California Statewide Gas Emerging Technologies

Final Presentation- ET22SWG0010

Market Assessment of Emerging Ultra-Low NOx Burner Technologies

11/7/2023

Agenda

- Project Objectives
- Interview Questions
- SME interviews and Site Visits
- Technology Findings
- Hydrogen Blending ULN Burners
- Conclusion
- Recommendation

Project Objectives

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- Collect market data and evaluate emerging ULN burner technologies
- Conduct a literature review to better understand burner technology and identify ULN burners
- Develop a list of SME's consisting of burner manufacturers and researchers to interview
- Conduct interviews and site visits to gather additional data on various ULN technologies

Interview Questions

Interview Questions

- A list of questions was developed to facilitate the interviews and site visits
- The survey tool included both open ended questions in order to better understand the technology, applications, market challenges, retrofit applications, and opportunities for broader product integration.
- The survey tool also collected specification data for each burner model

SME Interviews

SME Interviews

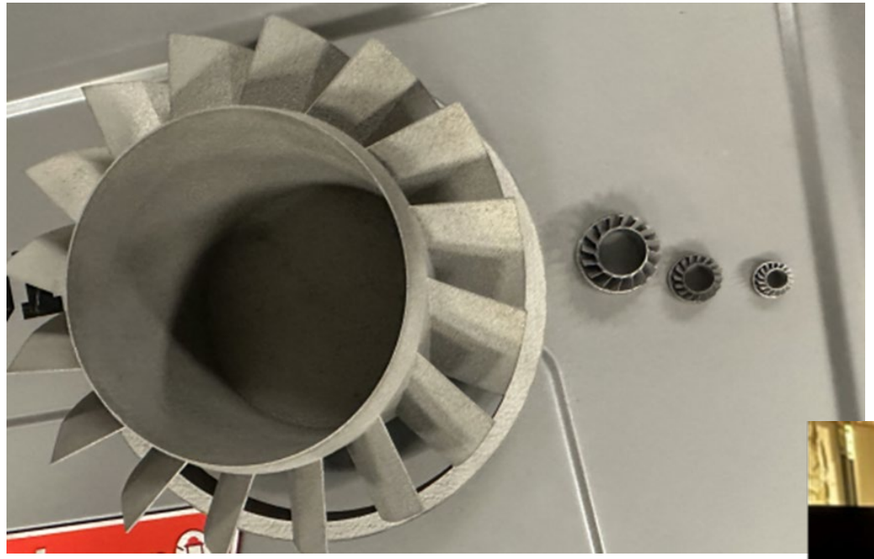
18 organizations contacted

33% response rate

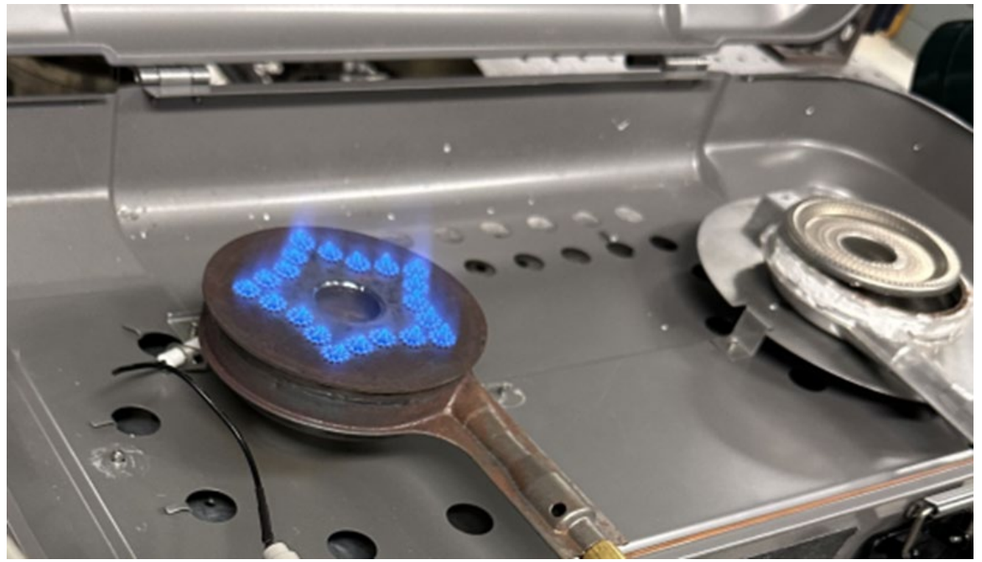
7 ULN Burner Manufacturers via the 2023 AHR Expo

Technology Findings

Technology Findings- LBNL



Low Swirl Burner



Ring Stabilizer Burner

Technology Findings – ClearSign Burners

- Process Burner
- Boiler Burner
- Flare Burner
- Patented ClearSign CORE Technology

Source: https://www.clearsign.com/process-burners/

Technology Findings- Rogue Combustion

Firetube Boiler Burner

- Demonstrated 1ppm NOx during site visit

Technology Findings – Powerflame Incorporated Burners

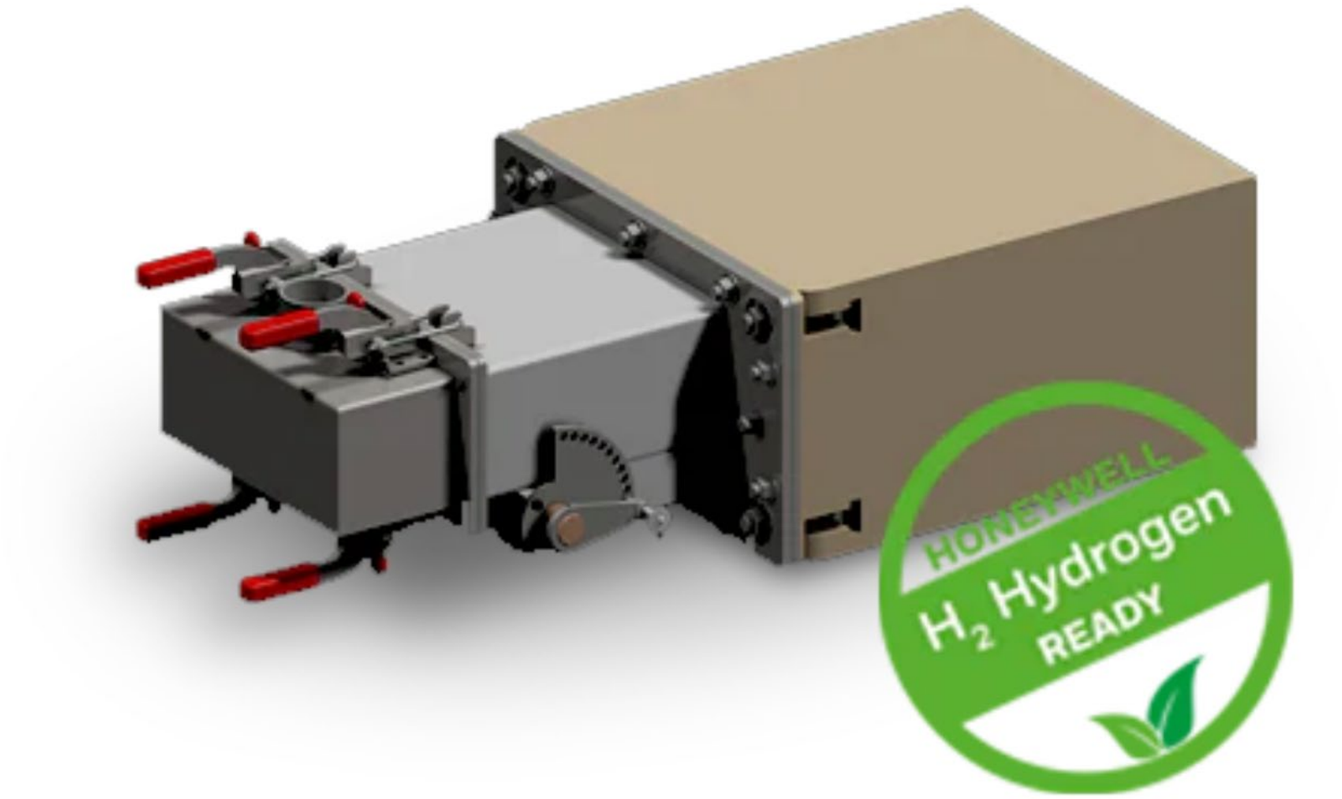
- Ultra Cmax burner
- NP2 burner
- NVC burner

Technology Findings – Vitotherm

- ULN burner line coming late 2023
- <5ppm NOx, 0ppm CO
- CA greenhouse market

Technology Findings- Honeywell

- Oxy-Therm® FHR Burner
- Ideal for high temperature applications



Source:
https://www.kromschroeder.de/marketing/adlatus/techlipedia/out/index.php?map=id_map_reh_20220104_155035-en

Technology Findings – Micron FiberTech

- Tube Burners
- In-Ward-Fired Cone (IWFC) Burners

Source: [IWFC Low NOx Burners : Micron Fiber Tech (mft-co.com)]

Technology Findings- Cleaver Brooks

- SBR-5 ULN Burner
- <5ppm NOx with FGR

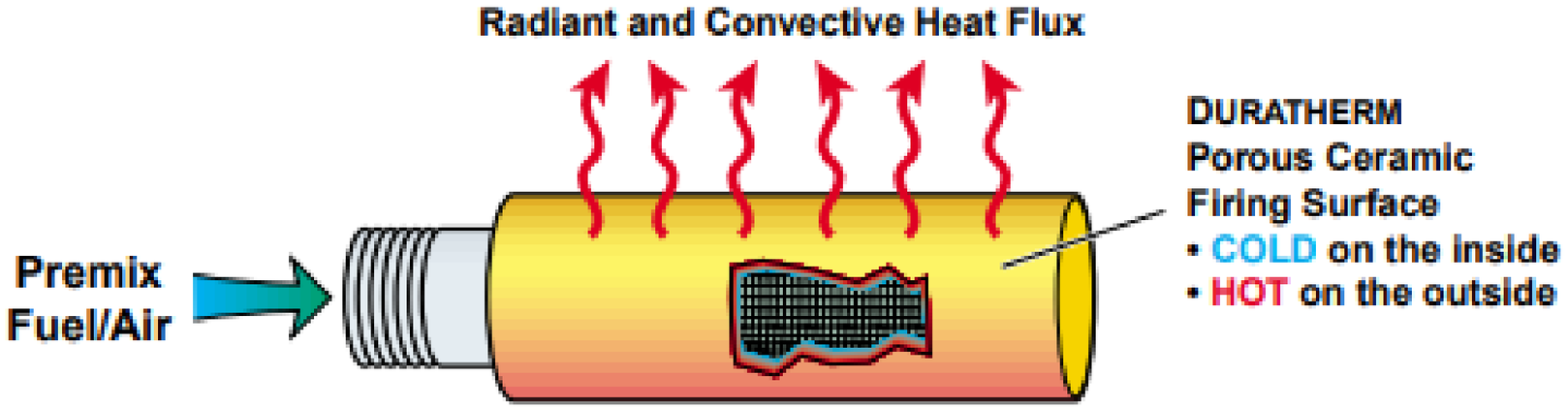
Source: SBR-5 Boiler Burner | Cleaver-Brooks (cleaverbrooks.com)

Technology Findings- CIB Unigas

- ULN burner design in development
- Testing hydrogen with their ULN burners up to 100% in laboratory setting
- Entered CA marketplace early 2023

Technology Findings- ALZETA

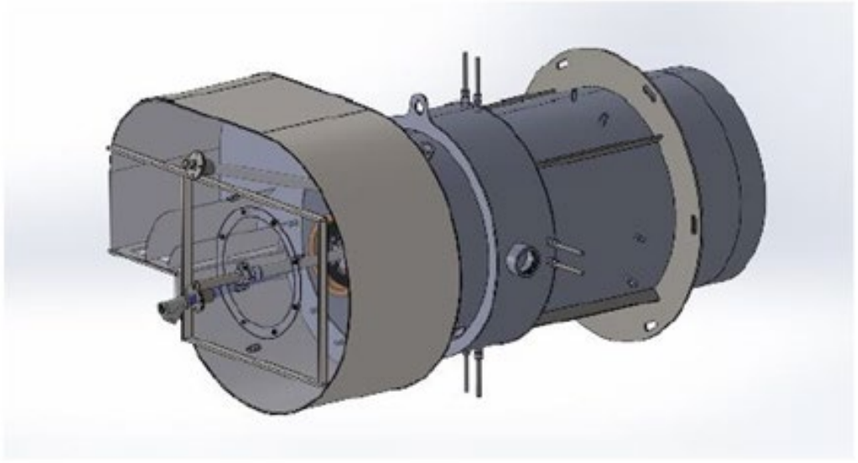
- ALZETA® CSB™
- Duratherm™
- ALZETA® nanoSTAR™

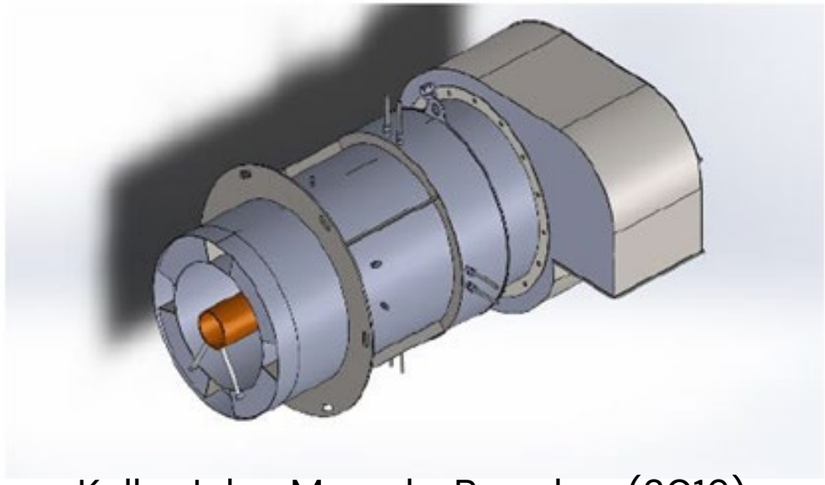


DuraTherm (alzeta.com)

Technology Findings – Altex Technologies Corporation

- Near-Zero NOx Burner (NZNB)
  - Post-combustion NOx reduction

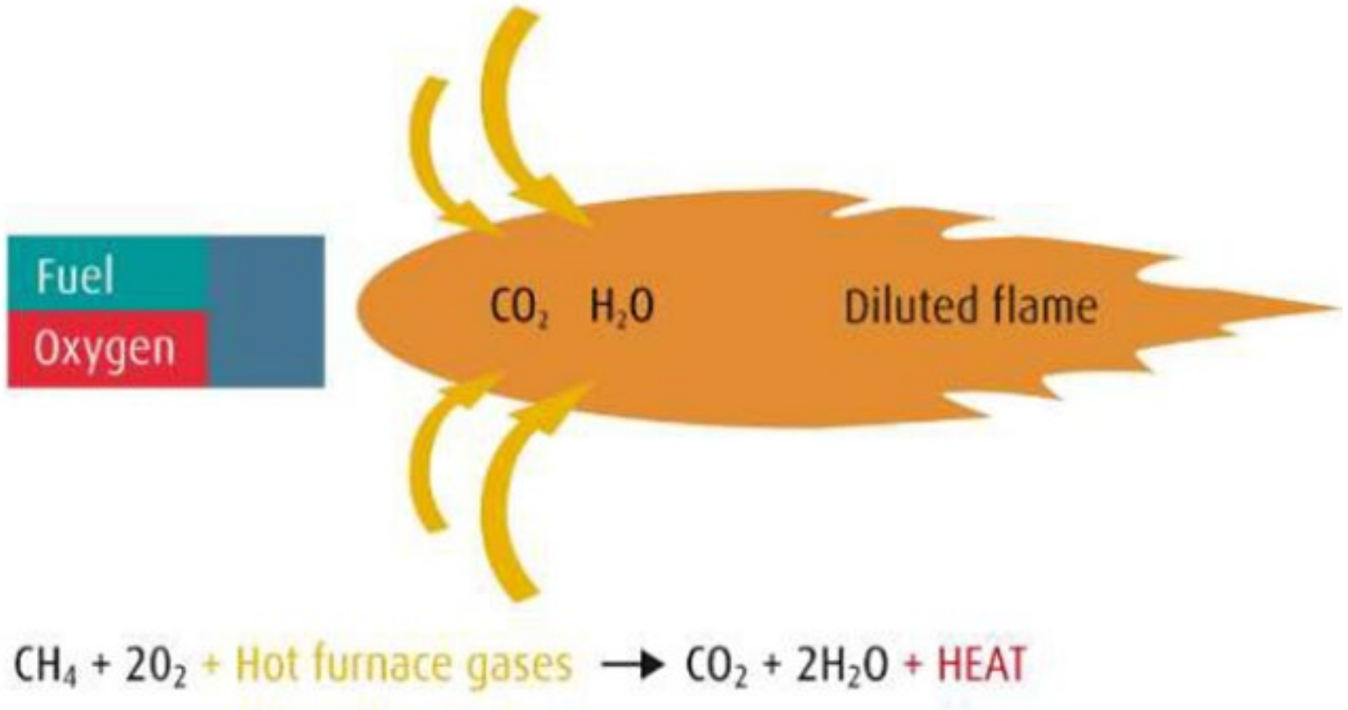




Kelly, John. Masuda, Brandon. (2016). California Energy Commission. *Near-Zero NOx Burner*. Publication number: CEC-500-2018-016

Technology Findings – Linde Technologies

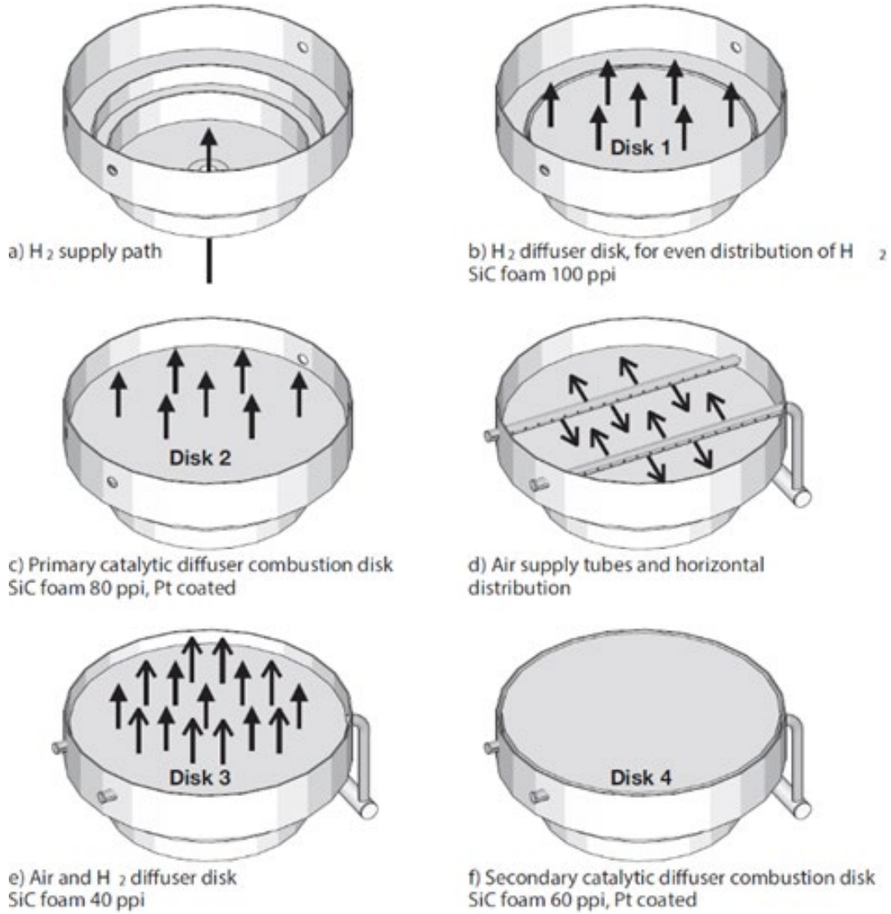
Flameless Oxyfuel Burner



Von Scheele, J. Carlsson, A. Jonsson, M. et al. (2022). Linde Technology. *New Oxyfuel Technology for Energy-efficient and Ultra-low NOx Annealing of Steel*

Technology Findings – Swiss Federal Laboratory for Materials Science and Technology

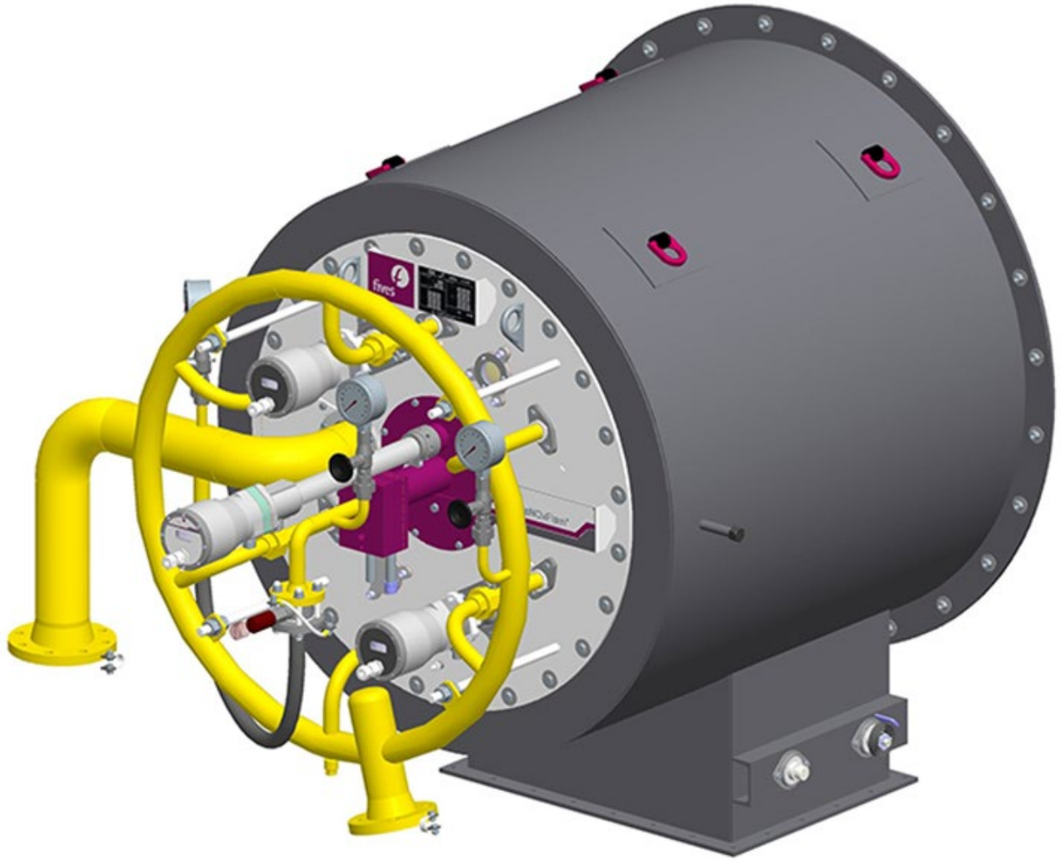
- Catalytic Hydrogen Combustion Burner



Fumey, B. Buetler, T. Vogt, U.F. (2018). Applied Energy. 334-342. *Ultra-low NOx emissions from catalytic hydrogen combustion*

Technology Findings- Fives Group

- Pillard NANOxFLAM® Burner
- Recognized by European Union as a Best Available Technique for preventing and minimizing NOx emissions



"Pillard NANOxFLAM® Boiler Burners." *Fives Group*, www.fivesgroup.com/energy-combustion/burners-systems/pillard-nanoxflam

Technology Findings – John Zink Hamworthy Combustion

- COOLstar® Burner
- SOLEX™ Burner
- Rapid Mix Burner (RMB™)

SOLEX Burner-5 Ppm NOx Performance. John Zink Hamworthy Combustion, 2018.

Technology Finding –Summary

Burner Name	Organization	NOx	CO	BTU Firing Range	FGR Present	Technology Description	Applications
Catalytic Hydrogen Burner	Swiss Federal Laboratory for Materials Science and Technology	<9.49 ppm <0.38 ppm at 33% H2	0 ppm	n/a	No	Catalytic oxidation process involving Pt coated porous SiC foams with non-premixing hydrogen and air	Residential and commercial cooking appliances
ClearSign Core™ Boiler Burners	ClearSign[1]	<2.5 ppm	<50 ppm	4-100 MMBtu/hr	Internal FGR	Combination of air fuel premixing, internal FGR, patented distil flame holder technology	Firetube boilers
ClearSign Core™ Flare Burner	ClearSign	<15 ppm	<15 ppm	1-30 MMBtu/hr	Internal FGR	Combination of air fuel premixing, internal FGR, patented distil flame holder technology	Digestor gas, landfill gas, thermal oxidizers, vapor combustors, water treatment plants, coker heaters

Technology Finding –Summary

Burner Name	Organization	NOx	CO	BTU Firing Range	FGR Present	Technology Description	Applications
ClearSign Core™ Process Burner	ClearSign	<5 ppm	<50 ppm	20 MMBtu/hr (Natural Draft Operation)	Internal FGR	Combination of air fuel premixing, internal FGR, patented distil flame holder technology	Vertical cylindrical canned heaters, cabin heaters, steam generators, steam methane reformer heaters, ethylene cracking furnaces
COOLstar®	John Zink Hamworthy Combustion®	<15 ppm	n/a	1.7-20 MMBtu/hr	Yes	Proprietary flue-gas entrainment and mixing technology	Large industrial processes such as coker heaters, horizontally fired platformers, crude and vacuum heaters, down fired methanol, ammonia, hydrogen reformers, ethylene cracking furnaces, hot oil heaters, charge heaters, and reboilers
CSB™	ALZETA®	<7 ppm	n/a	2 – 65 MMBtu/hr firetube boiler Up to 125 MMBtu/hr watertube boiler	FGR optional	metal-fiber burner, patented premixed surface-stabilized combustion process	Commercial and industrial boilers and process heaters

Technology Finding –Summary

Burner Name	Organization	NOx	CO	BTU Firing Range	FGR Present	Technology Description	Applications
Duratherm™	ALZETA®	<7 ppm	n/a	16 MMBtu/hr	n/a	Ceramic-fiber burner, premixed surface-stabilized combustion process using patented PYROCORE® technology	Residential and commercial heaters and boiler applications. Air heaters, furnaces, commercial cooking equipment
Firetube Boiler Burner	Rogue Combustion[1]	<2.5 ppm	<50 ppm	4-100 MMBtu/hr	Internal FGR	Combination of air fuel premixing, internal FGR, patented distil flame holder technology	Firetube boilers
Flameless Oxyfuel Combustion Burner	Linde Technologies	<9 ppm	n/a	n/a	FGR present	Flameless oxyfuel technology which replaces nitrogen in air with pure oxygen to boost efficiency	most types of furnace applications, but most notably steel reheating furnaces

Technology Finding –Summary

Burner Name	Organization	NOx	CO	BTU Firing Range	FGR Present	Technology Description	Applications
IWFC Low NOx burners	Micron Fiber-Tech	<9 ppm (standard) <5 ppm options available for certain applications	Near zero	16 MMBtu/hr	n/a	Proprietary metal fiber technology. Compact flame with stainless steel shell	Immersion Tube heating, direct air heaters, steam boiler heating, water heating
Low Swirl Burner	LBNL	<9 ppm	<50 ppm	4-60 MMBTu/hr	No FGR	Air swirler, premixed fuel	Boilers for wastewater treatment, IR heating, on-demand water heaters
nanoSTAR™	ALZETA®	<3 ppm	n/a	60 MMBtu/hr	n/a	Premixed, surface-stabilized combustion process	Industrial gas turbines for mechanical drive and power generation applications

Technology Finding –Summary

Burner Name	Organization	NOx	CO	BTU Firing Range	FGR Present	Technology Description	Applications
NP2 burner	Powerflame Incorporated	<9 ppm	Low CO	700-6,100 MBtu/hr	No FGR	A patented premixed surface stabilized combustion all-metal firing head technology	Process heating in hospitals, furnaces, boilers, ovens, bath vaporizers for LNG conversion, autoclave ovens, distillery/brewery
NVC Burner	Powerflame Incorporated	<9 ppm	<50 ppm	2-64 MBtu/hr	No FGR	A patented premixed surface stabilized combustion all-metal firing head technology	Wide variety of commercial, industrial, process applications
NZNB Burner	Altex Technologies Corporation	<5.7 ppm	<50ppm	3.1-6.9 MMBtu/hr	FGR present	Patented multi flame zone technology with post-combustion Nox reduction process	Firetube boilers, commercial boilers, water heaters, process heaters

Technology Finding –Summary

Burner Name	Organization	NOx	CO	BTU Firing Range	FGR Present	Technology Description	Applications
Oxy-Therm® burner	Honeywell	<9 ppm	n/a	1-24 MBtu/hr	No FGR	Patented staged oxygen design. No excess O2 required for complete combustion	High temperature applications like furnaces, glass furnaces, day tanks, incinerators, metal-heating furnaces, linear and rotary hearth furnaces, reheat furnaces
Pillard NANOxFLAM®	Fives Group	<9 ppm	<10 ppm	5-60 MW (17MBtu/hr-54MBtu/hr)	FGR Present	Patented premix technology	Firetube boilers and water tube boilers, as well as single burner and multi-burner applications.
Ring Stabilizer Burner	LBNL	<9 ppm	n/a	scalable	No FGR	Premixed air and fuel at low velocities, natural draft	Residential and commercial cooking equipment

Technology Finding –Summary

Burner Name	Organization	NOx	CO	BTU Firing Range	FGR Present	Technology Description	Applications
RMB™	John Zink Hamworthy Combustion®	<9 ppm	<25 ppm	Up to 300 MMBtu/hr	FGR Present	Rapid premixing system of air and fuel with proprietary burner geometry	Boilers, retrofits, refractory-lined furnaces for dryers, or fluid bed boiler-warm up applications
SBR-5 ULN burner	Cleaver Brooks	<5 ppm	n/a	10.5-42 MMBtu/hr	FGR present	Unique firing head to achieve controlled combustion	Firetube and water tube boilers, Process steam heating, industrial process heating, waste heat recovery, hospital space heating, laundry and dry cleaning, refinery, petrochemical applications
SOLEX™	John Zink Hamworthy Combustion®	<5 ppm	Near zero	1 MMBtu/hr-20MMBtu/hr	No FGR	Patent pending AIRmix™ technology and COOLmix™ technology	Variety of applications including upfired down fired, or horizontally fired applications

Technology Finding –Summary

Burner Name	Organization	NOx	CO	BTU Firing Range	FGR Present	Technology Description	Applications
Super Low NOx Series (10 MW N1060V)	CIB Unigas	<9 ppm Still undergoing testing	n/a	n/a	FGR Present	Staged combustion and FGR technology	boilers
Tube Burners	Micron Fiber-Tech	<9 ppm	n/a	100 MMBtu/hr	n/a	Proprietary metal fiber technology	Dryers, coffee roasters, Food service, ovens, industrial furnaces, paint (powder) curing, sugar condenser, outdoor IR heating
Ultra CMAX Ultra-Low NOx burner	Powerflame Incorporated	<9 ppm	<50 ppm	700-6,100 MBtu/hr	Yes	Premixed firing head and reduced blower power	Firetube boilers, Process heating in hospitals, furnaces, boilers, ovens, bath vaporizers for LNG conversion, autoclave ovens, distillery/brewery
Unreleased model (as of July 2023)	Vitotherm	<5 ppm	0 ppm	2-34 MMBtu/hr	n/a	n/a	Greenhouse applications, indoor applications

Hydrogen Blending and ULN Burner

Hydrogen Blending and ULN Burners

Burner Name	Organization	Hydrogen Blends tested	NOx
Low Swirl Burner	LBNL	100%	<9ppm
ClearSign Core™ Boiler Burners	ClearSign[1]	80%	<2.5ppm
Firetube Boiler Burner	Rogue Combustion[1]	80%	<2.5ppm
ClearSign Core™ Process Burner	ClearSign	100%	<5ppm
Ultra CMAX Ultra-Low NOx burner	Powerflame Incorporated	30%	<9ppm
ULN burner pending release by the end of 2023	Vitotherm	25%	<5ppm
Super Low NOx Series (10 MW N1060V)	CIB Unigas	75% (field) 100% (lab)	The exact number is unclear due to ongoing testing; however, representatives claim ULN levels.
Oxy-Therm FHR Burner	Honeywell	20%	<9ppm
COOLstar® burner	John Zink Hamworthy Combustion	100%	<15ppm
Flameless Oxyfuel Combustion Burner	Linde Technologies	100%	<9ppm
Catalytic Hydrogen Burner	Swiss Federal Laboratory for Materials Science and Technology	66%H2 *this is a H2-O2 ratio, this burner does not use natural gas.	<9.49ppm <0.38ppm at 33%H2

Conclusion

Conclusion

- **Total of 25 ULN Burner Models Identified**
- This study concluded that most ULN burners are easily able to be retrofitted into current heating systems such as boilers and furnaces without having to replace the entire unit.
- Since most ULN burners are smaller and compact, without the need for expensive add-ons like SCR which occupy additional space, manufacturers claim that operating costs are less compared to older low NOx burners, and size isn't usually concern for retrofits
- Most ULN technologies include some form of premixed air and fuel
- 11 ULN Burner models have been tested with hydrogen blends ranging from 20-100%
- Barriers:
  - Manufacturers have sited regulatory challenges, brand recognition, difficulty obtaining permits, lack of local representation as barriers to implementing their technology.

Recommendation

Project Recommendations

- Further cost analysis to quantify the benefits of ULN burner retrofits is recommended to further encourage its adoption.
- The study also recommends further testing of hydrogen blends with ULN burners in different equipment to further demonstrate how newer ULN burners perform in older equipment

→ Q&A

Next Event:

Topic: Annual Research Plan Update

When: December 5, 2023 1:00–2:00 PM PDT

Invitation to be sent soon

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