

Properties of Heated Coal*

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The outstanding properties of heated coal are those associated with (1) the destructive distillation of coal, that is, the behavior of coal at elevated temperatures in an inert atmosphere, and (2) the combustion of coal.

During the destructive distillation the physical condition of a compressed sample of powdered bituminous coking coal passes through characteristic softening, expanding, plastic and agglutinating stages. The temperature at which these changes or conditions exist are related with each other and with the carbonizing behavior of coal.

Proceeding from ordinary atmospheric temperature toward high temperatures, a point is reached near 350° C. at which the coal starts to soften due to melting of constituents in the coal. The softening occurs throughout a brief range in temperature and in the case of the compressed sample of powdered coal the mass starts to contract or deform under an applied stress. With continued rise in temperature the softening continues and is accompanied by relatively rapid contraction or deformation. During the softening of the coal the particles fuse and stick together, and the mass becomes plastic. The rapid contraction of the test specimen is terminated at the active decomposition temperature at which the evolution of gas in the softened, fused coal causes swelling or frothing.

With continued rise in temperature the expanding plastic coal reaches the solidification point at which sufficient carbon has been deposited in the agglomerating band to cement the particles of heated coal together. Expansion ceases and the plasticity of the coal disappears. After passing the solidification point the specimen retains its firm porous structure, but due to continued devolatilization it contracts or shrinks slightly.

The physical changes of the heated coal are interrelated with the decomposition of the coal substance, inasmuch as the plastic properties and solidification of the plastic coal are dependent in certain aspects on the decomposition which yields volatile gases, and a carbon residue. Thus the physical changes which occur in the coal are illuminated by a consideration of the destructive distillation of coal, the products obtained, and the governing influences.

The organic constituents of coal decompose and distil at elevated temperatures yielding gaseous liquid and solid products. The final volatile products obtained are not present as such in the coal and the composition and volume of the gas are governed by the constitution of the coal and by the time, temperature, pressure and cracking conditions of the distillation.

When the coal is heated to coking temperatures the first gases appear before the softening point is reached. These gases, water vapor and carbon dioxide, result in minor amounts from the mild oxidation of the coal due to the presence of inherent or absorbed oxygen. Traces of volatile hydrocarbons and other occluded gases are evolved also.

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At the softening point, decomposition of the coal becomes marked as shown by the loss in weight of the coal, and subsequently a large proportion of the volatile matter is driven off before the solidification point is reached. As the temperature continues to rise, further devolatilization is accomplished and at 900°C the solid residue contains only a small proportion of volatile matter which is chiefly hydrogen.

Due to the complexity of the chemical constitution of a coal and as a variety of compounds and reactions are involved, there is no apparent temperature at which the evolution of volatile matter begins sharply and proceeds rapidly as would be the case in the distillation of a pure chemical compound. However, to determine whether a compound or class of compounds could be isolated which would exhibit definite physical characteristics such as boiling point, coals have been extracted with various organic and inorganic solvents. In the case of an Illinois coal extracted with phenol subsequent tests showed that the rates of evolution of volatile matter from the extract, residue and original coal were practically the same. In a similar experiment upon an eastern coal the extract decomposed more rapidly and at lower temperatures than did the residue or original coal. In both instances the extracts lost weight appreciably at temperatures slightly above 100°C.

In addition to the evidence obtained in the solvent analysis of coal, including solvents other than phenol, the variation in rank influences the products of the destructive distillation. It is demonstrated by the available data that the amounts of carbon monoxide and carbon dioxide contained in the gases from the distillation greatly increases in the younger coals and there is a corresponding decrease in the hydrogen and saturated hydrocarbons. The unsaturated hydrocarbons remain approximately the same in the series of coals studied.

It is also characteristic of coal that the volatile products are subject to marked modification when exposed to the conditions which induce secondary or cracking reactions in the superheated gases. Catalytic influences are also present. Thus, in any distillation the gases and distillate obtained are not exactly the same as the constituents originally evolved from the coal substance. If the distillation is carried out in vacuo or at low final temperatures the secondary decomposition reactions are minimized.

The factors of temperature, time and pressure combined influence the cracking processes. Time is involved largely because the thermal conductivities of coal and coke are low, hence large heat gradients are set up in the coal being carbonized. The heat effects involved in the volatilization and decomposition of the coal are additional causes for the difficulty in obtaining uniform distillation. In the outer zones of the charge of coal being carbonized the distillate and gases are exposed to cracking surfaces while in the plastic zone the primary reactions are just beginning.

When coal is heated in an oxidizing atmosphere the distillation processes are obscured and modified by the combustion of the products. In active efficient burning, coal apparently does not yield the volatile distillation products, since they are burned as rapidly as they are formed. However, coking does occur in the combustion.

At moderate temperatures the lower rank coals absorb oxygen to the extent that weathering and spontaneous ignition are serious problems in the coal industry. In the case of Illinois coals the losses due to disintegration and to spontaneous ignition, arising from exposure to the atmosphere, are of greater importance than are the changes in weight and heating value. The temperature at which the spontaneous ignition occurs has been reported as 350°C or higher, depending on the condition and variety of the coal. In most cases the ultimate limit to the attainable combustion rate is set by the reactivity and thermal conductivity of the fuel in its coked form.