NOx emission control for Coke Oven

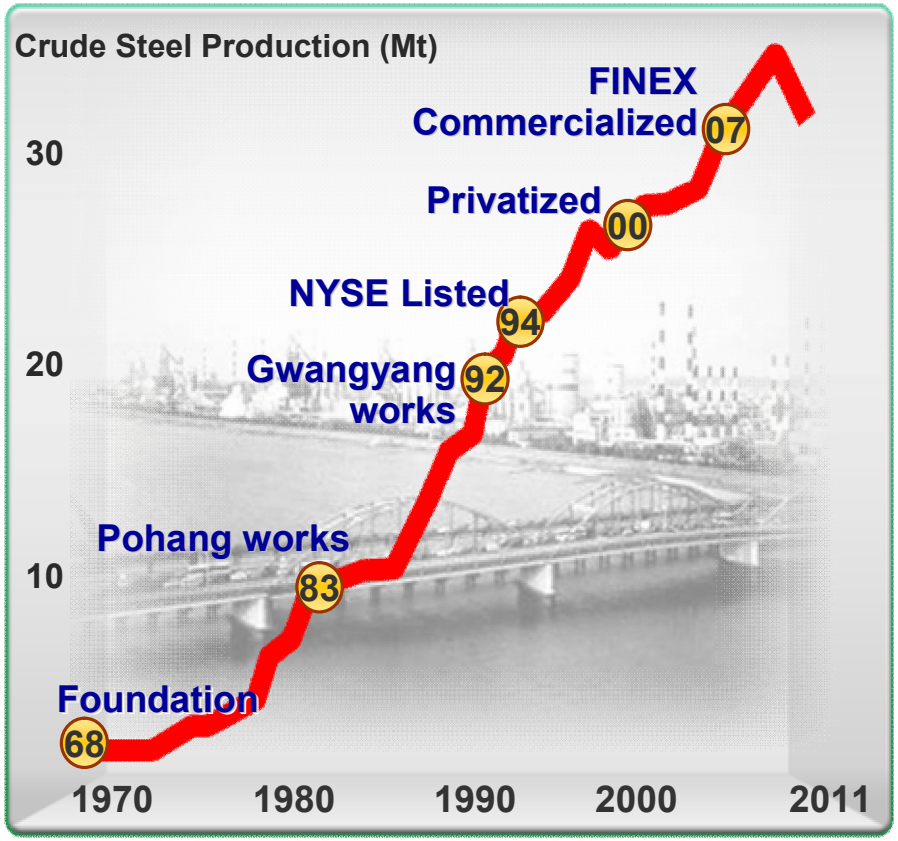
Application of Two-Staged combustion to the single-staged combustion chamber

Yang, Sung-Jae

Environment & Energy Department

1. POSCO at a Glance

- POSCO, the history of Korean steel industry built from literally NOTHING
- Steel, fundamental material of national economy supporting other industries



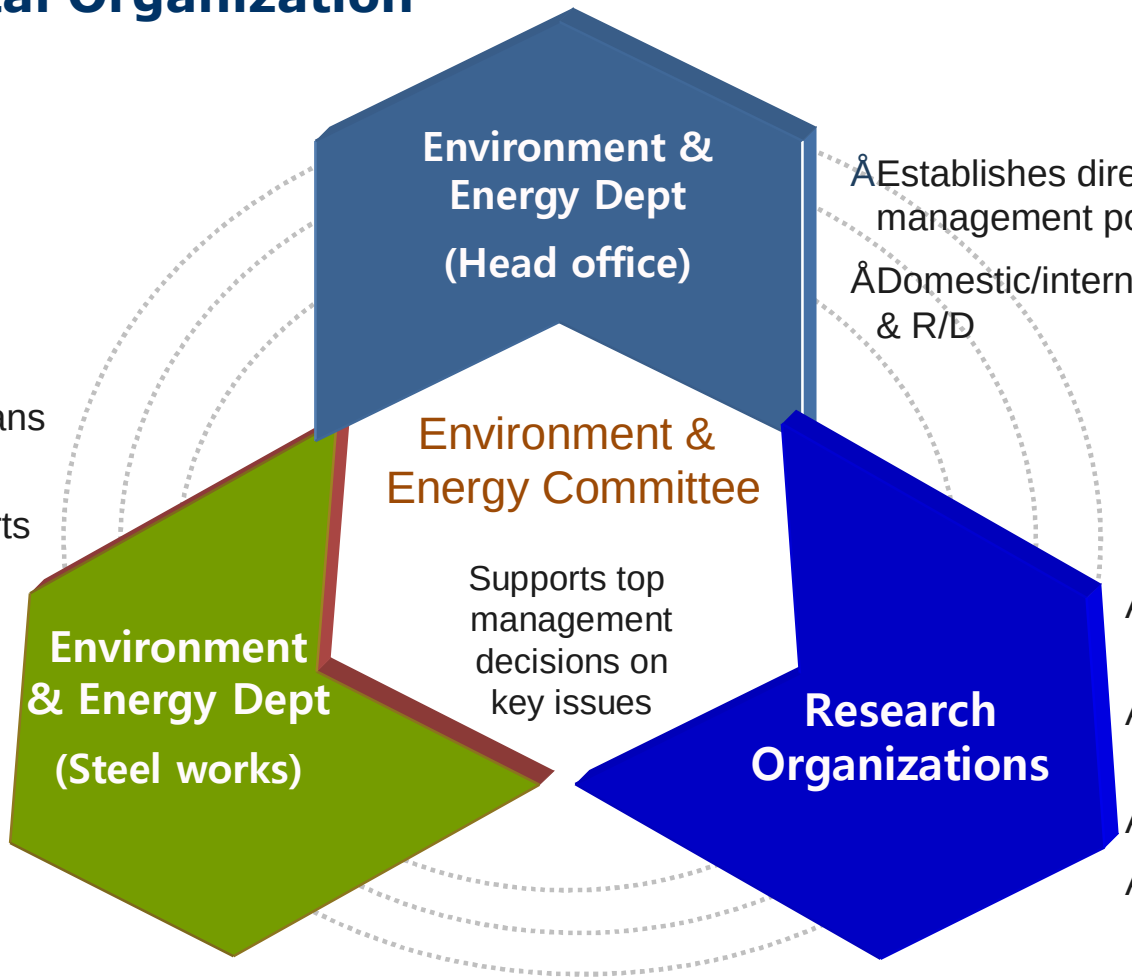
Overview (2011)

- **Steel Production**: Top 4th (37.3 Mt)
- **Employees**: 42 thousand including subsidiary companies
- **Sales**: 39 billion US$

Evaluations

- **DAVOS Global Top 100** (2010, 2012)
- **Dow Jones Sustainability Index (8 yrs since 2005)**
- **2011 CDP** Carbon Disclosure Leadership Index & Carbon Performance Leadership Index

• Environmental Organization



ÅEstablishes direction for environmental management policy

ÅDomestic/international agreements & R/D

ÅEstablishes action plans across all steel works

ÅOversees and supports related personnel

ÅPOSRI
: Environmental policy

ÅPOSTECH
Technical supports

ÅRIST

ÅOther research institutes

2. NOx regulation in Korea

Air quality standards

		Standards		USA	Japan	WHO
		2001~	2007~			
NO_2(ppm)	1hour	0.15	0.10	-	-	0.105
	24hour	0.08	0.06	-	0.04~ 0.06	-
	Year	0.05	0.03	0.053	-	0.021

Chimney emission standards

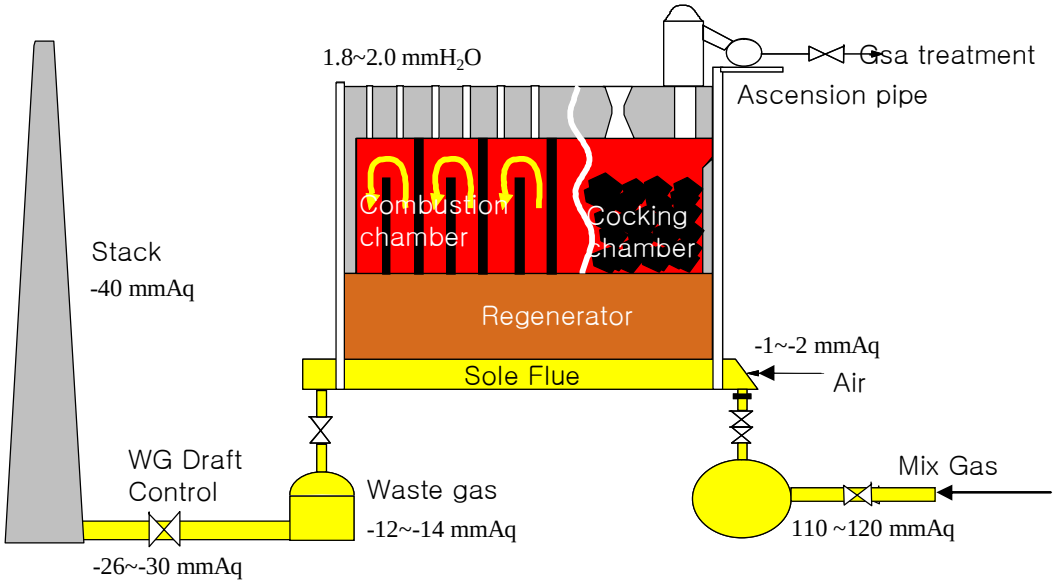
	O_2 %	2010~2014	2015~
Sinter plant	15	220[1] /120 [2]	200[1] / 120[2]
Reheating furnace	11	200 [1] / 150 [2]	200 [1] / 150 [2]
Coke Oven	7	250	250/150[3]
Power Generator	15	100[4] / 50[5]	80/50/20 [6]

[1] Built before 2007. Jan [2] Built after 2007.Feb [3] Built after 2007.Jan [4] Built before 2001. Jun
[5] Built after 2001.Jul , [6] built after 2017. Jan

☞ Following the adoption of PM 2.5 standard which will be effective in 2015, the government is going to regulate PM2.5 emissions from stacks
→ **NOx control is essential to reduce PM2.5**

3. Coke Ovens at Pohang Works

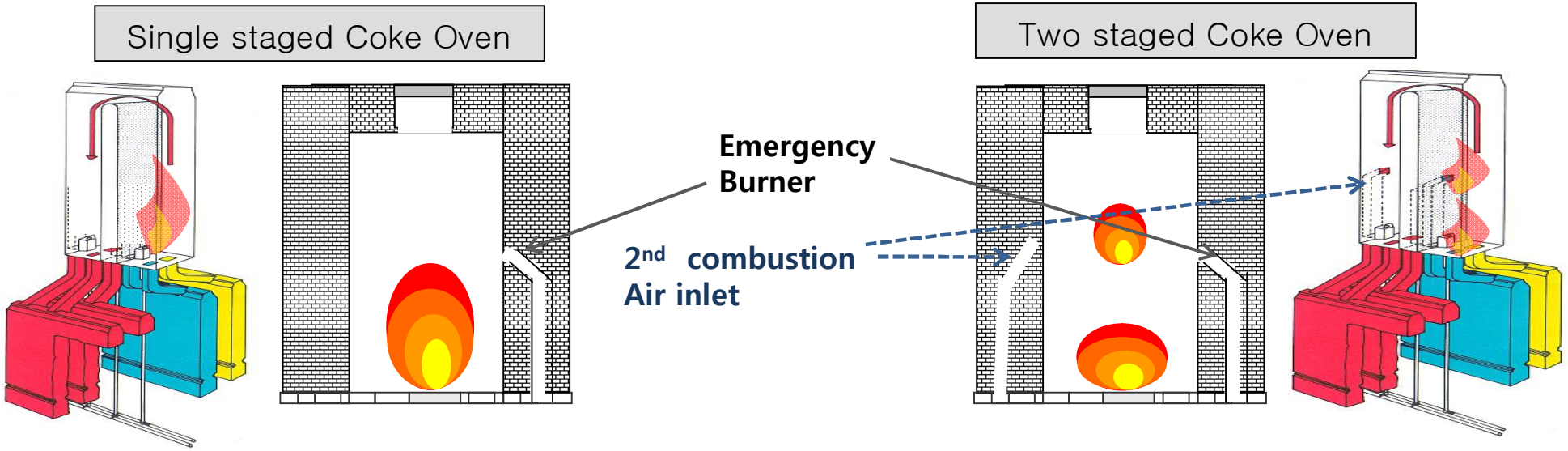
- **Pohang works operates single stage combustion chamber Coke Oven**



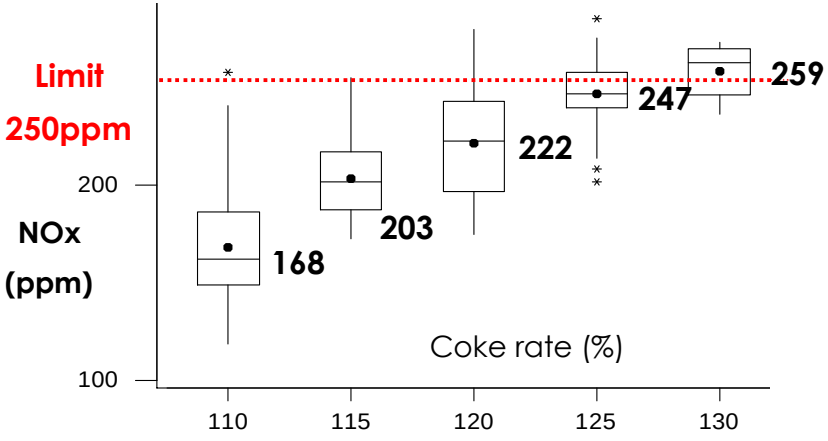
구분	#1 Coke plant				#2 Coke plat				#3 Coke plant	
Battery	1	2	3	4	5	6	7	8	9	10
Built year	1973	1976			1978		1981		1983	2009
Combustion	Single staged combustion									Two staged

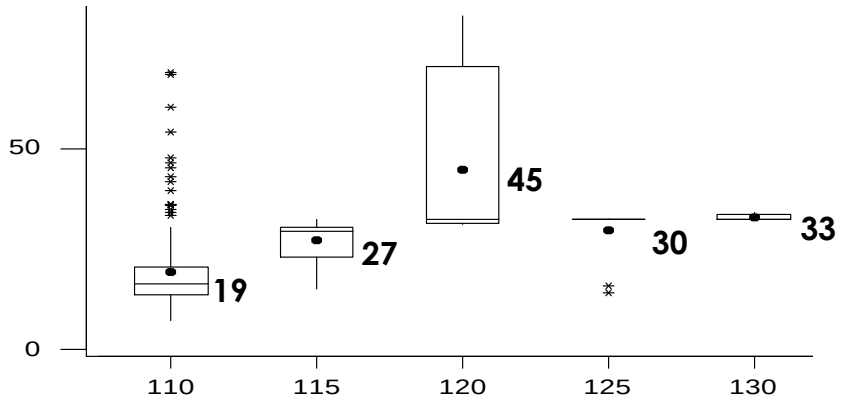
4. Coke oven & NOx emission

- **Schematic diagram of Coke Oven combustion chamber**



- **NOx emissions**





5. NOx emission control techniques

5.3.12.2 Reduction of NO_X by primary measures

Å**waste gas recirculation**: The lower O_2 and higher CO_2 concentrations reduce the flame temperature.

Å**staged air combustion**: by adding the combustion air in several stages, combustion conditions become more moderate, and NO_X formation is reduced

• **lowering coking temperatures**: A lower coking temperature requires a lower heating chamber temperature, which results in less NO_X formation.

For existing modern plants which **have already incorporated low-NO_X techniques, such as staged air combustion and waste gas recirculation**, NO_X concentrations of **322 – 414 mg/Nm³(150~200 ppm)** at 5 % O_2 are reported.

For existing plants **without process-integrated deNO_X measures,** achievable levels for NOX are in the higher range up to 1783 g/t coke, **with concentrations up to 1700 mg/Nm³(830ppm)** at 5 % O_2.

5.3.12.3 Reduction of NO_X by secondary measures Description

• NOX emissions from coke oven firing are **preferably minimized by process-integrated measures, but end-of-pipe techniques** may also be applied. (**applicable only to new plant**)

Reference : EU Best Available Techniques (BAT) Reference Document for Iron and Steel Production 2012 March

- How to reduce NOx for the conventional Coke Oven

  ➲ Application of SCR ?

  - Only applicable to New Plant

  ➲ Lowering Coking temperature ?

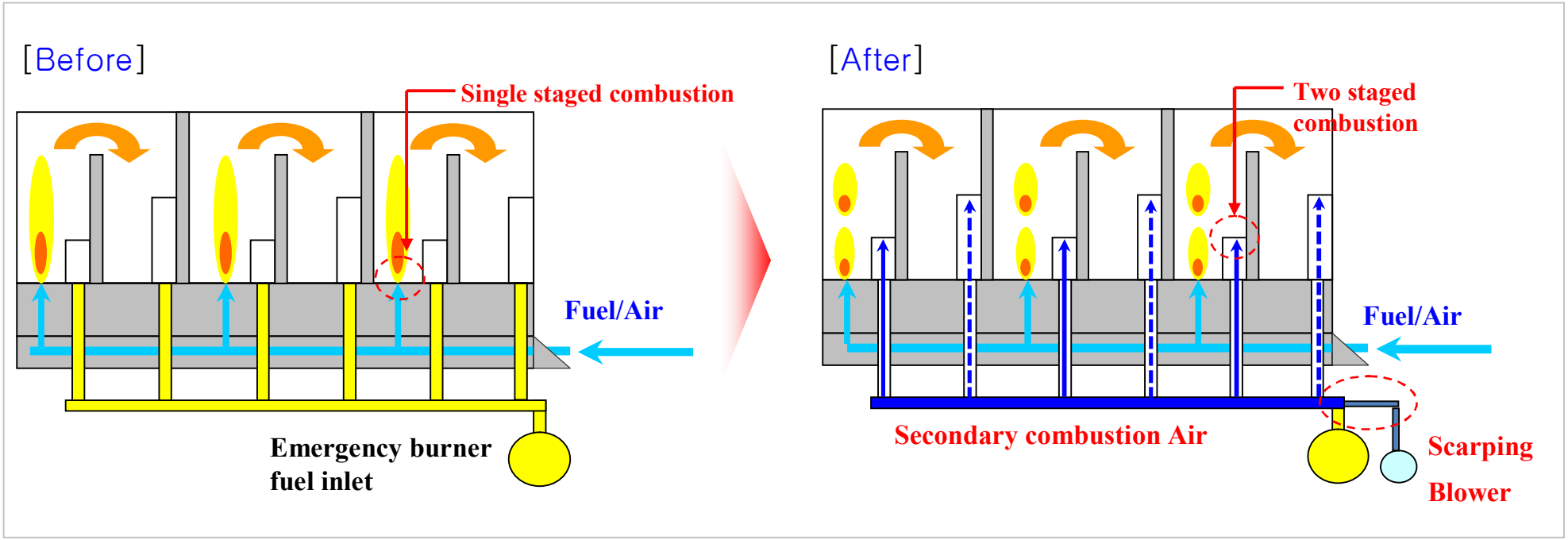
  - Decrease the Coke productivity

  ➲ Installation of Staged air combustion ?

  - Need to restructure of Coke Oven (refractory)

☞ Supplying air through the emergency burner pipe can be used as two-staged combustion

- **Concept diagram of two staged combustion using conventional Coke Oven**



- **TRIZ tool was introduced to find out the solution**

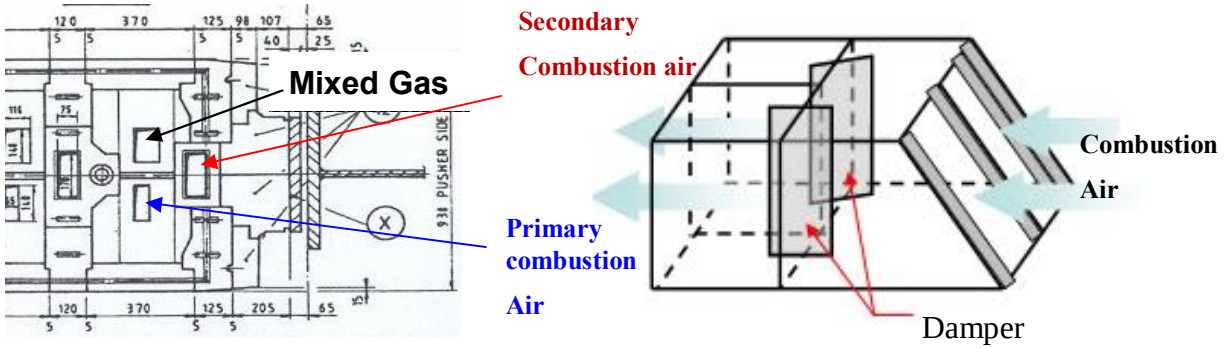
  - Technical contradiction (temperature ↓ ⇒ quality↓ , temperature ↑ ⇒ quality↑)
  - Forty principles : Segmentation, Asymmetry é

6. Pilot test at the #1 Coke Oven (19 combustion chambers)

● Conditions for stable operation

① Determination of secondary combustion air flow rate

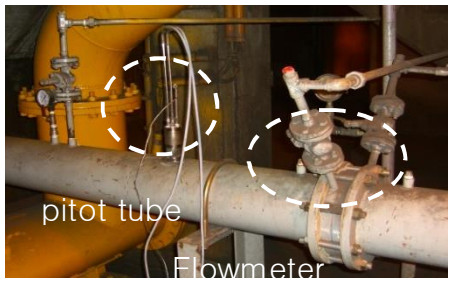
- Total air flow rate : 12,800Nm3/hr (3% O2, mixed gas calorific value 1000 Kcal/Nm3)
- Secondary air flow rate : 30% of total flow rate (benchmarked at the #10 Coke Oven) ⇒ **3,840Nm³/hr**



	1st	2nd
Damper open ratio	50%	50%
Air flow rate	69%	31%

[#10 Coke Oven operation conditions]

② Measuring Scarping Blower flow rate



[Scarping Blower Air flow rates]

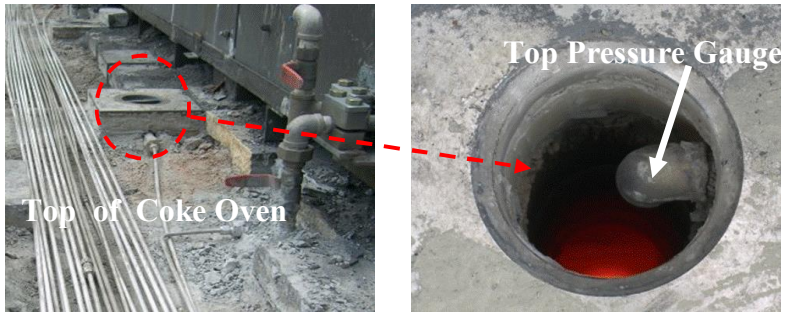
S/B : 5100Nm³/hr (Static pressure 260mmH_2O)

☞ **Not appropriate since it had low static pressure (requires > 1,000 mmH_2O)**

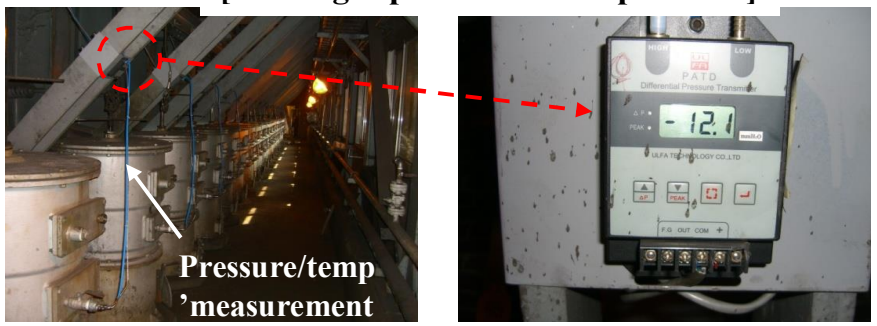
③ Maintaining optimal Coke Oven Pressure

- Target : O2 contents 2-4%, Pressure : 1.5 ï 3.5 mmH2O)
- Waste gas pressure was measured to adjust top pressure by adjusting damper

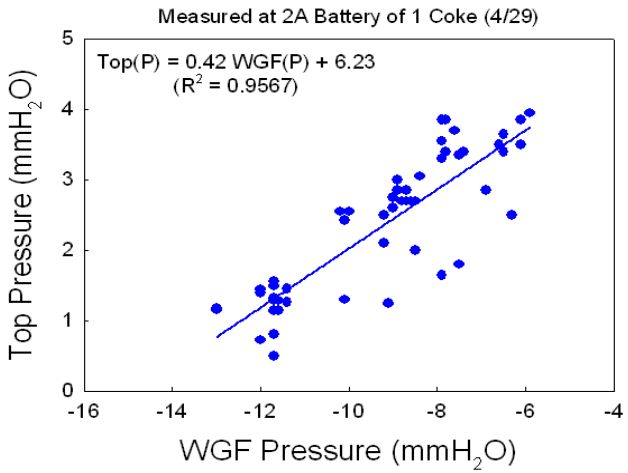
[Top measurement]



[Waste gas pressure & temperature]



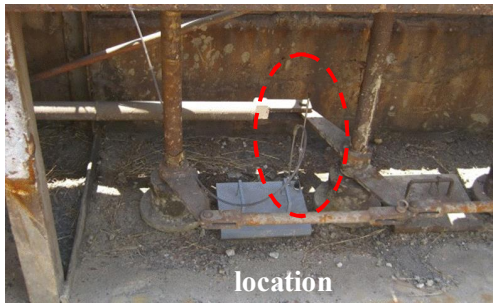
[Waste gas vs Top gas pressure]



-Waste gas Damper adjustment
(-12 → -8~-10 mmH_2O)

④ NOx Emission measurement

- CMS was installed on the chimney



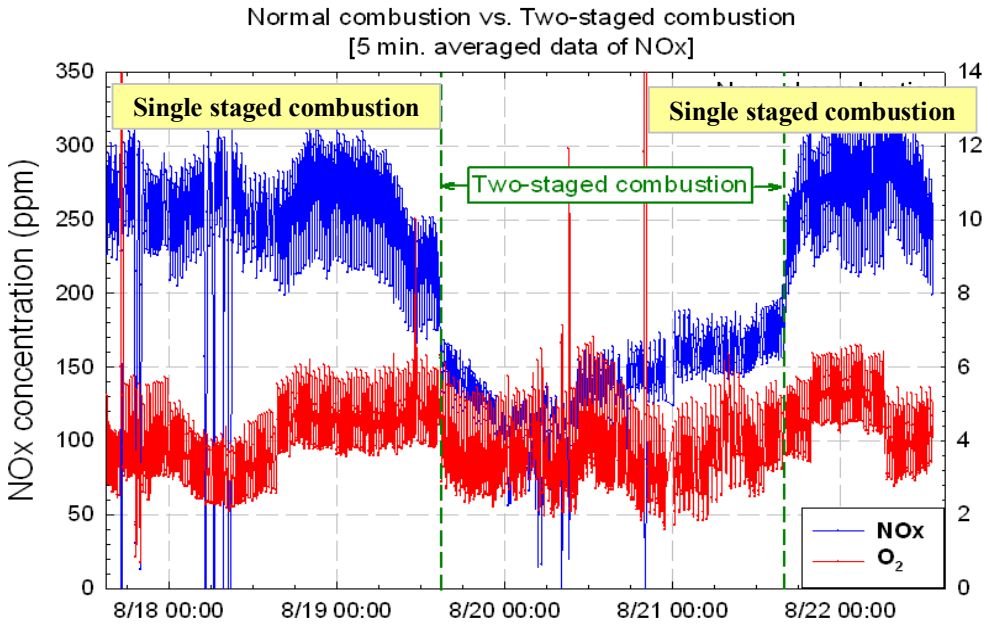
7. Results of the test

• Operation conditions were identified

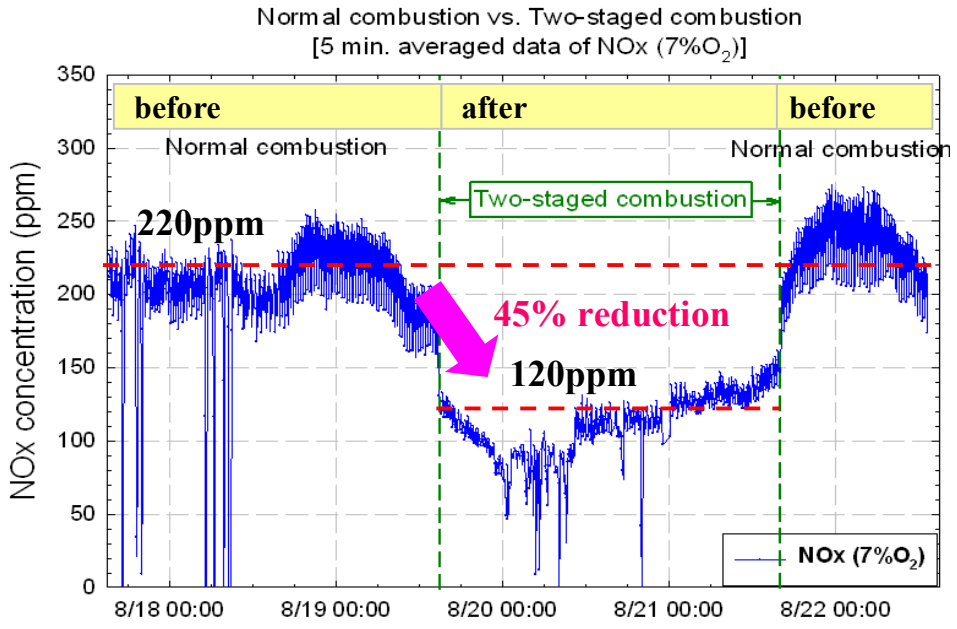
- Secondary air flow rate : 4,100Nm^{3}/hr (32% of total air flow rate)
- Coke rate : 115%, Temperature : 1088℃
- O_2 contents : 2-4%, Top pressure : 1.5 ï 3.5 mmH_2O

• Dramatic reduction of NOx

- **45% reduction (220ppm → 120ppm)**



[NOx 5min Raw Data]

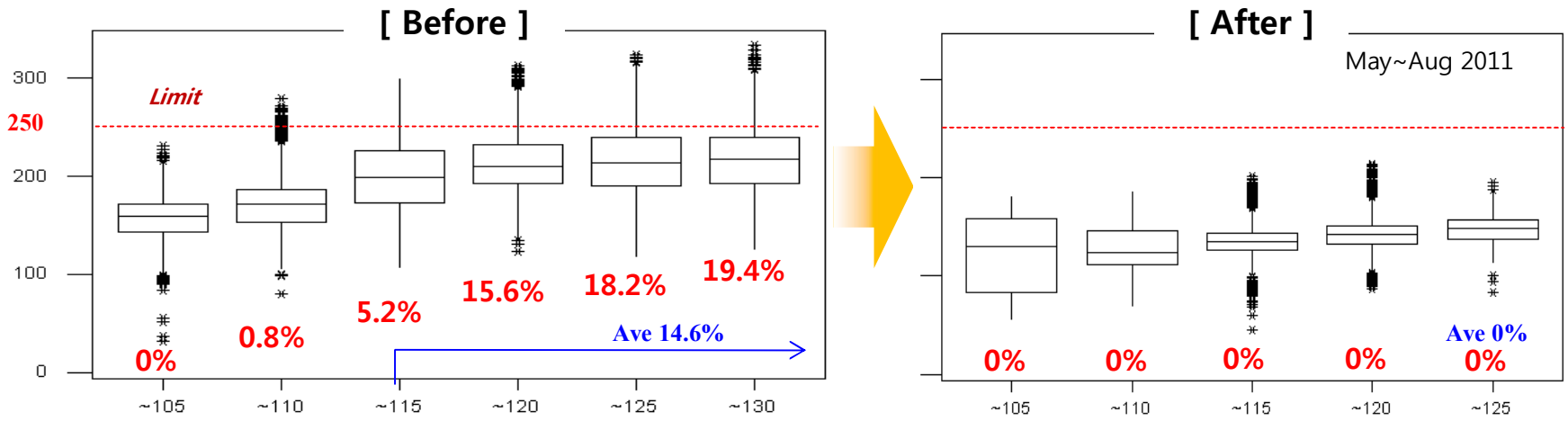


[NOx 5min O2 adjusted(7%) Data]

8. Replication at the #8 Coke Oven (76 combustion chambers)

• Replicated at the larger scale Coke Oven

- Period : 2010. Sep ~ 2011.Jan / Expenditure : 1.7 billion Won
- New air blower for supplying secondary combustion air



• Cost analysis

Index		POSCO Technology	SCR
Investment cost	Billion Won	1.7	6.2
Operation cost	(approx. 0.9 M$)	0.4	1.5

☞ Much more economical than end-of-pipe technology

9. Conclusions

- POSCO successfully reduced 45% of NOx emission at the conventional Coke Oven by applying secondary combustion air through COG scarping pipe.

- NOx emission control technology was successfully replicated at the #8 coke oven plant and it is under installation in other Ovens at the Pohang works.

- POSCO continues its efforts on developing new environmental technology