



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

INCINERATION 2

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Contents

- Definition and scope for application
- Mechanism
- Air requirement
- Performance factors and staged combustion
- Advantages and disadvantages
- Preferable feedstocks characteristics for incineration
- Process flowsheet
- Incinerators parts and their types/working
- Environmental impact and operational issues and divisions of real plant
- Case study



Type of incinerator / combustor

There are two most common types combustion systems are available

- Fixed-bed combustion
- Fluidized-bed combustion

Fixed-bed combustion

Fixed bed combustion system include **underfeed stokers and grate firings**. Primary air passes through a fixed bed, where drying, gasification, and charcoal combustion take place in consecutive stages. The combustible gases are burned in a separate combustion zone using secondary air.



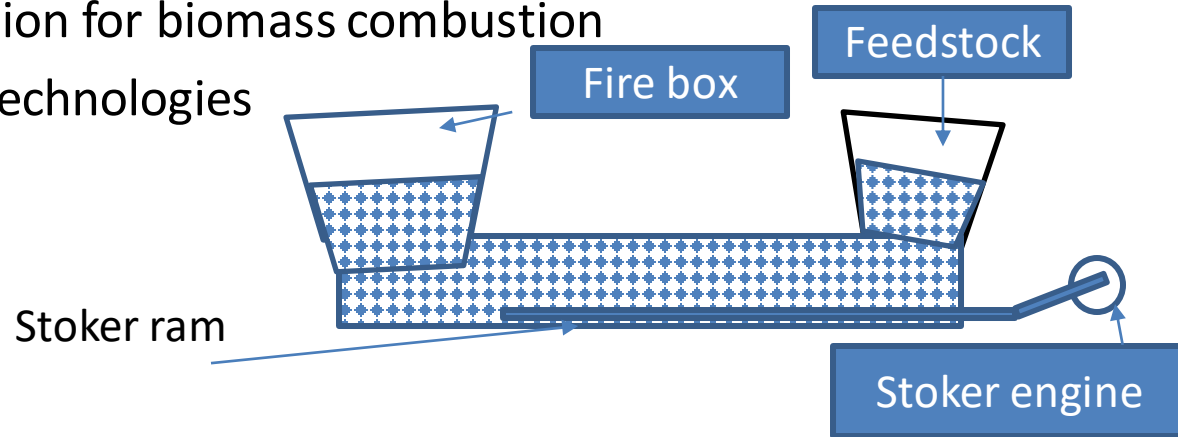
(i) Underfeed Stokers

Fuel is fed into the furnace from below by a screw conveyor and then forced onto the grate where the combustion process begins

Use only for small-scale systems

Relatively cheap and safe option for biomass combustion

Easier to control than other technologies



Limitations

It is use for only low ash content materials such as wood chips. **Underfeed Stokers**

(ii) Grate Firings

- Wastes are spread evenly over the grate surface.
- Air is distributed uniformly throughout the bed and thus combustion is kept homogeneous and stable.
- It can use materials with high moisture and ash content as well as with varying particle sizes.
- Different types of grate firing including fixed grates, moving grates, rotating grates, horizontal/inclined grate, water cooling grate, dumping grate, and travelling grates.

Important moving grate designs

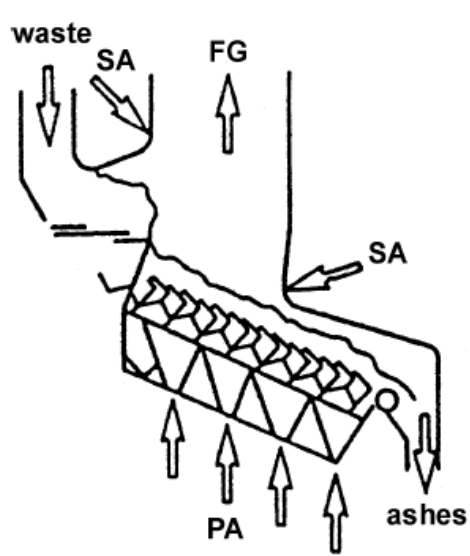
The reciprocating grate – This grate resembles stairs with alternating fixed or moving grate sections. The pushing action may be in the direction of waste flow or in an upward motion against the waste flow;

The rocking grate system – Pivoted or rocked grate sections produce an upward or forward motion, advancing the waste down the grate;

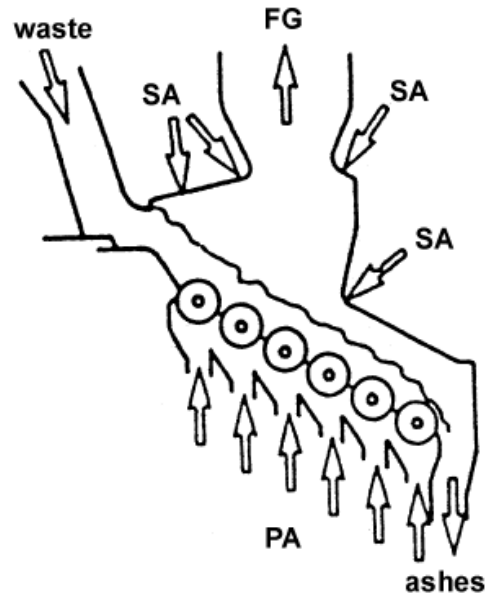
The roller grate – A series of rotating stepped drums or rollers agitate the waste and move it down the grate;

The rotary kiln – As an inclined cylinder rotates, it causes a tumbling action to expose unburned material and advance the waste down the length of the kiln.

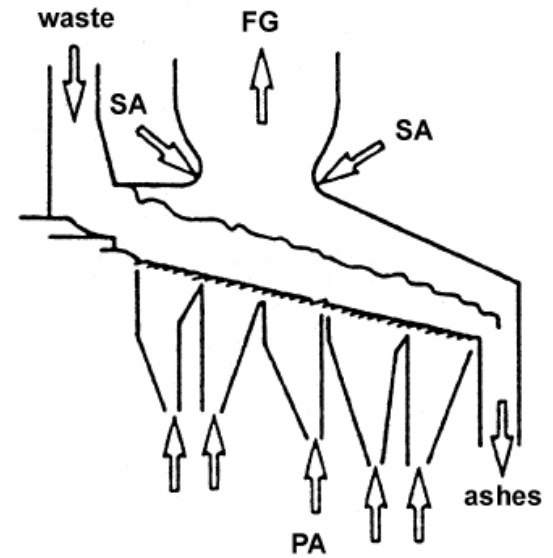




Reversed feed grate



Roller grate



Reciprocating grate

PA: Primary air

SA: Secondary air

FG: Flue gas

Source : **Waste Incineration European State of the Art and New Developments**, Prof. Dr.-Ing. Klaus Göerner, 2003

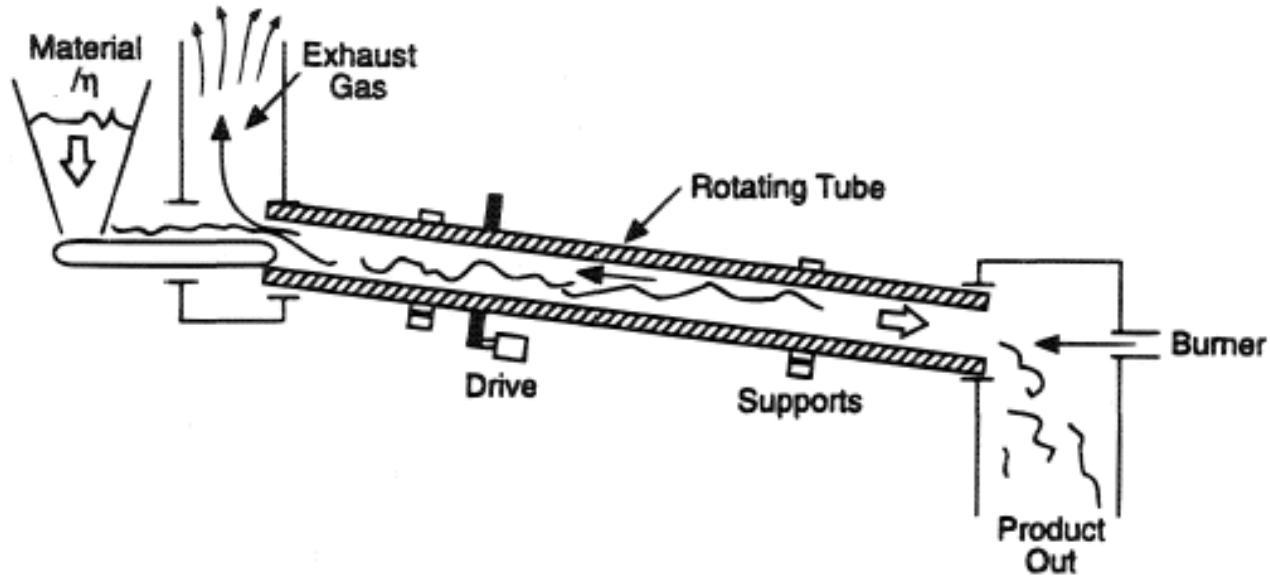


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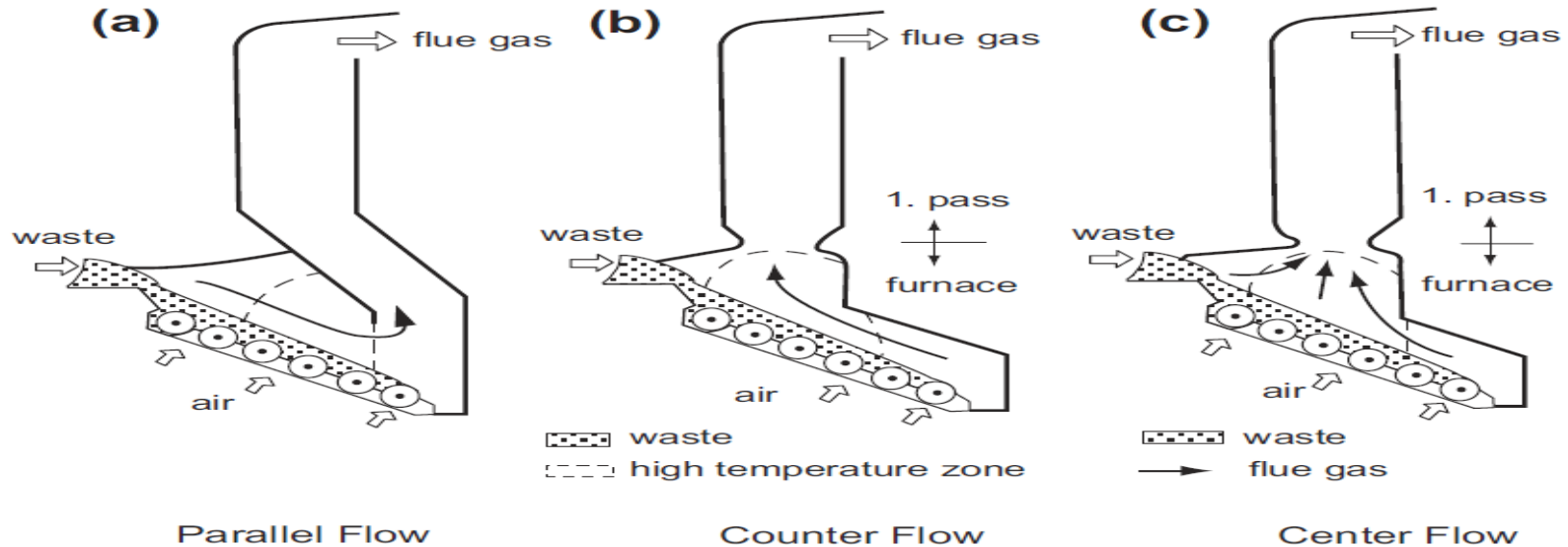
Rotary kiln



Source: <http://www.thermopedia.com/content/906/>

Mechanism of waste burning on grates

Grate combustion chamber design varies in geometry to accommodate to waste heating value and air starving conditions.



Source : **Waste Incineration European State of the Art and New Developments**, Prof. Dr.-Ing. Klaus Göerner, 2003

Advantages and disadvantages of different grate furnace geometry designs

	Parallel flow	Counter flow	Center flow
Advantages	Pyrolysis gases pass through hottest area providing high gas burn out.	Energy transfer from the main combustion area to the drying and gasification area.	Very flexible for variable heat release distribution across the grate area.
	Suitable for low LCV	Suitable for higher LCV	Suitable for wider range of calorific values.
Disadvantages	The transfer of energy from main combustion area to ignition area is just by radiation	Pyrolysis gases could bypass the hottest areas and may cause the gas burn out problem.	Flow and mixing pattern into the first path chamber are sensible to disturbances.

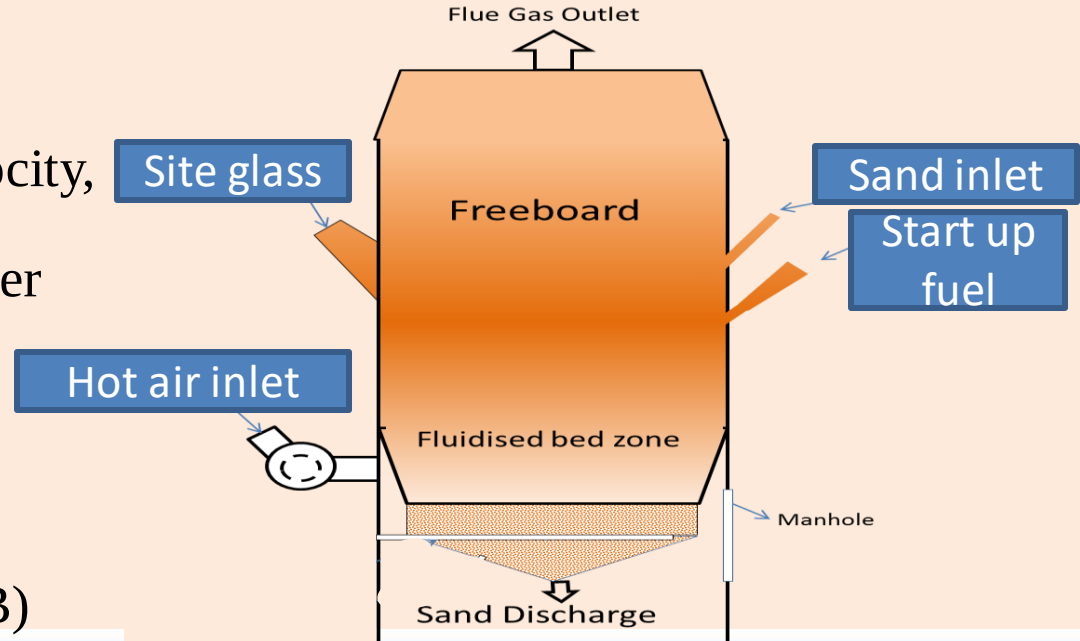
Source :Waste Incineration European State of the Art and New Developments, Prof. Dr.-Ing. Klaus Göerner,2003



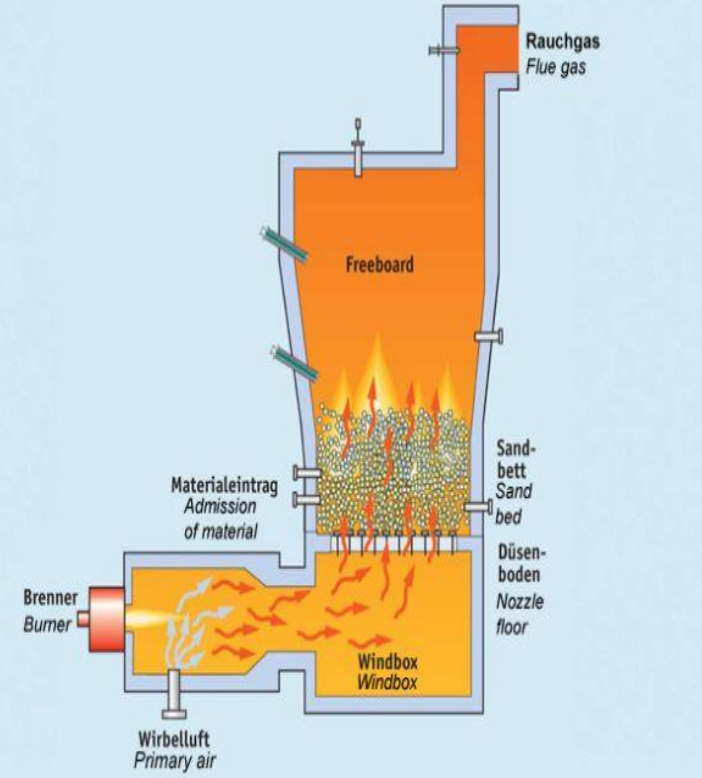
Fluidized-bed combustion uses silica sand, limestone, dolomite, or other non-combustible materials for the bed material. Which operates at temperature of 700–1000 °C.

Depending on the blowing air velocity, fluidized-bed systems can be further divided into two types

- (i) Bubbling fluidized-bed (BFB)
- (ii) Circulating fluidized-bed (CFB)



- Waste is dropped down a chute from above into the combustion chamber
- Air fed into the chamber through a nozzle distributor, fluidizes sand and the waste particles
- Typical sand velocity is between 1 and 2.5 m/s.
- The bed normally has a temperature of between 800 and 900 °C . Sand accounts for about 98% of the mixture,

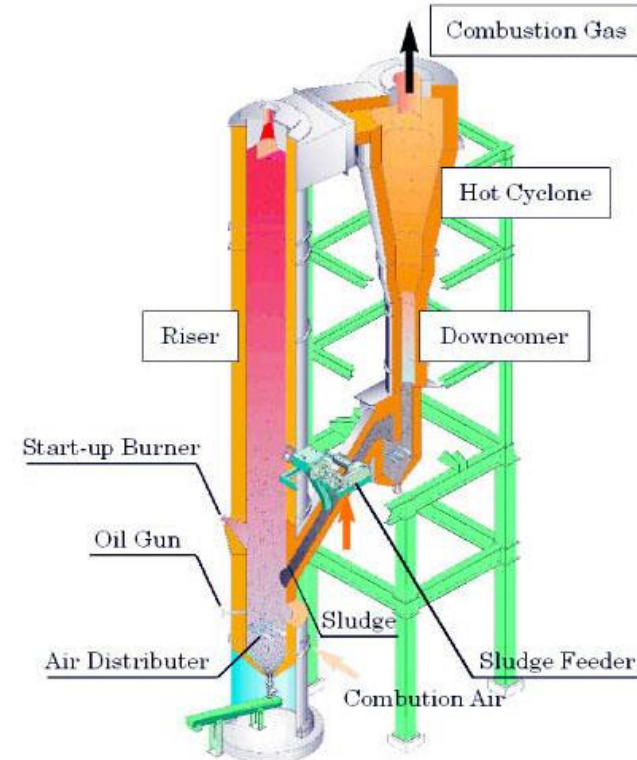


Bubbling fluidized-bed (BFB)

<http://a4academics.com/be-seminar-topics/19-be-mechanical-seminar-topics/718-incineration-plants>

Type of incinerator / combustor

- In this case air velocity is relatively more and part of sand and unburnt waste are recycled to the combustor after their separation from the flue gas in a cyclone



Circulating fluidized-bed (CFB)

Source: <http://www.ustudy.in/node/3147>

Advantages of fluidized-bed combustion over fixed bed combustion

- It is suitable for high-moisture fuel or low-grade fuel.
- The typical operating temperatures are lower than fixed-bed systems.
- Higher combustion efficiency.
- More suitable for large scale operations.



<i>Energy utilization</i>	<i>Recovery</i>	<i>Overall efficiency^a</i>	
Heat only	Heat	80%	80%
Steam only	Steam	80%	80%
Power only	Power	35%	35%
Combined steam and power	Steam	0-75%	35-75%
	Power	0-35%	
Combined heat and power	Heat	60-65%	85%
	Power	20-25%	

a. Efficiencies defined as usably energy related to energy content (lower calorific value) of the waste

<http://documents.worldbank.org/curated/en/886281468740211060/pdf/multi-page.pdf>

Environmental aspects of combustion / incineration

- NOX control system
- Hg and dioxine removal system
- Acid gas removal
- PM removal



Some operating problems

- The fouling of heat exchanger surfaces. Fouling occurs because of melting of low-fusion point alkali metal salt such as the alkali metal silicates in the conversion zone.
- Furnace-boiler systems for solid biomass fuels are often designed to keep the temperature in the combustors below about 900 °C to reduce slagging and formation of molten agglomerates.
- A slagging index developed by the coal industry has been used to rate solid fuels for fouling. This index corresponds to the mass of alkali metal as oxides ($K_2O + Na_2O$) per energy unit in the fuel and is useful for rating biomass feedstocks too. The calculation is made by

$$0.1 [(\% \text{ ash})(\% \text{ alkali in ash})](\text{MJ/dry kg})^{-1} = \text{kg alkali/GJ}$$



- An index range of 0 to 0.17 kg/GJ (0 to 0.4 lb/MBtu) ---- low slagging risk;
0.17 to 0.34 kg/GJ (0.4 to 0.8 lb/MBtu) ----- probably slag;
> 0.34 kg/GJ ---- virtual certainty of slagging(Miles *et al.*, 1993).
- Slagging index of poplar and pine biomass are 0.11, 0.009 kg alkali/GJ, respectively.
- Another fouling mechanism that can occur is corrosion of boiler tubing and erosion of refractories due to formation of acids and their buildup in the combustion units from conversion of sulfur and chlorine present in the fuel.
- Addition of small amounts of limestone/ dolomite/ kaolin/ custom blends of aluminum and magnesium to the media in fluidized-bed units or the blending of these with the fuel in the case of moving-bed systems are effective methods of eliminating this problem.

Divisions of an plant

- a) Waste receipt and handling installation
- b) A combustion system
- c) Heat recovery system (boiler)
- d) Air pollution control system
- e) Combustion solid residue handling system

Case study: Some **waste** incineration plants planned or built in India

Location	Company	Size
Narela, Delhi	Ramky	24 MW
Ghazipur, Delhi	Infrastructure Leasing & Financial Services	10 MW
Jabalpur, Madhya Pradesh	Essel infrastructure	11 MW
Pallavapuram, Tamil Nadu	Essel infrastructure	5 MW
Surat, Gujarat	Rochem	12 MW
Jawaharnagar, Hyderabad	Ramky	20 MW

http://articles.economictimes.indiatimes.com/2015-04-28/news/61616161_1_waste-incineration-waste-land-municipal-solid-waste

Robbins Resource Recovery Facility (RRRF) , Chicago

- Handling 1450 tonnes of MSW per day,
- Reducing landfill waste volume requirements by 95%, and producing 50 MWe.
- Two Foster Wheeler CFB boiler and Refuse derived fuel (RDF)
- Combustion temperatures of 830°C- 915°C at atmospheric pressure reduce the potential for ash slagging and tube fouling, minimizes high-temperature chlorine corrosion
- High-pressure steam (6.2 MPa, 443°C, 28.9 kg/s per boiler) produced in the CFB boilers is used to produce approximately 50 MW of electricity in a condensing, extraction turbine generator.
- Net electrical generation efficiency, for a feed rate of 545 t/d RDF per boiler (heating value 14.3 MJ/kg) is approximately 23%, based on MSW input



Thanks...

