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Classification of coals

Classification des charbons

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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

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Introduction

Coals occur worldwide and vary significantly in their physical and chemical characteristics for a variety of reasons, both with respect to the organic coal substance and to the associated mineral matter that is always present to varying extents. Coals are an important source of energy, as well as being essential for the production of metallurgical cokes, and are widely used as feedstock for other industrial processes such as in the production of gaseous fuels and synthesis gas. Hence, a wide range of procedures has been developed by the International Organization for Standardization (ISO) for the analysis and testing of coals. These ISO procedures are variously designated as being applicable to "hard coals", "brown coals" and "lignite", "bituminous coals" and "anthracite". There are, however, no ISO definitions that specify the boundaries that apply to these descriptive terms, which all relate to the geological maturity (rank) of the coals. Further, there is no simple system for the classification of coals that can provide, on a comparative basis, an indication of coal characteristics on a worldwide basis. This ISO standard provides a basis for addressing both these issues.

The classification is not intended to be used for commercial purposes because the assessment and selection of coals for a specific purpose require detailed information that enables the likely performance of a coal in a particular application to be anticipated. The wide-ranging list of ISO analyses and tests provides that information.

The development of this ISO standard has been guided by the recently published "*International Classification of in-Seam Coals*"[14]. The ISO standard, however, represents a simplified version that incorporates some significant modifications made for reasons given in the classification details that follow.

Classification of coals

1 Scope

This International Standard describes a simple classification system for coals providing

— guidance on the selection of the appropriate ISO standard procedures for the analyses and testing of coals,

— international comparison of coals in terms of some key characteristics,

— descriptive categorization of coals.

The system is applicable to coals of all ranks, but care is required in relation to the classification of some types of coal.

The system may be applied to a wide range of representative coal samples, provided their exact nature is stated. Such samples include bore-core seam sections and composite samples, raw (as-mined) coal, washed coal, blends of coals of similar rank and selected, specified size fractions.

The system provides a broad framework within which coals can be assessed. The selection of coals for a specific use requires detailed information that enables the likely performance of a coal in a particular application to be anticipated. The wide-ranging list of ISO analyses and test procedures for coals serve this purpose. The selection of the appropriate procedures to be used in assessing a coal depends on the intended use.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1213-2, *Solid mineral fuels — Vocabulary — Part 2: Terms relating to sampling, testing and analysis*

ISO 7404-1, *Methods for the petrographic analysis of bituminous coal and anthracite — Part 1: Vocabulary*

ISO 7404-5, *Methods for the petrographic analysis of bituminous coal and anthracite — Part 5: Method of determining microscopically the reflectance of vitrinite*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1213-2, ISO 7404-1 and the following apply.

3.1
coal
carbonaceous sedimentary rock largely derived from plant remains with an associated mineral content corresponding to an ash yield less than, or equal to, 50 % by mass (dry basis)

NOTE In the geological coalification sequence, the transformation from peat to coal is defined as occurring when the total *in-situ* moisture content has decreased to 75 % by mass. The upper limit for undisturbed coal seams in the normal coalification process leading to semi-graphite is defined as corresponding to a mean random vitrinite reflectance, $\bar{R}_r$, of 6,0 % or, preferably, a mean maximum vitrinite reflectance, $\bar{R}_{v,max}$, of 8 %, determined in accordance with ISO 7404-5. The upper limit, $\bar{R}_{v,max}$, for disturbed, contact altered, coals can exceed 10 %; see Table 1, Note 2.

3.2
vitrinite
group of macerals with a grey colour (as observed with reflected light under a microscope) and with a reflectance generally between that of the associated darker liptinite and lighter inertinite over the rank range in which the three respective maceral groups can be readily recognized

NOTE 1 In the upper range of medium rank, vitrinite reflectance can be less than that of liptinite (where liptinite is recognizable) whilst at very high rank ($\bar{R}_r > 4{,}0$ %), the maximum reflectance of both liptinite and vitrinite may exceed that of inertinite.

NOTE 2 In medium and high rank coals, vitrinite reflectance measurements should preferably be taken on telovitrinite or, in its absence, on the whole of the vitrinite population. Within low-rank coals, vitrinite reflectance measurements must be measured on the submaceral ulminite B, or preferably on Eu-ulminite, if present. Eu-ulminite consists of gelified plant tissues with the cell structures weakly visible in reflected white light. Ulminite B is the more highly reflecting part of ulminite; see [9].

3.3
inertinite
maceral group that is composed of particles having a reflectance in low and medium-rank coals that is higher than that of the macerals of the vitrinite and liptinite groups, but is lower than that of the corresponding vitrinite in very high-rank coals

NOTE The reflectance of inertinite macerals begins to be exceeded by that of the macerals of the vitrinite group when the vitrinite and inertinite reflectance, $\bar{R}_r$, has reached about 4 %; see [8].

3.4
liptinite
maceral group that includes sporinite, cutinite, suberinite, resinite, liptodetrinite and alginite

NOTE At low ranks, the reflectance of liptinite macerals is lower than that of vitrinite but converges with that of vitrinite at medium rank B to A. Liptinite macerals show stronger primary autofluorescence relative to that of macerals from the other maceral groups up to medium rank B.

3.5
lignite
brown coal
coal having a mean random vitrinite reflectance, $\bar{R}_r$, less than 0,4 %

NOTE The terms “brown coal” and “lignite” are frequently used as alternatives but the latter is the term now preferred by the International Commission for Coal and Organic Petrology; see [10].

3.6
sub-bituminous coal
coal having a mean random vitrinite reflectance, $\bar{R}_r$, equal to or greater than 0,4 % but less than 0,5 %

3.7
bituminous coal
coal, synonymous with medium-rank coal, having a mean random vitrinite reflectance, $\bar{R}_r$, equal to or greater than 0,5 %, but less than 2,0 %

3.8
anthracite
coal, synonymous with high-rank coal, having a mean random vitrinite reflectance, $\bar{R}_r$, equal to or greater than 2,0 % but less than 6,0 %, or, preferably, a mean maximum reflectance, $\bar{R}_{v,max}$, less than 8,0 % for geologically unaltered coal

3.9
hard coal
coal, comprising the medium-rank (bituminous) and high-rank (anthracite) coals, having a mean random vitrinite reflectance, $\bar{R}_r$, equal to or greater than 0,5 % and less than 6 % or, preferably, a mean maximum vitrinite reflectance, $\bar{R}_{v,max}$, less than 8,0 %

3.10
bed-moisture
natural moisture content of the coal *in situ* in the seam

NOTE It is necessary to take care to ensure that samples for this determination are free of open fissures, voids or other features that might entrain free water, and that there is no loss of moisture during sampling and sample preparation.

4 Classification

4.1 General

The physical and chemical properties of a coal are virtually all determined by its geological maturity (rank), petrographic composition and the amount (as well as the nature and mode of association) of the mineral matter present. Thus, for simplicity, this classification for coals is based on the following coal properties:

— vitrinite reflectance, expressed in percent: mean random reflectance, $\bar{R}_r$, to designate rank, where $\bar{R}_r$ is determined directly or calculated from $\bar{R}_{v,max}$; see ISO 7404-5;

— vitrinite content, expressed as percent by volume on a mineral-free basis: designation of the petrographic composition; see ISO 7404-3; see footnote to Table 5;

— ash yield, expressed as a percent on a basis: designation of the amount of inorganic material present; see ISO 1171.

NOTE For medium-rank coals, $\bar{R}_{v,max} = 1{,}07\ \bar{R}_r$ [6].

4.2 Rank — Primary categories

Three broad rank categories, low rank, medium rank and high rank, are defined in Table 1.

Table 1 — Definition of broad rank categories: low, medium and high rank

Rank	Definition
Low rank [a] (lignite and sub-bituminous coals)	bed moisture $\leqslant$ 75 % and $\bar{R}_r < 0{,}5$ %; see AS 2434-1[5]
Medium rank [a] (bituminous coals)	0,5 % $\leqslant \bar{R}_r <$ 2,0 %
High rank [b] (anthracites)	2,0 % $\leqslant \bar{R}_r <$ 6,0 % (or $\bar{R}_{v,max} <$ 8,0 %) [c]

[a] The boundary between low-rank and medium-rank coals is set at $\bar{R}_r = 0{,}5$ % since coals with $\bar{R}_r$ between 0,5 % and 0,6 % (the latter being the threshold value set for medium-rank coals in [14]) are texturally similar to coals with $\bar{R}_r$ greater than 0,6 %. The degree of gelification is high and shrinkage cracks are not observed when fresh coal is exposed to the atmosphere.

[b] $\bar{R}_{v,max} = 8{,}0$ % is just beyond the rank where $\bar{R}_{v,min}$ (~2,5 %) is falling rapidly from its maximum of $\bar{R}_{v,min}$ = ~3,5 % at $\bar{R}_{v,max} = 6$ % and marks the transition to increasing graphitization; see [16], [15]. (Contact-altered coals with $\bar{R}_{v,max}$ as high as 10,5 % are classified as anthracite in China.)

[c] $\bar{R}_{v,max}$ is preferred at this rank since $\bar{R}_r$ is difficult to measure reliably.

4.3 Rank — Sub-categories

To provide a greater classification resolution, the three primary rank categories are subdivided into sub-categories, as defined in Tables 2, 3 and 4.

Table 2 — Subcategories of low-rank coals [a,b]

Sub-category	Description
Low-rank C (lignite C)	$\bar{R}_r < 0{,}4$ % and bed moisture > 35 % and < 75 %, ash-free basis
Low-rank B (lignite B)	$\bar{R}_r < 0{,}4$ % and bed moisture ⩽ 35 %, ash-free basis
Low-rank A (subbituminous coal)	0,4 % ⩽ $\bar{R}_r < 0{,}5$ %

[a] It is required that $\bar{R}_r$ be measured on ulminite B, or, preferably, on Eu-ulminite if present; see 3.2, Note.

[b] The limit of 35 % bed moisture corresponds approximately to the bed moisture content used in Germany to distinguish between coals designated “soft brown” and “hard brown”. Soft brown coals, at the microscopic level, have a large pore volume with open cell lumens (textinite) with little evidence of gelification. Hard brown coals have a low pore volume, mainly filled cell lumens, and significant gelification.

Table 3 — Sub-categories for medium-rank coals

Sub-category	Description
Medium rank D [a] (bituminous D)	0,5 % ⩽ $\bar{R}_r < 0{,}6$ %
Medium rank C [b] (bituminous C)	0,6 % ⩽ $\bar{R}_r < 1{,}0$ %
Medium rank B [c] (bituminous B)	1,0 % ⩽ $\bar{R}_r < 1{,}4$ %
Medium rank A [d] (bituminous A)	1,4 % ⩽ $\bar{R}_r < 2{,}0$ %

[a] $\bar{R}_r = 0{,}6$ % approximates the onset, as the rank increases, of the formation of coke from the vitrinite under standard heating conditions (3 °C/min).

[b] $\bar{R}_r = 1{,}0$ % approximates the transition, under standard heating conditions (3 °C/min), as the rank increases, of the texture of the coke formed from the vitrinite, from fine to medium mosaic; also coincides approximately with the coalification stage where maximum oil generation occurs.

[c] $\bar{R}_r = 1{,}4$ % approximates the transition, as the rank increases, of the texture of the coke formed from the vitrinite, under standard heating conditions (3 °C/min), from medium mosaic to fibrous; also coincides approximately to the coalification stage where oil generation ceases.

[d] $\bar{R}_r = 2{,}0$ % approximates the end, as the rank increases, of the softening and swelling properties of the vitrinite, under standard heating conditions (3 °C/min).

Table 4 — Sub-categories for high-rank coals (anthracites)

Sub-category	Description
High rank C [a] (anthracite C)	$2{,}0\ \% \leqslant \overline{R}_r < 3{,}0\ \%$
High rank B [b] (anthracite B)	$3{,}0\ \% \leqslant \overline{R}_r < 4{,}0\ \%$
High rank A (anthracite A)	$4{,}0\ \% \leqslant \overline{R}_r < 6{,}0\ \%$ (or $\overline{R}_{v,\,max} < 8{,}0\ \%$)

[a] $\overline{R}_r = 3{,}0\ \%$ approximates the rank where the volatile matter yield has decreased to a level that results in a significant decrease in the ease of ignition and the bireflectance is beginning to increase strongly; see [1], [8], [11], [16].

[b] $\overline{R}_r = 4{,}0\ \%$ approximates the rank where the development of bireflectance is beginning to accelerate due to the onset of a decrease in $\overline{R}_{v,\,min}$ as $\overline{R}_{v,\,max}$ continues to increase.

4.4 Petrographic (maceral group) composition

The petrographic, or maceral group composition, as represented by the vitrinite content, is used to classify coals into four categories as shown in Table 5.

Table 5 — Classification by petrographic composition [a]

Vitrinite content % by volume, mineral-free	Vitrinite class category
< 40	Low vitrinite
$\geqslant 40$ and < 60	Medium vitrinite
$\geqslant 60$ and < 80	Moderately high vitrinite
$\geqslant 80$	High vitrinite

[a] The microscopically recognizable coal matter is a three-component system consisting of the vitrinite, inertinite and liptinite maceral groups; but the vitrinite content can be used as a simplifying manifestation of the petrographic composition since, in most instances, coal consists mainly of the vitrinite and inertinite maceral groups. It is important to recognize, however, that the determination of the vitrinite content alone is not sufficient to characterize the petrographic composition of a coal. Some of the lower-reflectance components of the inertinite maceral group may have reactive properties during coking. Also, a high abundance of liptinite ($> 10\ \%$) results in higher values for the volatile matter yield than would be expected from the vitrinite reflectance.

Thus, a cautionary note should accompany the use of the vitrinite content to signify the petrographic composition in the classification of a coal where the liptinite content is unusual.

4.5 Ash yield

The inorganic content of coal, as represented by the ash yield, is used to classify coals into five categories as specified in Table 6.

Table 6 — Ash yield classification

Ash yield % by mass dry basis	Ash class category
< 5	Very low ash
⩾ 5 and < 10	Low ash
⩾ 10 and < 20	Medium ash
⩾ 20 and < 30	Moderately high ash
⩾ 30 and < 50	High ash

5 Nature of the coal sample

The classification, within reason, may be applied to characterize any coal sample. The classification refers specifically to the coal sample being examined and this may not be fully representative of the coal in the seam(s) from which it was derived. The rank of blends, as indicated by the mean random reflectance, $\bar{R}_r$, of the vitrinite, is dependent on the $\bar{R}_r$ for each of the components in the blend; the petrographic composition and ash yields reflect the sampling, preparation and blending involved.

NOTE See comment in d), below.

Thus when a coal sample is classified, a brief definitive description of the nature of the sample with regard to its sampling and preparation shall accompany the classification. Answers to the following questions need to be specified for the sample classified.

a) Is it a full seam or seam section sample, either as mined or sampled *in situ*?

b) Is it a washed product?

c) Is it a specific size fraction?

d) Is it a blend? A blend should be of coals of similar rank only.

6 Descriptive classification terminology

The descriptive term used for each of the rank-dependent categories and sub-categories is accompanied by an alternative descriptive term (see Clause 4) that relates to the rank-dependent terms in use in existing ISO standards for the analysis and testing of coals.

Basing the classification system on three parameters (vitrinite reflectance, vitrinite content and ash yield) with descriptive class sub-category terms for each of these, permits the use of a relatively simple descriptive classification of a particular coal sample. Some examples are shown in Table 7.