In the Rohoznik plant a "bypass dust washing installation" has been installed to enable full incorporation of the bypass in cements and production of chloride salts that can be commercialized. This ReduDust process transforms the problem of a "bypass dust excess" into an opportunity for supplementary sales.

TEXT **Dr. rer. nat. Ernst-Michael-Sipple[1], Johannes Müllner[2]**

ReduDust building

A green building in a grey cement plant – Transforming bypass dust into industrial salt with the ReduDust Process

1 Introduction

To reduce its consumption of traditional fuels, like coal, oil or gas, the cement industry is increasingly using solid recovered fuel (SRF). SRF, produced in specialized installations from ordinary industrial or household waste, increases the chlorine input into cement plants. Cement plants typically react to this with a series of measures: extraction of kiln dust, fighting preheater build-ups, and finally installation of a chlorine bypass. Parallel to this, bypass dust can be expediently used in cements and other hydraulic binders. EN 197 sets an ultimate limit of 0.1 % Cl for the chlorine that can be incorporated in cements. This limits the total "chlorine input into the cement plant" to 1000 $g_{chlorine}/t_{cement}$, because ideally all chlorine "entering the cement plant" inside raw materials or fuels has to "leave the plant" inside products.

The cement plant has two possibilities to react in this situation:

1. Limit the chlorine content in incoming raw materials and alternative fuels (input control). The majority of plants has established maximum chlorine concentrations for incoming materials.
2. To increase the output stream of materials with elevated chlorine content (output control). These are primarily hydraulic binders, but the market demand for such products has proven limited in practice.

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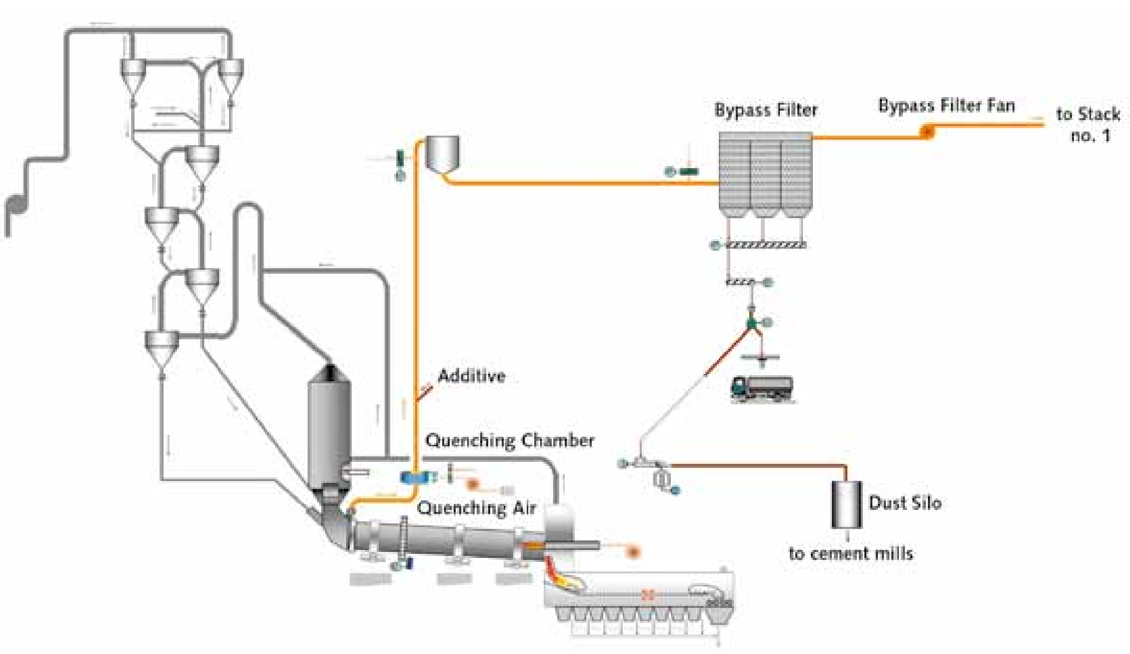


1 Flowsheet of an A TEC bypass system

2 Chlorine input, volatilization and impact on kiln operation

It has been observed in the past that high concentrations of chlorine in concrete may encourage the corrosion of the steel reinforcement inside the concrete element. This might lead to serious structural damage of concrete structures. Based on this (bad) experience, the chlorine content in concrete was limited. To comply with this limit in concrete, chlorine limits for concrete constituents have been introduced. The chlorine content of cement is limited to 0.1 %. In the production of cement, chlorine can come from raw materials or from fuels: If the plant is situated close to the sea, the limestone or marl is "impregnated with salt water". Solid alternative fuels (called SRF or RDF) can increase the chlorine input into the kiln. This chlorine is contained, for example, in ordinary PVC (polyvinylchloride).

In the kiln system, organic compounds are completely destroyed and the chlorine combines with sodium or potassium, both constitutive elements of clay minerals, contained in the fine ground raw material mix fed to the kiln (also called kiln feed), and forms ordinary salts (like sodium or potassium chloride).

These salts are volatile at the hot temperatures inside a rotary clinker kiln and condense in the "relatively cold" preheater tower, thus gluing kiln feed particles together and creating incrustations (This is often called an "internal recirculation of volatiles"). Such incrustations hinder air and material flows and might lead to "pre-heater blockage" and kiln stoppage.

3 Purpose of a chlorine bypass system

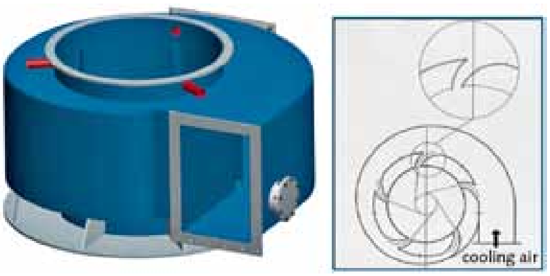
A "chlorine-bypass" is a technical system to reduce incrustations by removing chlorides from the kiln system. This "chlorine-bypass" is located in a position where a maximum concentration of chlorides is absorbed on the fine kiln feed particles. This material taken out from the kiln is called "bypass dust". As bypass dust might contain up to 15 % chlorine, only a relatively small amount needs to be taken out from the kiln system in order to reduce "chlorine recirculation" significantly and to stabilize kiln operation.

4 A TEC bypass system

A TEC has supplied its bypass plants for more than 40 projects in the last 20 years, for the most common kiln systems. The flowsheet of this compact and easy-to-operate system is shown in Figure 1. The design of the quenching chamber is shown in Figure 2.

This A TEC system has all the features required from a state-of-the-art bypass system:

» It enables the extraction of bypass dust with a very high chlorine concentration in the dust by means of two measures: position (close to the kiln inlet and on the side with the lowest amount of flowing kiln feed particles) and large dimension of the take-off chamber which allows a low take-off velocity. A cyclone can be added to redirect around half of the dust back



2 Quenching chamber of an A TEC bypass system

to the kiln. With these measures, only the finest particles with a maximum chlorine concentration are extracted.
- A specially designed quenching chamber ensures very intensive mixing of fresh cold air and hot bypass gas to immediately lower the gas temperature below the condensation temperature of the chlorides. The more efficient this gas cooling is, the less excess cooling air is required to protect the bag filter from overheating. In other words, the more efficient the mixing is, the smaller quenching chamber, ducts and filter can be built (less Capex). This quenching chamber is made of highly resistant alloyed steel without an internal refractory lining, so no lining maintenance is required. The cooling air is supplied and regulated with a speed-controlled fan.
- Compared to kiln stack exhaust gas, the bypass gas contains typically higher concentrations of SO_3 and HCl. For this reason, an additive to reduce SO_3 and HCl emissions can be injected before the bypass filter.
- The chlorides condensed on the dust are separated from the gas stream in a bag-house filter at a temperature of approximately 200 °C.

5 Using bypass dust in products

Bypass dust is composed of raw meal that is already partly de-carbonated, which means it is already partly transformed into clinker, and the volatile chlorides that are absorbed on these raw meal particles. It already exhibits hydraulic activity and can be used as a compound in cement. In most European countries, bypass dust is a commercially available product, certified according to REACH, and used in a wide variety of building materials.

6 Chlorine and bypass dust excess

By increasing the usage of alternative fuels like SRF or RDF, we save fossil fuel, which is a clear ecological benefit of alternative fuels. At high thermal substitution rates (TSR), we may introduce more chlorine into the kiln system than we can incorporate in the cement while complying with the respective cement standard (0.1 % of chlorine in all cement types in accordance with EN 197) or in other hydraulic binder. This results in a “chlorine excess” or a “bypass dust excess” in this cement plant.

This was the situation the Holcim Rohoznik plant faced some years ago. Bypass dust had accumulated inside the plant. As we did not want to landfill this excess bypass dust (which in ecological terms would have been the creation of a new waste stream, which is not optimal, and which also would have resulted additional costs, i.e. for disposal), we decided to work on an ecologically friendly solution that also would lead to an economical benefit, the ReduDust process.

7 Lessons learned from existing bypass or kiln dust treatment processes

The reduction of the bypass or kiln dust chlorine content is well documented in scientific papers and patents. But surprisingly few companies have developed detailed process concepts or even invested in treatment facilities on industrial scale to manage this bypass-dust problem. To put it simply, there are two ways to separate the chlorides from the kiln dust:
- Some patents is describe how to sublimate the chlorine from the bypass-dust in a separate kiln. To our knowledge, nobody is applying this technically challenging possibility on industrial scale.
- The second possibility consists of leaching out the chlorine with water from kiln dust. This is by far easier to realize and Holcim has been operating two installations of this type for a long time in Lägerdorf and Carboneras. Moreover, Holcim has wide operational experience with solid-liquid separation processes using filter presses from its semi-wet cement plants.

Both Holcim installations have a sound technical solution for the chlorine-leaching process step. In contrast, these plants are situated on the coast and can dispose of the salt water, after chemical cleaning, into the sea. This is not a suitable solution for inland cement plants and we had to develop these process concepts further in order to process the salt water.

8 The basic idea behind the ReduDust process – the process concept

The ReduDust process was developed jointly by A TEC and Holcim Rohoznik. A TEC and Holcim Emerging Europe had been business partners in this field for many years, because A TEC supplied all five bypass systems installed in Holcim Emerging Europe cement plants (in Prachovice, Rohoznik, Alesd, Beli Izvor and Campulung).

The basic idea of ReduDust is very simple. Bypass dust is composed of two “components”: partly decarbonized kiln feed which is, exactly like cement clinker, not very soluble in water, and sodium or potassium salts, which are, like table salt, very easily soluble in water. The ReduDust process uses this difference in solubility. ReduDust is composed of four basic process steps (Figure 3).
- Mixing of bypass dust with water to dissolve the alkali-chlorides of the bypass dust in water.
- This slurry is mechanically separated, filtered to separate the liquid, i.e. the salt solution, from the solid phase, i.e. the washed bypass dust (filter cake). This filter cake, which has a low chlorine concentration, can be used in cement grinding.
- The chemical treatment of the liquid phase to precipitate calcium and heavy metals.

» Fractionated crystallization aimed at separating salt in different fraction qualities. After complete evaporation of the water, a solid clean salt remains, which can be used as fertilizer or as a basic chemical in various industrial processes.

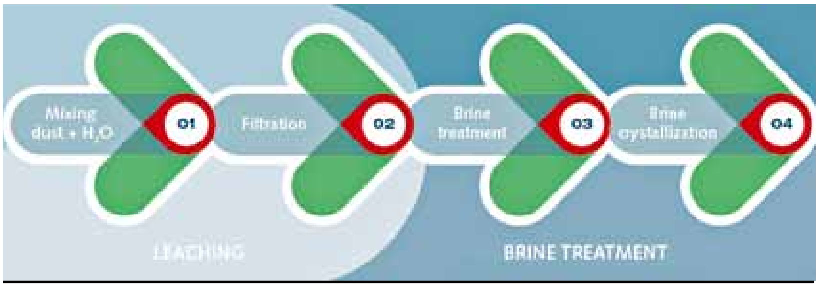
Because of the specific conditions inside a cement clinker kiln, we obtain mainly potassium chloride and only a minor fraction of sodium chloride. This is economically favourable because there are more sources of sodium chloride than potassium chloride and consequently potassium chloride has a higher market value than sodium chloride. The "ReduDust salts" have been registered in REACH and are already commercialized by Holcim Slovensko. Customers include a fertilizer producer.

The benefits include: no more need to dump bypass dust, the waste problem is eliminated and a cost (disposal fee) is transformed into a benefit (the income from salt sold).

9 Comparison of the ReduDust process concept with other bypass dust treatment processes

Compared to other projects realized on industrial scale, described in patents or in the scientific literature, several technical improvements have been realized in the ReduDust process:

» Former processes generally include a leaching step at a water-to-bypass-dust ratio of 3 to 5 parts of water per part of bypass dust. In the ReduDust, high-intensity mixing of the bypass dust in water is used and ReduDust needs 50 % less water than all other projects we found.
» In ReduDust, earth-alkali ions are eliminated with CO_2 or soda at alkaline pH very early in the process to avoid clogging further downstream. Such preventive cleaning steps are not included in other projects.
» Most projects only cover the leaching step and only few projects offer a complete solution from the bypass dust to the purified salt, comparable to ReduDust.
» The whole ReduDust process was designed as a "no waste" and "environmental friendly" system. Waste water is completely recycled and finally evaporated to avoid any water discharge and the "washed bypass dust" is completely reused in the cement process.
» The chemical process to "clean the salt water" uses only "basic chemicals", like soda or hydrochloric acid that are industrially produced all over the word. ReduDust does not need any specially designed "special chemicals". The chemicals are transformed into compounds that are already present in the product and the reactions do not produce a special "waste fraction".
» The heat required for the evaporation of water is produced in a waste heat recovery system that uses kiln exhaust gas.



3 Basic process steps of the ReduDust process

10 Process development and scaling-up

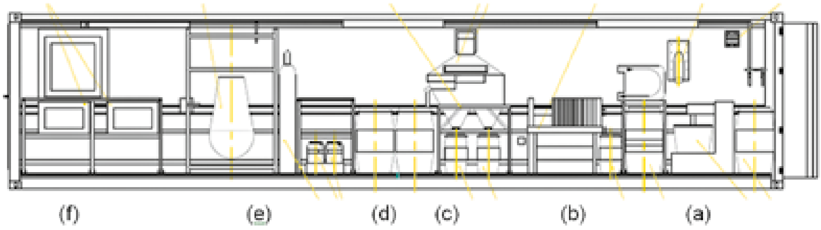
Our intention was not to invent something completely new, but to combine basic chemical reactions and proven process technologies to a new process chain covering the four basic process steps shown in Figure 3. Nevertheless, we had to select the appropriate technology carefully from the wide range of available solid-liquid mixing and separation processes, aqueous phase cleaning and crystallization technologies. We performed trials successively on three different scales before realizing an industrial-scale installation. In each phase of this process development, the process concept was improved and simplified. Over two years, we acquired sound process knowledge and finally came up with a detailed industrial-scale process concept. We think that the way in which we scaled up the process is quite interesting and shall present it in more in detail. Such a systematic scaling-up procedure is normal in organic chemistry, but relatively unusual in the mineral processing industry, where often we see ad-hoc choices instead of a systematic exploration and elimination of process alternatives.

10.1 Starting with small trials in the laboratory of Holcim Rohoznik cement plant

The first laboratory trials in the Rohoznik plant laboratory started in January 2010. Classical laboratory equipment was used to mix 200 g bypass dust with water with a magnetic stirrer. We filtered the suspension with laboratory filter paper, dried the filter cake and evaporated the salt water in our ordinary laboratory oven.

These trials were required to verify that the "basic chemistry works". Using up to seven different chemicals, we precipitated calcium carbonate and heavy metal sulphides stepwise at pH = 12. This pH corresponds to the saturated calcium hydroxide solution and is buffered by a calcium hydroxide excess from dissolving bypass dust compounds, especially free lime. The overstoichiometric sodium-sulphide was destroyed with hydrogen peroxide and the solution neutralized with hydrochloric acid and evaporated to dryness.

Already on this small laboratory scale, we were able to produce a very pure salt, mainly composed of potassium, sodium, chloride and some sulphate. In contrast, the amount of material treated in one trial was too small to see bulk properties and espe-



4 The process container of the 100 kg/day ReduDust pilot installation

cially sedimentation and agglomeration phenomena and we decided to test the physicochemical behaviour of a larger batch size.

10.2 First upscale to 5 kg/batch bypass dust trials in the Holcim Rohoznik cement plant

After the first encouraging results, we performed mixes with 10 kg of bypass dust per batch. Of course, this could not be handled with normal laboratory equipment. We mixed bypass dust with water in 50-l metal drums using a mortar mixer mounted on a regular drill. Ordinary household cleaning tissues were used to filtrate the bypass dust suspension into 20-l canisters. To precipitate the dissolved calcium hydroxide as carbonate, we purchased technical grade soda from the supermarket and in other trials, we sucked kiln exhaust gas through 200-l barrels filled with brine for several hours. In this way, we verified the possibility to remove hydrated lime from the brine with kiln gas instead of using chemicals. With this improvised procedure, we treated around 100 kg of bypass dust in three months!

The heavy metal was precipitated in 20-l household plastic buckets. This allowed us to study the sedimentation and agglomeration behaviour of the heavy metals suspension and to decide on the most appropriate and simple process technology to separate the heavy metals sludge from the brine.

We discovered that heavy metal sludge is unsuitable for filtration and found out that a sedimentation process is more appropriate to eliminate solid impurities from the chemically treated salt water.

These studies also showed that the chemical process can be drastically simplified: all in all, we need only four common chemicals of technical grade quality, available everywhere in the world. In comparison, we used up to seven different chemicals with p.a. quality in the laboratory-scale trials.

To crystallize the salt, we evaporated the water in ordinary kitchen cooking glass vessels. We were able to obtain a very pure potassium salt by means of fractionated crystallization, which we performed in a pilot-scale installation of a salt processing company.

10.3 Up-scaling to a 100 kg/day bypass dust treatment pilot installation, located in Holcim Rohoznik

Encouraged by these results, in September 2010 we decided to build a pilot plant capable of processing around 100 kg bypass dust per day. On this semi-industrial scale, we had already changed from a pure batch process to a semi-continuous running installation. The intention behind this was twofold:

» We needed to verify that the process variants we had identified as promising in our previous trials could also be realized on industrial scale and that the succession of the four elementary process steps, each composed of well-known standard physical-chemical processes, would fit together well into an overall process, resulting in one functional unit.
» This miniaturized model of the industrial-scale dust processing line helped us to explain this process to various stakeholders, which is quite unusual for the cement industry. In particular, we were able to convince the Holcim senior management that our concept of how the full-scale industrial installation would operate is well founded and supported our Capex request for the realization of the full-scale installation.

It took us the last four months of 2010 to realize this pilot installation. For our team, it was a very intensive and motivating period of designing, purchasing and installing, with a lot of improvisation, in order to correct small design features during the realization phase. The pilot installation was composed of several elements:

» A dry mortar silo to store the bypass dust and to feed to the process container
» All equipment had been installed in a 12-m "process container"
» An office container
» One container serving as warehouse and used for storage of samples or various materials

The heart of the installation was the "process container", shown in Figure 4.

The equipment in the container was arranged in the same order as it would have to be in the full-scale installation. Moreover, apart from their size, the machines we used were the same as foreseen for the full-scale installation (**Figure 5**).

a) The mixing of bypass dust and water was done in a 60-l concrete mixer

b) A peristaltic pump, often employed in slurry transport, was used to generate the pressure used for filtration in a filter press

c) The chemically treated salt solution was separated from precipitated heavy metal salts or limestone in a plastic lamella clarifier, similar to a waste water treatment sedimenter

d) We used 200-l plastic barrels to store the different salt water fractions. The final installation will also be equipped with several vertical brine and slurry plastic tanks.

e) The salt was crystallized at under-pressure to reduce the boiling point temperature. This is the same principle as that used in the full-scale crystallizer and saves thermal energy.

f) We purchased two large ovens to dry the various salt fractions.

During the four months this pilot installation was operated, we processed 2.6 t bypass dust, produced the equivalent of 300 kg of salt, and performed more than 500 chemical analyses in our cement plant laboratory, besides our normal cement plant quality control tasks. This analysis always had to be treated with high priority, as the results obtained were already required the next day so that we could adjust our trial plan and working schedule.

After all these trials, we were able to present a perfectly defined project for an industrial-scale installation, where all process steps had been proven and equipment and system performance were clear.

Parallel to the ReduDust process development, Holcim and A TEC submitted a patent on this new method of processing and utilizing bypass dust. An international patent was granted on 26 October 2012 and published in WIPO-PCT. The primary motivation to submit a patent was to protect some

5 Mixer (a), filter press (b) and sedimenter (c), crystallizer (d) and drying ovens (e) installed in the process container

technical innovations that we had included in different parts of the bypass treatment process, especially the simple and safe chemical treatment of a bypass dust slurry and its filtrate.

11 First industrial-scale ReduDust installation in Rohoznik

11.1 Project engineering

As should have become clear, ReduDust is like LEGO in that we have created something new by assembling well-known elementary bricks. Each chemical reaction or physical process we use is as such a standard process and we selected highly experienced suppliers for each of this "basic steps". We purchased from them standard equipment that they had already delivered and installed several times. The challenge was to assemble all this readily available standard equipment into a production plant.

It was the first time that the ReduDust process had been built on industrial scale and the tendering, supplier selection and contracting phase became an intensive "learning on the job" exercise in engineering chemical treatment, leaching or crystallization plants for A TEC and Holcim.

All through this engineering and construction phase, we worked together to solve uncountable issues with constructive details, interfaces between process steps, equipment controls, etc., etc.

11.2 Building permit and civil works

We received the building permit in March 2013 and the civil works were commenced then. Some months later, the structure was covered by a facade, coloured in two shades of green and white (Figure 6).

The colours emphasize the project's contribution towards sustainable development. This coloured building contrasts with the massive grey buildings and large installations of a cement plant, signifying that we are leaving the area of ordinary cement production and entering an area dedicated to chemical process technology.

11.3 Construction materials used for building and equipment

Only in the very first treatment step of the ReduDust process do we handle solid powders, in the rest of the installation we have to deal with salt water. This gives rise to two challenging tasks:

» We process huge amounts of water in this installation with the risk of it flooding the whole building or leaking into the surroundings.
» Salt water and vapour are very aggressive towards steel and concrete structures and elements. We had either to protect all elements built from these two materials or to replace them with elements made of plastic, wood or other corrosion-resistant materials.

6 ReduDust building

7 Network of tanks and pipelines inside the ReduDust building

We found technical solutions to avoid or reduce both risks. A quite sophisticated internal drainage system with retention tanks, to hold back water in case of leakages, was installed. This system is dimensioned to protect our equipment and to prevent any flooding out into the surroundings, to avoid any environmental impact from this. The whole installation is "waste water free": any water, including for cleaning or purging purposes, is recycled inside the process and ultimately evaporated.

Our final equipment list includes items that are not usually installed in cement plants:

- 1450 m^2 of flooring coated with epoxy, with high resistance to salt solutions
- Steel structures were covered with a special coating, resistant to high corrosion.
- 312 m^2 of platforms and 188 steps made from composite grating
- Storage tanks and vessels with a total volume of 390 m^3 made from plastic or fibreglass. We only chose one stainless steel tank for the slurry, because a plastic tank would not resist the high abrasion of the pumped slurry long enough.
- The final product, potassium chloride, is stored in a 150-m^3 wooden silo. Such silos are installed very often on highways for the storage of de-icing salt.

11.4 Material and energy in- and output of the ReduDust process

Looking from outside, the ReduDust process is just another building with in- and outputs to our cement plant material transport and energy supply networks

Input:

- Bypass dust and chemicals are delivered by truck and stored in silos, big bags or 1-m^3 containers for liquids inside or in front of the ReduDust building.
- We installed pipelines to pump thermal oil, the energy carrier for the water evaporation, between waste heat recovery and the ReduDust buildings.
- The ReduDust plant is connected to our cement plant water and electricity network.

Output:

- The washed bypass dust in the form of filter cake is transported on a belt to newly installed feeding installations in front of our cement mills.
- The pure potassium chloride, our main product, can be loaded onto trucks from the wooden silo situated close to the ReduDust building.
- The mixed salt, our by-product, is stored in big bags.

Beside these two material streams, which are utilized 100 %, the installation is quasi "waste free": water is ultimately evaporated and we expect less than 10 t/year of solid residue from chemical cleaning of the salt water.

11.5 Complexity of the process

If you enter into the ReduDust building, you get the impression of going from material-processing heavy industry with its massive structures such as large kilns and mills into the fine chemical industry with its forests of tanks and labyrinths of pipelines (Figure 7).

The complexity of this process is simply incomparable to any kind of installation we are used to in the cement industry. Of cause, we operate filter press systems in our semi-wet processes and installations for liquids, for example for waste oil or solvents. Nevertheless, these installations are simple processes compared with ReduDust, as can be illustrated with the following numbers:

- The number of elements and connections in the ReduDust flowsheet is higher than in the flowsheet of a complete cement plant.
- The flow of liquids is regulated by approximately 400 valves and more than 50 pumps
- The cumulated length of all pipelines is more than 5 km, connecting more than 20 tanks and basins

There are several reasons why this installation is so complex:

- This remains a prototype installation that offers great operational flexibility. Later installations might have a simpler process layout once we have determined the optimum way to operate such a leaching/crystallization facility.
- To avoid an interruption in one part of the process leading to the shutdown of the whole plant, we have chosen a modular layout, with buffers between each sub-process, like mixing, filtering, chemical treatment and crystallization. This makes the installation more robust, but increases the process complexity, as we have to add tanks, pumps and pipelines.
- Most of the pumps are redundant and the whole process is highly automated. This is more difficult to program at the beginning, but much easier to operate.
- We handle chemicals that can seriously harm people. Care has been taken that all chemicals are delivered in different packaging (liquid H_2O_2 and HCl in different containers, carbonate in big bags and sulphide in barrels) and are stored in separate rooms from each other, to avoid any mixing during unloading or storage. Also because of safety considerations, we have chosen a continuous process, but built with a sequential arrangement of separate reaction chambers to avoid any accidental mixing of chemicals. Such a process arrangement is safer, but more complex.

8 Bypass dust storage, dosing and mixing process

9 **Belt filter and filter cake**

12 Successful operation of the first ReduDust installation in Rohoznik

12.1 Design and achieved performance

The ReduDust plant has a design capacity of 20 000 t/year bypass dust. The plant is fully integrated in the cement plant power network and can be controlled from a local control room and from the cement plant central control room. Bypass dust with a chlorine content ranging from 5 to 15 % has been treated successfully. The chlorine leaching efficiency is more than 90 % and the annual salt production is 4 000 t/year salt. The heat for crystallization (below 1.4 MW) is supplied by a waste heat recovery installation, using the clinker cooler and kiln exhaust gas streams. The mixing and filtration process plant is operated by two full-time employees, working two 8-hour shifts/day, 5 days per week. The chemical treatment and crystallization processes work in fully automatic mode, 24 hours/day and 7 days/week, parallel to operation of the clinker kiln.

12.2 Modular design and layout

The ReduDust process is designed as a “modular system” to enable adjustment to the specific requirements of any cement plant. In particular, three basic configurations are readily available:

Mixing – filtration – chemical treatment – crystallization

This is the configuration realized in the Rohoznik cement plant. As the crystallization process requires thermal energy, the first three steps have been optimized to maximize the salt concentration in the brine. Overall, the water is used three times to leach out the bypass dust. All water for equipment or building cleaning is used and finally evaporated so that no water is discharged. The process output are the washed bypass dust that can be fully used in cement grinding or in the raw mix and salt crystals. This process variant is well adapted to treat material with elevated chlorine content, like bypass dust or other industrial powders. This installation fits perfectly to the European and American region with its strict quality requirements for waste water, simply because no water has to be discharged.

Mixing – filtration – chemical treatment

If permitted according to the local operation permit and regulations, the salt water can be directly discharged into waste water systems or surface water. In this case, no crystallization is required and the mixing and filtration processes can be simplified. In particular, the number of tanks can be reduced because there is no need to recycle water. The process outputs are the washed bypass dust and salt water. This simplified process variant is very flexible and can be adjusted to materials with a high chlorine content (bypass dust or other industrial powders) but also with a low chlorine content (ordinary kiln dust or other industrial powders). If the volume of the input and output water is not limited and the plant is not situated in a water scarcity area, ReduDust can be operated with saltwater of medium salt concentration. This is particularly interesting for the American region with its long wet or long dry kiln systems and for the Middle East region with its sometimes easy access to seawater.

Mixing – filtration

If the cement plant has its own waste water treatment installation and can discharge more water, the ReduDust process can be “stripped down” to the mixing and filtration steps and can be easily integrated into the existing network and process flowsheet. This “add-on” version is suitable for all dusts, irrespective of whether they have a high or low chlorine content.

Other variants

Beside these “standard configurations”, ReduDust can be tailored to utilize any existing installations as far as possible. One example is the integration of ReduDust into semi-wet raw material preparations. With the addition of a dust silo, powder dosing and a high-energy mixer, it is possible to


10 **Top and bottom view of the chemical treatment process**

prepare easily pumpable dust slurry that can be fed into the raw meal slurry circuit. This increases the chlorine concentration in the slurry, but as the slurry is partly dewatered in a filter press afterwards, chlorine leaves the system with the leaching water.

12.3 Design and performance of each process step

Mixing

The bypass dust is delivered by truck to the Redu-Dust installation and stored in two silos with a capacity of 50 t each (Figure 8). This enables the receiving and mixing of bypass dusts from different cement plants.

We observed in particular that bypass dust with a high free lime content can be expediently mixed with dust with a high chlorine content, because the endothermic salt dissolution absorbs the heat developed by the exothermic free lime hydration. Bypass dust and water are mixed in a batch mixer at a water-to-dust ratio of 1 to 1.5. This water/solid ratio is significantly lower than in other dust leaching processes because we use high-intensity mixing that breaks up the fine particle agglomerates, thus drastically reducing the slurry water requirement. The mixing time is adjustable and typically ranges from 5 to 30 min per batch. Up to 5 t/h bypass dust can be brought into suspension and the mixing energy is less than 10 kWh/t bypass dust. The entire dosing and mixing process runs in full automatic mode. The slurry is stored in a stirred stainless steel tank and the viscosity remains stable over several days.

Filtration

The bypass dust slurry is dewatered and washed on a belt filter. In the first part of the filter, the bypass dust slurry is dewatered under pressure. In the middle and the end zone, the filter cake is washed two times with water. This filter is operated in counter-current mode: bypass dust slurry and fresh water are fed to opposite ends of the filter. The fresh water is used for the second washing of the filter cake in the end zone. After this second washing process, the washing water is reused a second time in the middle zone and a third time in the slurry mixer (Figure 9).

This process has an extraction efficiency, in other words a chlorine reduction in the filter cake, of more than 95 % at a water/bypass dust ratio of only 1.5! The filtration rate achieved is up to 10 m^3/h, which corresponds to the design/nominal rate. The filter cake has less than 30 % moisture and a dry aspect and is suitable for transport on a belt conveyor.

Chemical treatment

The chemical treatment process consists of a succession of reaction and sedimentation chambers. Each chamber is closed and connected to a ventilation system to eliminate potentially harmful gases, like hydrochloric acid vapours or carbon dioxide, and to prevent any accumulation of these gases inside the building. Beside small dosing pumps for chemicals, no pumps are needed to transfer the brine from one reaction chamber into the next (Figure 10).

The whole installation is arranged as a descending cascade and works based on simple overflow. This makes the whole system intrinsically safe, because it avoids any backflow of brine and the whole process chain stops as soon as no more brine is fed into the first chamber. To prevent any confusion between chemicals, each chemical product is delivered in a different packaging and stored in different and clearly designated places: hydrochloric acid in 1-m^3 canisters, solid soda in big bags, and liquid hydrogen peroxide in canisters and solid sodium sulphide in bags. The whole installation works in automatic mode, 24 hours per day. Control loops for dosing chemicals are installed, mainly based on conductivity and pH measurements.

Crystallization

The brine contains mainly potassium, sodium, chloride and sulphate. We use the well-known difference in solubility as a function of the temperature of potassium chloride and sodium chloride to obtain pure potassium chloride as the main fraction and a mixed salt enriched in sodium chloride and sulphates as the minor fraction. Each of these two fractions are produced continuously under reduced pressure in a dedicated evaporation crystallizer, harvested by means of centrifugation and dried (Figure 11).

The major product, potassium chloride, has been obtained with a purity of 97 % KCl, the equivalent of 62 % K_2O. The dried crystals have a moisture content of 0.1 % and a grain size, expressed as D50, of approximately 0.4 mm and are easily transportable by truck.

13 ReduDust – suitable for all types of kiln systems and easily adjustable to specific plant needs

The ReduDust process is today a well-proven solution for bypass dust. Thanks to its modular concept, it can be adjusted to the specific requirements of virtually all types of cement processes. Beside bypass dust, also ordinary kiln dust or other chlorine-containing solid powders can be treated. The process is based on standard technologies (pumps, valves, etc.) and on basic industrial chemicals, which makes it easy to implement, maintain and operate ReduDust all over the world. The container with the pilot installation is used today by A TEC to test various materials and adjust the ReduDust concept accordingly before industrial realization.

14 Conclusion

By increasing our usage of alternative fuels like SRF or RDF, we are saving fossil fuel, which brings a considerable ecological benefit. At high thermal substitution rates (TSR) it can happen that we introduce more chlorine into the kiln system than we can incorporate in cement according to the respective cement standard (0.1 % of chlorine in all cement types according to EN 197) or in other hydraulic binder. Than we have a “chlorine excess” or a “bypass dust excess” in this cement plant.

This was the situation that the Holcim Rohoznik cement plant faced some years ago. As we did not want to landfill the excess bypass dust (which in ecological terms would have been the creation of a new waste stream, and ecologically not optimal, as well as resulting in additional cost, i.e. for disposal), we decided to work on an ecologically friendly solution that would also lead to an economic benefit, the ReduDust process.

After two years of process development, a ReduDust installation with a treatment capacity of 20 000 t/year bypass dust was built and is operated successfully in the Rohoznik cement plant today.

Today, the ReduDust process is a well-proven solution for bypass dust. Thanks to its modular concept, it can be adjusted to the specific requirements of virtually all types of cement processes. Beside bypass dust, also ordinary kiln dust or other chlorine-containing solid powders can be treated. The process is based on standard technologies (pumps, valves, etc.) and on basic industrial chemicals, which makes it easy to implement, maintain and operate ReduDust all over the world.

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11 View of the crystallizer, salt separation by centrifugation, and salt crystals