BURNERS FLARES THERMAL OXIDIZERS VAPOR CONTROL RENTALS AFTERMARKET







ZEECO

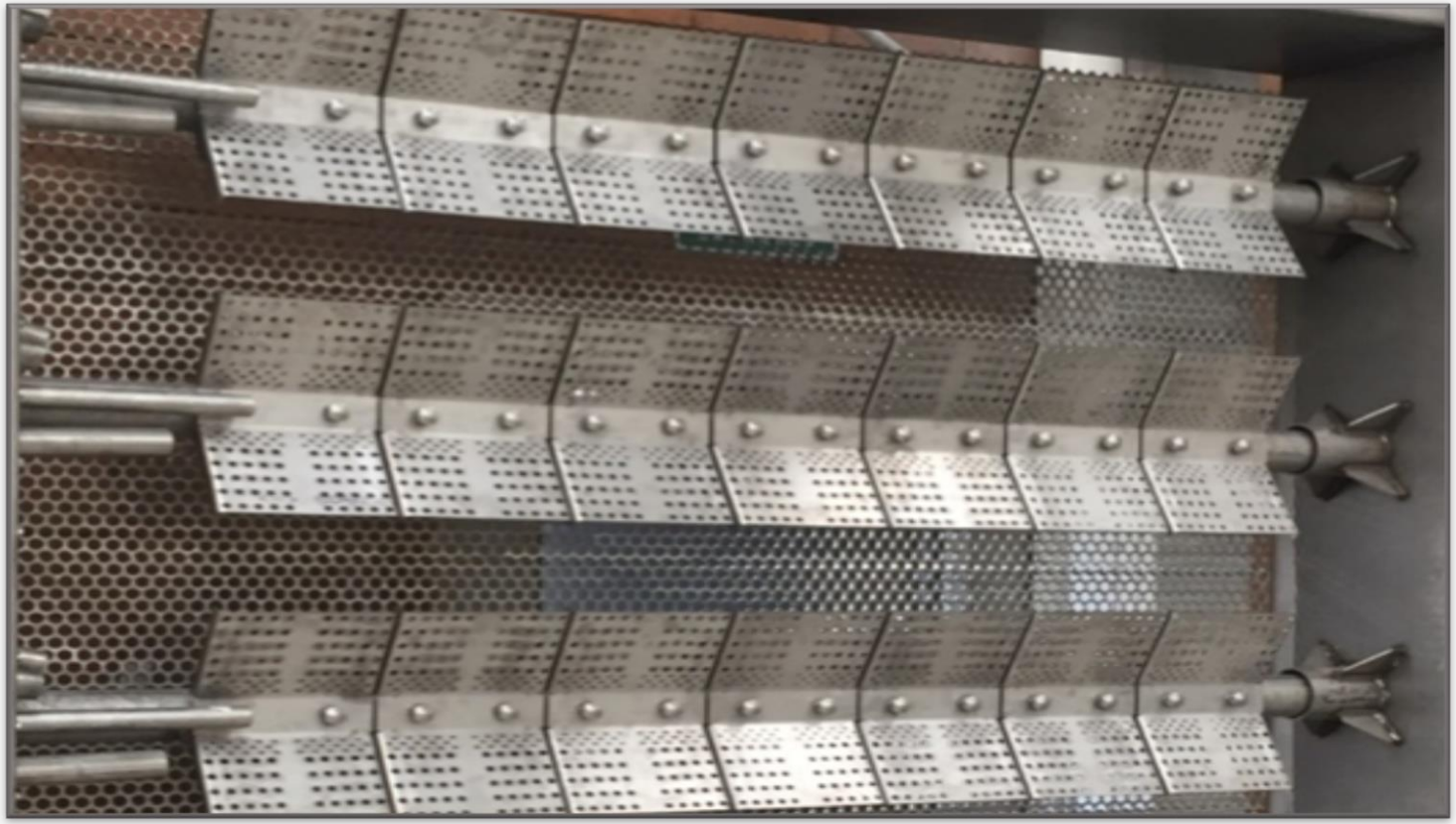
Duct Burner Systems: Application and Design Considerations

Duct Burner Systems:

- **Typically Applications:**
  - Supplemental Firing of Turbine Exhaust Gas (TEG)
  - Flue Gas Reheat for NOx Control
  - Air Heating/Process Drying

General Overview

- Duct Burners for TEG applications have traditionally been considered a straightforward technology to increased steam for power or process, requiring little capital investment and minimal upkeep … **if properly applied**!

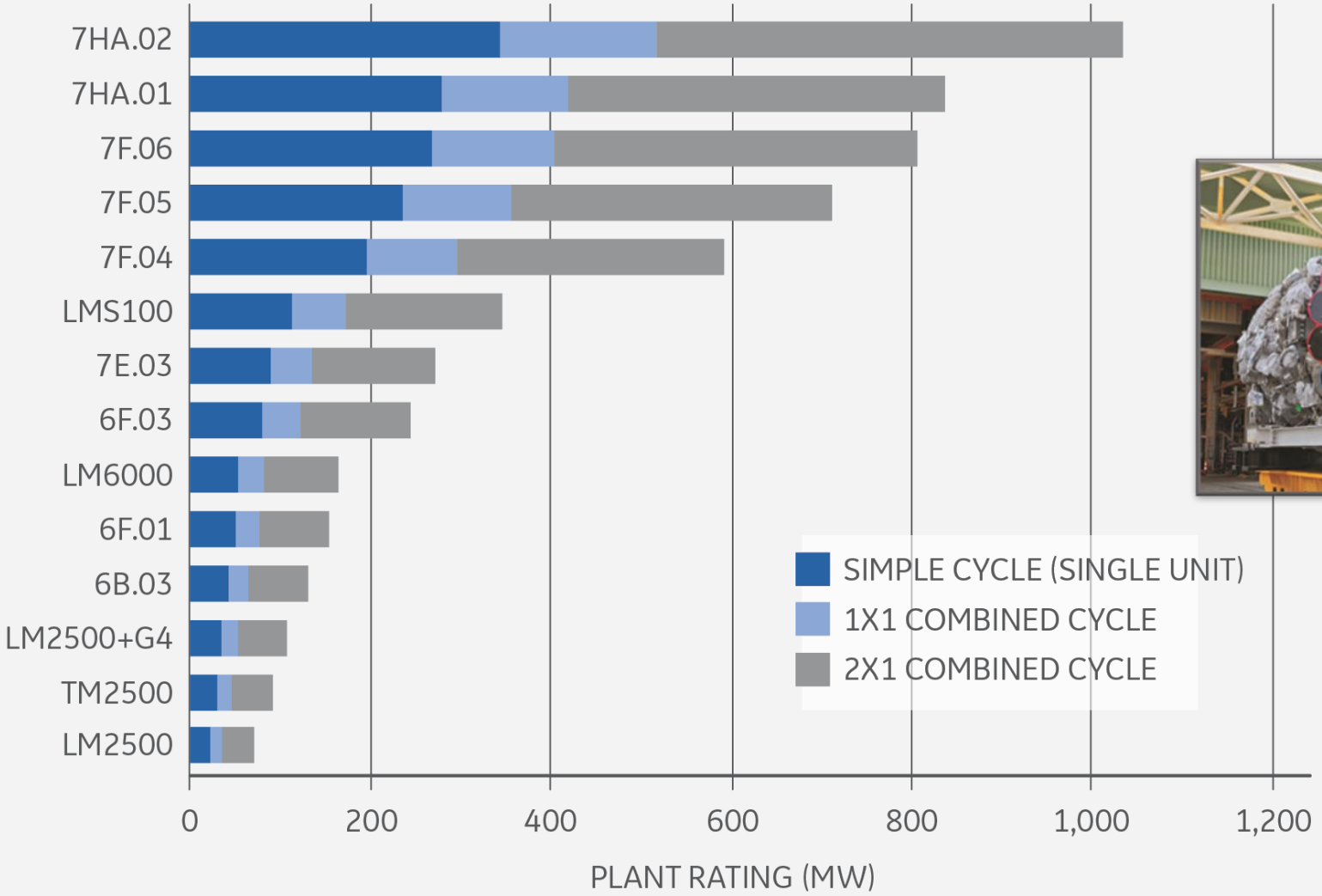


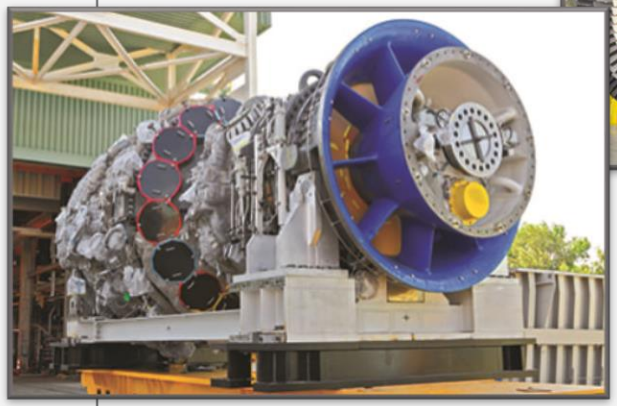
General Overview

- Small-to-mid-sized cogeneration and combined cycle plants: <100 MWe.

Gas Turbine Overview

GE Family of Gas Turbines

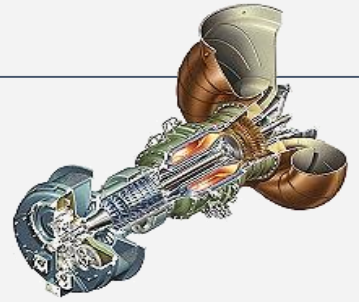




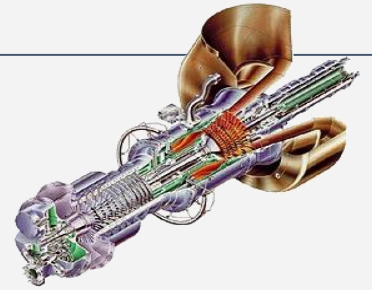
Gas Turbine Overview

Solar Gas Turbine Families

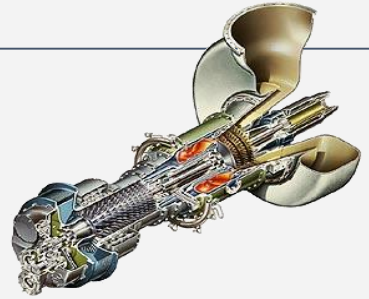
Saturn 20
1,210 kW



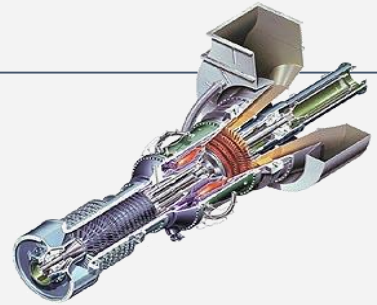
Taurus 60/65/70
5,500-7,520 kW



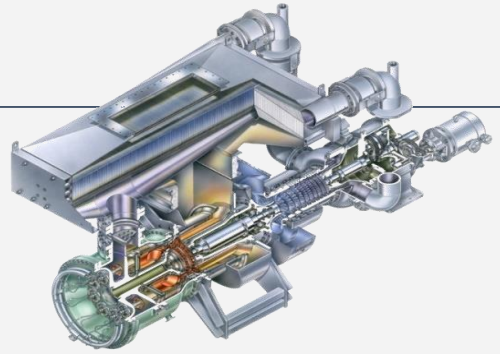
Centaur 40/50
3,515 / 4,600 kW



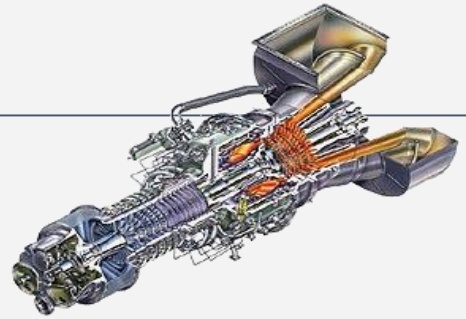
Mars 90/100
9,450 / 10,690 kW



Mercury 50
4,600 kW



Titan 130 / 250
15,000 / 22,000 kW



General Overview

- “Advanced Class Gas Turbines” Power Plants are centered on today’s F, G, H and J class turbine technologies

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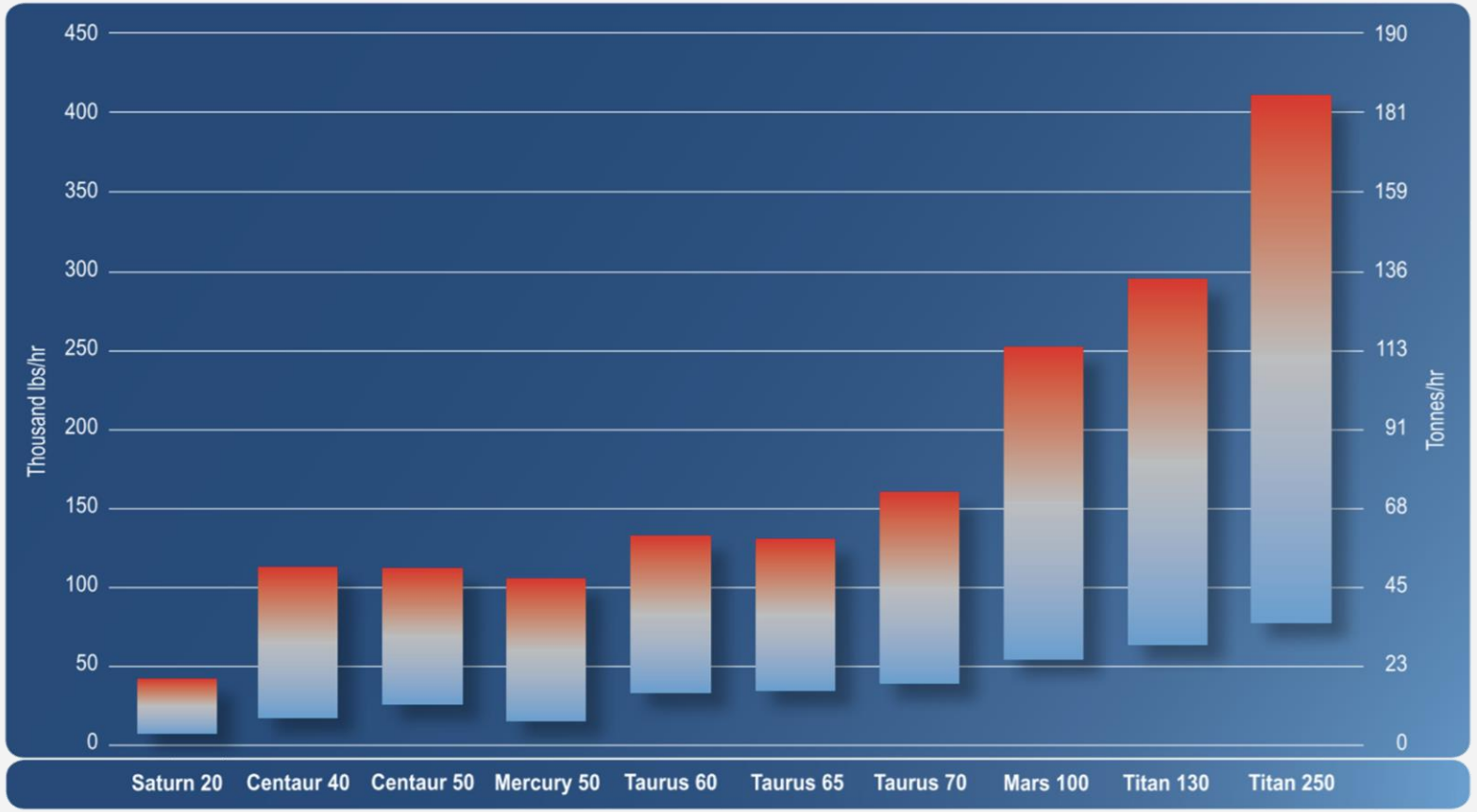
Duct Burner Installations - Partial Listing

End User	Location	Application	Heat Release MM BTU/HR	Fuel(s)	No. of Units	GT Specifics
Volkswagen Sued	Wolfsburg, Germany	TEG	65	Natural Gas	1	SGT-800
Nextera - Florida Power - Stanton Plant	Orlando, FL	TEG	488	Natural Gas	2	GE 7FA
GS Paperboard & Packaging SDN BHD	Malaysia	TEG	85	Natural Gas	2	Kawasaki GPB180D
PT Fajar	Indonesia	TEG	77	Natural Gas	1	GE-6F
Southern Power - Plant Harris	Prattville, AL	TEG	488	Natural Gas	4	GE 7FA
Jawa 2	West Java, Indonesia	TEG	720	Natural Gas	2	GT9HA.02
Georgia Power	Smyrna, GA	TEG	444	Natural Gas	1	Mitsubishi M501G
Marathon Green Power	Texas City, TX	TEG	458	Natural Gas	1	GE-7EA
Alabama Power	Bucks, AL	TEG	158	Natural Gas	4	GE Frame 7FA
Idaho Power	Boise, ID	TEG	218	Natural Gas	1	Siemens SGT6-5000F
BASF	Geismar LA	TEG	250	Natural Gas	1	GE Frame 6B.03
Kimberly Clark, Inc.	Chester, PA	TEG	81	Natural Gas	2	Solar Titan 130
Petronas	Malaysia	TEG	191	Natural Gas	1	GE MS5001PA
Bristol Myers Squibb	Lawerenceville, NJ	TEG/Register	110	Natural Gas	1	Solar - Taurus 70
University of Michigan	Ann Arbor, Michigan	TEG	102	Natural Gas	1	Solar - Titan 130
US DOE	Central Texas	Fresh Air	318	Natural Gas	1	R&D
Ciner	Green River Wyoming	TEG	132	Natural Gas	1	Solar - Titan 250
Enwave London District Energy	London, Ontario Canada	TEG Firing	88	Natural Gas	1	Solar - Titan 130
New Indy Containerboard	Ontario, California	TEG Firing	121	Natural Gas	2	Solar - Titan 130
Alabama Power	Theordore, Alabama	TEG Firing	98	Natural Gas	1	GE 7 "FA" Turbine
Milford Power, LLC	Milford, Massachusetts	TEG Firing	486	Natural Gas	1	Westinghouse W501D5A
CFE EVM II (Energia del Valle de Mexico)	Axapusco, Mexico	TEG Firing	189	Natural Gas	2	GE 7 HA
Kimberly Clark, Inc.	Mobile, Alabama	TEG Firing	114	Natural Gas	2	Solar - Titan 250
CFE (Comision Federal Electricidad)	El Carmen - Nuevo Leon, Mexico	TEG Firing	280	Natural Gas	2	Mitsubishi M501J
Cooper Tire and Rubber Co.	Findlay, Ohio	TEG Firing	46	Natural Gas	1	Solar - Taurus 70
EPM Waste Water Treatment Plant	Bello, Columbia	TEG Firing / Fresh Air	39	Natural Gas	2	Solar - Centaur 40
North Carolina State University	Raleigh, North Carolina	TEG Firing	31	Natural Gas	1	Solar - Taurus 70
Mankato Energy Center	Mankato, Minneapolis	TEG Firing	505	Natural Gas	1	Siemens 501FD4
Penn State University Hospital	Hershey, Pennsylvania	TEG Firing	48	Natural Gas	1	Solar - Taurus 70
Parris Island Energy	Parris Island, South Carolina	TEG Firing / Fresh Air	70	Natural Gas	1	Solar - Centaur 40
Eastern Michigan University	Ypsilanti, Michigan	TEG Firing	62	Natural Gas	1	Solar - Taurus 70
Panama Colon Power Project	Colon, Panama	TEG Firing	55	Natural Gas	3	GE 6 "FA" Turbine
ATA (Al Taweelah Alumina)	Al Taweelah, Abu Dhabi	TEG Firing	375	Natural Gas	2	GE Frame Nine "FA.03" Turbine
Panda Energy Mattawoman Plant	Brandywine, Maryland	TEG Firing	602	Natural Gas	2	Siemens SGT6-8000H
CFE (Comision Federal Electricidad)	Nuevo Leon, Mexico	TEG Firing	280	Natural Gas	2	Mitsubishi M501J
Shell Chemical - Franklin	Beaver County, Pennsylvania	TEG Firing	250	Natural Gas	3	GE 6 "B" Turbine
St. Joseph Energy Center	New Carlisle, Indiana	TEG Firing	35	Natural Gas	2	Siemens SGT6-5000F
NASA Johnson Space Center	Houston, Texas	TEG Firing	32	Natural Gas	2	Solar - Mars
Karbala Refinery Project	Karbala, Iraq	TEG Firing	293	Oil/Refinery Fuel Gas	4	Siemens SGT-800
Tate & Lyle, LLC	Lauden, Tennessee	TEG Firing	159	Natural Gas	2	Solar - Mars
PX Limited	Stallingborough, UK	TEG/FAF Register		Natural Gas	1	FKI Babcock Robey
NSRP Complex Project	Nghl Son, Vietnam	TEG Firing	140	Refinery Gas	2	GE 6 "FA" Turbine
Syncrude/ExxonMobil	Fort McMurray, Alberta	TEG Firing	700	Refinery Gas	1	GE 7 "EA" Turbine
Saudi Aramco	Hawiyah, Saudi Arabia	TEG Firing	165	Natural Gas	2	GE 7 "EA" Turbine
Saudi Aramco	Abqaiq, Saudi Arabia	TEG Firing	214	Natural Gas	2	GE 7 "FA" Turbine
Saudi Aramco	Ras Tanura, Saudi Arabia	TEG Firing	222	Natural Gas	2	GE 7 "FA" Turbine
Empire District Electric	Riverton, Kansas	TEG Firing	279	Natural Gas	1	Siemens V84.3 Turbine
El Paso Electric	El Paso, Texas	TEG Firing	124	Natural Gas	2	Westinghouse W501B Turbine
OCI Beaumont Methanol	Nederland, Texas	Flue Gas Reheat	169	Natural Gas	1	Air Augmented Design - Flue Gas Reheat
Petrobras RNEST Project	Recife, Brazil	Flue Gas Reheat	56	Natural Gas	2	Air Augmented Design - Flue Gas Reheat
Petrobras RNEST Project	Recife, Brazil	Fresh Air	48	Natural Gas	2	System Start Up Heater
Ferrero Group	Doherty, Quebec Canada	TEG Firing	16	Natural Gas	1	Solar Centaur Turbine
Diageo USVI St. Croix	St. Croix, US Virgin Islands	TEG Firing	62	Propane	1	Solar Centaur Turbine
Entergy Louisana	Westwego, Louisiana	TEG Firing	230	Natural Gas	2	GE 7 "FA.04" Turbine
Montclair State University	Clifton, New Jersey	TEG Firing	22	Natural Gas	1	Solar Mars Turbine
Formosa Plastics	Point Comfort, Texas	TEG Firing	120	Refinery Gas/Hydrogen	5	GE 7 "EA" Turbines
PetroLogistics Proplylene LLC	Houston, Texas	Fresh Air	164	Refinery Gas/Hydrogen	1	Regeneration Air Heater

Why Duct Burners?

- For Cogeneration (CHP) and Combined-Cycle applications, duct burners increase steam production above what can be recovered for the heat of the gas turbine exhaust (TEG) alone.



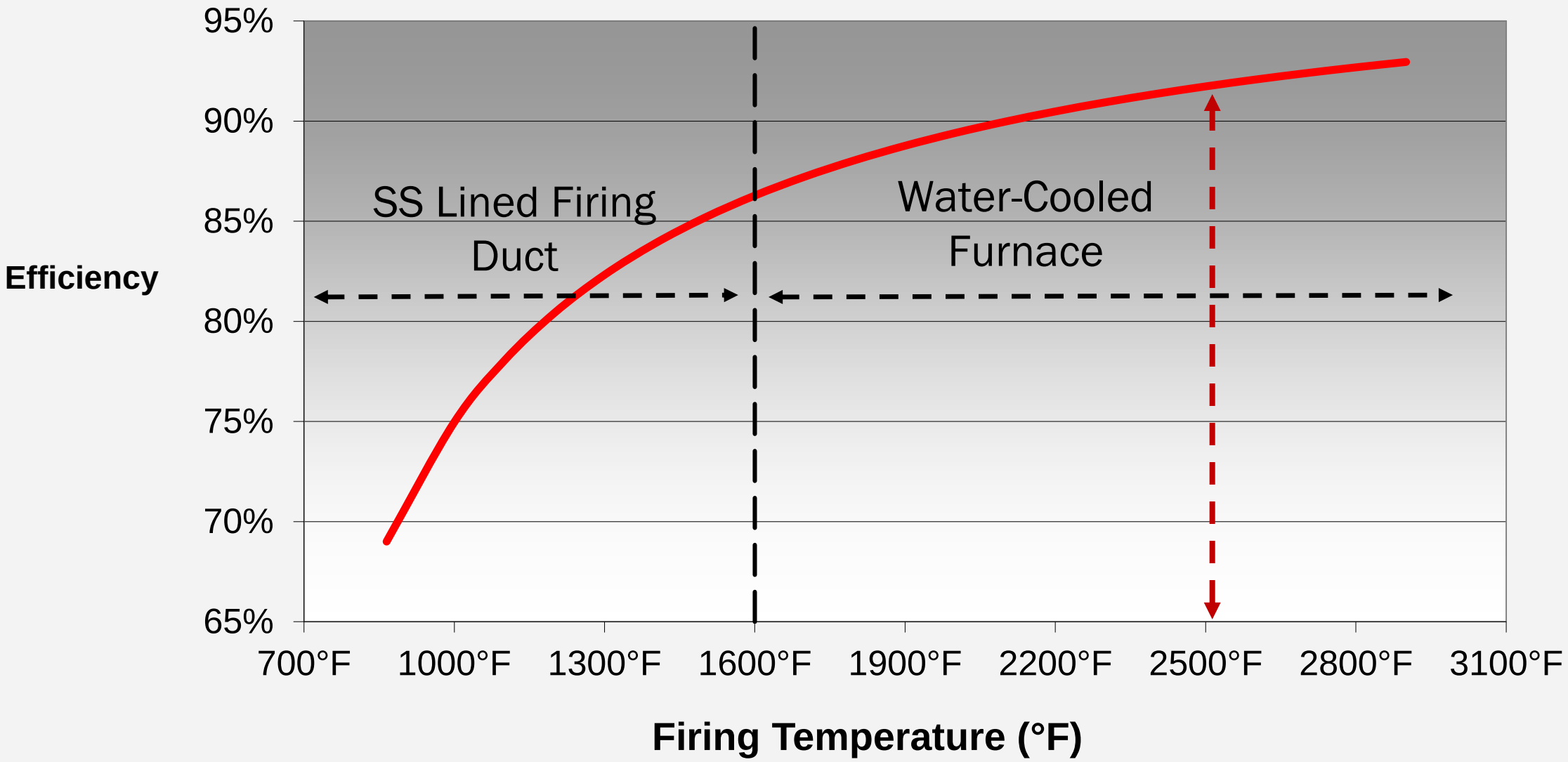
Note: Steam output ranges from an unfired basis to a max-fired rate .

Cogen System Performance

Product	ISO Power MWe	ISO Heat Rate Btu/kW-hr	Site Specific Performance – Thousand lbs/hr				
			Exhaust Temp. ºF	Exhaust Flow	Steam Production		
					Output Unfired	Fired to 1600ºF	Fired to 2800ºF
Saturn 20	1.2	14 025	952	51.5	8.9	18.5	40.0
Centaur 40	3.5	12 240	835	149.6	19.6	53.3	113.2
Centaur 50	4.6	11 630	956	150.3	25.3	53.0	112.4
Mercury 50	4.6	8 863	710	140.4	13.8	49.4	104.4
Taurus 60	5.7	10 860	960	171.3	29.8	62.0	130.5
Taurus 65	6.3	10 373	1032	163.4	32.1	60.5	128.3
Taurus 70	7.5	10 100	914	212.3	34.4	76.1	158.6
Mars 90	9.5	10 710	875	316.2	46.8	113.3	239.5
Mars 100	10.7	10 520	915	329.1	51.8	117.4	248.1
Titan 130	15.0	9 695	932	392.2	64.5	141.4	298.2

ISO Performance: 59˚ F; Sea Level; No Inlet and Exhaust Losses.
Specific Site Performance: 3 in. Inlet, 7 in. Exhaust Losses; Saturated Steam @ 150 psig

Thermal Efficiency vs. Firing Temperature



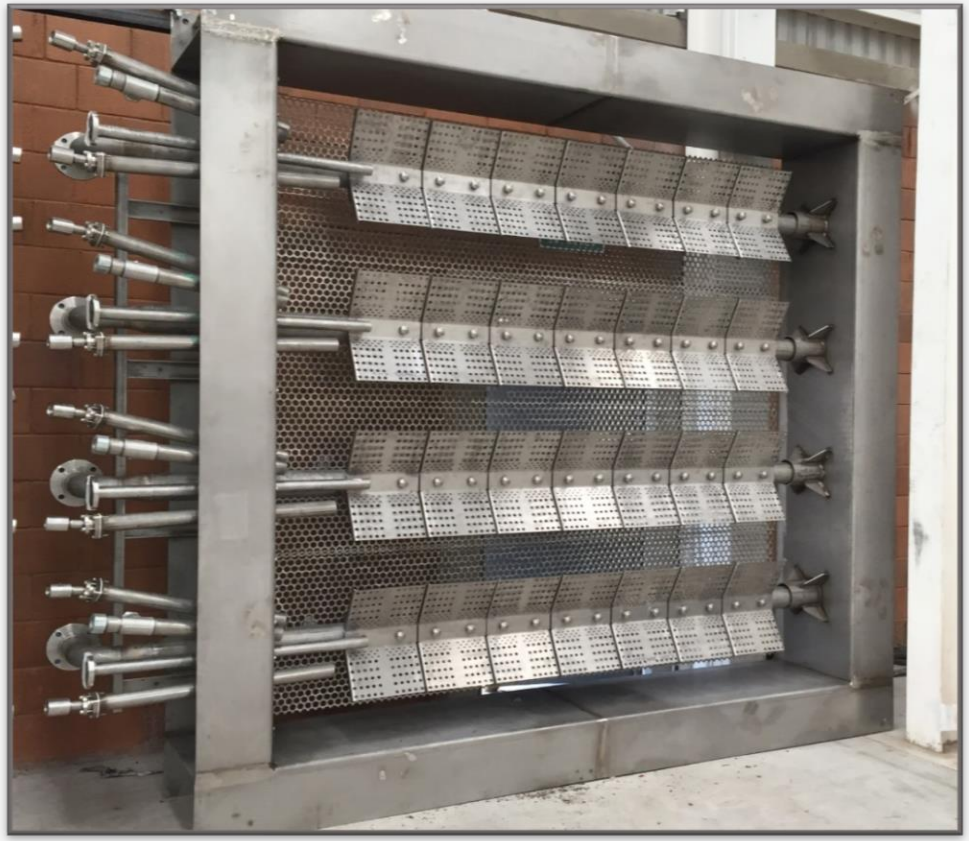
Additional Benefits

- More efficient process steam production than with a conventional boiler.
- Steam production can be maintained at lower GT load or even GT shutdown (FAF).
- Compensation for changing ambient conditions.
- Power markets are making use of duct burners in modified modes of operation.
- Ability to burn a variety of gases and/or fuel oil (including some not practical as turbine fuel):

Natural Gas	Refinery Gas
Hydrogen	Landfill Gas
Digester Gas	Low BTU Gases: COG, BFG and Syngas

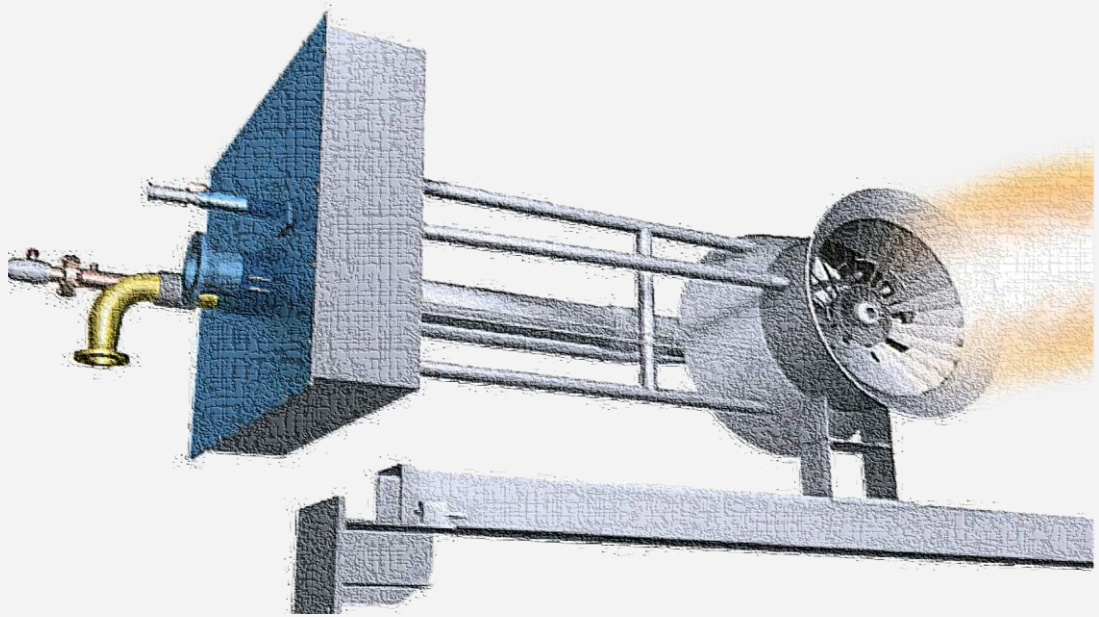
Duct Burner Technology

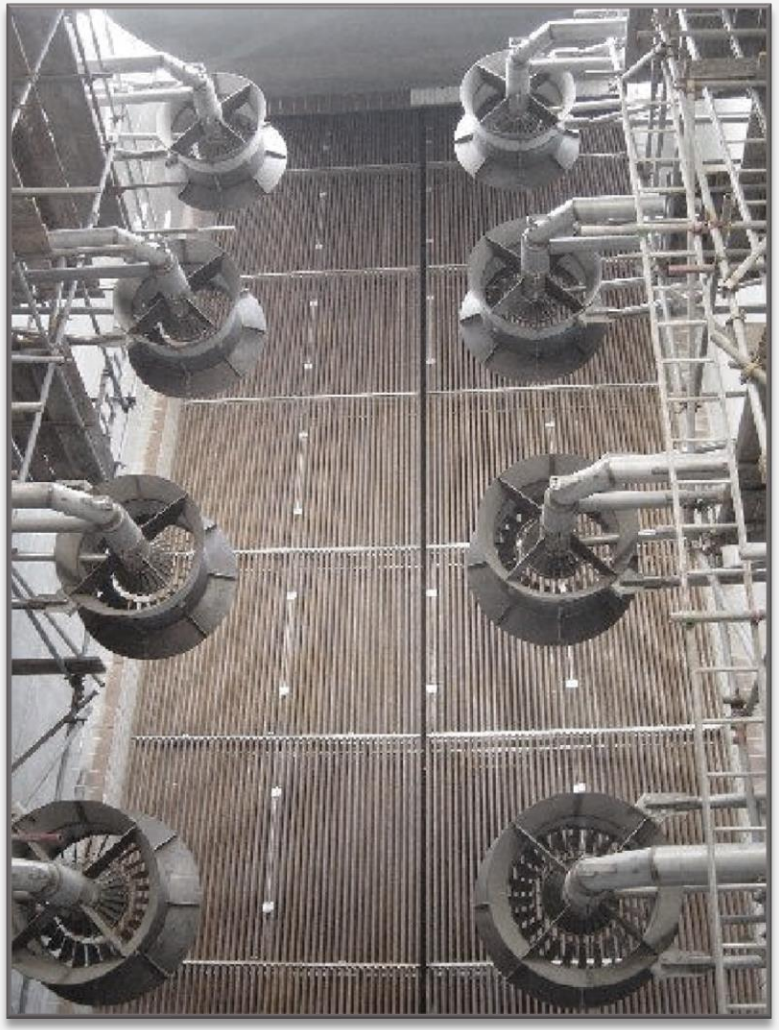
- The most common style of gas-fired duct burner is often referred to as “Grid” or “Runner” style



Duct Burner Technology

- Register-style duct burners are typically used on gas and oil firing applications, however not commonly applied in North America.





Duct Burner Technology

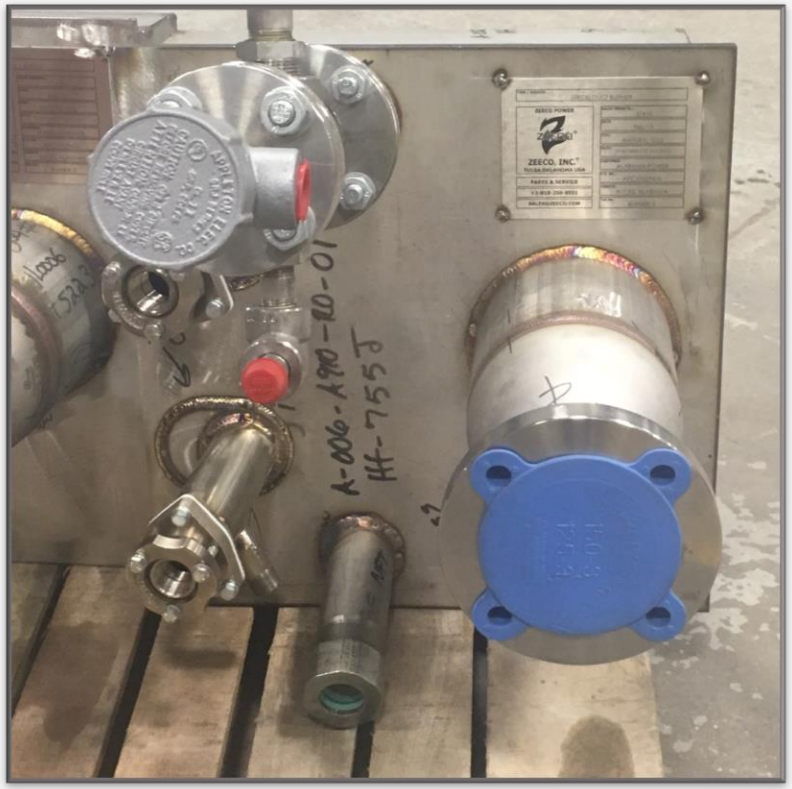
- Windbox Register-style duct burners provide additional benefits including gas and oil firing, ULN and high-firing application down to low O2 levels .

Duct Burner Technology

- Grid burners use a gas manifold to span the width of the HRSG firing duct containing: flame stabilizers and fuel nozzles evenly attached, along with a mounting flange, the igniter, scanners and a view port.

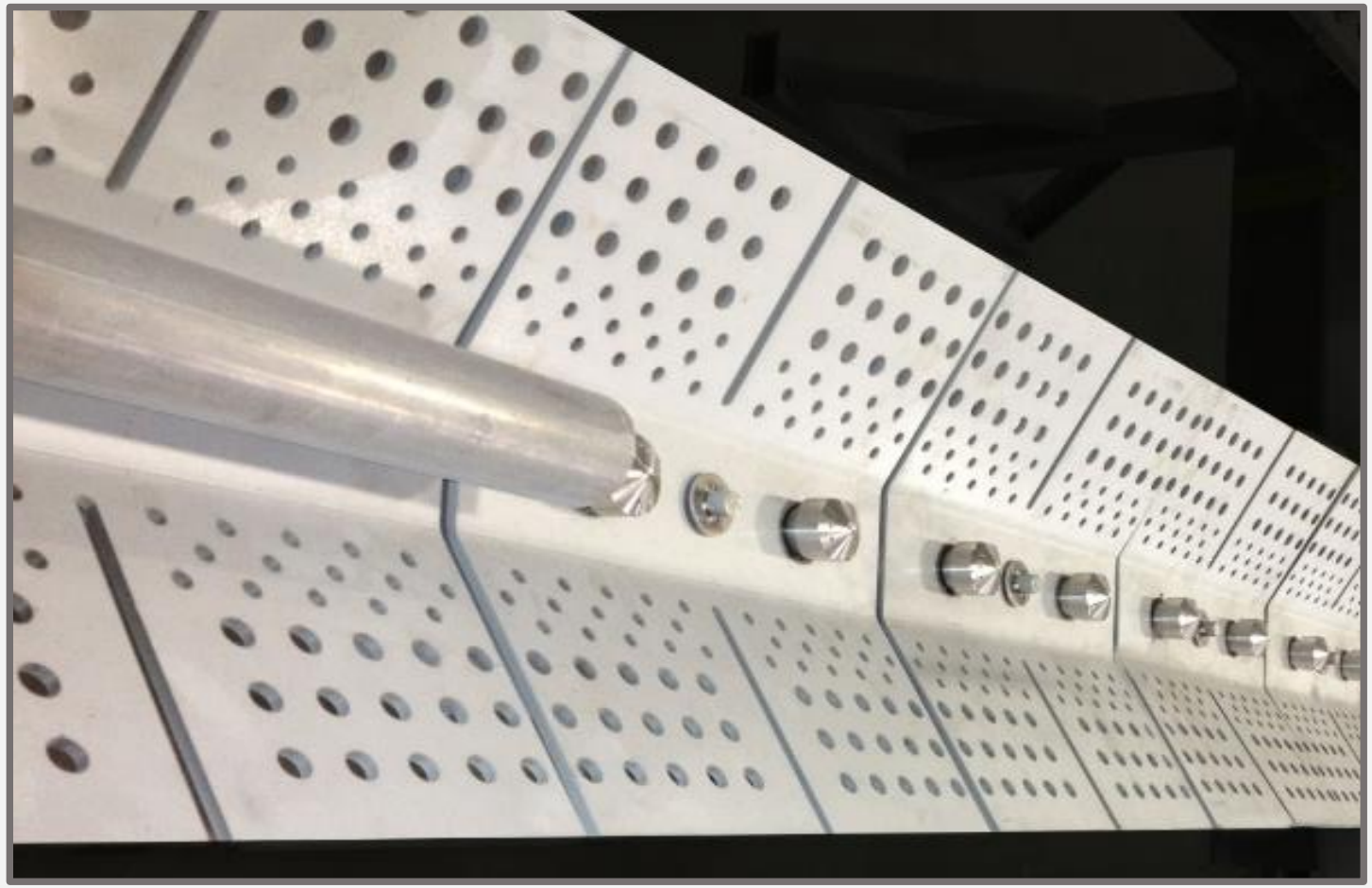
Duct Burner Technology

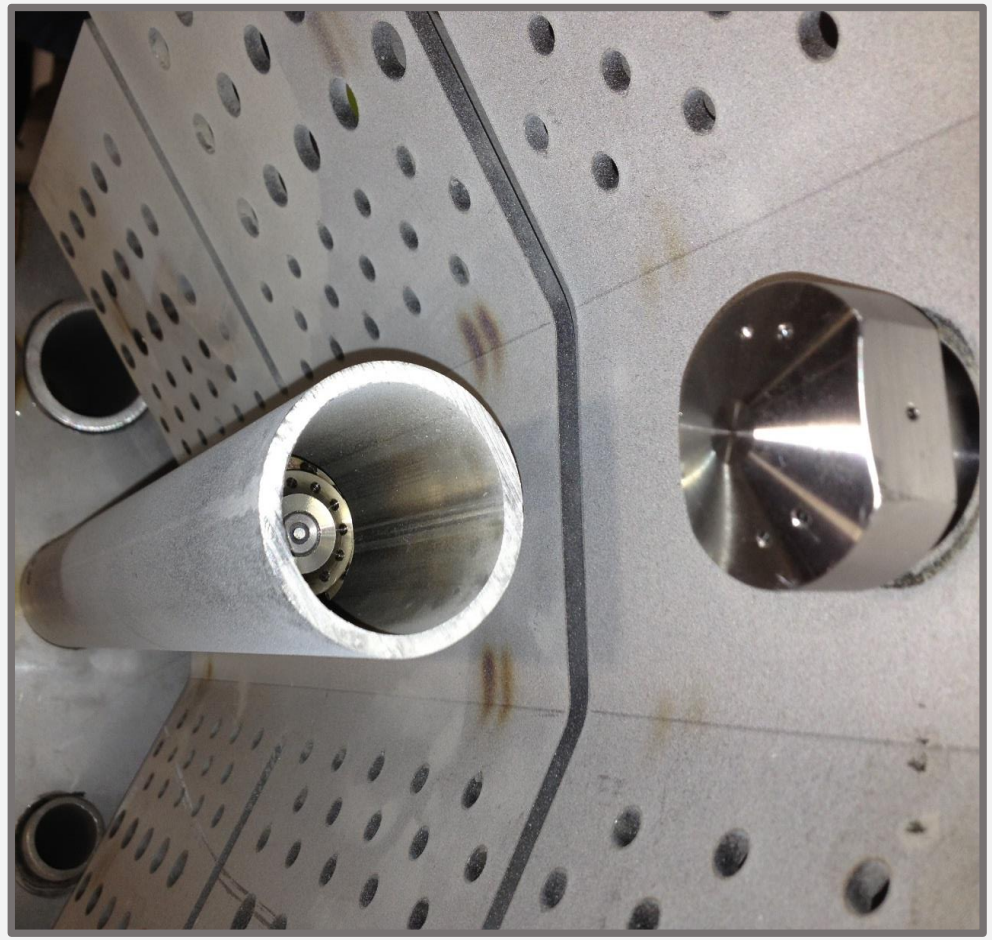
- Loose Element Design: “Business-end” includes Fuel Inlet Flange, along with Igniter, Scanners and View Port assemblies.



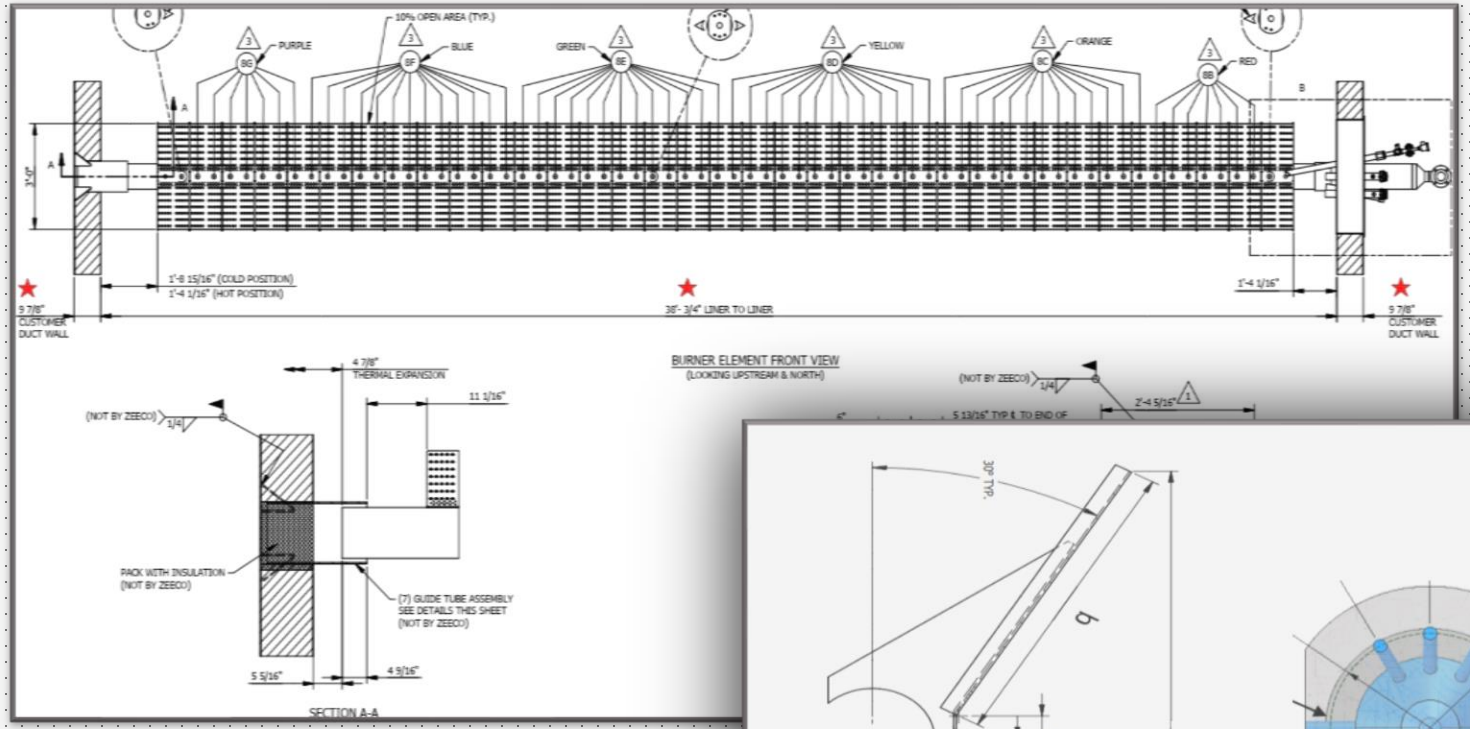
Duct Burner Technology

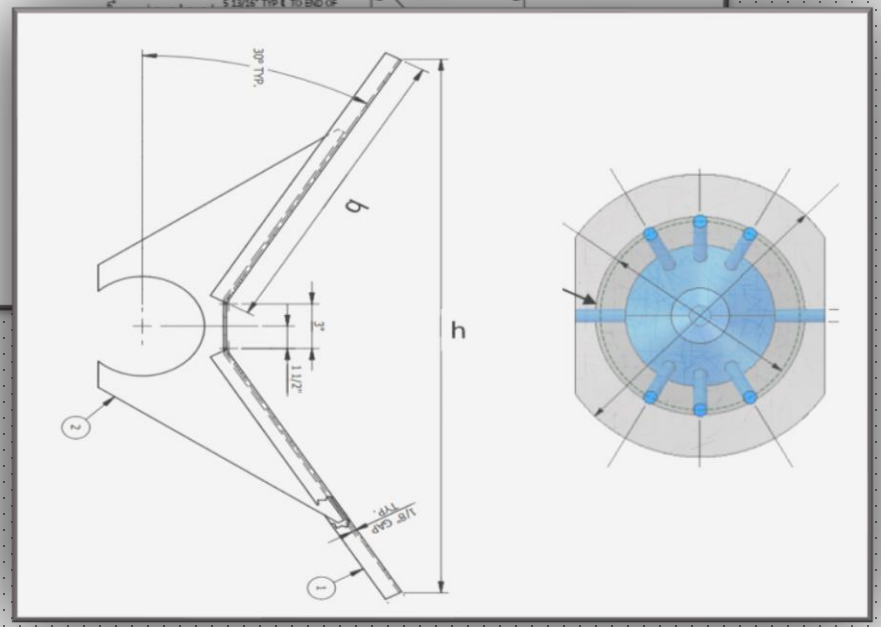
- Grid duct burner's igniter, flame stabilizers and fuel nozzles

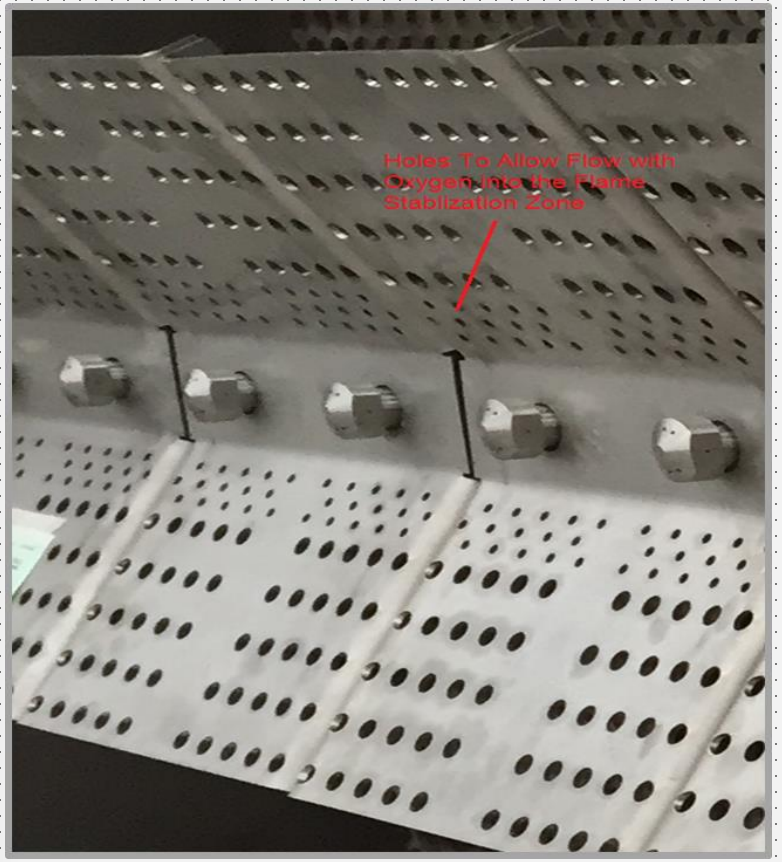




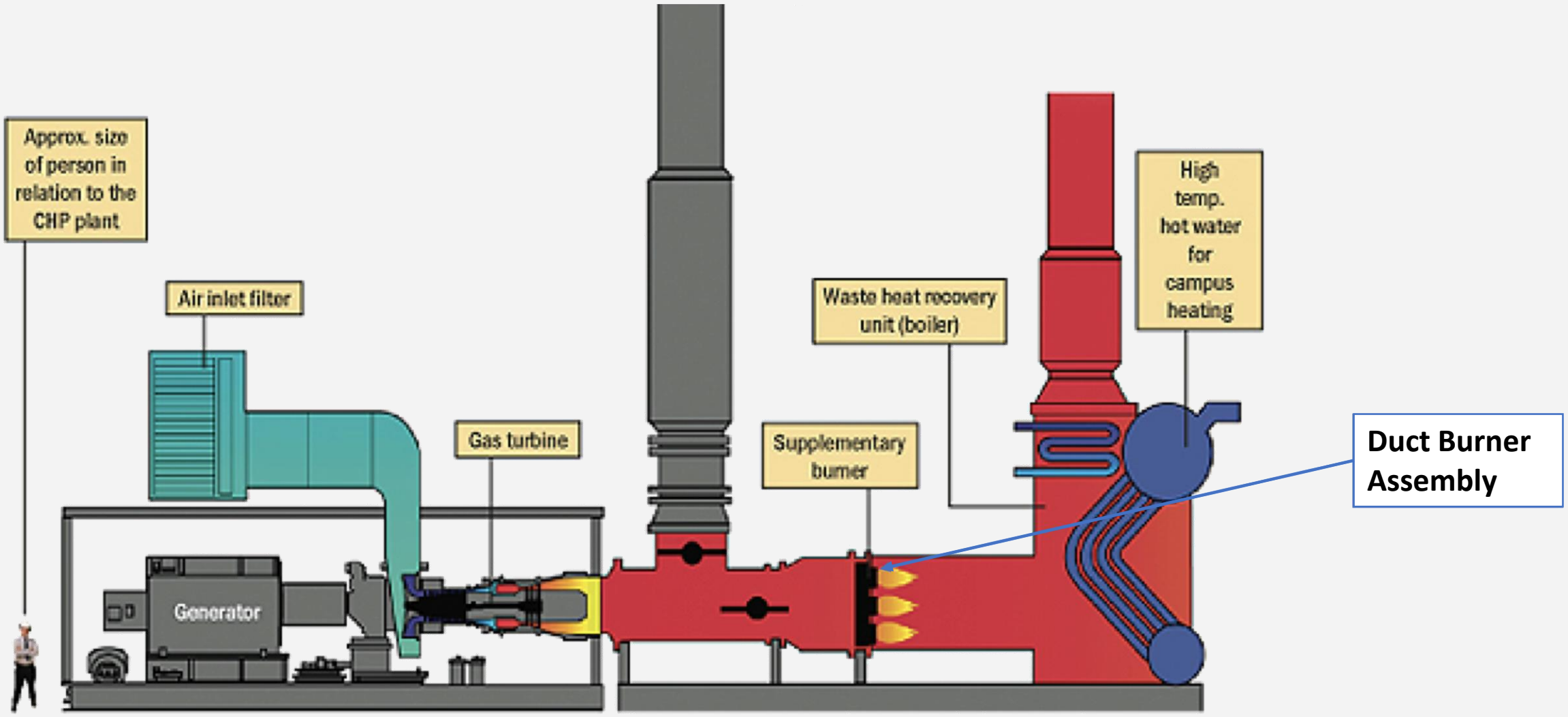
Duct Burner Technology





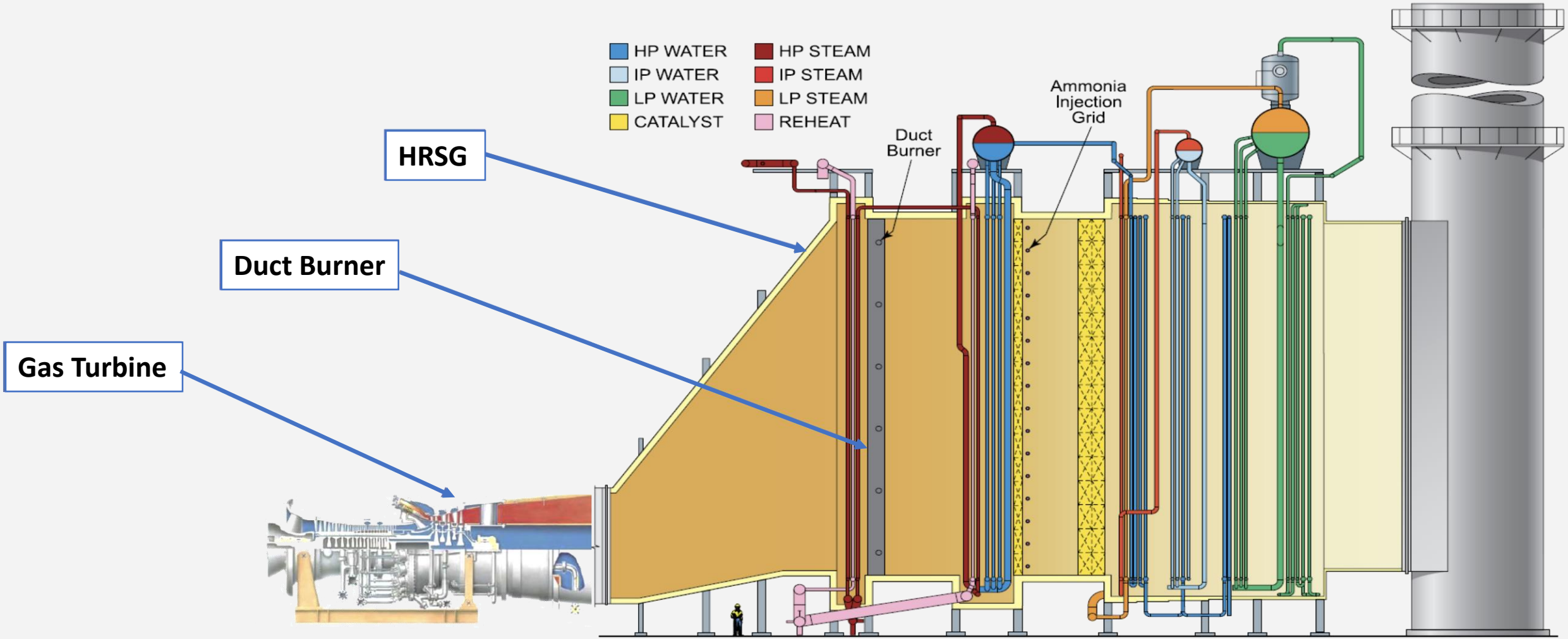


Cogeneration (CHP)



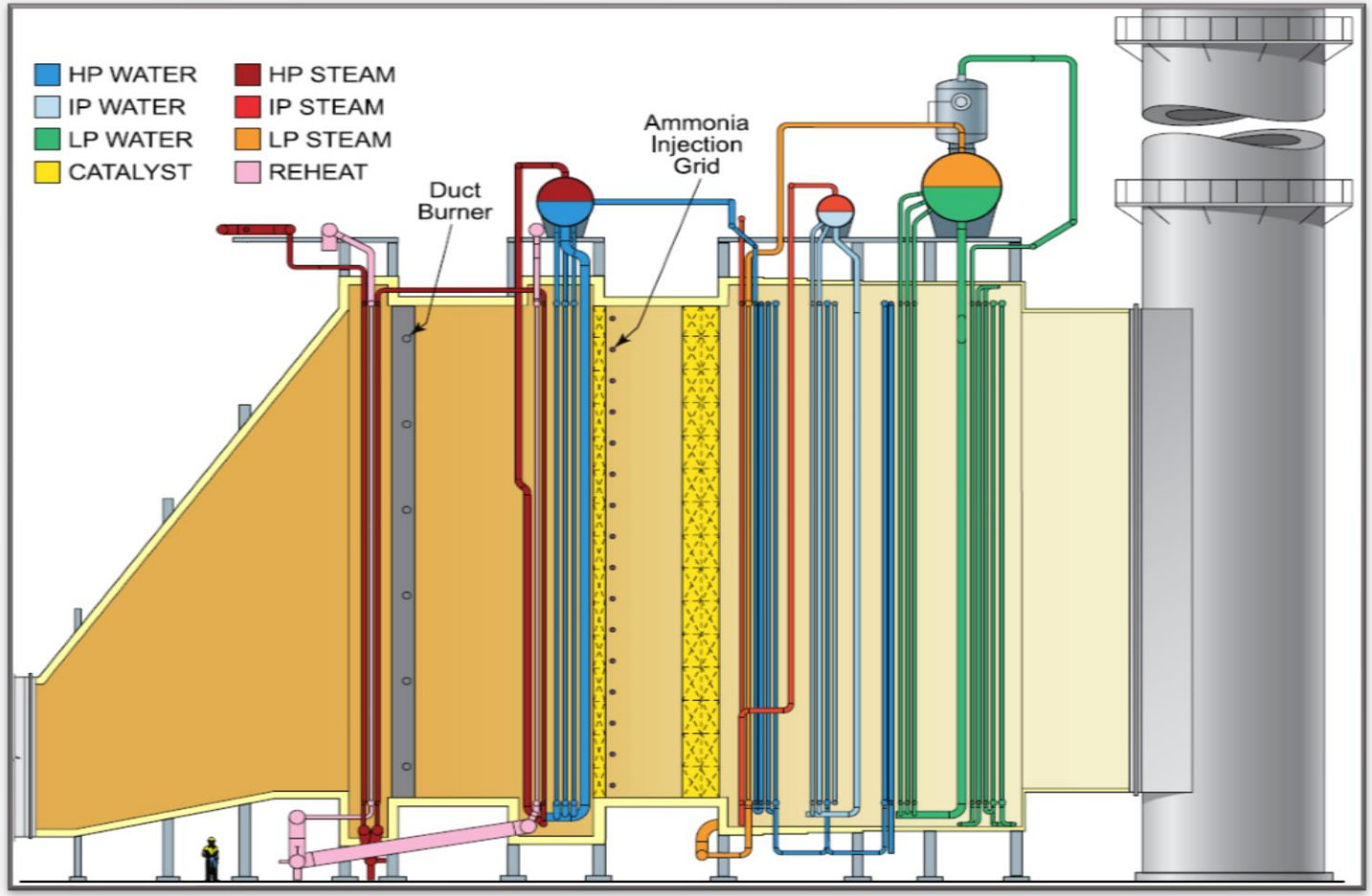
Combined Cycle Power

- Common Configuration for Combined Cycle System



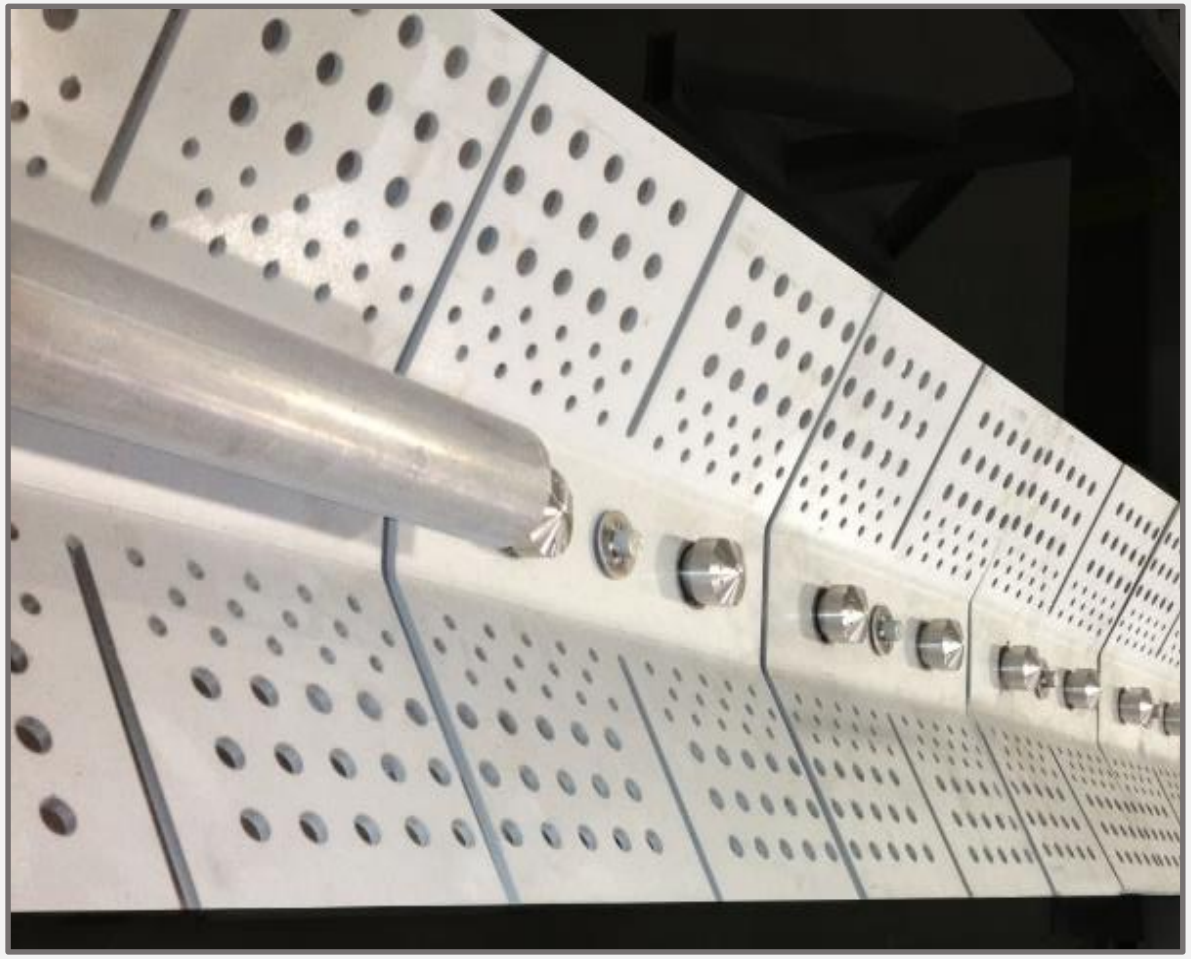
Design and Control Factors

- Main Design Considerations that Influence Duct Burner Performance:
  - TEG composition
  - TEG flow distribution
  - Firing duct length
  - Quantity of elements
  - Burner turndown
  - Pressure drop
  - Burner staging
  - Emissions requirements



Performance & Design Considerations

- Heat Release Range: 2.0 to 5.0 mmbtu/ft
- Firing Capacity: > 900 mmbtu/hr
- Flame Length: 7-8 ft
- Turndown: 10:1 (or higher range w/ staging)
- Pressure Drop : < 0.5” w.c.
- Gas Fuel Pressure Supply : 25-35 psig
- Max Element Length: 40 ft
- Temp Distribution +/- 150 degF
- NOx Emissions: 0.05 lb/mmbtu (HHV)



Duct Burner Inquiry Specification

	Case 1	Case 2	Case 3	Case 4	Case 5
Ambient Temperature (C)					
Turbine Emissions					
NOx					
CO					
VOC					
UHC					
SOX					
PM-10					
Duct Burner Heat Release (MW LHV)					
Composition (% Volume)					
O2					
N2					
CO2					
H2O					
Ar					

Duct Burner Inquiry Specification

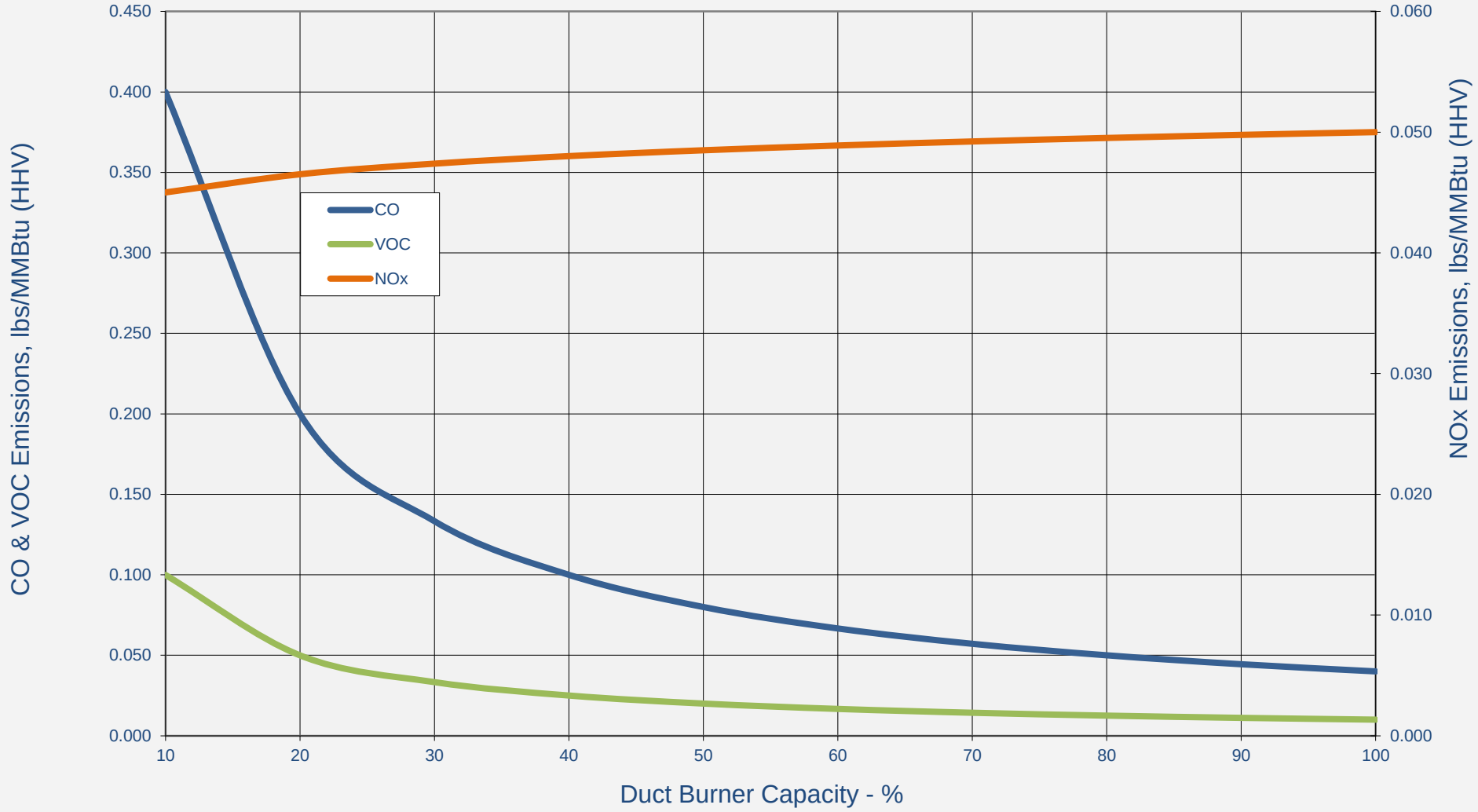
	Fuel 1	Fuel 2	Fuel 3
Fuel Name			
Fuel Temperature (C)			
Fuel Pressure (kPa g)			
LHV (kJ/Nm^3)			
HHV (kJ/Nm^3)			

Fuel Gas Composition (% Volume)	Fuel 1	Fuel 2	Fuel 3
Methane (CH4)			
Hydrogen (H2)			
Carbon Monoxide (CO)			
Ethane (C2H6)			
Ethylene (C2H4)			
Propane (C3H8)			
Propylene (C3H6)			
N-Butane (C4H10)			
I-Butane (C4H10)			
N-Butene (C4H8)			
I-Butene (C4H8)			
N-Pentane (C5H12)			
I-Pentane (C5H12)			
N-Pentene (C5H10)			
Hexane (C6H14)			
Hydrogen Sulfide (H2S)			
Sulfur Dioxide (SO2)			
Oxygen (O2)			
Nitrogen (N2)			
Carbon Dioxide (CO2)			
Ammonia (NH3)			
Water Vapor (H2O)			
Hydrogen Cyanide (HCN)			

Natural Gas **Refinery Gas**
Hydrogen **Landfill Gas**
Digester Gas **Low BTU Gases: COG, BFG and Syngas**

Emissions from Duct Burners					
NOx					
CO					
VOC					
UBHC					
PM-10					

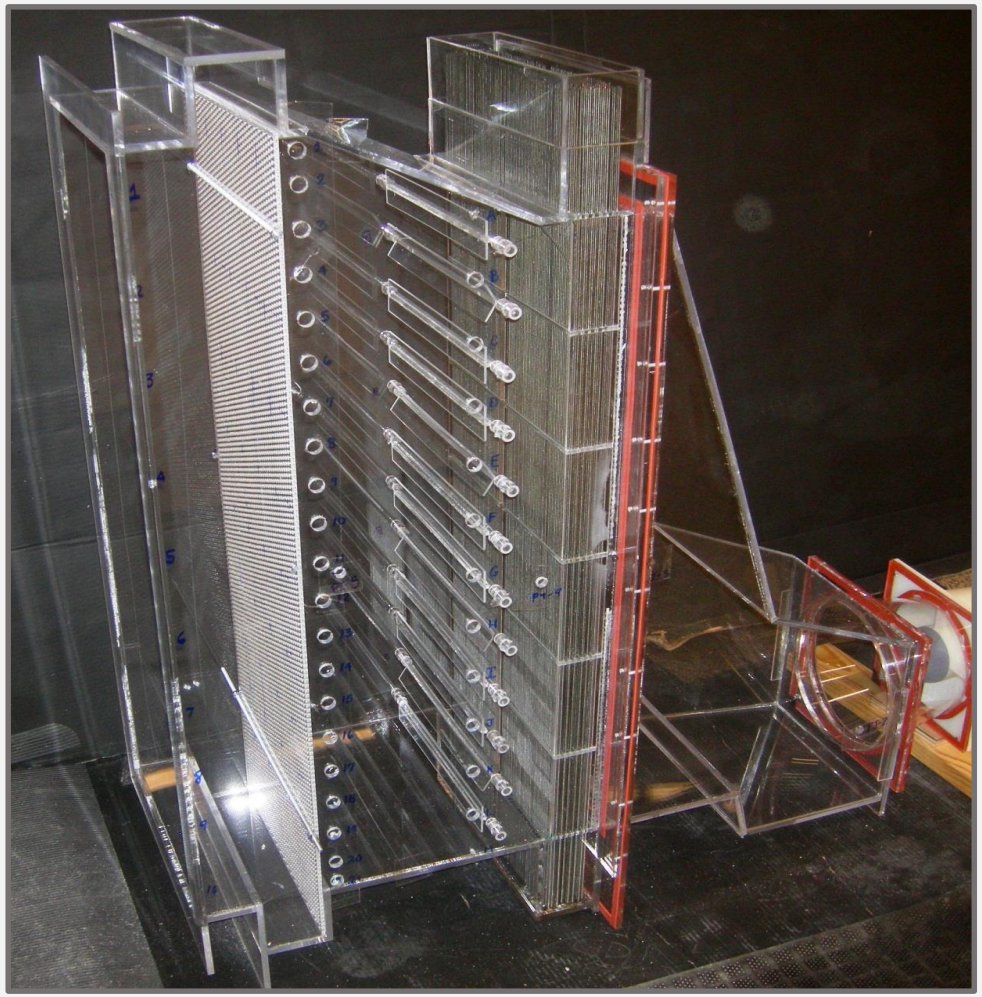
Duct Burner Emissions Performance

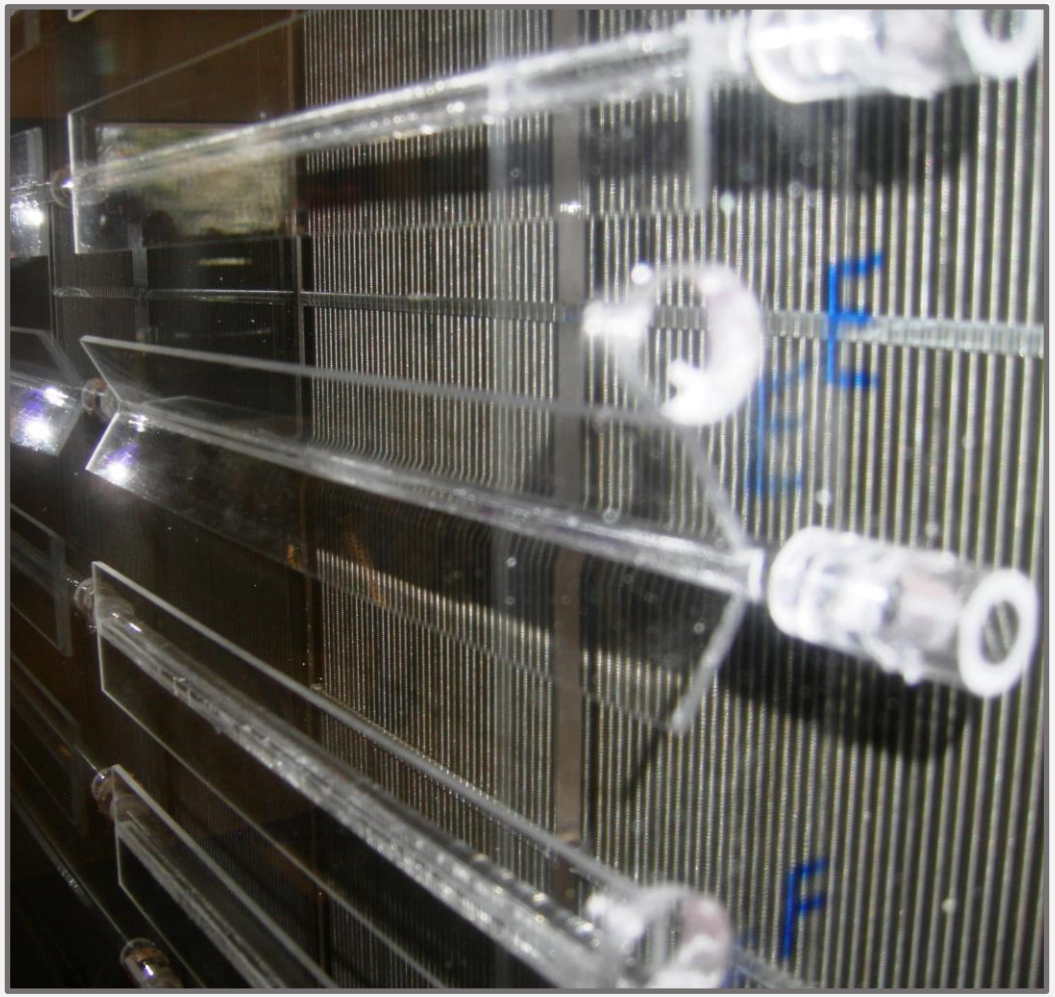


Common Design and Operational Challenges

- **Poor TEG distribution across DB**
- **Flame impingement:**
  - Flame impingement can occur on firing duct liners or downstream tube banks
- **Fuel gas flow maldistribution:**
  - The fuel gas flowing through the burner manifold will heat up as it flows
- **Sagging or binding firing elements**
- **Condensation and corrosion in fuel lines:**
  - A duct burner should have automatic isolation of individual burner runners

Physical Model: Duct-Fired HRSG





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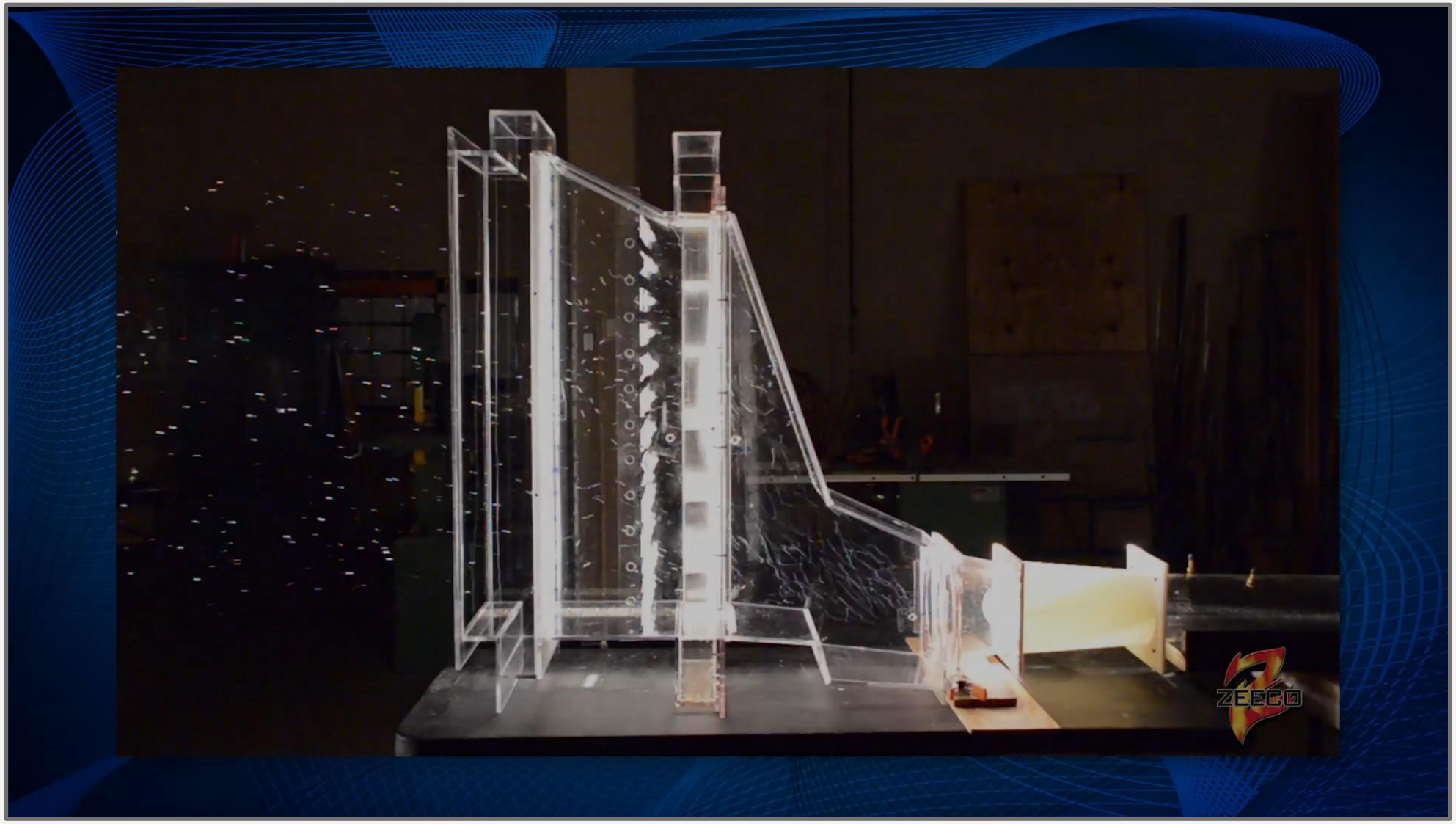
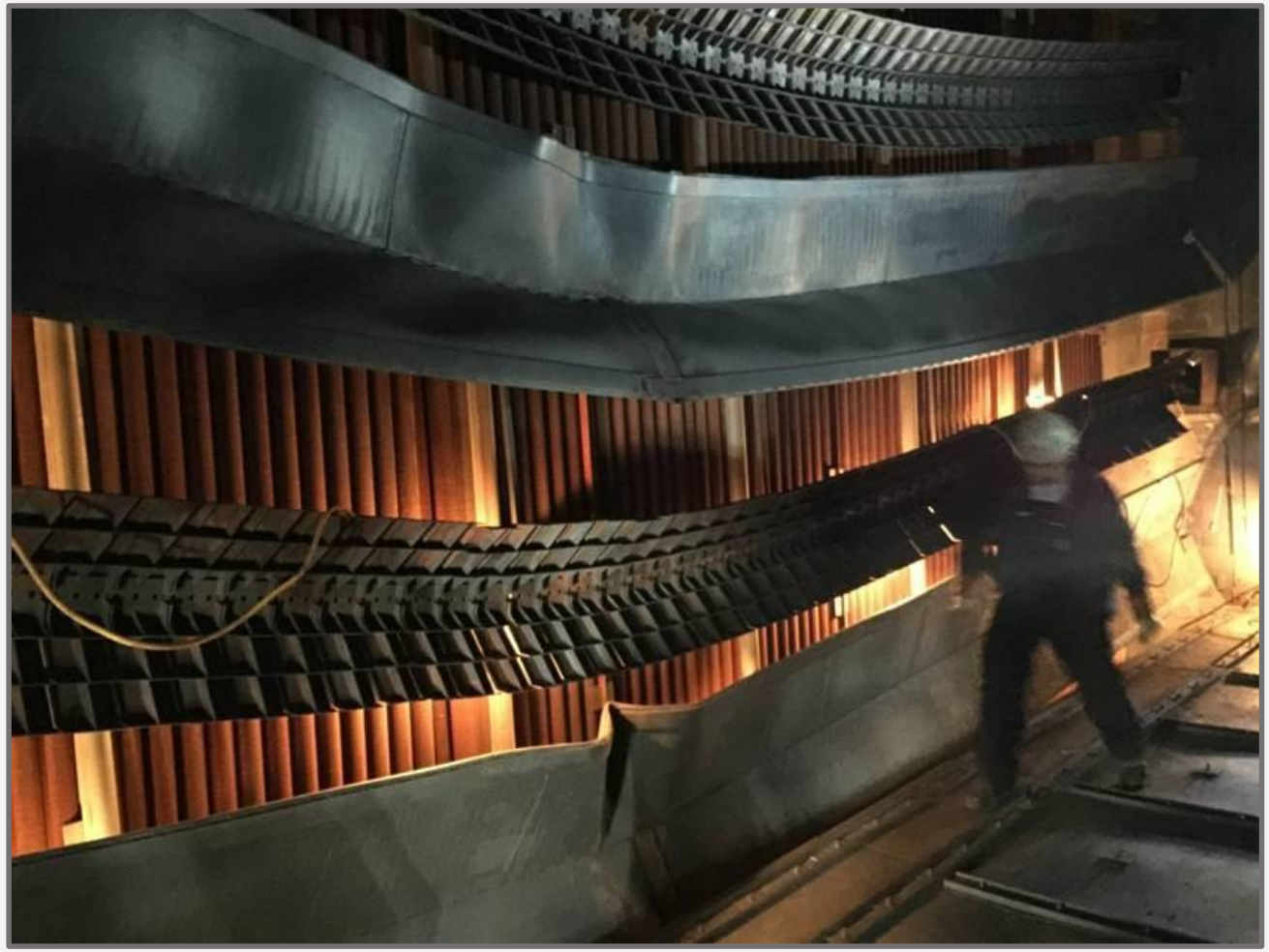
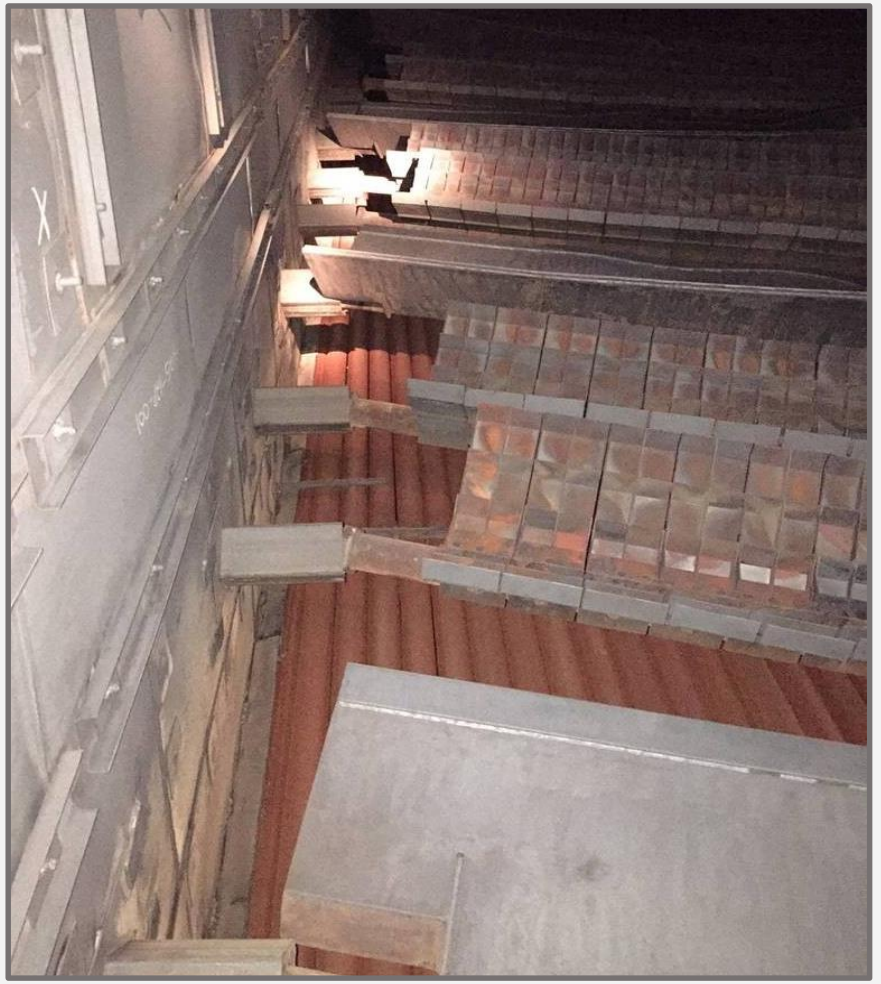


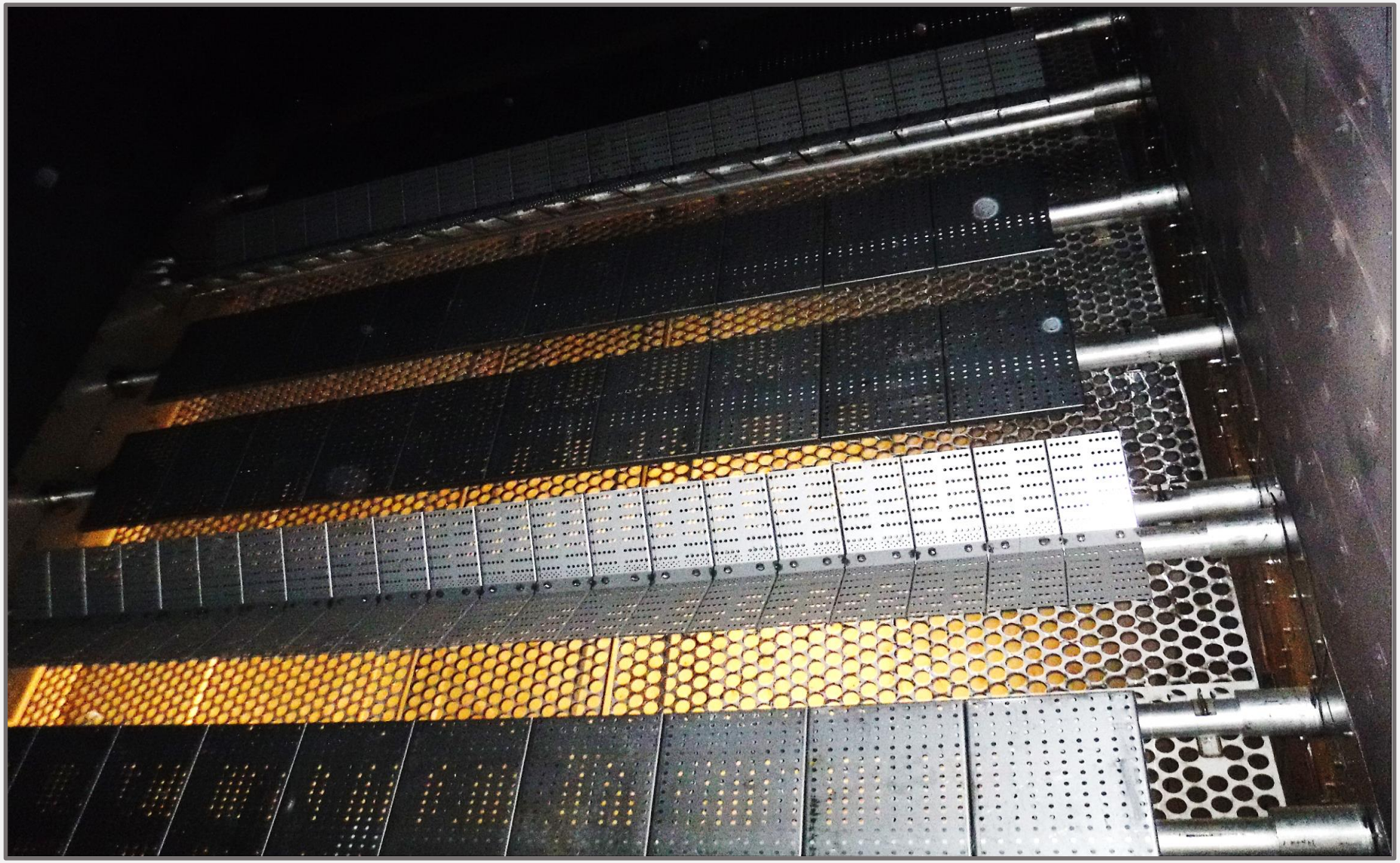
Common Design and Operational Challenges

- Sagging and/or binding elements





Retrofitted Duct Burner Runners & Flow Baffles



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