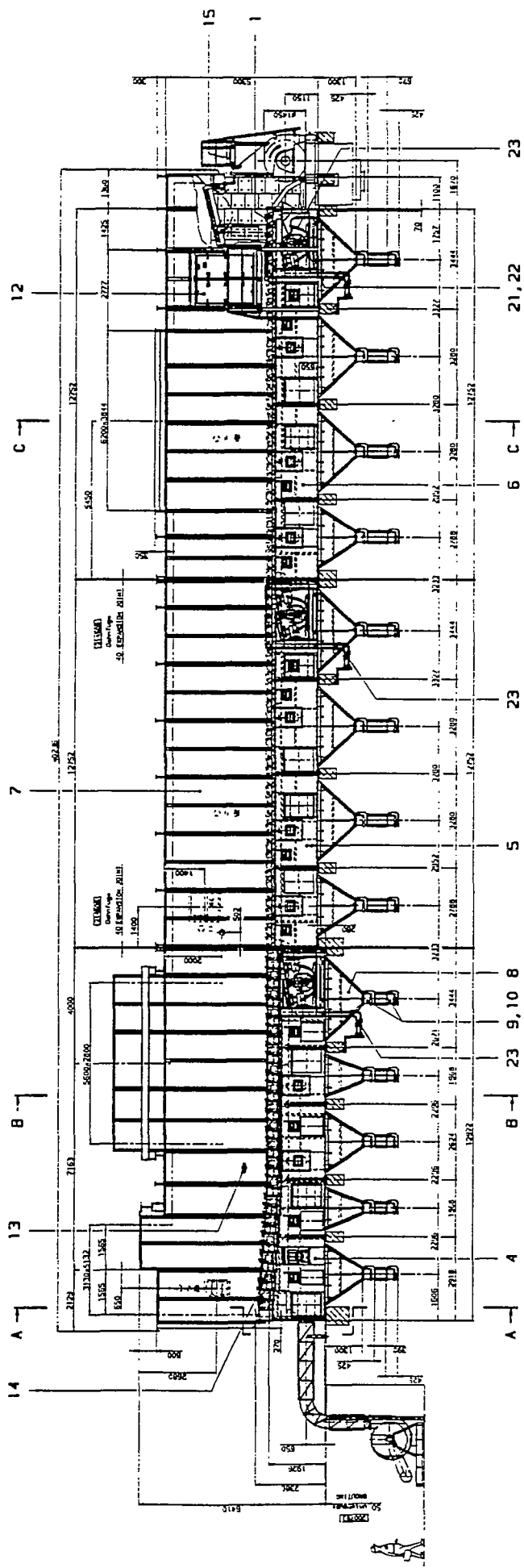
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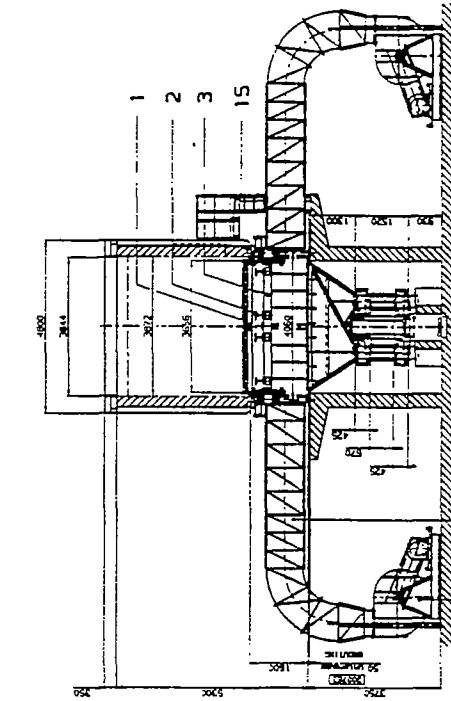
s.pr-1-34j

Zentrale Parallelführung der Roste
Central grate guidance

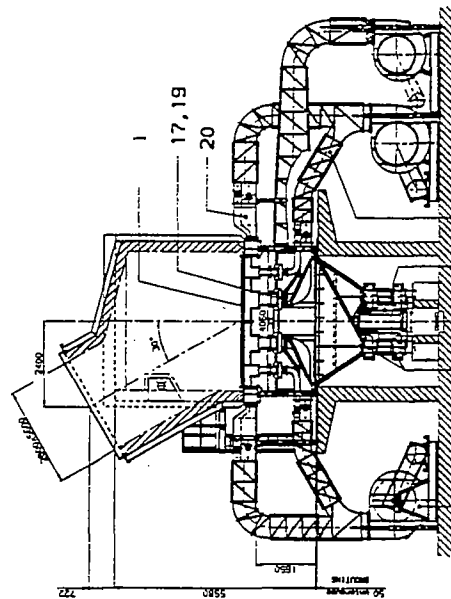




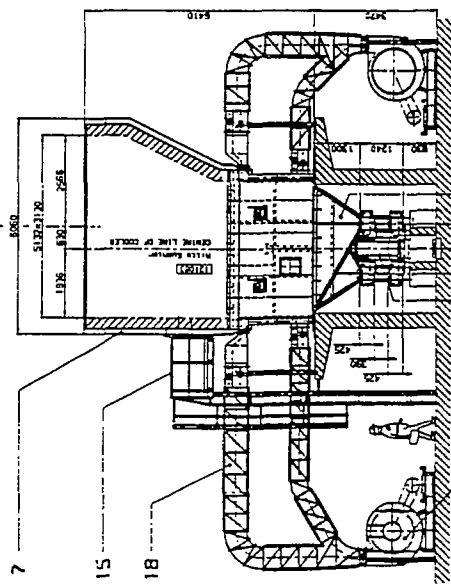
C-C



B-B



A-A



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