Combustion & Flame - Introduction

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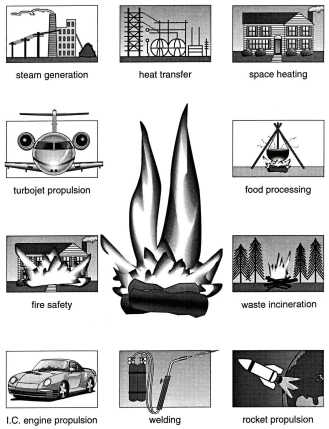
Start of Civilization!

T1195

Traditional three-stone fire for cooking

Typical Applications of Combustion[1]



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[1] E. Keating (2007). *Applied Combustion*. 2nd ed. Taylor & Francis.

Combustion

- Combustion of fuel-air mixture is one of the processes that controls output power, efficiency and emissions.
- Combustion commonly observed involves flame, which is a thin region of rapid exothermic chemical reaction.
- Flame propagation is the result of strong coupling between chemical reaction, transport processes of mass diffusion, heat conduction and fluid flow.
- Conventional spark-ignition (SI) flame is premixed unsteady turbulent flame, and the fuel-air mixture through which it propagates is in the gaseous state.
- Diesel engine (CI) combustion process is predominantly an unsteady turbulent diffusion flame, and the fuel is initially in the liquid phase.

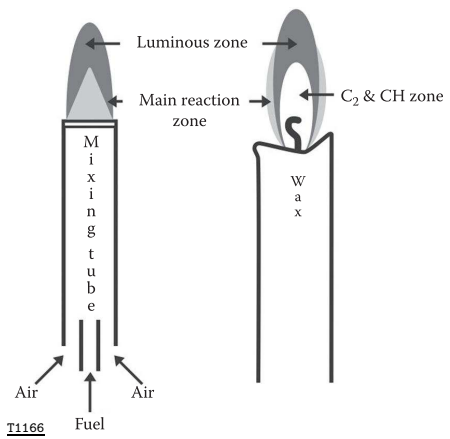
Classifications of Flames

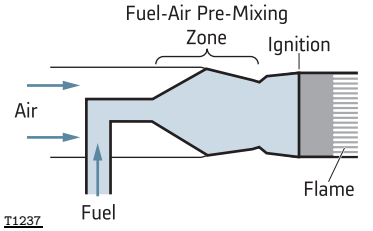
1. Premixed Flame: fuel and oxidizer are essentially uniformly mixed prior to combustion. It is a rapid, essentially isobaric, exothermic reaction of gaseous fuel and oxidizer, and flame propagates as a thin zone with speeds of less than a few m/s.
2. Diffusion Flame: reactants are not premixed and must mix together in the same region where reactions take place. It is dominated by the mixing of reactants, which can be either laminar or turbulent, and reaction takes place at the interface between the fuel and oxidizer.

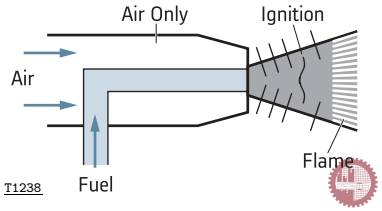
1. Laminar: flow, mixing and transport are by molecular process.
2. Turbulent: flow, mixing and transport are enhanced by macroscopic relative motion of fluid eddies of turbulent flow.

- Steady / Unsteady; Stationary / Propagating;
- Solid phase / Liquid phase / Gaseous phase.

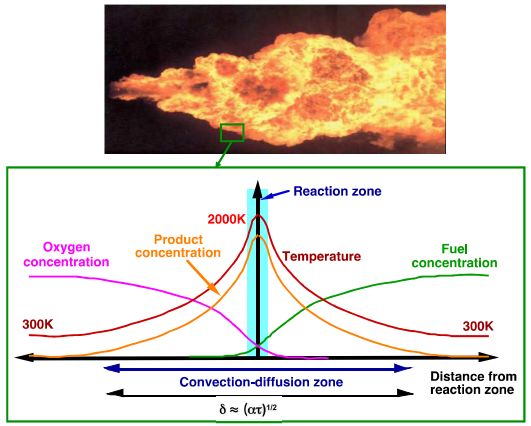
Premixed & Diffusion Flames





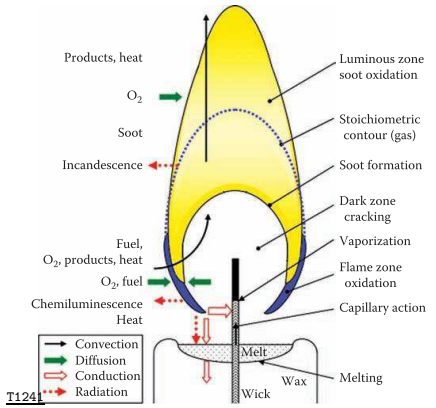


Autopsy of Premixed Flame[2]



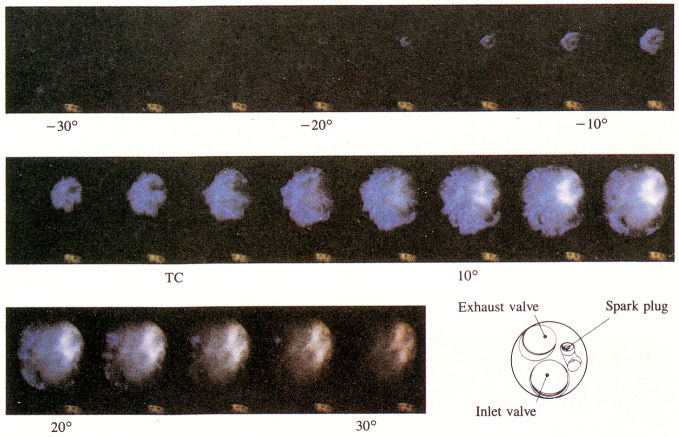
[2] S. McAllister, J. Chen, and A. Fernandez-Pello (2011). *Fundamentals of Combustion Processes*. Springer.

Autopsy of Diffusion Flame[3]



[3] J. Jarosinski and B. Veyssiere (2009). *Combustion Phenomena: Selected Mechanisms of Flame Formation, Propagation and Extinction*. CRC Press.

Typical Combustion in SI Engines[4]



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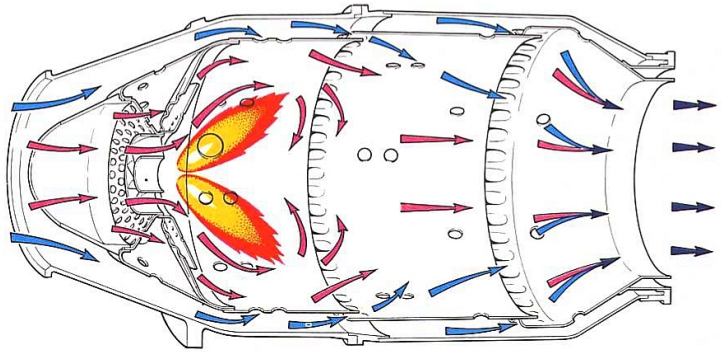
[4] J. Heywood (2018). *Internal Combustion Engine Fundamentals*. 2nd ed. New York, USA: McGraw-Hill Education.

Typical Gas Turbine Combustion[5]



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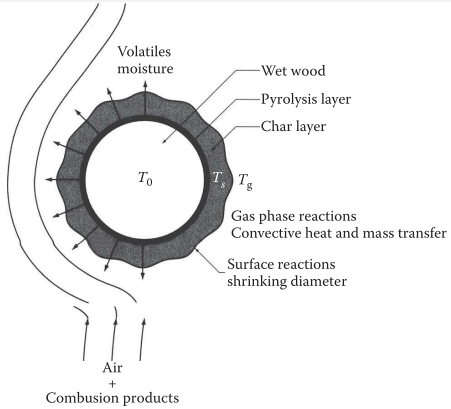
[5] Rolls Royce (2015). *The Jet Engine*. Wiley.

Typical Burning of Wood Log[6]



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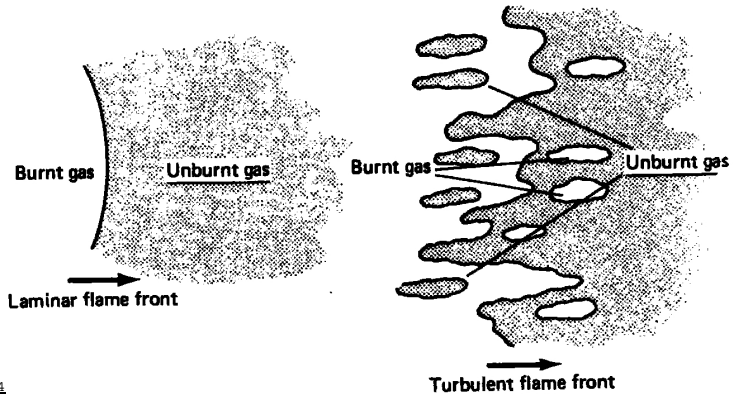
Cross-section of a reacting log showing char, pyrolysis, & undisturbed wood regions

[6] G. Borman and K. Ragland (1998). *Combustion Engineering*. McGraw-Hill.

Typical Premixed Flame Propagation



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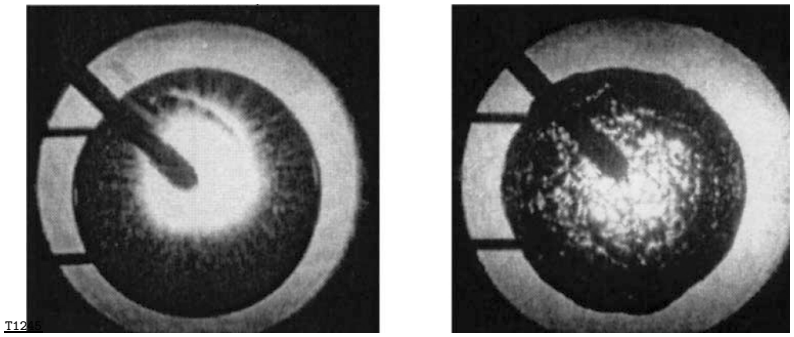
Schlieren Images of Laminar Flames[7]



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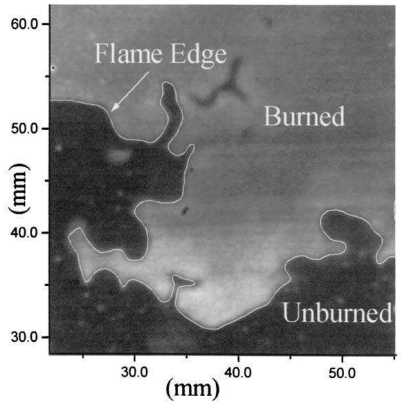
left: not cellular flame, right: cellular flame

[7] M. Z. Haq (2005a). "Correlations for the Onset of Instabilities of Spherical Laminar Premixed Flames". In: *Journal of Heat Transfer* 127.12, pp. 1410–1415.

LIF Image of Turbulent Premixed Flame[8]



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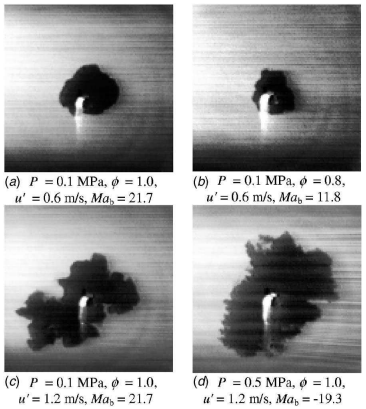
[8] M. Z. Haq et al. (2002). "Wrinkling and curvature of laminar and turbulent premixed flames". In: *Combustion and Flame* 131.1, pp. 1 –15.

Mie Scattering Images of Turbulent Premixed Flame[9]



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[9] M. Z. Haq (2005b). "Effect of Developing Turbulence and Markstein Number on the Propagation of Flames in Methane-Air Premixture". In: *Journal of Engineering for Gas Turbines and Power* 128.2, pp. 455–462.

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