



The Clear Path to Ultra Low NO_x Reduction

Cost-Effective Solutions for Refineries and Process Heaters

Jeff Lewallen and Matt Martin

Webinar

Tulsa, OK

28 October 2025

Company Overview

- Leading producer of cost effective, ultra low emission combustion products
- Offices in:
 - Tulsa, OK (Headquarters)
 - Seattle, WA
- Technologies provided with the support of our OEM partners
 - Boiler Burner = Rogue Combustion
 - Process Burner = Zeeco
- ClearSign Eye™ Sensor
- Publicly Traded NASDAQ: CLIR



ClearSign Zeeco Partnership



Bringing Revolutionary Process Technology to the Global Market

Zeeco and ClearSign Technologies Corporation are achieving industry-leading NO_x emissions reductions with their co-branded line of process burners. With the ability to fire conventional refinery fuels and hydrogen, this line of burners achieves sub 5 ppm NO_x emissions, meeting some of the world's most stringent emissions regulations.

[READ THE PRESS RELEASE](#)

ZEECO® CS5 Burner

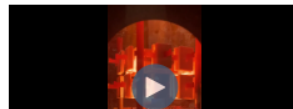
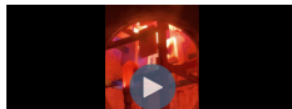
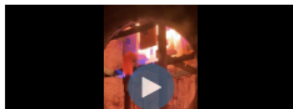
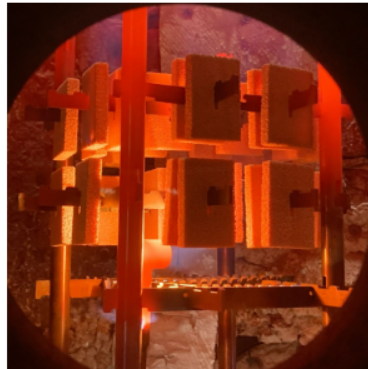
Powered by ClearSign Core™ Technology, the ZEECO CS5 burner is an unparalleled solution for achieving selective catalytic reduction (SCR) level emissions at a fraction of the cost. With its compact flame, reduced operating expenses, and large fuel ports, the ZEECO CS5 delivers optional NO_x reduction without the need for additional SCR equipment.

ZEECO Hydrogen CS5 Burner

Also powered by ClearSign Core Technology, the ZEECO Hydrogen CS5 burner can operate on 100% hydrogen, 100% natural gas, and offers seamless compatibility with any blend of refinery fuels. This innovative burner design also achieves sub 5 ppm NO_x emissions, paving the way for cleaner, more efficient combustion across a variety of fuel types.

Benefits of the CS5 and Hydrogen CS5 Burners:

- Sub 5 ppm NO_x emissions
- Fires 100% H₂, 100% natural gas, and a variety of fuel blends
- Forced and natural draft options
- Meet strict emissions regulations
 - BACT in California
 - Emissions Reduction Credits in Texas
- Simple retrofit capabilities



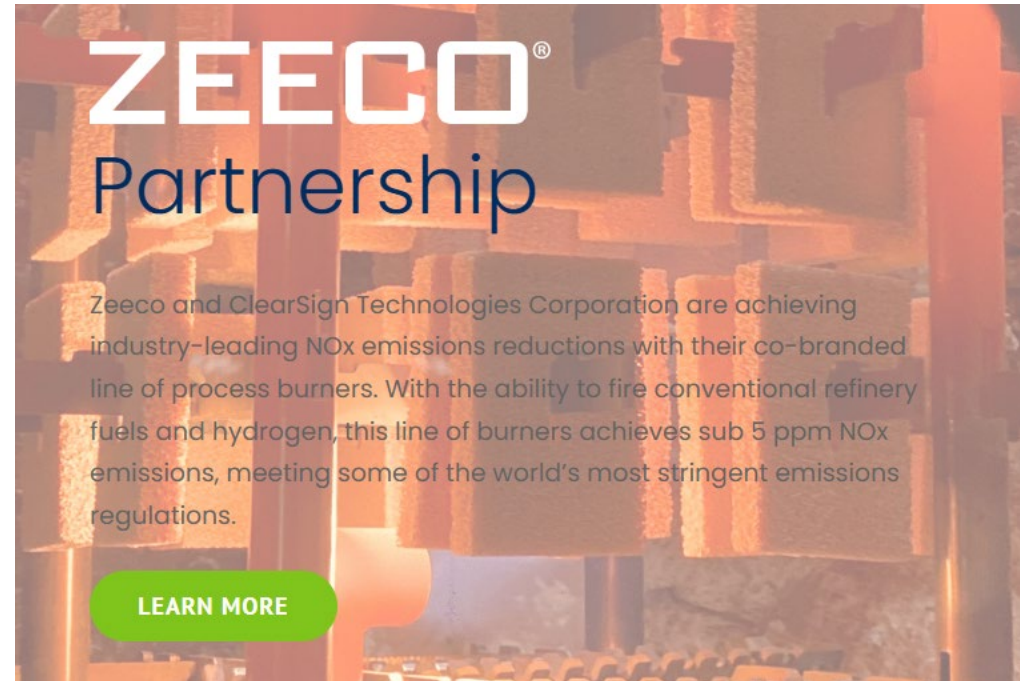
ZEECO WOULD LIKE TO CONTACT YOU ABOUT THE LATEST DEVELOPMENTS IN COMBUSTION TECHNOLOGY. PLEASE INDICATE WHETHER YOU WOULD LIKE TO HEAR FROM US IN THE CHECKBOXES BELOW. [CLICK TO VIEW OUR PRIVACY POLICY.*](#)

☐ I WANT TO RECEIVE MARKETING COMMUNICATIONS FROM ZEECO.

☐ I DO NOT WANT TO MARKETING RECEIVE COMMUNICATIONS FROM ZEECO.

[SUBMIT](#)

- Press Release Announcement of Co-Branded Burner Line December 2024
- Co-Branded Landing Page Launched March 2025



Co-Branded Landing Page

CLIR Website Feature

Available Burner Products



Process Burner

- Single or multi-burner heaters
- NOx Emissions from 5-15ppm
- Nat Gas, RFG, 100% H2
- 1-20 MM BTU/hr per burner
- Upfired orientation
- Natural or forced draft

Forced Draft (Boiler) Burner

- Horizontally fired, forced draft
- Boilers and similar equipment
- NOx emissions as low as sub 2.5ppm
- Nat Gas proven, other fuels tested
- 1 – 100 MM BTU/hr

Enclosed Flare/Combustor

- Upfired, natural or forced draft
- Regular services only
- 0.5-40+ MM BTU/hr
- Sub 15ppm NOx emissions
- 99.9%+ DRE
- No visible pollution – light, smoke, etc.

NOx emissions vary by product and service but in all instances offer industry leading performance with potential additional benefits

ClearSign Core Technology

Three technologies combined to achieve superior NOx performance.

- Fuel air premix
- Internal flue gas entrainment
- Downstream flame holder

ClearSign Core burners operate like conventional burners and fit into existing equipment

NOx emissions as low as sub 2.5 ppm have been achieved in field installations

No catalysts or chemicals



**Doesn't merely treat emissions –
reduces their creation in the first place**

Expanding Global Installation Base



31 installations (50 burners)
15 installations in progress (57 burners)
2 BACT projects

Who Needs Low NO_x?

- California: 2 – 9 ppm
- Alberta: 5 – 9 ppm
- Texas: 1.3:1 - New Capacity
- USA: Up to 1.5:1 - New Capacity

New Capacity Additions – Highest Profitability



Why Prefer a Combustion Solution?

- Selective Catalytic Reduction (SCR) is effective
 - 90-95% effective
 - New burners still required
 - Retrofits are expensive
 - Ammonia handling introduced
- Burners only
 - Lower capital cost
 - Lower operational cost



Air Permit Compliance Required for Continued Operations

Cost-Effective Solution - Process Burners



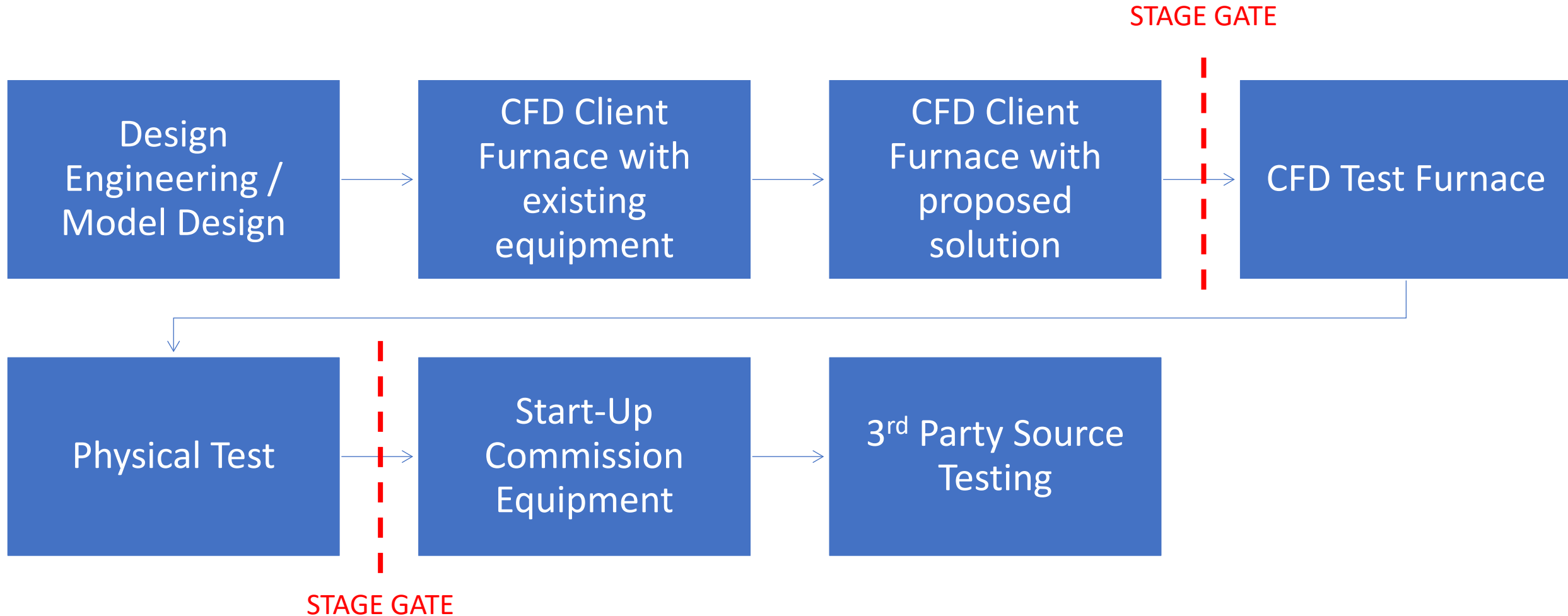
Infrastructure Client Los Angeles, CA

- Small process heater
- Original NOx = 30 ppm
- New permit NOx requirement = 7ppm

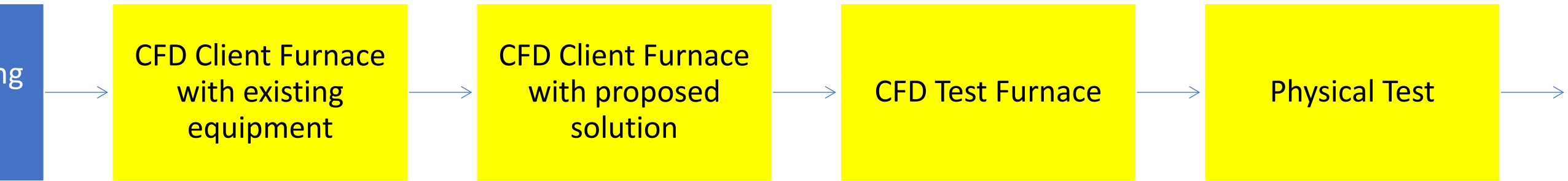
Economics	CLIR (Pre-combustion tech)	SCR (Incumbent, post- combustion tech)
NOx, ppm	6	5
Capital Cost	\$450,000	\$2,200,000
5 Yr Operating Cost	\$25,000	\$500,000
Total Cost	\$475,000	\$2,700,000
Cost Ratio	1.0	5.7

Provides a cost-effective solution versus additional cap-ex and op-ex costs associated with existing methods

Project Timeline

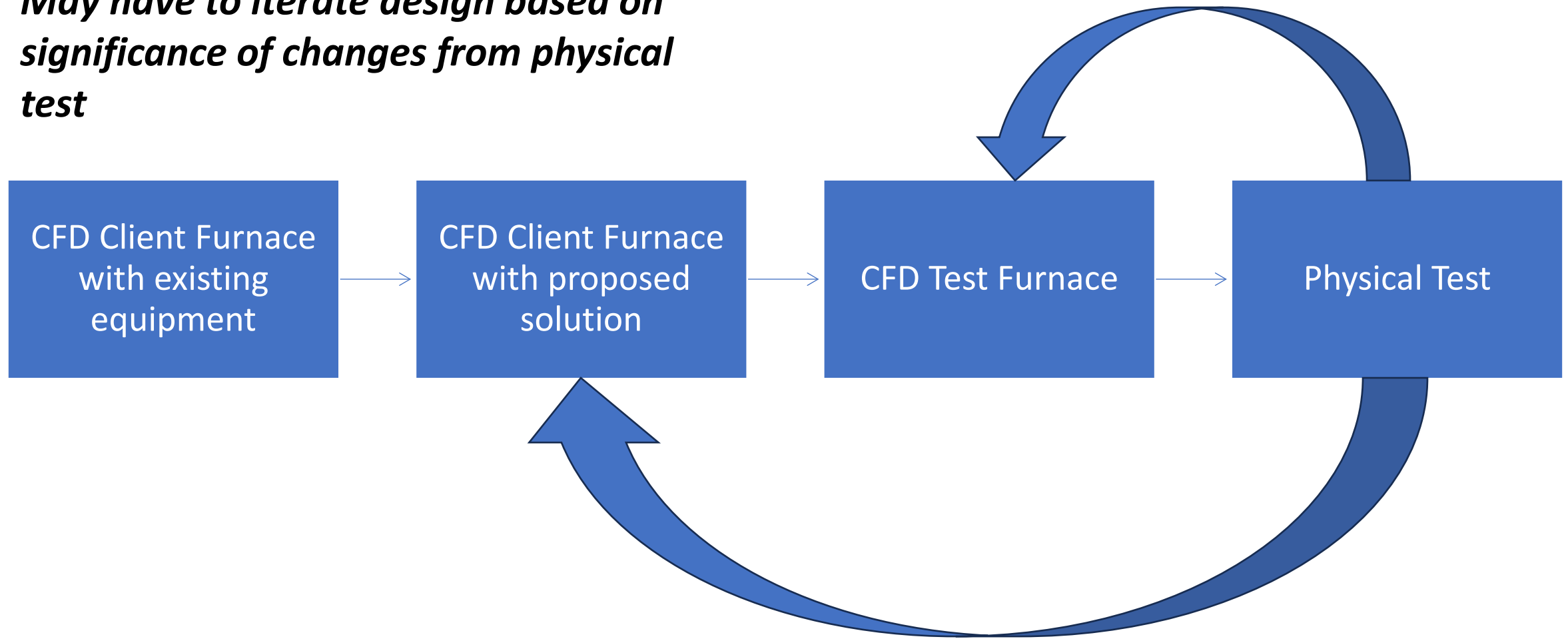


Project Timeline – Design Validation



Project Timeline – Design Validation

May have to iterate design based on significance of changes from physical test



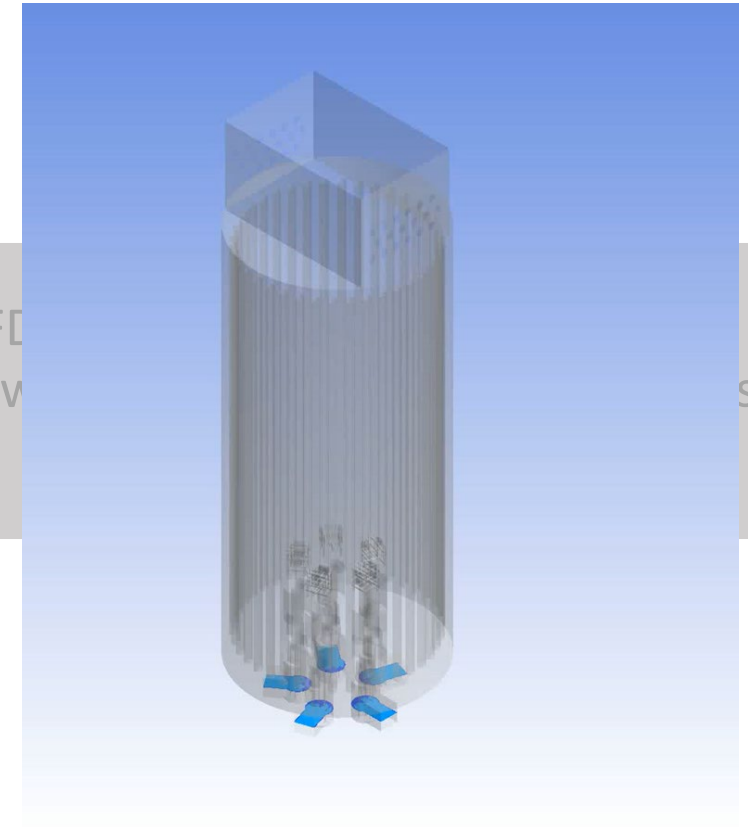
Project Timeline – CFD Client Furnace (existing)

(OPTIONAL STEP)

However, this step can:

- Identify existing issues
- Establish a quantitative basis for comparison to the proposed solution
- Field data for comparison may be hard to obtain

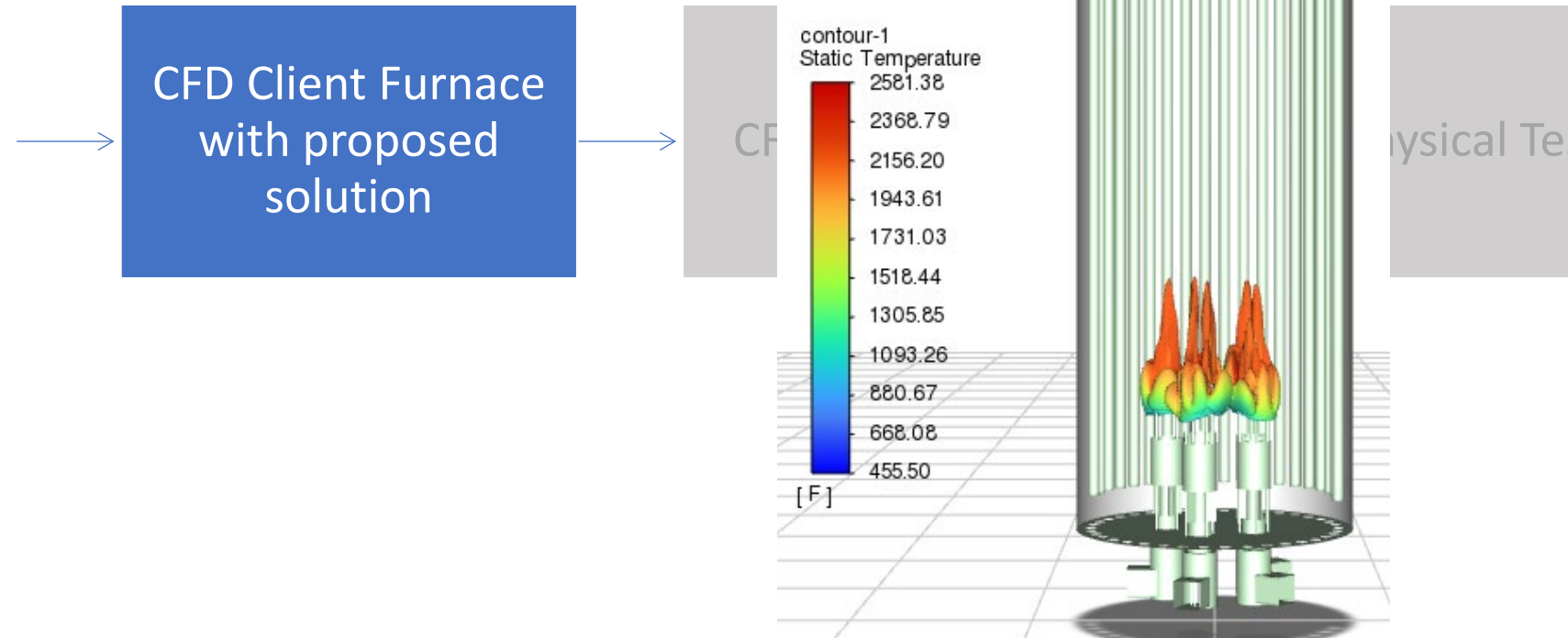
CFD Client Furnace
with existing
equipment



Project Timeline – CFD Client Furnace w/ Solution

CFD of Client Furnace Evaluates

- Tube Metal Temperatures (TMT)
 - Radiant Tubes
 - Shock Tubes
- Flame Impingement
- Heat Flux Profile
- Radiant Efficiency
- Emissions
 - NO_x
 - CO
- Flame Envelope
 - Length
 - Diameter



Project Timeline – CFD of Test Furnace

Differences in physical dimensions of test furnace and client furnace may impact test results on:

- Stability
- Emissions Performance
 - NO_x
 - CO
- Flame Dimensions
 - Diameter
 - Length
- Burner to Burner Interaction

CFD of Test Furnace allows for benchmarking against Physical Test results and ultimate comparison to Client Furnace



CFD Test Furnace



TEST
FURNACE



ACTUAL
FURNACE

Project Timeline – Physical Test

Physical testing collects data to compare to the Test Furnace CFD

- Flame Stability
- Flame Dimensions
- Emissions
 - NO_x
 - CO
- Operating Envelope

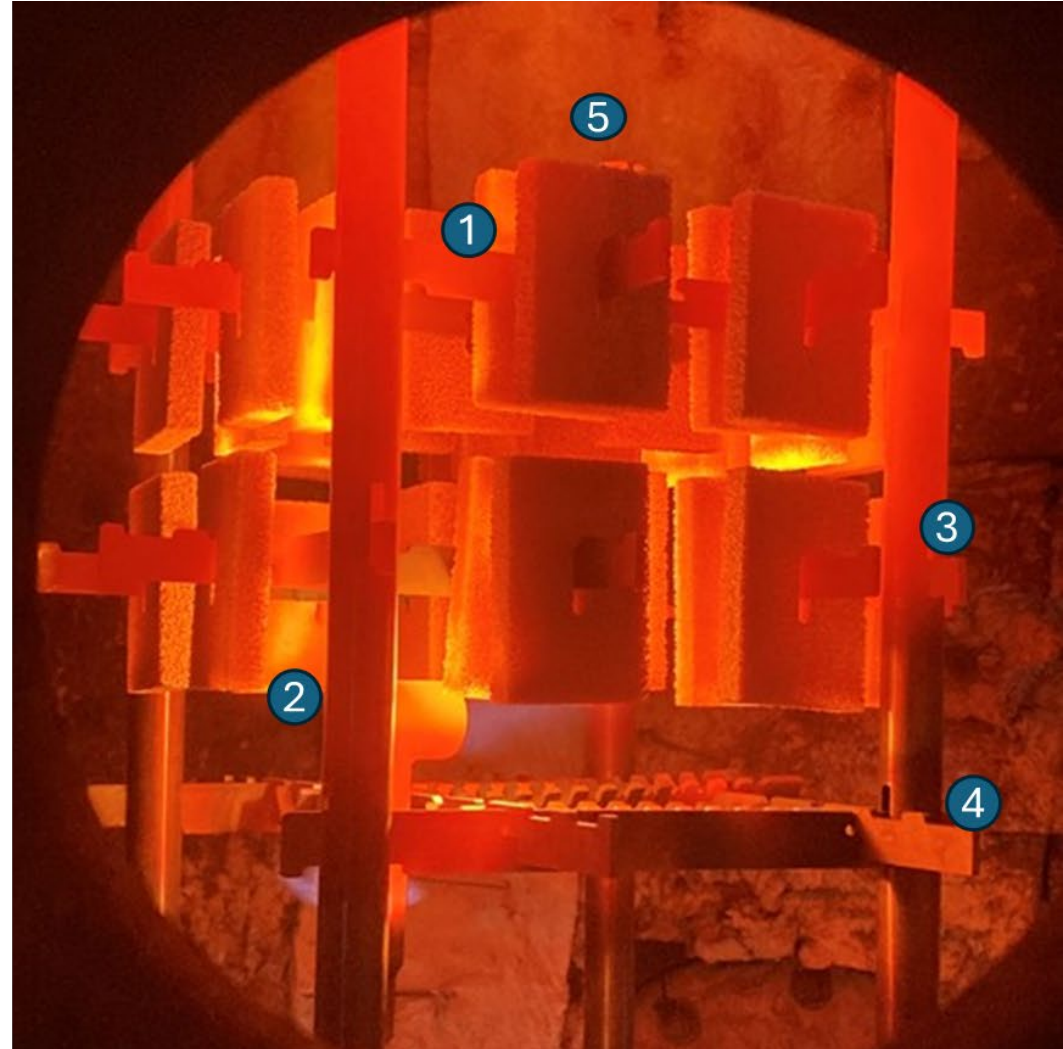
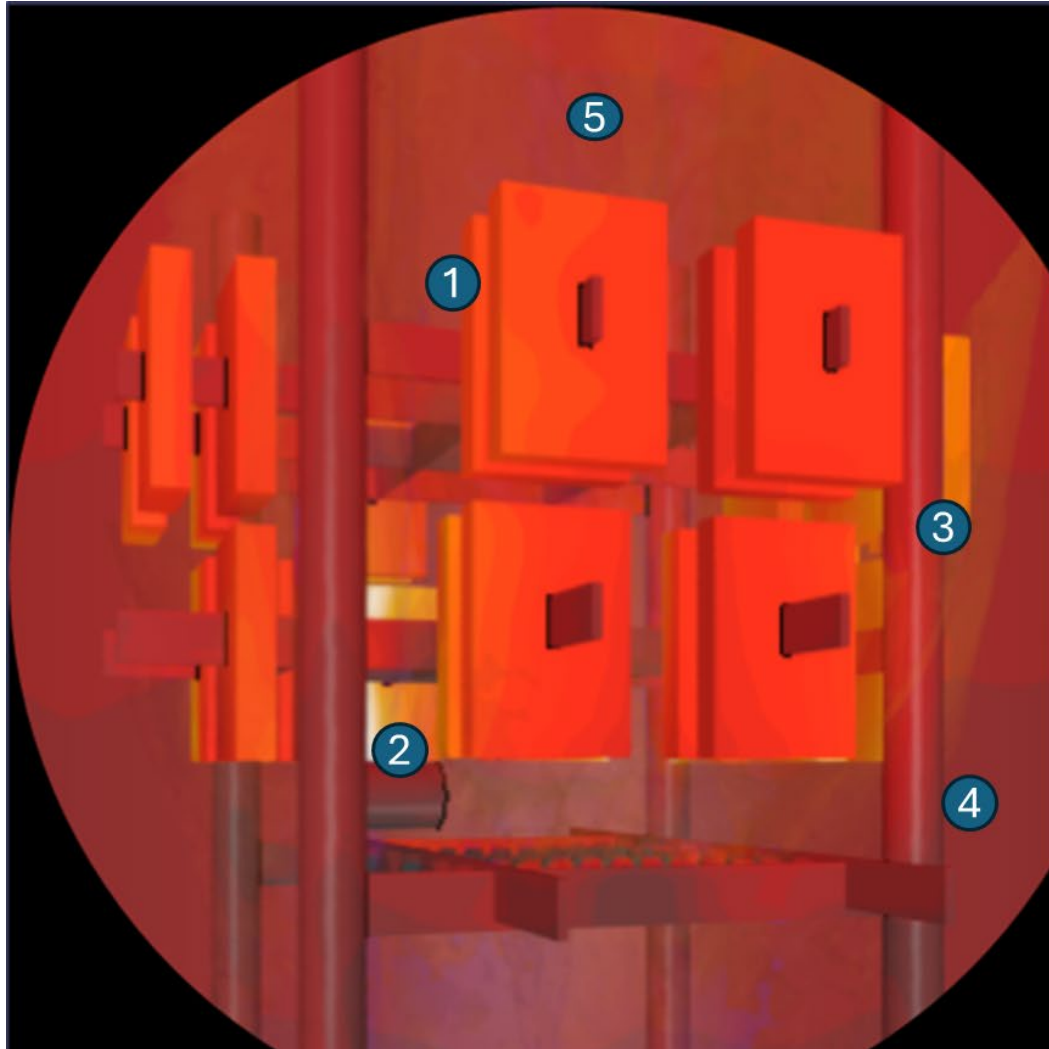


Physical Test

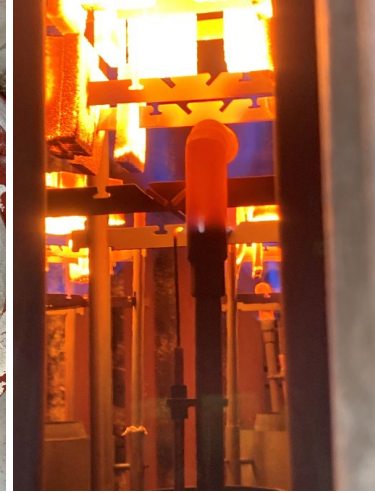
CO PROBE FOR
FLAME HEIGHT /
DIAMETER



Design Validation



Installations





Questions?