Cement Process & Energy Saving

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Hideyuki TANAKA
Technical Expert
International Engineering Dept.,
The Energy Conservation Center, Japan

Bird-eye View of Japanese Cement Factory

Layout of one Japanese cement factory

Chemical Composition of Raw Materials and Cement Product

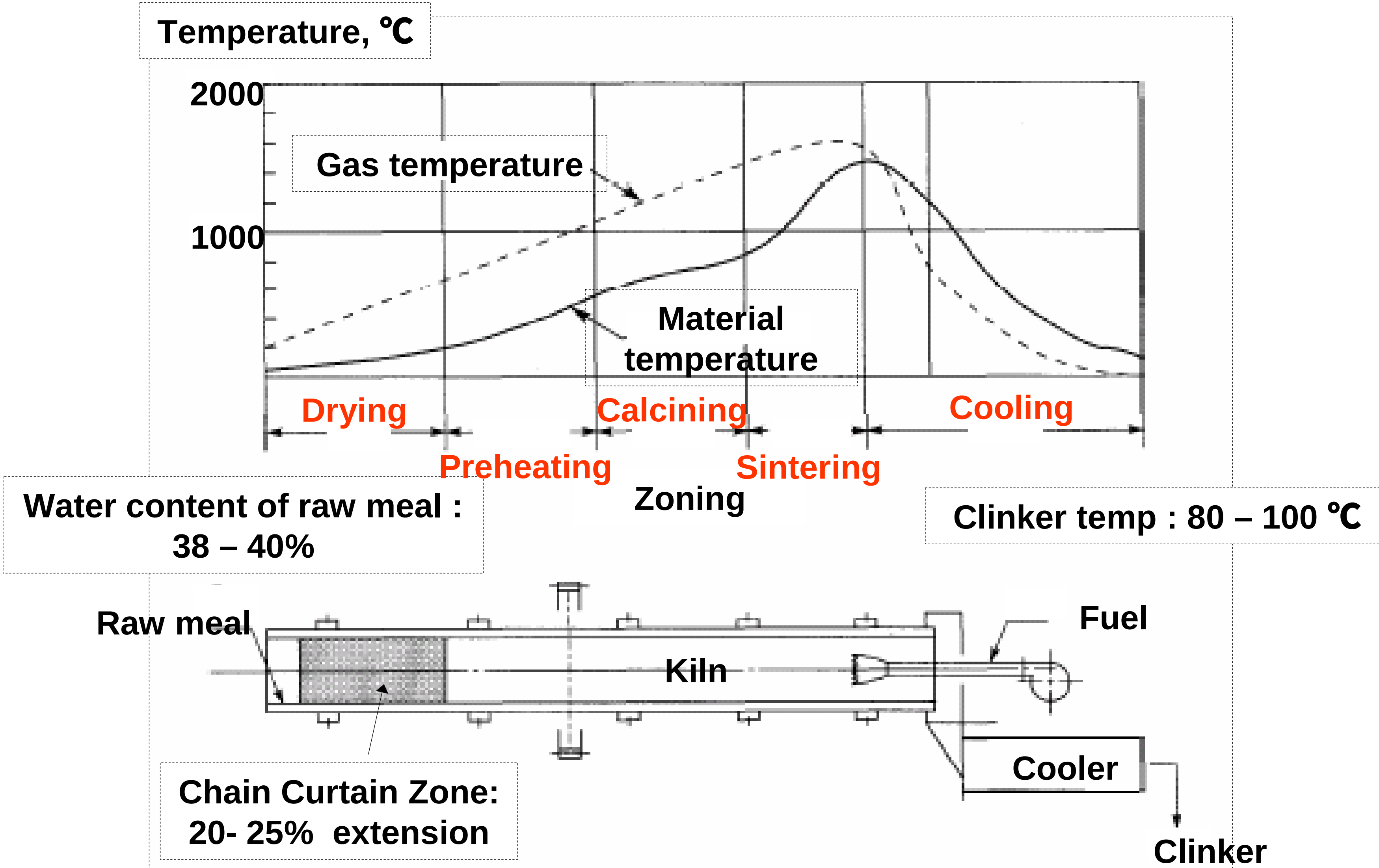
Raw Materials (%)

	CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	CO_2
Limestone	47-55					37-43
Clay		45-78	10-26	3-9		
Silica		77-96				
Iron-ore				40-90		
Gypsum	26-41			37-59		

Cements (%)

	CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	Others
Portland cement	63-65	20-23	3.8-5.8	2.5-3.6	1.5-2.3	
Blended cement (BF slag)	52-58	24-27	7.0-9.5	1.6-2.5	1.2-2.6	

Temperature Profile in Wet Process Kiln



Temperature Profile in Wet Process Kiln

Chemistry of Cement Process

Stage	Heating (℃)	Process
Drying	100～110	Vaporization of physically adsorbed water
	110～700	Vaporization of chemically bonded water
Calcining	700～750	Decomposition of $MgCO_3$
	750～900	Decomposition of $CaCO_3$, Formation of $2CaO \cdot SiO_2$
	950～1200	Transition to $\beta \cdot 2CaO \cdot SiO_2$
	1200～1300	Formation of $3CaO \cdot Al_2O_3$, $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$
Sintering	1300～1450	Formation of $2CaO \cdot SiO_2$, Sintering of Al_2O_3, Fe_2O_3, Na_2O, K_2O, etc
Cooling	150～200	

During a course of cooling, pebble-like black colored clinker is formed, which consists of the following components;

- $3CaO \cdot SiO_2$: Referred to as Alite or C3S
- $2CaO \cdot SiO_2$: Referred to as Belite or C2S
- $3CaO \cdot Al_2O_3$: Referred to as aluminate phase or C3A
- $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$: Referred to as ferrite phase or C4AF

Raw Materials and Energy required for production of 1 ton of Cement

Raw Materials (kg)	
Limestone	1,095
Clay	204
Silica	78
Iron-ore	30
Gypsum	34
Total	1,439

Energy Consumption	
Fuel (*1)	105
Electric power (kWh)	99
(*1) : kg of coal equivalent, where HHV of coal is 6,200 kcal/kg (= 25,958kJ/kg)	

Fuel by kind (%)	
Coal	78
Petroleum coke	13
Combustible waste	5
Heavy oil	4

Base : 1 ton of cement

Heat Requirement in Burning Section

Kiln	kcal/kg-cl	Source (1)	$m^3{}_N$/kg-cl (2)
Shaft kiln	940	Yogyo Kogaku H/B	1.65
Dry long kiln	1,487	JCA (1961)	2.62
Wet kiln	1,357	〃	2.38
Lepol kiln	954	〃	1.68
SP kiln	797	JCA (1981)	1.40
NSP kiln	773	〃	1.35

Note 1: JCA: Japan Cement Association

2: Estimated based on 1.40 $m^3{}_N$/kg-cl in SP kiln

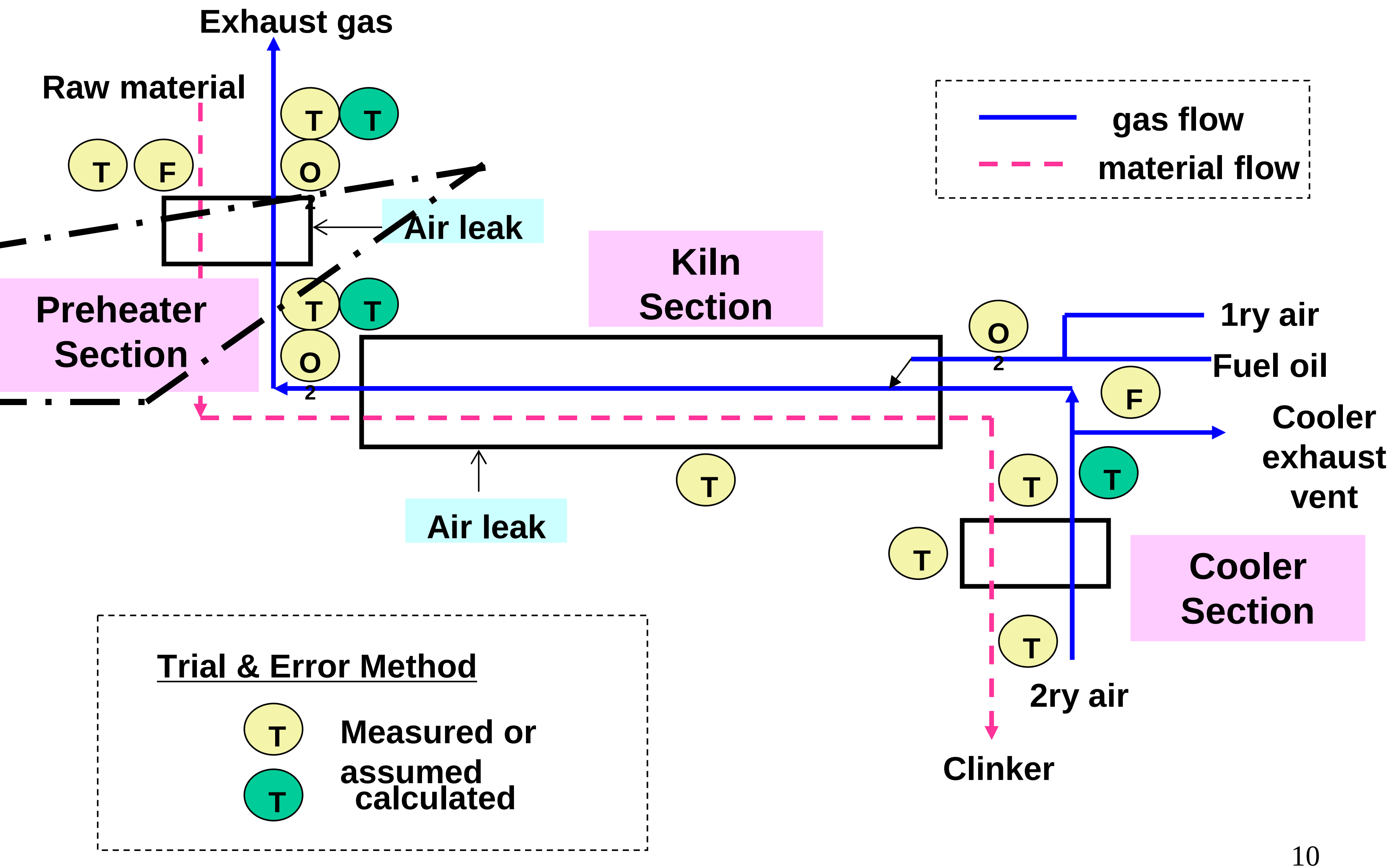
Energy Management System
(Cement Factory)

Aspect		Major Activity
Organization	Accountability	Employee education (awareness)
	Organization	EE&C promotion committee Energy manager
Monitoring	Monitoring	Data recording & reporting to employee
	Targeting	Specific energy consumption (SEC) Key efficiency parameters
Technology		Technical review (energy audit)
Operation & maintenance (O&M)	House keeping	Product yield (avoid off-spec product) Preventive maintenance (avoid unscheduled shutdown)

Energy Saving Measures in Cement Factory

	Raw material section	Clinker burning section	Finishing section
First step	1) Selection of raw materials 2) Management of particle fineness 3) Management of grinding media	1) Prevention of unscheduled shutdown 2) Selection of fuel 3) Prevention of leakage	1) Management of particle fineness 2) Management of grinding media
Second step	1) Replacement of fan rotor 2) Improvement of temperature and pressure control system 3) Improvement of mixing & homogenization system 4) Installation of closed circuit mill (separator)	1) Use of industrial waste (waste tire, etc) 2) Heat recovery of pre-heater exhaust gas and cooler exhaust gas (drying of raw material and generation of electricity) 3) Replacement of cooler dust collection from multiclone to EP	1) Installation of closed circuit mill (separator) 2) Installation of feed control system
Third step	1) Conversion from wet process to dry process 2) Replacement of ball or tube mill by vertical roller mill 3) Pneumatic transfer of raw material to mechanical transfer	1) Conversion of fuel from petroleum to coal 2) Conversion of SP to NSP 3) Conversion of planetary cooler to grate cooler	1) Use of industrial waste (slag, pozzolan)

Boundary of Heat Balance



Collecting Data (Wet Process)-1

Dry raw material (dry RM)	t/h	
Water content in wet raw material	wt% on wet RM	(40)
Clinker yield	-	(0.65)
Clinker temp at cooler exit	deg C	
Heat of clinkering (calcination & sintering)	kcal/kg-cl	
Specific heat of clinker (Cp)	kcal/kg-cl・deg C	0.192
Fuel rate (kiln)	m^3N/h	
Specific gravity of fuel	kg/m^3N	
Specific heat of fuel (Cp)	kcal/kg・deg C	
Low heat value of fuel	kcal/m^3N	
Fuel temperature	deg C	
Fuel rate (precalciner)	kg/m^3N	
Exhaust gas temp at kiln or preheater exit	deg C	
O_2 in exhaust gas	Vol %	
CO_2 generation in calcination	m^3N/kg-cl	0.27
Specific heat of exhaust gas	kcal/m3N・deg C	0.338

Collected Data (Wet Process)-2

Kiln surface temperature (average)	Deg C	
Surface area	m^2	
Convection coefficient (hc)	kcal/m^2・hr・deg C	(10.9)
Radiation coefficient (hr)	kcal/m^2・hr・deg C	(21.0)
Emissivity	-	0.95
Preheater surface temperature (average)	deg C	NA
Surface area	m^2	NA
Convection coefficient (hc)	kcal/m^2・hr・deg C	(10.0)
Radiation coefficient (hr)	kcal/m^2・hr・deg C	(19.1)
Emissivity	-	0.95
Cooler surface temperature (average)	deg C	
Surface area	m^2	
Convection coefficient (hc)	kcal/m^2・hr・deg C	(13.0)
Radiation coefficient (hr)	kcal/m^2・hr・deg C	(25.0)
Emissivity	-	0.95
Ambient temperature (outdoor)	deg C	

Items Listed on Heat Balance Table

Heat Input		Heat Output	
Heat of combustion of fuel	I1	Heat for clinkering	O1
Sensible heat of fuel	I2	Sensible heat of clinker at cooler exit	O2
Sensible heat of wet raw material	I3	Sensible heat of cooler exhaust vent	O3
Sensible heat of combustion air	I4	Heat for evaporating water in raw material	O4
		Sensible heat of kiln or preheater exhaust gas	O5
		Radiation heat on kiln surface	O6
		Radiation heat on preheater surface	O7
		Radiation heat on cooler surface	O8
		Unaccountable heat losses	O9
Base of temperature : Ambient air temperature Base of heat amount : kcal per kg of clinker (kcal/kg-cl)			

Thank you!