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FUEL RESEARCH INSTITUTE
OF SOUTH AFRICA

ONDERWERP:
SUBJECT: MOISTURE IN COAL

ITS OCCURRENCE, ITS IMPLICATIONS AND SOME OF THE

PROBLEMS MET IN PRACTICE.

AFDELING:
DIVISION:

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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

MOISTURE IN COAL

Its Occurrence, its Implications, and some of the Problems met in Practice

By: A. J. Petrick

SUMMARY

After dealing briefly with relevant physical and chemical properties of coal, the mechanism of adsorption of moisture is discussed.

It is pointed out that coal leaving the colliery's preparation plant may be thoroughly wet and that drainage of coal containing a high proportion of minus half millimeter coal may be a slow process.

Attention is drawn to the desirability of defining terms relating to the moisture content of coal clearly in contracts. This statement is clarified by a discussion of factors affecting the results of moisture determinations. It is concluded that explicit standard specifications for the analysis of coal samples are desirable.

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1. INTRODUCTION

Every producer and large consumer of coal has concepts about the moisture content of coal and its effects in practice. Terms such as "free moisture" and "inherent moisture" are frequently used without, however, clearly defining these terms or, possibly, fully appreciating how intrinsic properties of the coal and other factors affect the moisture content of coals under various circumstances.

It is, therefore, appropriate to consider some relevant properties of coal and other factors affecting its moisture content before discussing technical aspects of the problem of moisture in coal and of its determination.

2. SOME FUNDAMENTAL FACTS AFFECTING THE MOISTURE CONTENT OF COAL TYPES.

(a) The Coalification Process

The theory about the maturing or coalification of organic matter from peat through brown coal, bituminous coal types to anthracite is well known, coals being frequently characterised by their "rank".

It will be readily accepted that peat and even brown coals have a very open, relatively speaking, spongy consistency. They take up water readily and swell considerably in the process; in the bed or seam they are sopping wet.

During later stages of coalification the organic matter is considerably compacted by the pressure of overlying strata and chemical changes that occur.

Actually there is some discontinuity in the processes in the region of the rank stage: more mature coking coal. This, for example, has the highest packing. Chemically, the organic matter changes from peat to mature coking coal largely by losing oxygen as H_2O or CO_2 and there is a trend to form

more .../

more complex molecular structures. This provides one reason for the increasing compactness. Beyond the coking coal stage the trend is to lose other elements, mainly hydrogen and for molecular configurations to approach a graphitic, lamellar structure that may tend to have a somehwat more open stacking than the strutures composing the coking coals.

Weathering of the coal, either by exposure to the atmosphere or by sub-surface weathering, may be regarded as a reversal of the coalification process. It is accompanied by the chemi-sorption of oxygen and finally chemical combination of oxygen with the coal substance and a trend towards a more "open" molecular structure. On the other hand the effect of heat, e.g. the effect of a dolerite sill at no great distance from a seam, has a maturing effect. In fact, South African anthracites and even coking coals have probably been matured to these stages by such heat treatment since their geological age is the same as that of bituminous coals of relatively "lower rank" in their vicinity.

(b) Coal is a Porous Substance.

Although these are the general trends it must be realised that, notwithstanding the compression or compaction, all the coals are still porous substances. The pore size distribution or average pore diameters may change with rank but even the mature coals have an internal surface area, accessible to molecules of the size of water molecules, much in excess of the external surface of even quite finely ground coal samples.

(c) Physical Adsorption and Desorption of Water.

Water molecules are readily adsorbed, physically, on a coal surface. Oxygen groupings at the surface may provide active centers for such adsoprtion. When such a porous substance is placed in an environment where more or less water or water vapour is present than it contains itself, the trend is to strive towards an equilibrium with this environment, i.e. water vapour will either be desorbed from the coal

surface .../

surface (external or internal surface) and lost to the environment, or water molecules will be adsorbed. If the atmosphere surrounding the coal particles is saturated with moisture the adsorption may proceed to multilayer adsorption and finally to condensation of water in the pores and also on the external surface. Water adsorption is accompanied, even with high rank coals, by measurable, albeit not readily observable swelling. At the beginning of the above mentioned "condensation" the surface would not be visibly "wet". Such coal can, however, more readily take up more water than "fairly dry" coal. In completely wet surroundings, therefore, such coal will readily become "moist" or even wet to the touch or visibly wet.

Physically adsorbed moisture may be removed from the coal by placing it in an atmosphere of lower relative humidity than that in which the equilibrium was previously attained. It may also be reduced by raising the temperature, since the amount of water that can be physically adsorbed is temperature dependent, decreasing rapidly with rising temperature.

Since the rate of adsorption or desorption is dependent on the rate of diffusion to or from the coal surface, it will be appreciated that the rate of losing water will depend on how rapidly desorbed molecules can be removed from the immediate vicinity of the coal surface so as to ensure a high moisture-concentration-gradient from the surface outwards. Therefore, ventilation over, and preferably through a bed of coal by air having a low relative humidity will increase the rate or process of "drying" considerably.

This rather simplified summary provides a basis for the further discussion.

(d) <u>The Bed Moisture or Capacity Moisture content of Coal</u>.

It will be appreciated that, theoretically, one could distinguish between (1) physically adsorbed moisture — the maximum value of this moisture content would be represented by multi-layer adsorption excluding actual condensation

of .../

of water in pores or on the external surface — and (2) actually condensed water molecules, the amount of which may range from the limit of physical adsorption to the absolutely dripping wet condition.

Under more practical conditions one could draw the line a little higher to include, in the "adsorbed moisture", also that condensed in and filling pores.

This is probably the amount of moisture held by coal "in situ" in seams that lie below the general water table of a coal-field. (Most South African coal seams lie below this level, some may indeed be lower than the level to which moisture infiltration through the soil will normally penetrate. Nevertheless, the environment of all the seams may be considered to be equivalent to an atmosphere of virtually 100% relative humidity.)

The amount of moisture held by the coal "in situ" has been referred to as the "bed moisture content" or the "capacity moisture content". Its value can only be determined by taking samples of coal from absolutely fresh coal faces and sealing them immediately to ensure a minimum contact with the atmosphere before the moisture determination is done. The process is difficult and the determination is seldom done. One laboratory approach is to soak a fresh coal sample in water and to remove surface water by rubbing the sample between sheets of blotting paper, before transferring the sample to the moisture determination apparatus.

Another, probably more acceptable procedure is to place a fresh coal sample in an atmosphere kept at 100% humidity until equilibrium has been attained under specified conditions e.g. atmospheric pressure and ambient temperature. The danger is that if the temperature should fall, condensation of water may occur on the surface, vitiating the results. It is, therefore, preferable to hold the relative humidity at a level just below 100% (e.g. 96 to 97%) and to

avoid .../

avoid temperature changes during the determination as far as possible. This in fact is the procedure recommended by A.S.T.M.[*]

Theoretically, this capacity moisture content should be determined to arrive at the true value of the "condensed" moisture referred to as "free" or "surface" moisture present in a coal sample. In practice "free" or "surface" moisture is, however, usually defined as the loss on air drying i.e. "air-dried" moisture content is the criterion and not the capacity moisture content. The difficulties in determining the "air-dried" moisture content will be considered later.

3. PRACTICAL CONSIDERATIONS

(a) Moisture Condition of Coal at a Colliery's Surface Plant.

In practice the coal as mined can be expected to be in the capacity moisture condition.

Regulations require the coal to be sprayed with water to reduce dust formation. Further spraying may be done at transfer points underground. The coal, therefore, arrives at the surface plant in a fairly wet condition, so much so, that the moisture may cause difficulties in handling and screening. Wet screening may have to be applied before the coal enters the washing plant so as to avoid undue contamination of the washing medium with coal fines and slimes. The coal leaving the washing plant is dripping wet.

(b) Drainage of Water from Coal.

This is not a very serious matter for the coarser size grades (e.g. from peas upwards) provided this coal is free from fines. The matter is more serious where fines are

involved .../

[*]A.S.T.M. Standard Designation D1412-61.

involved as fine coal drains slowly.

To illustrate this point some results of experiments done at the Institute may be quoted. A sample of coal ranging from about 22 mm to zero was divided into size ˛ractions some of which were later recombined to produce samples containing more or less fines. All the samples were "preconditioned" to have a total moisture content of about 30%. The coal was then charged to a cylindrical vessel some 8 ft high and fitted with a reinforced half-millimetre screen at the bottom. The water draining from the vessel was collected and weighed at regular intervals. The residual total moisture was then calculated. The following are some of the results obtained:

TABLE 1.

Drainage from Coal Samples

having an original free moisture content of 30%.

	Residual Free Moisture Content at end of Drainage Period, (% by wt.)				
Size grading (mm)	22 x 5	5 x 3.2	5 x 1.6	5 x 0	1.6 x 0.5
Drainage Period (hrs)					
1	6.7	7.5	10.8	23.4	18.0
4	6.2	7.2	10.6	19.0	16.1
7	5.9	6.9	10.6	17.6	15.4
24	5.4	6.3	10.2	15.0	14.0
96	-	-	-	12.4	-

(c) Some Effects of High Surface Moisture or Free Moisture Content.

Coal with a moisture content exceeding about 10% is handled with difficulty in mechanical equipment and wet fine coal may settle into an almost solid mass in a railway truck. The producer of coal may thus find excessive moisture in the coal a nuisance in his preparation plant and in handling the coal, discards and slurries. He may also find it necessary to

provide .../

provide extra screen area or storage capacity to achieve reasonable drainage of water to acceptable free moisture levels before final dispatch. (A number of smaller bunkers is to be preferred to a large bunker when dealing with wet coal, because the charging of dripping wet coal into a bunker containing coal that has already drained is, obviously, undesirable.)

To the consumer, excessive moisture in the coal is undesirable because it must be considered as a diluent, decreasing the effective calorific value of the coal.

This would mean that - since the coal is generally only weighed at the colliery's weigh-bridge — the consumer might be liable to pay relatively too high a price, per Btu for wet coal. This is avoided, to a fair extent, by collieries making some allowance, based on general experience, for surface moisture in the coal when determining the weight of coal dispatched.

The consumer will, however, also be faced with grave handling problems at his works if fine coal such as mixed smalls or duff carries excessive moisture.

Small wonder that large consumers insist on a reasonably low moisture content in the coal and may impose penalties for moisture contents higher than an agreed percentage.

True enough, large consumers of duff or pea-duff mixtures may find it expedient to spray fairly dry coal with water as it is unloaded and brought into the plant. A certain percentage of moisture may also be advantageous when duff is fed onto a boiler grate. However, the consumer will prefer to add this moisture to the fine coal himself as he can then control the amount of water added in accordance with his particular requirements.

It is, therefore, obviously in the interest of the producer and the consumer to ensure that the moisture content of coal leaving the colliery is reasonably low.

(d) .../

(d) Equitable Basis for Negotiation.

When considering this matter, it must be agreed that one cannot insist on dispatching or receiving absolutely dry coal as this would be quite impracticable. The basis of discussion is, therefore, usually an "air-dried" moisture content, which may be exceeded by an amount determined by negotiation.

This air-dried moisture content is considered to be the equilibrium moisture content of the coal after exposure to the ambient atmosphere. Since the relative humidity of the laboratory atmosphere is normally less than 100% the air-dry moisture content will be lower than the "capacity moisture" content of the coal. Under circumstances where the moisture content of the coal "as received" is the subject of contractual agreement and money is involved, both producer and consumer should have a clear concept of the meaning of the various terms used and of the factors that may affect the results obtained when analysing samples.

4. PRACTICAL REASONS FOR A CLEAR DEFINITION OF TERMS AND SPECIFICATIONS OF ANALYTICAL METHODS.

The values of greatest practical interest are the "total moisture content" as produced, the moisture content of the coal as received and the "air-dried moisture content" of coal.

(a) The Importance of Proper Sampling.

It is outside the scope of this article to discuss sampling methods, although sampling is the most important step in coal evaluation, because, if the sample taken is not representative of the consignment, the analyses done on the sample have very little real meaning.

Let it be assumed that proper sampling will be done. The question may be posed: where should the coal be sampled?

(b) Correspondence of Points of Weighing and Sampling of Coal.

Whenever .../

Whenever the consumer is interested in the total moisture content of the coal he is purchasing, it is, clearly, essential to sample the coal at the point where it is to be weighed.

If the coal is expected to have a high total moisture content and therefore freight charges have to be taken into account, it would be advisable to take the sample at the producer's weigh-bridge and to ensure that the sample is placed forthwith in a container that can be sealed effectively.

Sampling of the coal, especially washed coal, before this point is to the disadvantage of the producer since appreciable quantities of water may drain from the coal between the point of loading into trucks and the weigh-bridge. Sampling, without simultaneous weighing, at the consumer's end, especially if the distance between the colliery and the consumer's works is great, is again to the detriment of the consumer.

He may desire to know the "moisture content of the coal as received at the works" and samples could and really should be taken for this purpose. This moisture content cannot, however, be related to the weight recorded at the producer's weigh-bridge unless a coal sample for total moisture was also taken at that end.

The results of analyses for "moisture as received" would have more meaning if the consumer would also weigh the coal at the time of sampling. He may, however, have no facilities for weighing loaded trucks.

(c) <u>The Point of Sampling and Weighing should be Determined during Contract Negotiations</u>.

In the case of wet coal the weights recorded at the producer's and consumer's ends would not tally. This may lead to arguments. It appears advisable, therefore, to establish clearly, beforehand, by negotiation between the interested parties at what point coal is to be sampled and weighed.

5. <u>THE</u> .../

5. THE TOTAL MOISTURE CONTENT OF COAL.

The determination of the total moisture content is generally done in two steps:

(a) The whole or a representative portion of the coal sample is taken from the sealed container, weighed immediately and exposed to the ambient atmosphere at the laboratory to allow excess moisture to evaporate. It is preferable to spread out the sample in a thin layer and to rake the coal from time to time.

(Frequently the sealed container is weighed on arrival at the laboratory, the coal is removed and allowed to air-dry — the container being also exposed to dry out — and finally the air-dried coal is returned to the container and re-weighed.)

(b) The residual moisture is finally removed by heating only or by distillation i.e. by applying heat and using e.g. toluene as carrier of the water vapour.

It may be advisable to interpose a crushing and subdivision process between the stages (a) and (b) so that representative samples, small enough for easy handling in laboratory apparatus can be taken from the bulk sample.

Care must be taken in this case to ensure that crushing and subdivision are done rapidly without undue heat generation or ventilation so as to avoid loss of moisture in the processes. Too far-reaching drying in stage (a) may not be advisable so that a gain of moisture during the intermediate treatment is avoided.

The reader may have missed a suggestion that the sample should be "air-dried" in stage (a). No reference to air-dry conditions has been made because air-drying also presents problems as will be indicated below.

6. THE .../

6. THE AIR-DRIED MOISTURE CONTENT

(a) The Significance of the Air-dried Moisture Content.

As already pointed out, moisture in coal acts as a diluent, reducing the effective calorific value of the coal and, where not completely compensated for when determining the weight of coal sold, the real price per Btu in the coal purchased.

Viewed from this angle the only moisture value of interest to the consumer should be the total moisture content of the coal as received at his works or, shortly, the "moisture content as received".

However, for various reasons, present negotiations and contracts between producers and consumers only refer indirectly to moisture as received and elaborate, rather, on the "free moisture content" or "air-dried moisture content".

Inasmuch as the free moisture content of the coal is defined as the loss on air-drying, and the determination of the total moisture content presents no real problems, particular emphasis falls on the air-dried moisture content. Incorrect determination of the air-dried moisture content may bring a consignment of coal within the penalty range. The air-dried moisture content also has particular significance in laboratory work. It is impractical to work with bone-dry coal in the laboratory, as such coal is always liable to adsorb moisture as soon as it is exposed to the laboratory air.

The theoretical differentiation between the moisture content due only to physically adsorbed moisture and "condensed" moisture is too difficult to be used in general laboratory work. Hence the general adoption of an "air-dried" coal value. However, the air-dried moisture content has no absolute value — without qualifying statements.

(b) Factors .../

(b) Factors Affecting the Value of the Air-dried Moisture Content.

It is, for example, difficult to decide when a wet coal sample, exposed to air has just lost all its "free" moisture.

True enough, a coal so exposed will tend to an equilibrium moisture content relative to the water vapour content of the surrounding air. However, the coal approaches this condition asymptotically. Under practical conditions one may have to decide whether "air-drying" is to be regarded as completed when either all traces of visible moisture have disappeared or when, the rate of loss in weight of a sample reaches a value of, say, 0.1% per hour. It must be clearly understood that these two approaches will yield different values for the air-dry moisture content of the coal.

The value of the "air-dried moisture content" will depend furthermore on factors such as:

1. The top size and size consist of the sample. (Coarse coal with a relatively very small external surface area relative to the internal surface area, will appear superficially dry long before equilibrium is established with reference to water adsorbed on internal surfaces.)

2. The relative humidity of the air surrounding the coal.

3. The temperature of the air and

4. The degree of ventilation over or through the coal being air-dried.

The significance of most of these factors has already been discussed. —

(c) The Need for Clear Definition of Terms and of the Methods of Determining the Air-dried Moisture Content in Contracts.

When the free-moisture content of coarse size fractions of coal is to be a subject of contractual agreement

the .../

the parties concerned may agree on the determination of the "free-moisture" by air-drying the coal as received, for example, until visible traces of moisture have disappeared. They should then agree on the procedure of air-drying such as the humidity of the air, its temperature and the degree of ventilation used.

If air-drying at ambient laboratory temperature in still air is agreed to, no party should attempt to reduce the period of air-drying by heating the coal or the air and by blowing air over or through the sample. The rate of air-drying would certainly be increased by adopting such procedures, but the final result obtained will differ from that obtained by the agreed procedure.

Both parties must be aware that the residual or air-dried moisture content obtained when drying coarse coal in this way will differ from that obtained on a crushed analysis sample of the coal even if the air temperature, its relative humidity and the degree of ventilation (if any) are the same. (Well-nigh true equilibrium is established sooner in finely ground coal.)

When the analysis of coal samples is contemplated, it is preferable to air-dry the coal after crushing. The top size of the coal to be air-dried should be specified (e.g. -60 mesh B.S.S.). The crushing would best be done after most of the superficial moisture has been evaporated.

(d) Changes in the Air-dried Moisture Content with Changes in Ambient Conditions in the Laboratory.

It must be clearly appreciated that the air-dried moisture content of even an analysis sample has only a relative value — relative to the relative humidity, the temperature and the movement (ventilation) of the air in the air-conditioning room and, generally, the laboratory atmosphere.

It is .../

It is especially necessary to bear this in mind in the high-plateau area of South Africa where most collieries and also most of the large consumers of coal are located.

In this area the relative humidity of the air may vary from below 30 per cent to well-nigh 100 per cent in a matter of hours (e.g. due to a thunderstorm).

The finely crushed analysis sample, if in contact with the air, will respond rapidly to such changes in relative humidity.

To illustrate this effect, the results of some experiments may be quoted. They were done for another purpose so that no attempt was made to obtain complete equilibrium between the moisture in the coal and its surroundings.

In these experiments, samples of coal crushed to minus one mm were air-dried in the laboratory and then subdivided into a number of sub-samples. These were placed in dessicators in which the relative humidity could be maintained at various levels. After 24 hours the samples were removed and their moisture content was determined in the usual way.

The results of these experiments are given in Table 2.

TABLE 2.

Moisture Content of S.A. Coals at Various Humidities of the Surrounding Atmosphere,

Rel. Humidity	0%	33%	A. D.	67%	100%
NATAL					
Anthracite	0.2	1.4	2.0	2.5	3.8
Med. Vol. Bit.	0.3	1.1	1.1	2.0	2.3
High Vol. Bit.	0.2	1.0	1.3	1.9	3.1
WITBANK					
No. 5 Seam	0.8	2.2	2.3	2.9	4.4
No. 2 Seam	1.4	2.6	2.6	3.6	4.6
WATERBERG	1.9	2.8	3.1	4.1	5.7
ORANGE FREE STATE	2.9	7.3	8.6	9.4	11.4

The .../

The "A.D." column refers to the coal air-dried in the laboratory atmosphere at Pretoria.

Considering such results it will be appreciated that the air-dry moisture content of a Witbank coal may be found to be 2% on one day and, after a drastic change in the weather may be found to be 3% the next day, an increase of 1% absolute and 50% relative.

It has been found at the Institute, where regular monthly samples of coal from most of the producing collieries are analysed that, when analysing samples, air-dried in the laboratory without taking special precautions, the ratio between the highest and lowest "air-dry moisture contents" of Natal, Witbank and Ermelo coals varied from about 2:1 to 1.5:1 absolute. The higher ratio applies to the higher rank coals of Natal having relatively low air-dry moisture contents (they have relatively low total surface area available for the adsorption of water molecules).

(e) <u>The Moisture Content of Samples, at the Time when Analyses are done, must be known</u>.

In view of these facts one should, ideally, strive to air-dry the samples in an air-conditioned room where the temperature and relative humidity of the air are kept constant, throughout the year at the average annual relative humidity and ambient temperature of the location of the laboratory or at some specified "standard value" for the country. Failing this, the sample should be air-conditioned in the balance room and as a further precaution, it should be general practice to determine the moisture content of the sample every time a calorific value determination or analytical work such as proximate analysis or carbon and hydrogen determinations are done on the sample. Since a 1% change in the moisture content of a sample can affect the value of the calorific value by from about 90 to over 100 Btu per lb (depending on the type of coal), it is clearly necessary that the moisture content of the sample on which a calorific value was done must be known.

When determining minor constituents on the coal the possible change in the air-dried moisture content will generally, not have a serious effect on the results.

(f) Explicit Specifications for Analytical Methods needed in South Africa.

In South Africa, laboratories presently refer to British, European or American specifications for methods of analysis of samples. Since relative humidities are not generally subject there, to as great and rapid fluctuations as in this country, the matters raised in this paper may not be sufficiently stressed in such specifications.

In view of the experience gained in South Africa, it appears desirable to have rather more explicit specifications here.

This is most desirable when contracts are entered into between producers and consumers embodying penalty clauses for "free moisture" above a stated level. In such cases, it is submitted, very explicit specifications should be laid down for the determination of total and air-dry moisture contents. Such rigid specifications are more important for low rank coals that have a relatively high moisture holding capacity.

7. RECOMMENDED NOMENCLATURE

Finally it may be as well to quote definitions from an unpublished document of Technical Committee No.27 (Solid Mineral Fuels) of the International Organisation for Standardisation (Document ISO/TC27 (Secretariat 478)676, August, 1962).

Total Moisture. The moisture in the coal as sampled and removable under standard conditions.

Moisture in Air-dried Coal. The moisture in the coal sample after it has attained approximate equilibrium with the air to which it is exposed.

Free.../

Free Moisture. The moisture which is lost by the coal sample in attaining approximate equilibrium with the air to which it is exposed.

Moisture in the Analysis Sample. The moisture in the analysis sample of coal reduced to less than 0.2 mm, after it has attained approximate equilibrium with the air in the laboratory.

Moisture-holding Capacity. The moisture in the coal sample in equilibrium with an atmosphere of 96-97% relative humidity at 30°C.

It was recommended that the term "inherent moisture" should not be used.

8. CONCLUSIONS

1. The term "air-dried moisture content" of a coal sample, should be used with circumspection, as:
   (a) Its value depends - apart from the physical and chemical characteristics of a particular coal — on the ambient conditions (relative humidity, temperature and degree of air changes — ventilation) to which the coal is exposed during air-drying and later on in the course of laboratory studies.
   (b) The amount of moisture in the coal at the time a determination is done will affect the values obtained, for example, the calorific value, the proximate analysis and the carbon and hydrogen contents when using "air-dried" coal samples for analyses.
2. To obviate mistakes and to ensure that meaningful results are reported:
   (a) The ideal would be to air-dry samples and to do all laboratory work in a fully air-conditioned laboratory and to state the laboratory conditions when reporting results or to report all results on a dry-basis.

(b).../

(b) Whenever complete air-conditioning is not possible the moisture content of samples should be determined simultaneously with every calorific value and carbon and hydrogen determination. (It is accepted that this is done in the course of a proximate analysis as moisture determination is a part of the approximate analysis.) Here also it would be preferable to report results on a dry-basis, or at least, on a stated air dry moisture content basis to which all results have been corrected.

3. The most significant moisture value to the consumer is the "total moisture content of the coal as received". For a full assessment of the value of a coal consignment the consumer should correct other analytical results to this moisture condition. The producer and the consumer should, therefore, be provided with a reliable basis in analysis reports, e.g. results given on a dry-basis or a stated, reliable, air-dried moisture content.

4. Sampling of the coal for total moisture determination should be done at the same time as the consignment (truck-load) is weighed. Ideally, sampling and weighing should, therefore, be done at the colliery's and the consumer's weigh-bridges.

5. For reasons advanced in this paper, clauses in contracts referring directly or indirectly to the moisture content of the coal should be very clear and explicit, including statements of analytical methods agreed to, so as to avoid subsequent misunderstanding and argument.

6. In view of the greater variability in the relative humidity of the air, especially in the high plateau areas of South Africa, compared with conditions in, for example, the United Kingdom, rather more stringent and explicit specifications for methods of analysis of coal samples are desirable in South Africa.

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