Efficiency and Design Improvements in Multiple Hearth & Fluid Bed Incinerators

CBE

Chavond-Barry Engineering
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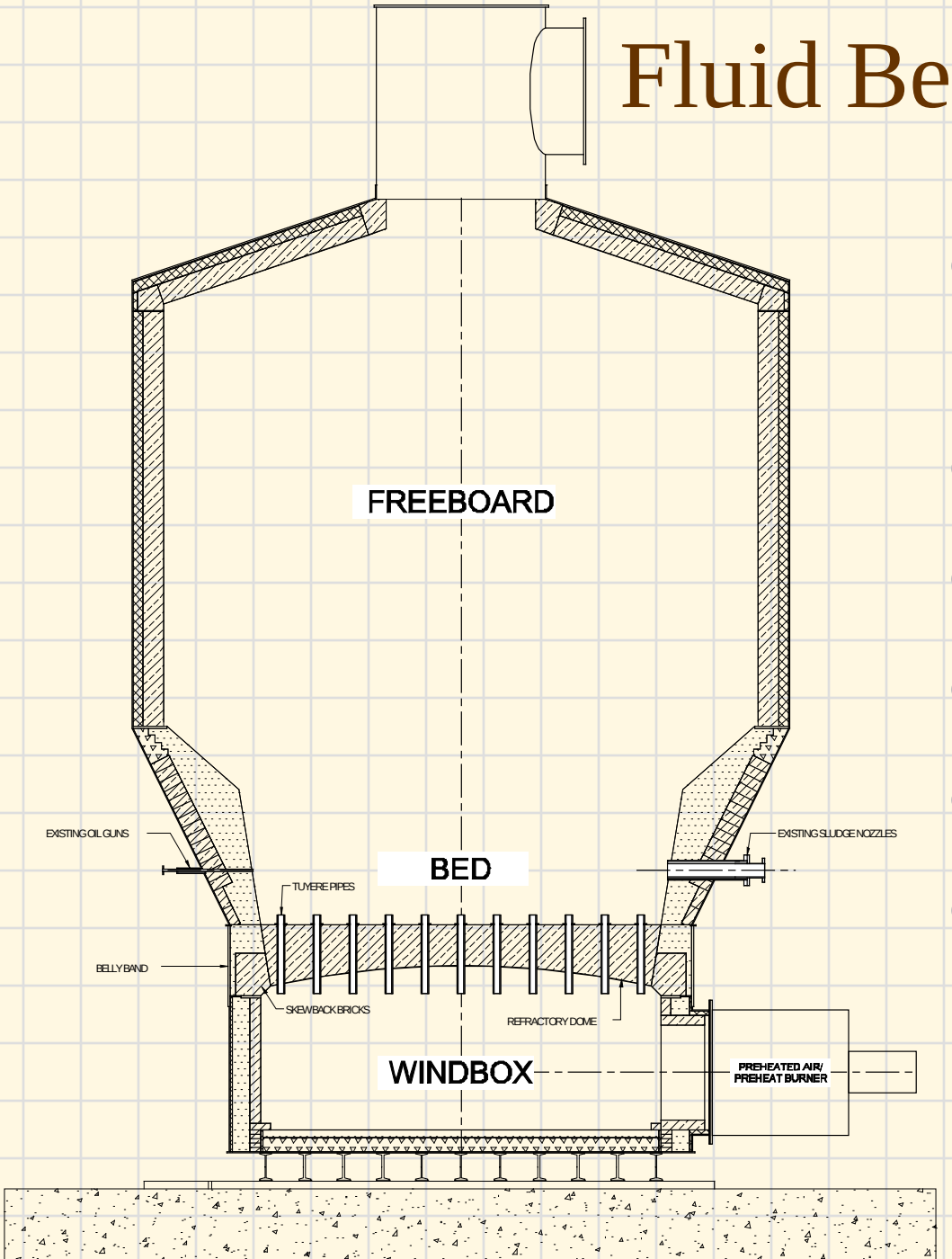
Outline

- 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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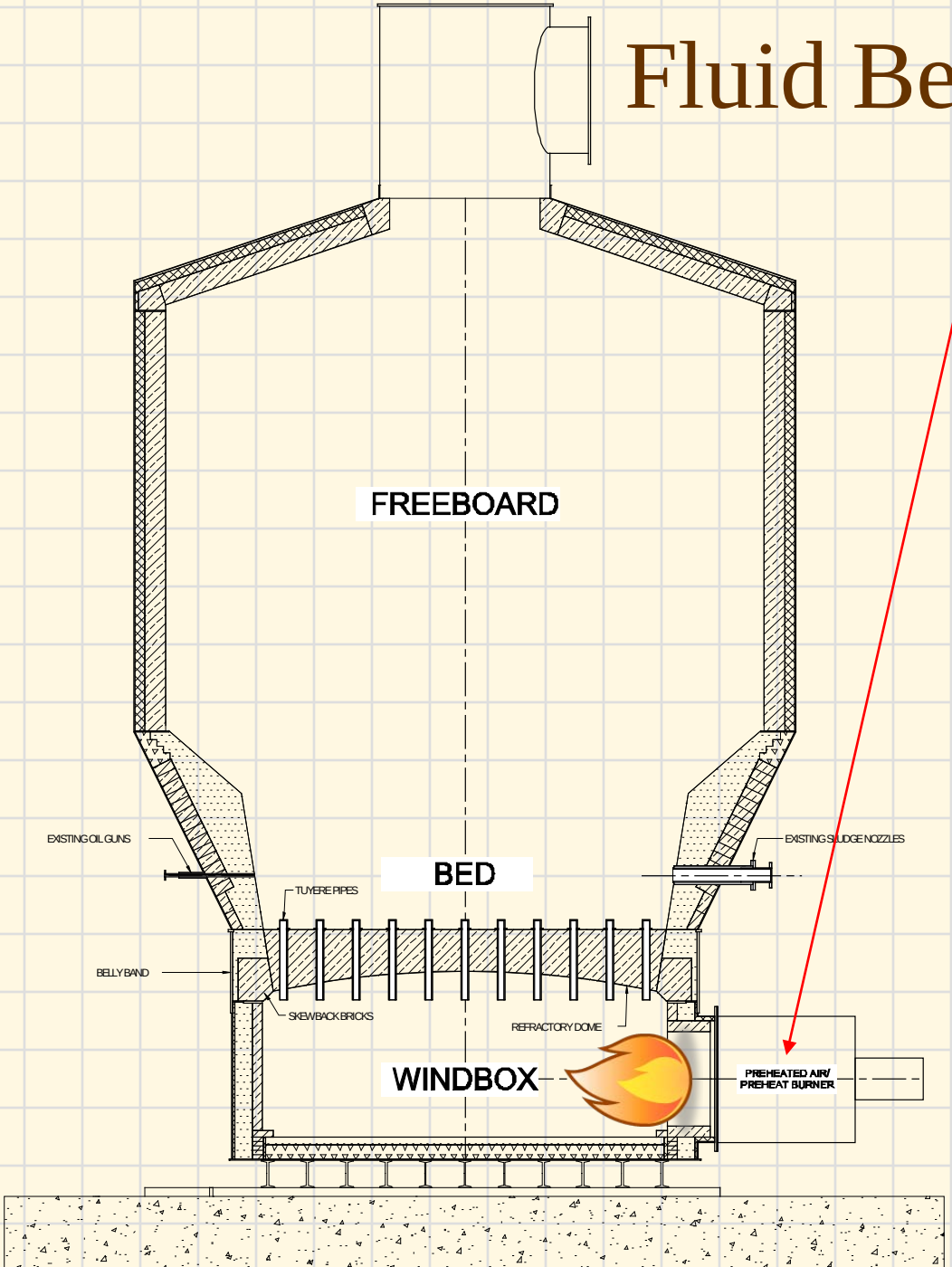

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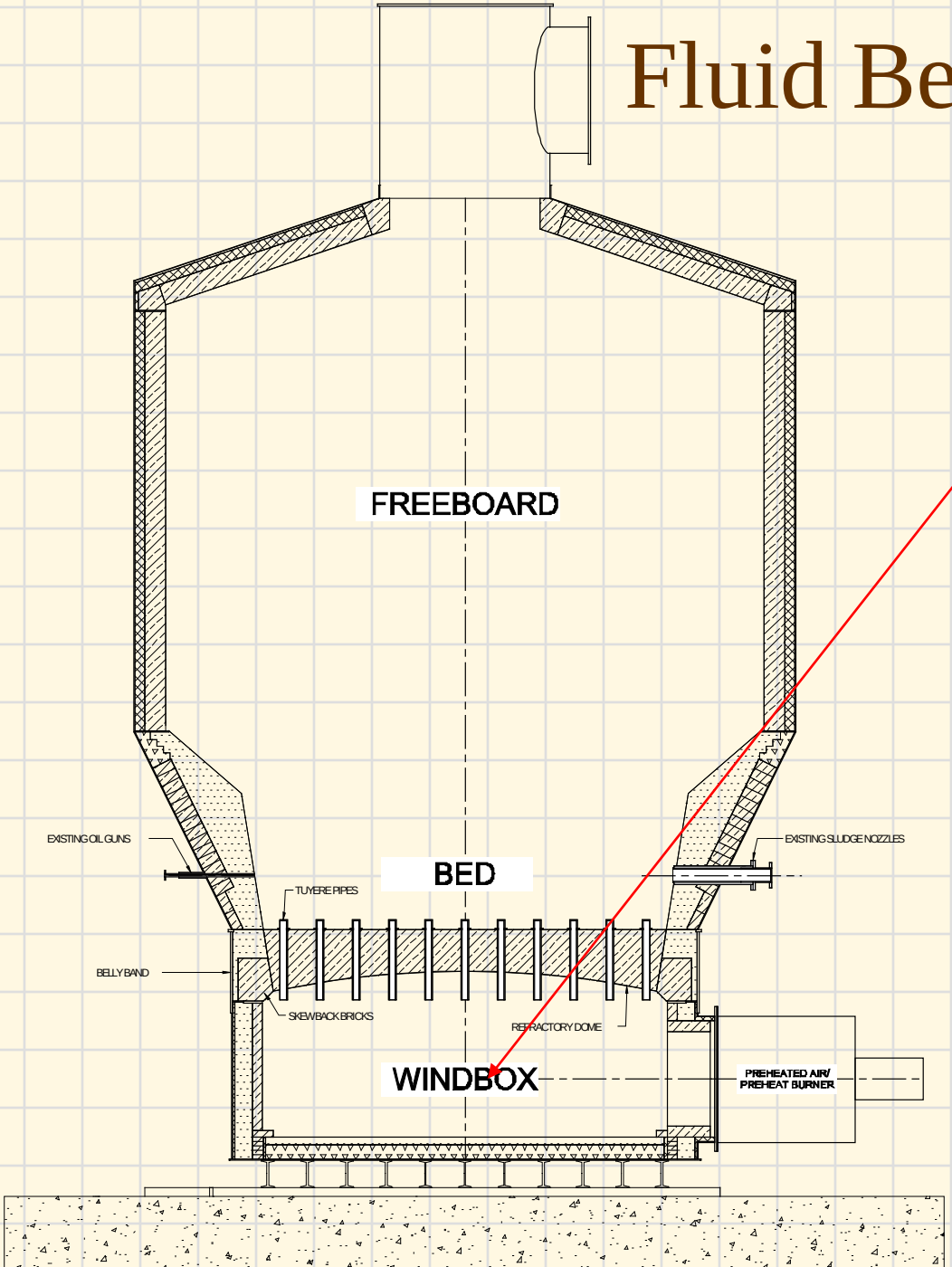

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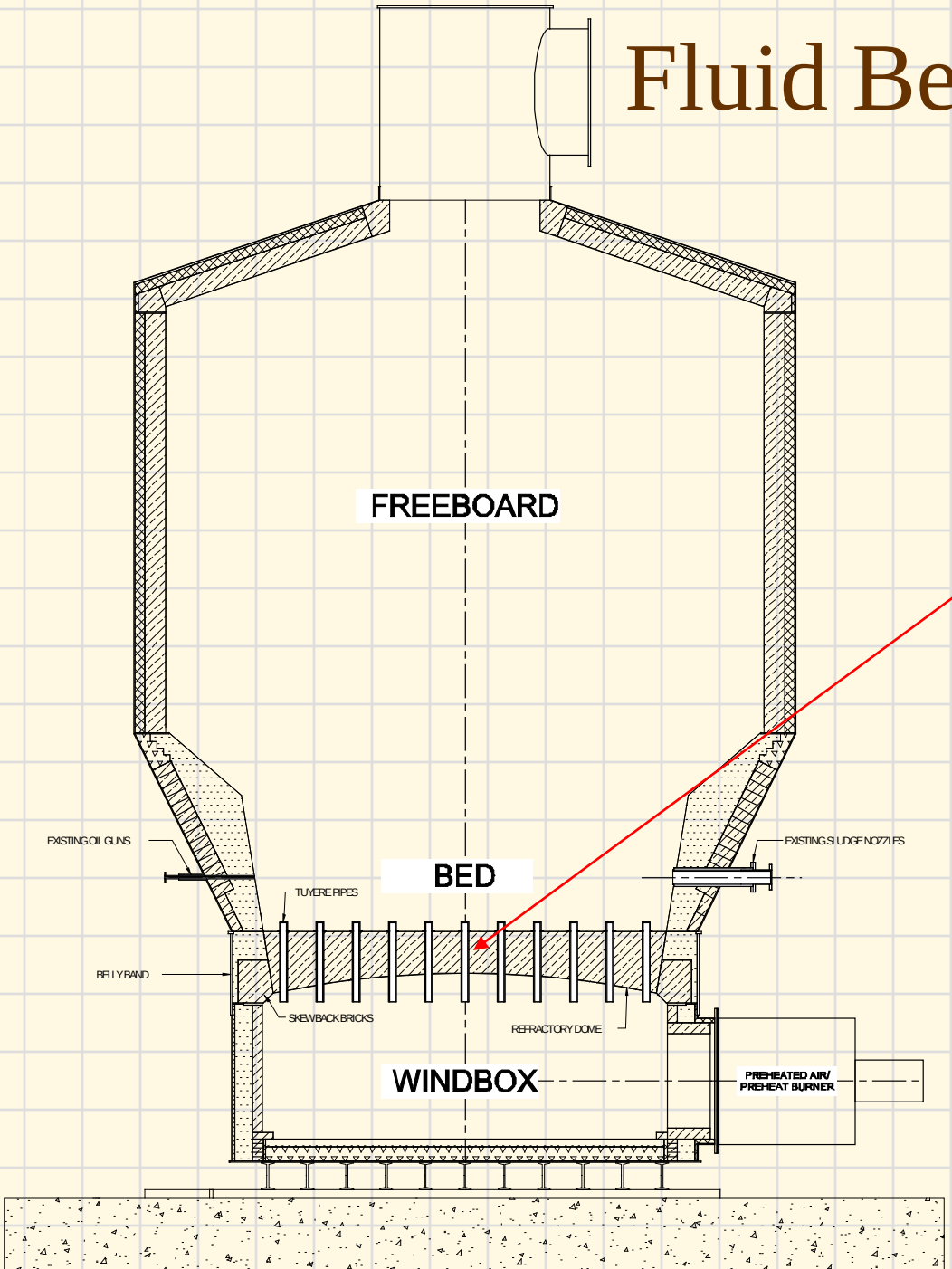

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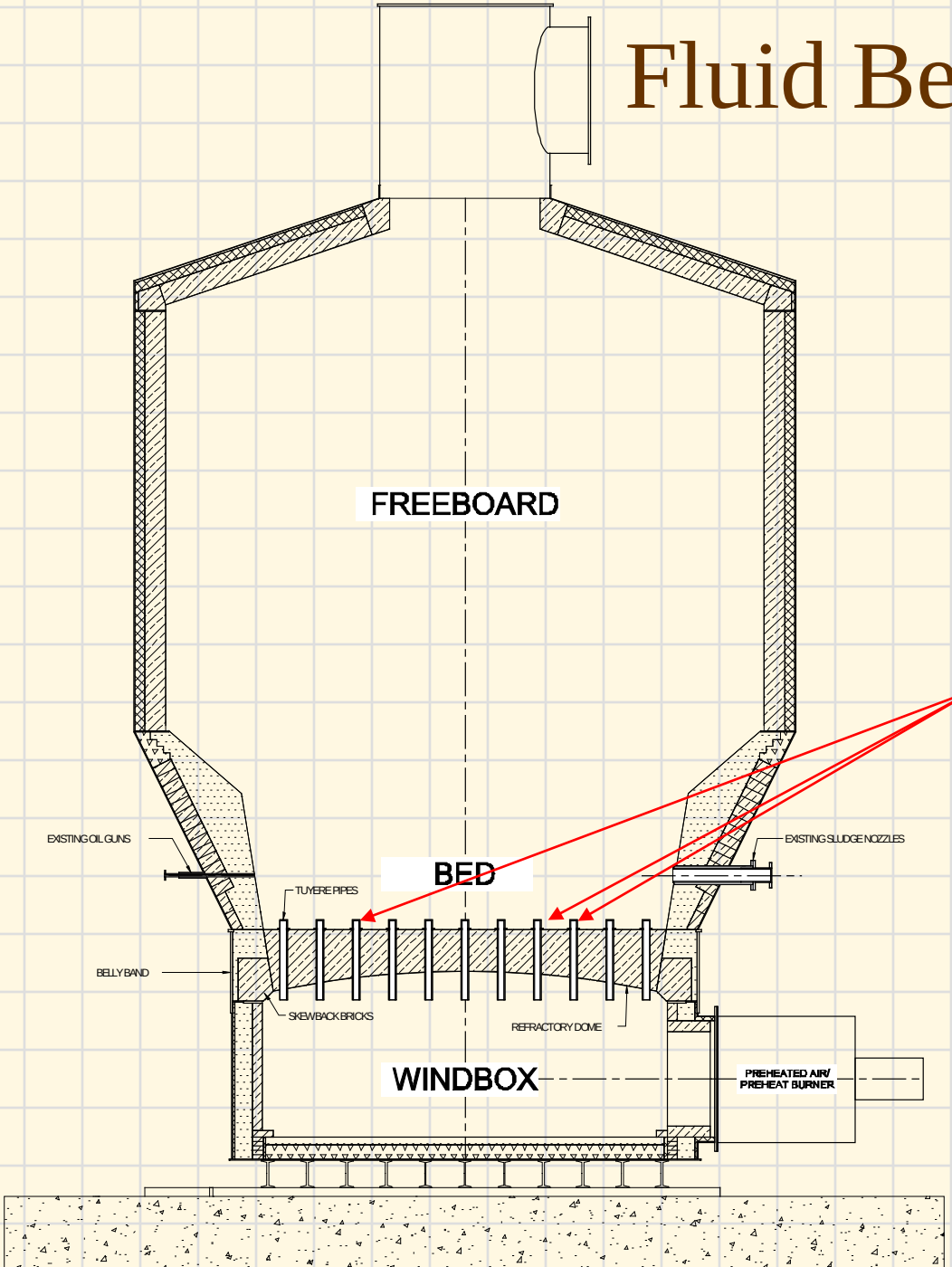

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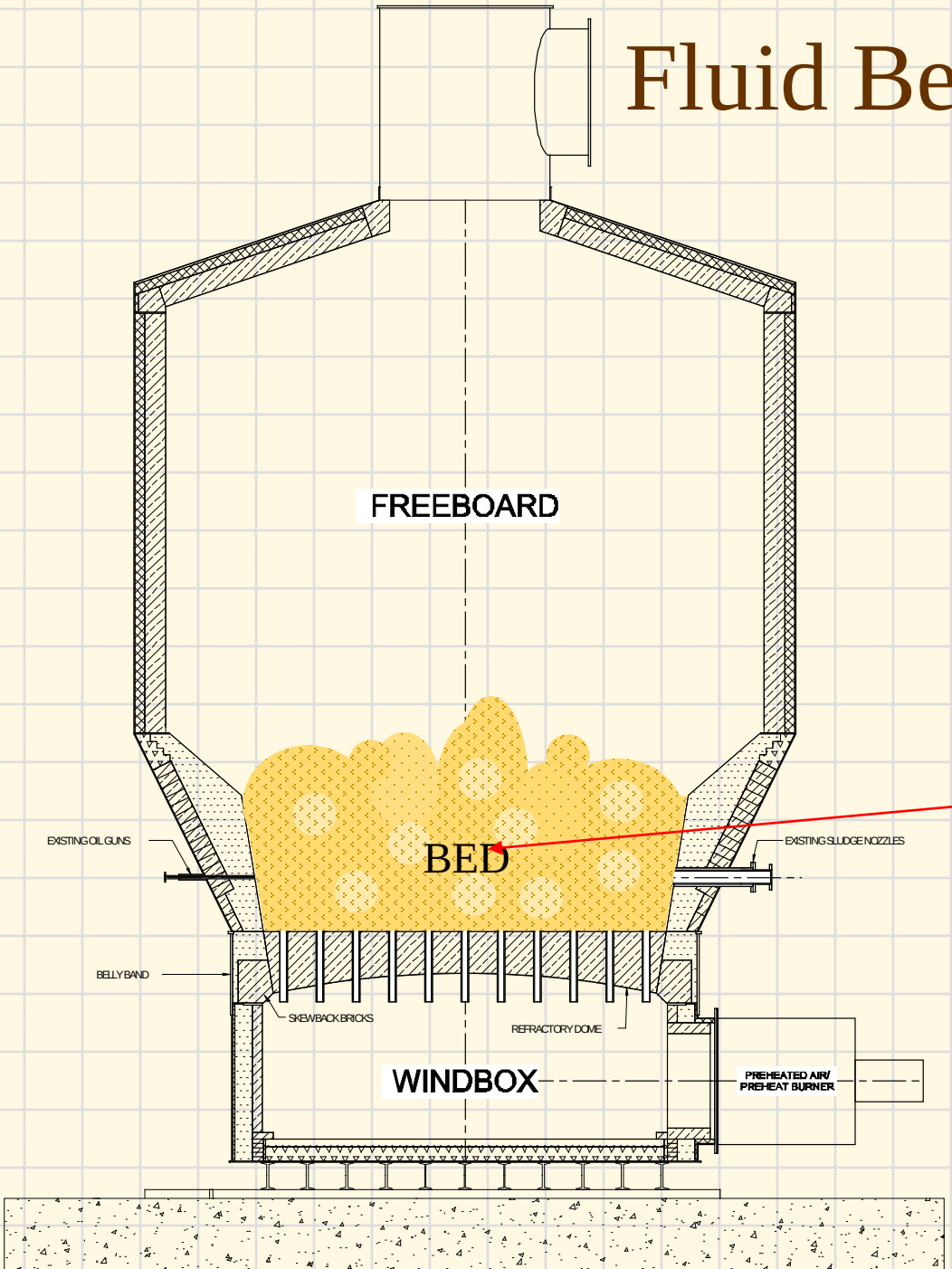

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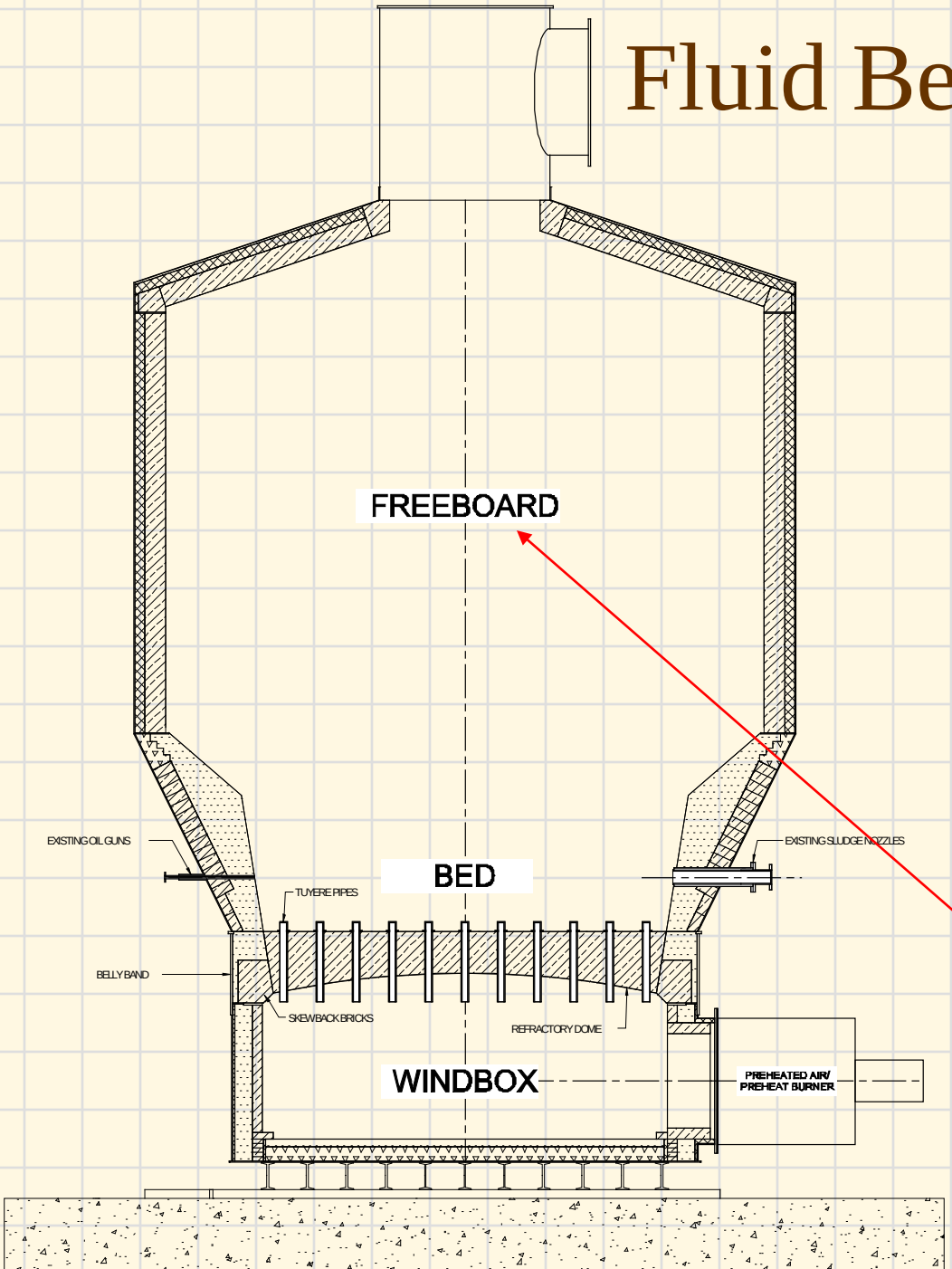

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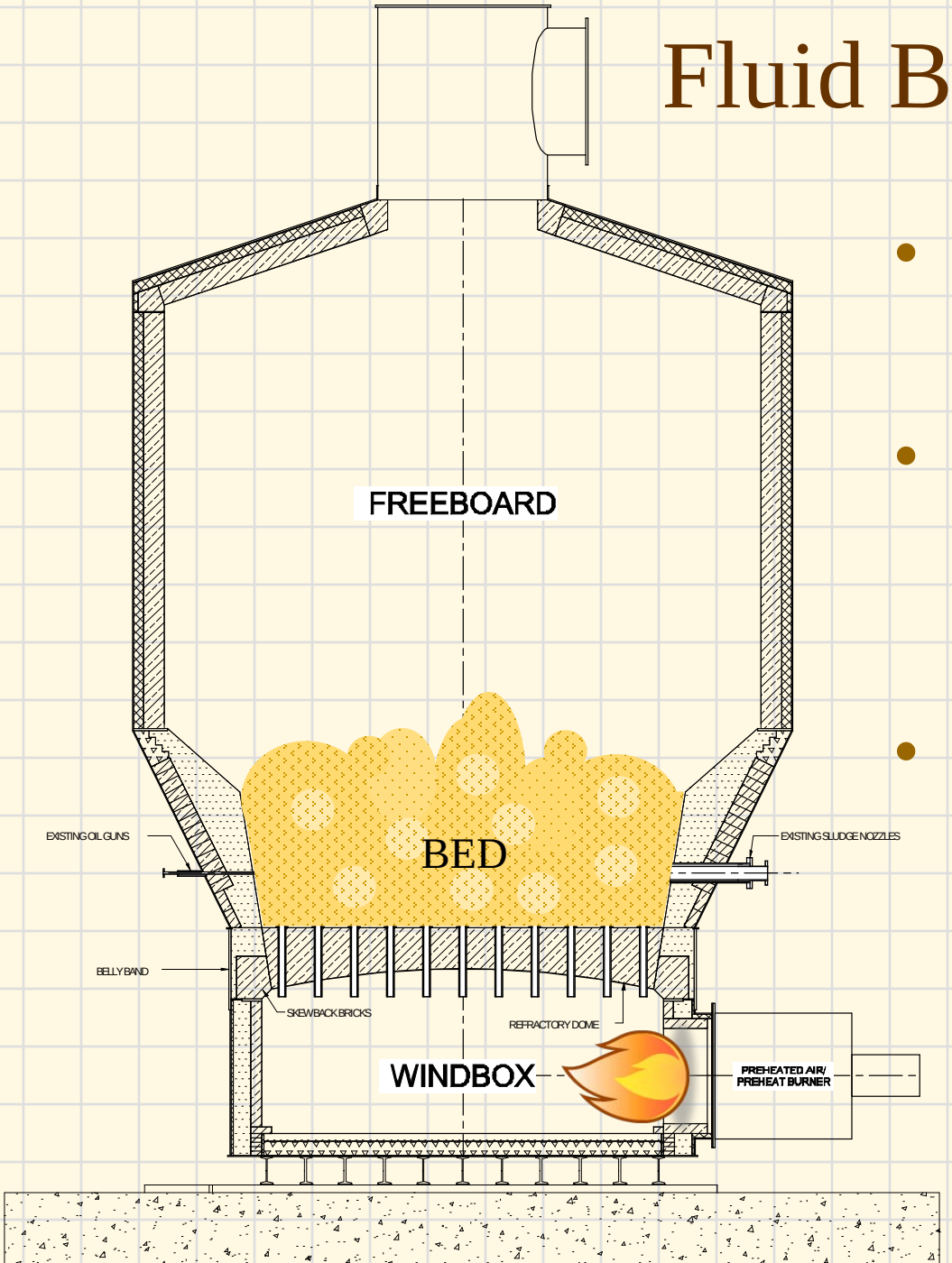
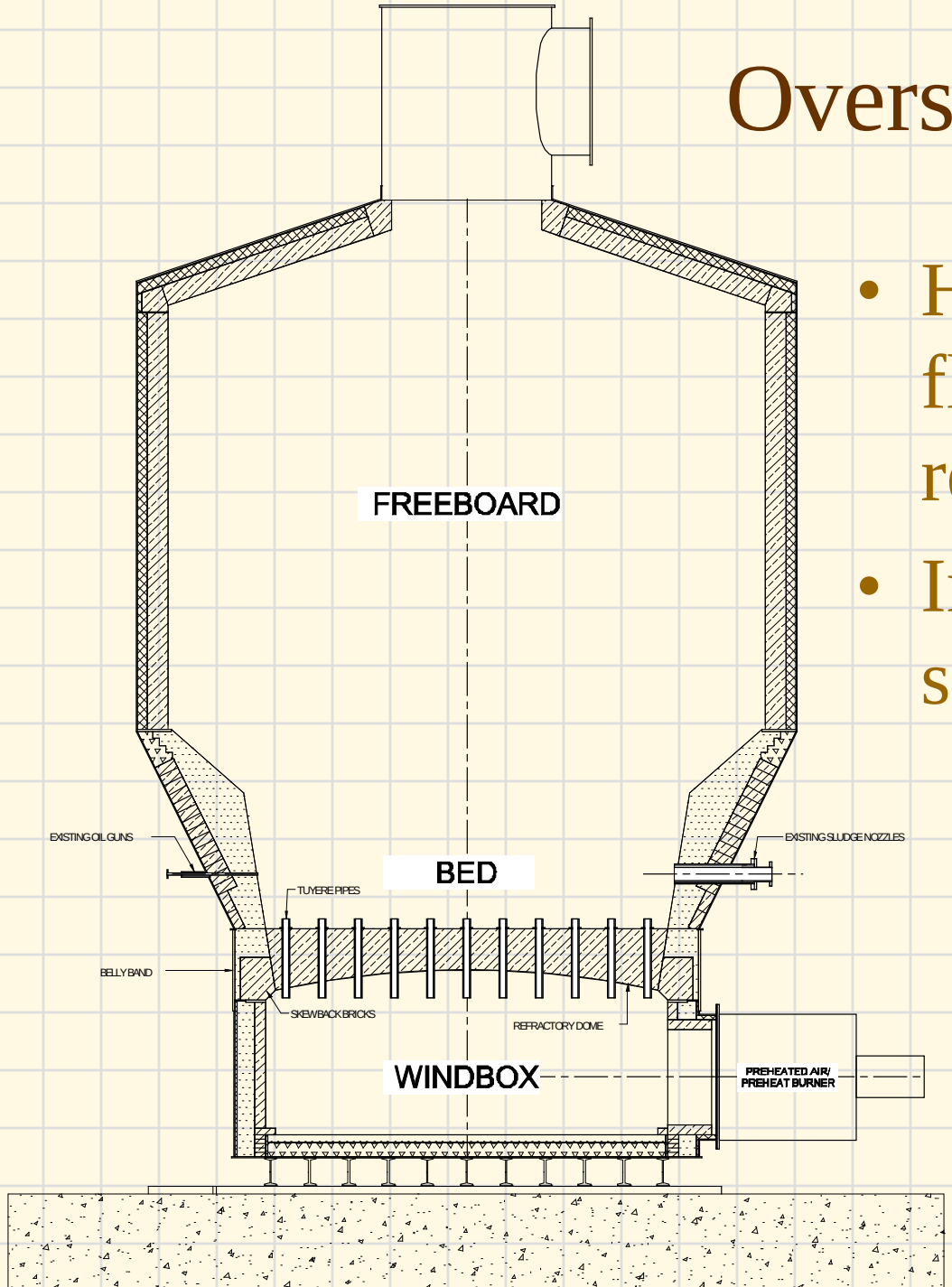


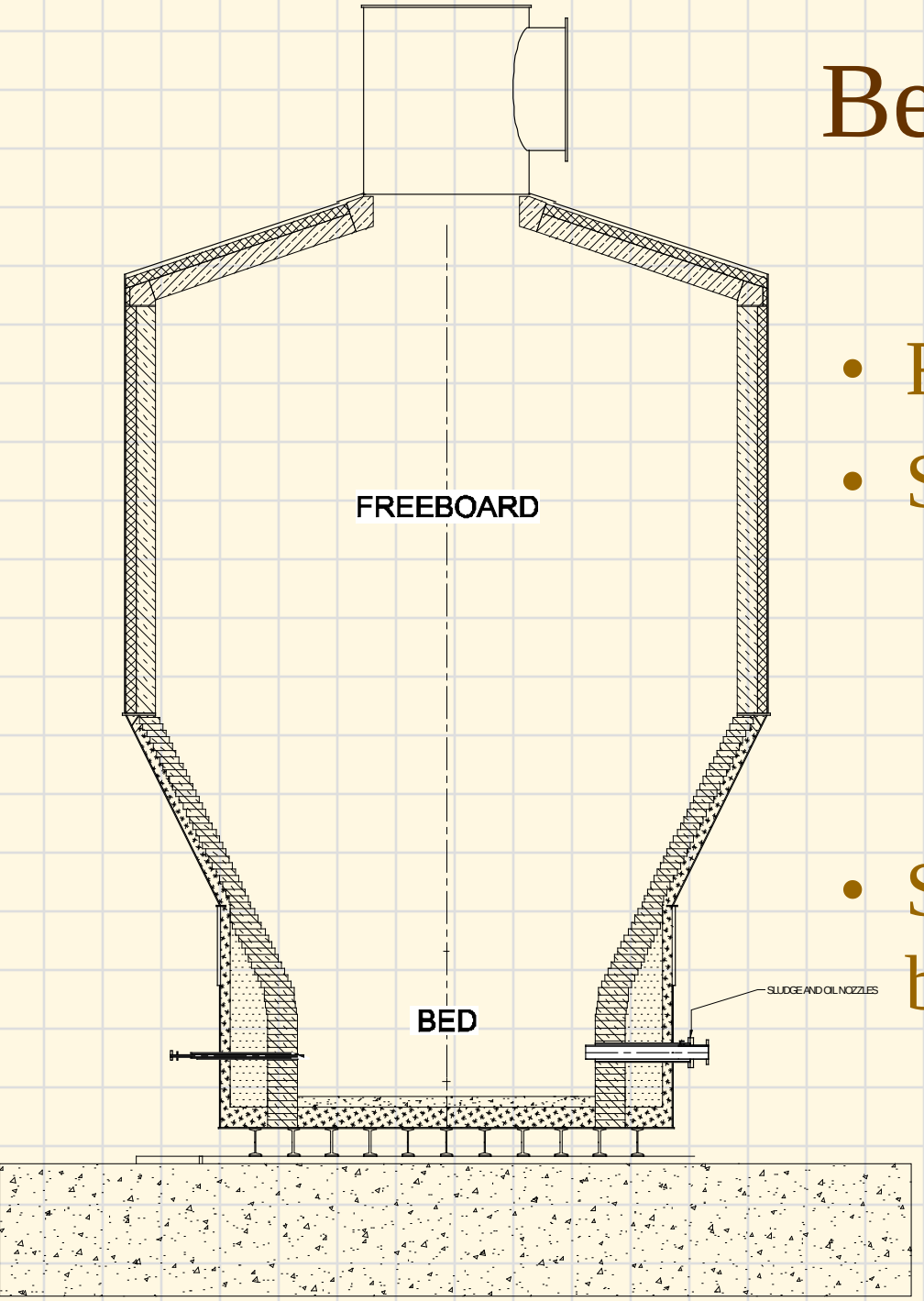
- Air enters through bottom
- Sludge and fuel introduced in the bed
- Ash and exhaust gasses exit through the top

Oversized FBI



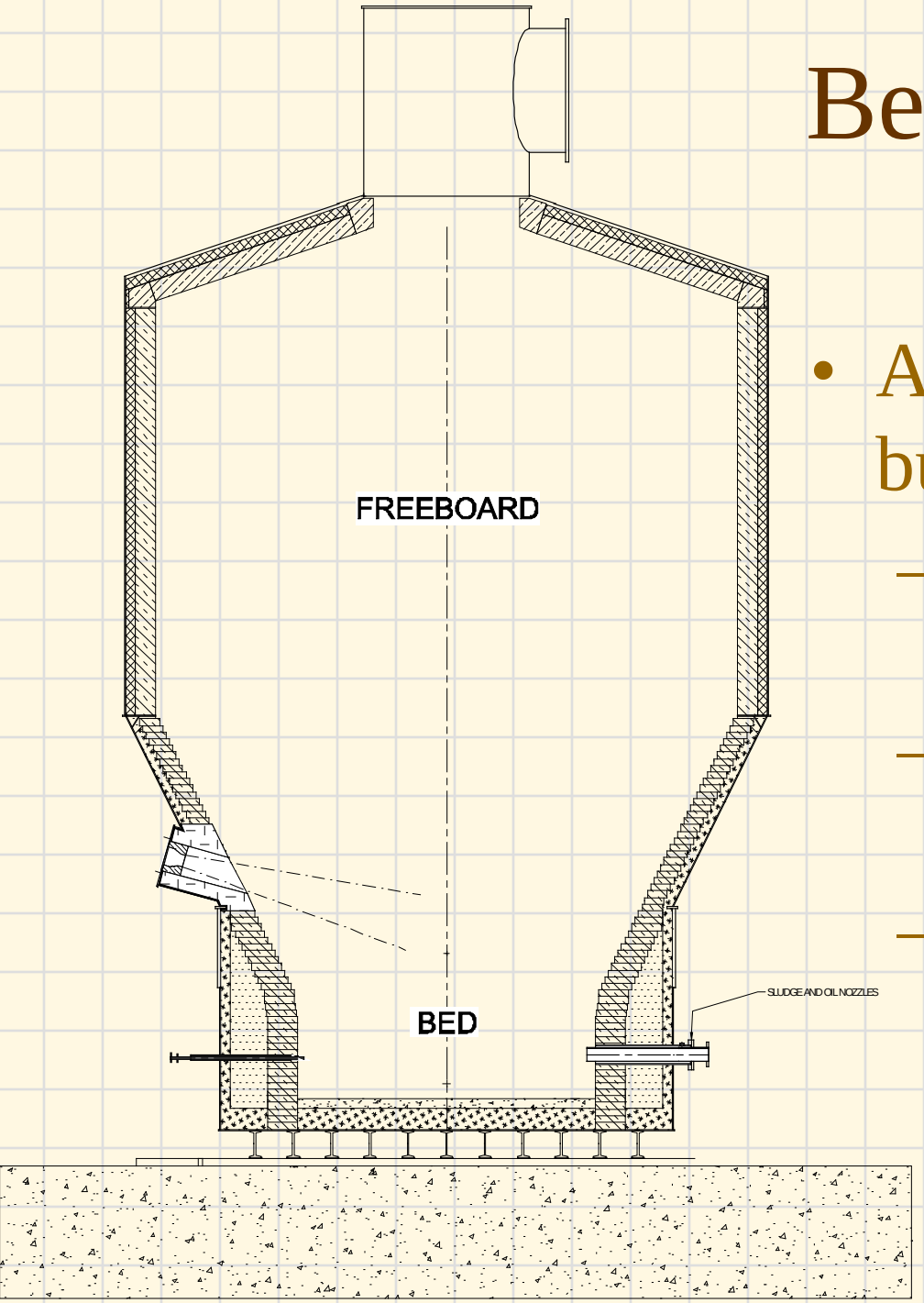
- High minimum fluidizing air required
- Inefficient at low sludge feed rates

Bed Resizing



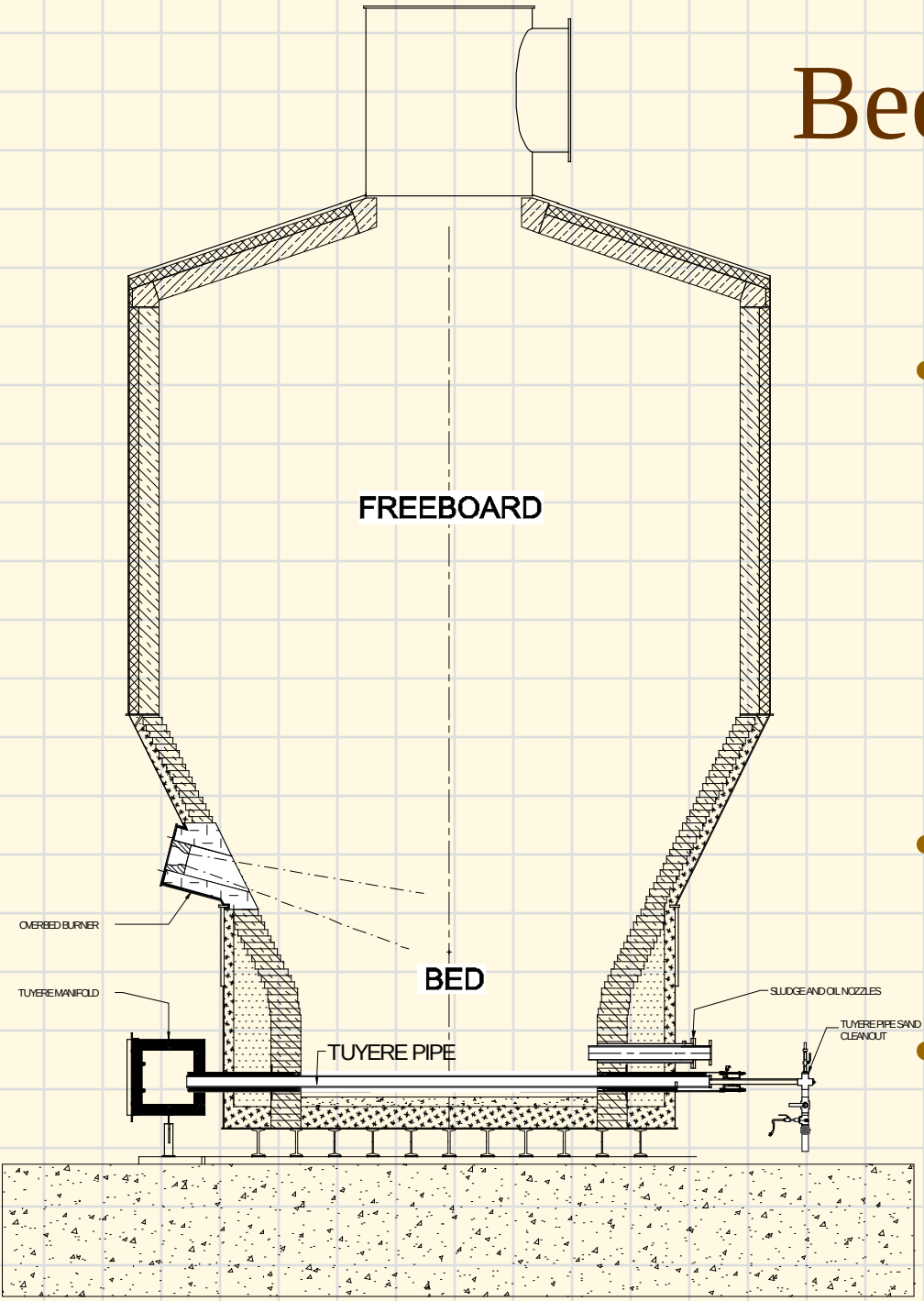
- Remove dome
- Shift bed downward
  - Oil guns
  - Sludge guns
  - Instrumentation
- Shrink diameter of bed

Bed Resizing

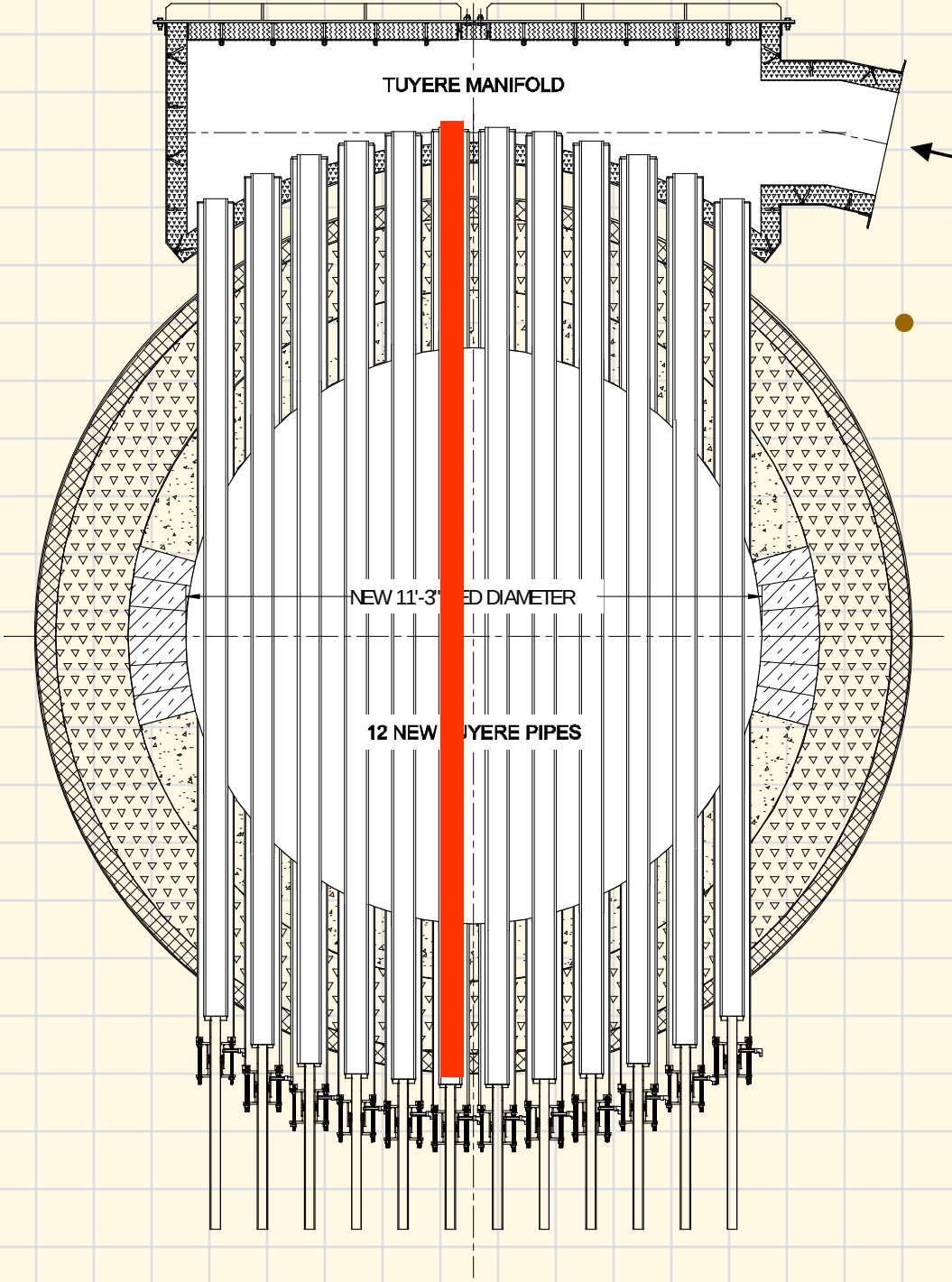


- Add over bed burner
  - Provides live flame in freeboard
  - Directed at top of sand
  - Can be used to heat freeboard directly

Bed Resizing

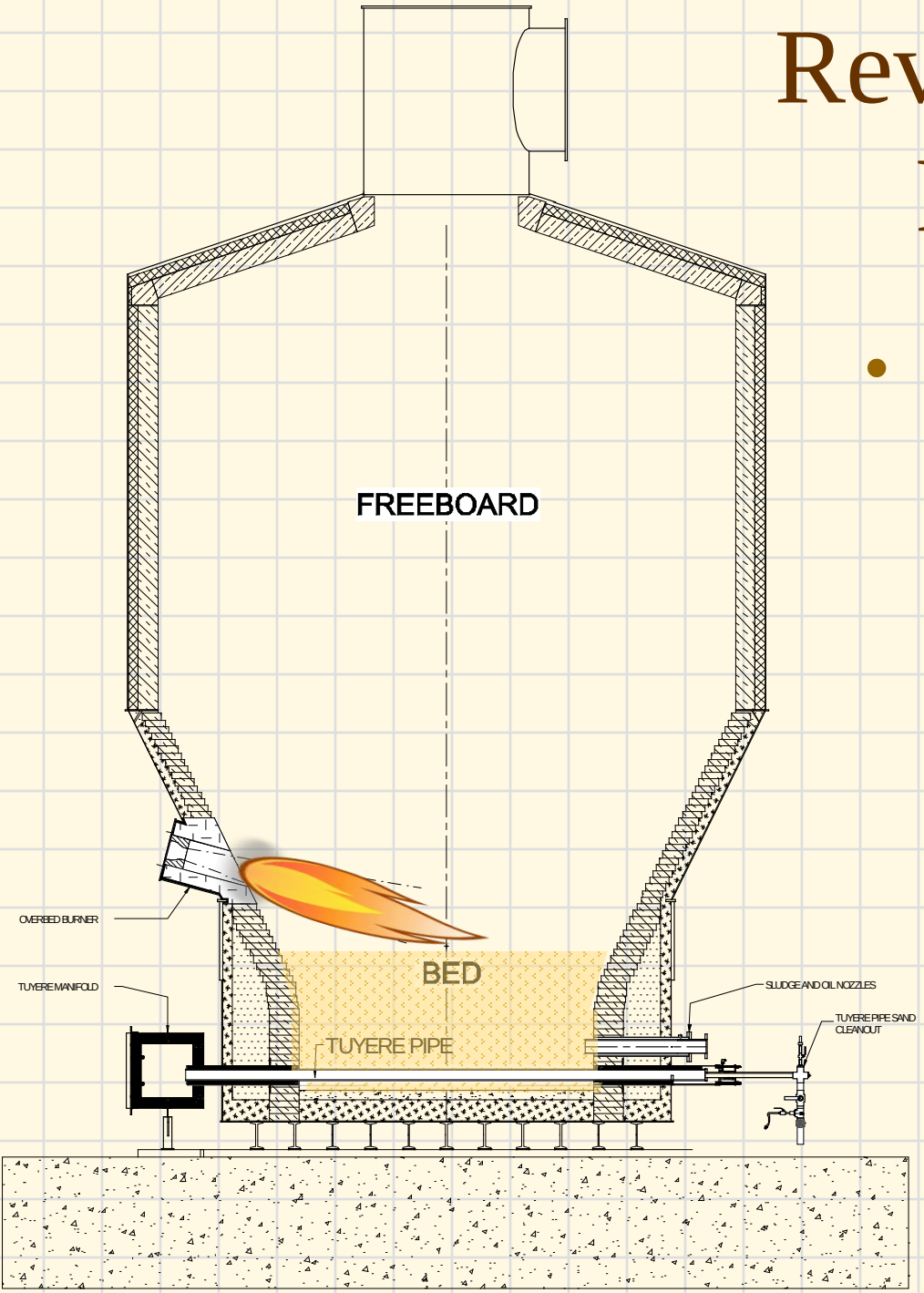


- Pipe Tuyeres
  - Set of parallel pipes
  - Holes in pipes to distribute air
- External air manifold
- Pipe clean out manifold



- Parallel pipe tuyeres receive through external manifold

Reversible Bed Resizing

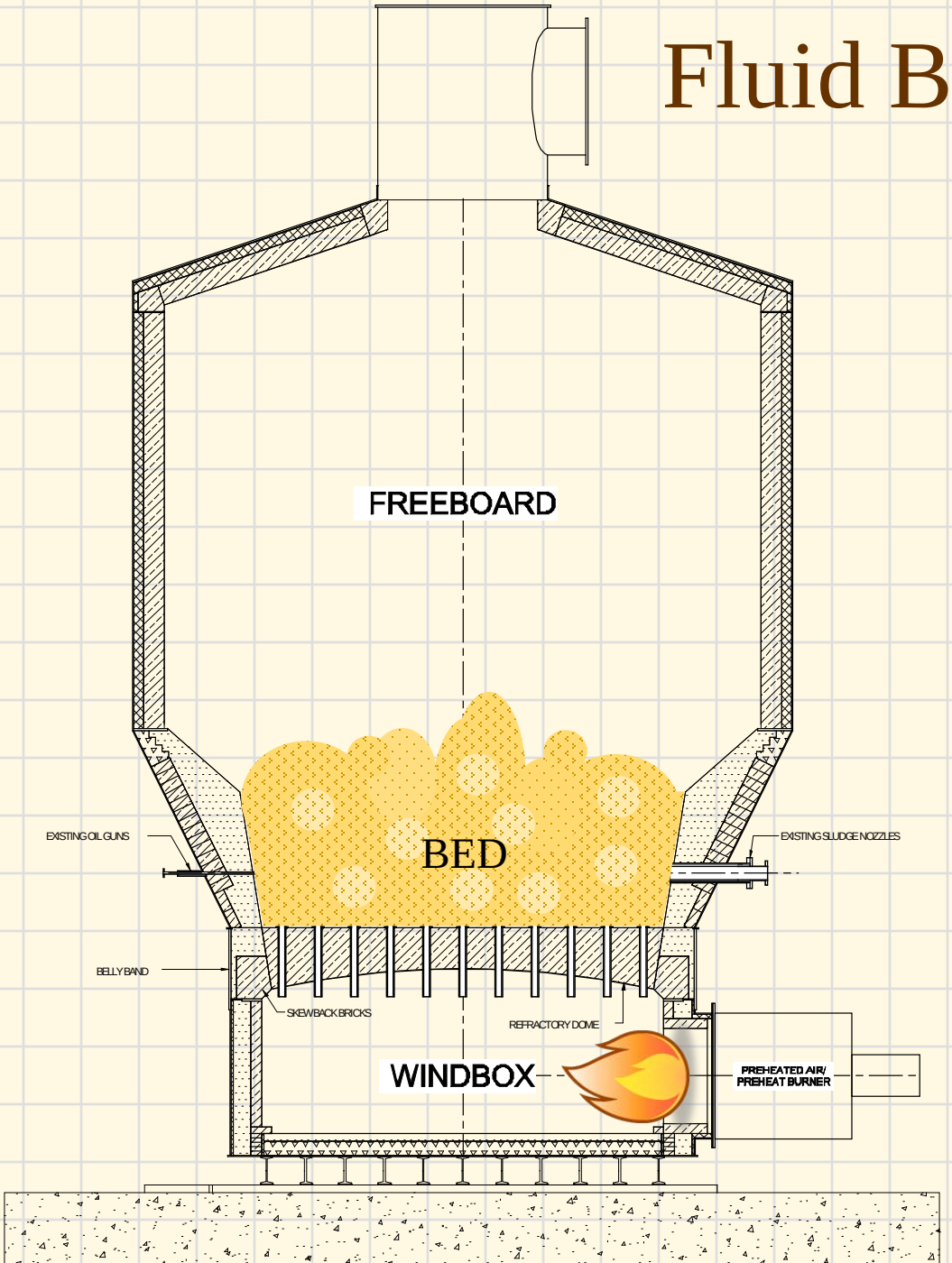


- Bed can be expanded incrementally back to original size if needed
  - Remove row of bricks
  - Drill additional holes in pipe tuyeres

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
- Dome
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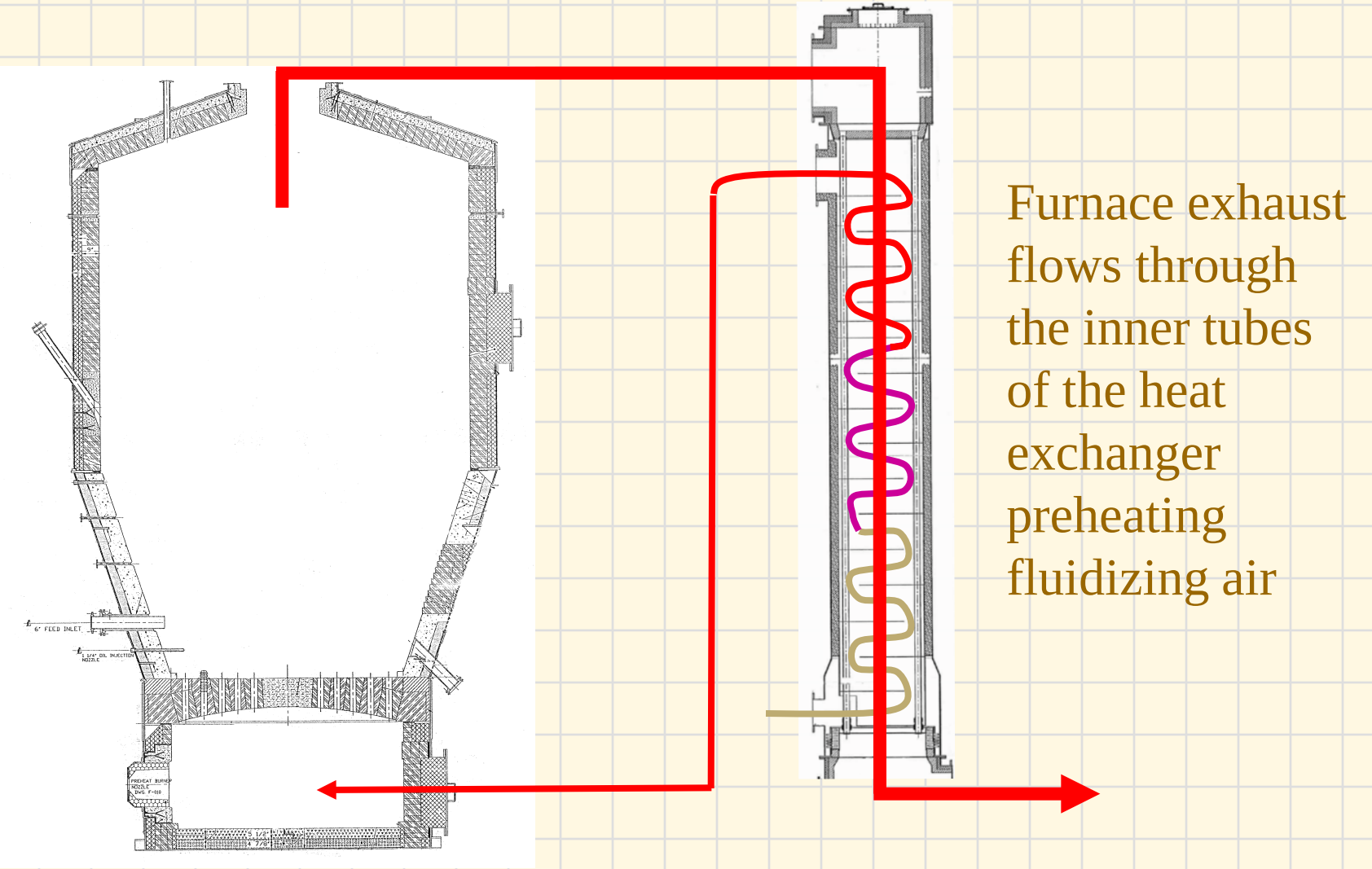
Preheating the Combustion Air

- 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:

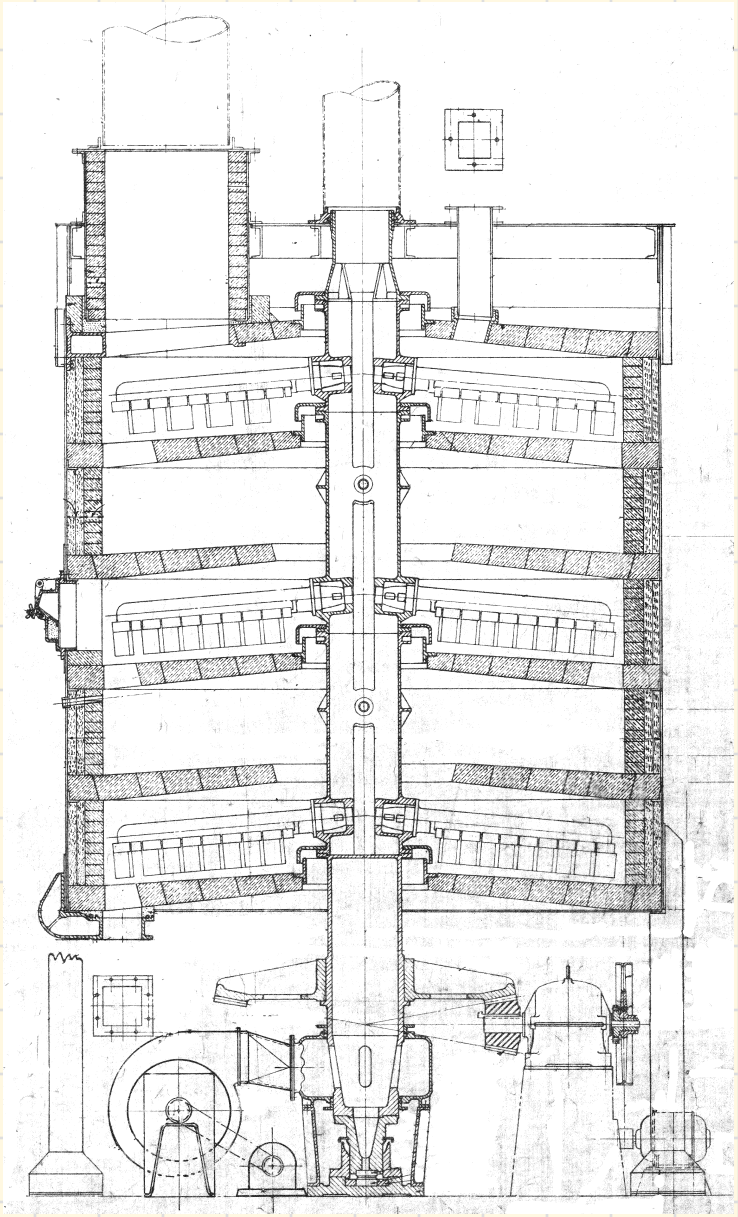
  - 5,000 SCFM, Preheated +1000°F

.25BTU/lbm°F*.075lbm/ft³*5000SCFM*1000°F

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

40 gal/hr*3$/gal*24hrs/day = $2880/day

Multiple Hearth Furnace



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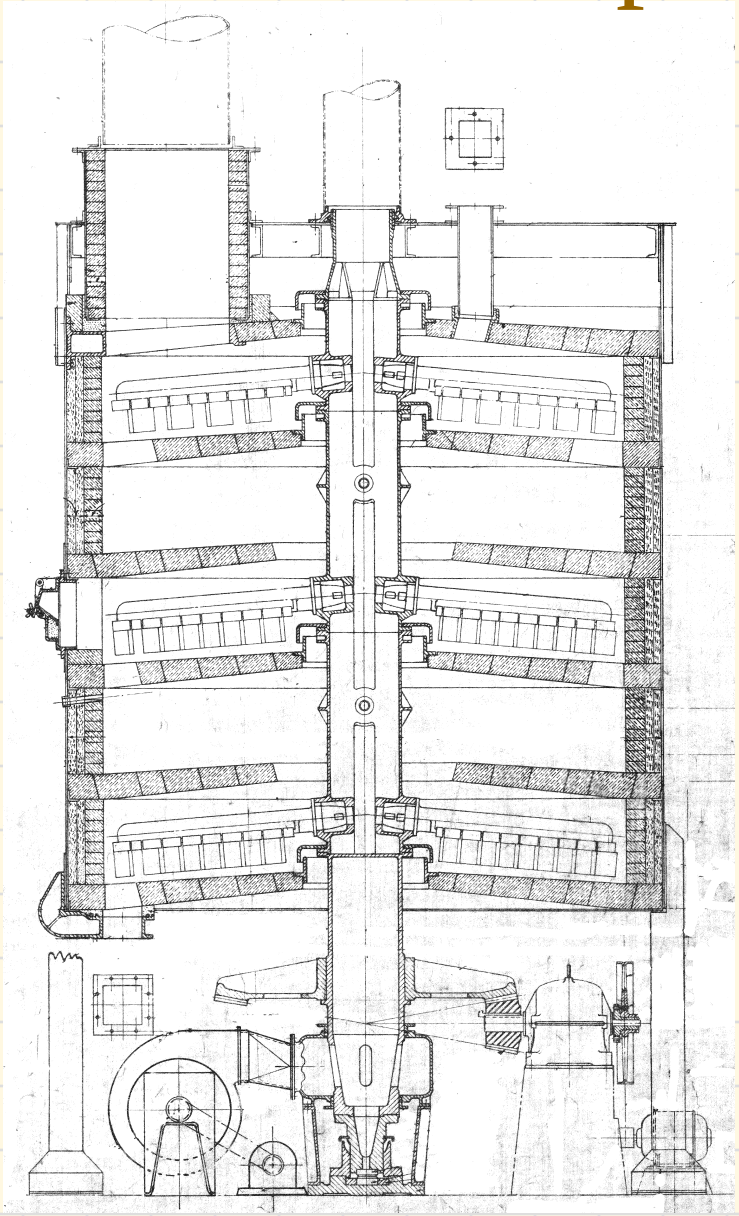
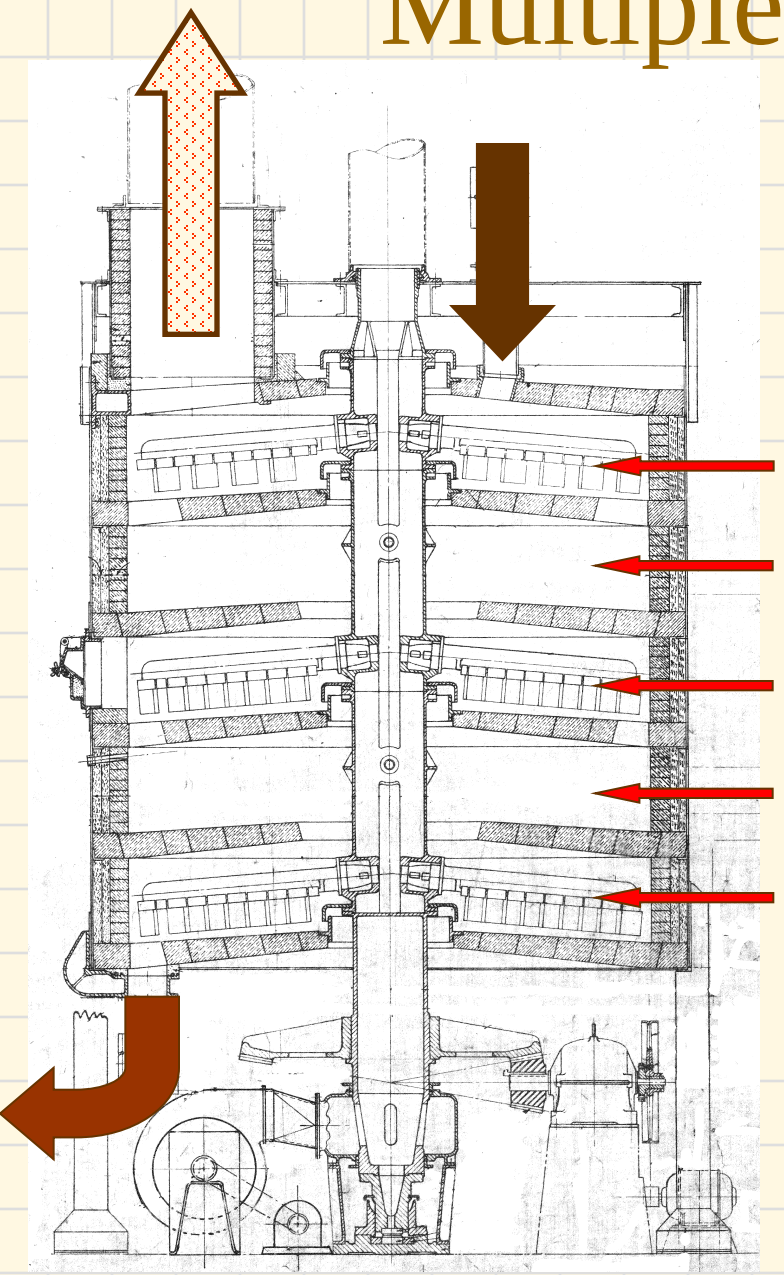


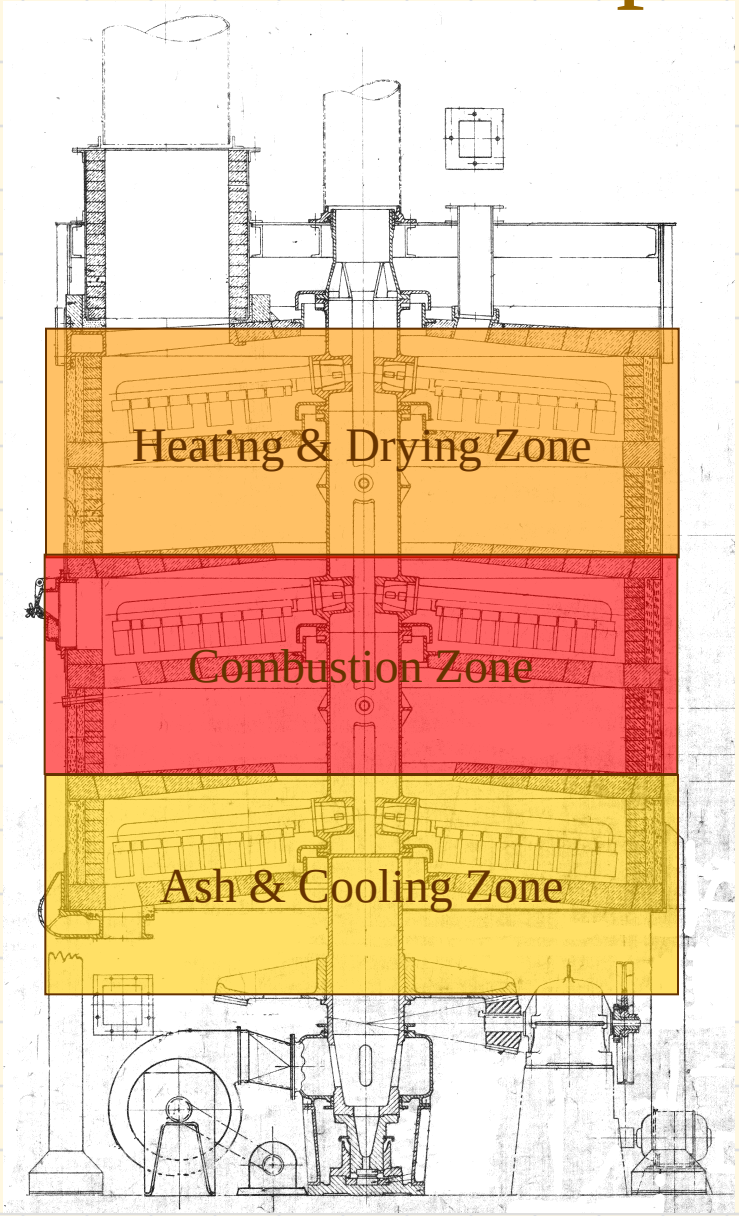
- Refractory lined cylindrical steel shell
- Separated into a series of combustion chambers - refractory hearths one above the other
- Temperature and reaction environment well controlled on each hearth

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



- Dewatered sludge Cake enters the furnace at the top
- Inject air and fuel where needed to maintain temperature and supplement the combustion process
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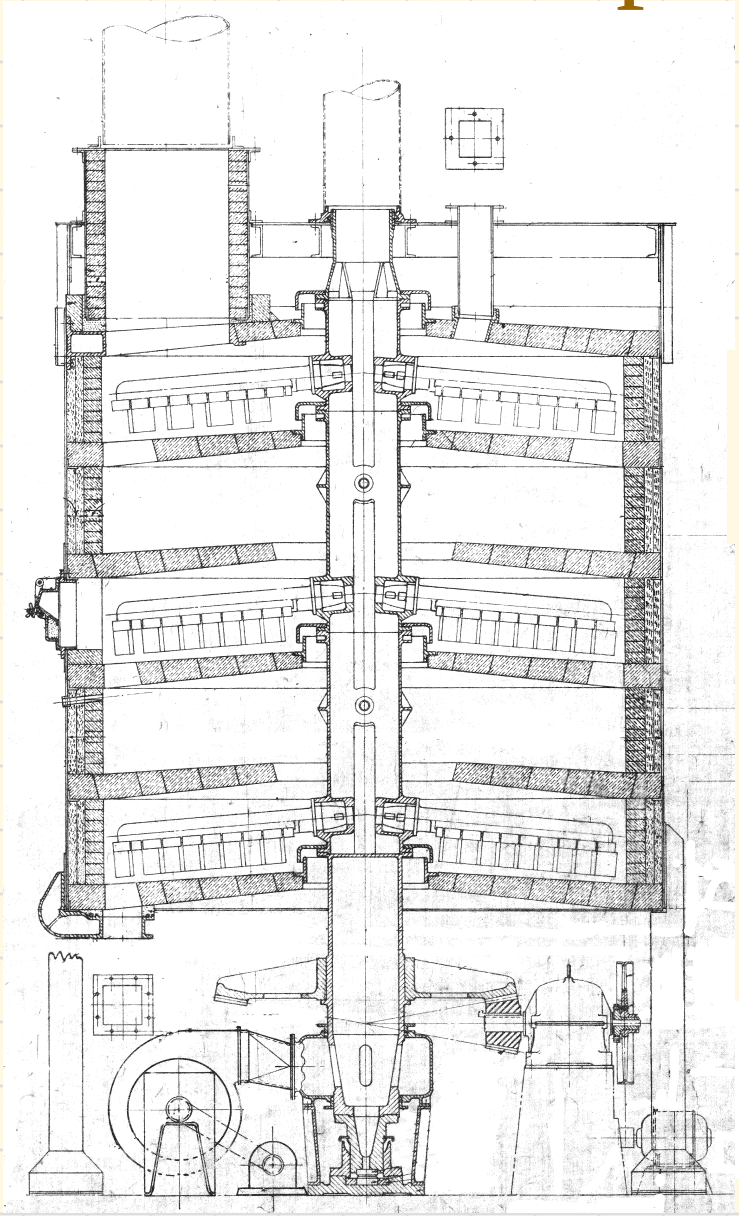
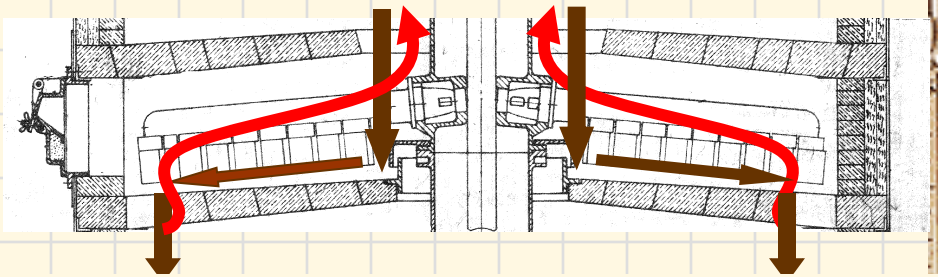
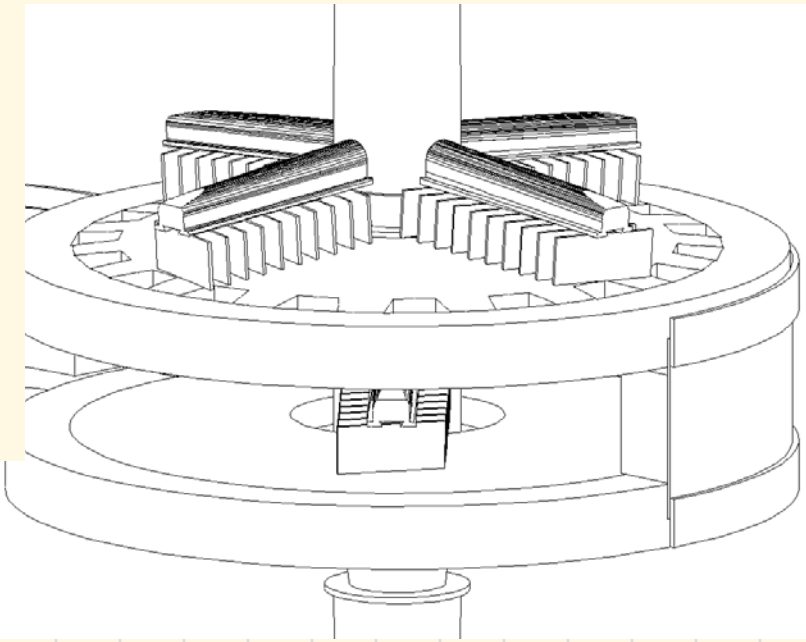
- **Generalized to three processing "zones"**

Multiple Hearth Furnace





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



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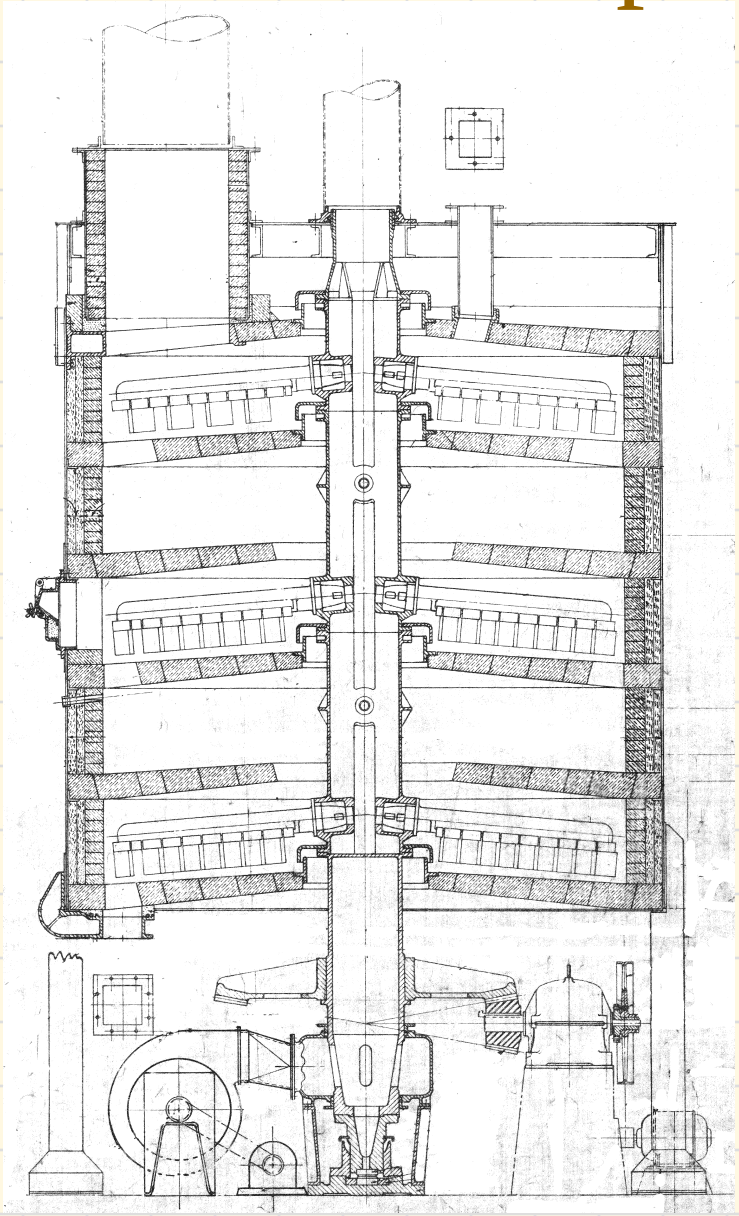
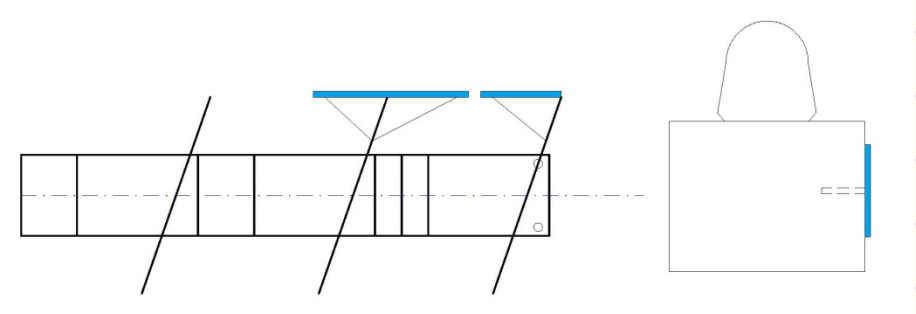


Poor distribution of sludge across top hearth:

- 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 heath with Jumper Flue
  - External Chamber
- Afterburners located directly after the incinerator (before APC equipment)

RHOX – Reheat & Oxidize Process

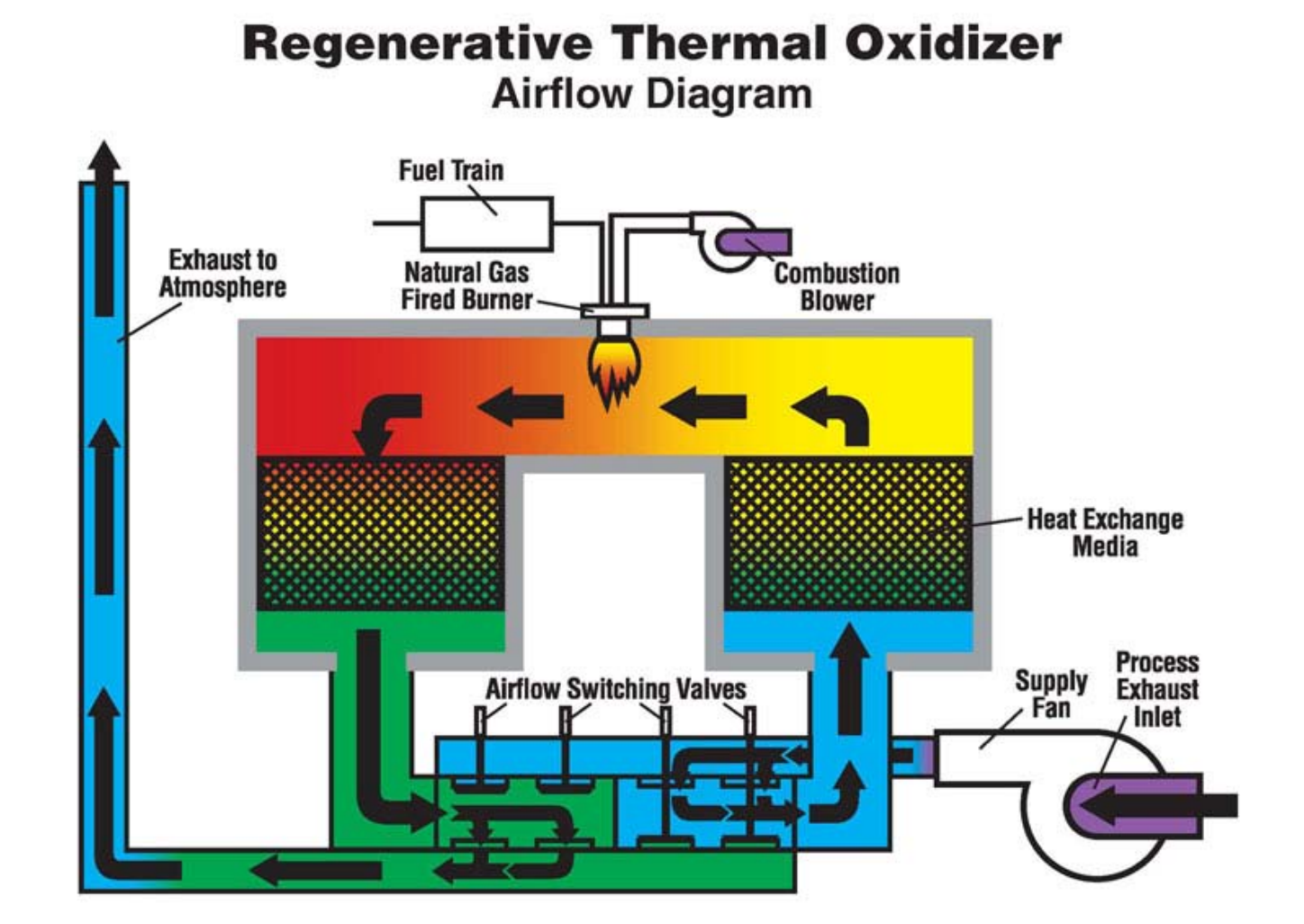
- Traditional afterburner designs require 1 or more burners
- Require high fuel usage to maintain afterburner temperature
- Additional burners can produce NOx

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



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

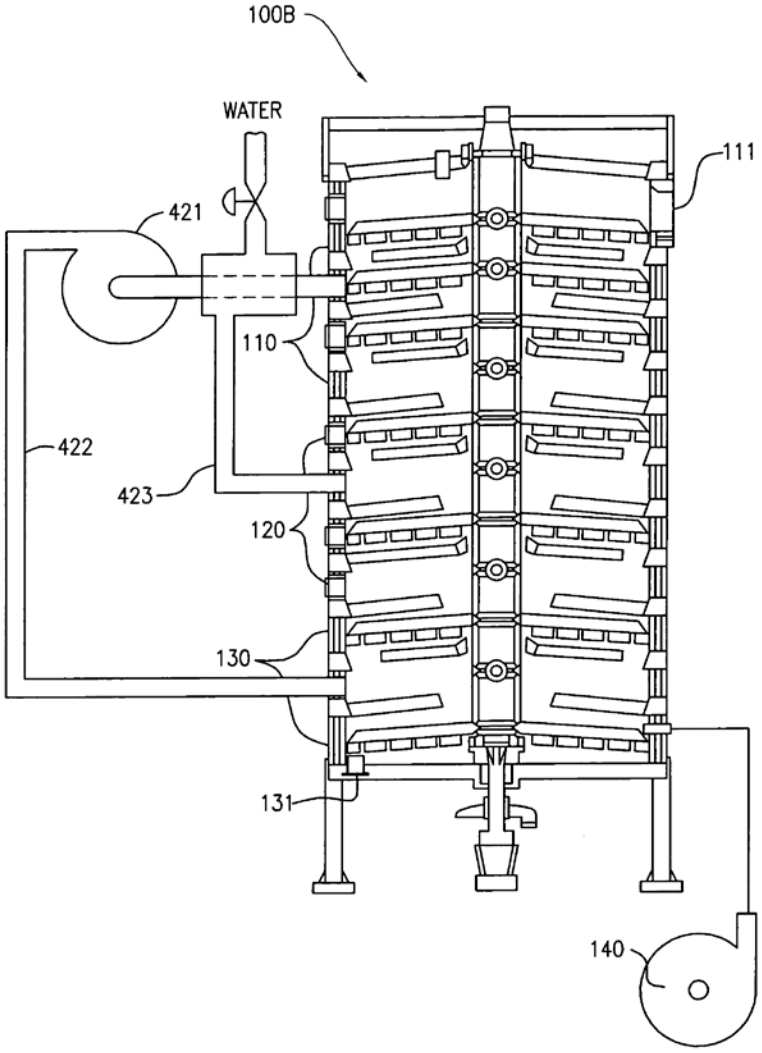
Regenerative Thermal Oxidizer

- 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 that 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

    lowering NOx production
    - Increases operational stability
    - Reduces flare-up during feed stoppage
    - Promotes complete ash burnout
    - Better solids gas phase mixing

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

    ~75% water

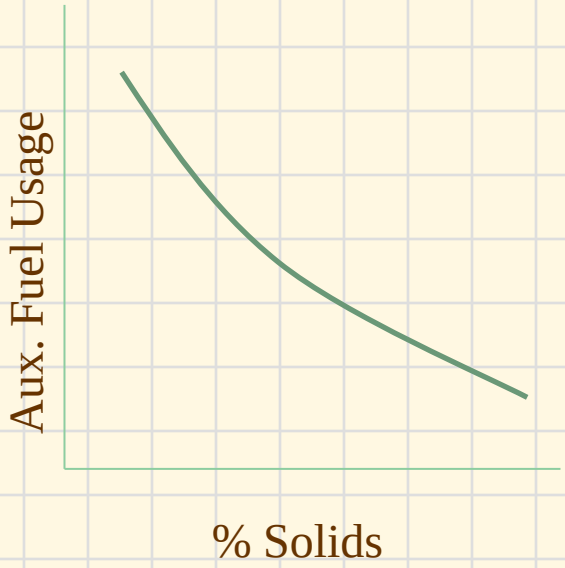
- Why does this matter?
  - Heating Value of Water = 0
  - Water requires a large heat *input* to vaporize

    ΔH_{vap} = -1059 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?

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