Risk Analysis of Fortum's 560MWe net Power Plant Retrofit to Oxyfuel Combustion

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Agenda

- Joint development **Fortum / Babcock-Hitachi / Air Liquide** for **oxyfuel retrofit**, 90+% CO_2 capture
- Main Results from Risk Analysis
- Conclusion on Oxyfuel risk analysis
  - Safe, retrofit compatible, reliable, efficient

Oxyfuel Retrofit, a Joint Development

- Fortum, Babcock-Hitachi and Air Liquide developed a concept for the oxyfuel retrofit of the Meri-Pori power plant:
  - **Fortum**, among top EU utilities, committed to reducing its Carbon Footprint
  - **Babcock-Hitachi**, a power plant & environment equipment manufacturer. It owns R&D test facilities for energy and environment technologies including Oxy-fuel combustion
  - **Air Liquide**, a world leader in gases for industry, health & environment, has led strong developments in oxycombustion in the past 10 years including pilot plants, extensive engineering studies, laboratory tests, etc.

Proposed retrofitted plant by Fortum, BHK & AL

- Retrofit of Meri-Pori Power plant, Supercritical, 565MWe net
  - Very low emissions (NO_X, SO_X, Hg, Particulates)
  - **Safe and reliable** operation in both oxy- and air combustion modes
  - **Efficiency drop ~ 7.8 points HHV,** goal of 6 points for retrofit in 2020

- **A risk analysis** was required and lead by Fortum, as a validation step for this **promising technology**

Risk Analysis Methodology

- Four fields of study:
  - Safety (S), Environment (E), Costs (C) & (un)Availability of power (U);
  - 4 levels of impact
  - 4 levels of probability

1 - Critical **Critical risk that can't be tolerated/intolerable magnitude**
2 - Significant magnitude
3 - Low /moderate magnitude
4 - Non critical / acceptable magnitude

Risk Criticality Table

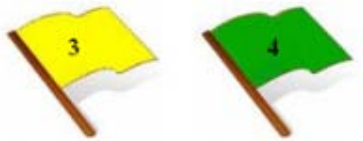
Maximum Impact	Probability			
Mini of (C; U; S; E)	1	2	3	4
1	1	1	2	3
2	1	2	3	3
3	2	3	3	4
4	3	4	4	4

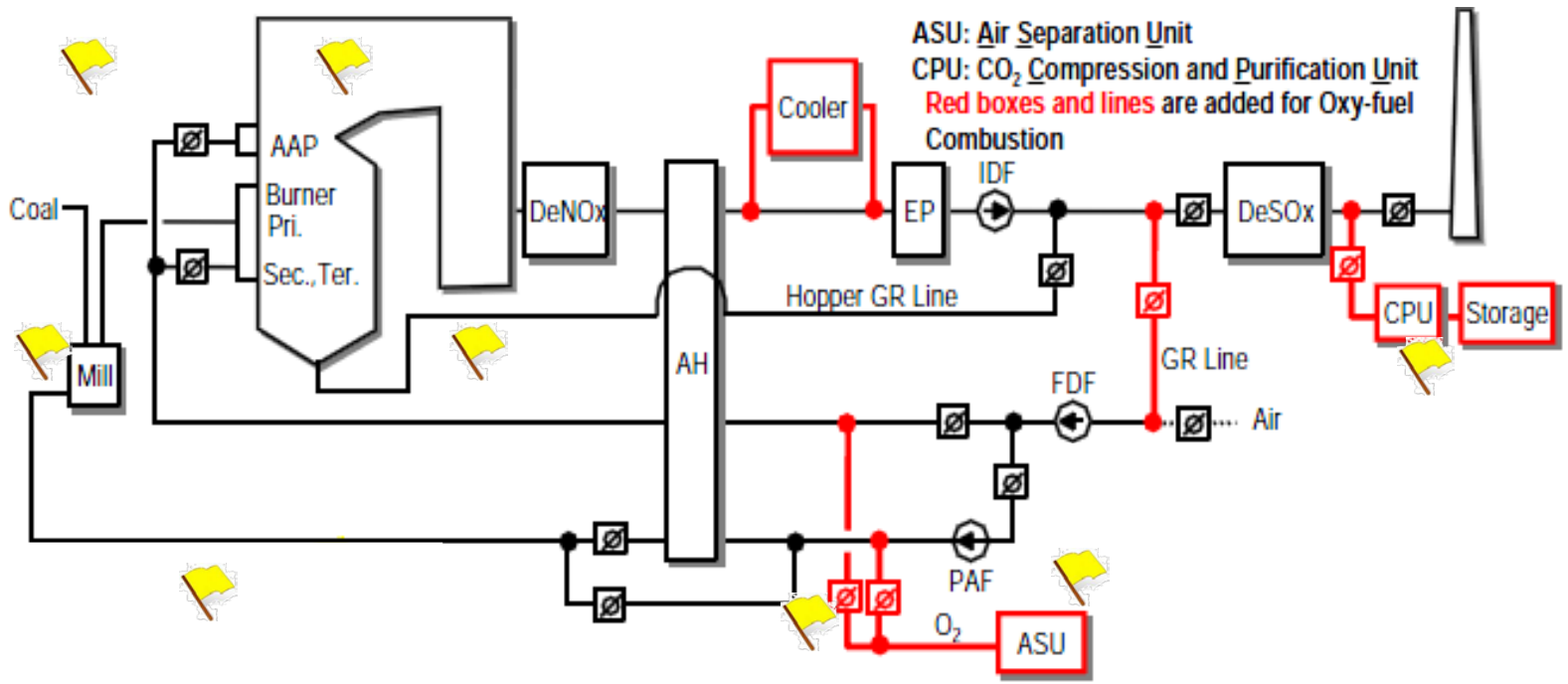
- Extensive involvement from all 3 companies:
  - 3 days in the power plant site with technical manager,
  - Led by Fortum risk analysis specialists, 7 experts from 3 companies
- 63 risks identified

Risk Analysis Main Results

- No critical risks or risks with significant magnitude (red & blue)

- 6 risks identified with a moderate magnitude
  - 4 [highest severity x lowest probability (extremely unlikely)]
  - 2 [moderate severity x moderate probability]





Moderate Risks #1 & 2 [ASU damage & Anoxia]

- **#1 Damaged ASU (due to HC ingress into liquid O_2)**
  - Major explosion: Extremely unlikely
    - only 3 Industry events in the past 50 years, over ~ 30 000 years operation from industrial gas companies (10^{-4} frequency of occurrence).
  - In coal fired PP environment, **explosion risk is reduced** compared to petrochemical environment as hydrocarbons are under a solid form and not vapour

Sources:

EUROPEAN INDUSTRIAL GASES ASSOCIATION // COMPRESSED GAS ASSOCIATION

www.eiga.org *www.cga.net*

- **#2 Release of inert gases leading to anoxia:**
  - Inherent risk to CCS
  - Known preventing strategies (SO_2 detectors in FGD rooms, etc.)

Example of ASU located in challenging environment

- IGCC plant:
  - 9 Air Liquide references > 1500t/d in the past 15 years

Example of ASU located in challenging environment

Frequency rate of hydrocarbon incidents under 10^{-6} thanks to Air Liquide Design and Operational experience

Other risks (such as anoxia): frequency rate even lower

Moderate Risk # 3 [Boiler and/or Mill explosion/fire]

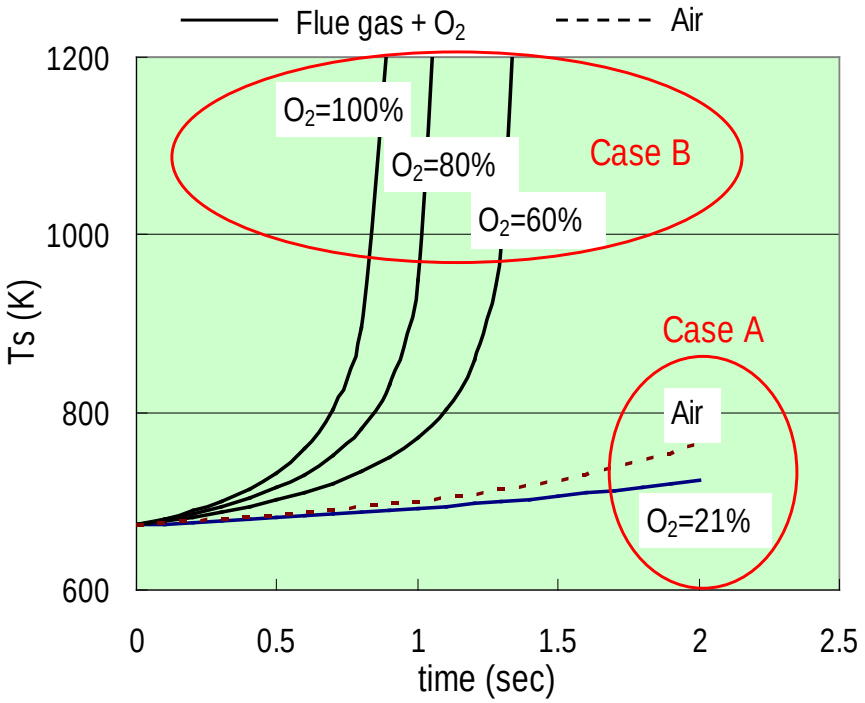
- Known Risk of Boiler/Mill Explosion/Fire:

  Case A: Worse flame stability → All flame loss→

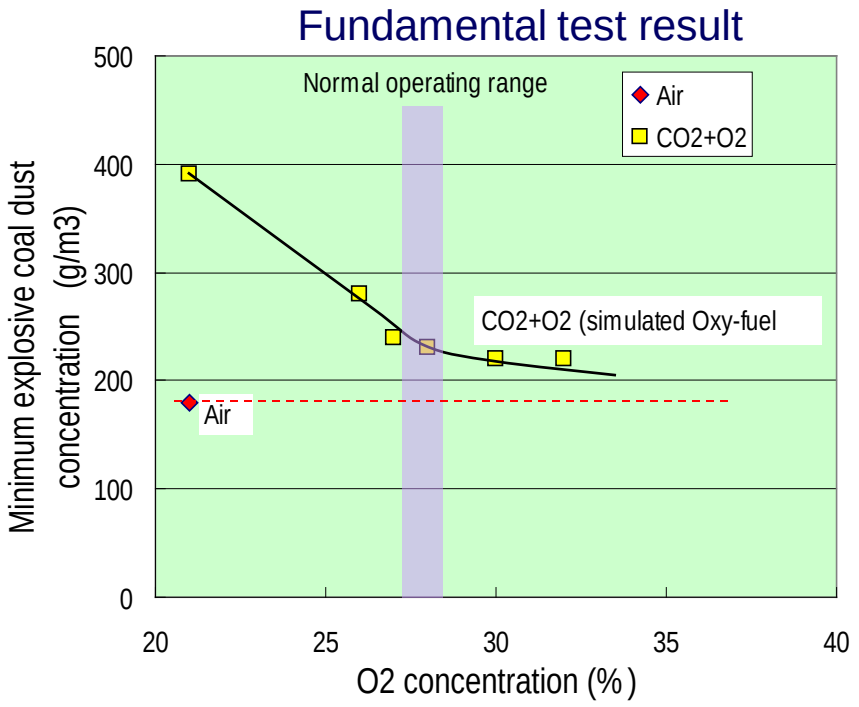
  → Accumulation of explosive mixture in furnace and enclosure + ignition energy

  → Boiler explosion

  Case B: Rate of temperature rise too fast → Mill fire or explosion



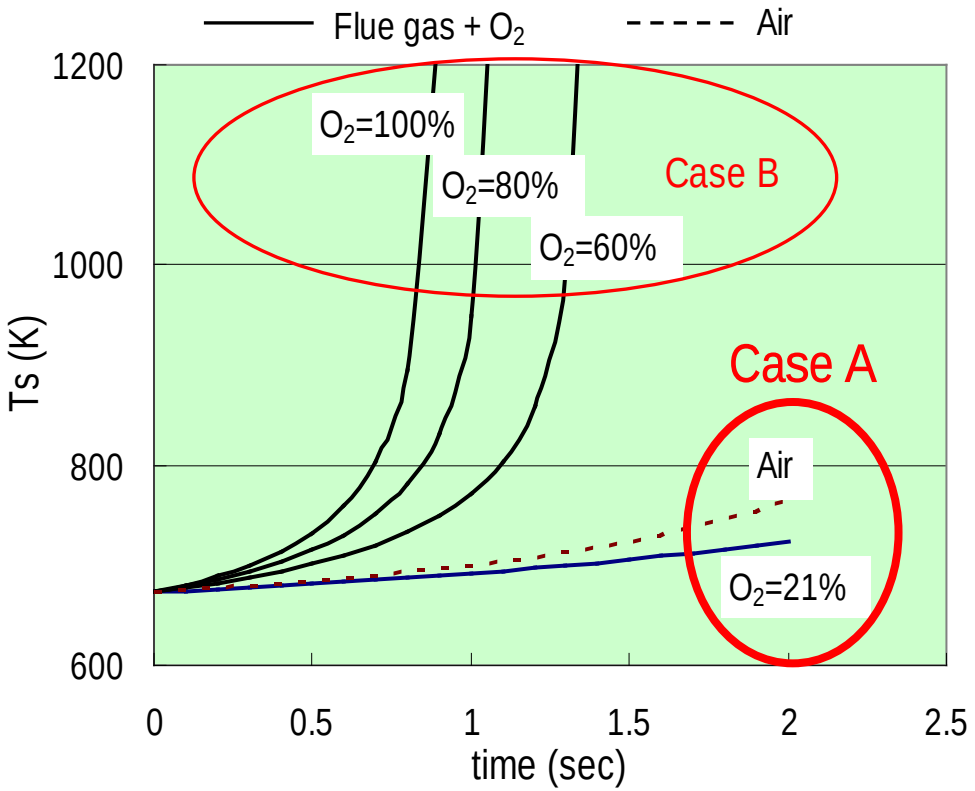
Influence of O_2 on Temperature rise



O_2 vs Explosive Limit

Moderate Risk # 3 [Boiler and/or Mill explosion/fire]

Prevention of Boiler Explosion in Case A

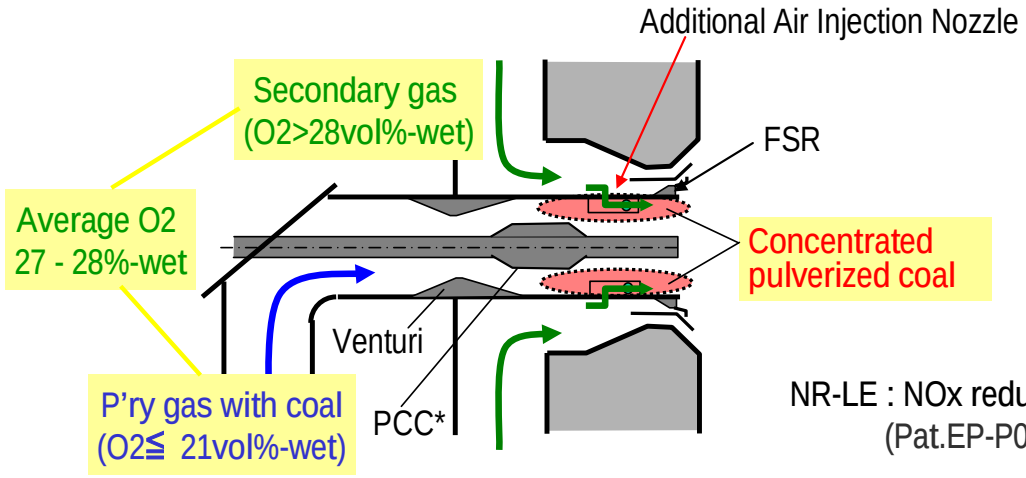


Moderate Risk # 3 [Boiler and/or Mill explosion/fire]

- Prevention of Boiler Explosion in Case A

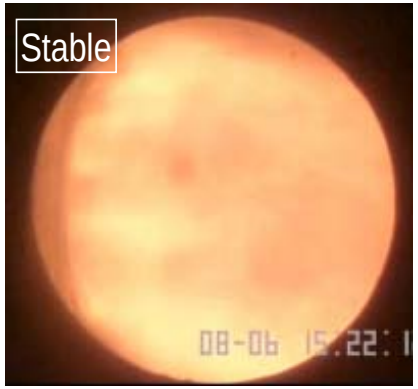
  NR-LE Burner to **enhance flame stability**

  ➔ Stable flame at low oxygen concentration of 10% assuming big deviation from normal oxygen setting of 21% (preliminary)



NR-LE : NOx reduction and load extension burner
(Pat.EP-P01312859,US-P07213522)

a. Pry O2=21%(wet)



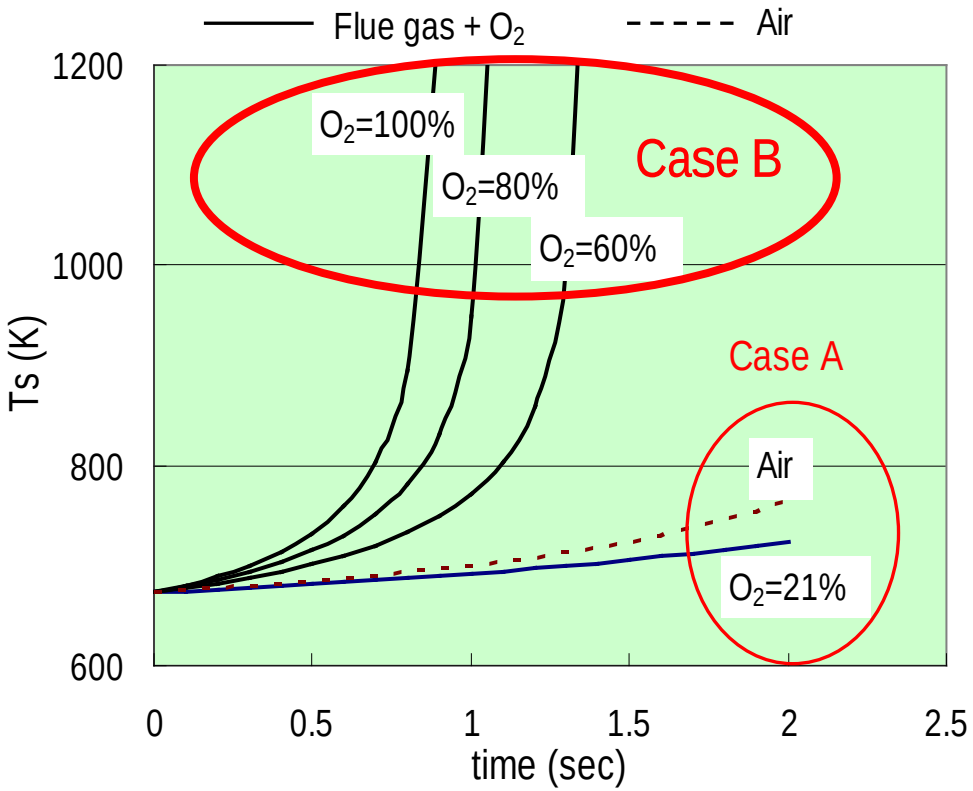
b. Pry O2=10%(wet)

*FSR: Flame Stabilizing Ring
*PCC: Pulverized Coal Concentrator

Test coal
- Australian bituminous coal
- Fixed Carbon (FC) : 55.2%,dry
- Volatile Matter (VM): 33.3%,dry
- Fuel Ratio (FC/VM) : 1.66
- Fineness : 80% through 75μ m sieve

Moderate Risk # 3 [Boiler and/or Mill explosion/fire]

Prevention of Mill Fire in Case B

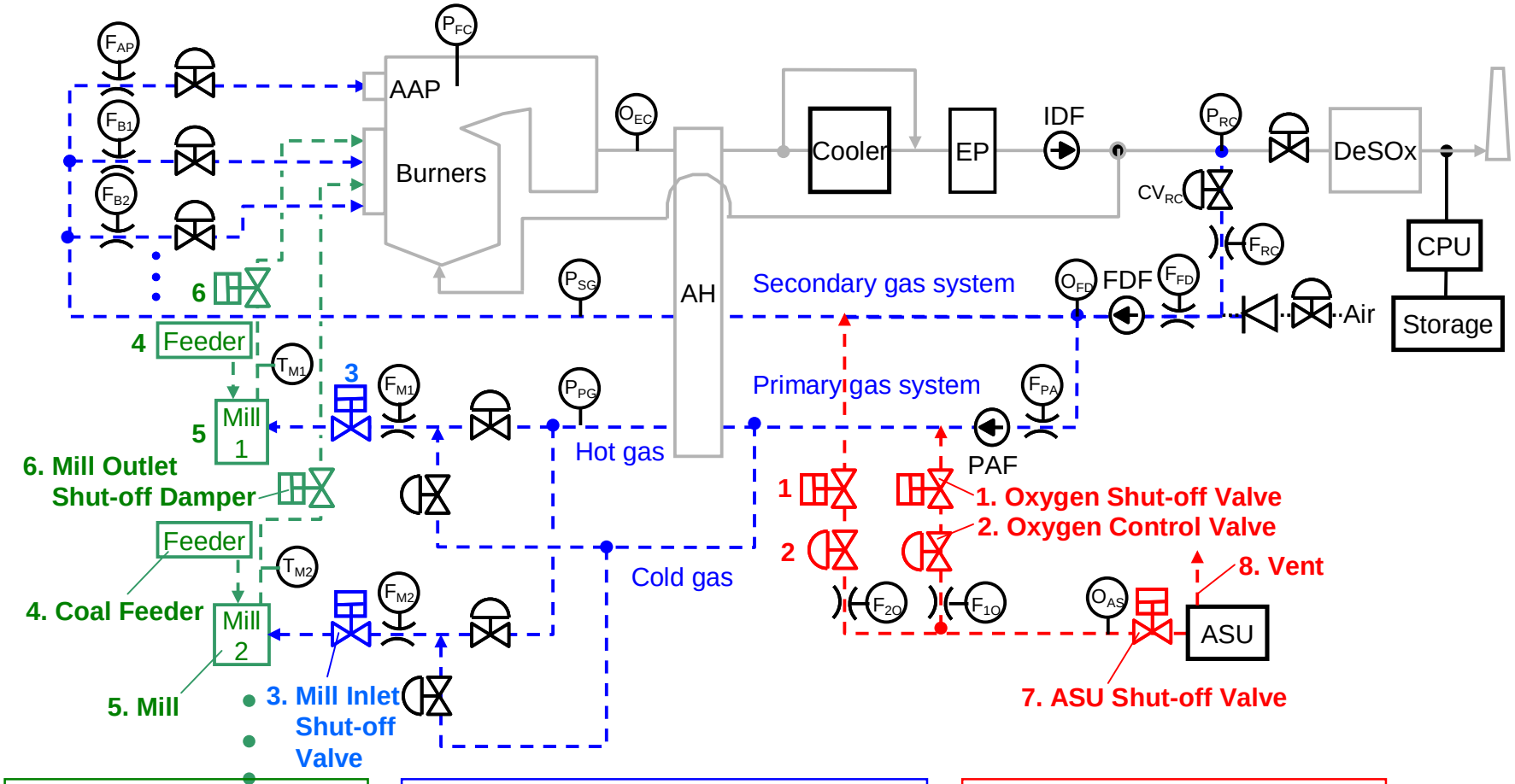


Moderate Risk # 3 [Boiler and/or Mill explosion/fire]

- Prevention of Mill Fire in Case B

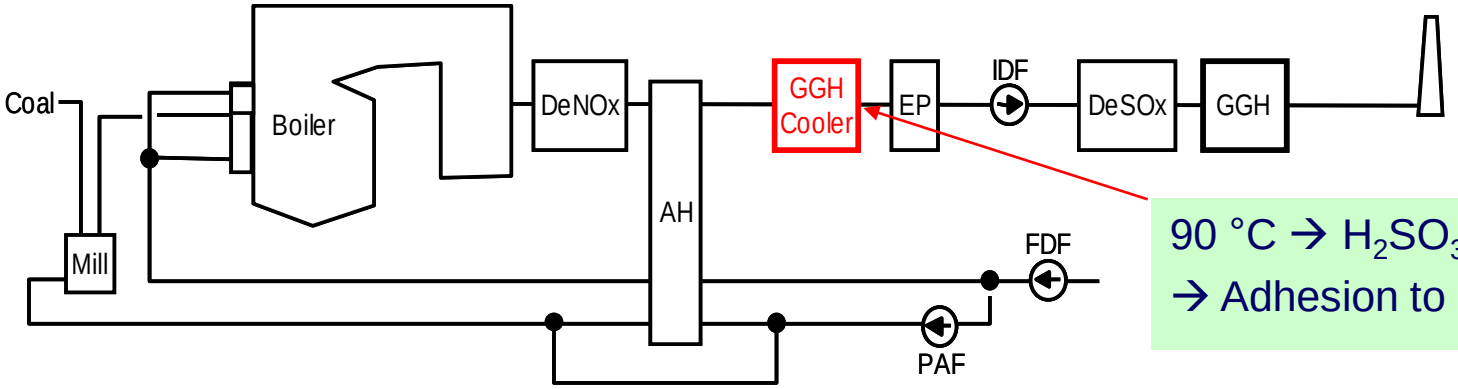
Emergency redundant shut down of oxygen & fuel

➔ To avoid formation of abnormally high oxygen & fuel mixture

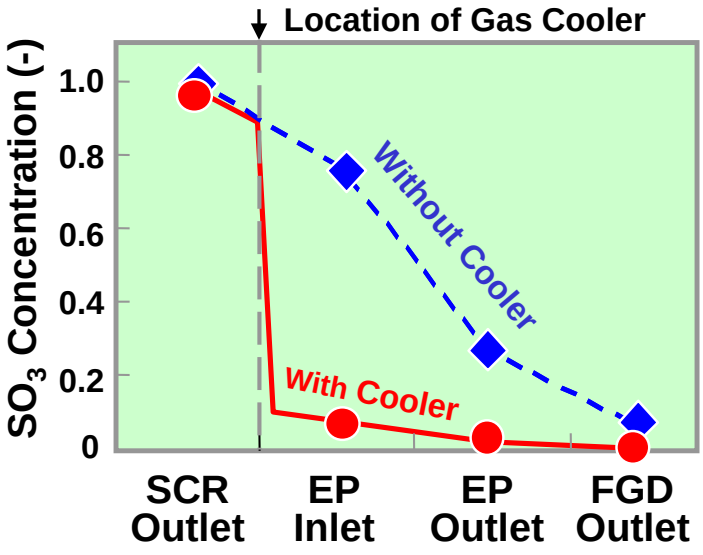


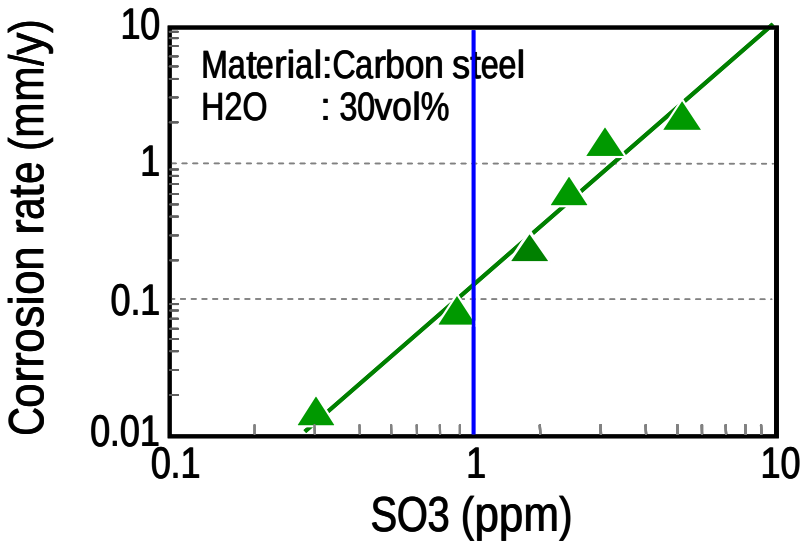
Moderate Risk # 4 [Sulfuric Acid Corrosion (SO_3)]

- Sulfuric acid corrosion (higher SO_3 content due to FG recirculation)
- Prevention of Corrosion
  - Gas Gas Cooler condenses sulfuric acid on ash particles, which is removed in EP (Proven design in actual plants for a decade)
  - Same system is applied to oxyfuel combustion



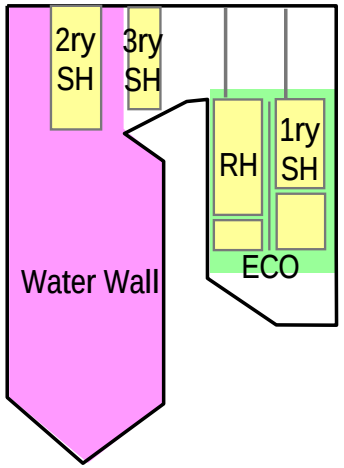
90 °C → H_2SO_3 mist
→ Adhesion to ash particles



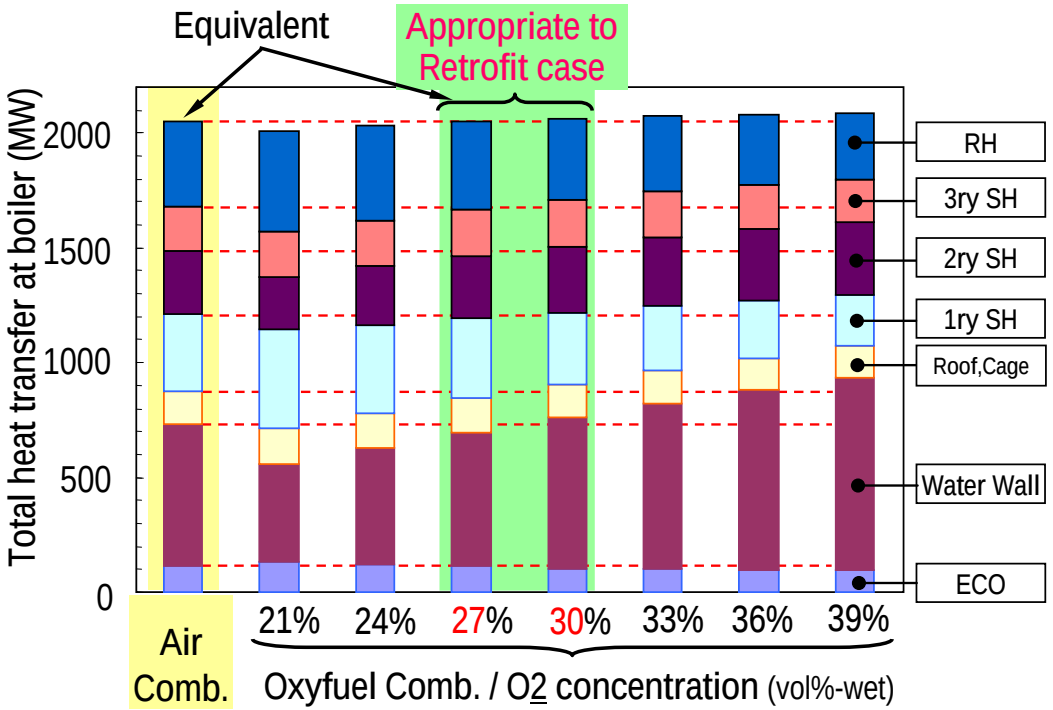


Other Modifications Without Risk Impact

- **Present Boiler, Mills, SCR, Air Heater, FGD and EP can be used** as they are (from test & simulation results)
  - Example for the boiler heat transfer sections:



Boiler Structure



- Smooth online changes between air mode and oxy mode are confirmed by combustion tests & dynamic simulations

Conclusions & Opportunities

- Oxyfuel is a real option for existing power plants today
  - It is Safe
  - It is Suitable for Retrofit
  - It will have similar reliability to air fired power plants
  - Oxyfuel is a nearly ZERO EMISSION process

Thank-you!

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