Is there a clear distinction between good or bad fuel? Apparently not! Fuels can be classified for suitability based on design or on retrofit conditions which allow the burning of a particular fuel or blend in that specific heat engine or boiler. Some fuels may contain higher heating values, but may possess characteristics which cause emission issues, as well as operational and reliability challenges. Some other fuels may be environmentally friendly, but may contain higher moisture content and lower heating values. Fuel that is burned in a boiler designed or retrofitted to burn that specific fuel is considered to be the right fuel. Otherwise it is the wrong fuel, regardless of how good its characteristics.

Fuel blending and switching became the norm after the EPA began imposing stringent emission regulations in the mid-90s. Congress extensively amended the Clean Air Act (CAA) in 1990. Note that there are other factors, such as cost, availability of mines, and meeting full load requirements in a dynamic environment, that have also influenced fuel blending or switching.

The use of Powder River Basin (PRB) coal, whether it is a blend or a switch, has tremendously increased in response to economic and political changes. PRB coal gained a tremendous amount of interest for its abundant availability, as well as its lower sulfur content, which results in lower SOx emissions and lower capital cost. Although PRB coal offers a lower heating value (~8000 BTU/lb) because of a higher moisture content (due to porous structure), it has economic advantages over high sulfur bituminous coals (~13,000 BTU/lb). The environmentally friendly, low sulfur characteristics of PRB coal and relatively low cost make it attractive for the power industry. The other major difference between PRB and bituminous coals are concentrations of ash, calcium oxide (CaO) and magnesium oxide (MgO). The concentration of these oxides in PRB coal is much higher than in bituminous coals, which affects the ash melting temperature and radiant heat absorption capacity in the furnace area. Reduced radiant heat absorption capacity in the furnace area is a product of
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higher reflectivity or lower emissivity of the deposit. This reduced heat transfer capacity in the furnace impairs the thermal efficiency by raising the furnace exit-gas temperature (FEGT). Slagging and fouling may be elevated in high temperature superheater or re heater circuits due to a combination of staged combustion and higher FEGT, as shown in Fig. 1. This situation is further exacerbated by low-NOx burners and over-fired air (OFA). The reducing conditions formed during staged combustion promote the formation of hydrogen sulfides and porous metallic sulfides on the pressure parts of the boiler or furnace. Note that these sulfide scales are more porous and less protective than oxides. Reducing conditions also promote carburization of T91 (Fig. 2) and stainless steel, resulting in a loss of corrosion and oxidation resistance.

Figure 1. Secondary combustion contributes to high FEGTs, resulting in slagging and fouling in high temperature circuits

Although PRB coal contains lower ash content, it requires higher throughput to meet full load conditions. Therefore, erosion problems may be exacerbated because of these lower heating values when switching from high-ranked coals. Higher FEGTs due to a combination of reduced emissivity and delayed combustion significantly affect the finite life of dissimilar-metal welds (DMWs), see Fig. 3. The material transitions are in place for a particular reason, specifically to support limited allowable stresses in high temperature circuits. Any additional thermal loading due to higher FEGTs reduces the remaining useful life of DMWs and materials used in primary superheat and reheat circuits. These often contain carbon and carbon-molybdenum steels, which are susceptible to metallurgical degradations at elevated temperatures, specifically graphitization (Fig. 4) and spheroidization.
With scrubbers in place, Illinois-basin coal gained tremendous demand for its higher heating value when compared to PRB coal, but it has its own challenges. It contains significant sulfur (~4%) and chlorine (typical range is 0.2%-0.3%; some have reported up to 0.5%). Sulfur and chlorine are detrimental to the environment since they produce sulfur oxides (SOx) and hydrochloric acid (HCl) emissions. Interestingly, chlorine helps mercury
(Hg) catalyze into oxidized Hg, which is very soluble in wet flue gas desulfurization (FGD), thus reducing Hg emissions. However, the presence of chlorine still produces harmful HCl emissions. Chlorine is like sulfur in that it promotes significant corrosion issues in the waterwall and high temperature circuits. A reducing environment exacerbates chlorine corrosion. There is an interesting question about a threshold value of chlorine, which can promote corrosion issues. This is a subjective question since some plants have managed to burn ~0.3% chlorine with limited corrosion. Some units have experienced severe corrosion even when less than 0.2% chlorine is present in the coal. However, the majority of the industry accepts that the threshold value of chlorine is ~0.2% to mitigate corrosion problems. Note that there are other factors, such as temperature, slag accumulation, the reducing environment and fuel blends, which influence chlorine corrosion. It is generally believed that a blend of low-sulfur coal and high-chlorine coal tends to reduce corrosion issues. However, this is anecdotal evidence. Using blends of high-chlorine and low-sulfur coals also increases liquid ash corrosion. High levels of chlorine can react with mineral rich coals, resulting in the formation of a corrosive environment.

![Figure 4](image.png)

**Figure 4.** Chain graphitization in C-Mo steel, SEM image

Adverse effects of fuel blending or switching can be minimized when improved operational, maintenance and repair strategies are implemented. Improper mixing of fuel blends may cause load swings due to variable heat content in the coal pockets. An “intelligent” cleaning system is required in the furnace; this effectively cleans the pressure parts where and when required. The effective cleaning of furnace tubes solves many
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secondary problems such as slagging/fouling, high FEGT and excessive usage of superheater/reheater sprays. Thermal efficiency and reliability are improved with effective cleaning in the furnace area. Better mixing of coal and increasing coal fineness reduces carbon carryover, which minimizes secondary combustion issues. Metallurgical and corrosion properties of metals and alloys used in high temperature circuits will not be compromised under oxidizing conditions and designed FEGT. According to the modern standards in coal-fired units, the following coal fineness is required: at least 75% of weight should pass through Sieve #200 (0.0029” opening) and 0-0.2% weight may remain in Sieve #50 (0.0117”). Coarse coal tends to increase carbon carryover and loss-on-ignition (LOI). Reducing the coal particle size increases the surface area to mass ratio, effectively making the coal more reactive. Consequently, improved coal fineness will improve a plant’s efficiency and reduce emissions.

To prevent failures related to higher FEGTs, DMW joints can be relocated to a position where they are exposed to lower temperatures. Also, the use of DMWs made with nickel-based filler metal (EPRI P87 or Inconel) is recommended, specifically in creep-strength-enhanced ferritic steels (CSEFs). Nickel-based filler metal compromises the differences in thermal expansion between stainless steel and ferritic steel.

Fuel blending or switching can be a successful economic journey. However, it demands proper studies and implementation of operational and maintenance changes. Otherwise, it can easily become be a nightmare without preparation and necessary adjustments.