# Dynamically Controlling FGR Recirculation Rates with an In Situ Oxygen Analyzer

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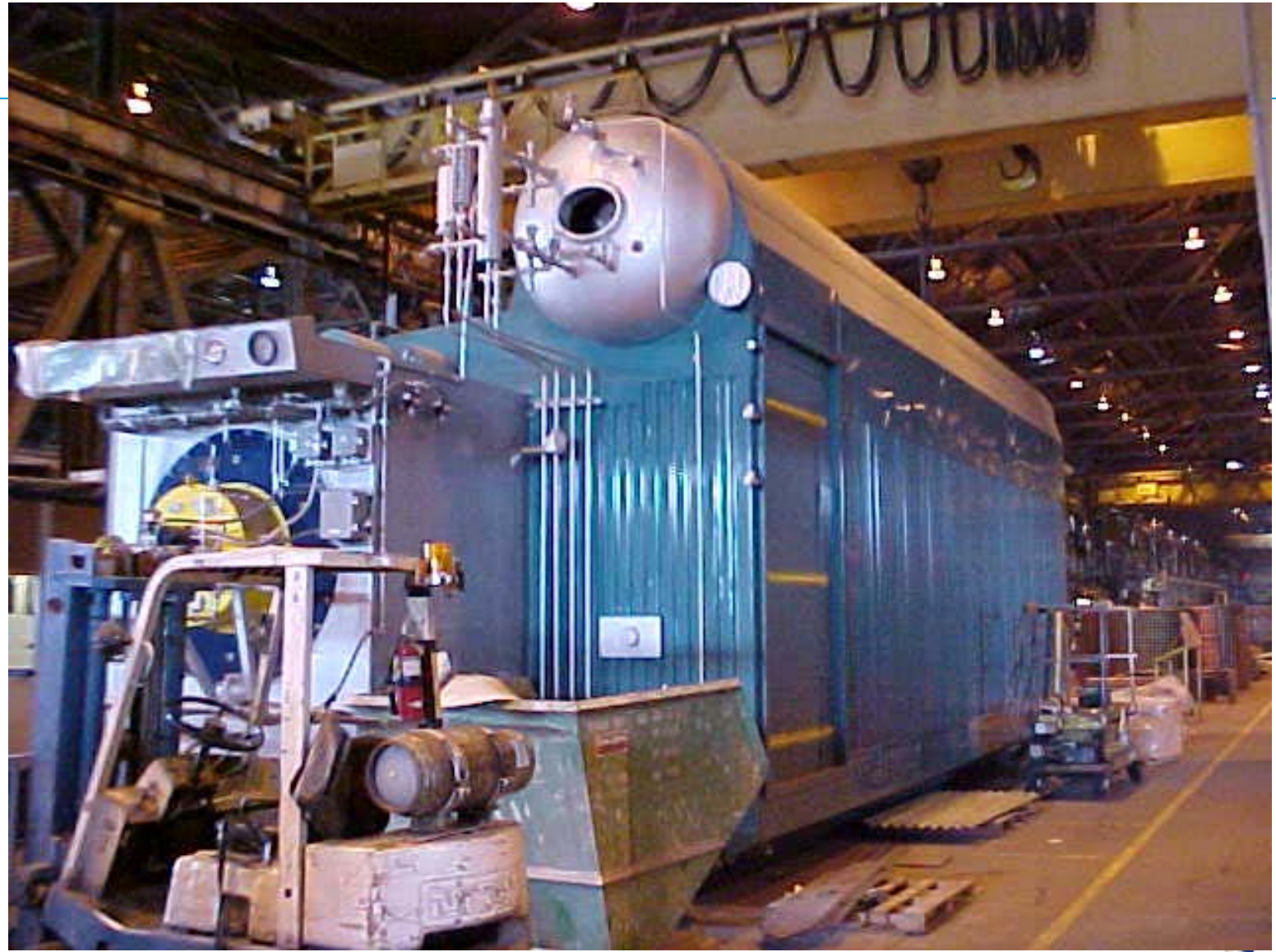

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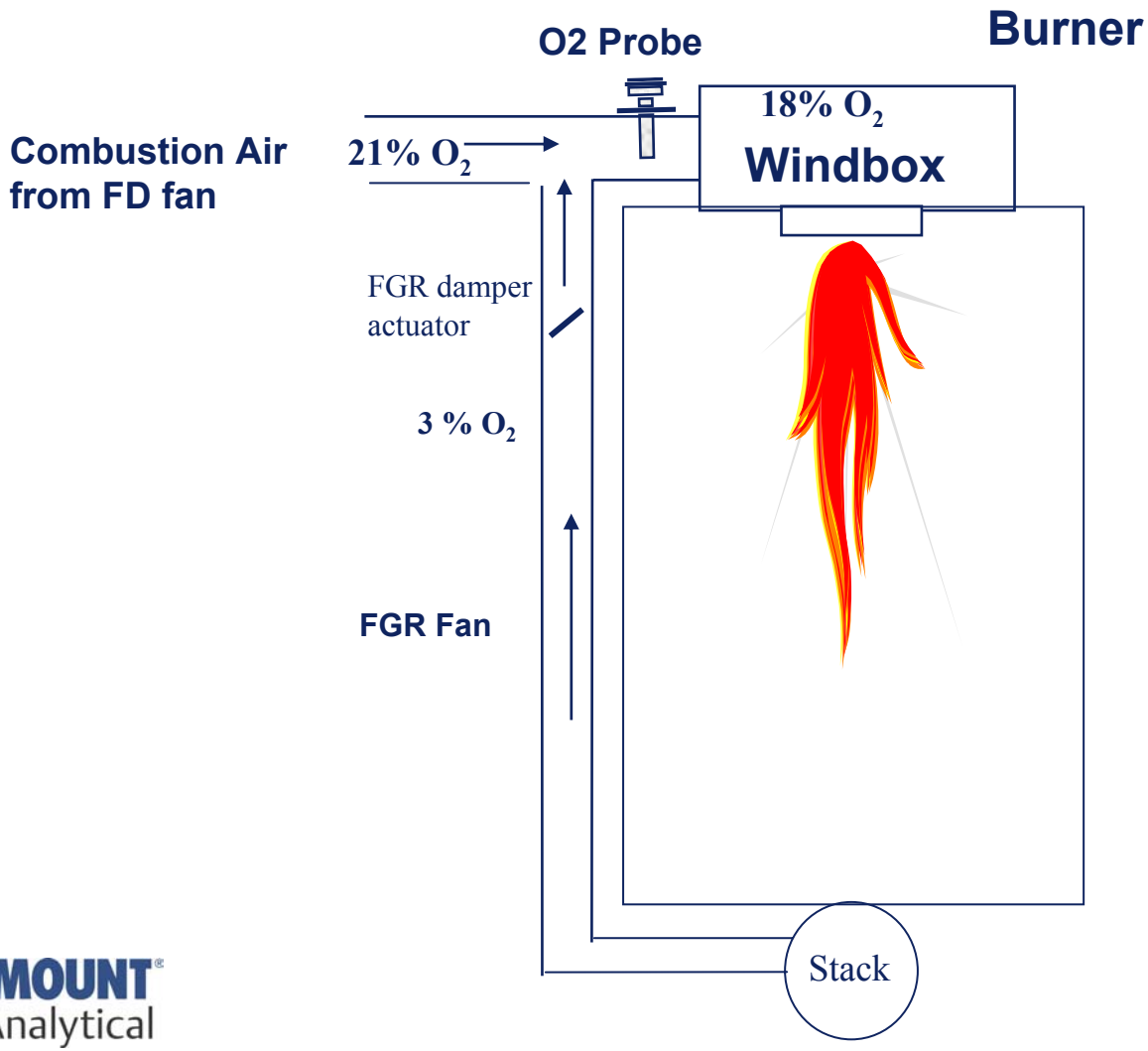
# Application

- Tertiary recovery of mature heavy oil formations thru steam flood injection
- NOx emissions on oil field steam generators are limited to 30 ppm by San Joaquin Valley Air Pollution Control District (SJVAPCD)
- External FGR has been the technology of choice for many steam generators
- Dynamically controlling final FGR rate at the burner windbox has proven to maintain the lowest NOx levels while maintaining good burner stability.

# Flue Gas Recirculation

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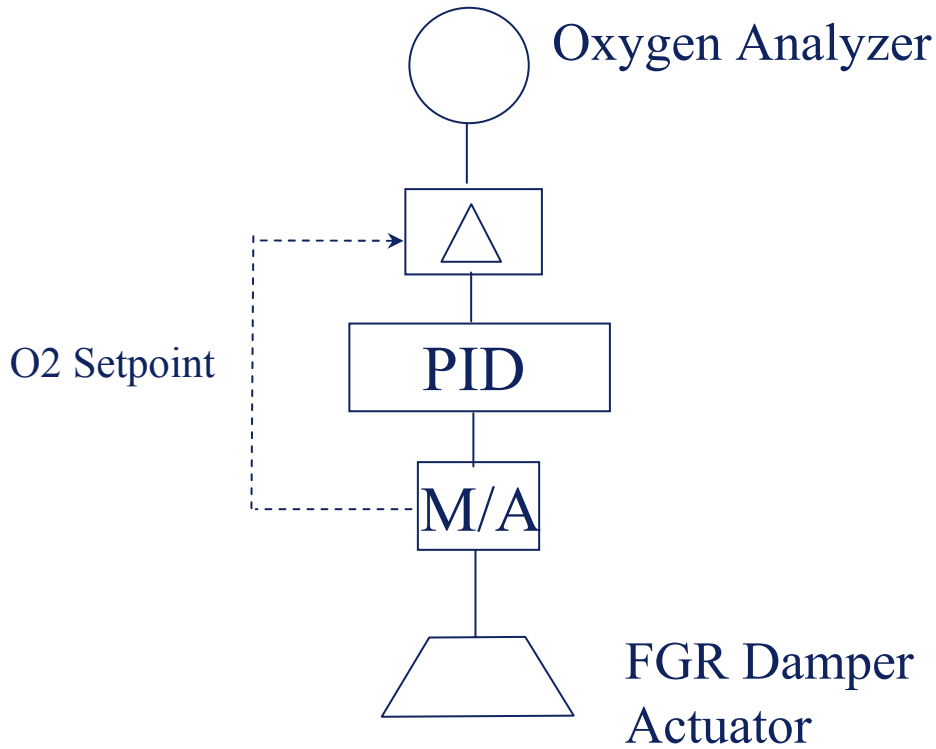
# Flue Gas Recirculation

## Control Logic

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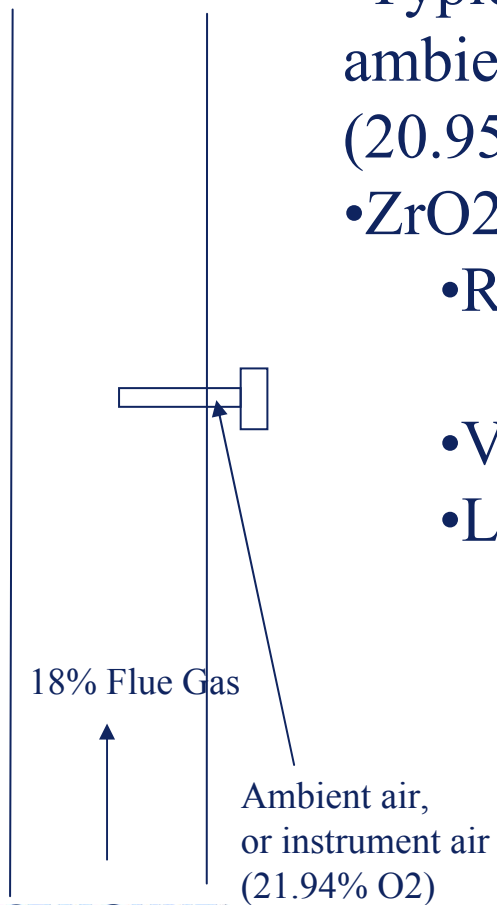
# Gaining greater sensitivity with the Zirconium Oxide O2 Analyzer




- Typical ZrO2 probe arrangement utilizes ambient air or instrument air inside the probe (20.95% O2) as a reference.
- ZrO2 sensing cell output is inverse, and logarithmic
  - Represented by the Nernst Equation

    **EMF = KT log10 (P1/P2) + C**
  - Very accurate at low levels of O2
  - Least accurate at ambient levels of O2

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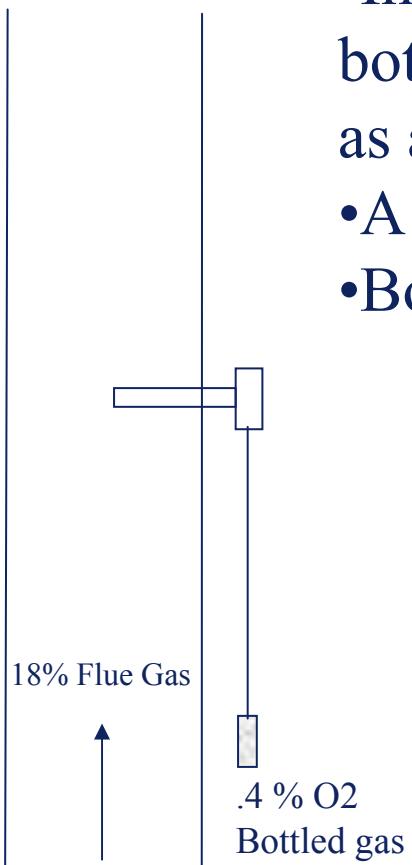


- Improved ZrO2 probe arrangement utilizes bottled gas inside the probe (.4% O2 (bal. N2) ) as a reference.
- A strong sensing signal results at near ambient levels
- Bottled reference is less variable
  - Constant moisture level
  - No oil or other contaminants
  - 2-3 months bottle life

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# Summary

- The amount of Flue gas required for recirculation will vary, depending upon
  - Changes in the density of combustion air
  - Firing rate of Steam generator
  - Changes in fuel BTU value
- Dynamic control of external FGR rates is required to meet NOx levels as established by SJVAPCD
- Design modifications to typical ZrO2 probe arrangement improve sensitivity at 18-20 % O2 levels.

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