एनटीपीसी
NTPC
Transforming lives

एनटीपीसी लिमिटेड
(भारत सरकार का उद्यम)
NTPC Limited
(A Govt. of India Enterprise)

Air Pre-heater

Dr. T K Ray
NTPC Limited
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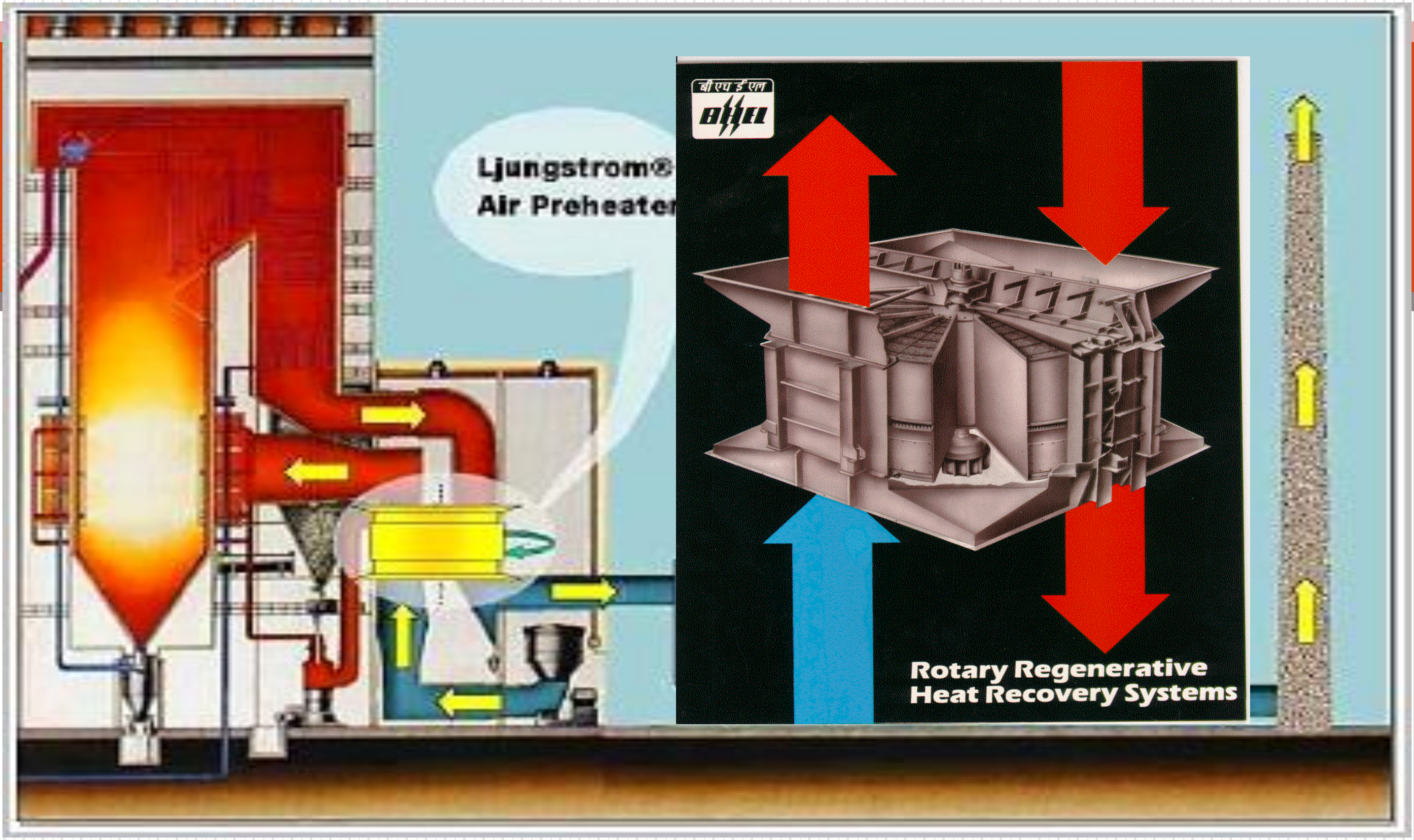
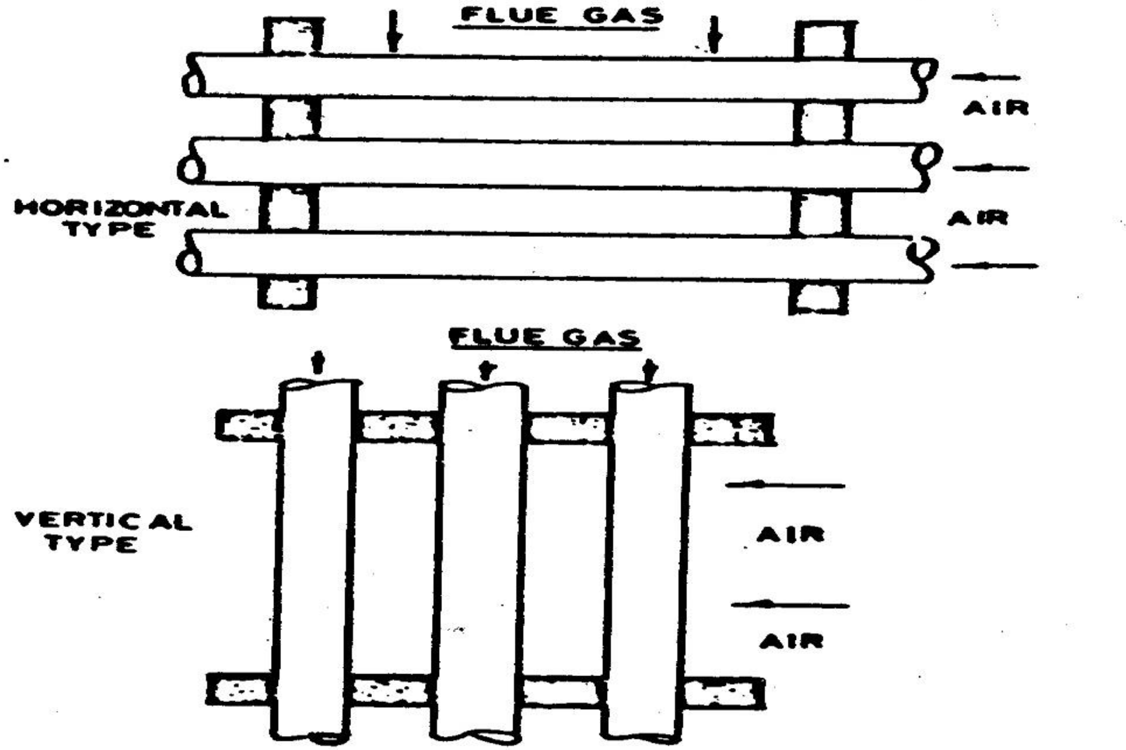
Air Heater in FG path



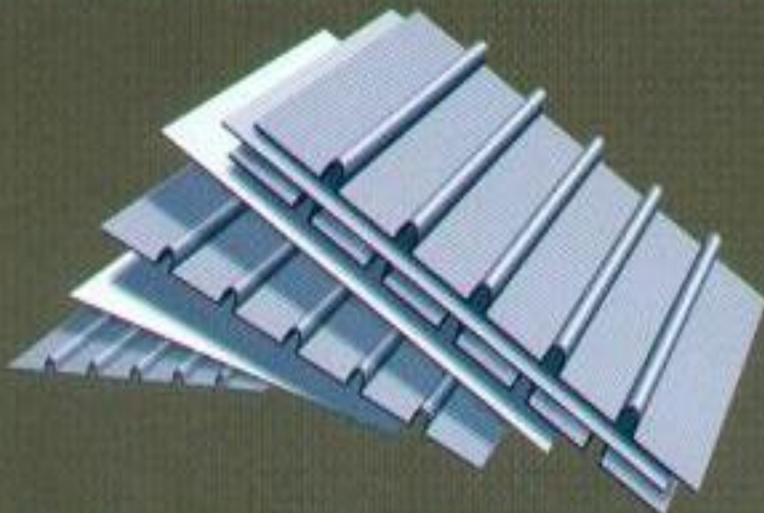
Tubular Air Heaters (Recuperative)



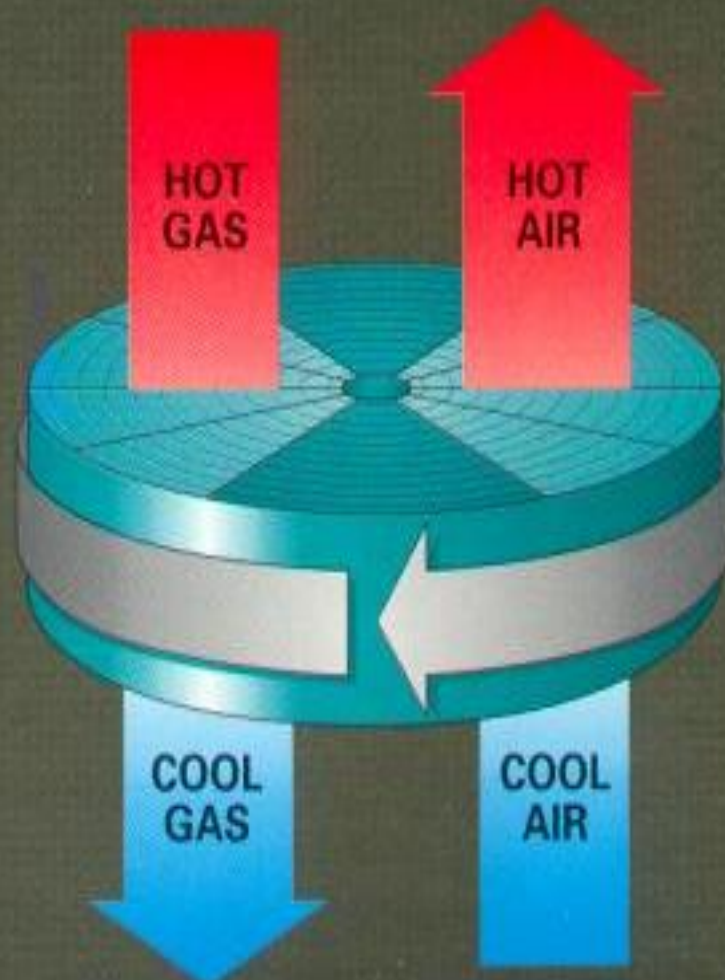
.-26 *Tubular Airheaters*

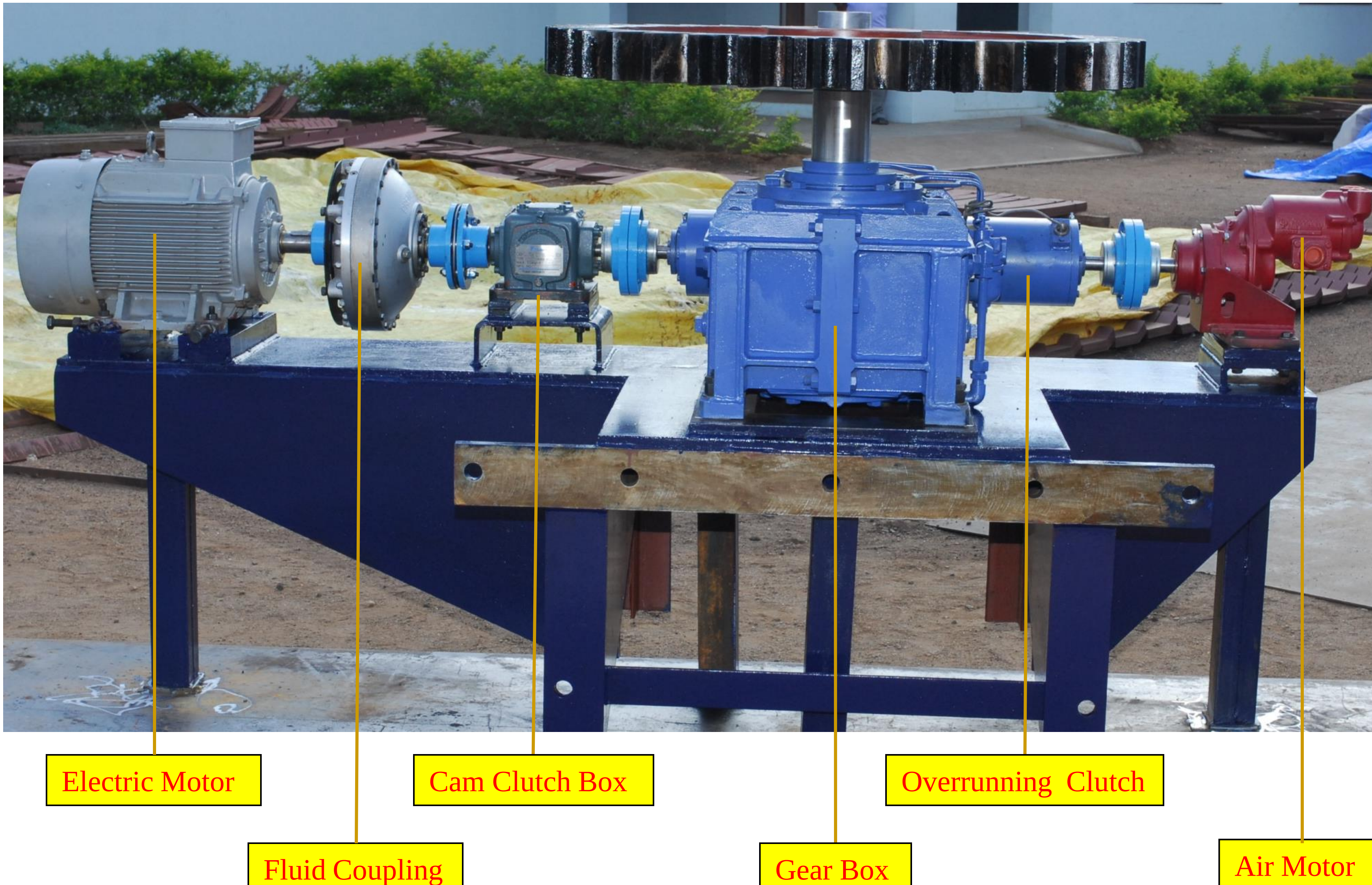
The Ljungstrom® Air Preheater Rotary Regenerative Heat Recovery Cycle

The basic component of the Ljungstrom® air preheater is a continuously rotating cylinder, called the rotor, that is packed with thousands of square feet of specially formed sheets of heat transfer surface.

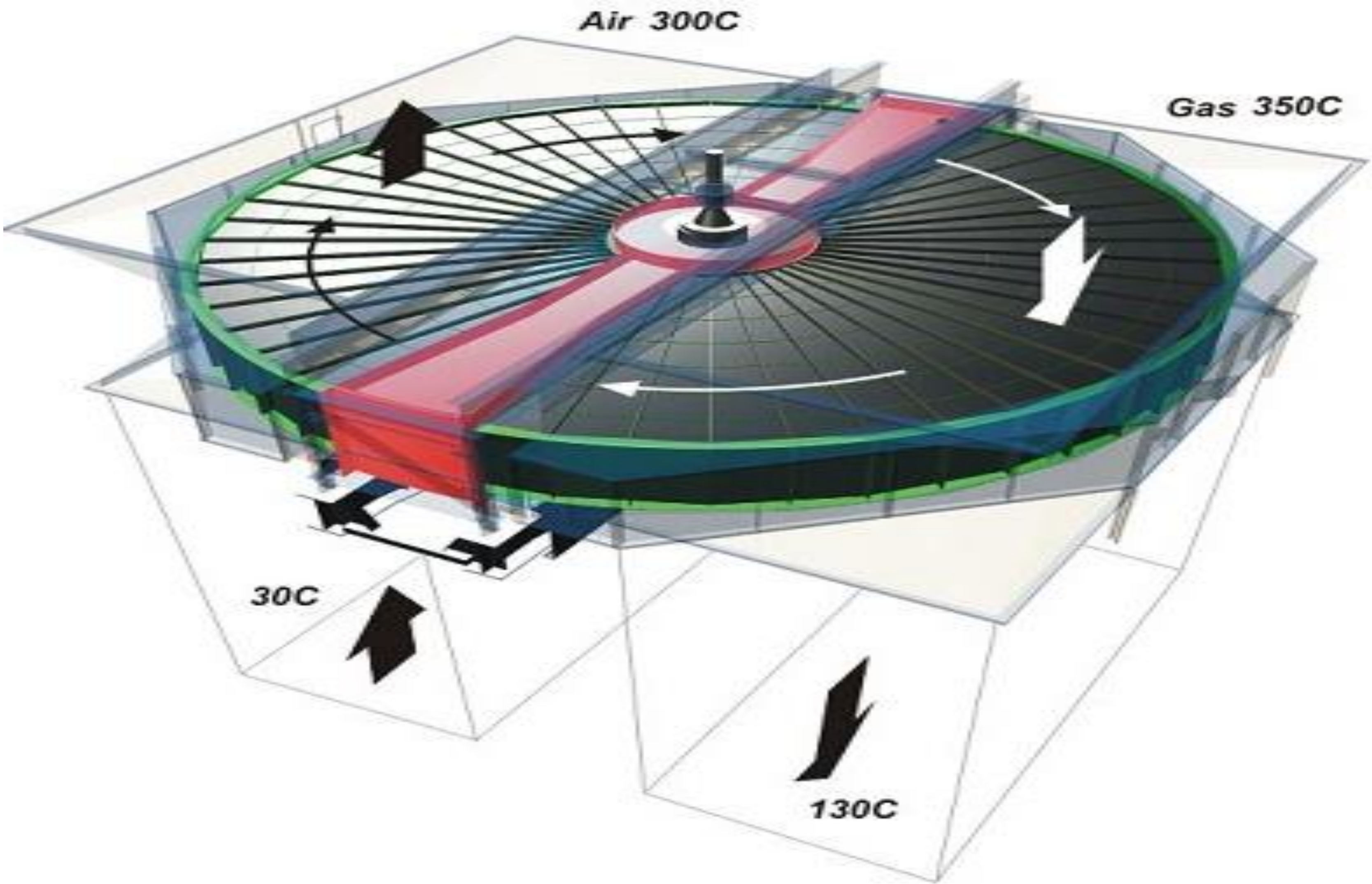


As the rotor revolves, waste heat is absorbed from the hot exhaust gas passing through one-half of the structure. This accumulated heat is released to the incoming air as the same surfaces pass through the other half of the structure. The heat transfer cycle is continuous as the surfaces are alternately exposed to the outgoing gas and incoming air streams

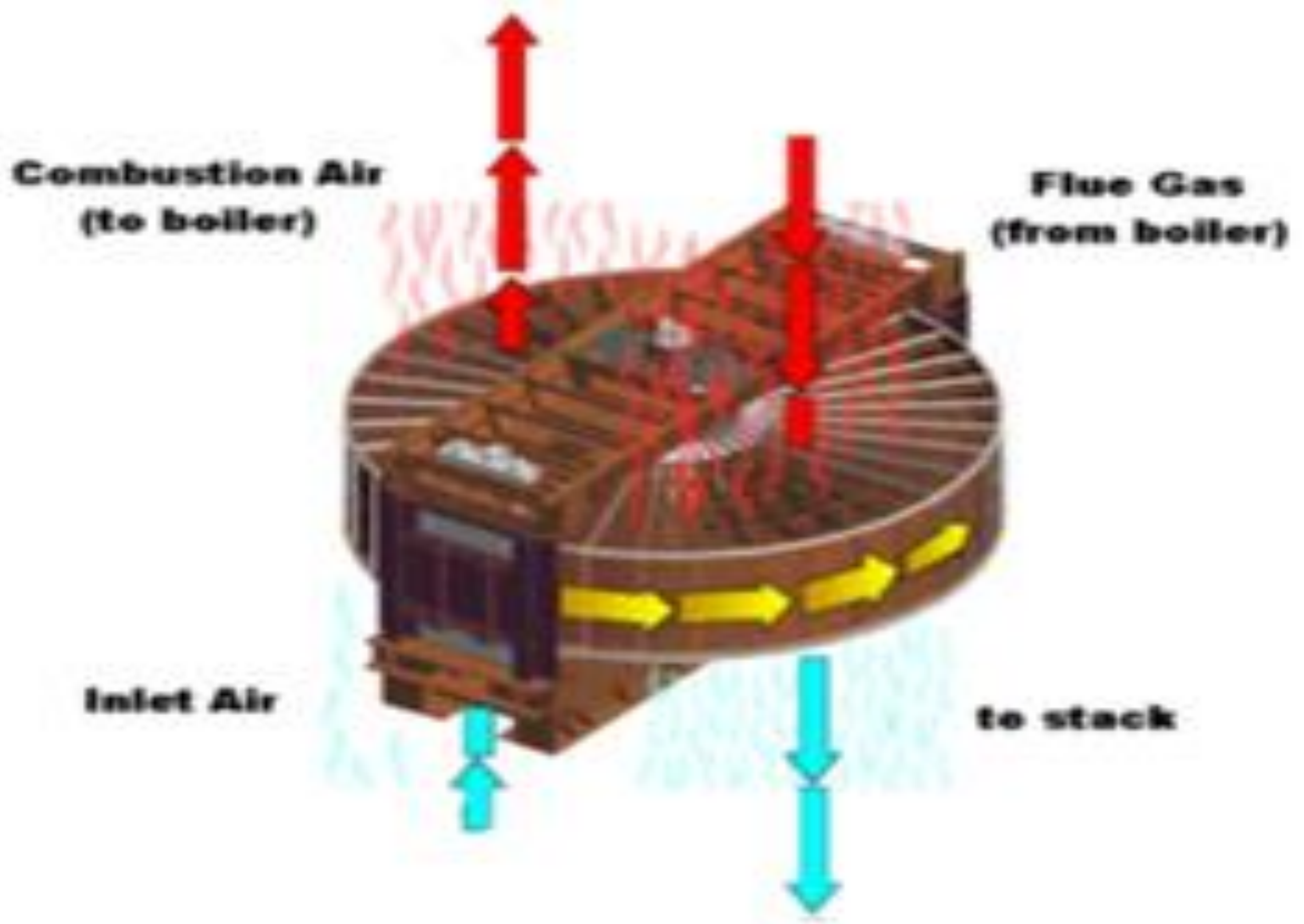


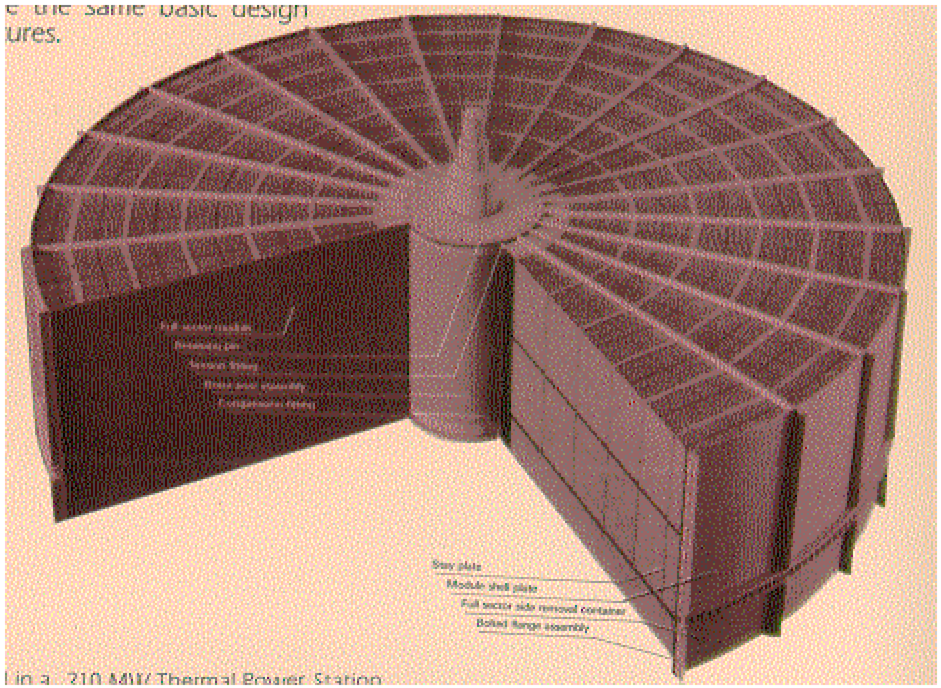

Electric Motor
Fluid Coupling
Cam Clutch Box
Gear Box
Overrunning Clutch
Air Motor

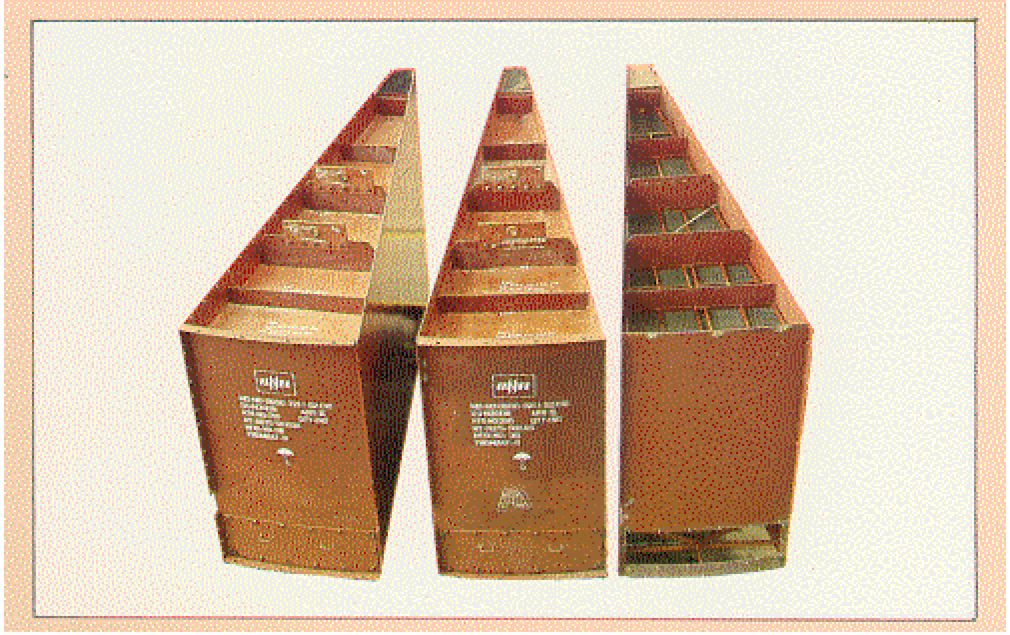
Regenerative APH

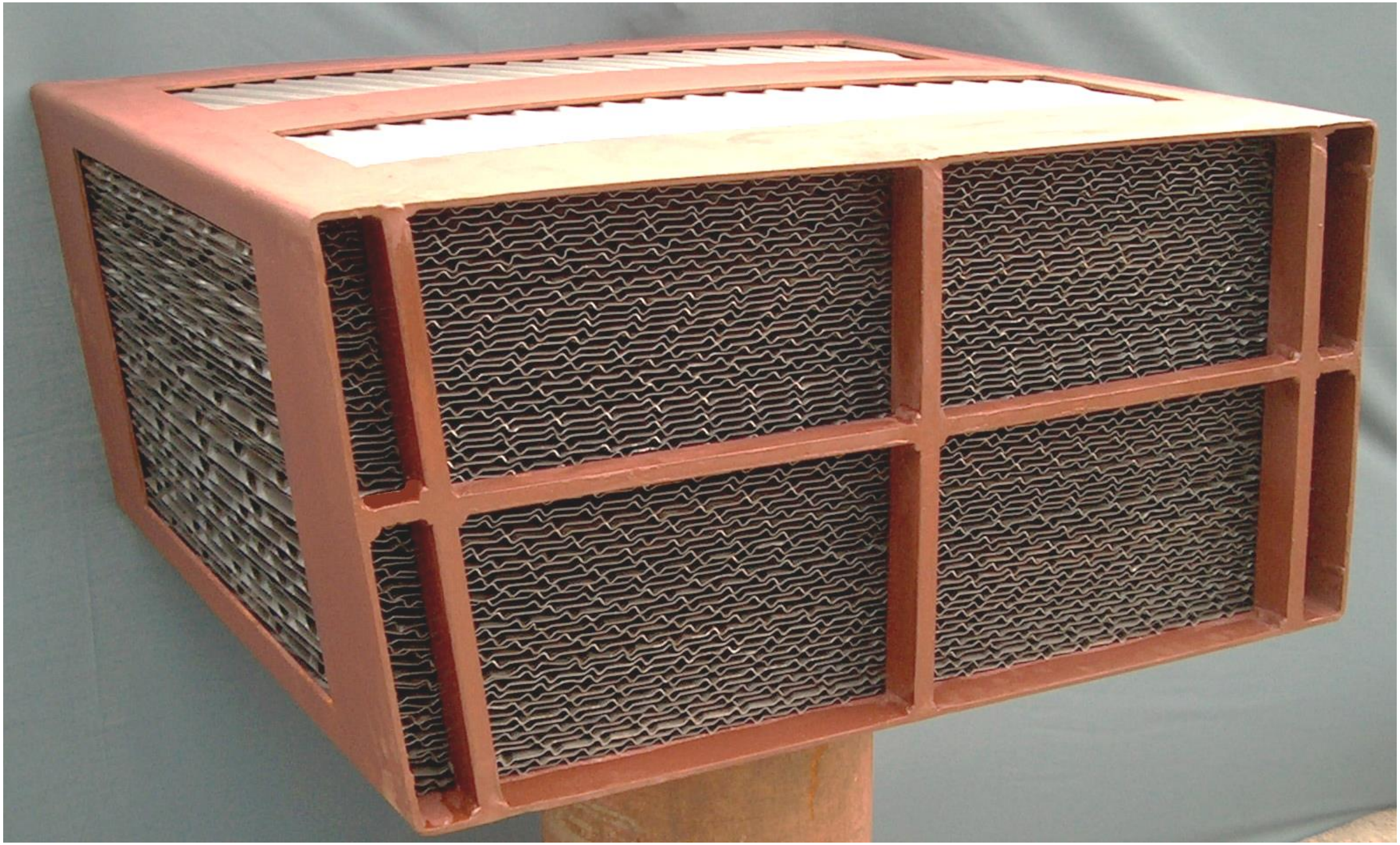


Regenerative APH

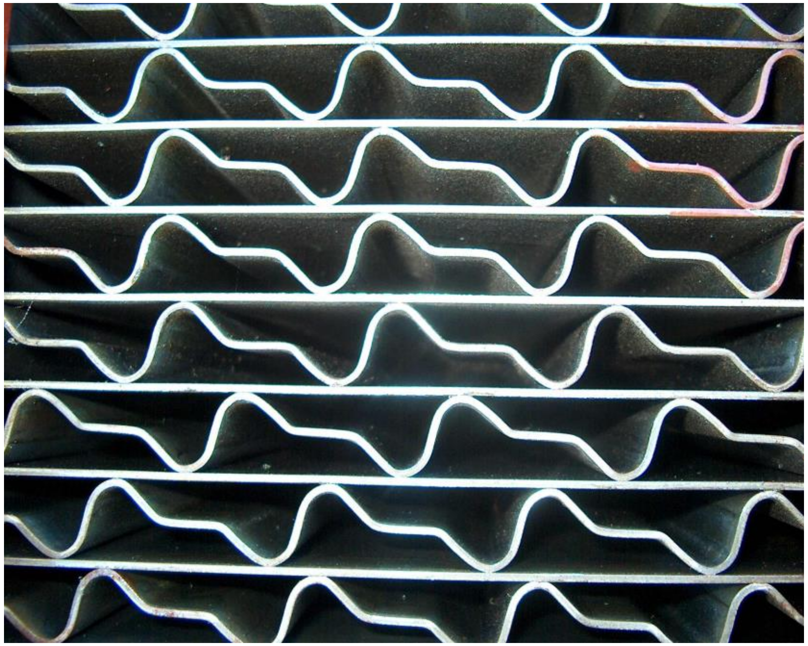


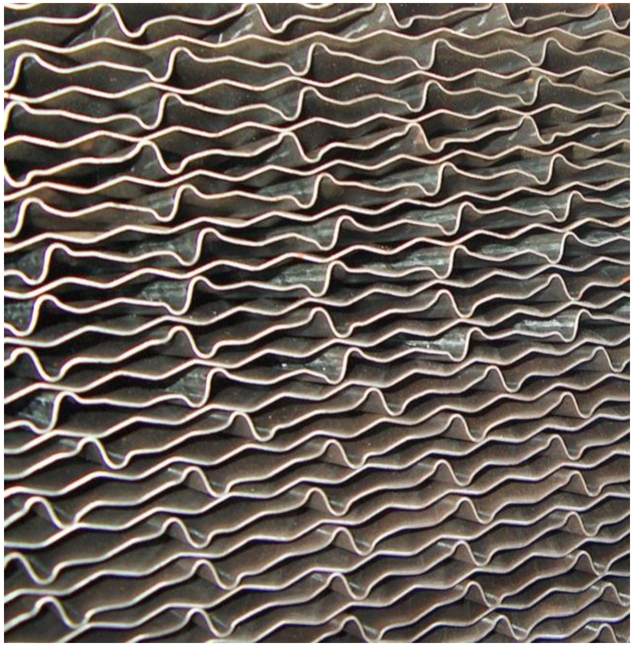

e the same basic design
tures.
Stay plate
Module shell plate
Full sector side removal container
Bolted flange assembly
l in a 210 MW Thermal Power Station





FNC Profile

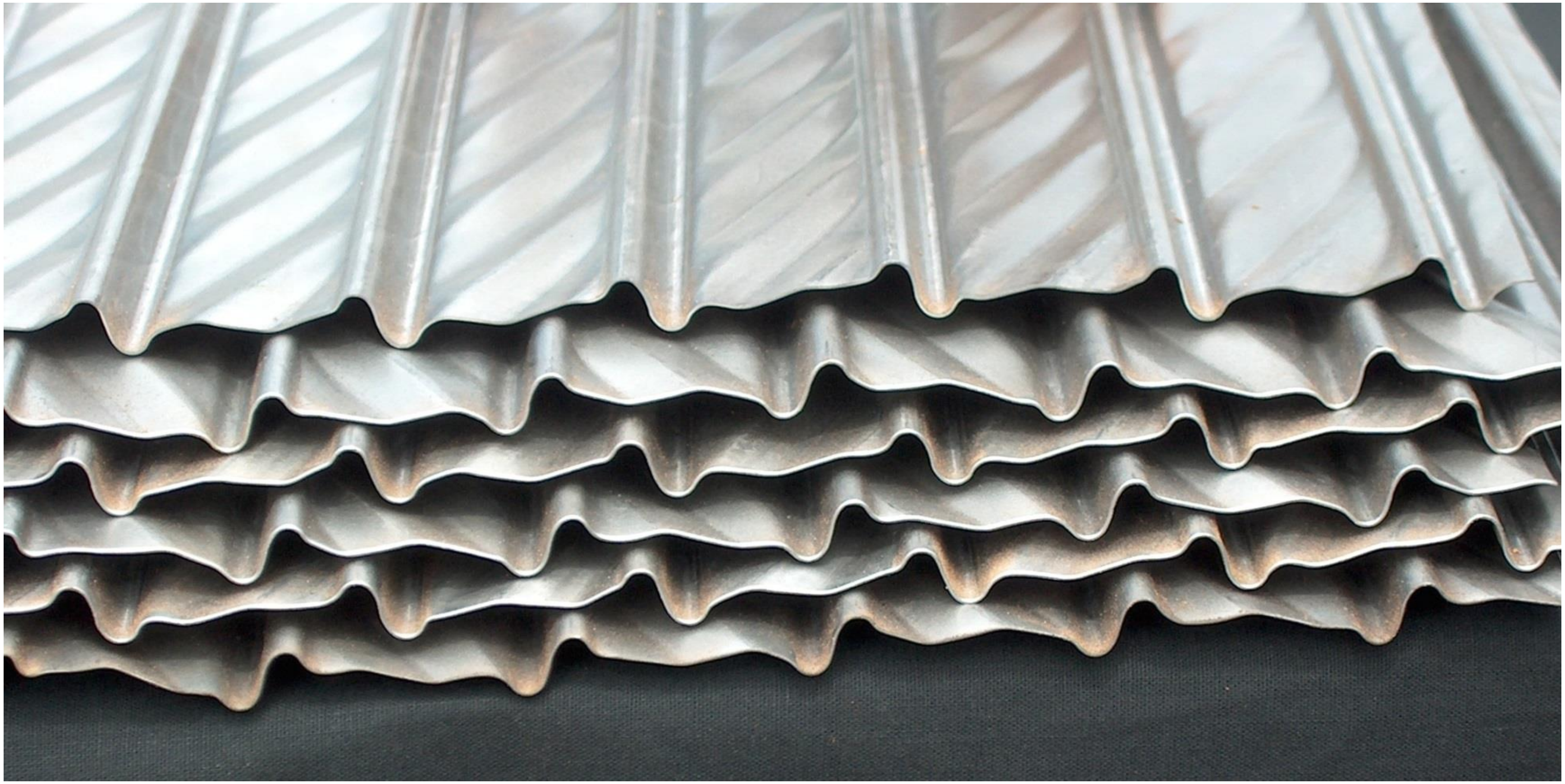




NF Profile
1.2 mm thick

DU Profile
0.8 mm thick

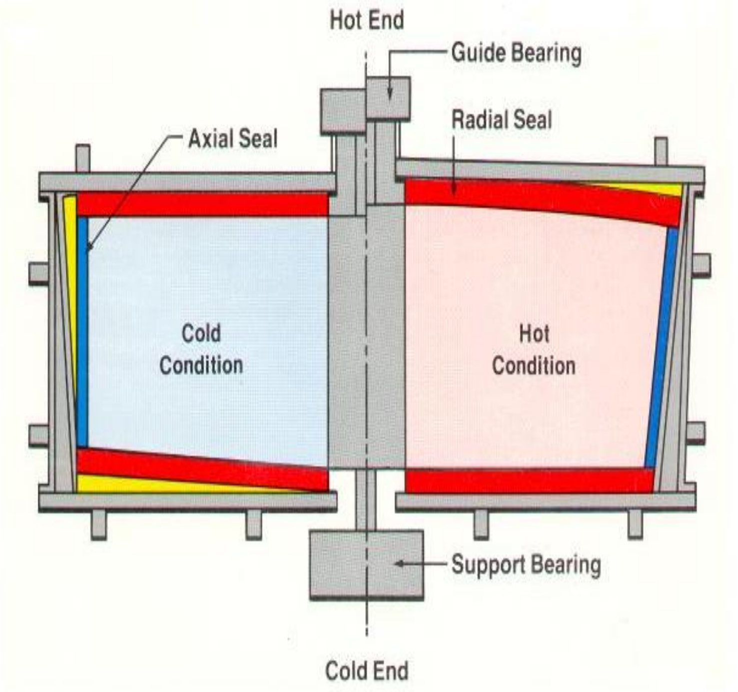
Change in Cold End Profiles



New Profile

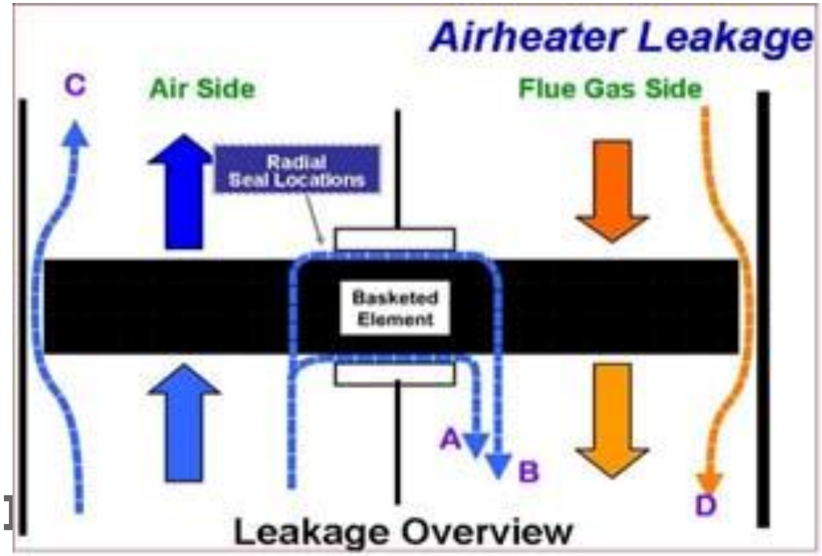
AH Leakage

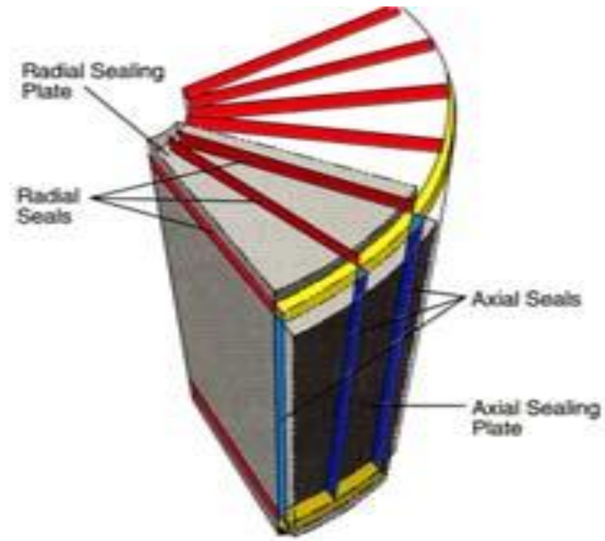
- The leakage of the high pressure air to the low pressure flue gas due to the Differential Pressure, increased seal clearances in hot condition, seal erosion/ improper seal settings.
- Direct – flow of air through gaps between rotating and fixed structure
- Leakage ≈ gap area x (density x ΔP)1/2
- Entrained – volume of air in porous elements carried via rotation from air side to gas side



Rotor Turndown – HE grows radially more than the CE, rotor goes outward and downward

Leakage paths





Reduced AH efficiency

Increased fan power consumption

Higher gas velocities that affect ESP performance

Loss of fan margins leading to inefficient operation and at times restricting unit loading

AH Leakage

Typically air heater starts with a baseline leakage of 6 to 10% after an overhaul.

- What we measure is mainly leakage through radial seals at hot & cold end.
- Leakage through circumferential seals is substantial and has a major effect on heat transfer but nominal effect on APC.
- Leakage is expressed as a % of inlet gas flow and not a % of fan input flow

Air Heater Leakage - Calculation

- This leakage is assumed to occur entirely between air inlet and gas outlet
- Empirical relationship using the change in concentration of O2 or CO2 in the flue gas

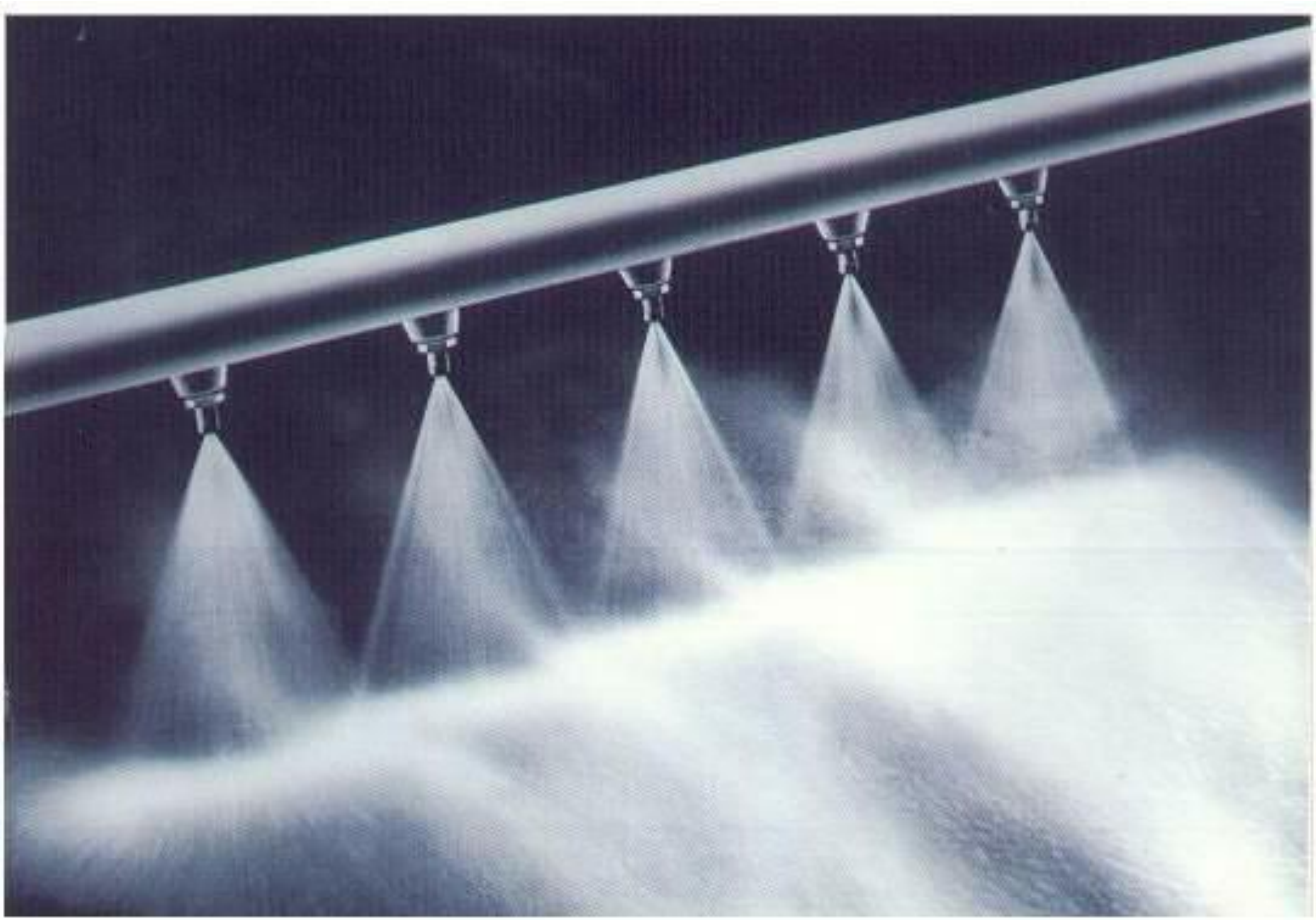
$$A_L = \frac{CO_{2\_in} - CO_{2\_out}}{CO_{2\_out}} * 0.9 * 100$$

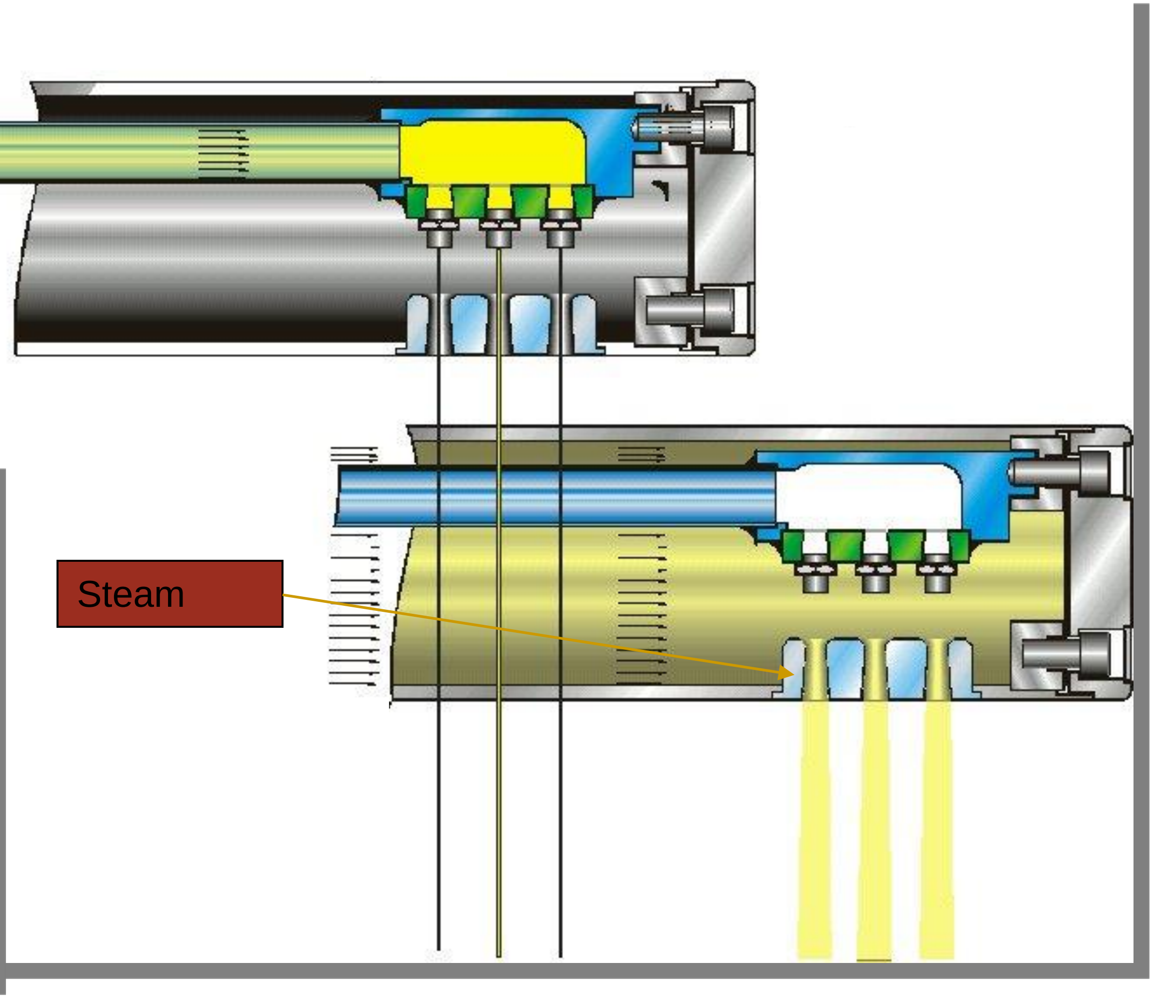
$$= \frac{O_{2\_out} - O_{2\_in}}{21 - O_{2\_out}} * 0.9 * 100$$

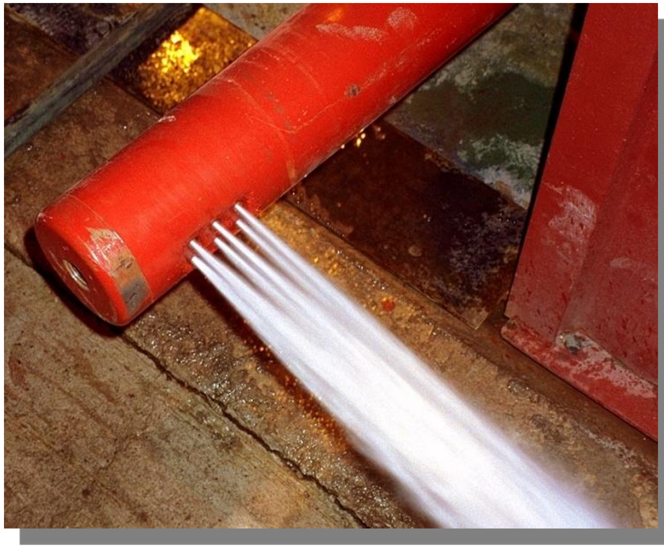
$$= \frac{5.7 - 2.8}{21 - 5.7} * 0.9 * 100$$

$$= 17.1\%$$

- Method of determination of O2 or CO2 should be the same at inlet and outlet wet or dry (Orsat)
- O_2 dry = O_2 wet / (1- FG Moisture)



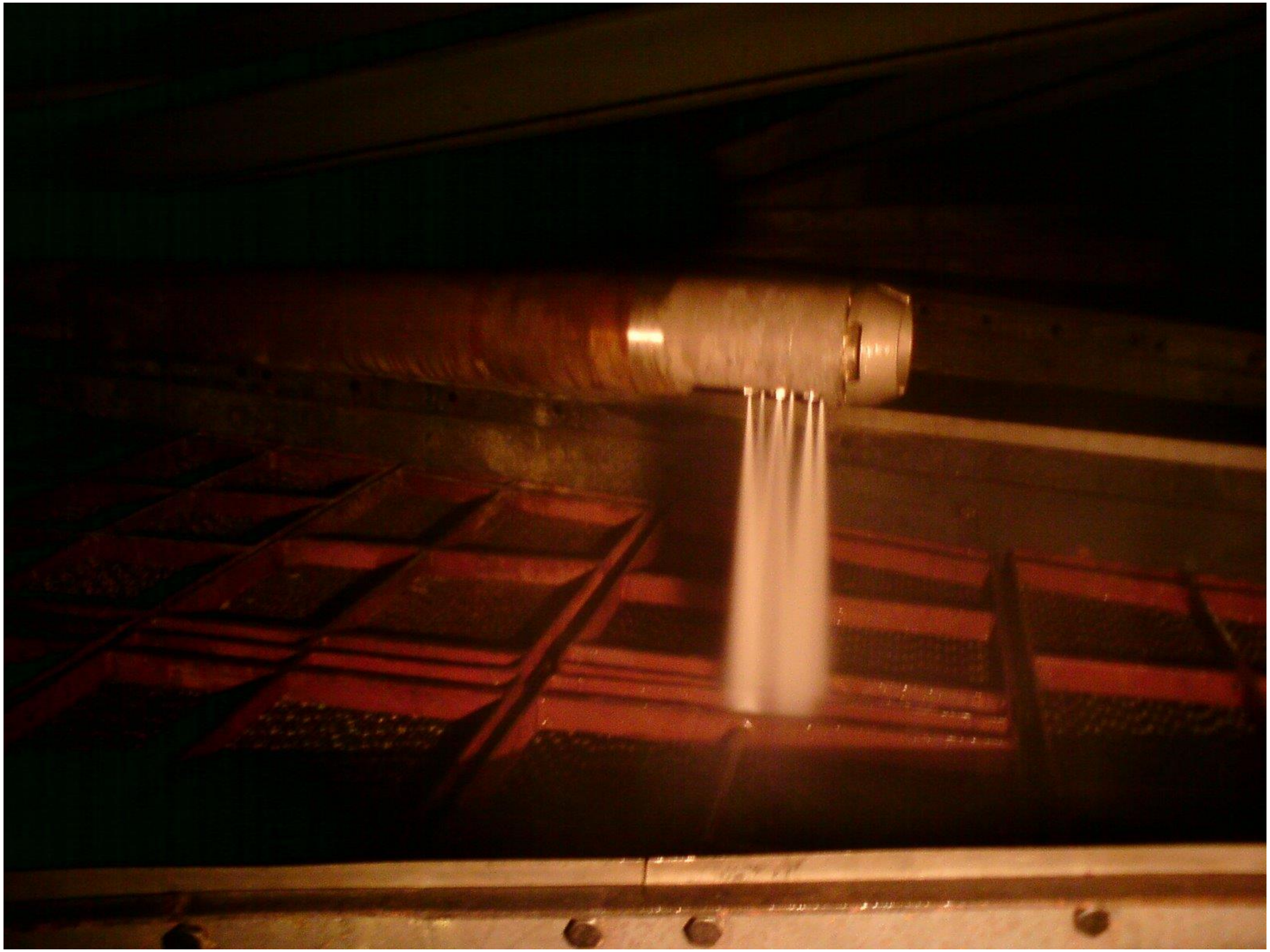




High Pressure Cleaning

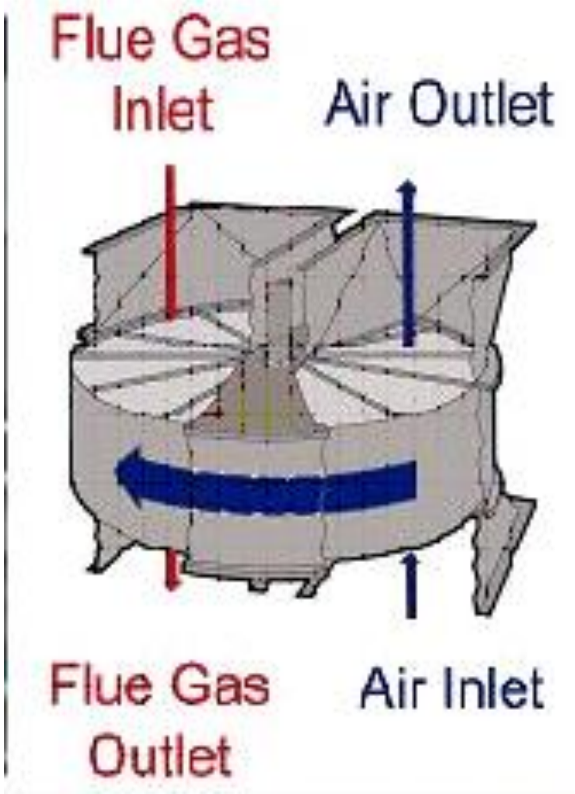
Cleaning device
Head design

- 14 bar soot blowing
- 100 - 140 bar HP wash
- Off-line washing
- On-line washing
- Fully retractable



Air Heater - Performance Indicators

- **Air-in-Leakage (~13%)**
- **Gas Side Efficiency (~ 68 %)**
- **X – ratio (~ 0.76)**
- **Flue gas temperature drop (~220^{0}C)**
- **Air side temperature rise (~260^{0}C)**
- **Gas & Air side pressure drops**



The indices are affected by changes in entering air or gas temperatures, their flow quantities and coal moisture.

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$$= 17.1\%$$

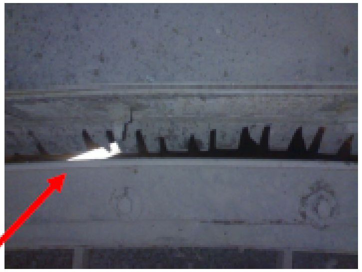
- Method of determination of O2 or CO2 should be the same at inlet and outlet wet or dry (Orsat)
- O_2 dry = O_2 wet / (1- FG Moisture)

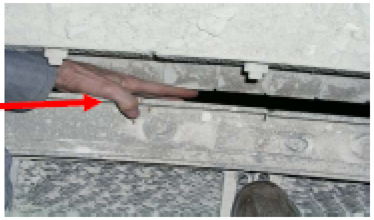
Air Heater Leakage

Air Heater Leakage ≈ *gap area x (density x ΔP)*$^{1/2}$

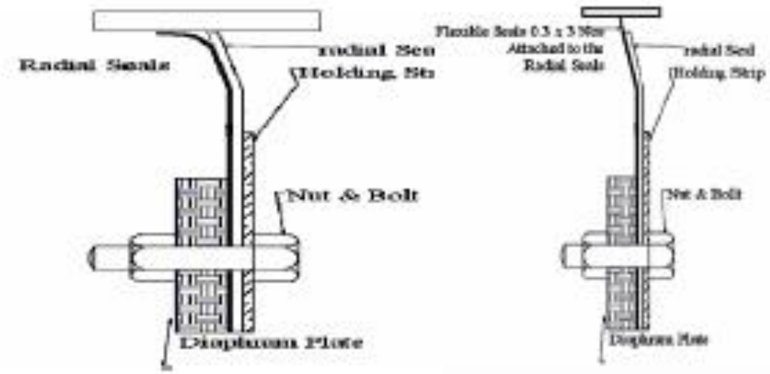
$$= \frac{CO_{2in} - CO_{2out}}{CO_{2out}} * 0.9 * 100 \quad = \frac{O2out - O2in}{(21 - O2out)} * 0.9 * 100$$

- *Typically air heater starts with a baseline leakage of 6 to 10% after an overhaul.*
- *What we measure is mainly leakage through HE/CE radial seals.*
- *Leakage is expressed as a % of inlet gas flow and not a % of fan input flow*
- *Leakage through circumferential seals is substantial and has a major effect on heat transfer but nominal effect on APC.*

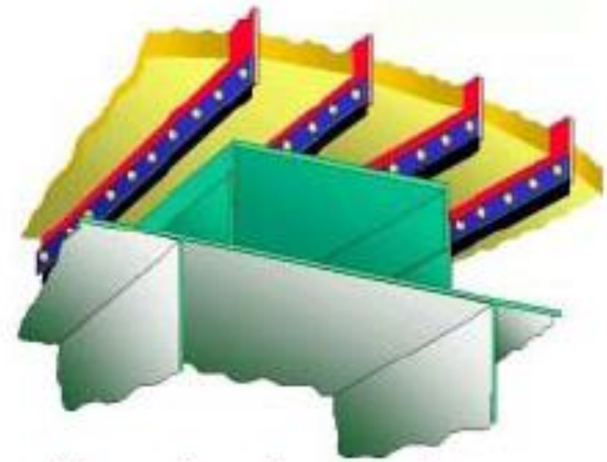




Air Heater Leakage Reduction



Haste alloy multiple leaf seals



Double seals reduce leakages
(Provided in PAPH of all recent units)

Double Sealing

- Two sectors between sealing surfaces
- Leakage ≈ gap area x (density x ΔP)1/2
- Pressure differential between sectors is halved
- 30% reduction in leakages vis-à-vis single seals
- Reduction in auxiliary power consumption

Gas Side Efficiency

Ratio of Gas Temperature drop across the air heater, corrected for no leakage, to the temperature head.

= (Temp drop / Temperature head) * 100

where Temp drop = Tgas in -Tgas out (no leakage); Temp head = Tgasin - T air in

Gas Side Efficiency = (333.5-150.5) / (333.5-36.1) = 61.5 %

Tgas out (no leakage) = The temperature at which the gas would have left the air heater if there were no AH leakage

$$= \frac{AL * Cpa * (Tgas\ out - Tair\ in)}{Cpg * 100} + Tgas\ out$$

AH leakage – 17.1%, Gas In Temp – 333.5 C, Gas Out Temp – 133.8 C, Air In Temp – 36.1 C

$$Tgasnl = \frac{17.1 * (133.8 - 36.1)}{100} + 133.8 = 150.5\ C$$

Thermal Performance - Air Heater Baskets

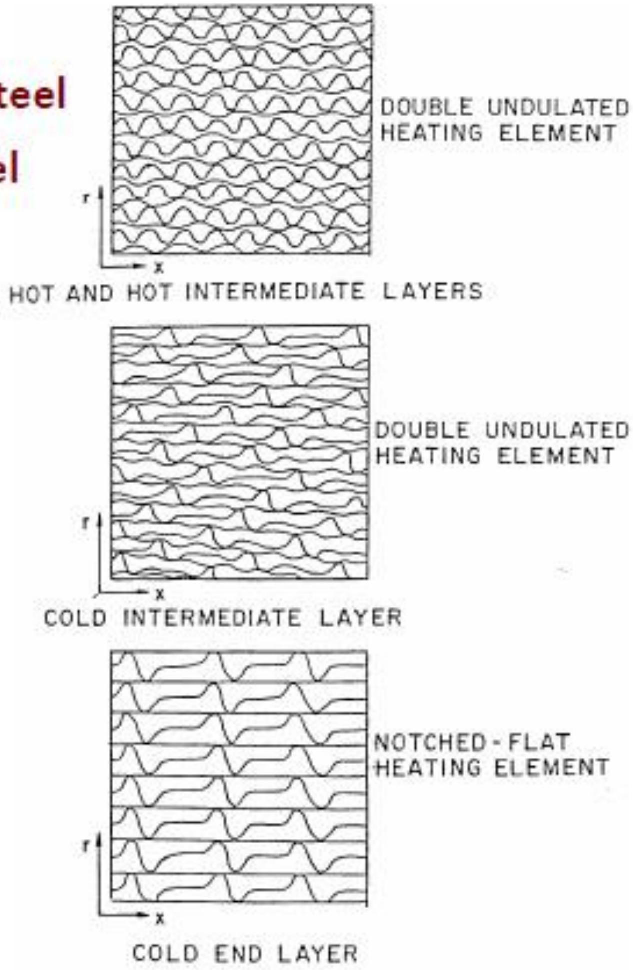
Hot/Inter – Double Undulated

Hot/Int Elements: C Steel

Cold End : Corten Steel

Seals: Corten Steel

Rotor/Housing:CSteel



Cold End–Notched Flat

Note the side wrapping on Cold end baskets.

X – Ratio

Ratio of heat capacity of air passing through the air heater to the heat capacity of flue gas passing through the air heater.

$$W_{air\ out} * C_{pa} * DT_a = W_{gas\ in} * C_{pg} * DT_g$$

$$X\ ratio = \frac{W_{air\ out} * C_{pa}}{W_{gas\ in} * C_{pg}} = \frac{T_{gas\ in} - T_{gas\ out\ (no\ lkge)}}{T_{air\ out} - T_{air\ in}}$$

X-Ratio depends on

- moisture in coal, air infiltration, air & gas mass flow rates
- leakage from the setting
- specific heats of air & flue gas

X-ratio does not provide a measure of thermal performance of the air heater, but is a measure of the operating conditions. A low X-ratio indicates either excessive gas weight through the air heater or that air flow is bypassing the air heater.

A lower than design X-ratio leads to a higher than design gas outlet temperature & can be used as an indication of excessive tempering air to the mills or excessive boiler setting infiltration.

Pressure drops across air heater

- *Air & gas side pressure drops change approximately in proportion to the square of the gas & air weights through the air heaters.*
- *If excess air is greater than expected, the pressure drops will be greater than expected.*
- *Deposits / choking of the basket elements would lead to an increase in pressure drops*
- *Pressure drops also vary directly with the mean absolute temperatures of the fluids passing through the air heaters due to changes in density.*

AH Performance Indices

Leakage	Weight of Air passing from Air Side to Gas Side (Gas Out Flow - Gas In Flow)
% Leakage	(Air Leakage / Gas In Flow) x 100 (%O_2Gas Out - %O_2Gas In) / (21 - %O_2Gas out) x 90
Air Temp Rise	Increase in Temp of Air in passing through the AH = Tao - Tai
Gas Temp Drop	Decrease in Temp of Gas in passing through the AH = Tgi - Tgo
Temperature Head	Temp of gas entering minus Temp of Air entering AH = Tgi - Tai
Tgas out (no leakage)	(AL * Cpa * (Tgas out - Tair in) / Cpg*100) + Tgas out
Gas Side Efficiency	Ratio of Gas Temp Drop to Temperature Head. (Tgi - Tgo) / (Tgi - Tai)
Air side efficiency	Ratio of Air Temp Rise to Temperature Head. (Tao - Tai) / (Tgi - Tai)
X - Ratio	Ratio of the Heat Capacity of air passing through the AH to Heat Capacity of the Gas passing through the AH (Wao x CpA) / (Wgi x CpG) ; (Tgi - Tgo) / (Tao - Tai)

Data Collected / Measured

O_2 or CO_2 in FG at AH Inlet

O_2 or CO_2 in FG at AH Outlet

Temperature of gas entering/leaving air heater

Temperature of air entering/leaving air heater

Diff. Pressure across APH on air & gas side

CO_2 measurement is preferred due to high absolute values; In case of any measurement errors, the resultant influence on lkg. calculation is small.

Factors affecting APH performance

- Operating excess air levels
- PA/SA ratio
- Inlet air / gas temperature
- Coal moisture
- Air ingress levels
- Upstream ash evacuation
- Soot blowing
- No. of mills in service
- Maintenance practices

Excess Air

- 20 % excess air is recommended for boiler operation; Actual optimal O2 varies from boiler to boiler
- O2 probes at economizer exit can be influenced by air infiltration. O2 reading in control room may be much higher than actual O2 in furnace. Air-in-leak through boiler casing fools the panel operator & Zironia probes, triggering reduction in total air.
- O2 measurement feedback using orsat is on dry basis while insitu zirconia measurement is on wet basis. No comparison.

Recommended

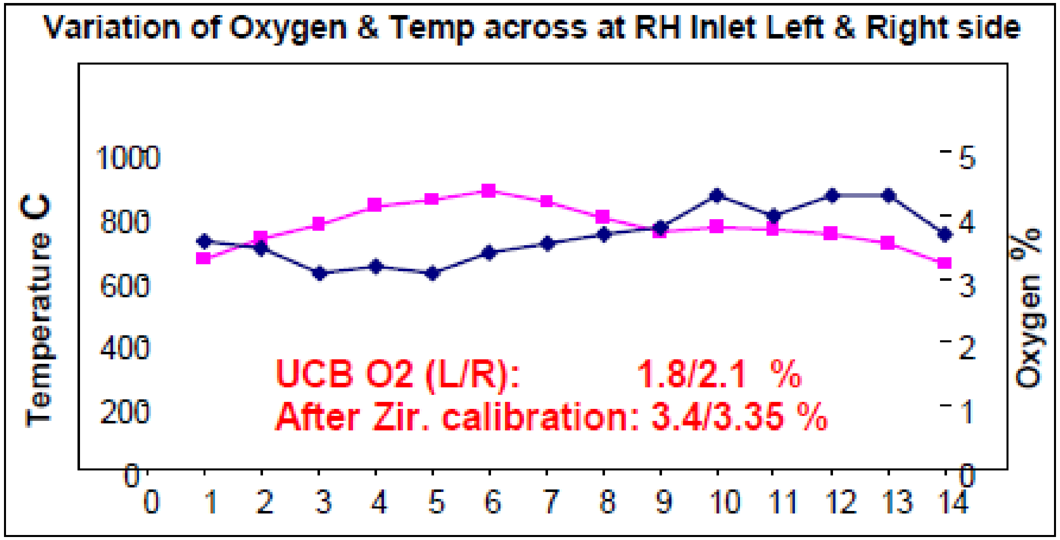
•2 Zirconia probes in each Flue gas duct at Eco outlet

•Periodic calibration of the probes with Cal gases

•Grid survey to ensure representativeness

•CO monitors at Eco Outlet / ID fan discharge

Excess air is amongst the most important factors affecting boiler performance – Periodic calibration of Zirconia probes



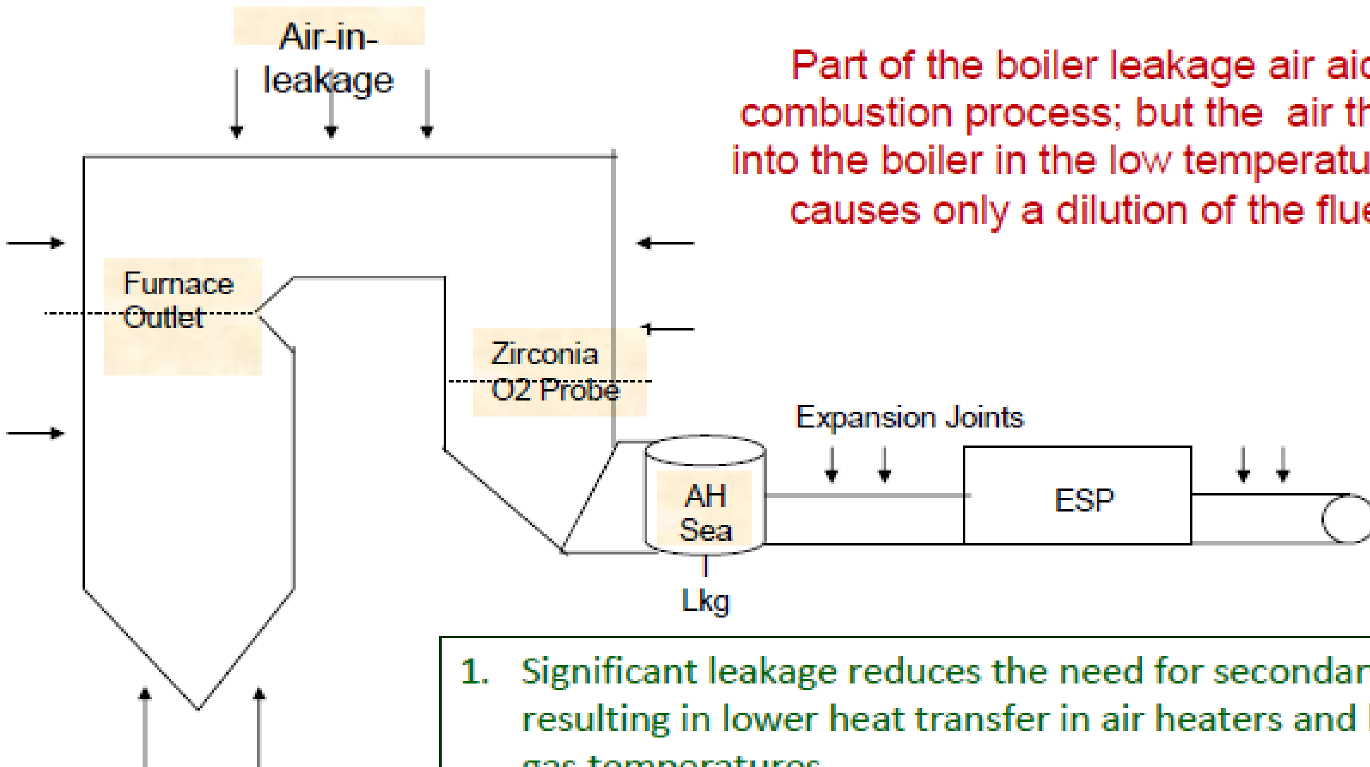
Low excess air operation ~

- unstable combustion (furnace puffs)
- slagging of waterwalls and SH
- increased CO / unburnts

High excess air operation ~

- Increased boiler losses
- High SH / RH temperatures
- Higher component erosion

Boiler Air Ingress – An Issue for old aging boilers



Part of the boiler leakage air aids the combustion process; but the air that leaks into the boiler in the low temperature zones causes only a dilution of the flue gas.

1. Significant leakage reduces the need for secondary air, resulting in lower heat transfer in air heaters and high exit gas temperatures.
2. Leakage from penthouse and ductwork affects reading of zirconia probes at Eco outlet.

210 MW Unit – Air In Leakage Points

Many times units are forced to operate at lower excess air with load restrictions on account of increased air ingress in boiler & ducts.

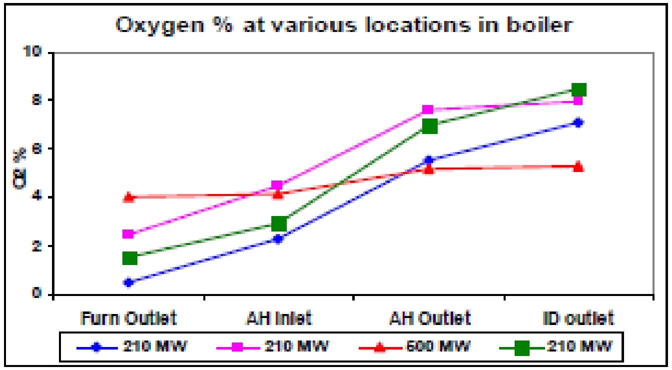
Large cracks in Bottom Hopper Seal Trough seal plates and trough connections to hoppers

Sagging Ceiling Tubes cause roof seals to fail and ash cooling and removal can take up a substantial time of overhaul duration. Leakage reduces the temperature throughout convection pass and SH/RH .

Eroded leaking Gas duct affect ID margins

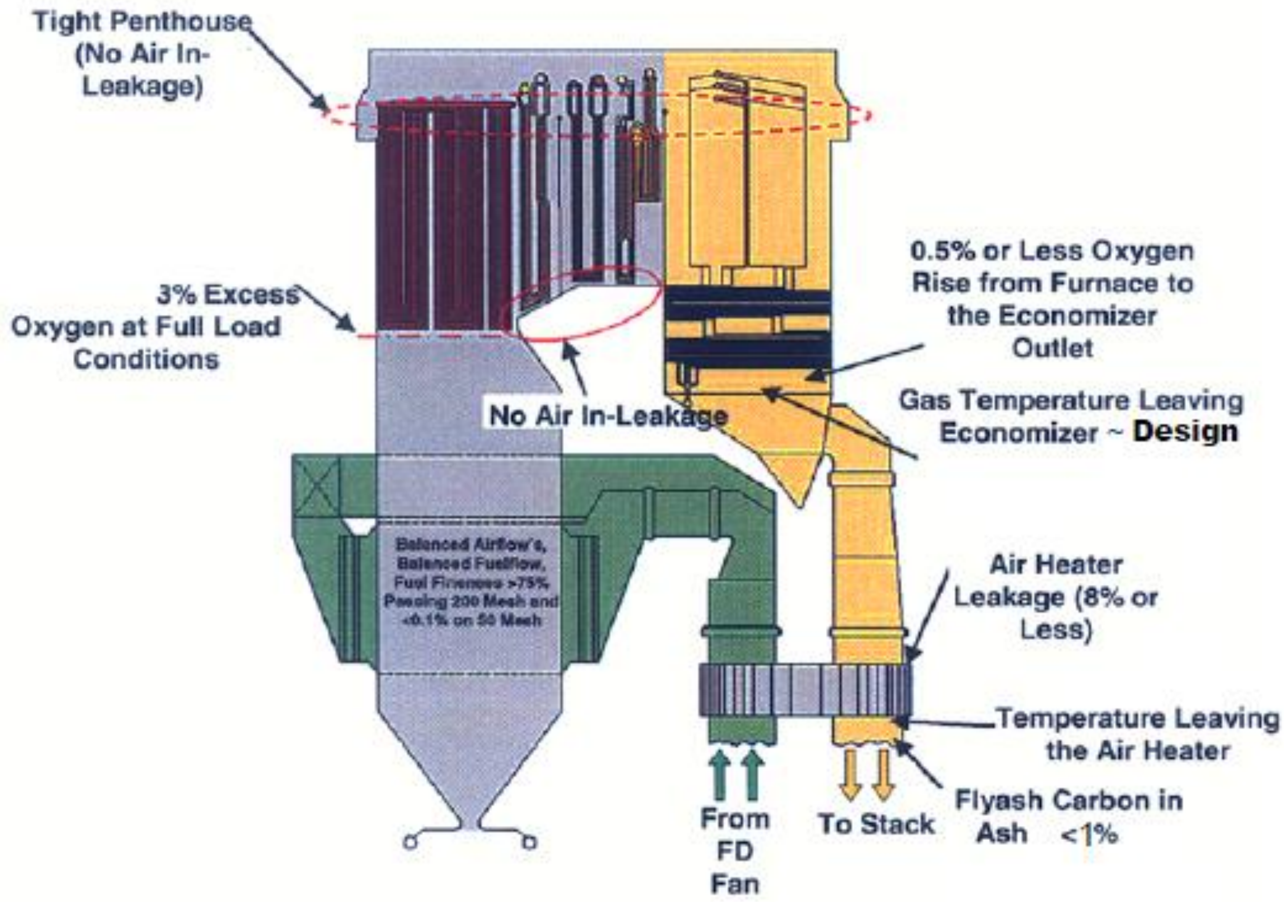
Boiler Air Ingress

Air ingress is quantified by the increase in oxygen % in flue gas; The temperature drop of the flue gas from air heater outlet to ID fan discharge also provides an indication of the same.



- Air tightness test by furnace / ducts pressurization
- Proper inspection after removing insulation
- Thickness survey of ducts by D-metering
- Comprehensive repairs in ducts & hoppers
- Replacement of Expansion joints during overhauls

Optimized Boiler



Thanks

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