Atmospheric Pollution Caused by Coal-Fired Power Stations and Motor Vehicle Engines

Photochemical smog is a mixture of chemicals which form in the troposphere region of the atmosphere. This smog consists of two groups of chemicals known as primary pollutants and secondary pollutants.

(fig 1)

As fig 1 shows primary pollutants being produced from various sources, the main producers of primary pollutants are motor vehicles and coal fired power plants. These produce many pollutants such as Nox, VOCs and CO

These primary pollutants react when given the correct conditions to form the secondary pollutants such as O3, NO2, H2O2, HNO3 and oxides of the VOCs.

Many of the primary pollutants formed in a coal fired power plant these are listed below:

* Nox - formed at high temperature and pressure of the combustion causes the atmospheric nitrogen and oxygen to react.
* VOCs (Volatile Organic Compounds) - produced when unburnt hydrocarbons are released through the chimney of the furnace.
* CO - carbon dioxide is a by product of incomplete combustion.

For photochemical smog to form there must be anticyclonic conditions, this means high pressure, in the lower troposphere above a source of primary pollutants. In such condition the air at ground level is normally very still this causes the pollutants to get trapped near to ground level. Also sunlight is needed because in some of the reactions a photon of electromagnetic radiation is needed to give the molecule the energy that it needs to break its bonds*1. These reactions are know as photochemical reactions and are represented by the symbol hv this is derived from the formula E=hv where E is the energy (in this case needed to brake the bond), h is planks constant and v is the frequency of the photon absorbed.

v< 1 Hz
435

$$O_2 + O \quad O_3$$

$$NO_2 \xrightarrow{hv} NO + O \qquad O_3 + NO \quad O_2 + NO_2$$

fig 2.

Fig 2 shows the reactions going on in relatively unpolluted areas of the troposphere it shows that the reactions balance each other out and that a stable background level of O3 is normally present.

O3 can be converted back in to O2 and O when a photon of wavelength under or equal to 310nm is absorbed

$$O_3 \xrightarrow{h\nu} O_2 + O^*$$

The O* molecule formed in this reaction is of a very high energy and will reacted with water to stabilise its self.

$$O^* + H_2O \rightarrow 2OH$$

However when the air becomes polluted with the common primary pollutants the VOCs react with OH radicals to form water and eventually the peroxy radical RCH2O2 where R is a hydrocarbon chain.

$$RCH_3 + OH \rightarrow RCH_2 + H_2O$$

$$RCH_2 + O_2 \rightarrow RCH_2O_2$$

The newly formed radical will readily react with NO to form NO2

$$RCH_2O_2 + NO \rightarrow RCH_2O + NO_2$$

this reaction uses up the NO used to 'clear away' the O3 fig2 and produces more NO2 which creates O3 fig2. This causes a rise in the concentration of ozone. Furthermore two OH radicals are created from the decomposition of O3 which in turn causes two more NO2 molecules, these react with light to make another two ozone molecules. So this assumption can be drawn:

$$O_3 \xrightarrow[\text{smog formation}]{\text{photochemical}} 2O_3$$

therefore wherever the conditions are right for photochemical smog to form the levels of O3 will double.

Longannet coal fired power plant like all other produces sulphur dioxide and NOx. The amounts of these chemicals which are produced must be limited because of the affect on the atmosphere.

There are a few ways of reducing the production of SO2 but the one used at Longannet is the sea water scrubbing method. This method was chosen as the BPEO (best practical environmental option) because of the availability of sea water and there is no solid waste products to be tipped or sold. Also other methods such as the limestone process need other materials which need to be mined or quarried.

Fig 3.

The diagram shows the processes involved in the desulphurisation of the flue gas. The pH of the sea water changes from around 7.5 to 6 when the sulphur dioxide dissolves to sulphite ions. The solution is then aerated to oxidise the sulphite to a sulphate which can then be safely deposited into the ocean.

The NOx, emissions must also be kept to a minimum and the BPEO for the reduction of NOx gases is a low NOx burner with gas reburn facilities. A low NOx burner works by lowering the temperature in the furnace so that nitrogen and oxygen in the air are less likely to react, also the nitrates in the fuel are less likely to oxidise due to the lower temperature and availability of oxygen. This has to be controlled because if too little air gets in then there will be incomplete combustion forming carbon monoxide and giving out less energy making the plant less efficient.

As fig4 shows the mixture is now entered into the reburning zone as it rises up the furnace here any NOx formed is reduced to N2. This happens because an injection of natural gas the alkanes react with the Nox to form safe products.

$$CH_4(g) + 4NO(g) \rightarrow 2N_2(g) + CO_2(g) + 2H_2O(g)$$

Any unburnt alkanes and CO molecules are fully oxidised in the third and coolest part of the furnace. The combustion of the gas here also adds to the heating of the water and aids the efficiency of the whole plant because the reaction is exothermic. This was chosen as the BPEO as it is the most environmentally friendly choice.

Research into the formation of photochemical smog is an important matter for all scientists at the moment. Chemists in particular have to suggest reasons for the reactions that take place and the speed at which they do so. For this reason several area of study have arisen. These are mainly to find out what is in the smog by monitoring the troposphere pollutants and by using controlled reaction in lad condition or in large smog chambers.

Craig Davis 9033