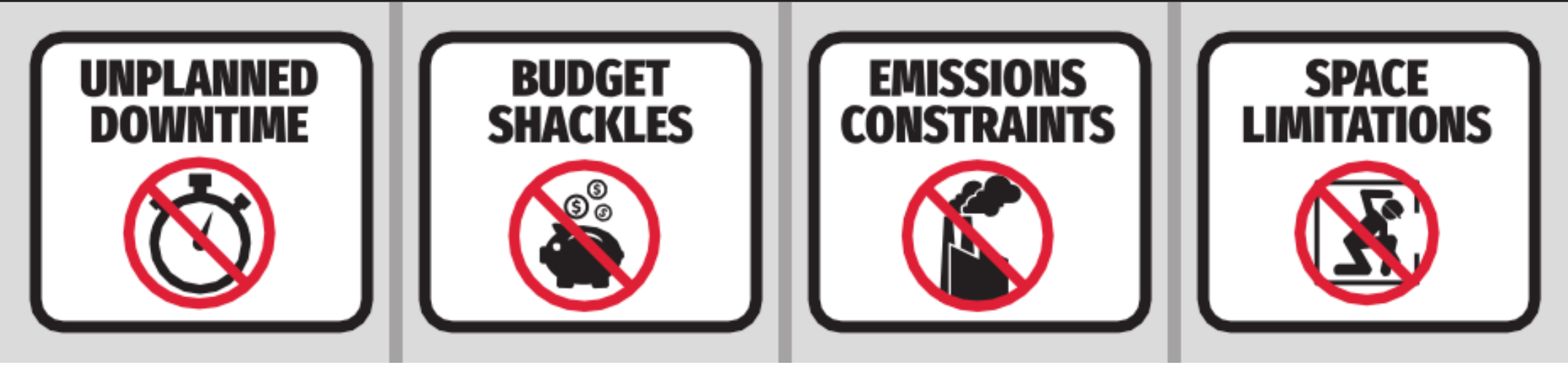
TURNING WASTE INTO POWER

Unlocking Biogas and Waste Heat Boilers

Superior Boiler helps you

outwit your challenges



SUPERIOR BOILER

For over 100 years, we've been finding **solutions to the world's greatest boiler challenges.**

BACKGROUND
THE SUPERIOR BOILER STORY

1917

Hugh C. Gass founds Superior Welding Shop in Hutchinson.

WORLD WAR II

Superior Welding Shop transforms into a training facility, preparing around 200 welders for the war effort.

1945

Superior Boiler Works moves into a 5,000 sq. ft. facility with 10 employees.

1960s

Equipment sizes increase, addition of the 3-pass dry back firetube boiler and the new firebox boiler requires more manufacturing space, expanding to 83,000 sq. ft.

1970s

Added 3-pass wetback, horizontal return tube boilers and waste heat recovery boilers. Now producing fire tube boilers up to 600hp and fireboxes up to 350hp.

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1984

Superior Boiler produces its first (of many) 1000hp gas and oil-fired boiler.

2002

Superior builds the largest single furnace firetube boiler in the industry, a 2200hp dry back.

2014

Superior Boiler purchases Triad Boiler. Product line expands to include both hot water and steam vertical firetube boilers commonly used in commercial heating applications.

2016

Superior purchases English Boiler, adding watertube boilers to its product offerings.

2021

Added another facility in Hutchinson, bringing the company to 300,000 sq.ft of manufacturing space.

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SCOTCH MARINE BOILERS

DRYBACK & WETBACK (10-2,500 BHP)

- Firebox/Modified Firebox Boilers (7-447 BHP)
- Waste Heat Boilers - engineered & customized for each project
- Horizontal Return Tubular (HRT) Boilers

WATERTUBE BOILERS

Up to 300,000 LB/HR

- Industrial package watertube boilers
- Heat recovery steam generators (HRSG)
- Forced circulation hot water boilers
- Solid fuel boilers
- Modular boiler systems

BOILER ROOM ACCESSORIES

- Spray & Tray Deaerators; 3,500 LB/HR – 500,000 LB/HR
- Boiler Feed Tanks
- Economizers
- Blow Down & Flash Tank Separators
- Modular water treatment systems

VERTICAL FIRETUBE BOILERS

7-150 BHP

CONDENSING BOILERS

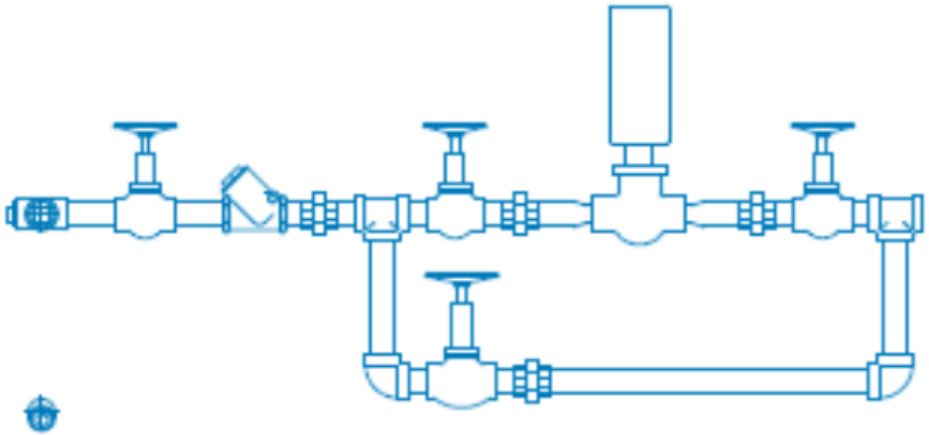
4,000,000 – 12,000,000 BTU/HR

SUPERIOR BOILER

Engineered and Built to Order

Customized packages to meet your requirements

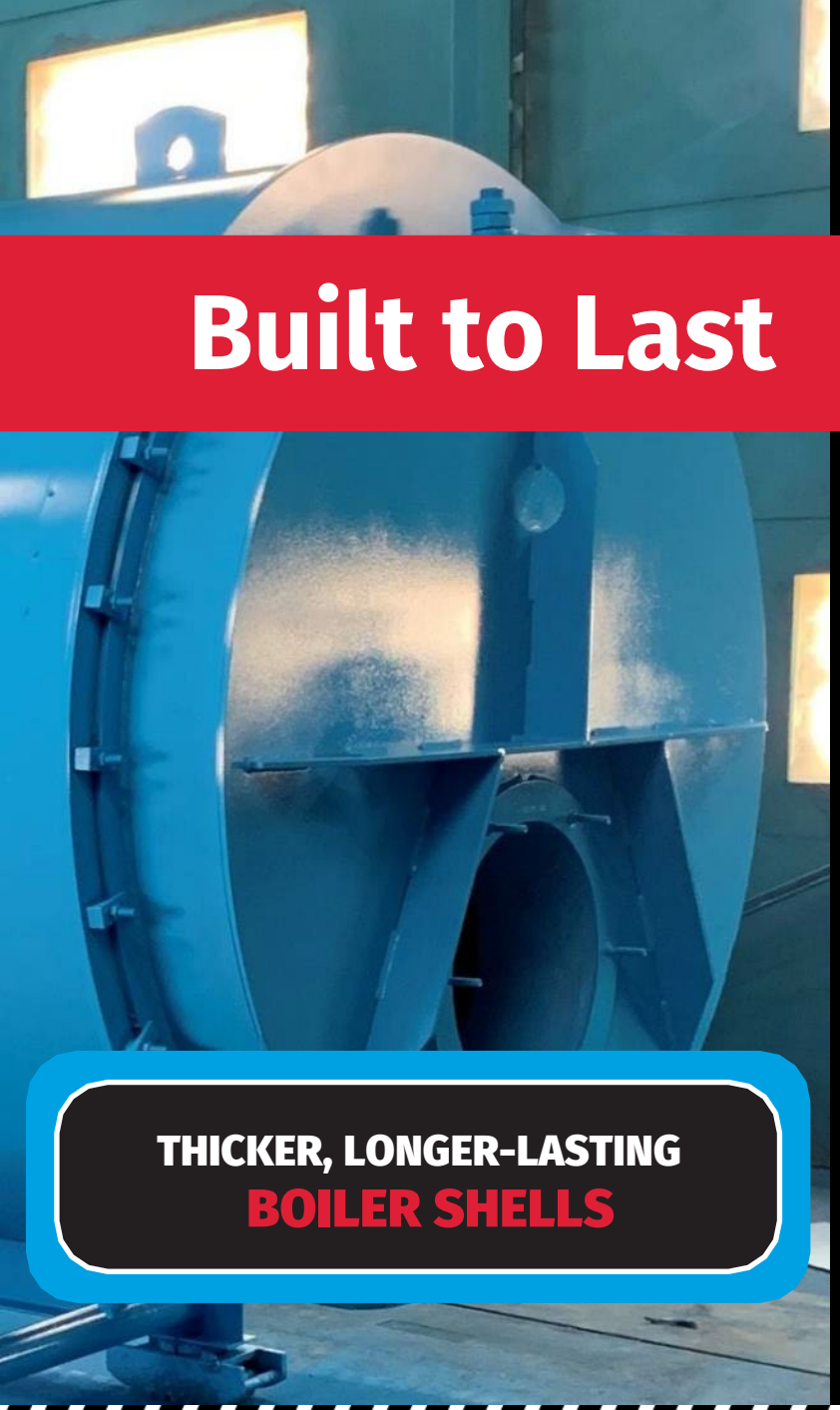
- ✓ Fluctuating load demands
- ✓ Emissions compliance
- ✓ Energy efficiency
- ✓ Fuel flexibility
- ✓ Redundancy
- ✓ Footprint challenges



Superior Quality

ISO 9001:2015

Built to Last



THICKER, LONGER-LASTING
BOILER SHELLS

THICKER, STANDARD-SPACED
TUBESHEETS

THICKER, CORROSION-PROTECTIVE
BOILER TUBES

Burner Flexibility

Superior boilers are burner neutral and work with any brand

- ✓ Easier and more cost-effective to maintain
- ✓ Use the qualified boiler technician of your choice for maintenance
- ✓ If burner ever needs to be replaced, use any compatible model

NON-PROPRIETARY PARTS

We use non-proprietary parts, so maintenance and repairs can be completed by the qualified boiler contractor of your choice.

SUPERIOR BOILER

SUPERIOR BOILER

At Your Service

Global Network of Problem Solvers

52 companies represent territories across the U.S. and around the world. 23 of these companies are full line watertube/firetube reps.

SUPERIOR BOILER

Today's Presenters

Trent Thurston

Trent Thurston is our Product Engineer for the firetube product line. Trent has been with Superior since 2012 following his graduation from Kansas State University with his B.S. in Mechanical Engineering.

Mike Meininger

Mike Meininger is our Inside Sales Manager for the firetube side of Superior Boiler. Mike has been with Superior for almost 12 years, with experience both on the manufacturing floor and in the sales department.

Agenda

01 **Intro to Waste Heat Boilers**

What is a waste heat boiler, what are their applications, and what are the challenges associated with them?

02 **Waste Heat Customization**

Why is customization important, what is the engineering process like, and what is needed to properly design the boiler?

03 **Superior Boiler's Solutions**

Superior Boiler has several waste heat boiler solutions, designed to fit your needs. Which one is right for you?

04 **What is Biogas?**

What is biogas, where is it found, and how can it be used in wastewater treatment facilities?

05 **Superior Boiler Solutions**

What does Superior Boiler need to design a product with biogas, what options do you have, and what do I need to keep in mind?

06 **Superior's Experience**

Superior Boiler has done several biogas boiler solutions over the years. Our problem solvers will cover a couple of examples.

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Definitions

WHRB (Waste Heat Recovery Boiler)

Any boiler recovering heat from another source for usable heat or energy

HRSG (Heat Recovery Steam Generator)

Heat from gas turbine exhaust (subset of a waste heat boiler)

Applications for WHRB

- Incinerator
- Gas Turbines
- Diesel Engines
- Biomass
- Syngas
- Thermal Oxidizer

Challenges with WHRB

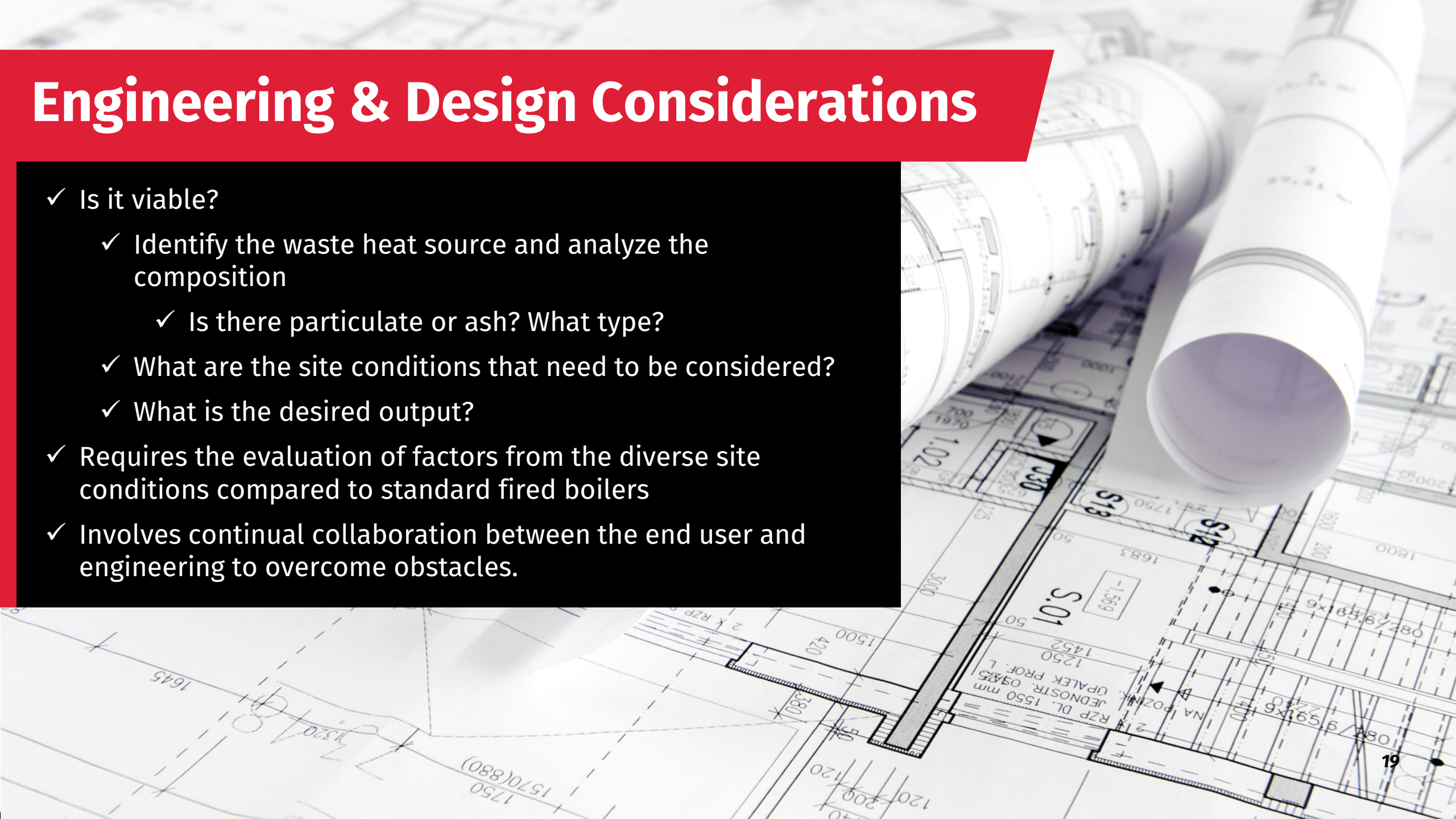
- Heat Source Not Well Defined
- Integration with Existing Infrastructure
- Meet Efficiency Expectations
- Lower Inlet Temperature than Fired Units
- Low Flue Gas Side Draft Pressure
- Supplemental Firing Requirements

Benefits of Custom Solutions

- Different Industrial Processes
- Varied Operating Conditions
- Sizing for Cost Effectiveness
- Site Constraints
- Seamless Integrations
- Environmental Compliance
- Meeting Sustainability Goals

Engineering & Design Considerations

- ✓ Is it viable?
  - ✓ Identify the waste heat source and analyze the composition
    - ✓ Is there particulate or ash? What type?
  - ✓ What are the site conditions that need to be considered?
  - ✓ What is the desired output?
- ✓ Requires the evaluation of factors from the diverse site conditions compared to standard fired boilers
- ✓ Involves continual collaboration between the end user and engineering to overcome obstacles.



Information to Plan Your Unit

Design Conditions

- ✓ Design Pressure
- ✓ Steam Pressure/Temperature
- ✓ Feed-Water Temperature
- ✓ Blowdown %

Flue Gas

- ✓ Gas Flow Rate
- ✓ Temperature
- ✓ Stack Temperature
- ✓ Max Flue Gas Pressure Drop

Gas Composition

- ✓ Carbon Dioxide
- ✓ Water
- ✓ Oxygen
- ✓ Nitrogen
- ✓ Hydrogen Chloride
- ✓ Sulfur Dioxide
- ✓ Ash or Soot

Job Specifications

- ✓ Steam Flow OR Stack Temp
- ✓ Ash Hopper
- ✓ Surge Flow
- ✓ Size Restrictions

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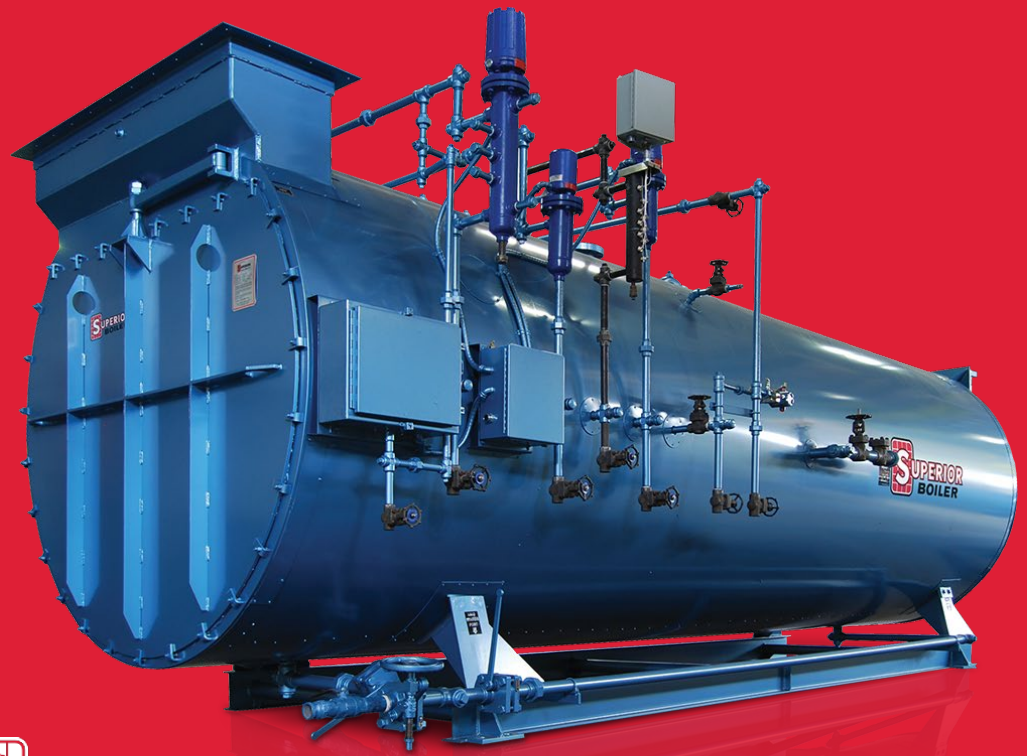
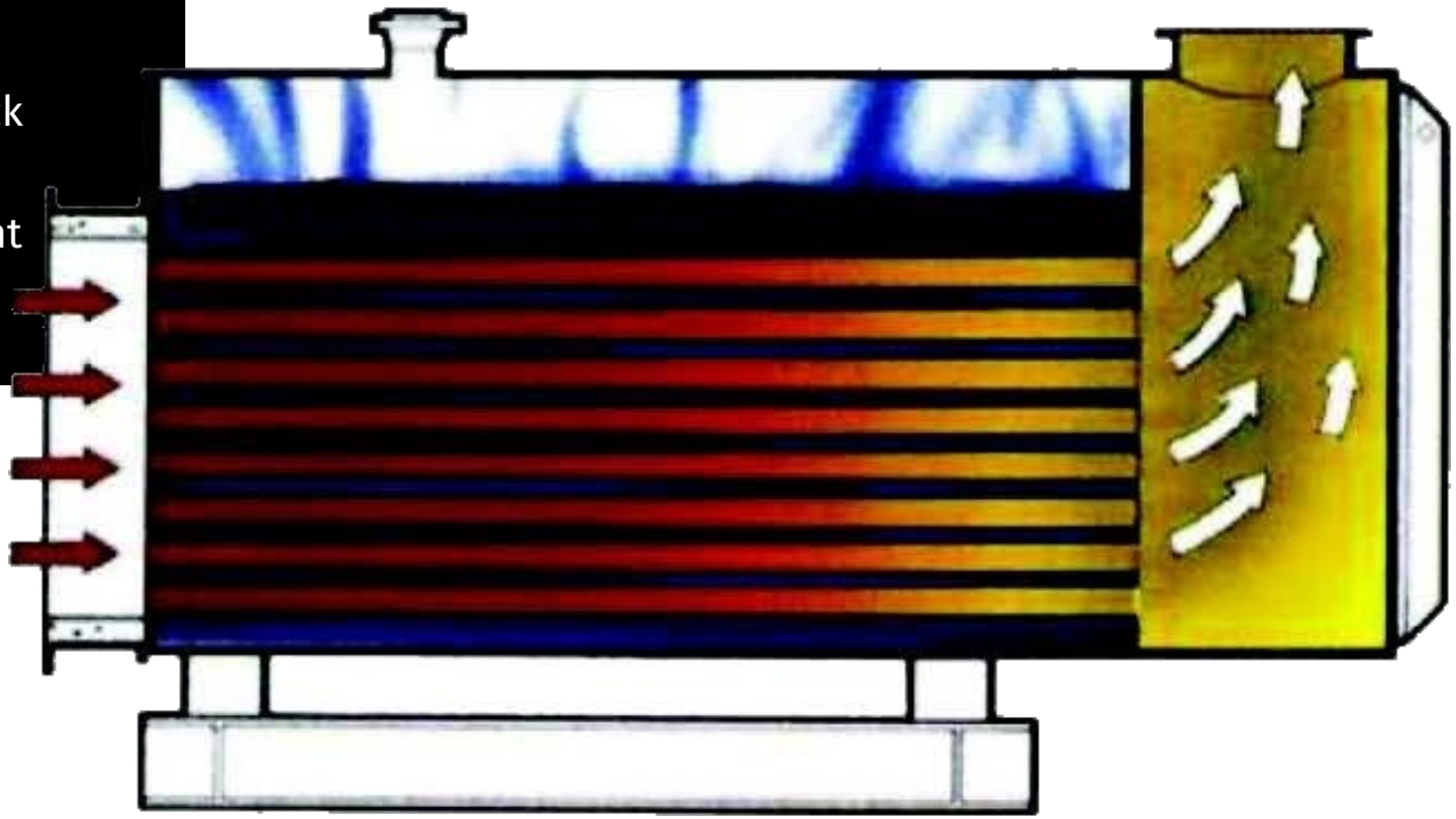
Superior Boiler's Waste Heat Offerings



SUPERIOR BOILER

Kiowa Style

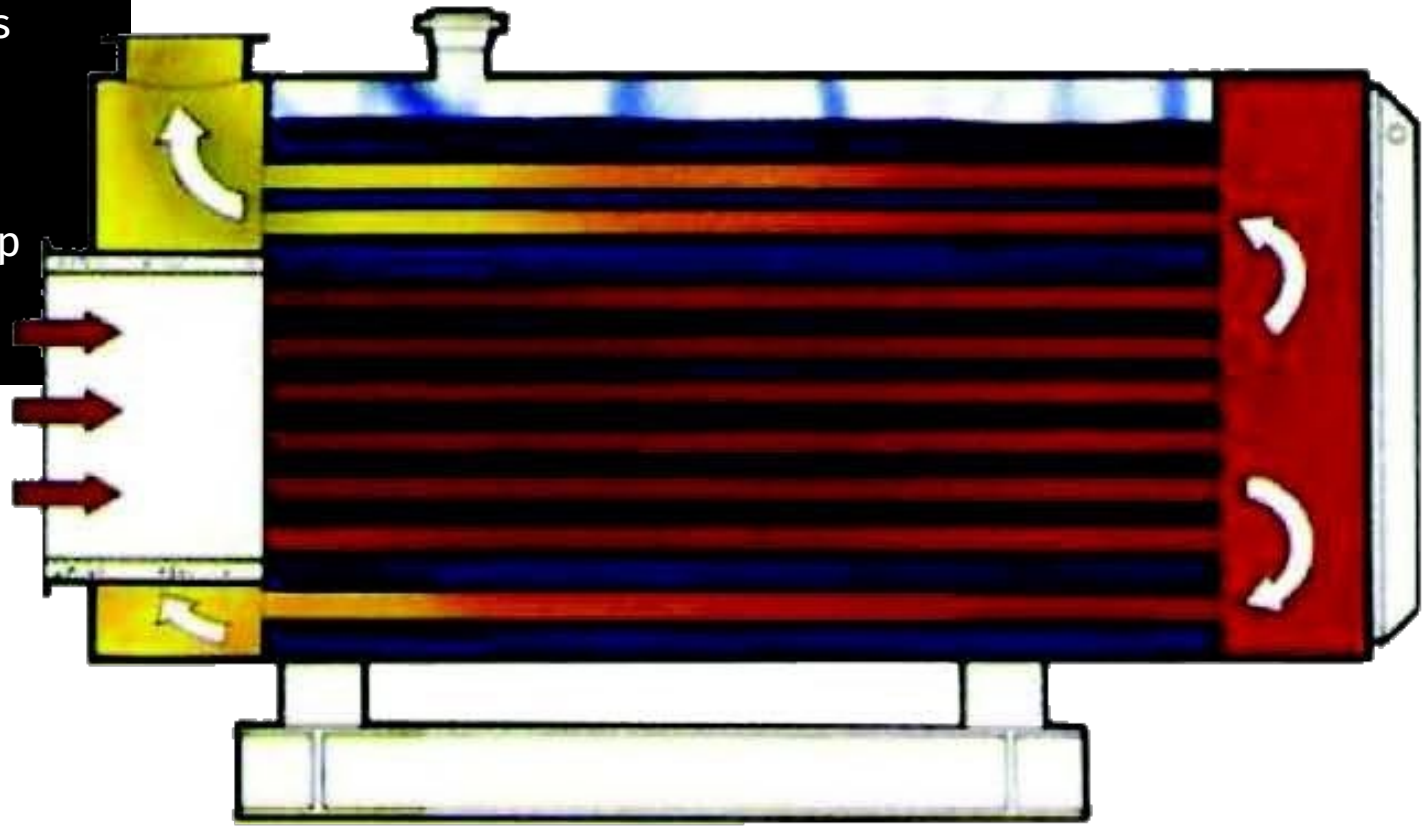
- ✓ 1-pass with all tubes
- ✓ **Limited to 1,800° F inlet gas temperature**
- ✓ Lowest pressure drop of any model
  - ✓ **Applications:** Gas turbine with strict back pressure requirement
- ✓ Rifled tubes can be added to reduce footprint
- ✓ Our most common model



SUPERIOR BOILER

Comanche Style

- ✓ 2-pass with all tubes
- ✓ **Limited to 1,800° F inlet gas temperature**
- ✓ Reduced overall length compared to single pass
- ✓ Rifled tubes can be added to reduce footprint
- ✓ Simplified bypass ducting
- ✓ Used in applications where higher pressure drop is permitted.



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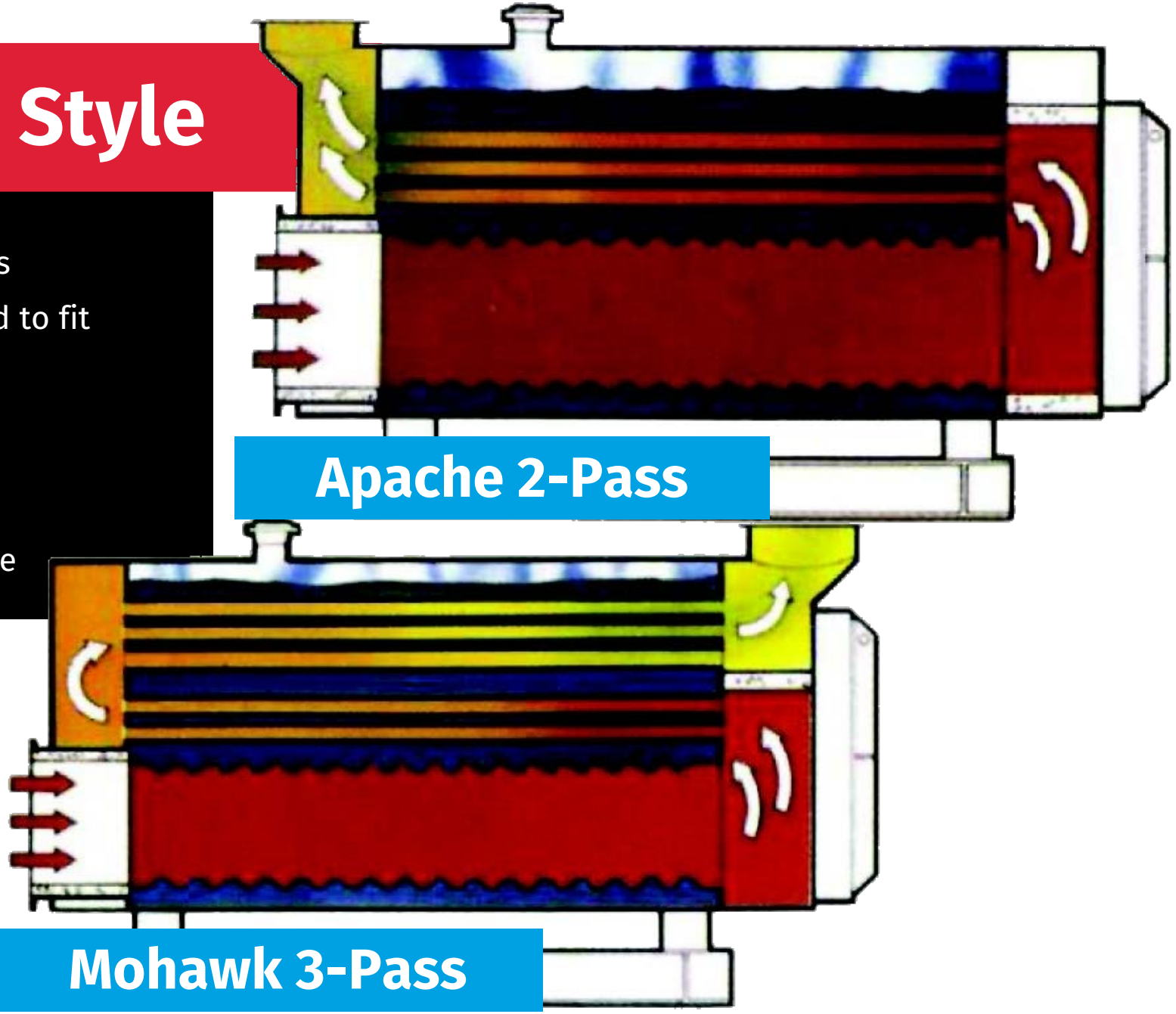
Apache/Mohawk Style

- ✓ Based on our 2 and 3-pass dryback units
- ✓ Furnace at tube patterns are customized to fit requirements
- ✓ **Up to 2,400°F gas temperature**
- ✓ Compatible with duct burner
- ✓ Used for higher gas inlet temperature applications or if there is a radiant flame



Apache 2-Pass

Mohawk 3-Pass

BIOGAS SOLUTIONS

Define Biogas

- ✓ **Biogas** is the broader term for the gas produced from organic waste
- ✓ **Digester gas** refers to the same gas specifically coming from an anaerobic digestor
- ✓ Biogas composition varies from different locations
  - ✓ Primary components are Methane and CO_2
- ✓ Typically has a heating value of 600 BTU/ft^3
- ✓ Potentially has contaminates such as sulfides and siloxanes
- ✓ Superior will need the gas composition to correctly design the biogas system

Why Biogas and Wastewater Solutions?

Growing Need for Energy Recovery in WWTP

- ✓ Rising energy costs and increased push for sustainability
- ✓ Increased push for renewable energy production in biogas usage such as in wastewater treatment plants

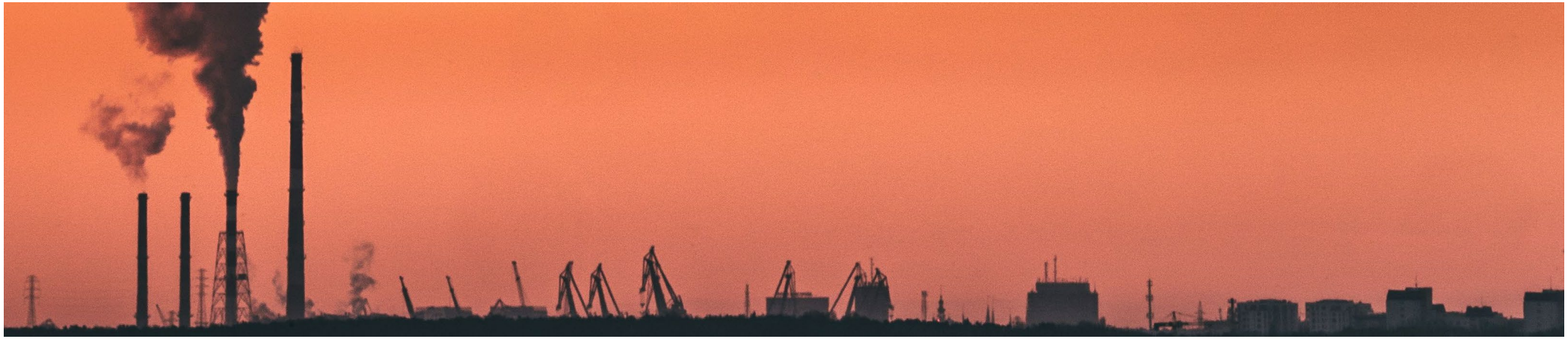
Why Boilers in Wastewater Treatment Facilities

- ✓ Recover and utilize methane from wastewater
- ✓ Provide heat for anaerobic digestion and facility operations
- ✓ Reducing operating costs by decreasing natural gas consumption

Committed to Sustainable Energy Solutions

- ✓ Decades of experience in industrial boiler manufacturing
- ✓ Proven expertise in engineering customized biogas-compatible boiler solutions
  - ✓ Superior Boiler's first biogas-compatible boiler shipped in June 1993
- ✓ Focus on efficiency, emissions control, and cost savings

Challenges of Using Biogas as Fuel



Variability in biogas quality: Impact on combustion efficiency

Lower BTU value than natural gas

Solution: Specially designed burners and controls optimize performance

Inconsistent biogas supply and pressure

Solution: Strongly recommend back-up fuel

Solution: Automatic fuel control systems that allow for auto-switch overs

Superior Boiler Solutions

Flexible Fuel Options

Dual-fuel capability for facilities with mixed fuel sources

Pre-Engineered Solutions

Options designed for wastewater treatment plants with varying biogas availability

Partner with Burner Companies

Collaborate to create custom burner configurations for biogas combustion that work with the boiler that is right for you

Biogas Fuel Composition & Burner Compatibility

- ✓ **<u>Question posed: What is the maximum allowable sulfur level in biogas?</u>**
- ✓ **Webster:** Dependent on the piping components materials, stack sulfur emissions regulations and H_2S exposure limits set by OSHA.
  - ✓ Biogas fuel analysis for gas valves to ensure that the levels of H_2S are within range of the valve materials.
  - ✓ The amount of sulfur emissions in the stack are set by state or local governments.
  - ✓ Finally, exposure of 100 ppm H_2S is lethal. *<u>H_2S should never be above 100 ppm</u>*.
- ✓ **CIB Unigas:** H_2S can be present in the fuel stream, you can even have up to around 10,000ppm if and only if you have no moisture and your gas train itself does not experience any condensate internally.
  - ✓ Must ensure that suitable gas valves are used, for example Siemens VRD valves or Dungs valves with stainless trim certified to burn methane with up to 1% H_2S
- ✓ **Weishaupt & Power Flame:** 1% H_2S maximum, trim selections limited above 0.1% H_2S

Biogas Fuel Composition & Burner Compatibility

- ✓ **Question posed: What is the maximum allowable for any other contaminants in the fuel?**
- ✓ **Webster:** Its important that the gas is dry. Any measurable moisture in the fuel can collect in the piping and react with sulfur containing components causing erosion.
- ✓ **CIB Unigas:** Most biogas is around 50-65% methane and the balance is CO_2/N_2
  - ✓ Moisture should really be zero, so gas should be dried
  - ✓ Can have up to 1% H_2S , but moisture must be zero with presence of H_2S otherwise you will have rapid and aggressive corrosion
- ✓ **Weishaupt:** 5 ppbv Siloxanes
- ✓ **Power Flame:** Ensure gas is dry to prevent damage to fuel train. 0.25 mg Si/m^3 Siloxanes; high value hydrocarbons C5 and greater to ≤ 2.5%

Boiler Challenges – Sulfides

- ✓ Acid Dew Point – Temperature where acidic elements in flue gas start to condense
- ✓ Dew point for sulfuric acid is determined by water vapor and Sulfur contents **(assumed 16.65% water vapor)**

Percent H_2S in Biogas	Approximate Acid Dew Point
1%	305° F
0.5%	290° F
0.1%	265° F
0.01%	230° F

- ✓ Will cause corrosion during cold startups and low temperature operation
- ✓ Economizers are not recommended due to condensation concerns with low flue gas temperature

Boiler Challenges – Siloxanes

- ✓ Siloxanes are Silicone particles formed from organic waste
- ✓ Physically these will resemble sand
- ✓ Potential concerns for the burner are valve seating, and flame detection
- ✓ Boiler concerns are increased erosion on fireside
- ✓ Critical to look for erosion during inspections
  - ✓ Important in every boiler, but the erosion will happen faster if siloxanes are present
  - ✓ Recommend bi-annual inspection at minimum (typical of natural gas boilers as well)
- ✓ If high enough amount of matter, you have the potential to use a soot blower/ash hopper.
  - ✓ Consider adding upstream processes that remove siloxanes.

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Superior Boiler Solutions – Selection Considerations

- ✓ Clean vs. Dirty gas composition
- ✓ Increased risk of condensation at lower operating temperature
  - ✓ Low pressure steam/hot water increases the risk of condensation
  - ✓ Corrosion risk increased with sulfuric acid
- ✓ Minimize cold start-ups and cycling
  - ✓ Optimize boiler sizing
  - ✓ Standby heating coil
- ✓ No FGR typically used – reduces opportunity for contaminant reintroduction
- ✓ Strongly suggest a secondary fuel train
- ✓ Digestor gas train components must be stainless/corrosion resistant

Superior Boiler Solutions

All options require all smooth tubes with no turbulators.

Osage

3-Pass Firebox
30 HP – 350 HP
Steam: Up to 15 psig
Hot Water: Up to 30 psig

Mohawk

3-Pass Dryback
30 HP – 1,000 HP
Steam: 15-300 psig
Hot Water: 30-160 psig

Seminole

3-Pass Wetback
50 HP – 1,800 HP
Steam: 15-300 psig
Hot Water: 30-160 psig

Expected Emission Levels for Biogas Combustion

- ✓ **<u>Question posed: While highly affected by biogas composition, what are the expected emission levels for 600 BTU/ft³ clean biogas composed of methane with the remainder CO_2 and N_2?</u>**
- ✓ **Webster:** This is highly affected by the type of burner and the combustion chamber (firetube, watertube, watertube with refractory floor, etc.).
  - ✓ Typically, you want more than a 30-50% reduction in NOx emissions of a burner with using biogas without FGR. CO emissions should be comparable with natural gas but will be dependent on the burner and combustion chamber.
- ✓ **CIB Unigas:** Typically, biogas has a lower NOx value, often about ½ that of natural gas, so if you have a burner that runs below 30 ppm NOx, you can often see 15-20 ppm NOx with biogas so long as the same NOx reduction techniques are used.
  - ✓ **Be careful though with biogas and FGR.** The FGR pipe can condense, and so FGR in our opinion should be avoided with biogas by not opening the FGR valve or adding a tight shutoff damper. When the burner is using biogas and FGR, the tight shutoff valve at the boiler outlet is shut not permitting FGR to flow into the burner when burning the biogas.
  - ✓ This is due to siloxanes and corrosion potential even with trace amounts of H2S plus moisture
- ✓ Weishaupt: NOx levels lower than natural gas setup due to lower flame temperatures

Burner Performance Differences vs. Natural Gas

- **Question posed: What difference (if any) is there in both turndown and also burner input ranges (ex. 50HP through 800HP) compared to natural gas combustion?**
  - **Webster:** Biogas heat input ranges and turndown are comparable to natural gas.
  - **CIB Unigas:** Turndown can be similar, but with biogas, the turndown is typically a bit more limited
    - Turndown on a hot water boiler with biogas should be limited to ensure that the stack temperature does not fall below about 240° F so that there is not acidic condensation dropping into the smokebox outlet
    - In general turndown on the smaller boilers with biogas will be about 1:4 up to around 100HP
  - **Weishaupt:** Turndown is similar to natural gas, possibly lower due to increased fan requirements with digestor gas having a reduced heating value

Burner Trim Selection & Material Considerations

- ✓ **Question posed: What trim selections are unavailable when using biogas?**
- ✓ **Webster:** None that I am aware of
- ✓ **CIB Unigas:** Must simply provide the biogas train with stainless trimmed materials
  - ✓ Often the piping itself should be stainless
  - ✓ Might consider check valves so when the burner is running biogas and dumping to a common single inlet, the gas does not backflow into a joint in the train
  - ✓ Could consider flame arrestors. These are sometimes called for and required on the fuel trains so that a flash back (would be extremely rare) would not travel into the digester or upstream gas supply reservoir
- ✓ **Weishaupt:** Gas analysis must be provided to ensure correct trim items are selected. Also, no mesh head type burner, FGR, or O_2 trim on digestor gas operations.
- ✓ **Power Flame:** In the case of "dry" fuel, traditional materials such as carbon steel piping and aluminum body Safety Shut Off Valves (SSOV's) may be used in general up to 1% (10,000 ppmv) H2S.
  - ✓ Check with the AHJ for regulations such as flamer arrestors.

Superior Experience Examples

Largest Boiler

Steam

(1) 1,500 HP

Meat Packing Plant

Built in 2019

Osage in KS

Hot Water

(2) 75 HP Boilers

WWTP in Hutchinson

Built in 2017

THANK YOU

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