Dasar-Dasar TEKNOLOGI PEMBAKARAN

COMBUSTION TECHNOLOGY & THERMAL ANALYSIS

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Instructor's Background

- BEng. (1995): Universitas Diponegoro
- Meng. (2000): Institut Teknologi Bandung
- PhD. (2006): Universiti Teknologi Malaysia

- Specialization:
  - Catalyst Design for Energy Conversion
  - Process Design for Energy Conversion
  - Combustion Engineering
  - Computational Fluid Dynamic (CFD)

SYLLABUS

- 1. Dasar-dasar Teknik Pembakaran (150')
- 2. Konsep Fundamental Kimia Sistem Pembakaran (2x150')
- 3. Konsep Perpindahan Panas dalam Sistem pembakaran (150')
- 4. Flame Impingement (150')
- 5. Perancangan Sistem Burner (2x150')
- 6. Troubleshooting Sistem Pembakaran (150')
- 7. Bahan Bakar untuk Proses Pembakaran (2x150')
- 8. Permodelan Proses Pembakaran (2x150')
- 9. Pengendalian Proses Pembakaran (150')
- 10. Keselamatan Proses Dalam Sistem Pembakaran (2x150')
- 11. Sistem Flare di Teknologi Pembakaran (150')

References:

- 1. C. E. Baukal (Editors), 2001, **THE JOHN ZINK COMBUSTION HANDBOOK**, CRC Press, Florida.
- 2. C. E. Baukal, 2000, **HEAT TRANSFER IN INDUSTRIAL COMBUSTION**, CRC Press, Florida.
- 3. Eugene L. Keating, 2007, **APPLIED COMBUSTION**, CRC Press, Boca Raton.
- 4. Fawzy El-Mahallawy, Saad El-Din Habik, 2002, **FUNDAMENTALS AND TECHNOLOGY OF COMBUSTION**, Elsevier B.V., Amsterdam.

IMPORTANCE OF COMBUSTION IN INDUSTRY

TABLE 1.1
The Importance of Combustion to Industry

	% Total Energy from (at the point of use)		
Industry	**Steam**	**Heat**	**Combustion**
Petroleum refining	29.6	62.6	92.2
Forest products	84.4	6.0	90.4
Steel	22.6	67.0	89.6
Chemicals	49.9	32.7	82.6
Glass	4.8	75.2	80.0
Metal casting	2.4	67.2	69.6
Aluminum	1.3	17.6	18.9

Source: From U.S. Dept. of Energy, Energy Information Administration as quoted in the *Industrial Combustion Vision,* prepared by the U.S. Dept. of Energy, May 1998.

TABLE 1.3
Examples of Processes in the Process Industries Requiring Industrial Combustion

Process Industry	Examples of Processes Using Heat
Steel making	Smelting of ores, melting, annealing
Chemicals	Chemical reactions, pyrolysis, drying
Nonmetallic minerals (bricks, glass, cement and other refractories)	Firing, kilning, drying, calcining, melting, forming
Metal manufacture (iron and steel, and nonferrous metals)	Blast furnaces and cupolas, soaking and heat treatment, melting, sintering, annealing
Paper and printing	Drying

Source: Adapted from G.F. Hewitt, G.L. Shires, and T.L. Bott, Eds., *Process Heat Transfer,* CRC Press, Boca Raton, FL, 1994, 2.

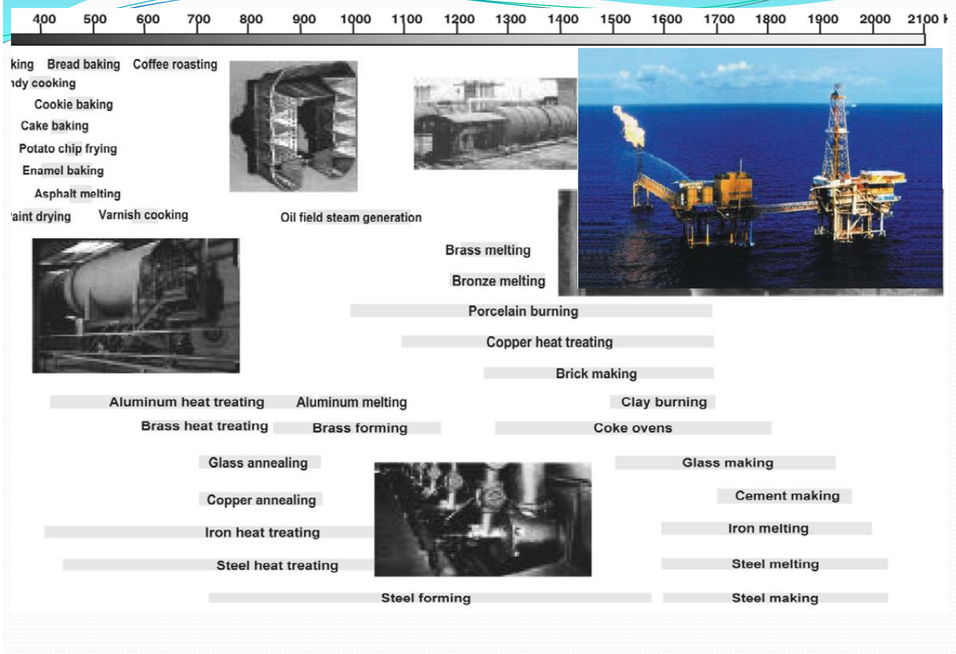
The major Combustion that included heat transfer were:

- Furnace design, heat and mixing patterns
- Heat recovery and energy efficiency of flares
- Recuperative burner for low heating value gases
- Impinging (pulsed) heat transfer
- Rich flames for higher thermal radiation

The following areas in experimentation need more research

- **Fluid dynamic problems**, including particle and velocity measurements in two-phase flows, turbulence measurements, and turbulence-particle interactions
- **Diagnostic tool development**, including diagnostics for two-phase flows, flow visualization, and improvements in velocity measurement, laser probes, and laser-based spectroscopic measurements
- **Investigation into specific types of combustion problems** where some of the latest diagnostic techniques have not been applied yet

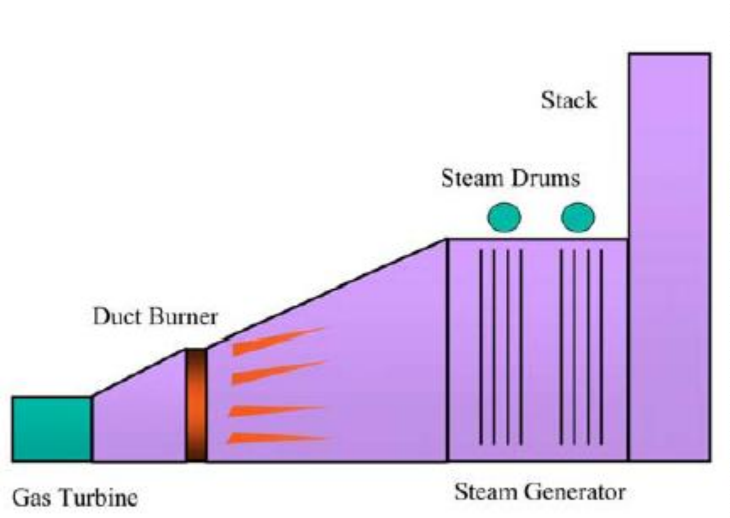
Temperature ranges of common industrial combustion applications



A number of research needs in industrial combustion, directly or indirectly concerning heat transfer:

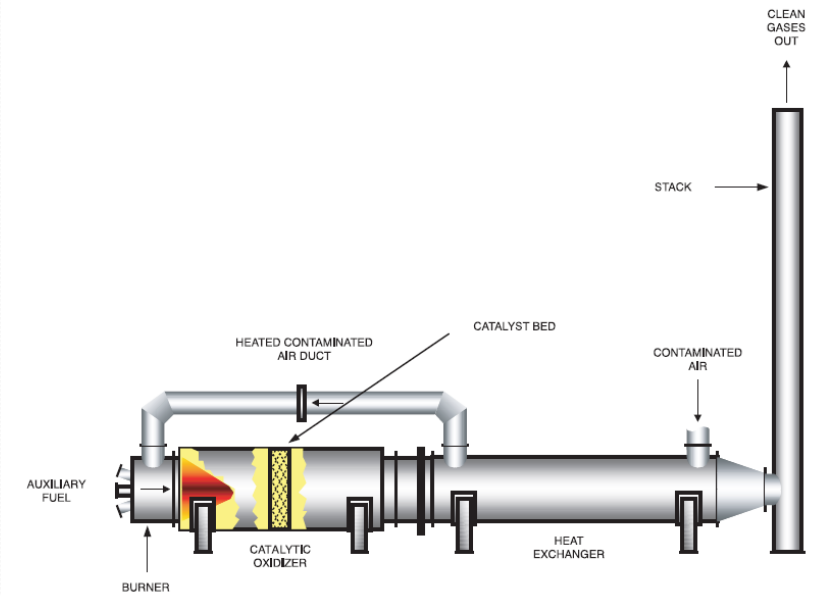
- New furnace designs (heat transfer needed for the analysis)
- Cost-effective heat recovery processes
- Optimization of the emissivity of materials used in furnaces or burners
- Increased combustion intensity (heat release per unit of furnace volume)
- Adaptation of computational fluid dynamics models to design burners
- Development of new equipment and methods for heating and transferring heat
- Development of hybrid or other methods to increase heat transfer to loads

Duck burner in large Duck



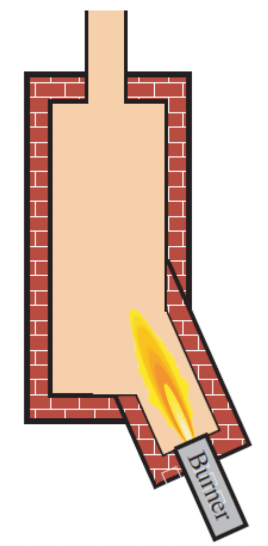
Front of a boiler burner

Thermal oxidizer

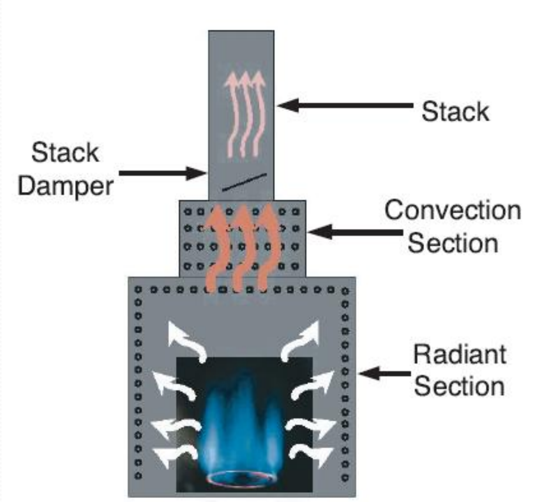


PROCESS HEATERS: FIRED HEATERS

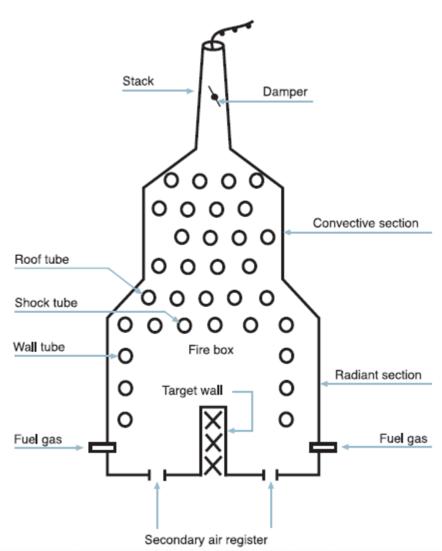
- Firing Furnace:

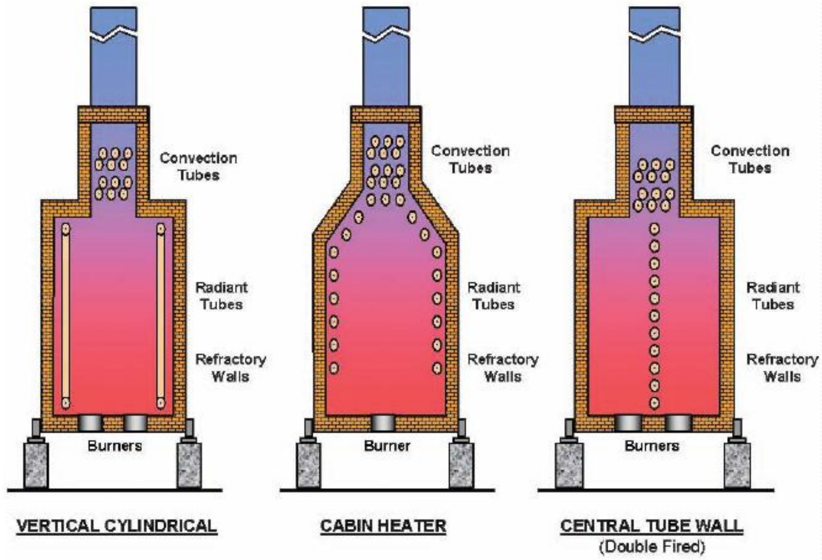


PROCESS HEATERS: FIRED HEATERS



TYPICAL PROCESS HEATERS





Major Refinery Processes Requiring a Fired Heater

Process	Process Description	Heaters used	Process heat requirements KJ/liter	Process heat requirements 10^3 Btu/bbl	Feedstock temperature outlet of heater, °F
	Distillation				
Atmospheric	Separates light hydrocarbons from crude in a distillation column under atmospheric conditions	Preheater, reboiler	590	89	700
Vacuum	Separates heavy gas oils from atmospheric distillation bottoms under vacuum	Preheater, reboiler	418	63	750–830
	Thermal Processes				
Thermal cracking	Thermal decomposition of large molecules into lighter, more valuable products	Fired reactor	4650	700	850–1000
Coking	Cracking reactions allowed to go to completion; lighter products and coke produced.	Preheater	1520	230	900–975
Visbreaking	Mild cracking of residuals to improve their viscosity and produce lighter gas oils	Fired reactor	961	145	850–950
	Catalytic Cracking				
Fluidized catalytic cracking	Cracking of heavy petroleum products; a catalyst is used to aid the reaction	Preheater	663	100	600–885
Catalytic hydrocracking	Cracking heavy feedstocks to produce lighter products in the presence of hydrogen and a catalyst	Preheater	1290	195	400–850
	Hydroprocessing				
Hydrodesulfurization	Remove contaminating metals, sulfur, and nitrogen from the feedstock; hydrogen is added and reacted over a catalyst	Preheater	431	65[a]	390–850
Hydrotreating	Less severe than hydrodesulfurization; removes metals, nitrogen, and sulfur from lighter feedstocks; hydrogen is added and reacted over a catalyst	Preheater	497	75[b]	600–800
	Hydroconversion				
Alkylation	Combination of two hydrocarbons to produce a higher molecular weight hydrocarbon; heater used on the fractionator	Reboiler	2500	377[c]	400
Catalytic reforming	Low-octane napthas are converted to high-octane, aromatic napthas; feedstock is contacted with hydrogen over a catalyst	Preheater	1790	270	850–1000

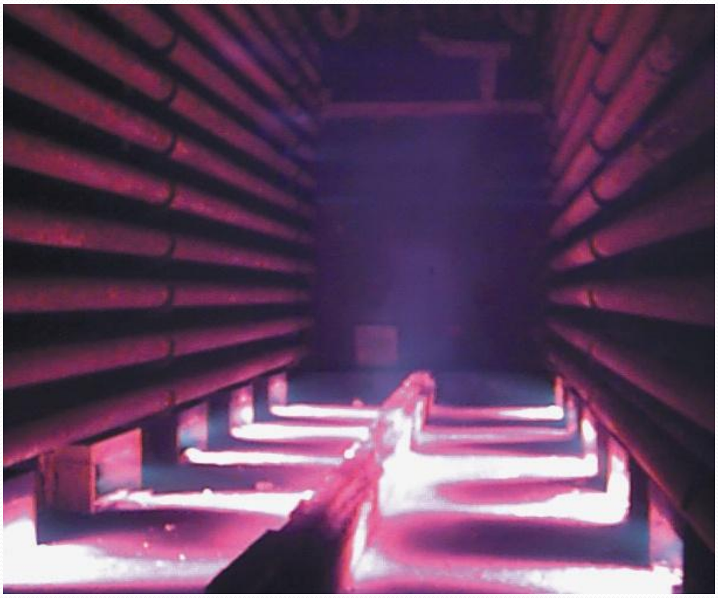
[a] Heavy gas oils and middle distillates.
[b] Light distillate.
[c] Btu bbl^{-1} of total alylate.
Source: From the U.S. EPA.[36]

Major Fired Heater Applications in the Chemical Industry

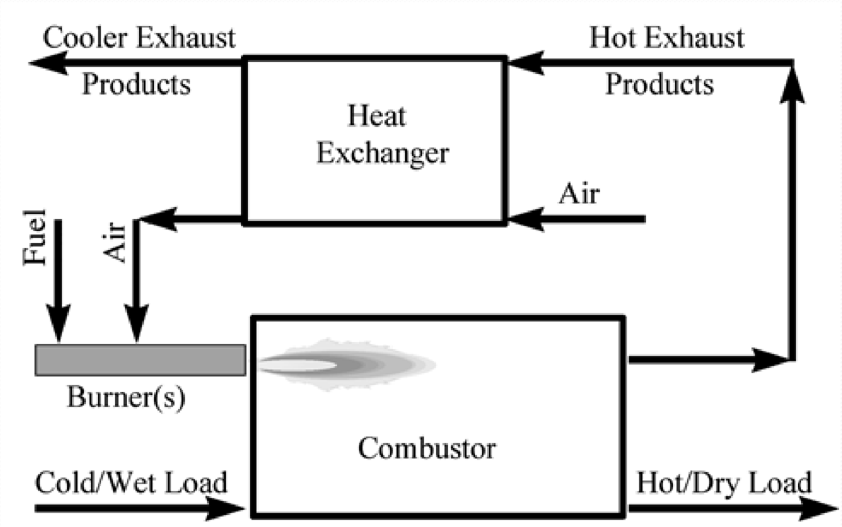
Chemical	Process	Heater Type	Firebox Temperature (°F)	1985 Fired Heater Energy Requirement (10^{12} Btu yr^{-1})	% of Known Chemical Industry Heater Requirements
		Low- and Medium-Temperature Applications			
Benzene	Reformate extraction	Reboiler	700	64.8	9.9
Styrene	Ethylbenzine dehydrogenation	Steam superheater	1500–1600	32.1	4.9
Vinyl chloride monomer	Ethylene dichloride cracking	Cracking furnace	N/A	12.6	1.9
p-Xylene	Xylene isomerization	Reactor-fired preheater	N/A	13.0	2.0
Dimethylterephthalate	Reaction of *p*-xylene and methanol	Preheater, hot oil furnace	480–540	11.1	1.7
Butadiene	Butylene dehydrogenation	Preheater, reboiler	1100	2.6	0.4
Ethanol (synthetic)	Ethylene hydration	Preheater	750	1.3	0.2
Acetone	Various	Hot oil furnace	N/A	0.8	0.1
		High-Temperature Applications			
Ethylene/propylene	Thermal cracking	Pyrolysis furnace	1900–2300	337.9	51.8
Ammonia	Natural gas reforming	Steam hydrocarbon reformer	1500–1600	150.5	23.1
Methanol	Hydrocarbon reforming	Steam hydrocarbon	1000–2000	25.7	4.0
	Total Known Fired Heater Energy Requirement			652.4	100.0

Source: From U.S. EPA.[36]

Horizontal floor-fired burners

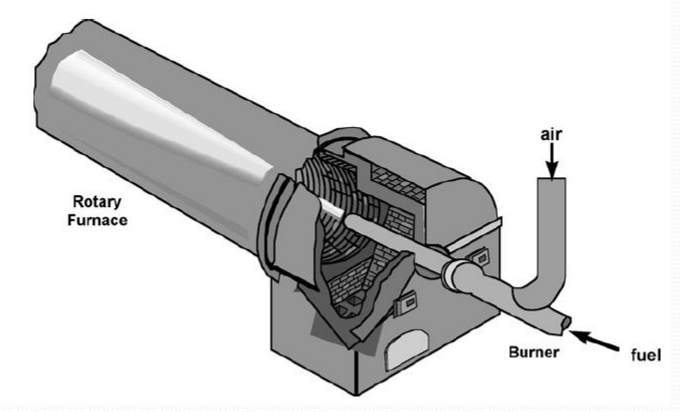


Schematic of the major components in a combustion system



COMBUSTION SYSTEM COMPONENTS

- **Burner and Oxidizer** (mixing type?) (diffusion or premixed)
- **Combustor** ➔load handling, heating type
- **Heat Load** ➔ process tube, moving substrate
- **Heat Recovery** ➔recuperator (integrated process); regenerator
  - What will the fuel savings be (compared to no heat recuperation)?
  - • What is the maximum allowable flue gas temperature?
  - • How big is the heat exchanger?
  - • What is the air pressure drop through the exchanger?
  - How long will the exchanger run without plugging?
  - • Is the flue gas path through the furnace altered?


air
Rotary
Furnace
Burner
fuel