Coal Quality
&
Boiler Efficiency
Introduction

• Kelvin Power currently consists only of the B-Station plant which is fitted with seven 60MW units.

• On the north side of B-Station, four Babcock/Wilcox PF boilers generate steam for four GEC turbine generators.
  – The Babcock/Wilcox boilers are fitted with four Babcock E56 vertical spindle mills each.
  – These boilers are capable of operating on three mills at a time which allows one mill to be on standby at all times.

• On the south side of B-Station, three Mitchell PF boilers generate steam for three Oerlikon turbine generators.
  – The Mitchell boilers were originally fitted with two horizontal tube mills each.
  – These mills were later replaced by four Babcock E56 vertical spindle mills each.
  – Due to the burner configuration these boilers need all four mills in service at all times to ensure flame stability. If one mill is taken out of service, oil burners are used to sustain flame stability.

• All seven boilers steam into a common steam range from where the turbine generators take steam. This allows steaming almost any boiler to almost any turbine generator.

"Proudly Kelvin"
Coal is a complex fossil fuel with various aspects which can impact on efficient boiler operation. The first step towards efficient and reliable boiler operation and steam generation is establishing the correct quality coal for the application. All properties and characteristics of the coal must be understood and then used to determine whether the coal is suitable for the specific application.

Calorific Value as reported in analysis reports is really just an indication of the potential heat energy contained in the coal. This heat energy is only useful when it is released completely and in the correct areas of the boiler.

When coal is sourced from more than one source for a specific application, it is important to ensure that all the coals in the supply mix are properly matched and compatible with each other. Not only does this ensure consistency in coal quality which leads to consistent and efficient boiler operation, it will also reduce the risk of spontaneous combustion in coal storage facilities.

Feed water heaters, air heaters, milling plant, air flow and oxygen presence in the boiler and proper operating of the boiler plant is as important to efficient steam generation as the correct and consistent coal quality.

Efficient boiler operation and the correct choice in coal for the specific application reduces the impact of coal combustion on the environment.
Coal Quality History

- Coal Quality 2004
  
  The coal supply mix consisted of only two sources which supplied raw coals (crushed and screened to 0x8mm and 0x12mm)

  - Ash: No data available
  - Volatile Matter: No data available
  - Calorific Value: 22.5 – 24.5 MJ/kg
  - Total Vitrinite: 28 – 33%
  - Total Reactive Macerals: 51 – 59%
  - Total Inertinite: 57 – 67%
  - Average Burn Rate: 0.66 t/MWh
Coal Quality History

- **Coal Quality 2008**

  The coal supply mix consisted of various sources, including beneficiated and raw coals. The two main sources from 2004 were still in the mix, but combined made up less than 40% of the total supply mix.

  - Ash: 21.5 – 25.%
  - Volatile Matter: 22.4 – 23.8%
  - Calorific Value: 22.5 – 27.5 MJ/kg
  - Total Vitrinite: 14 – 33%
  - Total Reactive Macerals: 42 – 59%
  - Total Inertinite: 57 – 75%
  - **Average Burn Rate:** 0.70 t/MWh
Coal Quality History

- **Coal Quality 2011**

  The coal supply mix consisted of two new main sources, but supplemented by a number of other smaller sources. All coals were beneficiated products.

  - **Ash:** 14.6 – 17.4%
  - **Volatile Matter:** 21.6 – 24.6%
  - **Calorific Value:** 25.5 – 26.3 MJ/kg
  - **Total Vitrinite:** 27 – 31%
  - **Total Reactive Macerals:** 50 – 55%
  - **Total Inertinite:** 62 – 68%
  - **Average Burn Rate:** 0.58 t/MWh
Coal Quality 2012

During 2012 the supply mix only consisted of two sources, the same two main sources as in 2011. It was however found that the one source mines and beneficiate a number of different areas together. Their quality is not as consistent as the other source.

The other source mines different areas, but the ROM from the different areas are beneficiated separately.

- Ash: 15% - 19%
- Volatile Matter: 19.5 – 24.5%
- Calorific Value: 25.4 – 26.4 MJ/kg
- Total Vitrinite: 26 – 31%
- Total Reactive Macerals: 51 – 55%
- Total Inertinite: 64 – 71%
- **Average Burn Rate:** 0.60 t/MWh
Coal Quality History

• Lessons learned
  – In 2004, despite the low Calorific Value (22.5 – 24.5 MJ/kg) of the coal purchased, the average burn rate for the year was 0.66 t/MWh. However the Total Vitrinite Content of the coals were around 30%, which indicates higher reactivity coals

  – Unfortunately there is not much data available for 2005 and 2006, but during these two years an increased number of forced outages on the boilers were experienced as a result of the Ash Handling plant not being able to cope. The coal supply mix consisted of a large number of sources which included coals with Ash of up to 30%.

  – 2008, the average burn rate was 0.70 t/MWh, despite the higher Calorific Value of the coal which went up to 27.7 MJ/kg. It was found that some of the higher CV coals purchased at that stage, some with Volatile Matter Content of up to 26%, only had a Total Vitrinite Content of 14%, thus having a much lower reactivity than some of the lower CV coals purchased.

  – 2011 and onwards the burn rates were reduced to around 0.60 t/MWh where it is currently maintained, since coals were purchased with Total Vitrinite around 30% and Total Reactive Macerals of more than 50%. These coals have Volatile Matter in the region of 22%.
Coal Quality

• Shifting the focus
  – During 2008, the focus moved to evaluating and purchasing coals based on Ash, CV and Total Vitrinite instead of Volatile Matter. This was to ensure that coals with a suitable reactivity for the application was purchased – to achieve the optimum heat energy release in the boilers in the required areas.
  
  – The Ash Constituents and Ash Fusion Temperatures of the coals also became part of the critical properties when evaluating new coal sources. This helps understanding the risk of clinker formation in the boilers.
  
  – From 2011 the focus moved to matching all coals purchased, based on the above mentioned properties and reducing the supply mix to a maximum of three coal sources. This improves the consistency of the quality of the various coals purchased, and resulting in easier, more consistent operation of the plant.
  
  – The coal offer and evaluation process was adjusted accordingly and became very comprehensive. For ‘borderline’ quality coals and coals where some uncertainty exists, a test burn process is included in the evaluation process of such coals.
Coal Reactivity

• Reactivity indicators of coal
  – The Total Vitrinite Content of coal, which is determined through Petrographic Analysis, is a good indicator of the reactivity of the coal. The most common form of Vitrinite found in South African coals is Collotelinite.
  
  – Another factor which is used to indicate the reactivity of the coal is the Total Reactive Macerals reported in the petrography analysis.
  
  – The Total Inertinite Content of the coal is considered when evaluating a new coal source. This is an indication of the inert Macerals contained in the coal.
  
  – In some cases it was found that when a coal has both a high Volatile Matter Content and Total Vitrinite Content, that there may be some carbonates present in the coal, which is usually forms part of the Volatile Matter Content result. Carbonates are inert.
Coal Reactivity

- **Influence of the reactivity of coal on combustion**
  The reactivity of the coal plays an important role in boiler efficiency as it will, along with various other factors of boiler operation, ensure that the fireball is in the correct area of the boiler furnace.

  - If the reactivity of the coal is too low for the specific application:
    - Late ignition of the coal and high back end flue gas temperatures
    - High final steam temperature but at a lower than required pressure
    - Incomplete combustion of the coal – increased unburnt carbon in ash
    - Potential damage to boiler nose and secondary super-heater

  - If the reactivity of the coal is too high for the specific application:
    - Low final steam temperature
    - Low economiser outlet temperatures
Coal Reactivity

Ideal fireball height

Fireball too high
Coal Reactivity

- Optimal Reactivity Indicators for Kelvin PF boilers
  - Total Vitrinite Content: 27 – 35%
  - Total Reactive Macerals: > 50%
  - Total Inertinite: < 70%
• Ash yield

The Ash Handling Plants of most of the older power plants were designed to for the handling of lower ash volumes, as these plants were intended to operate on low Ash coals.

At Kelvin we have experienced that the Ash Handling Plant can comfortably operate with coal up to roughly 24% Ash yield. Beyond 24% the Ash Handling Plant starts experiencing difficulties in handling the ash volumes produced, and either load on the plant needs to be reduced or inevitably boilers need to be shut down to catch up on ashing and dusting.
• **Ash Composition**

It is also important to understand the minerals present in the coal and their combinations formed during combustion. Combined with the Ash Constituent Analysis the Ash Fusion Temperatures are also important when investigating a new source for a specific application.

– Ash Fusion Temperatures are important as a Deformation Temperature lower than the flame temperature in the furnace will result in an increased risk of ash deposit formations on the wall tubes, boiler nose and super heater elements.

– Not only does these build ups reduce heat transfer to the tubes and water / steam, falling clinkers can cause damage to tubes below, with a potential to cause tube leaks. Falling clinkers can further result in a flame failure boiler trip when the clinker falls past the pyrometers.

– Also note that because these build ups reduce the heat transfer to the tubes, it also increase back end flue gas temperatures.
Ash Composition

Commonly the following properties are considered when reviewing the Ash Composition:

- $P_2O_5 < 1\%$
- $CaO + Fe_2O_3 < 8\%$
- $MgO < 1\%$

Combined with these properties the Ash Fusion Temperatures are also considered. The coal will be declined if the Deformation Temperature is less than 1 400 °C and any of the above properties are borderline as that indicates an increased risk of clinkering and or deposits forming in the boiler.
Other Properties

• **Vitrinite Reflectance Analysis**
  – Indicates the Rank (maturity) of the coal
  – Indicates whether a coal product is made up of coals from more than one seam / source

• **Sulphur**
  – Environmental legislation requires reduced SO\(_x\) emissions
  – Sulphur combining with moisture, especially in the Air Heater area of the boiler where condensation is likely to take place, result in the formation of H\(_2\)SO\(_4\) which will attack the Air Heater elements and can also cause to damage to the Fabric Filter bags.

• **Volatile Matter**
  – Kelvin is not as strict on Volatile Matter Content on day to day quality management, because of our focus on other, more accurate means of determining the ease of ignition in coals.
Other Properties

• Hardgrove Index
  – Indicates the grindability of the coal. This is important to ensure the efficient operation of the mill when pulverizing the coal - increased mill throughput.

• Abrasiveness Index
  – Serves as an indication of impurities in the coal such as stones, etc.
  – Important to reduce mill wear.

• Calorific Value
  – A balance between reactivity and the heat energy is crucial. A coal with the correct reactivity for the Kelvin PF boilers, will release the heat energy in the correct area of the boiler for optimal heat transfer. In such cases the a coal with a too high Calorific Value may result in an increased tube failure rate.
Coal Sourcing

• Coal selection
  – Only single seam coals are purchased for Kelvin - No ‘blended’ coals are purchased.
  
  – Only beneficiated coal products are purchased.
  
  – The coals are evaluated on Proximate Analysis results and Advanced Analysis results to ensure that the coals are properly ‘matched’ and thus compatible. This ensures that coal quality is consistent, despite any changes to the coal supply ratio from the various suppliers.
  
  – Suppliers need to inform Kelvin of any planned changes to the product supplied. New seams need to be evaluated and approved before the supplier may change the product supplied to Kelvin.
Auxiliary Plant

• Feed Water temperatures
  – The correct Feed Water temperature prevents over-firing of the boiler, and thus less coal consumed for the same amount of steam generated.
  – Reducing over-firing of the boiler, reduces the risk of tube leaks and thus increasing the reliability of the boiler

• Mill performance
  – Managing the coal quality, including the reactivity and grindability of the coal improves efficient mill operation to achieve the optimal boiler performance.
  – Correct air temperature and airflow through the mill is important to reduce moisture in the coal before delivering it to the boiler
  – Proper maintenance and adjustments of milling plant improves mill throughput – less work done by the mill to achieve the desired particle size
Special Thanks

– Ignus Cronje – Performance Engineer (Recently resigned)
– André Olivier – Boiler and Performance Supervisor
– John Kiewiet – Executive Manager: Engineering and Maintenance

The abovementioned persons play an important role in improving the efficiency and enhancing the overall performance of Kelvin Power. The Performance Engineering Department and Primary Energy Department work close together to monitor the impact of coal quality on boiler efficiency.
The End
Thank you