CII

Manual on
Thermal Energy Efficiency in Cement Industry

May 2012

Version 1.0

Confederation of Indian Industry
CII - Sohrabji Godrej Green Business Centre

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While every care has been taken in compiling this Manual on Thermal Energy Efficiency in Cement Industry, CII- Godrej GBC does not accept any claim for compensation, if any entry is wrong, abbreviated, omitted or inserted incorrectly either as to the wording space or position in the Manual. The Manual is a store of information so that it will be useful to the plant personnel involved in energy conservation and can be used by them readily.

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CII - Sohrabji Godrej Green Business Centre

Survey # 64, Kothaguda Post,

R R District, Hyderabad - 500 084, India.

FOREWORD

CII-Sohrabji Godrej Green Business Centre, as part of its World Class Energy Efficiency initiative, has been releasing several publications, case study booklets etc. on a regular basis to make the latest information available to all stakeholders in the cement industry. One such initiative was the release of Manual on Thermal Energy Efficiency in Cement Industry in 2012.

With PAT targets being announced, industry needs to focus more on Thermal Energy Efficiency. Additional incentives that can be obtained by exceeding PAT targets will reduce longer payback period of Thermal Energy Efficiency projects and makes them economically viable.

The Manual on Thermal Energy Efficiency in Cement Industry is an outcome of the feedback received from various stake holders of the industry. Indian cement industry has several successful case studies on Thermal Energy Efficiency and this manual is a small effort to recognize such good efforts, Up keeping knowledge on Pyro process including latest norms and to serve as a reference for Cement manufacturers to reduce thermal Specific Energy Consumption.

I would sincerely request all the readers to not only make full use of the Manual across your organizations but also to pass any comments /suggestions / feedback on the Manual you may have to CII-Sohrabji Godrej Green Business Centre. Your feedback will encourage us at CII-Sohrabji Godrej Green Business Centre to take such initiatives in future.

(G. Jayaraman)

Chairman, Green Cementech 2012, CII- Godrej GBC &

Executive President, Birla Corporation Ltd.

Acknowledgment

CII expresses sincere gratitude to the experts for sparing their valuable time to review the document offering inputs and suggestions to make this manual more useful to all stakeholders

The Manual has been sent to the following experts for their views, inputs and comments.

Mr Antony Chacko, ACC Ltd

Mr K N Rao, ACC Ltd

Mr R Vasudevan, ACC Ltd

Mr S Rama Rao, Ambuja Cements Ltd

Mr C Sudhakar, Chettinad Cement Corporation Ltd

Mr J V Gungune, Dalmia Cement Bharat Limited

Mr K C Narang, Dalmia Cement Bharat Limited

Mr R S Mani, FLSmidth

Mr Girish C Pandey, Heidelberg Cement

Mr R Madhusudhan, Ikn Engineering India Private Limited

Mr J Thirumeni, India Cements Limited

Mr Alok Joshi, Jaypee Cement Limited

Mr B L Saini, Jaypee Cement Limited

Mr P V R Murthy, KHD Humboldt Wedag International

Mr M Srinivasan, Madras Cements Ltd

Mr S Shanmugam, Madras Cements Ltd

Mr S V R K M Rao, Madras Cements Ltd

Mr P Ramasamy, Star Cement

Mr R Bhargava, Shree Cement Ltd

Mr Makarand Marathe, Thyssenkrupp

Mr L Rajasekar, Ultratech Cement Ltd

Mr C K Jain, Vasavadatta Cement

Mr Gopi Ranganathan, Zuari Cement Ltd

Contents

SECTION 1
Useful formulae, Model calculations, norms & CFD

Chapter - 1

Preheater

1.1 Spray cooling of gas[1]:

Amount of Water spray for cooling gas can be calculated as mentioned below:

Water t/h = Q.ρ.S.ΔT/[(100-Tw)+539)]

Where	Q	= gas flow Nm^3/h
	ρ	= gas density Kg/Nm^3
	ΔT	= gas cooling, ^0C
	S	= specific heat kCal/Kg ^0C
	Tw	= water temperature ^0C

1.2 Oxygen concentration at Preheater exit (for Preheater without air lift feeding)

Oxygen concentration at preheater exit to be maintained during steady state running of the Kiln : 2.5 to 3% O_2

Oxygen concentration at Kiln inlet : 1.5 to 2% O_2 (dry) CO < 0.01%

Target false air across Preheater tower : 5% of Preheater gases by volume or 1% increase in O_2 content

1.3 Separation efficiency of top stage cyclone : 92 –95 %

1.4 Gas Residence time in Precalciner:

Typical residence time of gas in precalciner for different fuels: 3-5 sec

1.5 False Air:

Air leakage through an aperture of area A (m^2) with pressure differential dP (mm H_2O) can be approximately calculated from

Volume (m^3/hr) = 8900 X A X $dP^{0.5}$

Air leakage between two points in the kiln exhaust system can be determined by oxygen measurement.

False air (in terms of outlet) % = 100 $(G_2-G_1)/(20.9-G_1)$

Where G_1 = initial O_2 %
G_2 = final O_2 %

1 Cement plant operations hand book for dry process plants 4th Edition 2005,

1.6 Typical heat balance of ILC kilns with Six-stage preheater:

Prodcution level	TPD	3400	3400	3400	3400
Ambient Temperature	Deg C	20	45	20	45
Cooler Type		SF / CB	SF / CB	CIS / CFG	CIS / CFG
Clinker tempeature @ cooler discharge	Deg C + ambient	65	65	65	65
Input cooling air	kg / kg cli	2.3	2.3	2.55	2.55
PH exhaust gas	kg / kg cli	1.95	1.98	1.98	2.01
PH exit temperature	Deg C	270	282	275	288
Cooler vent air	kg / kg cli	1.27	1.25	1.5	1.47
Cooler vent Temperature	Deg C	313	323	290	300
Heat balance in (kCal / kg cli)					
Heat in PH exhaust gas and dust		136.3	146.6	140.7	151.9
+ Radiation loss from Preheater		42.0	42.0	42.0	42.0
+ Radiation loss from Kiln		27.0	27.0	27.0	27.0
+ Radiation loss from cooler		6.0	6.0	6.0	6.0
+ Heat of Reaction		405.0	405.0	405.0	405.0
Specific Fuel consumption	KCal/ Kg cli	691.0	692.0	703.0	704.0

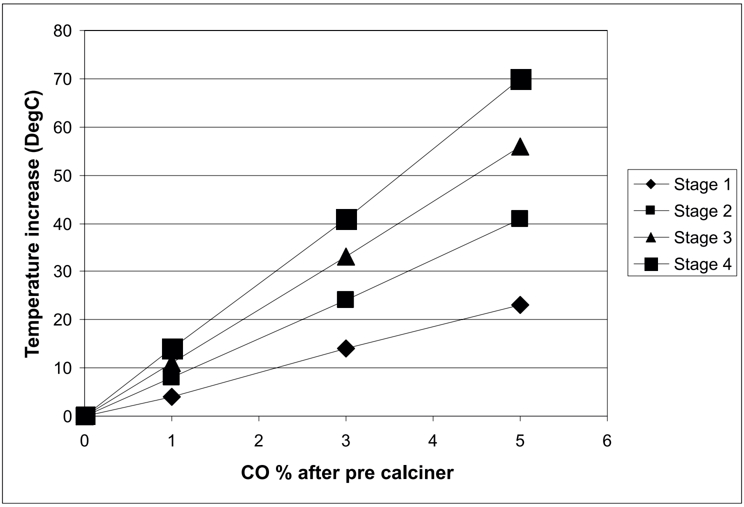
1.7 Effect of false air on heat consumption:

Effect of false air on heat consumption in a five stage preheater for 0.5% increase in cyclone exhaust O_2

	kCal/kg cli
Top stage-	12
II stage	22
III stage	34
IV stage	45
V stage	60

1.8 Effect of incomplete combustion (CO) in Pre Calciner:

Effect of incomplete combustion in Pre calciner in a 5 stage pre heater



1.9 Effects of improvements/losses of Kiln System:

Improvements/losses in kiln system

S.No	Details	Losses KCal/kg cli
1	Lowest 2 cyclones without dip tubes	14.3
2	No meal flap in lowest chute	4.8
3	10% additional primary air	14.3
4	0.1 Nm^3/kg cli false air at kiln inlet	22.7
5	10% additional excess air at combustion	7.2
6	10% higher moisture content of fuel	7.2

1.10 Effect of stage addition in Preheater:

Control parameter	Units	4 to 5 stages	5 to 6 stages
Heat consumption	kCal/kg cli	-18 to 25	-8 to -12
Exhaust gas temp	^{o}C	-40	-20
Exhaust gas flow	Nm^3/kg cli	-0.03	-0.015
SP exit pressure	mmWC	+50 to 80	+50 to 80

Chapter - 2

Kiln

2.1 Kiln burner performance:

Primary air momentum is calculated (% m/sec):

% m/s = Lp % x C

Where :

Lp : The primary air % of the total minimum air requirement for complete combustion of fuel fired in Kiln.

C : Primary air velocity at the burner nozzle

For a multi channel Burner:

Flame momentum of a multi channel burner when primary air is divided into axial air and radial air :

Total flame momentum flux = Axial air momentum flux+ Radial air montum flux

Model calculation:

Clinker production	=	200 TPH
Specific Heat consumption	=	725 kCal/kg clinker
Fuel fired in Kiln burner	=	40% of total fuel
Primary air	=	9270 m^3/hr at 30^0C
Net calorific value of fuel	=	7500 kCal/kg coal
Theoretical air required for 1 kg of fuel firing	=	8.1 Nm^3/kg of fuel
Air Channel Cross Section Areas:		
Axial A1	=	0.0101 m^2
Radial A2	=	0.0075 m^2
Air flow at Burner tip:		
Axial A1	=	9270 X 0.9 X 0.65
	=	5425 m^3/hr at 30^0C
	=	5397 Nm^3/hr
Radial A2	=	9270 X 0.9 X 0.65
	=	2920 m^3/hr at 30^0C
	=	2754 Nm^3/hr
Total heat requirement	=	$\frac{725 \times (40/100) \times 200 \times 1000}{10^6}$
	=	58 G.Cal/hr
Total air required for fuel	=	$\frac{58 \times 10^6 \times 8.1}{7500}$
	=	62,640 Nm^3/hr

Velocities at the nozzle:

Axial V1 = $\frac{5397}{(3600 \times 0.0101)}$

= **148.4 m/s**

Radial V2 = $\frac{2754}{(3600 \times 0.0075)}$

= **102 m/s**

Primary Air as a % of Stoichiometric Combustion air:

Axial air AA% = $\frac{5397 \times 100}{62640}$

= **8.6%**

Radial air RA% = $\frac{2754}{62640}$

= **4.4%**

Total flame momentum flux = 148.4 m/s X 8.6% + 102m/s X 4.4%

= 1725 % m/s

Specific impulse:
Specific impulse is the change in momentum

Optimum Specific Impulse: G = 10 - 11 N/MW

2.2 Kiln burner optimum design[2]:

Range of Kiln Burner Primary air momentum:

(with 6 to 8% primary Air) : 1250 to 2000 % m/s

(Primary Air as a % of Stoichiometric Combustion air)

Optimum Kiln Burner Primary air momentum:

(with 6 to 8% Primary Air) : 1400 to 1600 % m/s

(For strong, stable, short and narrow flame)

Lower Primary Air Momentum causes longer flame & high kiln shell temp in burning zone area, high kiln backend temperature, extended burning zone & lower burning zone temperature.

2 Kiln burner optimum design data

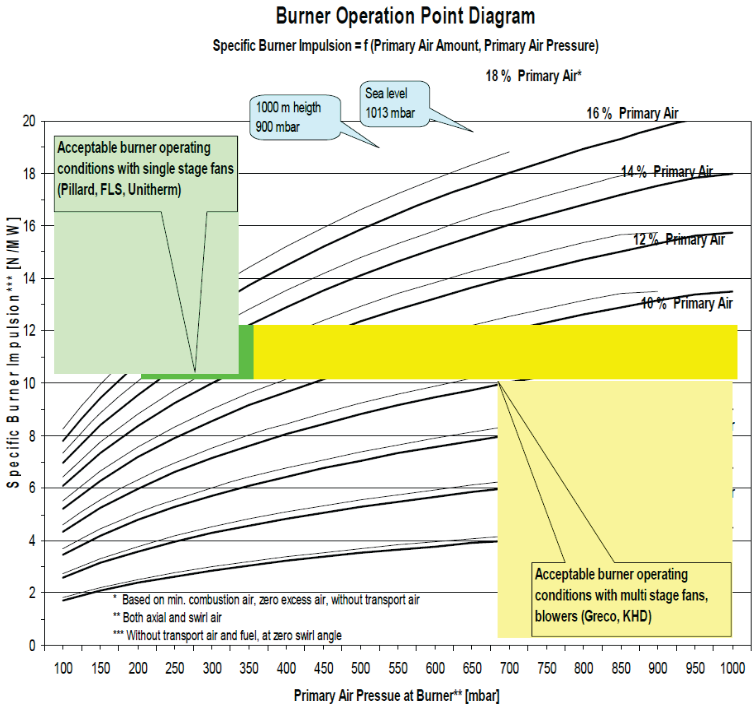
2.3 Main Burner solid fuel loading and injection velocity at burner tip :

Fuel	Solid Fuel Loading in Transport Duct (kg/m³ air)	Injection velocity at burner tip (m/s)
Peat / brown coal,	5 -7	35 - 40
Coal	5 -7	~30
Petcoke	3-5	~25
Anthracite	1.5 -2	20-25

- Feed of solid fuel (kg/s) divided by the transport air flow in duct (m³/s)
- Transport velocity of solid fuels in the transport duct: >25 m/s (acceptable)

2.4 Burner specification :

Volume flow of transport air (m³/s) at burner tip temperature divided by the area of the solid fuel injection channel at the burner tip.



Typical specifications used by vendors for burners with indirect firing

Parameter	FLS 'Duoflex'	Pillard 'Rotoflam'	KHD 'Pyrojet
PF conveying air	2%	2%	3.8%
Total primary air (axial + swirl)	6-8%	8%	4.3%
Axial velocity, m/s	140-160	200-230	350-450
Swirl velocity, m/s	(combined)	100-200	100-200

2.5 Kiln Exhaust Gas (Coal) calculation[3]:

Assume a typical bituminous coal with ultimate analysis (as dried basis)

C	80.0%
H	5.0
S	1.0
O	5.0
N	0
Ash	8.0
Net kCal/kg	7400

with indirect firing and specific fuel consumption of bituminous coal 0.127 kg/kg clinker. Combustion gases produced can be calculated as under:

C	0.80 X 127	--->	101.6g X 22.4/12	=	190 L CO_2	=	271 g O_2
H	0.05 X 127	--->	6.35g X 22.4/2	=	71 L CO_2	=	51
S	0.01 X 127	--->	1.27g X 22.4/32	=	0.9 L CO_2	=	1
							-------------
							323 g O_2

Then added O_2 required for combustion = 323g – 6.35g = 317g = 222 L

Or 0.222 Nm^3

Then equivalent N_2 from air = 222 L X 79/21= 835 L

Or 0.835 Nm^3

CO_2 from calculation of raw meal to yield 1kg clinker (assuming kiln feed LOI of 35%)

((1000/0.65)-1000) = 539 g = 274 L or 0.274 Nm^3

Then total CO_2 in exhaust gas = 274L+190L = 0.464 Nm^3

H_2O from Kiln feed (assuming 1.65 Kiln feed: clinker factor and 0.5% H_2O)

1 kg X 1.65 X 0.005 = 8.25 g = 10 L or 0.01 Nm^3

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Then exhaust gas with no excess air is:

CO_2	0.463 Nm^3	=	33.5%
H_2O	0.081	=	5.9
SO_2	0.001	=	0.1 (1000ppm)
N_2	0.835	=	60.5

	1.38 Nm^3		

Estimation of net **exhaust gas volume, Nm^3/kg clinker @ 0% excess O_2**

= (kCal/kg X 0.00129) + 0.284

Estimation of **gross exhaust gas volume, Nm^3/kg clinker with n% O_2**

= Net Nm^3/kg X (1+n/(21-n))

2.6 Gas velocities[4]:

Upper limits and lower limits of Gas velocities at different areas in Pre heater, Kiln and cooler are given below:

a) Upper Limits:

	m/sec
Through Cooler grate	10
Hood	6
Under Cooler bull – nose	15
Burning zone (1450^{0}C)	9.5
Feed end transition (1000^{0}C)	13
Riser	28
Preheater gas ducts	15

b) Lower Limits:

	m/sec
Tertiary duct	30
Pulverized Coal conveying	25

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2.7 Kiln thermal loading[5]:

Heat loading, $kCal/hr/m^2$		$= F \times GCV / \pi (D/2)^2$
Where	F	= kiln fuel rate, Kg/h
	GCV	= gross calorific value of fuel, kCal/kg
	D	= effective kiln diameter, M

Standard heat loading values:

LD (long dry kiln)	1.2 $kCal/hr/m^2$
SP (Preheater kiln)	2.0
AT (air through Precalciner)	3.0
PC (Precalciner)	4.0 to 6.0
NPC (New Precalciner)	5.0 to 6.0

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Chapter -3

Cooler

3.1 Grate Cooler :

- Specific grate area loading < 45 t/d m^2
  (Daily clinker production (t/d) / total active grate surface area (m^2)
- Specific grate width load < 1250 t /d m (Preferred)
  < 1500 t/d m (Maximum)
  (Daily clinker production (t/d) divided by grate width (m))
- Grate speed : 10 – 15 str/min
  Typical grate speed in strokes/ minute (higher speed means higher grate wear)
- Installed specific cooling air volume < 2.0 Nm^3/Kg cli (for new coolers)
  < 2.5 Nm^3/Kg cli (for old coolers)
  installed cooling air volume (Nm^3/h) / hourly clinker production (Kg/hr)
- Vent air take off velocity < 5 m/s For new installations
  < 6 m/s For old installations
- Tunnel velocity < 10 m/s
  (horizontal air velocity towards air extraction locations)

  Exact calculation of the tunnel velocity is difficult. Rough estimations can be made using cooling air distribution together with cooler drawings and an estimation of air temperature at the respective location.

3.2 Cooler recuperation efficiency:

Cooler efficiency E % = $(C_1 - (V+C_2+R))/ C_1$

Where C_1 = heat content of clinker from kiln

C_2 = heat content of clinker out

V = heat content of cooler vent air

R = Cooler radiation

Typical efficiencies:

Conventional Grate cooler	60 – 70%
Air beam	70 – 75%
Latest generation cooler	75 – 78%

Chapter – 4

Raw Meal & Fuels

4.1 Solid fuel heat value[6]:

Gross heat value kCal/Kg = 80.8 C + 22.45 S + 339.4 H -35.9 O

Net heat value, kCal/kg = 80.8 C+22.45 S + 287 (H-O/8) – 6 W

Where W is H_2O content, %

Gross - Net = 51.5 H*

Where H* is total % H_2 including H_2O

(Gross heat is the theoretical heat of combustion which assumes that water produced is condensed. In practice, water is usually released as vapour so that only Net Heat is recovered).

4.2 GCV & NCV of various fuels

Fuel	[12]Higher Calorific Value (Gross Calorific Value - GCV)
	kJ/kg
Acetone	29,000
Alcohol, 96%	30,000
Anthracite	32,500 - 34,000
Bituminous coal	17,000 - 23,250
Butane	49,510
Carbon	34,080
Charcoal	29,600
Coal	15,000 - 27,000
Diesel	44,800
Ethanol	29,700
Ether	43,000
Gasoline	47,300
Glycerin	19,000
Hydrogen	141,790
Lignite	16,300
Methane	55,530

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Oils, vegetable	39,000 - 48,000
Peat	13,800 - 20,500
Petrol	48,000
Petroleum	43,000
Propane	50,350
Semi anthracite	26,700 - 32,500
Sulfur	9,200
Tar	36,000
Turpentine	44,000
Wood (dry)	14,400 - 17,400
	kJ/m^3
Acetylene	56,000
	kJ/kg
Butane C_4H10	133,000
Hydrogen	13,000
Natural gas	43,000
Methane CH_4	39,820
Propane C_3H8	101,000
Town gas	18,000
	kJ/l
Gas oil	38,000
Heavy fuel oil	41,200
Kerosene	35,000

- 1 kJ/kg = 1 J/g = 0.4299 Btu/ lb_m = 0.23884 kCal/kg
- 1 kCal/kg = 4.1868 kJ/kg = 1.8 Btu/lb_m
- 1 dm^3 (Liter) = 10^{-3} m^3 = 0.03532 ft^3 = 1.308x10-3 yd^3 = 0.220 Imp gal (UK) = 0.2642 Gallons (US)

Typical Data for Solid Fuels (% as recd/mineral-matter-free):

	Coal A	Coal B	Coal C	Coal D	Lignite	Coke	Shale	Sludge	Refuse
C, %	82.8	78.4	82.0	82.5	66.0	85.2	77.8	53.0	50.2
H, %	4.5	4.8	6.2	4.3	0.6	3.7	9.5	7.7	6.8
N, %	1.86	1.54	0.82	1.91	1.20	1.5	0.20	5.00	1.25
S, %	0.35	0.52	0.82	0.70	0.40	5.5	1.70	0.80	0.20
O, %	10.4	14.6	10.1	10.5	31.8	1.7	10.8	33.5	41.6
Cl, %	0.07	-	-	-	-	-	-	-	-
Ash, %	8.0	3.0	36.8	12.9	16.1	0.3	47.1	37.0	20.8
H_2O, % 7.5	3.0	4.3	3.2	4.5	0.7	2.0	0.2	28.2	
Volatiles, %	27.2	38.7	22.0	28.1	43.0	11.0	51.4	-	-
Fixed C, %	57.3	55.3	41.2	57.1	40.9	79.1	1.5	-	-
GCV kcal/kg	6520	7100	4550	6500	5880	8200	2900	4440	2470
NCV kcal/kg	6280	6840	4220	6270	5850	8040	2710	4030	2170
Air required*	10.9	10.4	11.4	10.8	7.1	11.5	12.1	8.1	7.3
Hardgrove	60	45	57	65	>100	60	-	-	-

Ref: Coal A – Blair Athol, Australia   Coal B – El Cereon, S America   Coal C – CCL, India   Coal D – Amcoal, S Africa
Coke – Green delayed   Shale – Oil shale, Lithuania   Sludge – Dried sewage, UK   Refuse – Domestic, USA

Typical Data for Liquid Fuels:

	Kerosene	Gas Oil	Heavy Fuel Oil	Vacuum Residue	Orimulsion	Blended Waste
C, %	85.8	86.1	85.4	86.8	61.4	70.1 - 83.3
H, %	14.1	13.2	11.4	9.9	6.5	7.1 – 8.4
S, %	0.1	0.7	2.8	1.0 – 5.5	2.9	2.8 – 3.3
O, %				0.5		0.0 – 15.0
N, %			0.40	0.46	0.40	
Cl, %						4.0 – 6.7
Ash, %			0.04	0.20	0.22	
H_2O, %			0.30		29.8	
V, Ni, etc, ppm		5 – 70	70 – 500	460		
SG (water = 1)	0.78	0.83	0.96	1.00-1.05	1.01	0.80-1.00
Viscosity, cSt	1.48 @38°C	3.3 @38°C	862 @38°C	1000-3200 @100°C	600 @50°C	15-50 @38°C
GCV, kcal/kg	11,100	10,250	10,250	10,200	7,260	
NCV, kcal/kg	10,390	9,670	9,670	9,610	6,740	5-10,000
Solids						100%-200μ
Air required	14.7	13.8	13.8	13.5	9.3	9.3 - 12.6

API Gravity = (141.5/SG) - 131.5

1 BBL oil = 42 gals(US)

Typical Data for Gaseous Fuels:

	North Sea NG	W Aust NG	LPG	Blast Furn Gas	Coke Oven Gas	Digester Bio-gas	Landfill Gas
O_2					0.5		
CO_2	0.2			17.5	4.0	38.0	14-17
CO				24.0	4.0		
H_2				2.5	30.0		
N_2	1.5	1.1		56.0	4.0		0-47
CH_4	94.4	98.6			52.0	57.0	25-60
C_nH_m	3.9	0.3	100		5.5		
H_2S					5.0		
GCV kcal/M^3	9050	8930	22,430	760	8070	5730	2400-5730
NCV kcal/M^3	8270	8050	20,640	740	7260	5180	2150-5160
SG (air = 1)	0.6	0.6	1.5	1.0	0.6	1.0	0.9-1.0
Air required*	9.8	9.4	23.8	0.6	8.2	5.8	1.9-5.7
Flame speed	34.0	33.7	39.7	10.5	59.8	23.9	22.3-24.6

**Air required is theoretical Volume ratio*
Flame speed, M/sec

$$\text{Gross kcal/M}^3 = 90.3CH_4 + 159.2C_2H_6 + 229C_3H_8 + 301.9C_4H_{10} + 373.8C_5H_{12} + 57.6H_2S$$

Most natural gas is free from sulphur but, if it occurs, is usually removed before delivery.

Liquified gases yield the following:

1 L liquid	Methane – 606 L gas
	Propane – 139 L gas
	Butane – 119 L gas

4.3 Clinker Constituents

1. If alumina modulus > 0.64
   - $C_3S = 4.071\ CaO - 7.602\ SiO_2 - 6.718\ Al_2O_3 - 1.43\ Fe_2O_3 - 2.852\ SO_3$
   - $C_2S = 2.867\ SiO_2 - 0.7544\ C_3S$
   - $C_3A = 2.65\ Al_2O_3 - 1.692\ Fe_2O_3$
   - $C_4AF = 3.043\ Fe_2O_3$

2. If alumina modulus < 0.64
   - $C_3S = 4.071\ CaO - (7.602\ SiO2 + 4.479\ Al_2O_3 + 2.859\ Fe_2O_3 + 2.852\ SO_3)$
   - $C_2S = 2.867\ SiO_2 - 0.7544\ C_3S$
   - $C_3A = 0$
   - $(C_4AF + C_2F) = 2.1\ Al_2O_3 + 1.702\ Fe_2O_3$

4.4 Coating tendency[7]:

Coating tendency $= C_3A + C_4AF + 0.2\ C_2S + 2Fe$

Note index < 28 indicates light coating

\> 30 indicates heavy unstable coating, rings & snow men

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4.5 Burnability factor[8]:

Miller's empirical formula for burning at 1400^{0}C

% Free- lime$_{1400}$ =0.33 (%LSF–100)+1.8 (S/R-2)+0.93Q+0.33C+0.34A

Where Q = +45µ residue after acid wash (20% HCl) Identified by microscopy as quartz

C = +125µ residue which is soluble in acid (ie calcite)

A = +45µ residue after acid wash identified by microscopy as Non – quartz acid insoluble

4.6 Required burning temperature[9]:

Required burning temperature maintained for reaction of raw meal constituents to form clinker

Burning temperature, ^{0}C = 1300 +4.51 C_3S + 3.74 C_3A-12.64 C_4AF

4.7 Heat of Reaction :

The amount of heat required (kCal) to form 1 kg of clinker from kiln feed

Q = 4.11 Al_2O_3+ 6.48 MgO + 7.646 CaO – 5.116 SiO_2 – 0.59 Fe_2O_3

4.8 Conversion factors Calculation

Raw meal to clinker factor:

S.N.	Parameter		Unit	Value
1	Kiln feed rate	KF	tph	342.78
2	Loss on Ignition (LOI) of kiln feed	LOI	%	34.93
3	Coal Consumption	C	%	9.57
4	Ash content in coal	A	%	7.00
6	Raw meal to clinker conversion factor (On LOI basis) (CF 1)		-	1.53
7	Dust loss from Preheater	DL	%	9.00
8	Kiln feed to clinker conversion factor (with return dust) (CF 2)		-	1.677

Raw meal to clinker factor = (1- (C x A)/10^4)/ (1- LOI/100)

Kiln feed to clinker factor = Raw meal to clinker factor/ (1- DL/100)

8 (Note: Q,C&A are expressed as % of total total raw mix sample (DuToit; WC; 3/1997, page 77)

9 Cement plant operations hand book for dry process plants 4th Edition 2005

4.9 Raw materials:

4.9.1 Alkali bypass:

No damage to concrete was reported with 0.45% alkali in the Cement. Concrete was damaged in cases where alkali content of the cement was more than 1%. Highest admissible alkali content in cement is 0.6%. with a slag component of atleast 50% can have maximum alkali content of 0.9%. further total alkali of limit of 2% is allowed for cement with slag component of atleast 65%.

K_2O condensation rate in Preheater – 81 – 97%
Na_2O condensation rate in Preheater – 3 – 19%

More than 25% kiln bypass volume has negative impact on the Kiln heat economy. It yields relatively low alkali reduction. In most cases 3-10% bypass volumes are sufficient. Increase in heat consumption about 4-5 kCal/kg clinker for 1% bypass volume. Additional energy consumption is about 2kWh/Ton of clinker.

4.9.2 Melting point of various alkali compounds:

S No	Compound	Melting point ^{0}C
1	KOH	361
2	KCl	768
3	K_2CO_3	894
4	K_2SO_4	1074
5	NaOH	319
6	NaCl	801
7	Na_2CO_3	850
8	Na_2SO_4	884

4.9.3 Required grinding fineness of coal :

Coal is to be grounded finely to fire in the kiln, the required residue on 90 µm and 212 µm as below:
% **R** 90 µm ≤ 0.5 * (% volatiles)
% **R** 212 µm ≤ 2%

4.9.4 Required grinding fineness of pet coke:

Pet coke has to be grounded finely compared to coal. Typical fineness could be as below:

% **R** 90 μm ≤5 %

% **R** 212 μm ≤1 %

4.9.5 Required grinding fineness of pet coke/ Coal mixture:

%R 90 μm ≤ (coal fraction)*0.5*(% volatiles) + (petcoke fraction)*5%

%R 212 μm ≤1 %

Alkali to sulphar ratio of clinker: 0.8 - 1.2 acceptable range

$$\frac{Alk - Cl^-}{SO_3} = \frac{\frac{K_2O}{94} + \frac{Na_2O}{62} - \frac{Cl^-}{71}}{\frac{SO_3}{80}}$$

4.9.6 Maximum chlorine input:

For suspension Preheater and pre calciner kilns

Maximum chlorine input	< 300 g/t cli	without bypass
	300 – 400 g/t cli	Cl^- valve with dust filter
	> 400 g/t cli	with bypass

4.9.7 Apparent decarbonation of the hot meal:

92-96%	for PC systems
30-60%	with secondary firing
10-40%	for PH systems

4.9.8 Silo Homogenising Factor

for finding efficiency of homogenising silo we use the term homogenising factor, which is the ratio between inhomogenity before and after silo.

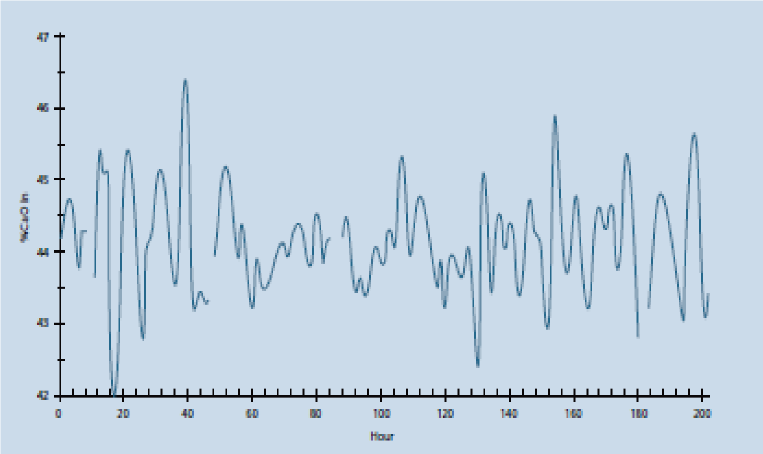
$$H = \sqrt{\frac{S^2_{in} - S^2_{an}}{S^2_{out} - S^2_{an}}}$$

Where H = Homogenising factor

S_{in} = the standard deviation of one chemical parameter in the feed to the silo

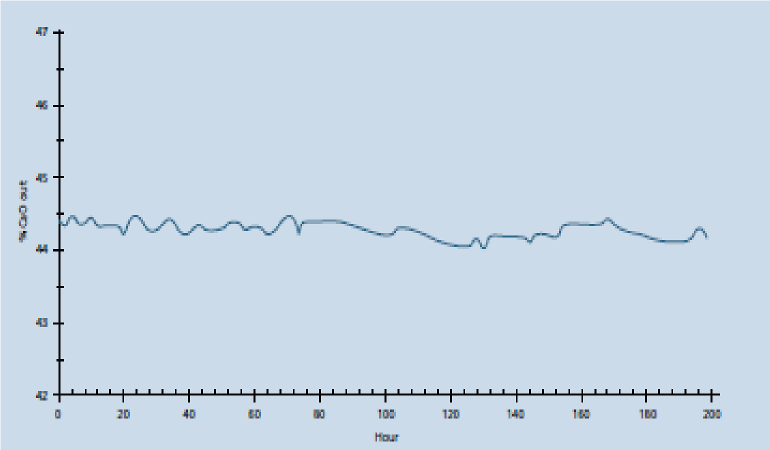
S_{an} = standard deviation attributable to analysis Errors / Standard deviation of the sampling And analysing process (measuring fault)

S_{out} = the standard deviation of one chemical parameter in the discharge from the silo



Chemical variation of input

Obtained result:
S_{in} = 0.70% Cao
S_{out} = 0.10% Cao
S_{an} = 0.03% Cao
Homogenising factor = 7.3



Chemical variation of output

When the true homogeneity of the kiln feed is less than 1% LSF, corresponding to 3% C_3S, 0.2% $CaCO_3$ or 0.1% CaO then there is no further improvement in kiln operational stability or cement quality can be achieved through additional homogenization.

In order not to exceed this level of kiln feed in homogeneity, an H-factor of order of 5-10 is usually required, but it must be considerably higher under adverse conditions.

In the modern silo in practice the Homogenising factor of 10 – 20 is can be achieved.

Chapter 5

Computational Fluid Dynamics

5.1 Introduction

Computational fluid dynamics (CFD) is one of the branches of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the millions of calculations required to simulate the interaction of fluids and gases with the surfaces used in engineering. CFD analysis could be employed to pinpoint high pressure drop zones in ducts.

CFD Predicts fluid flow with the complications of simultaneous flow of heat, mass transfer, phase change and chemical reaction, etc. using set of certain CFD softwares and calculations.

Most of the plants designed using the past technology or the needs at that time are operating close to its design limits in the current scenario as there is increase in the demand. With the rapid advancement in computers, Computational fluid dynamics is used across the world in all industries for validating designs, troubleshooting, maintenance and upgrading so that they operate safely and at peak efficiencies with optimum cost.

Benefits in Cement Plants

CFD study was conducted to pinpoint high pressure drop zones in ducts & cyclones by several cement plants. Benefits from CFD study are encouraging and are summarized below.

- Increase in top stage cyclone efficiency results in reduction in exit temperature
- Uniform gas flow and material distribution
- Reduction in pressure drop across cyclone

CFD applications belt processes by simulating and analyzing them so that it can be optimized the use of materials, tools, shape, time and most important Energy and Cost.

Duct, Cyclones, Preheater, Kiln, Coolers, Piping, Can be analyzed and improved upon by using correct CFD techniques.

Efficiency Improvements: Revisiting the Cyclone design can be a driver for higher collection efficiencies.

Pressure Drop Reduction: Revisiting the ducting and Cyclone designs can be a big driver for reduction in Pressure drops and there by Energy

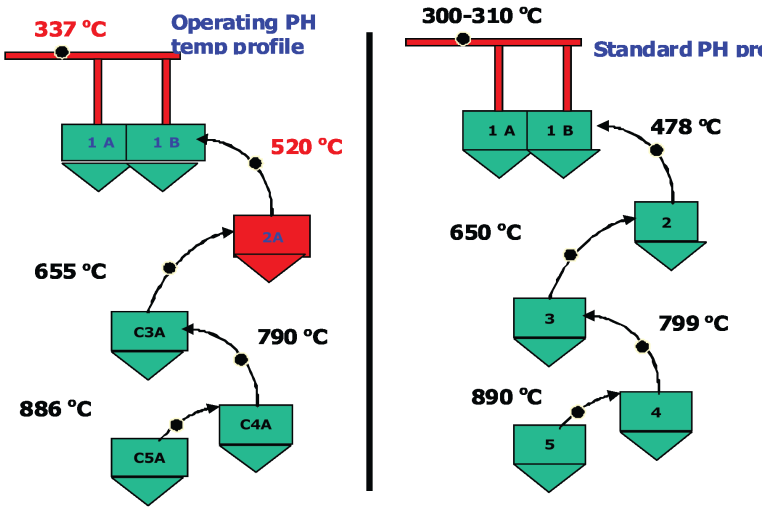
Savings.

The key benefit of CFD is it saves Time and Money as it is "Simulation Based Design" in stead of"Build and Test"

5.2 Pre heater exit temperature reduction :

Pre heater exit temperature in Cement plants is higher than the standard value during the steady operation also. In a plant It was observed that Pre heater exit temperature is 337^{0}C, which is high. The recommended PH exit temperature is 310^{0}C for similar stage Pre heater. This indicates that temperature drop of 27^{0}C is occurring in less. Heat loss is happening due to high Pre heater exit temperature.

The schematic and of the pre heater temperature profile:



From the above figure Cyclones with lesser temperature drop and :

Cyclones	Pre heater exit Temp (^{0}C)	Norm for 5 stage Pre heater exit Temp (^{0}C)
Cyclone No. C1A,C1B and C2A	337	300-310

General reasons for high PH exit temperature:

- High excess air
- High return dust (low cyclone efficiency)
- High velocity and improper material distribution.

Good energy saving potential prevails by reducing the PH exit temperature and thereby reducing the specific thermal energy consumption.

Benefits:

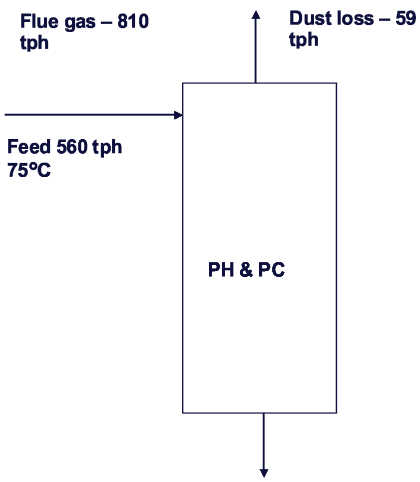
Depending upon margin available, Reduction in heat consumption about 5-20 kCal / kg clinker possible.

5.3 Minmising dust loss from Pre-heater by improving top stage cyclone efficiency:

Pre heater exit losses play a major role in specific thermal energy consumption of the plant. In prehaeter exit loss is divided into preheater exist gas loss and preheater exist dust loss.

Pre heater dust losses depend on the efficiency of top stage cyclone. Modern cement plants are operating with top stage cyclone efficiency of about 95-97%. If the efficiency of the preheater system is <90% then there is a good saving potential exists by minimizing dust losses from preheater.

In a plant the schematic of dust losses given below:



From the figure it is observed that the Preheater dust losses are around 10.5%. Excellent opportunity in reducing dust loss through CFD analysis or retrofitting of topstage cyclone. Positive results on dust loss reduction without increasing pressure drop of the cyclone has been successful in several Cement plants.

Benefits:

Reduction in thermal energy consumption about 2-5 kCal / kg clinker possible.

CFD Implementation Time

Time required to complete CFD study by supplier is depends upon the size and complexity of the problem can vary between 4 to 16 weeks. However, Cement Plant requires 2-3 days of shutdown for implementing this project i.e the installation of flow diverter plates inside the ducts. The major steps involved include:

1. Site Visit and data Collection and verification
2. Phase 1:
   - 3D Model generation
   - Mesh generation
   - Solution
   - Post Processing/ Validation
3. Phase 2 : (Design Modifications)
   - 3D Model modifications based on CFD results
   - Mesh generation
   - Solution
   - Post Processing

SECTION 2
Case Studies

Chapter 6

Thermal Energy Saving Opportunities In Cement Plant

6.1 Lower dispersion box height in riser duct and increase heat transfer in Preheater

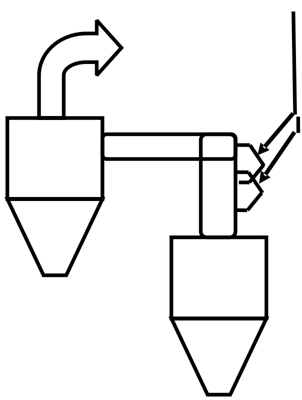
The Preheater system is one of the major areas for potential reduction in thermal energy consumption in the plant. The main aim of the PH system is to recover maximum heat from the kiln exhaust gases and to reduce overall thermal energy consumption.

In Preheater System, the overall system is counter current, whereas stage wise is a co-current heat exchange system.

Maximum heat transfer between the kiln feed & calciner exit hot gases takes place in the riser ducts. In the Preheater cyclones, the separation of feed material and hot air takes place. The feed material is then fed to the lower cyclone and the hot air moves to the higher elevation cyclone.

Almost 80% of the entire heat transferred from the hot gases to raw meal is in riser ducts. To ensure maximum heat recovery in the riser ducts, the feed pipe from the higher stage should be lowered as much as possible.

This increases the heat transfer between the hot gases and feed material in each stage, before they are separated in the cyclone. This will result in lowering of exit gas temperatures from the PH system.



The optimum point of feed inlet to the riser duct is at 1.0 m height from the cyclone top.

The lowering of feed pipes as shown in the Figure in the identified cyclones of Preheater would result in a reduction of at least 5 – 10^0C reduction in Preheater gas exit temperature.

Most of the Cement plants modified the dispersion box height and reduction in their Preheater exit temperature is observed.

Benefits:
Thermal energy savings: 2 - 5 kCal/kg clinker reduction in the thermal energy consumption of the plant.

6.2 Multi channel burner in place of conventional Burner:

Conventional Burner:

For a conventional burner Primary Air supplied for combustion of Coal is 15 to 20% of total theoretical air required for combustion (i.e high primary air to theoretical air ratio).

Disadvantages:

- It offers very little flexibility of operation
- The exit speed obtains a fixed velocity at the tip of the burner by design of the nozzle velocity. The velocity cannot be adjusted during operation.
- The shaping of flame by changing the burner adjustment is also not possible during the operation e.g. in order to optimise the temperature profile in the sintering zone.
- This will not help the kiln operator as necessary "tool" to quickly stabilize any upset conditions.

Multichannel Burners:

Latest plants have Multi channel Burners for similar application.

Latest multi channel Burners have following advantages compared to Conventional mono channel Burner.

- Multi-channel burners offer better flame shape control because of their separate primary air channels, allowing for adjustment of primary air amount and injection velocity independently of the coal meal injection.
- The most important flame control parameters are primary air momentum (primary air amount multiplied by discharge velocity) and amount of swirl (tangentially air discharge).

- A high momentum will give a short, hard flame whereas a low momentum will make the flame longer and lazier. Swirl will help creating recirculation in the central part of the flame. This will stabilize the flame and give a short ignition distance. Too much swirl however can cause high kiln shell temperatures due to flame impingement on the burning zone refractory. A good swirl control system is therefore important. The best solution would be a system where swirl could be adjusted independent of the momentum. Most modern multi-channel burners therefore have adjustable air nozzles.
- Require lower primary air volume. Multi-channel burner offers to fire Alternate fuels like liquid, solid, bio-mass and to achieve thermal substitution rates.
- Advanced technology burner always reduces the loss in production during kiln disturbances and also reduces NOX formation in the burning zone as the primary air ratio is low.
- NOx emissions can be reduced as much as 30-35 percent over emissions from a typical direct fired, mono-channel burner.
- The flame shaping with the multi-channel burner improves combustion efficiency and eliminates flame impingement on refractory.
- This will in all cases provide the kiln operator with the necessary "tool" to quickly stabilise any upset conditions.

Latest Multi channel Burners requires primary air of 5-8% only.
With the above benefits many plants have achieved 5 - 10 kCal / kg Clinker thermal energy savings.

6.3 Oxygen enrichment to reduce heat consumption[10]:

The introduction of oxygen into combustion space is used in variety of industries for enhancement of the combustion process. To date the use of oxygen in rotary kiln can be done in three ways: introducing oxygen into the primary air (i.e into the main burner); utilization of oxy-fuel burner in addition to standard air – fuel burner and oxygen lancing into the rotary kiln (between the load and the flame) for improved flame characterstics.

Introduction of oxygen in primary air:

Primary air limits the oxygen capable of being introduced into kiln (only 5-10% of the total air used as primary air). Oxygen enriched air in fuel prior to its arrival into kiln's combustion space can burn too early and may even results in explosion.

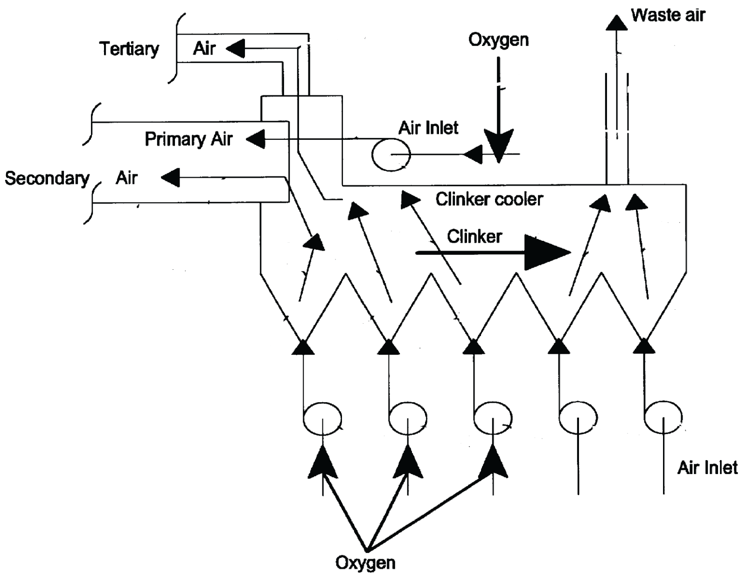
10 Kiln universal oxygen enrichment US patent: 6,309,210 B1 dated Oct 30, 2001

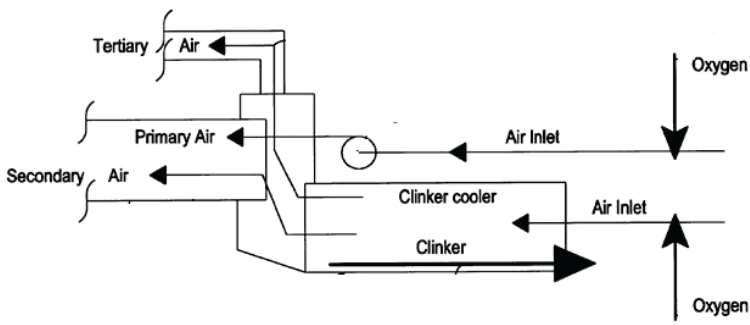
Use of separate oxy-burner:

Involved solution to increase the thermal transfer to the load, which in general requires requires significant quality of fuel such as gas or oil.

Use of oxygen lances:

Oxygen had been directly introduced at ambient temperature into the plant in the vicinity of combustion space.





Introduction of oxygen in accordance with above allows a reduction in flue gas volume (reduction in proportion of nitrogen in flue gas), as well as increased heat transfer to the load and increase in production. The addition of significant amount of oxygen to the air prior to the clinker cooler increases the thermal efficiency of the cooler by additional cooling of clinker and also increases secondary air temparature about 400 to 900^{0}C. From figures oxygen is injected into the air before entering the systems blowers . The oxygen enriched air can split between burner oxidant inlet and the clinker cooler oxidant inlet. Oxidant enriched air which is blown in clinker cooler. This pre heated oxidant-enriched air then allowed or cause to flow into the kiln chamber and pre calciner as secondary, pre heated, oxidant enriched air.

Introduction of oxygen prior to blowers increases the efficiency of the plant by upto 10% when compared to introduction of oxygen through conventional methods.

6.4 Installation of Latest generation High Efficiency Clinker Coolers:

The most common type of clinker cooler used in Indian cement industry is the reciprocating grate cooler. Enthalpy from hot clinker is recovered to preheat the incoming secondary and tertiary air for improving thermal efficiency. Based on the cooling efficiency, technology adopted and desired clinker temperature, the amount of air used in this cooling process is approximately 2-3 kg/kg of clinker.

Conventional grate coolers provide recuperation efficiency of 50 to 65 %, depending on the mechanical condition and process operation of the cooler, this corresponds to a total loss of about 120 -150 kCal/ kg clinker. Several cement kilns in India, as a result of continuous productivity increase measures, are operating at significantly higher capacities than rated. This results in significant increase in cooler loading, ranging between 50 to 70 TPD/m^2 of cooler area in several cases; further increasing the total heat loss from cooler.

Reciprocating cooler has undergone significant design developments and several leading manufacturers offer latest generation clinker coolers with significantly lower exit gas and clinker temperatures. As a direct conseqiuence, Secondary and tertiary air temperatures offered by latest generation coolers are in the range of 1250^{O}C and 1000^{O}C respectively.

Retrofitting existing reciprocating coolers with latest generation coolers offer significant potential for electrical and thermal energy saving in Indian cement industry today. Total loss of latest generation coolers stands at less than 100 kCal/ kg clinker and has recuperation efficiency in excess of 75%.

Benefits:

Thermal Savings	:	30 kCal / kg Clinker
Electrical Savings	:	0.5 kWh / MT clinker

6.5 Replacement of Kiln inlet pneumatic seal with Graphite seal

Replacement of Kiln inlet pneumatic seal with Graphite seal gives the following adavantages.

Advantages:

- Adjustable to any type and size of the Kiln
- Long lasting efficient leak tightness without any specific maintenance
- Prevents false air into the kiln and ensures pressure stability in kiln
- Prevents release of hot gases and dust from kiln
- Allows Increase in kiln throughput
- Lasts for 4-5 years

Principle:

- Circular bearing race is mounted on kiln and adjusted to compensate any pre- existing eccentricity
- Graphite plates are mounted on a specific support which is bolted on the fume box
- Graphite plates are held in contact with circular bearing with help of 2 metal wires and adjustable counter weights
- Graphite plates overlap on each other to enhance overall leak tight ness

Benefits:

Atleast 2-5 kCal/Kg clinker reduction in thermal energy possible.

6.6 Impact of very low lime saturation factor[11]

The lime saturation factor (LSF) of Ordinary Portland Cement (OPC) clinker typically ranges 88–95 in most of the Indian cement plants. In order to achieve advantages in terms of higher compressive strength particularly higher early strength, more and more C_3S is being targeted in the resultant clinker manufactured in Indian cement plants. In order to achieve higher C_3S in clinker, the lime content has to be increased in the raw mix. Ideally speaking, LSF is desired in clinker such that the actual lime present in the clinker is slightly more than sufficient to combine with the theoretically calculated lime required to combine with the other constituent oxides of clinker viz. silica, alumina and iron. Due to heterogeneous nature of kiln feed, 100% lime combination is difficult to achieve in industrially manufactured clinker. However, Indian Cement plants are able to produce adequate quality of clinker keeping LSF in the range of 88-95.

However, lowering of LSF is always beneficial in terms of conserving good quality limestone as well as reducing GHG emission due to lower limestone calcinations.Higher amounts of expensive and good quality limestone are required to achieve higher LSF.

OPC clinker with lower LSF values are produced with low grade limestone thus preserving fast depleting high quality limestone. Furthermore, raw mix with lower LSF require lower burning temperatures and the same are termed as soft burning mix which require reduced heat consumption.

The main disadvantage of OPC clinker with low LSF compared to OPC clinker with higher LSF is the reduced content of Alite and relatively increased content of belite and the consequential lower early strength at an equal fineness level of cement. Such reduction in early strength can however be made up to a limited extent by finer grinding of the cement, which requires additional electrical energy and also affects the output of the mill. Since the grindability of the clinker will depend upon burning temperature and time, estimation of additional electrical energy requirement is case specific. Clinker with lower LSF is found to contain higher amount of belite which is relatively harder to grind than alite thereby decreasing the Grindability index of the clinker.

Thermal savings: There will be reduction in thermal energy consumption due to relatively lower LSF and thereby corresponding low $CaCO_3$ content of raw mix.

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6.7 Improving the Burnability of Raw Mix by use of mineralizer[12]:

The potential use of mineralizers to improve the clinker quality and facilitate energy conservation in cement manufacture is well-established in view of the techno-economic aspects associated with them. There are two overlapping terms namely, fluxes and mineralizers used in cement manufacture. A 'flux' is an additive that decreases the melting point of the liquid phase formed during clinkerization process, whereas a 'mineralizer' is a substance that accelerates the reaction rates at all stages or at some of the stages of clinkerization. In doing so, most of the mineralizers act both as a flux; and as catalyst during clinkerization.

The possible reaction effects of mineralizers can be multifarious and the important ones are summarised as follows:

- Accelerate the de-carbonation and sintering reactions
- lowering the clinkering temperature
- Broadening or narrowing the sintering temperature range
- Modification of liquid properties, such as viscosity, surface tension, etc.
- Increasing the crystallization of the liquid phase
- Increasing clinker balling and ring formation tendency
- Promoting clinker-refractory interaction
- Altering the overall burnability and volatility conditions inside the kiln

A large number of oxides are reported to act as mineralizers when added as raw mix component during clinkerization. Some of the prominent mineralizers are as under:

- Fluorides (viz., NaF, MgF_2, CaF_2, Na_3AlF_6, etc.)
- Fluorosilicates (viz., Na_2SiF_6, $MgSiF_6$, $CaSiF_6$ etc.)
- Chlorides (viz., LiCl, $CaCl_2$, $MgCl_2$, $ZnCl_2$, $BaCl_2$, etc)
- Sulphates (viz., $CaSO_4$, $BaSO_4$, $FeSO_4$, $ZnSO_4$, $Al_2(SO_4)_3$, etc.)
- Phosphates (viz., apatite, phosphorite, etc.)
- Carbonates (viz., K_2CO_3, $MgCO_3$, $BaCO_3$, etc.)
- Oxides, (viz., B_2O_3, Cr_2O_3, CuO, ZnO, MgO, MnO, TiO_2, etc.)
- Industrial wastes, such as fly ash, non ferrous slags, etc.

Recent studies carried out have established that copper slag, a waste generated during the extraction of copper metal in mineral processing industry, has shown potential for use as mineralizer in cement manufacture. Investigations carried out at NCB established its suitability as a raw material (as a source of iron) in the manufacture of Ordinary Portland Cement (OPC). Burnability studies at (1,300^{o}C, 1,350^{o}C, 1,400^{o}C and 1,450^{o}C) of different raw mixes designed using conventional raw materials along with varying doses of copper slag (1.5–2.5%) showed

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mineralizing effect of copper slag. The clinkerization reaction was found to be completed at 1400oC with improved microstructure in the presence of copper slag as compared to control mix where phase development was appropriate at comparatively higher temperature i.e. 1,450^{0}C.

The mineralizers, in general, have been found to reduce the clinkerization temperature by about 50^{0}C or even higher without compromising on the quality of clinker. Such reduction in clinkering temperature has direct bearing on reduction of fuel consumption, besides improvement in clinker morphology. The selection and use of the mineralizers are generally governed by the following considerations:

- Reaction effects desired;
- Compatibility with a given kiln feed;
- Process adopted;
- Physical form of mineralizers;
- Economic viability of using mineralizers.

Occasionally, to suit the requirement of a specific situation, combination of mineralizers (viz., TiO_2 + CaF_2, $FeSO_4$ + $ZnSO_4$, $CaSO_4$ + $MgCO_3$ etc.) are reportedly used. Under practical conditions of clinker burning, both aspects of attainment of right temperature and the duration of holding of material at this temperature govern the quality of clinker manufactured and fuel consumption. Hence, the effects of mineralizers can be viewed from their influence on:

- Temperature of initial liquid formation:
- Rate of formation of liquid during burning and duration of its availability;
- Characteristics of the liquid such as viscosity, surface tension and wetting and the influence of minor oxides such as alkalies, SO_4 etc on these properties which in turn determine nodulisation and solid liquid interface reactions;
- Chemical composition of liquid or liquids (in case of immiscibility) and crystallization characteristics on cooling

Benefits

- Reduction in clinkering temperature by around 50^{o}C
- Reduction in heat consumption by about 13 kCal / kg cl
- Reduction in power consumption up to 1 kWh / t cement

6.8 Utilization of Advanced Automation Systems in clinker Manufacture:

Control and operation of kiln systems today are extremely complex, properties of input fuel & feed materials diversely varying and product standards becoming increasingly stringent. Cement kiln operators today encounter such sudden variations and dynamic control of kilns are therefore vital for achieving optimum results and lower costs of manufacture.

Against this background, an effective advanced automation and control system can bring in substantial improvement in overall performance of the kiln, increased material throughput, better heat recovery and reliable control of free lime content in clinker. Furthering the scope of automation in process control, quality is also maintained by continuous monitoring of the raw mix composition with the help of X-ray analyzer and automatic proportioning of raw mix components. New type of on-line bulk material analyzers have also been developed based on Prompt-Gamma-ray Neutron Activation Analysis (PGNAA) for giving maximum control over raw mix. The analyzer quickly and reliably analyses the entire flow-on-line providing real time results. The latest trends in on-line quality control include computers and industrial robots for complete elemental analysis by X-ray fluorescence, on-line free lime detection and particle size analysis by latest instrumental methods and x-ray diffraction techniques respectively.

The latest trend in control systems is installation of Adaptive Predictive control system. This Adaptive Predictive control system works based on soft sensors input. This prediction mechanism works on set parameters. The operation of system is predicted and corrective action is taken. If the corrective mechanism is not as per the requirement (or set value), the mechanism automatically refines itself. The system constantly upgrades itself to meet the system fluctuations and keeps improving with time.

Benefits:

- Thermal savings : 6 - 8 kCal / kg clinker

6.9 Alternate Fuel Use in the Cement Manufacturing Process:

Cement industry is capable to co process wastes as alternative fuels and raw materials to reinforce its competitiveness and at the same time contribute to solutions to some of society's waste problems in a way which valorizes the waste and is beneficial to the environment. Cement kiln have a number of characteristics which make them ideal installations for disposal of industrial wastes through co processing route in an environmentally sound manner.

- High temperature (Flame temperature > 1800°C and material temperature up to 1400°C)
- Long residence time
- Oxidizing atmosphere
- High thermal inertia
- Alkaline environment
- Ash retention in clinker

The use of waste as alternative fuels and raw materials in the cement industry has numerous environmental benefits such as

1. Reduced use of mined natural materials such as limestone, bauxite, iron ore etc and non-renewable fossil fuels such as coal. This also reduces the environmental impacts associated with mining of these natural materials.
2. Contributes towards a lowering of emissions such as greenhouse gases by replacing use of fossil fuels with materials that would otherwise have to be incinerated with responding emissions and final residues.
3. Reduced requirement of land required for land fill option thereby reducing the emission sand also liability associated with the landfills.
4. Maximizes the recovery of resources present in the waste. All the energy is used directly in the kiln for clinker production and the non-combustible part of the waste becomes part of clinker.

Alternative fuel use in the Indian cement industry is presently at very low levels; the country's average stands at less than 1% of Thermal Substitution Rate (TSR). Several nations globally have utilized cement kilns as an effective option for their country's industrial, municipal and hazardous waste disposal.

The alternative fuels used in Indian cement industry at present includes

1. Plastic waste
2. ETP sludge
3. Risk husk
4. Coal dust
5. Tire chips
6. Rubber dust

Switching from conventional fuels to alternatives fuels at higher substitution rates (>10 % of total thermal energy) may need additional infrastructure like testing facilities for monitoring the quality of wastes before usage, emission monitoring systems to achieve successful utilization of such fuels . Some of the most commonly encountered issues around utilization of alternative fuels are improper heat distribution if residence time is low, increase in specific heat consumption due to additional excess air, blockages in the preheater cyclones, unstable operation, build-ups in the kiln riser ducts and higher SOx, NOx, and CO emissions.

Latest dry process plants with state of the art technology however has many controlling facilities and equipments like low NOx burners, calciners with increased residence time, on line quality & emission monitoring systems and latest fuel feeding systems having higher accuracy & control that enables the cement plants worldwide to achieve higher substitution rates.

Efffect of AFR on Gate To Gate Specific Energy consumption as per BEE PAT scheme:

As per the current version of BEE PAT scheme any alternate fuel used in plant as a replacement of fossil fuel intake will not be considered as fuel for gate to gate energy consumption leading to reduction in gate to gate energy consumption.

The project implementation requires transportation system to carry the waste fuel from storage bin to calciner

Say a plant with Average thermal SEC for baseline years 2007-08 to 2009-10

	=	700 kCal/kg Clinker
Say Total clinker capacity	=	8000 TPD
Total Thermal energy required	=	8000 x 700 x 1000
	=	5600 MkCal/day
2 % alternative fuel substitution	=	5600 x 0.02
	=	112 MkCal /day
MTOE Savings	=	$\frac{\text{112 MkCal /day * 330 days/year}}{10}$
	=	3696 MTOE

6.10 Rotor weigh feeder installation for Coal firing:

Rotor weigh feeder is highly accurate and reliable gravimetric feeding of pulverised fuel.

Benefits:

1.Optimal flame Control:

The rotor weigh feeder actively compensates changes in material characteristics and supplies a constant stream of coal to the burning process. It supplies more accurate in deviation of set- and actual feedrate. The stable feeding results out of the pro-active control strategy and permanent gravimetric weighing and dosing.

2.Minimal Air Back-Flow from pneumatic transport system to material storage silo:

The rotor is designed with many small chambers, each one representing an air seal between the pneumatic transport and the material storage silo

3.Long Service Life and High Availability:

This is achieved by a slow rotation speed of the rotor, only 6-8 rounds per minute. The only moving part, the rotor itself, is made in a certain cast steel to minimise wear of both,sealing plates and rotor.

4.Instantaneously Adjustable Feedrate

5.Eliminated CO-peaks

6.Reliable Feeding:

Optimised silo cones, material activators and calibration-hoppers ensure reliable coal silo extraction. Accurate calculation of pneumatic transport pipes ensure the transfer of the accurate material stream from the rotor weighfeeder to the burner flame.

Installation of Rotoscale for Kiln coal and PC coal firing will result in atleast 2 kCal/Kg clinker thermal energy.

6.11 Installation of Cross Belt Analyzers

Sampling of the material either the crushed lime stone or the raw meal (input to the kiln) is done to maintain the stockpile quality and control the chemistry of the raw mix thereby the chemical composition in the clinker is maintained in proportion with the quality requirements. The sampling of the raw materials helps in maintaining the homogeneity of the raw mix such that the clinker quality is assured.

At present several plants are following conventional sampling and quality control methods where the samplers installed does the sampling for a few grams of material collected from large quantity of the material collected at several intervals. These collected samples are getting analyzed for its chemical composition through X-ray. Collection of the samples and the analysis, results in time delay and manual error. This results a lag time in doing the corrective measures for changing the chemical composition and thereby affects the clinker quantity and the energy consumption.

Whereas the cross belt analyzers, analyzes the chemical properties of the materials and can take the corrective actions much quicker when compared with the conventional sampling and quality control methods. The cross belt analyzer in place of normal samplers has an added advantage in terms of the quicker analysis results. These analyzers can be installed either in the upstream of the stock pile and or before the raw mill. The former option helps to track the cumulative chemistry of the pile thus allowing the operator to direct haul trucks to different sections of the quarry in a way that it will result in the final elemental composition of the pile close to target. While the installation before the raw mill can monitor the chemistry of the raw mix and automatically trigger an adjustment in the proportions of the reclaimed stockpile and take corrective actions in the varying the quantity of the additives.

The cross belt analyzers are needed in cases of heterogeneous deposits of limestone is present or the limestone is received from more than one mines. The advantage of cross belt analyzers in each stage is as below.

Upstream of Stock Pile

- Increase in mines life and conserves natural resource
- Reduces the raw material cost by minimizing the % addition of other raw material additives
- Maintains the good limestone deposit for a longer time

Before Raw Mill

- Maintain lower standby deviation in kiln feed and thereby reduces the specific energy consumption
- Stable kiln operation
- Consistent good clinker quality
- Reduces the cement grinding power
- Achieve higher blending levels of fly ash/slag in cement
- Maintain productivity levels in the kiln

Benefits:

Thermal savings : 3-5 kCal/Kg of clinker

6.12 Free Lime Control in Clinker Production with COSMA DP:

Freelime composition mostly used as indication for clinker burning. Over burning of clinker leads to freelime in clinker lower than optimum in most of the plants.

Overburning causes

1. Excessive fuel consumption
2. Reduced production
3. High NOx, short refractory life and harder to grind clinker

COSMA on-line analysis monitoring free lime and active clinker minerals.

Benefits:

1. Reduced free lime excursions
2. Increase average free lime content
3. Reduce overburning of clinker
4. Reduction in fuel consumption

5. Reduction in NOx emission
6. Every 10° C reduction in kiln burn temperature saves 1% fuel
7. Fuel saved increases cement mill throughput

Ultimate performance of the finished cement is largely determined in clinker production. COSMA online monitoring provides a real time picture of the mineralogical changes as they are taking place. Thus process engineers are able to construct control regimes that allow the operators to maintain the kiln process at optimum performance levels for both cost and quality.

6.13 Use Low Thermal Conductivity Refractory In Kiln inlet section

A modern cement kiln at present operates with 6 stage pre heater suitable precalciner system with tertiary air ducts and highly efficient burning and cooling Each plant is committed to become the most competitive and profitable one through increasing the clinker production at the reduced or optimum cost. In order to keep pace with the present scenario where the cement industry is progressing and modernizing fast it is essential to ensure maximum kiln availability and therefore optimum refractory lining scheme and its performance in a cement rotary kiln system For inspection and monitoring to identify areas of potential.

In general practice in the kiln 40% Alumina brick lining will provided from Kiln inlet about 20 m range. Thermal conductivity of this brick is 1.4 W/m.K (at 1200^{0}C hot surface temperature). Resulting in Kiln surface temperature will vary from 250^{0}C to 320^{0}C in this area.

Because of high surface temperatures, The heat loss through the surface is high. The radiation loss from Kilns will be 25- 35 KCal/Kg clinker, which is in higher side.

Thermal energy savings are possible by replacing these bricks with low thermal conductivity Bricks. Replacing the 40% Alumina bricks with low thermal conductivity refractory of thermal conductivity 0.6 W/m.K. helps to maintain Kiln shell temperature less than 250^{0}C in the Kiln inlet area.

Benefits:

Thermal savings : 2-3 kCal/Kg of clinker

6.14 UTILIZATION OF RENEWABLE ENERGY

Any renewable energy project implemented within the boundary of plant for replacement of power input to the plant will not be considered as energy for gate to gate energy consumption.

Renewable energy is a cleaner and greener way to generate power. A modern 1 million capacity plant today requires a total energy consumption of 10 MW. It can be very attractive to go for 100% renewable power generation by design.

Few of the renewable energy technology, their estimated potential and the area required to generate power is as mentioned below

Sl No	Technologies	Estimated potential (MW)	Tapped potential (MW)	Area required
1	Wind power	48,561	14,989	20-25 acres/ MW
2	Biomass power	16,881	1,083	1 to 1.5 acre/ MW
3	Biomass co-generation	5,000	1,779	0.75 to 1.2 acre/ MW
4	Waste to Power	2,700	73	4-5 acres/ MW
5	Solar PV	35 MW/Sq. Km	17.82	5 acres/ MW
6	Solar Thermal	35 MW/Sq. Km		7-12 acres/ MW
7	Small Hydro	15385	3105.63	

The Cost estimation of various different renewable energy projects is been mentioned below :

Sl No	Technologies	Capital Cost
1	Wind power	INR 40-50 million/ MW
2	Biomass power	INR 30-45 million/ MW
3	Biomass co-generation	INR 34-40 million/ MW
4	Waste to Power	INR 30 million/ MW
5	Solar PV	INR 140 million/ MW
6	Solar Thermal	INR 120 million/ MW
7	Small Hydro	INR 25 million/ MW

Section 3
WHR & CPP

CHAPTER 7

WASTE HEAT RECOVERY

7.1 Introduction:

In Cement plants significant amount of heat is carried by pre-heater exhaust gas and cooler exit air. Depending on the number of stages in the pre-heater and the type and technology adopted in the cooler section the temperature in these gas streams vary from 200 ^{0}C to 360 ^{0}C /400 ^{0}C.

If the moisture content in the raw material such as limestone, fly ash is high this heat is utilized effectively to remove the moisture present in these materials. Otherwise it is rejected to the atmosphere and hence potential exists to recover the same.

Three types of technological options are available in the market for waste heat recovery such as

- Rankine Cycle
- Ogranic Rankine Cycle
- Kalina Cycle

Both the Rankine cycle and Organic Rankine cycle plants are being operated in India as well as in abroad for the waste heat recovery. The Kalina cycle which is more efficient of all the three, is under implementation (2012) in cement industry.

Despite high investment costs the following other problems have to be considered while going for WHR systems:

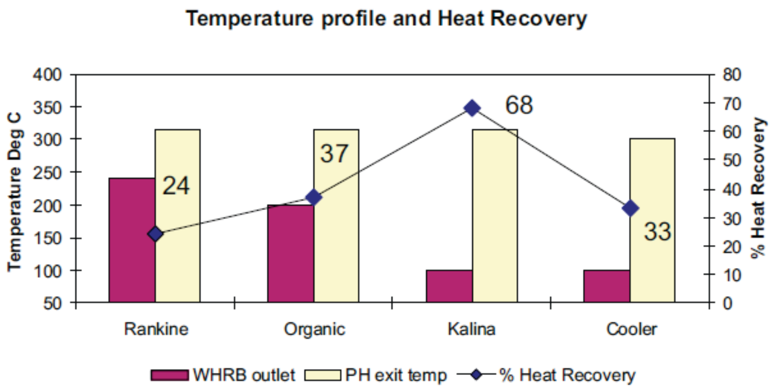
- Loading of the power plant
- Additional power consumption in preheater fan, cooler vent fan
- Dust load in the gas stream
- Water availability (if conventional Rankine cycle is considered)

Power generation from waste heat has the following advantages:

- Lower generation cost
- Green house gas reduction
- As a part of Corporate Responsibility for Environment protection
- Better corporate image
- Lower operating / Energy cost
- PAT benefits

Many of the cement plants in India / world have taken up this initiative by incorporating CDM route to meet the high initial investment.

%Heat Recovery and temperature profile of different types of Waste heat recovery systems:



The graph shows the recovery of heat from various technologies for the same preheater outlet temperature of 316 Deg C (5 stages). Cooler exit gas is considered as the preheating source in combination with the preheater waste heat recovery boiler and hence 33 % heat recovery is considered for cooler air for all the systems.

Most the clinker manufacturing units in India have 2 and more kilns in the same location or site to meet the clinker demand. It may be noted that though the heat availability in individual kiln / cooler may be less, the total heat availability in the locating including all the kilns may work out a sizable quantity to work out waste heat recovery potential.

7.2 Influence of dust in waste heat recovery:

- Presence of dust will affect the heat transfer rate by forming coating over the heat transfer areas in the Waste Heat recovery Boiler which in turn will affect the efficiency of the cycle.
- Presence of dust can result in abrasion there by failure of tubes / heat transfer equipment
- Dust may form coating / blockage

Problem of dust can be handled by

- Improving the efficiency of the top stage cyclone in the case of Preheater.
- Reducing the aeration velocity at the top of clinker bed in the case

of cooler by increasing the grate area or maintaining optimum cooler loading.

- Installing pre expansion chambers which will help to remove the bigger size particles
- Improving the distribution of the gas inside the Waste Heat Recovery Boiler (WHRB) to maintain uniform dust concentration and gas velocity and to avoid excessive wear in any particular location due to turbulence
- Carefully designing the WHRB such that the gas velocity is within acceptable range.

7.3 Estimation Of Waste Heat Recovery Potential

Basic data & Assumptions:

1. Kiln capacity : 3000 tonnes per day
2. No of stages in the preheater : 5
3. Preheater exit gas details
   a. Volume (m_{PH}) : 1.5 Nm^3/ kg clinker
   b. Specific heat capacity (CP_{PH}) : 0.36 kCal / kg / ^0C
   c. Temperature T_{PH1}: 316^0C
4. Cooler exit gas details
   a. Volume (m_C) : 1.0 Nm^3 /kg clinker
   b. Specific heat capacity C_{PC} : 0.317 kCal / kg / ^0C
   c. Temperature $_{TC}$: 300^0C
5. Limestone moisture content LM : 2 %
6. Raw mill running hrs : 22 hrs / day
7. Kiln running days per annum : 335 days
8. Heat transfer efficiency of WHR boiler - EFF_{WHR} : 75 %
9. Heat transfer efficiency of AQC boiler – EFF_{AQC} : 75 %
10. TG system efficiency EFF $_{TG}$: 33 %
11. Specific heat consumption : 700 kCal / kg clinker
12. Raw coal moisture : 15 %
13. Raw meal to clinker factor : 1.55
14. Heat requirement for moisture in raw mill & Coal mill: 950 kCal / kgwater
15. Calorific value of fine coal used: 5000 kCal / kg coal

16. Coal mill running hrs per day : 20

17. PH gas temperature at WHRB outlet T_{PH2} : 240 ^{0}C

18. Cooler exit temperature at AQC boiler outlet T_{C2} : 120 ^{0}C

Calculations:

1. Heat available in the preheater gas :

Q_{PH}	:	m_{PH} * CP_{PH} * T_{PH1}
	:	1.5 * 0.36 * 316
	:	170.6 kCal / kg clinker

2. Heat required for Raw mill

a. Raw mill capacity	:	3000 * 1.55 * 24 / 22
	:	5073 TPD
	:	211 TPH
	:	1.688 kg / kg clinker
b. Moisture in raw mill	:	[211 * 100 / (100 - 2)] – 211
	:	4.3 TPH
	:	34.4 kg / MT clinker
c. Heat requirement for raw mill	:	34.4 * 950 / 1000
	:	32.7 kCal / kg clinker
	:	33 kCal / kg clinker

3. Heat requirement for coal mill

a. Coal requirement

Specific coal consumption	:	700 / 5000
	:	0.14 kg coal / kg clinker
Coal mill capacity	:	0.14 * 125 * 24 / 20
	:	21 TPH

4. Moisture evoparation in coal mill : {21 * 100 /(100 – 15)}– 21

	:	3.7 TPH
	:	30 kg / MT clinker

5. Heat requirement for raw mill

	:	30 * 950 / 1000
	:	28.5 kCal / kg clinker
	:	29 kCal / kg clinker

Excess heat available in the preheater:

Heat available in the PH gas minus heat required for Coal mill & raw mill

Excess heat available (preheater)	:	170.6 – (29 + 33)
	:	108.6 kCal / kg clinker

6. Heat available in the Cooler exit gas :

Q_C : $m_C * C_{PC} * T_C$

: 1.0 * 0.317 * 300

: 95.1 kCal / kg clinker

7. Total excess or waste heat available :

Extra heat available in the preheater + cooler

: 108.6 + 95.1

: 203.7 kCal / kg clinker

8. Heat recoverable in Preheater side Boiler

Q_{WHRB} : $m_{PH} * C_{PPH} * (T_{PH1} - T_{PH2})$

: 1.5 * 0.36 * (316 – 240)

: 41.0 kCal / kg clinker

9. Heat recoverable in Cooler side Boiler

Q_{AQC} : $m_C * C_C * (T_{c1} - T_{c2})$

: 1.0 * 0.317 * (300 – 120)

: 57.0 kCal / kg clinker

Heat available to steam for power generation:

: $Q_{WHRB} * EFF_{WHR} + Q_{AQC} * EFF_{AQC}$

: 41.0 * 0.75 + 57.0 * 0.75

: 73.5 kCal / kg clinker

10. Power generation possible :

Heat available in the steam TG efficiency

: 73.5 * 0.33

: 24.2 kCal / kg clinker

: 0.0282 kWh / kg Clinker

: 28.2 kWh / MT of clinker

: 3.5 MW

11. Water requirement for Water cooled condenser:

Heat to be removed in the condenser:

: 83.3 * (100 – 33)/ (0.85*100)

: 56.3 kCal / kg clinker Make up

Water requirement : 56 / 540

: 0.104 kg water / kg clinker

7.4 PAT Benefits:

Total MW possible	=	3.5 MW
Annual power generation	=	3.5 x 1000 x 7000 hr/anum
	=	245 Lakh kWh
	=	$\frac{245 \times 105 \text{ (kWhr)} \times 3208 \text{ (kCal/kWhr)}}{10^7}$
	=	8252 MTOE

3208 kCal / kWh is the weighted average heat rate of All Cement plant CPP's is India during 2007-2010.

Chapter 8

Heat Rate Reduction Opportunities in Captive Power Plant

8.1 Arrest Air Ingress In Flue Gas Path Of Boiler

The performance of the APH can be analyzed based on the O_2 level in the flue gas at various points such as before air preheater, and after APH have been measured.

During analysis in a plant measured Oxygen concentrations given below.

	Before APH	After APH
O_2 %	3.0	7.6

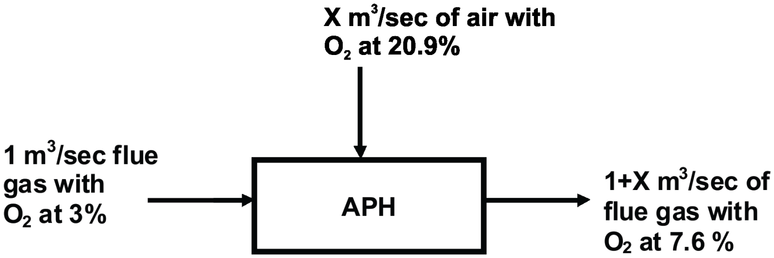
There is a continuous increase in O_2 level along the flue gas path. Significant increase in O_2 level is observed after APH. This clearly indicates that there is air leakage into the system. The leakage estimation calculations are given in the backup calculations.

The quantity of air leakage into the flue gas path is about-31.12 %.

This air leakage into the flue gas path leads to further reduction in flue gas temperature. The reduction flue gas temperature further increases the low temperature end corrosion and further increases the leakage level. The air infiltration also leads to increased load on the ID fan and hence increases ID fan power consumption.

There is a good potential to save energy by arresting the air leakage in the APH. This will also results in marginal reduction in ID fan power consumption.

Periodically monitor the O_2 level in the locations like before the air preheater, after the air preheater and after the ESP. Reduce the quantity of air infiltration in the ESP by improving the sealing. Cover the expansion joints with materials like thermofabric etc. Check for leakages in APH tubes.



Excess air at 3 % O_2	=	16.75 %
Excess air at 7.6 % O_2	=	57.14 %
Say Stoichiometric air required	=	4.96 kg of air/ kg of fuel
Flue gas generated before APH	=	4.96 x (1+0.167)
	=	5.79 kg/ kg of fuel
Flue gas generated after APH	=	4.96 x (1+0.571)
	=	7.794 kg/ kg of fuel
Air ingress	=	7.79 – 4.96 kg/ kg of fuel
	=	2.00 kg/ kg of fuel
Air ingress per hour	=	2.00 x 12000 kg of coal/hr
	=	24000 kg/hr

Thermal Savings:

Total thermal savings	=	m x Cp x Δ T
	=	24000 x 0.24 x (128-15)
	=	6,50,880 kCal/ hr

8.2 Reduce Steam Consumption In Steam Ejector In TG

In a plant the following observations made during the study of the performance of the vacuum system are given below.

- Steam jet ejectors are in operation for creating vacuum. Presently steam at a pressure of 10.00 kg/cm^2 is utilised as motive steam. This steam pressure is achieved by reducing the main steam from 64 kg/cm^2 to 10.00 kg/cm^2.
- The steam consumption is estimated indirectly by measuring the quantity of water flow and the temperature difference across

the ejector condenser. The detailed calculations are given in the backup sheet.

- The steam ejectors are designed for steam consumption of 0.67 TPH at 10 kg/cm2. The estimated steam consumption for the ejector is:
  - TG : 1.00 TPH
- When compared to design, about 0.33 TPH of steam is consumed more in the ejector of TG. This extra steam consumption can be saved by addressing the problems of ejector.

The steam flow through the ejector is estimated indirectly by measuring the water flow through the condenser and the temperature difference across the condenser.

Heat and Mass Balance:

X-TPH x 739.56 kCal/kg = 61 TPH x 49 kCal/kg + 61 TPH x 37 kCal/kg + X-TPH x 57 kCal/kg

X = 1.07 TPH

The steam consumption for TG steam ejector = 1.00 TPH

Design consumption of steam ejector = 0.67 TPH

Difference in steam consumption = 0.33 TPH

8.3 Improve The Heat Rate Of Steam Turbine

In a plant the performances of all heaters studied. There are two HP heaters, one Deaerator feedwater heater and four LP heaters to heat the boiler feed water at various stages. The order of heating is as follows:

Condenser →LPH-1→LPH-2→LPH-3→LPH-4→DEA→HPH-5 → HPH-6→ECO→Boiler

- The heat rate estimation of steam turbine in was done based on the actual measurements, online parameters and estimation.
- The design and operating parameters of steam turbine at various stages are given below:

Parameter	Design	Operating
Steam flow to the turbine (TPH)	206.8	202
HP steam flow to HPH – 6 (TPH)	12.56	7.99
HP steam flow to HPH – 5 (TPH)	11.18	15.7

- The steam temperature at the discharge of HPH – 6 is maintained below the Designed Economiser inlet temperature. Steam consumption is less for HPH – 6 when compared to that of the design.

- The design work output, heat rate and overall system efficiency of the steam turbine is
  - Turbine = 55.01 MW
  - Heat rate = 2299.69 kCal/kWh
  - Overall Turbine efficiency = 37.40%
- The operating work output, heat rate and overall system efficiency of the steam turbine is
  - Turbine = 49.63 MW
  - Heat rate is = 2618 kCal/kWh
  - Overall Turbine efficiency = 32.84%
- There is a significant deviation between the design and operating condition of the steam turbine.
- Possible reasons for increase in heat rate:
  - Poor Performance of HP heaters
  - Improper distribution of steam
  - Passing of valves mainly at distribution junctions and drain valves
  - Heat loss across the pipe lines
- The performance of HP heaters analysed to estimate the reasons for higher heat rate. Two basic parameters are required for any type heaters to analyse the performance. They are:
  - Drain Cooler Approach (DCA): It is defined as the difference between steam drain temperature and inlet feed water temperature.
  - Terminal Temperature Difference (TTD): It is defined as the difference between saturation temperature of inlet main steam and the outlet feed water temperature.
- The design and operating parameters of DCA & TTD of all the heaters are given below:

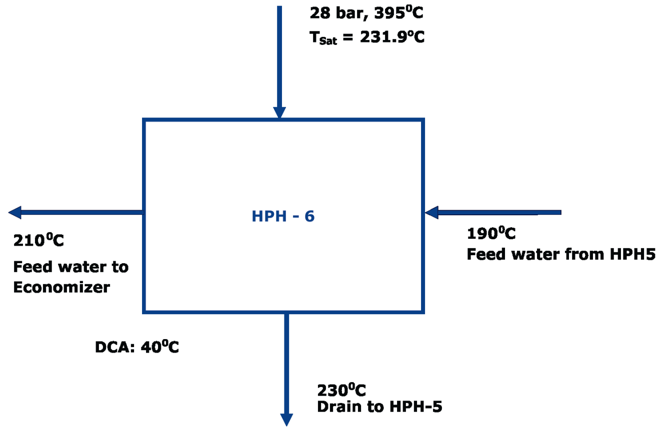
HEATER	Design		Operating	
	DCA	TTD	DCA	TTD
HPH6	10	3.5	40	21.9
HPH5	10	5	42	11.3
LPH4	27.6	5.8	28	16.2
LPH3	32	5.73	20	9.08
LPH2	20.87	5.3	16	10
LPH1	27.5	5.4	NA	

- The DCA and TTD of the heaters HPH 5 & 6 indicate that the performances of these heaters are affected badly.
- When compared to design, the DCA & TTD of HP heater–6 and HP heater–5 are higher. It is learnt that, the bypass valve of HP heater-6 was kept intentionally open because of mismatch between the designed heater outlet temperature and designed boiler economiser inlet temperature.
    - By doing so, the feed water temperature achieved at the outlet of HP heater-6 is only 210^{0}C against the design value of 232.7^{0}C.
- By increasing the feed water temperature at the HP heater-6 outlet, the flue gas temperature at the boiler outlet may increase, if we cannot utilize the heat effectively in Air-preheater.
    - By raising the feed water temperature at HPH-6 outlet, it is estimated that the performance of heater will improve and the performance of the boiler deteriorates. It is also calculated that gain on heater performance is more beneficial than losing on boiler efficiency.
- There is a good potential to improve the performance of heater as well as heat rate by avoiding the HP heater-6 bypass valve operation.

To improve the heat rate of turbine:

- Avoid bypassing HP heater-6. This can increase the feed water temperature up to the designed value at HP heater outlet there by improving its performance.
- Periodically check the performance of HP and LP heaters in all the units by monitoring the following parameters of the heaters:
    - Drain cooler approach
    - Terminal temperature difference
- Any deviation of the above parameters from the design value is a clear indication of deterioration in performance the heaters. In such a case, adjust the level of heaters and accordingly try to maintain the designed TTD and DCA.
- Check the status of drain valves, drag valves and control valves to eliminate the possibility of passing.

The schematic diagram for the HP heater is shown below:



Benefits

Heat rate reduction - 60 kCal/kWh can be saved.

8.4 Recover Flash Steam from Boiler Blow Down

In a plant steam saving opportunities were explored in boiler system.

- Four boilers are in operation in the plant. Which generate steam at a pressure of 95 kg/cm^2.
- TDS level in the boiler is monitored based on silica content at less than 0.2 ppm.
- In the four boilers installed, continuous blow down is practiced. The rate of blowdown is maintained steady and fine tuned based on the silica content of the blow down.
- At present a boiler blow down vessel is installed and the flashes from the blow down are being vented out in atmosphere and the remaining liquid drained. The quantities of this drain from different boilers are given below.

Boiler	Flow rate
Boiler #1	5.3 m^3/day
Boiler #2	6.2 m^3/day
Boiler #3	6.2 m^3/day
Boiler #4	5.8 m^3/day
Total	23.5 m^3/day
Average	~ 1 m^3/hr

- There is a good potential to recover flash steam from boiler blow down by putting flash vessel. The flash steam from the CBD vessel can be utilized in the deareator. This will result in reduction in steam consumption in the deareator by about 0.47 TPH.

Blow down water quantity measured = 1 TPH

Enthalpy Balance was carried out to estimate available flash steam

331 KCal/kg	=	"X" x 658.6 kCal/kg + (1- "X") x 160 kCal/kg
"X"	=	33 %
Quantity of flash vapour	=	1 TPH X 0.33 /(1- 0.33)
	=	0.47 TPH

8.5. Energy Saving Opportunities in Diesel/HFO Genset based Captive Power Plant:

8.5.1 Partial Gas Conversion to reduce Fuel Oil Consumption: Bi Fuel Conversion :

Conversion of Diesel Engines to Bi Fuel (two fuels at the same time Diesel/ HFO and Gas)

BI-Fuel (Dual Fuel) Conversion of Diesel & HFO generating sets:

With Bi-fuel conversion of the standard diesel engine the actual dieseling process must be always maintained. No Bi-fuel kit can replace 100% of the engines diesel use with available gas.

The natural gas will be introduced to the engine cylinders for the Bi-fuel conversion and used as the substitute fuel for the generation of cylinder power.

With the ComAp solution following parameters are controlled/monitored automatically:

1) The diesel portion

2) The Engine exhaust temperatures

3) The boost air temperatures

3) Knocking (via frequency based pre-detonation control system)

4) The actual load and electrical tolerances

Bi-fuel conversion requires virtually no engine modification and brings double benefits in every application:

- Affordable diesel engines combined with inexpensive natural gas
- Economic solution for slow-speed, middle-speed and high-speed engines
- Flexible use of fuel
- Guaranteed power output
- Efficient and safe operation with lower emissions
- Longer engine life and reduced maintenance costs makes it less payback period.

Original Parameters (before conversion)	
Fuel	Diesel
Nominal Gen-set output	3860 kW
Real output on site	3300kW
Parameters after conversion (dual – fuel)	
Fuel	Gas+Diesel
Nominal Gen-set output	3860 kW
Real output on site	3300 kW
Nominal Gen-set output	3860 kW
Real output on site	3300 kW

Norms of Specific Fuel Consumption for Diesel/HFO Gensets:

Diesel Engines – High Speed : 260 to 275 ml per Kwh

Diesel Engines – Slow Speed : 245 to 265 ml per Kwh

Density : 0.83 Kg per Litre

HFO Engines – Slow Speed : 190 to 210 ml per Kwh

Density : 0.96 Kg per Litre

8.5.2 Charge Air Cooling:

Effect of Charge air temp on Fuel Consumption & Loading:

Fuel Consumption : 1.5 gms/Kwh for every 100C temp rise

Engine Loading Reduction : 5 %

Check the following parameters for Engine loading is limitation

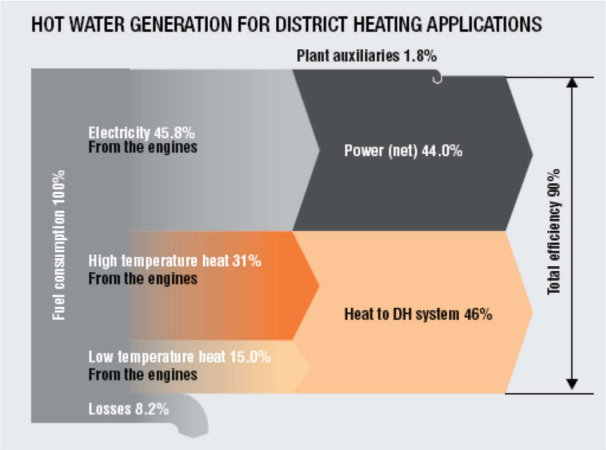
- High HT Water Temperature
- High Charge Air Temperature
- High Exhaust Gas Tempemperature

S.No	Period	4 MW Engine % Loading	Specific Fuel cons (gms/ Kwh)	Exhaust gas temperature before T/C (Deg C)	Fuel
a)	BeforeVAM & Charge air cooling	75.0	231	405	LSHS
b)	After Charge air cooling with VAM	80.1	228	360	LSHS

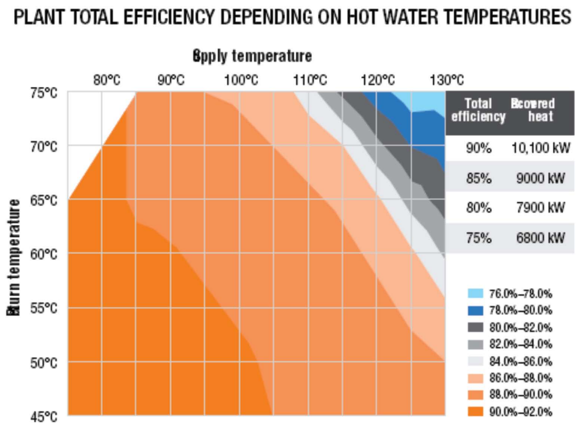
4 MW Engine Block Cooling Jacket Hot water based Chiller Capacity : 130 TR

8.5.3 Combined Heat and Power Generation:

Hot water generation from engine waste heat and use the hot water for absorption chiller to use in air conditioning application / cold storage.



Based on 30% RH & 25^{0}C



Based on 30% RH & 25^{0}C

8.5.4 Know the Fuel Oil Quality and its effects on Engine:

High dirt matter: Increased wear and tear and increase in specific fuel consumption.

High viscosity : Poor atomization and increase in specific fuel consumption

High Sulphur : Increased wear and tear and increase in specific fuel consumption / SOx Pollution

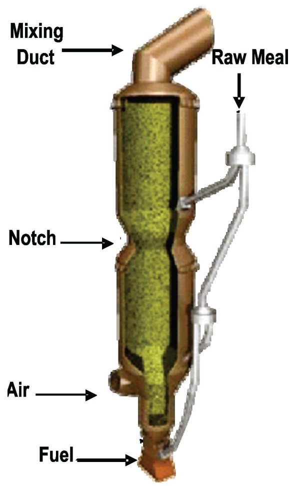
High Carbon Residue: Increased soot formation and increase in fuel consumption / smoke emission.

Section 4
Latest Developments

Chapter – 9

Other Latest Developments / Technology Upgradation

9.1 FL Smidth In-Line Calciner (ILC) for NOx reduction



In-Line Calciners:

In-Line calciners are generally known to generate lower NOx emissions than Separate-Line calciners since all of the kiln exhaust gases must pass through the calciner.

100% of the fuel is fired to the kiln riser duct. As a result, it is possible to obtain both reducing conditions and high temperature zone in one simple system (without multiple firing points) for the lowest possible NOx emissions.

The fuel is injected into the kiln riser below where the tertiary air enters at the base of the calciner. This so-called reduction zone, sized for a particular gas retention time, has an oxygen deficient atmosphere that promotes NOx reduction.

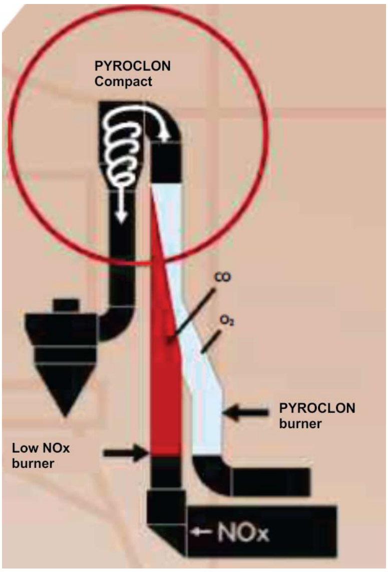
The optimum temperature in the zone is controlled by a material split from the second lowest stage between the calciner and the kiln riser.

This material split is also used to control possible build-up within the kiln riser. Above the reduction zone is the main calciner vessel, which is divided into two or more sections separated by a notch.

The changes in cross-sectional areas create turbulence that ensures effective mixing of fuel, raw meal and gas, improving heat transfer and combustion.

The calciner outlet loop duct ensures optimum gas retention time, further mixing and complete fuel combustion. Optionally, the second- or third-lowest stage cyclone material can be further split to allow for diversion of a portion of the meal directly into the upper section of the calciner. This creates a "hot zone" in the lower section of the calciner that is conducive to burning difficult fuels and further NOx reduction.

9.2 KHD Humboldt Wedag PYROCLON Calciner:



The standard calciner for oil and gas is the PYROCLON®- R with PYROTOP® compact swirl chamber. The PYROCLON®- R LowNOx with PYROTOP® is the standard calciner for using solid fuels.

Both calciners have proved their capabilities of reaching emission limits of worldwide legislation without the use of additives. The reduction of NOx emissions in the LowNOx calciner is based on the principle of "continuous staged combustion".

Meal and fuel are fed into both parallel gas flows. In the LowNOx zone, a portion of the fuel is burned with the kiln gases generating a reducing atmosphere zone which lowers the NOx content of the kiln waste gases.

The reducing gas strand from the LowNOx zone is united with the oxidizing gas strand and later intensely mixed in the PYROTOP® compact swirl chamber. Due to this turbulent mixing, the remaining CO oxidizes to CO_2 with the oxygen present in the gas stream.

To achieve a highly efficient thermal utilization for less ignitable fuels, e.g. petcoke or anthracite, the calciner can be easily extended to increase the retention time to more than five seconds.

Depending on the physical and chemical properties of the secondary fuels, up to 100 percent of the fuel required in the calciner can be substituted

The reducing gas strand from the Low NOx zone is united with the oxidizing gas strand and later intensely mixed in the PYROTOP® compact swirl chamber. Due to this turbulent mixing, the remaining CO oxidizes to CO_2 with the oxygen present in the gas stream. The use of lumpy secondary fuel or fuels characterized by poor ignitability becomes possible by additional installation of a combustion chamber equipped with a "hot spot" burner. Depending on the physical and chemical properties of the secondary fuels, up to 100 percent of the fuel required in the calciner can be substituted.

Advantages:

- Even distribution of raw meal, fuel and combustion air across
- the entire section
- Complete fuel burnout
- Optimum heat transfer between fuel and raw meal
- High calcination rate up to 95 percent.
- staged combustion
- Emission level: < 500 mg NO_2/Nm^3 with gas,oil, lignite and most kind of coals

9.3 Latest Generation Coolers:

9.3.1 Cladius peter η-Cooler:

Static inlet:

The HE-Module opens up from the kiln drop point to the transport lanes by means of refractory concrete. Here an optimal clinker distribution over the width is achieved. With the HE module, which consists of a static inclined grate, the risk of snowmen forming is virtually eliminated, while also ensuring a protective clinker layer on the module itself. The HE module is aerated via independent zones, each zone has it's own flap to adjust the air volume. Due to the flexibility of the air distribution, it is possible to control the kiln discharge conditions even with the changing environment, due to the use of different fuels and raw materials fluctuations.

Transport System:

The η-Cooler uses a transport system that is unique to any of the present coolers. The transport is based on the well proven 'moving floor' system that has long been in operation for materials handling. The η-Cooler consists of parallel transport lanes which are moved together in the direction of the clinker transport (forward stroke) and individually or alternatively in groups retracted (backward stroke).

Depending on the required throughput capacity, a corresponding number of parallel transport lanes is installed, each supported on independent rollers.

Due to Independent Lane Movement (ILM) (parallel, individually driven aerated lanes), the flow behaviour and material speed at the sides can be actively influenced. The slots for the air supply are integrated in the transport lanes by utilizing the Mulden grate plate principle Each transport lane is sealed by means of a labyrinth, which eliminates the need for a dust removal system. This together with the fact that the transport lane system is typically offered without any inclination makes the η-Cooler design extremely compact.

Aeration Concept:

Since no installations are required inside the clinker layer the entire cooler bottom is fully aerated leading to uniform cooling and optimum recuperation. Additionally the η-Cooler still makes use of the chamber aeration principle - a well-proven aeration concept in conventional grate cooler design. However, in contrast to reciprocating grate coolers the η-Cooler allows for a longitudinal division into chambers. This gives the advantage of chamber side aeration (CSA), which improves cooling at the critical side areas of the cooler. With Chamber Side Aeration (CSA) and Independent Lane Movement (ILM) Claudius Peters can, as no other cooler supplier, actively influence the two most important parameters in clinker cooling. This gives us the possibility to virtually eliminate such problems as red river.

Features:

- Extremely compact design
- No dust removal system required
- Complete autogenous wear protection
- Long strokes = low grate speed
- Variable stroke length over the cooler width
- No conveying parts within the clinker bed
- less wear significantly reducing maintenance
- no obstructions to the clinker flow
- constant transport efficiency over cooler life
- Controlled air distribution - chamber side aeration

Benefits:

- Low construction height
- Modular design - quick to install
- Optimum cooling and heat recovery
- Optimal distribution of clinker across cooler width
- Lower operating costs
- High reliability

9.3.2 FLS – SF Cross bar cooler:

Advantages:

- High thermal efficiency
- High secondary and tertiary air temperature
- Stationary air distribution plates
- Clinker conveying and air distribution systems are separated
- No sealing air
- Air distribution plates with mechanical flow regulators (MFR)
- Reduced electrical power consumption
- No thermal expansion of grate line
- Long service life of air distribution plates
- No fall-through of clinker
- No undergrate clinker conveying system
- Easy operation
- Easy maintenance
- Easy installation & Modular design

Innovative features: Cross-bars, separate clinker conveying device

The SF Cross-Bar Cooler has no movable grate plates. There is no fall-through of clinker and no undergrate clinker conveying system is required. A static layer of clinker protects the air distribution plates against heat and wear, so the plates will remain in service for a long time. Reciprocating crossbars fitted above the stationary air distribution system effectively convey, mix and shear the clinker while at the same time preparing the clinker for efficient exposure to the cooling air. The cross-bars work according to the same principle as reciprocating cooler grates, but gradual wear of the cross-bars has no effect on cooler operation and thermal efficiency, as the conveying and air distribution systems are separate.

The cross-bars are held in position by retainer brackets. All wear parts are easy to install and replace.

Mechanical flow regulators and air distribution plates

Mechanical flow regulator In the SF Cross-Bar Cooler each air distribution plate is equipped with a Mechanical Flow Regulator (MFR) which regulates the airflow to each plate via a self-adjusting orifice. The MFR maintains a constant airflow through the air distribution plate and clinker bed, irrespective of clinker bed height, particle size distribution, temperature, etc.

If for some reason the restriction of airflow through the clinker layer changes locally, the MFR automatically compensates for the variations in restriction and maintains the desired airflow.

The MFR working principle is entirely based on simple physical laws without any electrical controls. The MFR prevents the cooling air from taking the “path of least restriction”. This helps to optimise heat recuperation and distribution of air throughout the entire grate cooler, which in turn allows fuel savings and/or an increase in throughput.

Air distribution plate

The air distribution plates of the SF Cross- Bar Cooler are characterised by low pressure drop. The MFR system adds little to the pressure drop during normal operation, due to the large orifice area. So the undergrate pressure is considerably lower than in traditional coolers, which in turn saves electrical energy.

Air is supplied from one fan to each undergrate compartment, established when fitting the modules side by side together. The SF Cross-Bar Cooler has no internal ducting within the undergrate compartments.

The protective layer of static clinker between the cross-bars and the air distribution plates prevents wear of the air distribution plates.

Modular concept

The entire SF Cross-Bar Cooler is constructed as a modular system with a fixed inlet module followed by standard modules (1.3 m wide x 4.2 m long or 4 x 14 air distribution plates). The standard modules are preassembled in the workshop to ensure high quality and swift and easy installation. Each module includes a movable frame activated by a hydraulic cylinder. The movable frame is guided by four linear guide bearings and has two drive plates.

The drive plate penetrates the grate line via two slots, which extend throughout the entire module length. On top of the drive plates a patented sealing profile forms a dust trap, preventing clinker from entering the undergrate compartment and, consequently, eliminating the need for a dust spillage conveyor. The sealing profiles extend throughout the entire cooler length, which means that during the reciprocating movement of the profiles, the ends are never exposed to wear by the clinker.

Because the standard modules consist of standard mechanical components, very attractive equipment delivery times can be offered. The modular cooler concept allows different configuration patterns for various cooler sizes, depending on production level, clinker temperature requirements, etc.

Process improvements

The SF Cross-Bar clinker cooler concept features improved thermal efficiency, resulting in high secondary and tertiary air temperature, which lowers overall heat consumption. High thermal efficiency and reduced power consumption are maintained throughout the life of the cooler, irrespective of the wear on the conveying system.

This is due to the:

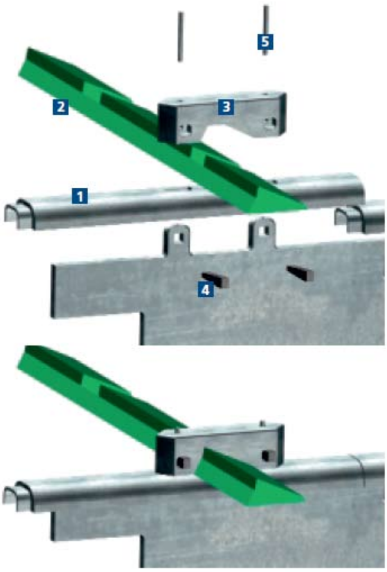
- impact zone with stationary inlet module
- compartment aeration without inefficient sealing air
- optimised air distribution throughout the service life of the cooler, ensured by the mechanical flow regulators reduced amount of cooling air and consequently
- lower air quantity for dedusting
- reduced number of cooling air fans
- separated mechanisms for conveying of clinker and cooling of clinker

Easy maintenance

The number of wear parts has been minimized through the simple design of:

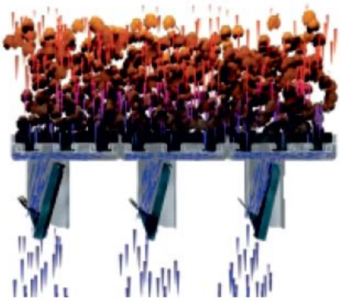
- Cross-bars
- Retainer brackets
- Sealing profiles.

Moreover, these parts are designed to last two "campaigns" or more. Grate plates are no longer considered wear parts. All wear parts in the cooler are easily replaced in less than four days.

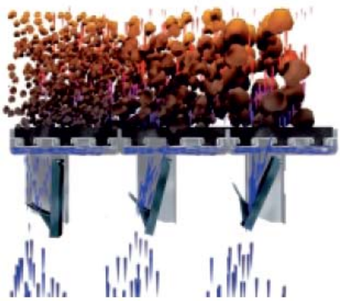


Replaceable wear parts

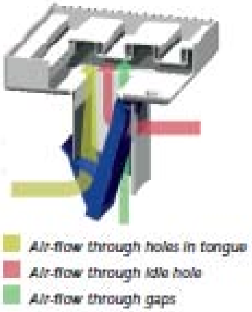
- Sealing profile
- Cross-bar
- Bracket
- Wedge
- Pin



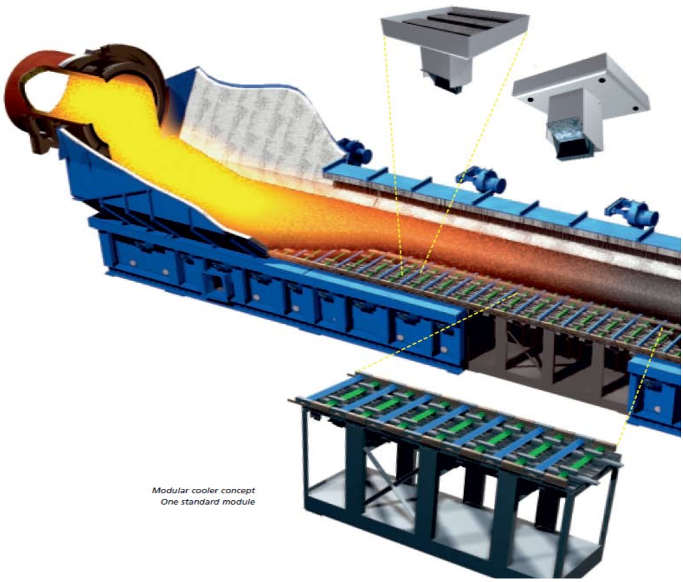
Uniform clinker size



Non uniform clinker size



SF Cross-Bar Cooler

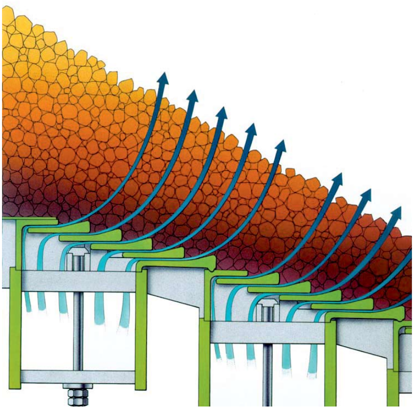


9.3.3 Humboldt Wedag grate coolers:

Advantages:

- Optimized heat transfer ensuring high thermal efficiency
- Reduced heat consumption for the kiln process
- High clinker quality due to rapid cooling
- Excellent control of cooled clinker temperature
- Less cooler vent air for greater ecological acceptability
- Suitable for all kiln processes
- Considerably reduced grate riddlings
- Higher specific grate loading
- Automatic operation
- High operational reliability due to the robust design
- Less maintenance

HUMBOLDT WEDAG grate coolers with capacities over 5000 t/d have been installed throughout the world. Experience gained with more than 400 rotary kiln cement plants has led to the development of the third generation of HUMBOLDT WEDAG grate coolers, The recuperation efficiency of a PYROSTEP® grate cooler is between 70 and 76 %, depending on the type of kiln systern.



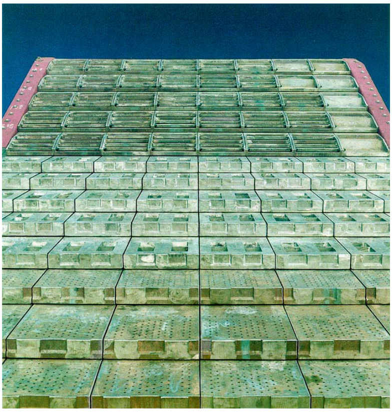
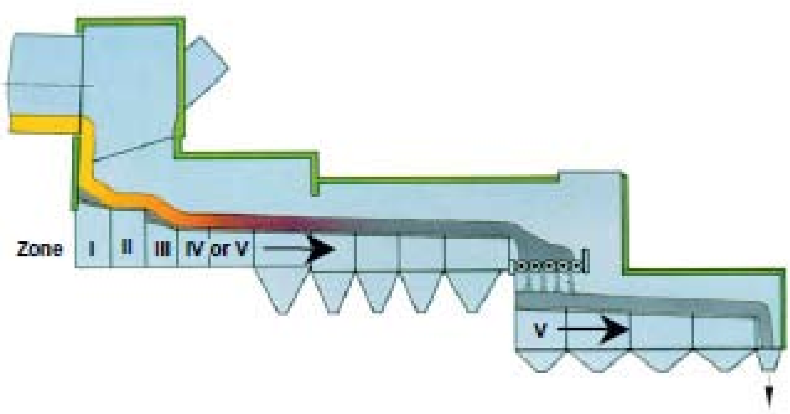


Fig: HUMBOLDT WEDAG grate cooler

The basic principle:



Zone I:

comprises a stationary step grate with horizontal air outlets in the plates. The individual rows are aerated in several transverse sections with a pulsating and individually adjustable stream of air. This design ensures that the clinker is uniformly distributed over the full width of the cooler.

The classical "horse-shoe" coverage of individual plates is reduced or disappears entirely and the creation of a "red river" is eliminated by directing the air flow to specific areas in the clinker bed.

The thermal and mechanical stresses imposed on the step grates are minimized by the constant presence of a layer of cold clinker.

Zone II

This is a reciprocating grate section equipped with newly developed omega plates for aeration in rows. These plates have small pockets in which the clinker accumulates, thus ensuring a widespread and uniform flow of air through the layer of clinker.

The lip of the omega plate is also cooled with air to extend the service life. A wearresistant external telescopic seal makes it possible to supply cooling air to the moving rows via rigid pipes, thus making hoses and flexible connections unnecessary. In the case of small cooler units, zone II is followed directly by zone V with chamber aeration.

Zone III

comprises a stationary step grate similar to zone 1. This ensures that the advantages of a step grate can be fully utilized, even at high clinker throughput rates, without the risk of clinker flushes.

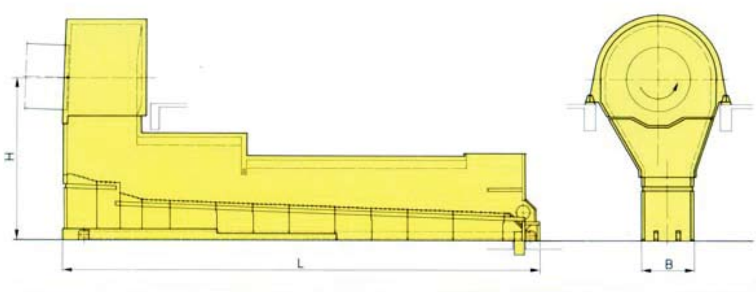
Zone IV

This is also equipped with omega plates (similar to zone II). The length of this one depends on the process requirements and the capacity of the pyro process System.

Zone V

This is aerated by chambers and can be equipped with standard or omega plates. The specific cooling air distributed to each plate is calculated to ensure the prevention of inrushes of air causing clinker to whirl up in fountains. The clinker is consequently cooled very uniformly. The gaps between the plates have been narrowed to reduce clinker trickling.

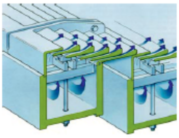
Design data	
Throughput	650 ... 10,000 t/d
Grate area	16 ... 188 m^2
Specific grate load	40 ... 55 t/(m^2d)
Grate inclination	3.5 %
Specific air flow	1.6 ... 2.1m^3/kg (0^0C; 1013.25 mbar)
Number of reciprocating frames	1 ... 3
Temperature of the cooled clinker	70^0C above ambient temperature



Nominal throughput [t/d]	Cooler type	Length "L" [m]	Width "B" [m]	Height "H" [m]
690	1-016.05	13.0	2.7	8.8
830	1-019.06	13.0	3.1	8.8
960	1-022.06	14.3	3.1	9.0
1200	1-025.07	14.3	3.4	9.0
1450	1-030.07	16.3	3.4	9.2
1650	1-034.08	16.3	3.7	9.2
1950	1-039.08	18.2	3.7	9.4
2150	1-042.10	16.3	4.3	9.4
2400	1-048.10	18.2	4.3	9.6
3000	2-059.10	21.9	4.3	9.8
3500	2-069.10	25.2	4.3	10.2
4150	2-083.12	25.2	4.9	10.2
4750	2-095.12	28.5	4.9	10.6
5200	2-103.12	30.5	4.9	11.2
5700	2-114.14	29.1	5.5	11.0
6200	3-123.14	31.1	5.5	11.2
6800	3-137.14	34.4	5.5	11.6
7800	3-156.16	34.4	6.1	11.6
8600	3-172.16	37.7	6.1	11.8
9500	3-188.16	41.0	6.1	12.0

Subject to improvements introduced to further advance our technology

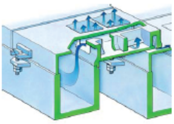
Stepped grate plates



with horizontal air outlets.

This ensures an optimum flow of air into the clinker bed and prevents hot clinker trickling through the plates. The air is routed through the box beam.

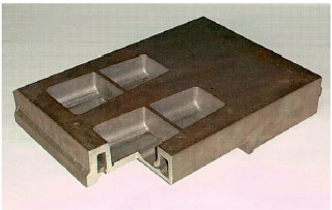
Omega plates for aeration by rows



The cooling air is routed through the beam to the plate outlet openings. These plates have pockets in which the clinker accumulates. Air streams disperse through the layer of clinker which is prevented from trickling through the plates.

Omega plates for chamber aeration

These plates are an alternative to the standard plates. The dispersed flow of air streaming through the layer of clinker improves cooling efficiency and furthermore reduces the risk of clinker whirling up in fountains, reduces the degree of wear and also the amount of clinker trickling through the plates.



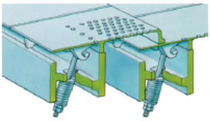
Standard Plates

Side seal

with universally adjustable sealing elements which reduce considerably the amount of cooling air loss and the plate riddlings over the entire reciprocating grate area.

Standard plate

with reinforced self locking fixture

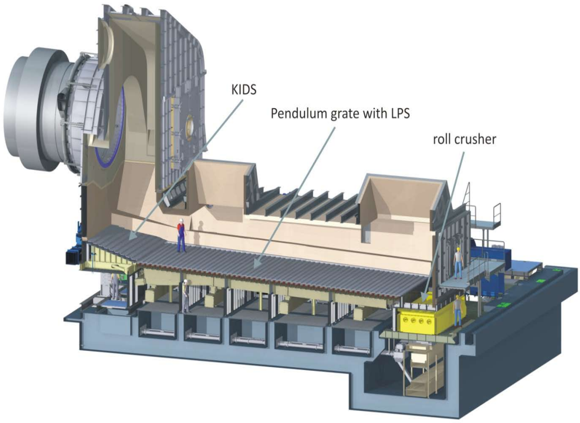


9.3.4 IKN Pendulum Cooler

Features and general process description

- Horizontal aeration (COANDA effect)
- Fixed clinker inlet distribution system (KIDS)
- Slow grate speed and reduced number of mobile rows
- Hydraulic drive with single or double cylinder located outside the cooler housing
- Low specific electrical energy consumption
- Constant thrust gaps and maintenance free grate suspension due to IKN Linear Pendulum Support (LPS)
- Cooler capacity of up to 13.000tpd in operation as of 2012

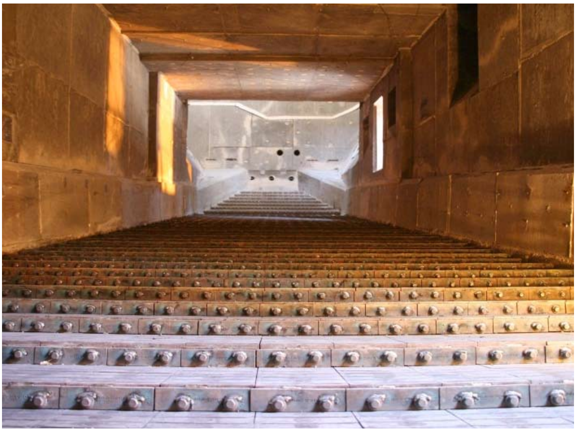
The sintered clinker leaves the outlet of the kiln with an estimated temperature of 1400°C and drops onto the static inlet (clinker inlet distribution system), referred to as KIDS (Fig.1), where the clinker is initially cooled and conditioned for uniform distribution to the pendulum-supported grate (Fig.2). The clinker is transported by linear strokes of the pendulum section, every third row being movable. The clinker bed, 550-650mm deep, travels past the middle air offtake which is located separately behind the kiln hood. Typically middle air is utilized for waste heat recovery systems or for drying purpose.



After travelling the total grate length the clinker temperature will have been reduced to a theoretical value of about 65°C plus the ambient temperature when it falls onto the roller crusher. The crusher has three to six rollers with maximum width of 4.8m.

Each crusher roll is driven by an electric motor with bevel planetary gear. After crushing the clinker maximum grain size is 25 x35mm and it leaves the cooler via a chute which discharges the clinker onto the clinker conveyor for transport to the clinker silo.

Fig. 2: IKN cooler including KIDS



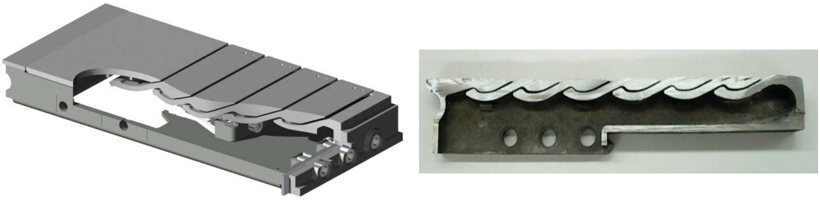


Fig. 3a/b: IKN grate plate with Coanda-Nozzles

The Coanda Nozzles of the pendulum section are formed by several blades which are inserted into a common supporting frame. The curved air openings between the blades generate the desired horizontal Coanda jets (Fig.4).

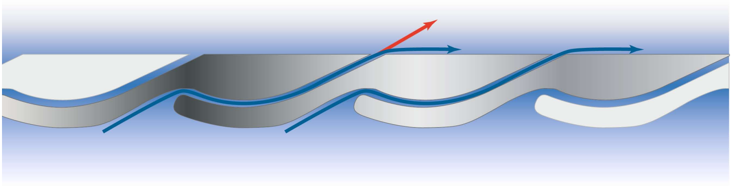


Fig. 4: Coanda-effect

The surface of the frame is completely covered by the blades to form a grate surface which is no longer composed of entire grate plates. The supporting frame is not subject to wear.The blades are loosely interlocked into a base frame and are free of mechanical and thermal stress. This is crucial as it allows the material composition to be optimized for wear resistance only. The blades are made as hard as the clinker, significantly increasing the service life of the grate surface. While each cooler has thousands of such blades, only single blade replacements have been reported.

Clinker Inlet Distribution System (KIDS)

The IKN KlDS (Fig.5) distributes the clinker evenly across the grate width and conditions the clinker bed to improve its air permeability. The inclined slots of the Coanda Nozzles generate horizontal air jets which pressurize the bottom layer of theclinker bed. The air jets become vertical upon striking against clinker particles and uniformly penetrate the clinker bed. Fines are sifted out of the voids between larger particles and accumulate at the surface where they fluidize.The bed voidage in each layer within the clinker bed is maximized. The main features of the IKN KIDS are:

- Uniform clinker distribution across the grate width
- Transport of the fines to the bed surface
- Rapid cooling of the lower clinker bed
- Lower clinker outlet temperature
- Less maintenance of the grate
- Improved recuperation
- Power savings due to reduction of cooling air and pressure
- Stabilized kiln/cooler operation

Fig. 5: KIDS erection

KIDS, stands for a revolutionary success in clinker cooling – in mechanical and process terms. Typical improvements are measured as heat savings of 20 to 100 kCal/kg depending on the base line. IKN guarantees savings in terms of cooler losses which result in a reduction of kiln fuel consumption.

Linear Pendulum Support

The high degree of precision in design and fabrication achieved with the blade technology called for a dedicated gap management between movable and stationary rows. This requirement was solved by the LPS support of the movable structure. LPS is short for Linear Pendulum Support (Fig.6), IKN's patented support, guaranteeing a linear movement, which provides a constant gap width at all times. The LPS is the advancement of IKN's pendulum strap suspension, which proved successful for almost two decades. It is a combination of wearless and maintenance free suspension blades making up a compact unit with dimensions of 1.3 m x 1.6 m.This makes it easy to place it underneath the grate or integrate it into the cooler housing.

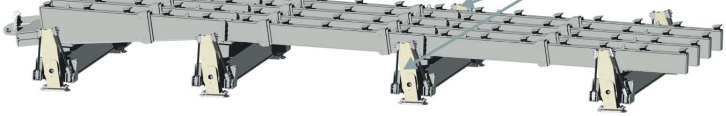


Fig. 6: Linear Pendulum Support (LPS)

The LPS had to perform a 1.5 million stroke test run with a simulated clinker bed.The optimum layout and its durability were confirmed by various tests ' and calculations. The first installation has been in operation since April 2003.

Grate system and Coanda-Effect

The effective conditioning of the clinker bed on the KIDS and the efficient cooling throughout the cooler is achieved through horizontal aeration. This is created by narrow, inclined and curved slots (Fig. 3a/b). They generate sharp jets of air with high dynamic pressure horizontally in the transport direction of clinker. The Coanda effect forces the jets to curve parallel to the surface of the grate plate instead of following the direction of the slot. Fines are swept to the clinker bed surface and the Coanda Nozzles are completely covered by cooling air. During normal operation a temperature of 30°C to 40°C is measured close to the grate surface making emergency power supply to any cooling fans obsolete. A high degree of precision in design and fabrication of the movable gaps results in the elimination of air ducts and the return to compartment aeration after the stationary inlet (KIDS).

9.3.5Thyssenkrupp Polysisus AG, POLYTRACK Cooler:

The POLYTRACK® clinker cooler is a combination of a static, horizontal aeration floor and an above-floor clinker conveying system. Its convincing advantages are the very high clinker bed transporting efficiency and strict separation of the functions of transportation and aeration, due to:

- Optimum transverse distribution of the clinker resulting in uniform and efficient cooling of all particle size fractions over the entire width of the cooler
- Extremely low overall height
- Very high thermal efficiency
- Robust, low-wear, easy-to-maintain design providing outstanding availability and Consistent modular construction

- Moreover, the POLYTRACK® tolerates fluctuations in the kiln process; its flexible and high-performance clinker bed transportation system copes with even the most difficult operating conditions

The clinker bed transportation principle:

The clinker bed transportation principle – a special feature of this clinker cooler - is very effective: In the direction of conveyance of the clinker, transport tracks move to and fro above the static aeration floor.

The rows of transport tracks are installed at a particular distance to each other. Between them the cooling air enters the bed of clinker. The required width of the cooler determines the number of transport track rows. Each row of transport tracks spans the entire length of the cooler.

To convey the clinker bed the transport tracks are moved forward together and are then individually moved back. By varying the transport stroke length and frequency, the conveying speed of the clinker bed and thus the clinker bed depth and the clinker throughput can be optimally controlled over the entire width of the cooler.

This well-tried clinker bed transportation principle of the POLYTRACK® provides the best preconditions for thorough cooling of all particle size fractions.

Aeration concept:

To prevent the wear of one component from affecting the efficiency or throughput of the machine, the functions „clinker bed transportation“ and „cooling air distribution in the clinker bed“ are strictly separated from each other in the POLYTRACK®.

The air distribution takes place via static aeration units located between the transport tracks. These large-area pockets integrated in the aeration floor are permanently filled with clinker and thus provide autogenous wear protection. Wear of the transport tracks is minimal, due not least to the robust design, and has no effect on the aeration of the clinker bed.

Sealing concept:

Special, wear-free sliding element pairs reliably seal the few contact zones between static and moving cooler components. Consequently, there is no need for wear prone conveyors for evacuating clinker that has fallen through the grate. This is a further advantage with regard to minimizing the overall height.

The modular concept

The modules are 4.8 m or 7.2 m long and available in widths of 1.5 m/2.0 m and 2.5 m. With small module dimension steps – of 0.5 m over the width and only 2.4 m over the length – it is possible to precisely design coolers to suit spatial and process technological requirements.

Particularly in the case of system conversions, these small module dimension steps permit optimum adjustment to the given building structures without detracting from the process technology.

The modules are preassembled in the manufacturing shop. This ensures optimum alignment of the transport tracks and aeration units, saving time and effort at the plant site, shortening the installation and commissioning periods and, in the case of conversions, also reducing the plant downtime.

The highly effective clinker bed transportation principle, there is no need for inclination of the cooler and the whole structure is therefore of horizontal design.

The POLYTRACK® consequently has an extremely low construction height. Despite the limited installation height, it is still possible to install a roll crusher as intermediate crusher in order to intensify the cooling process.

Intermediate crusher concept:

The intermediate crusher, the cooling process on the second grate is optimised, reducing the ultimate clinker temperature and thus also producing higher cooler exhaust air temperatures. These higher exhaust air temperatures have a decisive influence on the operating economy of cooler waste heat utilisation systems (e.g. heat utilisation for power generation; heat utilisation for drying etc. The exposed hot interior of the clinker broken by the intermediate roll crusher is effectively cooled on the second grate and the extracted heat is transferred to the cooler exhaust air.

9.4 Increasing pet coke consumption as a fuel:

Petcoke is characterised as a high grade fuel with high calorific value of more than 8,000 KCal per kg, having low ash content and low volatile matter but high sulphur content, up to 7%.

Petcoke provides scope for manufacturing higher grade of cement with the same raw material or same grade of cement using marginal and low grade limestone contributing to resource conservation. Due to higher calorific value compared to coal, less quantity of petcoke needs to be moved from source to plant site, which reduces the cost of transport.

However, as the sulphur content in petcoke is high, its larger use increases the sulphur cycle and aggravates build-up formation in the kiln system. The total sulphur content in the clinker needs to be maintained below 2 per cent from product quality point of view. For using petcoke in the cement industry, there is, therefore, a need for changes in raw mix design and finess of fuel and modifications in burner, calciner and cooler so that a trouble-free and cost effective operation is achieved.
Recent studies have shown that fuel costs can be reduced by promoting the use of petcoke. Fuel alone accounts for about 40% of the cost incurred by the cement industry.

Alternate fuels like petcoke can reduce fuel costs to a great extent. Studies shows that green delayed petcoke is suitable for use in calciner, fluid petcoke is suitable for use in burning zone and calciner.

Petcoke should be used when the plant is equipped with multi-chanel burner, when alkali deposits are high, when there is a margin in coal milling capacity and primary air fan quantity and when riser duct is fitted with coating repellent refactory.

Studies form the plant 1 and plant 2 shows that almost more than 80% of the fuel is pet coke only. These plants changed their raw mix design analysis of the average kiln feed and clinker is given below.

Constituent	Plant 1		Plant 2	
	Avg. Kiln feed	Avg. clinker	Avg. Kiln feed	Avg. clinker
SiO_2%	13.07	20.99	13.08	20.92
Al_2O_3%	3.65	5.63	3.63	6.64
Fe_2O_3%	2.69	3.71	2.69	3.74
CaO%	42.2	63.77	42.2	63.78
MgO%	1.58	2.76	1.59	2.68
Na_2O%	0.2	0.41	0.2	0.42
K_2O%	0.44	0.78	0.42	0.74
SO_3%	0.2	1.68	0.2	1.6
pet coke% of total fuel fired	80-85		80-85	
Source of alkalies	Limestone		Limestone	

It is observed that there is no aggrevates build up in the kiln/preheater after changing the raw mix design. Multi channel burner is used to fire pet coke and burner momentum increased to 1790 % m/s. Incase if alkali% in limestone is less then alkaline Feldspars added as an additive to fire higher amounts of pet coke firing in kiln and caliner.

Some of the plants are operating with 100% fuel as pet coke without any aggrevates build up in Kiln/prehear.

Publications by CII-GBC as part of World Class Energy Efficiency in Cement Plants

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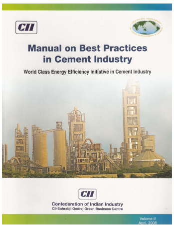
<td>Manual on Best Practices in Cement Industry
The publication details the best practices followed by the Indian plants in the areas of energy efficiency, quality and productivity improvement.</td>
<td>
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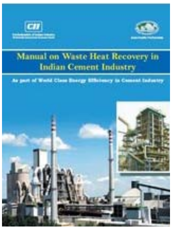
<td>Manual on Waste Heat Recovery in Indian Cement Industry
The manual focuses on description of technologies available for Waste Heat Recovery Potential and installations in the Indian Cement Plants. This also discusses the advantages and also the barriers towards the deployment of WHR Technologies.</td>
<td>
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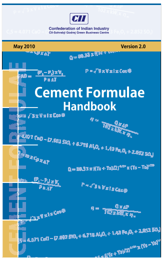
<td>Cement Formulae Handbook
The formula book is a compilation of useful formulas, norms available at various sources, intended as a store of information which acts as a quick reference for the plant personnel. This was very well accepted by the Indian cement plants and subsequently the second edition was released during the annual conference in 2010.</td>
<td>
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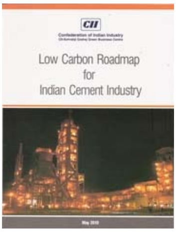
<td>Low Carbon Roadmap for Indian Cement Industry
The report is an effort to create a road map for Indian Cement Industry to achieve the reduction in its Green House gas emission intensity. This is meant for due contemplation, reflection and necessary action from the Indian cement industry in its road map towards a low carbon growth.</td>
<td>
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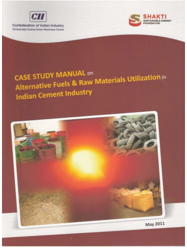
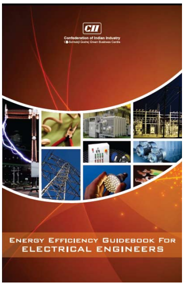
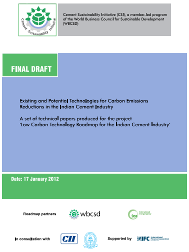
Case study Manual on Alternative Fuels & Raw Materials Utilization in Indian Cement Industry The purpose of this manual is to act as catalyst for promoting increased use of alternate fuel & raw materials in Indian Cement Industry through co processing of wastes and reducing cost of clinker production, thereby improving performance competitiveness of individual cement plants. The objective also is to promote a much needed ecologically sustaining solution to the waste management problem in the country through co processing in cement kiln.	
Energy Efficiency Guidebook for Electrical Engineers The guidebook is a quick reference for electrical engineers that covers the fundamental theory of basic electrical equipments and provides the latest information on electrical systems such as motors and its control, transformers, lighting systems etc. It also throws light on the possible energy saving opportunities and newest trends in electrical and lighting systems.	
Low Carbon Technology Roadmap for the Indian Cement Industry The report is a set of technical papers focusing on technologies, policy factors and financing needs for carbon emissions reduction and resource efficiency enhancement in Indian cement Industry. The technology papers are developed by Confederation of Indian Industry (CII) & NCCBM in partnership with International Energy Agency (IEA) and WBCSD's Cement Sustainability Initiative (CSI).	

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