PROCESS SAFETY ENGINEERING (0905477)

12- FIRES AND COMBUSTION: FLAMMABILITY DIAGRAMS

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The superior man, when resting in safety, does not forget that danger may come…. When all is orderly, he does not forget that disorder may come. Confucius (551 BC – 479 BC)

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Outline

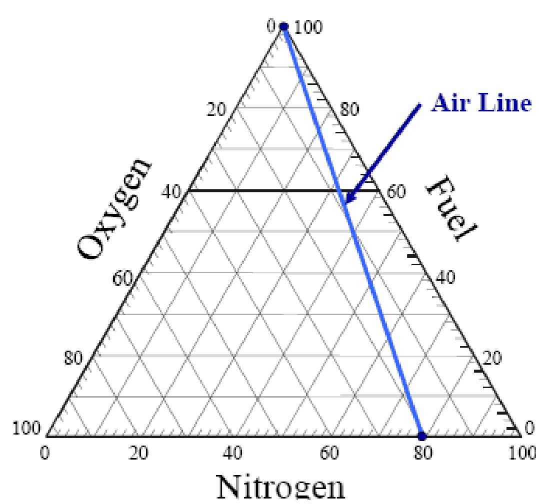
- Drawing an Approx. Flammability Diagram
- Flammability Diagram: Air Line
- Flammability Diagram: LFL and UFL
- Flammability Diagram: Stoichiometric Concentration
- Flammability Diagram: The Stoichiometric Line
- Flammability Diagram: Limiting or Minimum Oxygen Concentration
- General Shape of the Flammability Boundary

Drawing an Approx. Flammability Diagram

1. Draw Air line (0% to 21% oxygen in normal air)
2. Draw LFL and UFL on air line (% Fuel in air).
3. Draw stoichiometric line from combustion equation.
4. Plot intersection of LOC with stoichiometric line.
5. Draw LFL and UFL in pure oxygen, if known (% fuel in pure oxygen).
6. Connect the dots to get approximate diagram.

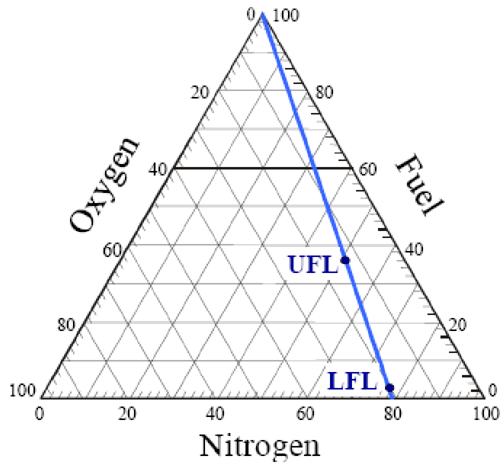
Flammability Diagram: Air Line

- The Air Line is drawn as a straight line between the upper apex, representing 100% Fuel, and the point on the lower line at 79% nitrogen/21% oxygen, Representing 100% air.



Flammability Diagram: LFL and UFL

- In Appendix B of the text, the **LFL** and **UFL** for ethylene are given as 2.7% and 36%, respectively.
- **These values are plotted on the Air Line at the corresponding Fuel percentages**

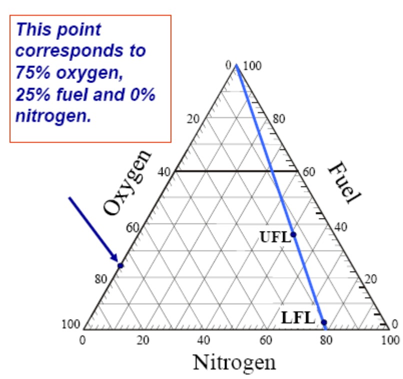


Flammability Diagram: Stoichiometric Concentration

- The general combustion reaction is used to determine the coefficient z, corresponding to the moles of oxygen required for complete combustion of one mole of ethylene.

$$C_mH_xO_y + zO_2 \rightarrow mCO_2 + \frac{x}{2}H_2O$$

$$z = m + \tfrac{1}{4}x - \tfrac{1}{2}y \quad = 2 + \tfrac{1}{4}(4) - \tfrac{1}{2}(0) = 3$$

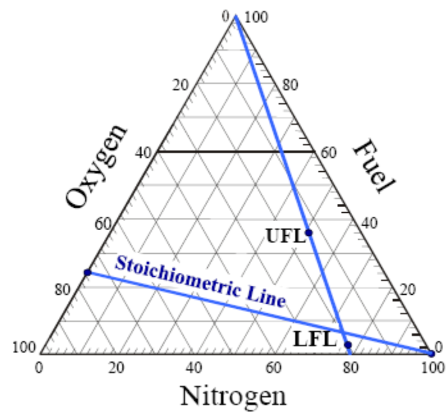


If 3 mol O_2 is required to burn 1 mol C_2H_4, the stoichiometric concentration C_{st} in pure oxygen is 75% O_2, 25% C_2H_4.

$$\left(\frac{z}{1+z}\right)*100 = \left(\frac{3}{1+3}\right)*100 = 75\%$$

Flammability Diagram: The Stoichiometric Line

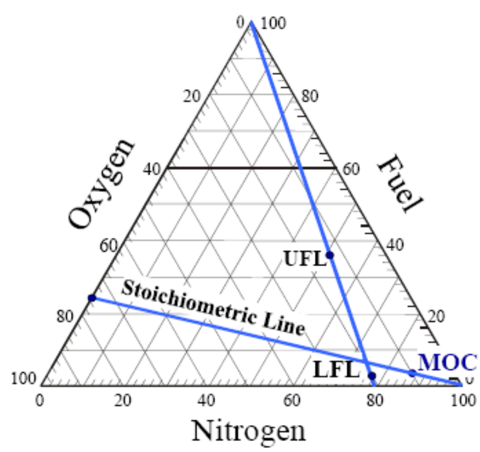
- The Stoichiometric Line is drawn.
- It represents all stoichiometric $C_2H_4+O_2$ mixtures, with varying amounts of inert nitrogen i.e., connect the stoichiometric concentration point with the 100% nitrogen apex.



Flammability Diagram: Limiting or Minimum Oxygen Concentration

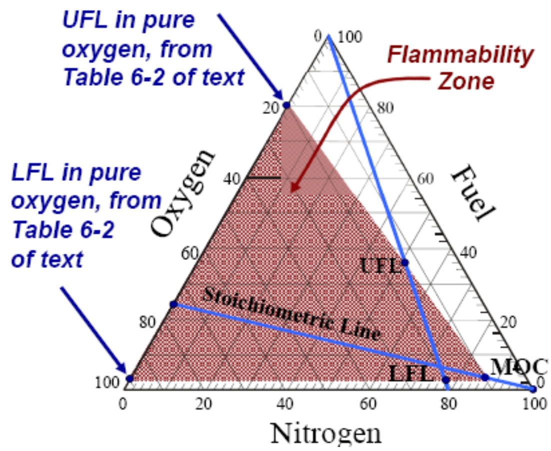
- In Table 6-2 of the text, the MOC for ethylene is given as 10 vol.% oxygen. It is plotted on the Stoichiometric Line as shown.
- Another way to estimate the LOC is by using the following approximation:

$$LOC = z(LFL).$$



General Shape of the Flammability Boundary

- This diagram reflects the fact that ethylene has relatively broad flammability limits; broader than typical alkane hydrocarbons.



Methane:

LFL: 5.3% fuel in air

UFL: 15% fuel in air

LOC: 12% oxygen

Pure Oxygen:

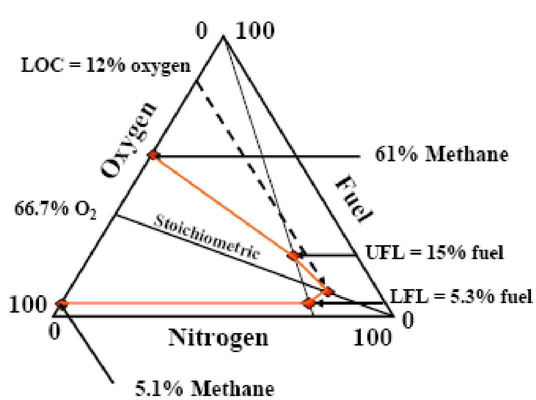
LFL: 5.1% fuel in oxygen

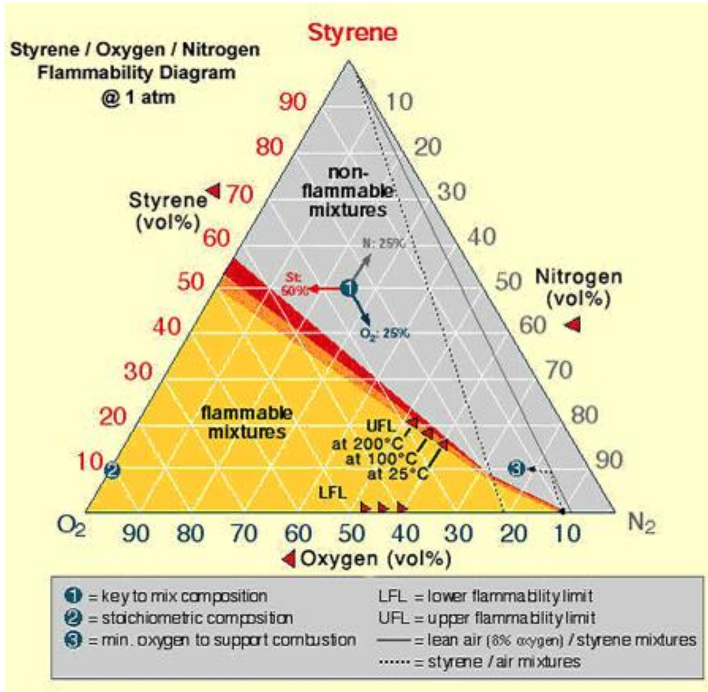
UFL: 61% fuel in oxygen

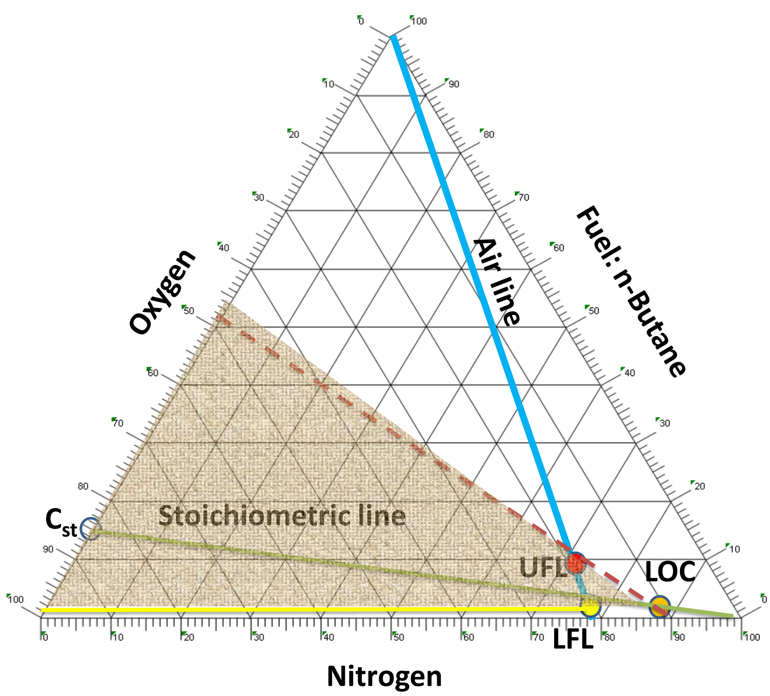
$CH_4 + 2\ O_2 \dashrightarrow CO_2 + 2\ H_2O$

--> $z = 2$

$$\left(\frac{z}{1+z}\right)*100 = \left(\frac{2}{3}\right)*100 = 66.7 \quad \text{\% oxygen}$$




Styrene / Oxygen / Nitrogen
Flammability Diagram
@ 1 atm
Styrene
Styrene (vol%)
Nitrogen (vol%)
Oxygen (vol%)
non-flammable mixtures
flammable mixtures
UFL
at 200°C
at 100°C
at 25°C
LFL
O2
N2
1 = key to mix composition
2 = stoichiometric composition
3 = min. oxygen to support combustion
LFL = lower flammability limit
UFL = upper flammability limit
—— = lean air (8% oxygen) / styrene mixtures
······ = styrene / air mixtures


Oxygen
Fuel: n-Butane
Air line
Stoichiometric line
Cst
UFL
LOC
LFL
Nitrogen

شكرا لحسن ألاستماع

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