Contract project-2004
With Ministry of the Environment, Japan

環境省

Ministry of the Environment

Air Pollution Control Technology In Steel Industry

March 2005

Overseas Environmental Cooperation Center, Japan

Air Pollution Control Technology in Steel Industry

Committee Members

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Prepared by

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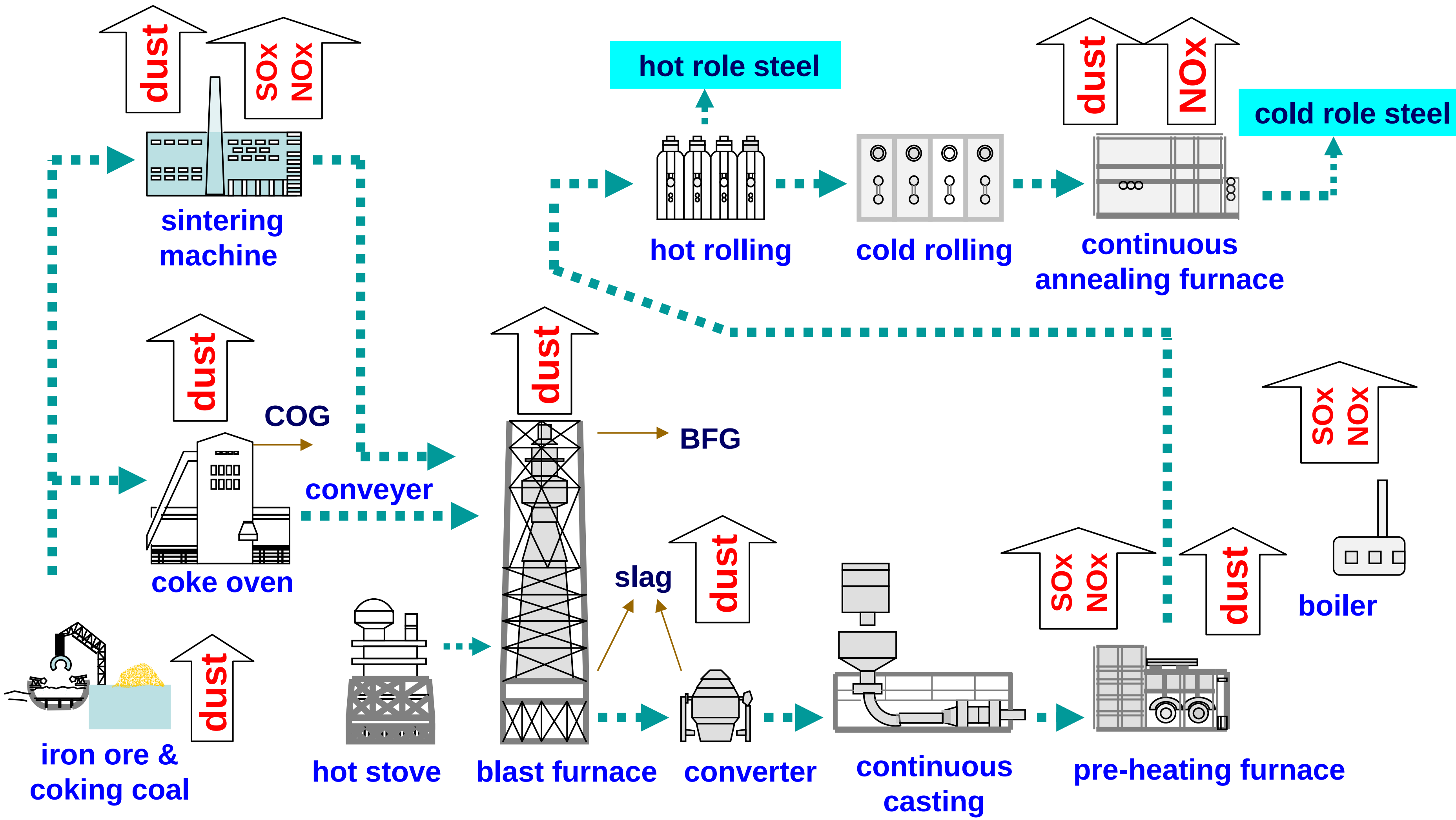
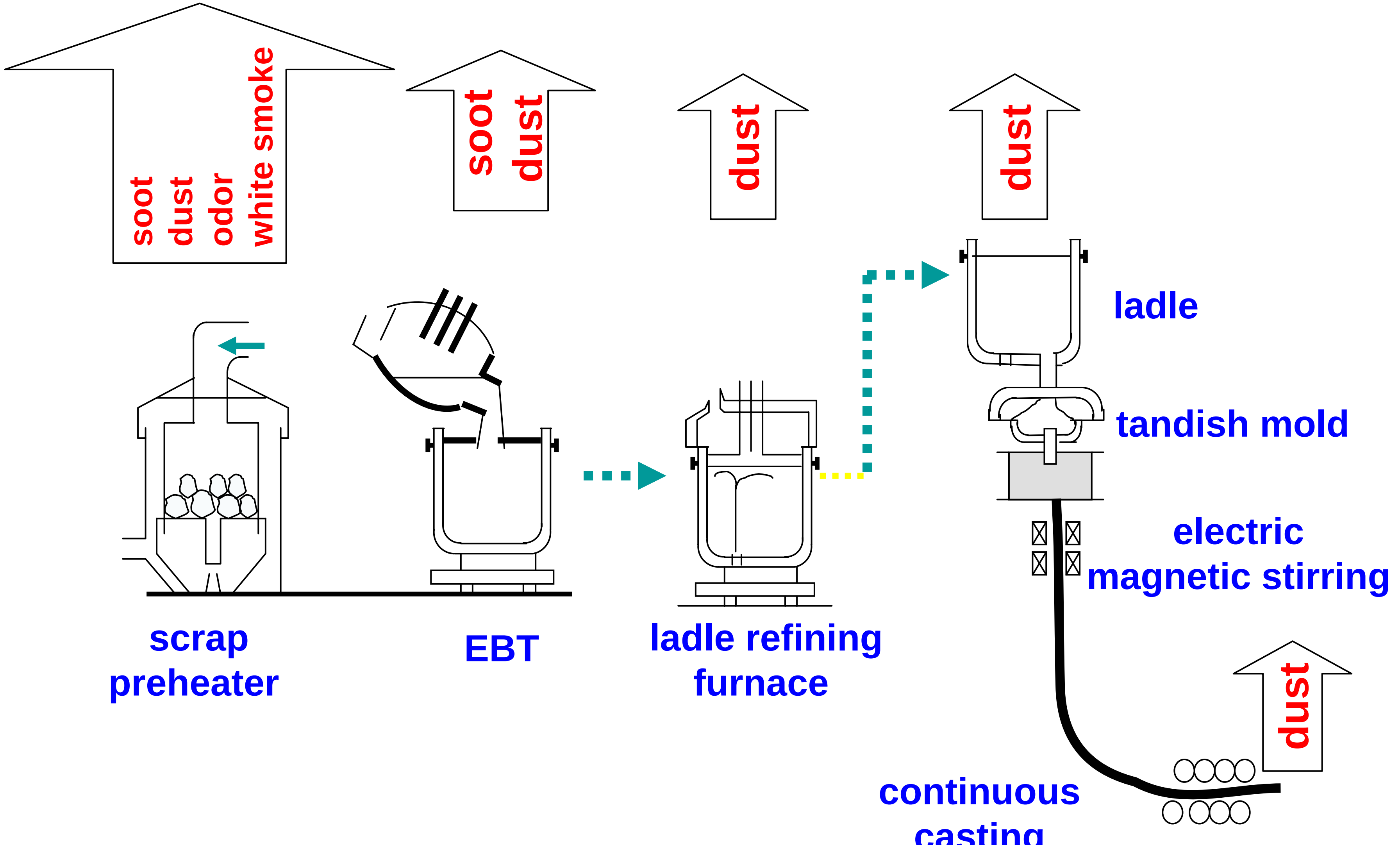
Steel mill lives close together
with neighboring people
(Kobe Steel Kakogawa Plant)
Steel manufacturing
processes
COG refinery
Coking
BF
Raw materials yard

1. Iron & Steel Making Process and Air Pollutants



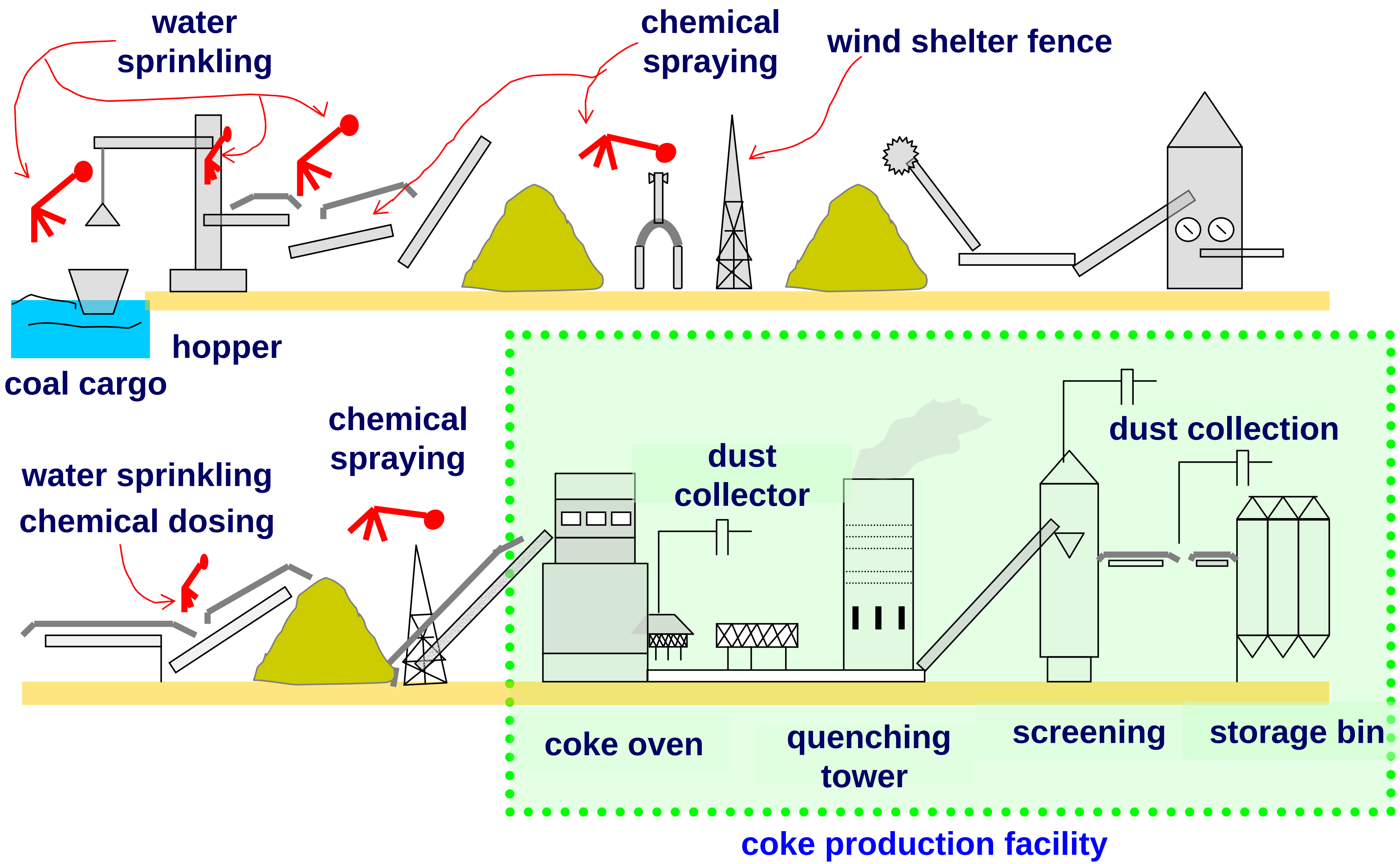
2. Process of Electric Furnace Plant and Air Pollutants



EBT: Electric Bottom Tapping

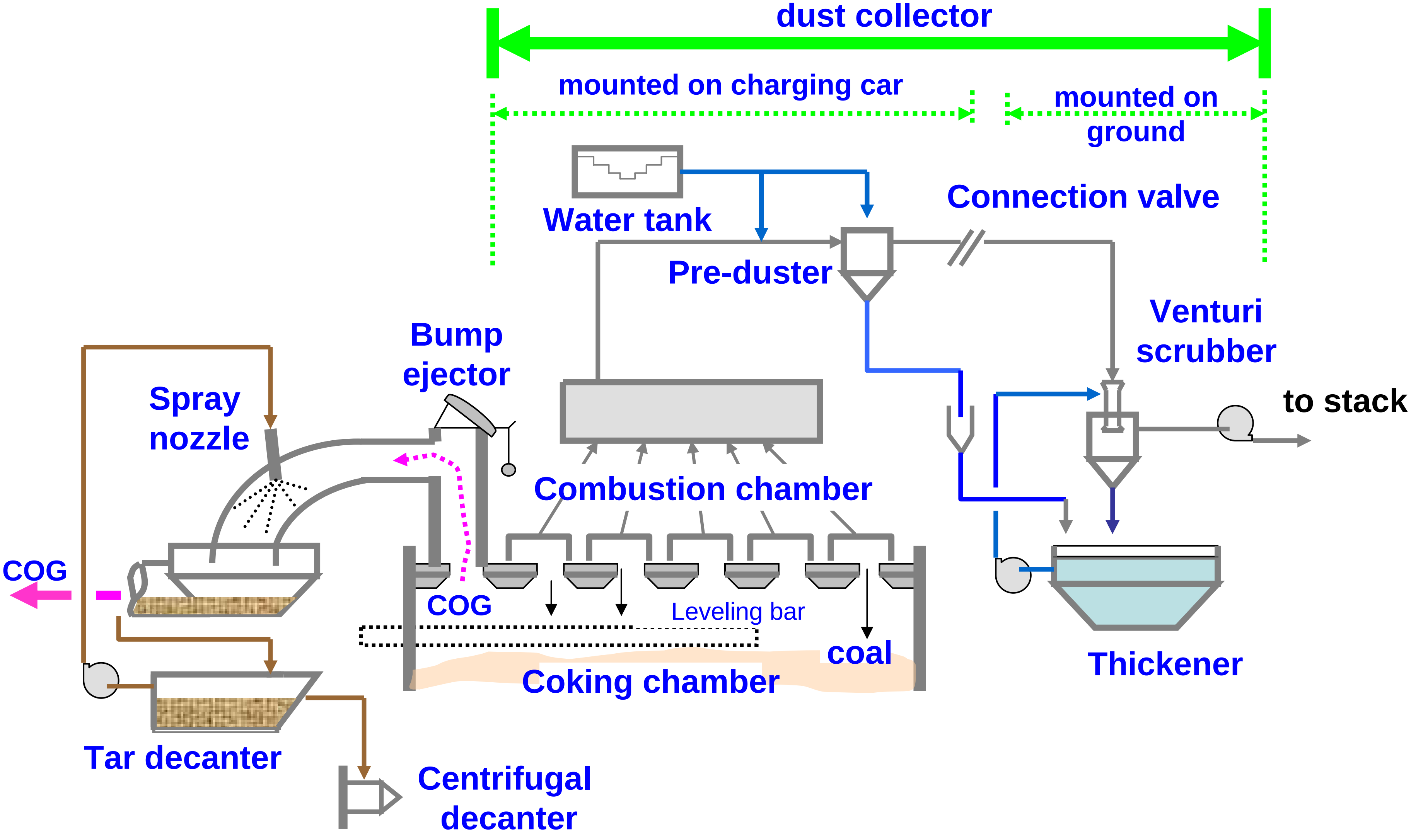
3. Coarse Particle Scattering Prevention

3-1 Coal Handling Process



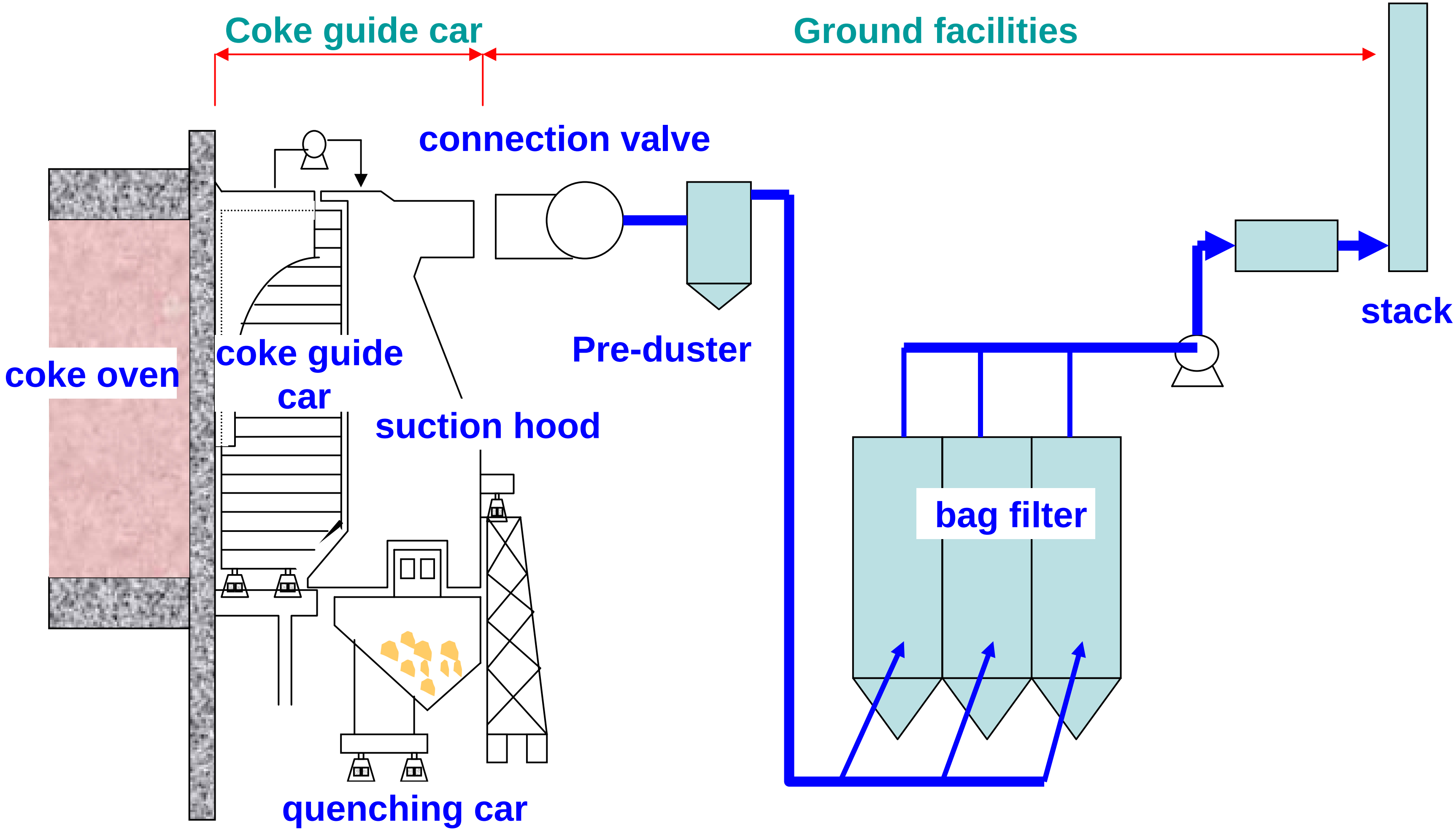
3. Coarse Particle Scattering Prevention

3-2-1 Coke Production — Coal Charging Process



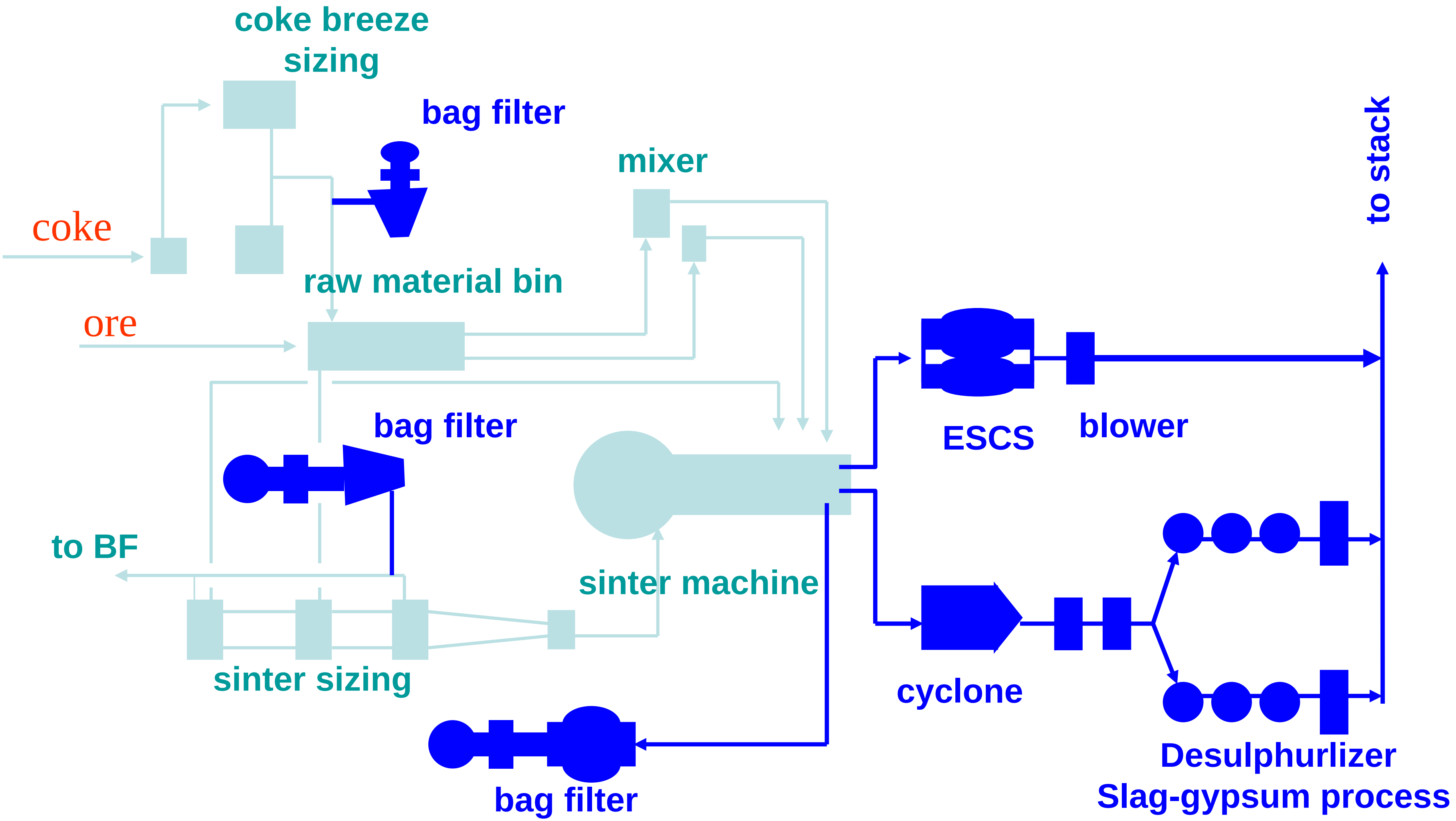
3. Coarse Particle Scattering Prevention

3-2-2 Coke Production — Coke Discharging Process



3. Coarse Particle Scattering Prevention

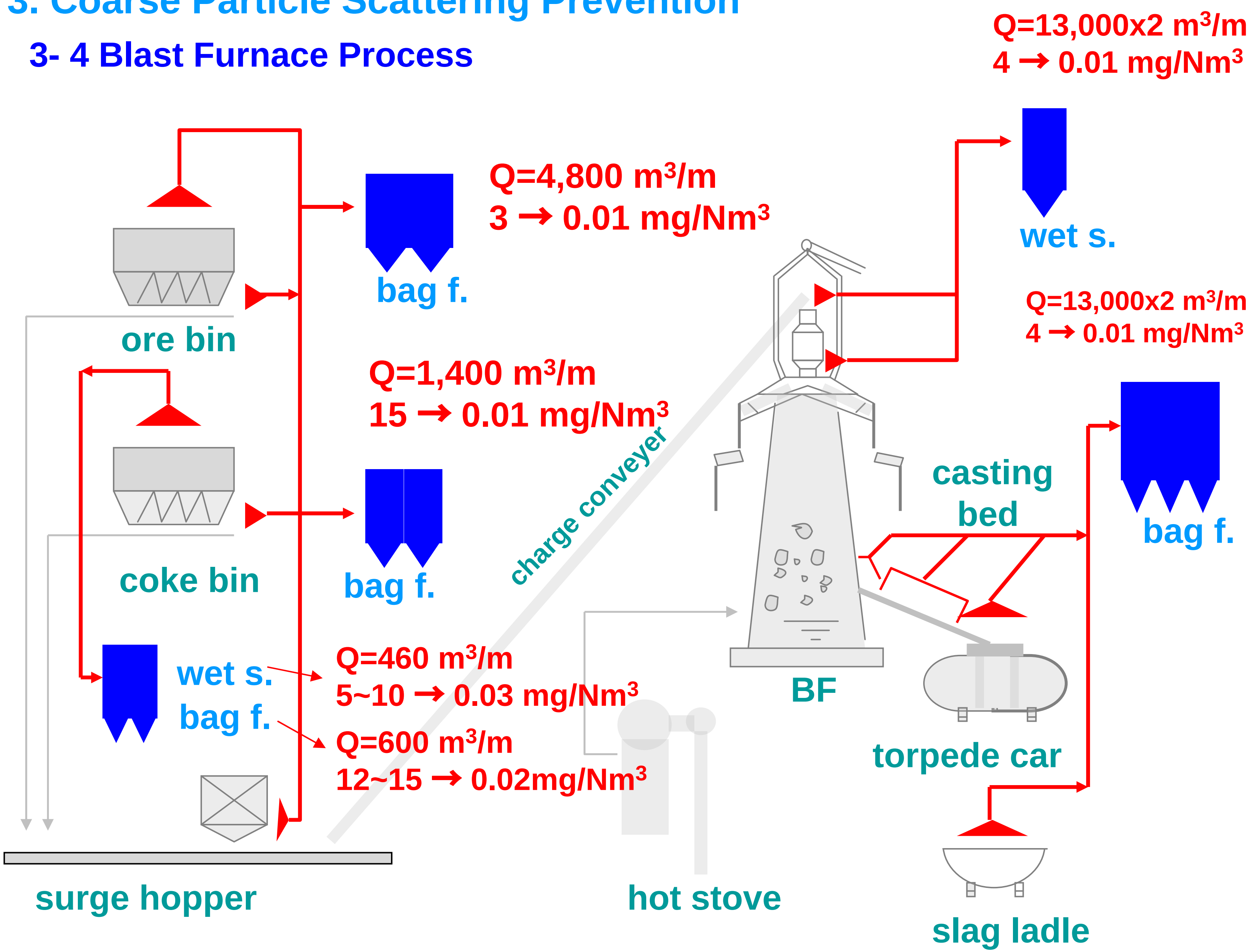
3-3 Sintering Process



ESCS: Electrostatic Space Clear Super

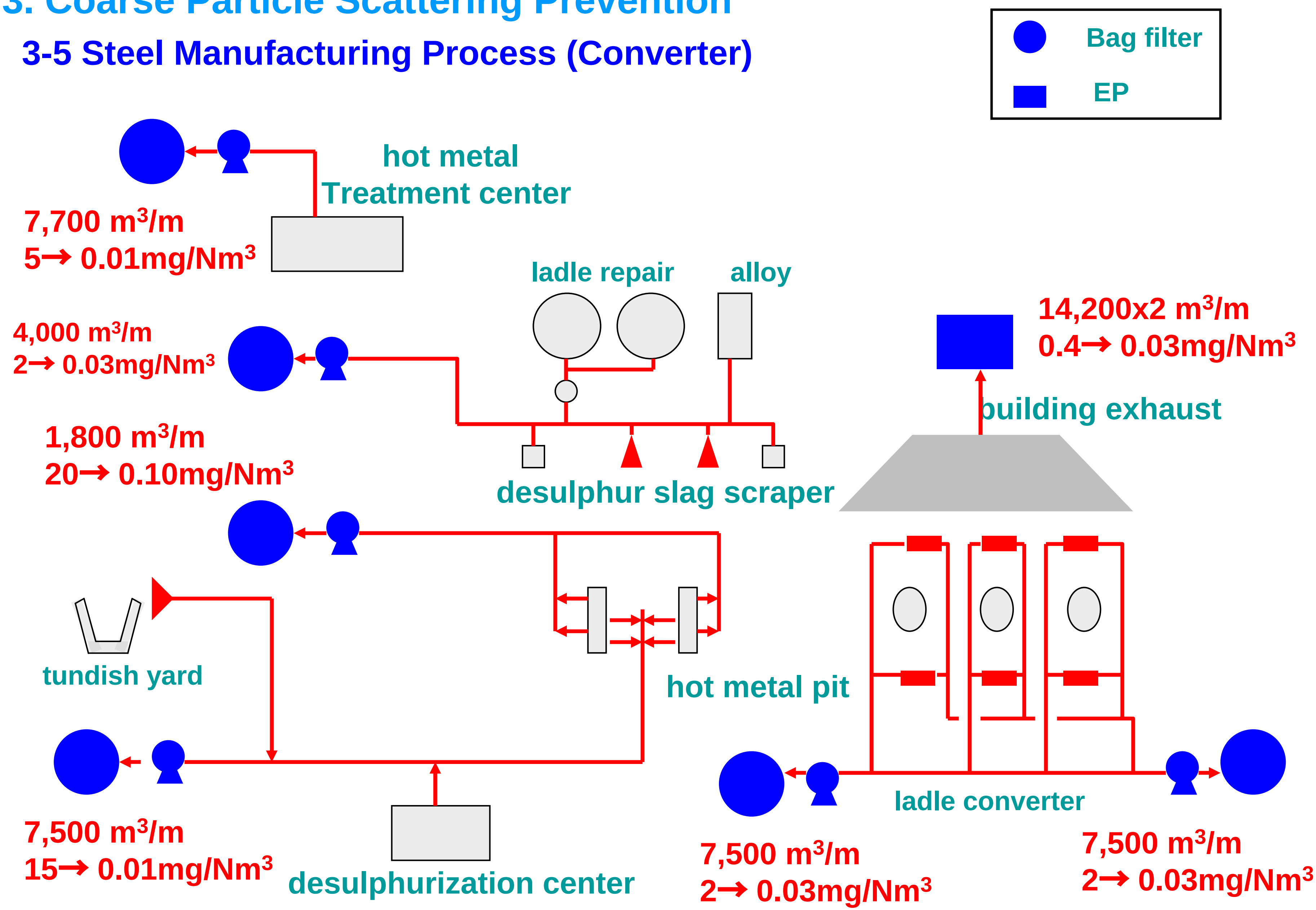
3. Coarse Particle Scattering Prevention

3- 4 Blast Furnace Process



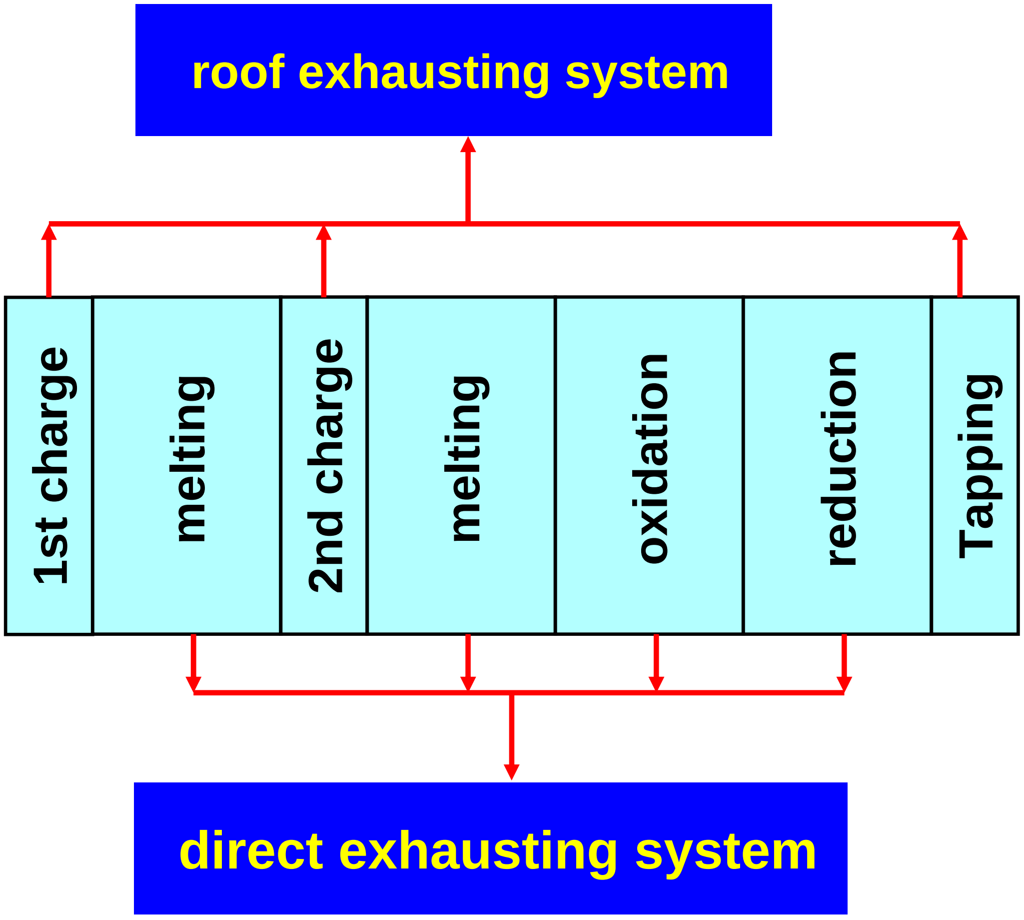
3. Coarse Particle Scattering Prevention

3-5 Steel Manufacturing Process (Converter)

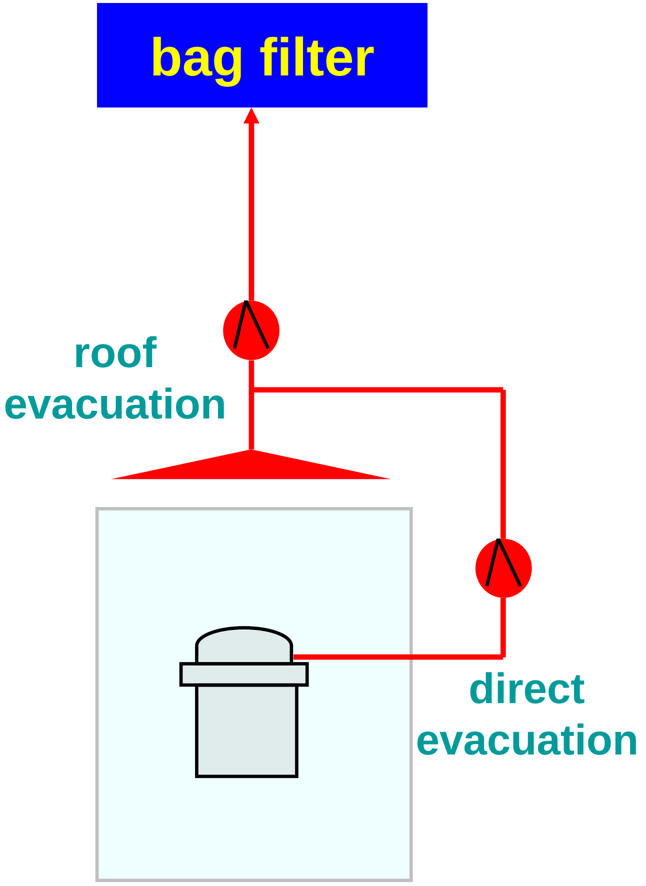


3. Coarse Particle Scattering Prevention

3-6 Electric Furnace



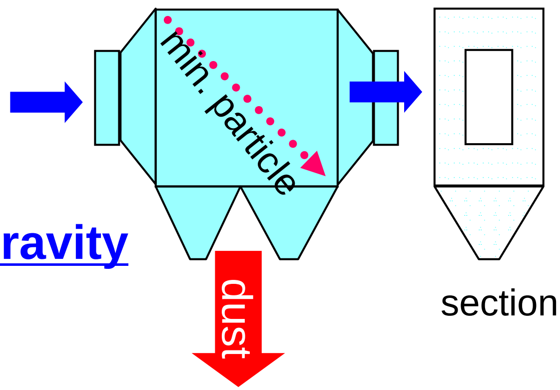
Conventional System



Doghouse System

4. Dust Collection System

4-1 Gravitational, Inertial & Centrifugal Dust Collector

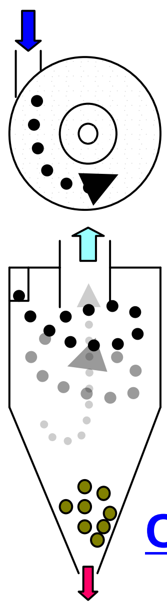


Gravity

Stokes' Law

$V = (g/18\mu)(\rho_1 - \rho) D^2$ (cm/s)

- V: settling velocity (cm/sec)
- μ : gas viscosity (kg/ms)
- g: gravitational acceleration (cm/s^2)
- ρ_1: particle density (g/cm^3)
- ρ : gas density (g/cm^3)
- D: particle diameter (cm)

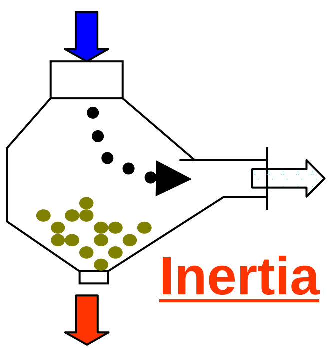


Centrifugal

Principle of dust collection ;

Centrifugal force (F) = mv^2/R (N)

- m: particle mass (kg)
- V: particle velocity (m/ s)
- R: cyclone radius (m)

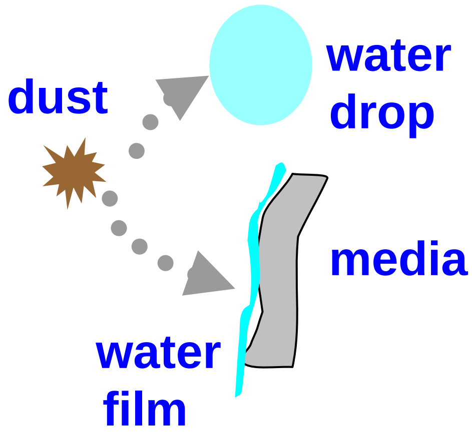


Inertia

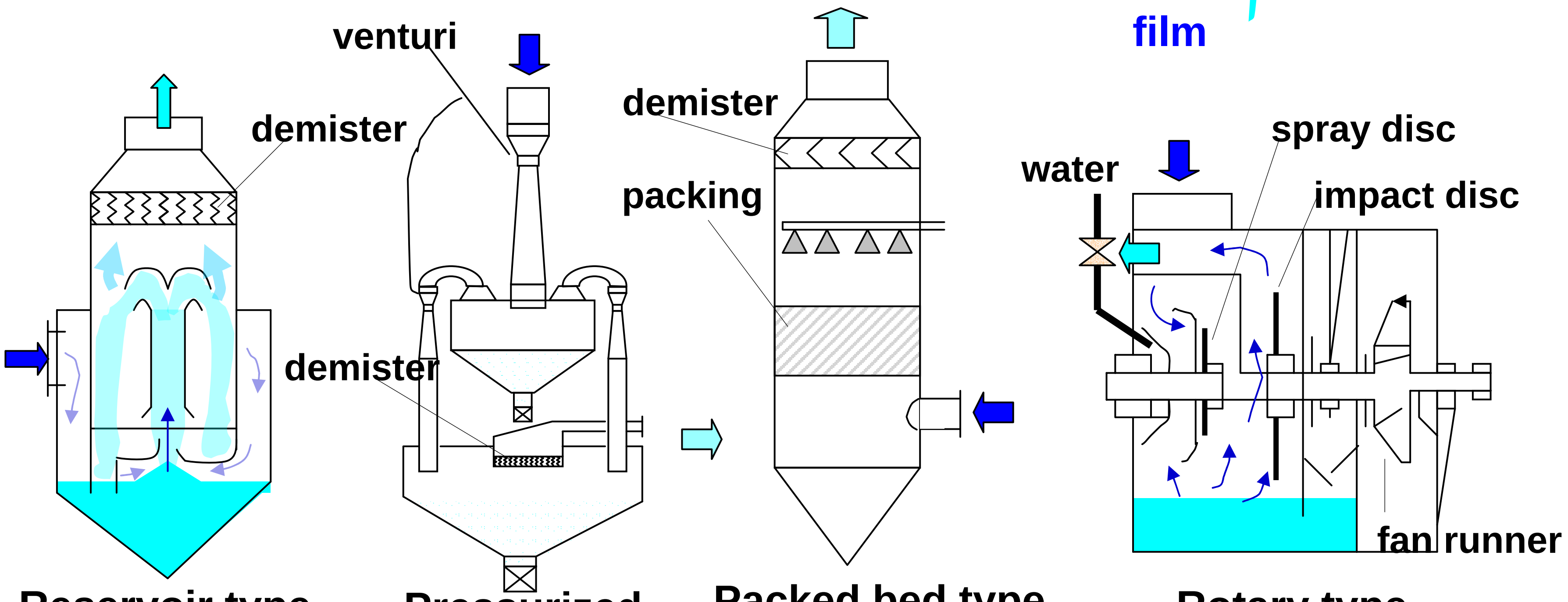
4. Dust Collection System

4-2 Scrubbing Dust collector

Principle of Scrubber Dust Collector ;



Scrubbers ;



Reservoir type

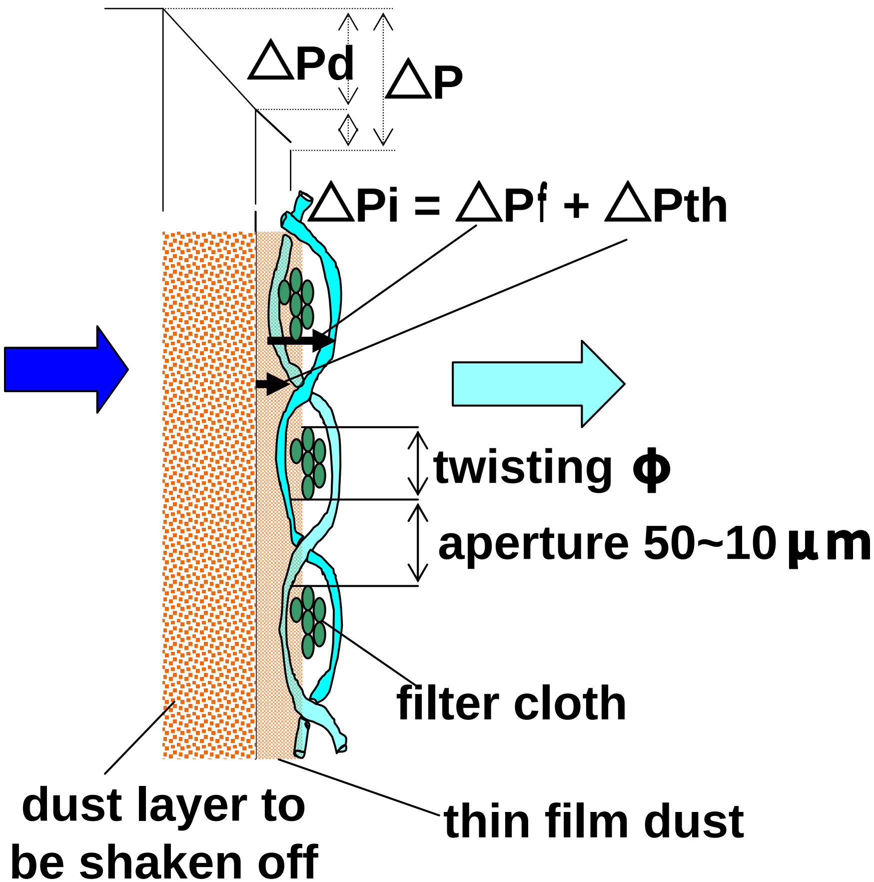
Pressurized water type

Packed bed type

Rotary type

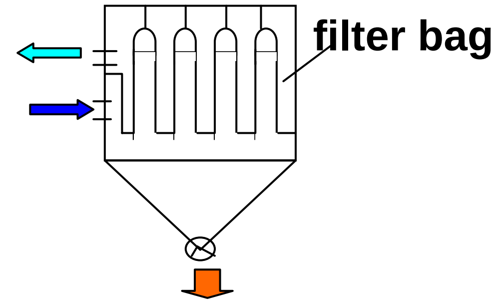
4. Dust Collection System

4-3 Filter Type Dust Collector



Filtration Mechanism

Schematic of typical bag filter unit



Type:

(1) bag filter
(2) cartridge filter

Filter cloth:

(1) woven fabric
(2) non-woven fabric

Dust shake-off:

(1) intermittent
(2) contimous

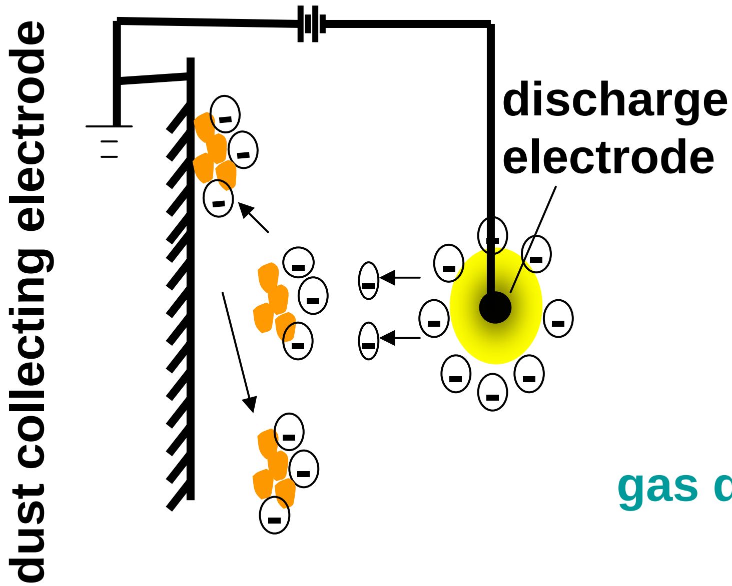
Apparent filtration rate:

0.3~10cm/s

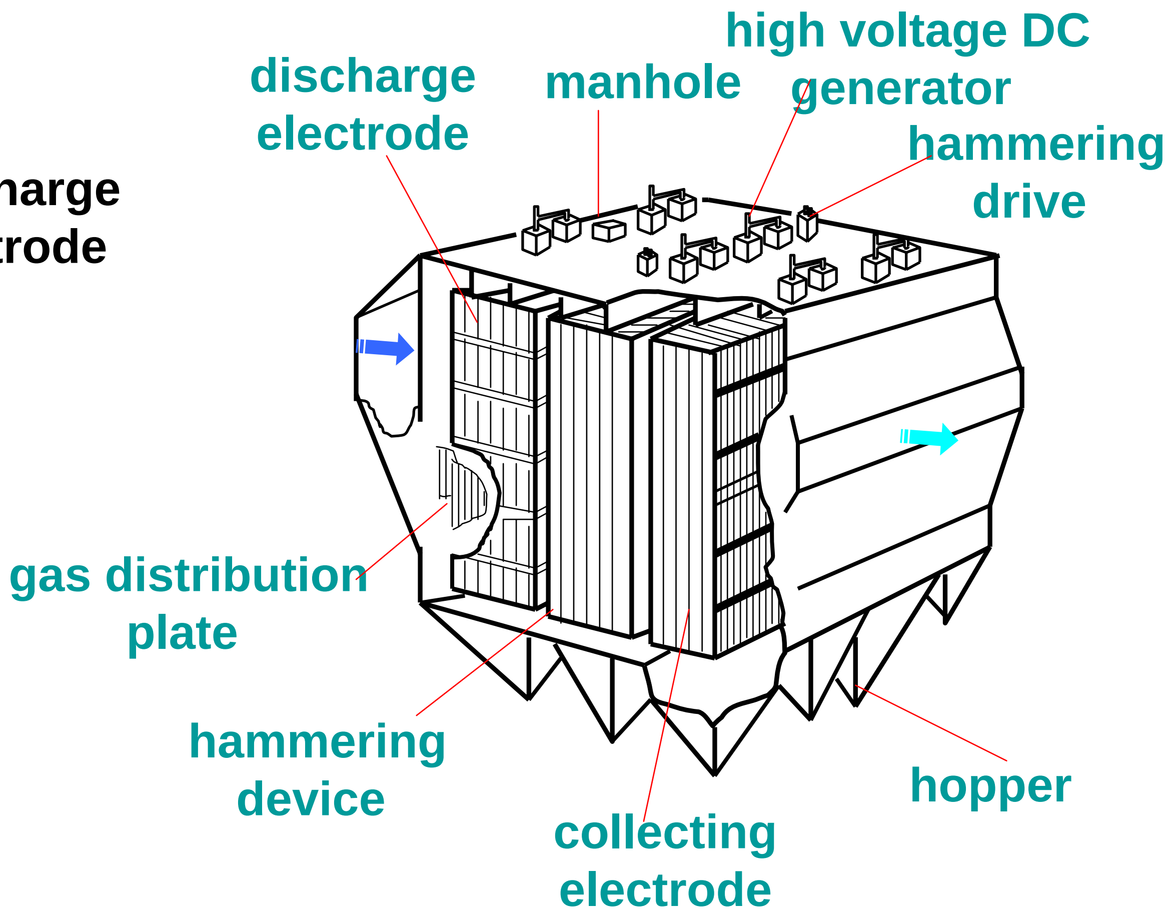
4. Dust Collection System

4-4 Electrostatic Precipitator

Principle of dust collection ;



Structure of EP



4. Dust Collection System

4-5 Selection of Dust Collector

Parameter

- particle distribution
- dust concentration
- specific gravity
- electric resistnace rate

- flow rate
- due point
- gas temp.

Collector	Applicable Particle (μm)	△p (mmH₂O)	Removal rate (%)	Equipment Cost (¥/y/Nm³/h)	Operating Cost (¥/y/Nm³/h)
Gravity	1,000~50	10~15	40~60		
Inertial	100~10	30~70	50~70		
Centrifugal	100~3	50~150	85~95	300~2,200	100~1,000
Scrubbing	100~0.1	300~900	80~95	400~2,200	100~1,300
Filter	20~0.1	100~200	90~99	300~2,100	300~1,100
EP	20~0.05	10~20	90~99.9	400~4,400	100~1,00

5. Desulphurization Technology

5-1 Flue Gas Desulphurization in Steel Mill

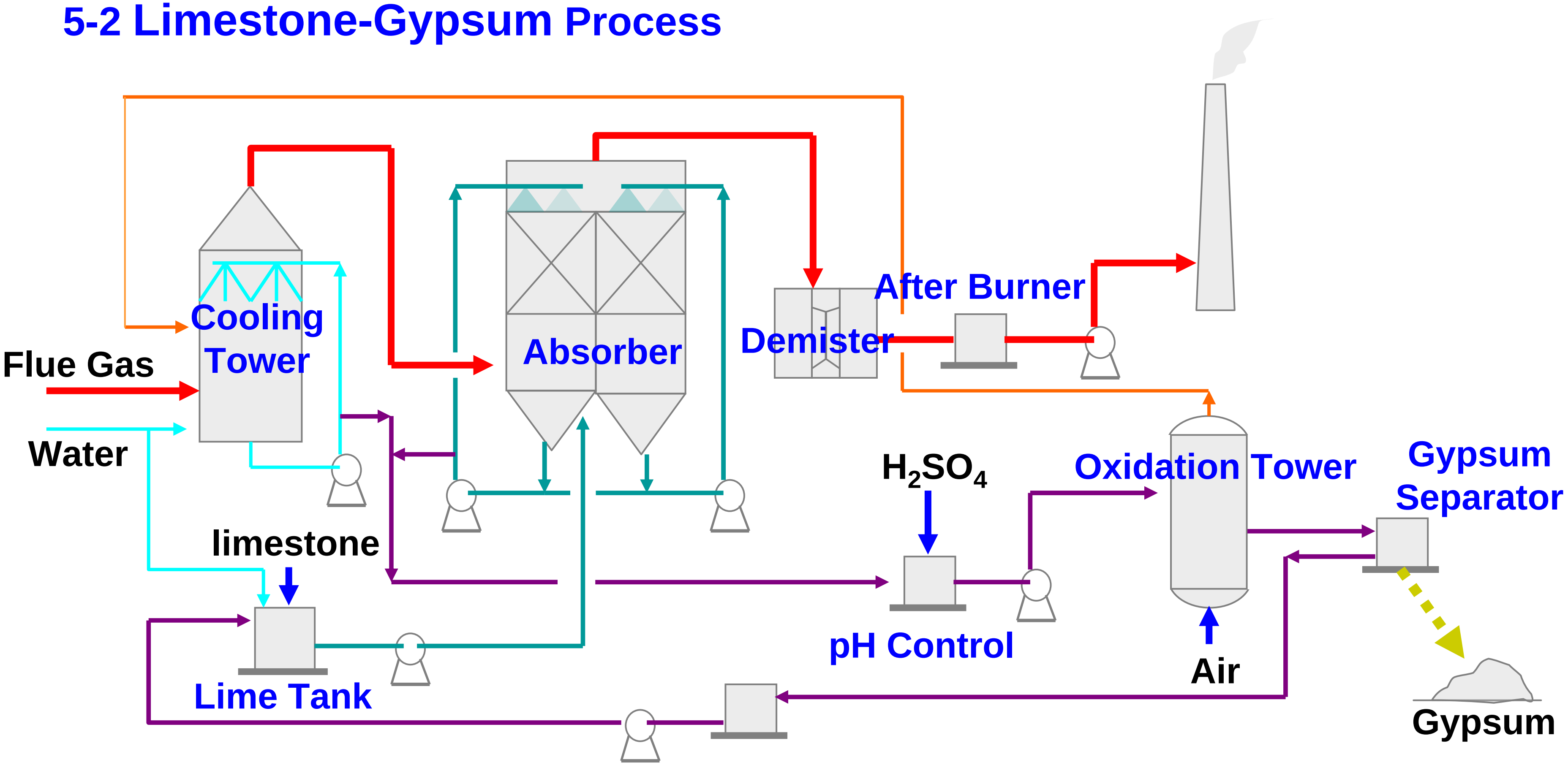
Method	Reaction	Byproduct
Activated carbon	$SO_2+H_2O+1/2O_2 \rightarrow H_2SO_4$	H_2SO_4
Caustic soda	$2NaOH+SO_2 \rightarrow Na_2SO_3+H_2O$ $Na_2SO_3+H_2O+SO_2 \rightarrow 2NaHSO_3$	Na_2SO_4
Ammonia	$2NH_4OH+SO_2 \rightarrow (NH_4)_2SO_3+H_2O$ $(NH_4)_2SO_3+SO_3+SO_2+H_2O \rightarrow 2NH_4HSO_3+H_2$	$(NH_4)_2SO_4$
Slaked lime	$CaO+SO_2 \rightarrow CaSO_3$ $CaSO_3 + O_2 \rightarrow 2CaSO_4$	$CaSO_4$

Limestone - Gypsum Process
SOx Rem. ＞90%
most popularly used method In Japan

- limestone ⇒ cheap
- initial & operating cost ⇒ economical
- systems stability ⇒ stable & safe
- gypsum ⇒ marketable

5. Desulphurization Technology

5-2 Limestone-Gypsum Process



Reaction

$$SO_2 + CaO \rightarrow CaSO_3$$

$$2CaSO_3 + O_2 \rightarrow 2CaSO_4$$

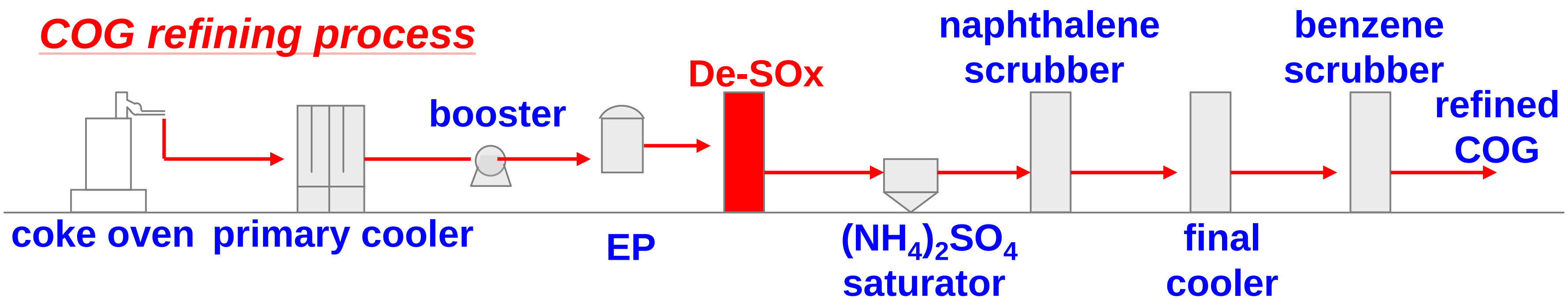
$$CaCO_3 + SO_2 \rightarrow CaSO_3 + CO_2$$

5. Desulphurization Technology

5-3 Coke Oven Gas Desulphurization Process

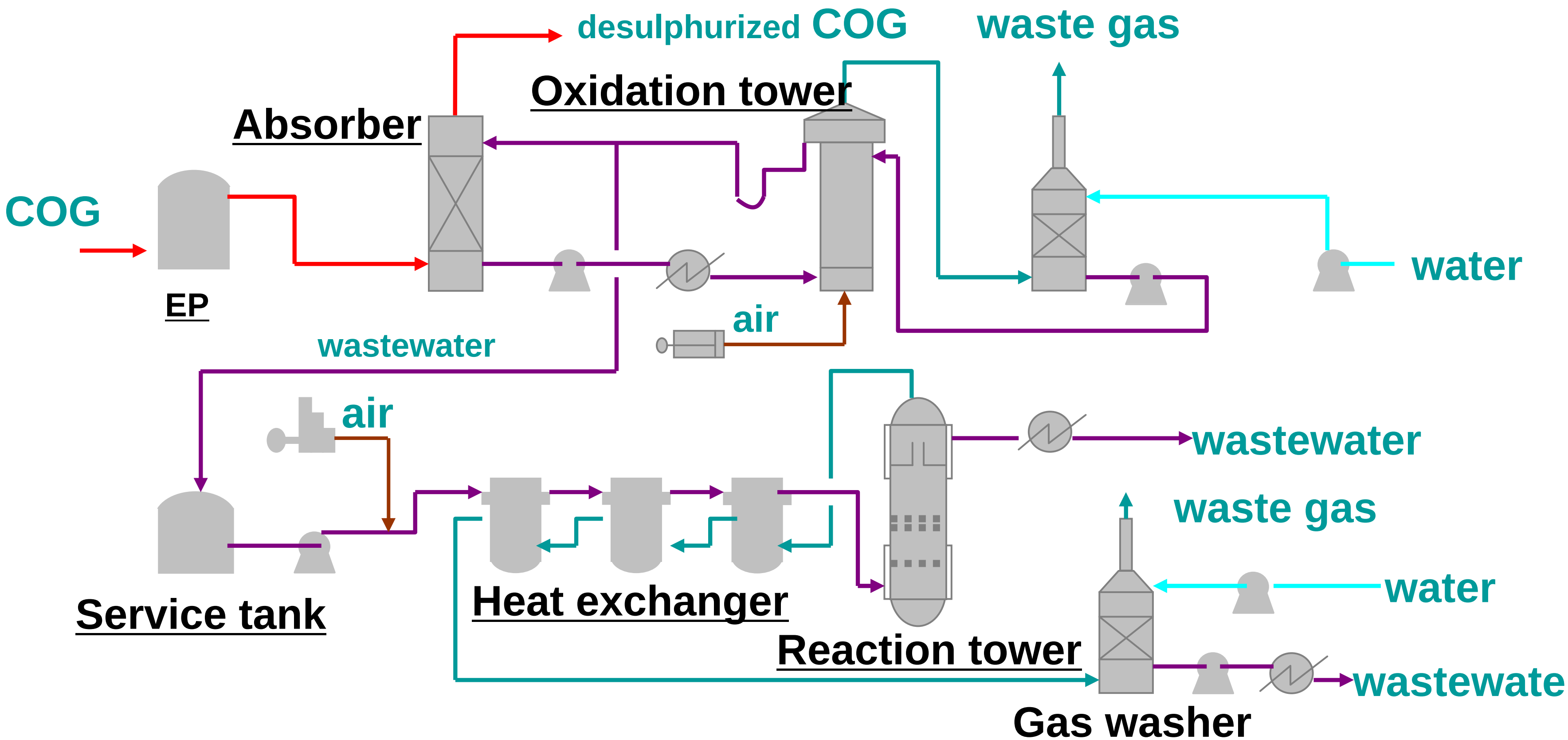
System	DeSOx-chemical	Catalyst	Byproduct
Takahax-Hirohax	NH_3	naphtoquinone salfonic acid soda	$(NH_4)_2SO_4$ + H_2SO_4
Takahax-Reduction Decomposition	Na_2CO_3	naphtoquinone salfonic acid soda	crude S
Fumax-Hemibau	NH_3	picric acid	H_2SO_4
Stred Ford-Combax flue gas De-Sox	Na_2CO_3	anthoraquinone sulfonic acid soda metavanadate soda Tartaric acid soda	gypsum
Diamox-claus	NH_3	none	pure S
Salfiban-claus	alkanol amine	none	pure S

COG refining process



5. Desulphurization Technology

5-4 Takahax-Hirohax Process



Reaction

$NH_3 + H_2O \rightarrow NH_4OH$

$NH_4OH + H_2S \rightarrow NH_4HS + H_2O$

$NH_4OH + HCN \rightarrow NH_4CN + H_2O$

$NH_4HS + 1/2O_2 \rightarrow NH_4OH + S$

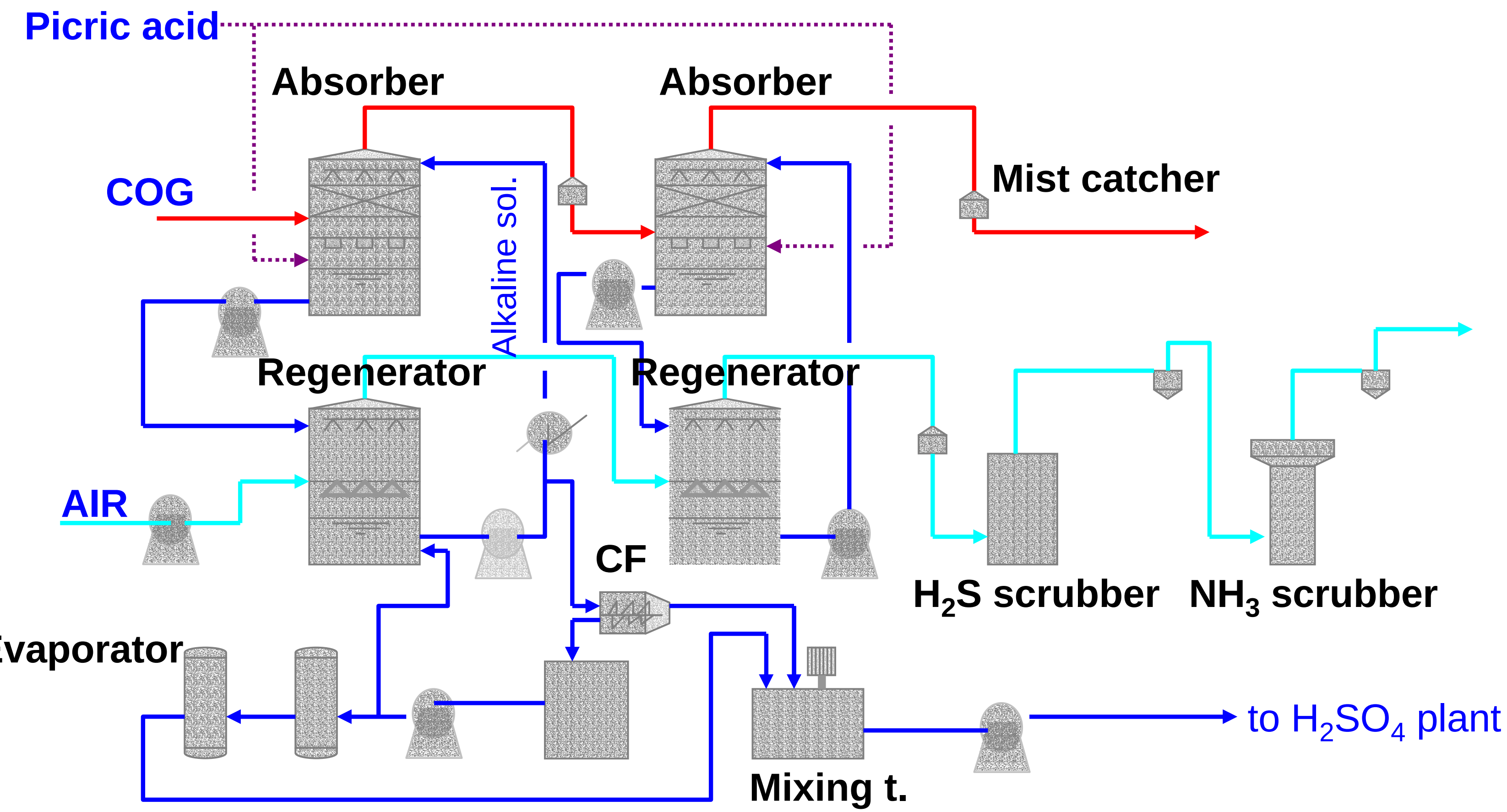
$NH_4CN + S \rightarrow NH_4NCS$

Removal rate

S, CN $>$ 90~99%

5. Desulphurization Technology

5-5 Fumax Process



Absorption

$NH_3 + H_2O \rightarrow NH_4OH$

$NH_4OH + H_2S \rightarrow NH_4HS + H_2O$

Regeneration

$NH_4HS + 1/2O_2 \rightarrow NH_4OH + S$

H_2SO_4 recovery

$S + O_2 \rightarrow SO_2$

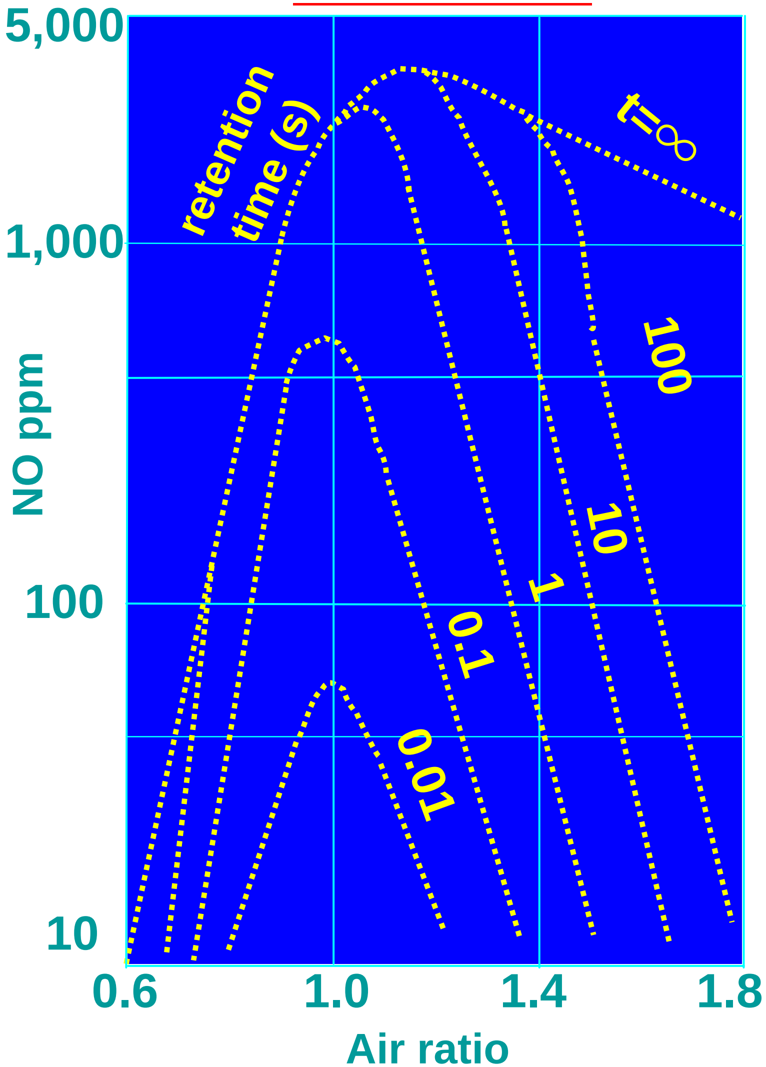
$SO_2 + 1/2O_2 \rightarrow SO_3$

$SO_3 + H_2O \rightarrow H_2SO_4$

6. NOx Control Technolpgy

6-1-1 NOx Generation

Thermal NOx



N & S Contents in Fuels

Fuel		N	S
Solid wt%	coal	0.7~2.2	0.3~2.6
	coke	0.6~1.4	0.2~1.0
Liquid wt%	crude oil	0.03~0.34	0.1~3.0
	C-oil※	0.2~0.4	0.2~0.3
	B-oil※	0.08~0.35	0.2~0.3
	A-oil※	0.005~0.08	0.2~0.3
	light oil	0.004~0.006	0.03~0.5
	kerosene	0.0005~0.01	0.001~0.2
Gas g/Nm^3	COG-crude	0~9	1.5~7
	COG-fine	0.02~0.5	0.05~0.7
	BFG	tr	tr
	LDG	tr	tr
	LPG, LNG	tr	tr

※ JIS K2205 kinematic viscosity (cSt, mm2/s)
C-heavy oil: 50≦~1,000, B-heavy oil: 20~50, A-heavy oil: ≦20

6. NOx Control Technology

6-1-2 Factors in NOx Generation & Reduction

Causes of generation

- N in fuel
- O_2 con.
- Flame temp.
- Retention time

- low N fuel
- lower O_2
- lower temp.
- shorter retention

Reduction methods

Improvement by Fuel

Fuel alternation

- Change of fuel
  heavy oil→ light oil→ gas

Fuel denitrification

- Denitrification of COG

Improvement by combustion

Changing operating conditions

- Low air ratio combustion
- Lowering dry hot air temperature
- Changing thermal load

Remodeling combustion system

- Multistage combustion
- Recirculation of exhaust gas
- Addition of steam or water
- Low NOx burner

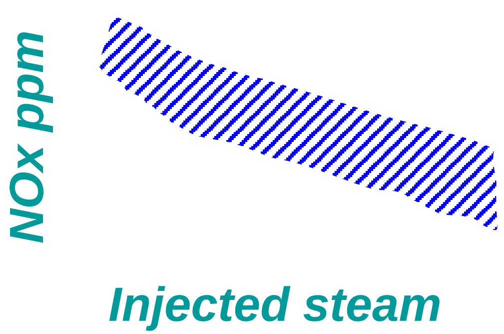
6. NOx Control Technology

6-2-1 Fuel Improvement

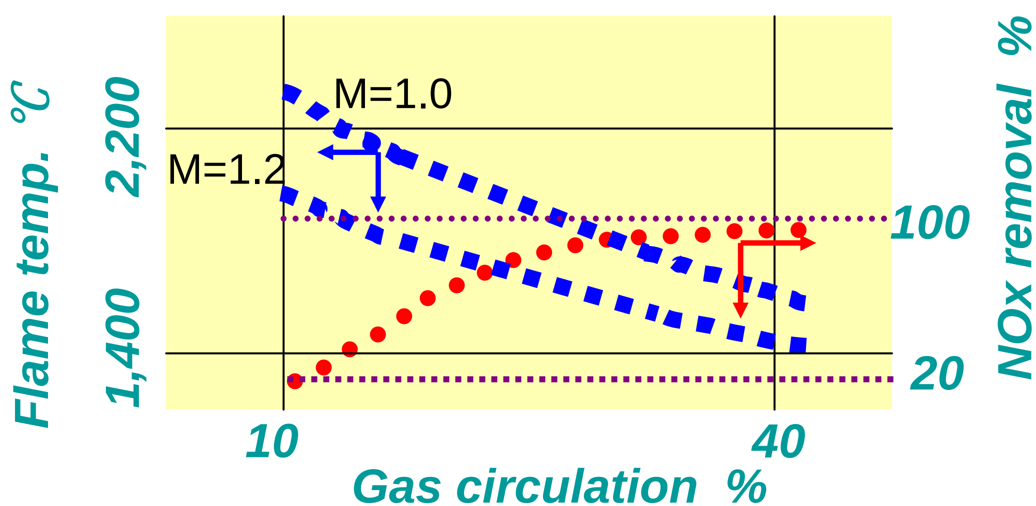
1. Use of low N and low S fuel (S ∝ N)
2. Denitrification of COG N 1~9 g/m³ 800~1,000℃, 4~6 sec.

6-2-2 Combustion Improvement

1. Low air ratio operation O_2 1% ↓ ⇒ NOx 10% ↓
2. Multistage combustion 1st stage air ratio; 80~90%
   rest air →2nd stage combustion → NOx ▲20%
3. Steam or Water injection flame temp. ↓ ⇒ Nox ↓
   no-change in generated calorie



4. Exhaust gas circulation

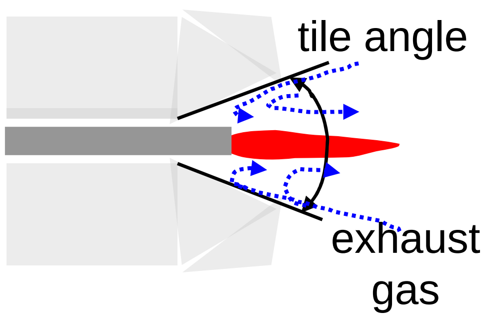


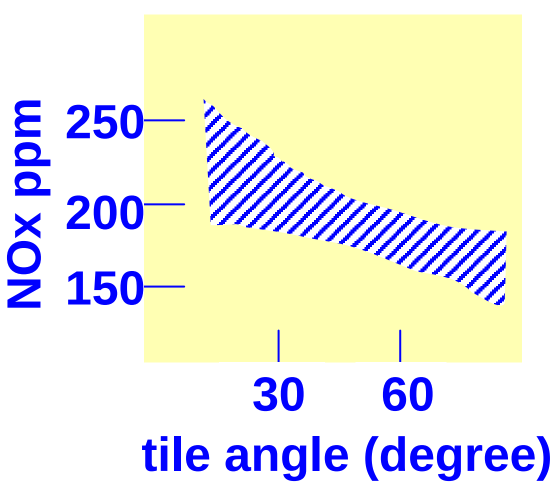
6. NOx Control Technology

— Continued from previous slide —

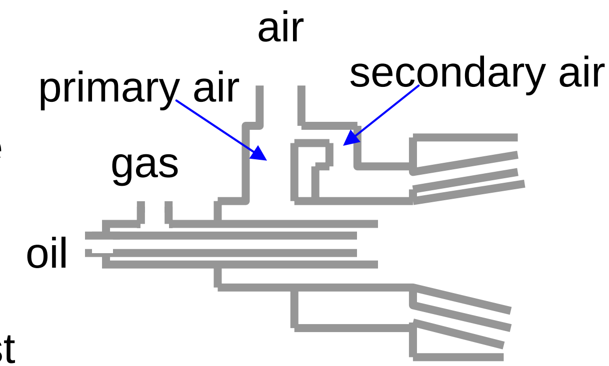
5. Low- NOx burner

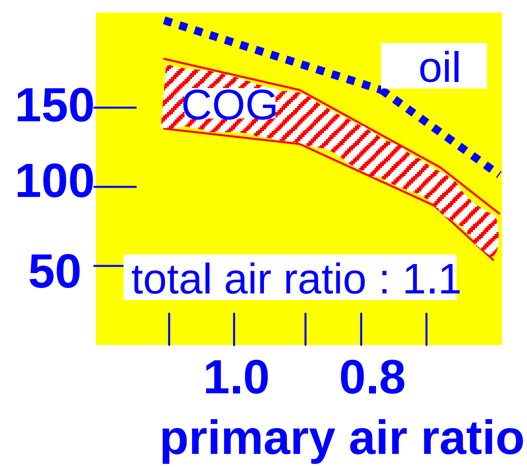
Wide-angle burner tile



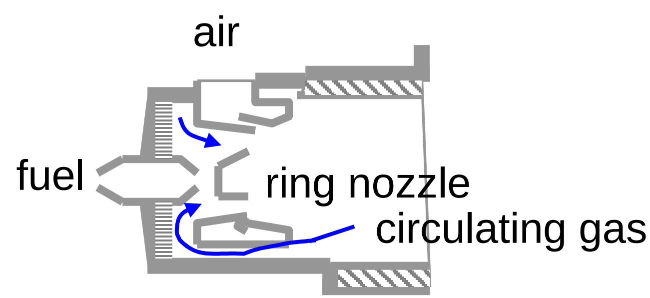


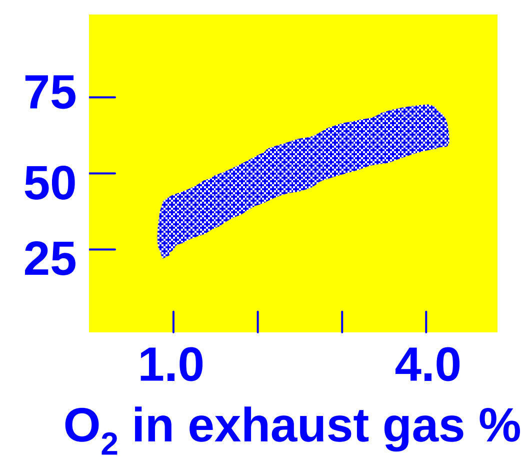
Double-stage combustion burner





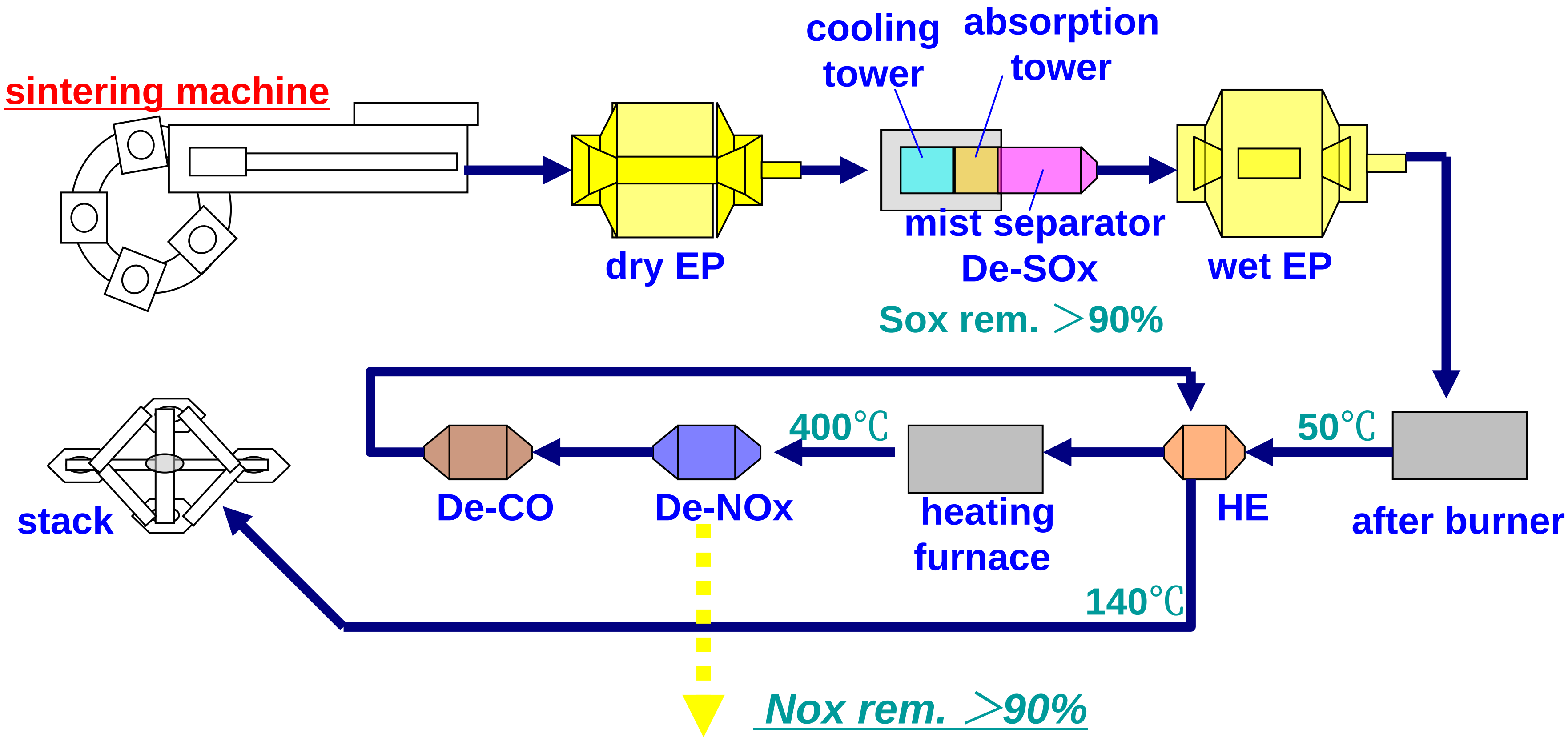
Self-circulate combustion burner





6. NOx Control Technology

6-3 Denitrification of Exhaust Gas

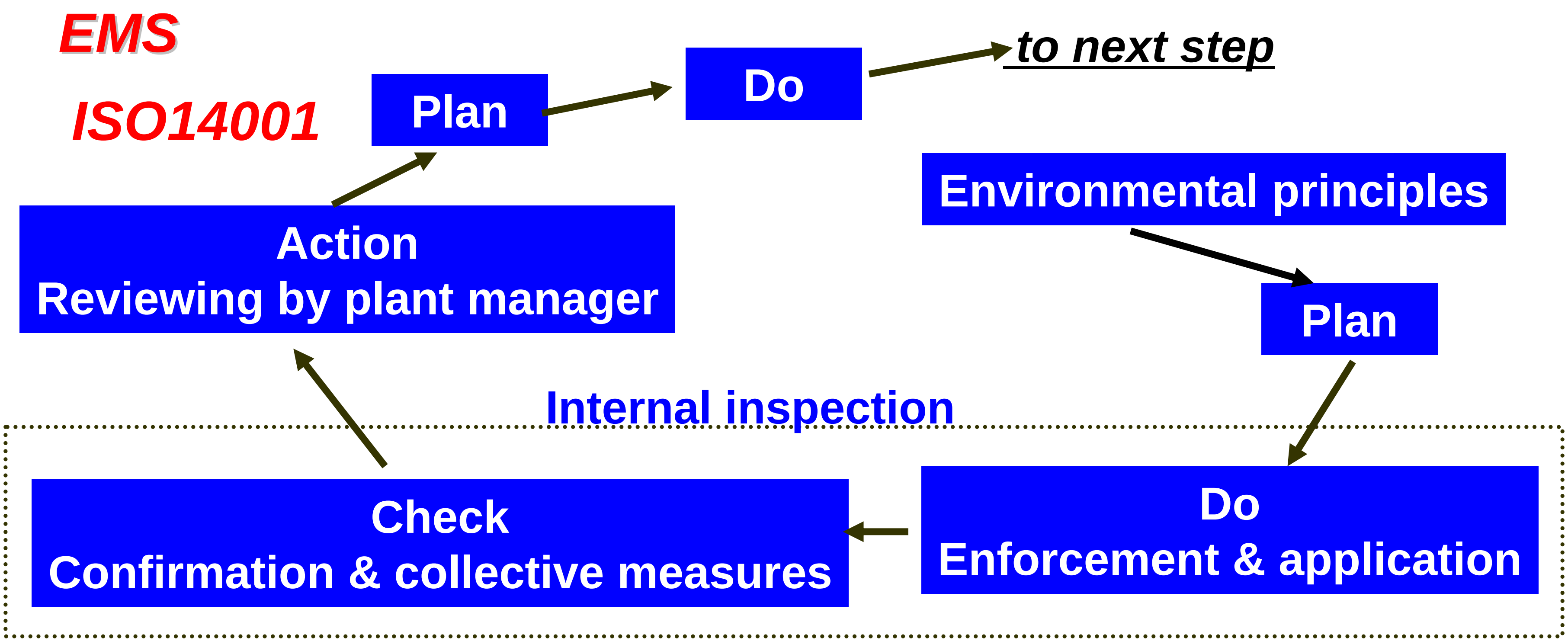


De-NOx: Dry Type Selective Contact Reduction using NH_3

$$6NO + 4NH_3 \rightarrow 5N_2 + 6H_2O$$

$$6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$$

7. Environmental Management System(1/2)



Items to be considered at factory construction & operation

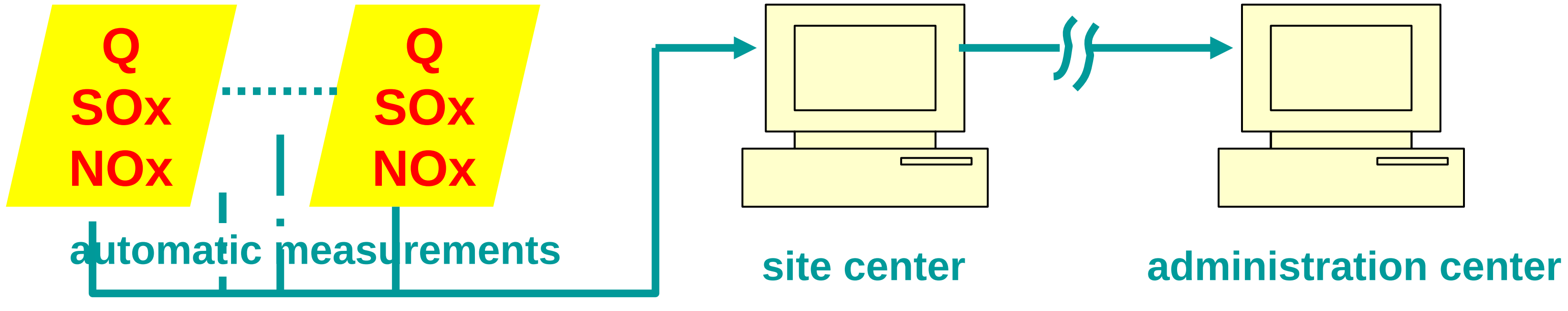
1. *Environmental impact assessment*
2. *Environmental standards & emission standards*
3. *Planning of plant & air pollution control equipment*
4. *Operation control & worker training*
5. *Environmental monitoring*
6. *Environmental management system*

7. Environmental Management System (2/2)

Measurement Items

	Emission Standard	EQS
Pollutants	dust	Suspended particle matter
	sulfur oxide	SO_2 (sulfur oxide)
	nitrogen oxide	NO_2 (nitrogen oxide)
	Cd, its compounds	
	Cl, HCl	
	F, HF, Si_nF_{2n+2}	CO
	Pb, its compounds	Photochemical oxidant

Telemeter System



8. Resources Saving

Dust Generation & Utilization

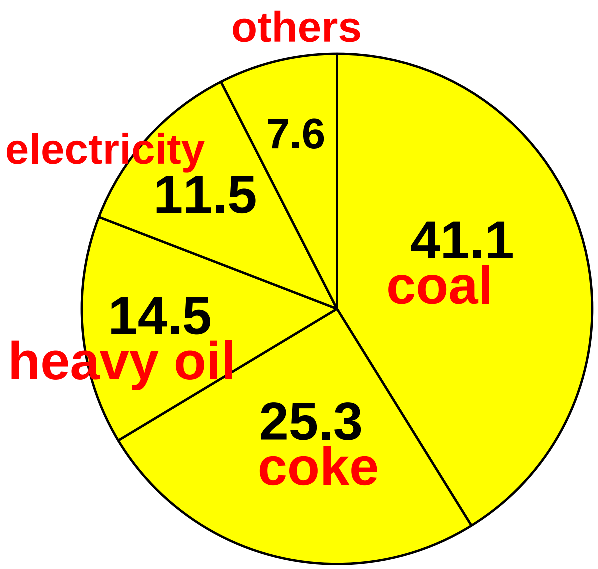
Dust Generation at 3 million-ton Crude Steel Production (t / y)

Process	Dry Dust Collector	Wet Dust Collector	Total
Material / Pig Iron	111,000	38,000	149,000 **(61%)**
Steel	33,000	60,000	93,000 **(38%)**
Rolling	2,700	300	3,000 **(1%)**
Total	146,700 **(60%)**	98,300 **(40%)**	245,000 **(100%)**

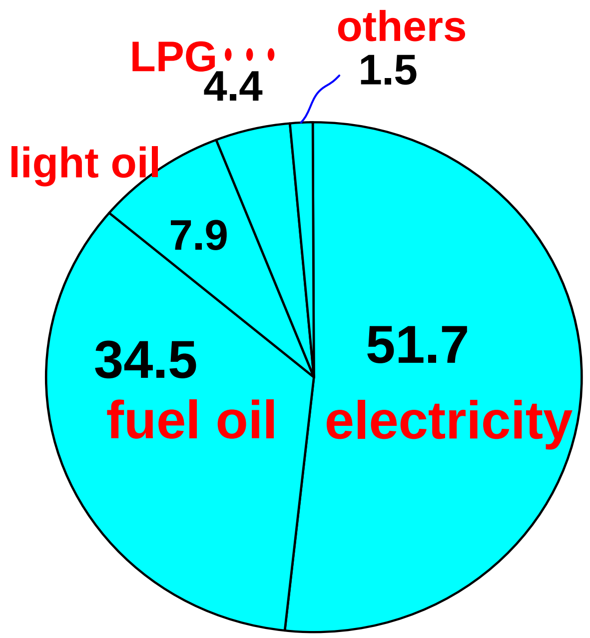
- **Dust generation in Integrated Iron Works: 4.9% of crude steel**
- **Ingredient of Dust: Iron Oxide, Limestone, etc.**
- **Utilization: Raw Material for**
  Sintering, Zn, ZnCO3, Neutralizing wastewater, BF

9. Energy Saving

Energy source ratio (%)



Integrated Steel Production



Non-Integrated Steel Production

Energy saving Method

- high efficient equipment & improving operation
- reducing the number of unit operations
  & changing to continuous process
- waste heat recovery