

# THE IMPORTANCE OF STANDARDS IN COAL PREPARATION

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**Abstract - The importance of coal standards is vital to improve business processes and facilitate trade nationally and internationally. In this presentation the use of national and international standards are highlighted giving references to its uses specially associated to sampling in coal beneficiation.**

**ISO TC27 the technical committee responsible for the formation of standards for solid minerals fuels with participation of 22 countries meets every two years to deliberate the necessity of required standards for industry. The secretariat of this TC presently in South Africa (SABS) is responsible to oversee the working of various sub committees and working groups.**

**Coal preparation and its associated activities have a need to use required standards for sampling, analysis, process efficiency, environmental, safety and management aspects.**

## **I INTRODUCTION**

Standards and their use in technical regulations on products, products methods and services play an important role in sustainable development and trade facilitation through the promotion of safety, quality and technical compatibility.

The benefits that are derived are significant; standardization contributes to the basic infrastructure that underpins society including health and environment while promoting sustainability and good regulatory practice.

International Standards, or national or regional adoptions of International Standards, assist in the operation of domestic markets, and also increase competitiveness and provide an excellent source of technology transfer. They play an integral role in the protection of consumers and the environment.

With the increasing globalization of markets, International Standards (as opposed to regional or national standards) have become critical to the trading process, ensuring a level playing field for coal transactions local and export, and ensuring imports meet internationally recognized levels of performance and safety.

Standards can be broadly sub-divided into three categories, namely product, process and management system standards of which includes to mention a few USI9000 series, ISO19000, ISO18000 and ISO17025 on laboratory accreditation.

Coal preparation mainly requires product, process and management standards of which is vital for sustainable business aspects. They are often used to help create a framework that then allows the coal producer to consistently achieve the requirements that are set out in product and process standards.

- Promoting market access: Standards provide better access to markets and facilitate trade. They promote competition in the market place by helping industries capture knowledge, share insight and, with it, reduce risk.

To this end Standards have the greatest positive effect on business; for they help improve processes of which coal processing is no stranger to this process. Standards play a vital role in coal logistical supply chain and specifically in coal processing which is highlighted in this paper.

ISO TC 27 Solid Mineral Fuels through its subcommittee on coal preparation, terminology and performance has various working groups with distinct mandate from most coal producing and user countries in supporting the development of selected standards in support of these processes.

National Standards bodies has a Technical Committee on Solid Mineral Fuels represented by industry mainly aimed to set up guidelines and to promote standardization fostered by technical developments and changing trade conditions. These standards are developed to achieve the widest possible acceptability in the coal industry. Active support for aligning with those of ISO is imperative.

## **II INTERNATIONAL STANDARDIZATION AND THE ROLE OF ISO**

The foremost aim of international standardization is to facilitate the exchange of goods and services through the resolution of technical barriers to trade.

ISO is a legal association, the members of which are the National Standards Bodies (NSBs) of some 130 countries (organizations representing social and economic interests at the international level), supported by a Central Secretariat based in Geneva, Switzerland.

The principal deliverable of ISO is the International Standard.

An International Standard embodies the essential principles of global openness and transparency, consensus and technical coherence. These are safeguarded through its development in an ISO Technical Committee (ISO/TC), representative of all interested parties, supported by a public comment phase (the ISO Technical Enquiry).

### **III STANDARDIZATION IN THE COAL BUSINESS**

#### **Coal Supply Chain**

From the start of a coal project, exploration to extracting the product out of the ground, upgrading it into a suitable marketable product either for local use specifically for power utilities or for export, the entire value chain includes various quality aspects to identify its composition. This can only be done if the product either bore hole cores, run of mine (ROM), upgraded product either when processed or sold, the entire process is in need for samples to be taken at the different supply chain activities before it can be analysed.

Coal is a heterogeneous substance showing considerable non-homogeneity even in a finely ground state. A number of the chemical tests by which its properties are determined are empirical and subjective, and emphasise the need for standard procedures. After the process stages ISO 13909 Hard Coal and Coke- Mechanical sampling is a vital standard in process coal sampling, this includes, Run of mine, Produced Products, Discard and Product dispatch (Load out) this standard has been revised and have been in 2016, this revision has major implications to the users of this standard.

ISO 13909 consists of the following parts, under the general title Hard coal and coke:

Mechanical sampling:

*Part 1 : General introduction*

*Part 2 : Coal – sampling from moving Streams*

*Part 3 : Coal – sampling from stationary lots*

*Part 4 : Coal – preparation of test samples*

*Part 5 : Coke – sampling from moving streams*

*Part 6 : Coke – preparation pf test samples*

*Part 7 : Methods for determining the precision of sampling, sample preparation and testing*

*Part 8 : Methods of testing for bias*

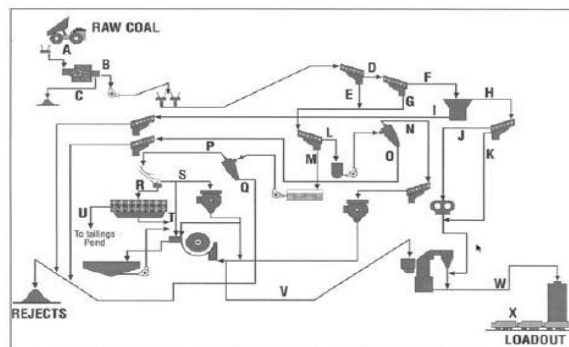
### **IV COAL PROCESSING SAMPLING REQUIREMENTS AND NESSESITY**

A processing plant design is normally based on expected feed tonnages and an envelope of yields i.e. from the geological and mining models. Additional information is used from source such as large-diameter boreholes to determine, for example

whether differential size washing should be used. The plant design should cater for adequate sampling capacity, but this is often incorporated as an afterthought. Lack of sampling capacity is sometimes used to support claims of great efficiency, inefficiency cannot be proven in the absence of data.

The cost of sampling is quite large in comparison with the cost of not sampling, the coal industry is large and errors of quality or yield can vary significantly and translate into huge losses. This dictates that sampling is essential for coal processing.

### Potential sampling points in a coal processing plant



### Feed blending

The ROM coal is crushed and delivered to the washing plant, preferably via a sampling plant. Normally, there should at least be minimal stockpiling capacity, but sometimes even this is not provided. It is ideal, through, as a minor plant stoppage can quickly bring mining to a halt if stockpiling facilities are limited.

Blending before the plant has the following advantages:

- Reduces feed size variability
- Reduces feed washability variability
- Allows sampling of feed to plant
- Decouples the mine and plant operations

A well-thought-out sampling system can allow feed-forward control in a plant by pre-determining coarse and fine SG cut-points. At the very least it should allow proper reconciliation between expected and actual plant feed. This may be critical if contractors are used for mining or plant operations, with a few percentage points on yield impacting the economics, ensuring that the forecast agree with the accruals, and therefore having a reliable sampling system, is critical in mine design.

## **Process Sampling**

The shape of the washability curve of any coal that is difficult to wash, dictates that over and under washing will result in a lower yield than if a consistent quality is produced.

Product samples are normally taken to produce hourly results for each product, e.g. coarse, small, fine and total for ash and CV only. These are then composite to give daily samples that are analysed for Proximate, CV and Sulphur. Cumulative product quality graphs will show the plant metallurgists is drifting out of product specification.

A particular important analysis is total moisture, almost all coal is transported and moisture is therefore a cost. In addition, during the combustion of thermal coal some of the heat is wasted in the removal of water. Penalties are normally applied by recalculating tonnage sold to a dry basis or NET AS Received CV basis.

On typical samples produced and what questions the analysis of these analysis answers, are outlined in the following sections.

- Feed composite sample

What yield should have been achieved from the target quality and from the actual quality achieved? What should have been delivered to the plant?

- Product Composite sample

Shows the variability in the coal produced and determines the difference between the target quality and the quality actually produced. Additionally it can show how correlations between parameters change as per the CV, ash, volatile percentages to establish the relationship change from seam to seam and mining area to mining area.

- Discard Composite sample

Determines whether misplaced material is within acceptable limits, and if not, the reason. Further it can be used to ascertain whether a further stage of washing could produce another, lower grade product. The re-treatment of discard material has been a significant development over the past 20 years.

- Magnetite Quality sample

Ensures that the magnetite received is of the correct quality to ensure that the washing units can operate at its optimum efficiency.

- Washing process efficiency samples

Determines the efficiency of each process equipment, including Cyclones, spirals, screens etc. The standard EPM is normally used.

## **Product or final product load out**

Coal is mechanically sampled before loading to the customer. A composite sample is produced per consignment, either train or trucks that represent the total cargo on which possible commercial transactions are based. Sampling systems can include, Cross belts sampling (Hammer sampler) and (Falling stream samplers) taken at the

end of a belt. When designing a sampling scheme in order to meet a required precision of results, equations are necessary that link certain fuel and sampling characteristics to that precision. The main factors to be considered are the variability of primary increments, preparation and testing errors, the number of increments and samples taken to represent the lot, and the mass of the samples.

## **V IMPLEMENTING THE REQUIRED ISO 13909 MECHANICAL SAMPLING STANDARDS**

Once a sampling system has been designed and installed, the precision which is being achieved on a routine basis should be checked. An estimate of the precision can be obtained from the primary increment variance, the numbers of increments, and sub-lots, and the preparation and testing variance. The preparation component is made up of on-line sample processing and off-line sample preparation.

Sampling variance is a function of product variability, so the same number of increments, sub-lots, and preparation and testing errors will yield different precision with fuels that exhibit different product variability.

An estimate of the precision actually achieved can be obtained by taking the sample in a number of parts and comparing the results obtained from these parts. There are several methods of doing this, depending on

- a) the purpose of the test, and
- b) The practical limitations imposed by the available sampling procedures and equipment.

Where a sampling system is in existence, the purpose of the test is to check that the scheme is in fact achieving the desired precision. If it is not, it may need to be modified and rechecked until it meets the precision required. In order to do this, a special check scheme will have to be devised which may be different from the regular scheme but which measures the precision of the regular scheme.

### **Equations relating to factors affecting precision**

#### ***General***

Precision is a measure of the closeness of agreement between the results obtained by repeating a measurement procedure several times under specified conditions, and is a characteristic of the method used.

If a large number of replicate samples,  $j$ , are taken from a sub-lot of fuel and are prepared and analysed separately, the estimated precision,  $P$ , of a single observation is given by Equation (1):

$$P = 2s = 2\sqrt{V_{SPT}} \quad (1) \quad (1)$$

Where

$s$  is the sample estimate of the population standard deviation;

$V_{SPT}$  is the total variance.

The total variance,  $V_{SPT}$ , in Equation (1) is a function of the primary increment variance, the number of increments, and the errors associated with sample preparation and testing.

### **Sampling**

Where the test result is the arithmetic mean of a number of samples, resulting from dividing the lot into a series of sub-lots and taking a sample from each, Equation (2) becomes:

$$V_{SPT} = \frac{V_I}{mn} + \frac{V_{PT}}{m} \quad (2) \quad (2)$$

where  $m$  is the number of sample results used to obtain the mean.

Since a sample is equivalent to one member of a set of replicate samples, by combining Equations (1) and (2) it can be shown that:

$$P = 2\sqrt{\frac{V_I}{mn} + \frac{V_{PT}}{m}} \quad (3) \quad (3)$$

Equation (4) gives an estimate of the precision that can be expected to be achieved when a given sampling scheme is used for testing a given fuel, the variability of which is known or can somehow be estimated. In addition

$$n = \frac{4V_I}{mP^2 - 4V_{PT}} \quad (4) \quad (4)$$

$$m = \frac{4(V_I + nV_{PT})}{nP^2} \quad (5) \quad (5)$$

### **Design of the sampling scheme**

#### **Material to be sampled**

The first stage in the design of the scheme is to identify the coal to be sampled. Samples may be required for technical evaluation, process control, quality control and for commercial reasons by both the producer and the customer.

#### **Division of lots**

A lot may be sampled as a whole or as a series of sub-lots, e.g. coal dispatched or delivered over a period of time, a ship load, a train load, a wagon load, or coal produced in a certain period, e.g. a shift.

## **Basis of sampling**

Sampling may be carried out on either a time-basis or a mass-basis. In time-basis sampling, the sampling interval is defined in minutes and seconds, and the increment mass is proportional to the flow rate at the time of taking the increment. In mass-basis sampling, the sampling interval is defined in tonnes and the mass of increments constituting the sample is uniform.

## **Precision of sampling**

After the desired sampling precision has been selected, the number of sub-lots and the minimum number of increments per sub-lot collected shall be determined and the average mass of the primary increments shall be determined

For single lots, the quality variation shall be assumed as the worst case the precision of sampling achieved may be measured using the procedure of replicate sampling (see ISO 13909-7).

## **Bias of sampling**

It is of particular importance in sampling to ensure, as far as possible, that the parameter to be measured is not altered by the sampling and sample preparation process or by subsequent storage prior to testing. This may require, in some circumstances, a limit on the minimum mass of primary increment

## ***Precision of results***

### **Precision and total variance**

In all methods of sampling, sample preparation and analysis, errors are incurred and the experimental results obtained from such methods for any given parameter will deviate from the true value of that parameter. While the absolute deviation of a single result from the "true" value cannot be determined, it is possible to make an estimate of the precision of the experimental results. This is the closeness with which the results of a series of measurements made on the same coal agree among themselves, and the deviation of the mean of the results from an accepted reference value, i.e. the bias of the results

The theory of the estimation of precision is discussed in ISO 13909-7. The following equation is derived:

$$P_L = 2\sqrt{\frac{\frac{V_1}{n} + V_{PT}}{m}} \quad (6) \quad (1)$$

where

$P_L$  is the estimated index of overall precision of sampling, sample preparation and testing for the lot, expressed as a percentage absolute;

$V_1$  is the primary increment variance;

$n$  is the number of increments per sub-lot;

$m$  is the number of sub-lots in the lot;

$V_{PT}$  is the preparation and testing variance.

### **Primary increment variance**

The primary increment variance,  $V_1$ , depends upon the type and nominal top size of coal, the degree of pre-treatment and mixing, the absolute value of the parameter to be determined and the mass of increment taken.

The number of increments required for the general-analysis sample and the moisture sample shall be calculated separately using the relevant values of increment variance and the desired precision. If a common sample is required, the number of increments required for that sample shall be the greater of the numbers calculated for the general-analysis sample and the moisture sample respectively.

### **Preparation and testing variance**

The value of the preparation and testing variance,  $V_{PT}$ , required for the calculation of the precision using Equation (1) can be obtained by either

- a) direct determination on the coal to be sampled using one of the methods described in ISO 13909-7, or
- b) assuming a value determined for a similar coal from a similar sample preparation scheme.

If neither of these values is available, a value of 0.5 for ash content can be assumed initially and checked, after the preparation and testing has been carried out, using one of the methods described in ISO 13909-7.

### **Number of sub-lots and number of increments per sub-lot**

#### **General**

The number of increments taken from a lot in order to achieve a particular precision is a function of the variability of the quality of the coal in the lot, irrespective of the mass of the lot. The lot may be sampled as a whole, resulting in one sample, or divided into a number of sub-lots resulting in a sample from each. Such division may be necessary in order to achieve the required precision, and the necessary number of sub-lots shall be calculated using the procedure given

#### **Calculation of number of sub-lots and increments**

The number of sub-lots and number of increments required per sub-lot are established using the following equations.

$$n = \frac{4V_1}{mP_L^2 - 4V_{PT}} \quad (7)$$

(2)

A value of infinity or a negative number indicates that the errors of preparation and testing are such that the required precision cannot be achieved with this number of sub-lots. In such cases, or if  $n$  is impracticably large, increase the number of sub-lots by one of the following means.

- Choose a number corresponding to a convenient mass, recalculate  $n$  from Equation (2) and repeat this process until  $n$  is a practicable number.
- Decide on the maximum practicable number of increments per sub-lot,  $n_1$ , and calculate  $m$  from the following equation:

$$m = \frac{4V_1 + 4n_1V_{PT}}{n_1P_L^2} \quad (8)$$

Required when measuring the increment variance, the preparation and testing errors are included more than once.

### Example

The lot is 8 000 t in a single load and the required precision,  $P_L$ , is 0,5 % ash. The quality variation is known and the following values have been determined:

Primary increment variance,  $V_1 = 5$

Preparation and testing variance,  $V_{PT} = 0,20$

- Number of sub-lots

The customer requires a result based on at least 2 samples.

- Number of increments per sub-lot

$$n = \frac{4 \times 5}{(2 \times 0,5^2) - (4 \times 0,20)} = \frac{20}{-0,3} = -66,7 \text{ Using Equation (2)}$$

This negative number indicates that the errors of preparation and testing are such that the required precision cannot be achieved with this number of sub-lots.

It could be decided that 50 increments is the maximum practicable number in a sub-lot and from Equation (3):

$$m = \frac{(4 \times 5) + (4 \times 50 \times 0,2)}{50 \times 0,5^2} = 4,8$$

This gives a practical sampling method of dividing the lot into 5 sub-lots and

taking 50 increments from each.

### ***Minimum mass of sample***

For most parameters, particularly size analysis and those that are particle-size related, the precision of the result is limited by the ability of the sample to represent all the particle sizes in the mass of coal being sampled.

The minimum mass of a sample is dependent on the nominal top size of the coal, the precision required for the parameter concerned and the relationship of that parameter to particle size. Some such relationship applies at all stages of preparation. The attainment of this mass will not, in itself, guarantee the required precision, because precision is also dependent on the number of increments in the sample and their variability

**Table 1 — Minimum mass of sample for general analysis and determination of total moisture content**

| <b>Nominal<br/>top size<br/>of coal</b> | <b>General-<br/>analysis<br/>samples and<br/>common<br/>samples</b> | <b>Samples for<br/>determination<br/>of total<br/>moisture<br/>content</b> |
|-----------------------------------------|---------------------------------------------------------------------|----------------------------------------------------------------------------|
| <b>mm</b>                               | <b>kg</b>                                                           | <b>kg</b>                                                                  |
| 300                                     | 15 000                                                              | 3 000                                                                      |
| 200                                     | 5 400                                                               | 1 100                                                                      |
| 150                                     | 2 600                                                               | 500                                                                        |
| 125                                     | 1 700                                                               | 350                                                                        |
| 90                                      | 750                                                                 | 125                                                                        |
| 75                                      | 470                                                                 | 95                                                                         |
| 63                                      | 300                                                                 | 60                                                                         |
| 50                                      | 170                                                                 | 35                                                                         |
| 45                                      | 125                                                                 | 25                                                                         |
| 38                                      | 85                                                                  | 17                                                                         |
| 31,5                                    | 55                                                                  | 10                                                                         |
| 22,4                                    | 32                                                                  | 7                                                                          |
| 16,0                                    | 20                                                                  | 4                                                                          |
| 11,2                                    | 13                                                                  | 2,50                                                                       |
| 10                                      | 10                                                                  | 2                                                                          |
| 8,0                                     | 6                                                                   | 1,50                                                                       |
| 5,6                                     | 3                                                                   | 1,20                                                                       |
| 4,0                                     | 1,50                                                                | 1,00                                                                       |
| 2,8                                     | 0,65                                                                | 0,65                                                                       |
| 2,0                                     | 0,25                                                                | 0,65                                                                       |
| 1,0                                     | 0,10                                                                | 0,65                                                                       |

## VI CONCLUSION

It is imperative that the implementation of required quality standards needs to support the entire process of coal preparation. The requirements of particular the ISO sampling standards was extended in this paper to give reference to the importance of designing your sampling scheme and process. This is not limited as the entire quality chain is covered by available ISO or national standards (SANS) that are derived from ISO standards. Down stream quality activities up to where an analysis is reported is supported by standard procedures. The structure of the ISO international committees as well entrenched to support your individual needs of which South Africa (SANS) is a participating member.

The use of independent inspection company to manage your on-site process laboratory must be considered, mainly to add value in addressing your quality requirements and ensuring your process is supported by the use of required national or international standards. This will give you ease of mind that possible risks that could evolve to financial risks is totally covered.

## REFERENCES

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