# Degree of Coalification

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# DEGREE OF COALIFICATION

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Contents: A discussion of the 'coalification degree' concept -- The possibility of finding various substances with different degrees of coalification within the same grain of coal -- A classification of the characteristic qualities of coal in relation to the degree of coalification.

The 'coalification degree' concept is widely known, and is frequently used in postwar publications, both here and abroad. In spite of that, it must be admitted that this concept is not very clearly defined. The concept has no doubt been derived from the observation that various kinds of mined coal contain varying amounts of carbon, i.e., the chemical element C, and thus are to a greater or lesser degree coalified (in Polish, the terms 'oweglone' or 'zwegione' [instead of "uweglone"] had previously been used). It has been found that the properties of coal vary in relation to its carbon content. The carbon content is inversely related to the content of volatile matter and thus either content can be used as an index to determine the degree of coalification of a given coal sample.

The problem of determining the degree of coalification would thus be solved, if it were not for the fact that different petrographic components of the same piece of coal contain many different proportions of carbon and of volatile matter. This is clearly apparent when the vitrain and fusain of the same coal sample are compared. Therefore, there can only be a question of the degree of coalification of pure microscopic petrographic components [1]. Strictly speaking, one should go much further and consider the degree of coalification of individual pure chemical substances contained in the original plant materials, i.e., one should simply speak of the degree of chemical and physical-chemical transformation of the original material.

The following definition of coalification degree can be derived from these considerations:

The degree of coalification is defined by the chemical, physical, and physical-chemical condition of the plant matter which had undergone a definite period of biochemical and geo-chemical transformation, specific to each coal grain

The term "coal grain" is used, since in practice only a definite piece (or grain) of coal is available for study.

It is assumed that the attained degree of coalification (SU) can be expressed by the equation

$$SU = x + y + z + u$$

where

x is the influence of biochemical factors on coalification degree

y is the influence of pressure on coalification degree

z is the influence of temperature on coalification degree

u is the influence of all other factors on coalification degree.

If two substances present in the original plant matter had undergone different coalification processes, then one will have attained the degree of coalification $SU_1$, and the other $SU_2$, whereby it may happen that $SU_1 = SU_2$; then $x_1 + y_1 + z_1 + u_1 = x_2 + y_2 + z_2 + u_2$, and the degree of coalification of the two substances is the same, in spite of the fact that they belong to two different coal grains, obtained from two different coal basins.

If, however, an entire coal grain is considered, ie, a mixture of various substances, then in grain No 1 the degree of coalification reached by all its component substances considered jointly will equal $SU_1$, whereas in grain No 2, which underwent a different coalification process, certain substances may reach the degree of coalification $SU_1$, whereas others may reach $SU_2$ or $SU_3$. This may happen as a result of differences in the magnitudes of individual factors influencing coalification and/or as a result of different sequences in which these factors had operated.

This can be expressed more clearly by means of an example, in which two substances contained in the original plant matter, eg, wax (W) and resin (Z) are considered. It is assumed that together they were acted upon by the factors $x_1 + y_2 + z_3 + u$, which resulted in a degree of coalification $SU_3$ for both substances. Now, if the conditions of this experiment were changed and the two substances were both subjected to the operation of the factors $x_1 + y_3 + z$ ? (illegible) + u, it might happen that one of them would attain a degree of coalification $SU_3$, and the other $SU_4$, since it is possible that the W substance reacts differently to a change in magnitude of the individual factors than does the Z



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substance. Hence, there may be a case where in two different coal grains the two W substances will have the same degree of coalification in both grains, while the Z substances will have different degrees of coalification (2), (3).

Thus, strictly speaking, the problem of determining the degree of coalification would be very complicated, or even altogether insoluble, if it were not for certain simplifying circumstances. These are:

1. The fact that similar plant matter, placed under similar conditions, probably underwent the same changes during the biochemical coalification period.

2. The great resistance to coalification of certain substances contained in the original plant matter. Thus different magnitudes of the various factors influencing coalification produced no changes, or only very slight ones, in the chemical structure of these substances.

3. The fact that, as the degree of coalification progresses from coal (wegle płomienne) to the anthracites, the differences between the individual petrographic components or between the various chemical substances constituting the coal tend to disappear (3).

4. The great preponderance of material is derived from ligneous or from ligneous-cellular substances in humus coals, especially in flaming coals. This preponderance means that any differences in the remaining coal substance will have little effect on the given degree of coalification of the coal mass as a

whole.

If these circumstances are taken into consideration, it may be assumed that for practical purposes, and for purposes of classification, the degree of coalification of normal humus coals may be measured either by the carbon content or by the volatile matter content.

For scientific research purposes, the measurement of the degree of coalification of the pure vitrain substance and particularly of its structural variation, telinite, is recommended in the case of humus coals (1).

The sapropelic or leptobiolithic coal varieties undergo separate sequences of coalification, so that the same carbon or volatile matter contents in humus coal and in sapropelic coal do not signify the same degree of coalification of the two materials.

All characteristic properties of coal may be divided in three groups:

1. Those properties which are in an approximately linear relation to the degree of coalification, ie, they are directly or inversely proportional to the degree of coalification (these could be called the "carbon" properties).

2. Those properties which are related to the degree of coalification in such a way that the curve describing this relationship has a maximum or a minimum point at a certain degree of coalification (the so-called "surface" or "hydrogen" properties). The maximum or minimum points usually occur either at about 85

percent C content, on the basis of moisture-free and ash-free matter, or else more often, at the transition point from (tluste) coking coals to susub-coking and semicoking ie, at about 90 percent carbon content.

3. Properties which show no relation to the degree of coalification.

Such differentiation of the properties of coal is of course based on the structure and the chemical composition of coal.

Riley's work (5) sheds interesting light on this problem. Riley determined the diameter and height of the crystalline of coal by means of X-ray investigations. It appeared that the diameter of the crystalline increases in linear relation to the degree of coalification, while its height reaches a maximum at the 92 percent C content point. Hence there is here a striking analogy with the so-called "carbon" and "hydrogen" properties of coal. Among the former properties are, among others: carbon content, oxygen content, the Wieluch index, volatile matter content, fixed carbon content, the so-called fuel ratio, ie, the ratio of fixed carbon to volatile matter, on the basis of moisture-free and ash-free coal, distillable tar content, the phenol content of the distillable tar, oxidizability and its indexes, such as the manganese rating, Kreulen's reactivity coefficient, ignition temperature, which is the main index of possible tendencies towards self-ignition, etc.

Among the properties of the second group are, among others:

coking power (maximum at about 88 to 93 percent C content, porousness (minimum at about 89 percent C); heat of moistening (minimum at 89 percent C); magnitude of inner surface (minimum at 89 percent C); pore diameter (minimum at 89 to 93 percent C); percentage of absorbed pyridine (7) (minimum for rich coking coals); percentage of absorbed methyl violet (8) (minimum for rich coking coals); rate of moistening (9) (minimum for rich coking coals), etc.

The individual properties listed are often derived from one or several basic properties of the coal, as for instance those properties which depend on the type of inner surface and its degree of development.

As far as the relation of hydrogen content to the degree of coalification is concerned, the curve initially runs parallel with the degree of coalification axis, ie, starting with cannel coals and proceeding through the splint-gas coals, gas coals, towards the gas-coking coals there is no change in the hydrogen content. (According to certain data the first portion of the H curve is parallel to the degree of coalification axis or is even somewhat inclined at an obtuse angle to this axis. This means that the hydrogen content is constant, or decreases very slightly, as the curve proceeds from splint (plomienne) to the gas-coking coals, ie, up to the point where there is a break in the curve. Data presented by Regnault and Gruner (Strache Lant: Kohlenchemie, Leipzig 1924, p. 60) seem to indicate that there is a maximum hydrogen content with gas coals (80 to 85 percent C, 5.8 to 5 percent H). Franklin's investigations similarly point towards the occurrence of a maximum point, since she states that hydrogen content is in linear relation to the specific volume of the coal, which in turn shows a maximum at 85 percent C content. It should be mentioned that by extrapolating the true density of coal to the point of zero hydrogen content, Franklin obtained much lower values than those of the density of graphite which, in her opinion, indicates that graphite cannot be considered the ultimate state of coalification.) After the region of gas-coking coal is reached, there is a sharp break in the curve as it proceeds in the direction of anthracite.

The true specific gravity of coal, measured by means of liquid helium, shows a minimum point at 85 percent C, or at the point where the hydrogen content drops rapidly (10).

It is worth remembering that at this point, ie, at the transition from gas coal to rich coking coals, the well known "coalification jump" occurs, which has been observed with durain coals.

A linear relation between moisture content and degree of coalification can be observed up to the point of rich coking coals, (or meta-coking coal, according to Laskowski and Roga (11) ). In this type of coal, as well as in the sub-coking and semi coking coals the moisture content amounts to about 1 percent, on the basis of air-dried coal samples. This writer has no adequate data concerning the moisture content of anthracitic types of coal and of anthracite. It seems, however, that the moisture content of these types of coal is greater (eg, the anthracite coal from the coal-mine M has a greater moisture content than coal with a lesser degree of coalification). Furthermore, moisture content is doubtlessly related to the nature and magnitude of the inner surface, which in turn has a type of relation to the degree of coalification which is similar to that of hydrogen. It would, therefore, seem that moisture content should also show a "hydrogen" type of curve in relation to the degree of coalification.

Among the coal characteristics which show a maximum point is the grindability (maximum for rich coking coal).

Nitrogen content and organic sulphur content are examples of properties of coal which probably have no relation whatever to the degree of coalification.

No relation has hitherto been observed between the degree of coalification and the content and composition of mineral substances present in coal.

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