Efficiency and Design Improvements in Multiple Hearth & Fluid Bed Incinerators
Outline

- Fluid Bed Incinerators (FBI’s)
  - Reversible Bed Resizing
  - Air Preheating
- Multiple Hearth Incinerators (MHF’s)
  - Reheat and Oxidize (RHOX) Process
  - Flue Gas Recirculation (FGR)
  - Center Shaft Air
- General
  - Improved Dewatering
  - Grease
Fluid Bed Incinerator

- Preheated Air & Burner
- Windbox
- Dome
- Tuyeres
- Bed
- Freeboard
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Freeboard
Fluid Bed Incinerator

- Air enters through bottom
- Sludge and fuel introduced in the bed
- Ash and exhaust gasses exit through the top
Oversized FBI

- High minimum fluidizing air required
- Inefficient at low sludge feed rates
Bed Resizing

- Remove dome
- Shift bed downward
  - Oil guns
  - Sludge guns
  - Instrumentation
- Shrink diameter of bed
Bed Resizing

- Add over bed burner
  - Provides live flame in freeboard
  - Directed at top of sand
  - Can be used to heat freeboard directly
Bed Resizing

- Pipe Tuyeres
  - Set of parallel pipes
  - Holes in pipes to distribute air
- External air manifold
- Pipe clean out manifold
Parallel pipe tuyeres receive through external manifold
Reversible Bed Resizing

- Bed can be expanded incrementally back to original size if needed
  - Remove row of bricks
  - Drill additional holes in pipe tuyeres
Pipe-Tuyere Design Considerations

• Fluidizing air
  – Blower efficiency at lower air flow
  – Heat exchanger bypass

• Pipe durability
  – No shutdowns from lost tuyeres
  – Can clean-out sand from pipes while operating
  – Can still operate with broken pipe tuyere

• Over-bed burner
  – Improved freeboard temperature control
  – Live flame can reduce CO
  – Better freeboard mixing
Fluid Bed Incinerator

- Preheated Air & Burner
- Windbox
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- Tuyeres
- Bed
- Freeboard
Preheating the Combustion Air

- **Fluidizing air**
  
  - Older FBI designs incorporate no or very low temperature, air preheating
  
  - Preheating combustion air reduces fuel required during operation
  
  - Higher preheat temperatures = less auxiliary fuel
  
  - Often accomplished with a flue gas heat exchanger
FGTT Heat Exchanger

Furnace exhaust flows through the inner tubes of the heat exchanger preheating fluidizing air.
Preheating the Combustion Air

• Example:

- 5,000 SCFM, Preheated +1000°F

\[0.25 \text{BTU/lbm}^\circ \text{F} \times 0.075 \text{lbm/ft}^3 \times 5000 \text{SCFM} \times 1000^\circ \text{F}\]

- 93,750 BTU/min, or < 40 gal/hr fuel oil

\[40 \text{ gal/hr} \times 3\$/\text{gal} \times 24\text{hrs/day} = 2880\text{$/day}\]
Multiple Hearth Furnace
Multiple Hearth Furnace

- Refractory lined cylindrical steel shell
- Separated into a series of combustion chambers - refractory hearths one above the other
- Temperature and reaction environment well controlled on each hearth
Multiple Hearth Furnace

- Dewatered sludge cake enters the furnace at the top
- Inject air and fuel where needed to maintain temperature and supplement the combustion process
- Ash product exits the bottom
- Furnace exhaust gases exit at the top and head to downstream air processing
Multiple Hearth Furnace

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- Furnace exhaust gases exit at the top and head to downstream air processing

• Generalized to three processing “zones”
Multiple Hearth Furnace

- Counter current flow of rising exhaust gases and good mixing of descending sludge ensure complete combustion
Multiple Hearth Furnace

Poor distribution of sludge across top hearth:

- Under utilization of furnace area, less efficient operation
- Uneven hearth temperatures
- Burning in lower hearths

Adding rabble improves sludge distribution
RHOX – Reheat & Oxidize Process

• In NJ, all MHF are required to maintain an afterburner at >1500°F
• Typical afterburner designs include:
  – Top Hearth
  – Top hearth with Jumper Flue
  – External Chamber
• Afterburners located directly after the incinerator (before APC equipment)
RHOX – Reheat & Oxidize Process

- Traditional afterburner designs require 1 or more burners
- Require high fuel usage to maintain afterburner temperature
- Additional burners can produce NOx
RHOX – Reheat & Oxidize Process

• **RHOX Process differs in that:**
  – Occurs after the APC equipment
  – Recovers heat from exiting exhaust gasses
  – Requires 1 burner (less potential Nox production)

• **Common RHOX process application is the Regenerative Thermal Oxidizer (RTO)**
Regenerative thermal Oxidizer

[Diagram of a Regenerative Thermal Oxidizer Airflow Diagram]

(http://www.thecmmgroup.com/custom-designed-regenerative-thermal-oxidizer-rto)
Regenerative Thermal Oxidizer

- **RTO:**
  - Utilizes 2 or more heat recovery chambers
  - Cold inlet gas passes through a heated chamber, preheating the gas
  - Hot exhaust exits through and heats another chamber
  - A single burner maintains gas temperature within the RTO
  - Periodically, a valve switches the inlet/outlet chambers
Regenerative Thermal Oxidizer

- RTO benefits:
  - More efficient than traditional afterburners
  - The use of waste heat recovery decreases the fuel requirements
  - Provides more control than traditional afterburners
  - Less affected by furnace upsets / changes
Flue Gas Recirculation (FGR)

• Another efficiency improvement for MHF’s is Flue Gas Recirculation

• FGR moves exhaust gas from the feed (top) hearth to a hearth below the volatile burning zone
Flue Gas Recirculation (FGR)

- FGR
  - Injection of cooler mostly inert gas:
    - Reduces fuel usage
    - Increases operational stability
    - Reduces slag formation
    - Lowers hearth peak temps
    - Reduces oxygen content
    - Increases operational stability
    - Reduces flare-up during feed stoppage
    - Promotes complete ash burnout
    - Better solids gas phase mixing
    - Lowering NOx production
Flue Gas Recirculation (FGR)

- Hearth without FGR (Left) and with (Right)
Center Shaft Air

- Another way to reduce fuel usage in MHF’s is by utilizing heated Center Shaft Air
- The Center shafts and rabble arms are air cooled
- Heated center shaft air can be:
  - Injected into the stack for steam plume suppression & increased dispersion
  - Utilized as burner air supply or furnace combustion air to decrease fuel usage
Improved Dewatering

- Typical Sludge Cake
  - Belt filter press: <21-25% solids
  - Centrifuge: 27-30% solids
  \[\sim 75\% \text{ water}\]

- Why does this matter?
  - Heating Value of Water = 0
  - Water requires a large heat input to vaporize
    \[\Delta H_{vap} = -1059 \text{ BTU/lb}\]

- More water = More auxiliary fuel
Improved Dewatering

• At low moisture content, sludge can burn without the addition of fuel oil (Autogenous).
• Typically at >26% for a Fluid Bed
• Super-Autogenous conditions limit operations
Fat, Oil & Grease

- Fat, Oil, and Grease are waste-products from the restaurant industry
- Consists of some food debris, mostly cooking oils & fats, and ~96% water
- Often concentrated to <50% water before added to an incinerator
- Grease can be used to supplement auxiliary fuel (sometimes up to 100% during operation)
Fat, Oil & Grease

- No petroleum products or other hazardous materials found in grease
- Non-processed fuel (concentrating aside)
- Restaurants typically pay a tipping fee for removal and disposal
- With current fuel prices, R.O.I. for a grease receiving/handling facility can be less than 3 years with tipping fees or 6 years without
Questions?

Chavond-Barry Engineering Corp.
400 County Route 518
Blawenburg, NJ 08504
Tel: (609) 466-4900
Fax: (609) 466-1231