

Clearsign Ultra Low NOx Technology

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Agenda

- Applicability
- How it Works
- Claimed Benefits
- Installations in the San Joaquin Valley
- Reports so far
- What's next
- Questions/comments



Applicability

- Developed to
 - Reduce NOx emissions in external combustion devices
 - Improve combustion equipment fuel efficiency
 - Overall lower operational cost
- Uses to date in in Valley
 - Oilfield steam generators
 - Refinery process heaters
 - Enclosed flares

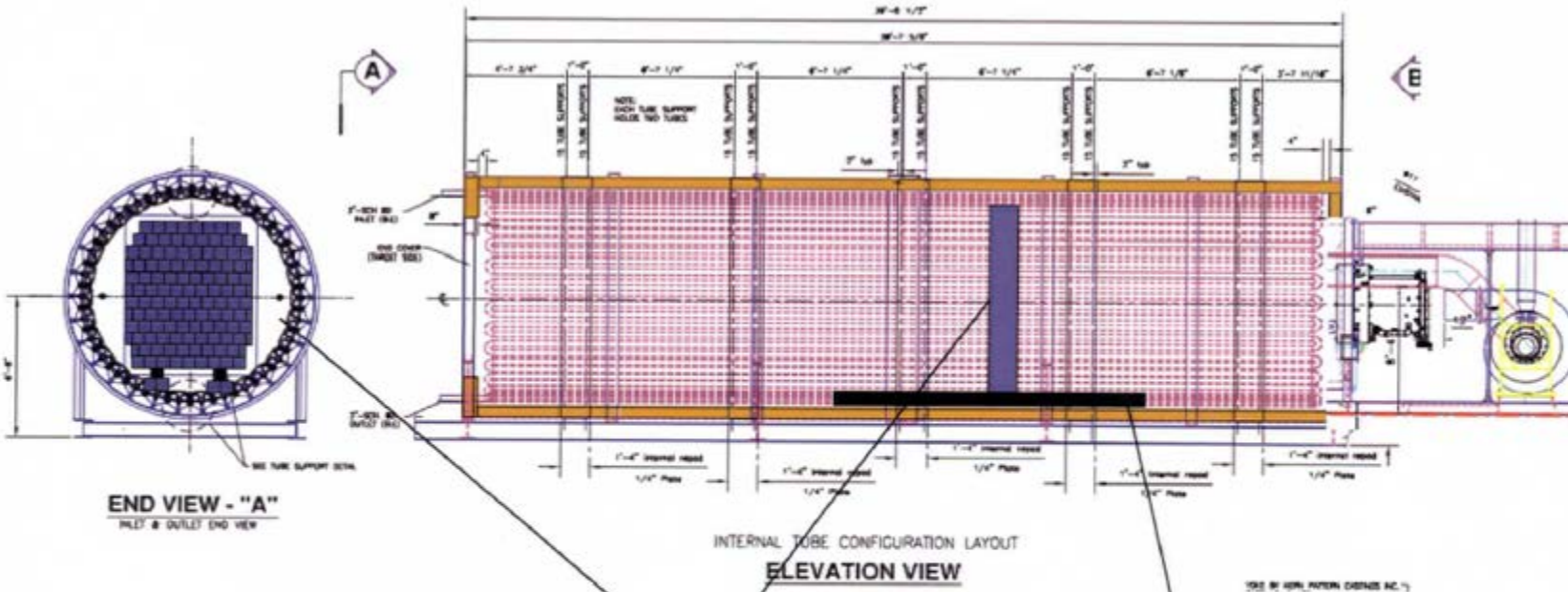


How It Works

- Porous ceramic body installed in the firebox downstream of the burner
- Burner ignited and ceramic body brought up to temperature
- Certain fuel ports closed
- Flame transitions from burner to ceramic body
- NOx emissions sub 5 ppmv @ 3% O₂

How It Works

oilfield steam generator



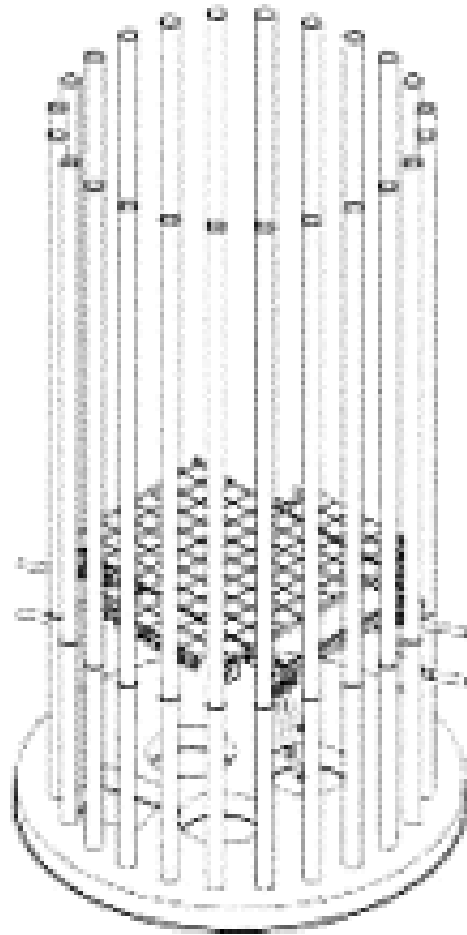
Duplex™ Tile

Rail System
(allows for adjustable Duplex position)



How It Works

refinery process heater



How it works

[Clearsign promotional video](#)



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Claimed Benefits

- No flue gas recirculation needed
- No complex air/fuel ratio controls needed
- Energy Savings
 - No need for larger combustion blower for FGR
 - Increased thermal efficiency due to no heating of flue
- Less costly than traditional ultra low NOx controls
- No data on costs though



Installations in SJ Valley

- Two small refinery heaters
 - One 15 MMBtu/hr heater
 - Working as intended but heater used very infrequently
 - NOx 6 ppmv @ 3% O₂
 - One 8 MMBtu/hr heater
 - Challenges with structural integrity
 - NOx 6 ppmv @ 3% O₂
 - Both fired on natural gas, not refinery fuel gas

Installations in SJ Valley

- Three 62.5 MMBtu/hr oilfield steam generators
 - Two natural gas fired units
 - Overcame problems with combustion stability
 - Ongoing challenges with structural integrity of duplex tile framework
 - Several design changes have improved durability, but challenges remain
 - Ongoing operation not yet sustainable
 - One natural gas/waste gas fired unit
 - Currently being installed
 - Required redesign of framework

Installations in SJ Valley

- Six enclosed flares
 - Oil production operation
 - Burning high Btu stranded gas
 - Proposed to be evaluated as a retrofit in existing low NOx “Coyote” flares
 - Expected NOx emissions ~ 6 ppmv @ 3% O₂
 - No operational/emission data available yet

Overall impressions

- Promising technology
- Simple design, no elaborate burner controls, no FGR required, no SCR
- Increased efficiency means can lead to lower fuel use
- Lower fuel use
 - Lower criteria emissions
 - Lower CO₂ emissions a benefit to operators subject to cap/trade

Overall impressions

However ...

- Ongoing challenges with structural integrity
- So far, technology is not sustainable for long periods of time
- Costs of technology unknown at this time
- Claimed 2 to 3 year payback when considering ALL operational costs (fuel use, NOx emissions, cap/trade requirements)
- More testing/demonstration needed before sustainability/durability is proven



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Comments/Questions



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