# Kent & East Sussex Railway

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# Combustion

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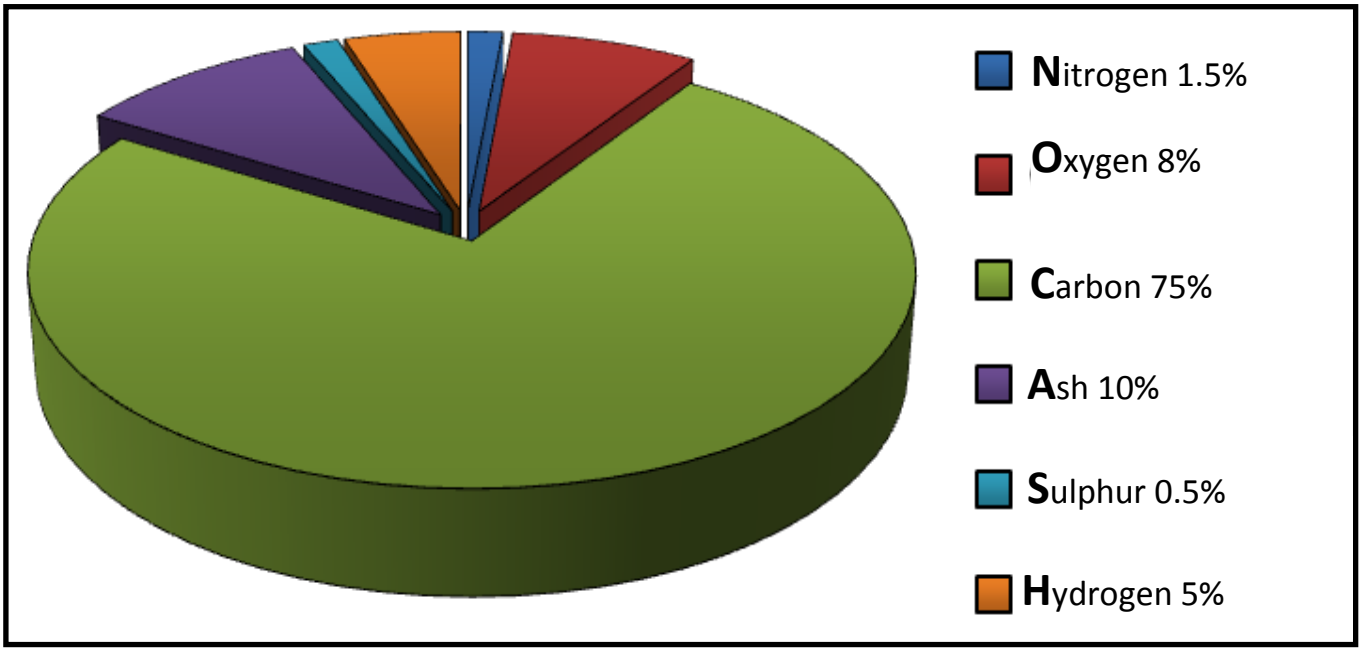
Combustion can be defined as the rapid chemical combination of a substance with oxygen, resulting in the production of heat and light. In our case the substance is coal, or rather the individual components that make it up. Coal varies in composition. It is useful to understand how to identify the differences in coal composition as these will impact on the burning qualities, directly affecting heat and subsequently steam generation. Therefore, the method of firing will need to be adjusted to suit the various types of coal.

The following diagram shows the average basic components of coal. A useful way to remember these is by the use of the acronym 'NO CASH'.




The most important component is carbon as this produces most of the heat, with a little more being provided by the hydrogen. On average this makes up about 75% of coal, with the rest being made up of various gases and ash.

Heat is produced when the carbon and hydrogen in the coal is burned in combination with oxygen in the air, starting the combustion process. Simply burning the coal does not guarantee efficient generation of heat. This is done by regulating the amount of oxygen introduced to the firebox, in accordance with the amount of gases being given off as a result of burning the coal.

As the coal begins to burn, carbon and hydrogen will be given off as gases, which are known as volatiles. It will then continue to burn carbon that is left behind in the form of coke, which is known as fixed solid matter.

The fire needs to reach a temperature of at least 2,500°F to burn the gases efficiently, as this is the point at which the hydro-carbon compounds in the gases split up into carbon and hydrogen. They then burn to form carbon dioxide and water vapour. If there isn't enough air present to provide the optimum levels of oxygen then some of these gases will escape up

the chimney before they can be burned, resulting in waste in the form of dense smoke. Until the temperature reaches 2,500°F, the gases burn incompletely to form carbon monoxide which produces around 70% less heat than if they were to burn completely to form carbon dioxide.

It is important to regulate the burning of the volatiles as well as the fixed matter to ensure efficient combustion. This can be controlled by adjusting the introduction of air into the firebox. Air is introduced into the firebox through two sources. The primary source of air is introduced through the fire grate via the dampers and is normally kept constant. In addition, a secondary source of air can be introduced via the fire hole door or flap.

When coal is fired onto a hot fire bed, the volatile gases start to be given off straight away. The oxygen entering the firebox via the fire grate usually isn't enough to complete the combustion, resulting in dense smoke. This can be regulated by allowing more secondary air into the firebox. However, introducing too much secondary air will have a cooling affect. This is caused by the excess air being heated up by the burning gases, which then escapes to the chimney rather than transferring to the boiler.

The part of the firebox that does most of the combusting is the space below the height of the baffle plate and brick arch, known as the primary combustion chamber. The baffle plate needs to be correctly positioned to direct air towards the centre of the firebox. This encourages the volatile gases to be caught under the brick arch while focusing the supply of oxygen to ensure that they are combusted efficiently.

Holes in the fire bed can be identified by looking for bright spots. It is important to prevent holes from forming in the fire bed as they will allow excessive air to be dragged though the fire, resulting in heat loss. The fire grate can be kept covered by firing at the same rate at which the coal is burning away, with care being taken to fill bright spots during each round of firing. Having too much coal on the shovel makes it difficult to place coal where it is wanted, causing holes to form where spaces are left between heaps of coal. Increasing the thickness of the fire when the engine is going to be worked harder will help to prevent holes from forming. The additional weight of the fire bed will help to counter the increased blast of air being drawn through it by the harder exhaust.

Over firing by adding coal to often will result in inefficient combustion by introducing too much fuel in comparison with the air available. It will also cause the firebox temperature to fall, as less heat is produced and excessive air is introduced through the fire hole. This will make it more difficult to maintain good steaming efficiency.

The fireman can predict where holes are likely to form in the fire bed by understanding the burning characteristics of the particular engine they are on. The shape of the ash pan, fire grate and positioning of the dampers will have an effect on where the majority of primary air is drawn through the fire bed. Firing more often to these areas will help to keep up with the increased rate of burning. In addition to keeping the fire grate covered, building the fire

up and shaping it according to the burning characteristics of the particular locomotive will also help. Wider, shallower fire grates tend to prefer the fire to be built up all around the edges of the firebox with the middle kept thin. Small fireboxes with a moderate depth prefer to have a 'step' towards the back with the rest kept thin, while slightly larger fireboxes prefer a horse shoe shape, with the fire built up across the back and along the sides. Smaller Great Western locomotives with sloping grates prefer the fire to be kept sloped in line with the grate, with it much deeper towards the back to allow the draught to draw the coal forward.

Understanding the differences between types of coal and adapting the style of firing to suit will also help. There are two main types of coal; hard and soft. Coal can be grouped according to its composition. Hard coal allows the fireman to fire only a few minutes before there is a higher demand for steam, as it contains higher levels of carbon and so ignites faster, giving off heat more readily. However, it also burns away quickly. A fire bed burning with hard coal needs regular attention to prevent holes from forming. In contrast, soft coal contains lower levels of carbon and takes longer to ignite. It can take around twenty to thirty minutes to reach maximum burning temperature and so needs to be put on the fire bed well in advance of a higher demand for steam. Soft coal takes longer to burn and a fire bed burning with this coal will withstand being built much thicker due to the lower levels of carbon.

| Grade of Coal. | Per cent. of Carbon. | Per cent. of Hydrogen. | Per cent. of Sulphur, Ash, etc. | Approximate Evaporation. | |
|---|---|---|---|---|---|
| | | | | Theoretical: lbs. of Water per lb. of Fuel. | Actual: on a Locomotive. |
| *Average Samples:* | | | | | |
| Welsh | 92 | 3·5 | 4·5 | 14 | 9 |
| Yorkshire | 79 | 5·0 | 16·0 | 13 | 8 |
| Lancashire | 76 | 5·0 | 19·0 | 12½ | 7½ |
| Scotch | 80 | 5·0 | 15·0 | 13 | 8 |
| Pennsylvanian | 90 | 2·5 | 7·5 | 13 | 8 |
| Indian | 60 | 3·0 | .. | 12 | 7 |
| Australian | 68 | 2·5 | .. | 10 | 6½ |
| South African | 50 | 3·0 | .. | 8 | 5 |

**Characteristics of Hard Coal**

- Darker and can be shiny in appearance
- Contains higher levels of carbon than soft coal.
- Gives off more volatile gases when burned and therefore needs more secondary air.
- Ignites quickly
- Burns away rapidly
- Burns with long flames
- If fired too heavily with too little air, it will produce dark black smoke with a green tinge.
- Tends to cake, sticking together while burning which can disrupt the airflow through the fire bed and cause smoke
- Burns more efficiently with a thinner fire bed.

**Characteristics of Soft Coal**

- Dull in appearance, often dusty and crumbly.
- Contains lower levels of carbon
- Gives off less volatile gases when burned and therefore needs less secondary air
- Ignites slowly
- Burns away slowly, taking 30 – 40 minutes to reach maximum temperature.
- Burns with short flames
- Tends to swell, expanding as it is heated to two or three times its original size
- If fired too heavily with too little air, it will produce dark smoke with a yellow tinge.
- Burns more efficiently with a thicker fire bed.

By understanding the individual burning characteristics of a particular locomotive, the fireman can ensure that the fire is built to the optimum shape in combination with maintaining a covered fire grate to enable optimum combustion. In addition, by being able to identify the type of coal and adjust firing technique to suit, a fireman can make their job much easier.