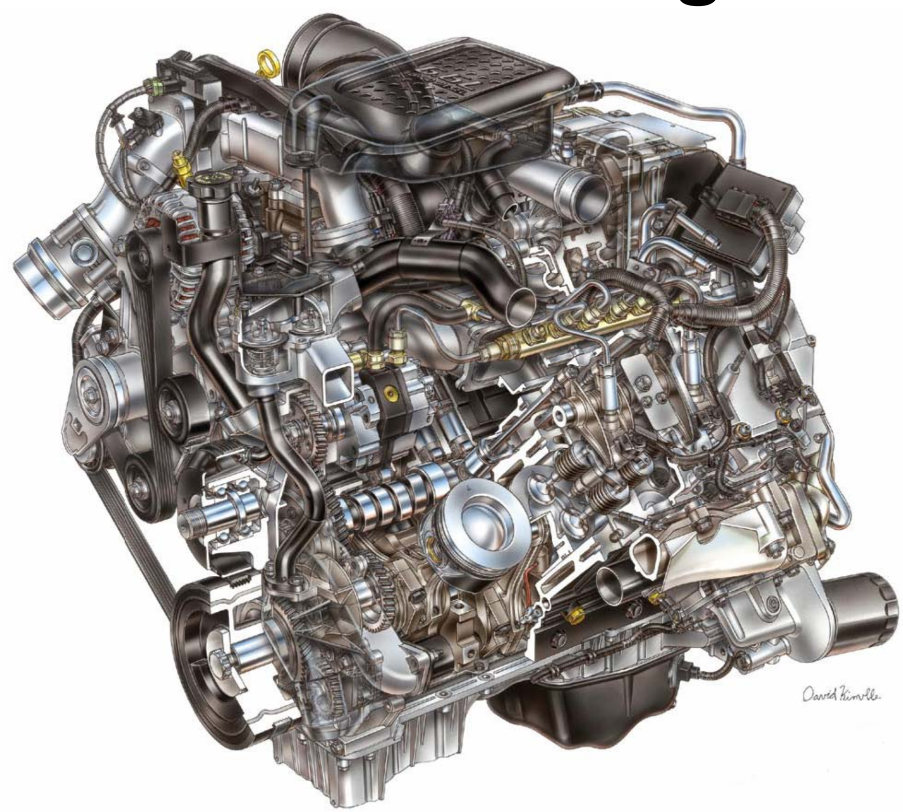
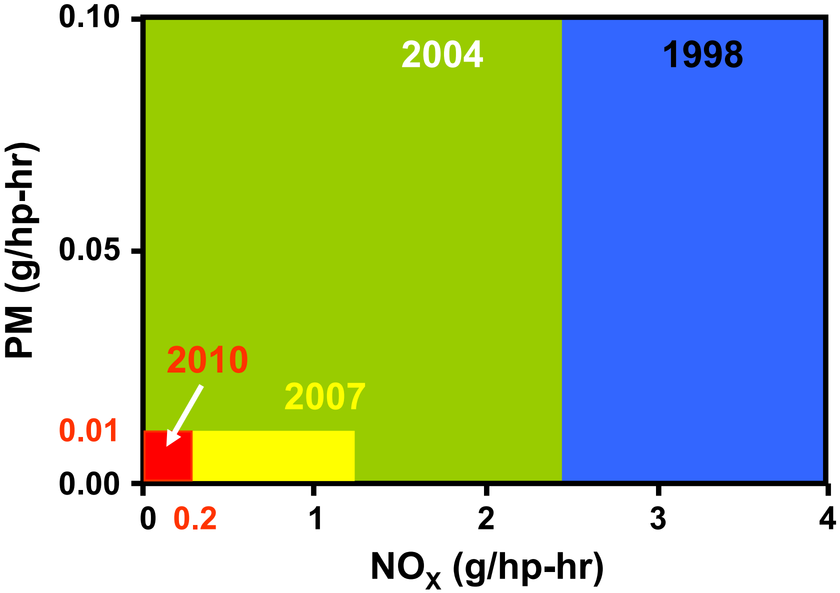
High-Efficiency Clean Combustion Design for Compression Ignition Engines



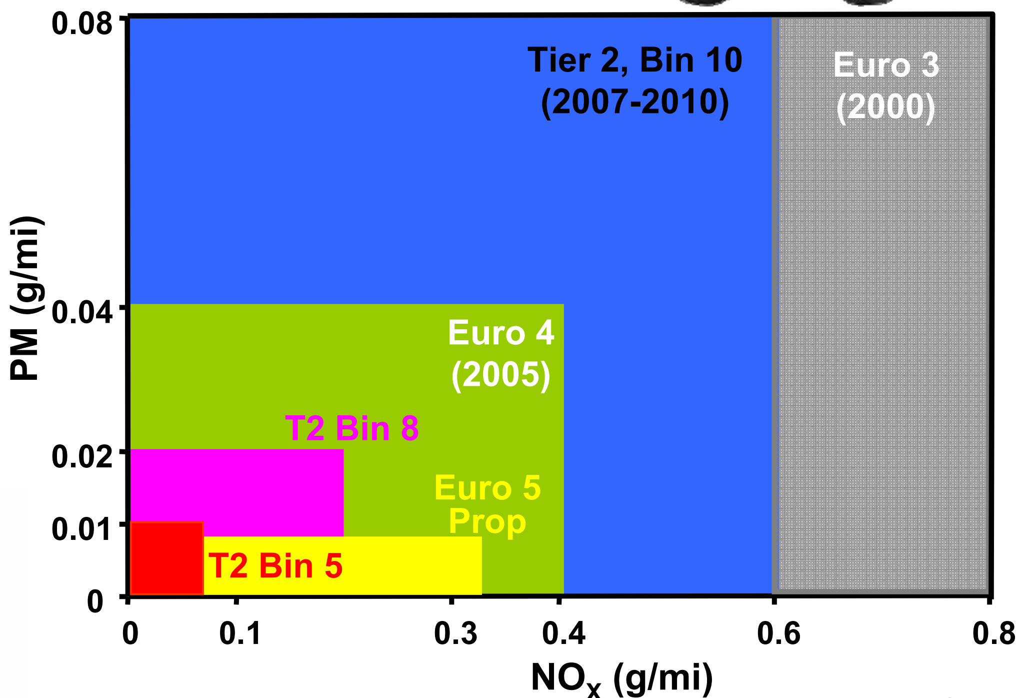
Mike Potter
Russ Durrett
General Motors
August 24, 2006

Overview

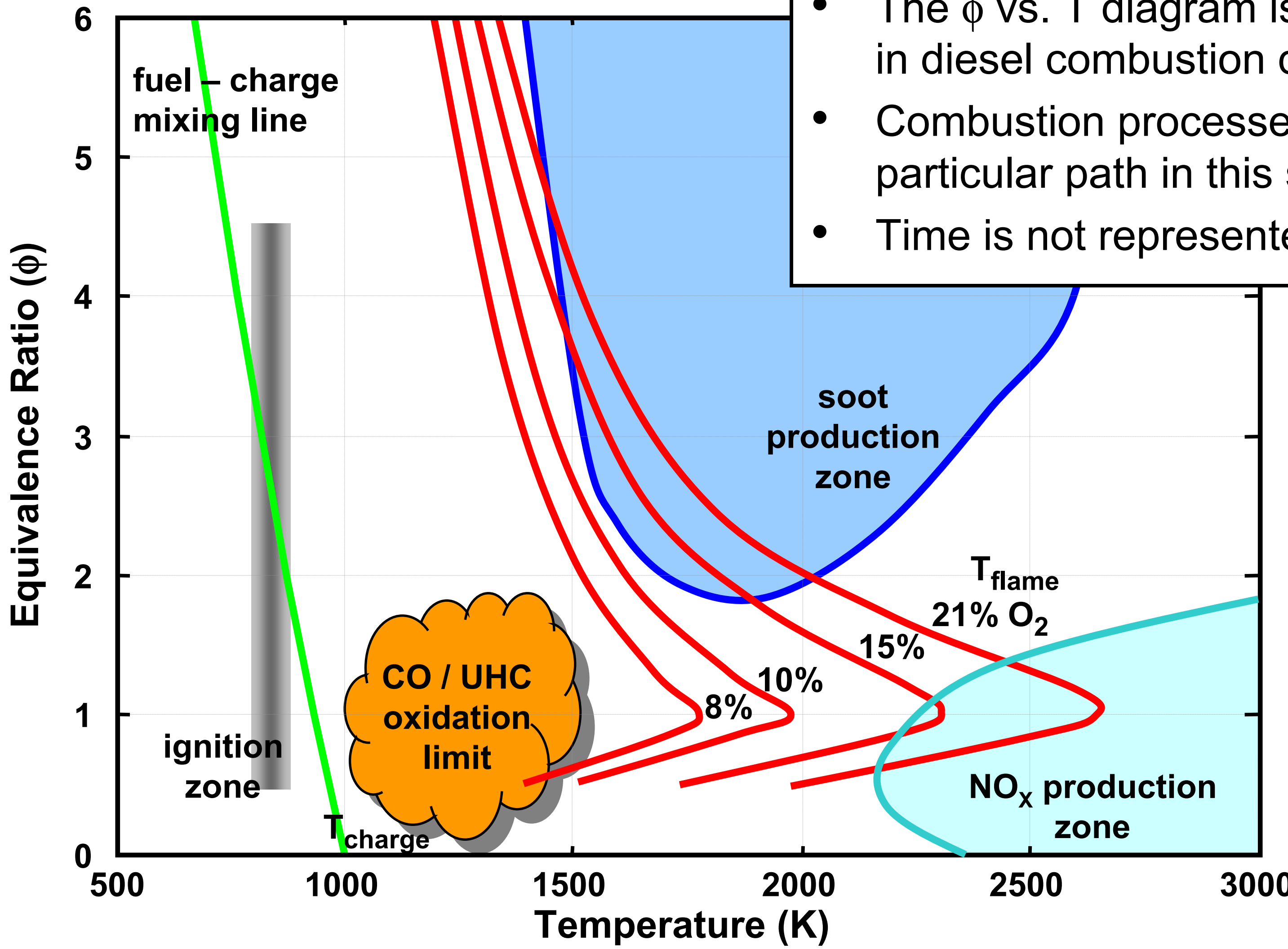
U.S. Heavy Duty Emission Standards



U.S. Light Duty Emission Standards

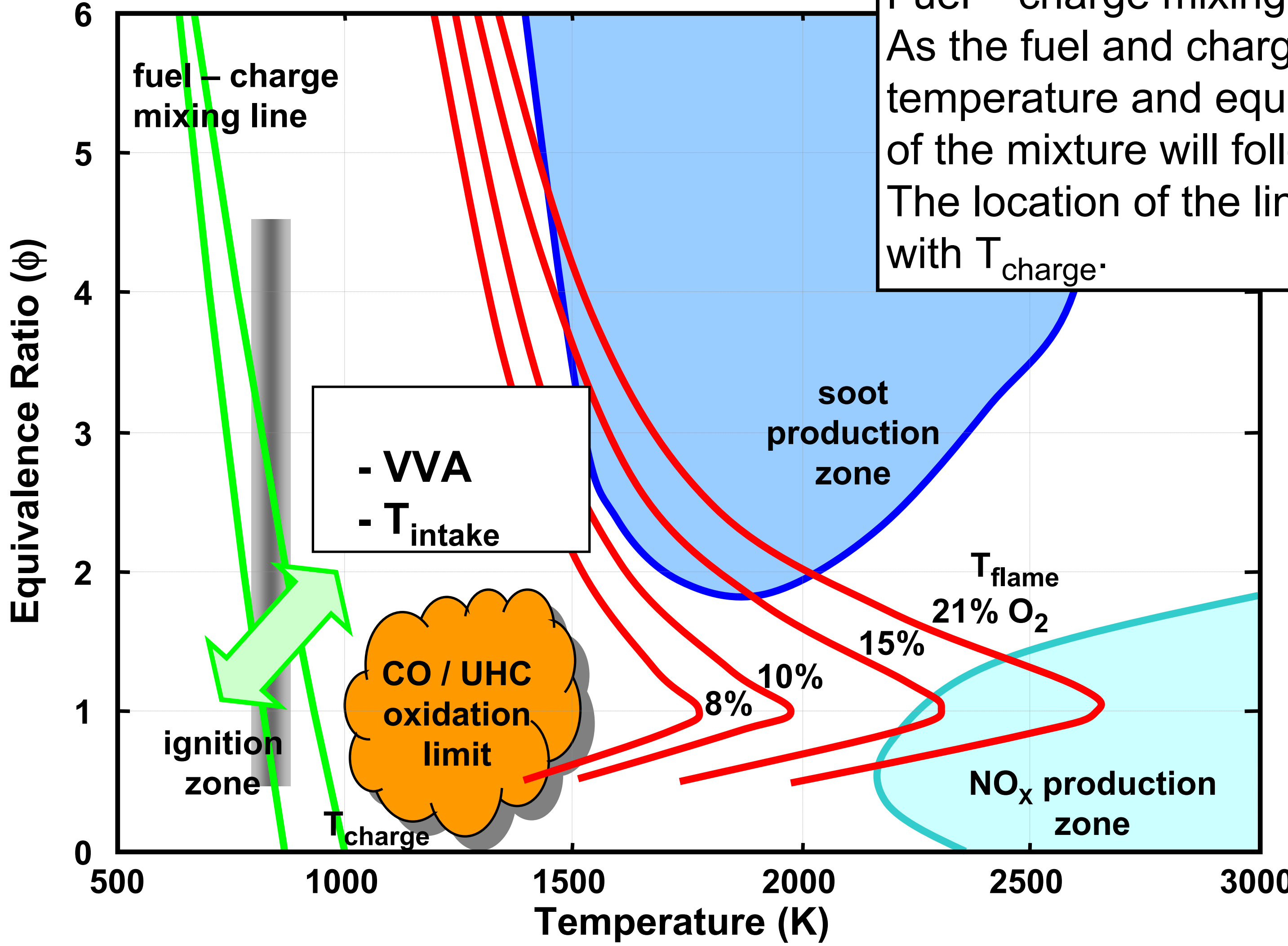


Equivalence Ratio (ϕ) vs T Space – Navigating the Terrain



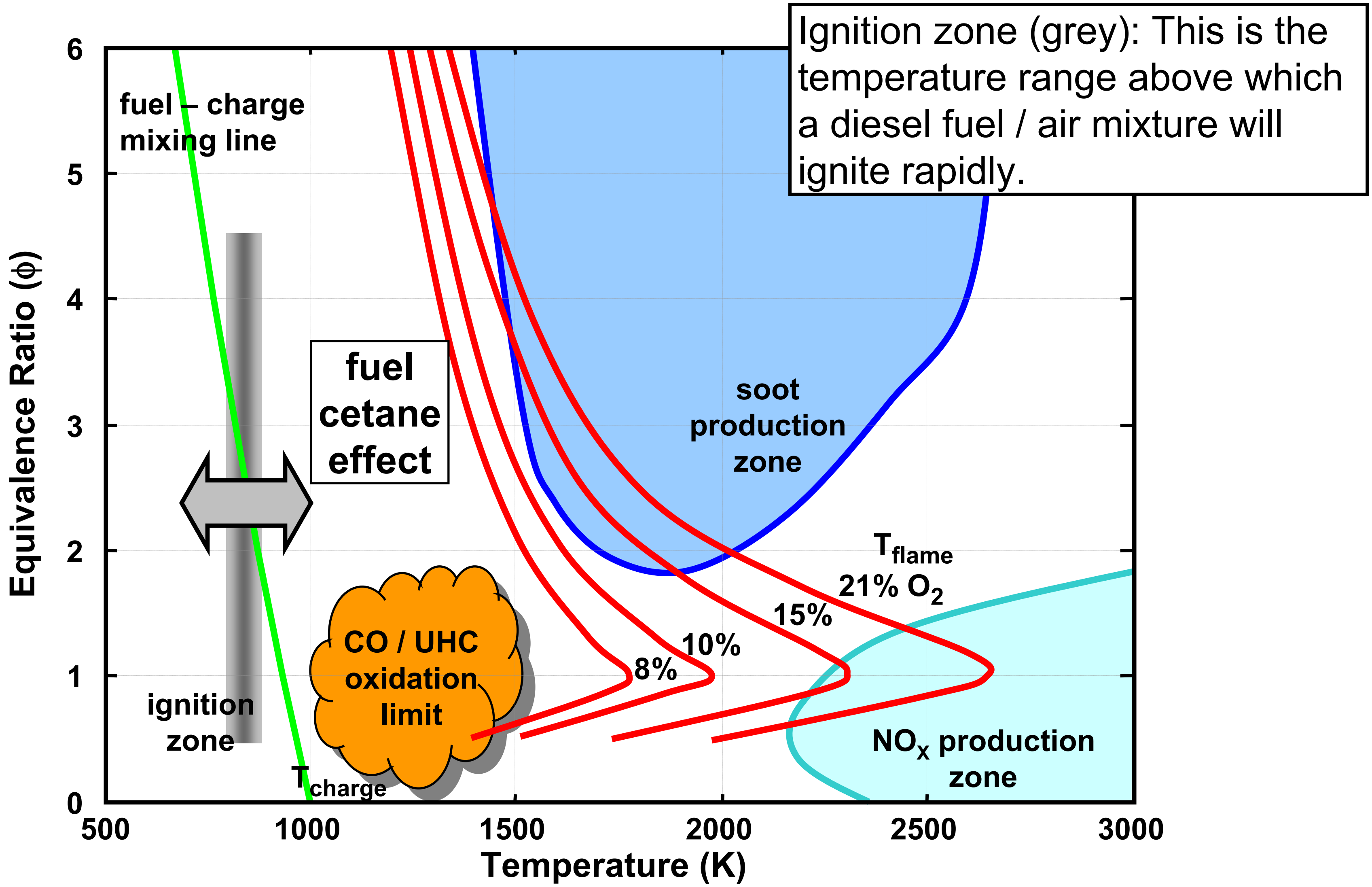
- The ϕ vs. T diagram is commonly used in diesel combustion discussions.
- Combustion processes pass through a particular path in this space.
- Time is not represented in the figure.

Equivalence Ratio (ϕ) vs T Space – Navigating the Terrain



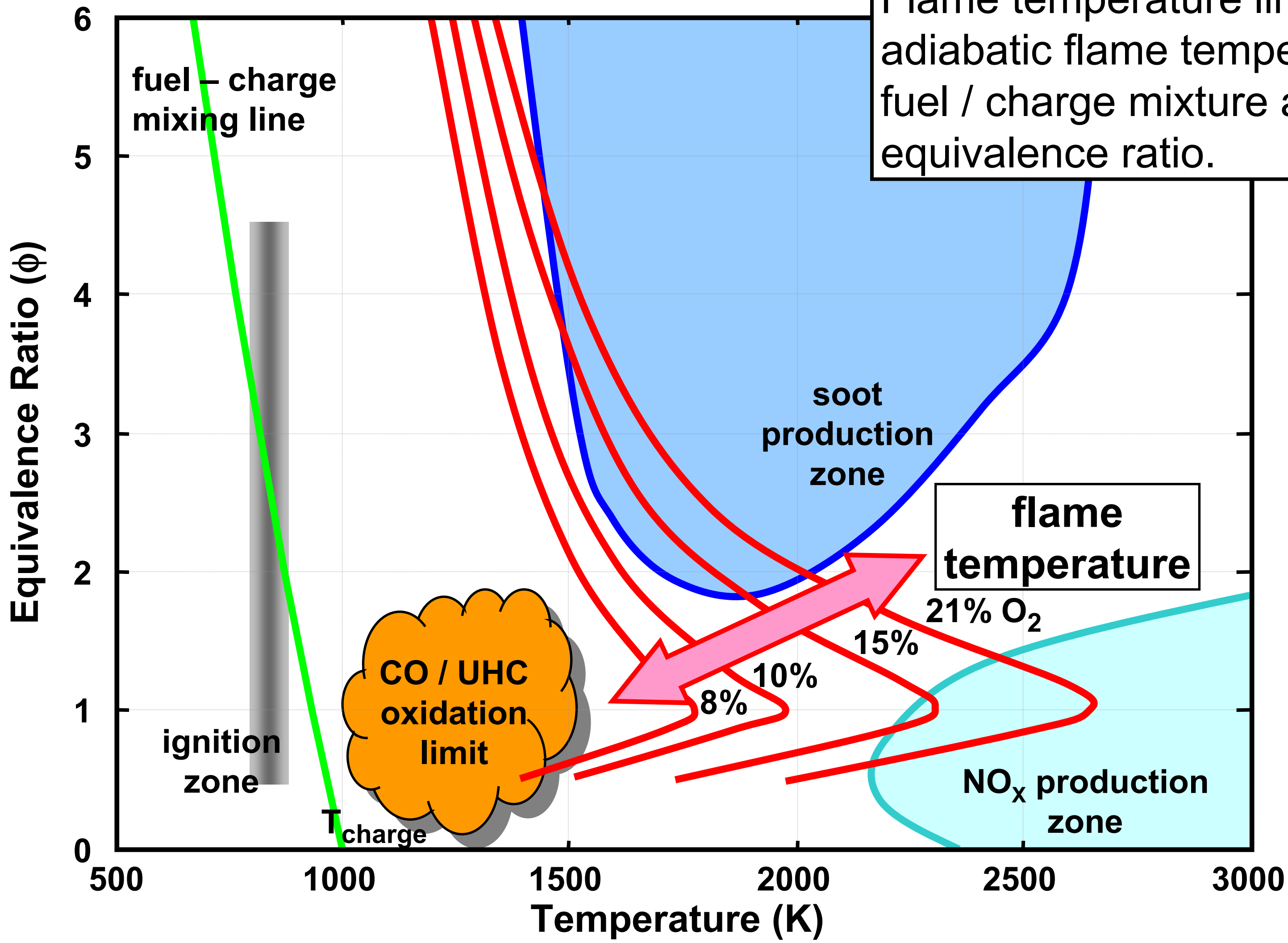
Fuel – charge mixing line (green): As the fuel and charge mix, the temperature and equivalence ratio of the mixture will follow this line. The location of the line changes with T_{charge}.

Equivalence Ratio (ϕ) vs T Space – Navigating the Terrain

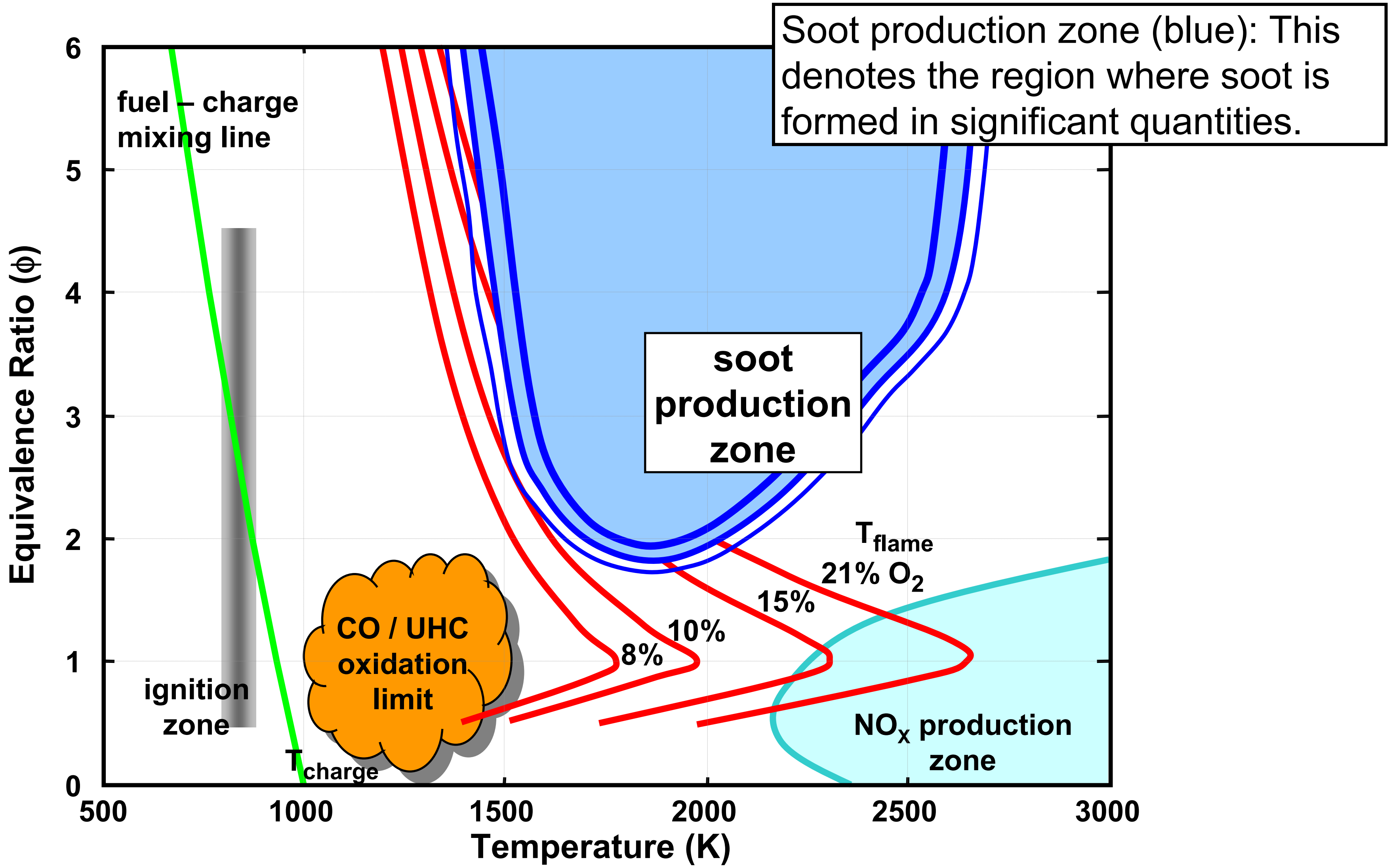


Equivalence Ratio (ϕ) vs T Space – Navigating the Terrain

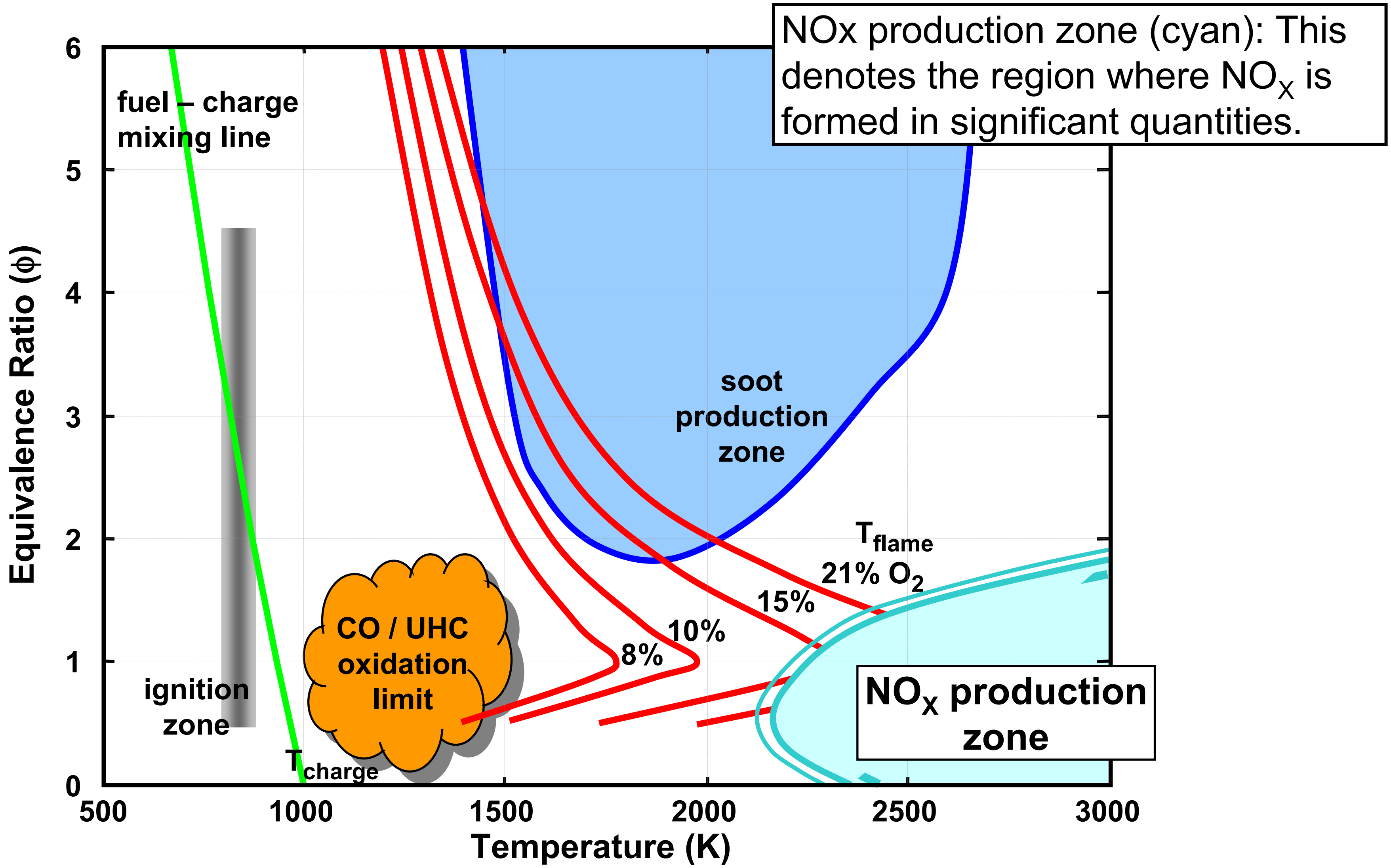
Flame temperature lines (red): The adiabatic flame temperature of a fuel / charge mixture at the given equivalence ratio.



Equivalence Ratio (ϕ) vs T Space – Navigating the Terrain

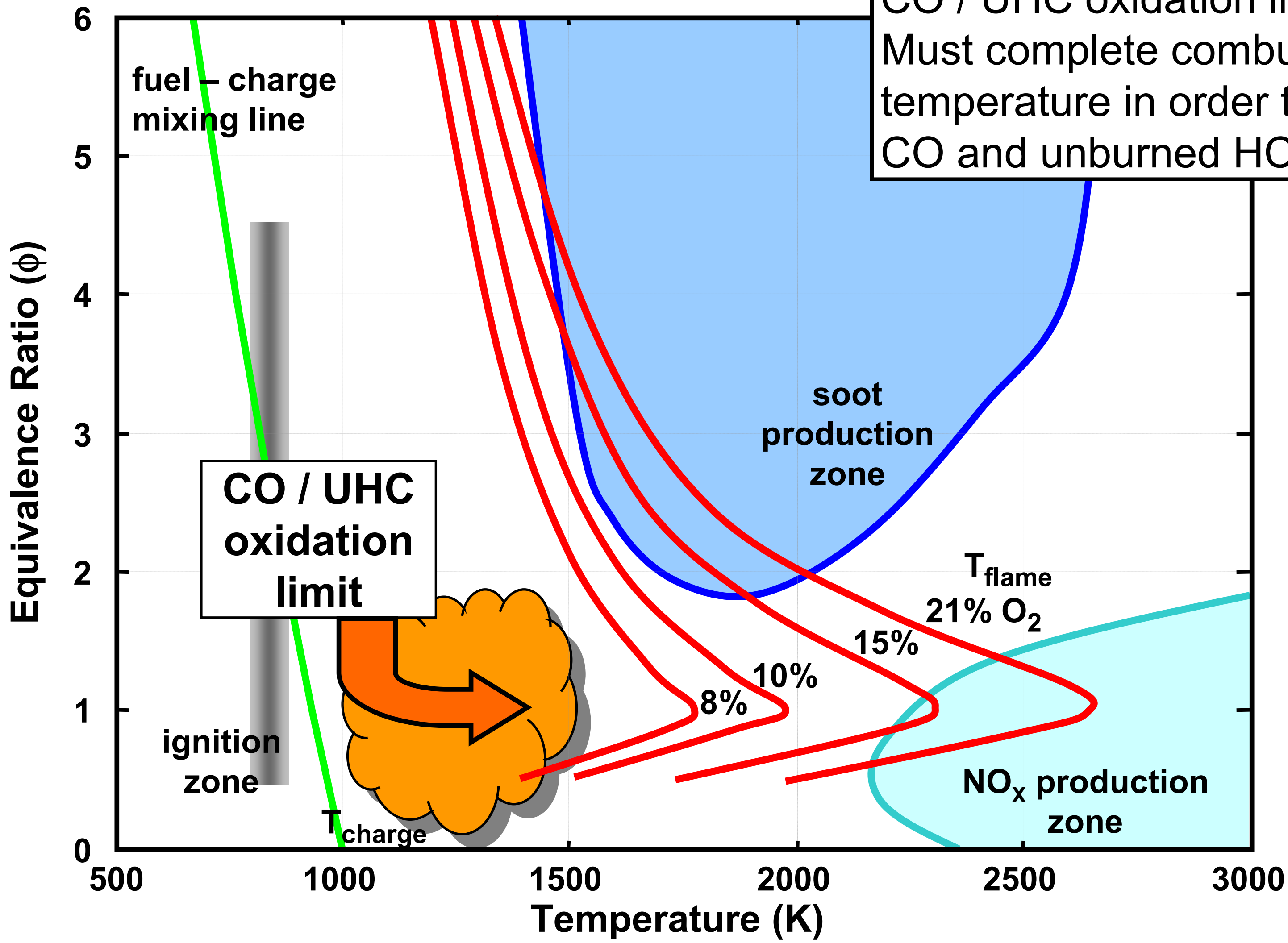


Equivalence Ratio (ϕ) vs T Space – Navigating the Terrain

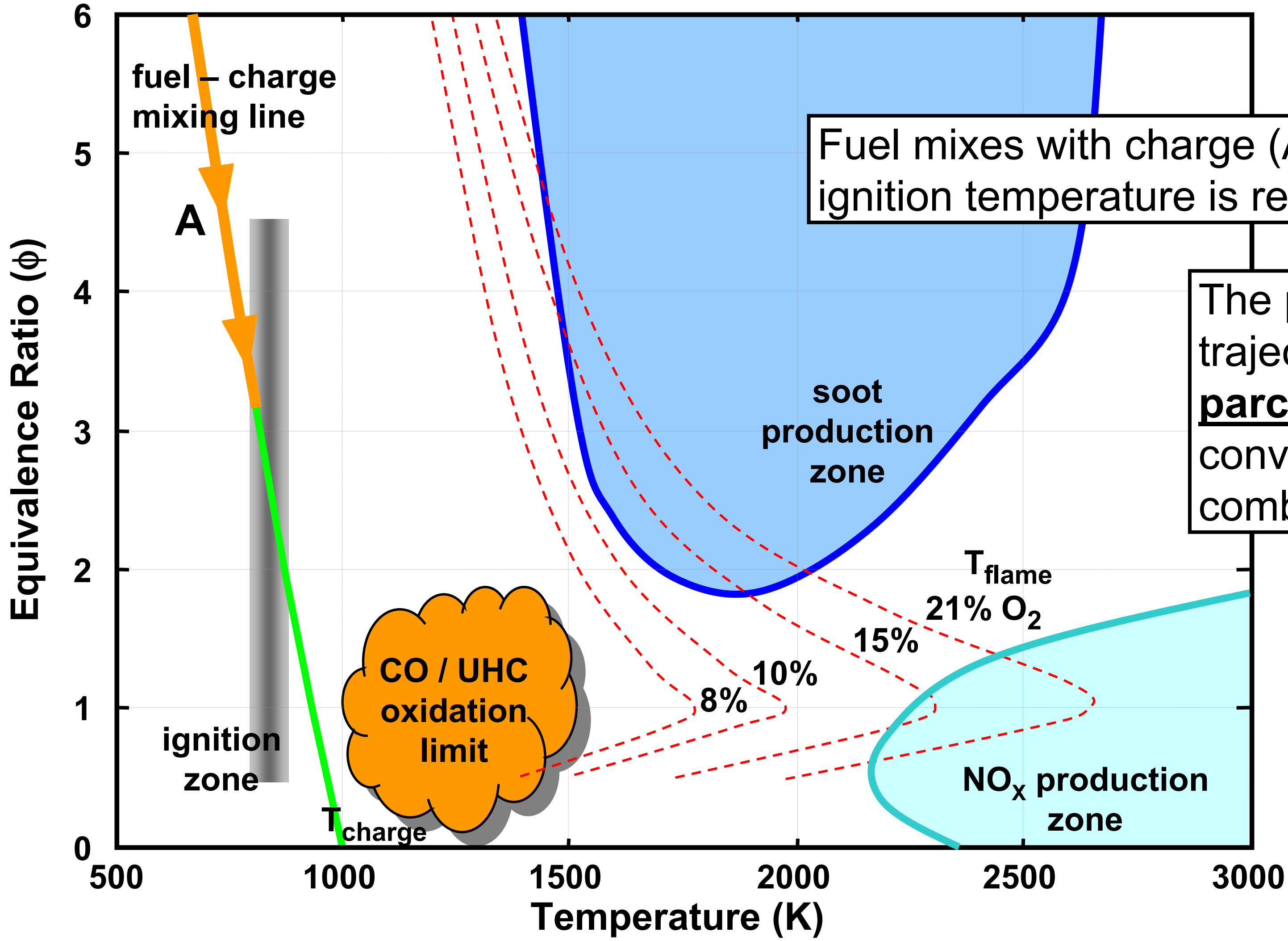


Equivalence Ratio (ϕ) vs T Space – Navigating the Terrain

CO / UHC oxidation limit (orange): Must complete combustion above this temperature in order to consume CO and unburned HC.



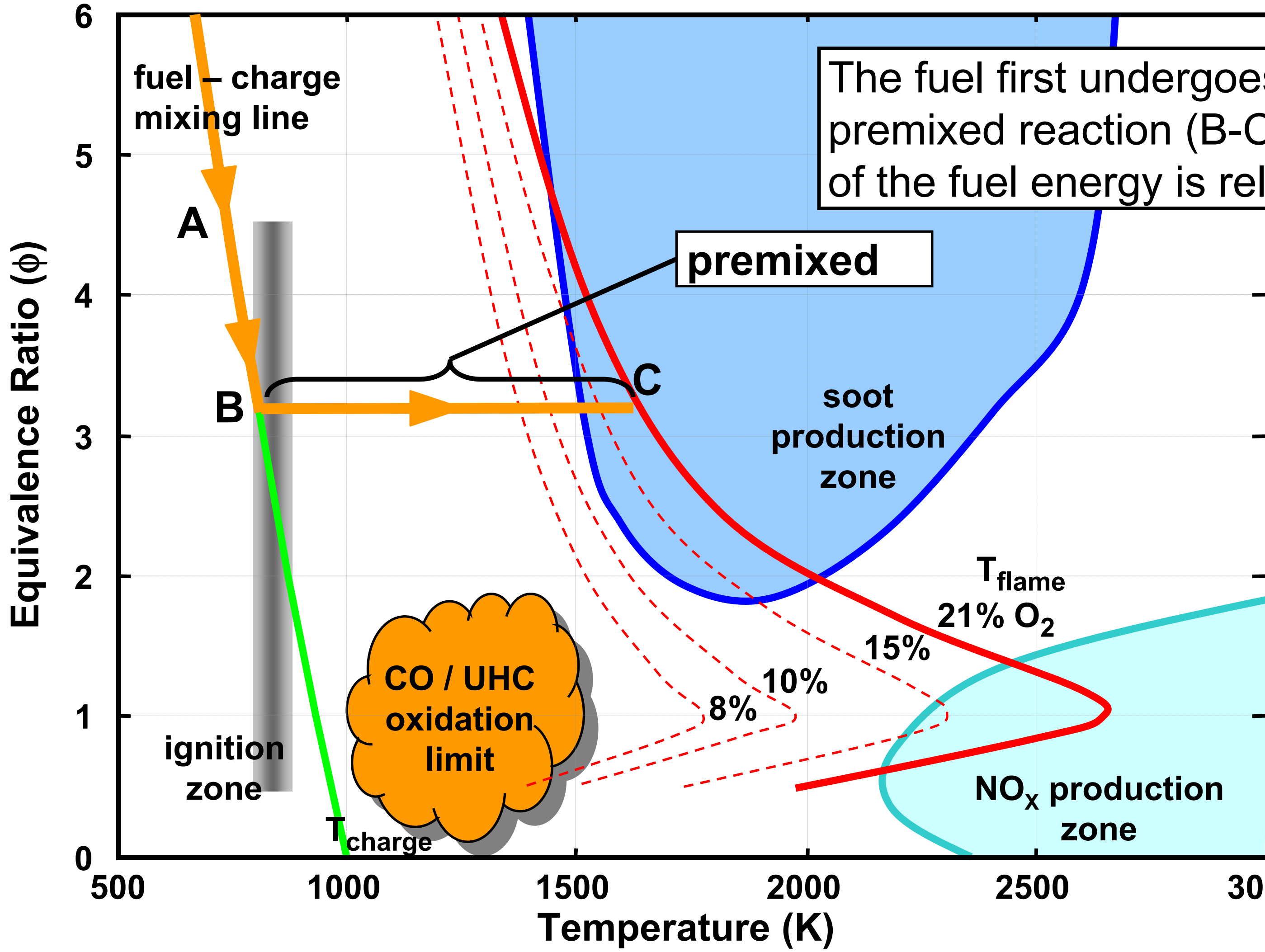
Conventional Diesel Combustion



Fuel mixes with charge (A) until the ignition temperature is reached.

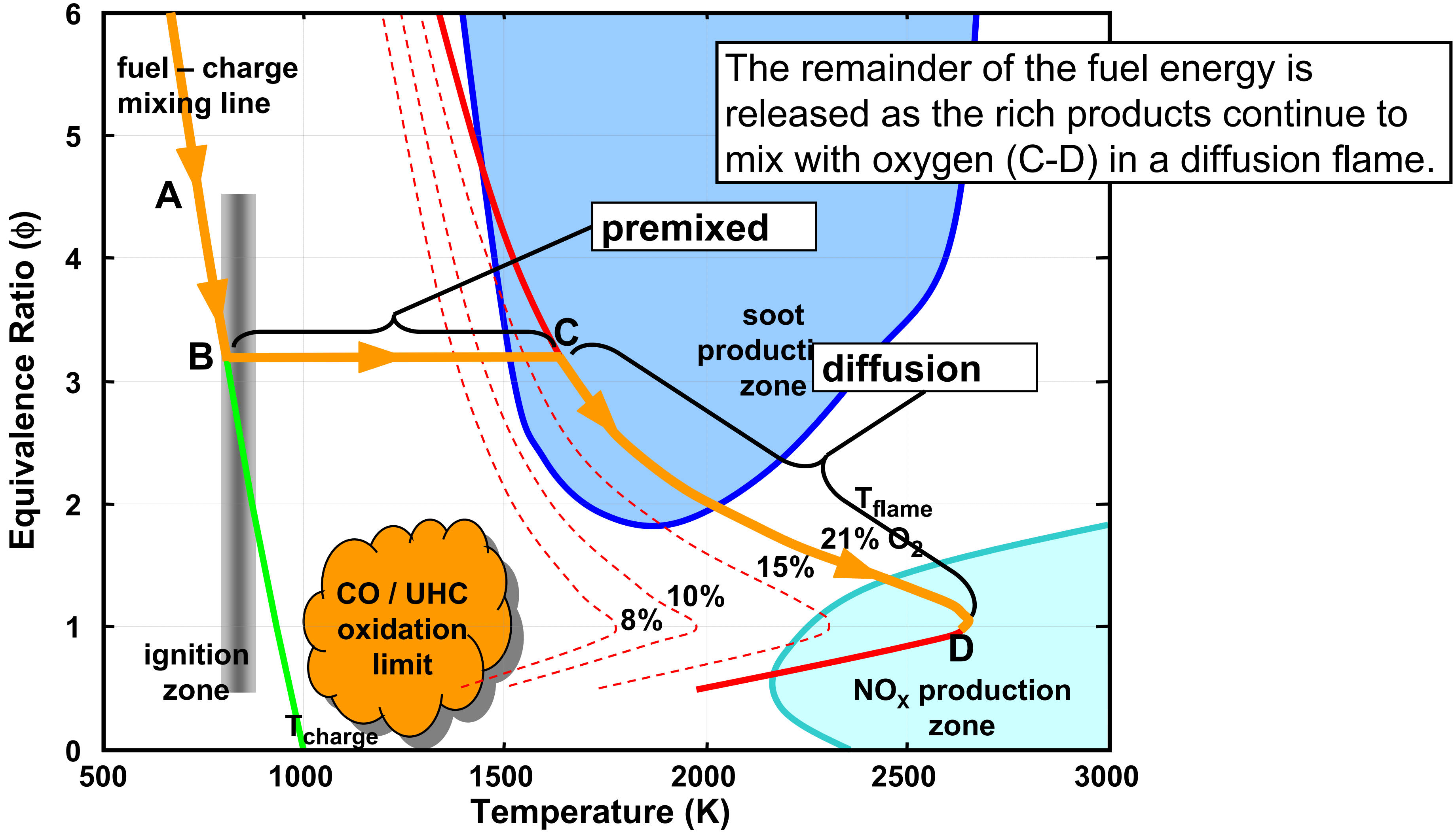
The path shows the trajectory of a **fuel parcel** undergoing a conventional diesel combustion event.

Conventional Diesel Combustion

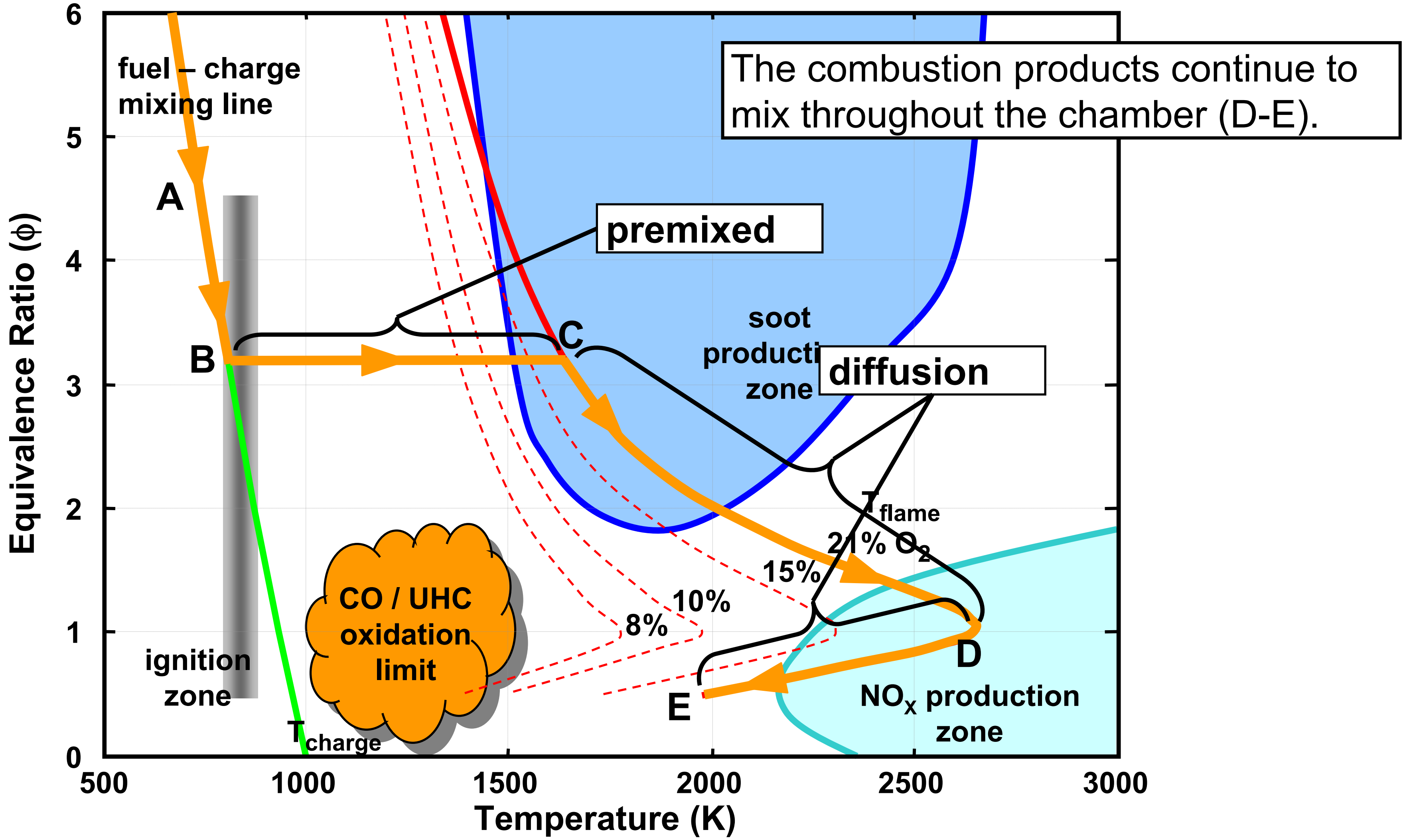


The fuel first undergoes a rich premixed reaction (B-C) in which part of the fuel energy is released.

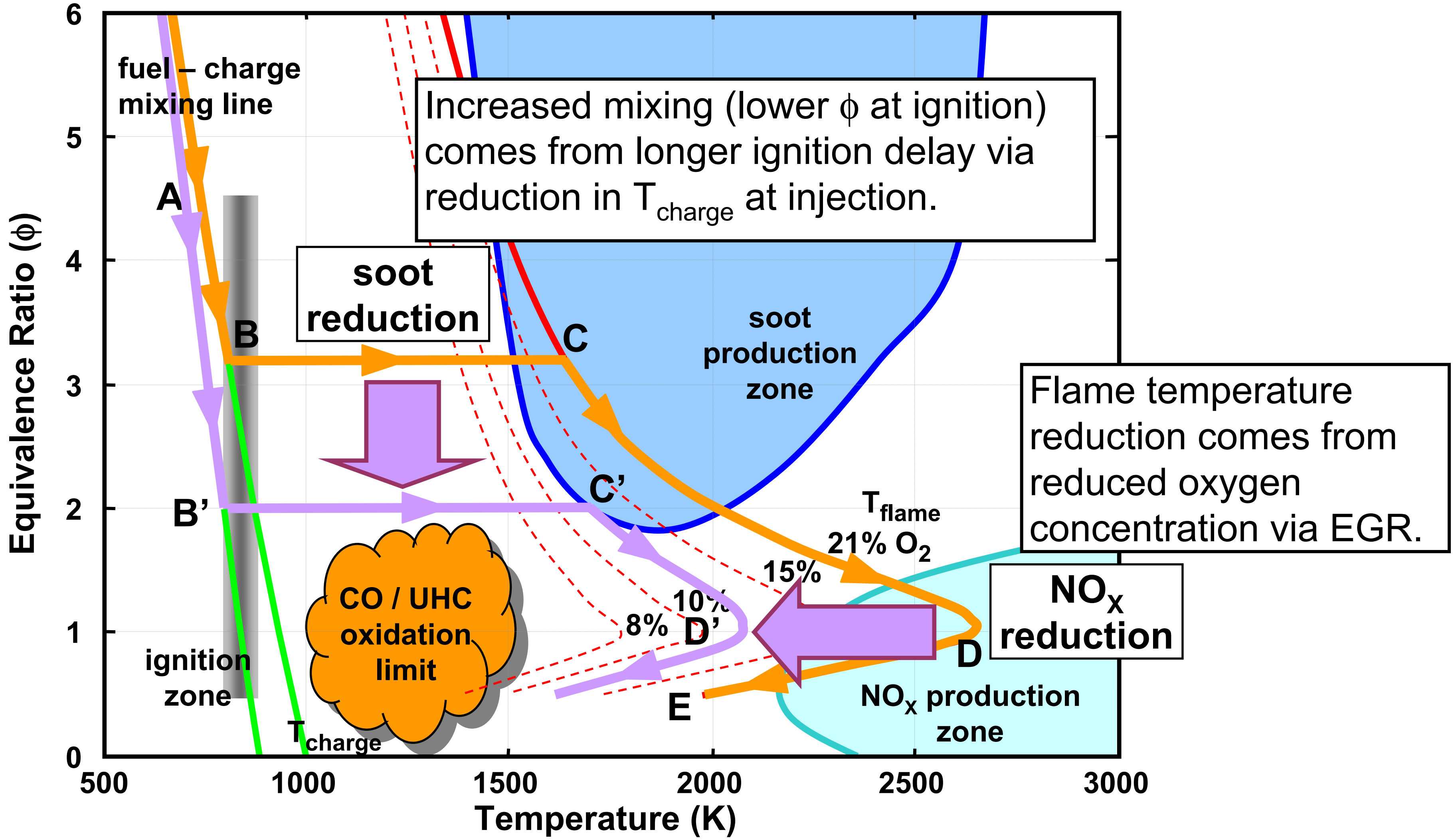
Conventional Diesel Combustion



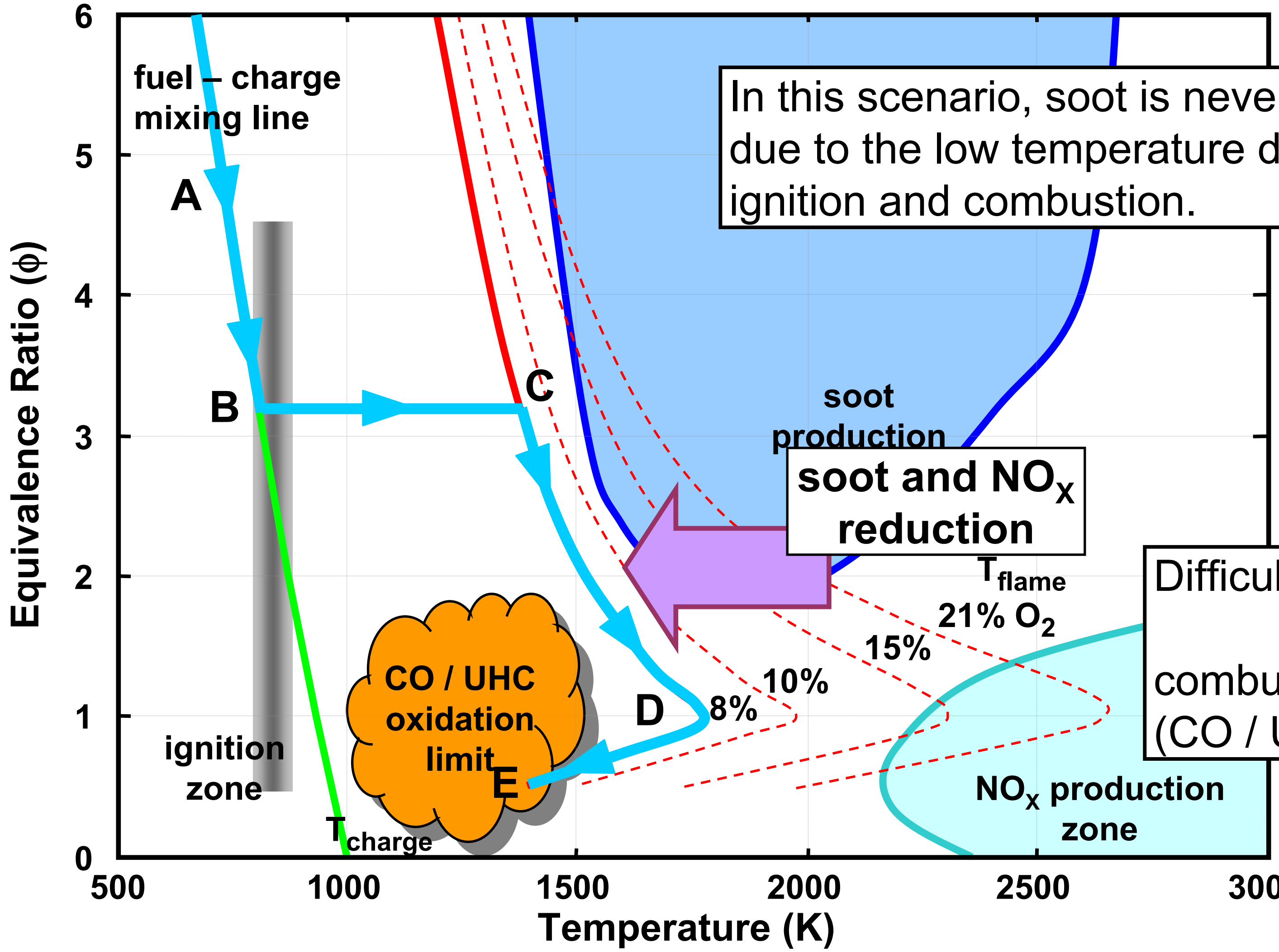
Conventional Diesel Combustion



New Combustion Modes (PCCI) – Reducing NOx and Soot



Soot Reduction Through Low O_2 Concentration

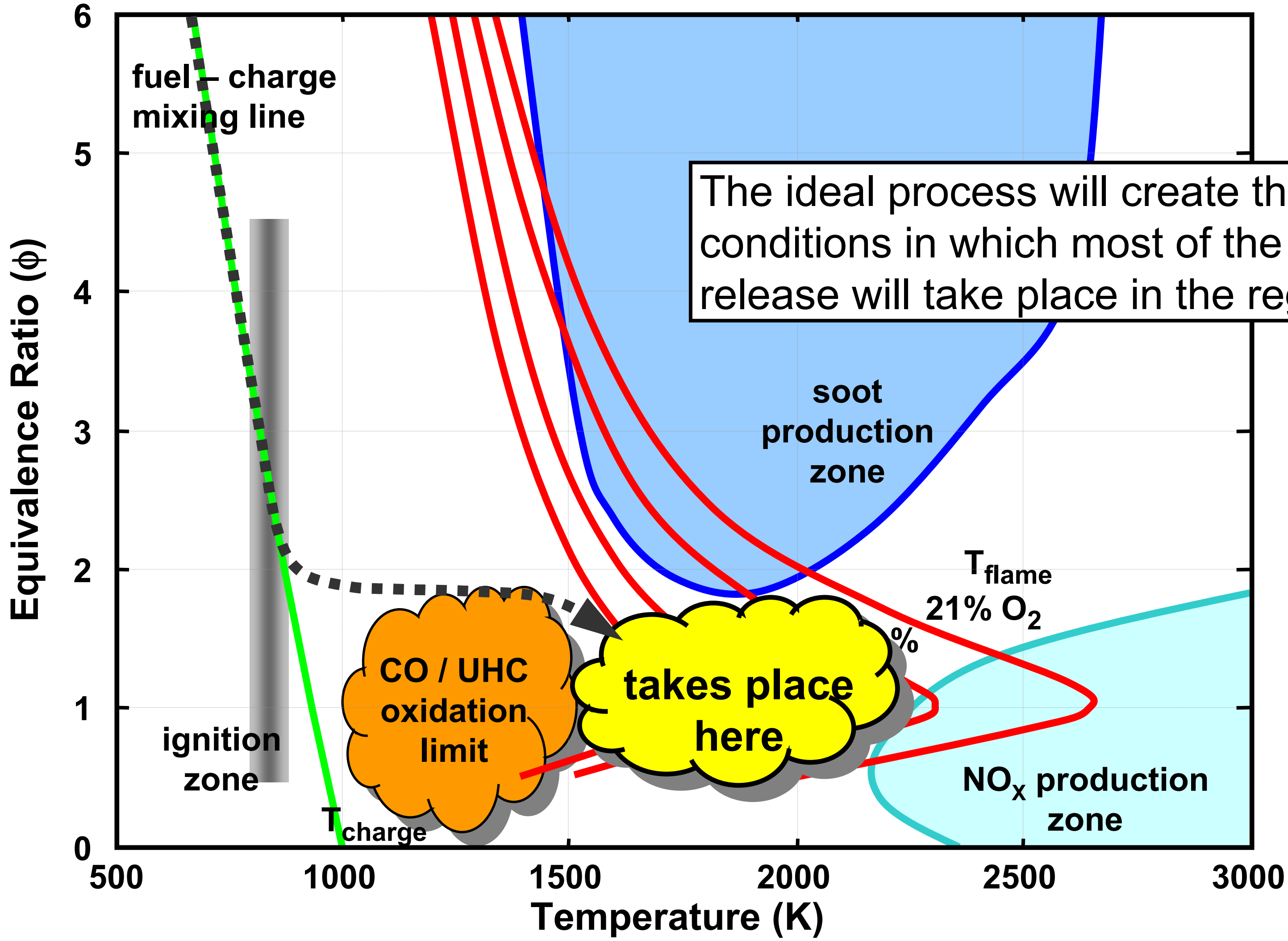


In this scenario, soot is never formed due to the low temperature during ignition and combustion.

Difficult to avoid

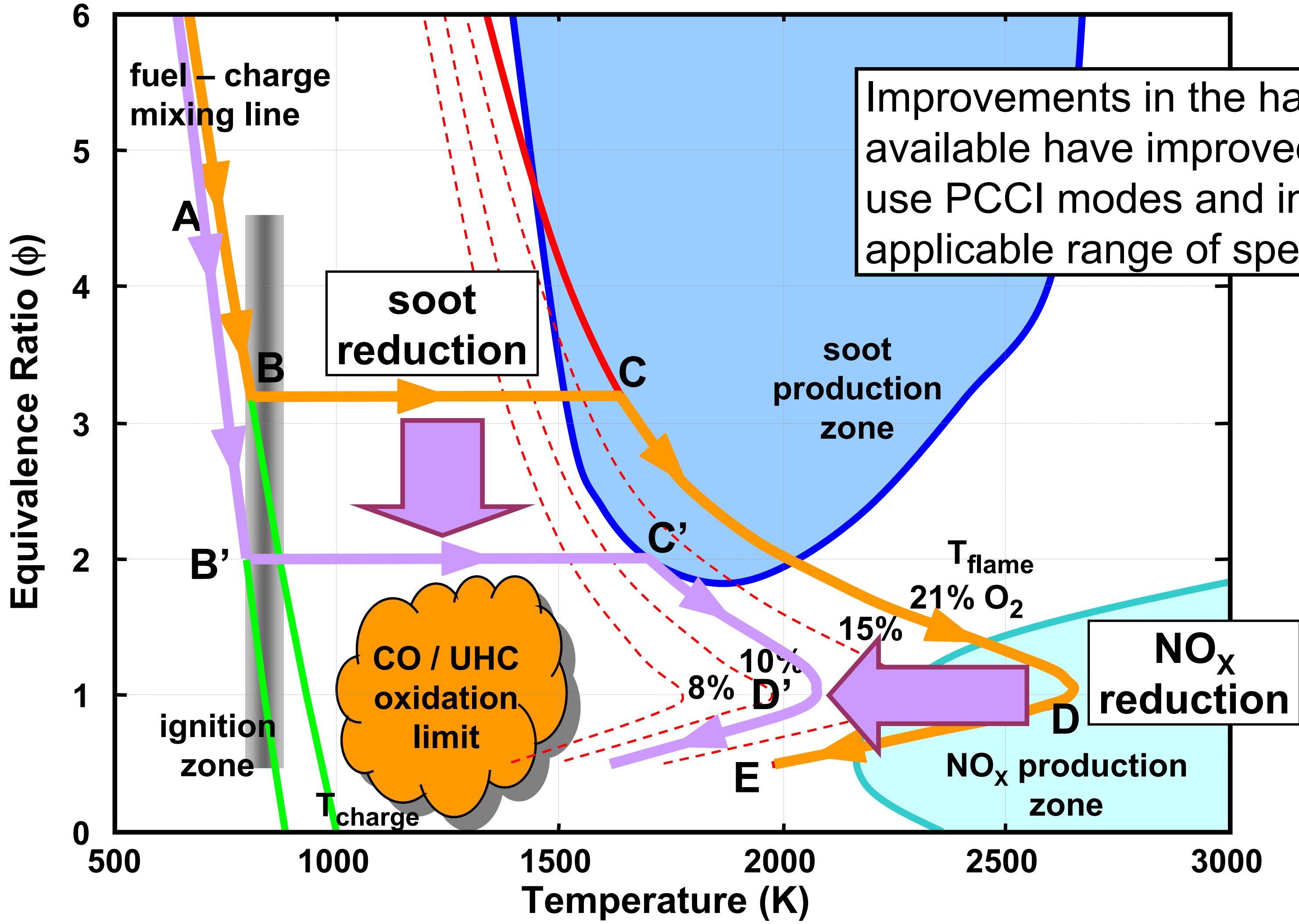
combustion products (CO / UHC).

Ideal Combustion Process



The ideal process will create the necessary conditions in which most of the energy release will take place in the region shown.

New Combustion Modes (PCCI) – Reducing NOx and Soot



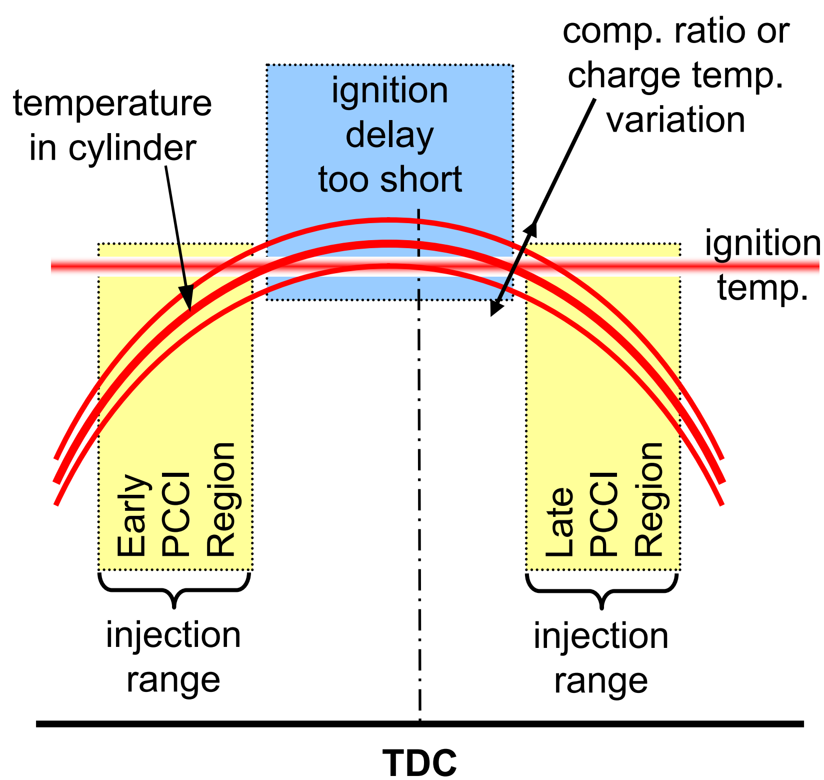
Improvements in the hardware available have improved our ability to use PCCI modes and increased their applicable range of speed and load.

End of Presentation

- BackUp Material

Early vs. Late PCCI

- PCCI mode requires a longer ignition delay.
- How to lengthen the ignition delay:
  - Lower T at SOI
  - Lower [O2] at SOI
- In order to access lower temperature, the injection must move away from TDC:
  - Advance timing for early PCCI
  - Retard timing for late PCCI
- Compression ratio and charge temperature will also affect the injection range.



Some Practical Limitations

- Impossible to achieve temperatures higher than the flame temperature – operation in the high T – high ϕ region is precluded.
- The ignition process must pass through the region shown (need better words here!)
- End of combustion temperature must remain high enough to insure complete oxidation of CO and UHC compounds.