CFB Boiler
for
TCP, Thailand.

General Overview

Jyrki Appelgren

Combustion systems
2006
- Various solid fuel combustion systems
- CFB Boiler introduction

The first known boiler

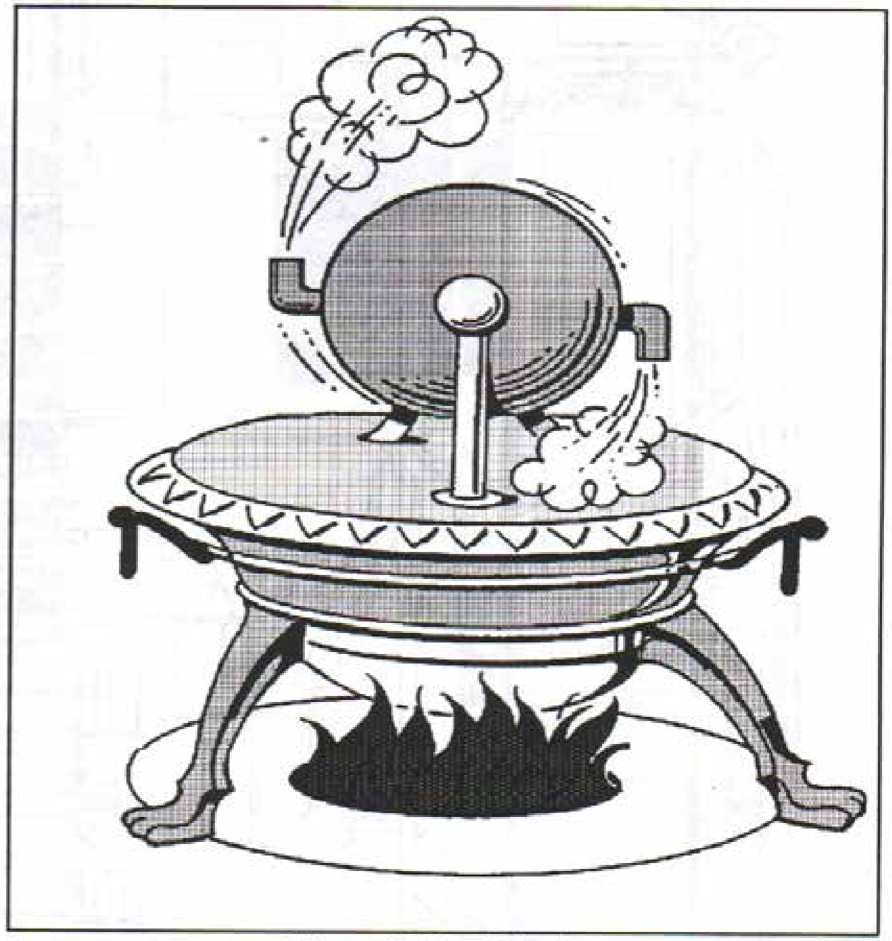
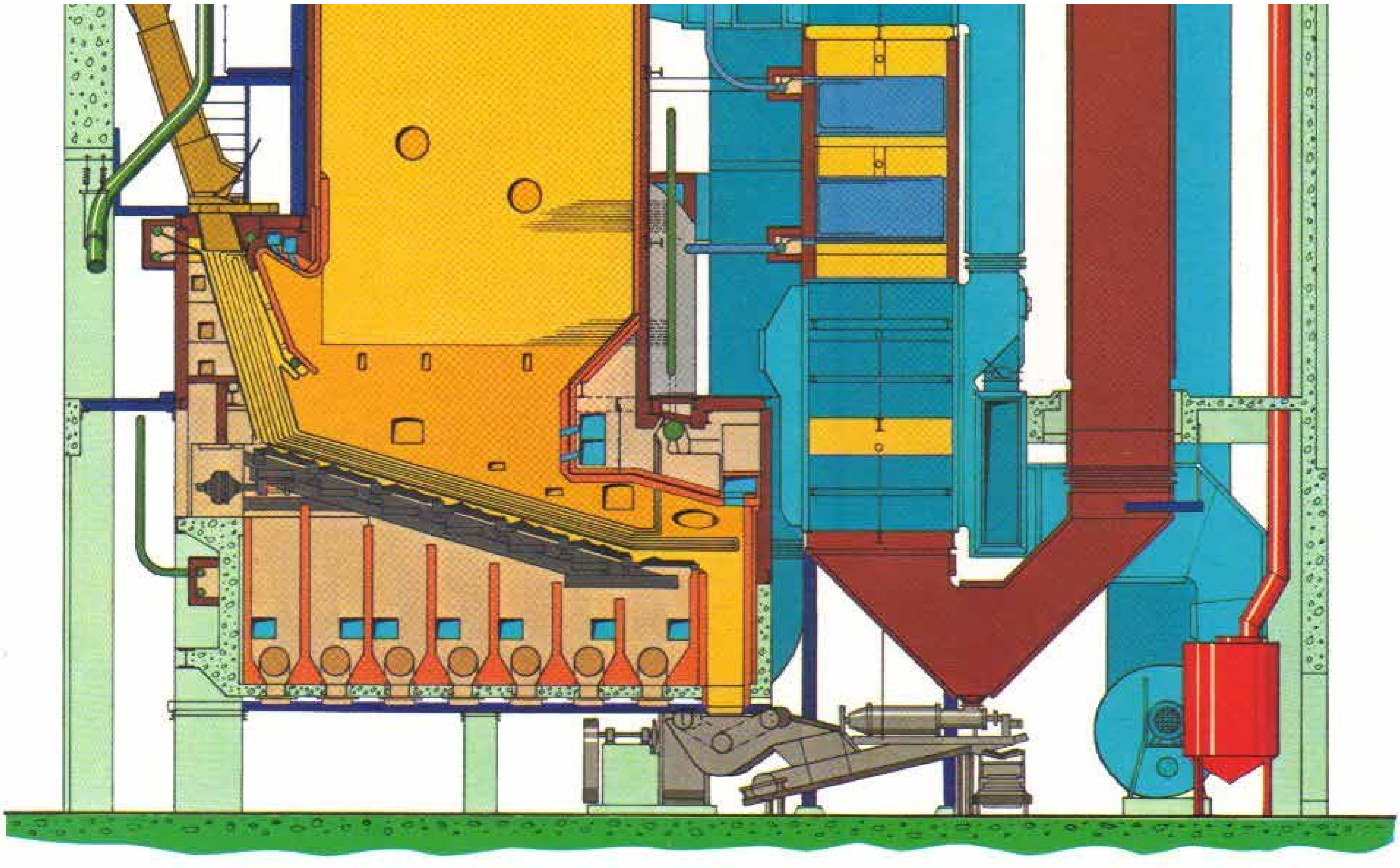


Figure 1 Hero's Engine

Stoker type boilers



Pulverized coal combustion – PC-boilers

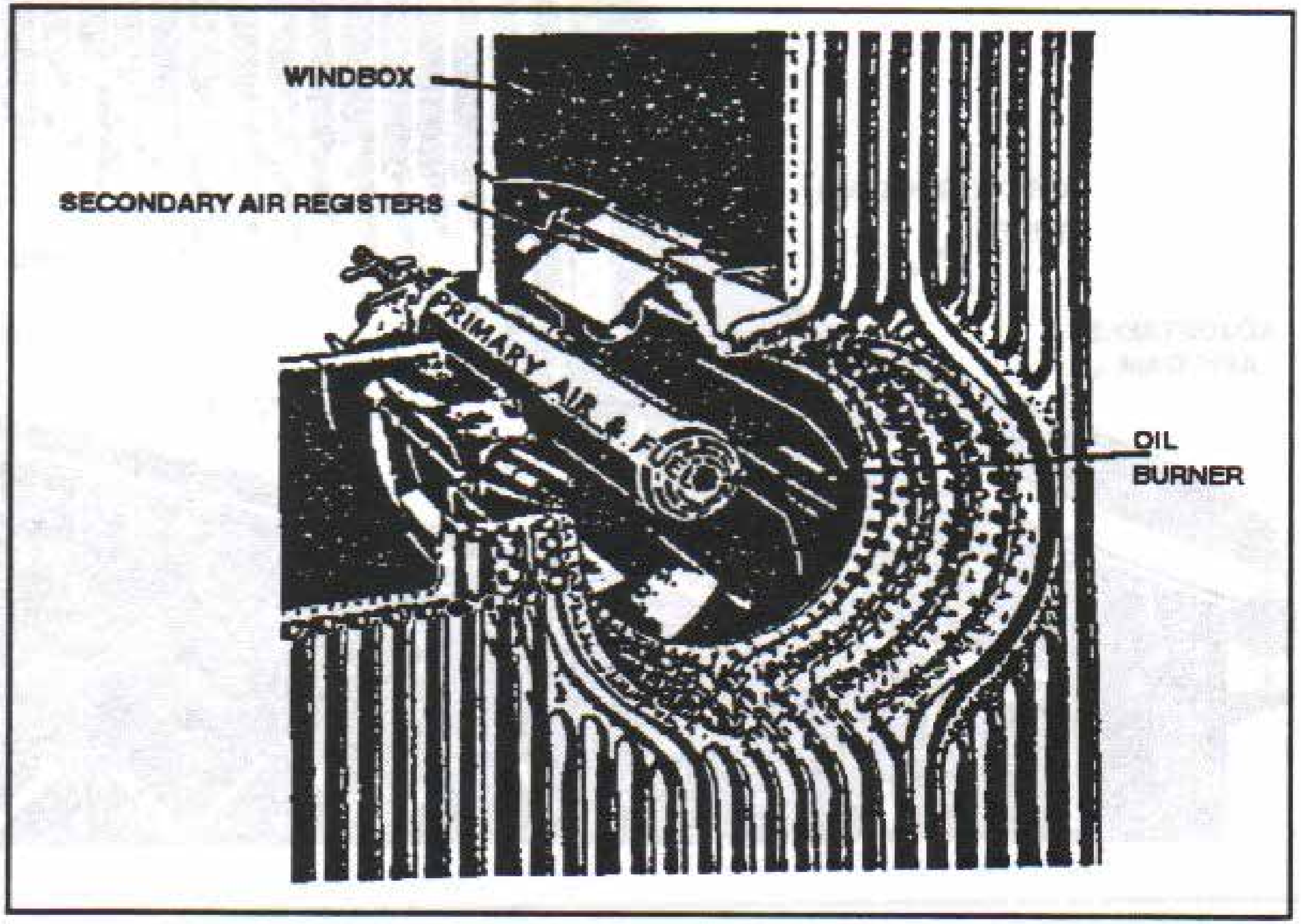


Figure 5 Typical Coal-firing Burner

Cyclones

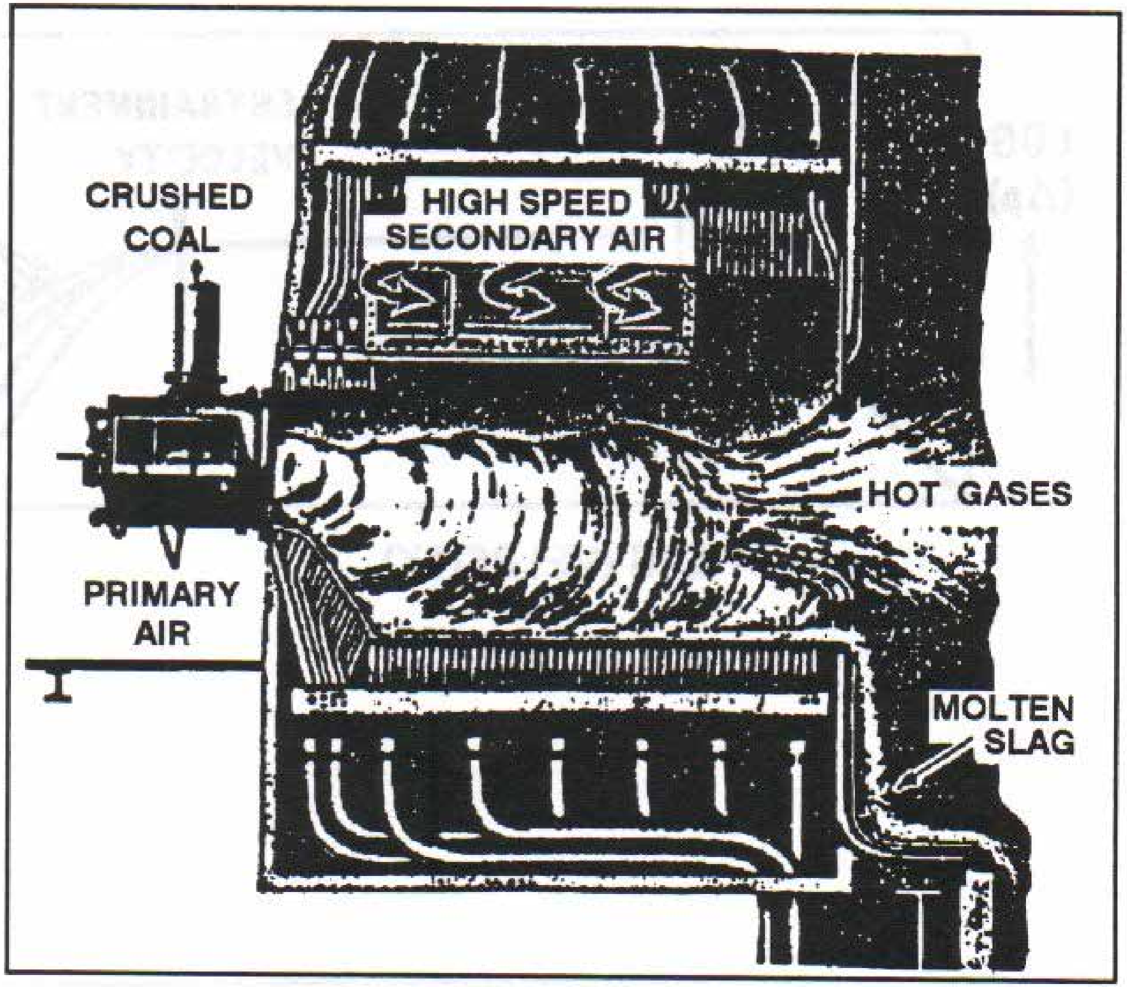


Figure 7 Typical Cyclone Burner

Fluidized beds

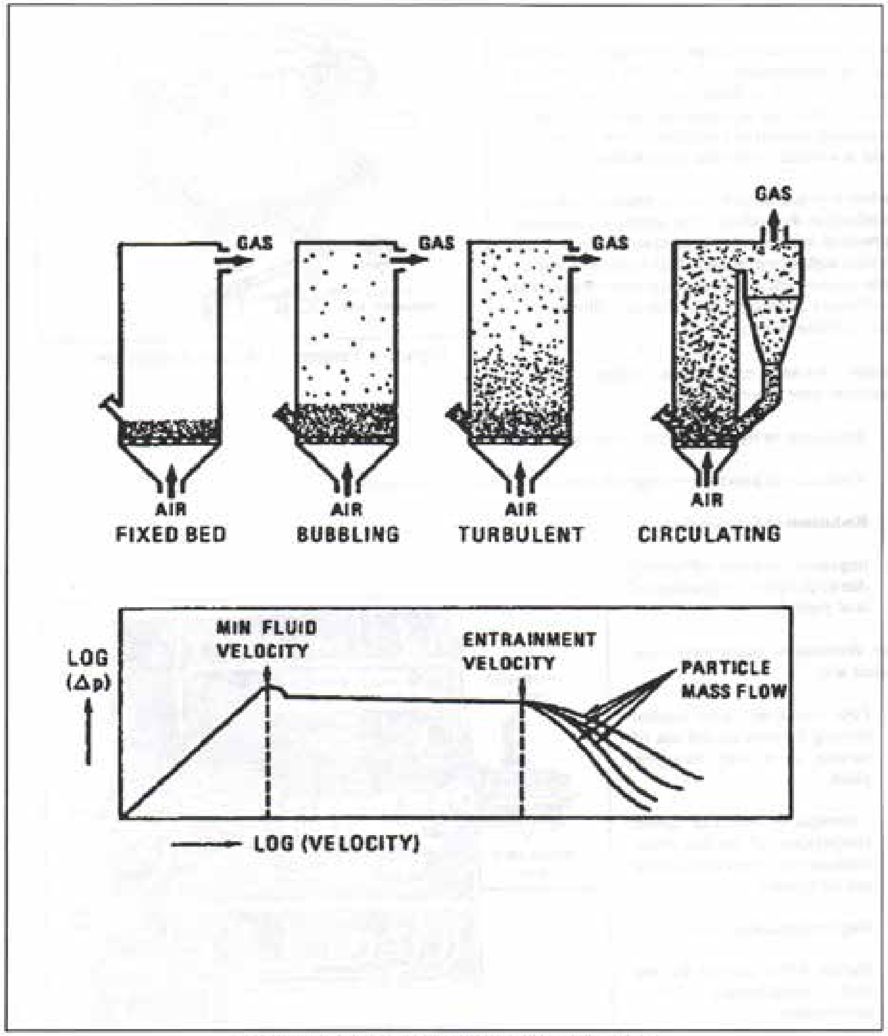
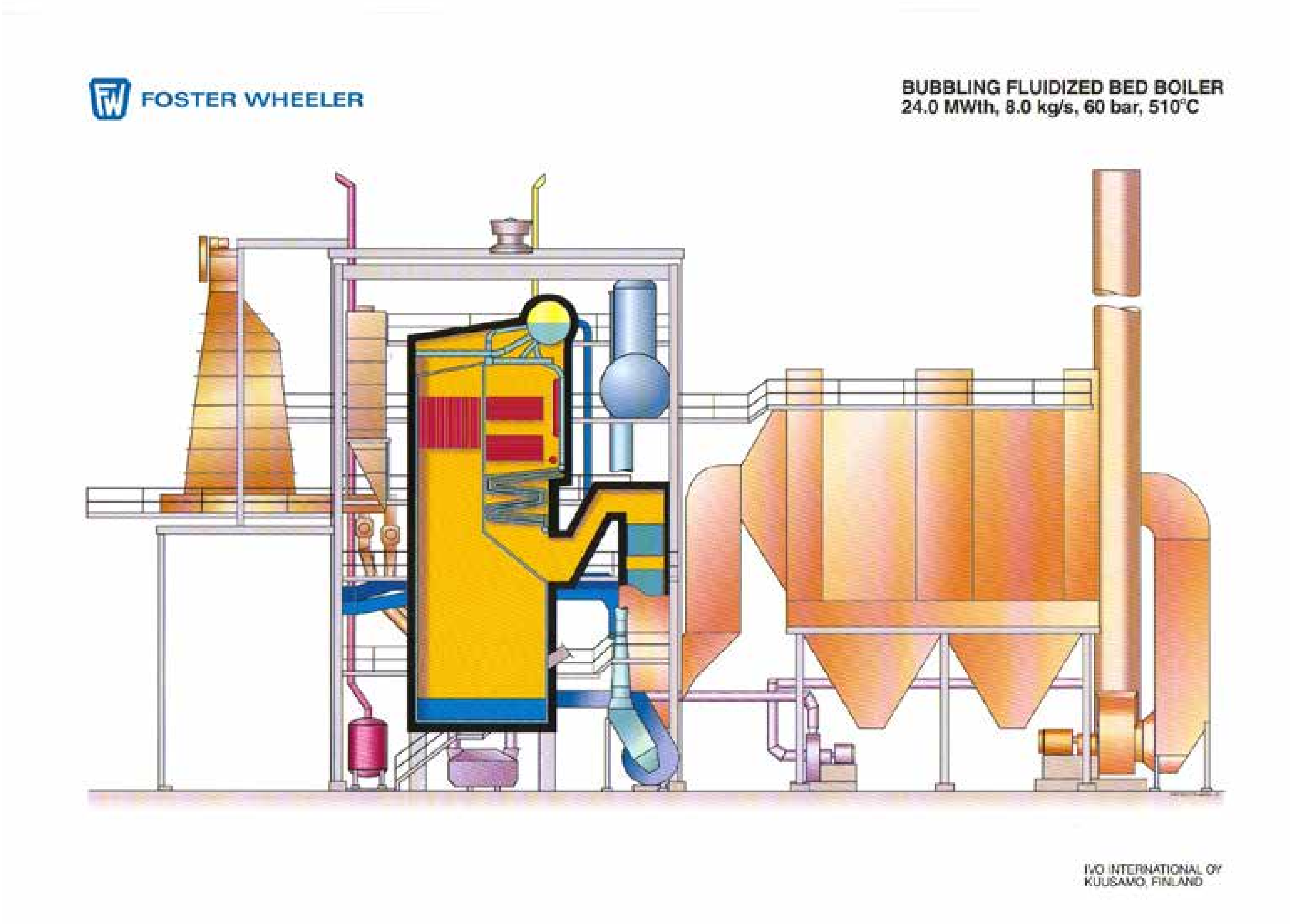


Figure 8 Fluidized Bed Combustion Systems

Bubbling beds – BFB-boilers



CFB Boiler Introduction

Subject for presentation:

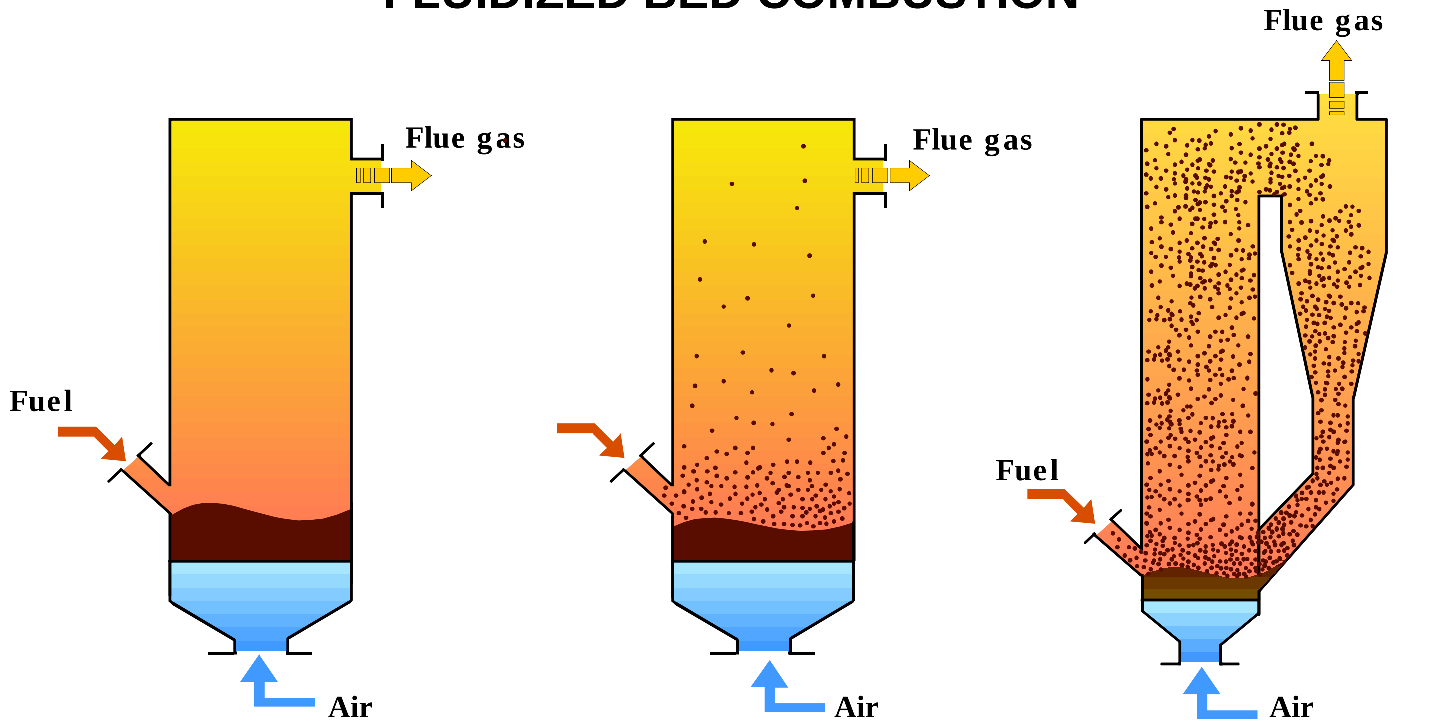
CFB Boiler

- CFB Boiler process
- Fuel selection
- Combustion
- Emissions
- References

CFB Boiler Combustion

FOSTER WHEELER

FLUIDIZED BED COMBUSTION



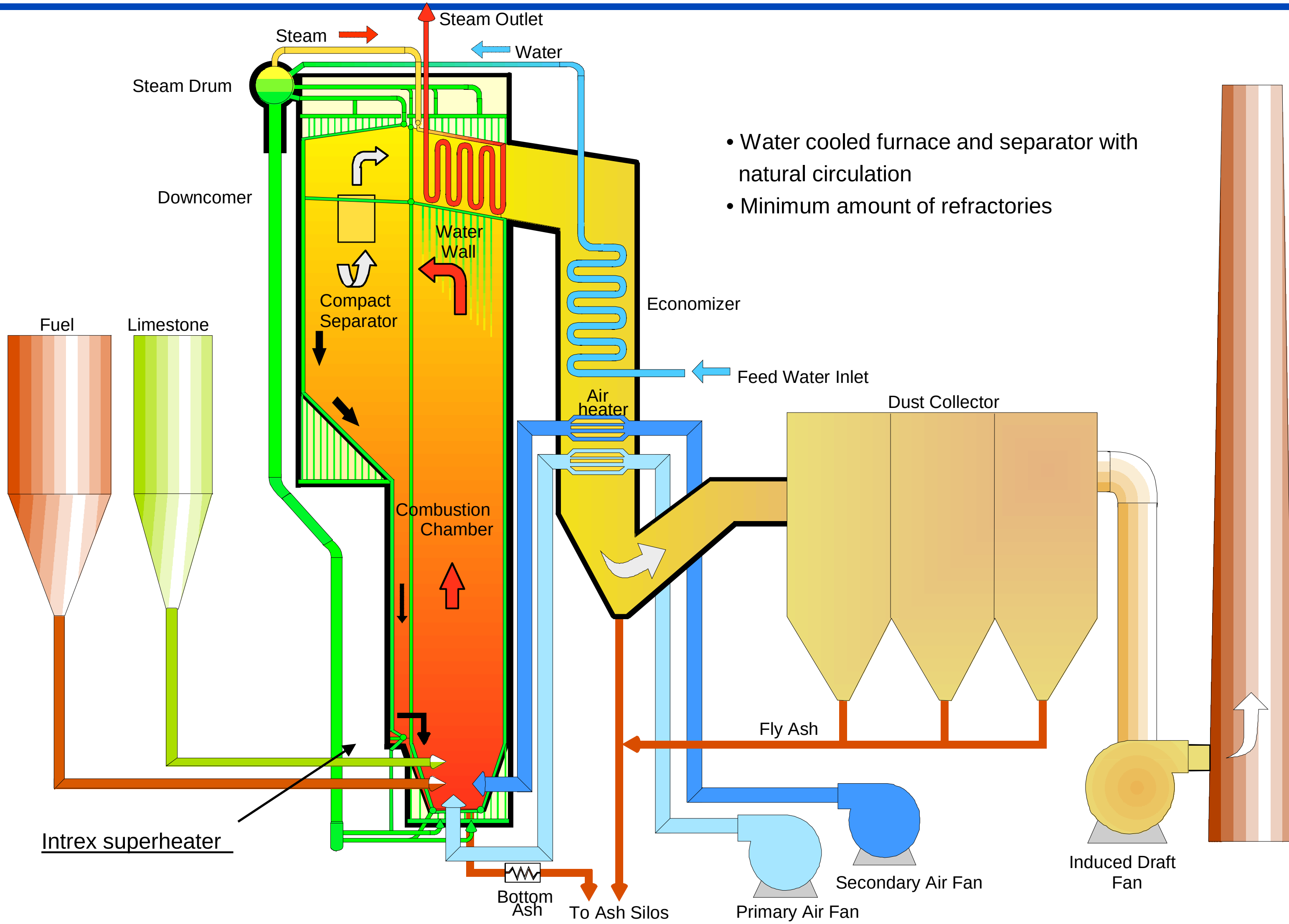
FIXED BED

BUBBLING FLUIDIZED BED

CIRCULATING FLUIDIZED BED

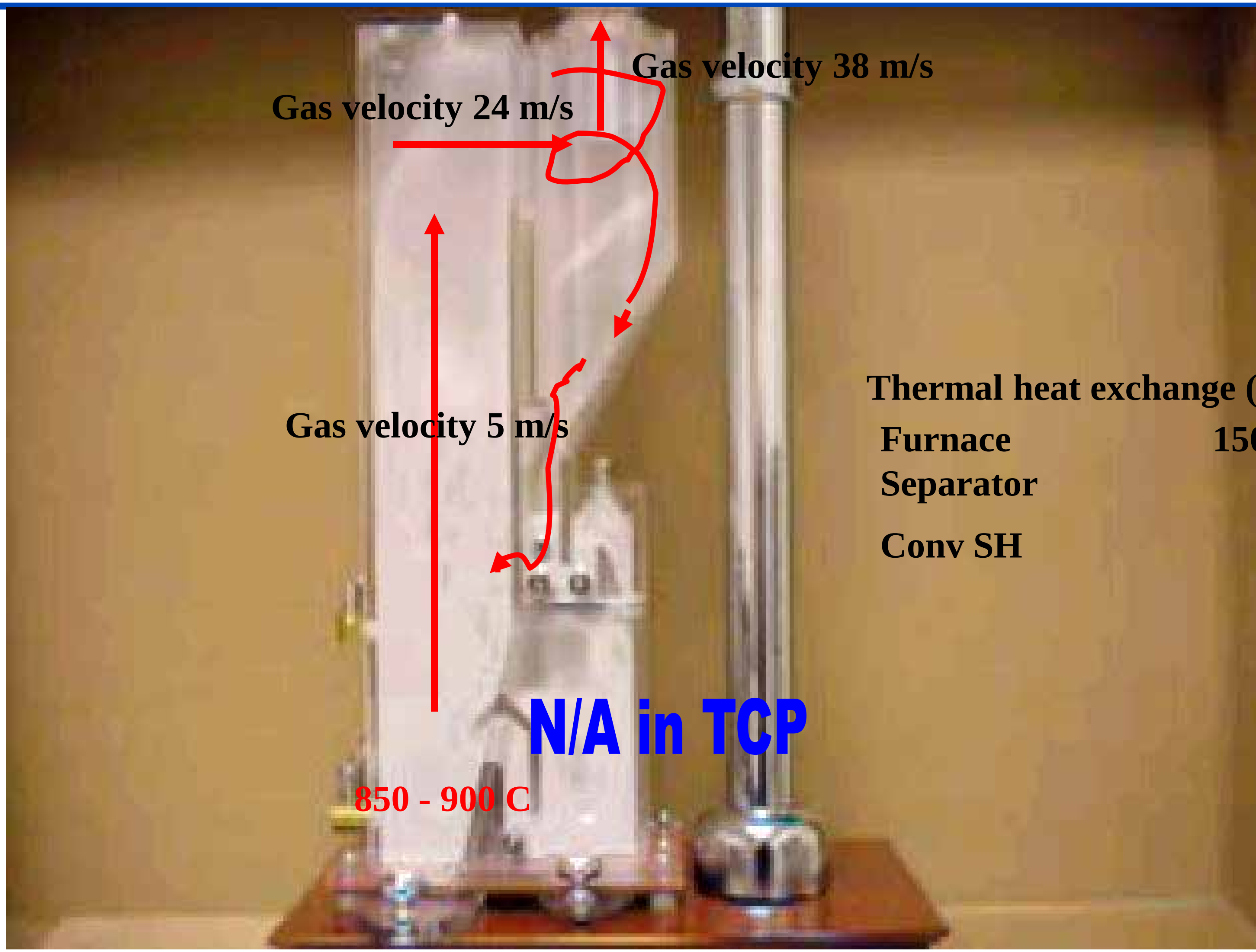
Intranet/eng/fbt/fbcom.ppt/1100

CFB Boiler overview



- Water cooled furnace and separator with natural circulation
- Minimum amount of refractories

CFB Hot Loop

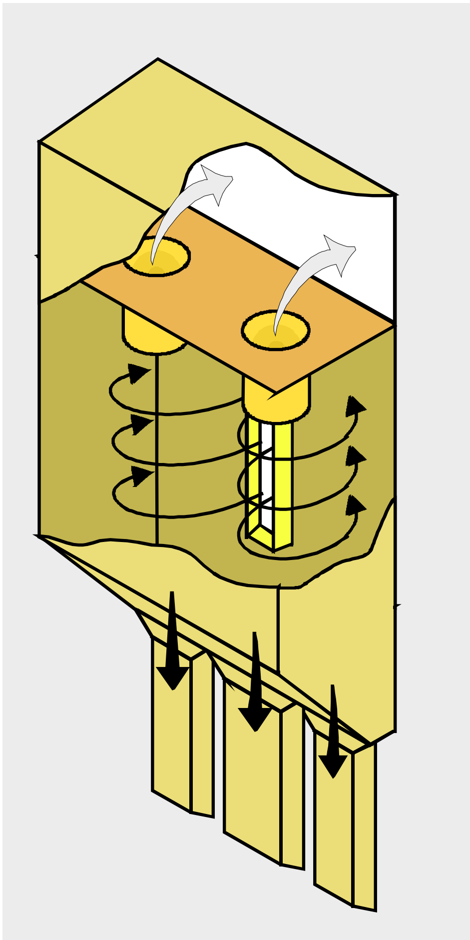


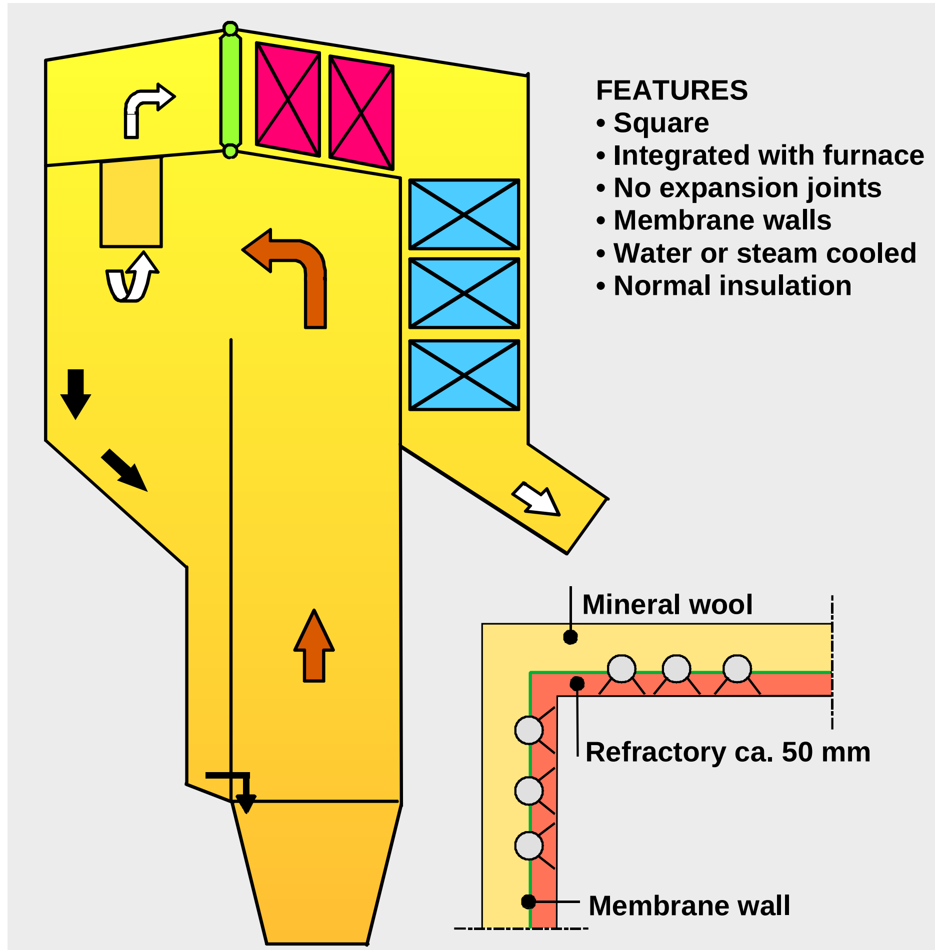
Thermal heat exchange (very typical):

Furnace	150 – 160 W/m2
Separator	25 W/m2
Conv SH	60 W/m2

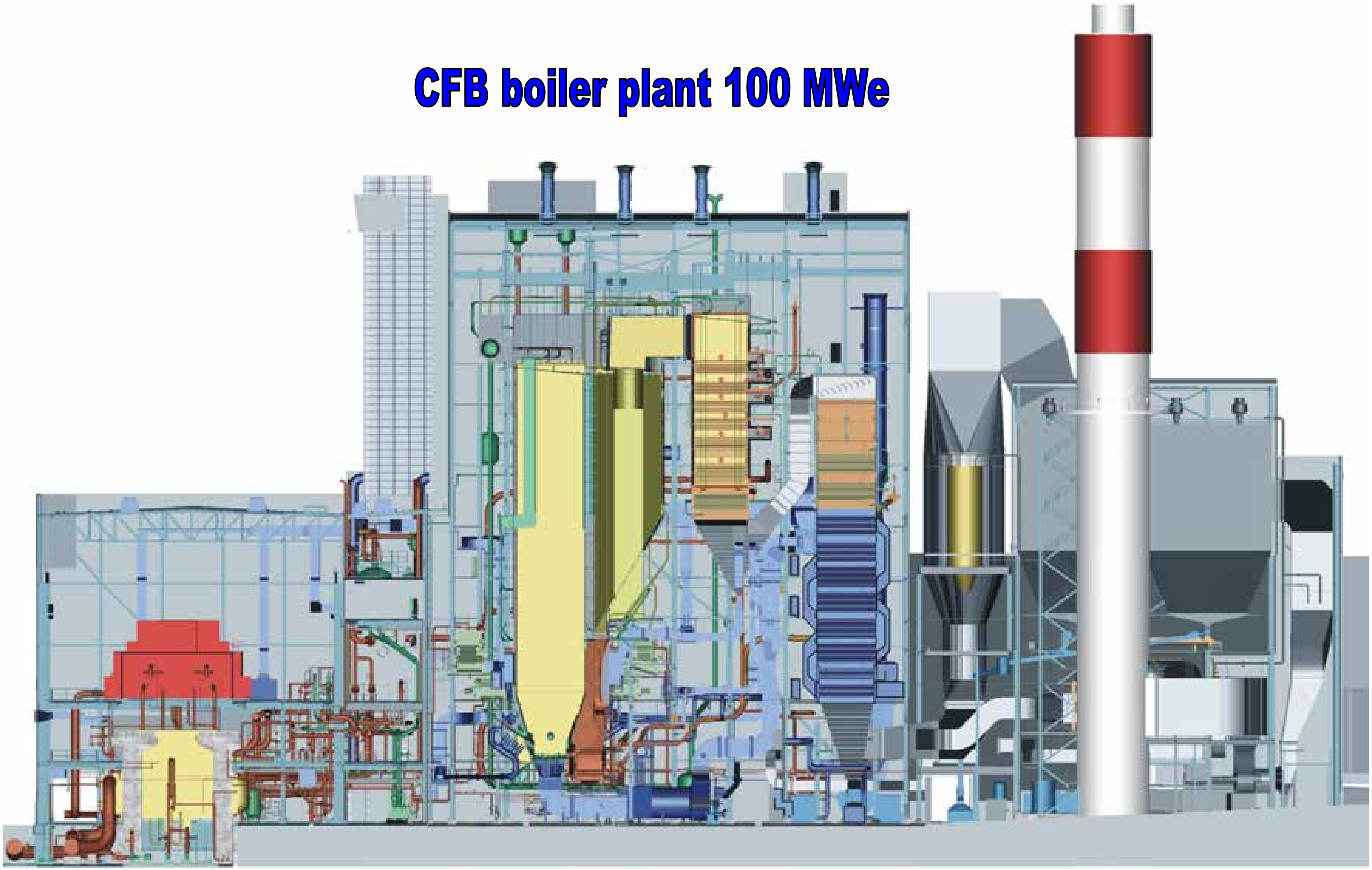
CFB Boiler separator overview

SOLID SEPARATOR FOR FOSTER WHEELER CFB COMPACT DESIGN



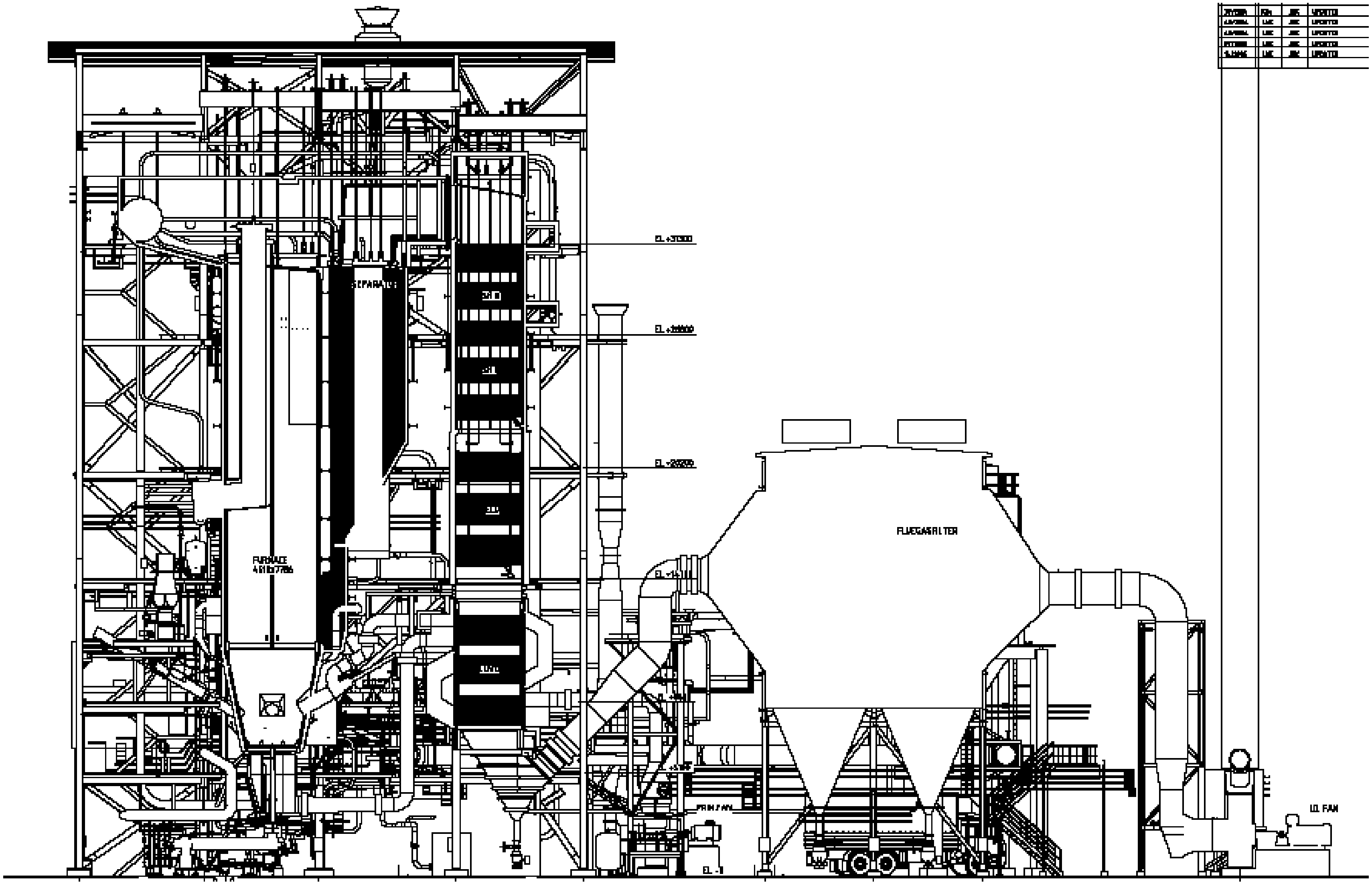


Power Plant side overview



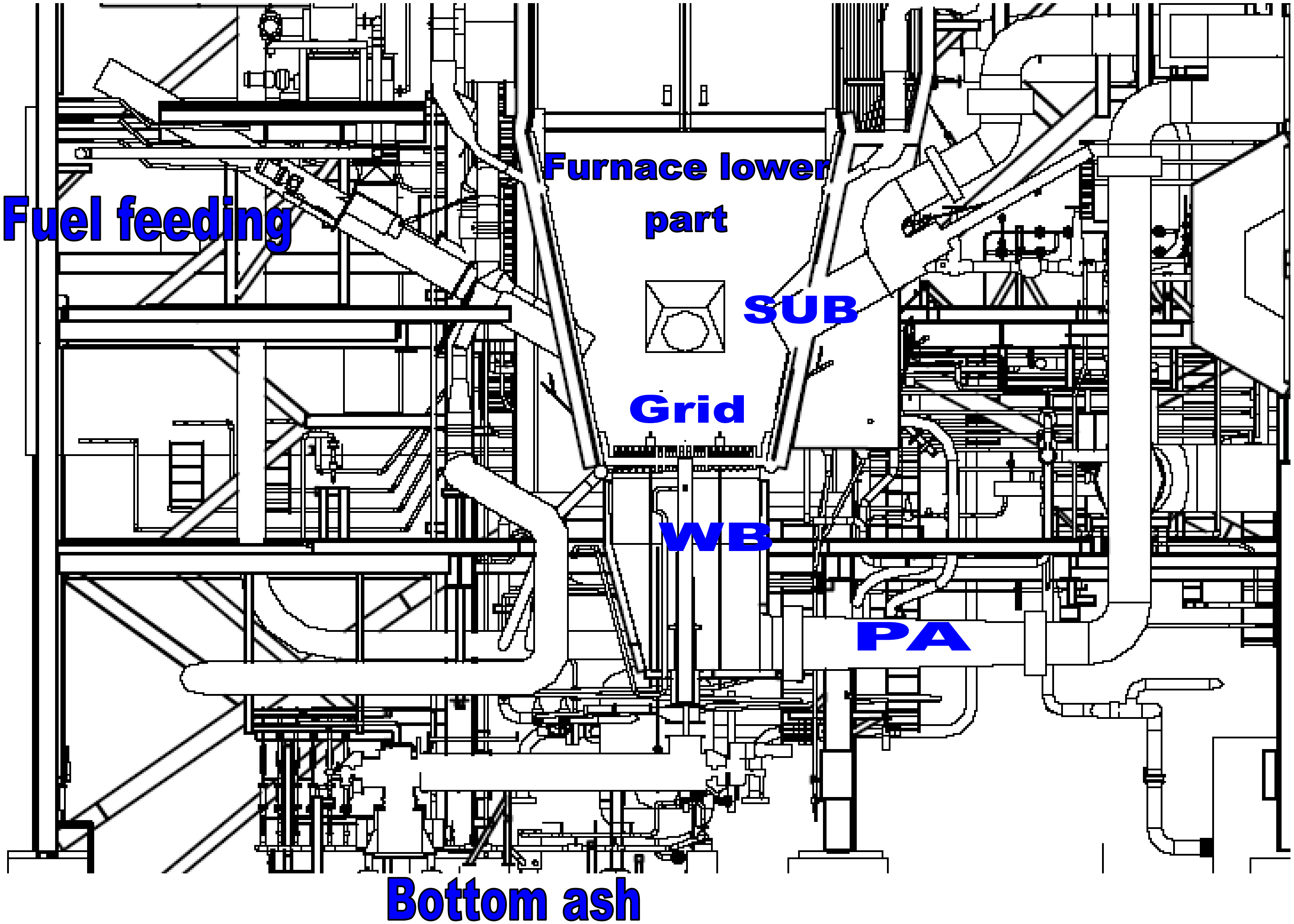
TCP Power Plant side overview

TCP Training

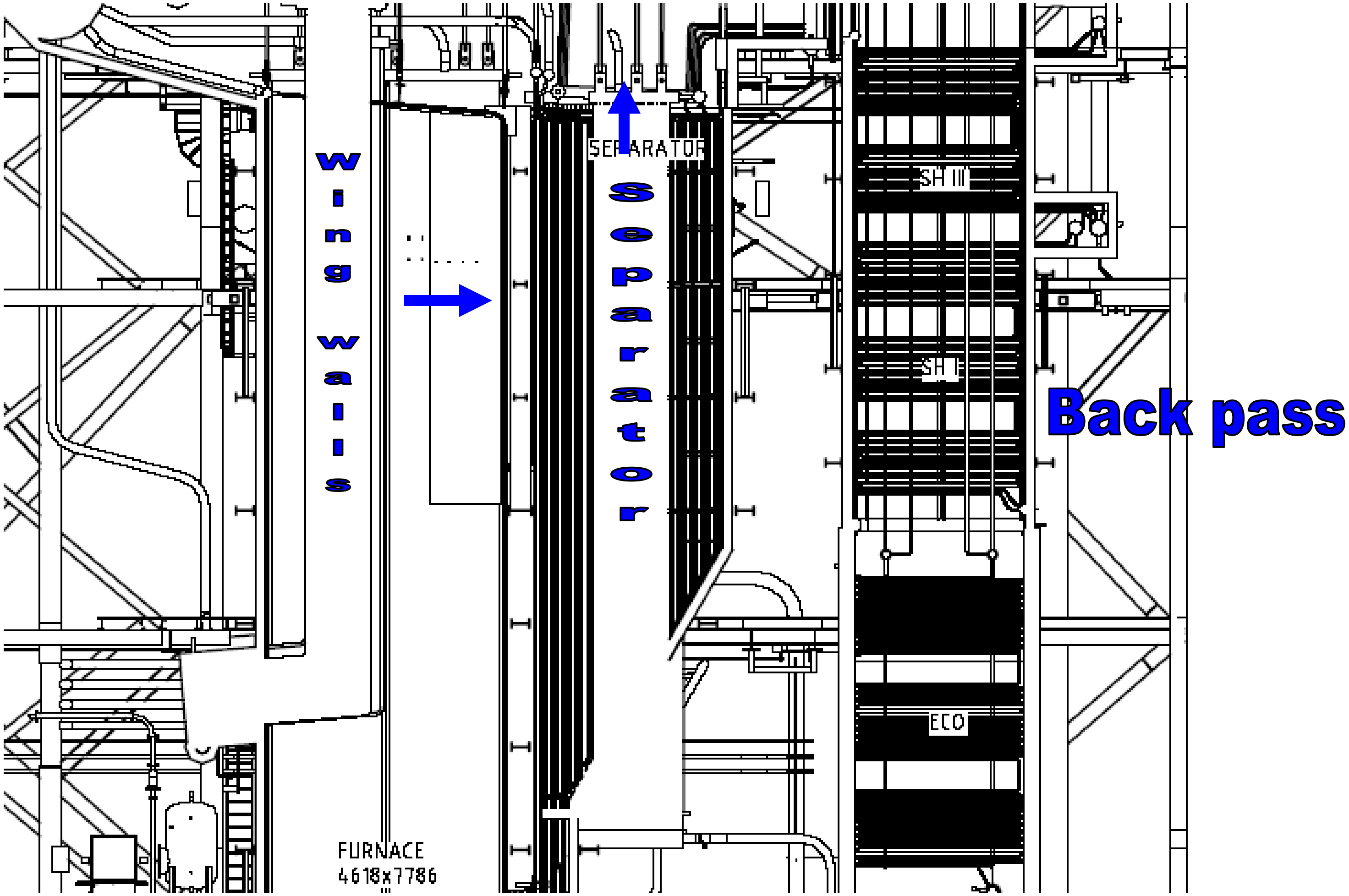


FOSTER WHEELER

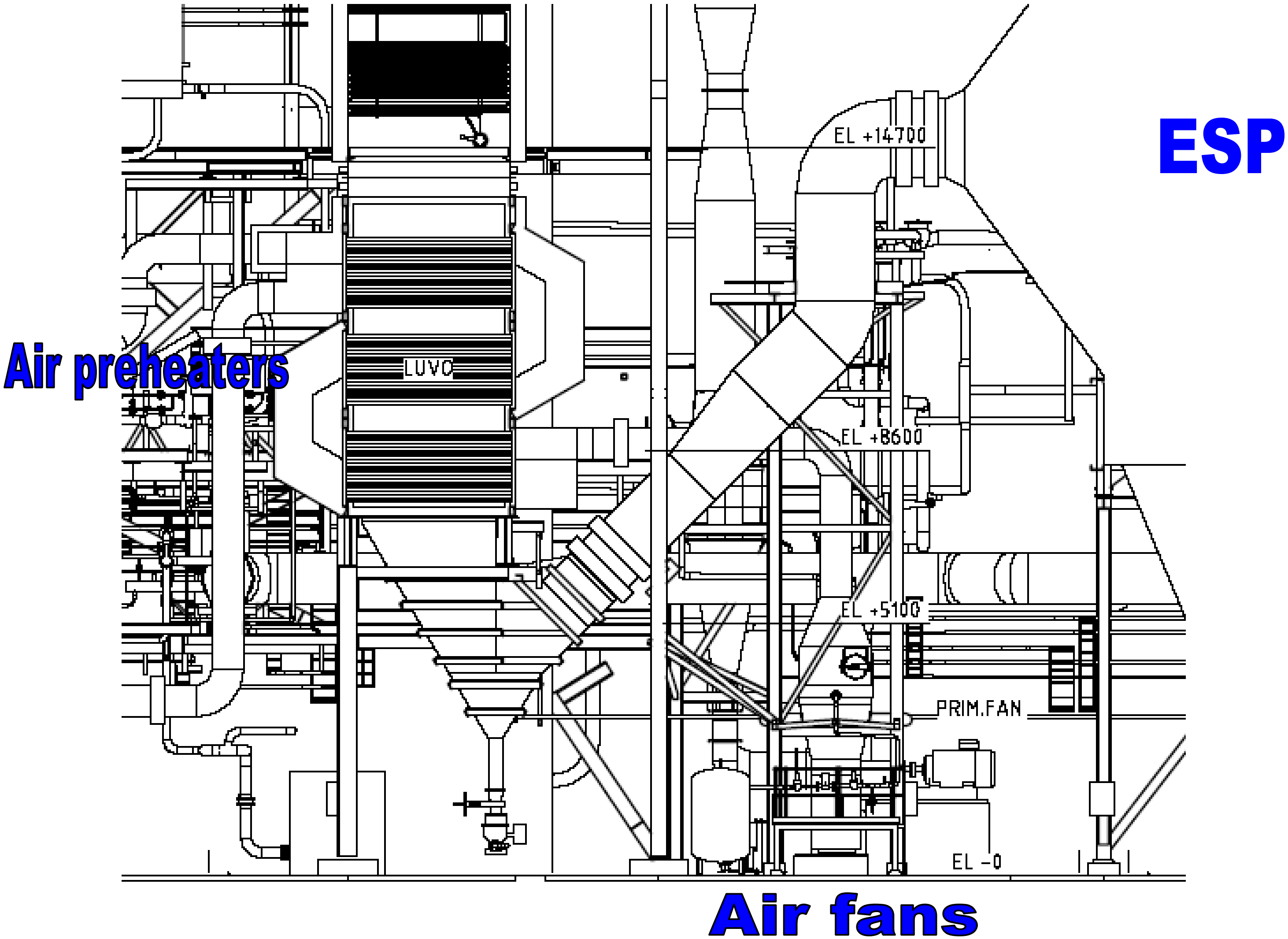
TCP CFB Boiler side overview



TCP CFB Boiler side overview



TCP CFB Boiler side overview



CFB Boiler for TCP

TCP – 35 MWe Coal-Fired Power Plant

Performance data at MCR

• Electric output	35 MWe gross, 98 MWt
• Steam data	85 bar, 504 C, +5/-10 C
• Live steam	36,8 kg/s

Performance data at 40% load

• Steam data	85 bar, 400 C, +5/-10 C
• Live steam	14,7 kg/s

CFB Boiler for TCP

TCP - Coal-Fired Power Plant

Emission data

• SO2	500 mg/Nm3
• NOx (calc.as N02)	400 mg/Nm3
• Particulates	150 mg/Nm3
• CO	300 mg/Nm3
• Indoor noise	85 db(A)

Emissions in Finland

Table 1. Finnish emission limits for solid fuel boilers.

Fuel effect *MW_{th}*	*SO_2 Peat* *mg/MJ*	*SO_2 Coal* *mg/MJ*	*NO_2 Domestic fuel* *mg/MJ*	*NO_2 Coal* *mg/MJ*	*Particles Domestic fuel* *Mg/m^3n*	*Particles Coal* *mg/m^3n*
50...150	140*	230*	150	150	25**	25**
150...300	140*	140*	150	50	50	50
300...	140*	140*	50	50	30	30

* SO_2 as an year average, NO_2 and particles as maximum

** mg/MJ

New LPC directive

Table 2. New LCP-diretive emission limits for solid fuel boilers.
Emission limits are daily averages and will be reported in 6 % of Oxygen content in dry flue gases.

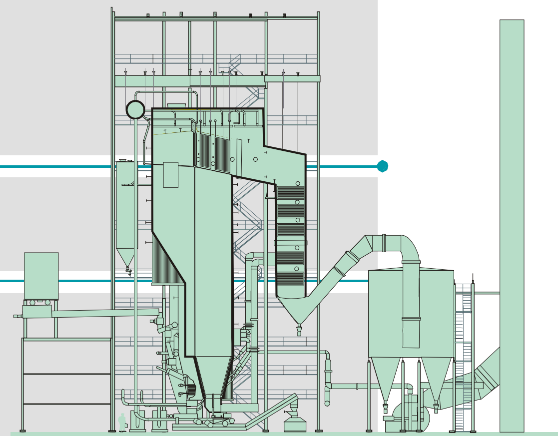
Fuel-effect *MW_{th}*	*SO_2 Biofuel* *mg/m^3n*	*SO_2 Other fuel* *mg/m^3n*	*SO_2 Domestic fuel* *mg/m^3n*	*NO_2 Biofuel* *mg/m^3n*	*NO_2 Other wood fuel* *Mg/m^3n*	*Particles* *mg/m^3n*
50...100	200	850	850	400	400	50
100...300	200	200	300	300	200	30
300...	200	200	400	200	200	30

CFB Boiler

CFB DEVELOPMENT

Fluidized bed technology known in petrochemical and pyrometallurgical industries over 50 years

1968	the development of Fluidized Bed Combustion technology started by Ahlstrom Boilers
1976	1st CFB pilot plant
1979	1st commercial CFB Boiler in operation
1987	1st CFB Utility Boiler 110 MWe
1991	Pilot plant for Compact CFB Boiler
1993	1st Compact CFB Boiler in operation
1995	Foster Wheeler acquired Ahlstrom´s Power Boiler Business
2002	185 Foster Wheeler CFB Boilers in operation 24 under construction



FOSTER WHEELER CFB BOILERS
Sales and Market Areas

	Units
USA	57
China	22
Finland	19
Sweden	14
Germany	14
Japan	12
Poland	11
India	8
Republic of Korea	8
Thailand	7
Czech Republic	6
Austria	5
France	5

	Units
Estonia	4
Indonesia	3
Taiwan	3
Norway	2
Switzerland	2
Canada	1
Chile	1
Denmark	1
Israel	1
Italy	1
Spain	1
United Kingdom	1

TOTAL 209 CFB BOILERS

Beyond the entrainment velocity

Beyond the entrainment velocity, the particles are carried out of the furnace, and a continuous process is maintained by circulating the same amount of particles to the bottom of the reactor. The entrainment velocity marks the transition from a bubbling bed to a circulating bed. Beyond this velocity, the differential pressure becomes a function of velocity and solid circulating rate.

The circulating fluidized bed system operates

The circulating fluidized bed system operates in the region between that of a bubbling fluidized bed and that of a circulating fluidized bed until normal bed temperatures are obtained, air flow is above minimum, and the entrainment velocity is reached. From that point the unit operates as a circulating fluidized bed. High turbulence, solids back mixing, and the absence of a defined bed level characterizes this fluidization pattern. The entrained bed material, with an average size in the range of 100 to 300 microns, (talcum powder) is separated by a solid separator and returned to the bed via a non-mechanical seal. Fuel is fed into the lower combustion chamber, and primary air is introduced through a lower grid.

Solid fuel combustion

In solid fuel combustion the amount of excess limestone feed into the furnace ensures efficient sulfur removal in all conditions, regardless of the amount of sulfur in the fuel, the temperature of the bed, and the physical and chemical characteristics of the brown coal. The ideal reaction temperature range is 840-860 °C.

ESB case has two stage sulphur capture:
-primary stage in the boiler furnace with limestone injection
- secondary stage in the tail-end desulphurization plant

FWE’s concept for CFB Boiler

- Membrane wall structure is used for the whole CFB boiler.
- The Compact separator forms a separate steam cooled circuit and return channel systems together with Intrex-Chambers are integrated with the furnace and connected into the same water circuit.
- Cooled walls eliminate the need for multi-layer, insulating refractory, which is exposed to high temperature gradients and thus may require maintenance. Thin, single layer of refractory is used in the CFB Compact design only in the locations that may be subject to wear. This refractory on the panel walls is water/steam cooled and the design has been proved in long term operation. The construction enables fast changes in process conditions and reduces limitations related to startup times that are caused by thick refractory.
- The high quality manufacturing of panel walls is routine work that is carried out at boiler works. The manufacturing of CFB Compact design can be completed in the boiler shop thus reducing the construction time and risks of unexpected delays.

FWE’s concept for CFB Boiler

- Solid separator operates as a heat surface and reduces the furnace size.
- The lower section of the combustion chamber includes a water-cooled air distribution grid and a bottom ash removal system.
- Provisions are made for primary and secondary air supply to the combustion chamber. The primary air is supplied through the lower windbox to the fluidizing grid and provides the initial fluidization airflow. The secondary air provides a staged combustion effect to ensure high combustion efficiencies and to minimize NOx production

FWE's concept for CFB Boiler

FOSTER WHEELER COMPACT CFB

Benefits

- Less refractory
  - Availability
  - Maintenance
  - Start-up time
- Cooled panel wall structure
  - Simple and compact construction
  - Automated panel welding
  - Eliminates expansion joints

FWE's concept for CFB Boiler

LOW EMISSIONS IN CFB

- No complex external cleaning systems

- Sulfur dioxide (with limestone injection)

  - Up to 95 % SO2 reduction
  - 0.03 lb/mmBtu/25 ppm demonstrated in continuous operation with 0.5 % sulfur coal

- Nitrogen oxide

  - Coal typically 0.3 lb/mmBtu/180 ppm without ammonia injection
  - Coal below 0.1 lb/mmBtu/60 ppm with ammonia injection
  - Biofuels typically 0.15 lb/mmBtu/60 ppm without ammonia injection

FWE’s concept for CFB Boiler

ADVANTAGES OF FOSTER WHEELER CFB BOILER

- Fuel flexibility
- Capacity to burn low grade fuels
- Multifuel burning capability
- Meets strict emission regulations easily
- No complex chemical cleaning systems
- Proven reliability
- Simple construction

FWE's concept for CFB Boiler

CFB TECHNOLOGY OFFERS WIDE FUEL FLEXIBILITY

Coal
- Anthracite
- Bituminous
- Sub-Bituminous
- Lignite

Waste Coal
- Bituminous Gob
- Anthracite Culm
- Coal Slurry

Petroleum Coke
- Delayed
- Fluid

Woodwaste
- Bark
- Chips
- Wood Dust
- Forest Residue
- Demolition Wood

Peat

Oil Shale

Oil

Gas
- Natural
- "Off"Gases

Sludge
- Paper Mill
- De-Inking
- Municipal

Refuse Derived Fuel

Paper Waste

Tires

Agricultural Waste
- Straw
- Olive Waste

FWE's concept for CFB Boiler

The three "T"s of combustion, all necessary for good combustion, are:

-
Time

Time to complete the combustion process;

Turbulence

Turbulence provides more effective mixing of fuel and air, causes even heat distribution and fills the entire combustor volume;

Temperature

Temperature of the combustor atmosphere must be kept above ignition temperature. Preheating incoming combustion air increases temperature of the furnace atmosphere. Ignition temperatures and combustion temperatures vary with fuel type and preparation.

Requirements for combustion

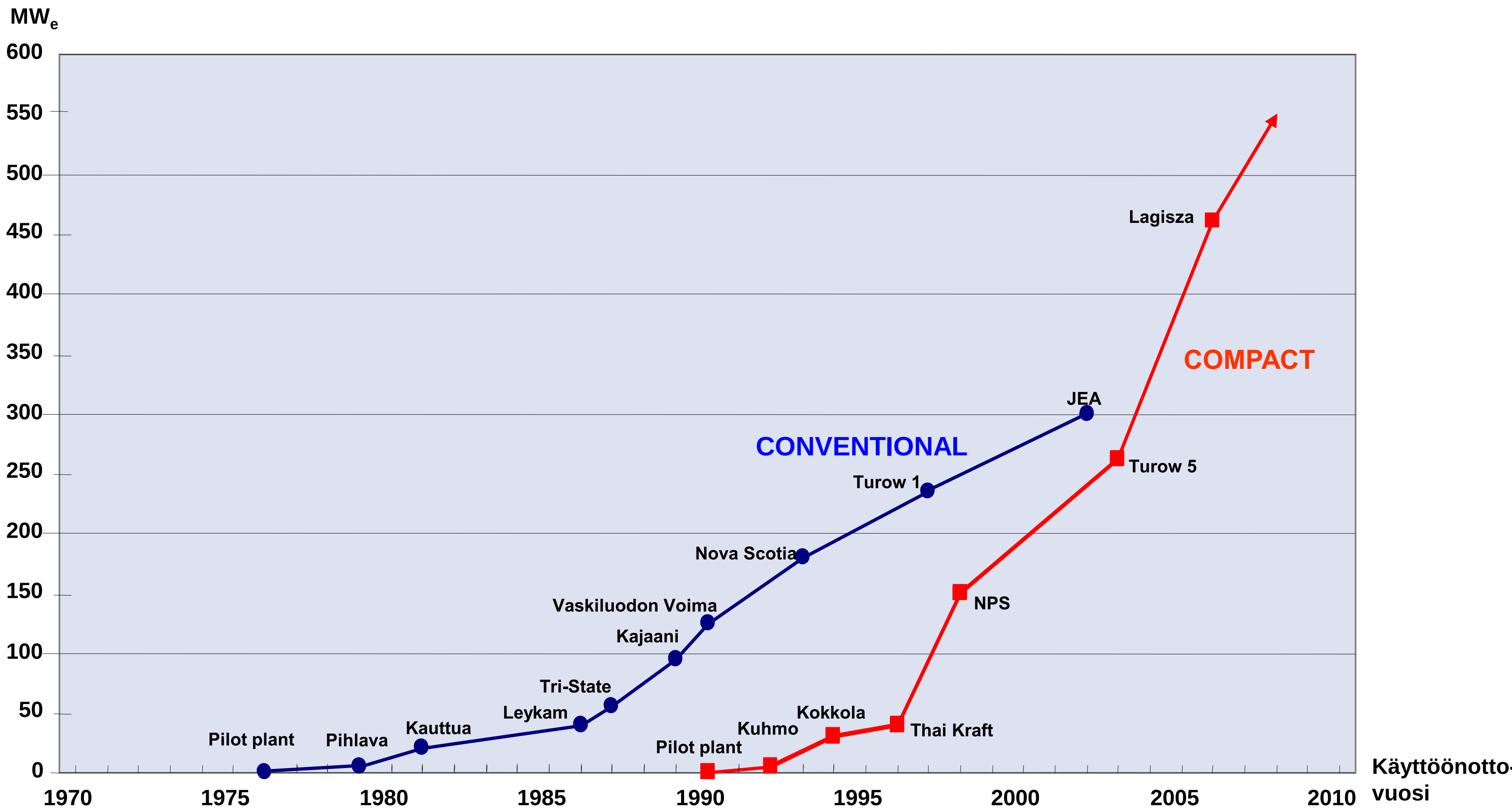
There are three factors or conditions necessary to produce combustion. These conditions are

1) the presence of a fuel (a combustible material),
2) enough oxygen to support combustion and
3) enough heat to bring the fuel to its ignition temperature and keep it there.

These three requirements are all necessary for combustion to occur. If you remove any one, there will no longer be a fire.

FWE's concept for CFB Boiler

TCP Training



CFB DELIVERIES OVER 80 MWe

DEL.YEAR	CUSTOMER	MWe	MWth	t/h	bar	°C	FUELS
1987	Tri-State Generation, Nucla, USA	110	291	420	104	540	Coal
1989	KAVO, Kajaani, Finland	88	240	360	136	535	Peat, wood, coal
1990	Vaskiluodon Voima Oy, Seinäjoki, Finland	125	299	400/348	139/48	540/540	Peat, coal
1990	ACE, Trona, USA	110	306	413	105	540	Coal
1991	RWE, Essen, Germany	100	313	400	115	504	Brown coal
1992	AES-Barbers Point, Hawaiian Island, USA	80	238	301/271	136/32	540/540	Coal
1992	NISCO, Louisiana, USA	2x110	2x285	374/331	112/32	540/540	Petroleum coke
1994	Nova Scotia Power, Nova Scotia, Canada	165	410	532/465	128/35	540/540	Coal
1994	AES Cedar Bay, Florida, USA	80	245	316/247	136/29	540/540	Bituminous coal
1995	Fortum Engineering, Toppila 2, Oulu, Finland	140	291	371/321	156/20	540/540	Peat, coal
1995	Northampton Energy Project, Pennsylvania, USA	125	277	360/331	174/40	540/540	Anthracite culm
1995	Colver Power Project, Pennsylvania, USA	120	270	356/356	174/37	540/540	Anthracite culm
1996	CMIEC/Neijiang, Neijiang, P.R.C.	100	285	410	98	540	Bituminous coal
1997	RAPP,Kerinci, Indonesia	110	314	468	140	540	Bark, coal
1998	Turow Power Station, Bogatynia, Poland	2x235	2x520	667/598	132/25	540/540	Polish brown coal
1998	NPS, Tha Toom, Thailand	2x150	2x370	482/439	161/35	542/542	Anthracite, bit. coal
1999	Map Ta Phut, Rayong, Thailand	2x115	2x360	434	182	568	Coal
1999	Asia P&P, Dagang, P.R.C.	2x100	2x287	400	125	537	Coal, sludge
1999	EC Katowice, Katowice, Poland	120	352	483	138	540	Coal
2000	Turow Power Station, Bogatynia, Poland	235	520	667/598	132/25	540/540	Polish brown coal
2000	Bay Shore Power Co., Ohio, USA	140	460	435/375	139/31	565/540	Petroleum coke
2001	Taiheiyo Cement, Niigata, Japan	149	341	475/385	170/36	569/541	Coal, pet. coke, RDF
2001	JEA, Florida, USA	2x300	2x689	904/804	182	540/540	Pet. coke, bit. coal
2002-2004	Turow Power Station 4-6, Bogatynia, Poland	3x262	3x557	704/650	170/40	568/568	Polish brown coal, lignite
2003	EC Chorzow, Elcho, Poland	2x113	2x274	404	135	538	Bituminous coal
2004	Zhenhai, Ningbo, P.R.C.	2x100	2x293	410	104	540	Bit. coal, pet. coke
2003, 2004	AS Narva Elekrtrijaamad, Narva, Estonia	4x100	4x234	324/279	131/27	540/540	Oil shale