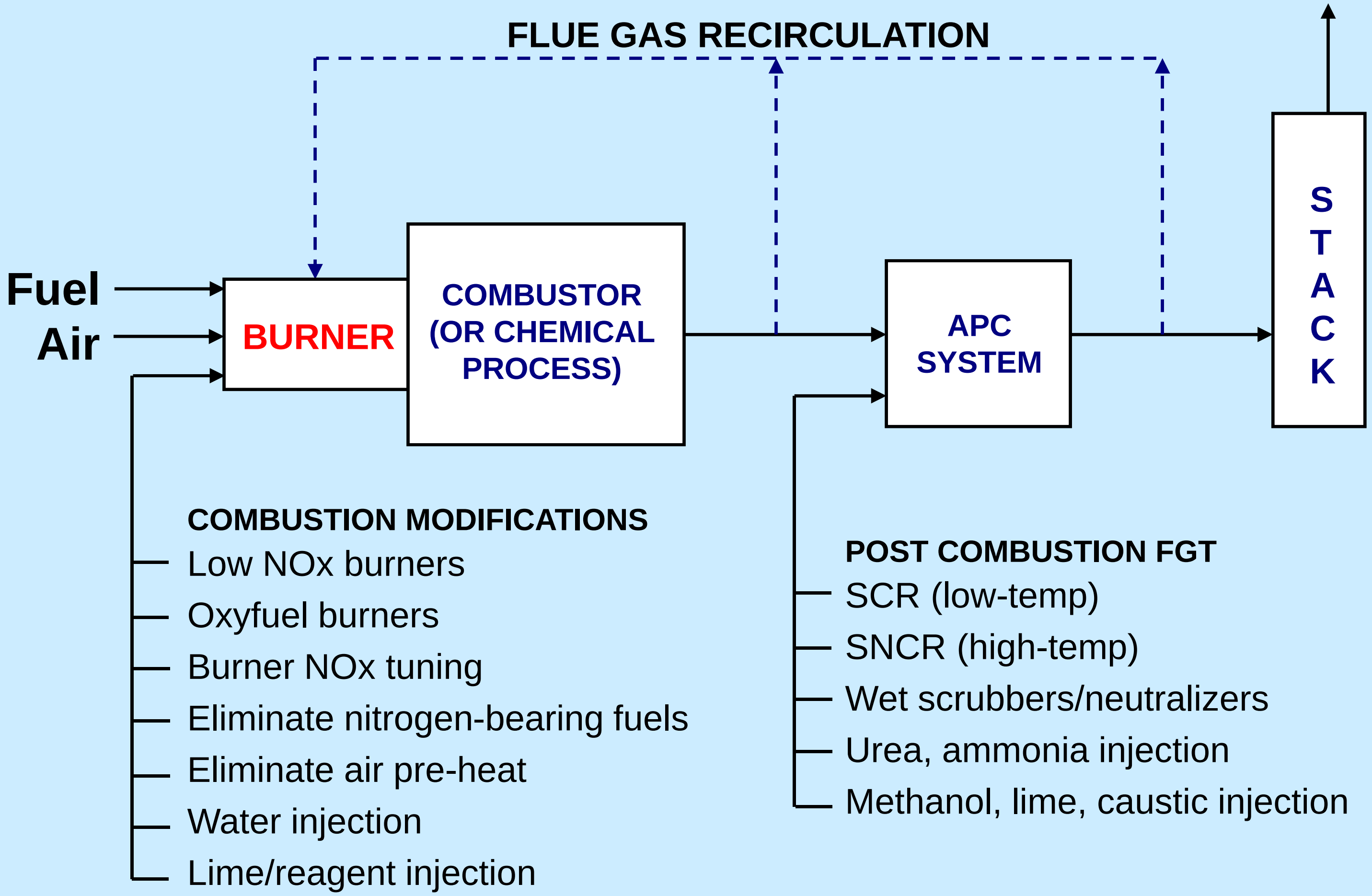
NOx CONTROL
for
STATIONARY SOURCES

TMTS

NOx Control Technologies



FLUE GAS RECIRCULATION

Fuel

Air

BURNER

COMBUSTOR (OR CHEMICAL PROCESS)

APC SYSTEM

STACK

COMBUSTION MODIFICATIONS

- Low NOx burners
- Oxyfuel burners
- Burner NOx tuning
- Eliminate nitrogen-bearing fuels
- Eliminate air pre-heat
- Water injection
- Lime/reagent injection

POST COMBUSTION FGT

- SCR (low-temp)
- SNCR (high-temp)
- Wet scrubbers/neutralizers
- Urea, ammonia injection
- Methanol, lime, caustic injection

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NOx Formation

- Produced by Thermal NOx, Fuel NOx and Prompt NOx
- Thermal NOx: At high temperatures, N_2 and O_2 dissociate and recombine to form NOx.
- Predominant mechanism is described (Ref. EPA-600/2-91-029) by Zeldovich equations:

$$N_2 + O \text{ ---> } NO + N$$

$$N + O_2 \text{ ---> } NO + O$$

- The rate of reaction and equilibrium constant favor high NOx at high temperatures.
- Thermal NOx is significant above 2,800ºF AFT.
- Excess oxygen is required; rich combustion mixtures reduce NOx formation.

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Fuel NOx

- Nitrogen "bound" in the fuel can be converted to NOx
- Generally associated with:
    - Coal, No. 6 oil, pet coke
    - Waste streams from nitrogen processes
- Conversion varies with process and type of burner
- Typically, 15-35% converted

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NOx Conversion Factors

- Converting ppm to $\mu g/m^3$
- ppm = (MW of gas/0.02404) $\mu g/m^3$
- MW NO_2 = 46, so 1 ppm NO_2 = 1910 $\mu g/m^3$
- MW NO = 30, so 1 ppm NO = 1248 $\mu g/m^3$

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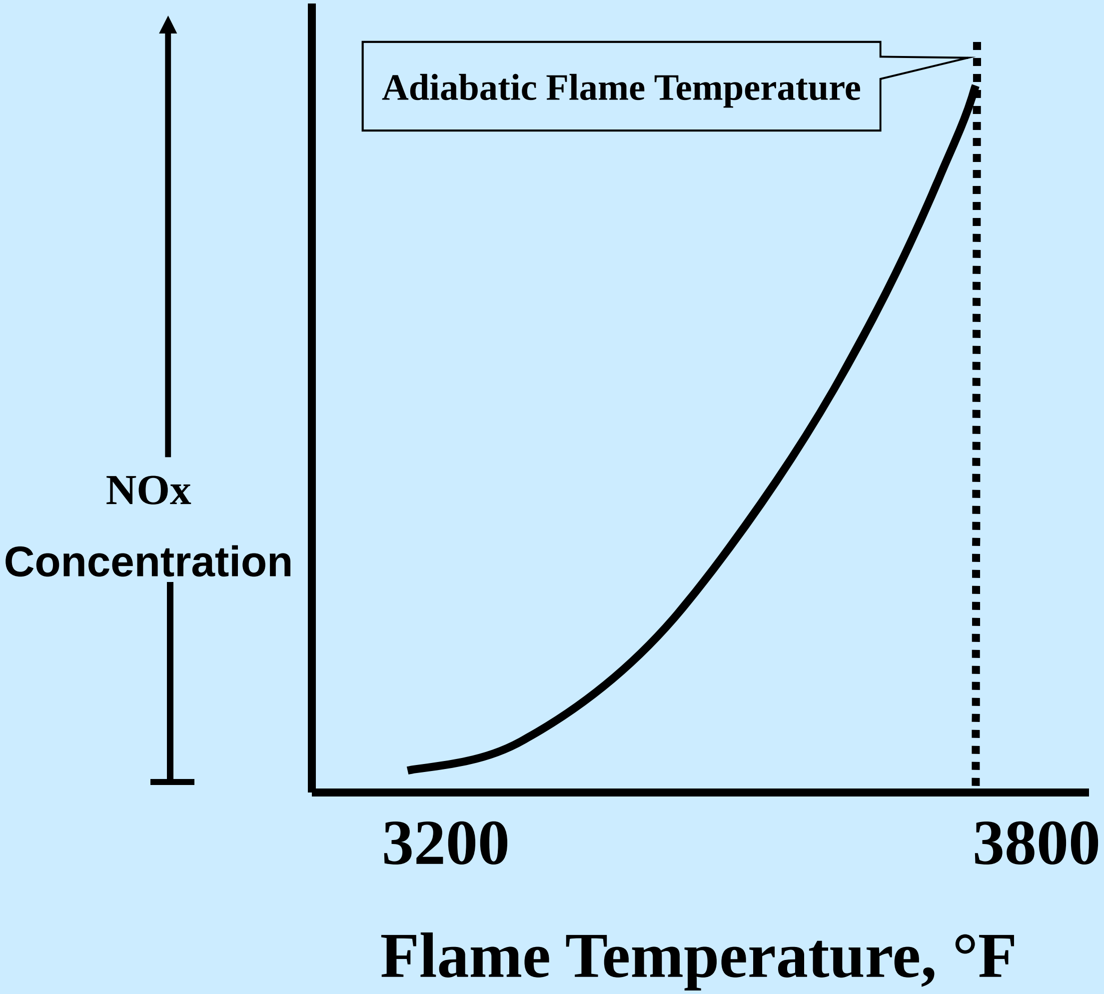
Thermal NOx Formation Dependence on Flame Temperature



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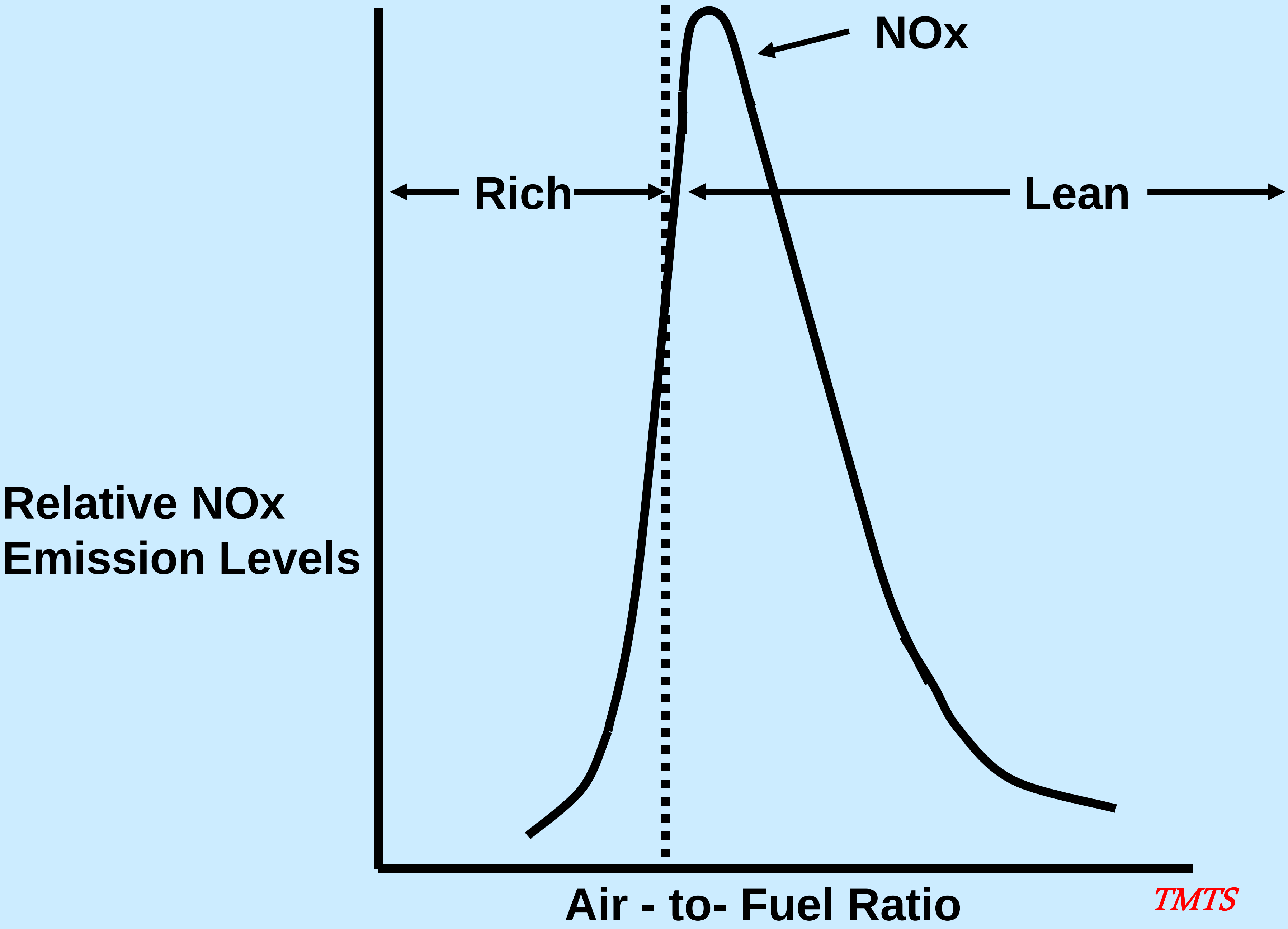
NOx
Rich
Lean
Relative NOx Emission Levels
Air - to- Fuel Ratio

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Equilibrium and Kinetics of NOx Formation

- Equilibrium predicts the maximum amount of NOx if there is an infinite time for the reaction to take place at a given temperature
- NO and NO_2 concentrations can be calculated using the Stanjan, HSC or similar software.
- However, there is usually insufficient time to reach equilibrium; hence, actual NOx < equilibrium NOx
- An exception is large secondary combustion chambers working at near-isothermal conditions

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Kinetics

- Predicts how complete the reaction is using standard models
- However, we rarely know the duration of the reaction in all but simple burners
- Caution: due to unknown/undocumented fluid dynamics, zones of rich and lean gases, NOx can vary widely and on rare occasions even exceed equilibrium predicted values
- When possible, use test data or AP-42 values

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Emissions from Stationary Sources

GENERAL GUIDELINES

Source	ppm
Normal industrial fired equip.	100-200
Utility boilers	400
High-temperature processes (cement kilns)	250-1,100
With pre-heated air	1,000-3,500
Low NOx burners	<50
Ultra-low NOx burners	<10

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Combustion Modifications

"Fuel NOx" from fuel nitrogen

- Reduce nitrogen in fuel, operate in a reducing atmosphere

"Thermal NOx" from high temperatures

it occurs in diffusion flames at high XS air

in pre-mixed flames, it occurs at low XS air

function of flame geometry, O_2, temp & time

- Reduce the maximum combustion temp by extending the flame zone and rapid cooling of hot gases

“Prompt NOx”

- Improve mixing to minimize rich pockets of gas, use high intensity burner design

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Post-Combustion and FGT

- **Typical reactions using ammonia or urea:**

  Urea + NOx ---> $N_2 + CO_2 + H_2O$

  NH_3 + NOx + O_2 ---> $N_2 + H_2O$

  (must prevent excess injection of reagent)

- **SCR (selective catalytic reduction),**

  Lower temperatures, 600 F to 700 F

  Approx. 90% NOx removal; uses titanium, vanadium,tungsten and zeolites as catalyst

- **SNCR (non-selective catalytic reduction)**

  Higher temperatures, 1,600 F to 2,100 F

  Lower capital costs, but less effective

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