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Optimization of Burner Kiln 7, Cementa Slite

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Cover: Cementa Slite, a calm winter morning during full production. The characteristic silos for storage and the high cyclone tower is clearly visible. Photo: Cementa AB

Abstract

In this report focus is put on the combustion process at a cement plant. Combustion is the heart of the cement making process and absolutely crucial to have under full control and well optimized.

The fuel is put into the process through a burner pipe and this burner pipe is modified to reach a more efficient combustion. The primary target is to enable burning of heterogeneous alternative fuels and increase the production level. Other positive effects from this type of optimization is lowered specific fuel consumption and lowered CO_2 emissions.
A redundant burner is chosen for the project and overall the project steps are the following:

1. Installing a Jet air nozzle ring in a way so it can move both axially and radially due to temperature changes.
2. Remove the present refractory from the burner and order a new form to decrease the weight of the burner
3. Place a K6 blower in operating the axial channel.
4. Install Gauging equipment (Temp, pressure, ampere blower etc)
5. Carefully observe process values during the modified burners run in time.
6. Evaluate the results of the project
7. With the help of proven potential in the kiln system be able to convince management of the proceeds to invest in a new burner
8. If point 7 is fulfilled with the help of experience, be able to operate as a project coordinator in the purchase of a professional burner. This task will include coordinating the project group in various meetings and then lead to an RFQ (Request For Quotation).

Results from the project show the great potential in an optimization of a burner at a cement plant. A production increase of 5% could be seen together with a lowered specific energy consumption which is extremely satisfactory results. Unfortunately a breakdown of the system occurred a bit down the path of optimisation that resulted in damages to the kiln. At this stage the optimization was stopped and the old burner was put back after finished kiln repair.

Finally crucial to underline is that the proven results in this study convinced the Group Management of buying a new burner. The benefits from a professional tailor made burner are far greater than the cost of buying it. The payback time is roughly around a year for such an investment depending on current market conditions.

Sammanfattning

Dagens cementtillverkning är en avancerad och storskalig process. Driften kräver högteknologisk produktionsutrustning och moderna övervakningssystem. Det är en blandning av kalksten och lermineral som utgör basen vid cementtillverkning. Blandningen krossas och mals till ett torrt och fint pulver, kallat råmjöl. Råmjölet bränns i stora roterande ugnar där temperaturen i slutskedet av processen uppgår till över 1400ºC. Vid dessa extrema temperaturer omvandlas råmjölet till flera glashårda mineral som kan liknas vid porslin, kallat klinker. Klinkern mals sedan tillsammans med bl.a. lite gips och järnsulfat till ett gråaktigt pulver – cement.

Rapporten fokuserar på förbränningen som är ”hjärtat” i tillverkningsprocessen. Bränsle och luft tillsätts genom en ”lans” och det är just denna lans som i rapporten modifieras för att uppnå en mer effektiv förbränningsprocess. De primära målen är att möjliggöra förbränning av förnyelsebara bränslen i anläggningen samt att erhålla en produktionsökning. En naturlig följd av optimeringen blir också en sänkt energiförbrukning per enhet tillverkad produkt och minskade koldioxidutsläpp. Vid förbränning av förnyelsebara bränslen tillförs som bekant ingen koldioxid ”netto” till atmosfären då den avgående koldioxiden redan är i kretslopp.

Förbränning handlar om att omvandla den kemiskt bundna energin i ett bränsle till värmeenergi. Vid cementtillverkning skall denna värmeenergi så långt som det är möjligt absorberas av råmaterialet så att detta på ett effektivt sätt omvandlas till klinker som sedan slutligen blir cement. Här handlar det både om att maximera förbränningen i sig och överföringen av värme.

Brännarmomentet är ett centralt begrepp som beskriver hur effektivt förbränningen sker i en roterugn. Brännarmomentet definieras enligt:

$$Ia = ma * va / Pth$$

där

Ia	= brännarmomentet [N/MW]
ma	= massflödet för primärluften [kg/s]
Va	= hastigheten för primärluften [m/s]
Pth	= termisk last genom brännarlansen [MW]

Nuvarande brännarmoment i anläggningen är 1,3N/MW och skall i projektet nå en nivå av ca 6N/MW vilket är lämpligt för att på ett effektivt sätt bränna aktuell bränslemix.

Första greppet i projektet är att öka massflödet och hastigheten för primärluften vilket sker genom ombyggnad av den befintliga brännarlansen som detta projekt utgår ifrån. En ny Jetluft kanal byggs som ökar Ia och ma i ekvationen. Vid byggnaden av denna kanal tas en rad kritiska faktorer i beaktning där den termiska expansionen är viktigast av allt. Denna löses av en jetluft ring som kan röra sig både axiellt och radiellt med växlande temperaturer längst fram i brännarnosen.

Nästa steg blir installationen av en ny kraftfull blåsmaskin som klarar av att leverera rätt volym primärluft med önskat tryck. Blåsmaskinen installeras i ett specialbyggt ljudisolerat utrymme och ny ledning för luften dras fram till brännarlansen.

Vid ombyggnaden av främst jetluftkanalen ökar brännarlansens vikt med följden att utrustningen som används vid monteringen inte klarar belastningen. Lösningen här blir att tillverka en helt ny form för gjutning av det eldfasta material som omger brännarlansen. Det skyddande eldfasta godsets tjocklek går från 70 mm till 55 mm vilket ger en viktminskning från 3250 kg till 2972 kg. Utrustningens kapacitet på 3000 kg är nu tillräcklig. Kvarvarande lager av 55 mm skall vara tillräckligt som skydd enligt den undersökning som görs.
En rad hjälpmedel för att kunna övervaka den förändrade processen på ett lämpligt sätt monteras. Apparatur för temperaturmätning, flödesmätning, tryckmätning, spjällägen och amperemätning installeras på flera punkter i systemet. Med dessa hjälpmedel bör den modifierade brännarlansen kunna operera på ett säkert sätt där operatören har goda möjligheter att vidta snabba pricksäkra åtgärder.

I nästa skede installeras brännarlansen och optimeringen av förbränningen kan börja. Tekniken är att öka brännarmomentet successivt och initialnivån är låg. Högre brännarmoment innebär också ökade temperaturer i lågan varför försiktighet måste iakttagas. Redan under första perioden med en måttlig höjning av brännarmomentet märks positiva effekter på ugnssystemet. När sedan jetlufttrycket ökas sker ett mekaniskt haveri på blåsmaskinen vilket ger ett luftläckage svårt att upptäcka. Detta fördröjer optimeringen som återupptas 10 dygn senare efter reparation av blåsmaskinen.

Optimeringen styrs nu mot 0,32 bar vilket motsvarar ett brännarmoment på ca 5N/MW och effekterna är tydliga. Trycket höjs stegvis där varje ny nivå och effekterna av det inställda trycket noggrant utvärderas. Effekter som sänkt specifik energiförbrukning visar på en väl definierad låga med ökat intensitet som på ett effektivare sätt överför värmeenergin från bränslet till materialet i ugnen. Temperaturen i förbränningsområdet ökar även den vilket tyder på samma scenario.

Effektivare förbränning möjliggör en ökad produktionsnivå och detta innebar att ugnen under försöket producerade ca 5 % mer produkt än den gjort under perioden innan. Understrykas ska att produktionsstörningar uppträdde under försöksperioden men periodvis var ugnsmatningen mycket hög. Alla monterade hjälpmedel för processövervakning fungerade som det var tänkt, dock framstod efterhand att fel temperaturintervall hade valts för övervakningen av brännarlansens temperatur. Under slutet av försöksperioden gick termoelementet upp i 600grader vilket var max och låg där. Beslutet togs att köra vidare med försöket trots att brännarlansens faktiska temperatur var okänd.
Kolmonoxid nivåerna studerades under försöket och pekade även de på en effektiv förbränning. Utmaningen vid förbränning i en cementugn är att undvika det lokala syreunderskott som uppstår fast det stökiometriska förhållandet är det rätta. Bättre blandning av bränslet och förbränningsluften är här nyckeln. Försökslansen är här synnerligen effektiv där den förhållandevis stora volymen primärluft som tillsätts med hög hastighet skapar en hög grad av turbulens genom friktion mellan luftlagren i brännzonen. Följden blir att även bränslet blandar sig effektivare med förbränningsluft med sjunkande kolmonoxid nivåer i ugnssystemet som följd.

Försöket kom aldrig längre än till denna milstolpe då ett större haveri inträffade. Stora svängningar i kvaliteten på råmaterialet i kombinationen med denna optimerade förbränningsprocess ledde till överhettning av förbränningsområdet. Ugnen stoppades omedelbart vid detta tillfälle och reparerades samtidigt som den äldre typen av brännarlans återigen monterades.

Slutligen bör understrykas att det som bevisades i denna studie övertygade koncernledningen om behovet av en modern brännarlans. Nyckelpersoner gavs insikten om att fördelarna med en modern brännarlans vida överstiger kostnaderna för densamma. Återbetalningen för denna typ av investering understiger ett år givet att marknadsförutsättningarna är de rätta. En kort tid senare kom inhandlingsförfarandet av en ny modern brännarlans igång.

De samlade erfarenheterna under detta examensarbete är förhoppningsvis betydligt mer värdefulla än kostnaden för att reparera ugnen efter haveriet.

Glossary

Kiln: Big oven for making of cement.
LSF: Lime saturation factor. A higher LSF means higher specific energy consumption, the material becomes harder to burn.
Clinker: The product is taken out of the kiln and is later on ground to cement.
Clinker factor: This is a fraction of what is put into the cyclone system as raw meal and taken out as clinker. The factor used here is 0.64. This means that every kg put into the process gives 0.64 kg of the product; clinker.
Shell: The outer boundary of the kiln in this case.
Refractory: Protection of the production system against heat. Especially the kiln section is crucial with high temperatures.
Coating: A layer of molten and then stiffened raw meal. This layer covers a big part of the kiln.
Volatile: A substance with a special property. It volatilizes and condensates in the kiln system and is therefore accumulated. A source to production related problems.
Momentum: Measurement of a burner and it´s capacity.
RFQ: Request for quotation
Alternative fuels: Fuels coming from biomass.
"K6 blower": Blower from an old part of the plant no longer in use.
Primary air: All air going through the burner itself.
Secondary air: Hot air used for combustion coming from the kiln system.
Radial air: A part of the primary air coming into the kiln almost perpendicular to the burner direction.
Stoichiometry: The theoretical air necessary for combustion.
Heat balance: A balance where heat in is compared to the heat leaving the system. Sources of false air and other leakages can be detected this way.
Flame impingement: If the flame is touching the outer boundary of the kiln.
False air: Air not wished for - leaking into the system because of the under pressure present.
Burning zone: The zone where the coating is present.
Run factor: How big part of the total time available the kiln is running.
Differential Pressure: Describes pressure drops within the system.

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1 Introduction

1.1 Background

After four years of studies at the university the ninth semester constitutes of this Final Thesis which will be carried out at Cementa Slite, Gotland.

Ever since 1998 the author of this final degree thesis has been employed within Cementa AB. The employment has through the years involved different duties. After finishing upper secondary school in 2001 the author got a permanent job as an operator at the Cementa plant in Slite, Gotland. As an operator at the plant the whole production spectra is “filled”. The entire process is to be studied and this makes a really good platform to start from. In August 2004 when the author moved to Uppsala and the university, the interest in energy related questions was awoken. The choice of Master of Science in Systems Engineering seemed natural at that stage.

Cementa AB is a part of the global Heidelberg Cement Group with 75000 employees all over the world.
The cement production in Slite started at 1919, annually around 2 million tons of cement is produced and the plant has 207 employees. At the plant many different types of cement is produced with different properties. Conditions on the market are quickly changing with some market areas increasing and others decreasing. At a big cement plant it is crucial to meet the customers’ demands from time to time and therefore the plant has different types of cement. Properties wanted by the customers are: high final strength, quick reacting cement and a cheap type for example. The cheap type is used within areas where money is a great limitation. A big part of this cheap cement goes to Africa. The different types of cements have different names and different markets where they are being distributed.
Times are quickly changing in the cement industry and new demands are coming up. As an engineer there is a never ending work in developing new solutions for the future.

At the cement plant on Gotland there are two different kiln systems where the clinker is being made. Kiln 8 is the most modern one with the highest production. It produces around 230t clinker/h under full production and the consumption of alternative fuels is also high. The environmental investments are done on this bigger and more modern kiln. The more modern system present here is a lot easier to adapt against alternative fuel firing than kiln 7. The older kiln 7 has a more moderate production of around 60t clinker/h and the main fuel is fossil. The target of this final thesis is to rebuild the burner and prove the potential in the kiln system with a modern burner design. Potential refers in this case to production level, energy consumption etc.

The background to the whole project is a rejection regarding current investment in a new burner. The burner used in the kiln 7 is outdated and needs to be replaced with a new one. Since 1969 when the current burner was installed an awful lot has happened to the kiln. Much indicates that the current problems with the chemistry of the kiln system and low production are associated with this outdated burner.

In a big group like Heidelberg Cement all investments have to be motivated in an adequate way. The “battery limit” of this project is to make a basis for a new burner investment and to prove the possibilities of production improvement. Each kiln system is unique and the theoretical and practical angles of approach are different when it comes to evaluation of the possibilities. If this project proves a great potential regarding kiln 7 this will be a strong argument for the future burner purchase.

Money earmarked for investment is limited and the arguments used to illustrate the necessity of a particular investment must be substantiated. If the project is successful and implemented in a good way it increases the likelihood that money is earmarked for burner purchase further on.

The larger investments made in Slite is roughly around 90 % for the bigger kiln 8. Regarding development on kiln 7 it is difficult to motivate the high costs of the investments. Therefore the decision was taken to use the skills of the employees on the plant to develop a “homemade” solution. The mechanical department is very experienced and in cooperation with an engineer’s calculations and drawings it can end up in a good way. The cost is also much lower when using material and competence from the plant.

1.2 Purpose and problem formulation

The purpose is to make a clear picture of the possibilities to increase the production rate and to burn alternative fuels on kiln 7 Cementa AB Slite. Measure taken is a modification of the burner U7 in an appropriate way. After proven, the potential in the kiln system with the new burner solution, the aim is to buy a “professional” tailor made burner. To motivate the money for the investment this burner modification project and final thesis are important.

The problem formulation is as follows; how do you rebuild the burner to increase the capacity of the kiln and to be able to burn alternative fuels?

1.3 Method

The following bulleted list explains the steps in the thesis briefly and structurally. Resources will be used internally in the company in order to reach a satisfactory result at the lowest possible cost. The work consists of a feasibility study followed by practical experiments and then a comprehensive evaluation. Overall, the work except the pre-study consists of the following elements:

1. Installing a Jet air nozzle ring in a way so it can move both axially and radially due to temperature changes.
2. Remove the present refractory from the burner and order a new form to decrease the weight of the burner
3. Place a K6 blower in operating the axial channel.
4. Install Gauging equipment (Temp, pressure, ampere blower etc)
5. Carefully observe process values during the modified burners run in time.
6. Evaluate the results of the project
7. With the help of proven potential in the kiln system be able to convince management of the proceeds to invest in a new burner
8. If point 7 is fulfilled with the help of experience, be able to operate as a project coordinator in the purchase of a professional burner. This task will include coordinating the project group in various meetings and then lead to an RFQ (Request For Quotation).

1.4 Not within scope

Make a complete picture of the possibilities to burn alternative fuels; plastic pellets etc. The aim of this project is to create a basis for further development regarding alternative fuels firing.

2 Cementa AB

2.1 Cement

Cement can be described as fine grained powder made out of limestone and clay minerals. With respect taken to volume it is used more than any other industrial product. Cement is used to produce concrete, a mixture between cement, water and a filler of gravel and stone. Concrete is highly durable and has got a high strength and formability. The technical and economic lifetime is also good and consequently concrete is our most important building material.

The cement industry is very energy intensive and the environmental work is important. Cementa has chosen to work with an environmental management system named ISO 14001. This is a framework for controlling, monitoring and evaluating environmental work. The hard work has resulted in among other things, 90% reduction in emissions of nitrous oxides and sulphur. In energy intensive industry the continuous environmental work includes reducing the dependence on fossil fuels. Within Cementa the usage of alternative fuels has broaden from the middle 90s when first introduced. Today the environmental companies delivering the alternative fuels can offer constant energy value and standard quality. The plant solutions are adapted for burning alternative fuels and the fraction of alternative fuels is increasing. The following table shows the development in alternative fuel usage at the Slite plant.

Year	Part alternative fuels (%)
2008	31% actual value
2009	41% target
2010	47% target
2015	70% target

Table 2.1-1 *Prediction of alternative fuel usage*

A big part of the major projects at the Cement plants are either to increase the use of alternative fuels or to lower the emissions. All this together makes Cement and the final product concrete environmentally competitive when compared to other building materials on the market. The environmental image has markedly improved in recent years. Classic issues that dealt with technology and economics were earlier mainly focused on. Today issues that deal with environmental impacts or different construction materials, comfortable housing, energy and health are becoming more and more important. Cementa has a motto often heard to show that concrete sufficiently meets the requirements set by today’s society; “Healthy building with concrete”!

2.2 Cement production

The tradition of using cement is long in Sweden. From an international standpoint Swedish architectural design and construction techniques is considered very advanced. Skånska Cement Ltd. was founded in 1871 and one year later the first cement plant in Sweden was opened. This was the beginning of today's Cementa and since then there has been a total of 14 cement plants in Sweden. Today three different plants are in operation. They are located in Slite on the Baltic Sea island of Gotland, in Skövde in Västergötland County and in Degerhamn on the Baltic Sea island of Öland.

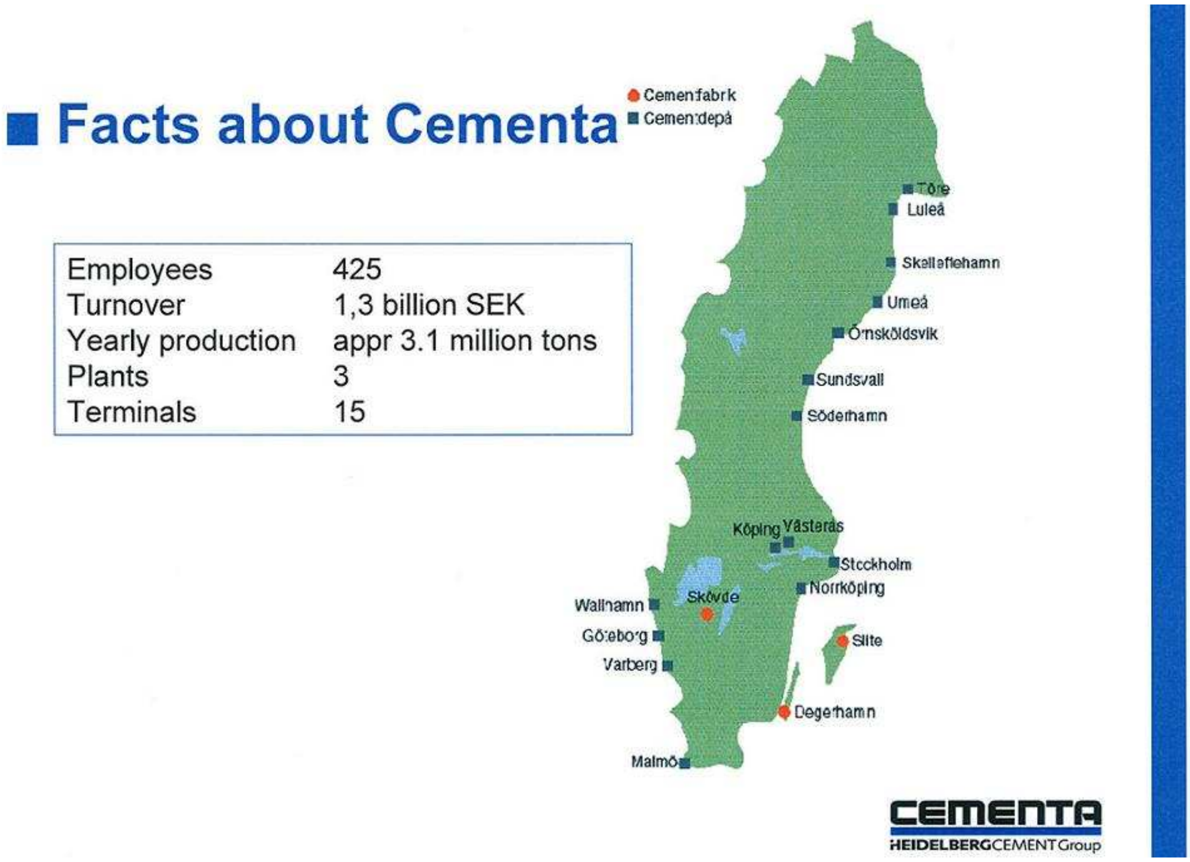

Figure 2.2-1 *Cementa in Sweden, Cementa AB 2007*

Cementa has also got 15 terminals located in different areas of Sweden. Cementa has developed a transport system with vessels and terminals to be able to distribute the goods in an environmentally-friendly manner. From the strategically located terminals the goods are further transported by train or special bulk-carrying trucks. The shipments are made in totally closed systems which mean that the management is practically dust-free. Cementa has got three custom-built ships to transport cement to the terminals as well as for export out of the country. Our transports by ship account for close to 8 % of the total Swedish coastal shipping. Of Cementa´s total production approx. half is exported and supplied from the Slite plant. A big part of the exported cement goes to the United States and Africa among other countries.

With experience and knowledge gained from over a century of operation, Cementa is today a high tech and modern company. Developing new products, keeping good quality and establishing in new markets are the main targets for the company.

2.3 Production process Cementa Slite, Gotland

The bedrock on Gotland is great for cement production purposes. Gotland has got a long history within the cement industry and as far back as the 11th century limestone was exported from the island. Especially in the northern part of Gotland the limestone was easily available and the limestone industry coloured the whole society there. In April the 4th 1919 the first rotary cement kiln was started up in Slite. The plant was top modern and ever since then there has been continued production in Slite.

Today the Slite plant is one of the biggest and most energy efficient cement plants in Europe. The production is controlled and supervised by computers and the emissions are minimal. The plant produces several types of cement; construction cement, rapid hardening cement and different types of cement for export. During the entire production process samples are taken and analysed to guarantee the quality of the cement produced. Advanced control systems are used for the analyses. The Slite plant produces 75 % of all cement in Sweden and the plant has 207 employees.

Shortly described cement is made from a mixture of limestone and clay minerals that are crushed and grained into a fine powder. In big rotary kilns the powder, called raw meal, is fired. The internal temperature in the kilns is about 1400°C and during the firing process the raw meal is converted into a number of minerals. When the material has gone through the kiln it´s called clinker, which is ground to cement. The cement is then distributed to big parts of the world. A schematic and more detailed description of the production process follows:

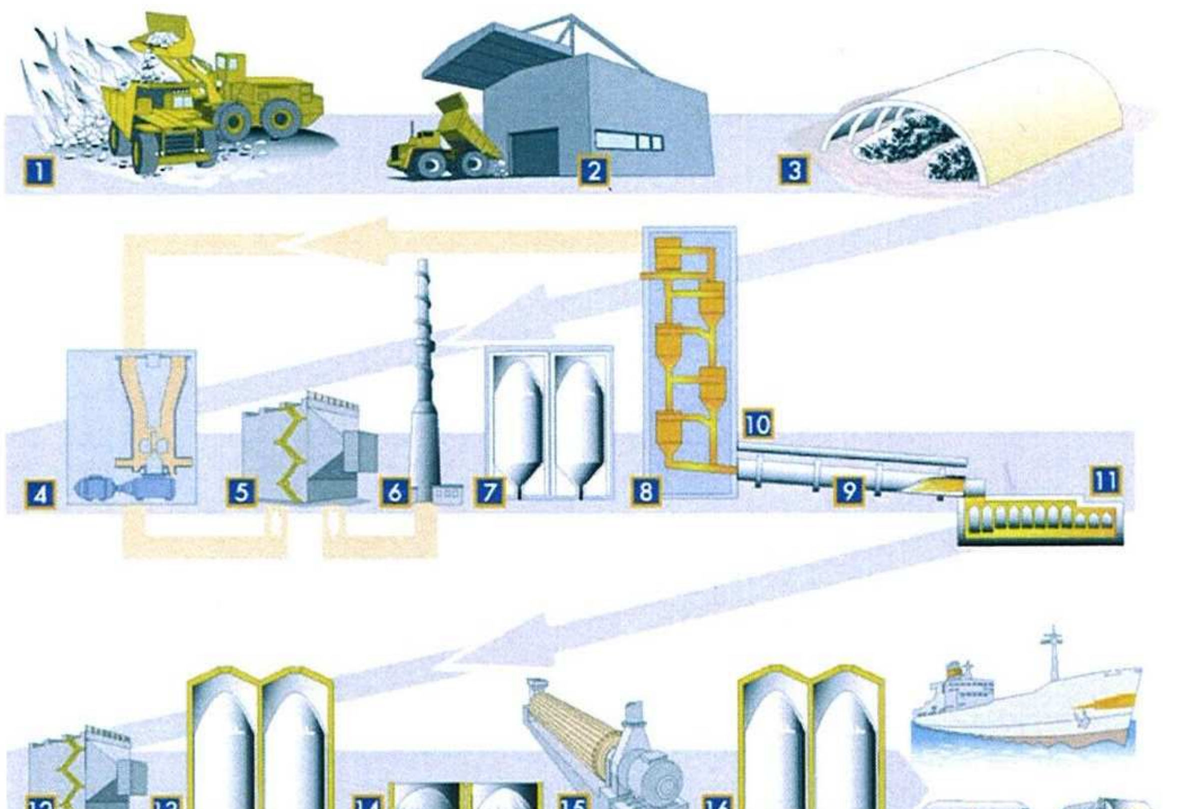

Figure 2.3-1 *Cement production flowchart, Cementa AB*

1. **Quarrying**. Limestone and marl are needed to produce cement and on Gotland the bedrock is favourable for this type of activity.
2. **Crushing**. In the big hammer-crush the rock is crushed to an appropriate size. The maximum size is 80 mm which makes it possible to transport and handle.
3. **Mixing storage piles.** In these stockpiles mixing of the raw material takes place to achieve the best possible uniform quality. This is very important to maintain uniform chemical properties. These stockpiles also act as a buffer stock for the raw mill.
4. **Raw mill.** The rock is ground into a fine powder in this mill which is the biggest in Europe. All grounded particles are below 0.09 mm in size. In this process the material is at the same time mixed, dried and ground.
5. **Electrostatic precipitator.** The flue gases are carrying a lot of dust released from the kiln. The particles are caught in this electrostatic precipitator due to their "static electricity" properties. This solution is highly efficient and almost all of the particles are caught.
6. **Sulphur removal facility.** This is a "wet scrubber" where the gases are being washed. The gases reach here after passing the electric precipitator. The acid flue gases are neutralized with the help of the basic solution; ground limestone in the scrubber slurry.
7. **Raw meal silos.** This is an intermediate storage for the ground limestone.
8. **Cyclone tower with pre-calcination.** This is an important step of the production and it takes a lot of fuel for the precalcination to occur. Under the precalcination process calcium carbonate is split into calcium oxide and carbon dioxide. This reaction is energy intensive and endotherm. The reaction formula is $CaCO_3 \rightarrow CaO + CO_2$
9. **Kiln.** The kiln is the most essential part of the production. The kiln is a rotating steel cylinder which is between 60 and 80 meters long. Inside the rotating steel pipe the material is slowly conveyed down to the burner and is converted into clinker. In the "burning zone" the temperature is around 1450 degrees. It is in this area the actual project "Optimization of Burner kiln 7 Cementa Slite" will take place. The heat comes from coal and alternative fuels. To optimize this part of the process is of highest importance.
10. **By-pass filter.** The cement produced at the plant is of a high quality and the bypass plays an important role to achieve that. Too much alkali content in the cement negatively affects the durability of the cement produced. Therefore a part of the gas stream in the preheater tower passes through a filter to remove the alkalis in a condensation process. The bypass filter acts as a kind of purification unit. Another effect of the bypass is a good environment in the preheater tower.
11. **Clinker cooler.** After the kiln the hot clinker passes though the clinker cooler. The heat (energy) in the clinker is recycled back into the kiln with the hot gases from the cooler. The air is blown through the clinker under high pressure. The purpose is both to reach better transport properties for the clinker later on in the "transport chain" and to take care of the important energy stored in the hot clinker to reach an effective combustion. This will be described in detail later on.
12. **Electrostatic precipitator.** Gases from the cooler pass through this filter where the cleaning process before the outlet takes place. The environmental regulations are becoming more and more sharp these days and the dust content allowed in the outgoing gases is very low; 30 mg/Nm^3.
13. **Clinker silos.** When the clinker is processed the storage of the finished clinker takes place in the clinker silos.
14. **Gypsum and additives storage.** In the next step the clinker is ground to become cement. (See 15). This grinding process is quite advanced and several additives are put in with the clinker. Gypsum and other additives are stored to be ground together with the

clinker. For example the additives affect the bounding time of the cement and many other things. Several qualities of cement are being made and the dosage of the additives plays a fundamental role when it comes to properties of the cement.

15. **Cement mills.** The finished cement is produced by the cement mills. The clinker is ground together with gypsum and other additives. Limestone is also put into the process here to gain the properties required.
16. **Cement silos and unloading.** The produced cement is put into an intermediate storage. From this storage the finished cement is loaded using a closed system onto ships or trucks.

3 Theory

3.1 Feasibility study

The target of the whole project is to increase the production of kiln 7 and enable alternative fuel firing. The goal is to reach 1500t/h production and among other things this final thesis will be one important part of the work to get there. During the “big stop” spring 2008 a lot of improvements were made in the kiln system. Therefore it is difficult to draw a conclusion on how big the burner’s contribution is to reach the goal. To reach the “production target” with a production of 1500t/h other issues must be addressed like (Taylor, 2007):

- *A functional kiln bypass*. This is a unit to catch the volatiles that circulate in a cyclone tower system of a kiln. It can briefly be described as a vacuum cleaner that cleans the system from elements not required. The bypass system on kiln 7 is newly installed and during the run-in time some problems arose. During the last period of time this setup has worked in a satisfactory manner
- *Burner alignment along the kiln axis*. To distribute the heat in the right way is crucial both for the combustion and for the refractory in a cement kiln. If the direction of the burner is not correct a likely development is that of a “hot spot”. This means that the refractory is damaged in a certain area and in the worse case the kiln has to be stopped and the bricks replaced. This is extremely expensive due to downtime of the kiln and refractory costs. When burner momentum is increased the alignment of the burner is even more important than before. To utilize the hot secondary combustion air at a maximum rate the burner needs to be centered and the distribution of the air around the burner uniform.
- *Correct fuel preparation metering and transport.* To have a uniform quality of the fuel is extremely important. When combustion and flame is optimized the margins become smaller and fluctuations in the quality must be avoided. The system is pushed closer to the border for what it is capable of and this places great demands on the surrounding equipment.
- *Appropriate oxygen target level.* This is for the combustion to be complete so all energy in the fuels can be used. The energy delivered from the combustion is depending on the level of completeness:
  The complete oxidation of carbon:
  $C + O_2 \rightarrow CO_2$ + 394kJ/mole (94 kcal/mole)
  The incomplete oxidation of carbon:
  $2C + O_2 \rightarrow 2CO$ *+ 221kJ/mole (53 kcal/mole)*
  This gives an indication of how important it is to keep the right oxygen levels.
  In the other case when the oxygen level is too high much cold primary air is dragged into the system and the energy utilization isn’t optimal because of the heat up of all this extra air.
- *An effective backend gas analyzer.* As already mentioned the O_2 and CO levels are crucial to measure and regulate.
  The NO_X level in the outgoing gases gives information about the combustion process. High peak temperatures in the combustion zone lead to higher NO_X levels amongst other things (Mrowald, 2007). Today’s environmental regulation is strict and the NO_X emissions are controlled by injecting ammonia dilution at the Slite plant. SNCR the method is called and it is highly effective. SO_X emissions also have to be kept in order by running the kiln in an appropriate way and by other measures.

- *Stable kiln feed chemistry* To keep the kiln feed chemistry in the right range is of highest importance. The specific energy consumption is among other things depending on the LSF factor. To maintain a high and constant feeding to the kiln is impossible if the LSF fluctuates too much. Either the kiln gets too cold and the feeding has to be reduced or the kiln gets too hot which is extremely dangerous. Sulfur recirculation is another issue that the kiln feed chemistry strongly influences. Circulation of volatiles is described thoroughly in the chemistry section later on.
- *Optimized heat transfer in the kiln preheater* Adaption of the gas flows and speed is crucial when it comes to heat exchange between the hot gases and the colder kiln feed. Simulating these gas flows is difficult and requires good knowledge in fluid mechanics and complicated simulations. Optimizations have been made a couple of times during the kilns history and it is important to bear in mind that all parts of the system are connected to each other. Particle size of feeding material, speed of gas streams, retention time of the material and so on are important parameters to evaluate and consider after every change of the preheater system.

Current burner at Kiln 7 Cementa Slite has a momentum of 1.3 N/MW which is far below the level of 6N/MW that is appropriate for burning pulverized coal. Different types of fuels require different level of momentum. When the fuel is of a heterogeneous type, a higher grade of momentum is necessary because of the varying quality and size of the particles. One of the main targets is to burn plastic pellets in the kiln system. A momentum between 10-11 N/MW will then be required. With such low momentum as today, other problems like poor flame conditions, bad cooler performance, high shell temperatures and high heat loss appear. To increase the momentum and therefore be able to burn a larger amount of alternative fuels and to contribute to a higher production, is the target. The way to get there is long and requires knowledge within several different areas like combustion theory, fluid mechanics, cement chemistry and refractory handling to mention some of the most important ones.

There are other things that are of utmost importance when it comes to design of a burner. Burner momentum plays an important role and is mainly focused on in this final thesis. Time is too short to cover all the details. With measures taken in this project a big step is made towards a more efficient combustion.

3.2 Combustion theory

3.2.1 Combustion cornerstones

Primary air is defined as air passing through the burner. The primary air consists of axial-, radial-, and fuel conveying air. The primary air ratio is often discussed and is the percentage of primary from the required air for combustion. The lower heat value and the heat consumption in the present system decide the total amount of air required for combustion. High heat consumption or a low lower heat value increases the requirement of air for combustion (Mrowald, 2007).

The effective air for combustion is composed of hot secondary air from the clinker cooler, the primary air discussed above and false air penetrating through openings and sealings. Almost all equipment installed for surveillance or operational purposes give rise to false air. Ideally from a thermo technical point of view primary air should be low and false air completely avoided.

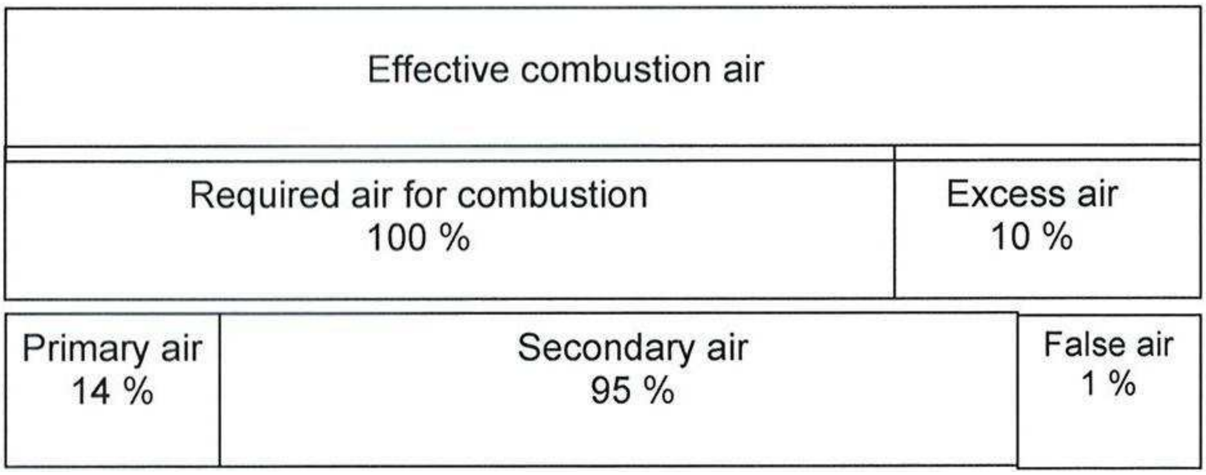

***Figure 3.2.1-1** Effective combustion air and its distribution*

The types of fuel used and the necessary excess air levels decide the effective combustion air volume. The excess air is important to, as far as possible, reach a complete combustion. The mixture between the different gas streams or between the air and the fuel is never perfect. Ideally an excess air level of 0 % is wished for because higher excess air levels give higher energy consumption. Without excess air the CO formation would increase and other issues arise like chemistry problems, combustion related energy losses to mention a few. To find the "correct" excess level is quite complex. With a new rebuilt burner the "correct" excess air level will be different than before. With higher primary air velocities the mixture between the gases and fuel will be better and a smaller amount of excess air is used at optimum. Today quite high CO levels are present despite the fact that the excess air level is high. This fact is explained by the current burner and it´s poor mixing capacity.

3.2.2 Combustion in a rotary kiln

In the rotary kiln of a cement plant the combustion is quite unique. Burner design is different from other industrial burners, only a portion of the combustion air passes through the burner and is controlled by the burner designer. The product cooler provides most of the air and the aerodynamics of the flow is dependent on others units in the production system (Bhatty et al, 2004).

The most common methods when it comes to designing rotary cement kiln burners are:

- Kinetic energy: the cross sectional areas of the burner nozzles are here based on the formula: PAV^2. With other words the **primary air flow multiplied with the (Velocity)^2**
- Momentum Flux: the cross sectional areas of the burner nozzles are here based on the formula: PAV. **Primary air flow multiplied with the Velocity.** Here the primary airflow is expressed as a percentage of the stochiometric air requirement.
- Jet Entrainment: The cross sectional area of the nozzles are here determined from quite complex calculations but can roughly be simplified to the relation; $\mathbf{m_e/(m_o+m_a)}$ where
  m_e = mass flow of entrained secondary air
  m_o = mass flow-rate of fuel and primary air through the burner
  m_a = mass flow of secondary air

The first two approaches assumes a type of ideal case where the fuel and air is unaffected by the secondary air and confinement of the rotary kiln. The last approach with the jet entrainment determines the degree of external recirculation as the burner fuel jet mixes with the secondary air. As mentioned earlier this approach is derived and carried out with the help of complex calculations and therefore simplified when used in this final thesis. A clear picture of the mixture between the jet and secondary air under present confinement conditions is crucial to have and is described in the picture below.

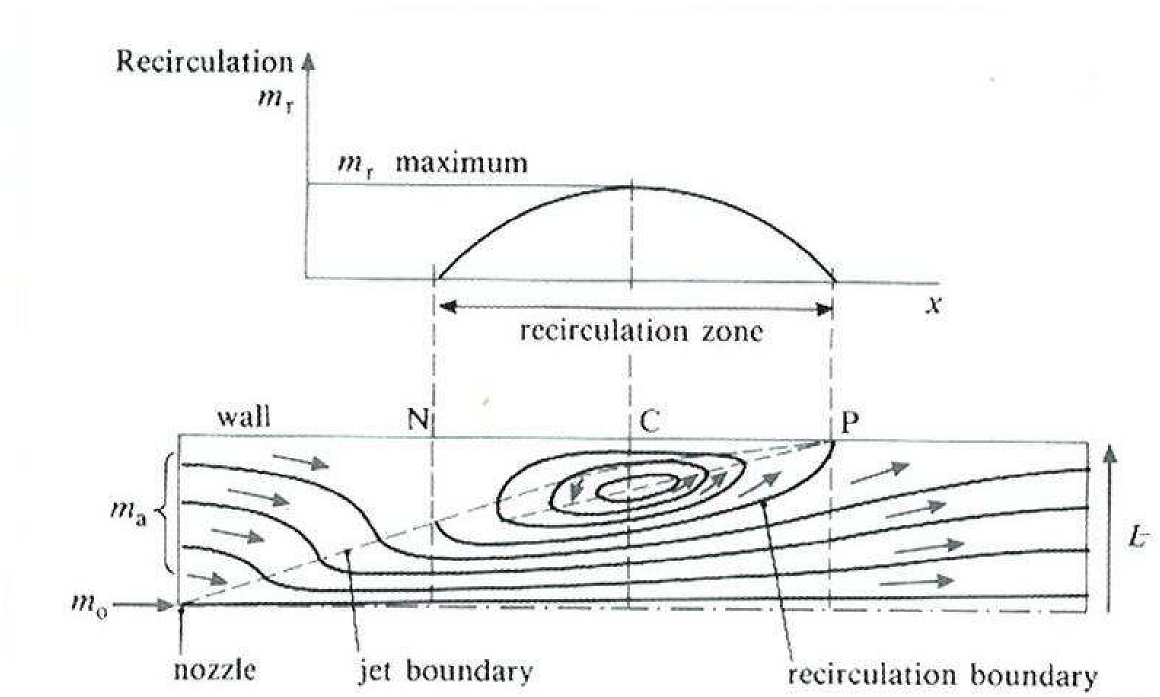

Figure 3.2.2-2 *Mixing and recirculation downstream a confined jet*

The jet entrainment technology is widely used in almost all of the modern burners. All of the methods mentioned above use the entrainment technology in some way. A very high primary air velocity comes out from the two first methods. The primary air typically employs 5-10% of the stoichiometric air requirement. More mass flow of primary air at a lower velocity is required of the jet entrainment method to provide enough momentum for external recirculation.

Within the cement industry the mass flow and velocity of primary air is a central debate. Heat balance calculations give a clear picture of the problem and suggest that increases in primary air at a low temperature should be avoided. The primary air reduces the thermal efficiency of the kiln by replacing hotter secondary air from the cooler. Ideally this is correct but in reality a certain level of excess air is required to avoid flame impingement and high carbon monoxide rates. To maintain the production at a certain level a unique amount of primary air is required depending on the feeding rate to the kiln, systems characteristics and false air to mention some of the most important issues. In practice, if the burner momentum is insufficient to effectively mix the fuel with the secondary air, the heat consumption increases by 2 % for every 1% increase in excess oxygen. When designing a kiln burner it is crucial to be aware of the competing forces between minimizing the amount of primary and excess air and to reach a high burner momentum. Many aspects are to be taken into consideration and working with contra productive targets is challenging.

For a safe and efficient combustion, good flame stability is important. The point of ignition should be constant and located close to the burner nozzle. A fluctuating point of ignition is severe and potentially dangerous. There is a high risk of flame out and therefore large amounts of un-burnt fuel can explode when lighting up again. Stabilization is effected by grind size, ash properties, volatile content and conveying velocity. The potential hazards are many but still it is possible to produce a burner with the right properties to ensure good flame stability. To form an internal recirculation zone just in front of the nozzle is the most effective technique. Burning particles are carried back from further down the flame and constantly ignite the incoming fuel. This really stabilizes the flame and anchors it to the nozzle.

There are a number of methods to achieve an internal recirculation zone:

- Swirl on the primary air
- Swirl on both fuel and primary air
- Swirl on the fuel

A very effective way of ensuring flame stability is through swirl on the primary air. Good stability requires high levels of air and this can have side effects on the overall flame characteristics like causing flame impingement on the refractory. Swirl on both fuel and primary air requires gas fuels and this option is therefore not present here in Slite. Traditionally re-radiation from the hot walls inside the kiln was used as the primary means of flame stabilization. Today other methods are preferred like those mentioned above. A stable and warm kiln contributes to flame stabilization and naturally support the main steering method with swirl on the primary air.

3.2.3Present coal firing burner

Coal has got a very high emissivity and is therefore the best fuel for rotary kilns when ash contamination can be tolerated. Compared to oil and gas the ash content in coal is high but within the cement industry this is not a problem. The high emissivity gives high heat transfer to the charge and the relatively low cost of coal gives a significant economic advantage compared to other fuels. A drawback compared to oil or gas is that coal is a solid material which makes it a little bit harder to handle. Coal is quite heterogeneous of varying composition and calorific value. Coal must always be ground and dried before firing in the kiln. Coal is by nature quite flexible and requires a flexibility of burner design to allow the use of differing grades of fuel.

The old burner on kiln 7 was initially built for oil firing and was during the 1970s converted to coal. The burner uses a relatively small amount of primary air and its poor performance is a consequence of inadequate fuel air mixing resulting from the low jet momentum.

Dual and multi fuel burners are nowadays widely used and very important. Present burner used for kiln 7 has earlier been used for multi fuel firing. The burner is not tailor made for this and it is always necessary to compromise the kiln capacity. Multi fuel firing gives a real flexibility in fuel choice which is important nowadays with a fluctuating world market. To make a prediction of future fuel cost, and hence investment decisions, are very difficult. A good working multi fuel installation allows utilization of the most economical fuel currently available. The primary fuel should as far as possible be replaced by other by-product fuels as petcock or plastic pellets for example.

3.2.4 Burner momentum

The rate limiting step in the combustion is the fuel air mixing process. With the correct mix combustion can occur rapidly with high flame temperature and high radiative heat transfer. Approximately 95 % of the heat distribution takes place through radiative heat transfer in this type of process and therefore a high flame temperature is of great importance. Negative effects like convective heat loss and reducing conditions in the kiln are minimized when the flame is kept in shape and are intense. Under conditions like the ones mentioned above the demand regarding refractory is higher and surveillance of the kiln shell is absolutely necessary (Taylor, 2007). In Slite, kiln 7 does not have a shell temperature surveillance system. This fact makes the system more vulnerable to temperature changes because a long time can pass before these variations are noticed. On the bigger kiln 8 a kiln shell scanner is installed and the operator receives continuous information regarding the kilnshell and its present temperature and trends.
Further on higher heat transfer increases the kiln production and decrease the energy consumption. Kiln chemistry is also clearly improved with decreased blockages in the preheater system. To minimize the reducing conditions it is important to avoid blockages and build-ups in the kiln system; i.e. process stability. Reducing conditions can also affect the final product regard to strength development, workability and a higher level of product variability. In this way it is all connected and the chemistry section of this report will go through this further.

The burner momentum describes how well the hot, and for combustion necessary, secondary air is mixed with the colder primary air. The primary air is added to the process under high pressure with high speed. There is a difference between radial and axial momentum and when momentum is mentioned it normally refers to the total momentum (Mrowald, 2007).

The various burner manufacturers on the market define different terms for how to calculate the momentum. The most useful and easiest definition seems to be for the momentum. The formula is described below and includes the product of primary air mass flow and it´s velocity at the burner tip divided by the thermal energy input.

$$I_a = m_a * v_a / P_{th}$$

with

I_a	= spec. axial momentum [N/MW]
m_a	= mass flow of axial air [kg/s]
V_a	= velocity of axial air [m/s]
P_{th}	= thermal power to sintering zone [MW]

For the equation to be useful the primary air volume must be known. Conditions to be fulfilled are measurements of the airflows that are reliable. Cross sectional area at the tip of the burner where the different air flow passes must also be known. Then the speed of the different airstreams can be derived. Finally the thermal power is composed of the total input of the fuels passing the burner.

The momentum formula is useful and makes it possible to compare different burners. Naturally difficulties occur when comparing the momentum for different installations because surrounding conditions are unique for each kiln system. Another fundamental question is about the significance of this momentum value. Burner momentum is the product of air mass flow and air velocity and therefore it grows with more air and/or higher velocity. Important things to consider are the energy cost and the overall heat consumption. The energy cost increases with more primary air and high air velocity. Bigger fans are necessary to provide higher primary air flows and high velocity requires high pressure fans. Higher energy costs are the result of that. High primary air flow increases the overall heat consumption. The drawbacks are negligible if the burn out of the fuels is enhanced. An important factor to be aware of is that the momentum increases against infinity with higher primary air flows and pressures. At a certain point the drawbacks become bigger than the advantages but most interesting is to find the optimum. This means that a higher momentum is not always better. To find the ***correct*** momentum is the main target and the aim of this project.

Back in the 90´s a lot of focus was put on the low emissions burners. Low emissions burners mainly refer to low NO_X emissions. During the last period of time the awareness has increased regarding NO_X and the environmental impacts it causes. NO_X acts as an indirect greenhouse gas and as an acidification element. Indirect greenhouse gas means that some of the NO_X is transformed into a direct greenhouse gas. A part of the NO_X is for example transformed into Methane (CH_4) which is a strong greenhouse gas (Nyberg, 2008).

Regarding the emissions, researchers are sure that they depend as well on other effects that are not influenced by the burner (Bhatty et al, 2004). Important things are secondary air temperature, sintering zone temperature or burnability of kiln feed. The benefit of a lower

NO_X from the burner is negligible when things are seen in this visual angle. Other measures are used to reduce NO_X emissions like the SNCR method. SNCR is the present method used at Cementa Slite where ammoniac is dosage into the preheater tower. This has a reduction efficiency of 10 – 85% depending on surrounding conditions (Alsop, 2007). In Slite the efficiency is quite high and there is extra capacity to handle higher NO_x if necessary. The emissions have to be kept at a low level and different burn abilities of kiln feed make the equation hard to solve. The future direction is towards more heterogeneous fuels with varying burn abilities. At the same time the recycling companies work hard to offer alternative fuels that are well prepared and of a quite homogenous quality.

To supply the plant with the right amount of energy and at the same time be environmentally friendly is important. The last 15 years development within the fuel market has lead to more and more of the existing kiln burners reaching their capacities because of the changing fuel market. The new types of alternative fuels are of a heterogeneous type with varying particle size and moisture content. This is a big challenge for burner designers all over the world and encourages development of the burners on the market. Keeping the burning zone in the right temperature range and position is crucial and requires a high burner momentum, adapted to the conditions in the kiln system.

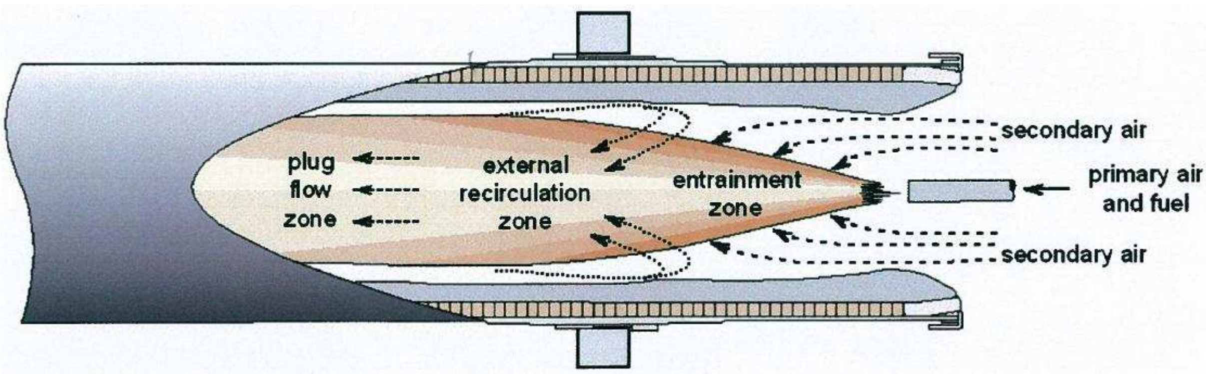

Figure 3.2.4-1 *Schematic picture of the flame envelope*

Regarding higher flame momentum several advantages appear:

- The kiln operation becomes more stable and fuel efficiency is improved
- Improved clinker reactivity and shorter burning zone. This gives more reactive cement which is useful and positive.
- Consistent clinker granulometry leads to more efficient cooler operation
- The volatility and recirculation of Sulphur is lowered which leads to improved partitioning of sulphur into the clinker. Less Sulphur is then volatilized and there is an overall improvement of the condition of the kiln.
- The tendency to form build-ups and rings is decreased
- The run factor is increased.
- Increased kiln capacity, i.e. more cement is produced

3.2.5 How to practically increase the burner performance

Most important is to raise the momentum by increasing the velocity and/or volume of the primary air. For a good combustion to take place a mixture between the primary air and the hot secondary air is necessary. The difficult task is to increase the momentum but at the same time maintaining the secondary air/primary air ratio as high as possible. To give an idea of how important it is to keep the primary air level down the following illustrates this in an obvious way:

$$Density\_of\_air \approx 1{,}2929(273{,}15p/0{,}1013T)$$

Where;
p = pressure in MPa
T = temperature in K

This gives the weight of one normal cubic meter at a certain temperature. Normal cubic meters is the properties of air at the temperature of 0°C and a pressure of 0,01325Mpa. The weight is from the formula = 1,29kg/Nm^3. This value is used further on to calculate the energy consumption. The specific heat capacity for air is $1.01*10^3$J $kg^{-1}K^{-1}$. To heat 1Nm^3 of air one degree requires:
1,29kg/Nm^3 * $1.01*10^3$J $kg^{-1}K^{-1}$ = $\mathbf{1.30*10^3 J\ (Nm^3)^{-1}\ K^{-1}}$

Properties	Primary air	Secondary air
Temperature before heat up	10°C	900°C
Temperature after heat up	1400°C	1400°C
Energy consumption /Nm^3	1,81 MJ	0,65 MJ

Table 3.2.2-1 *Comparative energy consumption*

This gives an idea of how important it is to keep the primary air consumption down. For each Nm^3 extra of primary air put in the process an energy loss of 1,16 MJ occurs. This amount energy must be compensated for by extra fuel firing. Ideally no primary air at all should be put into the process at all to maximize the energy utilization. Combustion consumes oxygen and the primary air acts as an oxygen source and is therefore extremely important in more than one way. Besides a good mixture between the fuel and the hot secondary combustion air is not possible without use of primary air. The aim is to minimize the primary air usage and achieve an effective mixture between the two gas streams.

3.2.6 Material load

When placing a high momentum burner with jet axial air in the kiln it is of highest importance to protect the refractory. This is done by setting the burner up at centre height in the kiln and aligned to the kiln axis. At the plant laser equipment is used to achieve the right position of the burner. Seen from the sintering zone the kiln is rotating clockwise with a rotational speed of 1,7 rpm during full production. The material bed in the kiln is therefore a bit dislocated and is to be seen at “7 o’clock”. Because of that some engineers think the location of the burner should not be as described above. It should be in centre height but not exactly aligned to the kiln axis. The correct direction is a little bit towards the clinker bed but of course the adjustment is very small to avoid refractory damage. A couple of degrees away from kiln axis alignment is an appropriate direction.
In this study the burner is located aligned to kiln axis.

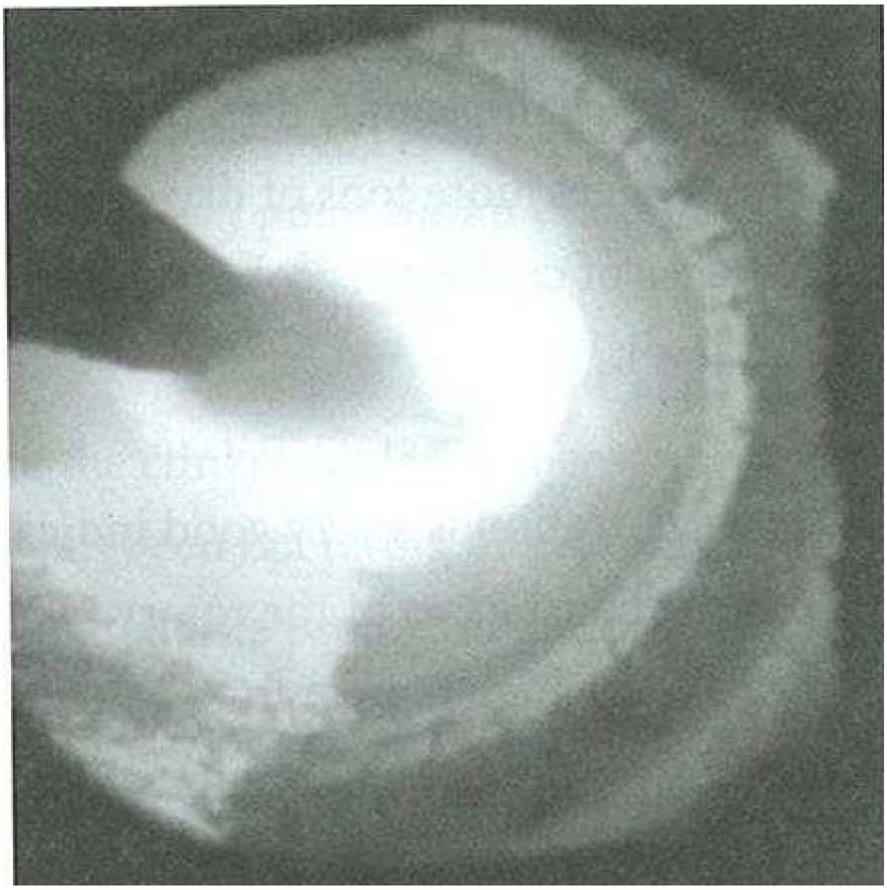

Figure 3.2.2-1 *Kiln burning zone showing flame and material load at “7 o’clock”*

3.3 Present situation Kiln 7

3.3.1 Burner kiln 7

The present burner is of an old type and the indications of poor burner performance are many. Although there is a high rate of oxygen present in the preheater system the CO-level is above what is considered okay. This means that the combustion which is not efficient enough. As mentioned earlier poor mixing of the different compounds in the burning process is the main problem to solve. Instead of burning in the concentrated burning zone the fuel burns “higher up” in the preheater system. The combustion is carried out in a fluctuating way which leads to a local lack of oxygen. A lack of oxygen in the local area leads to incomplete combustion and CO is created. This results in huge energy losses and a lot of chemistry related problems.

The energy consumption is also high because the fuels are not burnt in the most appropriate way. The whole preheater system is designed in a typical way and the energy uptake should take place in a special pattern to reach maximum effectiveness. A concentrated energy uptake in the burning zone is preferable but with the present equipment the flame is too long and soft. A long and soft flame is a flame that has not got well defined outer boundary. Sometimes this is wished for when considering the refractory but the energy exchange is poor.

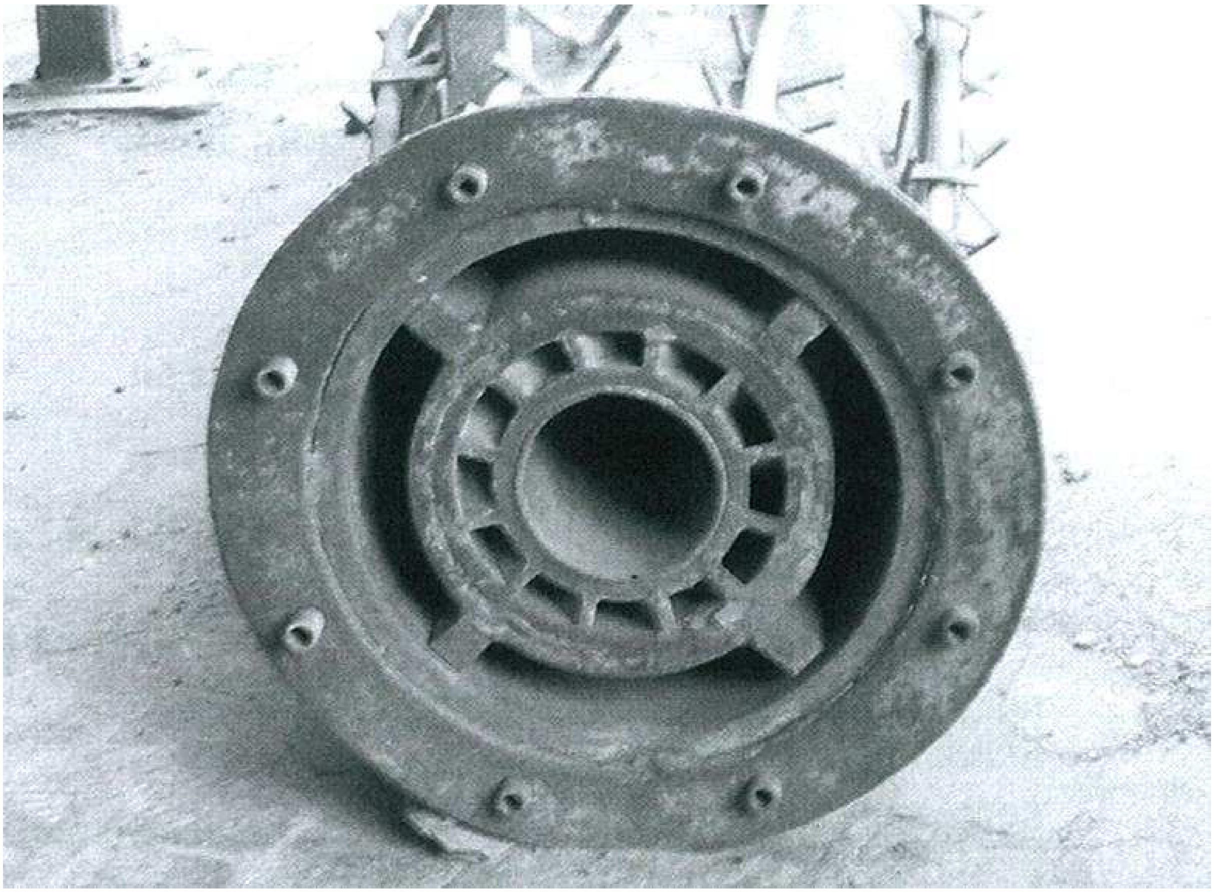

Figure 3.3.1-1 *Present burner kiln 7*

In a system like kiln 7 the heat exchange between the burner and the material in the burning zone takes place by three principle mechanisms; radiation, conduction and convection. The objective is to maximize the transfer of heat generated by the flame to the incoming material in the burning zone. The most important mechanism is radiation and in the burning zone about 95 % of the heat transfer is through radiation. Radiation between two materials takes place when the materials are not in contact with each other. The flame, refractory and coating radiate heat to the feed in the kiln. The formula normally used when considering radiation is:

$$Q = \sigma \varepsilon A (T_F{}^4 - T_P{}^4)$$

Where,
Q = rate of heat transfer in J/s
σ = Stefan Bolzmann constant in J/ (m^2 * s * ºK)
ε = emissivity (0.0 – 1.0)
A = area available for heat transfer in m^2
T_F= surface temperature of the flame in ºK
T_P= surface temperature of the product in ºK

Convection occurs through fluid motion. For example the hot kiln gases transfers heat to the incoming feed in a preheater tower. The convection formula is as follows:

$$Q = h * A(T1 - T2)$$

Where,
Q = rate of heat transfer in J/s
h = coefficient of heat transfer in J/ (m^2 * s * ºK)
A = area available for heat transfer in m^2
T1 – T2 = temperature difference in ºK

Conduction requires a direct contact between two materials or heat transfer within a given material. The heat is transferred by transfer of vibrating energy from one molecule to another. For example heat is transferred from the hot kiln coating to the cooler kiln- feed by conduction.

$$Q = k * A(dt / dx)$$

Where,
Q = rate of heat transfer in J/s
k = thermal conductivity in J/ (m^2 * s * ºK)
A = area available for heat transfer in m^2
dt/dx = temperature gradient in ºK /m

Focus will be placed on the radiation phenomena because of its importance. As an operator proper combustion is one of the most important issues. If the combustion is controlled in an adequate way this will result in a more efficient and higher production. Also the possibility of burning alternative fuels shows up and the produced clinker has got a higher quality. In a rotary cement kiln the primary target is to produce clinker as efficient as possible. With fuel prices going up and with hard competition from other plants development are necessary to keep or improve current position on the market. To do useful work with the heat generated by the flame is essential. The heat is transferred from the flame to the bed of material mainly by radiation. Heat transfer in the burning zone is a very quick process because the gas velocity is high. In the formula for radiation the heat transferred is proportional to the fourth power of the temperature of the flame. Therefore the flame temperature has got a very strong influence on the heat transferred.

An example:
A heat increase by 10 % gives a radiation increase of $(1.1)^{\wedge 4} = 46$ %

This gives a clear idea of the strong temperature related influence.

Too high flame temperatures can lead to damages on the coating and refractory. Other things like the temperature of the material in the kiln, the relative geometry of the flame and its surroundings and the flame emissivity also affect the rate of heat transfer. The emissivity is different for different fuels. In fact the clearest difference between gas, oil and coal flames is the emissivity or brightness:

- Coal flame emissivity ~ 0.85
- Oil flame emissivity ~ 0.5
- Gas flame emissivity ~ 0.3

When talking about emissivity it is roughly described as the ability to transfer heat from the flame through radiation to the cooler surroundings. In the real world nothing has the emissivity = 1 and the emitted radiation "factor" is a fraction of what the ideal emission would be. The emissivity of the flame specifies how well the flame radiates energy compared to a black body at the same temperature (Nordling & Österman, 2004).

$$M = \sigma T^4$$

Where,
M= is the power radiated per blackbody surface area (W/m^2)
σ = Stefan Bolzmanns constant; $5.6705 \cdot 10^{-8}\ Wm^{-2}K^{-4}$
T = Temperature in Kelvin (K)

The flame temperature is influenced by several parameters. The fuel/air mixing process is of highest importance. With a faster air and fuel mixture the combustion becomes faster and quicker heat liberation takes place.

The temperature of the combustion air has a strong influence on the flame temperature. To keep the secondary air temperature in the correct range is important. Ideally for combustion purposes it is appropriate to have the temperature as high as possible. In this type of process compromises are always necessary and the temperature needs to be below a maximum with respect to the cooler and its conditions. When gas streams are controlled properly with a well known temperature distribution, it is possible to run the plant on smaller margins. Of course this fact makes the operator´s work more challenging despite all technical aids available today.

3.4 Chemistry

3.4.1 Introduction

The burner is crucial when it comes to the chemistry issues of a cement plant. The length of the burning zone and CO levels are two of several key variables connected to the burner.
With a low momentum burner like the one present in kiln 7 problems with blockages and build-ups are very likely to appear. During spring 2008 big problems regarding build-ups in the lowest stage of cyclone tower 7 have started to appear frequently. The kiln inlet is also partly blocked from time to time. This has also created an incentive for the burner rebuilding because the planned burner change strongly influences this type of blockages.

Besides production increase and burning of alternative fuels improvement of the chemistry in the preheater tower is one of the cornerstones in this project. An important part of the cement chemistry is the "circulation phenomena". It refers to circulation of Sulphur and other volatiles. These substances come from both the raw materials and the fuels in the cement making process. These elements volatilize at a certain temperature. The higher the vapor pressures of a liquid at a given temperature, the higher the volatility and the lower the normal boiling point of the liquid. A higher temperature gives a higher vapor pressure and the normal boiling point is located where the vapor pressure becomes higher than the surrounding atmospheric pressure (Greco, 1997).

The substances come into the system with the fuel and the raw materials. When volatilized the substances follow the gases in the preheater system towards the material. When the temperature is decreasing the substances will form a high viscosity liquid phase. This phase will agglomerate and can be solidified if it enters a cold surface (i.e. preheater external shell). It leads to build-ups of different types that block the preheater system. Properties of the volatiles and knowledge of the temperature distribution in the preheater tower are important facts to map the circulation phenomena. Outtake of samples is another tool and through these measures a quite high awareness of the phenomena can be reached. The temperature where the build-ups mainly take place in the preheater tower kiln 7 is around 850°C which means that the phase that sticks the build-ups must have a melting point around that temperature. Analyses have shown that it's mainly the Calcium Langbeinite ($Ca_2K_2SO_4$ or $2CaSO_4.K_2SO_4$) that leads to the build-ups. Analyses show high concentration in the build ups (25%) and this is essentially due to circulation phenomena regarding sulphur ($CaSO_4$) and potassium.
The new burner installation will decrease these circulation phenomenons and this fact will have several positive effects.

It has been observed that (Larsson, 2008):

- A bigger air flow decreases the frequency of the build-ups
- A high CO concentration increases it
- A short and intense flame, synonym of a smaller "hot zone" decreases it. After burner modification the flame will strongly change in this direction.

The three points above can be interpreted as sulphur cycles. Equilibrium between Sulphur dioxide, Calcium oxide and Potassium oxide mainly influences the course of events.
Sulphates (K and Ca) are formed at a low temperature (~800°C):

$$SO_2 + 1/2O_2 + CaO \rightarrow CaSO_4$$
$$(SO_2 + 1/2O_2 + CaCO_3 \rightarrow CaSO_4)$$
$$SO_2 + 1/2O_2 + K_2O \rightarrow K_2SO_4$$
$$K_2SO_4 + 2CaSO_4 \rightarrow 2CaSO_4.K_2SO_4$$

Then $CaSO_4$ is dissociated at high temperature (~1300°C):

$$CaSO_4 \rightarrow SO_2 + 1/2O_2 + CaO$$

The decomposition rate is directly depending of the time that the sulphate will stay in the hot zone (above 1300°C). This time is shortened with the new burner which means a lower decomposition rate. It will have an extremely positive effect with less build-ups and a higher production.

The K_2SO_4 that has not reacted will melt and volatilise easily.

$$K_2SO_4^{sol} \rightarrow K_2SO_4^{liq}.$$

Finally a part of the sulphates will leave the system with the clinker (Bhatty et al, 2004).

Fundamental in the process at a cement plant is to be able to have the right gas flows. In different stages of the process there are several differential pressures that should be in the correct range. When channels and cyclones are partly blocked the pressure drop over the region is bigger. The fans must work harder to maintain the right climate in the preheater tower with increased power consumption and wear. The gas flows strongly influences temperature distribution in the system. To be in the right interval regarding the gas flows it is very important to keep the correct temperature distribution in the preheater. Another issue to be addressed is to provide the burner with the correct air mix. Every burner is unique and designed for a certain kiln system climate. This includes secondary air temperature, gas flows, CO levels, chemistry characteristics and preheater type to mention a few.

3.4.2 The burners influence

The new burner will decrease the circulation phenomena of Sulphur. As mentioned before the decomposition rate of $CaSO_4 \rightarrow SO_2 + 1/2O_2 + CaO$ is directly depending on how long the time in the hot zone of the kiln is (above 1300°C). With the modified burner the hot zone in the kiln gets shorter because of the short and intensive flame.

As discussed earlier in this report the main purposes of the burner change is an increase in production and to enable burning of alternative fuels. It is the very intense flame of the burner that is the basic condition which makes the combustion more rapid. At the same time the intense flame enables burning of the heterogeneous alternative fuels. More detailed fluid mechanics physics is discussed in section 3.2 of this report.

4 Method

4.1 Fundamental burner design

In order to minimize costs a redundant burner at Cementa AB was chosen for the experiment. With the necessary modifications carried out this installation should function in a satisfactory manner. Current burner and the front parts of it are shown in figure 4.1-1. The burner had only two channels for air and fuel from the beginning. In the current configuration the burner has got eight extra air jets to improve the climate of burning.

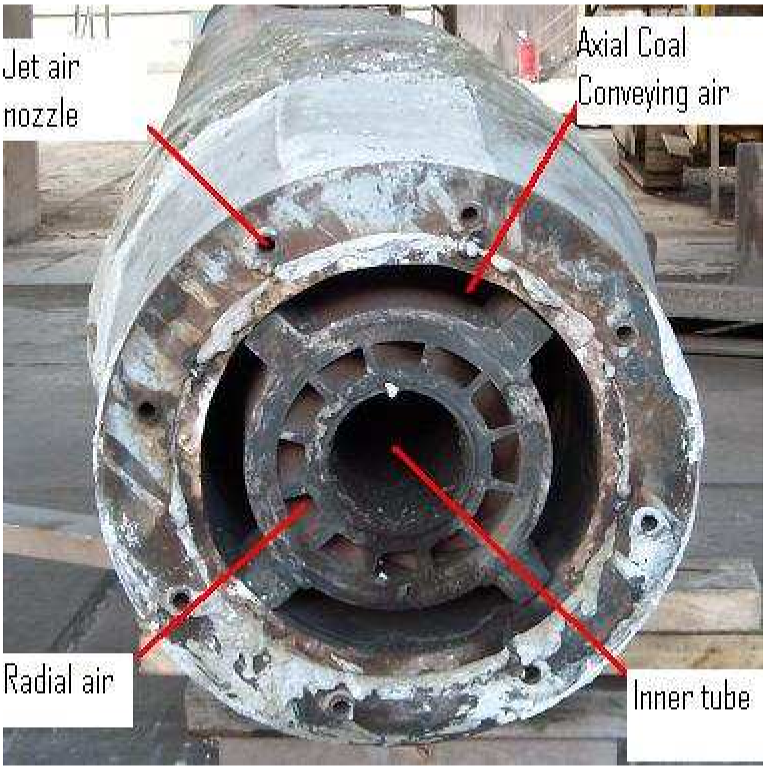

Figure 4.1-1 *Current burner installation. The inner tube is for the ignition of the kiln after long stops and through this an oil lance is pushed in. Beyond this single channel, the air-bearing channel with radial air is located. The radial air is driven perpendicular to the direction of the burner. Outside from this is the axial coal conveying air and this air stream carries the coal used for the combustion. Close to the burners outer boundary the jet air nozzles are placed. This high speed air stream is also in the axial direction.*

Increasing the number and size of the jet air nozzles is the main action taken in this project to achieve the targets. To allow this, a series of other measures have to be carried out which will be described further on.

Compared to the old burner the new burners jet stream area is 6.5 times bigger and therefore requires a lot more primary air. A blower from the earlier shut down kiln 6 is available which can provide the burner with the right amount of air and make this viable. Before this option is put into practise the critical burner dimensions is calculated using the actual blower performance curve data to ensure that the desired performance will be attained.

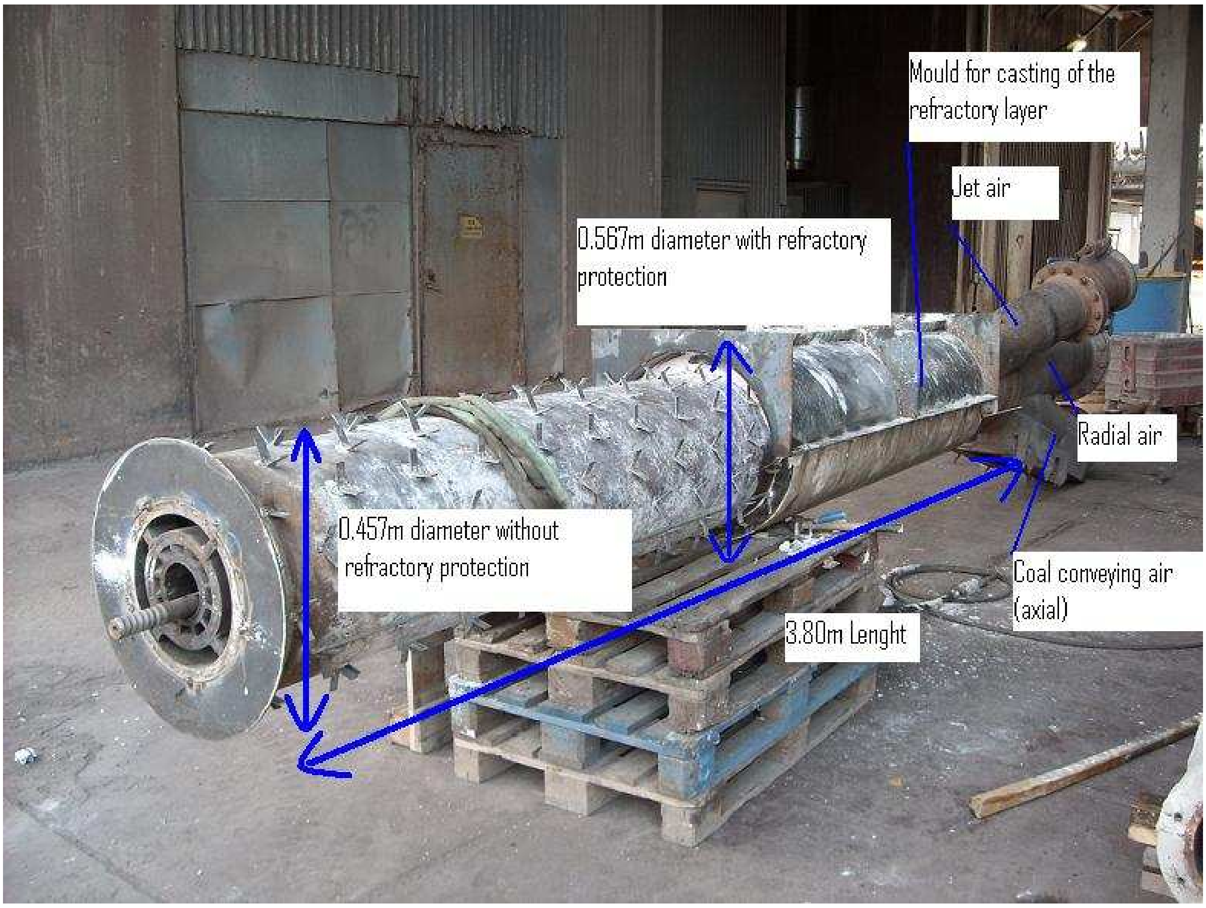

Figure 4.1-2 *Overview burner modification. The jet air channel pointing upwards in the picture is installed to provide the modified burner with the large amounts of jet air. This accumulates weight and the burner becomes unwieldy compared to its original configuration. This causes problems when changing the burner to a new one which is done every 3 months. Further on other important key dimensions are described. For example the shape of the casting is to be seen.*

4.2 Momentum before and after modification

Momentum for the present burner is calculated and presented in the table below. The continuous thermal input is:

1273tons per day clinker output gives a clinker output of 14.7kg/s. One part raw meal in the feeding gives 0.64 parts of clinker. This means that 23.0kg/s of raw meal give 14.7kg/s clinker output. The weight loss is mainly explained by the CO_2 that is emitted during the heat up process.
Every kg of clinker produced requires 900kcal of energy; 900kcal = 3.77MJ. With a production rate of 14.7kg/s the energy consumption every second is 3.77*14.7kg/s = 55.4MJ/s. 1W = 1J/s, and that gives 55.4MJ/s = **55.4MW**.

Measured and calculated values for the present burner on kiln 7 at an air temperature of 20°C and air density of 1.2047kg/m^3. (By convention momentum associated with coal transport air is not included in the burner momentum total.):

Air Channel	Flow rate (Nm^3/h)	Primary air (%)	Velocity (m/s)	Momentum (N/MW)
Radial/swirl air	1860	3.5	59	0.7
Coal/axial air	2910	5.5	52	0.9
K8 transport air	1800	3.4	52	0.6
Jet air	450	0.9	199	0.6
Total	7020	13.3	-	2.8
Burner momentum (coal transport air excluded)				**1.3N/MW**

Table 4.2-1 *Burner momentum before modification of the burner. K8 transport air distributes coal from coal mill 8 to kiln 7. The momentum number reached here should not be included in the total burner momentum.*

The Jet air flow of 450 Nm^3/h is here produced from the compressed air net at the plant. The compressed air system is pushed near its limit so an increase of jet air from here is impossible. The use of a blower to supply the new installation with jet air requires modification of the burner and its surroundings. A new gas duct for the jet air was constructed at the plant and put together in the zone behind the burner. The blower itself was placed in a soundproof space close to the burner and properly installed. The blower is quite old but if the performance of the blower is reasonably close to the original specification it should easily provide the burner with the right amount of air. The target is to raise both the velocity and volume of the primary axial air with the proposed burner design using 16 enlarged jet air nozzles.

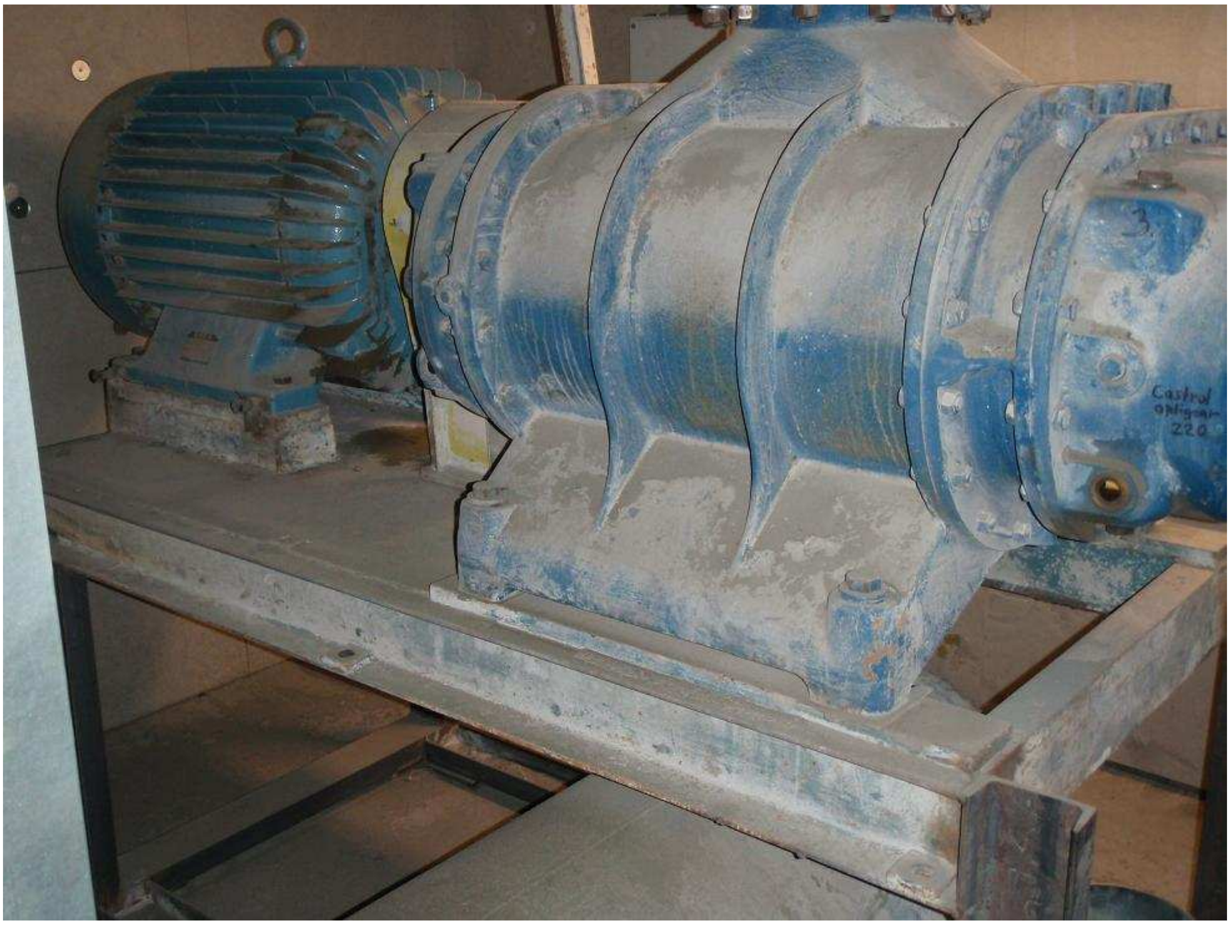

Figure 4.2-2 *High pressure/volume blower installed inside a soundproof house. The blower was found in- house and was checked according to Cementa AB standards. Despite the fact that the blower is old vibrations in bearings were within an acceptable range. Normally when blowers are standing still for years in industrial environments damage occurs to the bearings (Larsson, 2008).*

Several different scenarios have been modelled with different blower pressures at the burner tip. In the following, the burner is operated using coal mill 8 at the projected kiln output of 1500 tons per day. Current energy consumption is 900 kcal/kg and the primary air requirement is then around 61000 Nm^3/h. The 8 jet air tubes from the old burner are replaced with 16*1.80 cm diameter nozzles. The coal transport and radial air volumes are adapted to the new conditions.
As discussed earlier the aim is to optimize the total primary air usage and at the same time increase the momentum. With the numbers above the continuous thermal input is:

1500 tons of clinker produced per day = 17.4kg/s of clinker output
Every kg of output requires 900kcal of energy; 900kcal = 3.77MJ. With a production rate of 17.4kg/s the energy consumption every second is 3.77*17.4 = 65,4MJ/s. 1W = 1J/s, and that gives that 65.4MJ/s = **65.4MW**.

Measured and calculated values for the modified burner on kiln 7 at an air temperature of 20°C and air density of 1.2047kg/m^3:

Air Channel	Flow rate (Nm^3/h)	Primary air (%)	Velocity (m/s)	Momentum (N/MW)
Radial/swirl air	2000	3.3	63	0.6
Coal/axial air	1200	2.0	21	0.1
K8 transport air	1800	3.0	52	0.5
16 jet air nozzles @300mB	3610	5.9	239	4.4
16 jet air nozzles @350mB	3910	6.4	258	5.2
16 jet air nozzles @400mB	4170	6.8	275	5.9
16 jet air nozzles @450mB	4430	7.3	292	6.6

Table 4.2-3 *Predicted burner momentum with modified burner for different jet air pressures.*

On the following figure, the new front of the burner is in place. The momentum numbers shown earlier looks promising and with the new "nose part" of the burner in place it looks like this.

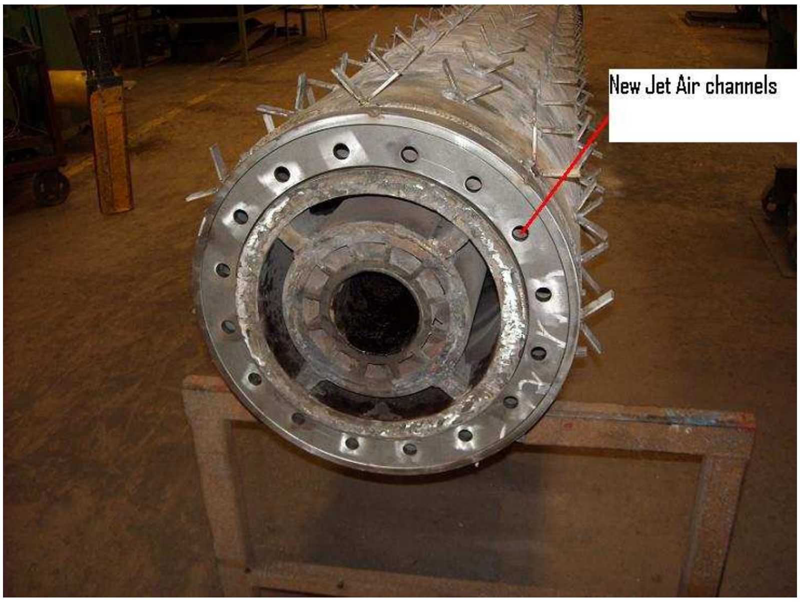

Figure 4.2-4 *Modified burner nose installation*

4.3 The fluctuating temperature issue

When designing a burner, it is important to take into account the different temperatures it will face. A study of temperature distribution over the burner shows that the temperature increases axially and is at the highest level at the front of it. Further temperature increases radially from the inside out, which means that the temperature is lower in the centre of the burner and higher in the outer edges.

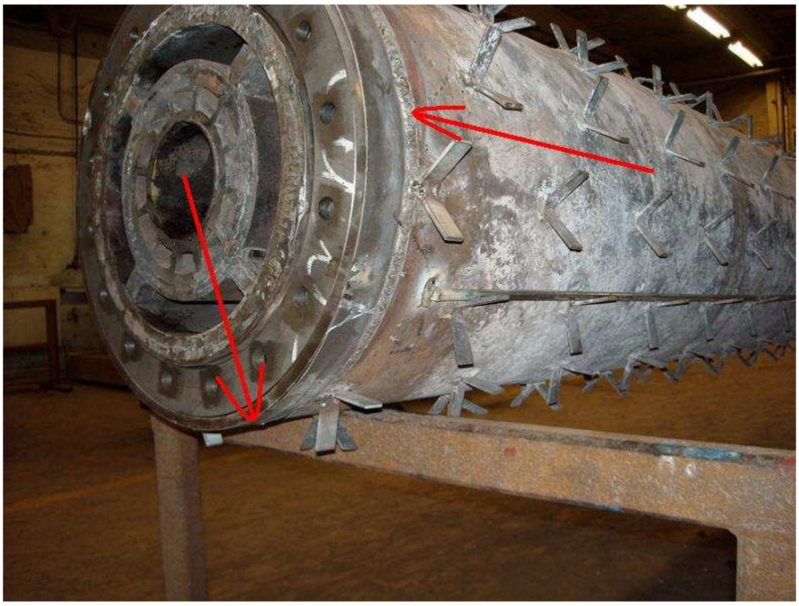

Figure 4.3-1 *The temperature of the burner is increasing in the direction of the arrows.*

In the reconstruction of the burner this was a central issue and a lot of effort was put into it. The steel used in the burner expands 1,17mm per meter and 100°C warm-up (Larsson, 2008). For this investigation the interesting part of the lance is 3.8 m long and the calculated temperature difference between the inner and the outer part will be about 400°K. This gives the following thermal expansion scope for the burner:

Thermal expansion of iron:	$11.7 \ 10^{-6} \ K^{-1}$
Length of burner section:	3.8 m
Expected temperature variation:	400°K

Difference in axial expansion:

$3.8*400*11.7 \ 10^{-6} \ mK^{-1} = 17784 \ 10^{-6} \ mK^{-1} =$ **0.0178 m**

This means that a solution must be used where the burner´s various parts are moving in relation to each other. There are examples on previous trials where these effects have been completely overseen. Below is an example of how these forces have previously deformed a jet air ring of the same type as the one used within the project:

***Figure 4.3-2** Ring shape indicative of deformation caused by temperature fluctuations. The outer parts of the burner have faced much higher temperatures than the inner parts, Cementa AB.*

In cooperation with Thord Larsson, Mechanical Engineer, a decision on how to solve this was taken. The solution involved a lot of extra work but the result of it was well proven in other trials within the same area. A basic outline of the construction is presented below with the vital parts clearly to be seen. The outer jet air ring is allowed to move 20 mm axially in direction of the burner due to heat expansion without damaging itself or its surroundings. The fact is that the jet air leakages are minimized during full operation of the burner relative the situation when it is cold. Furthermore the gas flow is driven in the correct direction before passing the jet air nozzle. This measure minimizes the energy losses that appear when changing direction of the air stream sharply.

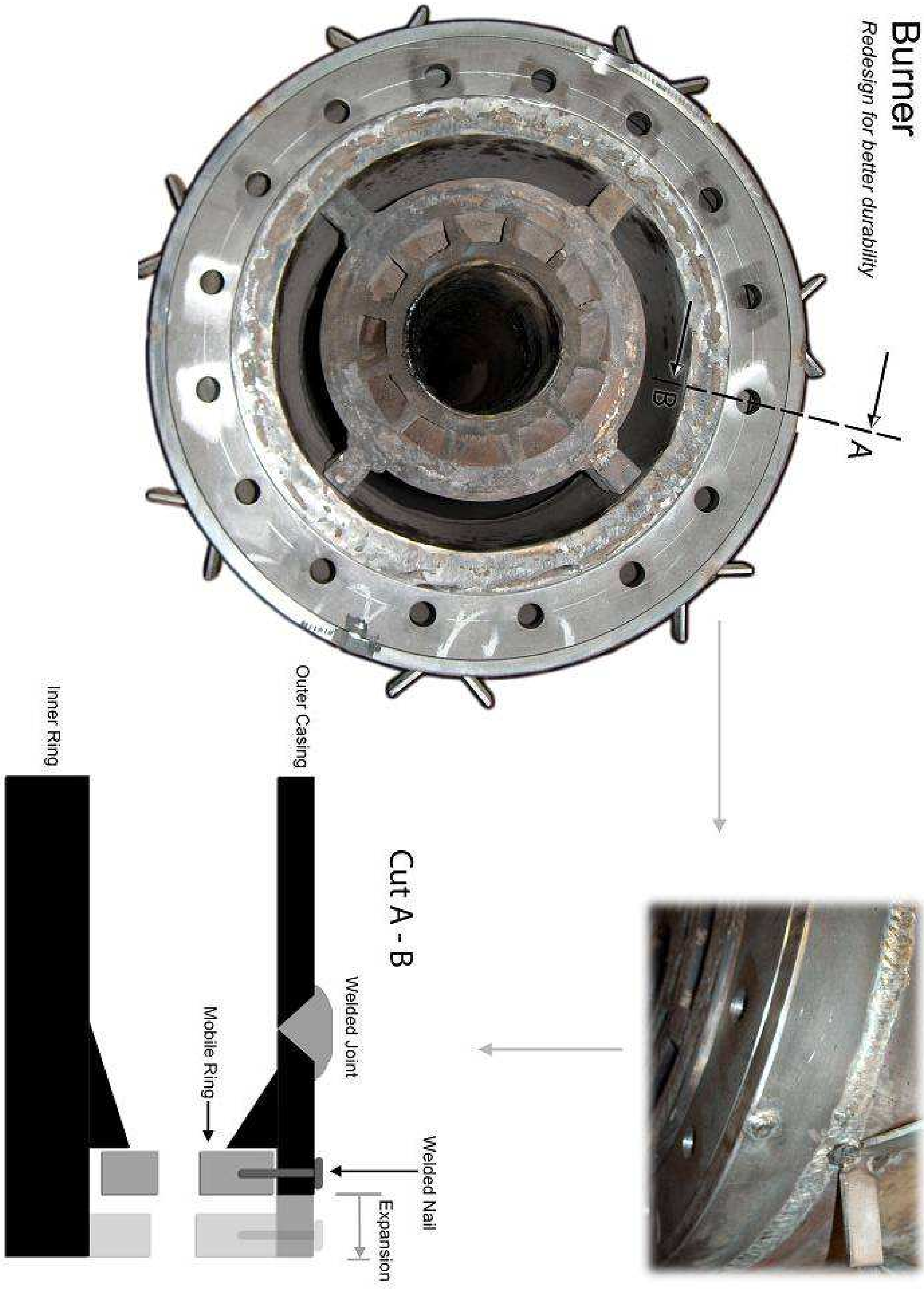

Figure 4.3-3 *Redesign of the burner nose for better durability***.** *As shown above the expansion of the burner can take place without damaging the important jet air ring. The suspension of the ring with the welded nail gives freedom for the ring to move both axially and radially. "Outside" the welded joint is an extremely heat resistant material located that can resist temperatures of 1400°C without problems.*

4.4 Refractory and weight

When changing the burner to a new one the lifting equipment is pushed to its absolute limit. The new burner solution includes an extra pipe for the jet air and the weight is increased compared to the traditional burner. Weight of the present burner will be 3250 kg and in cooperation with Per-Lennart Bohman, Refractory Supervisor, the decision was made to decrease the weight of it. On the burner the outer layer consists of refractory protection of 70 mm thickness. Sufficient protection should be reached with a protection layer of 55mm thickness. This measure will decrease the weight of the burner with ~280 kg.

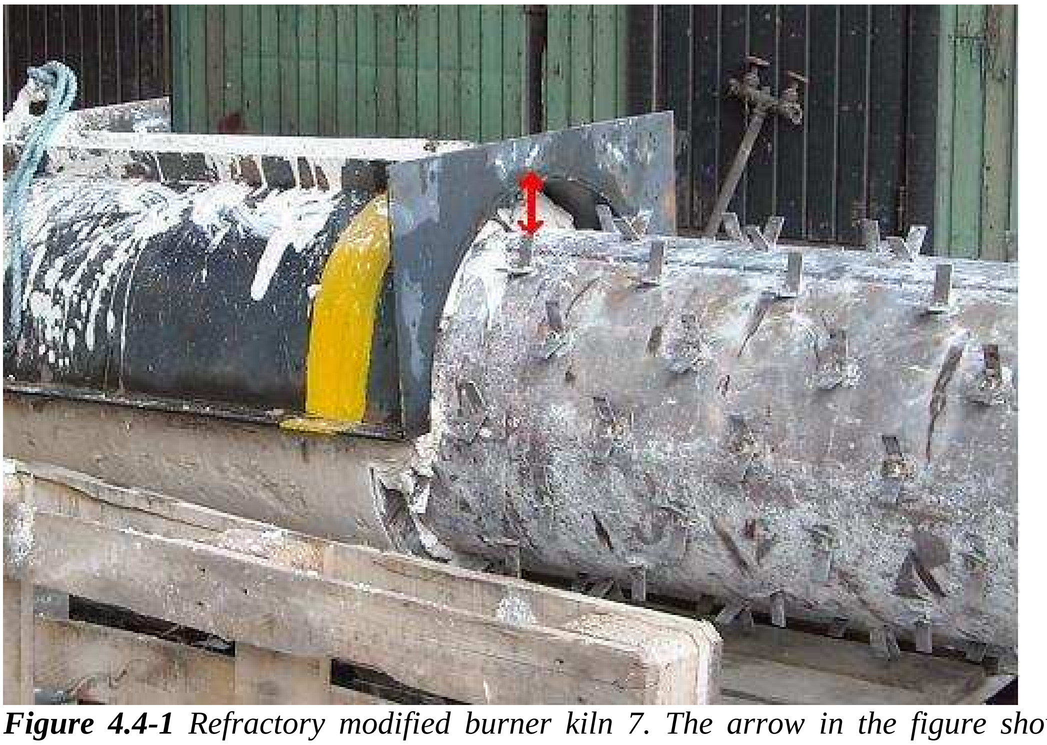

***Figure 4.4-1** Refractory modified burner kiln 7. The arrow in the figure shows the outer protection layer. It is a casting with a highly effective refractory mixture.*

Below the calculations used to predict the result of the measures taken:

$\pi * r^2 * h$ = volume of a cylinder of a certain diameter and height

Density refractory casting:
$\rho = 2650\ kg/m^3$

Volume of the burner with the 70 mm casting:
$\pi *3.8*0.3^2 = 1{,}0744 m^3$

Volume of the burner with the 55 mm casting:
$\pi *3.8*0.285^2 = 0.9697\ m^3$

The difference in volume consists of refractory casting:
$\rho = 2650 kg/m^3$

The lost weight is (1.0744 – 0.9697) m^3 * 2650 kg/m^3 = 277.6 kg

With modification, the new weight is 3250 – 277.6 = 2972.4 kg
The lifting equipment is capable of lifting 3000 kg so the modification will have the effect wished for.

4.5 Surveillance and processing aids

A good protection and surveillance of the burner is crucial. The surveillance should include:

- Temperature
- Pressure in air channels, especially in jet air duct.
- Ampere level on the blowers
- Air flows through the burner
- If the blower stops during production, a powerful alarm to the operator
- During warm-up of the system a box is marked and the correct jet air distribution takes place.

As shown below the temperature sensor is placed 100 mm from the burner nose and located at “7 pm” seen from behind the burner. As described earlier the kilns rotational direction gives a big material load in this position. The burner is the most exposed in this location due to the radiation from the load. Outside of the pipe casting of the refractory mass is performed with the 55 mm thick layer.

The temperature element used is quite unique and has got the shape of a wire. It is located inside a highly temperature resistant tube that can resist 1400°C and is thread inside the tube. One of the advantages is the fact that the wire can be exchanged without the burner taken out. The element is called type “K” and will with present installation show temperatures up to 600°C with exactitude of 1°C (Erlandsson, 2008).

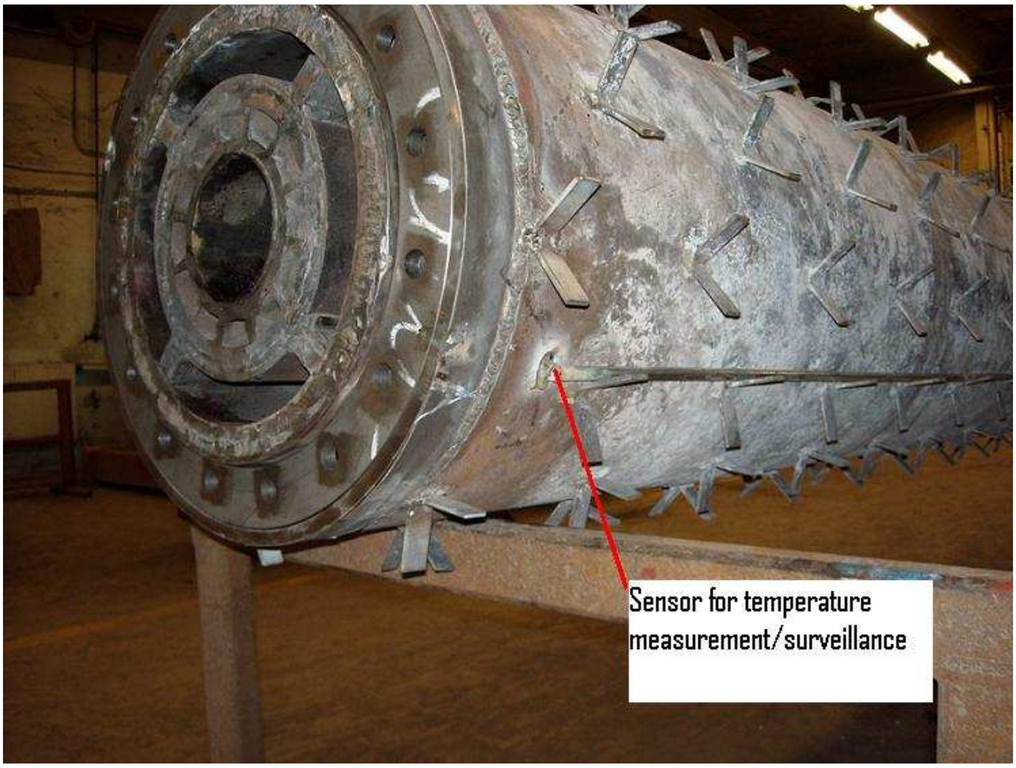

Figure 4.5-1 *Temperature measurement/surveillance.*

The pressure gauges are located at the ducts between the blower and the burner. A sudden change in pressure may indicate leakage or damage either to the ducting, blower or the burner. The ampere levels on the blowers indicate the resistance level. It is partly pressure related but can also give a picture of an upcoming blower failure, for example. Continuous measurement of the airflows through the burner and alarms set up by the programmers watching blower rotational speed vs. production is other effective measures to guarantee a high safety level of the system. Shown below is one of the operators´ views in the Sattline system where the new installed aids related to this burner modification are visualised. Sattline is the operational system used at the plant delivered from ABB. All programming related work was done by Bo Pettersson, Programmer.

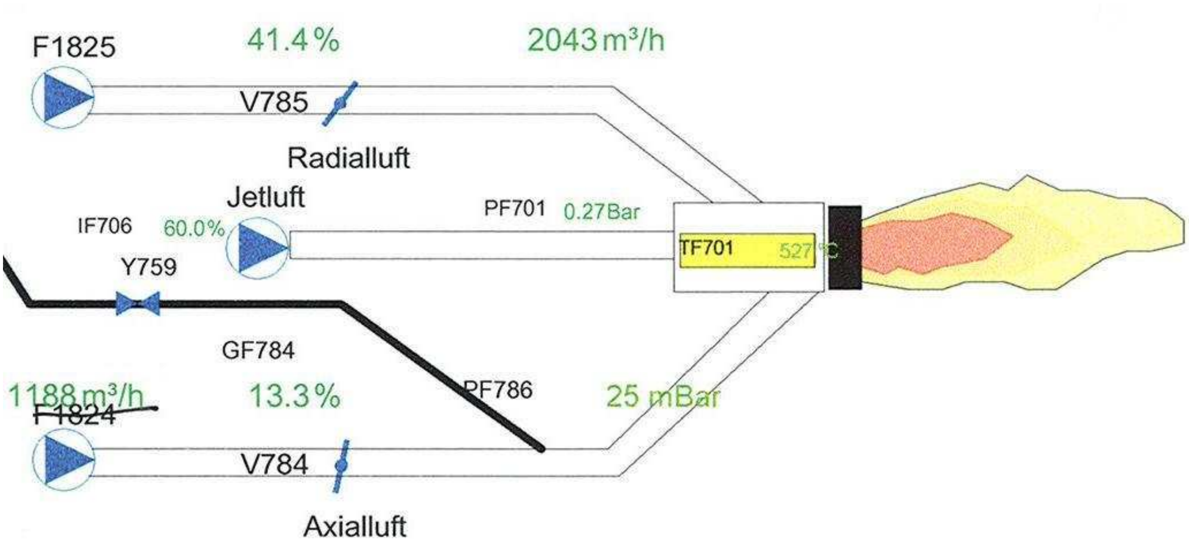

Figure 4.5-2 *Burner overview. Current system used at Cementa AB Slite is delivered from ABB and is called Sattline. This picture was taken during production with the new burner installed.*

- *The TF701 in the picture is the temperature measurement*
- *PF701 pressure in the jet air duct (see momentum calculations)*
- *IF706 is the relative ampere level of the jet air blower*
- *2043m^3/h is the radial air flow*
- *1188m^3/h is the axial air flow.*
- *PF786 is the axial air pressure*
- *41.4% is the position of the radial air damper*
- *13.3% is the position of the axial air damper*

With the help of these inputs, the operator can control the kiln and burner in a safe and satisfactory manner. When introducing new units within the present kiln system it is important to have a dialogue with all the operators involved. In this case a message of the changes was delivered orally and a written temporary operating instruction was placed on the lectern. The written instructions were updated from time to time and every change made by the operator during production should be reported to the project manager (Appendix 1 and 9).

4.6 Installation and initial operation

A big part of the installation work regarding the new burner with its surroundings can be made in advance meanwhile the rest of the kiln system is in full operation. The planning part of this is essential where as much as possible of the work should be done beforehand final burner installation. During final burner installation the kiln should be stopped and predicted time for this installation is approx. 6hours (Södergren, 2008). Compared to an ordinary burner change that takes 5hours the difference is quite moderate. As mentioned earlier the explanation of this is all the planning and preparatory work performed to minimize the downtime of the system. Date of the change is flexible and takes place when a natural stop on the kiln occurs. Stoppage of the kiln system is avoided as far as possible due to the large costs arising from this. It is not just the downtime itself but also the time-consuming re-optimization that is extremely expensive. If a five minute quick stop of the kiln takes place the real loss in production can be several hours thanks to this optimisation process.

Figure 4.6-1 *The finalized burner in overview*

The burner change took place early in the morning 21.08.08 and went as planned. In advance instructions were distributed to all the people involved both orally and written so a good preparation level was achieved. The old burner was dismantled and
the finished burner were lifted into place and all connections, both electrical and mechanical were successfully installed. During warm-up of the kiln system with the new burner the operators followed the guidelines given (Appendix 1).

During the first time of operation the primary target was to reach a pressure in the jet air channel of 270mbar. This process takes time and the pressure is to be regulated with care. The run- in time of a new unit requires a lot of extra work from the operators and is an extra burden for the mechanics (Appendix 1). During the first days of operation several problems arose with the kiln system not related to the burner change. Some of the problems that occurred were blockages in the cyclone system and breakdown of the cooler. After every stoppage a new optimisation phase has to take place as mentioned earlier. Within the first couple of days a maximum stable pressure of 230mbar was attained. Already at this pressure level the climate in the burning zone should be improved compared to the earlier situation. A better mixture between air and fuel takes place at quite moderate jet air pressures and leads to a more defined burning zone. A first reaction from the people working with kiln 7 was a better climate in the preheater tower. The build-ups decreased after just a few days with the new burner which most likely indicates a shorter and more intensive burning zone. But overall the kiln was quite unstable to run with CO levels and temperatures fluctuating up and down. This suggests that conditions in the system are not optimal and need adjustment. Crucial is to change one parameter at the time so the effect of every change can easily be followed up.

From 25.08.08, running of the kiln started to be a bit more successful. In the initial operational phase the kiln was stopped at least once a day, but from 25.08.08 the kiln was running for a week without any stops in the process. Despite this fact, it was not possible to bring up the pressure of the jet air to the desired level. The effect of the blower was gradually turned up step by step without the pressure responding. In the graph below, a relation between the pressure level and the ampere of the blower can be seen. The curves are matched so they follow each other quite well which makes sense. Within the marked area it is clear that something is happening to the system. The purpose of installing the amps display on the blowing machine is precisely because of early detection of variations like these. The ampere value indicates the resistance to blowing machine and in case of a leak proves this clearly. The early suspicions were regarding the nose of the burner and that a deformation had arisen with a leakage following. Another possibility is that there had been leakage between the different channels of the burner, but other data indicated otherwise. Gas flow measurements were during the period performed by Patrik Thulin, Cementa Research, and analysed. They underlined the suspicions that already existed and it was verified that the situation had changed dramatically in a very short time (Appendix 5, 6). It is a big difference between the values despite the fact that the blowing machine was driven in the same way at the time of the measurements.

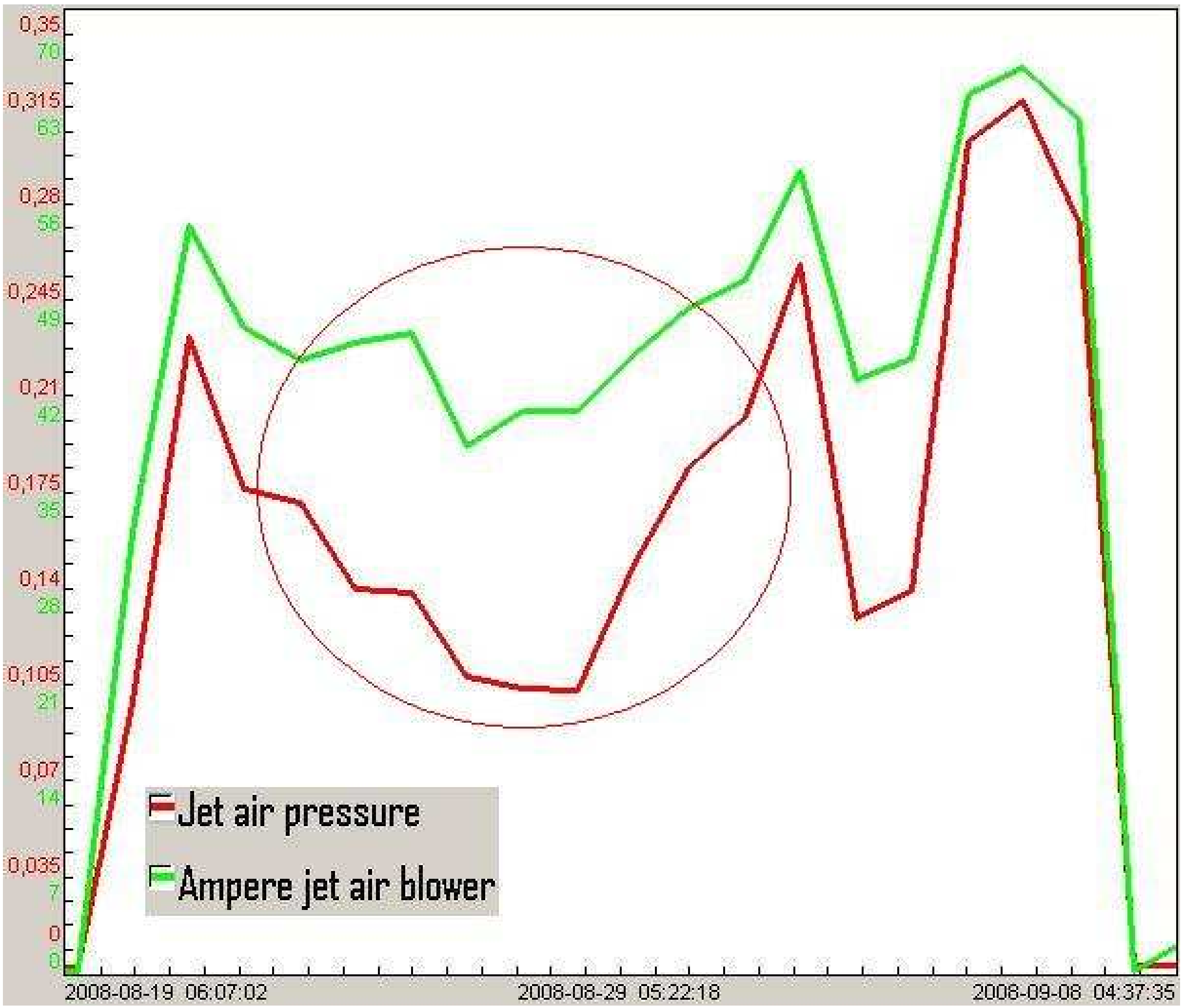

Figure 4.6-2 *Relation between the jet air pressure and the ampere of the jet air blower. It is clear that something has happened within the marked area of the graph.*

In the soundproof shed where the blowing machine is located, it is incredibly noisy and installation and connections were done in a serious manner. In the troubleshooting work the possibility that something could have happened here was partly overlooked. However, it was precisely in this position that the error was discovered several days later in connection with further inspection. A gable on the blowing machine had failed and partly the air was leaking out here instead of going the right way through the burner head.

Almost irrespective of how the blowing machine was driven a low pressure in the jet air at 100mbar was present during the period. The leakage rate also increased gradually until it reached a steady state level which can also be seen in the graphs. A dialogue took place whether it would be possible or not to repair the gable with blowing machine in operation. The risk with the closing of jet air (blower) during operation of the kiln is that the burner, despite emergency cooling system, is overheated. Decision was taken to repair the blower machine provisionally and await a natural stop when the gable would be welded properly. The gable was fixed with the help of two cargo strainers provisionally and immediately there was a sharp increase in pressure. The pressure immediately went from 100mbar up to 190mbar which was a major step in the right direction.

It continued in this way from 29.08.08 until 03.09.08 when the right opportunity with a natural stop of the kiln occurred. A few hours later the gable was welded in an exemplary manner and was completely tight.

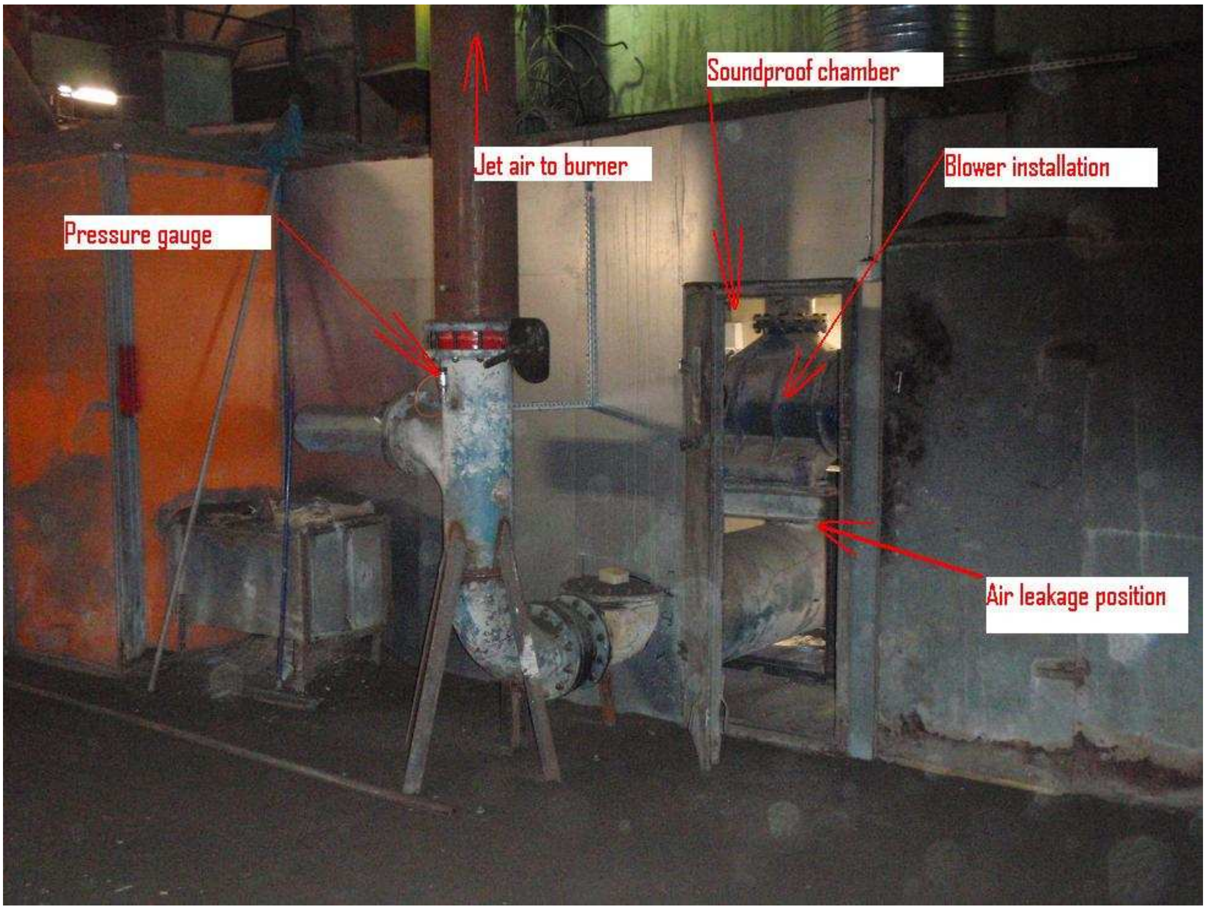

Figure 4.6-3 *Blower overview. The blower and its´ surroundings. Important to notice is the pressure gauge which is both linked to the control system and has a display for immediate readout on the spot. The soundproof chamber with the blower installation is also viable and the air leakage position is roughly marked.*

Some other measures were to be taken on the kiln system so it took ten more hours before the system was heated up again. On the next page is a picture that shows in detail the welding and how the leak was located. The unfortunate location of the leak made it difficult to detect even though there were relatively large volumes of air that leaked.

Figure 4.6-4 *Close up view of air leakage.* *Previously head bolts were used, but the installation was changed with bolts dismantled all the way around. The bolts were replaced by welding. The benefit of such intervention is a more sustainable solution but when in need of maintenance it will be necessary to cut off the gable.*

The primary target was now to reach the lowest calculated jet air pressure of 300mbar. A momentum of ~ 5N/MW is reached with a jet air pressure of 300mbar. If other related adjustments are correct burning at this level should be significantly effective.

4.7 Further operation

Step by step the optimization process could now move forward. An invaluable tool in the optimization work is Aspen Process Explorer, where all important data is saved. In this section of the report, it is a necessity with graphic illustrations to clarify the reasoning. After 08.09.09 it may be noticed that process related values go right down to zero. The reason for this is an accident in the kiln system which will be thoroughly investigated later in the report.

Seen below is the jet air pressure that was ruled out gradually and the desired value in the long term was now at 320mbar. The graph below illustrates pressure changes during the period. The process in a cement kiln is extremely dynamic, which is seen on the pressure that moves up and down without the operator´s settings being changed. During the latter part of the optimization the pressure was periodically above the desired setting. When the operators control the pressure they just give a relative percentage signal to the blower. The actual pressure obtained is partly dependant on other surrounding factors. This fact requires operators who are active and take action with minor adjustments to maintain the desired pressure. During the period the equipment reached the intended pressure.

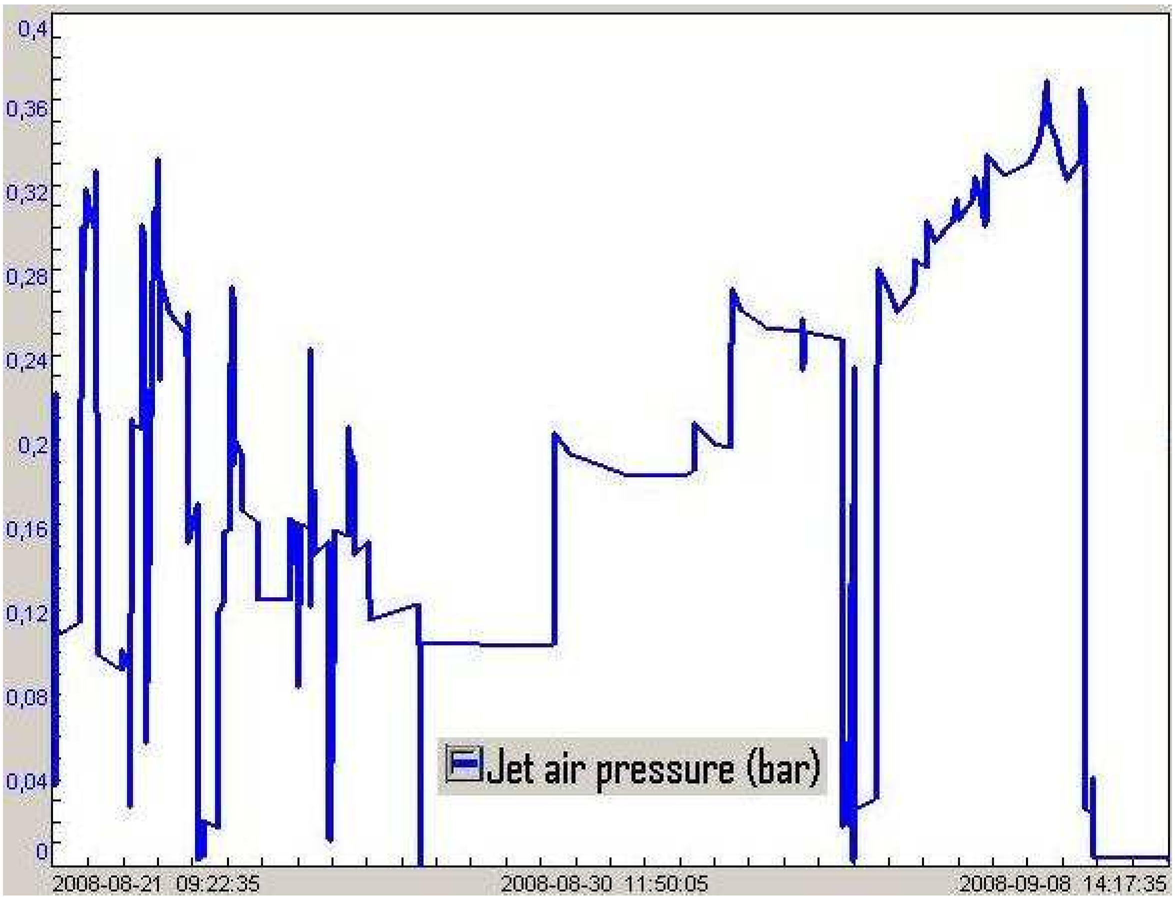

Figure 4.7-1 *Jet air pressure (bar)*

The specific energy consumption is a clear indicator of how the kiln system harmonizes. Obviously, this consumption depends on factors other than these of an incineration nature such as the raw meal composition or the preheater overall condition. Clarity of the trend outlined below, however, depends only on a more efficient transfer of energy from the fuel to the material in the kiln. The increased intensity of the flame is obvious and the heat transferred by radiation increases sharply. This is a clear indication of a higher temperature in the burning zone. The main trend is clear, but some fuel consumption peaks can be seen which are due to kiln stops. As discussed earlier the kiln must be over fuelled during the restart periods because the energy must be higher than usual to tighten up the process to full level.

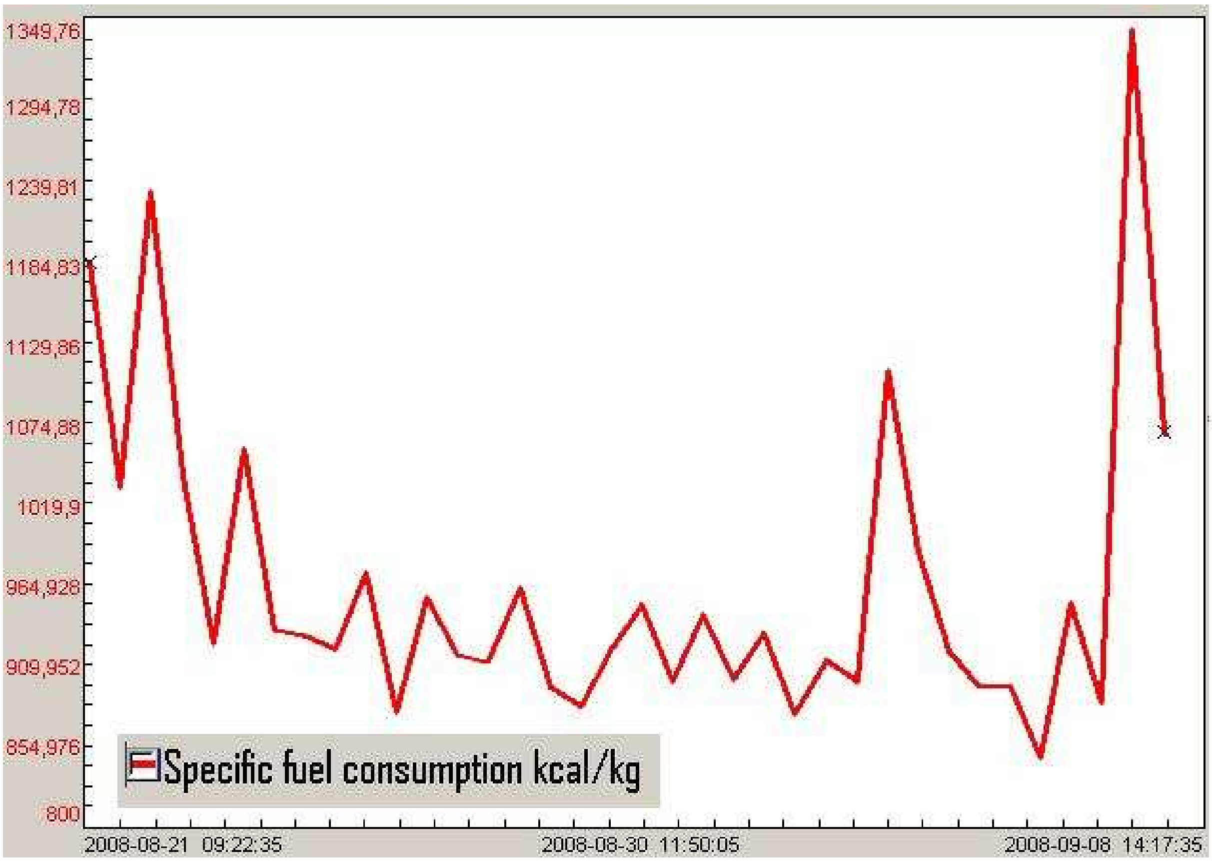

Figure 4.7-2 *Specific fuel consumption kiln 7 Cementa Slite*

The sintering zone temperature is one of the key parameters for cement manufacturing. This parameter, along with some others may be regarded as the most important for a process operator to master. Both short-term and long-term information obtained this way is crucial to avoid major disruptions and fluctuations in the process. Here a trend of rising temperature over time is seen which shows that the increased burner momentum gives an intensified combustion. Gradually when the temperature is raised this gives the opportunity to increase the kiln feed if other key parameters in the system are within the correct range. The cement chemical reactions taking place at these high temperatures are exothermic which means that energy is released when they take place. This gives even higher temperatures resulting in continued reaction to emit even more energy, etc. This is a kind of positive feedback that is important to have under control. If the temperature rises, it is important to compensate with more feed on the kiln or reduce the fuel. Otherwise the development is incredibly quick against the high temperatures that are directly harmful to the refractory in the kiln.

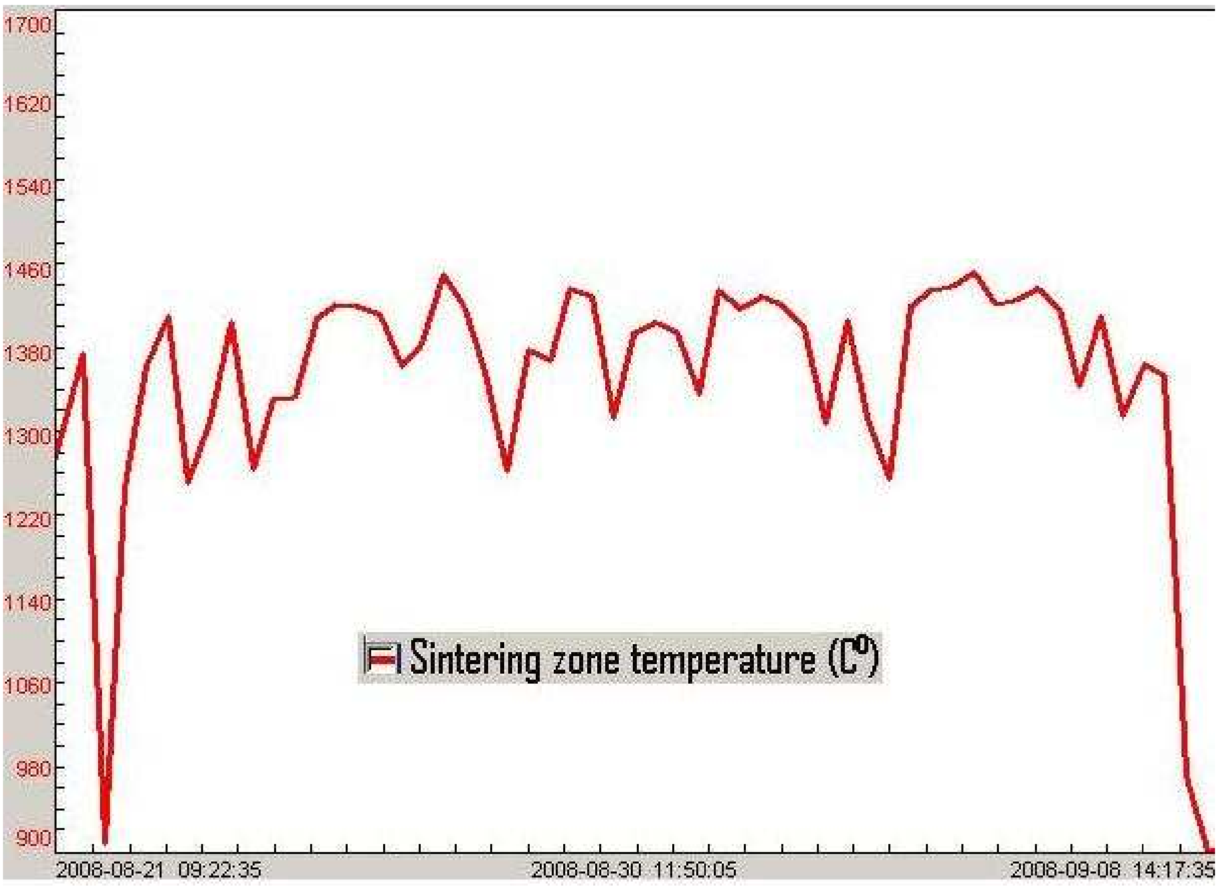

Figure 4.7-3 *Sintering zone temperature (C°)*

The kiln feeding seen below is a direct ruling on how much clinker that is produced. Around 64 % of the raw material weight put in comes out in the shape of clinker.

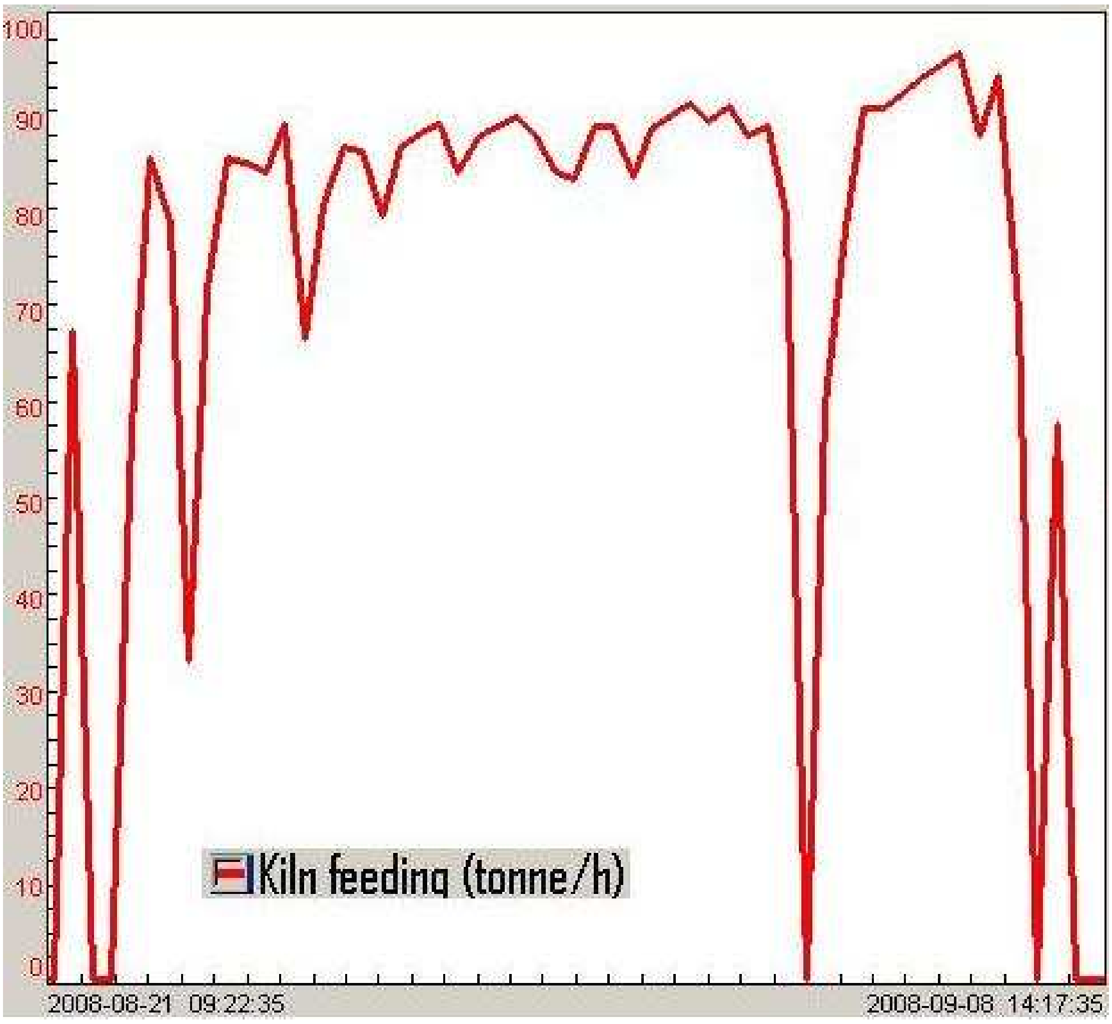

Figure 4.7-4 *Kiln feeding (tonne/h)*

Quality control of the clinker on a modern cement plant is extensive. When the feeding is increased the changes in clinker quality is followed up. During the test period with the new burner the feeding gradually increased with clinker quality kept in good condition. During the last couple of days the feeding averaged around 95 t/h, which is very high. One of the cornerstones of this project was to prove the potential in a burner modification when it comes to the kiln feeding and stability of the process.

SO_3 content in the cyclone meal and clinker is an important indicator of the condition in the preheater system. The circulation phenomena described in the chemistry section of this report is important to control. Comparing the SO_3 levels in the cyclone meal with the levels in the clinker gives a lot of information. If the SO_3 levels in the cyclone meal goes down and the levels in the clinker goes up this means that a big portion of the SO_3 leaves the system through the clinker. This scenario is likely because the hot burning zone becomes shorter with the new burner settings and the decomposition of SO_3 is directly dependant on the residential time in the hot burning zone. Of course the dynamics are really complex but roughly it follows the pattern pictured above. A varying feeding of the kiln also changes the conditions which makes is hard to draw any conclusions from the graph below. The peak value of the SO_3 in the clinker at 08.09.08 is because of the kiln stoppage and apart from that no clear trend is to be seen.

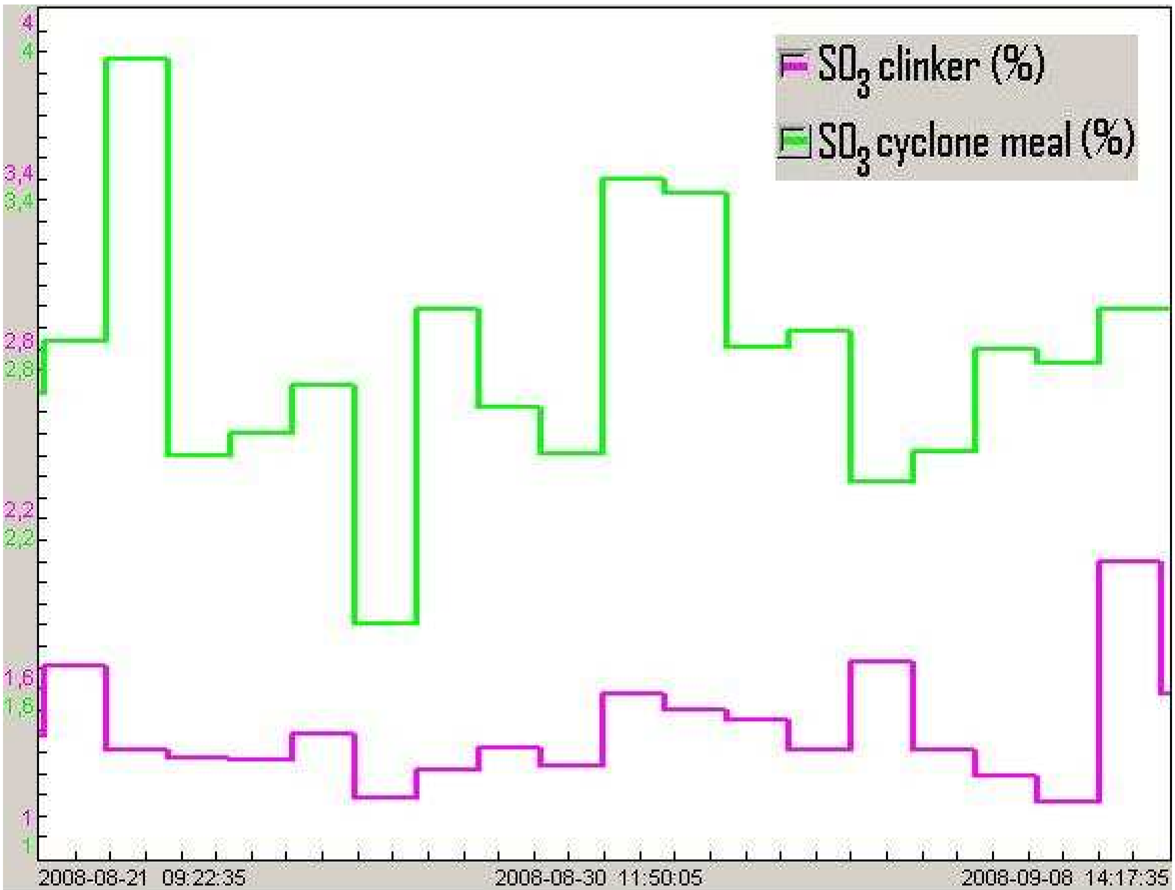

Figure 4.7-5 *SO_3 content in clinker vs. cyclone meal (%)*

During the period the burner temperature rose. A higher burner momentum gives a more intensive combustion and more heat through radiation reach both the material in the kiln and the burner itself. Concerning the material in the burner it is recommended to keep the temperature below 650 C°. During shorter periods of time the temperature can be above this limit without damaging the burner but this scenario should be avoided (Larsson, 2008). The jet air has got the strongest cooling effect which means that a higher momentum also gives a more efficient cooling of the burner. During the last period of time the measurement reached a maximum level of 600 C° which was severe. It stood clear that the wrong interval of the measurement had been chosen. Temperatures at this level were not expected although the burner can resist them as mentioned earlier. This was taken into consideration and a decision was made to continue with full production. To change the measurement interval the process had to be stopped, which was not an option at this stage. A switch to the same thermo element is possible during running of the system but not to change the measurement interval.

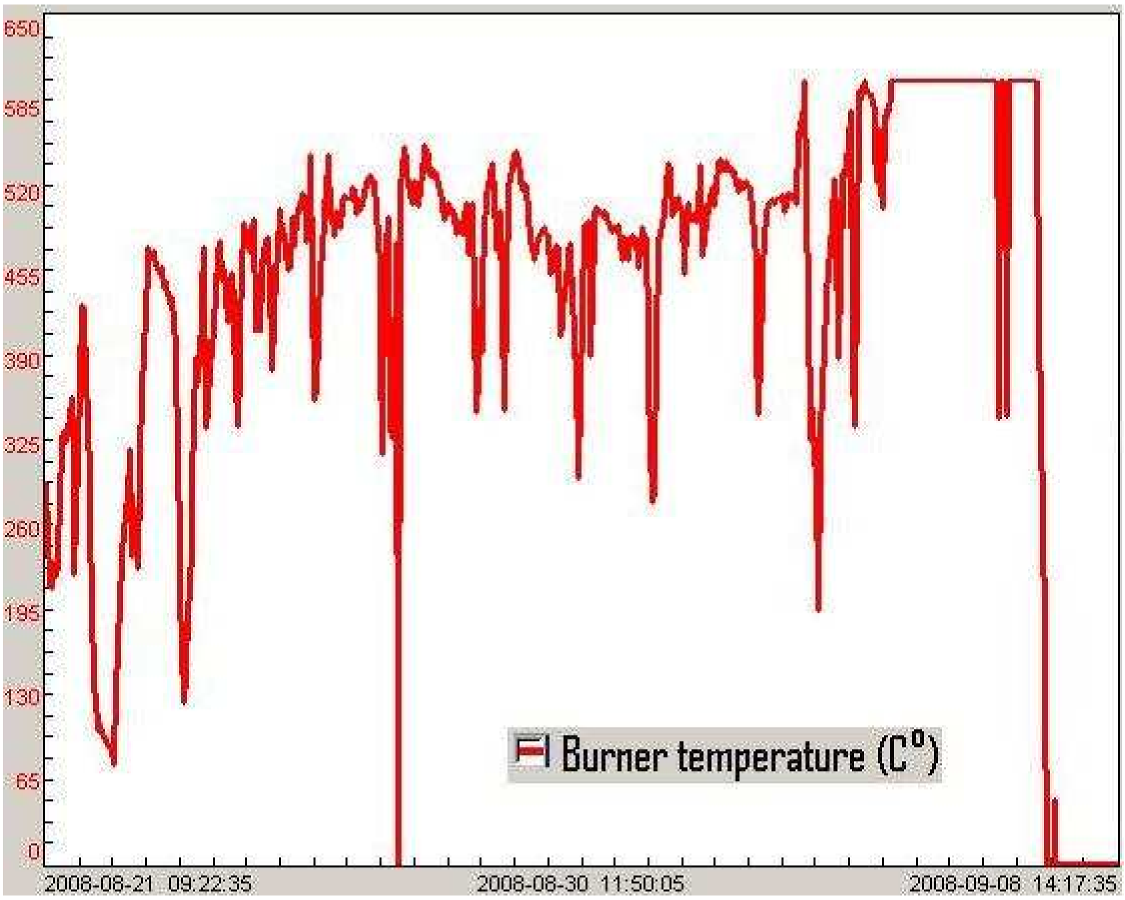

Figure 4.7-6 *Burner temperature (C°)*

The process of a cement plant is as mentioned earlier complex and every measurement has to be put into the correct context. The CO measurement below is a typical example. The CO values have to be seen together with the other measurements above, otherwise no conclusions can be drawn. A higher kiln feeding and lower specific fuel consumption together with CO levels kept in shape is something positive. This fact is explained by the improved mixture between the fuel and air. To have a good mixture between the primary and secondary air is also crucial and all this tends to be in order. Comparisons between the different graphs tell the story about the process development towards a more effective combustion. The complete oxidation of carbon can take place thanks to the good mixture conditions. Important to realise is that the total available amount of oxygen is not higher. The local lack of oxygen that leads to the incomplete oxidation of oxygen is avoided in the combustion region. This is thanks to the good mixture between the different air layers and fuels.

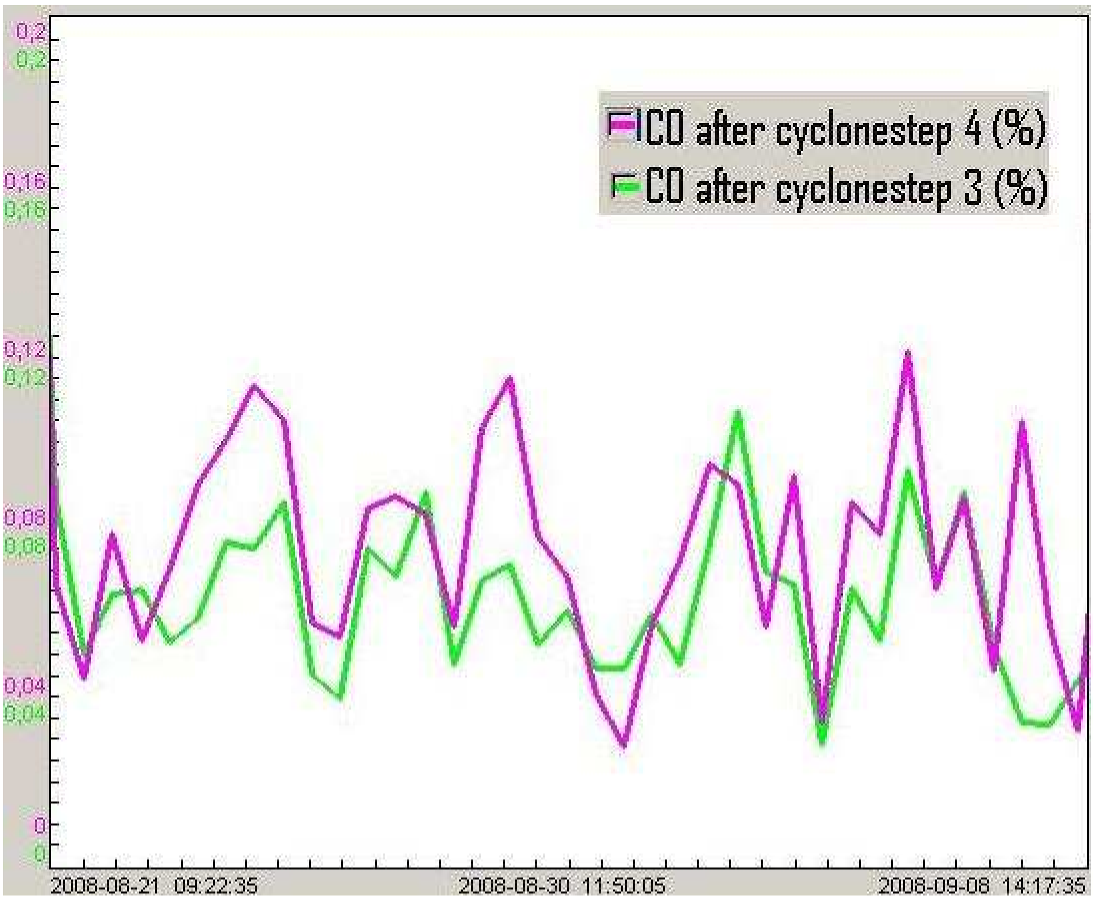

Figure 4.7-7 *CO levels kiln7 preheater (%)*

4.8 Investigation of breakdown kiln7

At this state of the trial when feeding of the kiln and other process parameters were coming close to full production a major failure took place. As often is the case the failure depended on a couple of factors combined in a wrong way. This part of the report will try to explain what happened and give a clear picture of the chain effects.

4.8.1 Background

The night between 06.09.08 – 07.09.08 problems with kiln 7 arose. At 4 am. 07.09.08 the kiln was switched off after visual registration of high shell temperatures. Between approx.5 – 9m from the outlet the shell was red all around with temperatures of approx. 550 - 600°C. The shell temperature is measured three times a day, once per shift. In the night shift at 02.15am the shell temperature was measured and nothing seemed unusual. The temperature distribution of the kiln shell seemed quite normal with a moderate maximum of 400°C. The whole occurrence took place within a couple of hours.

4.8.2 What happened?

Since a couple of weeks kiln 7 has got a modified burner with a more intense flame. The purpose with the modified burner is to reach a higher burner momentum. The higher burner momentum enables a higher production and further on combustion of alternative fuels.

Analysis of the kiln feeding during the period shows very unstable lime saturation in the raw meal (kiln feeding). The lime saturation factor went from 100 up to 119 and down to 89 within five hours. A check of the historical data in Aspen Process explorer shows that this variation is unique. A review of the LSF variations clarifies that such a variation hasn't occurred in at least the last ten years. It is unfortunate to rise to a very high level and then go straight down. The steering parameters of the kiln are then optimized for the extremely high LSF and such a quick drop results in this scenario.

It is clarified that the temperature became extremely high in the actual zone and that the coating was gone.

4.8.3 Description of the scenario

After consideration and checks the following conclusions were made:

<u>Most likely the breakdown was caused by fluctuations of the LSF in the kiln feeding. Although the operators acted in an appropriate way such fast changes of the LSF factor are impossible to deal with when you are going in full production mode.</u>

The huge variation of the LSF factor is caused by an earlier change of the marl feeder and by problems with the ball mills producing the sand slurry.

The change of marlstone feeder leads to a finer fraction of marlstone and that fraction causes the LSF to go down. The system (POLAB) then reacts by adding more limestone.

During this period of adding more limestone we ran into problems with the sand slurry. When the sand slurry disappears the LSF rises dramatically. This caused very high LSF in the raw meal.

This rise in LSF caused POLAB to decrease the amount of limestone and when the sand slurry problem was solved and the flow came back to normal, the LSF dropped again to an extremely low level.

Kiln 7 has got 3 raw meal silos. The normal procedure is to fill one silo while extracting from all 3 silos. This is to prevent fluctuations like this to the kilnfeed. In this case the fluctuations in the raw meal had an extremely high impact on the kiln feed LSF anyway. The maximum LSF from the mill was >140 and resulted in a maximum of 119 to the kilnfeed. The minimum LSF from the mill was 84 and the minimum LSF to the kilnfeed was 89.
The silo level was about 50 % in each silo which is about 15 meters of raw meal in each. This will affect the mixing factor in the silo, but the fact that kiln feed was extracted from all 3 silos prevented the whole 140 and down to 84 LSF from the mill to reach the kiln system.

The sand slurry problem depends on water supply failure. The raw mill has been running without sand slurry during several periods of time and this will cause LSF fluctuation problems. On the next page is a graph where the problems can be seen. Especially between 10am to 12.15 am the problems were severe. During the same period the feeder was switched but this is not logged in the Aspen Explorer system. The shift who was working during the period made a notation in their report and spoke verbally to Per-Åke Södergren, Supervisor kiln 7. A comparison between these two happenings confirms that they appeared at the same time.

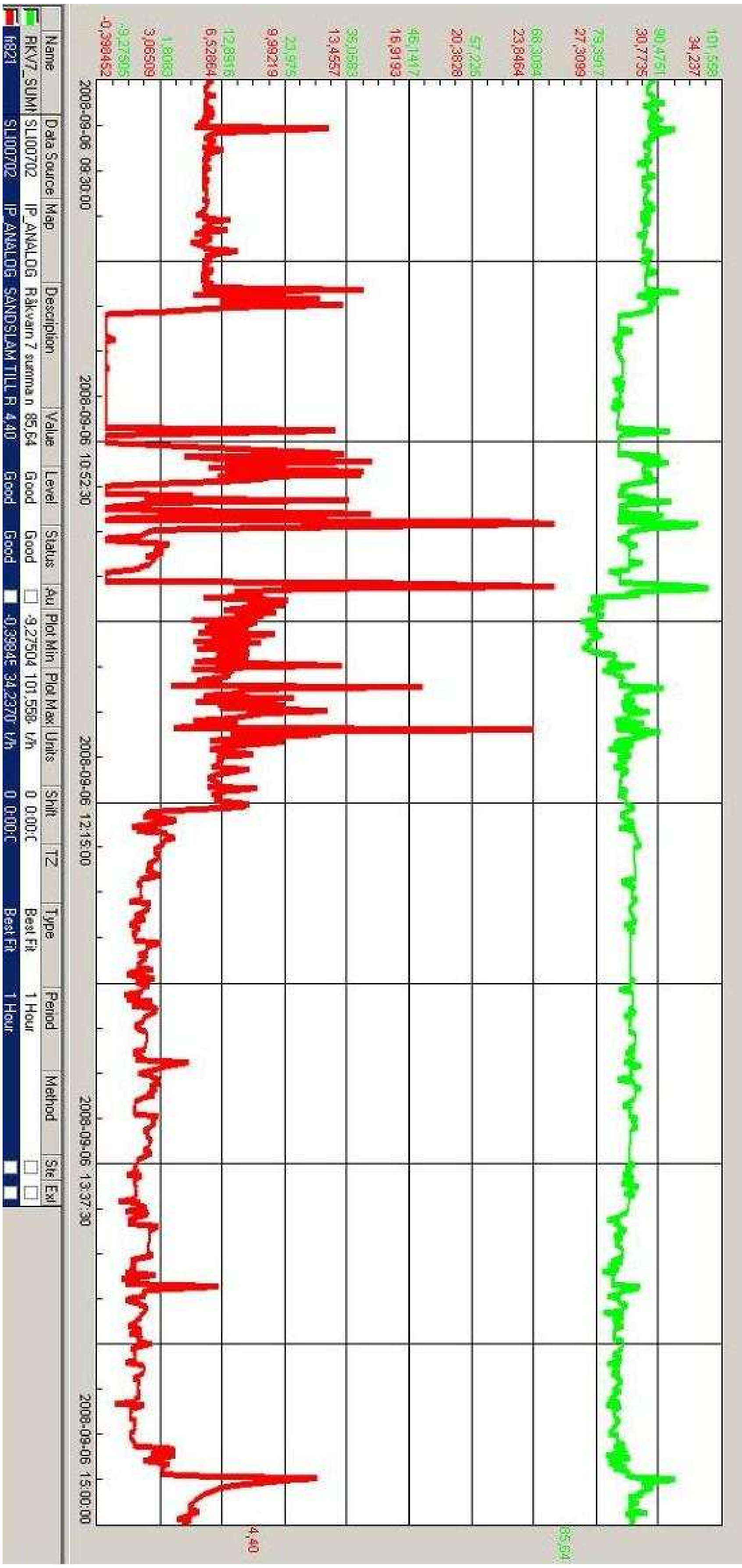

Figure 4.8.3-1 *Graph showing raw material feeding and sand slurry dosing concerning raw mill 7during the critical time interval. The red line fluctuation clearly shows the problem.*

4.8.4 Kiln Refractory

In the cement making process the temperatures are extremely high and a suitable protection for the vital parts of the producing system has to be used. With a temperature of approx. 1450°C in the burning zone the kilns outer boundary has to be protected. Bricks with high temperature resistance are being used and combined with other refractory components. The whole kiln system with preheater tower is protected but in the hottest zone close to the burner the conditions are extreme. The kiln tube itself is 60m long with a temperature distribution going from 1450°C in the burning zone down to around 950°C in the kiln inlet.

Regarding the bricks in the kiln the condition of the bricks were poor in five different regions. Counting from the outlet the affected areas is as follows: 0 – 1m, 3.5 – 7 m, 7 – 11 m, 19 – 22.5 m, 40 – 48 m (approx). This makes a total length of 20 m that has to be replaced. After inspections and several discussions with the man responsible for the refractory in Slite the following conclusions were drawn:

In the zone 0 – 1 m the bricks were replaced due to earlier damage and mechanical wear from the damaged kiln shell. This kiln shell damage is old.

In the burning zone the coating was gone between 3 – 7 m. Here the bricks were totally naked and the surface had molten and was glass-like which prevents it from forming the necessary coating.

In the zone between 7 – 11 m coating formation was really poor and after inspection it was decided to replace the bricks in this area

Further up in the burning zone between 19 – 22.5 m the coating was there but the thickness of the bricks was not enough for use until next spring.

In the section between 40 – 48m in the kiln the bricks had fallen out. It is difficult to predict exactly when this happened.

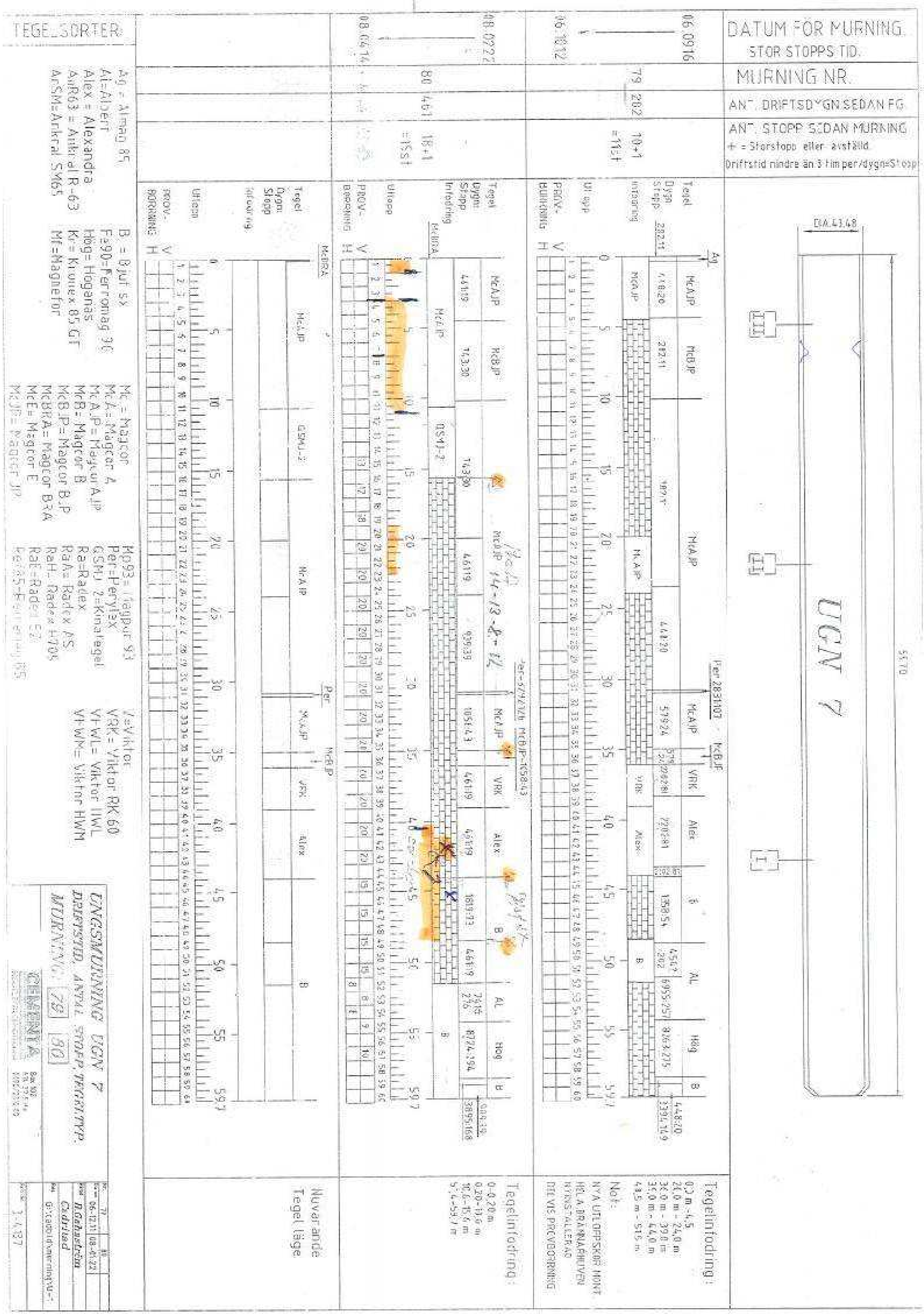

Figure 4.8.4-1 *Kiln 7 refractory, Cementa AB. Yellow areas are affected and about to be replaced.*

4.8.5 Continuous investigation

An estimation of the downtime is 8 days. “The red line” is the time needed to put the new bricks in place, in combination with welding of cracks in the kiln shell.

Routines
Did the alarm routines work?

- Did the operator notice the changing conditions? YES
- Alarm duty -> PÅS -> Per-Lennart Bohman were called out and arrived.

Action
The following actions have been decided upon to prevent a reoccurrence or that situations of a similar nature ever happen again:

In the future when alternative fuels will be used on kiln 7 and even more on kiln 8, the burner configuration with higher momentum will make the kiln system more vulnerable for changes in the LSF.

- An alarm system will be implemented that looks at the change in LSF and gives this alarm to the operator and if needed even to the kiln supervisor. This is to ensure that the appropriate measures are taken. This reinforced alarm system makes the operator aware of the upcoming serious situation if something like this happens again. Especially when the LSF leaves the normal level to first go up and after that straight down - the situation is severe. The opposite leads to a kiln impossible to run but will not cause any damage to the kiln refractory.
- Further analysis will be done later on. Samples will be prepared and sent to Olaf Kuehne, Team Leader Refractories, for investigation.
- We will not operate in automatic mode with our Polab-system when going into new piles for the future.
- Operators have reached a higher level of awareness concerning the LSF and its fluctuations. It’s not possible to burn their way through disruption of the sort that occurred at kiln 7.

Does the surveillance work? Yes, the shell temperature was measured and logged according to the schedule. Copies of the actual values of the measurements are being made. The shift employees measured the temperature at eight spots on the kiln 3times every 24 hours. The zone of the kiln nearest the outlet is the most interesting regarding the temperatures. It’s in this area the burning zone is located and the wear of the bricks is extensive. The measurements come every third meter from the outlet; 3, 6, 9, 12, 15, 18, 21, 24 (m). The measurement at 0m is not necessary because the burner is put into the kiln a bit and this zone acts as a cooling area more or less. The picture on the next page shows the expected flame envelope and it is clearly to be seen that the burner is put in around 2 m from the kiln outlet. This fact provides a temperature distribution in which the area closest to the outlet is slightly colder. Explained by this, the first part of the kiln is not necessary to monitor.

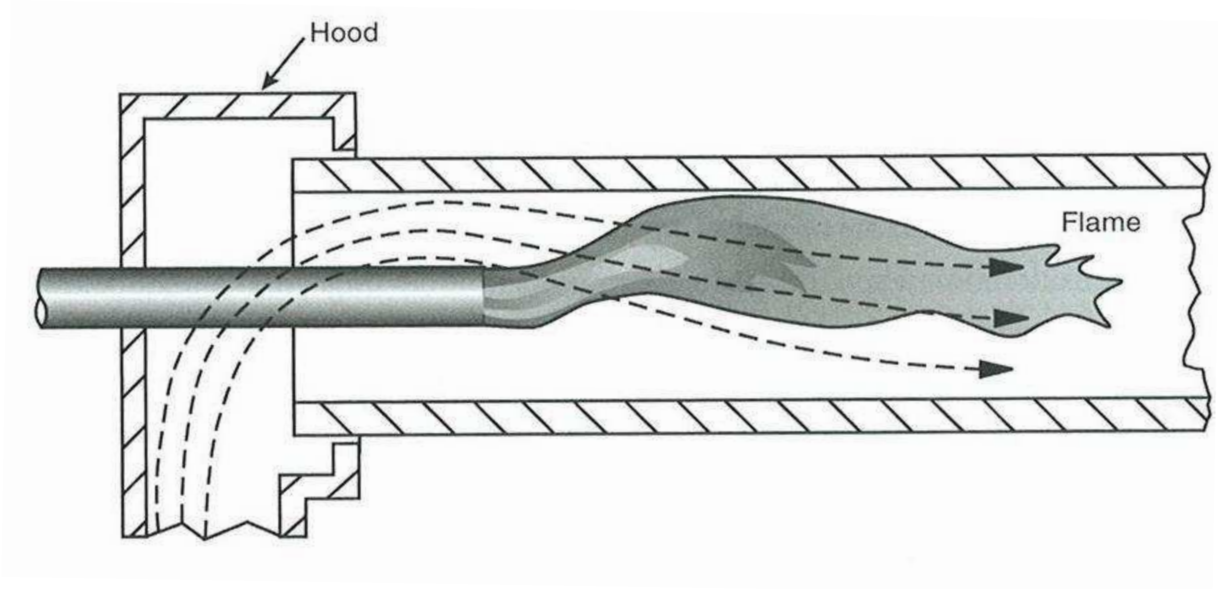

Figure 4.8.5-1 *Principle sketch showing the flame propagation in a rotary kiln (Bhatty et al, Innovations in Portland Cement Manufacturing, PCA 2004)*

The picture shows roughly how the flame expands in a rotating sintering kiln. The zone in the picture is measured with a manually held thermometer and at every point the measurement takes about 35seconds. In this way the whole circumference is covered. The rotational speed of the kiln is related to the kiln feeding and production. When the production is lower with a lower rotational speed the time of the measurement is adapted. The zone where the temperature rose the most was in the really intense zone of the flame. As mentioned before the whole occurrence was rapid and the values in the picture below were taken just 2 hours before the breakdown of the kiln. There were no signs of something strange going on and the employee just took the measurements and continued with other tasks.

Utlopp　　　　Inlopp

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Max	367	407	405	295	360	376	365	335							
Min	332	260	265	238	192	164	206	276							
Med															

Datum och klockslag: 20080906 KL 2,15　　Sign: PJ

Figure 4.8.5-2 *Copy of the temp measurements at 02.15 am.*

It was the column 2 and 3 in the diagram where the temperature rose to approx. 600°C. The kiln shell was then red all around and the process had to immediately be stopped. The burner was shut off and extra cooling air was put in to cool the kiln shell down to an appropriate temperature.

HTC (Heidelberg Technology Centre) has taken a major interest in the events that occurred. A report was written and sent down to the head office. Several experts within the area read the report about the breakdown and came back with additional input. To be aware of the risks/consequences this type of activity can cause, is essential. In this case the regulation system showed some clear problems dealing with this type of fluctuation. The action proposed for in this report has to be implemented within the nearest future. This will be carried out by me in cooperation with the programmers at the plant.

The whole production system was thoroughly investigated and gone through and every thinkable type of unexpected happening was planned for during this project. A fluctuation which takes place maybe one time in ten years is very hard to predict and be prepared for. Most important is to learn for the future and to use this awareness to prevent things like this to happen again. High momentum burners will be present in every plant all over the world within Heidelberg Cement Group in the near future.

5 Final discussion and result

Optimization of a burner in a modern cement kiln is a quite complex and demanding task. Crucial is to have an overview and to evaluate every possible factor within the process which might affect the trial. In this project the results were from the beginning really promising although some minor disturbances occurred along the path of optimization. At the state of the trial when feeding of the kiln and other process parameters were coming close to full production a major failure took place. As often is the case the failure depended on a couple of factors combined in the wrong way. This breakdown has been run through earlier so it will not be repeated here but it´s important to draw the right conclusion due to what has happened. Although thinking that every possible happening during the trial was thoroughly gone through, the big fluctuation in the LSF was a surprise. Something like this fluctuation has not been seen at least within the last ten years. What happened was a major tragedy both for the trial and for the company itself with high costs incurred as a product of the failure. If the plant had been running in the “traditional way” without the burner optimization the effect of the LSF fluctuation would probably have been smaller but still severe. An optimization of this type always means smaller margins and it puts bigger demands on the surrounding regulating systems and equipment. One thing considered was the question regarding a scanner to the kiln. A scanner gives continuously a good picture of the temperature distribution at the kiln shell. When things are moving in the wrong direction the operator can take measures early with the help of the scanner. Continuous information regarding the shell temperature should in this case have led to an earlier shutdown of the kiln and thereby cause only minor damages to the kiln. The temperature measurements taken just a couple of hours before the breakdown are a proof of this quick and dangerous temperature development. A serious attempt was made to motivate the senior management about the necessity of such an investment but they refused to install it on the “small” kiln 7. This is highly understandable because the money to spend is limited and many other process related investments are given a higher priority.

Further on the study shows the potential in optimizing an old burner. Within the refractory industry really big steps forward have been taken the last ten years which gives new opportunities. To run with higher flame temperatures and higher turbulence is nowadays normally not a problem. The bricks can in a much better way resist the excessive wear this type of flame from time to time gives. The development within the fuel market sets new standards for the bricks and this gives the industry a new degree of freedom. Without this development, an optimization of this type should have been quite difficult. More focus on a higher output is important on a strong market where every ton of cement is being easily sold. But most important of all is the possibility to burn alternative bio fuels with the help of this modification. Fossil fuels are fast moving out of the market in more than one way. At first the natural resources are limited and will in the near future come to an end. Point number two is the gradually higher taxes put on the fossil fuel emissions which make it impossible to continue running like this in the future. The taxes will take almost the whole profit from the cement sold and this is therefore not an option.

The result of this study will be useful for further development of the burner equipment used within Cementa AB and Heidelberg Cement. Even though solutions often are bought from specialized companies the in–house knowledge is extremely valuable. After gaining experience during this Final Thesis, the author immediately got the responsibility of writing a RFQ (Request for quotation) for a burner purchase (Appendix 7)]. The purchase was of a new professionally made burner for the kiln 7 and the results proven within this study were one of the cornerstones that made it possible to get the money for the investment. The payback time is roughly around a year for such an investment depending on current market conditions.

The gained experience in this Final Thesis is hopefully much more valuable than the cost of replacing the bricks after the breakdown.

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7. Appendix

Appendix 1

Operating Capture of modified burner kiln 7

A second attempt is to be made with the upgraded burner in kiln 7. The goal is to increase production and obtain a more stable operation. The tower will also certainly be better. A series of adjustments have been made with the hope that it will function well. As soon as a "natural" stop of the kiln occurs the burner will be mounted.

Settings of airflows
Warm up the cold kiln**:**
Made as usual.

Warm up the hot kiln:
The usual approach and select start jet-air block 2, check the heating (see picture).

Operation:
Radial air: 2000 m^3/ h
Axial air (coal transport): 1200 m3 / h (1800 to come from Pfister feeder).
"Jet Air" (New blower): 270 mbar (check out the heating in Block 2, see picture). This pressure is equivalent to a force usage of around 70% of the maximum but will be adjusted when the stable operation achieved.

Reliability / management

Here the operator access to a new process image. Info on this picture:

• Amps on the blower jet air

• The pressure in jet air channel

• Temperature at the burner outer bounding

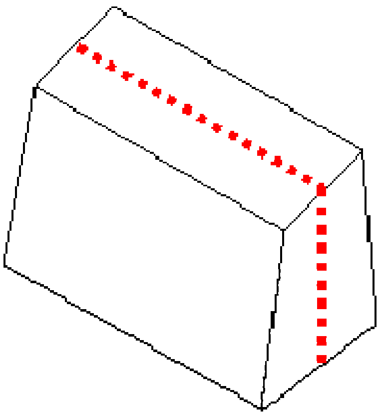
When blower stop occurs during the operation, the operator receives an alarm. If blowing machine is standing still when the system is hot, it is very important that the cooling air is turned on!
Close the valve (between the blower and burner), and open the pressurised air valve. Set 0.1 bar, it is for cooling purposes only.

• Kiln shell temperature is measured during the start-up period of the burner 2 times/shift. Await new directives from us before the measurements ends.
Regards
Fred and Per-Åke
15.08.08

Appendix 2

Hello Fred,

Please take some brick samples from the affected kiln section.
You should take bricks with better residual thickness. The small spits do not give much insight
Please cut the samples into half as shown in sketch hereafter and take some close shots from the cut cross section.



Wet cutting will be no problem for the sample.

Any suspicious idea so far what could have worn the bricks?

It looks very much like molten bricks which might be caused by extreme high temperature along with liquid phase reaction from clinker.
It's probably kind of eutectic reaction which normally shows up only in sections with bauxite bricks.

Best regards

Olaf

Appendix 3

I have talked to Per-Lennart Bohman about taking out brick samples. He told me it could be done next week and that the prepared samples preferably should be sent to you. Is that ok? Or are you in a hurry?

Regarding the worn bricks it was caused by a unique condition of the kiln system. The LSF went from the normal value of 100 up to 119 and then down to 88 within less than five hours. Such a big and quick change of the LSF in kiln feeding hasn't occurred in several years.

This scenario in combination with the modified high momentum burner which is currently in use most likely caused the breakdown. This led to extremely high temperature along with liquid phase reaction from clinker. I have written a short preliminary report of the scenario and the report is attached to this letter.

Regards

Fred G

Appendix 4

Hey Fred

I do not manage to reach you on the phone, so I'll send the results here by mail instead.

The file of 29.08.08 is the current measurement. I thought it looked like it was the same measuring point Patrick measured on Monday, so I sent the test report also (25.08.08). A major difference between the two measurements was the temperature of the gas flow; he measured more than 60 degrees when I got just under 40. The pressure was about the same, but it was a clear difference in the flow and channel speed.

Hope this helps you.

Regards

/ Roger

Appendix 5

DELRESULTAT

CEMENTA
HEIDELBERGCEMENT Group
Cementa Research AB

Sid: 1 (1)
Provnr: **148054**

CEMENTA RESEARCH AB
Cirkulation

624 22 SLITE

2008-08-29

Provnr	**148054**		
Märkning	**Luft brännarlans U7**		
Uppdrag / grupp	**Processmätningar för Slitefabriken 2007-2008, U7 Ansvarsområde 200340901**		
Variant	**Flödesmätning**	Ankomstdatum	**2008-08-29**
Handläggare	**Roger Lehrberg**	Klardatum	
Provtagningsdatum	**2008-08-25**		
Provtagning	**Insänt av kund**		
Provtagare		Namn (Roger Lehrberg)	

* ackrediterad analys

Analys	Metod	Resultat	Mätosäk. (%=rel, K=2)	Kommentar
Flödesmätning				
CO2	SS 02 84 25	**0,03** %		
N2		**78,14** %		
O2	SS 02 84 25	**20,90** %		
Kanaldiameter	SS-ISO 10780	**0,30** m		
Kanaltemperatur	SS-ISO 10780	**62,2** °C		
Kanalhastighet	SS-ISO 10780	**12,9** m/s		
Gasflöde 1	SS-ISO 10780	**2797** m3 ntg/h		
Gasflöde 2	SS-ISO 10780	**2842** m3 nvg/h	10 %	
Gasflöde 3	SS-ISO 10780	**3281** m3 dr./h	10 %	

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Appendix 6

DELRESULTAT

CEMENTA
HEIDELBERGCEMENTGroup
Cementa Research AB

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Provnr: **148054**

CEMENTA RESEARCH AB
Cirkulation

624 22 SLITE

2008-08-29

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Provtagning	**Insänt av kund**		
Provtagare		Namn (Roger Lehrberg)	

* ackrediterad analys

Analys	Metod	Resultat	Mätosäk. (%=rel, K=2)	Kommentar
Flödesmätning				
CO2	SS 02 84 25	**0,03** %		antagen
N2		**78,14** %		antagen
O2	SS 02 84 25	**20,90** %		antagen
Kanaldiameter	SS-ISO 10780	**0,30** m		
Kanaltemperatur	SS-ISO 10780	**39,2** °C		
Kanalhastighet	SS-ISO 10780	**7,4** m/s		
Gasflöde 1	SS-ISO 10780	**1747** m3 ntg/h		
Gasflöde 2	SS-ISO 10780	**1747** m3 nvg/h	10 %	
Gasflöde 3	SS-ISO 10780	**1874** m3 dr./h	10 %	

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Appendix 7
New burner kiln #7

Underlag: Finns på G:\Projekt\Pågående\Brännare Ugn 7
Där placeras all relevant dokumentation efterhand.

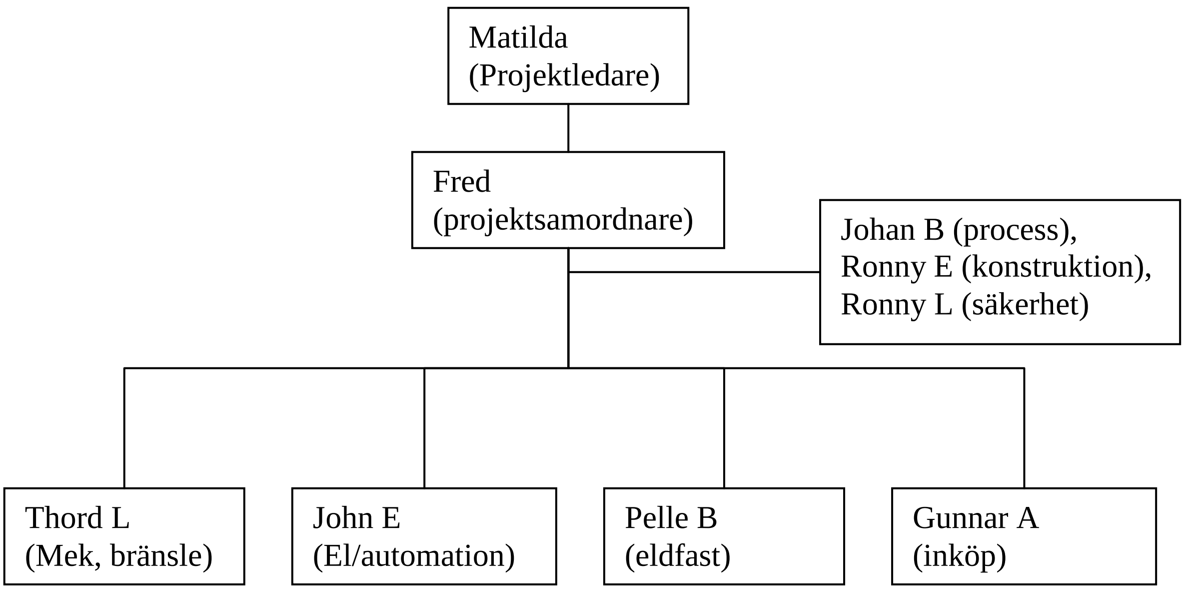
Uppgift: *Inköpsunderlag*
Att ta fram inköpsunderlag till en ny brännarlans till ugn 7, anpassad för den bränslemix vi planerar att använda framöver. I underlaget skall ingå all nödvändig teknisk information om processen, ugnen, bränslet, bränsletransporter, bränsledosering och tillgänglig plats, samt ”Battery limits”.
I underlaget skall också tas med kringutrustning som man vill skall ingå i offerten, eller på en separat förfrågan, ex. blåsmaskin, motor mm. Ingår gör också sammanställning av relevanta ritningar.

Materialet sammanfattas i en offertförfrågan (RFQ).

Tid
RFQ skall vara klar att skickas iväg till 081031

Projektbudget
Uppdatera projektbudgeten som finns påbörjad i projektmappen.

Projektgrupp:



/Matilda2008-09-30

Appendix 8

Ugn 7 inför helgen 2008-09-05 => 2008-09-08

En ”ny version” av den modifierade brännarlansen har monterats som alla vet och diverse test och utvärdering av denna pågår. Fred styr detta med järnhand, så om ni känner er frestade att testa att skruva lite på luftmängderna på egen hand så låt helst bli det, om nu inte saker och ting är på väg att gå helt galet. Vi behöver några perioder med olika definierade inställningar för att kunna få grunddata för en optimering och utvärdering av brännaren. Ha tålamod alltså.
Driftsvärden på lansen (uppdaterad 080905):
Radial luft: **2000 m^3/h**
Axial luft (kol transport): **1200 m^3/h** (1800 tillkommer ifrån pfister mataren).
”Jet luft” (Ny blåsmaskin): **0,32 bar.** Detta tryck motsvarar en utstyrning på ca 87 % men skall justeras in när stabil drift uppnåtts.

En skrotmagnet har monterats före råkvarn 7, så kolla gärna den minst en gång per skift i alla fall så inget märkligt har fastnat på den. Den är inställd på en (vad vi tror) lämplig höjd över bandet, men där pågår test. Det har redan fastnat lite småprylar på den, så den fungerar i alla fall, så mycket vet vi.

NOx-mätaren (den provisoriska) har reparerats och fungerar nu igen. Den ordinarie mätaren är ännu borta på service i tyskland.

Vi hade idag (fredag) ett litet problem när råkvarnen stoppades. När kyltornet ökade vattenmängderna så hann inte vattenpumpen under råmjölssilos med. Detta resulterade i min-larm i behållaren till kyltornet. Systemet verkade ha kapacitet för cirka 19 m3/h, sen orkade det inte längre.
Om detta händer igen så öka börvärdet på temperaturen efter kyltornet så att vatteninsprutningen styr ner något och styr sedan temperaturen in i filtret med friskluftspjället. Det är lite extra ”passning”, men tills vi har löst problemet med pumpen i mjölsilos så är det ett sätt att klara livhanken.
Fredagens värden blev ungefär så här. 230 grader som börvärde efter kyltornet och 60% öppet på friskluftspjället gav 140 grader in i filtret.

Ugnsmatning i helgen:
Försök peta på ett par extra ton på ugnen under helgen. Sikta på att nå 95 t/h och om möjligt kanske något ton till.
Råkvarnen ger vi lite lägre prio under helgen, men mjölet ska räcka till i alla fall.
Vi ska försöka få igång mjölöverföringen från RKV 8 i nästa vecka. Jag kommer att önska mig någon frivillig som kommer ut och hjälper till med detta. Gärna någon av dom som varit med om detta tidigare.

Trevlig helg.
20080905 /Per-Åke o Fred

Appendix 9

Project information

Project name: Burner modification U7	**Project number**	**SAP account**	**Proposed by** Fred Grönwall,

Project background

Modification of the burner U7 to increase the capacity of the kiln and to be able to burn alternative fuels

Project group objectives

1. Build a new Jet air channel
2. Install a redundant blower to provide air.
3. Have a solution to allow both axial and radial expansion of the burner head due to temperature differences.
4. Evaluation of the effect of the adjustments made.
5. Provide the operators with enough information for them to run the new burner safely
6. If time make a clear picture of the possibilities to burn alternative fuels; plastic pellets

Project overall objectives

Proposed action

1. Installing a Jet air nozzle ring in a way so it can move both axially and radially due to temperature changes.
2. Remove the present refractory from the burner and order a new form to decrease the weight of the burner
3. Place a K6 blower in operating the axial channel.
4. Install equipment for measurements (Temp, pressure, ampere blower etc)
5. Carefully watch process values during the modified burners run in time.

Project organisation

Project manager
Fred Grönwall

Project group
Roland Bengtsson *electrical technician*
Bo Persson *mechanic*
Joel Ganderborg *electrician*

Steering group

Johan Larsson
Thord Larsson
Per-Åke Södergren

Assumptions Other actions in the kiln/preheater must coordinate with the actions on the burner	**Battery limits of project and scope**
Not within scope Make a clear picture of the possibilities to burn alternative fuels; plastic pellets	
Resource Neil Taylor, Intec Services	**Time** **Costs** ??
Time schedule 20080630 - 20081030	
People to be informed	
Risks	
Documentation	

Appendices

This is Heidelberg Cements project plan which is always used when implementing details of a new project.

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