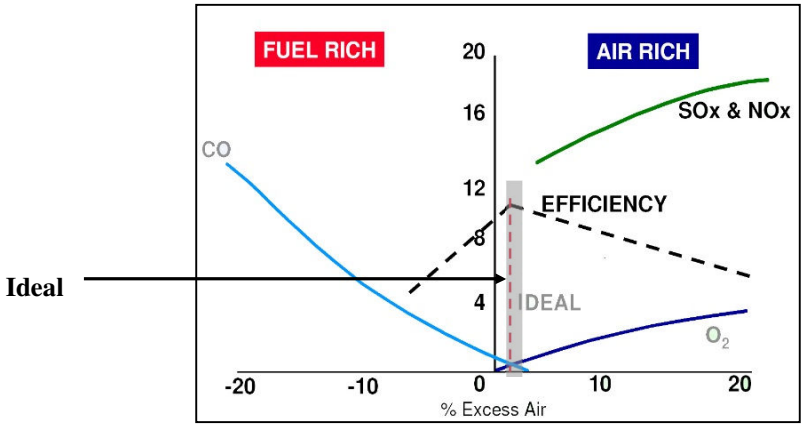
Why measure O2 ?

Why measure O2 may be rephrased as "Why increase combustion efficiency?"

- Combustion efficiency loss = heat loss + unburned fuel
- Combustion heat loss is the largest loss factor
- Heat loss is controlled by excess air and stack temperature
- Measure O2 to limit excess air (heat loss)
- Control fuel air ratio
- Increase combustion efficiency (save $$)
- Lower SOx, NOx



- Goal = decrease excess air to get as close as possible to the ideal mixture, minimizing heat loss
- Decreases fuel usage, increases efficiency and SAVES $$$

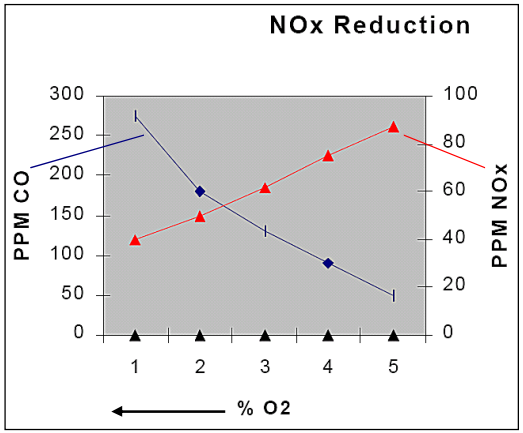
"O2 Trimming"

But elimination of all excess air is not practical, since a fuel rich mixture is even more inefficient and hazardous – so managing in an acceptable range is the key

There is a process emissions factor too

Air is mostly N2 anyway, so no surprise cutting the excess air also decreases the NOx

SO2 will decrease too



Combustion efficiency – Excess air and net temperature

- As O2 increases, heat loss rises (efficiency suffers)
- As net stack temp increases, efficiency also suffers

- Cutting O2% by 2% can increase efficiency by 1.5-2%.
- Depending on the fuel usage the ROI could be a few months

- To minimize heat loss, keep the excess air or O2% low (but not too low)
- Operate with a low net stack temperature

Excess Air (%)	O_2 (%)	CO_2 (%)	Percent Combustion Efficiency Flue Gas Temperature Minus Combustion Air Temperature (°F)					
			420	460	500	540	580	620
0.0	0.0	11.8	81.0	80.1	79.3	78.4	77.5	76.6
4.5	1.0	11.2	80.7	79.8	78.9	77.9	77.0	76.1
9.5	2.0	10.7	80.3	79.4	78.4	77.5	76.5	75.5
12.1	2.5	10.4	80.1	79.1	78.2	77.2	76.2	75.2
15.0	3.0	10.1	79.9	78.9	77.9	76.9	75.9	74.9
18.0	3.5	9.8	79.7	78.7	77.6	76.6	75.6	74.6
21.1	4.0	9.6	79.4	78.4				
24.5	4.5	9.3	79.2	78.1				
28.1	5.0	9.0	78.9	77.8				
31.9	5.5	8.7	78.6	77.5				
35.9	6.0	8.4	78.3	77.2				
40.3	6.5	8.2	78.0	76.8	75.6	74.5	73.3	72.0
44.9	7.0	7.9	77.6	76.4	75.2	74.0	72.8	71.5
49.9	7.5	7.6	77.3	76.0	74.8	73.5	72.2	71.0
55.3	8.0	7.3	76.9	75.6	74.3	73.0	71.7	70.4
67.3	9.0	6.7	76.0	74.6	73.2	71.8	70.4	69.0
81.6	10.0	6.2	74.9	73.4	71.9	70.4	68.9	67.4
98.7	11.0	5.6	73.6	72.0	70.4	68.8	67.1	65.5
119.7	12.0	5.1	72.0	70.3	68.5	66.7	64.9	63.1
145.8	13.0	4.5	70.1	68.1	66.2	64.2	62.2	60.2
179.5	14.0	3.9	67.5	65.3	63.1	60.9	58.7	56.4
224.3	15.0	3.4	64.2	61.7	59.1	56.5	54.0	51.4

MIL-HDBK-1125/1

Table 4
Combustion Efficiency for Natural Gas

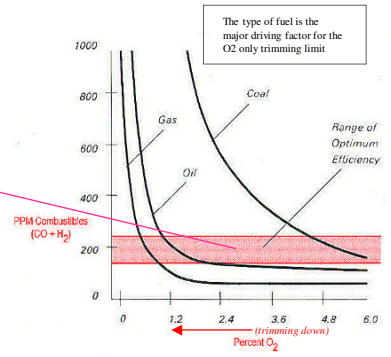
This table is based on the following fuel analysis (% by weight): carbon-70.8%, hydrogen-23.4%, nitrogen-3.8%, oxygen-1.2%, carbon dioxide-0.8%. The HHV is 21,700 Btu/lb.

What about the unburned fuel losses and don't I need to measure CO or combustibles equivalent?

- As O2% is to below 2% further accurate decrease will require simultaneous feedback monitoring of combustibles present
- The limit and if it actually occurs depends on a series of factors, most notably the fuel type, burner load, burner performance
- Combustibles is a separate measurement from a separate detector from O2, though it would be required to control combustion below 2-3% O2

Trimming combustion O2 has the most rapid efficiency payback (rapid ROI).

However, there is a lower limit when O2 trimming slows and combustibles accelerate. Then the trimming payback slows and other process factors will provide better payback (variable drive, etc)



Measuring O2 – Hot probe combustion applications

Several methods are available for measuring O2%

- Paramagnetic
- Low Temp Electrochemical (EC) depleting (Fuel Cell)
- High temp EC depleting Solid Electrolyte/Zirconia direct heated/passive heated
- Low temp trace EC non depleting (E.g. DeltaF)
- Cross Stack – TDL, NDIR, …

Each approach has advantages and disadvantages that are application, regulation, and/or cost dependent. Wet/Dry/extractive/dilution/response time …

But for standard insitu O2 trimming/combustion efficiency, the choice is Zirconia hot probe. (whether COe is measured in addition or not)

So what are the trimming applications for which zirconia hot probes are frequently selected?

Any process combustion application for which measurement is needed close to the combustion process, such as boilers, Furnaces, process heaters/reheaters, kilns
Most advantageous in the presence of aggressive temperatures and chemicals due to detector's resistance…most commonly

- Coal fired utility **
- Oil and Gas fired utility or furnace
- Waste or chemical incinerator
- Process heaters – Chemical & refining
- Package boilers
- Steel – reheat/soak/hot stove/coke exhaust/sinter
- Cement, Lime kilns
- Pulp and Paper (combustion, liquor)
- Combined cycle + auxiliary recovery
- Crematorium