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NATURAL RADIOACTIVITY IN IRON AND STEEL PRODUCTION

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British Steel
The company produced 16 Mtonnes of steel in 1997 making it third in the world in terms of production. To produce the steel involved use of 20 Mtonnes of iron ore, and the recycling of 2 Mtonnes of steel scrap. The sites which use the ore are the main production sites at Teesside and Scunthorpe on the east coast, and Llanwern and Port Talbot in South Wales. Other sites operate using steel scrap alone.

The Blast Furnace Process
The process of converting iron ore into iron centres on the blast furnace (see Fig. 1). A large modern blast furnace can produce 3 Mtonne of iron per year, and may run continuously for more than 10 years before major refitting is needed. The raw materials, consisting of sinter, iron ore and coke are fed into the top of the blast furnace, and pre-heated air is blown in around the base. Melting and chemical reduction occur within the shaft of the blast furnace. Liquid iron is removed at the base together with slag, whilst the off gases pass out the top of the furnace to be cleaned and used as a fuel. Efficient operation of the blast furnace requires the burden within the furnace to have adequate permeability so that the air flow is maximised. For this reason the raw materials used must be in the form of large particles, with adequate physical strength. Some iron ore has suitable properties to be used directly in the blast furnace, but much of it is too fine, and has to be sintered prior to use.

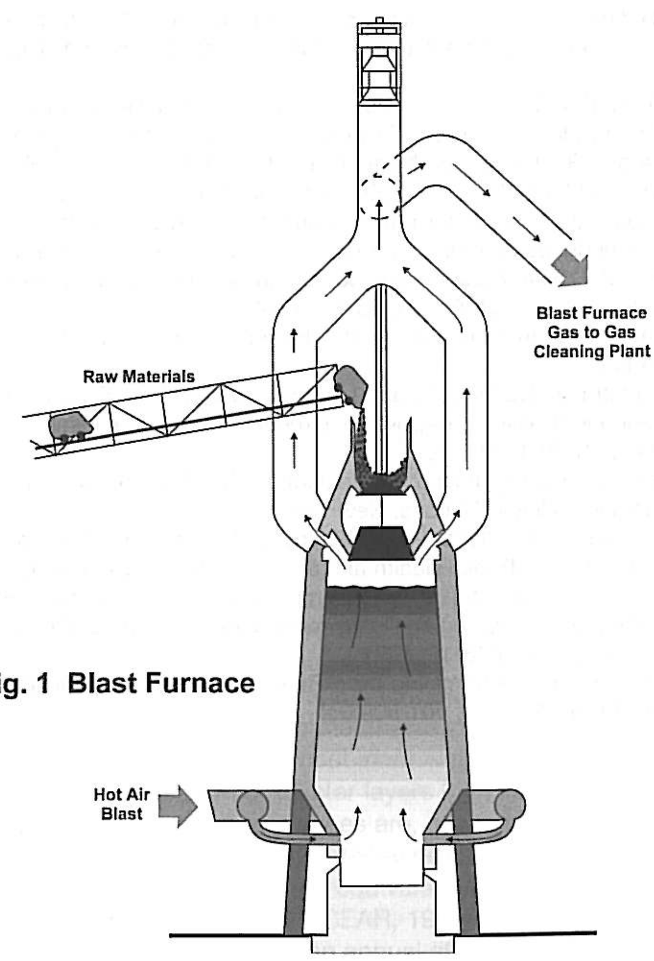

Fig. 1 Blast Furnace

are below 10 microSieverts/annum, and so in terms of the European Directive they are below regulatory concern. While the doses estimated for Llanwern exceed the 10 µSv value they are nonetheless very low compared with average annual doses for individuals in the UK of 2210 µSv from all natural radiation sources.

Calculation of the population doses was undertaken using the same computerised model. The results are also shown in Table 2. The doses were calculated for the population to a distance of 3000 km. This distance was chosen as being in excess of the distance within which the dust from the emissions would be deposited. All the doses are in excess of one man Sievert per annum. The European Directive regards population doses below one man Sievert per annum as being below regulatory concern.

***Table 2:* Doses from Sinter Plant Emissions**

Site	Dose to individuals in critical group microSieverts/annum	Collective dose manSieverts/annum
Teesside	1.8	2.9
Scunthorpe	1.9	3.8
Port Talbot	1.4	3.1
Llanwern	18.5	5.5

Authorisation of the Emissions

The Environment Agency was given the results of the work by British Steel and the NRPB, and these were subjected to scrutiny by independent experts. In addition the Agency undertook studies of its own, which included sampling from the sinter stacks and taking environmental samples (grass, leaves etc.) from around the sites. These samples showed that any enhancement of the levels of polonium 210 and lead 210 around the sites was too low to be distinguished from natural variations in the background levels.

The work by the Agency confirmed the conclusions reached by British Steel in respect of the amounts of radioactivity emitted and the impact on the critical groups and the population. Authorisations of the emissions from the sites have been granted by the Environment Agency. A condition of the authorisations is that each site has to monitor the emissions of radioactivity from the sintering process, and supply the results annually to the Environment Agency.

Examination of the Remainder of the Process

The sintering process has been the centre of interest, but the remainder of the production process has also been examined. Concentration of radioactivity also occurs during ironmaking in the blast furnace. The main raw materials used in the blast furnace are usually sinter and coke, and some iron ore in lump form. There is a wet gas cleaning system which removes most of the dust from the off gas, and the cleaned gas is used as a fuel elsewhere in the process. The final emissions to atmosphere from combustion of this gas are very low in radioactivity.

The off gas dusts recovered from the gas cleaning system contain enhanced levels of both lead 210 and polonium 210. The levels are typically a few Becquerels per g, and do not require to be registered as radioactive under current UK legislation. The quantities of dust arising on a single site are in the region of 20,000 tonnes dry weight per annum. 80% of this is coarse material, rich in iron and carbon, which can be recycled, and the fine material is mixed with other wastes, to achieve chemical neutralisation, before disposal.

A feature of the waste from the blast furnace is that the levels of lead 210 are much higher than those of polonium 210 (see Table 3). The likely reason for this is that much more polonium 210 than lead 210 has been removed in the sintering process, prior to the blast furnace. Hence the material entering the blast furnace contains more lead 210 than polonium 210. The sintering and blast furnace processes together remove nearly all radioactivity from the iron.

The products and wastes from the stages of the production further downstream in the process have been examined, and have failed to show any enhanced concentrations of radioactivity. The

Work Programme

Sampling of the Sinter Plant Off Gases

The first stage of the work was to assess the quantities of radioactivity which were being emitted from the five sinter plants operated by British Steel. Swinden Technology Centre, in conjunction with the environmental departments of each of the steel works, initiated a programme of sampling the dust in the waste gases. The Company is experienced in sampling emissions from its processes, and established methods were used to extract samples of dust from the waste gas stream. The samples typically weighed 20 mg. They were sent to specialist laboratories where they were analysed for polonium 210 and lead 210 using established methods. It was found that the activity of polonium 210 in the off gas dust averages 70 Bq/g. Lead is somewhat less volatile than polonium, and the activity of lead 210 averages 15 Bq/g.

The average result from the plants is shown in Table 1 in terms of the radioactivity per gram of gas emitted, as defined in the Radioactive Substances Act. The Table also shows the upper limits for emission of radioactivity without requirement for authorisation in accordance with the Radioactive Substance Act. It is clear that an authorisation is required.

Table 1: **Radioactivity in Sinter Plant Emissions**

	Po 210 Bq/g of Stack Gas Emitted	Lead 210 Bq/g of Stack Gas Emitted
Average radioactivity in emission	2.8×10^{-3}	1.0×10^{-3}
Radioactive Substance Act Emission limit without authorisation	2.22×10^{-4}	1.11×10^{-4}

Modelling the Dispesion of the Radioactivity

The dispersion of the emissions from the sinter plant stack was undertaken by British Steel Swinden Technology Centre using the computerised mathematical model called ADMS (atmospheric dispersion modelling system). This is a model developed by a group including NRPB, the UK Meteorological office, the Inspectorate of Pollution (now the Environment Agency), and Cambridge Research Consultants Ltd. It uses the results of recent research into the behaviour of the lower atmosphere, and particularly the variation of wind velocity, temperature, and turbulence, with height. It is accepted by the Environment Agency as one of the best predictors of atmospheric dispersion and ground level concentrations resulting from emissions. The model used the concentration of the radioactivity in the sinter plant stack emissions to predict the concentration in the air at ground level, and also the amount of deposition which would occur. According to the model the levels of lead 210 and polonium 210 at ground level are well below typical levels which occur naturally, so it would be difficult to confirm the modelling results by actual measurements.

Doses to People from the Radioactivity

The estimation of the doses to people was undertaken by the National Radiological Protection Board. The European Directive requires dose estimates to be made for the individuals in the critical group, and also for the dose to the whole population. The modelling was done using the computer program CREAM developed by the NRPB, and other organisations, under the sponsorship of the European Union.

Potential critical groups in urban and farming areas were identified around each site, and the doses from inhalation and ingestion were calculated. It was concluded that the main route of exposure was ingestion of foodstuffs. Inhalation contributed less than 22% of the dose at any of the sites. The calculated doses for the critical groups are shown in Table 2. The highest values are for the Llanwern site. The main reasons are that the stacks are lower there than at the other sites, and there is farmland close to the sinter plant stacks. For the other three sites the doses

The Sintering Process

Sinter plants are an integral part of the ironmaking process. In the sintering process (see Fig. 2) a mixture of iron ore and a small amount of coke is fed onto a moving grate. The material passes through an ignition zone, and air is drawn downwards through the bed of material to maintain combustion. The combustion zone moves gradually downwards through the bed of material while the grate moves along. The temperature reached in the combustion zone is in the region of 1400°C and the material partially melts and forms agglomerates. At the end of the travel of the grate the sintering process is complete throughout the thickness of the bed of material and the sinter is passed through a breaker to a cooler. The sinter produced has a large particle size and is physically strong, and so is acceptable in the blast furnace.

The volume of off gases produced during the sintering process is typically 2000 m³ per tonne of sinter (0°C dry), which can equate to more than 300 m³ per second on a large sinter plant. The off gases pass through a gas cleaning plant before being discharged to the atmosphere via a tall stack. Within British Steel the off gases are cleaned by electrostatic precipitators. At the point of emission to the atmosphere the dust content of the gas is typically 60 mg/m³. The dust in the emissions is almost wholly composed of particles of less than 10 µm in diameter.

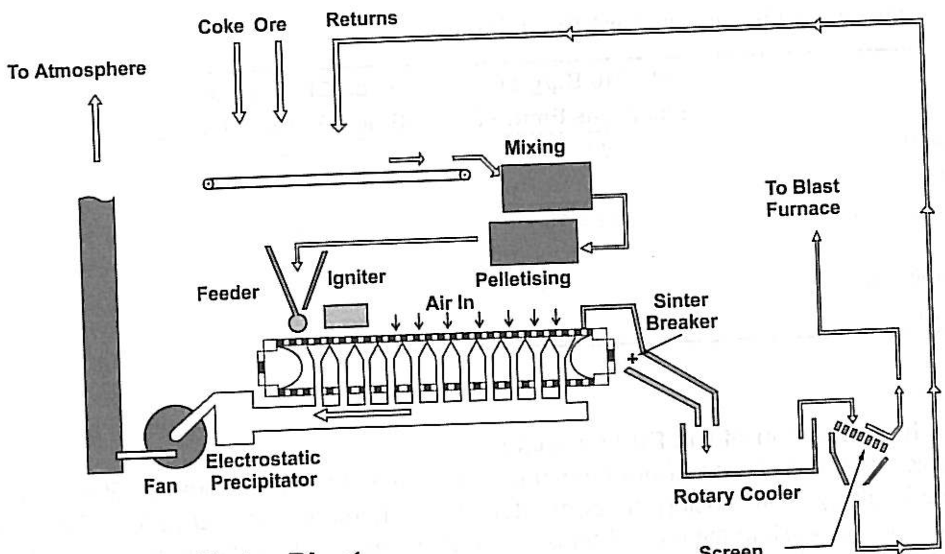

Fig. 2 Sinter Plant

Radioactivity in the Sintering Process

The materials which enter the sintering process, mainly iron ore and coke, contain trace amounts of naturally-occurring uranium and thorium, and their decay products. The average activity of the uranium decay products in the iron ore input to the sinter plant is 15 Bq/kg. These levels of radioactivity are so low that they had never been considered of any importance. It is only in recent times that the significance of the radioactivity in the sintering process was discovered in the Netherlands. The sintering process volatilises some minor constituents of the ore, including the radioisotopes lead 210 and polonium 210, which become concentrated in the off gases. British Steel has now assessed the situation within its sinter plants. Initial work confirmed that the radioactivity did concentrate substantially in the emissions from the sinter plant stack, and a detailed programme of work was commissioned to quantify the effect. It became clear that the emissions of radioactivity might need to be authorised under the Radioactive Substances Act, so the work was discussed with the Environment Agency, which is the responsible authority. In the Act the need for authorisations is based on the activity concentration (Becquerels per g of emission) emitted from the sinter plant in the off gases. In current UK law the maximum level allowed is defined for a number of radioisotopes, including polonium 210 and lead 210.

As a consequence of the European Directive on radiation safety the current Act will soon be replaced by new legislation. An assessment of the impact of the emissions was therefore also undertaken, as required by the Directive.

steel which is finally produced is well known as a material which contains extremely low levels of radioactivity.

***Table 3:* Radioactivity in Blast Furnace Off Gas Dusts**

	Po 210 Bq/g Dry Weight	**Pb 210 Bq/g Dry Weight**
Average radioactivity in the waste for disposal	2.8	8
Radioactive Substances Act Disposal limit without authorisation	15	15

Conclusions

British Steel has assessed the radioactive releases from iron and steel production. It has undertaken a programme of work to quantify the emissions, and in conjunction with the NRPB, assess the impact on people. It is concluded that the emissions to atmosphere from sinter plants exceed the limits for exemption in the UK Radioactive Substances Act. The impact on the critical groups is below the 10 μSv limit set for exemption in the European Directive at three of the sites, and slightly above it at the fourth site. The population doses arising from each site exceed the limit for exemption of 1 manSievert contained in the European Directive on radiation safety. Hence the emissions have been authorised by the UK Environment Agency, and British Steel is required to monitor the emissions and report the results.

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