# Quality Assurance of Cement from Production to Construction

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# Content

- Cement Standard in HK
- Cement Manufacturing Process
- Quality Assurance Planning
- Quality Control Schemes

# Quality Planning

- National Standards
- Customer Requirements
- Market Positioning
- Raw Material Constrains
- Process Constrains

QUALITY PLANS:

- Product Specification
- Process Specification
- Procedures
- Sampling & Testing Plans
- Work Instruction/Records
- Testing Data QA

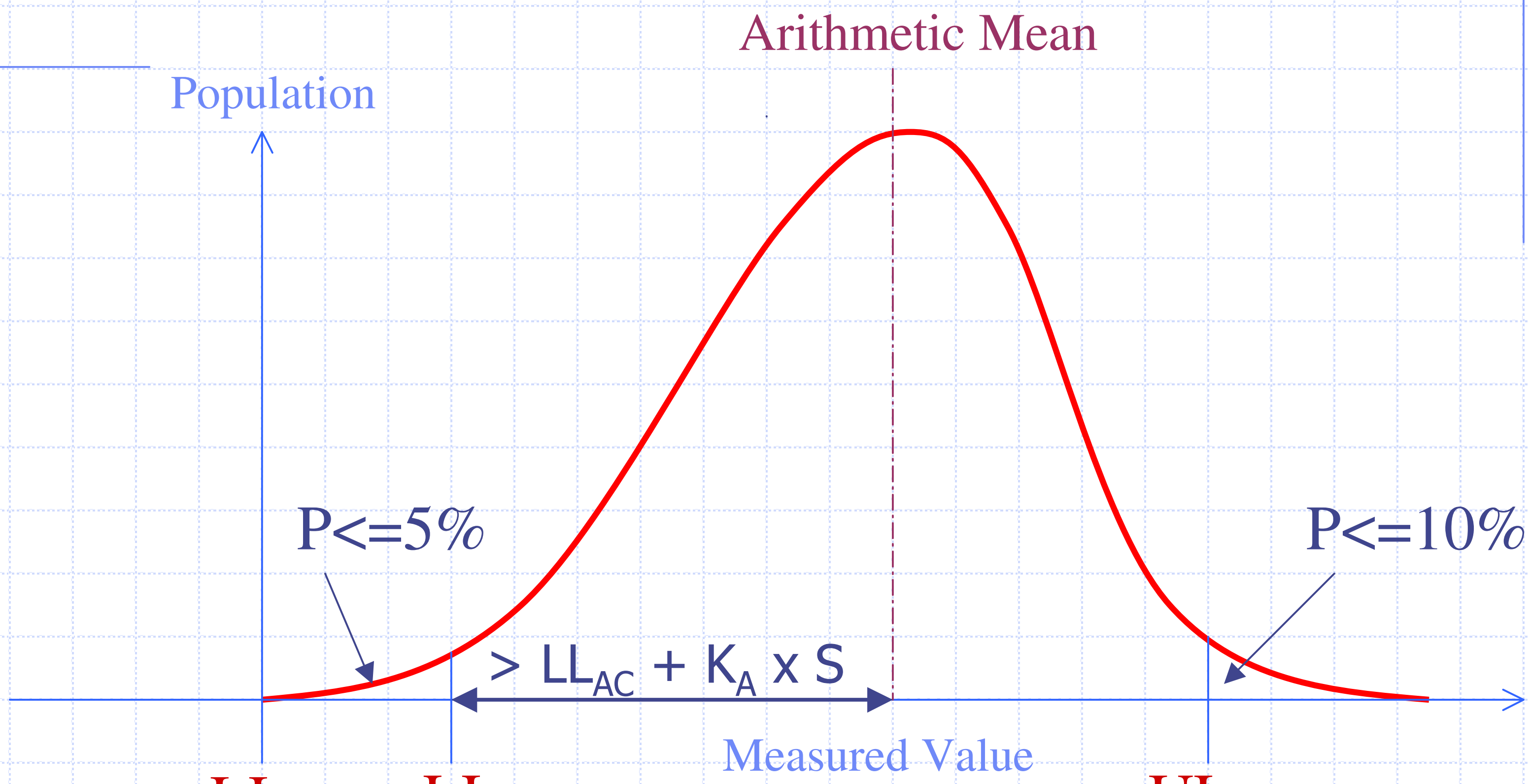
# Cement Standard Migration

| Portland Cement Standard | HK Adoption year |
|---|---|
| **BS12:1989** | 1992 |
| **BS12:1991** | - |
| **BS12:1996** | 2003 |
| **BSEN197-1:2000** | 2005 |

# Major Changes since BS12:1991

| | BS12:1989 | Since BS12:1991 |
|---|---|---|
| Test method | Mortar and Concrete cube tests to BS4550 | Mortar prism test to EN196 |
| Classification | By Fineness and early strength, into CFPC, OPC and RHPC | 4 major Strength Classes in BS, and 3 major strength classes in BSEN197:2000 |
| Minor constituents | Not permitted | Up to 5% |
| Compliance | Based on single sample and single test. Compliance based on absolute limits | Employs statistical method in strength class classification, and Single Sample Acceptance based on deviations. |

# Conformity Criteria




| Limits | $LL_{SS}$ | $LL_{AutoControl}$ | $UL_{AutoControl}$ |
|---|---|---|---|
| For class 52.5 N | | | |
| 2 days strength | 18.0 | 20.0 | |
| 28 days strength | 50.0 | 52.5 | |

$K_A$ is no. of test dependent

S is standard Deviation

# Target 28 days' Strength

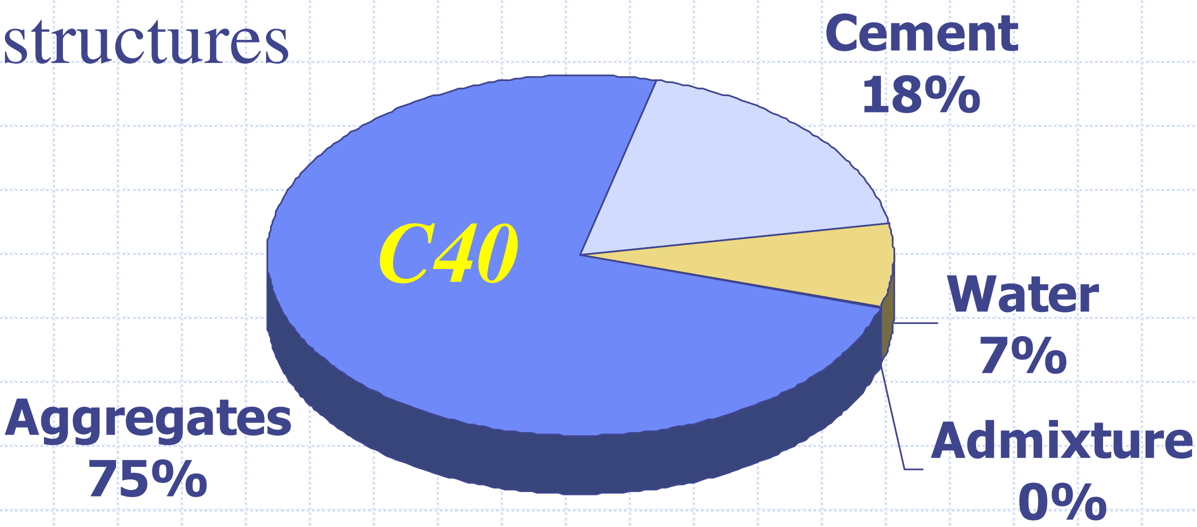
| | SD = 2.5 | SD=1.8 |
|---|---|---|
| No. of test = 310<br>$P_k$ = 1.80 | 57.00 | 55.74 |
| No. of test =55,<br>$P_k$ =2.07 | 57.68 | 56.23 |

+1.94

Reduce SD = Reduce target 28 d strength
= Reduce production cost
= Improve operation stability

# What is Cement ?

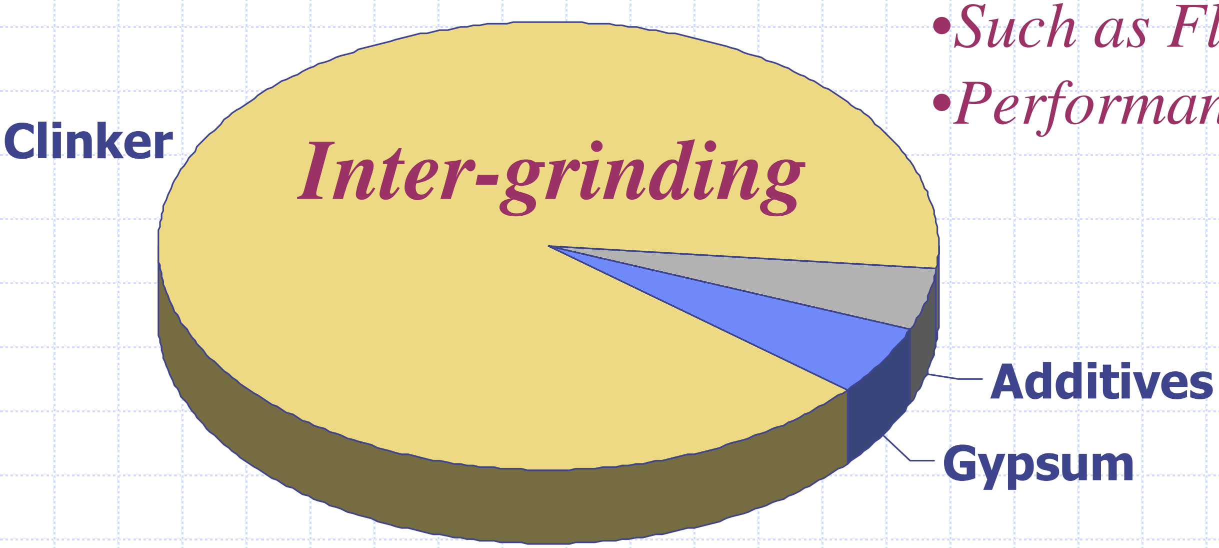
- Cement - A finely ground powder which has hydraulic properties when mix with water
- It is the most essential element in concrete for civil structures




***Typical C40 Concrete Composition***

# What's Inside the Cement

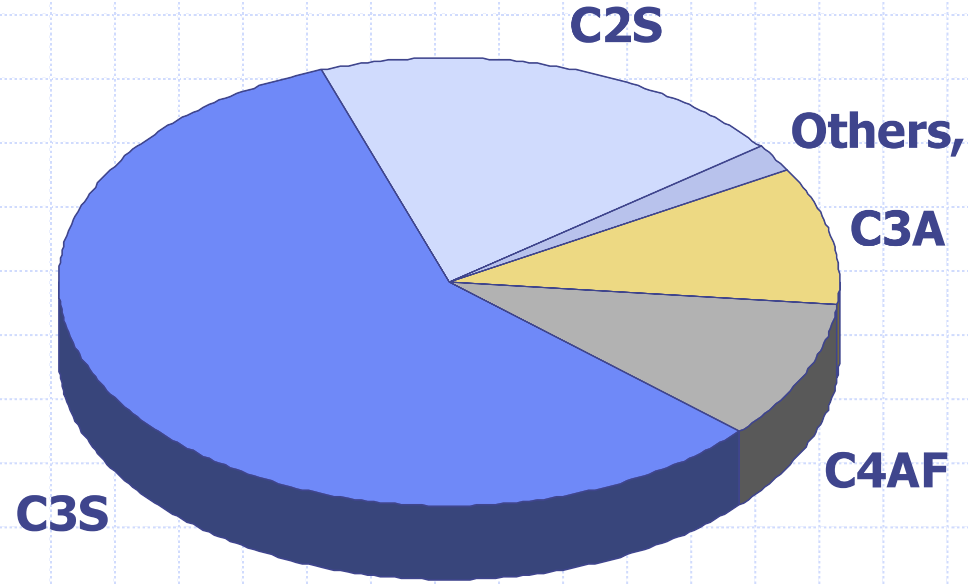
*Additives*
*•Such as Flyash, Limestone*
*•Performance modifier*




*Cement Clinker*
*•Major strength contributor*

*Gypsum*
*•Regulate the setting properties*

# Typical Type I Cement Clinker




Such as free lime, MgO, Alkali, sulphates

***$C_3S$ & $C_2S$***

- *Calcium Silicates, $xCaO.SiO_2$*
- *Amount up to 72-78 %*
- *Strength contributor*

***$C_3A$ & $C_4AF$***

- *$3CaO.Al_2O_3$,*
- *$4CaO.\ Al_2O_3.\ Fe_2O_3$*
- *Flux for the pyroprocess*

# Composition

- Type I cement clinker

| | |
|---|---|
| $C_3S$ | 45 - 65 % |
| CxS | 72 - 78 % |
| $C_3A$ | 8 - 12 % |
| $C_4AF$ | 10 - 11 % |

- Elementary Composition

| | |
|---|---|
| CaO | 63 - 66 % |
| $SiO_2$ | 20 - 23 % |
| $Al_2O_3$ | 4 - 6 % |
| $Fe_2O_3$ | 3 - 4 % |

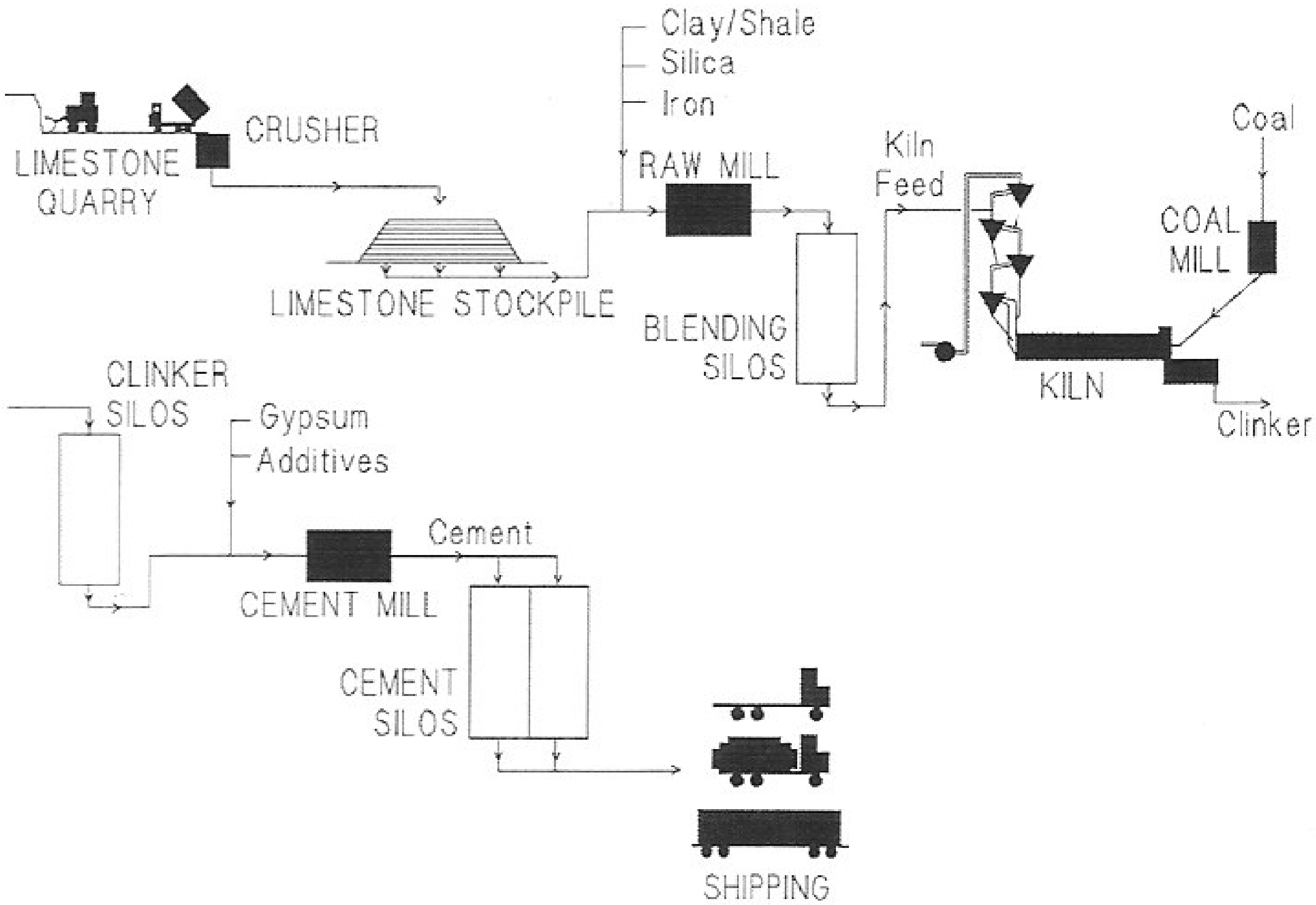
Bogue's formulas for calculating potential composition

| | CaO | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ |
|---|---|---|---|---|
| $C_3S$ | +4.071 | -7.602 | -6.719 | -1.430 |
| $C_2S$ | -3.070 | +8.602 | +5.068 | +1.079 |
| $C_3A$ | | | +2.650 | -1.692 |
| $C_4AF$ | | | | +3.043 |

# Cement Processes

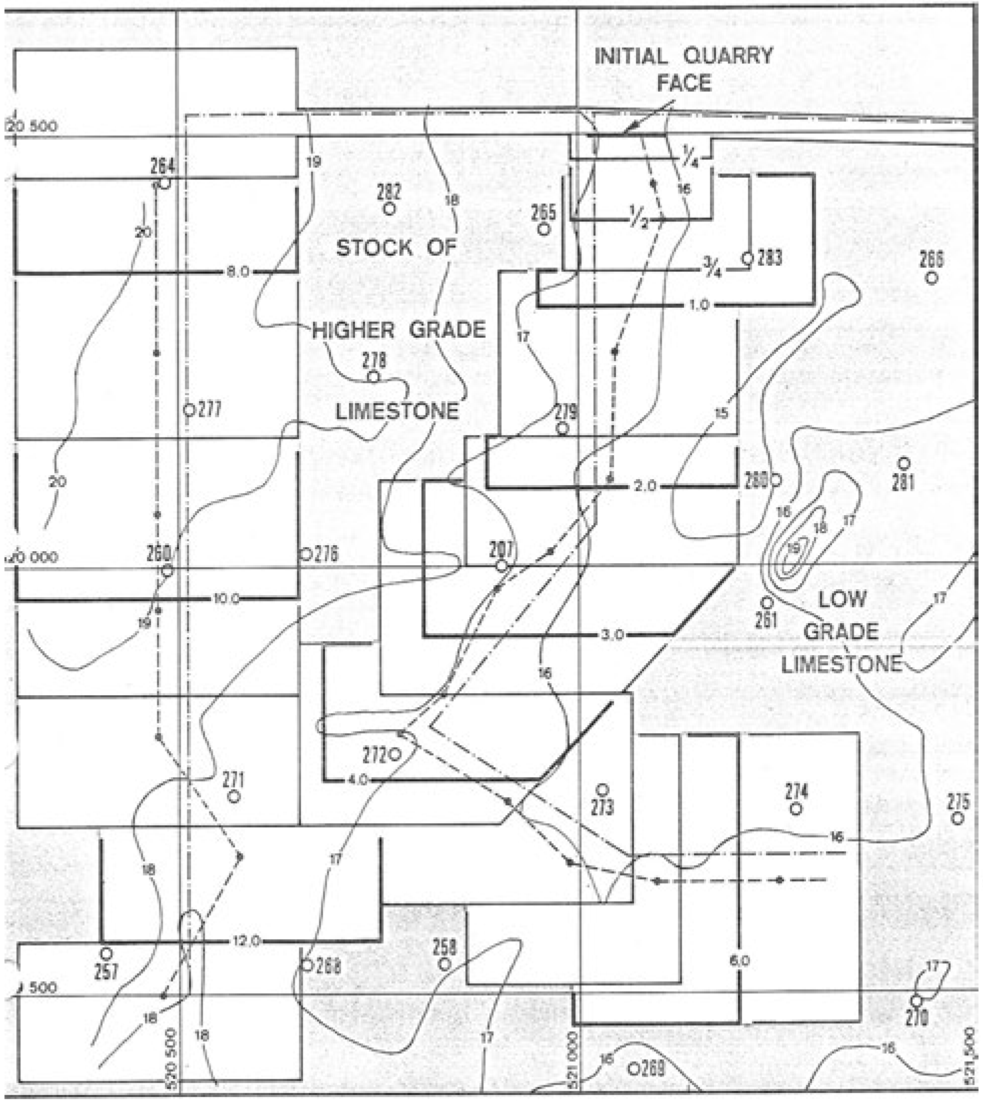
| | | | |
|---|---|---|---|
| I | Quarrying | Provide raw material | |
| II | Proportion of Raw Material | Provide correct chemistry | |
| | Raw Grinding | Provide surface area for heating process | |
| | *Precalcination* | Decomposition of $CaCO_3$ to CaO | |
| | *Sintering* | Formation of Clinker mineral | → Clinker |
| III | Finish Grinding | Provide surface area for cement hydration and properties modification | → Cement |

# Cement Plant Schematic Process Flow



# Quarrying

- Most limestone quarry are not uniform
- Origin from organisms like corals, algae in "Shallow marine carbonate platform"
- Complex structure due to formation mechanism, faults, foldings.
- Quarry planning
  - Resource conservation – Overburdens, Low Ca layers, High MgO layers, Gypsum
  - Controls of harmful elements, such as Alkali, Chloride, MgO




## LIMESTONE QUARRY LAYOUT

- - - - - TRACE OF MOBILE CRUSHER

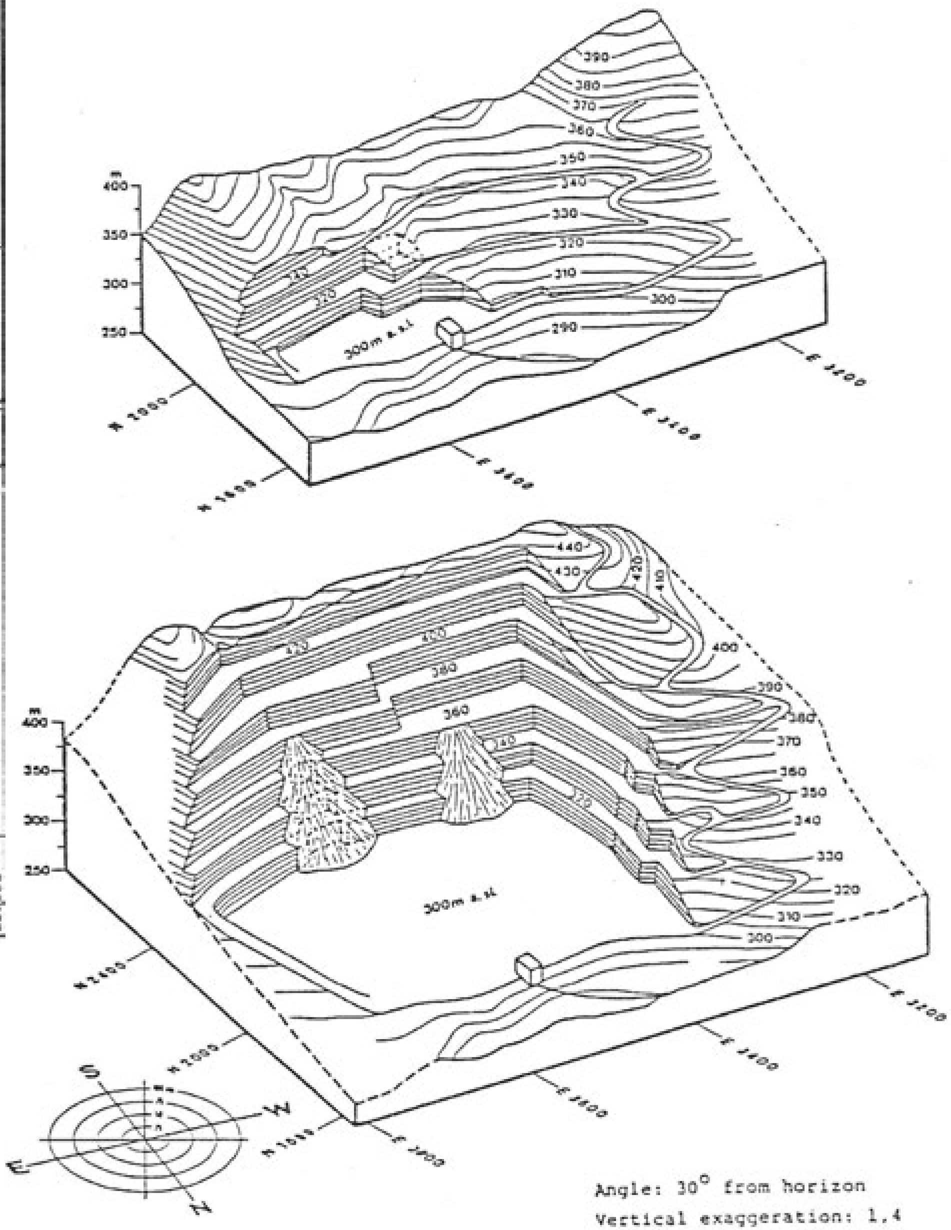
— · — · — BELT CONVEYOR

L 3.0 — QUARRY FACE AFTER 3 YEARS OPERATION

○ 273 DRILLHOLE LOCATION

## LIMESTONE QUARRY DEVELOPMENT

0,5 and 15 years after opening

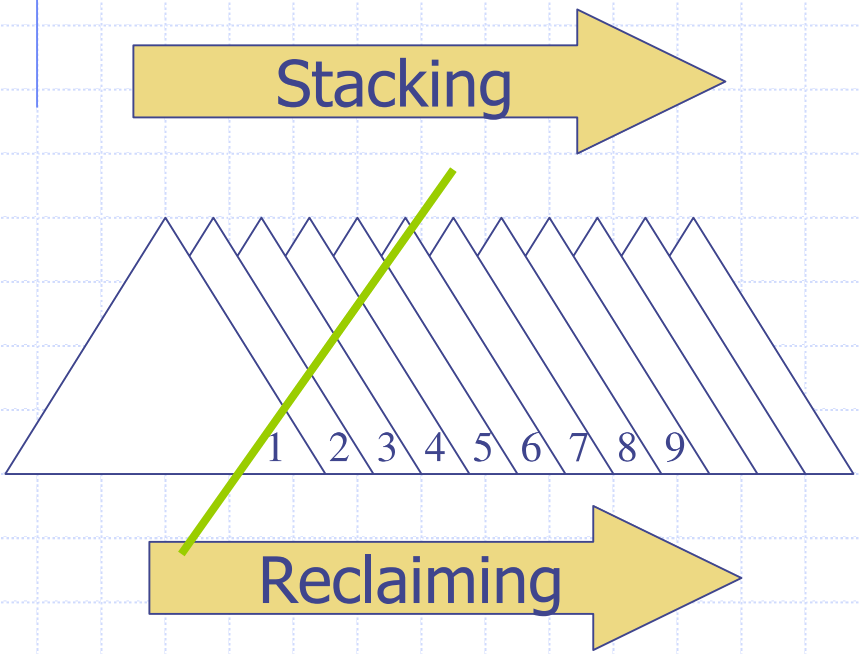


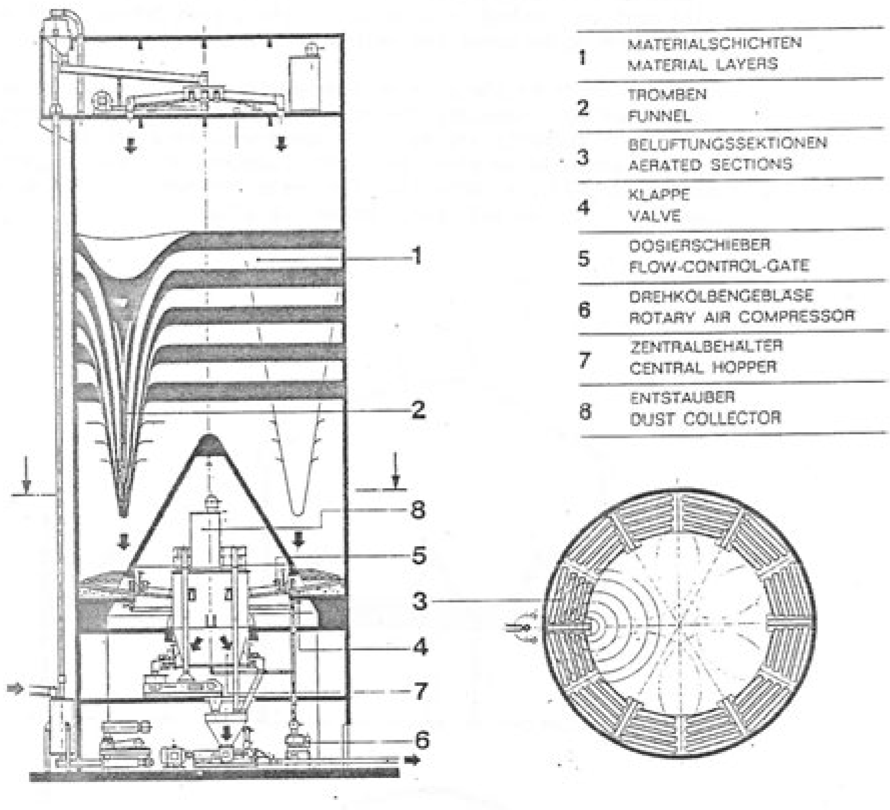

Angle: 30° from horizon

Vertical exaggeration: 1,4

# Pre-blending & Homogenizing

- Further reduce quality variation from quarry
- Applicable to limestone, clay, coal

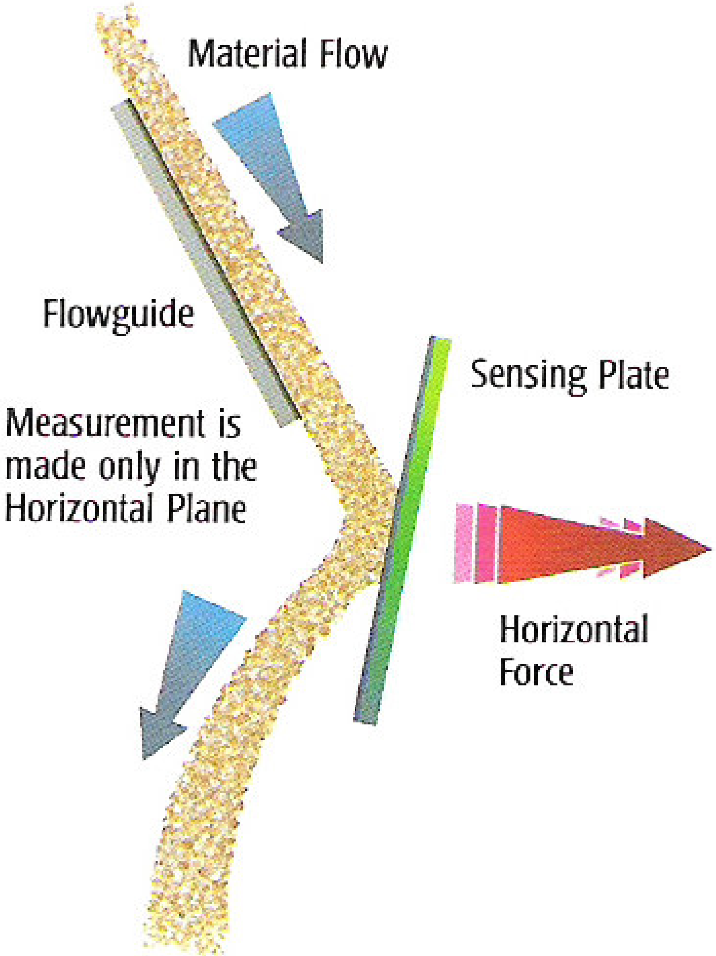


# Raw Meal Proportioning

- Raw Mix design
  - Clinker performance – Bogue's formulas
  - Burnability – Free lime VS temperature
  - Coal ash correction
  - Cost
- Control parameters – LSF, S/R, A/R
- Material dosing, drying and grinding

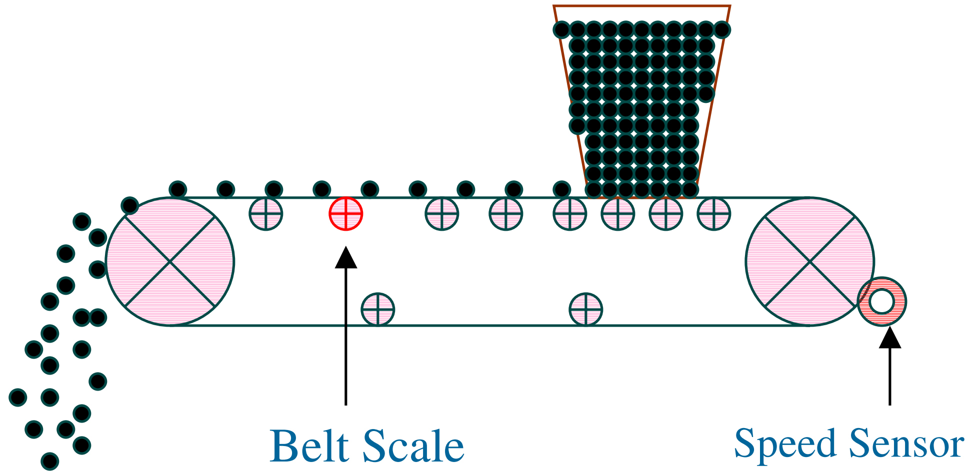
# Impact Flowmeter




Total enclosure, ideal for powder

Less accurate

# Belt Weight Feeder



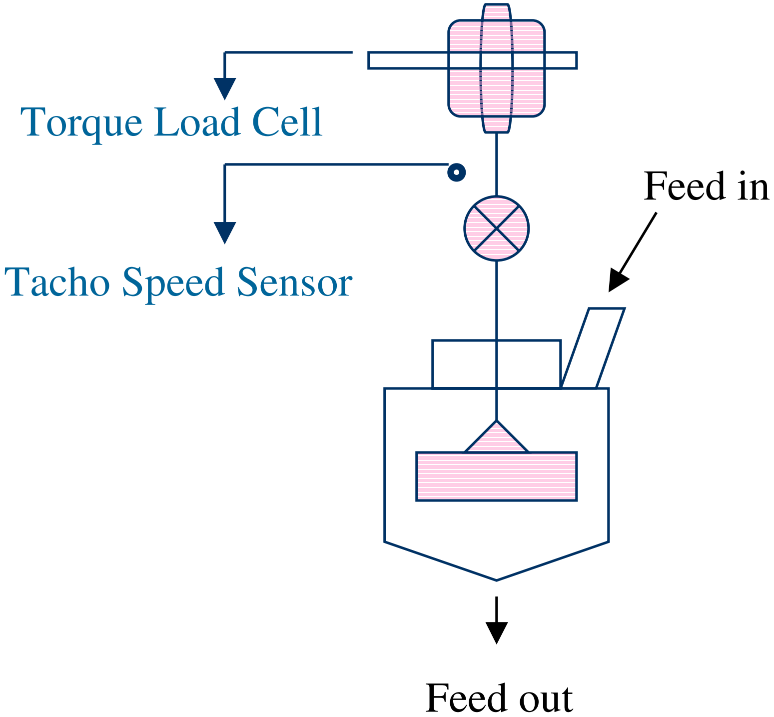


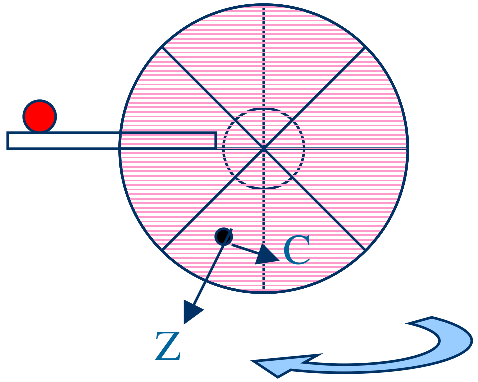
Flow (tph) = Weight x Speed

Accuracy : Better than 1%

Suitable for very high flow rate

# Coriolis Flowmeter



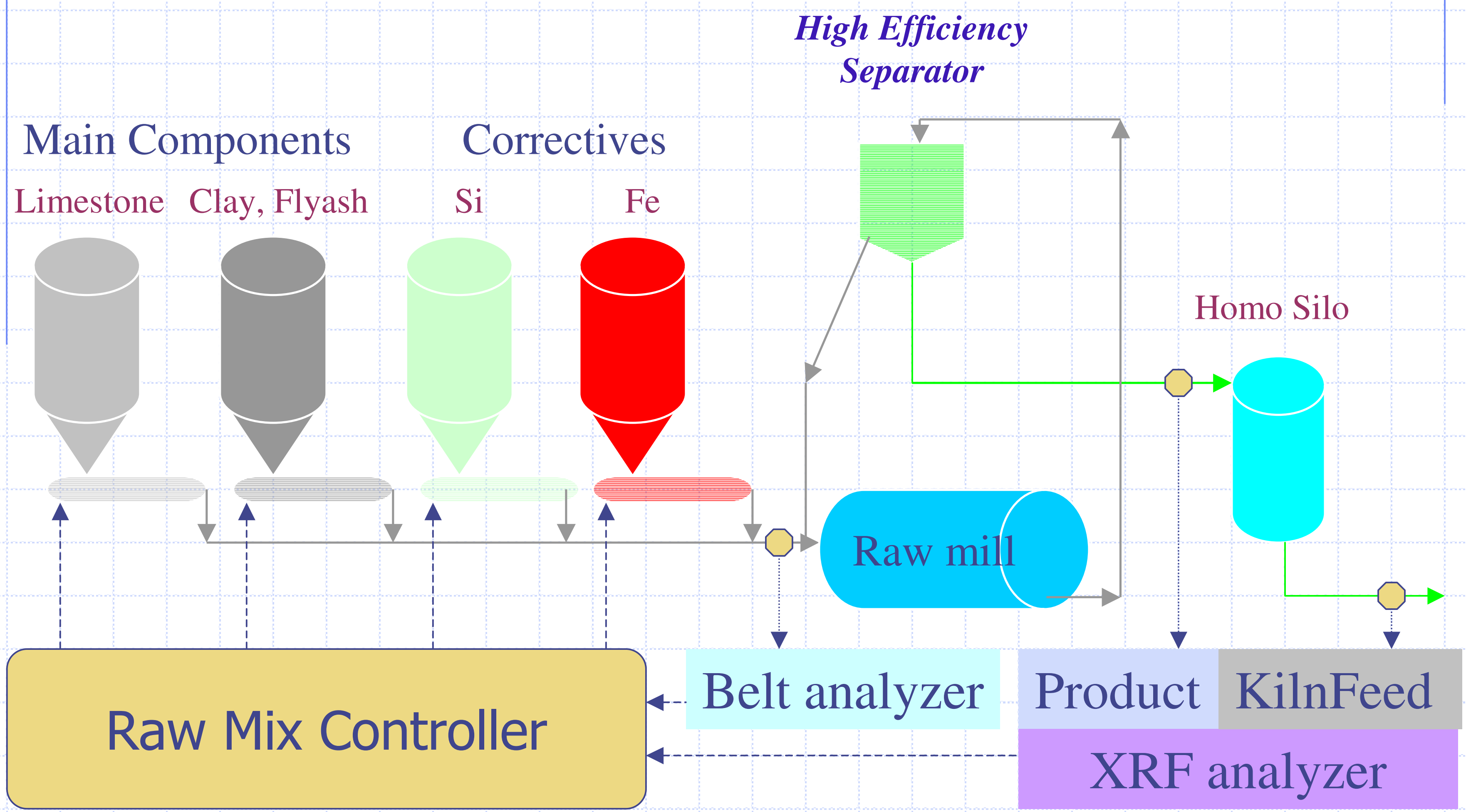




Flowrate * Angular speed * Radius^2 = Torque

Totally enclosure, ideal for powder

Very accurate : For Coal, Cement Additives Dosing

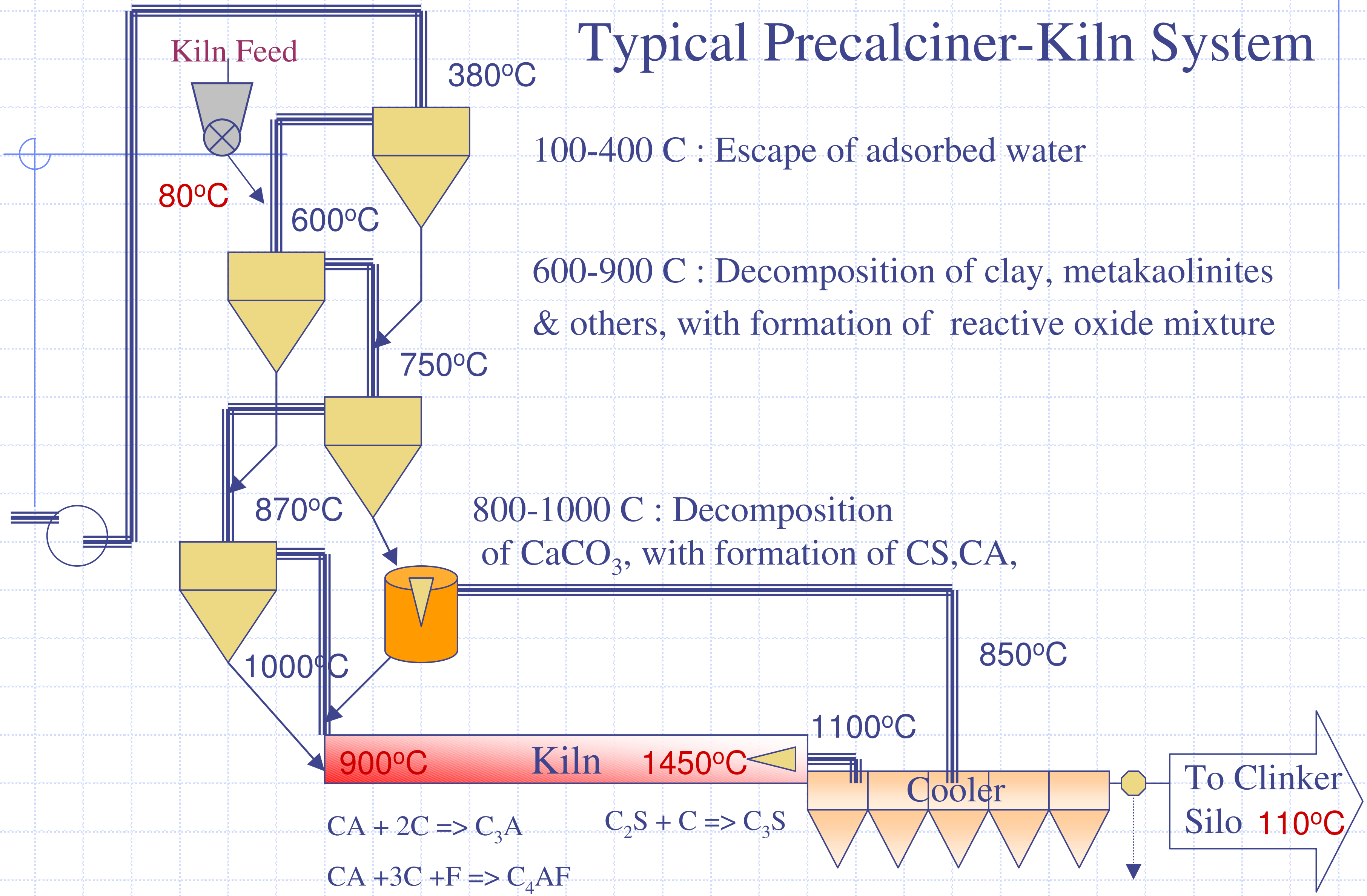
# Typical Close Circuit Raw Grinding with High Efficiency Separator



# Raw Mill Controls

| Processes | Objectives |
|---|---|
| Raw Material Dosing | ◆ Ensure correct potential clinker chemistry |
| Raw meal fineness | ◆ Ensure proper heat transfer in Preheater |
| Coal ash analysis | ◆ Provide data for ash correction |

# Typical Precalciner-Kiln System




100-400 C : Escape of adsorbed water

600-900 C : Decomposition of clay, metakaolinites & others, with formation of reactive oxide mixture

800-1000 C : Decomposition of $CaCO_3$, with formation of CS,CA,

$CA + 2C \Rightarrow C_3A$

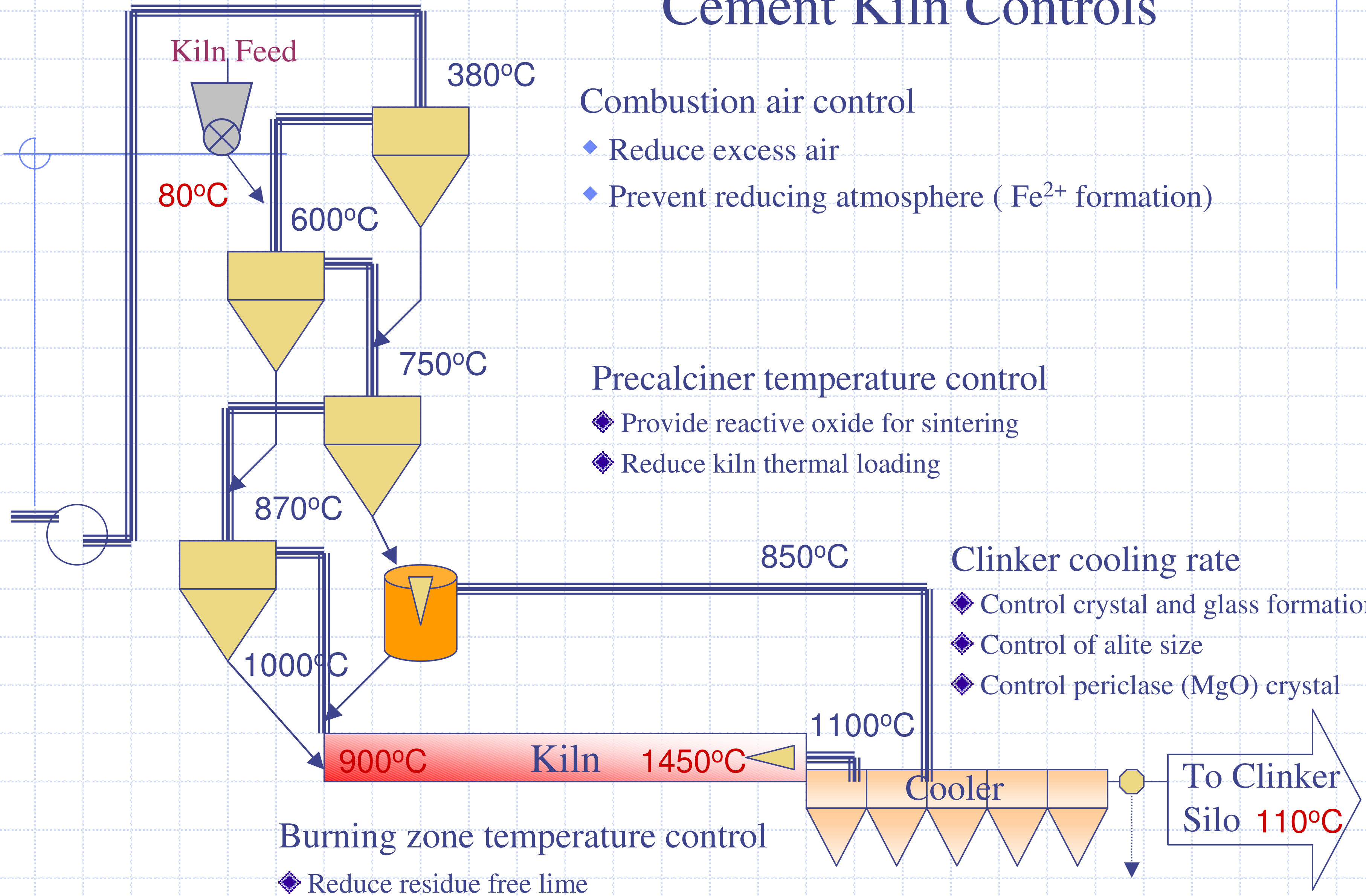
$CA + 3C + F \Rightarrow C_4AF$

$CS + C \Rightarrow C_2S$

$2C + S \Rightarrow C_2S$

$C_2S + C \Rightarrow C_3S$

# Cement Kiln Controls




### Combustion air control

- Reduce excess air
- Prevent reducing atmosphere ( $Fe^{2+}$ formation)

### Precalciner temperature control

- Provide reactive oxide for sintering
- Reduce kiln thermal loading

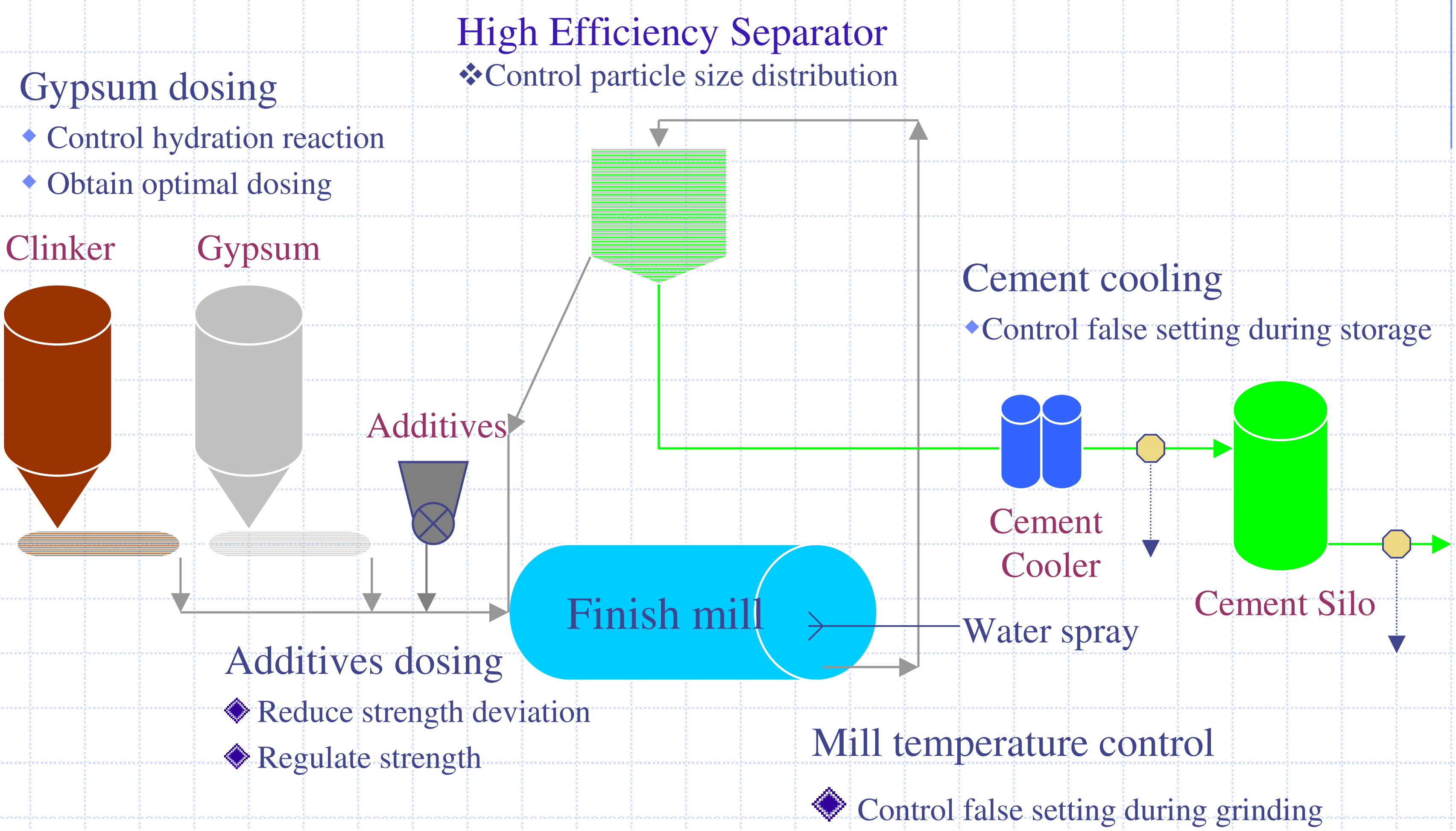
### Clinker cooling rate

- Control crystal and glass formation
- Control of alite size
- Control periclase (MgO) crystal

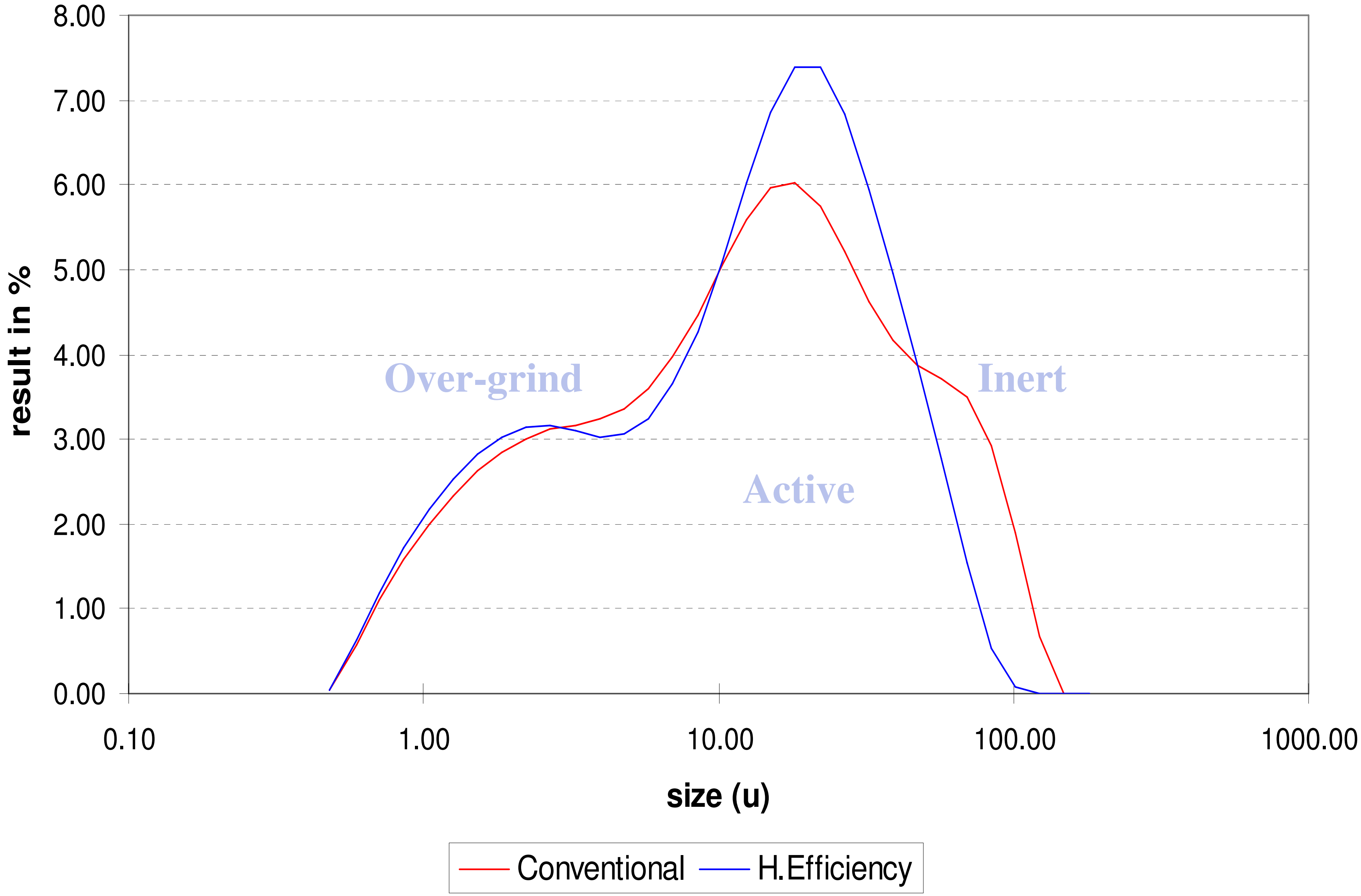
### Burning zone temperature control

- Reduce residue free lime
- Complete transform $C_2S$ to $C_3S$

# Typical Close Circuit Finish Grinding With High Efficiency Separator



# Comparison of Size distribution on Separator product



# Comparison of Separator

| | Blaine, $cm^2/g$ | 45um residue, % | Specific Power Consumption, kWh/t |
|---|---|---|---|
| Open Circuit | 3800 | 14% | - |
| Mechanical Separator | 3600 | 14% | 49 |
| H. E. Separator | 3200 | 8% | 45 (-8%) |

# Conflict between BS12:1989 & HE Separator

| Test items | BS12:1989 Limits | | 2002 Average | |
|---|---|---|---|---|
| | OPC | RHPC | HK | Japan |
| Fineness, $m^2/kg$ | >275 | >350 | 330 | 325 |
| Mortar Strength 3 days, MPa | >25 | >25 | 35.5 | 34.0 |
| 28 days, MPa | >47 <67 | >52 | 69.0 | 68.5 |

# Standards & Cement Process

- HE Separator drove the review of BS12:1989.
- Auto-Control scheme of BS12:1991 provides incentives to reduce SD through QA.
- Provision of 5% additive enables better control of strength variation and cost saving.
- End-users are benefit from the addition of 5% pozzolanas.

# Thank You