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Appendixes

1- High pressure water jet lances
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The basic cement kiln system includes a preheater in which raw material is prepared by heat exchange with hot exhaust gas. In this way, temperature rises from the ambient value at the preheater inlet to about 800-900° at the kiln inlet, thereby producing a calcination effect.

Cyclone preheater kilns technology is the more recent existing process and became the only type of cement kiln installed since the last 3 decades: it is called the dry process cement plant.

In the cyclone system, air suspension greatly increases the efficiency of heat exchange between hot gases and raw materials and allows significant calcination before the hot meal enters the rotary kiln. **The raw material is preheated in each successive cyclone.**

In addition, most cyclone preheater kilns have an auxiliary burner installed in the riser duct, pre-calciner or calciner (secondary combustion vessel between kiln and preheater) to allow an increase of unit capacities.

The most common configurations of cyclone preheaters are shown below.
The following sketch details the most typical geometry of cyclones fitted with temperature and gas flow pressure devices at the cyclone outlet, and filling detection system using gamma rays or pressure signal for the cyclone cone.
2- Build-ups, coating and cyclone chokes

In a preheater plug, material accumulates inside the preheater to the point that the normal downward flow of raw feed (kiln feed) and upward flow (kiln exhaust gases) is blocked (typically at the base of a cyclone). When this occurs, significant volumes of hot raw meal can build up above the point at which the preheater is plugged.

2.1- Build-ups...Why?

Minor elements are defined as chemical compounds characterizing clinker chemistry in addition to the main oxides (CaO, SiO₂, Al₂O₃ and Fe₂O₃).

In the past, many plants were using oil or natural gas as fuel for the clinker process and cyclones blockages were very limited. After the oil crisis that occurred in 1973, plants shifted their sources of fuel and used various products containing sulfur, chlorides and alkali.

A portion of these minor elements is considered undesirable because it could negatively affect the clinker burning process and emissions at the stack.

Minor elements tend to form cycles in the burning line. They evaporate easily when reaching the burning zone and condense in the lower part of the cyclone preheater. These phenomena depend mainly on:

- The kind of minor elements and intermediate compounds formed during clinker chemical reactions.
- The volatility of the minor elements contained in the raw meal and in the recycled compounds.
- The equilibrium between the different chemical species established in the gaseous phase.
- The specific surface of solid phases.
- The maximum process temperature (burning zone), and the residence time of the material at this temperature.

The molar ratio of sulfur (SO₃) with alkalis (K₂O and Na₂O), is evaluated calculating the “sulfate module”. Within a certain range of variation of this module, the process should evolve smoothly without serious problems in terms of coating. On the contrary, in case sulfur is in excess or defective compared to alkali, some problems will arise because of an increase of minor elements recirculation or important coating of sulfate spurrite in the coldest zones.
Recirculation of minor elements (alkali sulfates and chlorides), takes place during clinker pyro-processing and is one of the main reasons for coating formation in the cyclone preheater. If compared to other clinker components, sulfates and chlorides are characterized by lower melting point. Their stickiness facilitates the adhesion to hot meal and dust contributing to form build-ups and plugging in the lower part of the cyclone preheater. Generally, the importance of build-ups is well correlated with burning conditions, sulfur, chlorine and alkali contents in the raw meal at the kiln inlet.

### 2.2- Build-ups...Where?

Most cyclone preheaters are likely to be affected by build-ups, especially around the **kiln inlet chute**, in the **riser duct** and **lower cyclones**. Build-ups and plugs in the cyclone preheater occur through the combined action of recirculating compounds (e.g.: alkali sulfates and chlorides). They cause deposits and sticky intermediate compounds formed during the raw meal chemical reactions occurring inside an extremely dusty flow rate.
Hot meal in the **riser duct** and in the **lower cyclone stages** is particularly likely to build up at cold spots. These cold zones can be due to false air entrance or inadequate heat insulation. Lumps of coating may also build-up on the **cyclone roof and walls**, on the **cyclone cone** and **near the meal pipe**. After a build-up phase, they fall into the cyclone cone, causing cyclone plugs because of the gradual closure of narrow cross-sections, with particular reference to the meal duct.

**Frequency and severity of cyclone plugs can vary depending on kiln operating conditions, raw meal composition, type of fuel (coal, pet coke and waste fuels of various origins and compositions), and main combustion features.**

Material released when preheater plugs are cleared can flow through the entire kiln line. Hot raw mix that flushes from a preheater choke can endanger anyone working in or near the preheater tower, kiln, burn floor, clinker cooler, clinker transport systems, and surrounding areas. Personnel may also be exposed to hazardous conditions if they are working in areas affected by preventive cleaning activities or other routine work on the preheater. Each plant should maintain a plan for the evacuation of personnel in the event a preheater plugs or other emergency and establish procedures to control and monitor personnel working on the preheater tower.

### 2.3- Consequences of build-ups

**The kiln system must be stopped to remove these chokes by manual cleaning.** During this operation, **people are exposed to high risk of accident:**

- Hot meal can flow suddenly through the cleaning holes and inspection doors.
- The ID fan can switch off leading to a pressure increase in the cyclone. In this case, hot and dusty gases can come out of the cyclone through the cleaning holes or inspection doors, if they are open.
- Unexpected blasting may occur if air blasters have not been properly secured.

**Severe burn injuries and fatal accidents have occurred throughout the history of this kind of kilns.**

In addition, a cyclone choke is accompanied by the following disadvantages:

- Production loss.
- Increased energy consumption caused by stopping and restarting the plant.
- Damages to refractories due to thermal stresses when cooling and reheating the burning line and mechanical stresses caused by cleaning operations.
- Worse quality of emissions during transition phases (cyclone cleaning and kiln restarting periods).
Therefore, cement plants have different levels of experience in dealing with hazards resulting from faulty operations of the clinker burning line. Although there is no consistent technical equipment for preventing faults, there are some preventive actions that can decrease the number of cyclone plugs. Even if plugs occur, some equipments and methods – either manual or mechanical - can be used to facilitate plugs removal. It is a matter of risk assessment to find the best way of removing plugs in cyclones, protecting people and preserving productivity.
3- Operating methods and working means

3.1- Monitoring, control and prevention

Prevention will be achieved by monitoring and controlling cycles of minor elements (chlorine, sulfur and alkali) through:

- The monitoring of the chemical composition of kiln feed, clinker and hot meal at the lowest cyclone outlet i.e. kiln inlet (the semi-manual sampling device is recommended to avoid risk of burning).
- The monitoring of the chemical composition and main combustion characteristics of conventional and secondary fuels (e.g.: PCI (lower calorific value), fineness, humidity etc.).
- The spot sampling and analysis of build-ups.

Cycles of recirculating elements are strongly influenced by the burning process. Therefore, the clinker burning process has to be kept as steady as possible avoiding over-heating of the burning zone, which would tend to increase the vaporization of volatile components. Clinker burning in oxidizing conditions (oxygen in excess compared to stoechiometry) will minimize recirculation of alkali sulfates and chlorides.

Therefore, it will be necessary to monitor and control:

- The preheater and kiln main process parameters with particular reference to temperature and pressure profiles.
- Burning conditions by performing:
  - Gas analysis at the kiln back end and at lowest cyclone exit ($NO_x$ and CO at minimum).
  - Burning zone temperature measurements.

Moreover, there are special qualities of refractory lining permitting coating formation to be minimized.

Whenever cycles of minor elements are particularly severe, some design modifications shall be executed to dump negative effects on the burning process (e.g.: kiln gas by-pass system). These installations should be operated trying to minimize the by-pass flow rate in order to optimize specific heat and electric consumption and to reduce the quantity of dust to be handled and to be disposed of.
3.2- Plugging detection systems

To detect cyclones plugging, two types of measurements can be employed:

- **Process measurements**: e.g.: pressure and temperature in the gas duct at the cyclone outlet.
- **Specific measurements** to detect cyclone chokes, e.g.: cyclone cone negative pressure and gamma ray detectors.

**Process measurements**

When the cyclone plugging is going on:

- Gas temperature will increase due to a lower heat exchange between gas and raw meal in the cyclone where build-ups and/or plugging are forming.
- The negative pressure at the cyclone cone will decrease falling down to almost zero.

**Generally, process measurements are characterized by a certain time delay, which does not permit to anticipate cyclone plugging.**

**Specific measurements**

They are able to give early information about the ongoing cyclone plugging.

Concerning the main features of specific measurements:

- Cyclone cone negative pressure can be seen as a simple, reliable and low maintenance measurement, as it is not so sensitive to dust and temperature.
- Gamma ray detectors are considered as reliable systems if correctly positioned on the cyclone cone. However, these devices require an extensive authorization procedure.

3.3- Integrated anti build-up equipments

**Description of the tools:**

![Image of integrated anti build-up equipments]
Called **air blasters**, they consist in a vessel where is stored **compressed air** (up to 10 bars). Compressed air is expelled within milliseconds in an explosion-like manner. By aiming the air-blast parallel or tangential to the wall, coatings are literally “peeled off” from the wall. Various sizes of compressed air vessels and different nozzle shapes are available so that the equipment can be optimized.

Air blasters mapping has to be defined on a plant-by-plant basis taking into account the past experience and the previous chokes and build-ups locations. These units are generally installed at the kiln smoke chamber, the riser duct, the calciner, along gas ducts to the lowest stage of the cyclone preheater, on the cyclone and its meal pipe.

**Pressure vessels must be easily accessible to carry out maintenance works.** Optimized position and density of air blasters is recommended to **avoid or minimize manual cleaning operations.**

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**Main risks linked to presence of air blasters:**

- **Burn** by hot dust and / hot gases leakages coming out of air blasters.
- **Ear troubles** if operatives are located near air blasters during their deflagration.
- **Slip / trip on the floor** If cables or air blasters maintenance parts are laying on the floor.
- **Hurt of the head or a limb** due to the location of air blasters. Some of them are located at head-height and moreover they are generally located in narrow places.

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**Recommended precautions:**

- In addition of the 4 mandatory PPE (Safety shoes, safety glasses, helmet, high visibility jacket), people should wear at the vicinity of air blasters:
  - Uniform with long cuffs (to avoid any burn, either thermal or chemical due to the combined action of sweating + raw mill)
  - Ear-muffs

- Ensure that the floor is free of material, parts, tools, hoses, etc, and generally speaking **free of any object that can leads to slips / trips** of the working team members.
- Remain vigilant while moving in narrow areas.
4- Interventions in preheaters

In order to prevent unexpected exposure to hazards associated with routine work on the preheater and in the event of emergency, authorizing access and accounting for personnel working on the preheater tower during all phases of operation through a check-in / check-out system is a must.

4.1- Activities in preheaters and their associated hazards

Many various activities are performed in preheaters (most of them on a routine basis), such as:
- Raw meal sampling
- Maintenance activities
- Inspections
- Routine cleaning for coating
- Unblocking cyclones

These activities are extremely dangerous. Here are exposed their main common risks:

Burns and asphyxia
- Indeed, if cyclones and ducts are closed systems, most of the above activities require the opening of a hole or a door, so that people located near these openings are directly exposed to material projections or gases flowing out due to over-pressure.
- Resulting burns are always serious (material temperature can rise up to 1450°C and gases temperature can reach 2000°C).

Trips and falls
- Trips and falls can appear if some parts or tools are lying on the floor or if the floor itself is not regular.
- More than in any other place, it’s important to keep places such as preheater floors free of material, tools or rubbish, so that
people can easily move away in case of emergency.

- In addition, slips and trips can also lead to burns in case of fall in an accumulation on the ground of material that can be hot.

⚠️ **Hurts**

- During cleaning activities with bars and roding tools, operators can hurt their hands or a member between the bar and the cyclone casing.
- Also during cleaning operations, it may appear that a crust or a block located in upper stages fall down on the roding bar. Due to the shock and the lever effect, the operator can lose control of the bar and be hurt to the head, jaws or shoulder.
- During maintenance activities, operators can be hurt by falling parts, or during a hands activity (use of wrenches, etc...)

Each one of these activities and their associated specific risks will be detailed below.
4.2- Raw meal sampling

Meal sampling in the preheater tower is a task that can lead to severe injuries and burns in case of flushing material or air-blaster discharge. There are many examples of accidents occurred in Italcementi Group which resulted in burns on the head or hands, or eyes irritation due to projections.

**Historical sampling method:**
In most of the cases, taking a meal sample is consisting in the opening of a trap door and introducing a recipient with long handle.
In this case, there is high risk of projection of meal from the door (in case of over-pressure inside the cyclone), and also risk of direct contact with the meal during the decanting of the spoon to the bowl.

![Historical sampling method – high risk of burns and projections](image)

**Method to decrease the risk during sampling:**
In order to avoid the risks of material projections and direct contact with meal while taking the sample, some plants studied a device (semi-manual sampler) that isolates the meal from the operative during the sampling operation. So that the major risk remaining is during the transport of the sample bowl from the preheater to the laboratory.

For further information about this device, refer to the Safety Best Practice Hot meal sampling (B.P.04, June 2009).
Handle to decrease the contact risk with hot meal

Hermetic closing avoiding projections of hot materials

Tube to collect hot meal
4.3- Maintenance activities

Maintenance operations with risk of contact with hot meal should be avoided while the kiln is in operation. However, if the job is done, a risk assessment must be performed. It must take into account:

- The risk of burn. **Workers must be isolated from the openings** (e.g.: metal sheet to isolate pipes during jobs on air-blasters). According to the job performed, air-blasters have to be locked-out / tagged-out.
- The possibility to be **hurt by mechanical parts or tools** (wrenches, etc…)

In any case, **permanent contact (with walky-talky) must be kept with CCR operator**, and production parameters (e.g.: raw meal feed, kiln draft) can be modified accordingly.

4.4- Inspections

In case a door has to be open, the duration time must be as short as possible. **Even if the duration time is short, the risk remains present. Aluminized PPE must be worn.**

Open one door at a time, close the door before opening an other one. **Permanent contact (with walky-talky) must be kept with CCR operator**, and production parameters (e.g.: raw meal feed, kiln draft) can be modified accordingly.

The same preventive measures as during routine cyclone cleaning must be followed (see chapter 5) – in terms of communication, protection of external people, risk assessment, PPE, number of people and coordinator.
5- Focus on cyclones routine cleanings

Routine cleaning of some areas may be required on a regular basis. This task is undertaken during the shift. The task is carried out with the system in production and under suction. If suction is lost, there is a potential discharge of hot material (Temperature of material can reach up to 1450°C and temperature of gases can reach up to 2000°C).

This task must be described in a Safe Operating Procedure (SOP).

5.1- Routine cleaning procedure

The SOP (Safe Operating Procedure) is composed of 4 documents:
- A written procedure describing all steps of the job, its associated risks and their control measures.
- A training material.
- A quiz to assess the knowledge of the trainees at the end of the course.
- A check-list to periodically assess if the on-field operation is performed according to the procedure.

Written procedure:
The written procedure should be available to the operatives. This procedure should at least consider:
- Detail of the communication process and communication tools
- Organization and means to protect external people before starting the job
- A method of preparing the job
- A method of estimating the extent and position of the build-up
- A method of removing the build-up
- Detail of the personal protective equipments (PPE) to be used
- Detail of the tools to be used, their storage and maintenance
- A method of putting back the system into operation

Training:
Cyclone routine cleaning requires trained and competent operatives at all times. That means they must attend a training about this specific activity and be duly authorized. This training should include 2 sessions: one in classroom and the other one on the field.
It is important that the training material remains visual and includes pictures of on-field situations.
Quiz:
At the end of the training, a quiz test must be performed in order to assess the knowledge of trainees and deliver authorization for the job. This test is individual and named. Quiz test individual sheets and results must be kept and recorded (and available on purpose).

Check-list:
The check-list summarizing the main critical compliance points coming out from the procedure has to be established. Its goal is to ensure that the job on the field is performed in accordance with the related procedure. This monitoring must be done on a regular basis. Non compliance with the process required must lead to an immediate correction (re-train, remind, review, re-assess). If it is not possible, stop the job.
Check-lists have to be stored and available on purpose.

5.2- Factors to mitigate risks

Position of operator
- Operator and generally speaking all cleaning team members should remain above the level of the blockage they are cleaning.
- Operator should avoid standing in the direction of the flow (in case of material flushing out).
- He should also stand as far as possible from the cleaning hole / cleaning door.
- He must wear the specific PPE dedicated for this operation (see chapter 8) before opening the first cleaning hole / cleaning door and never leave his PPE as soon as a cleaning hole / cleaning door is open.

Position of team members
- They should remain above the level of the blockage they are cleaning.
- They should avoid standing in the direction of the flow (in case of material flushing out).
- They should also stand as far as possible from the cleaning hole / cleaning door.
- In case of a cleaning door, they should stand on the side of the door, and behind the door, so that the door is acting as a protective screen in case of flushing material.
- Team members must always have the operator in direct sight.
- They must wear the specific PPE dedicated for this operation (see chapter 8) before opening the first cleaning hole / cleaning door and never leave his PPE as soon as a cleaning hole / cleaning door is open.
• Carefully coordinate the activities of all team members. Work at one point on a preheater (like firing an air-blaster) can create significant hazards to personnel working at other locations.

Number of operatives and communication
The number of people in the area must be kept to a minimum and must include one person acting as coordinator. This person must keep a visual contact with the performers at any time and has to be in permanent link with the Central Control Room (CCR), through walky-talky for example.

In case of using high pressure water lances, the coordinator must always keep in hand the emergency pressure stop remote control in order to shut down the water flow in case of needs.

Cleanliness of the area
The working area should be clean, that means:
  • Free of material (that can be hot).
  • Free of tools and pipes that can obstruct movements and make operatives slip and fall.

Egress
Before starting the job, performers must ensure that there are 2 egress from where they can escape in case of emergency.

Physical warm-up
It should be useful for the operatives to perform a short physical warm-up stretching before the intervention in order to prepare their body and prevent any muscular trouble.
Water
The operation is very tiring and temperature under PPE is very hot. Moreover, the body is sweating a lot. That's why it's important to have water to drink and refresh operatives.

Status of doors
Open one door at a time.
Always close the open door before opening a new one.
### 5.3- Working methods

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Information</td>
<td>Job crew leader informs the machine owner about the job to do. Machine owner gives his authorization, check presence of people on the register and ask them to evacuate. Machine owner adjusts production parameters (if necessary).</td>
</tr>
<tr>
<td>2-Debriefing</td>
<td>Before every intervention, job crew leader makes a risk assessment with his team about the task to be performed (they can use the check-list). The team is composed of at least 2 persons.</td>
</tr>
<tr>
<td>3-Isolation of the area of the intervention</td>
<td>Team members put in place physical barriers, signs, lights, alarms to forbid access to the preheater. Team members perform a visual check at all floors to ensure that there is no one in the preheater.</td>
</tr>
<tr>
<td>4-Isolation of energies</td>
<td>Team members must lock air pressure circuit and discharge manually and one by one each air blaster. In case HP water lance is used, team members must check that all valves supplying lances are locked except the one they will use.</td>
</tr>
<tr>
<td>5-Check safety / rescue devices</td>
<td>Team members must block the elevator at the floor where is performed the operation (in order to be immediately available in case evacuation is required). Team members must check that hoses and connections are in proper shape.</td>
</tr>
<tr>
<td>6-PPE</td>
<td>Team members must ensure that all the PPE required for the operation are available and in proper working condition. Once they have put PPE on, each member of the team check his colleagues to ensure that PPE are correctly worn.</td>
</tr>
<tr>
<td>7-Preparation of the intervention</td>
<td>Team members have to ensure that no falling object can compromise their safety. Team members ensure that there is an emergency exit in case they need to escape.</td>
</tr>
<tr>
<td>8-Open energies</td>
<td>Start of the high pressure pump. The operative acting as coordinator must ensure that the HP lance remote control is working properly.</td>
</tr>
<tr>
<td>9-Intervention</td>
<td>Team members must start from the top and go through the floors downstairs. Team members must open one door at each time (refer to SDD safety alert #15 issued in May 2013). Team members must close each door before opening a new one. The operative acting as coordinator must always keep the unplugger in direct vision. The unplugger mustn’t stay directly in front of the open door (as much as possible).</td>
</tr>
<tr>
<td>10-End of the intervention</td>
<td>Team members must check that the preheater is unplugged. Team members must check the tools used, hoses and their connexions. Team members have to store the tools at their designated area. Team members must clean the working area.</td>
</tr>
<tr>
<td>11-Check</td>
<td>Team members must check that all the doors are closed. Team members must check that water lances and water pump are locked. Team members have to remove physical barriers, signs, lights, alarms. Team members must restore the elevator.</td>
</tr>
<tr>
<td>12-Restore equipments</td>
<td>Team members must restore equipments they locked (e.g.: air circuit for air-blasters). They put back LOTO devices and sign the end of operation.</td>
</tr>
<tr>
<td>13-Communication</td>
<td>Team crew leader must inform the installation owner that the operation is finished.</td>
</tr>
</tbody>
</table>
5.4- Tools used for cleaning / unplugging

In almost all cement plants, cleaning works are carried out while the kiln is in operation. Works are carried out by hand with roding tools, compressed air bars, high pressure (HP) water jet lances and compressed gas tubes.

Generally speaking, roding tools and compressed air bars are suitable for smooth and incoherent coating mainly due to accumulation of dusty material. On the contrary, HP water jet lances are more suitable for clearing stronger coatings. The compressed gas method is particularly effective for breaking compacted masses when performing cyclones and ducts cleaning operations.

5.4.1- Roding tools

**Description of the tools:**

These devices are long metal bars that are manually operated through appropriate cleaning doors positioned at the most critical points. This operation can be carried out to prepare an appropriate opening for inserting compressed air bars or water jet lances.

**Main hazards linked to the use of roding tools:**

- **Burn** by hot dust / hot gases coming out of the casing.
- **Asphyxia** due to flushing dust coming out of the casing.
- **Hurt of a member** (finger, hand, arm) with the casing while using the roding bar.
- **Hurt of a member** (shoulder, jaw, head) with the roding bar in case the operator loses control of the bar (e.g.: due to a block falling on the extremity of the bar and makes the bar unbalanced).
- **Slip / trip on the floor** while using the roding bar.
Recommendations for use of roding tools:

- **Open one door at a time** (always close the door before opening an other one).
- Start unclogging jobs from the **upper doors** and perform **going from upper floors to lower floors**.
- If the system is running, **open the door as few as possible** (a widely open door should be avoided).
- The operator should **stand as far as possible from the open door**.
- Other team members **never stay in the trajectory of the material** (in case of flushing out) and must **stay on the side where the door acts as a protection screen**.
- **Specific PPE must be worn at all times** (see chapter 8).
- Roding tools have to be equipped with **hands protections** in order to avoid fingers to be crushed between the roding bar and the casing.
- Ensure that the floor is free of material, parts, tools, hoses, etc, and generally speaking **free of any object that can leads to slips / trips** of the working team members.
- In order to avoid roding tools laying on the ground, they should be **stored in a proper and dedicated place**.

**Flushing material can lead to burns and asphyxia**

**Example of a simple and efficient way to store roding tools**

Users should position themselves so that their face and head are not over the lance / bar or in line with the port or door. Falling material inside the preheater can strike the end of the lance or rod causing it to strike the user in the face or head.
5.4.2-Compressed air bars

Description of the tools:

They consist of metal tubes fed with compressed air from the plant network (5-8 bars). Obviously, they are more efficient at cleaning dusty materials than demolishing crust formations.

Main hazards linked to the use of compressed air bars:

- **Burn** by hot dust / hot gases coming out of the casing.
- **Asphyxia** due to flushing dust coming out of the casing.
- **Hurt of a member** (finger, hand, arm) with the casing while using the compressed air bar.
- **Hurt of a member** (shoulder, jaw, head) with the bar in case the operator loses control of the bar (e.g.: due to a block falling on the extremity of the bar and makes the bar unbalanced).
- **Slip / trip on the floor** while using the compressed air bar.

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- **Specific PPE must be worn at all times** (see chapter 8).
- Compressed air bars have to be equipped with hands protections in order to avoid fingers to be trapped between the bar and the casing.
- Ensure that the floor is free of material, parts, tools, hoses, etc, and generally speaking free of any object that can leads to slips / trips of the working team members.
- In order to avoid roding tools and bars laying on the ground, they should be stored in a proper and dedicated place.
5.4.3-High pressure water jet lances

Description of the tools:

The high pressure water jet lance is a long metal tube equipped with a trigger that is fed with high pressure water (500-1000 bars). The water is provided through a high-pressure unit (pump) and a high-pressure pipeline (500-1000 bars) that feeds each lance. This pipeline can be either rigid (fixed) or flexible (movable). One high-pressure unit is able to feed many different jet lances via a proper network. Each high-pressure unit can be operated locally or by remote control.

Main hazards linked to the use of high pressure water jet lances:

- **Burn** by hot dust / hot gases coming out of the casing.
- **Asphyxia** due to flushing dust coming out of the casing.
- **Cut of a member** (finger, arm, leg), cut of the whole human body in 2 parts due to the high water pressure used.
- **Hurt of a member** (shoulder, jaw, head) with the bar in case the operator loses control of the bar (e.g.: due to a block falling on the extremity of the bar and makes the bar unbalanced).
- **Slip / trip on the floor** while using the high pressure lance.

Recommendations for use of high pressure water jet lances:

- **Open one door at a time** (always close the door before opening another one).
- Start unclogging jobs from the **upper doors** and perform **going from upper floors to lower floors**.
- If the system is running, **open the door as few as possible** (a widely open door should be avoided).
- The operator should **stand as far as possible from the open door**.
• Other team members never stay in the trajectory of the material (in case of flushing out) and must stay on the side where the door acts as a protection screen.
• Specific PPE must be worn at all times (see chapter 8).
• Ensure that the floor is free of material, parts, tools, hoses, etc, and generally speaking free of any object that can leads to slips / trips of the working team members.
• In order to avoid lances laying on the ground, they should be stored in a proper and dedicated place.
• Each working place in the preheater tower has to be equipped with a remote control for switching on / off the HP water unit, especially in case of emergency.
• Never leave the remote control unless it is in OFF position.
• Never activate the lance trigger if the lance is not pointed inside a cyclone.

• High pressure pump must be locked when not used.
• In case more than one HP lances are energized with the same HP water unit, each one of the non-used lances feeding pipe must be locked. That means it must be physically impossible to use 2 (or more) HP lances at the same time.
• Don’t forget that the high water pressure used can cut a body in 2 parts.

• It is essential to equip each hose connection with whip checks in order to avoid the uncontrolled motion of hoses in case of break of connections.

HP water feeding circuit MUST be locked when the lance is not used

Whip check so secure the motion of the hose in case of break of the connection
For further information about high pressure lances, refer to appendix 1 and to SDD safety alert #12 issued in August 2012.

5.4.4-Compressed gas tubes

Description of the tools:

Pressure gas steel tubes are filled with liquid CO₂, a chemical heater and a rupture disc, and are inserted into pre-drilled holes. When energized by the application of a small electrical charge, the chemical heater instantly converts the liquid carbon dioxide to a gas. This conversion expands the CO₂ volume and builds up pressure inside the tube to burst. This releases the CO₂ (600 times the original volume) through a special discharge nozzle to create a powerful heaving force, at pressures up to 3000 bars. This all takes place in milliseconds. Different discharge heads can be used to suit the requirements.
Main hazards linked to the use of compressed gas tubes:

- **Burn** by hot dust / hot gases coming out of the compressed gas tube.
- **Hurt of a limb** (if all or part of the tube is projected outside by mistake).
- **Hurt of a limb** (when drilling the hole).
- **Musculoskeletal troubles** during transportation of tubes.
- **Slip / trip on the floor** during transportation of tubes or during the drilling.

Recommendations for use of compressed gas tubes:

- The operating team should **stand as far as possible from the gas tube location** (during the explosion phase).
- **PPE must be worn at all times. Ear-muffs must be worn during tubes explosion phase.**
- Ensure that the floor is free of material, parts, tools, hoses, etc, and generally speaking **free of any object that can leads to slips / trips** of the working team members.
- Handle **one tube at a time**.
• Firing compressed gas tubes should be the topic of a dedicated training and authorization.
6- Focus on major blockages

The sooner a cyclone choke is detected, the smaller is the quantity of meal to be removed.

During the cleaning on major blockages the line is stopped (raw meal feed and fuel supply are stopped).
Unplugging jobs are much more dangerous because of the large quantity of hot material to which workers are exposed to. Moreover the material refreshing time is very long and internal parts of blocks are often incandescent.
So that the work must be undertaken in a more planned environment.
**Precautions must be the same as during routine cyclone cleanings (see chapter 5).**
*However there must be at least 3 members in the unplugging operative team.*

**Verification that the plug is cleared:**
After a plug has been cleared, the vessels, ducts and feed lines involved in the plug and those below the plug must be checked to verify that the plug has been cleared and that material has not created any obstructions below the original plug. This follow-up verification that the preheater is cleared should be clearly defined. This usually involves opening ports or doors to check for negative draft along with the monitoring of readings from pressure, temperature and ionized rays devices.
Dropping an object down through the preheater can also be used to verify that the preheater is clear. It should be understood that this method has the potential to cause damage to refractory and should be managed accordingly.
7- Gallery of collective protections on preheaters

In order to reduce risks of accidents, some plants implemented collective protections shown below as good practices.

7.1- Platforms for unplugging cyclones

Some plants are equipped with platforms located above roding holes. The person in charge of unplugging has to perform the job from the platform so that he is far from the flow in case of flushing hot material.

7.2- Distance opening system

They are usually coupled with platforms. They consist in a bar that allows the opening of roding holes directly from the platform, instead of staying near the roding hole itself.
7.3- Alarms, signals and sirens

For obvious safety reasons, access inside preheaters must be forbidden to anyone who is not participating in unplugging operation or routine cyclone cleaning.

Complete evacuation should be confirmed in a register (located in the CCR for example).

That’s why such operation must be signalized with proper lighting and sirens at any preheater entrance so that anybody who wants to enter the tower is aware about the forbidden access. They must be coupled with physical barriers such as chains with proper signalization.

Moreover, before such operation, the unplugging / cleaning team must ensure that no one is in the preheater.

**All jobs located in the preheater must be stopped during unplugging operations, whether they are performed by employees or contractors.**

7.4- Elevators

Due to the high risk of unplugging / cleaning cyclones operations, elevators must be considered as emergency devices. That’s why during such operations they must be dedicated to the working team and available at any time.

We all know that in case of injury or burn, the soonest the medical staff intervene, the better are the chances to reduce injuries or save the victim.

**So that a recommendation is to keep the elevator available (doors open) at the floor where is performed the unplugging / cleaning activity.**
8- Personal protective equipments for working in preheaters

Under the hierarchy of control measures, Personal Protective Equipment (PPE) is the last one to be considered. However, the type and effectiveness of the PPE provided for activities like coating removal or cyclone cleaning is vitally important.

PPE provided must be appropriate to the hazard encountered and take into account ergonomics. Comfort is very important because it is one of the factors that makes operatives wearing PPE all job long.

They should be compatible with any other PPE worn.

They should be properly stored and maintained and any defects should be reported.

Employees must be trained and instructed to the use of PPE.

8.1- Norm

Protective clothing for workers exposed to heat and flames (except welders and firemen) must comply with EN ISO 11612 (previously EN 531).

This norm is dealing with the following items:

- Contact with a flame (A)
- Convective heat (B)
- Radiant heat (C)
- Molten aluminium splash (D)
- Molten iron splash (E)
- Contact heat (F) (this aspect is new compared to the previous EN 531)

Each one of the above-mentioned criteria is tested.

Tests results are given with letters and figures (e.g.:AB1C2D1E3F1). In this example, C2 means that the equipment tested reached the level #2 according norm criteria for test C (radiant heat).

For further details, you can find all the tests in the whole norm in appendix 2.

Here is the pictogram for garments that comply with the norm:
8.2- Materials

Clothes are made of multi-layers fabrics with various properties:

8.2.1- Aramids

Aromatical poliamids (aramids) are fire-resistant materials with good mechanical properties. These poliamids have been discovered in the 60’s by Du Pont de Nemours company and are known under the brands “nomex” and “kevlar”.

- Nomex is not flammable within usual oxygen range (auto-extinguishability) and is widely used for firemen personal protective equipments, but also air-filtration and electrical isolation.
- Kevlar is a fire-resistant and cut-resistant material. Its mechanical characteristics are better than Nomex ones.

8.2.2- Proban

Proban is a flame retardant process for cotton fabrics developed by Rhodia company. It can be used as clothes under-layer. When exposed to flames, Proban fabrics form an insulating char, this stays in place and helps protect the wearer. Proban fabrics don’t melt and the flame doesn't spread outside the charred area.

8.2.3- Alumina

Clothes can be covered with an alumina sheet as external layer in order to get 2 more advantages:

- Protection against heat radiance.
- Avoid hot projections to stay on the garment and make them roll down to the floor.
8.3- Overview of the various PPE

We will deal here only with coating removal and unplugging cyclone activities. These activities are characterized by their high level of risk due to burns, and their uncomfortable working atmosphere due to heat and dust.

To protect operators involved in routine clearing work at the cyclone preheater from burn injuries in case of hot meal flushing and/or hot gas leaks, protective clothing made of non-flammable and heat-resistant material must be worn at all times.

Unplugging team members should wear at all times the following set of PPE:

- Protective garment made of non-flammable and heat-resistant material
- Full head and face protection with hinger screen, shoulders and torso coverage
- Special gloves with long cuffs
- Gaiters to protect feet

Insufficient protection of operatives.
2 operatives working at the same time on 2 different portholes

NOT ACCEPTABLE

Adequate protective clothing of the operative

ACCEPTABLE
Depending on local assessment based on the duration of the unplugging operation and the atmosphere (temperature and dust), additional breathe-helping devices should be used.

8.3.1- Protective garment made of non-flammable and heat-resistant material

Regarding the design, these garments can be found in a single piece (uniform) or 2 pieces (suit + pants). Both solutions are suitable. However, whatever is the solution chosen, it is important that:

- **People feel comfortable and the garment allows an easy motion.**
- **The suit is long** (in case of choosing suit + pants) so that there is no gap between suit and pants.
- **The garment closing system is dust-proof** (if facing the material flow in case of projection). Another solution is to have the closing system located on a side of the garment, or better, on the back side).

Here are shown below the main opening configurations:

<table>
<thead>
<tr>
<th>Opening Configuration</th>
<th>Dust-proof</th>
<th>Accepted</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 velcro straps in the front</td>
<td>Dust-proof</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>2 velcro straps on a side</td>
<td>Dust-proof</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>Snap-fasteners</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ 1 velcro strap in the front</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 velcro strap in the back</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zip in the front</td>
<td>No dust-proof</td>
<td>NOT ACCEPTED</td>
</tr>
<tr>
<td>Snap-fasteners in the front</td>
<td>No dust-proof</td>
<td>NOT ACCEPTED</td>
</tr>
</tbody>
</table>

A risk assessment should be performed on site to determine if the garment needs alumina or not. The main advantage of alumina is its efficiency against radiant heat, but these garments are a little bit heavier so that people motion is more difficult.

The risk assessment should take into account the atmosphere temperature, the duration of the exposure and also the feeling of people who perform the operation.
Here are shown some examples from the French supplier EDC

Suit with right or left side closing. Closing system with snap-fasteners and velcro strap

Apron with back side closing system with velcro strap and light chain. Protection again face-sided projections only.

Here is shown below an example from the Egyptian supplier Carrera, with neck and nape protection, including balaclava. Not aluminized on the torso (covered by helmet), nor on the back side. Closing with 2 velcro straps on the front side.
Presented below the example of garments used in Spain and Morocco (Supplier MEDI)

8.3.2- Full head and face protection with hinger screen and shoulders

Helmets should include large protections like shoulders and torso coverages in order to avoid hot material burns due to gaps between helmet and clothing, especially in the neck area.

The screen is removable and can be separately changed in case of wear or damage. Face screen can be transparent or golden colored. Golden color is better thanks to its protection against heat radiance. It is also more comfortable for the worker because it prevents dazzling (useful for kiln snowman burner removal operation). Face screen is made of triplex glass or polycarbonate.

Spare screens
With head and nape coverage, torso and shoulders protections. Dust-proof. **ACCEPTED**

With head and nape coverage and removable eyeshade. This type is not accepted due to its un-proof characteristic (projections can reach the face of the worker). Moreover, the lack of torso and shoulders protections is not recommended. **NOT ACCEPTED**

8.3.3- Special gloves with long cuffs

Long cuffs are highly recommended in order projections not to enter under the sleeves and burn arms or hands. They must also be tightened at their extremity.

Palm is usually made of leather, while the back is made of kevlar and aluminized. **ACCEPTED**

Short cuffs. Risk to be burnt on the hand or arm. **NOT ACCEPTED**
8.3.4- Gaiters

Aluminized gaiters cover safety shoes realizing a protective screen. They avoid projections to enter inside the shoes and burn the feet.

They must be put under the pants so that there is no way for material projections to reach the feet.

8.3.5- Air ventilation devices

Depending on the duration of the operation and the atmosphere (temperature, dust), it can be useful to add a ventilation system coupled to the helmet. The principle is the following: the system brings clean and fresh air inside the helmet. In this way, the helmet is always under pressure, so that the worker’s head is not in contact with dust or hot air. An other advantage is that it is easier for the worker to breathe.

2 systems are existing:

- A portable and self-sufficient one (waist-fitted) consisting in a small engine that sucks the air around the worker, blows it through filters and then inside the helmet.
- A system connected to the site air network that filters air network and insulates inside the helmet via dedicated hoses.

Both systems are equipped with pressure control so that the worker can adjust the air flow at his convenience.

Various brands like 3M, Scott, MSA or Pureflo ESM are manufacturing such systems.
8.3.6- Manufacturers

Here is a non-exhaustive list of manufacturers that can provide approved PPE

<table>
<thead>
<tr>
<th>PPE</th>
<th>Manufacturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protective clothing</td>
<td>EDC – EUROMAST – Carrera – MEWA - MEDI</td>
</tr>
<tr>
<td>Helmet</td>
<td>EDC – EUROMAST - MEDI</td>
</tr>
<tr>
<td>Gloves</td>
<td>EDC - EUROMAST</td>
</tr>
<tr>
<td>Gaiters</td>
<td>EDC – EUROMAST - MEDI</td>
</tr>
<tr>
<td>Air-ventilation devices</td>
<td>3M – SCOTT – MSA – PUREFLO ESM</td>
</tr>
</tbody>
</table>
8.4- Storage of PPE

PPE should be stored in a dedicated room. This place should be free of dust and hot temperature. PPE should be inspected before and after each use and repaired or replaced if not fully serviceable.

Storage on the field and exposition to hard atmosphere (temperature and dust) **NOT ACCEPTED**

Proper storage in a dedicated room to keep PPE in good condition **ACCEPTED**
9- Types and treatment of burns

During unplugging operation, workers are exposed to 2 types of burns:
- Thermal burns
- Chemical burns

9.1- Thermal burns

When a burn occurs, the body holds heat and the burning process can last for several minutes to several days or longer in case of serious burns. These burns can also lead to the loss of sweat glands, nerve endings and may lead to skin grafts.

First aid for thermal burns:
\[\text{The more quickly the burn is cooled down, the better are the chances of reducing its effects.}\]
- Use water from the closest source, whether it is a shower, a hose or a sink. Hold the burn under cool running water.
- Seek medical advice

9.2- Chemical burns

Raw meal contains alkali that may cause chemical burns. They react with sweat when they are in contact with the skin and a reaction which releases heat can occur. It is often a painless process and the victim doesn’t know for hours that a burn has occurred. The severity of the burn is generally measured by the duration of the exposure.

First aid for chemical burns:
- Brush off dry particles from the victim’s skin.
- Wash with soapy water and rinse for at least 20mn.
- Seek medical advice.

For more information about chemical burns, you can refer to SDD safety alert #14 issued in December 2012.
9.3- Showers and wash eyes

Despite of all protections, if burn injuries occur, it's important to cool the injured area as soon as possible. Some plants have installed permanent safety showers and eye wash stations at each floor where unplugging operation can be performed. These devices can be connected to the water network.

Eye wash or body shower stations can be also made of portable pressurized vessels with a special sanitized liquid. Such equipments must remain close to the workplace, ready for use during the whole operation and stored in a clean place after the job completion. Regular checks must be performed to assess the “ready for use” status.

Some providers: Prevor, Comimex, Labotherm, MSEI Environnement, …

Shower and eye wash system connected to the water network
Note that eye wash stations must be kept perfectly clean and be regularly rinsed and dedusted.

Portable wash eyes and body shower pressurized vessels protected near the job location

This document is available on Group intranet portal I-Like under the chapter 6 “Standards for performance”. For more information, contact SDD Safety.