Advanced Controls for a Biomass Boiler

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Overview

- Acknowledgments
- Combustion Issues
- Combustion Control
- CV Corrector
- CV Corrector Benefits
- Other improvements
- Conclusions

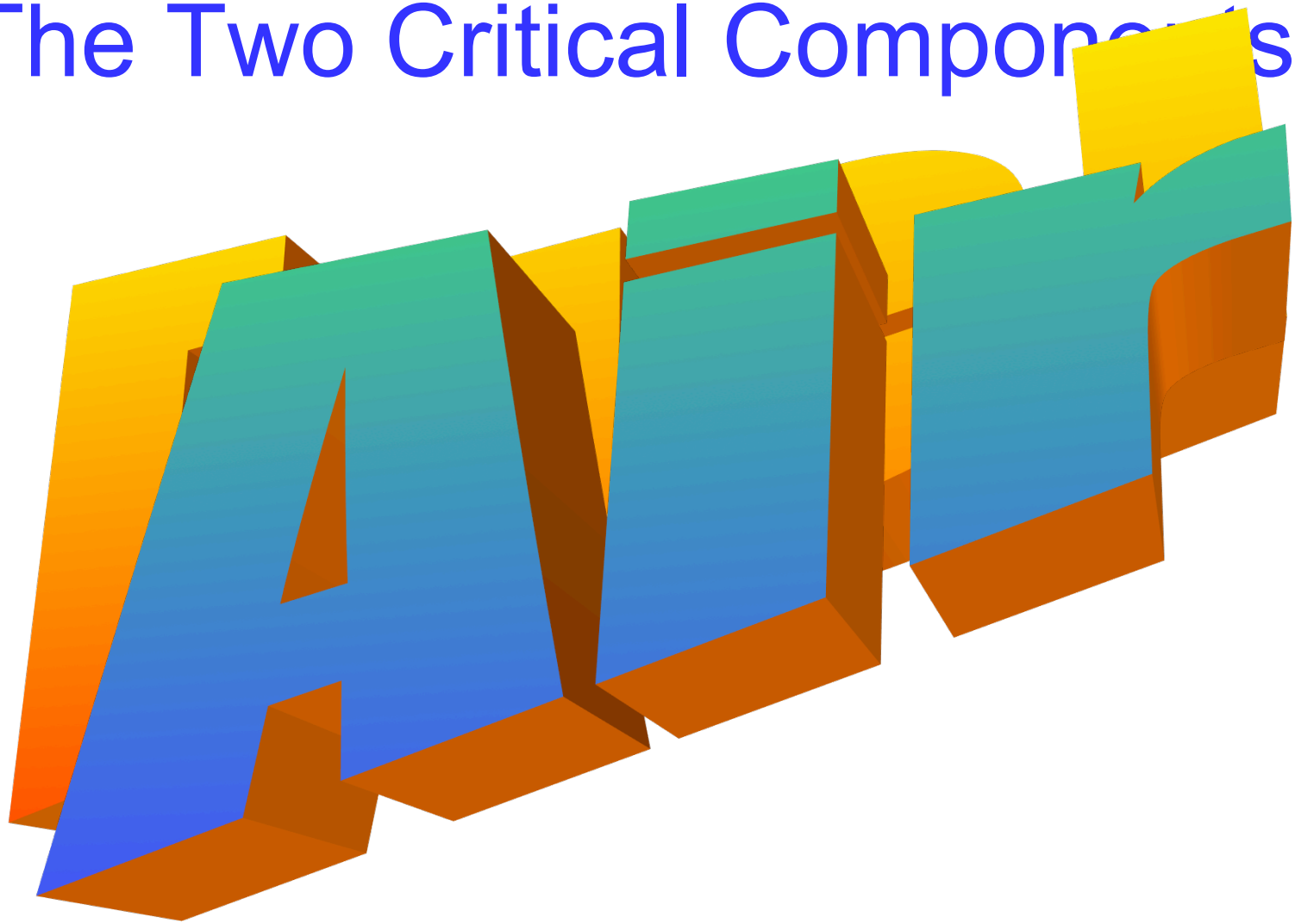
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The Combustion Challenge

- In order to have efficient boiler operation it is important to be able to :-
  - Control the amount of fuel into the boiler
  - Add the correct amount of air to allow efficient combustion of the fuel
  - Burn the fuel in a controlled manner
  - Control the final steam conditions exiting from the boiler

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The Two Critical Components



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Fuel Characteristics

- Basic Biomass Fuel Characteristics include:-
  - Moisture
  - Density
    - **Calorific Value**
  - Particle Size and Distribution

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Different Biomass Fuels - Bagasse



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Woodchip



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Ground Wood



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Camphor Chip



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Mixed Wood



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Mixed Bagasse and Woodchip



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Boiler Control Before Improvements

- Boiler Master controls the steam pressure using 3 element control.
- Boiler Master output controlled:-
  - Feeder Speeds
  - Air Demand
- Oxygen Trim biased the air demand to give a desired exit oxygen level.

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Problems with “Standard” Control

- Difficulty coping with fuel variation
- Poor exit oxygen control
- Poor fuel distribution with fuel changes

- High Stack emissions during fuel changes

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Problem Example

- The boiler is operating on well Bagasse based fuel during a non crushing period
- A load of dry woodchip is added to the system
- The fuel composition changes from bagasse to woodchip in 2 min
- Fuel is thrown into the boiler at the bagasse rate
- The woodchip piles on the grate

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Problem Example Continued

- Eventually the piles of fuel catch alight
- Steam Pressure Rises dramatically
- Boiler Master winds down quickly
- Air flow drops corresponding to drop in the Boiler Master control
- There is now a considerable amount of fuel on the grate, burning with little or no air added.

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Fuel Calorific Density

- Calorific value is one of the key components of the boiler operation
- The boiler fuel control devices are volumetric feeders

Calorific Density :- Heating Value of the fuel per unit volume

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Calorific Measurement

- Ideally we need an on line system of measuring Calorific Density of the current fuel type.
- Any available measurement is costly and requires significant calibration
- All direct calorific measurement is expensive

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What is Calorific Value ?

"The heat of combustion (ΔH_c^o) is the energy released as heat when a compound undergoes complete combustion with oxygen under standard conditions"

Anon (2010) Calorific Value Definition http://en.wikipedia.org/wiki/Heat_of_combustion (accessed 22 December 2010)

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Why not use the energy in the Steam?

- Given that the inlet conditions for the turbine are very limited, it can be said that the steam pressure and steam temperature are constant.
- This means that the energy in the steam is proportional to the steam flow.
- Assuming the heat losses from the boiler are consistent, the energy in the steam is the main variable to measure the energy released from the combustion of the fuel.

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Development of the Control Loop

- Need to convert both steam flow and fuel input to a common unit:- %MCR
- Process Variable – Steam Flow %MCR
- Set Value – Fuel Flow – Boiler Master Output %MCR
- Manipulated Variable – Calorific Value Corrector (CV Corrector)

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CV Corrector

- Range is limited from 0.3 to 1.5
- The CV Corrector adjusts the maximum feeder speed.
- Note:- Actual feeder speed is still controlled from the Boiler Master Output

CV Corrector Value	Maximum Feeder Speed
0.3	300
1	1000
1.5	1500

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CV Corrector Operation

Fuel Type	CV Corrector Value	Maximum Feeder Speed (r/min)	Boiler Master Output (%)	Actual Feeder Speed (r/min)
Bagasse	1.0	1000	100	1000
Dry Wood	0.3	300	100	300
Bagasse + Wood	0.7	700	100	700
Bagasse	1.0	1000	50	500
Dry Wood	0.3	300	50	150
Bagasse + Wood	0.7	700	50	350

Interactions

- Boiler Master Controls Steam Pressure
- CV Corrector matches the energy in the Steam flow to the Boiler Master Output

- The two loops are acting independently on two different things however there are still interactions.
- Primary Control is the Boiler Master, with the CV Corrector on a slower control loop.

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CV Corrector Benefits

- Allows the Boiler Master to use it's full range of output to control all fuel types
- There is now a quick and direct indicator of current boiler fuel quality.
- Improved total Air Control (Combustion Stoichiometry)
- Useful for automatic control of other boiler features such as Spreader (Distribution) air control.

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Boiler Master Output

- Prior to the introduction of the CV Corrector all changes in fuel calorific value were compensated using the Boiler Master Control.
- On good fuels this may mean only 15% output for full steam flow. – Very Difficult to tune.
- Now the full 100% range is available for all fuel types.

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Direct Indicator of Fuel Quality

- The CV Corrector can be used as a direct (relative) indicator of fuel quality.
- Especially when receiving non bagasse fuel into the fuel system, the quick indication allows feedback to the fuel supplier

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Improved Air Control

- With the Boiler Master now using it's full range of output to control steam pressure, the air flow master is now adding close to the correct amount of air for the fuel type.
- This has removed the relationship between the feeder speed and air flow and replaced it with the Boiler Master output to air flow.

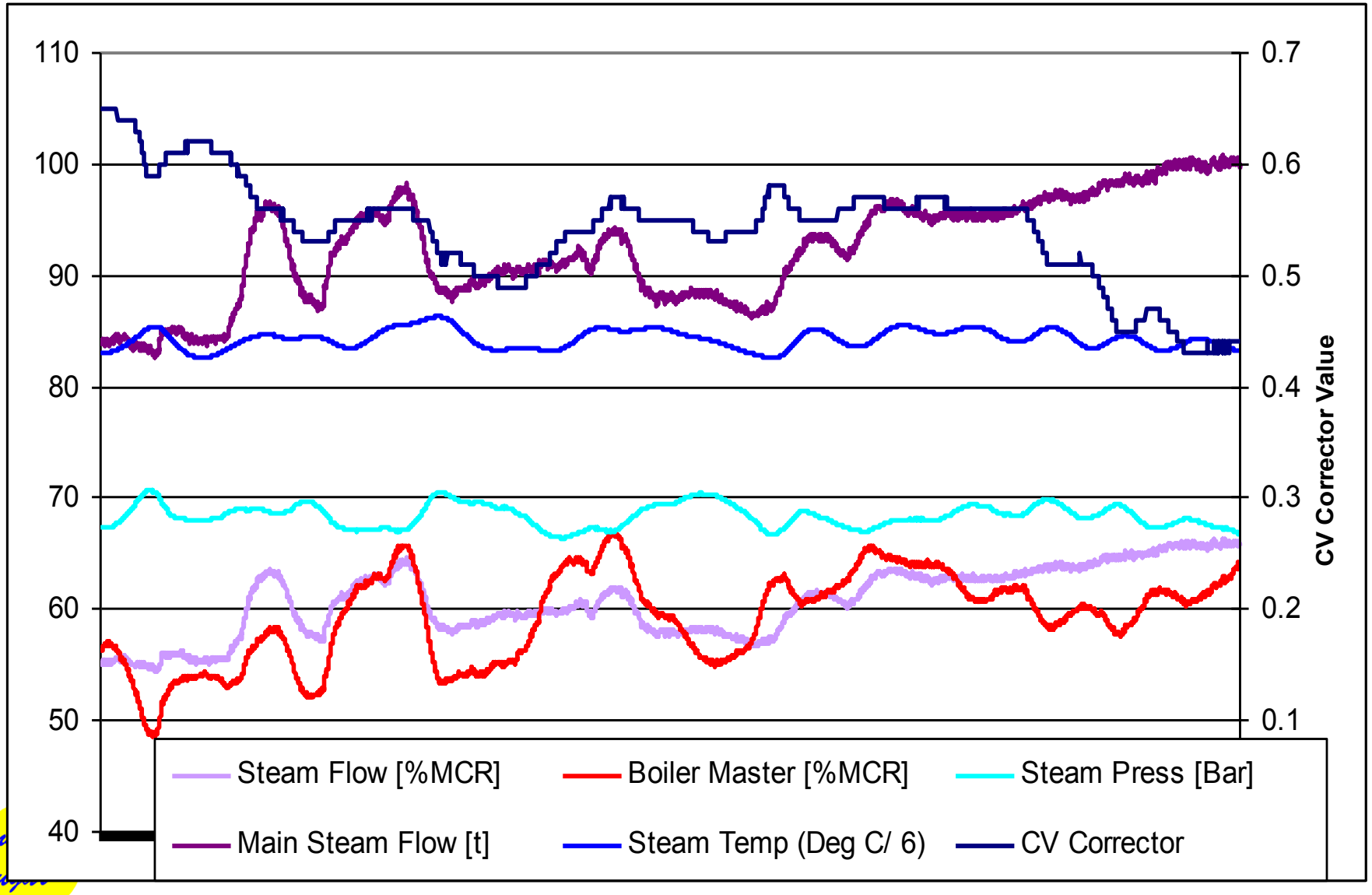
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Secondary Control Benefits

- Spreader or Distribution Air.
- Air that is added to the feeders to ensure an even spread of fuel across the grate.
- As the CV Corrector value goes lower, this indicates a heaver, denser fuel and thus the pressure is increased to ensure good distribution
- As the CV Corrector value is about 1.0 this indicates a good bagasse based fuel and so the pressure may be reduced to ensure that the bagasse is not all thrown to the back of the furnace.

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CV Corrector in Operation



Other Control Features

- Oxygen Trim
- Steam temperature Control using Secondary Air

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Oxygen Trim

- Given that the total air flow demand has been improved by using the full boiler master output, tight oxygen trim may be achieved.
- At lower firing levels, high excess air settings are used to assist with the air transport properties for combustion.
- The excess air is then reduced as the firing rate increases
- The trim controls a multiplier on the total air flow setting (from 0.8 to 1.2)

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Steam Temperature Control

- Due to the tight inlet steam conditions for the turbine, good steam temperature control is required. (510±10°C)
- Primary steam temperature control achieved using an inter-stage de-superheatering attemporator between the two stage superheater.

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Additional Steam Temperature Control

- The location of the fireball in the furnace can also dramatically effect the proportion of the heat radiated to the superheater elements.
- The location of the fireball is controlled using the secondary air pressure control

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Secondary Air Control

- Manual External dampers control the location/direction of the secondary air.
- These are set for the majority of the secondary air to be injected near the grate
- The secondary air pressure is controlled (in Cascade) from the de-superheater control valve.
- Total air flow is constant.

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Secondary Air Control Continued

- As the desuperheater control valve starts to open too far, the secondary air pressure is increased.
  - This reduces the amount of under-grate air.
  - The fireball is lowered and the steam temperature starts to drop off.

- More efficient than de-superheating alone?

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Further Work

- Add in a calculator that corrects the %MCR steam flow for the different energy in the steam at different conditions

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Conclusions

- A simple control loop using existing available information, has greatly increased the operational stability of the boiler.
- May be applicable to bagasse only as well as biomass fuel boilers
- Some simple, smart control has paid off with greatly improved results.

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