



# ENERGY RECOVERY SOLUTIONS

**Recover wasted energy to increase efficiency  
and save money immediately.**

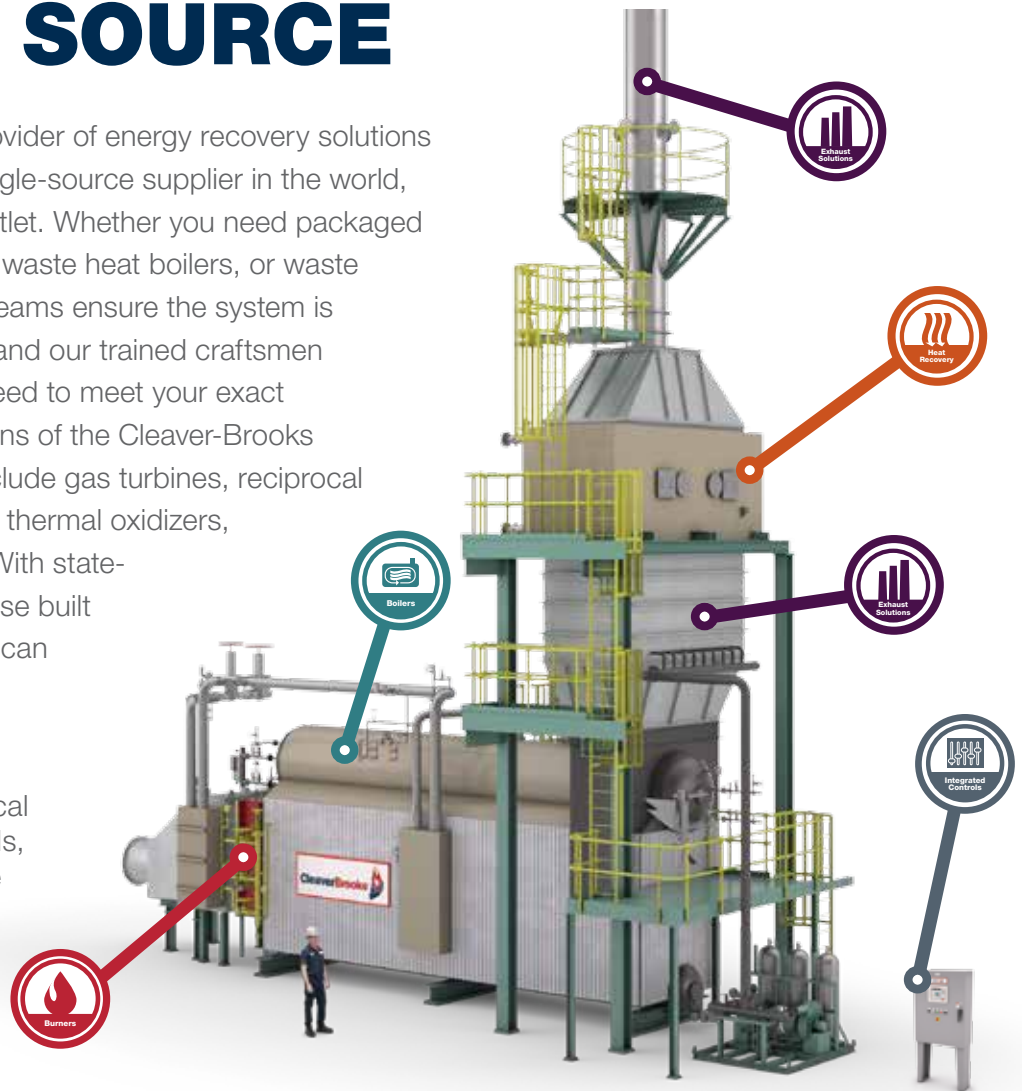
**Cleaver-Brooks Engineered Boiler Systems**  
Manufacturers of HRSGs, Waste Heat  
Recovery Units, and Waste Heat Boilers

# TOTAL INTEGRATION FROM A SINGLE SOURCE

Cleaver-Brooks is the leading provider of energy recovery solutions and the only totally integrated single-source supplier in the world, from the fuel inlet to the stack outlet. Whether you need packaged heat recovery steam generators, waste heat boilers, or waste heat recovery units, our project teams ensure the system is designed to your specifications, and our trained craftsmen produce boilers that are guaranteed to meet your exact standards. Typical implementations of the Cleaver-Brooks Energy Recovery product line include gas turbines, reciprocal engines, FCC, FGC, incinerators, thermal oxidizers, economizers, and fluid heaters. With state-of-the-art technology and expertise built over 80 years in the industry, we can meet practically any need.

## Markets served

Aerospace & Military, Chemical and Allied Products, Hospitals, Industrial, Installations, Large Office Buildings, Petroleum Refining, Power Generation, Pulp & Paper, Universities

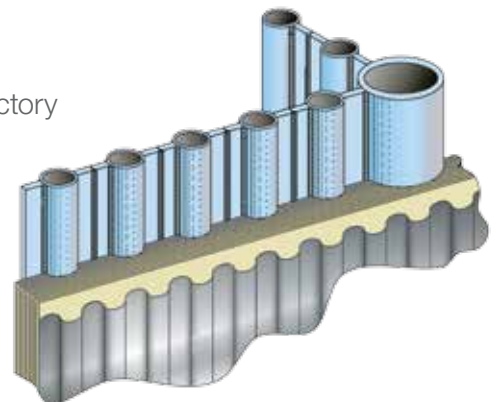


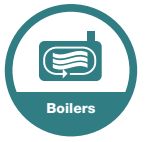
## Applications

Biomass Combustors, Cement Furnaces, Fluidized Bed Combustors, Gas Turbine Exhaust, Hazardous Waste Incineration, Industrial Furnaces, Refinery / Chemical Processes, Rotary Kiln, Sewage Sludge Incineration, Solid / Liquid / Gaseous Incineration

## Membrane Wall Construction

Our Energy Recovery line features innovative designs to help eliminate refractory wherever possible. Water-cooled membrane walls allow the boiler to safely withstand firing or flue gas temperatures up to 2,800°F. They also minimize high-maintenance refractory, provide a positive inner gas seal, add structural strength, eliminate flue gas entrapment, and help maintain thermal efficiency. The adjacent fins of each outboard tube are seal-welded together, forming a robust gas-tight and water-cooled enclosure.





# The Cleaver-Brooks Energy Recovery Line

## HRSG (Heat Recovery Steam Generators)

We are the only manufacturer that offers truly integrated heat recovery steam generators, including our in-house duct burners and control systems.

### Slant HRSG Series

- Gas Turbine (GT) nominal electric output < 15 MWe
- With or without supplementary firing to  $\approx 1,700^{\circ}\text{F}$
- Includes internally insulated casing construction

### Max-Fire HRSG Series

- Gas Turbine (GT) nominal electric output < 60 MWe
- With or without supplementary firing to  $\approx 2,800^{\circ}\text{F}$
- Incorporates membrane wall construction

### Modular HRSG Series

- Gas Turbine (GT) nominal electric output < 60 MWe
- With or without supplementary firing to  $\approx 1,700^{\circ}\text{F}$
- Multiple pressure levels

## Waste Heat Recovery Units

We also provide a complete line of waste heat recovery units for fluid heating from gas turbine exhaust, internal combustion engine exhaust, process heat sources, and other heat sources.

### Fluid Heater

- Duty – Up to 200 MMBTU/hr
- Heat recovery or supplementary firing
- Includes internally insulated casing construction

### Max-Flow<sup>®</sup>

- Duty – 20-200 MMBTU/hr
- Direct or supplementary firing
- Incorporates membrane wall construction

## Waste Heat Boilers

Cleaver-Brooks offers a complete selection of waste heat boilers to recover heat from process and generate steam, reducing the need for fired steam generation, or recovery heat from solid, liquid, or gaseous incinerators.

### Single-Pass Open Bottom A- or O-type

- Applications with dust and/or ash loading
- Inlet temperatures below the ash slagging temperature
- Bare or combination bare and finned tubes
- Incorporates membrane wall construction

### Two-Pass Waste Heat Boiler with Furnace

- Applications with dust and/or ash loading
- Elevated inlet temperature
- Partial combustion occurring in furnace
- Bare-tube construction
- Incorporates membrane wall construction

### Vertical Tubes/Cross Flow Series

- Clean gas applications
- Combination bare and finned tubes
- Includes internally or externally insulated membrane wall construction

# Heat Recovery Steam Generators

## Packaged systems for economical steam

We lead the industry with our packaged heat recovery steam generators, which have natural circulation designs with design pressures up to 2,300 psig and steam temperatures up to 1,050°F. For supplemental and/or fresh-air fired applications, our heat recovery steam generator is integrated with a NATCOM duct burner and our in-house controls systems for the highest efficiency and lowest emissions possible.

## Slant HRSG Series

### Single Pass Energy Recovery in a compact design

The Slant series of natural circulation heat recovery steam generators features the traditional Slant model and the VC (Vertical Drum Cross Flow) model, both tailored for applications with gas side inlet temperatures less than 1,700°F. This series is capable of steam flows from 10,000 – 150,000 lb/hr at steam pressures up to 2,300 psig, and superheated steam is available up to 1050°F. The Slant Series is ideal for gas flows from 50,000 – 400,000 lb/hr at near atmospheric pressure with gas flow perpendicular to the steam and water drums (cross flow).

The traditional Slant model incorporates a steam and water (mud) drum positioned diagonally, which maximizes the amount of heating surface for a given shipping profile. This yields a compact and efficient method of heat recovery.

The VC model is a drum-over-drum design well suited for higher-pressure steam applications, integral CO / SCR systems, and horizontal exhaust flow arrangements. It can be customized with a stainless steel inner liner, refractory lining, or watercooled membrane wall construction, depending on your process requirements.

Both models are single-pass designs. The absence of gas baffles eliminates flue gas bypass and associated baffle maintenance. Convection access doors on both sides of the tube bank provide easy inspection, maintenance, and replacement of gas side heating surface and other components. Full-length steam and water drums with manways on each end allow access for inspection and maintenance of internal waterside surfaces. Unheated downcomers, completely external to the boiler casing, ensure maximum natural circulation.

Steam
10,000 to 150,000+ lb/hr
Pressure
Up to 2,300 psig
Gas Flow
Up to 400,000+ lb/hr
Steam Temperature
Up to 1,050°F

Integrated Components
Flue Gas Bypass Systems; Superheaters; NATCOM duct burners; Fresh Air Firing, CO / SCR Systems and Cleaver-Brooks Integrated Control Systems



## Slant Model



### Features

- Highly suited for gas turbine heat recovery or waste heat with low particulate loading heat recovery applications
- Multiple gas flow options conform to space restrictions and minimize cost
- “Cold” casing design with stainless steel floating inner liners

## VC Model



### Features

- Cross drum gas flow design is suitable for horizontal gas flow applications
- Optional in-line tube arrangement promotes effective soot blowing and ash removal
- Multiple casing options including membrane wall construction.

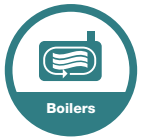


# MAX-FIRE® HRSG Series

**Cleaver-Brooks innovations are built in to every unit**

The Max-Fire® series incorporates an integral furnace in a single, shop-assembled packaged HRSG. Cleaver-Brooks offers the MF and VL models available in both O- and A-style configurations. This series is capable of steam flows up to 300,000 lb/hr at steam pressures up to 2,300 psig. Superheated steam is available up to 1,050°F. The Max-Fire® is well-suited for gas flows up to 1,000,000 lb/hr at near atmospheric pressure. The gas flow is in-line to the steam and water drums.





**The MF (O-style) and MFA (A-style) models** combine a waterwall combustion chamber formed from membrane wall construction with an evaporator section in a single shop-assembled boiler. The integral watercooled furnace allows for supplemental firing temperatures up to 2,800°F. The evaporator section is a combination of bare tubes and various degrees of finned tubes in a staggered or in-line arrangement for optimized heat transfer and pressure drop.

**The VL (O-style) and VLA (A-style) models** offer an evaporator section with no furnace, but still enclosed with membrane wall construction.

**Features**

- Watercooled membrane wall construction extends throughout the boiler and eliminates high inner casing temperatures
- Vertical (top) or horizontal gas outlet helps meet tight space restrictions
- Combination of bare and finned tube sections provide efficient heat recovery
- Hard or aluminum casing, depending on your preference
- Downcomers on both ends of the boiler

Steam
10,000 to 300,000+ lb/hr
Pressure
Up to 2,300 psig
Gas Flow
Up to 1,000,000+ lb/hr
Steam Temperature
Up to 1,050°F



**Integrated Components**

Flue Gas Bypass Systems; Integral, External, or Combination Superheaters; NATCOM duct burners; Fresh Air Firing, CO / SCR systems; Cleaver-Brooks Integrated Control Systems

# Modular HRSG Series

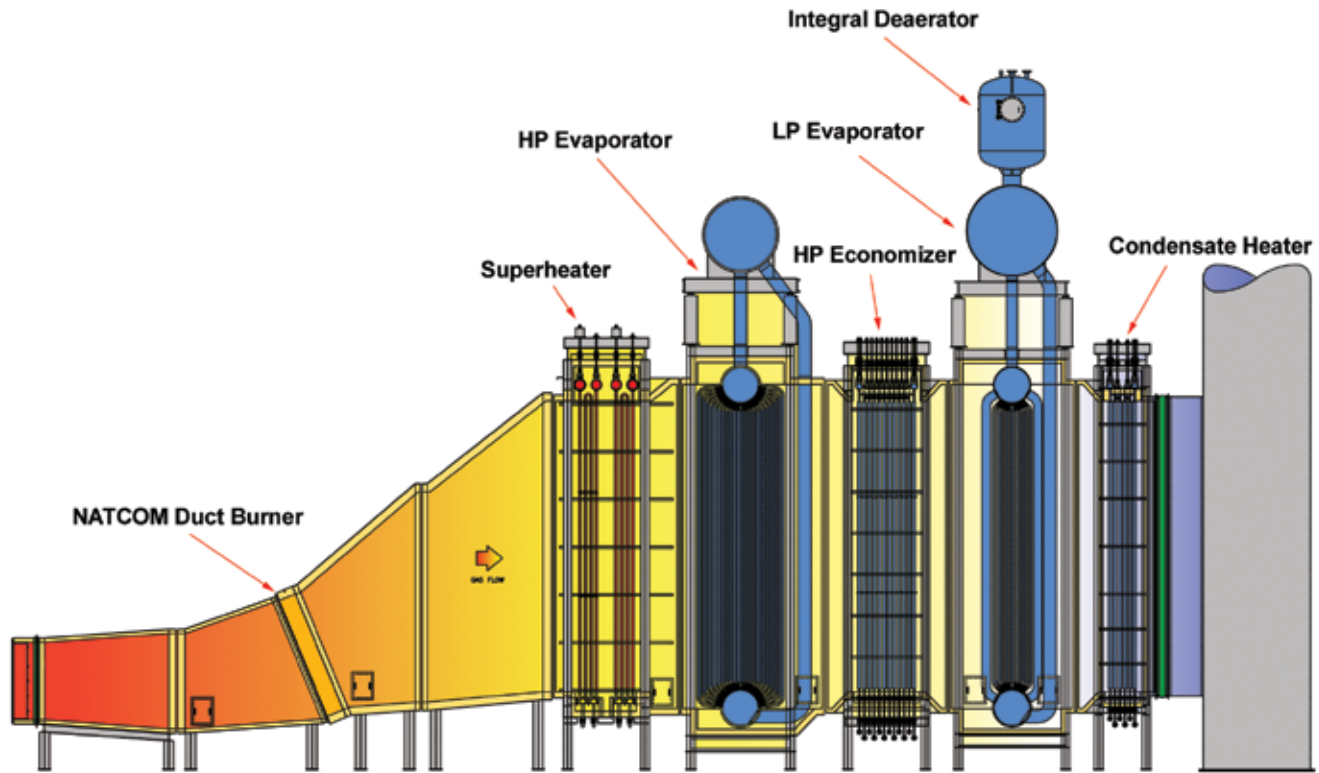
## Maximum shop assembly, minimum field labor

Modular HRSGs are designed to accommodate exhaust from combustion turbines greater than 15 MWe output or greater than 400,000 lb/hr of gas flow. Cleaver-Brooks strives to provide the maximum amount of shop assembly in our Modular HRSG system. The pressure vessel modules with casing are shipped as single pieces and require minimal field work to assemble multiple sections. We offer natural circulation designs for minimal parasitic power consumption and reduced maintenance of rotating equipment. Our Modular HRSG is available in single or multiple pressure levels to optimize cycle efficiency. Our expert engineering teams review every aspect of the design including, but not limited to, thermal performance, mechanical fatigue evaluation, circulation studies and pipe stress analysis. This robust design benefits from more than 80 years of experience in the industry and incorporates design features proven across all product lines.





# Modular HRSG Diagram



## Features

- Vertical tube natural circulation design
- Top or bottom support designs available
- Tube bundles pre-installed in a shop-assembled casing to minimize field erection costs
- Large external steam drum
  - High efficiency separators meet the most stringent steam purity requirements
  - Large water holding capacity is ideal for load swings
- Unheated downcomers, completely external to the boiler casing, provide maximum natural circulation
- Convection access doors on both sides of the tube bank allow for ease of inspection, maintenance, and replacement

Steam
10,000 to 1,000,000+ lb/hr
Pressure
Up to 2,300 psig
Gas Flow
400,000+ lb/hr
Steam Temperature
Up to 1,050°F

## Integrated Components

Flue Gas Bypass Systems; Superheaters; NATCOM duct burners; Fresh Air Firing, CO / SCR Systems; Cleaver-Brooks Integrated Control Systems

# Waste Heat Recovery Units

## Heat recovery for a variety of fluid heating applications

Cleaver-Brooks leverages our extensive experience and expertise in heat and mass transfer to supply custom waste heat recovery units for gas turbine exhaust, process furnaces, and other heat sources for water, glycol mixtures, and thermal oil fluid heaters. Waste Heat Recovery Units (WHRUs) are available in vertical, horizontal, or combination gas flow arrangements to conform to any space requirements.

## Fluid Heater

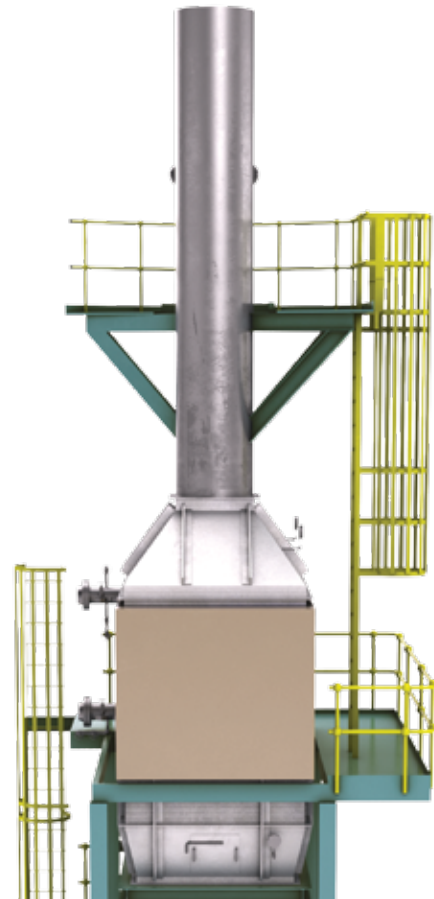
### Liquid heat for high-pressure applications

These units are specifically designed for minimal fluid pressure drop, proper outlet conditions, and allowable fluid film temperatures. The fluid heater can be supplementary fired up to 1,700°F.

#### Features

- Optimized combination of bare and finned tubes to control film temperatures
- Inline or staggered tube arrangements per application
- Fluid circuits are properly evaluated to obtain the desired mass flow, fluid velocity, and pressure drop
- Custom designs for high gas side pressure applications

Duty
Up to 200 MMBTU/hr
Pressure
Up to 3,500 psig
Gas Flow
Up to 1,000,000+ lb/hr



#### Integrated Components

Flue Gas Bypass Systems; NATCOM duct burners; Fresh Air Firing, CO / SCR Systems; Cleaver-Brooks Integrated Control Systems

# MAX-FLOW®

## High temperature fluid heating

Cleaver-Brooks Max-Flow Thermal Fluid Heater (TFH) and High Temperature Hot Water (HTHW) generators are available for most applications ranging from 20-200 MMBTU/hr. They incorporate a fluid-cooled membrane wall construction for the furnace and heating coil enclosure, creating a highly efficient, shop-assembled package. They can be fitted with a register burner or designed to recover heat from turbine exhaust and supplemented with a duct burner, up to 2,800°F. This is a forced circulation design that will last for years to come.



### Features

- Fluid-cooled membrane wall construction extends throughout the boiler
- Optimized flow pattern controls film temperature and local heat flux rates
- Combination of bare tubes and various degrees of finned tubes in a staggered or inline arrangement for optimized heat transfer and pressure drop
- Vertical or horizontal outlet fits any space requirement
- Steel or aluminum casing, depending on your preference

Duty
20 to 200 MMBTU/hr
Pressure
Up to 2,300 psig
Gas Flow
Forced Circulation

### Integrated Components

Flue Gas Bypass Systems; NATCOM duct or Register Burners; CO / SCR systems; Cleaver-Brooks Integrated Control Systems

# Waste Heat Boilers

## Traditional designs, tailored to your needs

Cleaver-Brooks offers custom waste heat boilers in the single or two-pass A-style, single-pass O-style, and D-style designs. This series is well suited for steam flows from 10,000 – 500,000 lb/hr at steam pressures up to 2,300 psig. Superheated steam temperatures up to 900°F are available. Waste Heat Boilers (WHB) are available for gas flows up to 1,000,000 lb/hr at near atmospheric pressure.

Our one-pass gas side design allows for low pressure drop, and a combination of bare and finned tubes provides efficient heat recovery. Our two-pass gas side designs allow for a furnace or radiant section to temper the heat of flue gases below the ash melting and softening temperature before entering the main evaporator or screen bank, resulting in longer operational lifespans. Either option includes water-cooled membrane wall construction, providing a positive gas seal.

Standard options include retractable or rotary soot blowers, single-, or dual-stage superheater(s) with steam temperatures up to 1,050°F, and economizers.



	Single-pass Open Bottom A- or O-type	Two-Pass Waste Heat Boiler with Furnace	Vertical Tubes / Cross Flow
Steam Flow	10,000 – 150,000 lb/hr	10,000 to 300,000 lb/hr	500,000 lb/hr
Steam Temp.	Up to 900°F	Up to 900°F	Up to 900°F
Steam Pressure	Up to 2,300 psig	Up to 2,300 psig	Up to 2,300 psig
Gas Flow	Up to 200,000 lb/hr	Up to 200,000 lb/hr	Up to 1,00,000 lb/hr
Membrane Wall	X	X	—





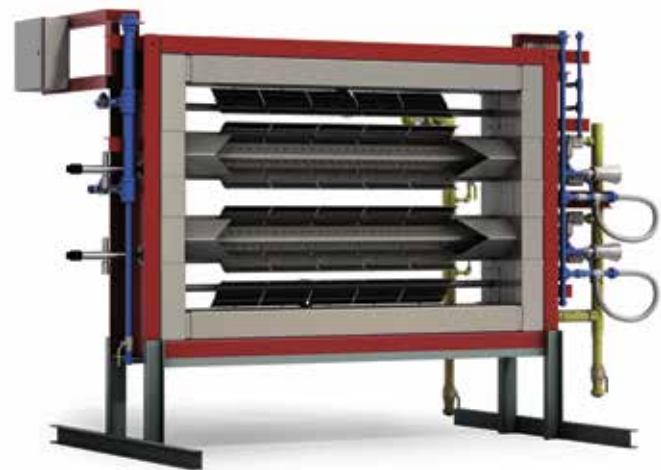
# NATCOM Duct Burner

## Boost the efficiency of your HRSG

NATCOM Duct Burners supplement the turbine in heat recovery steam generator (HRSG) applications with an innovative flame stabilizer system. For every BTU via the duct burner, the HRSG will have an additional BTU of heat output. Duct burners can fire a variety of gaseous fuels, including natural gas, LFG, digester gas, refinery gas and H<sub>2</sub>, as well as fuel oil. Our in-house simulation experience allows accurate and complete modeling of the turbine exhaust flow, distribution grid, combustion, heat recovery system, and selective catalytic reduction (SCR) for every HRSG we build. We can offer a complete control system for the HRSG, duct burner, and SCR, or a stand-alone BMS for the duct burner.

### Features:

- Self-supporting, high-temperature stainless assembly with diamond shape eliminates common “element sagging” issues
- An exclusive Retro™ fuel injection system enhances turbine exhaust gas (TEG) and fuel mixing for optimal flame control
- Complete Computational Fluid Dynamics (CFD) analysis, design, and fabrication of TEG flow correction devices, including distribution grids, turning vanes, and anti-swirl systems



## Custom Controls

### Integrated industrial controls

Cleaver-Brooks manufactures control systems for any combustion application. Regardless of the level of complexity of your system, we will provide state-of-the-art hardware and programming for safe, reliable, and efficient operation with a user-friendly interface.

### Features:

- Custom control systems save energy
- Completely custom PLC controls
- Color touch-screen controls
- Factory Acceptance Test (FAT) and Site Acceptance Test (SAT)





# Integrated Exhaust Solutions

## Lower emissions from heat recovery and steam generation

Whether you're in need of installation-ready or freestanding stacks, Cleaver-Brooks manufactures an exhaust solution for virtually every application with the latest engineering and technology in combustion gas venting. We engineer and produce our exhaust systems to exacting standards quickly and efficiently.

## SCR & CO Catalyst for HRSG

### Reduce NOx to single digit ppm levels

Cleaver-Brooks designs and incorporates Selective Catalytic Reduction (SCR) into our energy recovery systems to meet the most stringent emission requirements. Computational Fluid Dynamics (CFD) analysis along with years of field experience, allows us to accurately predict the flue gas distribution through the entire HRSG and optimize the duct burner design in conjunction with the SCR design.

#### Features

- Integration of a Cleaver-Brooks Burner, Control System, and SCR ensures fast response & minimal Ammonia Slip for increased operation flexibility & lowest emissions for any application
- Designed with CFD and validated through field results
- Optimum temperature window for maximum NOx & CO reduction



## Freestanding and Installation-ready Stacks

### Exhaust Solutions for any application

Cleaver-Brooks engineers and manufactures freestanding stacks according to project specific requirements and constraints. In addition, we offer installation-ready stacks that feature our exclusive Male-to-Female Jointing System, which allows the parts of all models to fit into one another, thus decreasing installation time by up to 40%. Our highly qualified engineering department has diversified experience and knowledge in exhausting and venting stacks and can provide a customized solution for any size project.

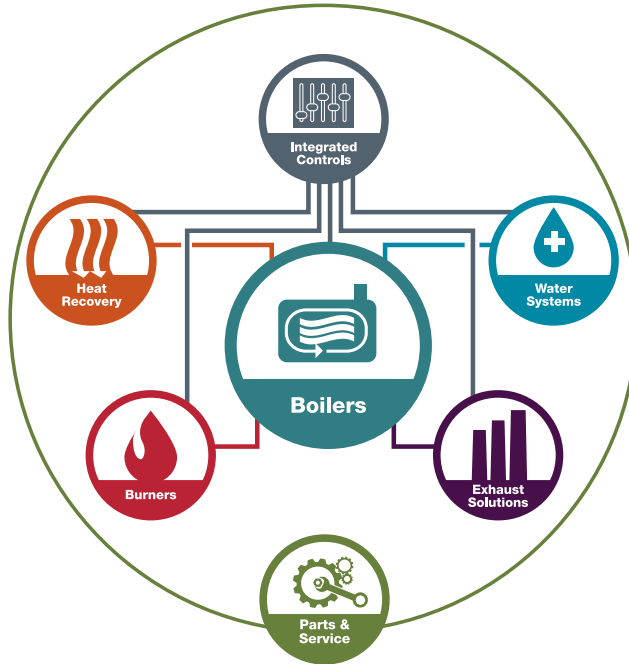
#### Features

- Factory laser-welded joints
- Available in carbon steel, COR-TEN® steel and stainless steel
- Integral stack dampers and/or silencers

# Custom solutions across the entire energy recovery line

Cleaver-Brooks can meet virtually any need, based on expertise developed over more than 80 years in business. We have the capability and expertise to provide custom HRSG, WHB, or WHRU designs focused on maximizing the amount of shop assembly while minimizing the costly field labor often associated with other heat recovery steam generators. Our commitment to total integration is built into our custom solutions, as every one still incorporates genuine Cleaver-Brooks components designed and engineered to function together at peak efficiency. Regardless of your application or need, we can help you design a solution that meets your unique needs and lasts for years to come.





# Total Integration goes far beyond energy recovery.

For more than 80 years, Cleaver-Brooks has built a reputation for innovation in the boiler solutions industry. We remain committed to introducing technology and products that enable a more energy-efficient and environmentally friendly generation of steam and hot water.

When you come to us for a fully integrated solution, you can know that each element is created to the highest standards and all will work seamlessly together to give you a highly efficient and reliable solution for protecting your boiler system. To learn more, please call or visit us online at [cleaverbrooks.com](http://cleaverbrooks.com).



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