STANDARD DESIGN CRITERIA (StDC)

MECHANICAL EQUIPMENT

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HOLCIM

Change Index

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HEALTH & SAFETY

Health and Safety is our core value. At Holcim, we want to do more than prevent accidents. We want to create a healthy and safe environment for our employees, contractors, communities and customers based on a true safety culture.

Health and Safety is at the center of everything we do, from the daily routines in our plants to our customers' project worksites and our actions in our neighboring communities. Our aspiration is to conduct our business with zero harm to people. We believe in visible leadership and personal accountability for Health and Safety at all levels and throughout our organization.

To reach this aspiration, we are committed to:

- Maintain a global Health and Safety Management System designed to continuously improve our performance and actively manage risk in our business
- Drive for operational discipline by instilling a mindset of safe execution and follow-up
- Communicate openly with all stakeholders on relevant health and safety issues

INTRODUCTION

Objectives of the Standard Design Criteria (StDC)

- Provide standard technical specifications to the Holcim community that is based on proven technologies and practical experiences from constructing, maintaining and operating plants.
- Achieve an optimized balance between high Overall Equipment Efficiency (OEE) and Mean Time Between Failures (MTBF) during the expected lifetime of the assets considering the lowest possible CAPEX.
- Ensure transparency and consistency among Supplier's offers to Holcim projects.

Application and General instructions

- This Mechanical Standard Design Criteria (StDC) covers Cement and Geocycle.
- The StDC is a reference guideline for designing new plants in Greenfield, Brownfield replacement and revamping projects. This document is also equally applicable and relevant for quarry & plant operation and maintenance teams for achieving efficient operation & maintenance which will ultimately improve the overall plant performance.
- All health and safety related statements and paragraphs marked with  are design provisions for safe construction, operation and maintenance of the plant. Deviations and exceptions are not allowed.
- All other deviations to the StDC shall be justified and recorded.
- For non-safety related design variations, justification of the alternative must be properly recorded.
- The Basic Requirements document contains general specifications applicable for Mechanical, Electrical and Civil design.
- Specifications for Mechanical, Electrical and Civil components of the projects shall be reflected in the Data Sheets (where available). They are intended to standardize the way Suppliers present specifications to Holcim.
- The Standard Design Criteria lists certain codes and standards. In the event that any such specified codes and standards are inconsistent with any codes or standards enforced by law, the most stringent standard shall govern the Contractor's performance as far as not in conflict with local regulatory obligations.

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1. GENERAL

The following Design Criteria shall apply to all Mechanical Equipment for Cement, Aggregates and Geocycle. The given Design Criteria identify the minimum Equipment requirements. The project specific requirements are outlined in Contract document Owner's Project Description and Scope.

All supplied Equipment shall be of robust design and manufacture and shall use state of the art technology of Cement, Aggregates and Geocycle technology. Selected Equipment shall have a high degree of availability, require minimum maintenance and operate with high efficiency. Electrical and thermal energy consumption shall be minimized. Equipment shall be designed for heavy-duty industrial application, capable of handling abrasive to very abrasive materials in dusty environments. Equipment shall be suitable for continuous operation at uniform maximum load without adverse effect on the lifetime expectation or maintenance intensity of the Equipment under prevailing conditions.

Furthermore, the Equipment shall suit all local climatic and operating conditions at the site. Buildings, housings and frames shall be adequately protected against corrosion.

Loads on all platforms connected to mechanical equipment shall be designed based on the design loads specified in the Standard Design Criteria for civil and structural works.

Equipment such as bucket elevator, bag filter and components such as ducts shall be insulated when the temperature of the casing can go below the dew point of one of the gas components. Adequate anti-corrosion shall be applied.

The Equipment shall be designed with sufficient safety margins from a technical and process performance point of view. It shall be capable of restarting after stopping due to power failure or other process related interruptions (i.e. interlock).

Standardization of Equipment, sub-Equipment, accessories and internal components shall be ensured where possible.

1.1 DEFINITION OF NOMINAL AND DESIGN

"NOMINAL" capacity corresponds to expected continuous operation which is the reference for the performance test.

"DESIGN" capacity is "NOMINAL" capacity plus the applicable reserves for main and auxiliary equipment sizing.

For the kiln systems, the **"Nominal Gas Flow"** is a defined gas flow that anticipates the effects of fuel type (refer to Paragraph 2.3.3).

1.2 SLOPE, ANGLE, INCLINATION

All the figures given in this document for slope, angle and inclined are defined as **measured from horizontal**.

2. MAIN EQUIPMENT

2.1 Raw Material Preparation (Cement)/Rock Processing (Aggregates)

2.1.1 Crushing

a) Main access doors shall be separately locked to prevent crusher start-up when housing is open. The unique “trapped” key for the lock shall be obtained from the respective motor feeder/switchgear during stoppage (see Electrical Equipment Systems StDC – General Requirements).

b) All relevant parts shall be protected by replaceable wear-resistant liners.
The wear liners shall be of a modular design.

c) Main mechanical components shall be equipped with seals for effective protection against dust intrusion.

d) All crushers shall be supplied with a central lubrication.

e) Crusher lubrication systems shall be designed to permit ease of servicing of filters, pumps, cooling systems, and lubrication changes from the ground or a working platform. The crusher lubrication system shall be supplied to respect the environmental conditions. Containment systems and/or spill cleanup pads are required to protect against escape of oil or other contaminants from lubrications systems.

f) Monitoring gauges and systems shall be visible and installed such that the gauge faces, or sight glass can be within reach for cleaning and checking. Maximum and minimum operating ranges shall be clearly marked and visible for daily walk around inspection purposes.

g) Anti-vibration pads shall support the crusher on the building.

h) During transport from offloading point to crusher inlet, free section shall slightly increase to prevent any blockage.

i) If a hydraulic hammer is provided for breaking blockages, a safe platform and/or remote control from a safe position shall be provided.

j) Crushers shall have working platforms around each machine with a minimum clear width to allow maintenance of the crushers. They must be accessible by stairs.

k) Working platforms around crushers to be of “checker plate” construction.

l) Crusher stations shall be designed to permit removal of crusher parts and motors by crane without interference from the structure or other equipment.

m) Access doors sized and suitable for access and fitted with vibration proof locks must be provided for clearing feed/discharge blockages and for maintenance inspection purposes.

n) Direct drive arrangements are preferred wherever possible.

o) Crusher motors shall incorporate soft starts or variable speed drives (as required by the process).

p) In absence of ducting layout and pressure drop calculation, the crusher dedusting system shall be designed for a min. fan static pressure of 30 mbar and air volume safety margin of min. 15%.

q) In areas where the dust source cannot be enclosed (i.e. crusher feed hopper) a wet dust suppression system shall be considered.

2.1.1.1 *Impact Crusher Types*

2.1.1.1.1 Hammer Crusher

a) Housing shall have a hinged split casing with hydraulic actuator for rotor(s) access and maintenance. Opened casings shall be fixed by lockable safety arms.

b) Safety sensors shall be installed on housing and doors to prevent crusher start-up when housing is open.

c) A chain curtain shall be provided for crusher inlet opening.

d) The width of the crusher feeding devices (feeders, scalpers or screen) shall be equal or slightly smaller to the width of the crusher rotor(s).

e) Hammers shall be reversible.

f) Operating rotor tip velocity shall be in a range of 30 - 36 m/s.

g) Rotors shall have horizontal locking holes for maintenance.

h) Discharge grates shall have a hydraulic device for adjustment.

i) Grates shall be designed with tapered bars and progressively widening gaps with regard to sense of rotation.

j) Crusher supply shall include a hydraulic tool for hammer axle removal.

2.1.1.1.2 Impact Crusher

a) Housing shall have a hinged split casing with hydraulic actuator for rotor(s) access and maintenance. Opened casings shall be fixed by lockable safety arms.

b) Safety sensors shall be installed on housing and doors to prevent crusher start-up when housing is open.

c) A chain curtain shall be provided for crusher inlet opening.

d) The width of the crusher feeding devices (feeders, scalpers or screen) shall be equal or slightly smaller to width of the crusher rotor(s).

e) Crushers shall have a device for adjustment of the impact plates and grinding path to continuously control the product size, to compensate for wear and to release against tramp metal.

f) Blow bars shall be reversible.

g) Operating rotor tip velocity shall be in a range of 30 - 40 for primary and 30 - 50 m/s for secondary crusher.

h) Rotors shall have horizontal locking holes for maintenance.

i) Crusher supply shall include a hydraulic tool for impact bar removal.

2.1.1.1.3 Vertical Impact Crusher

a) Rotor circumferential velocity shall be in the range of 60 to 80 m/s. Crusher shall have an inspection door for the crushing compartment.

b) Crusher and drives shall be mounted on a common frame.

2.1.1.2 *Compression Crusher Types*

a) Main mechanical components shall be equipped with seals for effective protection against dust intrusion. Blowers shall be added in addition to seals.

b) Crushers shall be equipped with a central lubrication unit for the eccentric and the pinion shaft.

c) Crushers shall be equipped with a permanent hydraulic adjustment device for the main shafts to compensate for wear and to release against tramp metal.

d) For Aggregates applications, automatic “on the run” closed side setting is required to compensate for liner wear via programmed logic.

e) For Aggregates, all crushers shall have interlocked automation systems for lubrication temperature, flow, high and low feed bin level, feeder/cavity control and crusher motor operation.

f) Cone crushers shall be equipped with a level sensor over the crusher to ensure choke feeding. The sensor will be automated with the control system and the feeder to the crusher.

2.1.1.2.1 Cone Crusher (Symons type)

a) Ring and upper frame structures shall be equipped with a combined hydraulic device for release against tramp metal.

b) The hydraulic device for bowl adjustment on the ring shall be equipped with a screw and shall be locked by hydraulic clamps.

c) Crusher and drive shall be supported on a common frame.

2.1.1.2.2 Cone Crusher (Hydrocone type)

a) The design of Hydrocone type crushers shall be in accordance with Paragraph 2.1.1.2.3 (Gyratory Crusher) except for the hydraulic jacks not being required.

b) Crusher and drive shall be supported on a common frame.

2.1.1.2.3 Gyratory Crusher

a) Crushers shall be equipped with hydraulic jacks for disassembly and replacement of liners and shells.

b) Assembly surfaces of liners and shells shall be flanged with conical draw fit.

c) The eccentric sleeve bushings shall have at minimum 2 eccentric throws.

2.1.1.2.4 Jaw Crusher

a) Crusher shall be equipped with a hydraulic device for adjustment of the mobile jaw by moving wedges.

b) Crusher and drive shall be supported on a common frame.

2.1.1.3 *Roller Crusher Types*

2.1.1.3.1 Mineral Sizer

a) Peripheral speed at rotor shall be in the range of 2 to 3 m/s.

b) Scrapers or teeth shall be installed on the side walls for shafts cleaning purposes.

c) Crusher shafts shall be driven by electric motor(s) through a reducer. Drive train shall include a hydraulic coupling device.

2.1.1.3.2 Roller Crusher

a) Safety sensors shall be installed on housing and doors to prevent crusher start-up when housing is open.

b) Rotor locking devices should be made available to prevent rotation during maintenance & Inspection.

c) The width of the crusher feeding devices (feeders, screens or scalpers) shall be equal or slightly smaller to width of the crusher rotor(s).

d) Roller circumferential velocity shall be in the range of 5 to 10 m/s.

2.1.1.4 *Crusher Feed*

2.1.1.4.1 Crusher Feed Hopper

a) A truck stop block shall be placed at the edge of the hopper. The height shall be half of the wheel diameter of the biggest truck/front loader and shall not hamper the dumping process.

b) Safe platform and access shall be provided to allow for inspection, maintenance and de-blockage of hoppers.

c) Hopper live capacity shall be at least 2.5 times the truck capacity if not otherwise specified in the project description.

d) If the hopper design is steel, the slope of the hopper valley shall be:
   - at least 60 degrees for free-flowing materials (H_2O < 8% indicative)
   - at least 65 degrees for sticky materials (H_2O > 8% indicative)

e) Corners of the hopper shall be rounded for sticky materials.

f) Hopper geometry in the sense of advancement of the apron shall allow free easy flowing of material.

g) Hopper wall linings shall be suitable for materials characteristics, especially for wear and stickiness.

h) Connection between hopper and extraction equipment shall be fitted with bolt-in liners of suitable thickness. These liners shall be fixed on a frame that is independent to the hopper support frame.

i) In case of concrete hopper it will be reinforced by rail included in the concrete.

j) Distance minimum required from hopper to crusher (to the control material to crusher).

k) Chain curtain or other suitable device are to be provided to prevent feed material running through and damaging the crusher.

l) The hopper and extraction shall be designed such that the area above the crusher that is required for servicing can be made clear for removal of crusher parts with a crane.

m) The feed hopper shall be designed to allow for removal of the feeder by unbolting of the support structure.

n) Feeder to be sized and designed to prevent bridging in the hopper.

o) The feed hopper level shall be automatically controlled with radar type level sensor coupled to a traffic light configuration to control truck tipping. Tipping on to an empty feeder should be avoided. CCTV camera or mirror to be provided to enable the operator to have better control.

2.1.1.4.2 Secondary (and Fine) Crusher feed ***(For Aggregates only)***

a) Every secondary, tertiary and quaternary crusher will be protected with a metal detection system that will shut the feed off to the crusher or surge bin prior to metal entering these.

b) In all other instances, and for in particular for all closed circuit applications, secondary tertiary and quaternary crushers will be control fed using a surge bin with a variable rate feeder.

c) All crusher surge bins shall have a minimum of 15 minutes of live feed capacity based on the maximum instantaneous feed rate between 15% and 85% of the live feed storage levels.

d) All surge bins shall operate with bin level radar sensors to measure the bin volumes.

e) All surge bins shall be of rock box type to minimize wear.

f) All surge bins shall be enclosed to minimize fugitive dust with inspection covers on top and maintenance doors on the lower sides for personnel access provided.

g) Discharge areas under crushers shall be fully contained to prevent material spillage and escape of dust.

h) Spill isolation (rod) gates shall be provided above the extraction feeders for maintenance purposes.

i) Bin discharge feeders can be variable speed controlled pan feeders or conveyor belts. Pan feeders can feed directly to the crusher or to an intermediate belt.

j) The bin and feed arrangement shall be designed such that the area above the crusher required for servicing can be made clear for removal of crusher parts with a crane.

2.1.1.4.3 Apron Feeder

In addition to Paragraph 4.4 (Apron Feeders), the following criteria shall be met:

a) Inclination angle shall be 19 - 26 degrees with open hopper.

b) Inclination angle shall be less than 26 degrees with closed hopper fitted with layer height regulating system.

c) Apron shall be supported in the impact zone by heavy duty fixed rollers under chain or impact profiles with automatic greasing.

d) Speed variation shall be of adequate range (typically 10:1) in order to cope with the feed rate and the materials to be fed.

2.1.2 Screening

a) Preference will be given to screen sizes and types standardization within the whole plant to the extent possible without compromising on screening efficiency.

b) Screen synthetic cloth set-up shall be staggered to minimize carry-over.

c) Screens will be preferably fed from behind. If design does not allow, engineered solutions shall be provided and reviewed by the Owner to address maintenance and housekeeping issues.

d) Screens shall be fed preferably by feeders having width equal to the screen's width to ensure even distribution of the material over the entire width of the screen. Only in exceptional situations when the feeder cannot be accommodated in the layout, feeding can be done from a conveyor discharge rock box that will be designed to distribute the material centrally and evenly over the width of the screen to ensure maximum usage of available open screening surface/area.

e) The conveyor discharge/screen feed box shall include a dead bed to prevent material from being discharged directly from the conveyor onto the screen in absence of the feeder.

f) Screen towers will provide continuous vertical support columns under the screen spring mounts to the foundation.

g) Provisions will be provided for lifting with sufficient clearance and capacity in order to remove and install the regular wear material and drive system components.

h) Prior to installation of the screen, the support base will be checked for level from side to side and to ensure that the mounting holes are in the correct locations. Steel shims will be added to level bases that are to the same size as the screen mount and these shall be stitch welded to the tower.

i) Hoppers/under-pans under screens will have a hinged and bolted closed access doors that will open out. The access door is to be accessible from the screen tower walkways and will be able to be used to clean the hopper/ under-pan and perform maintenance within the hopper.

j) Screen under-pans will be fitted with bolt in wear protection. This is preferable in the form of "rock ladders", but abrasion resistant liner plates where material characteristics dictate, may be acceptable.

k) Screen under-pans will be designed such that no material build up takes place which will create spillage or contact with the screen body. Minimum valley angle shall be adapted to material characteristics.

l) When the screen hood is in the rolled out position, handrails will protect the area between the screen and the hood from access. An access platform is required to provide access to the upper and lower screen areas when the hood is rolled out of position. Platform has to be adequately articulated and hinged to allow positioning with no effort.

m) Discharge hoods shall be of roll away design and be provided with anchor points to permit hoods to be opened and closed with mechanical assistance.

n) Each discharge hood will include an inspection door on each side to inspect the intermediate and lower screen deck at the discharge end of each screen. The inspection door shall be able to be opened and closed without the use of heavy tools.

o) Discharge hoods shall be considered as chutes in accordance with the relevant section of this StDC.

p) Maintenance access shall be provided in discharge hood/chute for wear component inspection and replacement.

q) Screen set up and media selection shall ensure no “blinding” takes place.

r) Screen tubes or exposed members feed box and discharge lips to be rubber lined.

s) Side plates to be protected by wear media fastened above screen media.

t) Spring guards to be fitted to prevent pinch points.

u) For stopping the device oscillation shall be controlled by an electrical break function.

2.1.2.1 *Grizzly (Scalper)*

a) The Grizzly frame shall be bolted and its internal side walls shall be wear protected with replaceable liners.

b) The Grizzly shall be supported on the frame by means of vertical springs.

c) The screening bars shall be of trapezoidal shape.

d) Collecting hopper valley (corner) angles shall not be less than 65 degrees to ensure the material flows freely.

2.1.2.2 *Wobbler (Scalper)*

a) Frame side walls shall be covered with replaceable, bolted wear resistant liners.

b) Adjustable scrapers or teeth shall be installed underneath each shaft.

c) Sprockets shall be of segmented design with reversible segments.

2.1.3 Vibrating Screen

a) Vibrating screens shall be of the inclined type minimizing wedging and plugging.

b) Vibrating screens shall have a central lubrication unit.

c) For dry screening, collecting hopper valley (corner) angles shall be minimum 65 degrees.

2.1.4 Preblending Storage

2.1.4.1 *General*

a) Preblending Storages shall be covered to comply with the local/country regulations for environment protection against fugitive dust emissions.

b) Preblending pile formation shall be according to:

- The Chevron or the Windrow method for longitudinal preblending piles
- The Continuous Chevron (Chevcon) method in case of circular preblending piles

c) Piles width shall allow for at least 250 layers of material.

d) The length to width ratio of longitudinal preblending piles (including the end cones) shall be not less than 4:1.

e) Circular preblending storages shall be sized based on a stacking angle of minimum 110 degrees.

f) Preblending storage sizing shall ensure a minimum distance of 1m between nominal pile base and reclaimer rails.

g) Stockpiles and surge piles perimeter shall be enclosed, with restricted access signage.

2.1.4.2 *Stacker*

a) The luffing boom type stacker is the preferred selection for pile formation of preblending piles.

b) Preblending storage sizing design shall aim at a high number of layers. The stacker travel velocity shall ensure the number of layer of at least 250.

2.1.4.2.1 Side Stacker

a) For longitudinal preblending storages, the stacker shall be operated with variable travel reversing points to minimize segregation effects in the end-cones.

b) The stacker shall not interfere with the reclaimer boom to allow crossing.

c) Stacker boom luffing control shall allow for limited height of fall of the material (less than 1.5 m) thus ensuring reduced dust development. The end of the boom in its lowest position shall be not more than 1.5 m from the pile floor.

d) Boom luffing system shall be designed to avoid any uncontrolled boom luffing movement.

e) Boom belt conveyor design shall be in accordance with the Design Criteria for belt conveyors whenever it applies, refer to Paragraph 4.6 (Belt Conveyors), with the exception of:

- The boom conveyor velocity shall not be higher than 2.5 m/s

f) The stacker feed chute shall be protected by replaceable (bolted) wear liners.

g) Boom design shall either allow for adjustment of the head pulley position or include an adjustable baffle plate in order to optimize pile positioning.

2.1.4.3 *Bridge Type Reclaimer*

Selection Application of bridge type reclaimer is prerequisite for any preblending.

2.1.4.3.1 Rake Type Reclaimer (for “A”-shaped Piles)

a) Rake design shall ensure adjustment of the rake’s operating inclination in a range of at least +/- 5 degrees with devices available on board of the reclaimer.

b) Scraper chains shall be of wear resistant design. The chain sub-supplier shall be named and approved in writing by Owner.

c) Safety factor on chain based on nominal conditions shall be higher than 8.

d) Scraper blades shall be equipped with:

- Replaceable (bolted) liners at the cutting edges
- An adequate number of ripping teeth for loosening the stockyard floor

e) Chain guide tracks shall be lined with replaceable wear bars or easily replaceable supporting U-bars.

f) The chain drive sprocket wheels shall be:

- of segmented design with reversible segments,
- designed with at least 8 teeth, at least 12 teeth where reclaiming capacities exceed 800 t/h.

g) Scraper chain velocity shall not exceed 0.6 m/s.

h) The chain direction change for reclaimer with inclined delivery chute (for longitudinal preblending storages) shall preferably be realized with curved guide tracks rather than guide wheels (sprockets).

i) Reclaimer for circular storages, handling sticky materials, shall preferably be designed with the scraper chain running through the center column and discharging at the center of the collecting hopper.

j) The reclaimer shall be equipped with an automatic chain lubrication unit.

k) The relocation velocity of the reclaimer for longitudinal storages shall be at least 10m/min.

2.1.4.3.2 Bucket Chain-Type Reclaimer (for Preblending Pits)

a) Scraper chains shall be of wear resistant design. The chain sub-supplier shall be named and approved in writing by Owner.

b) Safety factor on chain based on nominal conditions shall be higher than 8.

c) Scraper buckets shall be equipped with replaceable liners at the cutting edges.

d) The reclaimer shall be equipped with a bucket cleaning device.

e) Scraper buckets shall be supported by outbound rollers.

f) The chain drive sprocket wheels shall be of a segmented design with reversible segments.

g) The reclaimer chain velocity shall not exceed 0.5 m/s.

h) The reclaimer shall be equipped with an automatic chain lubrication unit.

i) Transversal belt conveyor design shall be in accordance with Paragraph 4.6 (Belt Conveyors) exception that the conveyor speed shall not exceed 1.6 m/s.

j) The relocation velocity of the reclaimer shall be at least 10m/min.

2.2 Raw Meal Preparation

2.2.1 Raw Material Grinding

2.2.1.1 *Vertical Roller Mill*

a) For maintenance operations, the mill shall be isolated from hot gas (up- and downstream) by a shut-off gate guillotine type located in the ducts.

b) Main access doors shall be separately locked to prevent mill start-up when housing is open. The unique “trapped” key for the lock shall be obtained from the respective motor feeder/switchgear during stoppage (see Electrical StDC – General Requirements).

c) Safety sensors shall be installed on housing and doors to prevent mill start-up when the access door is open.

d) A short collecting belt conveyor collecting fresh feed and recirculation material shall be considered.

e) External material recirculation shall be designed for minimum 50% of nominal production rate.

f) Material feed rotary airlock is preferred. Special design considerations (i.e. heating, number of compartments) in case of difficult material shall be considered.

g) If reaction time between weight feeders and mill is longer than 50s, variable speed drives in the transport circuit shall be installed.

h) Mill shall be protected against tramp metal by a magnetic separator and a metal detector.

i) Water injection shall be provided in front of the rollers for the control of mill stability. The water flow shall be controllable and equal to each roller. The spray pipes shall be positioned close to the bed of material and shall be abrasive resistant and easy to remove.

j) In case no permanent installation is required, the design of the system shall allow for the installation of a temporary HGG.

k) Fresh feed chute and reject cone shall feed material to center of table.

l) Special attention shall be given to the design of chutes to avoid blockages. The mill feed chute shall be equipped with an inspection door.

m) Roller specific force of pressure shall not exceed 800 kN/m2 for raw material grinding. The mill main drive shall be based on a fixed speed of 900 rpm for a 60 Hz motor, or 1000 rpm for a 50 Hz motor if fix speed motor is applied.

n) Templates (i.e. gauges) for measuring roller and table wear shall be provided. Maximum permitted wear shall be indicated.

o) Material for roller and table liners will allow resurfacing operations, except in case of liner with ceramic inserts.

p) The mill shall be wear protected in the areas from the housing to the separator. Choice and location of wear materials shall be approved in writing by the Owner.

q) The specific loading of the rotor of the internal separator shall be ≤ 10t/hm2.The separator cage shall be capable of achieving minimum 25 m/s circumferential velocity.

r) Equipment for the grinding force generation (“mill’s hydraulic system”) shall allow for a reduction of 10% of actual grinding force within a time period of maximum 10 seconds. Lifting of the grinding rollers during operation shall be possible.

s) Oil piping shall be routed in channels covered by steel gratings.

t) The hydraulic and lubrication units shall be installed in a closed room with proper filtration and cooling devices.

2.2.1.2 *Other Raw grinding systems*

Design Criteria of alternative raw grinding systems shall be reviewed and approved in writing by the Owner.

2.2.1.3 *Cyclones*

a) Cyclone cylinders and riser ducts shall be equipped with openings for support beams in order to facilitate the erection of scaffolding inside the vessels.

b) The cyclone(s) separating the meal from the gas flow shall be equipped with wear protection lining at inlet section. Exceptions shall be subject to written approval by the Owner.

c) Insulation of the cyclones is required.

d) Rotary type airlocks shall be provided at the material discharge.

e) Only high efficiency cyclones are accepted. The pressure drop across the cyclones shall not exceed 12 mbar.

f) Manual slide gate shall be provided above rotary air lock.

2.2.2 Raw Meal Homogenizing - Continuous Blending Silo

a) All access openings in silo roofs shall be equipped with a removable and lockable safety grate under its cover.

b) The silo roof shall have (y) openings arranged around its perimeter to permit access to the silo for cleaning and inspection. The number of openings shall be calculated according to the formula: y = D/2.5, where D = nominal silo diameter in meters. The number of openings shall be not less than 4. Size of clear opening shall be minimum 1000 mm X 1000 mm.

c) The silo feed shall be arranged to ensure equal distribution (spider/umbrella airslide feed).

d) The silo shall be equipped with a pressure equalization valve.

e) In the case of a central inverted cone silo, the preferred width of the annular bottom section between vertical silo wall and base of inverted cone shall preferably be 1.5 – 2 m, but not exceeding 2.5 m.

f) The number of sectors (z) for all central inverted cone silos shall be related to the silo diameter. Calculated as follows: z = D, where D = nominal silo diameter in meters.

g) The length of the bottom aeration air pad elements shall be shorter than 2.5 m, preferably shorter than 2.0 m.

h) Aeration air distribution shall be based on solenoid valves and not on mechanical air distributors.

i) Aeration Equipment shall allow emptying of silos to at least 98%.

j) Every silo outlet shall be equipped with a manual and automatic shut-off gate, as well as a modulating flow control gate (the latter two functions may be combined in a single device).

k) Every silo outlet line shall be sized to allow material reclaiming at nominal silo extraction rate.

l) In case of flat bottom silos, the side bottom wall shall be provided with 4 numbers of openings (1.5 meter from bottom), 90 degree apart. Sizes of clear opening should be minimum 1000 mm X 1000 mm.

m) In case of inverted cone silos, the side bottom wall shall be provided with 2 numbers of openings (1.5 meter from bottom), 180 degree apart. Sizes of clear opening should be minimum 1000 mm x 1000 mm.

n) In case of inverted cone silos, cone inside shall be provided with 2 numbers of opening (to be located at 1/3 of cone height from top) 180 degree apart. Sizes of clear opening should be minimum 1000 mm x 1000 mm.

2.3 Clinker Production

2.3.1 Kiln Feed System

2.3.1.1 *Kiln Feed Bin*

a) Kiln feed bins shall be sized to enable kiln operation at nominal rate for at least 20 minutes.

b) Kiln feed bins shall be placed on load cells to enable on-line loss-in-weight calibration of downstream dosing Equipment.

c) Kiln feed bins shall be equipped with two outlets. One of the two outlets shall be designed as a bypass of the kiln feed rate control system to be used in case of a failure. The by-pass outlet shall be equipped with an impact flow meter for control.

d) Each outlet shall be equipped with a manual and an automatic shut-off gate as well as a modulating flow control gate (the latter two functions may be combined in a single device).

2.3.1.2 *Kiln Feed Rate Control*

a) The kiln feed dosing Equipment shall be designed with 20% reserve based on nominal kiln feed rate.

b) Kiln feed rate shall be preferably controlled by means of a gravimetric rotor scale or a Coriolis-type flow meter. In case of specific requirements, also belt weigh feeders may be considered.

c) Required accuracy of the feed rate control Equipment:

- Long term accuracy better than +/- 0.5%
- Short term accuracy better than +/- 1%

d) Adjustment range shall be not less than 10:1.

e) Response to set point changes < 10% shall be less than 1 min, (i.e. that 1 min after changing the set point, the values shall be in 1.0% range of the corresponding 10 min mean value).

2.3.2 Kiln Dust Handling

2.3.2.1 *Kiln Dust Transport*

a) A separate transport line shall be provided for conveying kiln dust from the dust collector to the kiln feed bin directly or to a dust silo if foreseen.

b) In case of compound mode operation the bag house dust and the dust separated at the cyclones of the raw mill shall go together directly to the homogenization silo and in case of direct mode operation the baghouse dust shall go directly to the kiln dosing system or a separate kiln dust bin alternatively depending on quality requirements. Deviation from the Standard shall be defined specific to the scope of project.

c) Possibility for kiln dust weighing by truck shall be possible.

d) The kiln dust delivery to the kiln feed bin shall be arranged close to its center, when the kiln dust is transported to the kiln dust bin.

2.3.2.2 *Kiln Dust Bin*

a) A separate kiln dust silo as future option shall be included in the layout.

b) Kiln dust bin shall be equipped with:

- dust collector
- pressure equalization valve

c) The conical part of the kiln dust silo shall be inclined by not less than 65 degrees.

d) Each outlet shall be equipped with a manual and an automatic shut-off gate.

2.3.2.3 *Kiln Feed Transport and Distribution to various Preheater Feed Points*

a) Vertical kiln feed transport to preheater feed points shall be by bucket elevator. It shall be belt type.

b) Kiln feed distribution to the different preheater feed points shall be realized by means of air slide diverter devices.

c) Kiln feed chutes to the preheater shall include for all feeding points a rotary air lock followed by an automatically operated slide gate.

d) Kiln feed conveying lines shall be sized with a 20% reserve based on nominal kiln feed rate.

2.3.3 Basic Data for Equipment Design, Nominal Gas Flow

a) The Standard kiln system shall be designed assuming that all available AFR is fed only to the precalciner, and in the main burner only project specific (noble) fuel is fired.

b) In order to consider all effects from fuels and AFR, the kiln system shall be designed according to the **Nominal Gas Flow.**

c) **Nominal Gas Flow** is using 100% of the project specific fuel.

d) The **Nominal Gas Flow** is the gas flow for nominal production at calculated heat consumption and fuel split main burner/precalciner: 40%/60%.

e) The thermal energy consumption shall be calculated by the supplier using his equipment performance and calculation tool. Preferably, the guaranteed heat consumption figure of the supplier shall be used for calculation of the nominal gas flow. However, the guaranteed heat consumption figure of the supplier shall be checked in any case by Holcim.

f) The Nominal Gas Flow for sizing the kiln system shall be based on the following O2 levels depending on the fuels specified in the Project.

g) Depending on the Project specific fuels, the following O2 levels shall be used for calculation of the Nominal Gas Flow for sizing of the main equipment:

Fuels	Rotary Kiln inlet	Calciner exit	Preheater exit
	% O2		
Fuel oil, natural gas	2.0	2.0	3.0
Bituminous coal, lignite	3.0	3.0	4.0
Petcoke, anthracite, AFR	5.0	4.0	5.0

Table 1: O2 levels for Nominal Gas Flow on dry basis

h) The equipment sizing specified on the actual gas flow shall be based on the existing altitude of the kiln system.

2.3.4 Preheater

2.3.4.1 *Preheater General*

a) The preheater shall be equipped with sufficient poke holes including adequate refractory design.

b) Platforms shall be provided to all cyclone roofs, cyclone outlets, tipping valves, poke holes, air cannons, instruments and access openings.

c) Cyclone cylinders, cyclone riser ducts shall be equipped with openings for support beams in order to facilitate the erection of scaffolding inside the vessels.

d) A scaffolding concept for future repair, replacement or checking of refractory and dip tubes, including transport & storage of material shall be prepared by the Supplier.

e) The cyclone preheater shall have 5 stages unless the project specific requirements, as elaborated in Contract document Owner’s Project Description and Scope, specify a different number of stages.

f) Single string preheaters are preferred over double string preheaters unless the project specific requirements, as elaborated in Contract document Owner’s Project Description and Scope, specify multiple strings.

g) If defined in the scope of project the preheater tower shall be designed for future optional installations of Equipment for the processing of Alternative Fuels and Raw materials to be fed at the correct places to the precalciner. The following shall be ensured:

- Space for future installation of transport Equipment, feeding Equipment and small intermediate bins; alternatively, a building extension close to the calciner (see chapter 3.2. Alternative Fuels Preparation and Handling). A sketch showing the future installation for transporting and feeding of AFR to calciner shall be prepared by the supplier.
- Additional load bearing reserves for the preheater structure at precalciner level shall be included.
- The location and details of the Alternative Fuels and Raw materials feed points shall be approved in writing by the Owner.

h) The size of the cyclone preheater shall be selected in order to achieve a low pressure drop. Pressure drop from inlet of bottom cyclone to exit of top cyclones shall be < 45 mbar (for 5 stage preheater) at Nominal Gas Flow.

i) The gas velocity in the riser ducts of the cyclones at Nominal Gas Flow shall not be less than 11 m/s. The preheater shall be capable of operating at 70% of Nominal Gas Flow without material dropping down the riser ducts in counter flow to the gas stream.

j) In case of uncritical fuel and raw material, a minimum of 25 air cannon connections including adequate refractory design shall be installed. For difficult fuel and raw material, this shall be increased and agreed with the Owner. In any case, an additional set of 15 air cannons including nozzles shall be supplied and put on stock. For the project it shall be ensured that at least 40 air cannons can be operated after the commission period and sufficient provision for compressed air, electrical connections and control is provided. The air cannons shall be designed with 100l vessels and operated with 8bar net. Isolation possibility of the air blasters shall be ensured in any case.

k) All meal chutes and upper cyclones shall have refractory lining inside.

l) The selection, design and installation of refractory in the preheater shall be according to the refractory Design Criteria. Refer to Paragraph 2.3.11 (Refractories).

m) Material selection for load bearing components in the hot section shall provide for possible peak temperatures resulting from the Holcim refractory concept as specified in Paragraph 2.3.11 (Refractories).

n) In order to prevent premature failure due to corrosion, the following minimum steel thicknesses shall be provided:

Section	Thickness mm
Kiln inlet chamber	10
Kiln riser duct incl. calciner orifice	10
Bypass extraction	10
Riser ducts	8
Precalciner	8
Lowest cyclone roof/cylinder/cone	10/8/8
Downcomer gas duct	6

Table 2: Minimum steel thickness

2.3.4.2 *Cyclones*

a) All stages shall be equipped with dip tubes.

b) Segmented dip tubes shall be provided for all preheater cyclone except for top two stage cyclone.

c) The two lowest cyclones shall be designed to carry dip tubes with 25 mm thickness.

d) The cyclones shall have a cone angle of minimum 65 degrees.

e) The top stage cyclones dust loss shall not exceed 7% of kiln feed mass flow.

f) Horizontal surface shall be reduced to a minimum.

2.3.4.3 *Splash Boxes and Meal Chutes*

a) Splash boxes shall be equipped with inspection holes and poke holes on both sides. Covers of pock holes shall be secured with locking mechanism.

b) The meal chutes diameters shall be designed with a diameter of 0.1 x diameter of the cyclone, the 2 lowest cyclones shall be designed with a diameter of at least 800 mm (inside refractory). Minimum distance between splash box bottom and next lower cyclone roof shall be 0.5 m.

c) Minimum inclination of all meal chutes shall be 60° to horizontal at least for the two lowest cyclone stages.

d) Tipping valves shall allow full opening of the meal chute cross section.

e) Tipping valve shall be equipped with external knife or external roller bearing.

2.3.4.4 *Downcomer Duct between Top Stage of Preheater and ID Fan*

a) Vertical straight line downcomer duct arrangement shall be aimed for.

b) The downcomer duct shall be insulated to prevent dew point corrosion.

c) The exhaust gas duct from top cyclones to fresh air damper and/or down comer spray system shall be made of 16Mo3 or equivalent. In case of 6th stage preheater this guideline can be exempted.

d) In order to protect the ID-fan against overheating operating measures shall be taken (i.e. fresh air butterfly damper and downcomer spray system with twin fluid nozzles).

2.3.4.5 *Partial Kiln Gas Extraction ("Bypass")*

a) If specified by scope of project the layout shall foresee the future installation of a complete bypass with filter and stack.

b) Sufficient height of the kiln inlet chamber shall allow for later installation of a kiln gas bypass. The height shall allow the installation for the extraction of at least 10 % of the kiln exit gas volume.

c) The location of the kiln gas bypass take-off shall be a minimum 2 m distance from any meal feed points and before any meal curtain, if applied. The by-pass take-off shall be installed above the kiln and in kiln axis.

2.3.5 Precalciner

2.3.5.1 *Precalciner General*

a) Sufficient access for manual and automatic cleaning shall be provided along the entire calciner, riser and transition chamber. Design of civil structure shall be designed accordingly.

b) The entire precalciner shall be equipped with openings for support beams in order to facilitate the erection of scaffolding inside the vessels.
A scaffolding concept for future repair, replacement or checking of refractory including transport & storage of material shall be prepared by the Supplier and shall be discussed and agreed with the Owner.

c) The basic design for precalciner is an inline calciner type. Separate line precalciners are not accepted. A Pre-combustion chamber can be considered on specific projects.

d) The precalciner active volume shall be sized for the following gas retention time and fuel types according to the defined Nominal Gas Flow listed in Chapter 2.3.3 and at a gas exit temperature of 880°C.

Fuels	Gas retention time seconds
Fuel oil, natural gas	3.0
Bituminous coal, lignite	3.5
Petcoke, anthracite, AFR	≥ 5.0

Table 3: Precalciner gas retention time

e) For calculation of retention time, the volume inside refractory between first fuel feed point and inlet of bottom cyclone shall be used.

f) The solid AFR intended to be burnt in the calciner shall be sized for < 50 mm for 3-dimensional particles and for < 200 mm, if 2-dimensional particles are used.

g) The precalciner shall be capable of reducing thermal NOx generated in the rotary kiln (low NOx calciner).

h) Preferred technology is staged tertiary air design and staged meal feed to the calciner, so that a combustion zone with reduced burning conditions is ensured.

i) The layout shall allow later installation of a staged tertiary air supply.

j) The staged meal split is to provide a controlled hot zone in the calciner.

k) The precalciner shall be designed for reduction of CO to <500 ppm, e.g. by intense mixing of the gases after the NOx reduction zone.

l) Layout and design of precalciner and preheater structure shall provide sufficient space to allow easy installation of SNCR equipment. General layout shall include provision for storage and unloading facilities.

m) In case of an installed SNCR, the injection shall be installed at the last section of the precalciner, where gas retention time of min 2 seconds at about 900°C is ensured.

n) The selection, design and installation of refractory in the precalciner shall fulfill the criteria as detailed in Paragraph 2.3.11 (Refractories).

o) Material selection for load bearing components shall provide for possible peak temperatures resulting from the Holcim refractory concept (Refer to Paragraph 2.3.11 (Refractories)).

2.3.5.2 *Precalciner Orifice*

a) The gas velocity at the narrowest cross section of the riser duct (orifice) shall be designed for a gas velocity of 40 m/s at Nominal Gas Flow.

b) In cases where initially no coarse solid Alternative Fuel feeding to the precalciner is foreseen, the orifice can be designed for a gas velocity of minimum 30 m/s at Nominal Gas Flow, with the provision for future restriction to achieve 40 m/s. Minimum refractory thickness is 250 mm, maximum 400 mm, for adjustment of the gas velocity at the orifice.

c) The orifice length shall be minimum 1 meter including the expansion joint. The expansion joint shall be installed at the lower end of the orifice.

2.3.5.3 *Tertiary Air Duct*

a) The tertiary air duct take-off is detailed in Paragraph 2.3.10 (Clinker Cooler) of this document.

b) Adequate allowance for thermal expansion and sealing of the tertiary air duct is required.

c) Straight-line tertiary air duct arrangement shall be aimed for.

d) The air velocity in the main duct and in all non-vertical branches of the tertiary air duct shall be 30 m/s at Nominal Gas Flow.

e) Tertiary air dampers in horizontal sections shall be guillotine type, dampers in vertical sections shall be butterfly type.

f) At the bottom of any upwards bend of the tertiary air duct, provisions for safely cleaning-out of dust shall be provided.

g) One access door near the inlet to the tertiary air damper shall be provided.

2.3.6 Kiln Inlet Chamber

a) The kiln inlet chamber shall be sized to achieve a gas velocity of < 23 m/s at Nominal Gas Flow at the smallest cross-section.

b) The angle of the meal inlet chute shall be minimum 50 degrees.

c) The roof of the kiln inlet chamber (transition to the calciner orifice) shall have an angle of minimum 45 degree.

2.3.7 Selective non-catalytic reduction (SNCR)

2.3.7.1 *SNCR General*

a) The SNCR equipment has to be designed according to the Holcim & local health and safety guidelines, whichever is stringent. Additionally, ATEX norms shall be followed.

b) Design should have flexibility of changing reagents (40% Urea/25% aqueous ammonia solution) in view of varying market scenarios.

2.3.7.2 *Unloading and storage*

a) Unloading area shall be sealed by a concrete slab with a bottom slope > 1.5 % and the spillage shall be captured in the catchment basin underneath the tank.

b) Gas sensors with audio/visual signals for the operating personnel should be installed (alarm at ~ 400 ppm/stop at ~800 ppm) at the unloading area.

c) Emergency showers and eyewash stations must be available for the body and eyes close to the truck unloading area.

d) Unloading pumps shall have MOC of EN1.4571 or equivalent.

e) Flexible hoses with quick release coupling should be provided on the filing line and return vapor line from the tanker to the storage tank.

f) Double shell stainless steel tank shall be preferred over single shell tank for aqueous ammonia storage. Material of construction of aqueous ammonia storage tank and vapor collection tank shall be SS304/EN1.4307.

g) In case of single shell reagent storage tank, a concrete basin (emergency bund) shall be considered of at least 1.2 times of one tank volume to collect leaked aqueous ammonia solution.

h) Sprinkler system above the reagent storage tank shall be installed to suppress ammonia leakage.

i) The space between the double walls shall be equipped with a leakage indicator/NH3 sensor.

j) Flame arrestor on the storage tank venting valve shall be provided.

2.3.7.3 *Dosing of reagent*

a) A pressure control valve shall be installed in the upstream so as to ensure enough pressure is delivered to the injection controls.

b) Variable speed drive (VSD) for reagent dosing pump is preferred. The dosing ranges i.e. turn down ratio of reagent pumps and nozzles shall be approx. 10:1.

c) Flow meters in each nozzle line or at least for the total flow shall be considered.

d) The Reagent distribution unit shall be installed in a protected cabinet and shall be equipped with the gas detectors giving both sound and light alarms, and spillage tray.

e) Flushing system with water to be considered for injection pipes and nozzles during SNCR.

f) Shutdown in view of safety during maintenance.

g) Stainless steel (SS304) pipes shall be considered for the transport of the reagents from pump to nozzle, and pipe connections shall be welded to avoid leakage of reagent.

h) Reagent transfer pump shall be made of EN1.4571 or equivalent.

i) Nozzle shall be twin fluid design (compressed air & reagent), made of EN 1.4541 or equivalent and shall be heat and chemical resistant.

j) Nozzle shall be preferably automatic retractable type with quick release coupling.

k) At the preheater outlet NOx analyzer shall be considered for better control of NOx emission.

2.3.8 Rotary Kiln

2.3.8.1 *Process Technological Dimensioning of Kiln*

a) The rotary kiln length diameter ratio shall be between 12 and 15 and agreed with the Owner.

b) Fuel split main burner/precalciner of 40%/60%.

c) Kiln slope shall be designed for 3 – 4 %.

d) Entire kiln shell shall be of a single diameter.

2.3.8.2 *Mechanical Dimensioning of Kiln Shell*

a) The maximum bending stress for the shell under the tire shall be <12 MPa.

b) The maximum bending stress for the shell in the burning zone shall be <15 MPa.

c) The maximum bending stress for the shell in other sections shall be <20 MPa.

d) The Supplier shall prove the kiln design by static load calculations, as well as by submitting shear, bending and reference stress diagrams.

e) For 3 support kilns, kiln shell material shall be 16Mo3 (or equivalent) steel for elevated service temperature, starting from kiln discharge to tire #2 (including first section uphill). The remaining shell can be made of S235JRG2 or equivalent.

f) For 2 support kilns, 50% of the kiln length from kiln discharge, shell material shall be 16Mo3 (or equivalent) steel for elevated service temperature. The remaining shell can be made of S235JRG2 or equivalent.

g) The thickness changes from one kiln shell section to the other shall not exceed 25% (e.g. 80-60/60-45/45-35/35-25mm). In case the thickness change exceeds 25%, a chamfer of max. 10 degrees shall be applied.

h) Shell under the tire shall be equipped with a chamfer of maximum 14° to smoothen the transition to the neighbor sections.

i) In order to avoid spillages, gap of kiln inlet seal shall be restricted to max. 50 mm.

j) Kiln Inlet seal to be equipped with spillage collection. Area below kiln inlet seal to be barricaded and access to be restricted. Kiln Tires and Rollers.

k) The first and the last tire shall have the same diameters and width that a spare tire would fit on both places.

l) The support rollers of the first and the last station and their bearings shall be interchangeable.

m) The kiln shall be equipped with automatic hydraulic axial thrust equipment or equivalent. In case of 2 thrusters they shall be interchangeable and shall have its own accumulator as close as possible to the hydraulic cylinder.

n) The roller bearing housing shall be equipped with an oil sight glass for checking oil level and inspection doors properly located, enabling to check oil feeding distribution, clearance and trust ring and journal condition.

o) The bearings shall have lubrication with forced oil circulation for slow (inching) rotation speed (oil filter shall be installed in the stream coming from the pump).

p) The specific bearing pressure shall be below 4.5 N/mm2 (radial load on bearing divided by projected bearing area).

q) The surface of roller stations pits shall be sealed oil-tight to prevent that oil penetrates into the concrete pier.

r) The Hertzian pressure on kiln tires support rollers and thrust roller shall not exceed 450 N/mm2 for rigid supports or 550 N/mm2 for supports with self-alignment capabilities.

s) The hardness of tires (working surface) shall be > 190 HB, with max. 10% discrepancy compared to average.

t) The harness of rollers (working surface) shall be > 20 HB harder than the tire, with max. 10% discrepancy compared to average.

u) The Supplier shall prove the kiln tire support roller and thrust roller designs by static load calculations, which show bending stress and Hertzian pressure.

v) The thrust roller shall be designed with an application factor of 1.5 on axial load.

w) On two station kilns, supports with self-alignment capabilities, to maintain a uniform contact between tires and rollers, are mandatory.

2.3.8.3 *Kiln Drive*

2.3.8.3.1 General

a) In case of power loss (e.g. at incomer/utility) and/or communication loss, provisions (e.g. UPS) shall be made for immediate and reliable continuation of turning the kiln.

b) Kiln drives shall be of electro-mechanical type (no hydraulic drives).

c) Girth gear drives shall be self -aligning and keep the center distance between girth gear and pinion constant.

d) Mechanical requirements for equipment drives are described in chapter 4.35.8.

e) The kiln drive to be capable of turning the kiln from stop in the fully loaded condition. Starting torque versus operating torque shall be 250% during 60 seconds.

2.3.8.3.2 Normal operation

a) The maximal kiln speed shall be designed for a material residence time of 20 minutes.

b) Speed range shall be from 0.5 rpm up to maximum 5 rpm.

c) Speed steps shall be adjustable in steps of 0.1 rpm.

2.3.8.3.3 Start-up/stop

a) It shall be possible to turn the kiln continuously and/or in intervals at a speed of approx. 0.1 rpm.

b) The transition to normal operation shall be done automatically without human intervention (e.g. by using an overrunning clutch).

2.3.8.3.4 Maintenance

a) It shall be possible to stop the kiln at any position and to lock it safely.

b) It shall be possible to turn the kiln continuously and/or in intervals at a speed of approx. 0.1 rpm.

c) The auxiliary drive shall be defined as per basic requirements in safety document.

2.3.8.4 *Brick Retaining and Heat Protection Systems*

a) A double brick retainer (or a comparable design) with a minimum height of 50 mm, made of heat resistant steel shall be foreseen in diameter distance from the kiln outlet segments to allow 4 to 6 uncut brick rings.

b) The brick retainer ring design and location shall be approved in writing by the Owner.

c) Minimum specific installed cooling air flow is 1000m3/h per m2 shell area to be cooled. Minimum requirement is to simultaneously cool 25% of the kiln length with this specific cooling air flow. The system shall allow moving these 25% within 60% of the total shell length on the discharge side.

d) The static pressure of the kiln shell cooling air fans shall be at least 5 mbar. Fans shall be located on the down turning side (hot side) of the rotary kiln.

e) Additional cooling air fans for cooling of the tire shell sections (uphill and downhill) with minimum 20 m3/s per tire shall be provided.
This requirement does not apply to the feed side tire.

f) Nose ring cooling air nozzles shall be arranged evenly around 360 degrees of the kiln circumference.

g) Minimum nose ring cooling air shall be 0.33 m3/s per meter of kiln shell circumference. The air pressure at the nozzle inlets shall be minimum 20 mbar. For kilns with diameter ≥ 4.6 m, two cooling air fans shall be provided.

h) Kiln drive and roller bearings shall have a heat shield to protect them from heat emitted by the kiln.

2.3.9 Kiln Discharge Hood

a) Kiln seals shall be safely accessible for maintenance activities.

b) Sufficient number of openings shall be provided for manual or automatic cleaning with shock blowers of inclined sections.

c) For air velocity in the critical cross section of the kiln hood, refer to Paragraph 2.3.10 (Clinker Cooler) of this document.

d) Take off point for tertiary air; refer to Paragraph 2.3.10 (Clinker Cooler) of this document.

e) The seal between the kiln discharge hood and the grate cooler shall be of the labyrinth type. Refer also to Paragraph 2.3.10 (Clinker Cooler) of this document.

f) Openings shall be provided at kiln hood back wall and at kiln hood side walls for observation of burner and flame and clinker discharge. The openings at back wall shall be at least 200x200 mm big and the openings at the kiln hood side walls shall be at least 300x300 mm big. The openings at the kiln hood back wall shall be equipped with heat resistant zirconia or ceramic glasses and there shall be the possibility to remove safely clinker dust agglomerations.

2.3.10 Clinker Cooler

2.3.10.1 *Safety*

All inspection windows at lower and upper parts shall be made of security-glass (impact and heat resistant) and to equip with lighting.

2.3.10.2 *General*

a) The supplier shall provide the air- and heat balance of the cooler at nominal- and upset conditions. These balances shall be calculated based on the Nominal Gas Flow and for a clinker inlet temperature of 1450°C.
If the cooler is equipped with a middle air extraction, an air and heat balance at cooler upset condition shall be provided both with and without middle air extraction.

b) The supplier shall provide an aeration scheme (flows and pressures) at nominal and up-set aeration rate.

c) Cooler Upset Condition is defined as 130% of nominal clinker production, 100% of installed cooling air volume, fuel rates and combustion air volumes as specified in Nominal Gas Flow.

d) In addition, thermal efficiency shall be calculated using the reference recuperation airflow to kiln of 0.8 Nm3/kg clinker.

2.3.10.3 *Grate*

a) The specific grate area loading of the cooler shall be maximum 45 t/(d m2) at nominal capacity up to an altitude of 1000 m ASL. For plants located higher than 1000 m ASL, the specific grate area load shall be reduced and shall be approved in writing by the Owner.

b) The grate section at cooler inlet shall be of static type and equipped with adequate numbers of air cannons with vessels of at least 100 liter and 8bar (for coolers > 8000 t/d 10 bar) and adequate number of nozzles.

c) Clinker cooler drives shall be of the hydraulic type. A stand-by pump shall be installed.

d) The specific grate width load shall be within the range of +/- 150 t/(d m) of 930 t/(d m) + Clinker production [t/d] x 0.08 m-1.

e) The inclination of the fixed grate shall be in the range of 12-15 degree.

f) The clearances in between grate plates shall be submitted to the Owner for review and confirmation.

g) The horseshoe of the fixed cooler inlet shall be equipped with at least 6 air blasters up to 2000 t/d and at least 10 air blasters for more than 4500 t/d clinker capacity for reliable snow man removal.

2.3.10.4 *Aeration Equipment*

a) The cooling air fans shall include suction side silencers and expansion joints at the outlet.

b) The installed specific cooling airflow shall be not less than 2.2 Nm3/kg clinker including fan reserves at the highest monthly average daytime ambient temperature.

c) The installed pressure of each fan shall allow the above 2.2 Nm3/kg clinker aeration at nominal capacity.

d) The installed specific aeration on the fixed inlet section shall be minimum 1.8 Nm3/(m2 s).

e) The static pressure of the fans for the fixed inlet shall allow an under-grate pressure for a minimum of 120 mbar.

f) Air velocity in the air ducts shall not exceed 20 m/s at nominal capacity.

g) All the cooler outlet ducts shall be wear-protected (including expansion joints).

h) Fan speed shall not exceed 1500 rpm for 50 Hz motors and 1800 rpm for 60 Hz motors.

i) All impellers shall be directly driven by the motor shafts.

j) Before shipment to site, the Owner shall be given the opportunity to attend a performance test of all cooling air fans at the manufacturers' premises, to verify compliance with the technical specifications.

k) The cooling air intakes shall be equipped with a mesh at the inlet duct to prevent entering of pieces from outside into the fan. Furthermore, the arrangement needs completely prevent rainwater from entering the equipment and to minimize sucking in of ambient dust.

l) Minimum fan efficiency shall be 80% at the normal operating point.

m) Static fan pressure at the fan outlet shall be indicated in the relevant data sheets.

n) Standard motor sizes shall be selected, ensuring a reserve of at least 10% of the power required for the installed fan capacity.

o) All fans shall be equipped with variable speed drives.

p) Each compartment shall be equipped with one fan only.

2.3.10.5 *Housing and Hoppers*

a) All viewing ports shall allow safe observation.

b) Clinker falling height (from inside kiln refractory to top of static inlet grate plates) shall be of ≥ 3.0 meters.

c) The tertiary air duct take-off shall be from the kiln hood.

d) In order to minimize clinker dust entrainment and "red river" formation, the take-off point of tertiary air shall be on the side where coarse clinker is discharged or in kiln axis.

e) Air Velocity in the kiln hood (and tertiary air take off from cooler roof if applicable) shall be less than 5 m/s at Nominal Gas Flow. The cross section is the area inside the kiln hood at the cooler roof level.

f) The Cooler casing height and location of middle- and waste air extraction points shall be designed for tunnel velocities not exceeding 8 m/s in the entire cooler.

g) Air velocity in the extraction hood of waste air and middle air shall be less than 7 m/s in all normal operating modes.

h) The seal between the kiln discharge hood and the grate cooler shall be of labyrinth type. Refer also to Paragraph 2.3.9 (Kiln Discharge Hood).

i) The cooler “bullnose” section (lower end of vertical back wall of cooler shaft, i.e. extension of kiln hood back wall) shall be equipped with a cooling air channel and fan. Adequate refractory consoles around the bullnose shall be provided, to isolate the bull nose mechanically from the surrounding refractory of the cooler roof and kiln hood back wall.

j) A minimum of two access doors shall be included above the grate level.

k) At least four viewing ports shall be provided: One at the discharge end wall of the cooler housing and the second at the side enabling observation of the static inlet zone. Minimum one viewing port shall also be installed at each side wall to allow observation of the clinker bed depth in the area of the second chamber or recuperation zone. Marks for clinker bed height detection shall be installed accordingly. Opportunity for safe cleaning of the viewing windows shall be ensured. The window at the cooler inlet shall be equipped with heat resistant glasses.

l) Each under grate compartment shall contain viewing ports and lights to allow observation of the mechanical components (rollers, cylinders) during operation.

m) Waste air and middle air channel arrangement shall ensure complete extraction of the burner (in one piece) from the kiln hood.

2.3.10.6 *Clinker Crusher*

a) Crusher rollers shall be retractable for maintenance. Supports and space shall be provided.

b) The clinker crusher shall be a roller crusher across the full cooler width.

c) All rollers except for the first and last, shall be reversible.

d) Automatic roller reversing control equipment shall be provided.

e) Safety factor for crusher power sizing: 1.5.

2.3.10.7 *Clinker Conveyor*

a) In addition to the Design Criteria in Paragraph 4.5 (Apron/Pan Conveyors), the following shall be applied:

- The clinker conveyor from clinker cooler to clinker storage shall be fabricated of steel. Bucket belt conveyor (for high conveying rates combined with large center distances) is Subject to Owners written approval.
- The clinker conveyor from clinker cooler to clinker storage shall be sized for 180% of nominal production; in case of an existing hammer type clinker crusher, this capacity shall be 200%.

2.3.11 Refractories

2.3.11.1 *Selection of Refractory Qualities and Refractory Design for Static Parts of the Kiln System (Preheater to Clinker Cooler)*

2.3.11.1.1 General Requirements for Static Parts

a) Refractory set up shall not exceed two layers.

b) Where winter- and summer conditions differ such that acceptable shell temperatures cannot be achieved mostly at both distinct conditions or where wind velocities are extreme, cladding of the buildings shall be considered.

c) Calcium-silicate-boards are only allowed in the cold section of the clinker cooler, cyclone stages I-IV (but not in the roof of cyclone IV), the hot meal ducts and the upper part of the tertiary air duct. Alumina lightweight firebricks or monolithic lining shall be used exclusively in all other applications.

d) All circular cross sections and arches shall be lined with bricks or precast and pre-tempered monolithic blocks and additionally with an insulating layer of monolithic lining or bricks.

e) In all flat walls with process temperatures above 650°C and monolithic lining, brick consoles shall be placed every ~ 2 m.

f) All brick consoles shall be cut perpendicularly at the hot face every ~ 0.5 m (to avoid warping of the consoles), if prevailing process temperatures are above 650°C.

g) All brick consoles shall be cut in the area of the expansion joints of the monolithic lining.

h) Tertiary air duct elbows (and tertiary air damper, where applicable) shall be equipped with SiC rich refractory material.

i) The cooler waste air duct up to the first cooling point (fresh air or heat exchanger) shall be refractory lined.

j) The cooler middle air duct up to the first cooling point (fresh air or heat exchanger) shall be refractory lined.

2.3.11.1.2 Requirements for Holcim Alkali Resistant Refractory Concept

The Holcim AR refractory concept shall be applied where high resistance against chemical attack and high temperature corrosion is needed, due to the use of alternative fuels and high sulfur petcoke.

a) Selection of Refractory Qualities and refractory design for Static Parts of the Kiln System shall be supplied according to reference refractory drawings per Contract document Refractory Concept (supplier specific).

b) The thickness of the insulation refractory shall be designed according to the expected average climatic conditions in Contract document Local Conditions, thus ensuring that steel shell temperatures of kiln system remain mostly above the water dew point and sulfuric acid (H2SO4) dew point temperatures. The required target steel shell temperatures for the different components of the system are specified in Contract document Contractor’s Information.

c) The kiln inlet chamber as well as all flat roofs and walls of the calciner, cyclones, gas risers and clinker cooler with prevailing process temperatures above 650°C shall be lined with a gas tight monolithic lining exclusively using high alkali resistant refractory materials.

d) All brick consoles shall be completely covered gas-tight by monolithic refractory lining and wrapped with insulating material (e.g. 3 mm ceramic paper to reduce the heat load on the consoles).

e) The detailed quality specifications for refractory, exemplary refractory design drawings as well as further illustrative information on the Holcim Refractory Concept and installation requirements are detailed in Contract document Contractor's Information and Contract document Project Description.

2.3.11.2 *Selection of Refractory Qualities and Refractory Design for Rotary Kiln*

a) Chrome-free refractory materials shall be used.

b) In order to ensure consistency, each supplied refractory quality shall be from the same production site (refractory plant).

c) Bricks shall be laid with mortar over a length of 1 kiln diameter in the tire areas.

d) In the section from the kiln outlet to the lowest tire bricks shall be laid with mortar.

e) The nose ring segments of the kiln outlet shall preferably be covered with a monolithic or precast refractory design.

2.3.11.3 *Selection of Steel Qualities and Design of Steelwork for Static Parts of the Kiln System (Preheater to Clinker Cooler)*

a) Anchors for the hot section of the clinker cooler, the kiln inlet, calciner, combustion chamber and bottom cyclone stage shall be heat resistant in air up to at least 1000°C and shall be made of a steel that does not readily form sigma-phase or other forms of embrittlement in repeated temperature cycles (e.g. AISI 310 H with Si <0.75%). The anchor diameter shall be at least 10 mm and the minimum anchor density shall not be less than 12 anchors/m2 in walls and 20 anchors/m2 in roofs. Where ceramic anchors are used also, the number of ceramic anchors is limited to 1/3 of the total number of anchors.

b) Anchors for the colder section of the clinker cooler and in the pre-heater tower (second lowest stage up to top cyclone stage) shall be made of AISI 304 or similar qualities. The anchor diameter shall be at least 8 mm and the minimum anchor density shall not be less than 12 anchors/m2 in walls and 20 anchors/m2 in roofs.

c) All steel anchors shall be of modern design (undulated and annealed, no welding at the hot face) and made of a single flat or double round bar.

d) In the hot sections of the Static Parts of the Kiln System (clinker cooler, kiln inlet, precalciner, combustion chamber and bottom cyclone stage), the following shall be applied:

- Load bearing brackets of cyclones shall be designed for at least 200°C in permanent operation.
- Structural beams that are in direct contact with vessels and gas ducts shall be designed for at least 200°C in permanent operation.

- Protection of civil structural beams against radiation of the vessels and gas ducts where necessary shall be provided by installing adequate insulation.
- Steel compensators of the vessels shall be designed for at least 200°C in permanent operation.

2.3.12 Firing Equipment

2.3.12.1 *Safety Requirements*

a) The safety requirements for combustion and fuel handling systems according to European Standard EN 746-2 shall be ensured. However, any other local regulations of the concerned country shall be considered, in particular, if these regulations are going beyond the European Standard EN 746-2.

b) Furthermore, panic stop push buttons shall be installed for emergency tripping of the complete kiln firing at following areas:

- Central control room
- Burner platform, close to kiln burner
- Precalciner, close to precalciner burners
- Hot gas generator

The complete kiln firing (all concerned fuel feeders and transports) shall be stopped immediately if one of the mentioned panic stop bottoms is pressed. The stop of the concerned fuel feeders and transports shall be done via a failsafe system.

2.3.12.2 *Sizing of Burners and Fuel Proportioning Equipment*

Equipment sizing shall be based on calculated heat consumption of the entire pyro-process, according to Nominal Gas Flow data as mentioned in Paragraphs 2.3.4 (Preheater), 2.3.5 (Precalciner) and 2.3.8 (Rotary Kiln).

a) Design thermal power of kiln burner:

- The **design thermal power** of the kiln burner shall be based on the required heat input into the rotary kiln at nominal production and nominal heat consumption at 45% fuel split to kiln burner.
- The nominal thermal power is used as basis for the design/calculation of the specific burner momentum. Refer to Paragraph 2.3.12.4 for Design Criteria on burner tips.

b) Design thermal power of precalciner burner:

- The nominal thermal power of the precalciner burner shall be based on the required heat input into the precalciner at nominal production and nominal heat consumption at 65 % fuel split to precalciner burner.

c) Coal mass flow to kiln burner and precalciner burner:

- Refer to Paragraph 3.1.6 (Pulverized traditional solid fuel feed rate).
- Minimum net calorific value of the used coal shall be considered.

2.3.12.3 *Precalciner Burners*

a) Design of separate pre-combustion chambers (i.e. downdraft calciner type) shall allow easy vertical adjustment and complete extraction of the burner in one piece.

b) The primary air amount including transport air shall not exceed 5% of stoichiometric combustion air, at burner nominal capacity.

2.3.12.4 *Kiln Burners*

a) The burner shall be designed project specific for a specific axial momentum of >10 N/MW. The total axial momentum is calculated by summing up the axial air momentum, axial component of radial momentum and coal/petcoke transport air momentum but excluding any other alternative fuel transport air momentum and fuel mass momentum. The axial momentum shall be calculated at the nominal thermal power of the kiln burner.

b) The specific burner impulsion of a single air flow at the burner is calculated by following formula: I = (m * v) / Q (I = specific impulsion [N/MW], Q = Thermal heat input at burner [MW], m = mass flow of primary air by blower [kg/s], v = air injection velocity at burner tip [m/s].

c) For the burners where the axial and radial air is a single adjustable stream (e.g. Unitherm MAS, Polflame VN), the momentum can be lower than 10 N/MW with the impulsion calculated using the axial-radial air nozzle speed and the mass flow in the nozzle (no radial angle).

d) Swirl of 0.15 shall be achievable.

e) The primary air blowers shall be designed for a static pressure at burner inlet of minimum 450 mbar. If a primary air fan is used, it shall be designed for a static pressure at burner inlet of minimum 200 mbar.

f) The primary air blower shall be equipped with a variable speed drive with at least 10% motor reserve. If a primary air fan is used, the fan shall be equipped with a variable speed drive with at least 10% motor reserve.

g) Burner carriage, slope of rails and supporting structure as well as connections shall allow for proper adjustment of the burner position within the kiln (center of kiln cross section, parallel to the kiln axis, adjustable from 0.5 m out of the kiln tube to 1.0 m in the kiln tube at hot kiln condition).

h) The burner static structure shall be designed for burner refractory load of 100 mm thickness.

i) The burner outside diameter, including refractory, shall be smaller than 20 % of the inside kiln diameter, inside refractory.

j) The burner channel for solid AFR feeding shall be 125 mm or larger.

k) The solid fuel injection velocity at the burner tip shall be according to the fuel type:

Solid fuel	Injection velocity at the burner tip m/s
Lignite	35 - 40
Coal	~25-35
Petcoke	~25
Anthracite	20 - 25
Solid Alternative Fuels	25 - 45

Table 4: Injection velocity at the burner tip

l) For solid fuel transport velocities: see Paragraph 3.1.7.

m) Burner platform design shall ensure the complete extraction of the burner in one piece from the kiln.

n) The burner shall be equipped with an emergency fan to protect the burner lance against overheating in case of primary air blower trips.

o) Burner shall be equipped to control for light diesel oil (LDO) and high speed (HSD) diesel flow from CCR (if LDO/HSD is applicable for heat up).

2.3.13 Fuel Preparation

2.3.13.1 *Coal/Petcoke*

Refer to Paragraph 3.1 (Traditional solid Fuels Preparation and Handling).

2.3.13.2 *Fuel Oil*

The preparation Equipment shall be capable of providing a heavy fuel oil temperature of at least 120°C minimum at the burner at the required pressure.

2.4 Cement Grinding

2.4.1 Vertical Roller Mill (VRM)

a) For maintenance operations, the mill shall be isolated from hot gas (up- and downstream) by a shut-off.

b) Main access doors shall be separately locked to prevent mill start-up when housing is open. The unique “trapped” key for the lock shall be obtained from the respective motor feeder/switchgear during stoppage (see Electrical Equipment Systems StDC – General Requirements).

c) Safety sensors shall be installed on housing and doors to prevent mill start-up when the access door is open.

d) Material feed rotary airlock is preferred. Special design considerations (i.e. heating, number of compartments) in case of difficult material shall be considered.

e) External material re-circulation shall be designed for minimum of 50% of production rate.

f) Contact between hot clinker/recirculation and moist additives on the transport system shall be avoided by separate transport systems. Fresh feed chute and reject cone shall feed material to center of table.

g) If reaction time between mill feed weight feeders and mill inlet is longer than 50s, variable speed drives in the transport circuit shall be installed.

h) Special attention shall be given to the design of chutes to avoid blockages. Mill shall be protected against tramp metal by a magnetic separator and a metal detector.

i) The mill main drive shall be based on a speed of 900 rpm for a 60 Hz motor or 1000 rpm for a 50 Hz motor if a fix speed motor is applied.

j) Ratio start-up/nominal motor torque, rollers in working position shall be >1.8.

k) The mill main drive shall be equipped with a variable speed motor where a wide range of products are produced or high fineness is required.

l) Water injection shall be provided in front of the rollers. The water flow shall be controllable and equal to each roller. The spray pipes shall be positioned close to the bed of material and shall be abrasive resistant and easy to remove. Use of internal water spray shall be limited to:

- Process gas dew points of maximum 55°C.
- The extent to which it does not impair cement quality, as indicated by dry powder flow ability, pack set index, false set index, and mortar strengths.

m) Templates (i.e. gauges) for measuring roller and table wear shall be provided. Maximum permitted wear shall be indicated.

n) Material for roller and table liners will allow resurfacing operations, except in case of liner with ceramic inserts. The mill shall be wear protected in the areas from the housing to the separator. The separator shall be capable of achieving min. 35 m/s circumferential cage speed.

o) Radial air velocity through the separator shall not exceed 4 m/s.

p) Equipment for the grinding force generation (“mill’s hydraulic system”) shall allow for a reduction of 10% of actual grinding force within a time period of maximum 10 seconds. Lifting of the grinding rollers during operation shall be possible.

q) Design shall allow to heat up to min 90°C gas temperature mill exit.

r) Oil piping shall be routed in channels covered by steel gratings.

s) The hydraulic and lubrication units shall be installed in a closed room with proper filtration and cooling devices.

t) Fresh air flap design shall result in a maximum inlet gas speed of 10 m/s.

2.4.2 Roller Press (RP)

a) Roller press shall be equipped with:

- Pressure relief devices fitted for security on hydraulic cylinders and accumulators
- An inching device for the maintenance of the press
- A hold-to-run control for inching drive
- A hold-to-run control if the inching device is being used

b) Main access doors shall be separately locked to prevent mill start-up when housing is open. The unique “trapped” key for the lock shall be obtained from the respective motor feeder/switchgear during stoppage (see Electrical Equipment Systems StDC – General Requirements).

c) If reaction time between weight feeders and RP is longer than 50s, variable speed drives in the transport circuit shall be installed.

d) Proper homogenizing and distribution of the feed material over the RP width shall be ensured.

e) RP shall be protected against tramp metal by a magnetic separator on RP feed and a metal detector associated with a diverter on RP feed and recirculation.

f) Special attention shall be given to the mill feed concept thus avoiding contact between hot clinker and moist additives on the transport system.

g) The design absorbed power shall be achieved by a specific pressure of max. 5000 kN/m2.

h) Special attention shall be given to the design of feeders and chutes to avoid blockages. The roller press main drives shall be based on a speed of 900 rpm for a 60 Hz motor or 1000 rpm for a 50 Hz motor if a fixed-speed motor is applied.

i) Templates (i.e. gauges) for measuring roller wear shall be provided. Maximum permitted wear shall be indicated.

j) Equipment for the grinding force generation (“mill’s hydraulic system”) shall allow for a reduction of 10% of actual grinding force within a time period of maximum 10 seconds.

k) For slag and slag cement grinding only highly wear resistant rollers are accepted.

l) Vibration level measured during operation on the gearbox input shaft shall be less than 8mm/sec.

2.4.3 Cyclones

a) Cyclone cylinders, cyclone riser ducts shall be equipped with openings for support beams in order to facilitate the erection of scaffolding inside the vessels.

b) The cyclone(s) separating the cement from the gas flow shall be equipped with wear protection lining at inlet section.

c) Insulation for the cyclones is required.

d) Rotary type airlocks shall be provided at the material discharge.

e) Only high efficiency cyclones are accepted. The pressure drop across the cyclones shall not exceed 12 mbar.

2.4.4 Tube Mill

a) Main access doors shall be separately locked to prevent mill start-up when housing is open. The unique “trapped” key for the lock shall be obtained from the respective motor feeder/switchgear during stoppage (see Electrical StDC – General Requirements).

b) The mill bearings shall be of the slide shoe type. Each slide shoe bearing shall be accessible for inspection through a sealed inspection door.

c) The minimum slot area in diaphragm shall be 7% of the total diaphragm area.

d) The inching drive (with anti-rollback device) shall be able to fix the mill in any position.

e) Mill rotation speed shall be less than 78% of the critical speed (using diameter inside liner).

f) At air velocity above ball charge of 1.5m/s, maximum speed at mill discharge shall not exceed 25 m/s. Maximum speed in partition wall shall not exceed 14m/s.

g) Maximum Temperature of material at mill exit shall not exceed 110°C.

h) Nominal mill capacity shall be achieved at ball filling degree of <30%. Mill internals design shall allow up to 32% of ball filling ratio.

i) Reducer and motor shall be designed for 105% mill power at 32% filling ratio.

j) Mill shell shall be stress released after welding completion and before final machining. Steel grade used for mill shell shall be weldable to allow repair work.

k) Mill design shall take into account at least one door per chamber, without opening close to the middle of the shell length. Shell reinforcement around door shall be done with one thick plate, riveted plate is not allowed.

l) To limit stress concentration, the ball mill slide ring design on “T” shape welds shall include a machined radius of R≥30mm after welding completion, with a roughness of Ra≤3.2.

m) To limit stress concentration, all openings on the ball mill shell such as doors, material outlet in case of central discharge, shall be designed with a radius of R≥100mm with a roughness of Ra≤3.2.

n) To limit stress concentration, liner bolts holes on the ball mill shell shall be machined with a roughness of Ra≤3.2 and shall be trimmed inside and outside the mill on about 1mm.

2.4.5 High Efficiency Separator

a) The separator shall be wear-protected.

b) A bolted opening shall be installed on the hopper and on the elbow above the rotor, for maintenance purpose.

c) The inspection door shall be designed at a minimum size of 500x500 mm.

d) A ball trap shall be installed on the dynamic separator feeding.

2.4.6 Cement Cooler

a) The cement cooler shall be of the internal mechanical lifting type.

b) The cooler shall be equipped with a manhole and cover for inspection of the internals.

c) The material feed and discharge openings of the cooler shall have flanged connections.

2.5 Cement Storage and Shipping

2.5.1 Cement Silo

a) All access openings in silo roofs shall be equipped with a removable and lockable safety grate under its cover.

b) The inverted cone concept is acceptable for all silo diameters independent of the discharge rate.

c) The regular cone concept for silo diameters greater than 12 m is acceptable only in cases when the discharge rate is greater than 500 t/h and the silo operation concept allows for complete emptying of the silo at regular intervals.

d) The silo roof shall have a number of openings (y) arranged around its perimeter to permit access for the purposes of silo cleaning and inspection. The number of openings (y) shall be calculated as follows: y = D/2.5 (rounded up to the next integer, but not less than 4), where D = silo nominal diameter in meters. Size of clear opening shall be minimum 1000 mm x 1000 mm.

e) In case of flat bottom silos, the side bottom wall shall be provided with 4 number of openings (1.5 meter from bottom), 90 degree apart. Sizes of clear opening should be minimum 1000 mm x 1000 mm.

f) In case of inverted cone silos, the side bottom wall shall be provided with 2 number of openings (1.5 meter from bottom), 180 degree apart. Sizes of clear opening should be minimum 1000 mm x 1000 mm.

g) The silo shall be equipped with a pressure equalization valve.

h) In the case of a central inverted cone silo, the preferred width of the annular bottom section between vertical silo wall and base of inverted cone shall preferably be 1.5 – 2 m, but not exceeding 2.5 m.

i) The number of sectors (z) for all central inverted cone silos shall be related to the silo diameter. Calculated as follows: z = D, where D = nominal silo diameter in meters.

j) The length of the bottom aeration air pad elements shall be shorter than 2.5 m, preferably shorter than 2.0 m.

k) Aeration air distribution shall be based on solenoid valves and not on mechanical air distributors.

l) Aeration Equipment shall allow emptying of silos to at least 98%.

m) Every silo outlet shall be equipped with a manual and automatic shut-off gate as well as a modulating flow control gate (the latter two functions may be combined in a single device).

n) Every silo outlet line shall be sized to allow material reclaiming at nominal silo extraction rate.

o) Provision shall be made for future installation of lump breakers after the manual shut off gates of all silo outlets.

p) Design of Silo dedusting shall prevent contamination of products.

q) A vibrating screen shall be installed in front of a packing plant and depending on local requirements also in front of truck bulk loading.

2.5.2 Truck/Rail Bulk Loading

a) ONE stop loading concept shall be implemented (opening of the hatch at the loading position).

b) Safe access shall be provided to reach the top of the trailer.

c) Permanently installed deployable handrail systems shall be used to provide continuous fall protection to any worker requiring horizontal mobility over a railcar or truck.

d) Loading platforms and access gangways shall be used to provide access to the top of cement bulk trucks and rail car loading station(s). An interlocking system shall ensure that the loading platform or gangway is safely and sufficiently out of the way before movement of the truck or railcar.

e) Loading spouts shall be retractable, vertical and horizontal travel shall be sized to reach the lowest hatch of a vehicle.

f) The loading spout shall be connected to a dust collector.

3. FUEL PREPARATION AND HANDLING

3.1 Traditional solid Fuels Preparation and Handling

Traditional solid fuels denomination applies to coals (anthracitic, bituminous, subbituminous, lignitic) and pet coke.

3.1.1 Traditional solid fuel – general

a) The Explosion and Fire safety concept shall be approved in writing by the Owner and a reputable commonly agreed third party expert.

b) Co-grinding shall be avoided in case of significant differences in grindability and volatiles.

c) The mill shall be equipped with water spraying Equipment for cooling of process gas (e.g. in coal mill inlet duct or in coal mill).

d) Preheater gases shall be cleaned preferably by a cyclone and a booster fan between preheater and coal mill.

e) The traditional solid fuel grinding unit shall be located near the suspension preheater in order to ensure the shortest possible gas ducts.

f) The accumulation of combustible dust layers on inside structures shall be avoided.

g) All endangered plant sections shall be designed to withstand explosion pressure shocks either up to the maximum explosion pressure encountered in an explosion or, when pressure relief devices are installed, up to the corresponding reduced maximum explosion pressure.

h) The following operation temperatures shall be respected for the grinding and drying design:

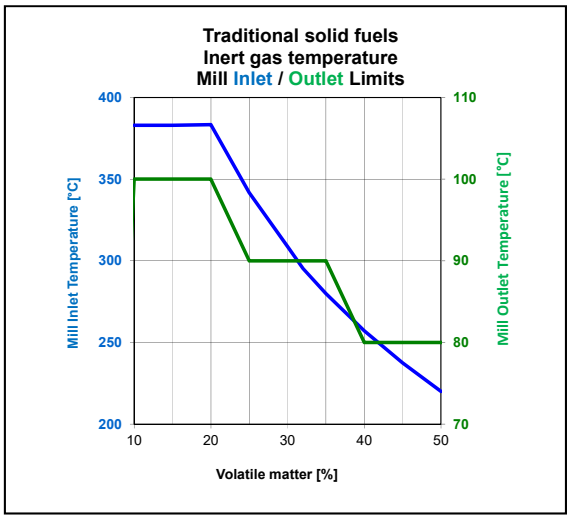


Figure 1: Grinding and drying operation temperatures

i) The mill shall be equipped with an inertisation facility (N_2 or CO_2).

j) Selection of low- or high-pressure CO_2 storage shall be approved in writing by the Owner.

k) The CO2 tank shall be sized for 4 kg CO2/m3 to allow for 2 times inertisation of free space (mill and separator, filter duct and empty fine coal bins).

l) The mill shall be isolated from hot gases by shut off gate (self-closing guillotine type).

m) An explosion protection concept for the whole grinding plant shall be developed by the supplier and approved in writing by the Owner.

n) The feeding Equipment shall be a rotary airlock of heat able or mechanically cleanable design if required by ambient conditions and coal moisture, or a screw type feeder.

3.1.2 Vertical Roller Mill

a) In case of grinding of different traditional solid fuel types the table speed shall be variable.

b) The entire installation shall be equipped with certified self-closing explosion valve(s).

c) The mill shall be wear protected in the areas from the housing to the separator. Choice and location of wear materials shall be approved in writing by the Owner. Dimensions of the mill structure shall allow removing the gearbox without dismantling equipment.

d) Material for roller and table liners shall allow resurfacing operations, except in case of liner with ceramic insert.

e) Templates (i.e. gauges) for measuring roller and table wear shall be provided. Maximum permitted wear shall be indicated.

f) Oil piping shall be routed in channels covered by steel gratings.

g) The hydraulic and lubrication units shall be installed in a closed room with proper filtration, cooling devices and adequate access for maintenance.

h) A metal separator and detector shall be installed upstream of the mill.

i) The mill main drive shall be based on a speed of 900 rpm for a 60 Hz motor or 1000 rpm for a 50 Hz motor.

3.1.3 Air-swept Ball Mill

a) Length to diameter ratio shall be larger than 2.3 (drying chamber not considered).

b) Drying chamber size shall be calculated for a maximum evaporation ratio of 150l/h/m3.

c) Mill rotation speed shall be less than 78% of the critical speed (using diameter inside liner):

- Nominal air velocity above ball charge shall be designed for more than 2m/s and limited to 4m/s. Maximum speed at mill discharge shall not exceed 22 m/s. Maximum speed in partition wall shall not exceed 12m/s.
- Ball filling ratio for mill design shall be <30%. Mill internals design shall allow up to 32% of ball filling ratio.
- Reducer and motor shall be designed for 105% mill power at 32% filling ratio.

3.1.4 Raw traditional solid fuel - Mill feed bin

In addition to Paragraph 4.14 (Feed Bins), the following Design Criteria shall be applied:

a) The conical outlet shall be manufactured of stainless steel.

b) Sufficient temperature monitoring devices shall be installed.

c) Internal surfaces shall avoid any material accumulation.

d) The bin shall be equipped with a dedusting unit.

3.1.5 Pulverized traditional solid fuel storage

a) Storages shall be equipped with:

- Explosion vents (sized according to EN 14491 or equivalent regulation)
- Vacuum breaker
- Dedusting units
- CO, O2 and sufficient temperature monitoring devices
- Provision to inert the bin at the top and bottom

b) The conical outlet of bins shall be manufactured in stainless steel and inclined by not less than 70 degrees.

c) Silo outlets shall be equipped with:

- Pneumatic or mechanical flow promotion device, ensuring the activation of the outlet. Pneumatic aeration shall be designed that either compressed air or CO2/N2 from Inertisation facility can be utilized.
- Manual and automatic shut-off gates for each outlet.

3.1.6 Pulverized traditional solid fuel feed rate control

a) Every feed rate control system for raw feed shall consist of a feed bin and gravimetric feeder.

b) Dosing equipment for kiln burners shall be designed to cover the heat input into the rotary kiln at design capacity and design heat consumption allowing 55% fuel split to kiln burner.

c) Dosing equipment for the precalciner burner shall be designed to cover the heat input into the precalciner at design capacity and design heat consumption allowing 75% fuel split to the Precalciner.

d) Feed rate control Equipment for pulverized fuel shall be gravimetric feeders.

e) Required feeder accuracy:

- Adjustment range: not less than 10:1
- Long term accuracy better than 0.5 %
- Short term accuracy better than +/- 1.0 %

f) Response to set point changes < 10 % shall be less than 30 seconds (i.e. 30 seconds after changing the set point, the values shall be within a 1.0 % range of the corresponding 10 seconds mean value).

g) Fuel rate control Equipment (feed bin and feeders) shall be weather protected.

3.1.7 Pulverized traditional solid fuel Transport Line

a) Pneumatic transport lines for pulverized traditional solid fuel shall be designed to provide pulsation-free transport.

b) Pulverized traditional solid fuel transport lines feeding the burners shall be shorter than 80 m and shall not have more than 5 bends.

c) Transport lines shall avoid any inclined or declined sections, i.e. horizontal and vertical sections only.

d) In case of split of the piping towards the calciner, the geometry and length of the coal pipes shall be similar to have approximately the same pressure drop and coal flow from the split to the injection points.

e) Diverter pots shall be installed exclusively (exception: the first directional change after the traditional solid fuel feeder shall be a tube bend).

f) The transport velocity for solid fuel (lignite, coal, petcoke, anthracite) shall be in the range of 24 - 35 m/s. in the entire transport line to the burner.

g) Dust concentration in transport air shall be <7 kg/m3 for pulverized coal, and < 5 kg/m3 for pulverized petcoke in the complete transport line.

h) Pressure fluctuations at the end of the transport line shall be less than 10% of average pressure and less than 5 mbar.

3.2 Alternative Fuels Preparation and Handling

a) Design for Alternative Fuels Handling shall be based on Volume Flow (m3/h) at a certain bulk density (t/m3).

b) Conical Hoppers are not permitted.

c) AFR, which may be carried away by wind or are source of dust, bad smell or leachate, shall be stored/handled in enclosed facilities/conveyors.

d) To avoid dust settlements on building structures, the “inside cladding approach” shall be applied for buildings handling solid AFR.

3.2.1 Coarse Solid AFR for Precalciner/Preheater Firing

a) The Design Criteria are applicable to coarse solid alternative fuel suitable for calciner firing with the following size specifications:

Particle Class	Example Material	95% < [mm]	100% < [mm]
1D	tapes, fibers, wires with width <50mm		2000
2D	plastic foils, single layer textiles and paper	200	300
2.5D easy deformable	2.5D is material which is “flat” but not as thin as a foil (max. thickness “2.5 mm”): hard plastic sheet, strong cardboard, foot wear, multi-layer 2D material	150	200
3D hard	tire chips, wood, rubber & plastic profiles, filter cake lumps	100	125 or 50 x 50 x 150
3D deformable*	Pet bottles		250

Table 5: Acceptable amount [mass-%] and chip size [mm]

The indicated numbers specify the longest side of a particle/chip. In worst case all three sides have this dimension (cube).

**) deformable by pipe conveyor when closing*

b) Screw conveyors/feeders: Only cantilevered screw design permitted (no shaft fixation/bearing at discharge side in order to avoid material wrapping around shaft).

c) Bucket elevators are only permitted for specific applications with Owners approval.

d) All conveyors after the gravimetric dosing shall be equipped with VSD.

e) A scarifying conveyor is required before calciner/kiln feed chute in order to protect the long conveyor coming from ground.

f) The belt conveyors shall be designed to have a filling rate lower than 75% at design capacity with the lowest bulk density. Unless specified differently the lowest bulk density shall be 0.1 t/m3.

g) In case of a magnetic separator, Magnetic Force Density shall be not less than 20 kDynes/cm3 in 200 mm distance. Magnetic separator shall be installed at the discharge point of the belt conveyor. Equipment within 1 m radius shall be non-magnetizable.

h) Feeding chute size shall be in minimum 650 mm x 650 mm (free opening section) and have an inclination of at least 65°.

i) Rotary airlocks shall be of heavy-duty design (must be able to cut a 5 cm wood log) and designed for max 33% filling degree. They must reverse in case of blockages. Infeed chute must be arranged such, that the material flows into the up-moving rotary cell. The circumference speed of the rotor shall not exceed 0.4m/s.

j) A power-fail safe (normal close) and heat resistant automatic shut-off gate shall be installed below the airlock device.

3.2.2 Fine Solid AFR for Main Burner or Calciner Control fuel firing

a) The Design Criteria are applicable to fine solid alternative fuels suitable for kiln firing (nominal < 50 mm).

b) The pneumatic transport rotary airlock shall be 10 bar pressure shock resistant and have pressurized purged air sealed bearings.

c) Pneumatic transport system shall be equipped with a VFD.

d) Wear protection shall be provided and easy rotor blade sealing shall be ensured.

e) Rotary valve leaking air shall be captured and dedusted if required.

f) Oversize particle separator shall be installed.

g) Magnetic separator shall be installed. Magnetic Force Density shall be not less than 20 kDynes/cm3 in 200 mm distance. Materials within 1 m radius shall be non-magnetizable.

h) The injection line to the kiln shall be short as possible, straight and of constant cross-section. Transport velocity shall not exceed 30 m/s. Bend radius shall be 10 x D.

3.3 Fire detection and fighting

a) All fuel installations shall be designed to meet applicable fuel design safety criteria based on a suitable Fire Risk Assessment (FRA) determining the probable areas where fuel sources and ignition sources could be in contact.

b) Suitable fire detection and alarm systems shall be installed for any covered/ enclosed storage/handling/processing area for combustible fuels.

c) Fire detection and alarm systems shall be redundant for flammable fuels or areas defined as High fire risk areas in the FRA.

d) All fire detection and firefighting systems shall be connected to a fail-safe power supply.

e) A suitable fixed installed fire control/suppression system shall be provided for any covered/enclosed storage area for flammable fuels. For combustible fuels such a system is only required, if a potential fire poses a high risk to the surrounding area/neighborhood.

f) Fire control/suppression systems shall be installed in accordance with local regulation. Without specific data, the discharge density shall be in no case less than 15 mm/min over a design area of 300 m2.

g) Fire control/suppression systems in high risk fire areas shall be automatically and manually activatable.

h) In case of sprinkler systems the maximum ceiling height (delta between roof and floor) shall not exceed 10.7 m.

i) Closed heads sprinkler systems (wet-type systems) are not permitted.

j) Firefighting systems must be of frost-proof design where the weather conditions require.

k) All belt conveyors conveying fuel shall be equipped with fire detection and shall be redundant for flammable fuels or areas defined as high fire risk areas in the FRA. Conveyor belts in areas defined as high fire risk in the FRA shall have a fixed installed fire suppression system for the carrying belt. At conveyor loading and discharge point (up to 15 m distance from pulley) it shall also cover the return belt. Discharge density shall be at least 10 mm/min per conveyor surface to be protected.

l) A redundant fire detection combined with a fixed installed suppression system shall be provided for the gravity feed point area, where combustible solid fuel is injected. The fire detection & fighting system shall in minimum cover, the transfer chute to the intermediate conveyor, the intermediate conveyor (before the airlock) incl. carrying and return belt, the transfer chute to the airlock and the airlock. Excluded from this requirement are pneumatic feed points.

m) Materials shall be not burnable to the prevailing temperature of 900°C at the feeding point.

3.4 Explosion prevention

a) In case of fuel containing fine combustible and dispersible dust/flammable vapors, equipment shall be Ex (ATEX or NFPA, etc.) certified. Ex zoning must be carried out as per IEC 60079-10-1 and IEC 60079-10-2 by a competent person who is independent of the project or contractor. Zone shall be assigned conservatively taking into account the foreseeable operating conditions and worst case scenario. ATEX Zoning and Equipment classification shall be formally approved by the Owner.

b) Inert gas shall be used exclusively for traditional solid fuel grinding and drying. A new mill shall be designed for 10% O2 dry basis concentration after the baghouse in order to grind any solid traditional solid fuel.

c) For all closed systems identified as zone 21/1 or 20/0 safe explosion venting must be ensured. Where safe venting cannot be ensured, flameless venting must be applied.

d) Explosion protection systems, including explosion vents, shall be sized and certified by a competent person or company taking into account the layout. The explosion protection system shall be designed for the worst case scenario as well as the best case scenario.

e) Efforts shall be put into minimizing the Ex Zone extent by design, equipment selection and operations. Where possible, the layout shall be modified to minimize the number of Ex equipment being placed within classified Zones.

4. STANDARD EQUIPMENT

4.1 Health and Safety

4.1.1 Greasing and Lubricating

a) Greasing points shall be accessible from walkway without removing guards.

b) If necessary, all the greasing points shall be equipped with a grease recovery box for old and excess grease coming from the equipment, this box shall be easily dismountable for cleaning.

c) Guards shall allow for safe access to lubrication, inspection- and measurement points without removal and while equipment is running.

4.1.2 Fans and Blowers

a) For all fans for which intake and or exhaust are not equipped with noise reducer or dust filter; safety mesh shall be installed to prevent any foreign body to enter the fan. The mesh shall be flanged and dismountable with tools.

4.1.3 Storage, Bins, Bunkers, Hoppers and Silos

a) Where bins, bunkers or hoppers are loaded by truck or wheeled equipment, suitable wheel guards and bump stops made of steel or concrete wall shall be provided to a minimum height equal to half the wheel diameter of the largest vehicle accessing the area to prevent the equipment from running onto or over the hopper or the side of the ramp.

b) In order to prevent from falling, a lockable metallic grid at each opening located at the top of silos shall be provided.

4.1.4 Air Blaster

a) Each air blaster shall be secured by installing restraining cables for the tank and connecting pipe & discharge valve assembly.

b) Air Blasters shall be properly secured from moving in case of breakage of the discharge pipe.

c) A lockable air supply shut off system shall be provided at the air supply pipe. All air blasters shall be provided with a lockable, self-draining isolation valve.

d) A manual shut off gate must be provided to allow dismantling of the air blaster during operation.

4.1.5 Compressed Air Systems

a) Air tanks and receivers shall be equipped with inspection doors and tanks over 0.9 m in diameter shall have a manhole.

b) A safety (spring type) pressure relief valves shall be installed to protect the tank against exceeding the maximum allowable working pressure. The release valve shall vent to the outside of the building.

c) Lockable exhaust ball valves shall be installed to release air pressure when it is required.

d) Compressed Air must not be used for the purpose of dust cleaning.

4.1.6 Conveying Equipment

a) Inclined or vertical conveying systems shall be equipped with a non-return stop device.

b) Downhill conveyors shall be fitted with brakes.

c) All belt conveyor systems shall be equipped with fail safe pull cord emergency switch, on both sides of conveyor (if accessible at both sides).

d) All the accessible nip points shall be adequately guarded (Nip Point – a point in between two moving parts or between one moving and one fixed part of a machine where an individual's body may be caught and injured).

4.1.7 Ball/Tube Mills

a) Head room clearance below tube mills less than 2.4 meters shall be guarded off.

b) Maintenance doors shall be accessible by a fix installed platform above the mill tube.

c) Monorail hoist shall be arranged to facilitate cover removal and ball charge filling.

4.1.8 Packing

a) If a panel enclosing the packer shall be removed, the packer shall shut down automatically.

b) A safety cut-off device shall be installed at packer access point.

c) The Visual Cut-off Switch (VCS) of the packer drive shall be installed close to its access door.

d) A dead man safety switch and emergency pull cord shall be installed on the internal part of the casing of the packer.

e) The packer shall be equipped with an automatic bag applicator.

f) The loading machines for cement bags loading in rail wagons shall be equipped with a remote-control system to enable the operators to operate & control the machine remotely while taking the machine in & out of wagons.

g) Electrical Control Systems for truck and wagon loading equipment shall comply with IEC 62061 and ISO 13489 safety standards to ensure a fail-safe safety mechanism.

4.1.9 Audible and visual warning devices

a) Shall be installed in each plant section or department for purpose of notification of the start of process equipment.

b) Shall be installed on all moving equipment and being activated before and during transition.

4.2 Auxiliary Equipment Drives

4.2.1 Gear Reducers

a) All gears shall be rated based on the installed motor power.

b) All speed reducers shall be in accordance with ISO, DIN or AGMA standards and shall be air cooled.

c) The required application factor shall be considered and shown in technical specification.

d) The gear shall be manufactured according to fatigue strength calculation. The guaranteed lifetime shall not be less than 50000 hours of operation.

e) Reducers shall include filtered air breather (maximum 10 µm) and a magnetic drain plug.

f) Gear motors are acceptable for drives up to 75 kW.

g) Hollow shaft gear motors acceptable.

h) All auxiliary gear boxes shall have a minimum service factor of 2.0 on motor rating (kW) and for geared motor it shall be 1.5 on motor rating.

4.2.2 Couplings

High-speed fluid couplings shall be of the Supplier's standard design fitted with pin-fuse and thermal plug.

4.3 Roller Bearings

a) Permanently greased roller bearings shall be sized for a theoretical lifetime of at least 24'000 hours.

b) Roller bearings shall be sized for a theoretical lifetime of at least 50’000 hours.

4.4 Apron Feeders

4.4.1 Drive

a) Gear reducer, planetary gear box or hydraulic drive shall be directly coupled to the head shaft.

b) Non-return stop for inclined arrangement shall be integrated.

c) The maximum velocity for apron feeders shall be 0.3 m/s.

4.4.2 Chain and Rollers

a) Drive sprockets shall be of segmented design with reversible segments.

b) All apron feeders shall be designed with chain safety factor on minimum 10 at its design capacity.

c) Rollers:

- If fixed to the chain or aprons, rollers shall be outboard mounted.
- If fixed to the frame of the conveyor, rollers shall be easily accessible for replacement without removing the apron assembly.

4.4.3 Aprons

a) Aprons shall be designed to minimize spillage by appropriate overlapping of the individual aprons.

b) Aprons shall be highly resistant to shocks and deformations from impacts of material being dumped into feeder hopper (intermediate impact support rails with bolted wear plates and central greasing unit shall be provided if required).

4.4.4 Skirt Plates and Material Cut-off Gate

a) Skirt plates shall have replaceable liners.

b) A material cut-off gate shall be incorporated at the hopper outlet. This gate shall be easily adjustable with jack-bolts for settings 20% above and 20% below the designed material bed height. For feeders handling primary crusher feed materials, this gate is not required.

4.4.5 Spillage Conveyor

The feeder arrangement shall include spillage chutes or scraper-type spillage conveyors to capture spillage and feed to downstream Equipment, thus ensuring a spillage-free operation. In any case, the provision for the future installation of a spillage conveyor shall be made.

4.5 Apron/Pan Conveyors

4.5.1 Health and Safety

Steep inclined conveyors greater than 30 degrees and components thereof shall be safe against sliding down or falling off its support structure by the installation of hold-down rails.

4.5.2 Drive

a) Gear reducer, planetary gear box or hydraulic drive shall be directly coupled to head shaft.

b) Non-return stop for inclined conveyors shall be integrated.

c) Maximum velocity for pan conveyors shall not exceed 0.3 m/s, maximum 0.6 m/s for bucket belt type conveyors.

d) The drive shall be designed for 110% conveyor filling degree considering the highest possible density of the material to be conveyed.

4.5.3 Chain and Rollers

a) Safety factor on chain based on nominal conditions shall be higher than 8.

b) Drive sprockets shall be of segmented design with reversible segments.

c) Rollers fixed to the chain or aprons shall be outboard mounted.

4.5.4 Aprons and Pans

a) Aprons shall be designed to minimize spillage by appropriate overlapping of the individual aprons.

b) Aprons and Pans shall be highly resistant against shocks, and deformations.

c) At nominal capacity the filling degree of the conveyor shall not exceed 85% of the manufacturer's theoretical loading for the slope used.

d) Maximal admissible slopes are 28° for pan conveyors without baffles and 45° for pan conveyor with baffles. Bucket conveyors shall be used above 45°.

4.5.5 Dust Covers and Protection Guards

a) Removable protective guards on all accessible nip points shall be provided. Greasing points shall be accessible from walkways or inspection platforms without removing guards.

b) Properly sealed, removable dust covers at feed section shall be provided.

c) Inspection doors at discharge chute shall be hinged.

4.5.6 Spillage Conveyors

Conveyor discharge arrangements shall include spillage chutes or, for materials difficult to handle, scraper-type spillage conveyors to capture spillage and feed to downstream equipment, thus ensuring a spillage-free operation. In any case, the provision for the future installation of a spillage conveyor shall be made.

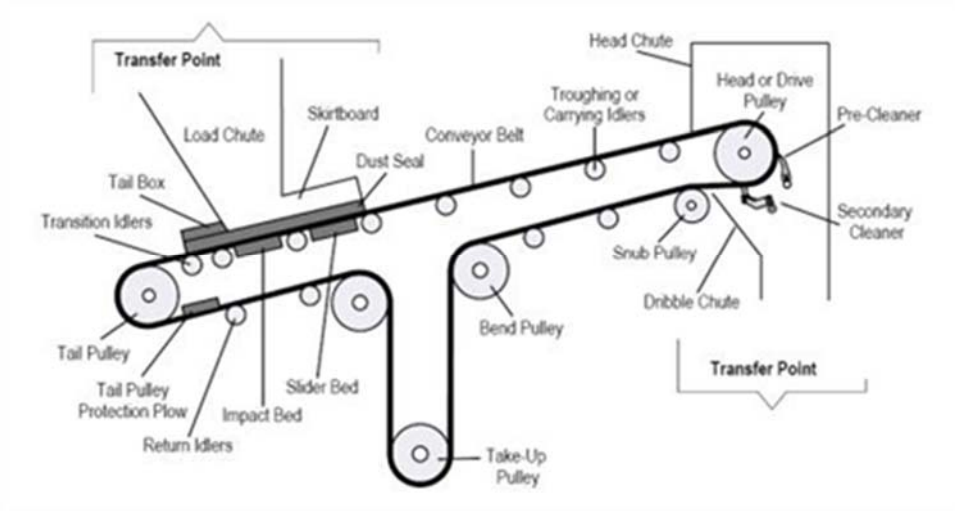
4.6 Belt Conveyors

All belt conveyors shall be designed in accordance with EN, DIN, MSHA, CEMA or ANSI standards.

4.6.1 Health and Safety

a) Removable protective guards on all accessible nip points shall be provided including:

- Drive drums and pulleys.
- Bend and snub rollers.
- Loop take-up rollers.
- All accessible troughed carrying idlers.
- All accessible return idlers.
- Roller assemblies for conveyor belt tracking.
- Locations preventing access to persons to underneath part of the conveyor e.g. bridges or underpasses.



b) An enclosure shall protect the area where gravity take-up counterweight could fall. For long distances between the gravity take up and the ground, the counterweight shall be connected to the take up drum with a cable in order to prevent the counterweight box from falling on the ground.

c) Walkway on both sides shall be provided for inspection & maintenance. For conveyor belts with a width of 800 mm or smaller only one walkway can be accepted. Size of walkways is specified in the Civil and Structural Works StDC.

d) Safety emergency shut-down pull rope shall be provided on both sides accessible, all along the conveyor.

Examples for typical belt conveyor guarding are shown below.

4.6.2 Drive

a) Gear reducer shall be shaft mounted or directly coupled to the head shaft.

b) Non-return stops for inclined arrangement shall be integrated.

c) Brake to keep belt in position is required for downhill conveyors.

d) The application factor KA shall be 1.5.

4.6.3 Belt Design

a) For alternative fuel applications oil resistant, fire retardant and antistatic type belts shall be used.

b) Safety factor on belt breaking load shall be higher than 8 for one way conveyor.

c) Belt seams shall be exclusively vulcanized.

d) Trough angles shall not be less than 30 and not more than 45 degrees.

e) Belt speed:

- Maximum belt velocity shall not exceed 2.0 m/s for in plant belt conveyors.
- Overland conveyors may operate at velocities in excess of 2.0 m/s but shall not exceed 5.5 m/s (upon owner's approval).
- Conveyors handling dry fine material (i.e. raw meal, cement, sand (<1mm), solid alternative fuels) or at hopper extraction, shall not exceed 1.0 m/s (exception are air-supported belt conveyors and pipe conveyors).

f) Belt width shall not be less than 800 mm (1000 mm in case of AFR) except for bag handling applications in packing plants, where 650 mm belts may be used.

g) Vertical (concave) curves shall be designed to avoid lifting of the belt from the idlers under any conditions and hence shall have a radius of at least 250 m.

h) A minimum of 3 plies for synthetic fabric rubber belts shall be provided.

i) Conveyor belt quality shall be standardized as far as practical for each belt width.

j) Minimum distance between the center of the tail pulley and the backplate of the skirting arrangement shall be greater than 1.5 times the belt width. As a minimum, the skirting shall not start until full belt trough angle has been achieved.

k) Maximum conveyor slope:

Maximum Slope	Raw Material wet Slag	Clinker	Cement	Coal Petcoke	AFR and AGG
	degrees				
All sections other than loading point	16	10	6 (1)	15 coal 12 petcoke	18
At loading point	6 (2)	0	0	0	6 (2)

(1) Consideration shall be given to maximize the horizontal section after the last feed point thus allowing the cement to properly de-aerate and prevent back-flushing on inclined section. Change from horizontal only after a distance equivalent to 60 seconds belt travel from the feed point is desirable. Steeper slopes can be accepted depending on the usage of grinding aids and/or material bed thickness on the belt, subject to the Owner's written approval.

(2) Steeper slopes may be acceptable depending upon the application, subject to written approval by the Owner.

Table 5: Maximum Conveyor Slope

4.6.4 Pulleys

a) All drive pulleys shall have rubber lagging.

b) Tail and take up pulleys: rubber lined or spiral wrapped wing pulleys. Wing type pulleys without spiral are not acceptable.

4.6.5 Idlers

a) Carrier and return idler diameter shall be designed according to DIN (15207-1/22107) or CEMA (Class C, D or E).

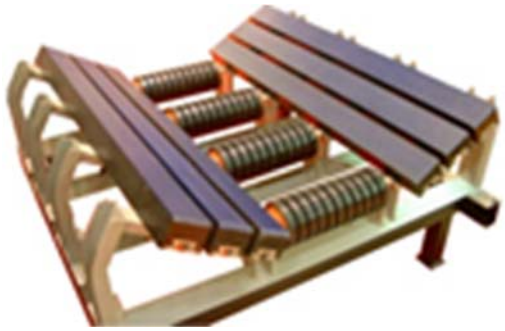
b) Carrier and return idler diameter:

- 89 mm for 650 mm belts
- ≥ 100 mm for > 650 to 1000 mm belts
- ≥ 133 mm for belts greater than 1000 mm
- ≥ 159 mm for high speed conveyors above 4 m/s
- Air supported belt allowed to have different size or even no idlers depending on design

c) Carrier idler spacing shall not exceed 1250 mm for all belt widths.

d) Carrier idler spacing for overland conveyors shall be selected in order to limit the belt sag to maximum 1% (100% is defined as the distance between the idler center lines).

e) High-density polyethylene impact bars or rubber protected impact idlers with spacing of maximum 300 mm shall be used at loading points. However, combination of impact bars with center rollers at spacing of max 300 mm are preferred to only impact idlers or only impact bars (as shown in the figure below). The length shall be 100 mm more than chute length at either end (total 200 mm more).



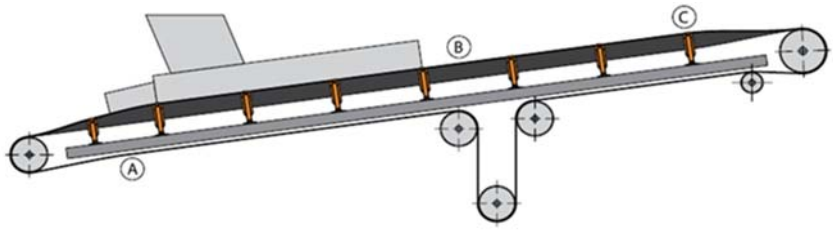
f) Return idler spacing shall not exceed 3000 mm for all belt widths.

g) The Self-aligning belt idlers/belt training devices should be installed at following locations as a minimum (refer to the figure below):

h) A. Just before the return belt enters the tail pulley – to ensure it is centered into the pulley & feeding zone.

B. Shortly after the feeding zone - to make sure the belt is tracking in the center after receiving feed material.

C. Just before discharge pulley – to make sure the belt is in center of discharge pulley when releasing the material discharge into the discharge chute.



- If additional belt training/self-aligning idlers are required, they should be spaced 30 to 35 m apart, and at least one training idler should be used on conveyors less than 30 m long.
- Belt training idlers should not be used in areas of belt transitions.
- Fixed guide rolls placed perpendicular to the edge of the conveyor belt are not generally recommended, because continuous contact with the conveyor belt accelerates belt edge wear, appreciably reducing belt life.
- Return belt training idlers should not be used in the areas where carryback material is present on the return belt.

i) For conveyors handling sticky materials and for all AFR materials, return idlers shall be rubber disc rolls or anti-adhesive rubber tubes.

j) All Idler bearings shall be sealed for life with permanent lubrication.

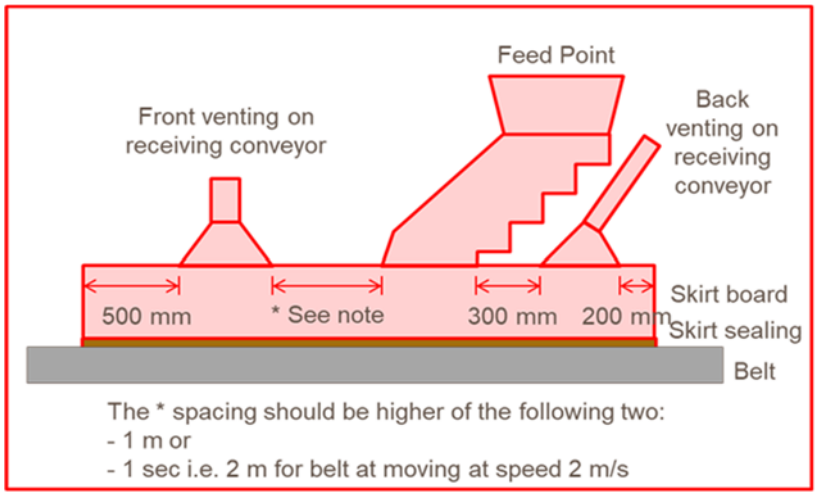
4.6.6 Belt Tensioning Stations (Take-up method)

a) For belt conveyors less than or equal to 50 m horizontal center distance the screw tensioning method shall be used.

b) For belt conveyors over 50 m horizontal center distance the gravity take-up or the winch tensioning method shall be used. Minimum take up travel is 2% of pulley center distance.

4.6.7 Skirting Plates and Dust Hood

a) Skirting plates and dust hood shall extend not less than 2 m but maximum 5 m from loading point. Refer to the figure shown below for more details:



b) Skirting plates shall be made of wear resistant material.

c) Skirting plates shall be equipped with adjustable sealing rubber stripes or pads and shall be of the quick release type (i.e. wedge clamping) for easy adjustment.

4.6.8 Covers

a) Conveyors or parts thereof installed outside of buildings and of tunnels shall be covered depending on local weather conditions and material properties.

b) Belt covers shall be semi-circular metal sheets and easily to open and close from one side of the walkway.

c) For conveyors handling dry fine material (e.g. cement, raw meal, sand (<1mm)) the lower edges of the covers shall extend to 300 mm below the return belt line.

4.6.9 Belt Cleaning Devices

a) Primary and secondary belt cleaners with twist or spring tensioner with segmented scraper blades shall be provided for all conveyors. The tensioner should fit on the mainframe. The twist tensioner has the characteristic of maintaining the necessary torque over a larger rotational movement of the cleaner mainframe. This means the user has to re-tension the cleaner less often. It must be possible to adjust the tensioner without any problems in order to set the correct tension in a simple way. One unique primary cleaner can be accepted for dry/not sticky product, (e.g. clinker, clean aggregates). Accessible inspection door(s) shall be provided for maintenance.

b) V-ploughs shall be used on return belts to remove spillage in front of tail pulleys, bend pulleys and for vertical gravity tensioning stations.

c) Reversible belts shall have NO primary belt cleaner at either end but only secondary belt cleaners at both ends, i.e. at head & tail pulley, with blade at zero rake angle (i.e. vertical) and diagonal type belt ploughs. Belt ploughs shall be attached to the tail pulley take-up frame. The rubber strip of the plough shall be always in contact with the belt surface (either by gravity/spring loading).

d) Conveyor layout shall allow both primary and secondary belt cleaners to discharge directly into head chutes/hoppers. Adequate slope shall be provided to direct the material to the next following Equipment without build-up.

e) Metal deck plates between carrying belt and return belt at feeding points shall be provided.

4.6.10 Conveyor Discharge

a) Discharge curve (trajectory) of the material corresponding to the selected belt velocity shall be considered for all transfer stations.

b) Wherever necessary trajectory is not achieved, measures for feed centering on receiving belts shall be applied (in case of free-flowing materials).

c) The feed chute of the receiving conveyors shall be designed such that the speed of the material is almost equal to the speed of belt conveyor in the direction of the flow (not valid for sticky materials).

d) Conveyor head chute shall have replaceable wear liners where abrasive materials are conveyed. Suitable liner material such as UHMW polyethylene or stainless steel shall be used for the conveying of sticky material.

4.6.11 Dedusting

a) For belt conveyor transfer points requiring nuisance dust collection at least 3 dust take-off points shall be installed at each transfer point: at the top of the transfer chute, before and after material impact on the following conveyor.

b) In exceptional cases, if space is not available at the tail end for dedusting, the volume of front (after impact) and back side (before impact or towards tail pulley) dedusting on the receiving conveyor shall be combined into the single dedusting point provided on the front side of the chute.

c) Design of discharge chutes shall minimize hood openings by using bolted closing plates with adjustable rubber seals.

4.6.12 Spillage Conveyors

Conveyor discharge arrangements shall include spillage chutes or, for materials difficult to handle, scraper-type spillage conveyors to capture spillage and feed to downstream equipment, thus ensuring a spillage-free operation. The drive of the spillage conveyor must be located at the belt pulley side, opposite of the belt drive.

In the case that no spillage conveyor is considered in the design, the provision for the future installation of a spillage conveyor shall be made.

4.7 Chain Conveyors

4.7.1 Drive

a) Gear reducer shall be shaft mounted or directly coupled to head shaft.

b) The velocity for chain conveyors shall not exceed:
- 0.2 m/s for very abrasive material
- 0.3 m/s for moderately abrasive materials

c) Extraction chain conveyor drive shall allow start up with a full hopper.

4.7.2 Casing

a) The casing shall be dust tight and weatherproof.

b) Replaceable bolted wear liners shall be provided on the sidewalls extending approximately 100 mm above the material bed.

c) Casing bottom shall have bolted wear liners or be designed to utilize a stationary layer of material to protect the bottom plate.

d) Inspection doors shall be hinged. Inspection openings shall have a protection mesh removable only with tools, mounted under the inspection cover to prevent physical contact with moving machinery.

4.7.3 Chain, Flights and Sprockets

a) High wear resistant chain and flights shall be used.

b) Drive sprockets or traction wheels shall be of segmented design with reversible segments.

c) Chain- and sprocket cleaners shall be used to prevent material accumulation on sprockets and chain if sticky material has to be conveyed.

4.8 Screw Conveyors

4.8.1 Health and Safety

Inspection hatch shall be hinged. Inspection openings shall have a protection mesh removable only with tools, mounted under the inspection door to prevent physical contact with moving machinery.

4.8.2 Drive

a) Gear reducer shall be shaft mounted or directly coupled to the head shaft.

b) Drive train for screw conveyors shall be designed for 100% filling degree and be able to start and convey material with full hopper.

c) Safety factor for motor power shall be 1.8 without hopper and 2.5 under hopper.

4.8.3 Screw

a) At least one inspection hatch shall be provided. Protection mesh shall be mounted under the inspection door to prevent physical contact with moving machinery.

b) The diameter of screw conveyor flights used for conveying dust discharged from bag filters (nuisance filters and process filters) shall not be less than 230 mm; smaller diameters are acceptable for other applications.

c) Screws shall be of continuous flight design. Ribbon flights are not acceptable.

d) Intermediate hanger bearings inside the trough shall be mounted to the trough, i.e. separated from the cover.

e) Intermediate hanger bearings for screw conveyors for dust handling after process gas filters are not acceptable.

f) Capacity of screw conveyors shall be sized for a filling degree of 33% during normal process operation.

g) Screw peripheral speed and screw rotation speed shall be lower than:

- 0.5 m/s and 30 rpm for clinker and slag dust
- 0.75 m/s and 35 rpm for cement and coal
- 1.2 m/s and 55 rpm for raw material

h) Covers shall be flanged-type, sealed, with quick-release type fasteners.

i) Screw conveyors for special applications may differ from the above design.

4.9 Bucket Elevators

4.9.1 Health and Safety

a) Local Isolator and Hold to run control for inching drive shall be provided, at drive- and tail station as well as at the door for assembly.

b) One blocking device shall be assembled on the drive shaft end opposite to the drive. A safety pin to lock mechanically the drive shaft in any position. The safety pin position shall be interlocked accordingly.

c) If the bucket elevator is fed by an air slide there should be a vertical pneumatic slide gate before inlet chute of the bucket elevator to prevent boot filling in case of power failure/trip of circuit.

4.9.2 Drive

a) Gear reducers shall be shaft mounted or directly coupled to the head shaft.

b) Drive trains of bucket elevators shall be designed for 110% of bucket filling degree (waterline).

c) Drives shall be supported at elevator steel casing.

d) Drives shall have non-return stops and fluid coupling.

e) Only direct-coupled auxiliary drives are acceptable. Provisions shall be incorporated to prevent over-speed of the auxiliary drive by accidental torque transmission from the main drive.

f) The application factor KA shall be 1.8.

4.9.3 Casing

a) Casing shall be self-supporting, braced every 8-12 meters and at the head-platform.

b) For abrasive materials, boot casing loading chute and discharge chute shall be provided with wear liners.

c) Casing with openings for inspection, maintenance and cleaning, approximately 1.5 m high, having hinged doors shall be provided. Access shall be provided on both sides of the elevator.

d) In addition to the inspection doors, the Bucket Elevator shall be equipped with a protection mesh only removable with tools to prevent physical access with moving parts.

4.9.4 Buckets

a) Buckets shall be designed for nominal capacity of maximum 75% filling rate.

b) Buckets for handling abrasive and/or coarse material shall be provided with a hard-faced edge for wear protection.

c) Buckets shall have air vent holes for aerated material.

4.9.5 Chain Type

a) Safety factor between chain breaking load and nominal load shall be higher than 10.

b) High wear resistant central chain design is preferred.

c) Welded or forged link chains as well as “round link anchor type chains” (calibrated link) are acceptable.

d) Joining U-type shackles are not acceptable.

e) Drive sprockets or traction wheels shall be designed with replaceable segments, designed to be installed without removing chain.

4.9.6 Belt Type and Pulley Design

a) Safety factor between belt breaking load and nominal load shall be higher than 10.

b) Belt shall be made of steel reinforced rubber.

c) Belt shall be heat resistant if required, depending on the temperature of the material conveyed.

d) Drive pulley face can be either solid or lagged (rubber, ceramic) but shall be crowned, i.e. convex.

e) Self-cleaning cage type boot pulley shall be provided.

4.9.7 Conveying Velocity and filling degree

Type of Material	Filling Degree %	Maximum speed in m/s depending on carrier element		
		Chain type		Belt type
		Round link	Central	
Raw meal, Cement	< 75	1.3	1.9	1.9
Clinker, coarse materials	< 85	1.0	1.6	-

Table 6: Bucket elevator maximum conveying speed and filling degree

4.10 Apron Weigh Feeders

In addition to Paragraph 4.4 (Apron Feeders) the following guidelines shall apply:

4.10.1 Health and Safety

Emergency shutdown device shall be installed close to each apron weigh feeder.

4.10.2 Drive

Speed variation shall be of adequate range with due consideration for the expected variations in feed rate and materials density.

4.10.3 Skirting Plates

Skirting plates and lower section of feed bins shall be tapered, i.e. progressively opening in direction to feeder discharge.

4.10.4 Apron width

a) The apron weigh feeder shall be sized for 133% of nominal production.

b) For raw material dosing (premix or other main component), the width of the feeder shall be at least 1400mm during tendering phase until shear test results determine the size of discharge area of feed bin.

c) The width of the feeders for correctives and additives dosing shall be at least 1000mm during tendering phase until shear test results determine the size of discharge area of feed bin.

4.10.5 Frame

a) If, however, a mechanical extraction device is arranged inside of the feed bin (i.e. for sticky materials) which is able to prevent the forces of the material-column in the feed bin from the weigh feeder, then the feeder can be supported on the building floor.

b) The bottom of the feed bin shall be fitted with a needle gate.

4.10.6 Spillage Conveyor

a) The feeder arrangement shall include spillage chutes or scraper-type spillage conveyors to capture spillage and feed to downstream Equipment, thus ensuring a spillage-free operation. In any case, the provision for the future installation of a spillage conveyor shall be made.

b) Weigh feeders which are arranged longitudinally above of the downstream conveyor are not in need for a spillage conveyor but shall be equipped with a lateral spillage chute over the whole feeder length.

4.10.7 Weighing Device and Weighing Accuracy

a) Required feeder accuracy:

- Long term accuracy better than 0.5%
- Short term accuracy better than +/- 1.0%

b) Response to set point changes < 10% shall be less than 1 min (i.e. 1 min after changing the set point, the values shall be within a 1.0% range of the corresponding 10 min mean value).

4.11 Belt Weigh Feeders

In addition to Paragraph 4.6 (Belt Conveyors), the following guidelines shall apply:

4.11.1 Drive

a) Speed variation shall be of adequate range with due consideration for the expected variations in feed rate and materials density.

b) For Cement applications, feeder velocity shall not exceed 0.5 m/s. For Aggregates, higher velocities may be considered in case lower accuracy of the Weigh Feeder is acceptable.

4.11.2 Belt Design

a) Belt seams/splices shall be exclusively vulcanized.

b) For flat belts: Minimum belt width shall be 300 mm wider than the calculated base width of the material layer on the belt.

c) Minimum bed depth shall be 3 times the maximum lump size but not less than 100 mm (Not applicable for Aggregates).

d) For raw material dosing (in cement applications - premix or other main component), the width of the feeder shall be at least 1400mm during tendering phase until shear test results determine the discharge outlet size of the feed bin.

e) The width of the feeders for correctives and additives dosing shall be at least 1000mm during preliminary design phase until shear test results determine the size of discharge area of feed bin.

4.11.3 Frame, Skirts and Material Cut-off Gate

a) The frame of feeder shall be of cantilevered design enabling easy replacement of endless belt.

b) If however a mechanical extraction device is arranged inside of the feed bin (i.e. for sticky materials) which is able to prevent the forces of the material-column in the feed bin from the weigh feeder, then the feeder can be supported on the building floor.

c) The bottom of the feed bin shall be fitted with a needle gate.

d) Feed sections shall be tapered, i.e. skirt plates and lower section of feed bin, i.e. progressively opening in direction of feeder discharge.

e) A material cut-off gate shall be incorporated for setting 20% above and 20% below the manufacturer’s theoretical designed bed depth.

f) Leaf spring loaded belt cleaners with segmented scraper blades shall be provided if required.

g) Wear liners shall be provided inside the load skirts when abrasive materials are handled.

h) Feeders for dusty materials shall be fully enclosed (open bottom) with adequately sized and easily removable access panels.

4.11.4 Spillage Conveyors

a) The feeder arrangement shall include spillage chutes or scraper-type spillage conveyors to capture spillage and feed to downstream Equipment, thus ensuring a spillage-free operation. In any case, the provision for the future installation of a spillage conveyor shall be made.

b) Weigh feeders which are arranged longitudinally above of the downstream conveyor are not in need for a spillage conveyor but shall be equipped with a lateral spillage chute over the whole feeder length.

4.11.5 Weighing Device and Weighing Accuracy

a) Required feeder accuracy:

- Long term accuracy better than 0.5%
- Short term accuracy better than +/- 1.0%

b) Response to set point changes < 10% shall be less than 1 min (i.e. 1 min after changing the set point, the values shall be in a 1.0% range of the corresponding 10 min mean value).

c) Wheel type conveyor jockey shall not be used.

4.12 Belt Scales

a) Belt scale design shall allow for the use of idlers which are installed at the belt conveyor.

b) Required scale accuracy range:

- Long term accuracy better than 0.5%
- Short term accuracy better +/- 1.0%

4.13 Air Slides

4.13.1 Conveyor Design

a) Inspection openings at upper channel are required, one after each feeding point and at least one per section.

b) At material feed points, cloth shall be covered by metal screen, wire mesh or similar.

c) Upper compartment shall be of high-top design (i.e. height is larger than width) to ensure proper material flow and evacuation of conveying air.

d) Ratio of fluidized layer height versus active air slide height shall be between 20% and 45%.

e) Flanged dust air take-off shall exclusively be at discharge end of the air slide conveyor. Air slides longer than 50 m shall be equipped with a top casing of stepped heights. The intermediate venting of the conveyor by means of a dedusting unit shall be avoided wherever possible.

f) Clean-out ports on the air chamber shall be located ahead of the discharge point and ahead of any distribution/turn pots and diversion gates.

g) Air pipes with throttle valve and manometer on each inlet shall be provided (air inlet lateral or from bottom with deflector plates).

h) Airslides outside a building shall be water tight.

i) Air permeability of the fabric shall be approximately 150 m3/m2h at 30 mbar. Depending on bulk material characteristics, the air quantity may deviate from this figure.

Type of Material	Minimum Slope degrees
Cement	6
Separator feed	10
Cyclone rejects	10
Cement separator grits, Fly ash	12
Raw meal	5
Raw meal separator grits	15

Table 7: Slope of air slides (based on polyester fabric)

4.13.2 Fan-Type Blowers for Airslides

a) Guide values for air pressure (including reserve) are:
- Conveyor width δ 500 mm 60 mbar
- Conveyor width > 500 mm 80 mbar

b) Guide values for specific air volume are:
- Fine material (e.g. cement, raw meal): 2 m^3/m^2 per minute
- Coarse material (e.g. separator grits): 3.5 m^3/m^2 per minute

c) Maximum speed: 3000 rpm for 50 Hz electrical supply, 3600 rpm for 60 Hz electrical supply.

d) Every air slide conveyor shall be equipped with its own fan.

e) Fan shall be mounted on platform (not on Airslide).

f) Air filters shall be provided at fan inlets.

g) Fans installed outdoors shall be protected against taking in of rain through the suction inlet.

h) Casing mounted fans are as well accepted.

4.14 Feed Bins

4.14.1 General

a) Feed bins shall be equipped with:
- An adequate number of access openings for cleaning and inspection in the roof. It shall be designed with collars of 150 mm minimum height and with a removable safety grate under every cover.
- A pressure equalization valve if needed.

b) Feed bins shall preferably be placed on load cells as to enable on-line loss-in-weight calibration of downstream feeders.

c) Feed bins shall be connected with a dust collector if required.

d) Feed bin outlets and feeders shall be weather protected.

4.14.2 Feed Bins for Coarse Bulk Materials

a) All feed bins shall be of mass flow type and their design based on materials flow characteristics which shall be determined by shear test methods. The test results shall be provided to the Owner.
Flat bottom design for clinker feed bins and coarse aggregates are preferred for wear reduction purpose.

b) Unless differently stated in the shear test report, bin conical outlet part shall be inclined by not less than 70 degrees.

c) Height to diameter ratio for the bin shafts (cylindrical bin sections) shall not be less than 2:1.

d) Bin outlet depends on the material property but the width shall be min. 10 times the maximum product size in the bin but not smaller than 800 mm.

e) Adequate and replaceable wall liners shall be provided in case of abrasive or sticky materials.

f) Mechanical bin extraction devices shall be provided in cases that the shear test results show cohesive (or worse) flow behavior of the material to be reclaimed from the bin.

g) Shut-off devices (e.g. needle gates, slide gates) shall be provided as part of the bin.

h) Design of the bin-to-feeder-interfaces and sizing of the feeders shall ensure full activation of the bin outlets (i.e. tapered design opening in direction of material flow).

i) An adjustable material height limiter (i.e. a slide gate) shall be incorporated at the bin discharge section. This gate shall be easily adjustable in a range of +/- 20% of design material bed height on the feeder.

j) Feed bins containing wet or sticky materials shall be adequately protected against freezing considering material properties under local weather conditions along the whole year.

4.14.3 Feed Bins for Fine (Pulverized) Bulk Materials

a) The following additional Design Criteria shall apply:

- The bin conical outlet shall be inclined by not less than 70 degrees.
- A 2:1 height to diameter ratios for the bin shafts (cylindrical bin sections).
- An outlet width not smaller than 400 mm.

b) Feed bins shall be equipped with:

- A pneumatic or mechanical flow promotion device, ensuring full outlet activation up to at least 1500 mm diameter.
- Mechanical and automatic shut-off gates.

4.14.4 Feed Bins for moist Sand (for Aggregates)

a) The following additional Design Criteria shall apply:

- The bin conical outlet shall be inclined by not less than 70 degrees.
- A 2:1 height to diameter ratios for the bin shafts (cylindrical bin sections).
- A mechanical outlet and automatic shut off gate with a width not smaller than 400 mm.

4.15 Transfer Chutes

a) The construction of the chute shall be designed to contain all material on the belt from the transfer points and to control the dust.

b) All transfer chutes that may have more than one product passing through the system shall be designed to prevent cross-contamination of products.

c) Chutes shall be designed with removable top covers or large access doors for replacement of the liner plates.

d) Minimum valley angle shall correspond to the material characteristics but shall not be less than 60 degrees. For clinker and coarse Aggregates, a minimum valley angle of 50 degrees is acceptable.

e) The valley angel for coal/petcoke chutes shall not be less than 70 degrees.

f) All chutes, skirt-boards and dust hoods shall be designed for effective dust suppression and shall be provided with flanged exhaust duct connections.

g) Chute connections are preferably flanged and bolted.

h) The transfer chute design shall allow for the easy removal of the head pulley without the need to remove the entire chute. Unless differently specified (i.e. for Aggregates), all chutes handling clinker or other free flowing abrasive materials shall be provided with rock boxes/shelves and replaceable lining (Ni-hard, Hardox or similar, minimal 8 mm thick).

i) Chutes handling sticky materials shall be lined with materials with low adhesion characteristics (polyethylene, stainless steel). Heated chutes can be accepted based on requirement.

j) Chutes shall be designed to avoid material plugging considering material properties under local weather conditions along the whole year.

k) Plate thickness shall be at least 6 mm for coarse materials (e.g. crushed raw material, clinker) and at least 2.5 mm for fine materials (e.g. raw meal, cement).

l) Inspection doors shall be hinged, shall be held in closed position by quick release clamps and shall ensure at least 1.0m clearance from internal moving parts. If clearance can’t be ensured, the locks of the inspection doors shall be bolted or lockable. Door design shall incorporate effective sealing design and gasket.

4.16 Gas Conditioning

4.16.1 General

The kiln exhaust gas shall be conditioned in the downcomer duct for required gas temperatures down to about 180°C. The downcomer shall be dimensioned accordingly.

For required gas temperatures of <180°C a conditioning tower shall be installed.

A fresh air in-take with fan shall be installed in the downcomer duct. For the control of the fresh air volume flow an adjustable butterfly damper shall be installed.

4.16.2 Conditioning Tower

a) Inlet gas duct arrangement shall be from top down to the center of the conditioning tower.

b) The gas inlet cone shall be equipped with at least one gas distribution device.

c) Only swirl free gas inlet is accepted. Laminar gas flow shall be shown by CFD modelling.

d) The conditioning tower shall include dust extraction Equipment, which shall be a reversible screw conveyor subsequently with manual shut-off gate and motor actuated double tipping valves at both ends.

e) Insulation thickness shall not be less than 100 mm industrial rock wool; in the outlet cone section not less than 200 mm.

f) The water quenching system shall be designed for a capacity to handle upset conditions, with an additional operation margin of plus 25% above nominal gas flow.

g) The mechanical strength (buckling) of the downcomer shell and its stiffeners shall be calculated for the maximum possible under pressure, written document shall be submitted to the Owner.

4.16.3 Downcomer

a) The downcomer duct shall be sized for a gas velocity not exceeding 15 m/s at Nominal Gas Flow.

b) The downcomer shall be designed with a vertical straight duct only.

c) Insulation thickness shall not be less than 100 mm industrial rock wool; in the outlet cone section not less than 200 mm.

d) Twin fluid nozzles shall be installed for water injection in the downcomer. The water quenching system shall be designed for a capacity to handle upset conditions with an additional operation margin of plus 25% above nominal gas flow.

e) The downcomer duct shall be supported from the ground floor level.

4.17 Process Bag Filters

4.17.1 Health and Safety

Process bag filter penthouses shall have a second door as emergency exit.

Online maintenance by disconnecting compartments during operation is not desired for safety reasons.

4.17.2 General

a) Process bag filters include the dedusting filters for kiln/raw mill, clinker cooler, bypass as well as cement- and coal mills.

b) For bag filters only pulse jet type are accepted. Reverse air filters are not acceptable for new plants.

c) Maximum net air to cloth ratio 1.0 m3/m2min for nominal conditions shall apply for all process filters except for by-pass and semi-wet filters. For Bypass dust and semi-wet process filters net air to cloth ratio of 0.9 m3/m2min shall be applied.

d) Nominal Conditions for sizing of kiln/raw mill filters shall be for Nominal Gas Flow of the kiln system and the raw mills operating mode with the highest actual gas flow to the filter and any other gas take-offs (e.g. coal mill, WHR) to be switched off.

e) Nominal Conditions for sizing of cooler waste air filter is defined as installed cooling air volume [Nm3/h] minus 0.8 Nm3/kg clinker at nominal production and 120°C.

f) Nominal Conditions for sizing of cement mill filters shall be for the operating mode with the highest actual gas flow to the filter.

g) Filter bag distribution:

- Maximum gas velocity between bags in any direction at any point in the filter (absolute of velocity vector) shall not exceed 1.3 m/s.
- Maximum can velocity is for cement mills 1.0 m/s (if applicable) and for coal mills 1.0 m/s (if applicable). Can (canyon) velocity (theoretical) is the calculated vertical raw gas velocity using 100% gas flow between the filter bags in the area of the bag bottom).
- A minimum distance of 75 mm between bags and walls/internal stiffeners shall be provided.
- A minimum distance of 48 mm between bags shall be provided with the design.

4.17.3 Bags

a) Filter cloth for bags and bag collars:

- Kiln/raw mill filters shall be equipped with glass-fiber/PTFE bags or Polyimide/PTFE bags.
- Bypass filters shall be equipped with glass-fiber/PTFE bags or Polyimide/PTFE bags.
- Glass-fiber/PTFE bags: nominal temperature = 200°C, maximum temperature = 260°C
- Polyimide/PTFE bags: nominal temperature = 200°C, maximum temperature = 260°C
- Clinker cooler bag filters shall be equipped with Polyimide bags.
- Cement mill filters shall be equipped with needle felt made of high quality.
  - Polyester fibers for dry gas lower or equal to 120°C
  - Polyacrylonitrile or similar fibers for wet gas lower or equal to 120°C

b) For coal mill applications, Polyacrylic bags such as Polyacrylonitrile shall be used.

c) Bag length shall not exceed 10.0 m for the raw mill/kiln filter and shall not exceed 8.0 m for other process filters.

d) Maximum number of bags per row shall not exceed 16.

e) Bag-to-cage size differences for glass-fiber/PTFE-bags:

- Bag circumference = cage polygonal circumference + 4 mm
- Bag length = cage length + max 15 mm, depending on length and temperature

f) Cleaning pressure for glass-fiber/PTFE-membrane bags shall not exceed 3.5 bar at header.

4.17.4 Bag Cages

a) Maximum distance between longitudinal wires:

- With glass-fiber/PTFE-membrane bags: 25 mm
- With needle felts: 40 mm

b) The following materials for bag cages are required:

- Kiln/raw mill filter at high temperature ≥ 160°C Mild steel, untreated
- Kiln/raw mill filter at low temperature < 160°C Epoxy coated
- Kiln gas bypass filter: Stainless steel
- Clinker cooler filter: Mild steel, untreated
- Coal mill filter: Stainless steel
- Galvanized cages are not accepted with exception of cement mill filters

c) Split cages are acceptable

4.17.5 Bag Monitoring, Control and Protection Equipment

a) Filters shall be equipped with pressure transducers (analogue signal 4-20 mA current output and local indication) to indicate the differential pressure across the bags and the clean air plenum negative pressure.

b) Cleaning cycle shall be controlled by differential pressure. The differential pressure measurement shall be continuous.

c) Kiln/raw mill, cooler waste air, and bypass filters shall be equipped with controlled fresh air damper and forced air cooling fan connected to emergency power supply.

d) On coal mill filters, one Broken-Bag-Detector shall be installed at clean gas duct directly after filter outlet for identifying the location of failed bag.

4.17.6 Compressed Air Equipment

a) Isolation valve with automatic discharge for manifold, filter, dryer and regulator on compressed air inlet line shall be provided.

b) Manual or automated condensate drain, pressure gauge and regulator on compressed air receiver/manifold shall be provided.

c) Equipment shall be designed to constantly deliver 110% compressed air requirements for all possible combinations of cleaning cycles.

4.17.7 Housing, Plenum and Hopper Construction

a) Dust collection hoppers shall be equipped with a manual shut-off gate. Hoppers for dust of sticky nature (e.g. bypass) shall include heaters to prevent condensation on the hopper walls. The dimensions of the hopper outlets shall be minimum 400 x 400 mm for bypass filters.

b) The mechanical strength (buckling) of the casing, tube sheet, and plenum shall be calculated with the maximum possible under-pressure brought by the fan.

c) Dust hopper inclination:

- Hopper valley (corner) angles shall not be less than 55 degrees; except that the valley angle for bypass filters shall not be less than 70 degrees and for kiln/raw mill filters not less than 60 degrees.
- Corners of hoppers shall be rounded for dust that tends to agglomerate or leads to clogging (especially coal mill and bypass filter).

d) For bag replacement, outdoor filters shall be equipped with weather protection of sufficient height to vertically extract the cages.

e) Minimum one access door for each hopper is required. Such doors shall have screw-tensioned latches and heavy-duty hinges.

f) In all cases, the minimum insulation thickness shall not be less than 100 mm of industrial rock wool insulation.

g) The clean gas plenum of kiln/raw mill, coal mill and bypass filters shall be constructed of corrosion resistant materials or coated.

h) Platforms, for replacement of bags, shall be dimensioned to provide lay down area and suitable lifting Equipment shall be installed.

i) In order to avoid corrosion, the filter should always be operated with gases at a temperature of minimum 25°C above the acid and water dew point. In case this is not feasible, corrosion protection measures such as corrosion resistant coating (i.e. FlueGardTM or similar) or stainless steel (AISI 316L or higher quality) shall be considered for the tube sheet and filter plenum.

4.17.8 Dust Extraction

a) Chain or screw conveyors for extraction shall be of robust design and without intermediate hanger bearings.

b) External air slide conveyors underneath the inverted-pyramidal-type hoppers are acceptable for all materials except of coal, clinker, bypass dust and other materials with temperature above 120°C.

4.17.9 Coal/Petcoke Mill Bag Filter: Additional Requirements

a) General

- Self-closing explosion vents are required and shall have limit switches to indicate when vents are improperly closed.
- The bag filter shall be equipped with fast acting isolating gates in the duct sections just before and after bag filter.
  - The gates shall close automatically within a few seconds in the case of an emergency and/or power failure.
  - The gates shall be designed to avoid propagation of a fire out of the filter and to flood the filter with inert gas. It is thus important that the filter outlet gate does not close completely, allowing the inert gas to displace the critical process gas out of the filter without a pressure increase inside the filter.
  - Instrumentation shall be located to bag filter side of fast acting dampers.

- All internal surfaces exposed to the process gases shall be protected against corrosion or be of material which will resist corrosion.
- Explosion prevention measurement shall be considered.
- Inertisation and fire suppression injection ports are required to be located along the bag filter hopper.

b) Bags and Bag Cages:

- A grounding measure to prevent static electricity charging shall be incorporated in the bag design. Corresponding certificate shall be presented to the Owner.
- Wire cage supports shall be corrosion resistant, and the protective coating used shall also be electrically conductive.

c) Housing, Plenum and Hopper Construction:

- Minimum valley angle for hoppers shall be 70 degrees thus avoiding coal dust accumulation. Hoppers shall have rounded corners.
- Internal structural stiffening design shall consider the prevention of coal dust precipitation and retention.
- Gas inlet section shall be designed avoiding coal dust accumulation.
- Access doors shall have limit switches to indicate when doors are improperly closed.
- Dust extraction Equipment shall be fitted with a rotary airlock. The airlock shall be designed to withstand an explosion pressure consistent with the design pressure for the upstream/downstream Equipment (filter, pulverized coal bin).

4.18 Electrostatic Precipitators

a) Electrostatic precipitators are only accepted for clinker cooler waste air dedusting.

b) If electrostatic precipitators for clinker cooler dedusting are selected, the criteria as per Paragraph.4.16 of this document are valid as far as applicable. Additionally the following criteria shall be applied:

- Rigid type discharge electrodes only (spiral type is not acceptable).
- Number of fields shall be adjusted in function of the guaranteed dust emission in normal and upset condition.
- Air to air heat exchanger shall not be installed before cooler electrostatic precipitator.
- A water injection system from cooler roof shall be provided in order to limit peak air temperatures at upset condition.
- A fresh air in-take with butterfly type damper shall be installed in the cooler exit air duct just after the cooler take-off.

4.19 Air to Air Heat Exchangers

4.19.1 General

a) The following criteria refer to air-to-air heat exchangers in which the process gas flows vertically through tubes, being cooled by ambient air blown horizontally across the tube packages/bundles by axial fans.

b) Nominal air flow for sizing of air-air heat exchanger for clinker cooler waste air is defined as installed cooling air volume of the clinker grate cooler [Nm3/h] minus 0.8 Nm3/kg clinker at nominal production, and for a maximum waste air inlet temperature of 500°C and outlet temperature of maximum 200°C.

4.19.2 Cooling Air Fans

a) Cooling fans shall not blow against the main wind direction.

b) Cooling fans shall be equipped with direct drive.

c) At least one row of the Cooling fans shall be controlled by VFD.

d) Cooling fans (in case of stoppage) shall withstand the heat radiation of the tubes without any damage.

4.19.3 Housing, Tube Bundle, Plenum and Hopper Construction

a) The gas velocity at the inlet tubes shall not exceed 20 m/s at up-set conditions.

b) Additionally, replaceable wear inserts for the inlet of each cooling tube shall be provided.

c) Inlet duct and inlet hood shall be designed to withstand a short time peak temperature of 650°C.

d) Tubes shall be fixed on one side and floating on opposite.

e) Fresh air damper in front of the heat-exchanger is required for emergency cooling.

f) Inlet duct and inlet guide vanes shall be wear-protected.

g) Hoppers shall be provided with wear liners.

h) Hopper valley (corner) angles shall not be less than 55 degrees.

i) Access doors for each hopper shall have screw-tensioned latches and heavy-duty hinges.

4.19.4 Dust Extraction

a) Chain or screw conveyors for extraction of clinker dust are acceptable. However, screw conveyors shall be of robust design and without intermediate hanger bearings.

b) Conveyor outlets shall be equipped with a manual shut-off gate and a motor actuated double tipping valve.

4.20 Nuisance Bag Filters (Jet Pulse Type)

4.20.1 General

a) Bin vent style (silo filter) bag filter shall be provided with suitably reinforced bag/man-catcher screens.

b) For all fuel applications explosion safe Equipment shall be provided.

c) Self-closing explosion vents equipped with limit switches to indicate when vents are improperly closed are required for filters handling coal dust or dust originating from alternative fuel handling.

d) All filters applied for fuel dust wherever originating from shall be equipped with back pressure valves.

e) Not more than 8 dust sources shall be connected to a single nuisance dust filter.

f) The following maximum air to cloth ratios shall apply:

- 1.5 m^3/m^2min for general nuisance dedusting
- 1.2 m^3/m^2min for slag, fly ash, coal, kiln bypass and clinker dust
- 1.0 m3/m2min for cement
- 2.0 m^3/m^2min for fluffy alternative fuel dust

g) Filter bag distribution:
Can (canyon) velocity (theoretical calculated vertical raw gas velocity between the filter bags in the area of the bag bottom) shall be maximum

- 1.3 m/s for general applications

- 1.0 m/s for cement application

- 0.8 m/s for dedusting fluffy alternative fuels

h) For AFR applications 20% spare capacity shall be provided in sizing of the dedusting filter and fan.

4.20.2 Bags

a) Filter cloth:

- Dry gas application up to 120°C: Needle felt made of high quality Polyester fibers.
- Application temperatures above 120°C: Polyimide, Polyphenylene, glass-fiber PTFE/graphite coated or equivalent.
- Fluffy alternative fuel application (dry air): Needle felt made of high quality Polyester fibers with anti-adhesive cloth coating. A grounding measure to prevent static electricity charging shall be incorporated in the bag design.
- Coal/petcoke application: Polyacrylic material such as Polyacrylonitrile, PEAC or equivalent that is anti-static. A grounding measure to prevent static electricity charging shall be incorporated in the bag design.
- Filter bag must be rated for the maximum foreseeable temperature, and minimum of 30min of fire resistance.

b) Pleated filter bags and star bags shall not be used, except for electrical room pressurization. Modern design cartridge filters may be considered where layout constraints do not allow installing conventional filters and vent ducts, subject to written approval by the Owner.

c) For standardization of bags (e.g., diameter of 140/160 mm) most filters shall be matched in such a way that only one size (i.e. diameter, length) and filter bag type is used for similar applications.

d) Maximum number of bags per row: 16 bags.

e) Bag cages shall be provided with longitudinal wires:

- 8 to 12 for bag diameter < 160 mm.
- 20 for membrane bags
- Bag cages shall be of single piece design and shall be corrosion-resistant (galvanized, stainless steel or epoxy coated), depending on application.

4.20.3 Bag Monitoring and Protection Equipment

a) Bag cleaning to be controlled primarily on DP mode, with timer mode as backup in case the DP does not trigger the cleaning for a long time.

b) Manual condensate drain, pressure gauge and regulator at the inlet of compressed air receiver/manifold shall be provided at easily approachable location and readable position.

4.20.4 Housing, Plenum and Hopper Construction

a) Hopper valley (corner) angles shall not be less than 55 degrees for dust from general applications and 70 degrees for dust from fluffy alternative fuels and coal, thus avoiding dust accumulations. Hoppers of all fuel dust filters shall have rounded corners.

b) For filters with the risk of operation below the water dew point, the casing insulation shall be minimum 50 mm of rock wool and heat tracing shall be considered.

4.20.5 Dedusting Air Volume

Dedusting air volume shall be sufficient to maintain pollution-free operation. The minimum dedusting volumes for typical applications in ambient air are:

a) Belt and Apron Conveyors

Transfer station of belt/apron Width of conveyor mm	Belt: volume m^3/h	Apron: volume m^3/h
650	4’000	-
800	5’250	6’500
1’000	6’500	7’500
1’200	7’750	8’750
1’400	8’750	9’500
1’600	10'000	10'000

Table 8: Dedusting air volume for Belt and Apron conveyors (total venting air volume for 3 venting points at each transfer)

b) Bucket Elevators

Drive Concept	Belt	Chain	Belt/Chain
Location of dedusting	Header		footer (> 40 m)
Bucket width mm	m^3/h		
400	1’800	1’400	1’250
630	2’500	2’000	1’250
800	3’000	2’500	1’250
1000	3’500	3’000	1’500
1250	4’500	3’500	1’500
1600	6’000	4’000	1’500

Table 9: Dedusting air volume for Bucket elevators (all venting points)

c) Screw and Chain Conveyors:

Diameter/width mm	Volume at discharge point m3/h
315 to 500	750
500 to 800	1’200
1’000 to 1’250	1’800
1’400 to 1’600	2’400
> 1’600	3’000

Table 10: Dedusting air volume for Screw and chain conveyors

The dedusting volume for subsequently installed screw conveyors shall be determined at the end of the transport series (i.e. at the end of the set of conveyors).

d) Air Slides:

Venting air quantity (m^3/h) 125 % of the fan inlet air quantity. If one fan/blower is connected to multiple airslides, dedusting volume should be considered as 1.25 times of the fan/blower flow calculated based on cloth area**.**

Intake velocity at venting hood: maximum 1.5 m/s

e) Bins:

Dedusting volume = 3.5 x incoming material volume + 1.8 x pneumatic transport air volume (expanded to ambient pressure) + 1.5 x Aeration volume

4.21 Fans

4.21.1 Health and Safety

For all process fans, a device shall allow to brake and block the shaft during maintenance operation.

All process gas fans shall have on-line vibration sensors and be interlocked accordingly.

4.21.2 Process Gas Fans

Included are kiln ID fans, mill fans, kiln gas bypass fans, cooler waste air fans, kiln and mill filter fans.

4.21.2.1 *General*

a) Process fans shall only be installed on ground level, with the exception of the separator fans for ball mills.

b) Airfoil blade type impellers are not acceptable for kiln ID fans and raw mill fans operated with dust-laden mill waste gas.

c) Minimum fan System efficiency shall be 80% at nominal operating point and nominal gas condition. The fan system is defined between the inlet and outlet flange including control damper if applicable.

d) All process fans shall be equipped with VFD. Fix speed process fans (raw mill and cooling air in case of low electrical power cost) shall be subject to written approval by the Owner.

e) Speed of process gas fans above 250 kW operating in dust laden gas shall not exceed 900 rpm (for 60 Hz motor) or 1000 rpm (for 50 Hz motor).

f) Critical shaft speed shall be a minimum of 150% of the fan nominal speed. For the kiln ID-fan, 180% shall be considered.

g) Mechanical drive requirements for the fans shall be considered see Chapter 4.33.

h) Dynamic balancing shall satisfy ISO 1940 quality level G 2.5.

i) Kiln ID fan design shall allow future installation of dynamic balancing systems.

j) Kiln ID fan shall be installed with an auxiliary drive (with over-running clutch).

k) The service factor for coupling (coupling rated torque/installed motor torque) shall be 1.25.

l) All critical components, exposed to wear & tear due to dust-laden gas flow, shall be made of wear resisting steel-alloys or shall be protected with liners. Wear protection concept (impeller, casing…) shall be subjected to Owner approval.

4.21.2.2 *Capacities Reserves*

a) All fan volume flow and pressure reserves are based on actual gas conditions (actual temperature, pressure and density):

b) Kiln ID fans:

- Gas flow: +20 % of Nominal Gas Flow.
- Pressure differential: +40 % at Nominal Gas Flow.

c) Main filter fan:

- Gas flow: +20% of Nominal Gas Flow at compound mode operation and coal mill switched off.
- Pressure differential: +30% of Nominal Gas Flow.

d) Clinker cooler filter fan:

- The gas flow is designed on up-set conditions without margin.
- Pressure differential: +30% of Nominal Gas Flow.

e) Bypass filter fan:

- +10% gas flow reserve of Nominal Gas Flow.
- Pressure differential: + 30% of Nominal Gas Flow.

f) Mill fans:

- +10% gas flow reserve of nominal gas flow.
- Pressure differential: +20% of nominal gas flow, to be optimized if fan with fixed speed is used.

g) Booster fans:

- +10% gas flow reserve of nominal gas flow.
- +20% gas pressure reserve of nominal gas flow.

4.21.3 Nuisance Bag Filter Fans

a) Fans shall be designed for 115% of bag filter nominal flow rate (for AFR projects 120%).

b) Fan speed shall not exceed 1500 rpm for 50 Hz motors and 1800 rpm for 60 Hz motors, unless otherwise approved in writing by the Owner.

c) Manually operated, accessible fan inlet damper shall be provided.

d) Flexible joints shall be provided for connection to the duct (on outlet for air slide fan).

e) Fan motor shall be adequately sized for the nominal flow at the lowest ambient temperature.

f) Fans shall be mounted on anti-vibration pads, if located on steel structures. In all cases, fans shall be mounted on structural members.

g) An access door, bolted and gas tight sealed, shall be provided in the fan inlet spiral for visual impeller inspection.

4.22 Hot Gas Generator

a) Solid fuel fired unit shall be vertically arranged and shall include measures to cool down the hot gas generator in the case of an emergency shutdown.

b) Hot gas generators shall be located so that any ash generated will not settle and will be introduced into the process gas stream. Ash extraction device shall be included if applicable.

c) The burner shall be equipped with means of adjusting the axial- and swirl air flow to enhance fuel/air mixing and control the flame shape in case of solid fuels and/or alternative liquid fuels.

d) If a dilution air fan is required it shall be included in the supply and it shall be considered as part of the Hot Gas Generator and being complete with motor and appropriate regulation control.

e) Shut-off gate damper shall be provided to insulate HGG from the other gas circuit.

f) Nominal thermal capacity shall be calculated for maximal moisture of the design material to be dried. An inconsideration of the minimal ambient temperature.

g) An additional reserve of 10% on the nominal thermal capacity shall be considered.

h) Both process air fans shall include safety margins of at least:

- 20% pressure (static) rise.
- 10% volume flow rate.

i) The main operating point of the fans shall be set on the efficiency curve corresponding to at least 80%.

j) The primary air fan shall be equipped with a variable speed motor.

k) The mixing of the recirculation with the hot gas from the HGG gas shall be as such that both gases can be optimally mixed.

l) Any required dampers shall be of the flanged type consisting of a sufficient number of louvers for precise control of gases by set points requests.

m) A flame monitor shall be included with self-checking circuitry. 

n) The local control cabinet shall allow basic controls from the plant central control room.

o) A pilot flame device shall monitor the operation of the firing unit. 

p) In case of a firing with fuel oil (heavy oil) the turn down ratio of the flow shall be designed considering expected flow ranges.

q) In case of firing with natural gas after the HHG CH4 and CO shall be measured continuously. 

r) In case of firing of natural gas or solid fuel all safety equipment and control systems shall be applied as requested by Owner. 

s) Standard refractory bricks shall be applied where applicable.

4.23 Ductwork

4.23.1 General

a) All duct joints and branch entries shall be designed to minimize airflow resistance and wear and to prevent dust build-up.

b) Portions of ducts exposed to excessive wear from dust-laden gas shall be properly protected.

c) All duct welds shall be full penetration welds.

d) Using process filters for nuisance dedusting shall be avoided at all times.

4.23.2 Process Ducts

a) All ducts shall be sufficiently designed for all loads, including loads due to extreme dust accumulation during upset conditions which can be up to 100% if applicable. The minimum load for the design of duct support structures is specified in the Civil and Structural Works StDC.

b) Inclined ducts for dust-laden upwards gas flows shall have the following minimum inclination:

- 70 degrees for all applications
- 60 degrees where velocities >18 m/s and exclusively conveying non-sticky materials (except coal/petcoke)

c) Inclined ducts for dust-laden downwards gas flows shall have the following minimum inclination:

- 70 degrees for all coal/petcoke applications
- 45 degrees for applications where velocities >16 m/s

d) Horizontal ducts shall be avoided wherever possible. It shall be designed for a minimum gas velocity of 20 m/s.

e) Maximum gas velocity in ducts shall not exceed 25 m/s under normal operation.

4.23.3 Venting Ducts

a) Inclined vent ducts for up- and downwards dust-laden air flow shall have an inclination of at least:

- 60 degrees for limestone, slag and cement dust application
- 45 degrees for clinker dust application
- 70 degrees for coal dust application

b) Horizontal vent ducts are acceptable for the applications of dust of fluffy alternative fuels. Clean out ports to be provided in the line wherever possible and accessible for cleaning.

c) The guide value for air velocities in the vent ducts are:

- 18 m/s for general dedusting applications
- 16 m/s for slag and clinker dust applications
- 18 to 24 m/s for coal dust application
- 22 m/s for application of dust from fluffy alternative fuels

d) Minimum venting duct diameter shall be 133 mm (outside).

e) Air velocity at venting hood entries shall be between 1.3 and 1.5 m/s (max. 0.8 m/s for fluffy alternative fuel).

f) Minimum duct and hood wall thickness shall be 3 mm, except for fluffy alternative fuels: 2 mm. In case of abrasive materials like clinker, minimum 6 mm thickness is required.

g) Orifice plates with wear protection shall be used for balancing the dedusting air volumes from the various dedusting points of a single filter if wear is predicted (e.g. for clinker and slag). For low wear applications butterfly dampers with minimum 6mm plate thickness shall be applied for balancing the air.

h) For fluffy alternative fuel a false air valve at dedusting hood shall be provided for balancing the dedusting air volumes and to prevent condensation in duct work.

i) For fan discharge ducts the velocity preferably shall be in the range of 15 to 20 m/s at maximum continuous rating.

j) The ducting shall have static pressure measurement points at each venting point above the damper, bag filter inlet & outlet, fan outlet etc., as minimum, to allow pressure mapping of the system for troubleshooting.

4.24 Expansion Joints

a) All major equipment shall be isolated by the use of expansion joint when they are subject to forces due to thermal expansion from ducts or piping or when they are able to transmit high level of vibration to the connected equipment.

b) Axial and lateral movements shall be based on upset temperatures.

c) All expansion joints shall have bolted flange-to-flange type connections on both sides of expansion joint for removal of complete unit. Minimum flange thickness shall be 6 mm.

d) All joints shall be provided with internal overlapping flow liners and full cavity insulation pillows to prevent dust particles from entering the cavity.

e) Expansion joints located in ducts conveying coal dust shall be designed to withstand a vented explosion.

4.25 Isolation Gates and Dampers

a) Isolation gates for the purpose of isolating certain plant sections from the operating process (e.g. raw mill-off operation) shall be of lockable guillotine type, zero leakage and preferably with rack and pinion drive. Other mechanical drive concepts are subject to written approval by the Owner. Time to fully open/close the damper shall typically be within 1 to 2 minutes.

b) Modulating control dampers shall be of opposed blade louver type, for example fresh air intake dampers.

c) Pneumatically actuated gates shall have position lock devices to allow the release of air during maintenance without gate movement.

4.26 Exhaust Stacks

Exhaust stacks shall in all instances be designed and constructed to meet requirements of all Permits; however the following minimum requirements shall be fulfilled:

a) Minimum height of every exhaust stack for kilns, raw mills and bypasses shall be at least equal to the preheater height and at least 5m taller than the highest preheater accessible point.

b) Stacks shall be equipped with a service platform with direct access from preheater tower thus ensuring access to continuous emission monitoring Equipment and relevant test ports for manual measurements.

c) Stack design (height, diameter and gas exit velocity) shall comply with the Owner's detailed air/gas emission and Immission modelling where such modelling exists.

d) The gas speed shall not exceed 20 m/s at nominal gas flow. The main stack or mill/kiln exhaust gas shall be attached to the preheater structure.

e) Separate stacks of clinker coolers, coal mills, cement mills and dryers located within 30m radius from buildings or structures shall be minimum 5m taller than the tallest of those buildings, structures or installations (S).

f) Special attention shall be spent on the location of the coal mill stack to prevent that these gases can pass through the preheater tower and other buildings to prevent corrosion.

g) Stacks of nuisance bag filters, -heaters or -similar purposes shall be at least 2 m higher than the roof of the building in which they are installed. Lateral exhausts shall not blow against the main wind direction.

h) The design shall take into account all relevant process data (type of process, operating conditions) and in particular the exhaust gas properties such as:

- Varying gas temperatures
- Dew point for water and sulphurous acid
- Varying gas velocities
- Varying gas composition

i) Fixation point design for non-free-standing stacks shall allow expansion/contraction of the stack shell.

j) All exhaust stacks shall be made of appropriate materials or shall be insulated, thus preventing corrosion.
If operating temperatures close or below the acid and water dew points cannot be avoided, the stack shall be protected with an internal anti-corrosion coating (e.g. StackGardTM, FlueGardTM or similar). In extreme cases, a double wall stack with inner tube in stainless steel (AISI 316 Ti or higher quality), external tube in carbon steel (for the structural stability) and an intermediate insulation layer (60 to 80 mm rockwool) between the two walls might be required.

k) For kiln stacks made from mild steel, the corrosion allowance shall be between 5 and 8 mm, depending on the specific requirements.

l) All stacks shall incorporate emission test ports according to the Holcim EMR guidelines.

4.27 Airlocks

4.27.1 General Application

a) Airlocks shall be of rotary type for raw material, raw meal, cement dust and coal.

b) Double pendulum type shall be provided for all clinker dust applications.

c) Motor operated units requiring power-to-open and force-to-close (i.e. fail closed) are required. Minimum size for airlocks shall be 250 mm x 250 mm.

4.27.2 Airlocks for Feeding Moist and Sticky Materials to Vertical Roller Mills

a) Rotary airlocks shall not be composed of more than 6 cells/pockets.

b) Cell/pocket filling degree shall not exceed 33%.

c) A rotary airlock with axial heating is mandatory. Lateral heating is not accepted.

d) The hot gas temperature shall be maintained at 200 to 350°C, passing the rotary valve.

e) The design of inner rotary airlock parts and its related ductwork shall ensure a hot gas velocity of 20 m/s.

f) Hot gas duct inclination either up- or downward shall not be less than 60 degrees.

g) The rotary valve rotor tip speed shall not exceed 0.5 m/s.

4.28 Magnetic Separators (Tramp metal removal)

a) To allow the safe removal of tramp metal objects, the magnet shall be installed with a minimum clearance of 120 mm above the belt conveyor edge.

b) The magnet shall be of the electro- and self-cleaning type.

c) Same machine guarding requirements as for Belt Conveyors apply.

4.29 Samplers

a) Location of samplers shall ensure that 100% of material flow will pass the sampler, e.g. sampling at air slide discharge where air venting (and consequently dust loss) takes place, shall be avoided.

b) Mechanical, fixed sampling devices are required at least for raw meal, kiln feed, kiln filter dust, hot meal, clinker, and all cement mills and cement shipping.

c) Automatic samplers for raw meal, kiln feed and cement mills: It consists of a motorized screw type sampler equipped with a mixing tank, a receiving pot, and the possibility to return excess material to the main material stream. The samplers shall be able to take spot or composite samples at selectable time intervals. The samplers shall have local and remote control to operate them.

d) Hot meal samplers must be designed in a safe way to prevent human contact with hot gas, fugitive dust or the material being sampled. Automated hot meal samplers with integrated cooling are preferred.

e) Manual samplers for raw meal, kiln feed, and cement mills shall be installed near the automatic samplers as a back-up and as cross-check samplers.

f) A simple manual sampler shall be installed for sampling of the kiln filter dust (e.g. on transport after bag filter). Cement sampling for the shipping area requires manual sampler as a minimum requirement, but bulk cement loading may be automated (motorized) if deemed necessary by customers' requirements.

g) Pneumatic sample transport, and automated shift laboratory shall be evaluated case by case, depending on plant size, complexity, H&S issues.

4.30 Overhead Cranes, Hoists and Trolleys

a) The Contractor shall demonstrate to the Owner regarding procedures necessary to bring supplied equipment to the ground floor of any building, next to a main equipment access door or to the ground adjacent to the building. Priority shall be given to use the mobile crane or mobile equipment designed for that purpose.

b) Only when use of such equipment is not practical due to height or restricted access alternative methods such as monorail, trolley or overhead crane shall be foreseen.

c) Overhead cranes, hoists and trolleys for maintenance shall be capable of carrying the heaviest piece of Equipment to be moved in the respective production area plus a margin of 20% as safe working load.

d) Cranes shall be supplied with certificates prepared for load test and tested by third party if required.

e) All lifting beams shall be tested by third party, if required.

f) Maximum permissible hoisting load shall be shown on the hoist beam.

g) Security hooks shall be provided.

h) All landing/drop area shall be clearly marked on ground; the surface of the marking shall correspond to the biggest equipment that could be lifted by the lifting equipment.

4.31 Safety Requirements for Automatic Moving Elements (Cranes, Motorized Doors)

a) All control mechanisms shall be designed in such a manner that operating personnel encounter no danger from overhead loads and have unhindered visibility over the total operation zone. Manual electric controls shall be provided.

b) Between the uppermost parts of a double girder mounted overhead travelling crane and the lowest parts of the roof construction, the minimum spacing is 500 mm. Single girder mounted overhead travelling cranes require no safety margin.

c) Self-operating or remote-controlled movable elements in areas of human occupation (particularly gates and lift doors) shall be fitted with security pressure-reactive devices against accidental entrapment.

d) Movable cranes in workshops and other work areas (excluding stores) shall display a flashing yellow light during operation.

e) Equipment which is only occasionally operated shall have their danger zones clearly defined by oblique black/yellow stripes.

4.32 Goods and Passenger Elevator

a) Make and type shall be of industrial type

b) A minimum rated load shall be specified

c) The following criteria shall be taken into account when designing the elevators as per ASME A17.1:

   a) Car frame and Platform Stress and Deflections

   b) Impact on Buffer support

c) Gravity Stopping Distance
d) Governor Tripping Speed
e) Stopping distance for Car and Counterweight safeties
f) Factor of safety for suspension wire ropes
g) Shall be designed for required seismic zone

d) The elevator shall be guarded and protected to eliminate fall risks

e) The following critical parts shall be tested and certified:

- Car and counterweight oil buffers
- Hostway door interlocks, combination mechanical lock, electrical contacts
- Car door or gate electrical contacts, and interlocks
- Entrance fire tests hydraulic control valves
- Elevator brakes
- Hydraulic overspeed valves
- Safety nut and speed limiting device of screw column elevators
- Suspension member

f) Provisions shall be made for periodic engineering check and maintenance of critical parts of the elevators ensuring provisions for proper LOTOTO.

g) Shaft-type elevators:

- Elevator shafts shall be of a dust tight design.
- Elevators shall be equipped with electro-mechanical drive located on top of the elevator shaft.

h) Outdoor elevators:

- Elevators may be of rack and pinion design with electro-mechanical drive located on top of elevator car.
- Cars/cabins shall be enclosed.

4.33 Process Measurements

a) The Project required process measurements are stipulated with respective document.

b) Ports for manual measuring shall be accessible safely and installed nearby the respective instrument sensor.

c) Additional locations shall be defined according to specific Project requirements.

4.34 Access Doors (Manholes)

Minimum size of Access Doors to Equipment shall be 600 mm x 800 mm.

4.35 Main Process Equipment Drives

4.35.1 General

All drive line shall be designed based on the installed motor power.

The Supplier shall include design details for the purpose of carry out a design review regarding the specified criteria and the general set-up (e.g. self-aligning/fixed pinion, material, profile correction). The design review shall take place **before** manufacturing to allow for modifications, if needed.

For this purpose the Supplier shall include an arrangement drawing and the information requested below.

4.35.2 Dynamic of Entire Drive Train

The design of the entire drive train from motor (or VSD where applicable) to working machine shall be verified, and if required, de-tuned regarding the dynamics of the torsional and bending system. The final results showing all input values inertias and stiffness shall be presented to the Owner before manufacturing to allow for modifications, if needed.

The torsional analysis of the drive line shall have a minimal difference of 15% between natural modes and exciting frequencies.

4.35.3 Couplings

a) The coupling shall have elastic and damping properties in order to compensate for the tolerated deviation from ideal alignment and to reduce load peaks in the drive train.

b) Motor couplings for ASD systems with an installed motor power of 500 kW and larger shall have sufficient electrical isolation properties in order to avoid shaft current flow from the motor to the coupled machines and to protect them from electro-erosion.

4.35.4 Gear Drives General

a) The mechanical safety factors for breakage, pitting and scuffing of gears for crushers, ball mills and kilns shall be calculated according to ISO 6336 method B or DIN 3990. Refer to the ISO Technical Report ISO/TR 13989-1/2 for the calculation of ISO scuffing safety.

b) The safety factors shall be:

Surface durability	> 1.1
Bending strength	> 1.4
Scuffing safety	> 1.5

c) The minimum KH® value shall be not less than 1.2.

d) The application factor KA shall be:

Driven equipment	KA
Kiln and Ball mill lateral drive	1.50
Kiln and Ball mill lateral dual drive	1.80
Ball mill central drive	2.00
Vertical roller mill	2.00
Separator	1.8
Roller press	2.50

Table 11: Application Factor

e) The gear reducers shall be designed for a lifetime of not less than 100'000 hours of operation.

f) Supplier shall provide a print out of the calculation showing all decisive input values (geometry, kinematical data, quality of gearing, correction factors and the operational coefficients such as application factor, transverse coefficient, face coefficient, dynamic factor, power distribution factor) and the resulting stresses, allowable levels and the safety factors.

g) Additionally the teeth profile modifications shall be listed and provided with comments.

h) Contractor shall provide detailed interlocking diagram showing warning and trip limits with descriptions of actions to be taken at warning limit to avoid tripping.

4.35.5 Closed Reducers

a) The gears and speed reducers shall be designed for an input speed of maximum 1500 rpm for 50 Hz, or 1800 rpm for 60 Hz motors.

b) Large gears and speed reducers for Equipment, such as crushers, raw mills, cement mills, roller presses and where otherwise applicable, shall be designed for input speeds of 1’000 rpm for 50 Hz or 900 rpm for 60 Hz motors if fix speed is applied. Exceptions are only allowed for ball mills equipped with central drives. In this case Supplier shall prove that the specified speed limits cannot match his standard design for reducers.

c) The housing of reducers shall be equipped with a fine dust filter (maximum 10 µm) in the desiccant breather.

d) Oil-water coolers shall be of tube bundle type.

e) Inspection doors and openings shall be positioned for easy visual inspection of gear wheels and for maintenance purposes.

f) Reducer and motor for all mills (raw- and cementitious materials) shall be equipped with condition monitoring Equipment and oil sample points:

- All vibration sensors shall be appropriately positioned to accurately reflect the vibration of the gear (i.e. casing near bearing in horizontal, vertical and axial direction).
- Useful measurement points which are not yet equipped with vibration sensors shall be prepared/machined for future temporary or permanent vibration measurements.
- All the sensors shall be wired to a central collecting point beside the reducer. There the signals can be picked up by handheld measurement Equipment.

- A transfer of these signals from there to the central control room and/or modem access to them shall be enabled.
- The reducers shall be equipped with an appropriate oil filter in the main oil-supply line. Filter fineness shall not exceed 40 µm (nominal).
- Reducers with rated power higher than 1000 kW and with external lubrication shall be equipped with a fine filtration unit not exceeding 10 µm (absolute).

4.35.6 Additional Requirements for inching drives of kiln, ball mill and rotary dryer

Automatic Inching drive shall be fitted with back stop, hydraulic coupling, and parking brake and over running clutch.

The brake and clutch system shall be guarded.

4.35.7 Additional Requirements for Reducers of Vertical Roller Mills

4.35.7.1 *All Vertical Roller Mills (VRMs)*

a) Installed motor shaft power shall be at least 10% higher than the nominal capacity absorbed power of the mill. Rated Design power of the reducer shall be 15% higher than the nominal capacity absorbed power of the mill. This requirement is to cope with grindability fluctuations.

b) Reducer housing and internals shall be designed to absorb specified forces, dynamics and load regimes. Deformations of the casings shall be limited to ensure proper tooth meshing and satisfactory load distribution. The following criteria shall be fulfilled:
   - Radial forces can be up to 30% of the vertical (static) forces (where roller and table wear liner meet).
   - Torque fluctuates with +/- 100% of the nominal value (between 0 - 200% of the nominal value).
   - Negative torque peaks can occasionally occur.

c) Oil supply to thrust pads shall be ensured by individual single lines, i.e. one piston per pad.

d) Use of oil flow measurement devices on external oil supply lines for gears and bearings are preferred. As a minimum flow switches with alarming to the control room shall be installed.

e) The reducers shall be equipped with an appropriate oil filter in the supply lines. For the main low pressure supply line a filter fineness of max. 25 µm (nominal) shall be applied. Additionally, a filtration unit of max. 10 µm (absolute) shall be installed.

4.35.7.1.2 Gear drives

Reducers shall be designed based on the following calculation methods and boundary conditions calculated using the rated power of the reducer. The minimum resulting safety factors shall be as follows:

a) Spur and Helical gear

   Method of computation for Spur gear and helical gear: ISO 6336 or DIN 3990 (for scuffing safety according to ISO the Technical Report ISO/TR 13989-1/2 may be used)

- Safety factor for bending strength (General) SF > 1.6
- Safety factor for bending strength (Engagement ring gear – planetary wheel) SF > 1.4
- Safety factor for surface durability SH > 1.2
- Safety factor for contact temperature SB > 1.8
- Safety factor for integral temperature Ssint > 1.8

b) Hypoid bevel gear

Method of computation DIN 3991 or ISO Standard

- Safety factor for bending strength SF > 1.6
- Safety factor for surface durability SH > 1.2
- for rated power above 2000 kW SH > 1.5
- Safety factor for integral temperature Ssint > 1.8

4.35.7.2 *On-line Condition Monitoring Equipment*

Dalog online condition monitoring equipment shall be installed in accordance with the frame agreement between Dalog Diagnosesysteme GmbH/Germany and Holcim Technology Ltd as specified for the respective reducer type.

4.35.8 Open Gear Drives (girth gear and pinion drives)

a) Conventional kiln drives with girth gear shall be equipped with self-aligning pinions. Other designs are subject to written approval by the Owner.

b) Method of computation for Spur gear and helical gear: ISO 6336 method B or DIN

- The safety factors shall be:

Bending strength	SF	≥ 2
Surface durability	HS	≥ 1.1

- The KH® factor shall be:

For ball mill	>	1.3
For kiln	>	1.4

- Girth gear and pinion shall be designed for a lifetime of not less than 100'000 hours of operation.

c) For conventional girth gear/pinion kiln drives the module shall be not less than 36 mm.

d) The tooth type for kilns and mills shall be spur gear (helix angle 0°).

e) The gear quality according to ISO 1328-1 shall be:

- For kilns: Level 9 or better (for the helix deviation level 8 or better).
- For mills: Level 8 or better.

f) The width to diameter ratio of pinions shall be < 2.

g) The girth gear will have at least one machined reference surface permitting easy measurement of the axial and radial run out.

h) The working pitch diameter shall be scribed on both sides of the tooth by a tool mark on pinion and girth gear.

i) Open gear drives shall have inspection doors in the protection cover which allow checking backlash and rooting clearance on both sides of each pinion.

j) Additional inspection door shall allow direct sight on the working flank of pinion and girth gear to check and adjust the spray lubrication Equipment and measure radial and axial run-out.

k) Above the inspection doors dust deflectors shall be mounted in order to avoid dust avalanches contaminating the pinion.

l) Girth gears shall be made of two halves.

m) The two halves of the girth gear shall be joined by Multi-Jack bolt Tensioners from SUPERBOLTS®.

n) Either circulating lubrication Equipment with filter units or spray type lubrication Equipment shall be applied.

o) Spray type lubrication Equipment design shall fulfil the following criteria:

- Spray nozzles shall be aligned on working flank of the pinion (not on girth gear).
- The function of each nozzle shall be controlled (flow monitoring of air and lubricant).
- The pre-commissioning procedure shall be documented in detail.
- Drum-heating Equipment including heat sensors shall control minimum and maximum temperatures of lubrication drums.
- Lubrication unit shall be equipped with auxiliary devices preventing contamination (e.g. barrel, drum pump).
- Lubricant lines shall be trace heated and insulated, as required by local climatic conditions, to ensure correct operating temperatures at start-up.

p) Circulation type lubrication equipment design shall fulfill the following criteria:

- It shall be designed for high viscosity oil circulation (e.g. low speed pumps, suitable filter size, heating system).
- The pump unit shall be redundant (equipped with additional pump on stand-by).
- The oil flow and filter condition shall be controlled (condition and alarm signal in control room).

q) Any application of lapping compound (abrasive lubricant) on the gears is prohibited.

4.35.9 Hydraulic Drives

a) Shall be made of the hydrostatic type.

b) Shall be of the compact type; factory assembled as far as possible on a rigid frame and shall be arranged for easy handling and installation. A stand-by pump shall be included.

c) Shall include kidney filters for the main hydraulic system.

4.36 Hydraulic Pressure Station

a) Pressure to all equipment and sub-equipment shall be able to be released prior to be disassembled.

b) Valves and procedures to inhibit pressure in the circuit and equipment shall be displayed on its hydraulic unit.

c) Floors shall have oil resistant, easy to clean surfaces.

d) Shall be of the compact type; factory assembled as far as possible on a rigid frame and shall be arranged for easy handling and installation.

e) Shall be installed in dust proof housing ensuring easy access for maintenance and handling of hydraulic fluids and lubricants.

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