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Schenck Process Group: Gravimetric Feeders

McIlvaine Hot Topic Hour: “Monitoring and Optimizing Fuel Feed, Metering and Combustion in Boilers

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COMBUSTION DEFINITION

Combustion is the rapid chemical combination of oxygen with the combustible elements of a fuel

FOSSIL FUEL ELEMENTAL REACTIONS

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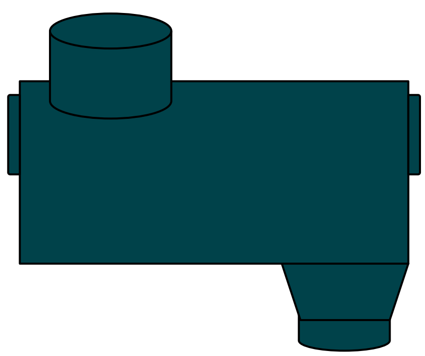
There are only three significant combustible elements in fossil fuels:

- Carbon: $C + O_2 = CO_2$ + 14,093 BTU/lb C
- Hydrogen: $2H_2 + O_2 = 2H_2O$ + 61,029 BTU/lb H (51,558 BTU/lb Net)
- Sulfur: $S + O_2 = SO_2$ + 3,980 BTU/lb S

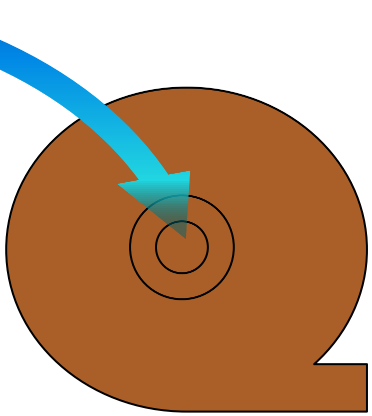


FOSSIL FUEL ELEMENTAL REACTIONS

Oxygen is the other element needed for combustion: The oxygen source for normal combustion in a steam generator is atmospheric air.

Composition of dry air:

	% by volume	% by weight
Oxygen, O_2	20.95	23.14
Atmospheric Nitrogen, N_{2a}	79.05	76.86

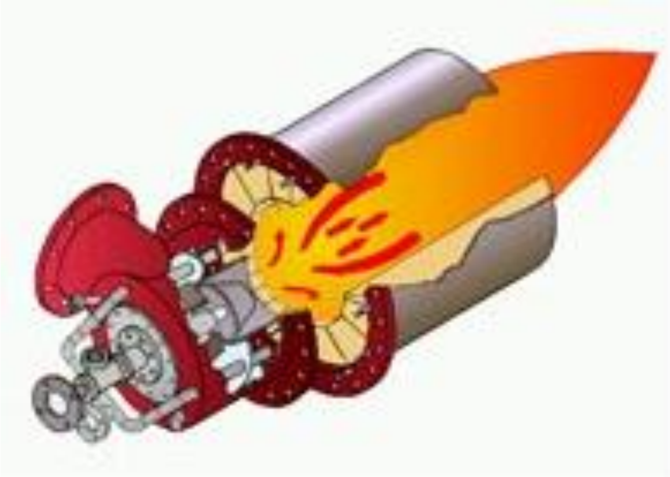


COMBUSTION CALCULATIONS

In addition to heat, substances combine directly in proportion to their molecular weights resulting in carbon dioxide, water and sulfur dioxide

Molecular weights (lb-mole):

Carbon (C)	12.011
Hydrogen (H_2)	2.016
Sulfur (S)	32.066
Oxygen (O_2)	31.999



$C + O_2 = CO_2$

12.011 lbs C + 31.999 lbs O_2 = 44.01 lbs CO_2

1 lb C + **2.66** lbs O_2 = **3.66** lbs CO_2

$2H_2 + O_2 = 2H_2O$

4.032 lbs H_2 + 31.999 lbs O_2 = 36.03 lbs H_2O

1 lb H_2 + **7.94** lbs O_2 = **8.94** lbs H_2O

$S + O_2 = SO_2$

32.066 lbs S + 31.999 lbs O_2 = 64.06 lbs SO_2

1 lb S + **1.0** lbs O_2 = **2.00** lbs SO_2 / lb S

Dry air requirements for complete combustion (Theoretical Air):

Carbon 2.66 lbs O_2 / lb C x 4.32 = 11.51 lb Air / lb C

Hydrogen 7.94 lbs O_2 / lb H_2 x 4.32 = 34.29 lb Air / lb H_2

Sulfur 1.00 lbs O_2 / lb S x 4.32 = 4.32 lb Air / lb S

Nitrogen (N_{2a}) addition to combustion products:

Carbon 11.51 lb Air / lb C x 0.769 = 8.85 lb N_{2a} / lb C

Hydrogen 34.29 lb Air / lb H_2 x 0.769 = 26.35 lb N_{2a} / lb H_2

Sulfur 4.32 lb Air / lb S x 0.769 = 3.32 lb N_{2a} / lb S

EXCESS AIR

Because fuel and air distribution and mixing is not perfect in commercial applications, more than theoretical air is required to assure combustion efficiency.

We have seen in the range of 15-20% as a typical value. Any reduction in this is direct savings, but to reduce it you must be sure of your feed rates.

Not enough air:

- Carbon monoxide emissions
- Increased slagging potential
- Unburned carbon = loss in efficiency

Too much air:

- NOX emissions
- Heat rate ↓

Excess air data point!
5% excess air → 0.2% HR → $295,000/yr for an 800MW unit

Practical Example

		Sub-Bituminous	Bituminous
Fuel Input to Furnace	10^6 Btu/hr	8,000	8,000
Fuel Heating Value	Btu/lb	8,400	11,500
Total Fuel Flow	10^3 lbs/hr	952.4	695.7
Theoretical Air (dry)	lb/lb coal	6.277	8.763
Theoretical Air (dry)	lb/10KBtu	7.473	7.620
Total Theoretical Air Flow (dry)	10^3 lbs/hr	5,978.1	6,096.0
Air Moisture	lbs/lb dry air	0.013	0.013
Total Theoretical Air Flow (moist)	10^3 lbs/hr	6,055.8	6,175.2
Excess air	%	15	15
Total Air Flow to Combustion Equipment	10^3 lbs/hr	6,964.2	7,101.5

WHY GRAVIMETRIC?

Since there is currently no effective way to measure BTU flow, this value must be inferred from either a volume or weight flow. The gravimetric feeder compensates for the variation in bulk density by feeding a known weight of coal in response to a feed rate demand that was based on the expected BTU value of the coal. This ability to accurately weigh the coal on an “as-fired” basis provides significant improvement over volumetric types in terms of matching the BTU delivered by the feeder to the actual process energy required on coal fired units. Therefore, in order to optimize boiler performance, achieve lower emissions and realize the resulting cost savings, gravimetric feeders have become the industry standard in coal fired power plants.

WHY GRAVIMETRIC?

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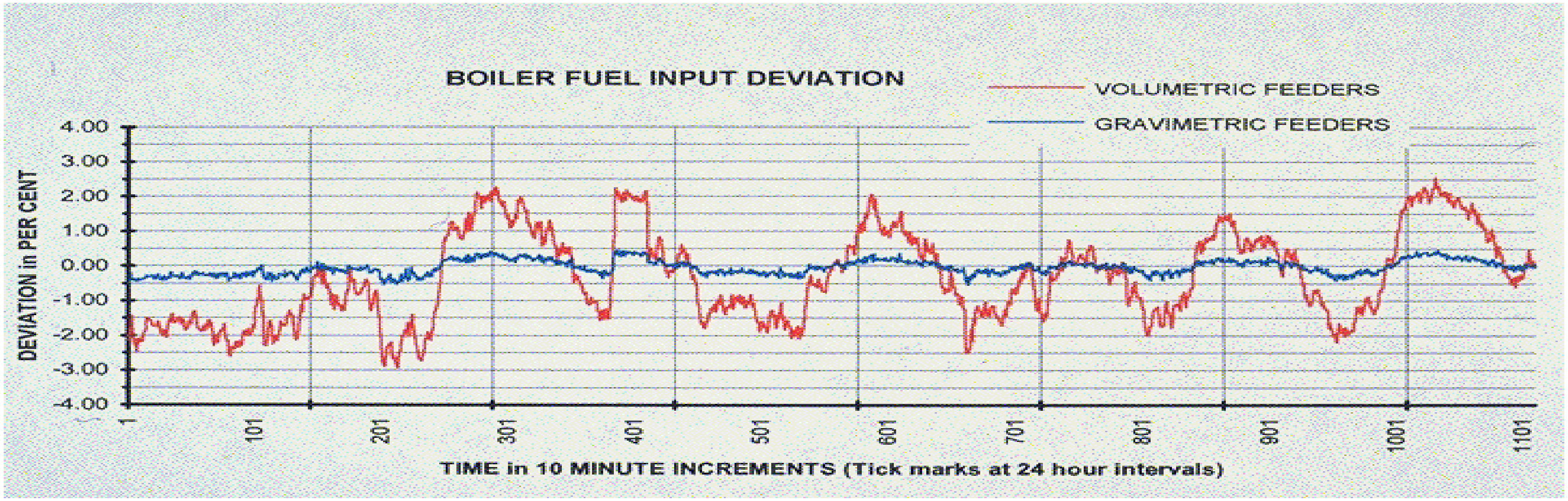
Data collected on an operating boiler diagramming the relationship of a gravimetric feeder verses a volumetric feeder.



WHY GRAVIMETRIC?

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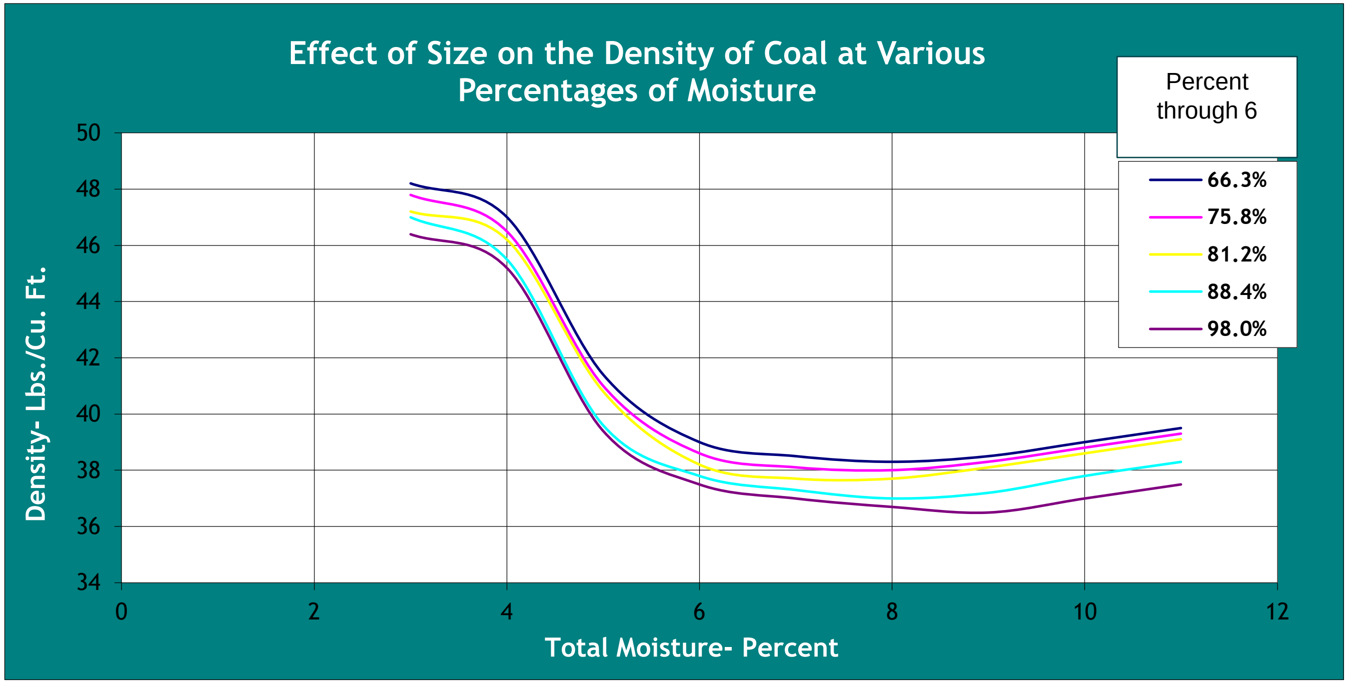
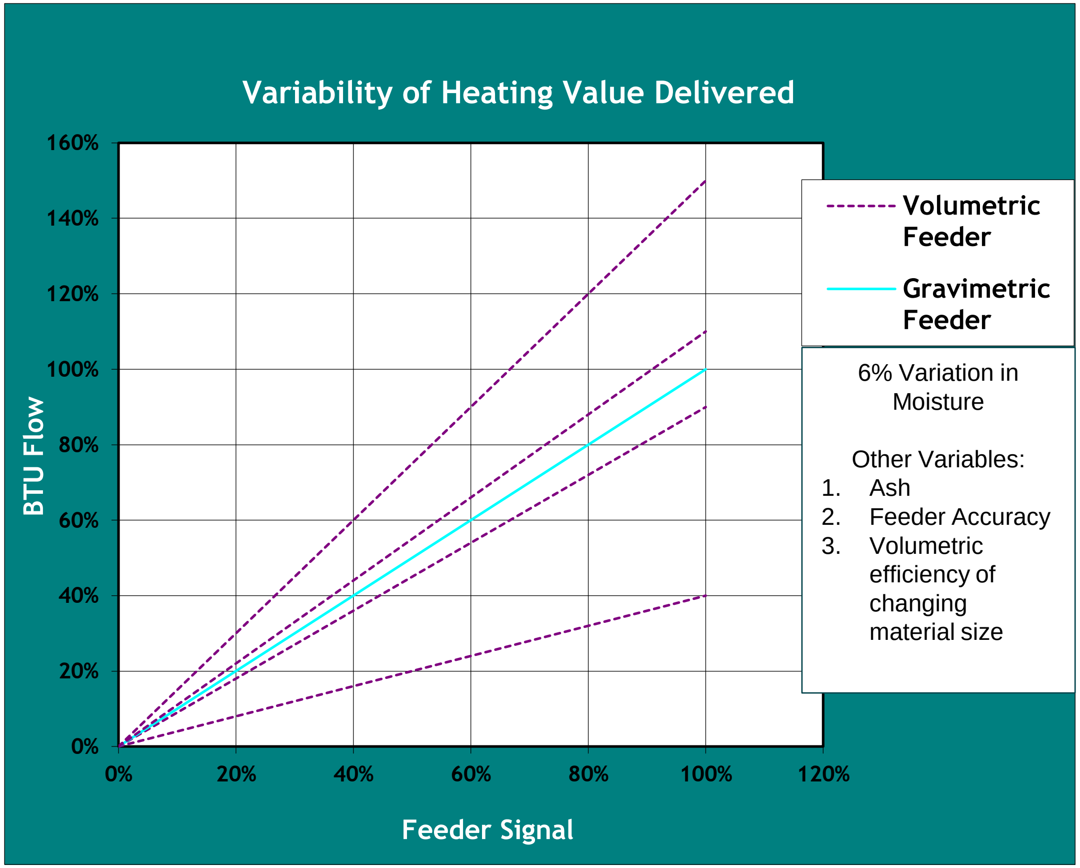
The addition of moisture to coal actually results in a decrease in density of a cubic foot of coal! As seen in the example below, a size of 66% passing 6 mesh, will lose >25% of its density when the moisture raises from 4% to 8%.

On a gravimetric feeder this is accounted for automatically. On volumetric feeders, eventually the boiler control will increase feed rate when one of the monitoring controls detects a problem. i.e. excess O_2, low steam pressure, etc.



WHY GRAVIMETRIC?

Variability of the effect BTU delivered by a volumetric feeder is plotted against that of a gravimetric feeder. Based on the density of the coal, which is effected by moisture and other variables, one could be over feeding or under feeding by as much as 50% when the fuel steam is converted to an effective BTU feed rate.



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Practical Example

With Bulk Density taken into account and fed with a volumetric feeder

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Fuel Heating Value	Btu/lb	8,400	11,500
Total Fuel Flow	10^3 lbs/hr	952.4	695.7
Nominal Bulk Density	lbs/cu. ft.	37.0	42.0
Theoretical Air (dry)	lb/lb coal	6.277	8.763
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Total Theoretical Air Flow (dry)	10^3 lbs/hr	5,978.1	6,096.0
Air Moisture	lbs/lb dry air	0.013	0.013
Total Theoretical Air Flow (moist)	10^3 lbs/hr	6,055.8	6,175.2
Excess air	%	15	15
Total Air Flow to Combustion Equipment	10^3 lbs/hr	6,964.2	7,101.5
Total Volume of Coal to Combustion Equipment	cu. ft./hr	25,740.0	16,563.1
Bulk Density Minimum (high moisture)	lbs/cu. ft.	33.0	38.0
Bulk Density Maximum (low moisture)	lbs/cu. ft.	43.0	48.0
Fuel Under-Fed at Min Density	10^3 lbs/hr	103.0	66.3
Fuel Over-Fed at Max Density	10^3 lbs/hr	154.4	99.4

SUMMARY

There are significant monetary advantages to installing and properly maintaining gravimetric feeders:

1. Savings in coal due to better control of excess air
   - Excess air to low = carbon loss
   - Excess air to high = heat loss
2. Less stratification of air between burners
   - Feed rate is more consistent from a BTU standpoint from feeder to feeder
3. Less slagging
   - Better control of excess air combined with less stratification between burners results in more even furnace gas temperatures; therefore, less slagging
   - Additional savings in soot blower operating costs and outage time.
4. Lower NOX levels
   - Less stratification and lower excess air equals fewer areas forming NOX
5. Super heat and furnace wall corrosion lowered
   - Corrosion is higher in zones with less excess air
   - Less stratification due to more accurate feed and better excess air control limit these conditions.
6. Optimum air/fuel ratio when changing loads
   - Coal (BTU's) and air are kept parallel and can be controlled by the feed rate signal and dangerously low air/coal ratios can be avoided
   - Maintaining air/coal ratio avoids hot spots on the boiler wall
   - More important than ever with so many load changes, reduced operating levels, and start-ups.

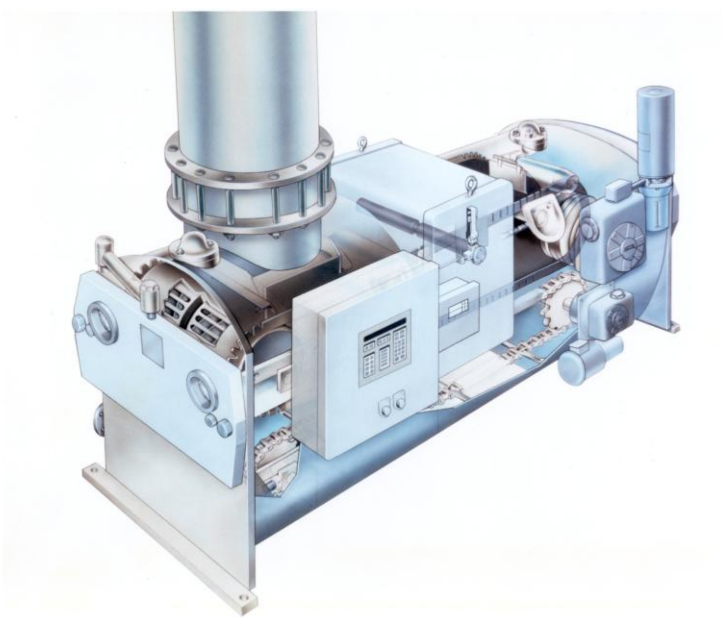
SUMMARY

At the most basic, only two things are needed for combustion: Fuel and Air

Your gravimetric feeder is **half** of that formula and fuel is the biggest cost of electric generation

Treat the feeder like an "instrument"

- Calibrations
- Regular maintenance
- OEM parts



Treat it like you would an instrument; It's controlling half the combustion process

CASE STUDY: REDUCTION OF NOX LEVELS

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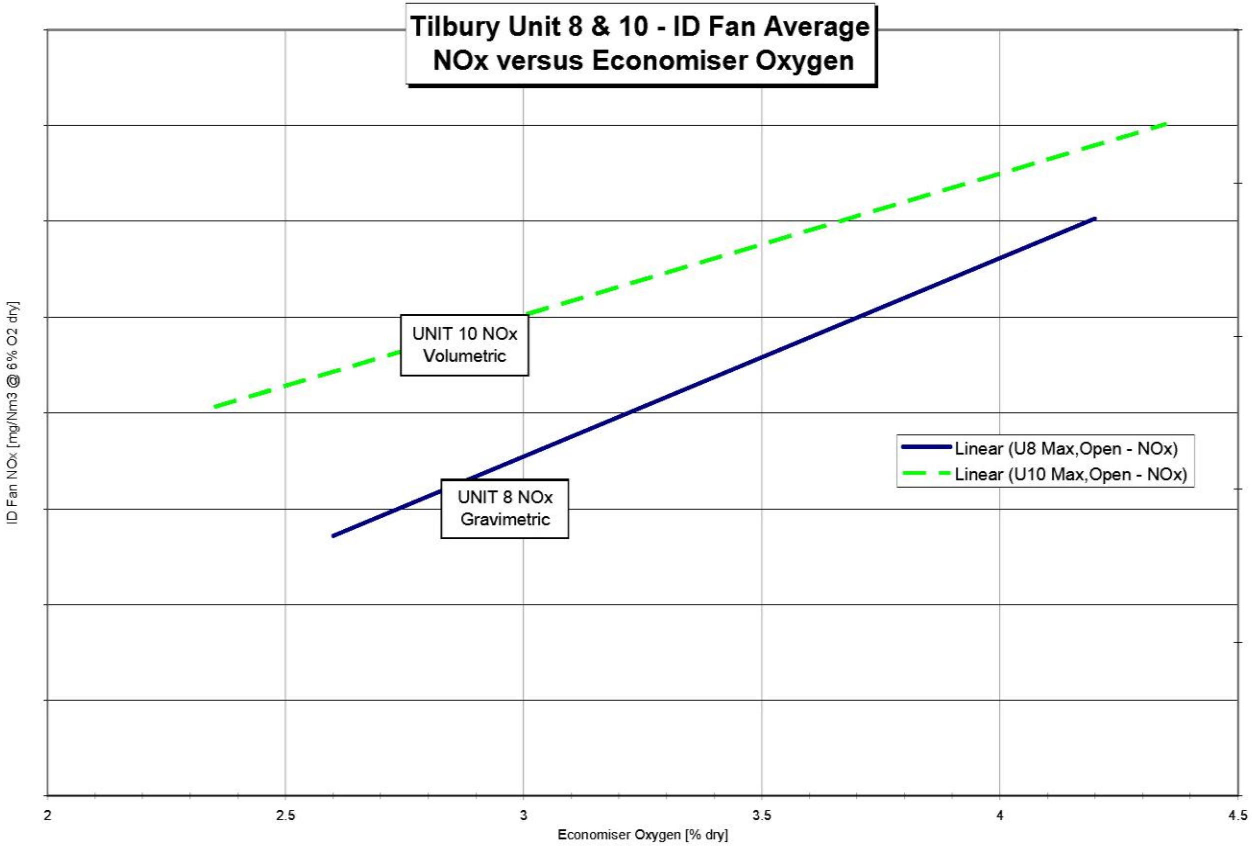
NOx reduction 15% without any adverse impact on carbon-in-ash due to Stock Gravimetric Feeder.



Comparison of NOx performance for Volumetric and Gravimetric equipment installed on identical 340 MW boiler units in a UK Power Station.

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CASE STUDY: EXCESS AIR + RECOVERED CAPACITY

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For 340 MW Boiler at 70% load factor:

1% excess air reduction = 0.25% efficiency saving

Based on $3.70/GJ energy cost – approximately saving = $550K per annum

Extra Revenue

Recovered generating capability approx. 20-30 MW = $370k - $550k per year

THANK YOU VERY MUCH.

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