Pollutant formation and mitigation in combustion, Anders Lyngfelt

Overview

Sulphur

Nitrogen oxides

Incomplete combustion

CO_2 capture and storage in separate presentation

COMBUSTION

component	emission	impact	measure
CH_x	CO_2 (not biofuel)	climate	C P F
-"-	volatile organic hydrocarbons etc	health, sec.air pollutants (SEP)*	C P
-"-	soot, low volatile polycyclic aromatic hydrocarbons (PAH)	health	C P
N in air	NO_x (thermal)	health, "SEP" acid rain, eutrophication	C P
N in fuel	NO_x (fuel-)		C P
	N_2O	climate, str.ozon	

*SEP, e.g. tropospheric ozone

measures:
C combustion, P post combustion, F change/clean fuel

COMBUSTION (CONTINUED)

component	emission	impact	measure
S	SO_2, -> SO_3	acid rain, environment, (health)	C P F
heavy metals	heavy metals	health, environm	P
Hg	Hg (=mercury)	health, environm	P
Cl (chlorine)	dioxins	health, environm	C P F
mineral ash	solid waste	place, leaching	(F)

measures:

C combustion, P post combustion, F change/clean fuel

sulphur capture in fluidized beds

by addition of limestone

$CaCO_3 \rightarrow CaO + CO_2$

$CaO + SO_2 + \frac{1}{2}O_2 \rightarrow CaSO_4$

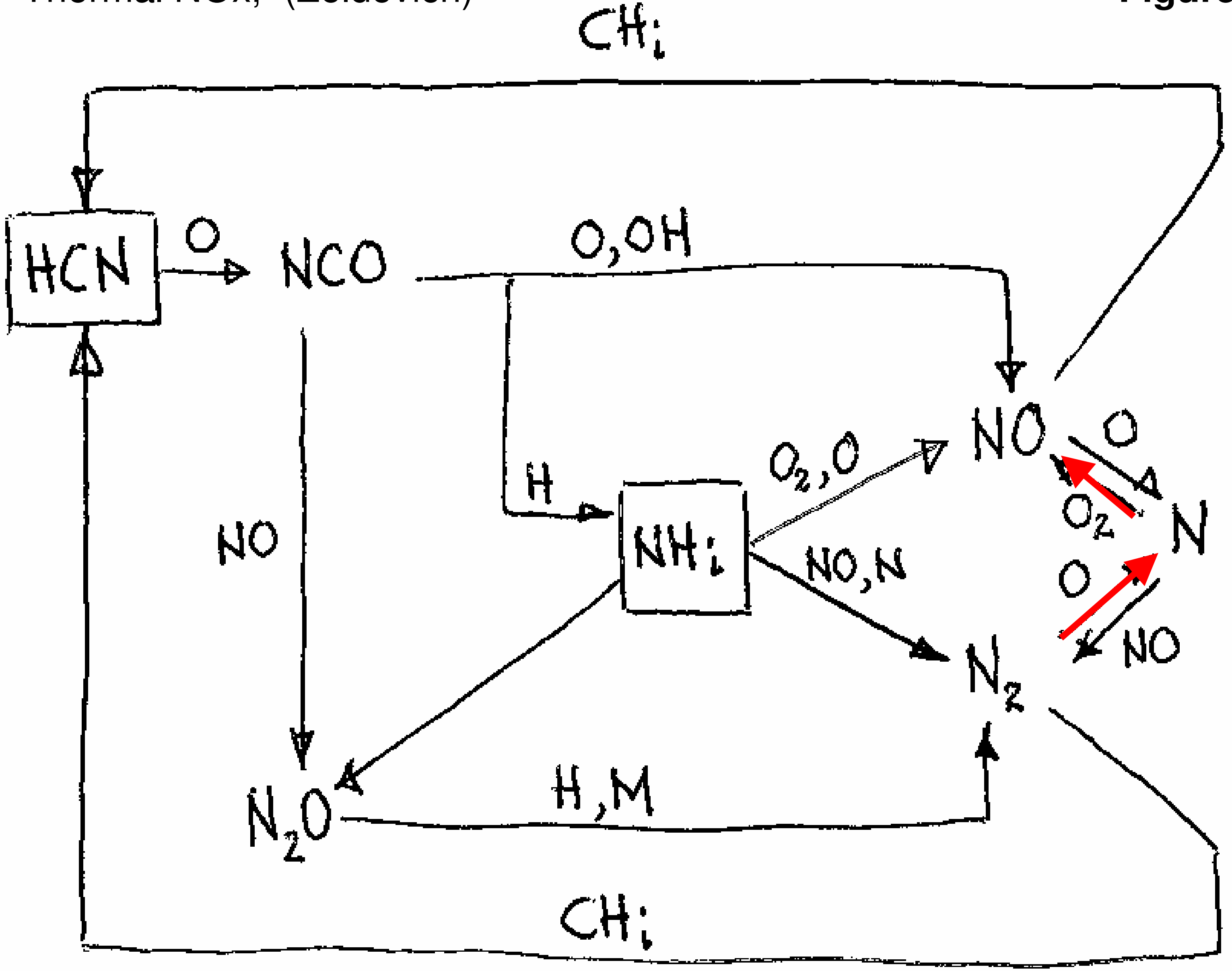
Thermal NOx, Zeldovich mechanism:

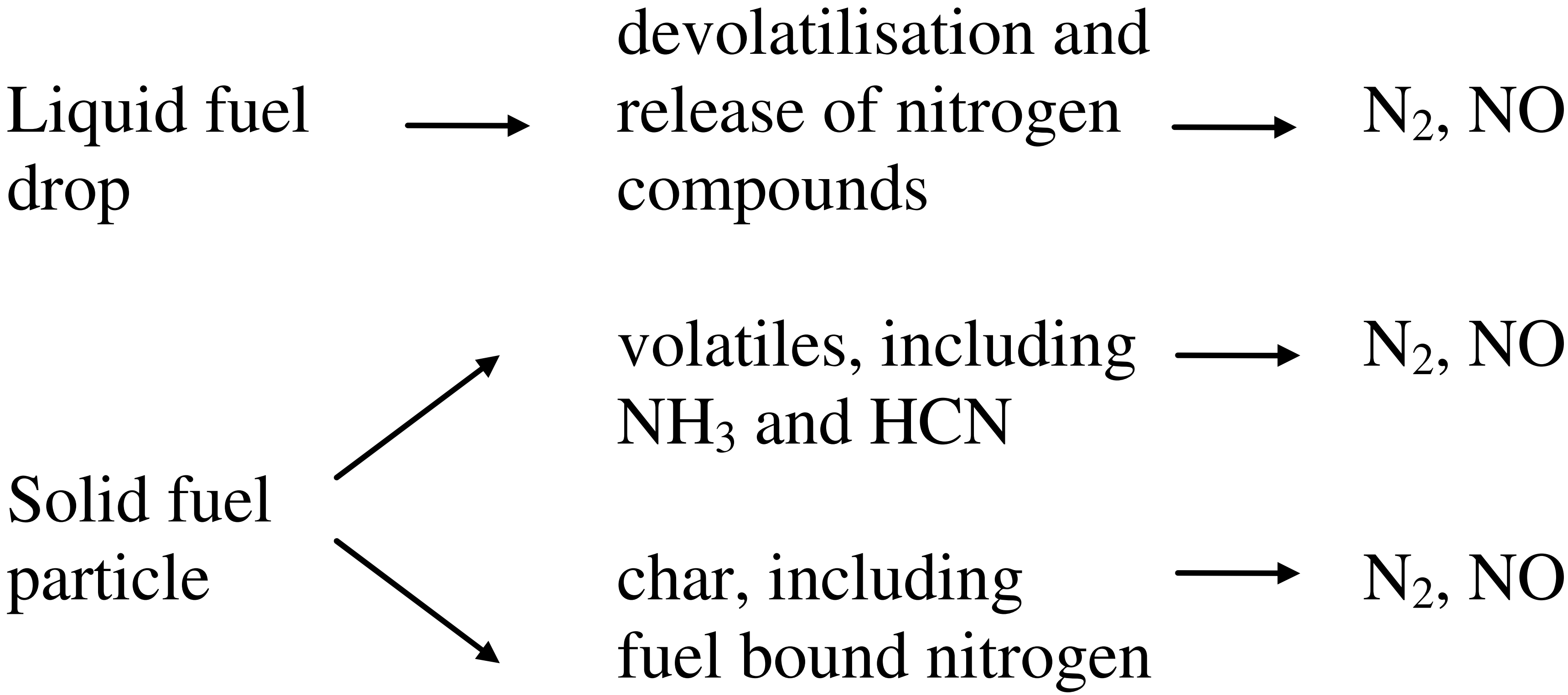
$N_2 + O \Leftrightarrow NO + N$

$N + O_2 \Leftrightarrow NO + O$

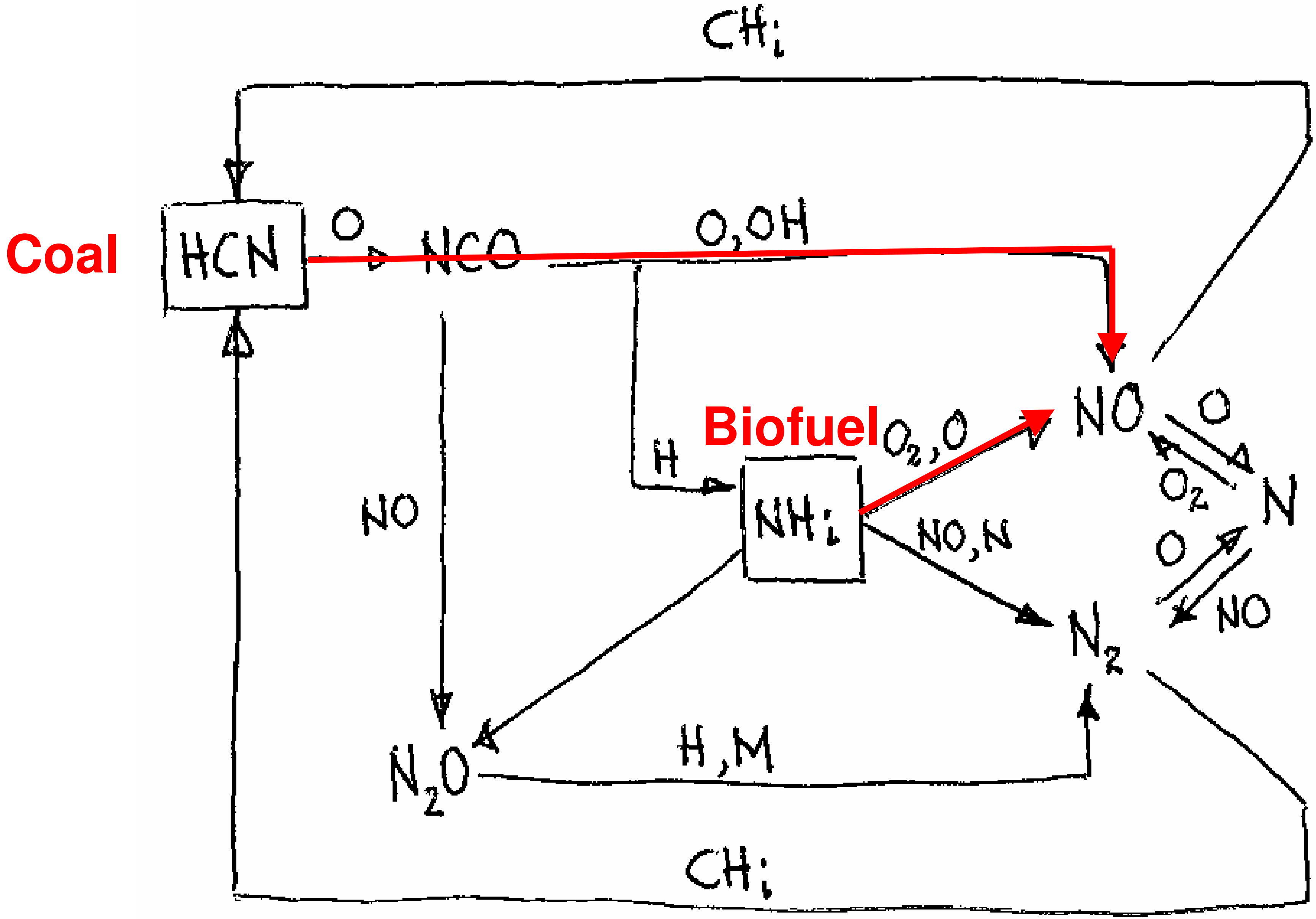
$N + OH \Leftrightarrow NO + H$

1. Thermal NOx, (Zeldovich) **Figure 10.2**




Liquid fuel drop
devolatilisation and release of nitrogen compounds
N2, NO
Solid fuel particle
volatiles, including NH3 and HCN
N2, NO
char, including fuel bound nitrogen
N2, NO

2. Fuel NOx


CH$_i$
Coal
HCN
O
NCO
O,OH
NO
H
Biofuel
O$_2$,O
NH$_i$
NO
O
O$_2$
N
O
NO,N
NO
N$_2$
N$_2$O
H,M
CH$_i$

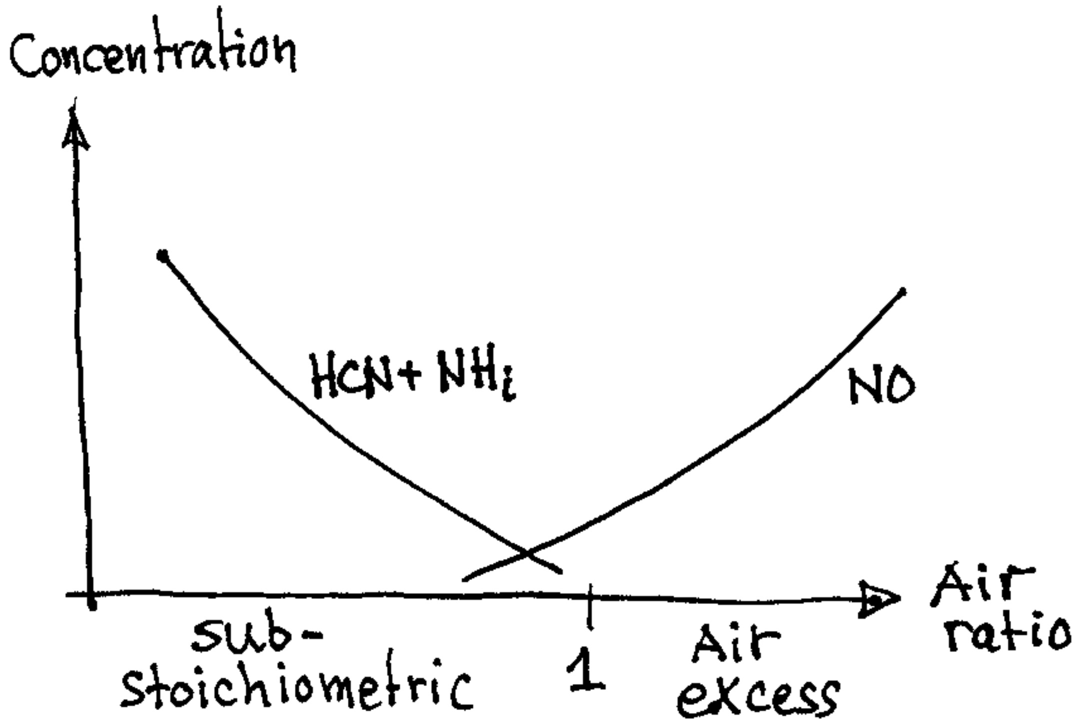
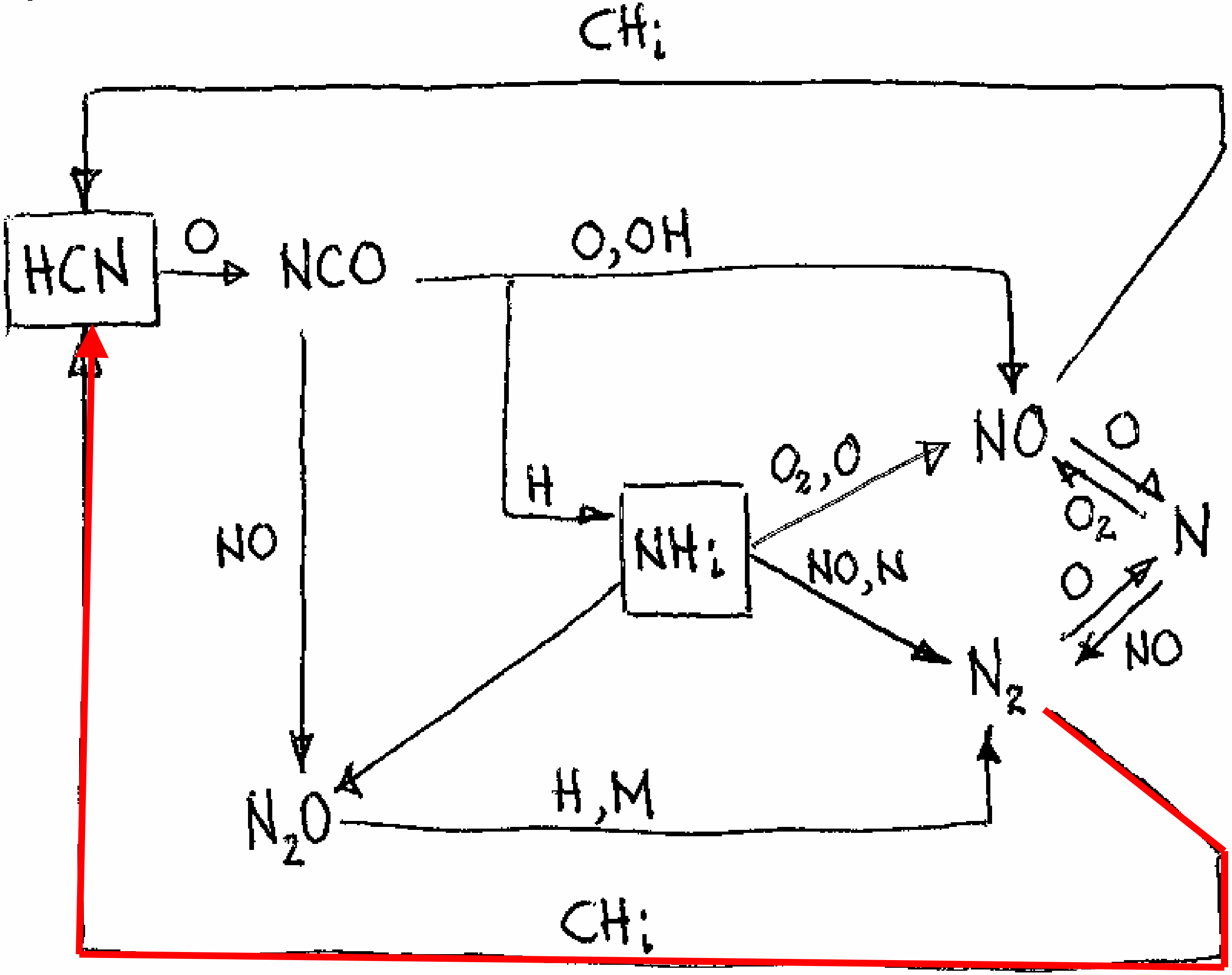
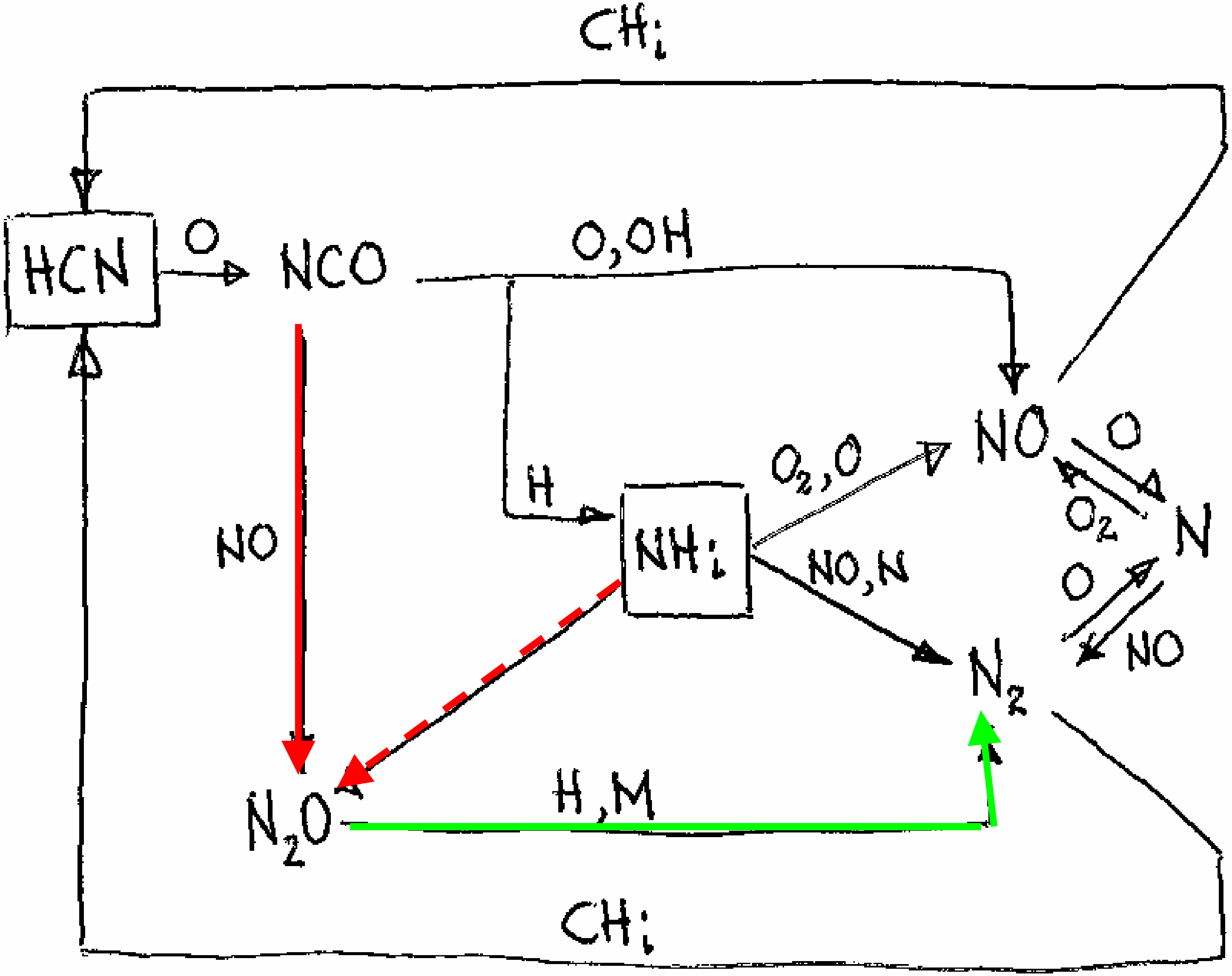


Figure 10.3.
Trade-off between unburned nitrogen compounds and nitrogen oxide

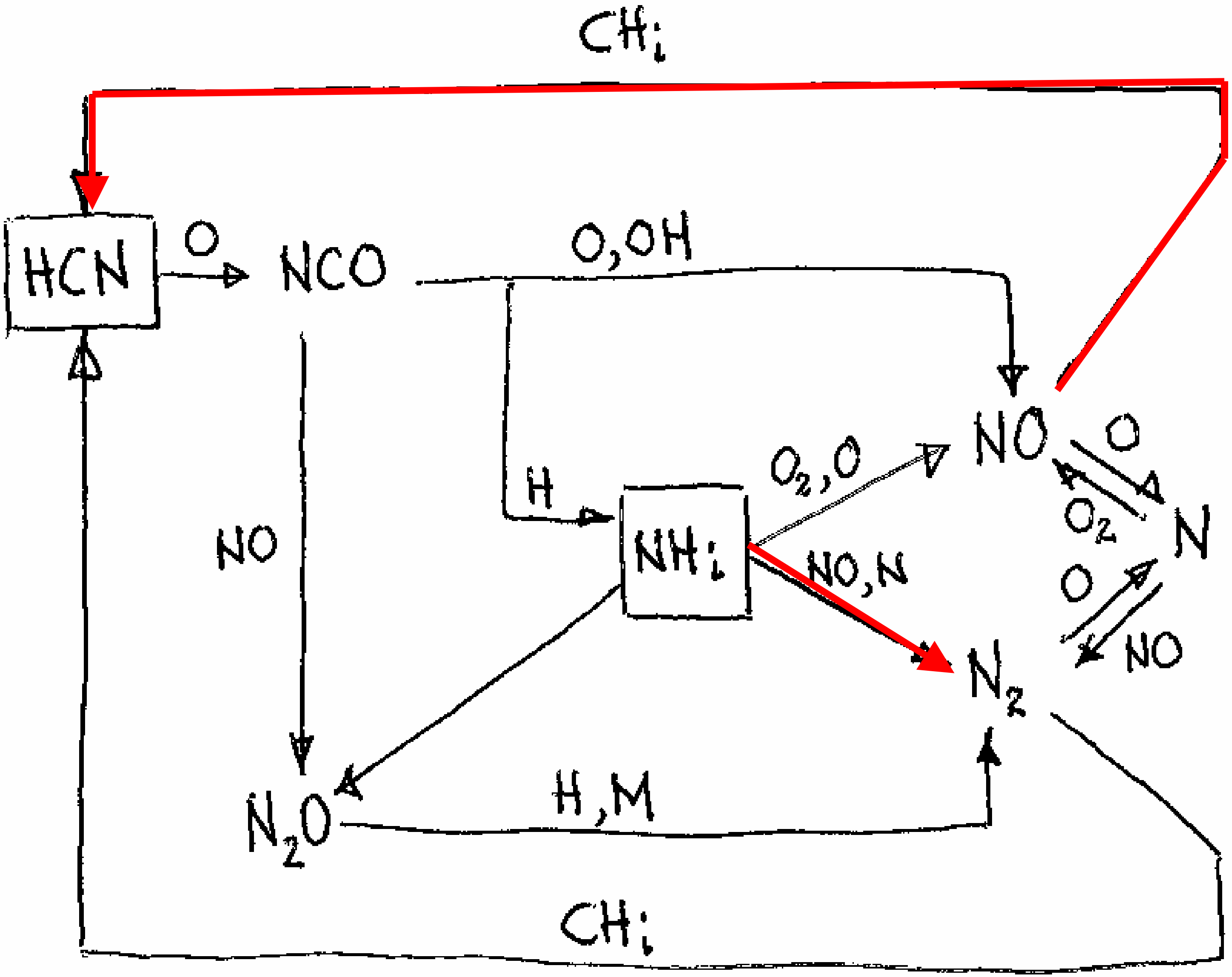
3. Prompt NOx

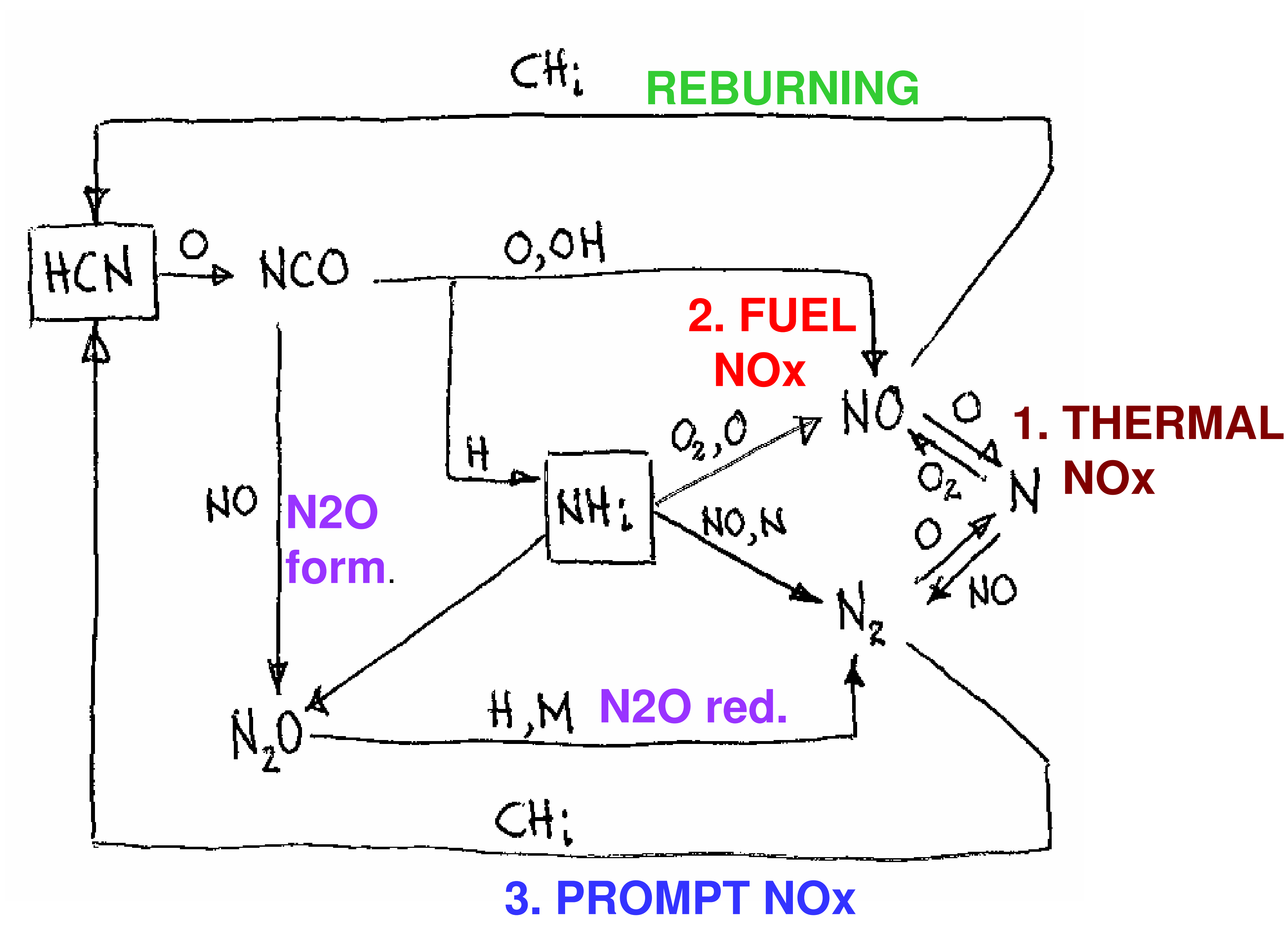


N2O formation/reduction



Reburning




CHi
REBURNING
HCN
O
NCO
O,OH
2. FUEL
NOx
NO
O
1. THERMAL
NOx
H
O2,O
O2
N
NH i
NO,N
O
NO
N2O
form.
NO
N2
N2O
H,M
N2O red.
CHi
3. PROMPT NOx

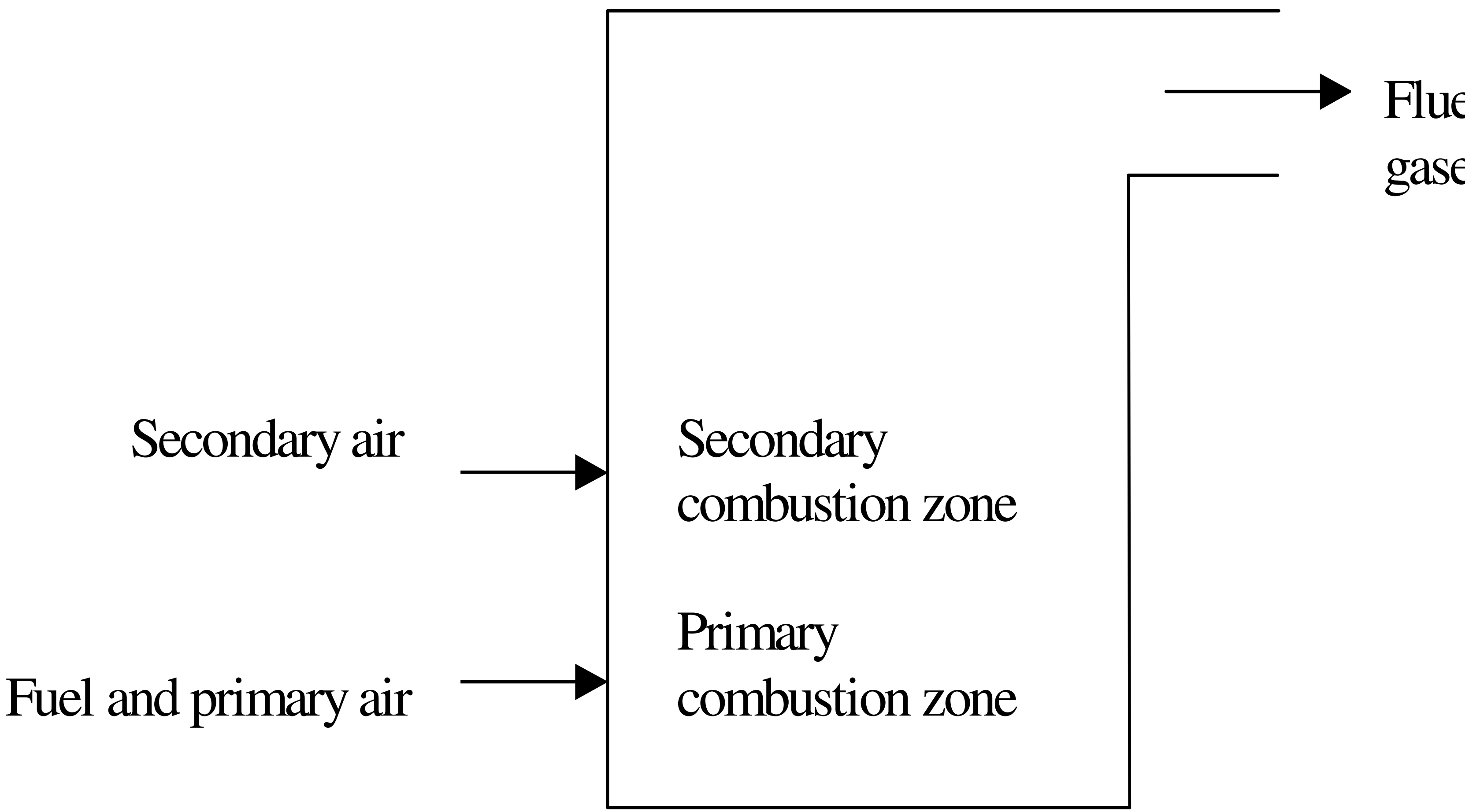
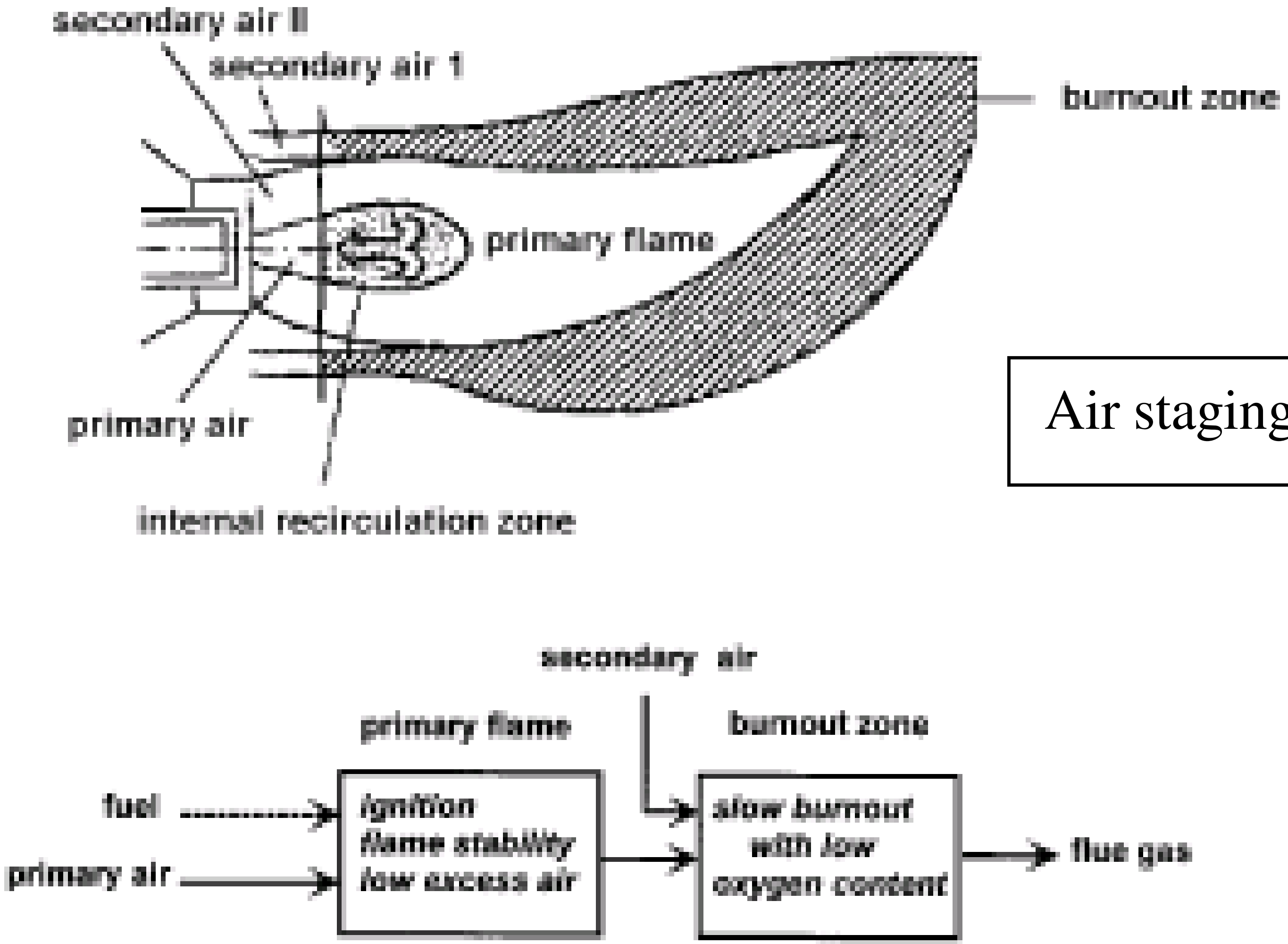


Figure 10.4.
Air staging in bed and suspension combustion

Air staging


secondary air II
secondary air 1
burnout zone
primary flame
primary air
internal recirculation zone
secondary air
primary flame
burnout zone
fuel
primary air
ignition
flame stability
low excess air
slow burnout
with low
oxygen content
flue gas

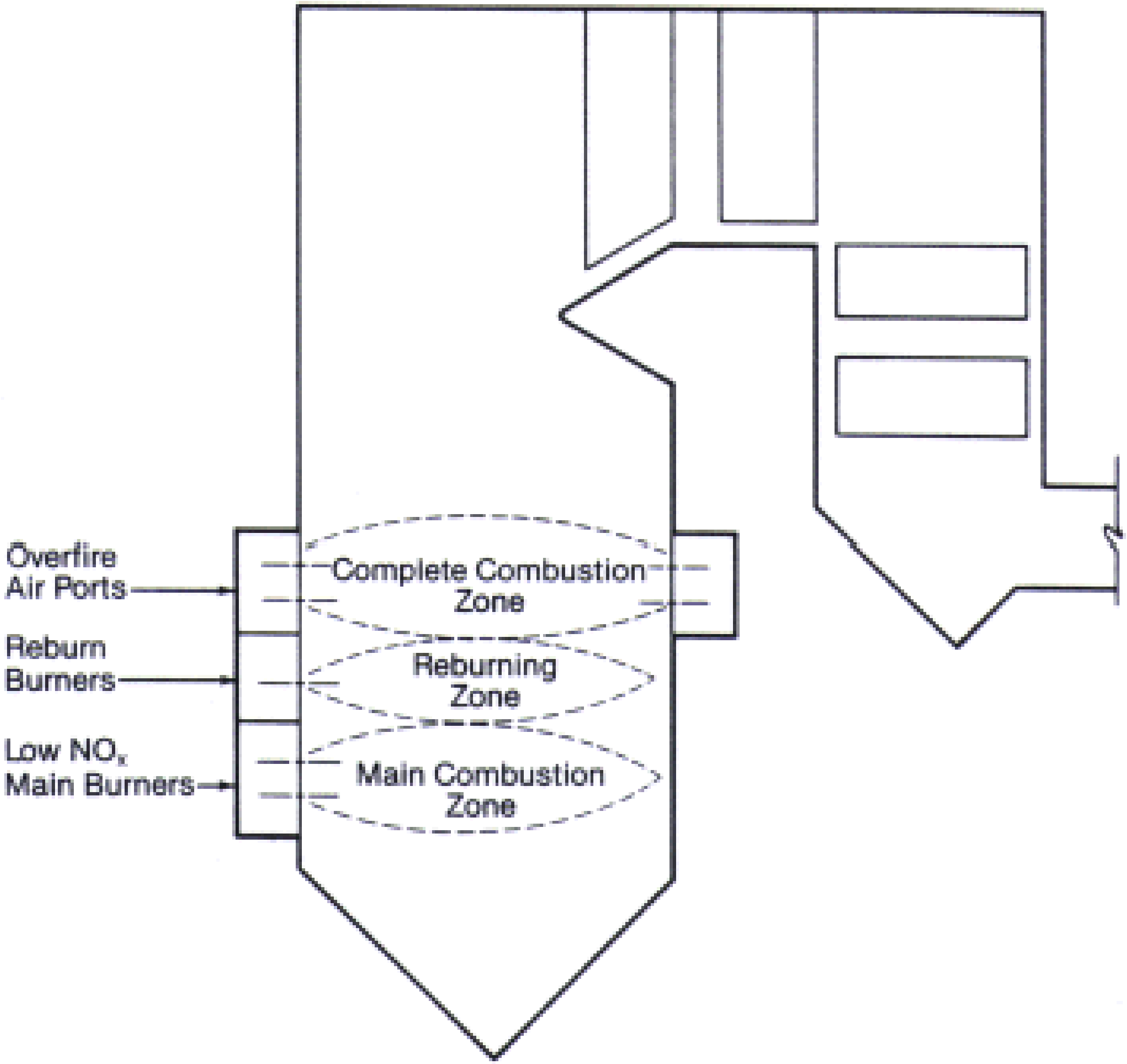


Figure 10.5. Reburning in a utility boiler

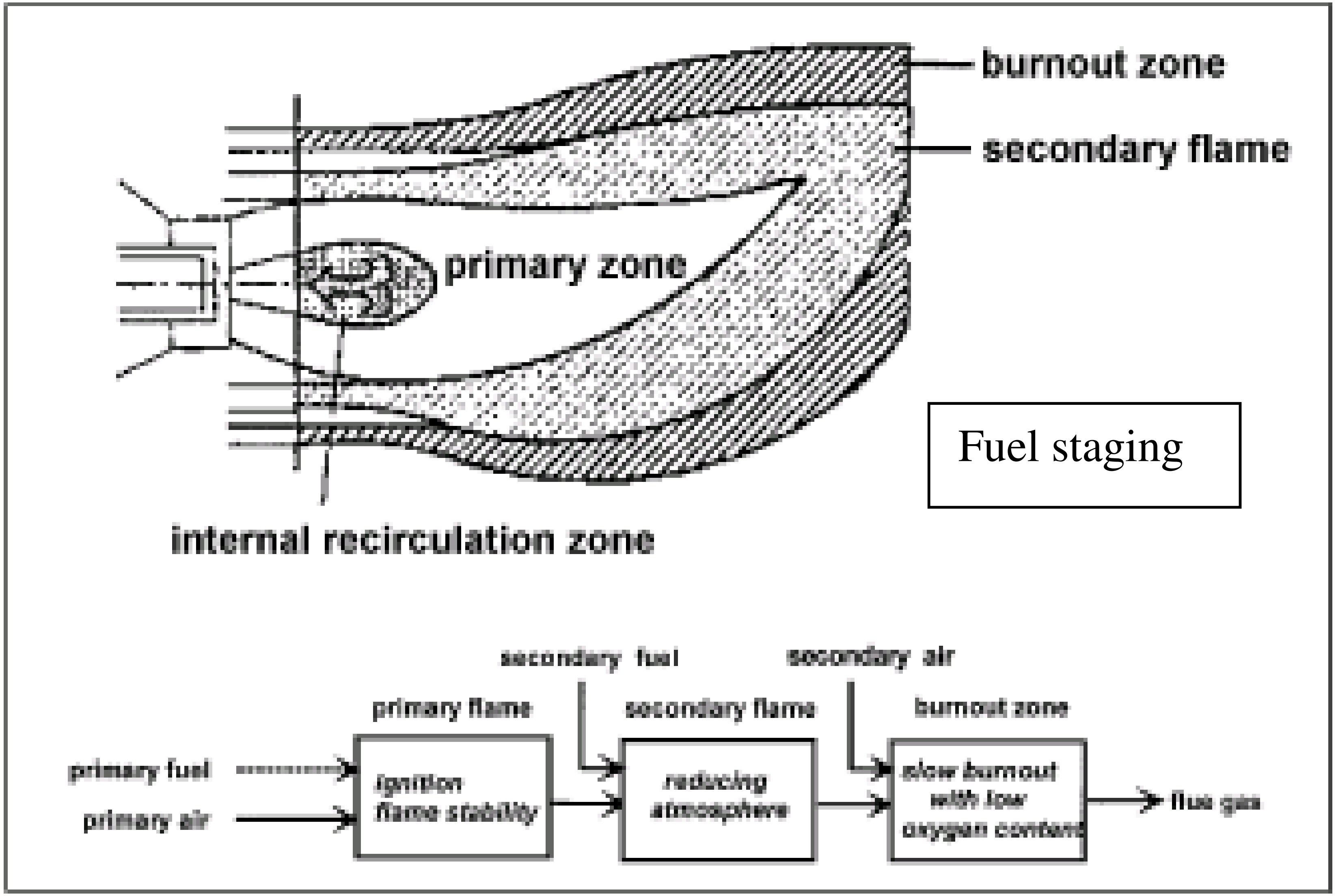
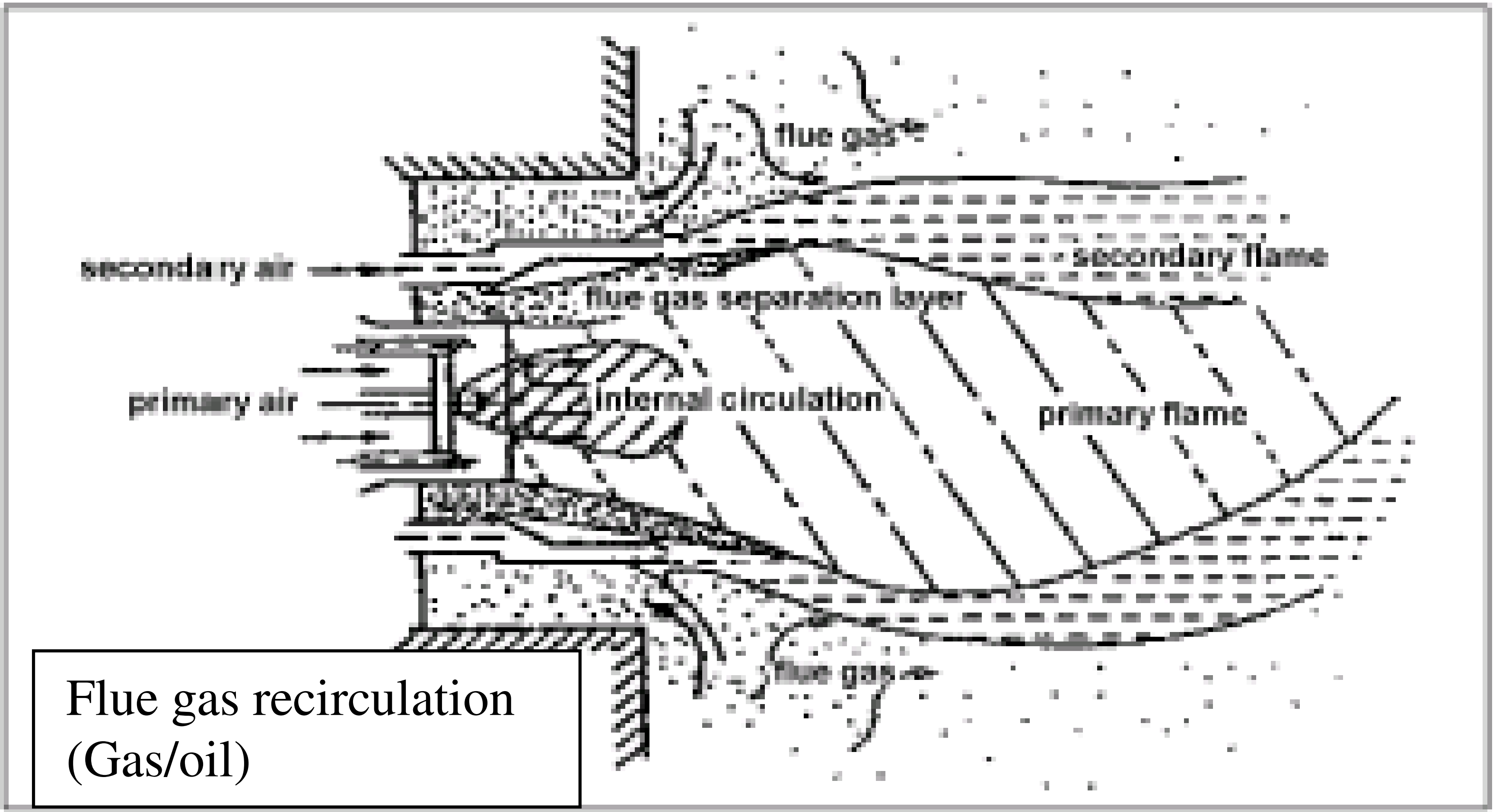

burnout zone
secondary flame
primary zone
internal recirculation zone
Fuel staging
secondary fuel
secondary air
primary flame
secondary flame
burnout zone
primary fuel
primary air
ignition
flame stability
reducing
atmosphere
slow burnout
with low
oxygen content
flue gas

Figure 10.6.



Flue gas recirculation
(Gas/oil)

Table 10.1. NO_x reduction measures and their potential (van der Lans et al.)

Control Method	NO_x reduction Potential*	Investigation and Baseline
low excess air level	0-15%	(Guidelines for retrofit; study sponsored by EPRI)[137]
	10-15%	Lowering from 6 to 4% O_2 in several industrial installations with brown coal. Baselines from 200-350 ppm.[138]
over fire air	15-30%	(Review)[139]
	25%	Baseline 220 ppm in a 300 MW_e boiler with brown coal.[138]
	20%	Baseline about 500 ppm in a tangentially fired furnace.[140]
	15%	Baseline about 300 ppm in a 600 MW_{th} opposed-fired boiler.[141]
	15-50%	Typically 15% for wall-fired and 25% for tangentially fired.[137]
low NO_x burners	23-40%	Two tangentially fired and two front wall-fired boilers. 40% reduction from baselines of 500-650 ppm, 23% reduction for 350 ppm

		tangentially fired.[137]
low NO_x burners	23-40%	Two tangentially fired and two front wall-fired boilers. 40% reduction from baselines of 500-650 ppm, 23% reduction for 350 ppm as baseline.[142]
	50%	500 and 250 MW_{th} wall-fired, baseline about 900 and 600 ppm respectively.[143]
	55%	600 MW_e opposed-fired, baseline about 800 ppm.[144]
	40-70%	(Guidelines for retrofit; study sponsored by EPRI)[137]
flue gas recirculation	up to 30%	For wet bottom boilers; only few percent for dry bottom boilers (hard coal).[139]
	9-13%	150, 300 and 600 MW_e boiler with brown coal. Baselines about 120 ppm, 10% recirculation.[138]
reburning	50%	300 MW_e opposed-fired, baseline about 600 ppm.[145]
	60-70%	71 MW_e tangentially fired (baseline about 550 ppm) and 158 MW_e wall-fired (baseline about 400 ppm).[146]
SNCR	30-80%	(Review)[139]
SCR	60-90%	Most installations have been designed for a reduction around 60-70%, but over 90% can be reached at high initial NO concentration.[139]

*Compared to baseline value

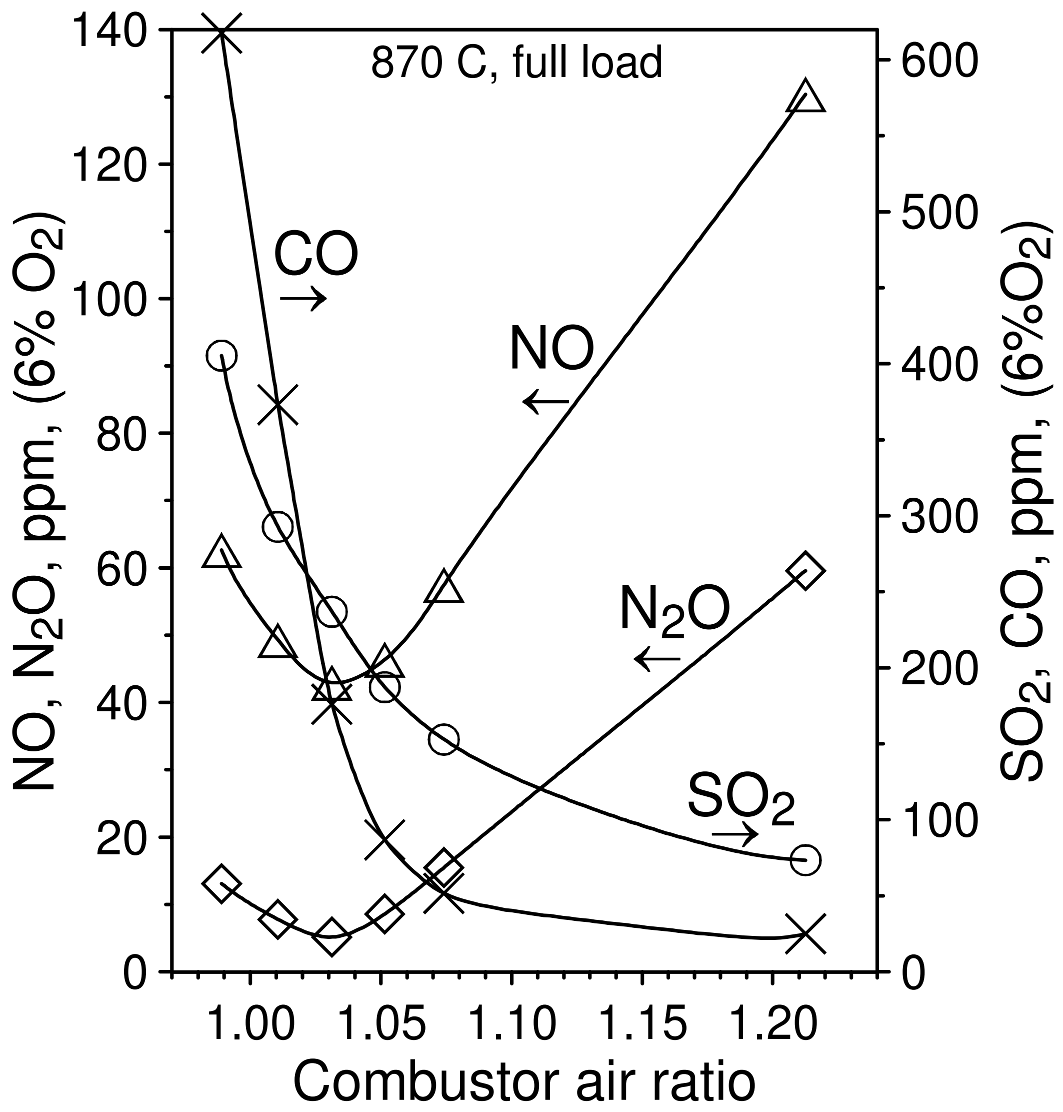
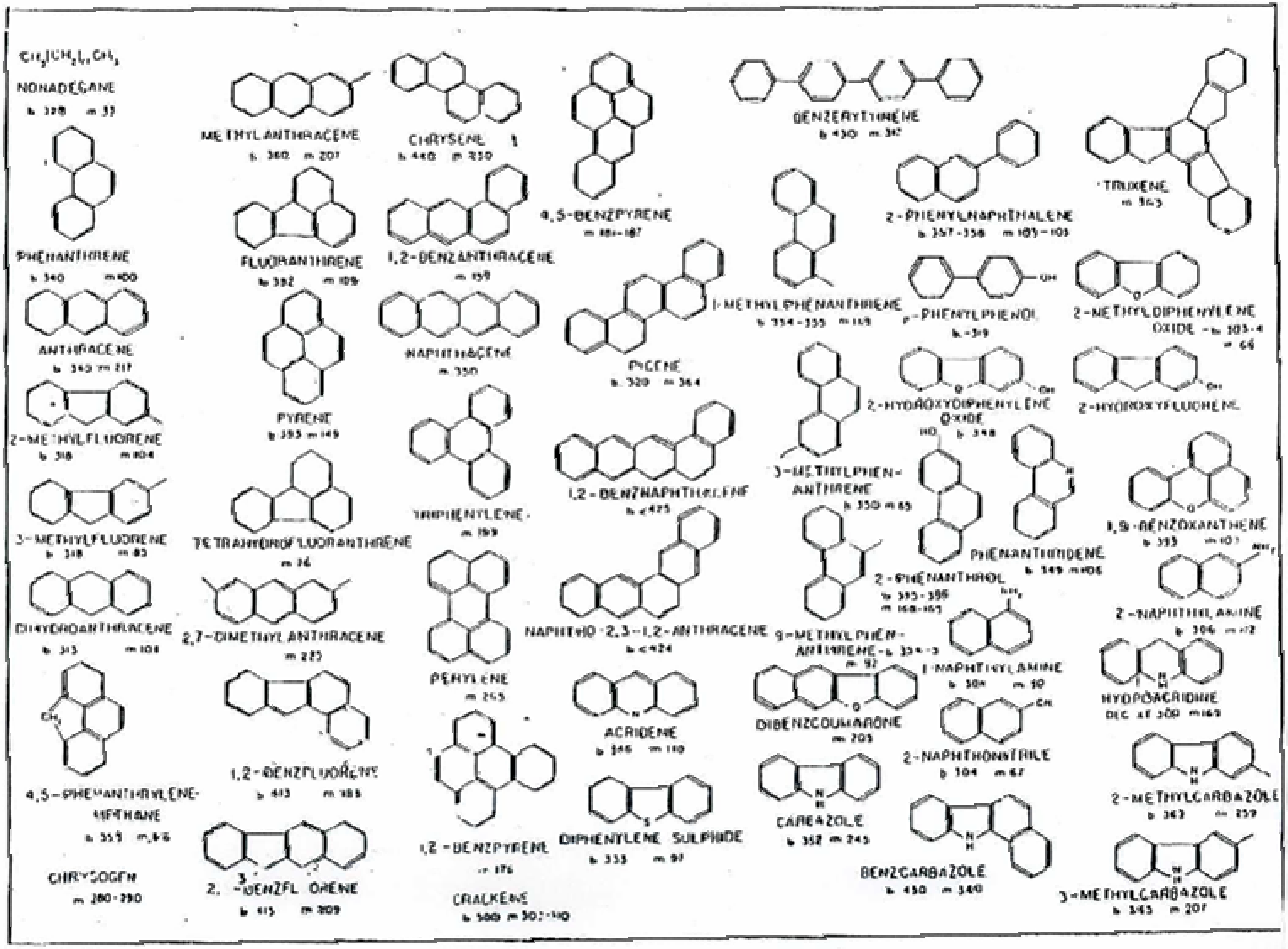


Figure 10.7.
Emissions from a CFB boiler operated at 870° C and a total excess air ratio of 1.2. From Lyngfelt et al.

Figur 35. Kok- och smältpunkter för olika PNA. Alla kokpunkter är >330 oC (ref 56).



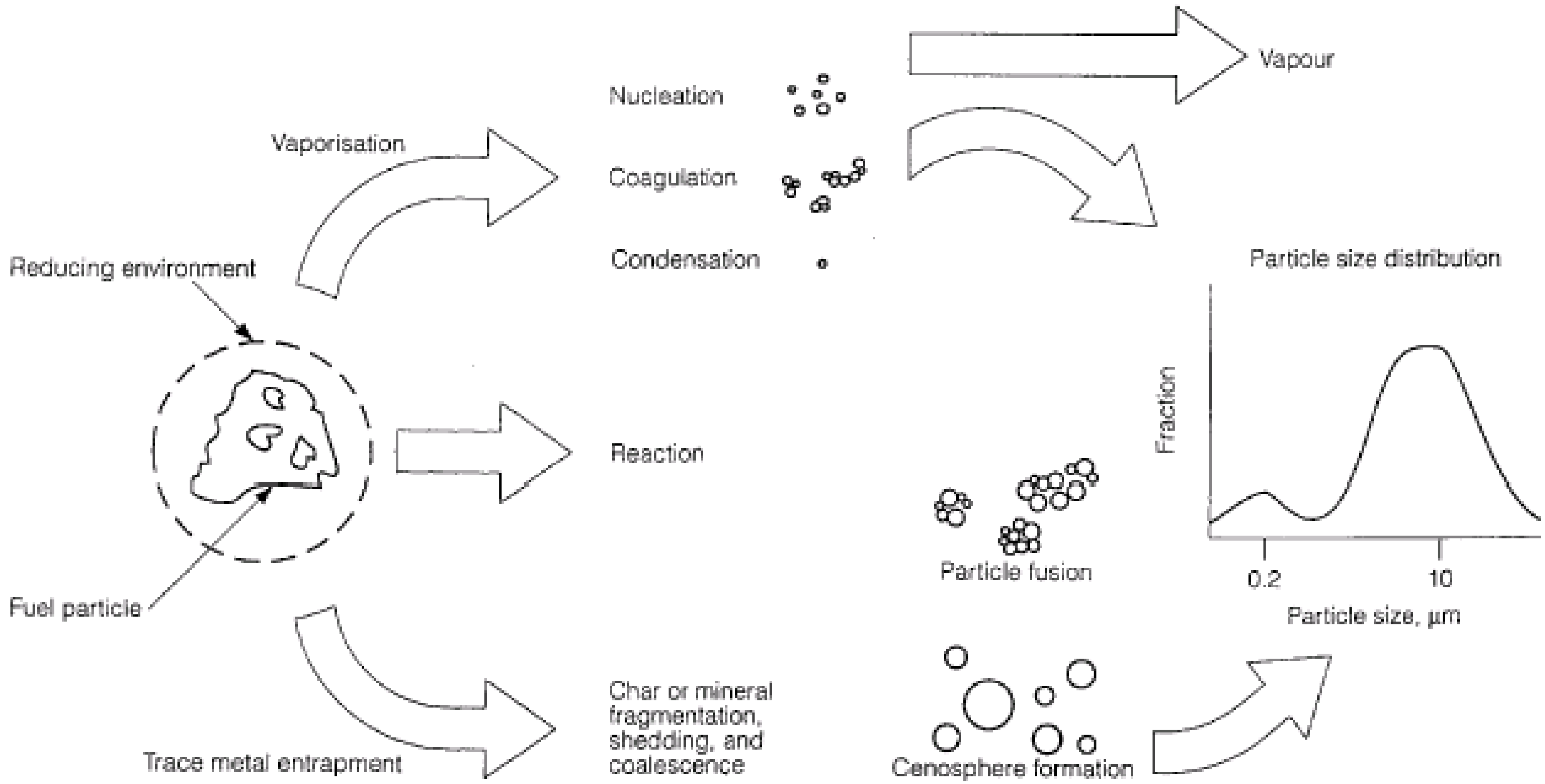


Figure 10.8.
Distribution of trace elements during coal combustion. Davidson, 2000