CENTRAL ELECTRICITY REGULATORY COMMISSION (CERC)
3rd & 4th Floor, Chanderlok Building, 36, Janpath, New Delhi – 110 001
Tel: 23753915 / Fax : 23753920

Ref: Tariff Petition No. 283/GT/2014 **Dated: 17.9.2015**

NOTICE OF HEARING

Sub: **Petition No.283/GT/2014-**Approval of tariff of Kahalagaon STPS-Stage-II of NTPC for the period 2014-19

Ref: **Writ Petition No.1641 of 2014** (NTPC-v- CERC) filed by NTPC before the Hon'ble High Court of Delhi

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The Hon'ble High Court of Delhi in order dated 7.9.2015 in C.M.No.6643/2015 in Writ Petition No.1641/2014 (filed by NTPC challenging the *vires* of some of the provisions of the CERC (Terms and Conditions of Tariff) Regulations, 2014 (''the 2014 Tariff Regulations'') has directed as under:

''13. In the light of the voluminous material produced by both the parties to substantiate their respective contentions, it appears to us that the question as to at what stage the samples have to be collected for measurement of GCV of coal on 'as received' basis is a highly technical issue which needs to be considered, in the first instance, by the expert body like the Central Commission.

14. Therefore, we deem it appropriate to direct the Commission to decide, in the first instance, the claim of the petitioner that even as per the measurement of GCV of coal on 'as received' basis, the samples are to be taken after secondary crusher only.

15. Accordingly, without expressing any opinion on merits of the case, particularly, the rival submissions made by the parties with regard to the stage of collection of samples for measurement of GCV of coal on 'as received' basis, the application is disposed of with a direction to the Central Commission to decide the issue i.e. the stage at which the GCV of coal has to be measured on 'as received' basis and pass an appropriate order within four weeks from today.

16. The petitioner is at liberty to place before the Central Commission the relevant material to substantiate its plea that the collection of samples for measurement of GCV of coal shall be only after the secondary crusher stage *within coal shall be only after the secondary crusher stage within one week from today. The application is, accordingly, disposed of."*

2. In terms of the above order, NTPC by affidavit dated 14.9.2015 has placed on record its submissions in Petition No. 283/GT/2014. A scanned copy of the affidavit containing the submissions made by NTPC is attached with this notice.

3. The hearing of the matter regarding the stage of measurement of GCV of coal on 'äs received' basis as per the directions of the Hon'ble High Court is fixed for hearing before the Commission on **24.9.2015**. Notices are hereby issued to the beneficiaries of the thermal coal based generating stations of NTPC and other generating companies whose tariff is subject to determination in accordance with the 2014 Tariff Regulations, to participate in the proceedings and present their views on the issue. It is clarified that since the order in the matter is required to be issued within four weeks (i.e by 5.10.2015), no request for adjournment of the hearing, on any ground whatsoever, shall be entertained.

Sd-

(Shubha Sarma)

Secretary

एन टी पी सी लिमिटेड
(भारत सरकार का उद्यम)

NTPC Limited
(A Govt. of India Enterprise)

केन्द्रीय कार्यालय/Corporate Centre

14th September 2015

To,
The Bench Officer,
Central Electricity Regulatory Commission
3rd and 4th Floor, Chanderlok Building,
36, Janpath,
New Delhi- 110001

Subject: NTPC's Submissions in Petition No. 283/GT/ 2014

Sir,

As directed by Hon'ble High Court of Delhi in NTPC's Writ Petition No. 1641 of 2014, please find attached 10 copies (1 original + 9 copies) of the Submissions of NTPC in Petition No. 283/GT/2014 for Kahalgaon Super Thermal Power Station, Stage-II (1500 MW) for the period 1.4.2014 to 31.3.2019.

Thanking you,

Yours Sincerely,

(Rajnish Bhagat)
GM (Commercial)

के. वि. वि. आयोग
14 SEP 2015

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एन टी पी सी भवन स्कोप काम्पलैक्स, 7, इंस्टीट्यूशनल एरिया, लोधी रोड, नई दिल्ली-110003, टेल/Tel.: 24360100, फैक्स/Fax : 011-24361018
NTPC Bhawan, SCOPE Comple, 7, Institutional Area, Lodhi Road, New Delhi-110003, वेबसाइट/Website : www.ntpc.co.in

BEFORE THE CENTRAL ELECTRICITY REGULATORY COMMISSION,
3RD AND 4TH FLOOR, CHANDRALOK BUILDING,
36, JANPATH, NEW DELHI - 110 003

PETITION NO. 283/GT/2014

IN THE MATTER OF:

Petition under Section 62 and Section 79 (1) (a) of the Electricity Act, 2003 read with Chapter V of the Central Electricity Regulatory Commission (Conduct of Business) Regulations, 1999 for approval of tariff for the Kahalgaon Super Thermal Power Station, Stage II (1500 MW) for the period 1.4.2014 to 31.3.2019

AND

APPLICATION FOR PLACING ON RECORD THE RELEVANT MATERIAL AND DOCUMENTS IN PURSUANCE OF THE ORDER DATED 7.9.2015 PASSED BY THE HON'BLE HIGH COURT OF DELHI IN WRIT PETITION NO 1641 OF 2014

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BEFORE THE CENTRAL ELECTRICITY REGULATORY COMMISSION,
3RD AND 4TH FLOOR, CHANDRALOK BUILDING,
36, JANPATH, NEW DELHI - 110 003

PETITION NO. 283/GT/2014

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AND

IN THE MATTER OF:

NTPC Limited - Petitioner

Versus

GRIDCO Limited and Ors - Respondents

APPLICATION FOR PLACING ON RECORD THE RELEVANT MATERIAL AND DOCUMENTS IN PURSUANCE OF THE ORDER DATED 7.9.2015 PASSED BY THE HON'BLE HIGH COURT OF DELHI IN WRIT PETITION NO 1641 OF 2014

MOST RESPECTFULLY SHOWETH:

1. The Petitioner, NTPC Limited (hereinafter referred to as `**NTPC;**) has filed the above mentioned petitions before this Hon'ble Commission for determination of tariff under the provisions of

the Central Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations, 2014 (hereinafter called the Tariff Regulations, 2009) in respect of its different Coal Based Thermal Power Stations.

2. NTPC has also challenged certain provisions of the above mentioned Tariff Regulations, 2014 in Writ Petition No. 1641 of 2014 filed before the Hon'ble High Court of Delhi. One of the Regulations challenged before the Hon'ble High Court relates to the measurement of Gross Calorific Value (**`GCV'**) of coal used in the generating stations. Regulation 30 (6) of the Tariff Regulations, 2014, inter alia, provides as under:

> *(6) Energy charge rate (ECR) in rupees per kWh on ex-power plant basis shall be determined to three decimal places in accordance with the following formulae:*
>
> *a. For coal based and lignite fired stations*
> *ECR = {(GHR - SFC x CVXF) X LPPF / CVPF+SFCx LPSFi + LC x LPL} X 100/(100 - AUX)*
>
> *b. For gas and liquid fuel based stations*
> *ECR = GHR x LPPF x 100 / {CVPF x (100 - AUX)}*
>
> *Where,*

AUX = Normative auxiliary energy consumption in percentage.

*CVPF= (a) Weighted Average Gross calorific value of **coal as received**, in kCal per kg for coal based stations*

c. Weighed Average Gross calorific value of primary fuel as received, in kCal per kg. per litre or per standard cubic meter, as applicable for lignite, gas and liquid fuel based stations.

3. The contention of NTPC before the Hon'ble High Court is that in the above provision, for the reasons as detailed in WP 1641 of 2014, the Weighted Average GCV of the coal should be considered on `as fired' basis, consistent with the dispensation followed from the beginning and for many years till the coming into force of the above Regulation and not on an `as received' basis provided in the said Regulation. Accordingly, the legality and validity of Regulation 30 (6) of the Tariff Regulations, 2014 is pending for decision in the above mentioned Wit Petition (C) No. 1641 of 2014.

4. During the pendency of the above mentioned Writ Petition (C) No. 1641 of 2014, an issue had arisen regarding the interpretation and application of the Regulation 30 (6) on the aspect of "as received" basis, namely, the stage at which the GCV of the coal should be measured on `as received' basis. NTPC's contention has been that if the GCV of the coal has to be measured on `as received' basis, it should be considered at a stage after the Crusher which is installed along with the Automatic Mechanical Sampler (`**AMS'**) in many of the generating stations or manual sampling after the crusher (at places where the AMS has so far not been established) and it should not be on the basis of the samples taken from the stationary railway wagon when the wagon reaches the power plant.

5. By order dated 7.9.2015 the Hon'ble High Court has decided as under in the interim application filed:

> *"1. the petitioner - NTPC Ltd. which is a Government of India undertaking, is engaged in the business of generation and supply of electricity.*
>
> *2. The main writ petition is filed with a prayer to declare certain provisions of the Central Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations, 2014 notified by the Central Electricity Regulatory Commission (CERC) in exercise of the powers conferred under the Electricity Act, 2003 for determination of tariff for the Power Generating Stations as ultra vires the Electricity Act, 2003 apart from being violative of Article 14 of the Constitution of India.*

3. Along with the main petition, the petitioner also filed CM C.M.No.6643/2015 in W.P.(C) No.1641/2014 seeking stay of the operation of the impugned Tariff Regulations, 2014. However, no such relief is granted and this court by order dated 03.03.2015 made it clear that the participation of the petitioners in the tariff proceedings shall be without prejudice to their rights in the main petition.

4. The present application came to be filed in April, 2015 again praying for stay of implementation of the impugned Tariff Regulations, 2014 as well as the proceedings for determination of tariff for the generating stations of NTPC till the disposal of the writ petition.

5. We have heard the learned counsel for both the parties.
6. the Electricity Act, 2003 has been enacted consolidating the Indian Electricity Act, 1910, The Electricity (Supply) Act, 1948 and the Electricity Regulatory Commissions Act, 1998 and also making certain changes in the manner of operation of electricity industry in India. In terms of Section 76 of the said Act, the CERC established under the repealed Electricity Regulatory Commissions Act, 1998 is deemed to be the Central Commission for the purpose of the Electricity Act, 2003. The Central Commission is empowered under Section 178(2)(s) of the Electricity Act, 2003 to make Regulations providing for the terms and conditions for determination of tariff for supply of electricity by a generating company to a distribution licensee and etc. In exercise of the power so conferred, the Central Commission notified the Tariff Regulations from time to time. So far as the period 2014-2019 is concerned, the impugned Tariff Regulations were notified vide notification dated 21.02.2014 and the same came into force on 01.04.2014.

7. As could be seen from the averments in the writ petition, the C.M.No.6643/2015 in computation of Gross Calorific Value (GCV) of coal is one of the essential factors for fixation of tariff. It is pleaded in the petition that the computation of GCV since inception was on 'as fired' basis, i.e., the GCV samples would be taken just before feeding *the coal into the bunkers of the generating unit for power generation. The grievance of the petitioner is that a departure has been made in the impugned Regulations for measurement of GCV by adopting 'as received' basis for the computation of GCV. It is explained that as per 'as received' basis the GCV samples would be taken at the time when the coal is unloaded from the wagons of Indian Railways. The petitioner is primarily aggrieved by adoption of 'as received' basis instead of 'as fired' basis for computation of GCV. It is contended by the petitioner that the change in the methodology of measurement of GCV under the impugned Regulations was affected without affording proper opportunity for the petitioner and others to represent their case and that the new methodology adopted on 'as received' basis is not workable since it is impossible at the time when the coal is received to measure the quality of coal in same manner as it is measured at the time when the coal is fired in the generating stations.*

8. The present application has now been filed pleading that the Central Commission in its counter affidavit dated 21.07.2014 described the concept of 'as received' basis as taking samples after the secondary crusher and before stacking and that the same has been reiterated in the counter affidavit filed on 18.10.2014 in W.P.(C)No.2050/2014 filed by the Association of Power Producers. However, a different stand has been taken in the surrejoinder dated 25.03.2015 filed by the Central Commission stating that due to inadvertence it was wrongly stated in the counter affidavit dated 21.07.2014 that in terms of 'as received' basis the measurement of GCV of coal would be after the secondary crusher and that the measurement of coal in fact would be at the Railway wagon stage itself as per the concept of 'as received'. While contending that the admission made by the Central Commission in its earlier counter affidavits cannot be given a go by merely on the ground of inadvertence, it is further pleaded that the contradictory stand now taken by the Commission in the sur-rejoinder would cause serious prejudice to the petitioner since the petitioner had already submitted the data in the tariff proceedings on the *premise that the GCV of coal would be measured only after the secondary crusher.*

9. Shri M.R. Ramachandran, the learned counsel appearing for the applicant/petitioner submitted that in fact there is no crushing activity at all at the wagon stage and therefore the question of measurement of GCV at that stage is not possible. The learned counsel also refers to the Coal Supply Agreement entered into between NTPC and Northern Coal Fields Ltd. which provides for the measurement only at the secondary crusher stage. It is also submitted by the learned counsel that the homogenous mixture would be available only at the secondary crusher stage and, therefore, a direction may be issued for measurement of the GCV of coal after the secondary crusher.

10. The application has been opposed by the Central Commission contending that the Central Commission has decided to switch over from earlier practice of measuring the GCV on 'as fired' basis to 'as received' basis in order to induce transparency, efficiency in fuel handling by generating companies and computation of energy charges in a just, fair and equitable manner. It is stated in the counter affidavit that the present application is nothing but an attempt to stall the tariff determination process by not providing the data as required by the respondent. The contention of the petitioner that there was an admission in the counter affidavit initially filed on behalf of the Central Commission with regard to the measurement of GCV has been categorically denied.

11. As mentioned above, the primary contention in the main writ petition is that the measurement of GCV of coal on 'as received' basis is erroneous and ultra vires the provisions of the Electricity Act, 2003. Without prejudice to its rights and contentions in the main petition that the measurement of GCV shall be only on 'as fired basis', it is contended in the present application that even as per the measurement of GCV on 'as received' basis the stage of the collection of samples shall be after second crushing only but not at the unloading point.

12. While it is vehemently contended by the learned counsel for the petitioner that no data is available with the petitioner regarding GCV measurement of coal at unloading point and therefore subject to the outcome of the writ petition, the petitioner may be permitted to submit the data collected after secondary crushing stage for the purpose of the determination of tariff under the impugned regulations, the learned counsel appearing for the respondent has seriously opposed the same contending that it would virtually amount to granting stay of operation of the impugned regulations.

13. In the light of the voluminous material produced by both the parties to substantiate their respective contentions, it appears to us that the question as to at what stage the samples have to be collected for measurement of GCV of coal on 'as received' basis is a highly technical issue which needs to be considered, in the first instance, by the expert body like the Central Commission.

14. Therefore, we deem it appropriate to direct the Commission to decide, in the first instance, the claim of the petitioner that even as per the measurement of GCV of coal on 'as received' basis, the samples are to be taken after secondary crusher only.

15. Accordingly, without expressing any opinion on merits of the case, particularly, the rival submissions made by the parties with regard to the stage of collection of samples for measurement of GCV of coal on 'as received' basis, the application is disposed of with a direction to the Central Commission to decide the issue i.e. the stage at which the GCV of coal has to be measured on 'as received' basis and pass an appropriate order within four weeks from today.

16. The petitioner is at liberty to place before the Central Commission the relevant material to substantiate its plea that the collection of samples for measurement of GCV of coal shall be only after the secondary crusher stage within

one week from today. The application is, accordingly, disposed of.
W.P.(C) No.1641/2014
Re-notify on 18.11.2015 along with W.P.(C) No.2050/2014, W.P.(C) No.2282/2014 and W.P.(C) No.2277/2014"

6. It is respectfully submitted that the term `as received' can be and should be applied only with reference to the measurement of the GCV of the coal when the samples are taken during movement on the Conveyor Belt and when it also undergoes the crushing to the requisite size and has passed through the AMS or has been taken by manual sampling and not at the stage when the wagon arrives at the power plant and is stationary.

7. Before dealing with the justification for the claim of NTPC for measurement of the GCV after the Crusher stage instead of measuring the samples from the wagon, it would be appropriate to set out in the schematic diagram, the coal flow upon the coal reaching the power station till the coal passes through the bunkers before it is fired in the Boiler for generation of electricity. The coal flow diagram is attached hereto and marked as **Annexure `A'.**

8. A perusal of the coal flow diagram at Annexure `A' would indicate that the railway wagons are taken to the location where the coal has to be unloaded into a hopper either through the wagon tippler or through manual means to track hopper into a pit from where it is immediately moved via a Conveyor Belt towards the crusher house.

9. The above arrangement of coal unloading at power station end is used where coal rakes use bottom opening (BOBR) wagons. In pit-head stations, BOBR rakes are used to carry coal from the mines to power stations through NTPC's dedicated MGR systems. At the track hopper, the bottom gate of wagons are opened and coal falls onto the hopper through gravity. During the process the coal rakes stop for a very brief period of time for unloading only. For collecting samples from BOBR wagons, it is necessary to send the personnel to the top of the wagon. The unloading process has to be stopped entirely during the process of collection of samples keeping in the view safety of the people collecting the samples from the wagon top. This would involve stoppage of the rakes for a significant period of time to complete the process of sample collection and unloading of the wagons. This would result in very high turn around time and will impact the coal receiving capability

seriously. In the case of Indian Railways rakes, coal is normally transported through BOXN wagons. In this case, for unloading purpose, each wagon is separated and turned upside down through an equipment called wagon tippler to unload coal from wagons to the hopper. In this case also, for sample collection, personnel have to go to wagon top and collect the samples. This can be done only through sequential operation i.e. first sample collection process has to be completed and then only the wagons can be tipped for unloading. Sample collection is not possible when the coal is getting unloaded considering the safety of persons. This would also lead to significant delays in the unloading process and will impact the coal receiving capability of the stations.

10. The distance between the wagon tippler/track hopper place to the crusher house ranges from 200 meters to 500 meters. The conveyor belt speed being in the range of 3 meters per second, the time taken for moving the coal from one wagon of approximately 60 metric Tonnes, namely, unloading and moving the same through the Conveyor Belt to the crusher house for sampling is not more than a few minutes. It is also submitted that the process of unloading the coal, either through the wagon tippler or through the track hopper, and the movement of the coal up to the crusher house is continuous in most of the stations, without any break. Only in 1 station station (Badarpur), there is a provision to take this coal to primary stockyard without crushing, if required. The distance from the wagon tippler/track hopper to the crusher house when the coal is moved through the Conveyor is used for undertaking essential operations, namely, removal of Boulders, Stones and other external material through manual process and through magnetic separator.

11. In the above process by the time the Boulders, Stones etc. are removed, the coal reaches the crusher house where the coal is crushed to the required size for sampling and the GCV of the coal is measured from the samples so drawn. In most of the generating stations, the GCV is measured through the AMS and in generating stations where AMS has not been established, the GCV is measured through manual sampling from belt conveyor.

12. The above computation of GCV is, therefore, done on a sample duly crushed and taken out while the coal is in transit and not

when the coal is stationary. After the above process of taking samples, the coal from the crusher house is taken to the stockyard unless the coal is immediately required for firing for generation of electricity in which case it is taken to the bunkers directly. The samples drawn in the above manner is the homogenous mixture of the coal drawn almost immediately on the unloading of coal from the railway wagon and duly crushed to the required size.

13. NTPC is required to maintain adequate quantum of coal in the stockyard to meet the requirement of generation and supply of electricity. Accordingly, most of the coal from the crusher house is taken to bunkers and the excess coal after meeting the consumption requirement is taken to the stockyard to be maintained as a stock available to be used in the generation of electricity. In case of less receipt of coal as compared to consumption, on any particular day, the required coal is reclaimed from the stockyard to meet the requirements of the unit.

14. In the above process, the coal received at the generating stations through wagons immediately undergo a continuous movement from the time when the coal is unloaded till it reaches the crusher. There is no time lag as such. In the above process, the coal which is taken to the crusher house and sized is the most representative of the coal which has been supplied by coal companies without there being any factors affecting the GCV of the coal from the stage of wagons arriving at the generating station till the crusher house. There cannot possible be any argument as regards the loss of GCV in the above movement of the coal from the railway wagon till the crusher house. In any event, the process generally takes a few minutes and further proves that it is an essential part of preparing the coal for computation of the GCV.

15. NTPC submits that, admittedly, the coal GCV needs to be measured after-

(a) removal of Boulders, Stones and other foreign material; and

(b) after crushing the samples to the required size.

The crusher house with an attached AMS serves exactly the same purpose but in a contiguous manner as in the case of measuring the GCV of the coal samples taken from the railway wagons and therefore there cannot be any objection to the above.

16. NTPC submits that collecting samples from the railway wagons can never be an effective and appropriate process for computing the GCV of the coal received at the generating stations. In the context of the provision `as received' used in Regulation 30 (6) of the Tariff Regulations, 2014, the computation of GCV of coal `as received' should necessarily be at the stage of the crusher house and not before. In this regard, the salient aspects are as under:

(a) since inception, NTPC as well as almost all other generating companies have been following the method of computing GCV of the coal on `as fired' basis at the bunker stage i.e. immediately before the coal is fed into the boiler for generation and sale of electricity. Such a coal is a homogenous mixture and not heterogeneous in nature namely consisting of material which have characteristics of coal and also external material which have no characteristics of coal. The sampling process at the stage of bunker is reflective of the coal quality which could generate the requisite heat;

(b) The purpose of recommending GCV of the coal to be measured on `as received' basis instead of `as fired' basis is basically to avoid losses which occur during stocking and handling upto the Boiler . When the coal is stacked for a period of time, that is between 9 days to 30 days in the coal stockyard, there is loss in calorific value due to self ignition, windage, spillage etc.

(c) The Hon'ble Commission in the Tariff Regulations, 2014 has proceeded to direct the GCV to be measured on `as received' basis for computation on the ground that the generator should not be rewarded for its inefficiency in stocking and maintaining the coal in the stockyard. In the reasoning given by the Hon'ble Commission as well as in the CPRI Report or the CEA recommendation, there is no reference to anything other than the loss of moisture content, self-ignition and efficiency of the generating companies in maintaining the coal after it is received. All the above relate to the activities after the stage of crusher and are not in any manner related to the short time spent on unloading of the coal and movement to the crusher house. Also most of the coal received is directly sent to Bunkers without stacking.

(d) If the only objective behind the change in Regulation 30 (6)Tariff Regulations, 2009 was to avoid the above losses, the measurement of GCV on `as received' stage should replicate the same process as at the stage of `as fired'. If so, the coal is to be crushed to the required size and the measurement should be of homogenous mixture of coal instead of heterogeneous material. If otherwise, the samples to be taken for computation of the GCV may contain more of other material which have no characteristics of coal in a pre-dominant manner or may contain coal in a pre-dominant manner, depending upon the discretion of the person picking up the samples. This would extensively vary the GCV computed, either in favour or against the generating company.

(e) If a homogenous coal mix is essential and was considered important for the purpose of measuring of the coal on `as fired' basis, the same should necessarily be adopted for the purpose of computing the GCV on `as received' basis also. If the GCV of the coal is not measured in a homogenous manner, it will not serve the basic purpose of sampling of coal and the measurement of the GCV. Admittedly, the samples taken from the railway wagons on an adhoc selected quantum would not be representative of the GCV of the entire coal as received at the station.

(f) In any event, the samples taken at the crusher house serves the correct purpose of measuring the coal on `as received' basis. Even if the samples are collected from the railway wagons, it is still to pass through the various process of crushing as referred to in the CPRI Report (Table 12). Finally, the coal of the requisite size is obtained which is taken to the laboratory for computation of the GCV. In the process indicated by NTPC regarding the movement of coal through the Conveyor to the crusher house and thereafter, the sampling is completely akin to the above process of crushing samples taken and measuring GCV. The advantage in the process described by NTPC is that the sampling of homogenous mixture and not on adhoc random samples taken from the railway wagons is considered.

(g) In addition to the above, the procurement of coal and its arrival in the station is a continuous process. In various generating stations of NTPC, the railway wagons carrying coal is received on a continuous basis i.e. in a day about 500 wagons (for a 2000 MW station). If the coal has to be measured through samples drawn from the wagons, the wagons will be held up for considerable time till the samples are collected by manual means. This would amount to delaying the entire process involved in the rake movement cycle, making even the receipt/ unloading of the entire requirement impossible to achieve. NTPC will be subject to huge amount of demurrage and cycling of coal received and taking it to the stockyard cannot be maintained. This is more particularly as the Hon'ble Commission has directed that NTPC should maintain the GCV of the coal separately for various form of purchase of coal, namely, linked coal, e-auction purchase, imported coal etc. The entire efficacy of the operation of the generating stations in regard to the coal handling will be seriously prejudiced. On the other hand, there is absolutely no difference or disadvantage to the beneficiaries in the computation of the GCV, if it is done with homogenous nature of coal after the crusher house.

(h) It is also of utmost importance that the samples collected are of a small size. In case the samples are to be collected from the wagon top, it has necessarily to be of a larger coal size. It would amount to handling larger increments of bigger coal size for being broken into small size for representative sampling. This is not an efficient way of handling the coal for requisite size. If the samples are collected at the crusher stage, this issue gets resolved. It is no longer necessary for taking large increments of coal for the purpose of sampling from the railway wagon.

(i) It is further submitted that generally NTPC gets coal of size in excess of 250 mm size at its stations from the various coal mines. Considering the sampling point for 'as received' coal to be from loaded wagon, will involve handling of huge quantity of coal for sampling purpose. This would become a very unwieldy process and may not result in a correct approach for measurement of GCV. As per the IS 'Methods for sampling of coal and coke' the weight of gross samples is related to the size of coal for which sampling is to be

17. In regard to the above submissions, NTPC relies on the following authorities on the coal sampling process

Bureau of Indian Standard -

A. The Indian Standard method for sampling of coal and Coke (IS 436 Part I/Section 1 – 1964) is relevant for the present case. A copy of the 1964 Indian Standard is attached hereto as **Annexure B.** Paras 0.3.4.2 provides as under:

> *"0.3.4.2* ***For obtaining reliable conclusions, it is recommended that coal may be sampled when it is in motion, that is, from conveyers or during loading or unloading.*** *For this purpose the sampling procedure as laid down in 3, 4 and 5 shall be followed. If, however, it is desired to sample the coal when it is stationary as, for example, from a stock pile or a loaded wagon, the procedures as laid down in 6, 7 and 8 may be followed.* ***It may, however, be mentioned that the representativeness of the samples drawn in this manner and hence the reliability of the conclusions is not likely to be assured.***

While the above sampling procedure has been referred to in Paras 3, 4, 5, 6, 7 and 8, the Indian Standard provided for sampling from the Conveyor in Para 3 and sampling from loaded wagons in Para 7. In regard to the sampling from wagons, the procedure is provided under Appendix `A'.

Accordingly the Indian Standard does not recommend sampling to be drawn when the coal is in a stationary position. In this regard, Para 0.3.4.2,(quoted above) inter alia, provides that the representativeness of the sample drawn when the coal is in a stationary position from the stock pile or loaded, the wagons does not lead to the reliability of the conclusion or assurance of the GCV. Thus, according to the Indian Standard, the sampling should be done when the coal is in motion i.e. from the Conveyor or during the loading or unloading.

In the case of the process described in Annexure `A' where the unloading movement to the Conveyor and the coal reaching the crusher house being one contiguous and immediate process, samples are drawn at the crusher house when the coal is cut into requisite size, becomes the appropriate coal for measurement of the GCV in accordance with Para 0.3.4.2 of IS 436, namely, for obtaining reliable connection. Thus, IS 436 itself negates drawing of sample from the railway wagons before it is unloaded.

B. Similarly, the Indian Standard: 436 (Part II)- 1965 Method for Sampling of Coal and Coke- Part (II) Sampling of Coke provides as under:

> *SAMPLING OF COKE*
> *2.1 General- Samples collected from the surface of coke in piles, bins, or wagons are, in general, unreliable, because of size segregation. Coke shall be sampled, wherever possible, in motion while it is being loaded into or unloaded from wagons, barges or trucks or, when it is being discharged from supply bins.*

A copy of the relevant extracts of the Indian Standard: 436 (Part II)- 1965 is attached hereto and marked as **Annexure C.**

C. Similarly, IS: 436 (Part I/Sec 2)-1976: Methods for Sampling of coal and coke, dealing with the Indian Standard the method of sampling. A copy of the relevant extracts of the 1976 report is attached as **Annexure D.** The said report, inter alia, provides as under:

3. MECHANICAL SAMPLING SYSTEMS

3 .O General - An essential condition of sampling is that the whole bulk of coal to be sampled should be exposed, so that all parts are equally accessible to the sampling implement and have the same chance of being included in the sample. The most favourable situation in which the whole of the coal is exposed for sampling is when it is being conveyed on a belt or similar device so that it passes the sampling point in a stream. *If the belt is stopped and a section of adequate length is taken across the whole width of the belt, all the coal particles in this section can be taken so that there will not be any significant bias. Sampling from a stopped belt is therefore the most satisfactory way of ensuring that the sample is free from bias and it is recommended as the reference method.*

....

4.2 Automatic Samplers for collection of increments

4.2.0 General- It is desirable to use a sampler which cuts through the full width of a falling stream of coal. However, where it is not possible, an alternate method is to scoop the sample from a moving conveyor belt. While using the alternate method it is important to have the sampler properly adjusted to the belt curvature across its width so that true cross section of the conveyed material is removed, including fine particles which segregate to the bottom of the material on the belt while in motion. The cutter employed should also not cause turbulence while sweeping through the stream of coal pushing aside large coal pieces and thus rejecting them. Therefore, its speed has also to be carefully adjusted to avoid taking a biased sample."

Report of CPRI given to the Punjab State Power Corporation Limited

D. The CPRI Report also provides that samples should crushed to the requisite size before sampling. A copy of the CPRI report is attached as **Annexure E.** In this report the recommendations of the CPRI at Page 15 is as under:

> ***Observation:*** *the sample preparation equipment in all three stations is not confirming the BIS. The sample crushers are not crushing the coal of the required size.*
> ***Sample preparation improvement:*** *Sample preparation must be through standard crushing and pulverizing equipment.*
> ***Recommendation:*** *It is recommended to go for additional set of sample primary and secondary crushing equipment including pulverizers.*

Table 12 of the CPRI Report provides for the procedure for sample preparation on receipt of coal at the generating station of PSPCL. A detailed coal sample preparation is given. While Table 12 deals with the samples preparation at `as received' stage, Table 14 deals with the sample preparation of bunker coal. Table 12, inter alia, reads as under:

Table 12: Procedure for sample preparation of received coal at the three PSPCL plants.

COAL SAMPLE PREPARATION

1. Coal sample is first passed through the primary crusher and crushed to 12.5 mm size; it is then mixed properly and two times quarter coning is done.
2. The coal sample is then passed through secondary crusher and crushed to 3.0 mm size; it is then mixed properly and reduced to 1.5Kg by quarter coning.
3. The coal sample is then pulverized and passed through 212 micron sieve. Again quarter coning is done and packed in two polythene bags (250 gms each).
4. These two coal sample packets being jointly sealed and signed by PSPCL and respective company representatives. One coal sample is being sent to PSPCL laboratory for analysis. Referee coal sample kept in joint custody of PSPCL and respective company representatives.

Flow chart is given below.

Gross sample (approx 350 kg)
↓
Crush to pass through 5 cm
↓
Coning and quartering twice
↓
90 kg (approx)
↓
Crush to pass through 12.5 mm
↓
Coning and quartering twice 22 kg (approx)
↓
Crush to pass through 6 mm (approx)
↓
Coning and quartering once
↓
11 kg (approx)
↓
Crush to pass through 3 mm (approx)
↓
Coning and quartering successively to obtain 1.5 kg-2 kg
↓
Grind to pass 72 mesh (212 micron)
↓
Divide it into 2 equal parts (final samples)

Thus, the recommendations contained in Page 15 of the report read with the Table clearly emphasise the need for crushing of the coal before measuring of the GCV. In the CPRI Report, the matter was dealt because of the scope of reference which is given in Para 1.1 which is the method of testing of coal at site and at plant. The issue was not considered as to the efficacy of taking samples from the wagons and not at the stage of the crusher house. However, the process described in Table 12 clearly bring out that the samples drawn at the crusher house would be the appropriate method of determination of the GCV.

Study by Central Fuel Research Institute

E. A study has been conducted on the third party sampling of coal by the Assistant Director and Director of the Central Fuel Research Institute, Dhanbad and presented at a seminar entitled New Challenges for the Indian Coal. A copy of the study report is attached hereto and marked as **Annexure F.** The said report, inter alia, provides as under:

> ***"Sampling of Power coals.***
>
> ....
>
> .
>
> *Manual method of wagon top sampling of large size raw coals is not only difficult but also violates some of the fundamental principles of sampling. As per requirement, samples are to be drawn from the full depth of the wagons, which is impossible to be collected manually. Furthermore, due to size segregation the samples collected from the wagon top does not satisfy the criteria of representativeness of the whole samples. Since the ash distribution in the different size fractions is not homogeneous, results from the samples, which do not reflect the*

true size distribution of the lot, are likely to be biased. More importantly, sample collection by a shovel from the top is a function of human discretion and not governed by the probability rule. Wagon sampling when practiced in other parts of the globe is done on smaller and uniform sized washed or blended coals (say, below 50mm), normally by auto-mechanical auger systems.

Ministry of Environment and Forest

F. The Office Memorandum of the Ministry of Environment and Forest, Government of India dated 26.8.2015 is attached hereto as **Annexure G.** It states as under:

*"5.0 **Ash content monitoring (sampling and analysis) technique of coal:***

Coal is highly heterogeneous in nature consisting of particles of various shapes and sizes each having different physical characteristics, chemical properties and residual ash content. Sampling is further complicated by the sampling equipment available, the quantity to be represented by the sample mass, and the degree of precision required. In addition, the coal to be sampled may be a blend of different coal types and how the coal is blended has a profound effect on the way a representative sample is obtained. National and international standards have been developed to provide guidelines for coal sampling procedures under different conditions, sample preparation and bias test procedures for the purpose of obtaining unbiased samples.
Real Time monitoring using auto mechanical sampling (online) from moving streams shall be used for sampling fuels. This shall be effective from a date not later than 01 September, 2013 in order to enable the Coal Companies and thermal power plants to install and opeationalise the real time monitoring system. Manual

sampling and analysis may be done so as to verify the online monitoring results.
In case of manual monitoring, coal samples may be taken from a moving conveyor belt since sampling from stationary coal such as a coal storage pile or rail cars may be problematic. The analysis of samples shall be carried out by third party appointed by the respective thermal power plant/coal mine or company, as applicable, as per the guidelines of Coal Controller."

Wiley - James J. Speight in the Handbook of Coal Analysis.

G. The celebrated Authority on Coal Analysis, namely, Wiley – James J. Speight in the Handbook of Coal Analysis has specifically dealt with the subject. The relevant part of the above authority is extracted hereunder. The relevant chapter of the book are attached hereto and marked as **Annexure H.** The extracts read as under:

> *"For homogeneous materials, sampling protocols are relatively simple and straight- forward, although caution is always advised lest overconfidence cause errors in the method of sampling as well as introduce extraneous material. On the other hand, the heterogeneous nature of coal (Speight, 1994, and references cited therein) complicates the sampling procedures. In fact, apart from variations in rank (Chapter 1), coal is often visibly heterogeneous and there is strong emphasis on the need to obtain representative samples for testing and analysis (Gould and Visman, 1981).*
>
> ....
>
> *Thus, to test any particular coal, there are two criteria that must be followed for a coal sample (1)*

ensure that the sample is a true representative of the bulk material, and (2) ensure that the sample does not undergo any chemical or physical changes after completion of the sampling procedure and during storage prior to analysis. In short, the reliability of a sampling method is the degree of perfection with which the identical composition and properties of the entire body of coal are obtained in a sample. The reliability of the storage procedure is the degree to which the coal sample remains unchanged, thereby guaranteeing the accuracy and usefulness of the analytical data.

....

Conventional design of most mechanical sampling systems for large tonnages of coal use some form of cross-stream primary cutter to divert the primary increments from the main stream of coal (Figure 2.2). A major advantage of these systems is that they sample coal from a moving stream, and most of them satisfy the principle that every particle in the entire mass has an equal opportunity to be included in the primary increments."

H. Further, in a study conducted by George S. Pope on the 'Methods of Sampling Delivered Coal' in 1916, under the aegis of the Bureau of Mines, US, the author had prescribed certain methodologies for sampling of coal. The relevant extracts of the Study are attached hereto and marked as **Annexure I**. The Study states as under:

"THEORY OF SAMPLING

Top determine with utmost accuracy the ash content and heating value of a quantity of delivered coal would require the burning of the entire quantity and special apparatus arranged to measure the total heat liberated, or would require crushing the whole quantity, and reducing it by an elaborate scheme of *successive crushings, mixings and fractional selections to portions weighing approximately 1 gram, the minute quantity which the chemist requires for each determination. Either of these procedures is obviously impracticable if the coal is to be used for the production of heat and power.*

The method actually employed is to select portion from all parts of a consignment or delivery of coal and to systematically reduce the gross sample, obtained by mixing these portions, to quantities that the chemist requires for making ash determinations or that can be burned conveniently in the calorimeter, an apparatus for determining the heating value. The gross sample should be so large that the chance admixture of pieces of slate, bone coal, pyrite or other impurities in an otherwise representative sample will affect but slightly the final results. Increasing the size of the gross sample tends toward accuracy, but the possible increase is limited by the cost of collection and reduction. In reducing the gross sample by successive crushings and halvings or fractional selections, the object is to procure a small laboratory sample that, upon analysis will give approximately the same results as the gross sample itself, or in fact, the entire quantity of coal from which the gross sample was obtained.

....

WHEN TO COLLECT SAMPLES

The best opportunities for procuring representative samples are afforded while the coal is being loaded into or unloaded from railroad cars, ships, and barges, or while it is being dumped from wagons. Once the coal is stored in piles or bins, or loaded on cars or vessels, the procuring of representative samples is practically impossible unless the whole quantity of coal is immediately handled again and the conditions for sampling become favourable. Samples collected from the coal exposed in piles, bins, barges, cars, or ships can be considered representative only under the condition that the mass of coal is homogeneous throughout. Such a condition is highly improbable and uncertain, and the analysis of samples collected from the surface may give results that are very unreliable as indicating the nature of the entire quantity, and that may be worthless as a basis for determining an equitable price to be paid for the coal.

....

COLLECTION OF GROSS SAMPLES

When coal is being loaded into or unloaded from wagons, railroad cars, ships, or barges, a shoved or a specially designed tool may be used for taking portions or increments of 10 to 30 pounds to make up the gross sample of coal. As the size of the increments should be governed by the size and weight of the largest pieces of coal and impurities, increments of more than 30 pounds may be required for colas containing large pieces of coal and impurities.

If one chute or conveyor is under for delivering a considerable quantity of coal to or from wagons, cars, or ships, it may prove expeditious and economical to devise a mechanical means for collecting portions from fractional parts of the discharged coal, or continuously deflecting a portion of the coal as it falls down the chute, or diverting from the conveyor definite portions of coal, and thus mechanically and automatically collecting the gross sample.

The mechanical collection of samples is preferred to shovel sampling, as it eliminates the personal equation. The mechanical sampler does not discriminate for or against taking more or less slate or other impurities. A person should collect samples with a shovel in the main without regard to impurities, leaving the amount of the impurities included in a sample largely to chance, as it is impossible to rate correctly the proportion of the impurities concealed in the coal, however competent the sampler may be. A mechanical sampler should preferably take the whole of the stream of coal flowing down the chute a part of the time rather than a part of the stream all the time, because the sizes and character of the pieces of coal and impurities are not apt to be evenly distributed across the stream. Excellent opportunity is afforded for procuring representative samples if the entire consignment of coal is crushed immediately after it is weighed and delivered, for then the samples can be collected from the crushed coal. If the coal is conveyed from the crusher by a conveyor, means can be devised for mechanically and automatically diverting from the conveyor definite portions of coal to make up the gross samples.

....

METHOD OF SAMPLING COAL DELIVERIES

1. *The coal shall be sampled when it is being loaded into or unloaded from railroad cars, ships, barges, or wagons, or when discharged from supply bins, or from industrial railway cars, or grab buckets, or from the coal conveying equipment, as the case may be and as may be mutually agreed upon. If the coal is crushed as received, samples usually*

can be taken advantageously after the coal has passed through the crusher. Samples collected from the surface of coal in piles or bins, or in cars, ships, or barges, are generally unreliable.

I. Study by IEA Clean Coal Centre of International Energy Agency

In regard to the sampling of coal, the IEA Clean Coal Centre which works under the aegis of International Energy Agency, provides as under:

Method of sampling

Coal samples can be taken at various locations from a moving stream or from a stationary lot either manually or by mechanical sampling systems. The selection of a sampling method depends upon factors such as sampling purpose, accuracy desired, accessibility of the site and technical, economic and time constraints.

Sampling from moving streams

Sampling from a falling stream

The best location for sampling from a moving stream is at the discharge point of a conveyor belt or chute where the complete stream can be intersected at regular intervals. Sample increments are taken by an automatic mechanical sampler from the whole cross-section of a continuously moving stream at a transfer point.

Sampling from stationary coal

Sampling of material that is stationary such as a coal storage pile or railcars, is particularly problematic because in many cases it is not possible to ensure that all parts of the material are accessible and have an equal probability of being collected and becoming part of the final sample for analysis.

Summary

Coal sampling

Coal is highly heterogeneous in nature consisting of particles of varied shapes and sizes each having different physical characteristics, chemical properties and residual ash content. Proper sampling and sample preparation are critical for accurate analysis. Obtaining a representative sample implies that every particle has an equal chance of being selected. A correct and representative sample requires that every particle in a lot being sampled is equally represented. A representative sample is collected by taking a definitive number increments, periodically throughout the entire coal lot being sampled. The number and weight of increments required for a desired degree of precision depends on the variability of the coal which increases with increasing impurities. The sampling of coal can take place from either stationary lots or from moving streams. Sampling from stationary lots is particularly problematic because in many cases it is not in compliance with the fundamental sampling principle stipulating that all parts of the lot being sampled must be accessible for physical sampling. Therefore, sampling from moving streams is preferred. The best location for sampling from a moving stream is at the discharge point of a conveyor belt or chute, that is a falling stream where the complete *stream can be intersected at regular intervals. However, cross-belt cutters are now more popular and are widely used in the coal industry. The stopped-belt sampling, when properly executed, is considered as bias free and is recommended by several standards as a reference sampling method when carrying out a bias test procedure.*

Sampling can be carried out manually or mechanically. Manual sampling is subject to human errors and is known to be incorrect and unreliable. Whenever possible, mechanical sampling from moving streams should be the choice for coal sampling.

The relevant extracts of the report has been placed at **Annexure- J.**

J. In addition to the above, the United States Environment Protection Agency undertook a research study for coal sampling in 1985. The Study provides as under:

3.1 OBJECTIVE OF COAL SAMPLING

The sampling of coal, whether performed manually or automatically, must extract a quantity of coal much smaller than the original lot but with proportionately the same characteristic qualities and quantities present in the entire lot. It has long been realized that the properties in coal are not distributed uniformly. The variability of coal makes it difficult to collect a sample that is representative of a large mass of coal. For instance, grab samples of coal from the same source may show different analytical values if *tested in different laboratories or by different technicians in the laboratory.*

Besides coal's inherent variability, other factors such as how the coal was handled or how the samples were obtained, affect the collection of a representative sample. The coal may have become segregated during loading, transport, or unloading operation so that the particles are grouped together by size. When samples are taken from a stationary source, such as a coal storage pile or railroad car, it is difficult to obtain an accurate sample because the material located in the centre of the pile will be inaccessible when conventional sampling techniques are used. Generally, samples taken around the pile will be limited by the depth of penetration of the sampling device into the stationary source. Similarly, when sample are taken from a moving stream, such as a conveyor, they should be taken from the entire width of the belt to avoid biasing the sample.

To be effective, a sampling plan must employ measures to reduce the effect of segregated particles, minimize the effect of the variability of the coal properties, and identify any mechanical bias due to the sampling method. Sampling material from a conveyor or a chute through which the coal is flowing provides access to a cross-section cut of the entire stream. This cross-sectional cut will provide a characteristic sample even though the vertical distribution of material on the conveyor may be segregated by particle size.

Mechanical sampling bias may be reduced by the use of automatic equipment which is not dependent on human discretion for operation. These systems are generally elaborate and have been designed for a specific plant's application.

Manual sampling methods can be used, but care must be taken to ensure that the sampling technique has been consistently applied.

3.2 SAMPLING GUIDELINES

With all these factors contributing to the inaccuracy of coal sampling, there has been concern over the reliability of coal analysis data. Inaccurate data, whether due to an error in sampling, poor analytical techniques or some other factor, can result in data misuse. Because of this, there are many opinions concerning guidelines for sampling coal and the establishment of standard methods.

As early as 1914, the United States Bureau of Mines (USBM) presented a procedure, written by A.C. Fieldner for sampling coal in a mine. The Bureau also developed guidelines for representative sampling for analysis. The author, G.S. Pope points out that it is difficult to obtain a representative sample from a stationary source such as a railcar or storage pile. He further states that the only representative sample that can be collected from a heterogeneous mixture of coal is one from a moving stream of coal as it is being loaded or unloaded. Popel also offers general directions for the number, size and frequency of sample increments.

Sources. U.S. Steel recommends the collection of one increment every 30 minutes for moving streams and provides guidelines for gross sample requirements using different sampling schemes. A minimum of 1000 pounds is specified for a gross sample. A sample increment weight of six to eight pounds is recommended when samples are collected from *chutes or stationary sources. When sampling from a stopped belt a much larger increment is required. The cross-sectional cut should be a minimum of one foot in length.*

To achieve a more uniform, systematic method for collecting coal samples, the USBM published a paper for government employees to use as a guideline in obtaining representative samples. This paper suggests systematic collection of a large number of increments of equal weight. The exact number and size of increments is dependent on the maximum size of the coal. In the case of a coal whose top size is ¾ inches, 50 increments of 10 pounds each are required. For larger sized coal, the number of increments remains at 50 but the increment weight is increased. For example, a coal whose top size is 8 inches requires increment weights of 20 pounds each. The USBM recommends a full cross-stream cut be taken from a moving stream. They discourage top sampling from railroad cars or barges. If, as a last resort, top sampling is used, increments should be taken from throughout the car or barge.

6.3 SAMPLING LOCATION

Cola can be sampled at many locations in a power plant depending on the method of coal handling, accessibility, and sampling objective. Most frequently, coal is sampled from a conveyor belt because this affords good accessibility and brings the coal to the sampling equipment rather than vice versa. Some operators, however, take samples from delivery vehicles to monitor incoming coal quality or from bunker storage in the plant. The most important difference between locations is *whether the sample represents "as -received" or "as -fired coal.*

As- fired samples are taken at any location after the storage bunker outlet. These samples are frequently taken from the coal feeders or from a clean-out pipe on the bunker line going to the feeders. Samples are usually not taken from the pressurized lines after being pulverized, although on plant contacted did this with the aid of in-line cyclone samplers.

Received samples are collected from any point before the bunker outlet. The main difference between as received and as fired samples is that the as received samples represent coal that will be fired at some time after being retained in the bunkers or storage piles and after passing through the coal handling system. The retention time caused by this storage as well as any blending which occurs depends on coal handling system characteristics and boiler operating parameters; it can vary significantly.

The relevant extracts of the Study has been attached hereto and marked as **Annexure K.**

18. Without prejudice to the above the Fuel Supply Agreement entered into with the Fuel Supplier Coal India Limited also provides for the measurement of coal after the crusher stage. In this regard Para 4.7 of the Fuel Supply Agreement dated 24.7.2009 entered into with Northern Coalfields Limited for Singrauli Super Thermal Power Station provides as under:

"4.7 Assessment of Quality of Coal
4.7.1 Sample Collection:
i) Samples of Coal shall be collected by third party by manual method during each of the shifts and at each of the Delivery Points for determining the quality of Coal provided that in case of loading through Silo the Seller shall install AMS within a period of 24 months of signing of this Agreement at all such Silo loading points which are not having AMS at present. The AMS existing at the Silo loading point shall be made operational by the Seller within a period of 6 months from the date of signing of this Agreement. In the event of AMS at Silo loading point not being operational beyond the above specified period, the sample shall be collected jointly through the AMS at the Purchaser's unloading point till such time the loading end AMS becomes operational. The Seller shall also ensure that AMS at the Silo loading points shall be operational for 90% of the period in a year. Also if, for any reason the AMS at ***Seller's Silo loading point remains non operational for a continuous period of more than 10 days, then the samples shall be collected jointly through the AMS at the Purchaser's unloading point till such time the loading end AMS becomes operational."***

19. A combined reading of the above authorities unequivocally establish that the essential features of the coal sampling as under:-

(a) That the coal samples for determining the GCV should not be taken when the coal is in a stationary form. The sampling of coal taken out of the wagon while they are stationary is, therefore, not correct;

(b) The sampling should be done of the coal taken when the coal is in movement. The sampling should, therefore, be done when the coal is unloaded and is moving on a Conveyor;

(c) sampling of coal should be after the external material like Boulders, Stones etc are manually removed. This is done during the short time when the coal passes through the Conveyor till it reaches the crusher;

(d) sampling of the coal should be done which is crushed to the required size as more fully described in the CPRI Report. The size of the coal should be less than 20 mm. This occurs at the crusher stage;

(e) sampling should be of homogenous mixture. This again occurs at the crusher stage.

20. Accordingly, the sampling of the coal at the crusher stage is the true sample of the coal on 'as received' basis for computation of the GCV of the coal.

21. In view of the above NTPC most respectfully submit that the stage for drawing the coal samples on as received basis is the crusher stage in the coal flow diagram given in **Appendix A.**

NTPC craves leave to make further submissions at the time of hearing.

(PETITIONER)

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BEFORE THE CENTRAL ELECTRICITY REGULATORY COMMISSION,
3RD AND 4TH FLOOR, CHANDRALOK BUILDING,
36, JANPATH, NEW DELHI - 110 003

PETITION NO. 283/GT/2014

IN THE MATTER OF:

Petition under Section 62 and Section 79 (1) (a) of the Electricity Act, 2003 read with Chapter V of the Central Electricity Regulatory Commission (Conduct of Business) Regulations, 1999 for approval of tariff for the Kahalgaon Super Thermal Power Station, Stage II (1500 MW) for the period 1.4.2014 to 31.3.2019

AND

IN THE MATTER OF:

NTPC Limited	-	Petitioner
	Versus	
GRIDCO Limited and Ors	-	Respondents

AFFIDAVIT

I, Rajnish Bhagat son of Shri B D Bhagat aged 55 years resident of P-367, Sector 21, Noida, do solemnly affirm and state as under:

1. That I am working as General Manager (Commercial) in Petitioner Corporation, NTPC Ltd. and am well conversant with the facts of the case and am competent to swear the present affidavit.
2. That I have read the contents of the accompanying Affidavit and have understood the contents of the same.
3. That the contents of the above Affidavit being filed by NTPC are based on information available with the petitioner in the normal course of business and believed by the deponent to be true.

R.V. SINGH NOTARY PUBLIC GOVT. OF INDIA

(Deponent)

VERIFICATION

I, the deponent above named, do hereby verify that the contents of the above affidavit are true to the best of my knowledge, no part of it is false and nothing material has been concealed therefrom.

Verified at New Delhi on 14th September, 2015.

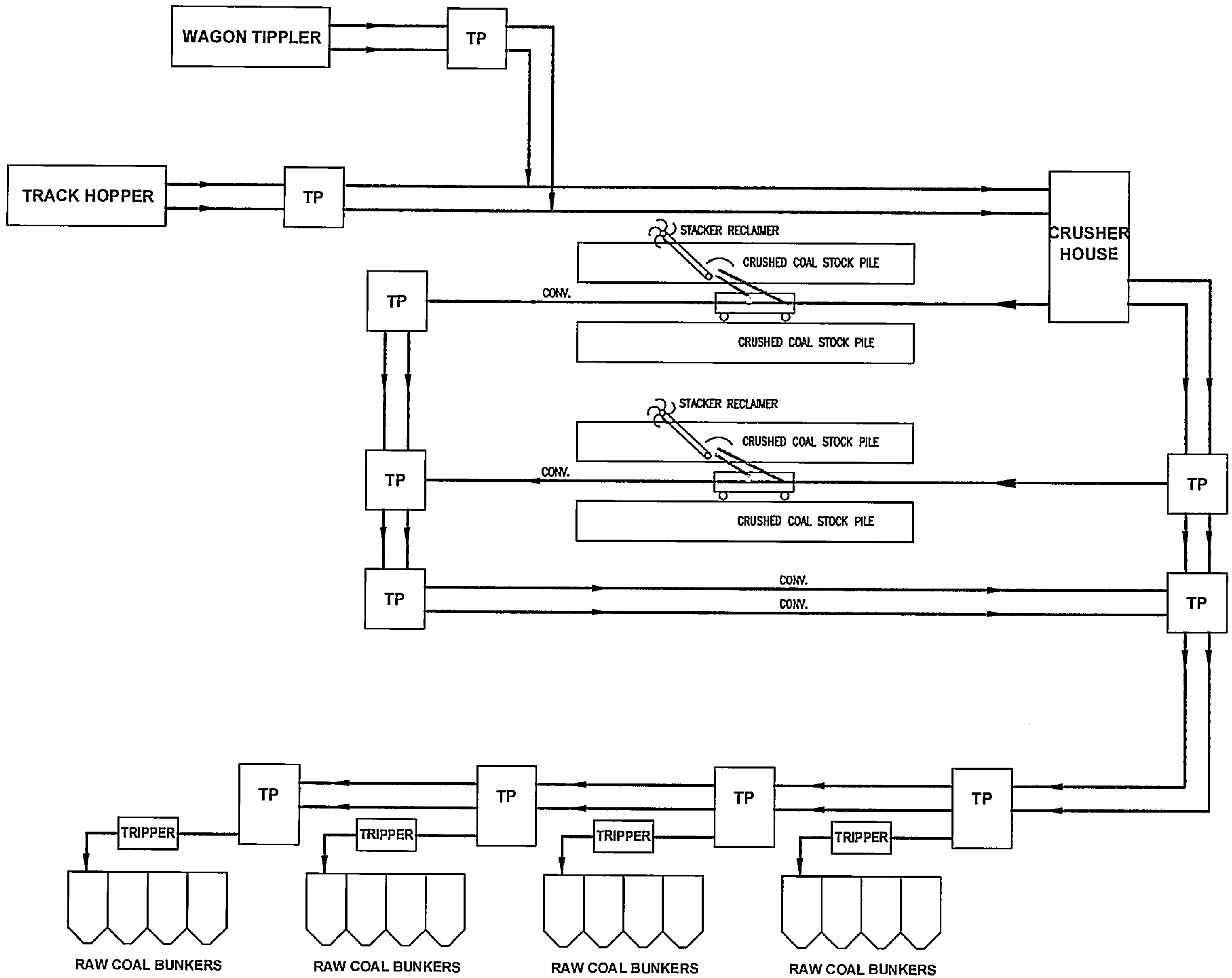
(Deponent)

NOTARY PUBLIC
R.V. SINGH
GOVT. OF INDIA

FIVE RUPEES
NOTARIAL

Solemnly affirmed before me, read over & explained to the deponent.

Notary Public, DELHI



COAL FLOW DIAGRAM

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Annexure-A

(1.0) Annexure-B

इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

"जानने का अधिकार, जीने का अधिकार"
Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

"पुराने को छोड नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"

IS 436-1-1 (1964): Methods for Sampling of Coal and Coke, Part 1: Sampling of Coal, Section 1: Manual Sampling [PCD 7: Solid Mineral Fuels]

"ज्ञान से एक नये भारत का निर्माण"
Satyanarayan Gangaram Pitroda
"Invent a New India Using Knowledge"

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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IS : 436 (Part 1/Sec 1) - 1964

(Reaffirmed 2001)

Indian Standard

METHODS FOR SAMPLING OF COAL AND COKE

PART I SAMPLING OF COAL

Section 1 Manual Sampling

(Revised)

Eighth Reprint MARCH 1991

(Incorporating Amendment No. 1)

UDC 662·66:620·113

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 6 *February* 1965

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Indian Standard

METHODS FOR SAMPLING OF COAL AND COKE

PART I SAMPLING OF COAL

Section 1 Manual Sampling

(Revised)

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(*Continued on page* 2)

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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(*Continued from page* 1)

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Shri U. N. Jha (*Alternate*)	
Shri E. B. Hall	Bird & Co Private Ltd, Calcutta
Shri L. D. Hughes	Indian Mining Association, Calcutta
Dr A. Khan	Hindustan Steel Limited, Rourkela
Shri D. B. Lahiri	Indian Statistical Institute, Calcutta
Dr A. Matthai (*Alternate*)	
Shri F. G. Massmann	Mining, Geological & Metallurgical Institute of India, Calcutta
Shri L. D. Hughes (*Alternate*)	
Shri D. K. Samanta	Indian Colliery Owners' Association, Dhanbad
Shri S. B. Sarkar	Coal Controller, Calcutta
Shri M. Sen Gupta	Indian Mining Federation, Calcutta
Dr A. V. Sukhatme	The Tata Iron & Steel Co Ltd, Jamshedpur
Shri F. S. Watcha	Coal Consumers' Association, Calcutta; *and* The Tata Iron & Steel Co Ltd, Jamshedpur

Indian Standard

METHODS FOR SAMPLING OF COAL AND COKE

PART I SAMPLING OF COAL

Section 1 Manual Sampling

(Revised)

0. FOREWORD

0.1 This Indian Standard (Part I) (Revised) was adopted by the Indian Standards Institution on 20 July 1964, after the draft finalized by the Solid Mineral Fuels Sectional Committee had been approved by the Chemical Division Council.

0.2 This standard was originally issued in 1953 with a view to prescribing the procedures for obtaining representative samples of coal and coke for test purposes. However, in view of the fact that at that time experiments on Indian coal under Indian conditions had just been initiated, it was issued as a tentative Indian Standard. The present revision incorporates the information obtained from the extensive investigations since carried out and the experience gained during the last eleven years.

0.3 The present revision differs from the earlier version in several important respects.

0.3.1 For purposes of sampling, Indian coals had originally been divided into five size groups, but the Sectional Committee responsible for the preparation of this standard felt that the division of coal into so many size groups was rather stringent. Hence, it decided that for the purpose of sampling, coal should be divided into the following three size groups only (*see* Note), which would generally be adequate in practice:

Name	*Nominal Size*
Run-of-mine coal	23 to 0 cm
Coal, large	15 to 5 cm (the upper limit not exceeding 23 cm)
Coal, small	5 to 0 cm

NOTE — The size groups given in **0.3.1** are meant only for convenience in sampling. As regards the size grading of coal, the various sizes as specified in IS : 437-1956* shall apply.

*Size grading of coal and coke for marketing (*revised*). (Second revision of this standard also issued in 1965.)

0.3.2 Depending upon the ash content, the Indian coal had originally been divided into two ash groups, namely, with ash less than 10 percent and with ash 10 percent or more. But since the ash content of most of the Indian coals was found to be generally more than 10 percent, and since the variation in the quality of Indian coal does not depend on ash content, it was felt that the division of coal into two ash groups was not necessary and that it may be dispensed with. Accordingly, this standard lays down the sampling procedures for coal without any regard to its ash content.

0.3.3 The earlier version had specified the minimum number of increments and the minimum weight of the gross sample for an accuracy of ± 10 percent of the value sought with 95 percent probability. These recommendations had been made on the basis of results obtained for American coals. The experiments conducted on Indian coals, however, revealed that the average and the standard deviation for the ash percentage were not correlated, implying thereby that the standard deviation does not increase or decrease with the average ash in any well-defined manner. This finding made it imperative that the number of increments and the weight of the gross sample for Indian coals be determined differently. Accordingly, the optimum weight for a gross sample was first determined by trying out different sample weights and adjudging their optimal nature by taking the minimum standard deviation criterion. That is, the weight of the gross sample for which the observed standard deviation was found to be minimum was deemed to be the minimum weight for drawing samples in practice. The weight of the increment was then determined separately and thus the number of increments to be taken for constituting the gross sample became known.

0.3.4 Regarding the sampling procedure recommended in the earlier version it was also felt that this procedure did not provide any means for checking whether the expected accuracy (of ± 10 percent of the value sought with 95 percent probability) was being maintained in the course of sampling or not. This checking becomes essential as the errors introduced due to uncertainties at the various stages of reduction of a gross sample might, in effect, render the confidence limits obtained for the true average ash content inapplicable. To obviate this difficulty, it was considered desirable to always test more than one gross sample so that the test results themselves may furnish an estimate of the sampling error which can be utilized in setting the confidence limits.

0.3.4.1 Accordingly, this standard recommends the division of a lot into a number of sub-lots (*see* Table 1) depending upon the weight of the lot and then drawing a representative gross sample from each of the sub-lots separately. The gross samples after suitable reduction are to be tested individually for determination of important characteristics of coal and compositely for others. The standard also lays down a proper procedure for valid interpretation of the test results so as to evaluate the average level of quality as also the extent of variation in the average for a lot with 95 percent confidence.

0.3.4.2 For obtaining reliable conclusions, it is recommended that coal may be sampled when it is in motion, that is, from conveyers or during loading or unloading. For this purpose the sampling procedure as laid down in **3**, **4** and **5** shall be followed. If, however, it is desired to sample the coal when it is stationary as, for example, from a stock pile or a loaded wagon, the procedures as laid down in **6**, **7** and **8** may be followed. It may, however, be mentioned that the representativeness of the samples drawn in this manner and hence the reliability of the conclusions is not likely to be assured.

0.4 Careful consideration was given to the various conditions under which coal may be available or supplied, for example, coal reserves, wagons, stock piles, conveyers, ships, etc. However, taking into account the many variations in the sampling conditions as also from the commercial point of view, the Committee responsible for the preparation of this standard felt that the sampling procedures should be prescribed only for conveyers, wagons, ships, stock piles and seams.

0.5 In drawing up the tables for the minimum weight of gross samples, consideration has been given to the fact that the distribution of impurities varies more in some coals than in others. The recommendations made in Tables 2 and 3 for the increment sixes and the total weight of the gross samples are based on the variation of ash percentage in coal. But since this is the most variable characteristic of coal, the recommended quantities of samples are expected to be adequate for the determination of other characteristics also.

0.6 This standard as originally issued had also included the sampling procedure for coke. The investigations on coke are, however, still in a preliminary stage and it will take quite sometime before sufficient information is collected. In the meanwhile, there exists a great and expeditious demand for the sampling procedure for coal. The committee responsible for the preparation of this standard, therefore, decided to first publish the methods for sampling of coal as Part I of this standard. Part II, dealing with the sampling of coke, will be issued later on as and when the investigations on coke would be over. In the meantime, through an amendment all references for coal have been deleted from IS : 436-1953*. Sampling of Coke (Part II) of IS : 436-1953* has been redesignated as IS : 436 (Part II)-1953* 'Methods for sampling of coal and coke, Part II Sampling of coke'.

0.7 In preparing this standard considerable assistance was derived from the statistically designed investigations carried out at the various collieries in the country by the Central Fuel Research Institute, Jealgora, Dhanbad.

*Since revised.

0.8 This standard forms one of a series of Indian Standards on coal and coke. Other standards in the series are:

*IS : 437-1956 Size grading of coal and coke for marketing (*revised*)

†IS : 439-1953 Hard coke

†IS : 770-1960 General classification of coal

‡IS : 1350-1959 Methods of test for coal and coke — proximate analysis, total sulphur and calorific value

IS : 1351-1959 Methods of test for coal and coke — ultimate analysis

IS : 1352-1959 Methods of test for coal and coke — special impurities

IS : 1353-1959 Methods of test for coal carbonization — caking index, swelling properties and gray-king assay (L.T.) coke types

†IS : 1354-1959 Methods of test for coke — special tests

IS : 1355-1959 Methods of test for ash of coal and coke

0.9 For the determination of the various sizes of coal, as well as for the reduction purposes, sieves conforming to IS : 460-1962‡ shall be used. Where these sieves are not available, other equivalent standard sieves as judged by the aperture may be used. For corresponding sizes of British Sieves and Sieves of the American Society for Testing and Materials, reference may be made to IS : 460-1962§.

0.10 Metric system has been adopted in India and all quantities and dimensions in this standard have been given only in this system.

0.11 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960||.

1. SCOPE

1.1 This standard prescribes the methods for sampling of coal from (a) conveyers, (b) wagons, (c) ships, (d) stock piles and (e) seams. It also lays down a procedure for reporting the quality of the material sampled.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Coal, Large — Coal with nominal size 15 to 5 cm, the upper limit not exceeding 23 cm.

*Second revision issued in 1965.

†Since revised.

‡Since revised and split into various parts.

§Specification for test sieves (*revised*).

||Rules for rounding off numerical values (*revised*).

2.2 Coal, Run-of-Mine — Unscreened coal containing all sizes, mainly 23 to 0 cm.

2.3 Coal, Small — Coal with nominal size 5 to 0 cm.

2.4 Composite Sample (for the Lot) — The quantity of coal obtained by mixing together equal quantities of coal from each of the laboratory samples representing the sub-lots into which the lot has been divided.

2.5 Gross Sample — Sample as collected from a sub-lot, that is, the quantity of coal obtained by aggregating together all the increments drawn from the same sub-lot.

2.6 Increment — The quantity of coal taken by a single operation of the sampling implement.

2.7 Laboratory Sample — The quantity of coal obtained by reducing a gross sample (*see* **2.5**) by following a specified procedure for laboratory testing.

2.8 Lot — The quantity of coal offered for disposal at one time.

2.9 Moisture Sample — A sample to be used exclusively for the purpose of determining total moisture.

2.10 Sample Division — The process whereby a part of the sample is retained and the remainder rejected.

2.11 Sample Reduction — The process of crushing or grinding the sample to reduce the particle size and of mixing and sample-dividing in successive stages.

2.12 Sub-lot — The quantity of coal in each of the groups into which a lot is divided for the purpose of sampling; a lot may consist of two or more sub-lots.

3. SAMPLING FROM CONVEYERS

3.1 Sub-lots — For the purpose of sampling, a lot, while it is being discharged over a conveyer, shall be divided into a number of sub-lots of approximately equal weight as specified in Table 1.

TABLE 1 NUMBER OF SUB-LOTS/GROSS SAMPLES

(*Clauses* 0.3.4.1 *and* 3.1)

Weight of the Lot (Metric Tonnes)	No. of Sub-lots/Gross Samples
Up to 500	2
501 „ 1 000	3
1 001 „ 2 000	4
2 001 „ 3 000	5
Over 3 000	6

3.1.1 A representative gross sample shall be drawn from each of the sub-lots and shall be kept separately. Thus, there will be as many gross samples as the number of sub-lots into which the lot has been divided.

3.2 The number of increments to be taken from a sub-lot for drawing the gross sample shall be governed by the weight of the gross sample and the weight of the increment as specified in Table 2 for various size-groups of coal. This number shall be evenly distributed over the sub-lot. The increments shall be drawn with the help of a suitable shovel (*see* Fig. 1) at regular intervals.

TABLE 2 WEIGHT OF GROSS SAMPLE AND NUMBER OF INCREMENTS FOR CONVEYERS

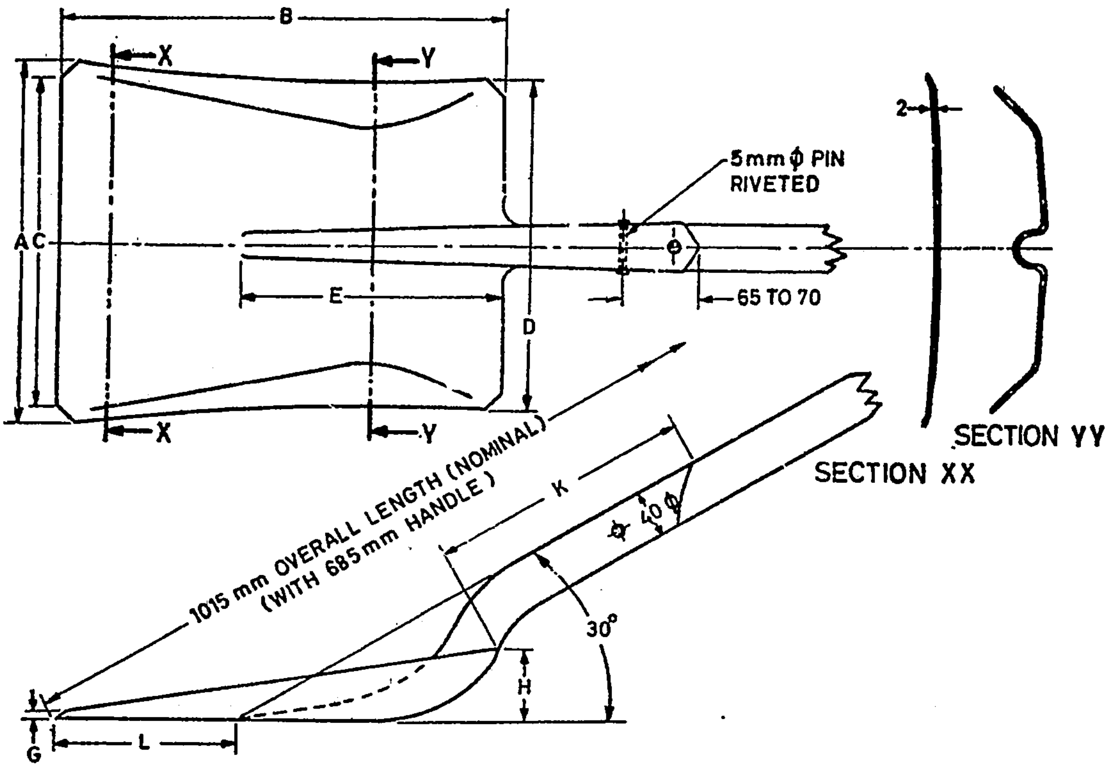
Sl No.	Sample	Run-of-Mine Coal	Coal, Large	Coal, Small
(1)	(2)	(3)	(4)	(5)
i)	Weight of gross sample, *Min*	350 kg	175 kg	75 kg
ii)	Weight of increment (approx)	5 kg	5 kg	5 kg
iii)	Number of increments, *Min*	70	35	15

3.2.1 The increments shall preferably be taken from the full cross-section and thickness of the stream in one operation. When coal is in motion, the most reliable means of obtaining such increments is to sample at a point where the coal discharges from the belts. The best possible increment is one which cuts accross entirely a falling stream of the material by means of a suitable receptacle passed from one side of the stream to the other without allowing the receptacle to overflow. If the whole of the stream cannot be covered by one increment without overfilling the receptacle, the stream should be sampled systematically by taking material from all portions.

3.2.2 If it is not possible to sample satisfactorily at a point of discharge, the increments may be drawn from the moving belt itself. In this case, the increments shall be collected from the centre and the left and right sides of the belt along the same width. To ensure that very small material is also correctly obtained in the sample, the scoop should sweep the bottom of the conveyer.

3.2.3 If it is practicable to stop the belt periodically, increments may be collected from the whole cross-section of the stream by sweeping the whole of the coal lying between the sides of a suitable frame placed across the belt. The frame should be inserted in the coal until it is in contact with the belt across its full width.

Note — Before collecting the increments, the speed of the conveyer and the quantity of material passing a certain point in a given time shall be ascertained so that an appropriate spacing of the increments may be arranged over the whole of the lot.



Capacity	Weight of Blade	*A*	*B*	*C*	*D*	*E* (Nom)	*G* (Nom)	*H*	*K*	*L* (Nom)
5 kg	1·8 kg	280	340	255	255	200	6	55	200	140
7 kg	2·0 kg	305	370	280	280	200	6	60	200	170
Tolerance	+10% −5%	±6	±6	±6	±6	—	—	±3	+6 −0	—

All dimensions in millimetres.

Fig. 1 Dimensions of Shovel (Capacity 5 kg and 7 kg Approx)

3.2.4 In case automatic samplers are available they may be utilized for drawing increments from a conveyer belt. The setting of such-machines shall be carefully adjusted to ensure that the whole thickness of the stream is taken.

3.2.5 The material collected from all the increments in a sub-lot shall be mixed together and shall constitute a gross sample.

4. SAMPLING FROM WAGONS DURING LOADING OR UNLOADING

4.1 Sub-lots — For the purpose of sampling, all the wagons in a lot shall be divided into a suitable number of sub-lots of approximately equal weight in accordance with the requirements of Table 1.

NOTE — The object of dividing a lot into a number of sub-lots is only to facilitate the drawing of a representative gross sample rather than to indicate its physical division.

4.1.1 One gross sample shall be drawn from each of the sub-lots so that there are as many gross samples as indicated in Table 1.

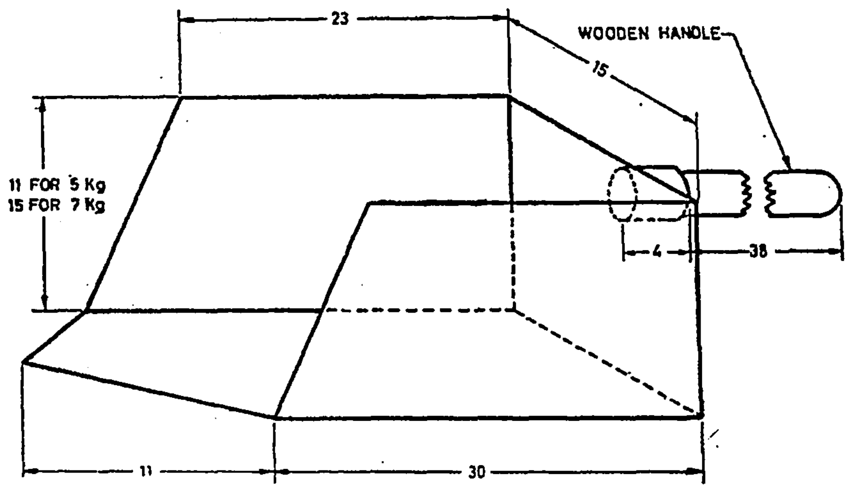
4.2 In order to get a representative gross sample, coal shall be sampled as far as possible in steady motion during loading or unloading of the wagons.

4.2.1 A minimum of 25 percent of the wagons shall be selected at random from the sub-lot and to ensure the randomness of selection the procedure as given in Appendix A may be followed. The number of increments to be taken from the selected wagons and the weights of the increments and the gross sample shall be in accordance with Table 3. The increments shall be evenly distributed over the selected wagons, with a view to determining the necessary number of increments that should be collected from each of the selected wagons of the sub-lot for making up the gross sample. These increments shall be drawn with the help of a suitable scoop or shovel (*see* Fig. 1 and 2), depending upon the size of the coal (*see* Table 3), at regular intervals at the time of loading or unloading of the wagons.

NOTE — In case bigger lumps are encountered which are not accommodated in the scoop or shovel, they shall be collected and crushed separately. The corresponding increments shall then be drawn from the crushed material.

TABLE 3 WEIGHT OF GROSS SAMPLE AND NUMBER OF INCREMENTS FOR WAGONS

SL No.	SAMPLE	RUN-OF-MINE COAL	COAL, LARGE	COAL, SMALL
(1)	(2)	(3)	(4)	(5)
i)	Weight of gross sample, *Min*	350 kg	175 kg	75 kg
ii)	Weight of increment (approx)	7 kg	7 kg	5 kg
iii)	Number of increments, *Min*	50	25	15



All dimensions in centimetres.

FIG. 2 SAMPLING SCOOP (CAPACITY 5 kg AND 7 kg)

4.2.2 The material collected from the selected wagons in a sub-lot shall constitute a gross sample.

5. SAMPLING FROM SHIPS DURING LOADING OR UNLOADING

5.1 Sub-lots — For the purpose of sampling, the entire quantity of coal in a ship shall be divided into a suitable number of sub-lots of approximately equal weight as specified in Table 1.

5.1.1 A gross sample shall be drawn from each of the sub-lots and shall be kept separately so that there will be as many gross samples as the number of sub-lots into which the lot has been divided.

5.2 Sampling of coal from ships shall be carried out, as far as practicable, when coal is in motion. If it is taken on a conveyer, the gross sample shall be collected as per the procedure laid down in **3**. If not, the gross samples may be drawn during loading or unloading of the ship. For this purpose, the number of increments to be taken shall be governed by the weight of the gross sample and the weight of increment as specified in Table 3 for various size groups of coal.

6. SAMPLING FROM STOCK PILE

6.1 Sub-lots — For the purpose of sampling, the quantity of coal in stock pile shall be divided into a suitable number of sub-lots approximately equal weight as specified in Table 1 by suitably marking the lines of demarcation on the surface of the lot.

6.1.1 The surface of each sub-lot shall be levelled and one point for approximately every 250 metric tonnes of material in the sub-lot shall be chosen at random. A gross sample shall then be taken from each of the sub-lots as per the procedure given in **6.1.2** and **6.1.3**.

6.1.2 In case the height of the stock pile is not more than 1·5 m, the material shall be collected at every selected point by taking the whole section of coal from top to bottom over the area of a circle of 30 cm diameter. For doing so, coal from the surface up to a depth of approximately 50 cm shall be collected at first. The bottom of the hole so formed shall then be covered by a plate and the coal lying on the sides shall be removed up to that plate so that when the hole is dug further (to collect further samples), the coal from the sides may not fill up the hole by falling down. This procedure is repeated till the bottom is reached.

NOTE — If the quantity of the material collected in the above manner is less than that specified in Table 3, additional quantity of material shall be collected from other point(s) chosen for the purpose.

6.1.3 In case the height of the stock pile is more than 1·5 m, the sample shall be collected at every selected point by taking the material over an area of a circle of 30 cm diameter and up to a depth of 1·5 m. The manner for taking out the sample shall be as described in **6.1.2**.

NOTE — Pipe sampling may be resorted to for coals of small size which have been closely screened or sized so that the material is approaching uniformity and is in any case not more than 4 cm top size. The equipment and the procedure to be used for pipe sampling is described in Appendix B.

7. SAMPLING FROM LOADED WAGONS

7.1 Sub-lots — For the purpose of sampling, the loaded wagons in a lot shall be divided into a suitable number of sub-lots of approximately equal weight in accordance with Table 1.

7.1.1 One gross sample shall be drawn from each of the sub-lots, so that there are as many gross samples as indicated in Table 1.

7.2 The gross sample shall be collected from a sub-lot according to the method described in **6.1.2**. For this purpose a minimum of 25 percent of the wagons shall be selected from the sub-lot at random (*see* Appendix A) and one point shall be located at random on the coal surface of each of the selected wagons. At every selected point a sample shall be collected by taking the whole section of coal from top to bottom over an area of 30 cm diameter as described in **6.1.2**.

8. SAMPLING FROM LOADED SHIPS

8.1 Sub-lots — For the purpose of sampling, the quantity of coal in a loaded ship shall be divided into a suitable number of sub-lots of approximately equal weight as specified in Table 1.

8.1.1 A gross sample shall be drawn from each of the sub-lots according to the method given in **6.1.1** to **6.1.3** and shall be kept separately so that there will be as many gross samples as the number of sub-lots into which the lot has been divided.

9. SAMPLING OF COAL SEAM *in situ*

9.0 Sampling of coal *in situ* gives a measure of the quality of coal to be mined. The analysis of this sample, however, will seldom give the same results as those of a run-of-mine sample.

9.1 The section of seam to be sampled shall be exposed from the roof to the floor. The exposed surface shall be as smooth as possible so that a rectangular channel may be cut. It may often be necessary to penetrate into the seam for a few decimetres to avoid taking weathered coal especially if the 'face' has been standing exposed for some time. The seam sample shall be taken in a channel representing the entire cross-section of the seam having the dimensions of 30 × 10 cm, that is, 30 cm in width and 10 cm in depth. For this purpose, two parallel lines, 30 cm apart end at right angles to the bedding planes of the seam shall be marked by a chalked string on the smooth, freshly exposed surface of the seam. Obvious dirt bands exceeding 10 cm in thickness shall be excluded. The channel between the marked chalk lines in the seam shall be cut to a depth of 10 cm and the coal sample collected on a clean strong cloth or tarpaulin placed immediately at the bottom so that the chances of pieces flying off during excavation of coal are minimised. The total height of the channel shall be measured and noted. The excluded dirt bands shall, if required, be separately collected and analysed.

10. REDUCTION OF GROSS SAMPLE

10.1 Run-of-Mine Coal — The gross sample shall be crushed to 5 cm, preferably by mechanical means, mixed thoroughly and quartered. Two opposite quarters shall be retained and the rest rejected. The retained material shall be further mixed together, halved and one-half retained. Thus, ultimately one quarter of the original gross sample is retained and the rest rejected. The material so obtained shall be crushed to 12·5 mm by a jaw crusher and then to 3·35 mm by a palmac type of reduction mill (*see* Fig. 3). The crushed material shall be reduced either by coning and quartering or by riffling (*see* Appendix C) till 2 kg of sample is obtained.

10.1.1 *Laboratory Sample* — The sample as reduced under **10.1** shall be finally ground to pass through 212-micron IS Sieve (*see also* **C-4**). From the ground material, 1·5 kg shall be taken which shall constitute the laboratory sample.

10.1.1.1 Each laboratory sample shall be divided into three equal parts, one for the purchaser, another for the supplier and the third for the referee. The samples shall be kept in glass or polyethylene containers and shall be sealed and marked properly.

10.2 Large Coal — The gross sample shall be crushed to 5 cm, preferably by mechanical means, mixed thorougly and then quartered. Two quarters shall be retained and the rest rejected. The material so obtained shall be crushed to 12·5 mm by a jaw crusher and then to 3·35 mm by a palmac type of reduction mill (*see* Fig. 4). The crushed material shall be reduced either by coning and quartering or by riffling (*see* Appendix C) till 2 kg of sample is obtained.

10.2.1 *Laboratory Sample* — From the sample as reduced under **10.2**, the laboratory sample shall be prepared as under **10.1.1** and **10.1.1.1**.

10.3 Small Coal — The gross sample shall be crushed to 3·35 mm in two steps, namely, through 12·5 mm by a jaw crusher and finally through 3·35 mm by a palmac type of reduction mill (*see* Fig. 5). The crushed material shall be reduced either by coning and quartering or by riffling (*see* Appendix C) till 2 kg of the sample is obtained.

10.3.1 *Laboratory Sample* — From the sample as reduced under **10.3**, the laboratory sample shall be prepared as under **10.1.1** and **10.1.1.1**.

10.4 Ash Fusion Sample — Following the procedure laid down under **10.1**, reduce the gross sample in successive stages and take an additional 1 kg sample, passing 12·5 mm IS Sieve for the determination of ash fusion. If, however, it is desired still further to avoid any contamination whatsoever with iron, take separate quantities of about 5 kg of the coarsely broken coal (12·5 mm and below) for the test. Do not grind the sample further in iron mills or vessels. Grind the ash obtained by incineration in an agate mortar to pass 75-micron IS Sieve.

10.5 Moisture Sample — In view of the fact that mixing and crushing or grinding of coal has been shown by experiment to lead, in certain cases, to considerable loss of moisture and since it is usually necessary to know the moisture content of the original coal, collect, as prescribed under **10.5.3**, two or three special moisture samples, as required, from the gross sample.

10.5.1 Where the moisture samples have to be reduced it is preferable to use machinery which crushes rather than machinery which grinds.

10.5.2 It is essential in all operations, especially if the coal has been partially or totally air-dried, that it should not be exposed for any length

REDUCTION OF GROSS SAMPLES

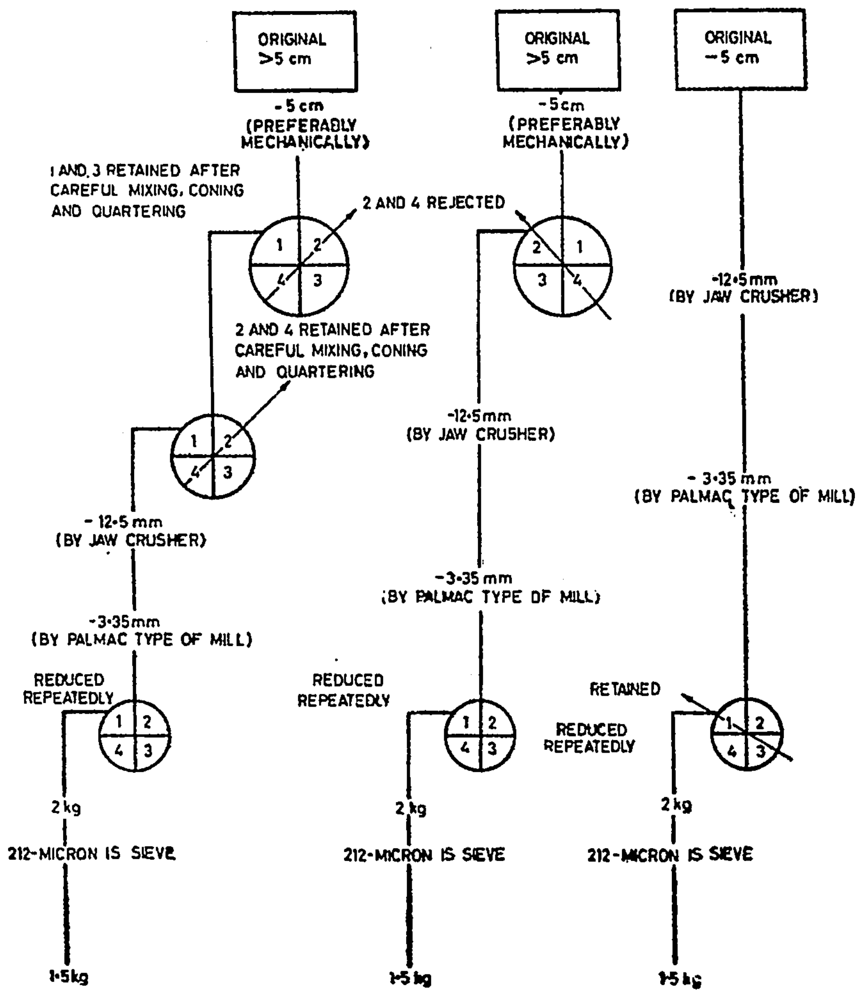


FIG. 3 RUN-OF-MINE COAL

FIG. 4 LARGE COAL

FIG. 5 SMALL COAL

of time to a current of air or to an atmosphere of appreciably different temperature or humidity.

10.5.3 At the first stage of reduction of the gross sample to 12·5 mm (*see* **10.1**) collect 5 kg of sample (*see* Note below) by not less than 10 approximately equal increments. while the coal is being discharged from the jaw crusher or after it has been collected in a heap. Reduce this sample to as near to 1 kg as possible and put the sample so reduced in an air-tight tin and seal it without delay.

NOTE — If it has been found necessary to air-dry the coal before crushing and it is required to know the excess moisture, a similar 5 kg sample (or more) of the original wet coal should be taken in a dry container subsequently to be used for the determination of excess moisture by air-drying.

11. NUMBER OF TESTS

11.1 The laboratory samples representing the various sub-lots in a lot shall be tested individually for the important characteristics like ash percentage, moisture, etc. For the remaining characteristics like ash fusion, a composite sample prepared by mixing equal quantities (by weight) of the material from each of the laboratory samples shall be tested.

12. REPORTING OF TEST RESULTS

12.1 For those characteristics where a composite sample has been tested, only one test result shall be available and that result shall be reported as the value of the characteristic for the lot.

12.2 When only two laboratory samples have been analysed individually from a lot, the average of the two available test results shall be reported as the value of characteristic for the lot sampled. The individual test results shall also be reported to give an indication of the range of variation in quality.

12.3 When three or more laboratory samples have been tested individually, the average (X) and the range (R) of the test results shall be calculated as follows for assessing the average level and the extent of variation in the average:

If, for any characteristic, X_1, X_2..................X_n are the results of analysing n laboratory samples, then

$$\text{Average } (X) = \frac{X_1 + X_2 + \ldots\ldots\ldots\ldots X_n}{n}$$

Range (R) = the difference between the maximum and the minimum of the test results.

12.3.1 The average level of the characteristic in the lot shall be reported as equal to X.

12.3.2 The limits for variation of the average quality in the lot shall be reported as $X \pm hR$, where h is a constant, the value of which depends upon the number of laboratory samples analysed (*see* Table 4), implying that the average quality of the material in the lot varies between these limits.

TABLE 4 VALUES OF THE CONSTANT, h

Number of Laboratory Samples Analysed, n	Value of the Constant, h
3	1·30
4	0·72
5	0·51
6	0·40

12.3.3 In case any of the test results deviates considerably from the others, it may be desirable to determine whether such a result may be rejected or whether it may be accepted as part of the normal variation expected. The procedure given in Appendix D may be followed for this purpose. If the suspect test result appears to be rejected, the average and the range shall be re-calculated from the remaining test results and appropriate inference drawn as in **12.3.2**.

APPENDIX A

(*Clauses* 4.2.1 *and* 7.2)

RANDOM SELECTION OF WAGONS

A-1. GENERAL

A-1.1 To ensure the randomness of selection of wagons from a sub-lot, the use of random number tables as described in **A-2** is recommended.

A-2. RANDOM NUMBERS

A-2.1 Two sets of random numbers are given in Table 5. The first set of random numbers shall be used if the number of wagons in the sub-lot is less than or equal to 100, whereas the second set shall be used if the number of wagons in the sub-lot is more than 100 but less than 1 000. Having selected the set, any one numeral shall be chosen from it at random. Starting from the selected numeral and continuing on with the numerals in any direction, right or left, up or down, the succeeding numerals shall be copied out one by one till the number of numerals copied out is equal to the number of wagons to be chosen. The numerals which are greater than the size of the sub-lot or which have already occurred shall be omitted. The numerals noted down in this manner shall then be arranged in the ascending order of magnitude.

A-2.2 Starting from any wagon in the sub-lot and counting them in one order, the wagons corresponding to the numerals already noted down shall be selected for drawing gross samples.

TABLE 5 RANDOM NUMBER TABLES

(*Clause* A-2.1)

First Set of Random Numbers

81	74	67	95	70	56	51	54	50	53
61	37	42	62	93	96	34	18	22	89
52	07	16	29	39	04	71	14	76	78
43	08	77	25	72	49	86	03	83	45
65	32	27	40	63	57	97	84	82	87
21	58	11	23	80	10	30	01	100	44
31	90	55	38	13	36	24	91	19	64
73	98	20	05	68	46	69	85	94	59
33	15	35	26	79	92	38	12	41	17
75	66	99	09	06	47	48	60	28	02

Second Set of Random Numbers

288	302	957	018	109	053	044	058	849	285
898	732	965	943	462	554	146	318	313	540
090	553	340	096	870	654	605	967	968	085
370	252	657	094	698	056	813	728	351	266
619	151	079	473	763	886	097	893	506	662
573	866	835	785	689	529	992	283	964	416
304	855	222	564	247	726	626	370	569	002
759	996	232	804	271	605	536	173	607	504
020	357	975	079	547	746	272	659	500	487
039	821	904	130	633	750	579	419	722	753
395	463	995	067	695	681	279	885	746	493
121	732	123	413	978	882	953	243	007	380
876	871	606	733	298	482	384	482	801	332
197	628	957	646	776	436	936	237	913	581
376	581	715	933	367	497	659	196	884	954
227	967	689	687	405	412	088	466	685	099
305	216	474	185	280	576	273	320	270	564
226	712	640	231	789	872	395	896	237	514
238	786	906	967	245	315	316	029	024	692
036	461	087	973	762	208	505	849	449	440

Example:

Suppose there are 60 wagons in a lot of approximately 1 200 tonnes. According to Table 1, this would require the division of the lot into 4 sub-lots, each consisting of 15 wagons of approximately 300 tonnes. Considering any particular sub-lot, if 25 percent of the wagons (*see* **4.2.1**) have to be selected at random for drawing the gross sample, it shall imply that 4 wagons have to be selected out of 15 in the sub-lot.

A-2.3 Taking the first set of random numbers as given in Table 5, suppose, further that numeral 07 occurring in the third row under second column is chosen at random. Proceeding further in any direction, say right, and omitting the numerals which are greater than 15, the numerals encountered are 07, 04, 14 and 08. Arranging them in one order, the sequence 04, 07, 08 and 14 is obtained. It then follows that the 4th, 7th, 8th and 14th wagon counted from the beginning of the sub-lot shall be selected for drawing the gross sample.

APPENDIX B

(*Clause* 6.1.3)

EQUIPMENT AND PROCEDURE FOR PIPE SAMPLING

B-1. EQUIPMENT — The equipment (*see* Fig. 6) required for pipe sampling shall consist of a sampling pipe 120 cm long, 10 cm inside diameter and 0·5 cm wall thickness fitted with a 10 cm collar at the top and a separate steel beater. The pipe shall be tapered from 10 cm to 7·5 cm diameter within the bottom 15 cm and provided with 18 teeth at the bottom end which shall be bent slightly inwards. There are two holes in the collar, diametrically opposite to each other and of 2 cm diameter through which a 60-cm long rod of a slightly smaller diameter passes.

B-2. DRAWING OF SAMPLE — For drawing a sample, the sampling pipe shall be driven through the coal from the top downwards by means of blows with a 3-kg hammer on the beater inserted in the collar. If necessary, a rod shall be inserted through the holes in the collar to rotate the pipe between the blows to prevent jamming. After 115 cm of the pipe has been inserted in the coal bed, the hammering shall be stopped. To withdraw the sample, the rod shall be inserted through the two holes in the collar and the pipe then pulled out with the help of the rod. The sample shall be collected on a clean strong cloth or tarpaulin, tapping the pipe, if necessary.

NOTE — If the coal consists of fines and is dry, it is occasionally necessary to spray some water round the pipe to moisten the coal. This will be found essential only in exceptionally dry weather.

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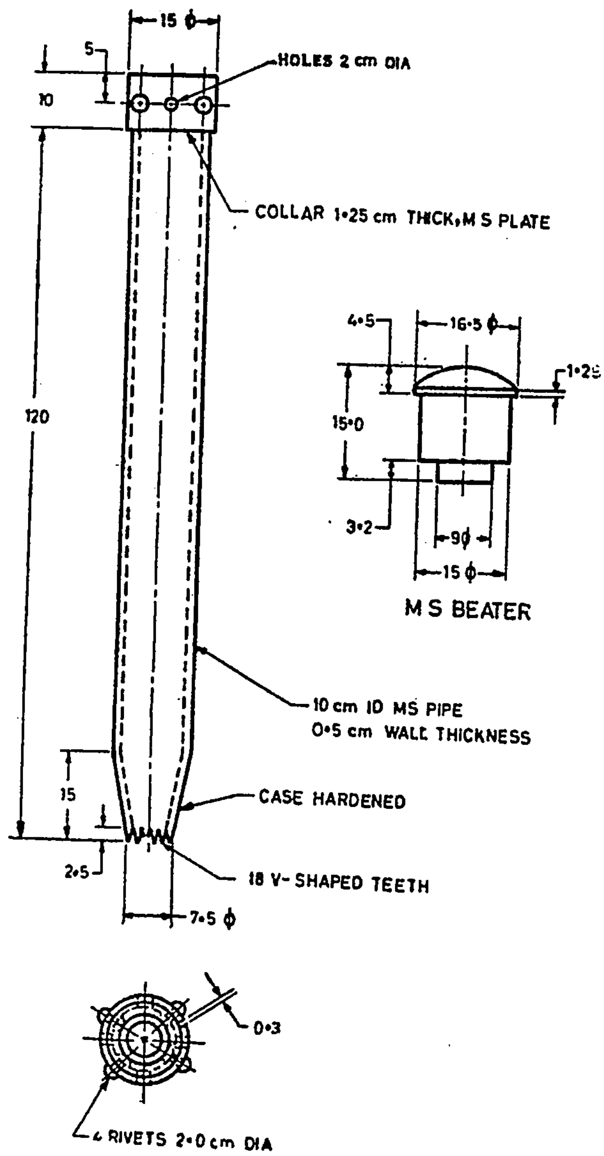

All dimensions in millimetres.

FIG. 6 COAL SAMPLING PIPE AND BEATER

APPENDIX C

(*Clauses* 10.1, 10.1.1, 10.2 *and* 10.3)

REDUCTION OF GROSS SAMPLES

C-1. GENERAL PRECAUTIONS

C-1.1 The place set apart for the treatment of gross samples shall preferably be enclosed, roofed over, cool and free from draughts. Where this is not possible, precautions shall be taken against (a) loss of fine wind-borne sample, (b) contamination with moisture, and (c) contamination with foreign matter.

C-1.2 Select a hard and clean surface free of cracks for sample mixing, quartering and other operations. Do not let cinders, sand, chippings from the floor or any other foreign matter get into the sample.

C-2. CONING AND QUARTERING

C-2.1 The material which has been crushed to 3·35 mm (*see* **10.1**) shall be heaped into the shape of a cone by pouring one scoopful of the material after another at the apex of the cone till the entire sample has been coned. The material shall be allowed to slide down the sides of the cone only under the influence of gravity.

C-2.2 Flatten the cone evenly so that it forms a low circular pile. Cut the pile into four quarters along two diameters which intersect at right angles. Retain one pair of opposite quarters and reject the other. Repeat till the size of the retained sample is reduced to the required weight of 2 kg.

C-3. RIFFLING

C-3.1 The material which has been crushed to 3·35 mm shall be dropped uniformly in the riffle. One half shall be retained and the other half rejected. This procedure shall be repeated several times till 2 kg of material is obtained.

C-4. GRINDING (FINE SIZE)

C-4.1 In grinding the sample to pass 212-micron IS Sieve (*see* **10.1.1**), it has been found that unnecessarily fine grinding is harmful. The ground coal should have the following approximate particle size distribution:

a) Passing 212-micron IS Sieve and retained on 125-micron IS Sieve	35 percent
b) Passing 125-micron IS Sieve and retained on 63-micron IS Sieve	30 to 35 percent
c) Passing 63-micron IS Sieve	Remainder

APPENDIX D

(*Clause* 12.3.3)

CRITERIA FOR REJECTION OF SUSPECT TEST RESULTS

D-1. GENERAL

D-1.1 It may sometimes happen that a test result is obtained which deviates considerably from the other test results and therefore arouses suspicion that it may have arisen from a mistake in sampling or sample preparation rather than in the course of normal variation. If the analyst knows that a mistake has occurred, the test result must be rejected irrespective of its magnitude. If, however, only a suspicion exists, it may be desirable to determine whether such a result may be rejected or whether it must be accepted as part of the normal variation expected.

D-2. CRITERIA

D-2.1 The procedure as given in **D-2.1.1** may be followed for determining the acceptability or rejectability of the suspect test result.

D-2.1.1 Arrange all the test results obtained by analysing n laboratory samples in the ascending order of magnitude and designate them as x_1, x_2, x_n, when x_1 is the smallest and x_n the largest test results. If x_n is suspect, calculate the value of K_1 from

$$K_1 = \frac{x_n - x_{n-1}}{x_n - x_1}$$

If x_1 is suspect, calculate the value of K_2 from

$$K_2 = \frac{x_2 - x_1}{x_n - x_1}$$

If the calculated value of K_1 or K_2 exceeds the corresponding one given in Table 6, the suspect test result shall be rejected, otherwise not.

The above procedure can also be applied repeatedly to remove the suspect test results other than the one first removed.

TABLE 6 VALUES OF CRITERION K_1 OR K_2

Sample Size (n)	Value of K_1 or K_2
3	0·941
4	0·765
5	0·642
6	0·560

D-3. EXAMPLE

D-3.1 In an investigation on ash percentage of coal, the following test results are obtained:

28·9, 26·9, 26·8, 26·7, 26·1

It is required to find out whether 28·9, which deviates rather unduly from the others, could be considered to be a suspect.

The test results, when arranged in ascending order, are:

26·1, 26·7, 26·8, 26·9 and 28·9

According to the criterion given in **D-2.1.1**,

$$K_1 = \frac{28{\cdot}9 - 26{\cdot}9}{28{\cdot}9 - 26{\cdot}1} = \frac{2{\cdot}0}{2{\cdot}8} = 0{\cdot}714$$

Since this value of K_1 exceeds the corresponding tabulated value 0·642 (*see* Table 6) for sample size 5, the test result shall be rejected.

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Annexure-C

IS : 436 (Part II) - 1965
(Reaffirmed 2000)

Indian Standard
METHODS FOR SAMPLING OF COAL AND COKE
PART II SAMPLING OF COKE
(Revised)

Sixth Reprint SEPTEMBER 1993

UDC 662.74:620.113

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 3

March 1966

since this is the most variable characteristic of coke, the recommended quantities of sample will be ample for the determination of other characteristics. Should any inconsistency be discovered between the general methods prescribed in this standard and the requirements of the methods prescribed with respect to a specific characteristic, the latter methods shall prevail.

0.6 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. This has been met by referring to the following standards:

B.S. 735 : 1944 Methods of sampling and analysis of coal and coke. British Standards Institution.

ASTM Designation D 346-35 Methods of sampling coke for analysis. American Society of Testing and Materials.

0.6.1 The Committee, responsible for the preparation of this standard, also had the opportunity of studying the draft ISO proposal for sampling of coke prepared by the Technical Committee for Solid Mineral Fuels, ISO/TC 27, of the International Organization for Standardization (ISO).

0.7 This standard is one of a series of Indian Standards for coal and coke (*see* page 13).

0.8 For the determination of particle (screen) size, the aperture size (of square holes) is based upon IS : 460-1962*. Where these sieves are not available, other equivalent standard sieves, as judged by the aperture may be used.

0.9 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960†.

1. SCOPE

1.1 This standard prescribes the methods for sampling of coke from normal consignments.

2. SAMPLING OF COKE

2.1 General — Samples collected from the surface of coke in piles, bins or wagons are, in general, unreliable, because of size segregation. Coke shall be sampled, wherever possible, in motion while it is being loaded into

*Specification for test sieves (*revised*).

†Rules for rounding off numerical values (*revised*).

or unloaded from wagons, barges or trucks or, when it is being discharged from supply bins.

2.1.1 In case it is necessary to collect a sample of coke from the surface of loaded shipments, nine equal increments shall be taken about 30 cm below the surface. The nine sampling points shall be located as shown in Fig. 1.

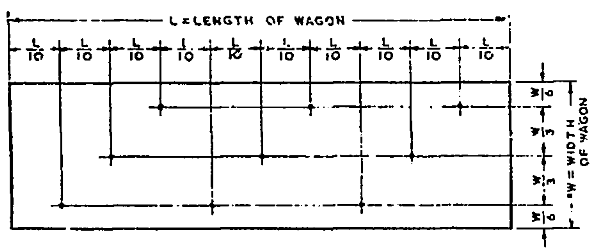

FIG. 1 LOCATION OF SAMPLING POINTS FROM SURFACE OF OPEN WAGON

2.2 Quantity Represented — A separate gross sample shall be taken for each 250 tonnes or fraction thereof or, in case of larger tonnages, for such quantities as may be agreed upon. Each lot of coke arising from a different source or known to be of different quality or size shall be sampled separately.

2.3 Weight of Increments and Gross Sample — The total weight of gross sample and the number of increments by which the sample should be collected shall be in accordance with Table 1. The minimum weight of increments shall be 1 kg (the actual increment has often to be considerably greater, as will be seen from Table 1) and the increments shall be approximately of equal weight. It is essential that the sample should be taken by not less than the stated number of increments regularly and systematically collected, so that the entire quantity of coke sampled is represented proportionately in the gross sample.

2.4 Reduction of Gross Sample and Preparation for Analysis

2.4.1 *General Precautions* — The following general precautions shall be taken:

a) The place set apart for the treatment of the gross sample shall be enclosed, roofed over, cool and free from draughts. Where this is not possible, precautions shall be taken against (1) fine wind-borne samples, (2) contamination with moisture, and (3) contamination with foreign matter.

b) The sample should preferably be reduced to 12·5 mm size by mechanical crushers or stamps, but where manual crushing is

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IS : 436 (Part I/Sec 2) - 1976

Indian Standard

(Reaffirmed 2000)

METHODS FOR SAMPLING OF COAL AND COKE

PART I SAMPLING OF COAL

Section 2 Mechanical Sampling

(Second Reprint MAY 1990)

UDC 662.66 : 620.113

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 4 *March* 1977

0.5 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard (Part I/Sec 2) prescribes the methods of sampling and sample preparation of coal using mechanical systems and lays down a procedure for the reporting of test results.

NOTE — Sampling and sample preparation of coal using manual methods have already been given in IS : 436 (Part I/Sec 1)-1964†.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 3810-1977‡ shall apply.

3. MECHANICAL SAMPLING SYSTEMS

3.0 General — An essential condition of sampling is that the whole bulk of coal to be sampled should be exposed, so that all parts are equally accessible to the sampling implement and have the same chance of being included in the sample. The most favourable situation in which the whole of the coal is exposed for sampling is when it is being conveyed on a belt or similar device so that it passes the sampling point in a stream. If the belt is stopped and a section of adequate length is taken across the whole width of the belt, all the coal particles in this section can be taken so that there will not be any significant bias. Sampling from a stopped belt is therefore the most satisfactory way of ensuring that the sample is free from bias and it is recommended as the reference method.

3.0.1 In many installations it is not possible to stop the belt without considerable interference with the work in the installation and other methods of sampling have therefore to be used. Alternatively, samples from the cross section of a moving stream are collected, to ensure that each increment is a representative of the cross section. It is this principle on which most of the mechanical sampling systems work.

3.1 Requirements of Mechanical Sampling Systems

3.1.1 The design of the systems for sampling and sample preparation should be guided by the type of coal to be sampled, test requirements to be

*Rules for rounding off numerical values (*revised*).

†Methods for sampling of coal and coke: Part I Sampling of coal, Section 1 Manual sampling (*revised*).

‡Glossary of terms relating to solid mineral fuels: Part I Terms relating to coal and its preparation (*first revision*) and Part II Terms relating to coal sampling and analysis.

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Annexure- A

No.: CPRI/ERED/ EA/117/12

Report

Submitted to

Punjab State Electricity Regulatory Commission, Chandigarh

On

Fuel Audit of PSPCL's Thermal Generating Stations

(Work order No.PSERC/Tariff/T/152/8792)

Submitted by

August 2012

ENERGY EFFICIENCY & RENEWABLE ENERGY DIVISION
Central Power Research Institute,
Prof. Sir C.V. Raman Road, P.B. No 8066,
Sadashivnagar, Bangalore – 560 080.
E-mail: ered@cpri.in
Web-site: http://www.cpri.in

The bomb calorimeter [accuracy: ± 0.1 % (4 to 5 kcal/kg) with a thermometer accuracy of 0.0001 °C] is of the required accuracy and reliability for determination of GCV of coal samples. The equipment in all stations has a valid calibration certificate.

Recommendation:

- The ***receipt coal GCV*** may be determined on equilibrated basis. The total moisture may also be determined for the same sample and the effect of moisture may be added to the receipt coal GCV at the rate of 145 kcal/kg for 1% increase in surface moisture.
- The ***bunkered coal GCV*** may also be determined on equilibrated basis. The total moisture may also be determined for the same sample and the effect of moisture may be added to the bunkered coal GCV at the rate of 145 kcal/kg for 1 % increase in surface moisture.
- The difference between receipt and bunkered coal GCV may be worked out and minimized to be within 150 kcal/kg.

Recommendation: Periodic surprise checks of witness the GCV determination for both receipt coal as well as bunkered coal in a bomb calorimeter by committee members is essential.

Recommendation: Random samples of both receipt coal as well as bunkered coal or a certain percentage of samples (5 to 10 %) as well as third party testing samples may be sent to independent, impartial truly third partly central laboratories whose result must be final, such as the following:

- Central Institute of Mining & Fuel Research (CIMFR) (formerly CFRI), Nagpur
- Central Institute of Mining & Fuel Research (CIMFR) (formerly CFRI), Dhanbad
- CPRI, Bangalore

The list of truly neutral third party laboratories in Northern India is given in Table 16.

Observation: The sample preparation equipment in all three stations is not confirming the BIS. The sample crushers are not crushing the coals of the required size. ***Sample preparation improvement:*** Sample preparation must be through standard crushing and pulverizing equipment.

Recommendation: It is recommended to go for additional set of sample primary and secondary crushing equipment including pulverizers.

Recommendation: Presently, the three stations are having only bomb calorimeter. Usually, in many other utilities there are separate bomb calorimeters for Stage 1 & Stage 2. One additional automatic multi-sample bomb calorimeter is recommended for each station along with room air conditioners for maintaining the temperature control of the cooling water.

Table 12: Procedure for sample preparation of received coal at the three PSPCL plants.

COAL SAMPLE PREPARATION

1. Coal sample is first passed through the primary crusher and crushed to 12.5 mm size; it is then mixed properly and two times quarter coning is done.
2. The coal sample is then passed through secondary crusher and crushed to 3.0 mm size; it is then mixed properly and reduced to 1.5Kg by quarter coning.
3. The coal sample is then pulverized and passed through 212 micron sieve. Again quarter coning is done and packed in two polythene bags (250 gms each).
4. These two coal sample packets being jointly sealed and signed by PSPCL and respective company representatives. One coal sample is being sent to PSPCL laboratory for analysis. Referee coal sample kept in joint custody of PSPCL and respective company representatives.

Flow chart is given below.

Gross sample (approx 350 kg)
↓
Crush to pass through 5 cm
↓
Coning and quartering twice
↓
90 kg (approx)
↓
Crush to pass through 12.5 mm
↓
Coning and quartering twice 22 kg (approx)
↓
Crush to pass through 6 mm (approx)
↓
Coning and quartering once
↓
11 kg (approx)
↓
Crush to pass through 3 mm (approx)
↓
Coning and quartering successively to obtain 1.5 kg-2 kg
↓
Grind to pass 72 mesh (212 micron)
↓
Divide it into 2 equal parts (final samples)

Table 14: Procedure for sample preparation of bunkered coal.

BUNKERED COAL/CONVEYER BELT COAL SAMPLE PREPARATION PROCEDURE

PREPARATION OF LABORATORY SAMPLE

Gross Sample from RC Feeder Belt 90 kg. (Approximate)

Crushed to Pass 12.5 mm

Conning and quartering twice

22 kg. (Approximate)

Crushed to Pass through 6 mm Approximate

Conning and Quartering once

11 kg. (Approximate)

Crushed to Pass 3 mm (Approximate)

Coning and Quartering successively to obtain 1.5 kg-2 kg.

Grinded part to Pass 72 mesh **(212 micron).**

Grinded sample thus prepared is sent to Coal Testing Lab for its testing in which Total Moisture, ash, Air dried Moisture, & GCV are determined.

Annexure - F (87)

An Experience of third party sampling of coal

Ashim Choudhury* & Kalyan Sen**

Introduction

Coal is a highly heterogeneous substance in terms of the inorganic and organic constituents and exhibits wide variability with respect to size and chemical composition of the particles. An estimation of the true value of the desired parameters of a bulk material, to a certain of degree confidence, through analysis on a few grams of **test sample** is definitely a daunting problem. The basic purpose of collecting and preparing a **sample** of coal is to provide a test sample which when analysed will provide the test results representative of the **lo**t sampled. In order that the sample represents the coal from which it is taken, it is collected by taking a definite number of **increments** distributed throughout the whole volume of coal.

The procedure for sampling will, however, differ with the purpose and method of sampling. Samples may be required for technical evaluation, process control, quality control or for commercial transactions. For quality assessment of coals from new sources, samples are to be drawn from in-situ coal seams, either as rectangular blocks or pillars cut from full seam height, or from seam channels or from borehole cores. To check the quality of coal consignments, it is desirable to sample from conveyor belts. The reference method of 'stopped belt' sampling is often implemented to standardise any other mechanical automatic sampling systems. Detailed documented procedures are laid down in National and International standards for executing the job of representative sampling pertaining to different methods of execution.

The major consumers of indigenous coals belong to the core sectors such as steel, power, cement, chemicals and domestic sectors. Quality monitoring of coal is an important activity for any commercial transactions between the consumers and the producers. As already mentioned the method of sampling for quality monitoring differs and is governed by many factors. The sampling procedure will depend mainly on the nature of sample collection i.e. by mechanical or manual means, from moving belt or from stationary lots like wagons, stockpiles, etc. Normally any sampling scheme is supposed to conform to relevant national or international standards. However, due to technical, cost and time constraints, very often some modifications are made in the method of sampling jointly by the seller and the purchaser. It is a known fact that about 80% of the total variances involved at the different stages of sample collection, preparation and analysis comes from errors during its collection only.

Seminar entitled " New Challenges for Indian Coals"

* Assistant Director, Central Fuel Research Institute, Dhanbad

** Director, Central Fuel Research Institute, Dhanbad

Before initiating discussions on the existing practice of sampling some basics of sampling need to be touched upon.

General principles of Sampling

The fundamental requirements of sampling are,

- All particles of coal in the lot to be sampled are accessible to the sampling equipment and each individual particle shall have an equal probability of being selected and included in the sample.
- The dimension of the sampling device used should be sufficient to allow the largest particle to pass freely into it.
- The first stage of sampling known as primary increments is the collection of an adequate number of coal portions from positions distributed over the entire lot to take care of the variability of the coal. The primary increments are then combined into a sample, as taken or after reducing the mass of the sample to a manageable size. From this gross sample, the required number and types of test samples are prepared by a series of processes jointly known as **sample preparation**.
- The minimum mass of the gross sample should be sufficient to enable particles to be present in the same proportions as in the lot of coal from which it is taken.
- To ensure that the result obtained has the ***required precision*** the following issues are to be considered.

- Variability of coal
- Number of samples from a lot
- Number of increments comprising each sample
- Mass of sample relative to the **nominal top size**

While drawing increments great care should be taken to avoid the occurrence of bias in the results.The ideal method of sampling is the **stopped belt** method,which is considered free of **bias.** As implementation ofsuch method will affect the continuity of plant operations,it is not always practicable for routine sampling.However, any mechanical sampling device needs to be checked for bias by comparing with the results fromstopped belt reference method.

Precision: This is a measure of the closeness with which the results of a series of measurements made on the same fuel agree amongst themselves under prescribed condition. This indicates the reproducibility of the results and is a measure of the chance error as expressed by variance. The smaller the random error the more precise is the method. A commonly accepted index of precision is twice the population standard deviation.

Bias: Systematic error which leads to the average value of a series of results being persistently higher or lower than those which are obtained using a reference sampling method which is intrinsically unbiased

General procedure for establishing a sampling scheme

1 Decide for what purpose the samples are taken e.g. plant performance evaluation, process control, commercial transactions etc.

2 Identify the quality parameters to be determined, i.e general analysis, total moisture, size analysis, washability, etc.

3 Define the lot

4 Define the precision required

5 Decide whether **continuous** or **intermittent** sampling is required

6 Determine the number of sub-lots and the number of increments per sublot to achieve the required precision.

7 Determine or estimate the nominal top size of the coal

8 Determine the minimum mass per increment and the minimum mass of the total sample

9 Decide on the method of combining the different increments to produce the gross sample

10 Decide on drawing common or separate samples, for general analysis and moisture

Design of sampling scheme

Sampling scheme has to be designed based on the purpose of sampling and after ascertaining at what stage of coal handling operation the sample is required.

- **Division of lots:** A lot may be sampled as a whole or a series of sublots. Each sublot will constitute one sample.
- **Basis of sampling :** It can be either time basis or mass basis. In time basis the sampling interval is defined in minutes/seconds and mass is proportional to the flow rate, whereas in mass basis the interval is defined in tonne and the mass of increments is uniform.
- **Precision :** In all methods of sampling, sample preparation and analysis, errors may be introduced at every stage and the measured value may differ from the true value of the parameter. As the true value is not exactly known it is difficult to assess the accuracy of the results, but an estimate of precision of the results can always be made.

The required precision for a lot for each parameter has to be decided and then the number of sub-lots, number and mass of increment are to be estimated.

Joint sampling

Normally, joint sampling is carried out at the loading end by the representatives of the producer and the customer, following a methodology mutually agreed upon by both parties. Depending on the nature of the agreement, the loading point results can be taken exclusively for commercial transactions. In some cases the mean value of the results of joint sampling at both the loading and unloading ends is considered. The tolerance values in the quality parameters are often defined, beyond which several bonus/penalty clauses are imposed. What needs to be stressed is whether the tolerance value identified is compatible with the sampling scheme. More clearly, whether the tolerance value lies within the precision limit that can be achieved through the implementation of a particular sampling scheme. This requires periodic testing, which unfortunately is rarely practiced in India.

It is a common experience that in spite of joint sampling, there often exist wide discrepancies in the results at the two different ends. There may be multiple reasons for this :-

- Identical procedures for sampling and sample preparation are not followed at the two ends.
- In case of manual sampling human discretion becomes a significant factor
- Deviation from the procedures identified in the agreement
- The level of precision remained undefined while designing the sampling scheme.

Sampling of washed coking coal

High ash coking coals are washed before despatching to steel plants. Most of the coking coal washeries in the eastern region have automatic mechanical samplers. Samples are drawn from the automatic samplers and results are given on the railway rake basis. The collected samples are reduced by offline mechanical and/or manual means to produce the final test samples. The automatic samplers are different from Automechanical Sampling Systems (AMS) which have integrated size reduction units. For day to day commercial transactions the quality parameters are ash and total moisture percentages.

The methodology that needs to be followed can be derived from the following tests.

- Carry out tests to estimate the increment variance and preparation & testing variation.
- Decide on the level of precision of the ash value
- With known values of the two variances, calculate the number of sub-lots and the number of increments per sub-lot to arrive at the desired precision level
- Carry duplicate sampling with the existing procedure and estimate the precision achieved. Modify the number of increments and number of sub-lots accordingly to arrive at the required level of precision.
- The minimum mass per sublot can be obtained from standard table, which considers the nominal top size of the coal and the precision level. The minimum mass per increment can then be derived accordingly.

Increasing the mass of the increments above the minimum requirement does not improve the precision. Depending on the variability of the fuel the precision of results can be improved by increasing the number of increments and number of sub-lots. It is desirable to conduct the sampling on sub-lot basis and the mean result of the sub-lots can be considered as the final result of daily rake despatched.

The tests enumerated above can be simultaneously carried without disrupting the routine sampling. The tests are essential as they provide the required basis for the agreement between the purchaser and the consumer.

Furthermore, the off line sample preparation and size reduction until the pulverisation stage, should be done by mechanical means. Manual grinding should be strictly avoided.

The sampling scheme designed on the basis of the above tests, if followed with all seriousness by the representatives of the two parties can significantly reduce the discrepancies in the results at both ends. If result is to be given as an average of those at the two ends, then identical means of sampling and preparation are to be adopted. Results obtained from automatic samplers at one end cannot be compared with those of manual sampling at the other end, as it will definitely be affected by human discretions.

Sampling of Power coals.

Most of the non-coking coals, which are mined today, are consumed by the power sector. Thermal Power Stations under NTPC are the major consumers of power coals. NTPC stations receive coals of widely varying characteristics from different coalfields under Coal India Limited/ Subsidiaries. Very often power stations receive coals from multiple sources and for commercial purposes, source wise results are required. As per the agreement, sampling for general analysis and total moisture has to done at the loading point. If Auto-mechanical Sampling System (AMS) exists at the loading point sampling should be done through AMS. In case of nonexistence of AMS or malfunctioning of AMS, sampling for general analysis is to be done at the unloading end, provided AMS exists. If AMS is not installed at either ends, sampling is carried out at the loading point from the wagons by manual means.

In some cases, sampling at the loading point is done manually from wagons, as the AMS even if installed, are not functioning. The coal that is being despatched is generally upto 200mm size. Depending on the existing facility, the coals are loaded into the wagons by rapid loading system, pay loaders etc.

Manual method of wagon top sampling of large sized coals is not only difficult but also violates some of the fundamental principles of sampling. As per requirement samples are to be drawn from the full depth of the wagons which is impossible to be collected manually. Furthermore, due to size segregation the samples collected from the wagon top does not satisfy the criteria of representativeness of the whole samples. Since the ash distribution in the different size fractions is not homogeneous, results from the samples which do not reflect the true size distribution of the lot are likely to be biased. More importantly, sample collection by a shovel from the top is a function of human discretion and not governed by the probability rule. Wagon sampling when practiced in other parts of the globe is done on smaller and uniform sized coals, generally washed and blended, and preferably by automechanical auger systems.

Other important points that need to be stressed are the steps that are taken for sample preparation. Most of the loading point sites are not equipped with mechanical size reduction units. Manual practice of size reduction of a large quantity of samples on a regular basis is time consuming and involves human errors.

To get a correct assessment of the quality parameters, it is recommended that sampling should be done through auto mechanical sampling systems. Immediate steps need to be taken to bring the existing AMS in working conditions, followed by testing of bias. The system should be studied for a prolonged period to identify its limitations and constraints.

The best alternative for monitoring power coals at the loading point is to use AMS on coals crushed to size below 50 mm. Since at the power plant end the coals are further crushed to 20/25 mm size as a feed to grinding mills, the loading point coal size can be rationally fixed to 20/25 mm size. Automatic sampling on crushed coal of 20/25 mm size has several advantages. The AMS for 25 mm size is less costly, available in Indian market, requires less maintenance and generally has less wear & tear compared to AMS for 200 mm size. It also ensures true representative sampling and less handling of material. The additional advantage of crushed coal is that in case of nonfunctioning of AMS, wagon top sampling can be resorted to, which will provide more representative sample than can be obtained from large size coals.

In the absence of any immediate option to switch over till the AMSs are installed or the existing systems are not brought into working conditions, wagon top sampling on the large sized coals has to continue. However, the procedure needs to be established considering the respective variances of sampling and sample preparation & analysis. It is always desirable to perform the sampling on the basis of different sub-lots. A sub-lot can constitute a fixed number of rakes, depending on the total daily despatch.

Concerted efforts have to be made by both the seller and purchaser to operate the existing AMS at the loading points and test its effectiveness for a prolonged period. For futuristic planning of quality monitoring of power coals, the automechanical sampling on crushed coal of 20/25 mm size needs to be enforced.

Conclusion

It is a well known fact that sampling from wagon top introduces bias. However, as this practice is likely to continue for some more time there is a need to evolve a procedure that will give results with lesser variance. It needs to be stressed that meticulous supervision of sampling and preparation procedure, increasing the number of increments and expressing the daily result as a mean of different sub-lots may increase the precision but in no way decrease the bias that is inherently present in the system. The precision value can be used by the customer and seller to match the results from the loading and unloading ends to settle the disputes on the results, if any.

In this changed ambience of competitiveness and efficiency enhancement imperatives of the core sectors, quality assessment of the primary fuel assumes greater significance. The matter is not simply confined to commercial transactions only, but has direct relevance to the efficiency of end use. If the quality parameters are to be determined at a reasonable precision level and nearer to the true value, automechanical sampling system has no substitute. Considering the technical constraints like spillage, impact of large lumps, rapid wear & tear etc. associated with AMS for large sized coals and other factors involving ease of handling, maintenance, availability in the Indian market, utilisation of AMS for sampling at the loading or unloading point on crushed coals (size 20/25 mm) is the best option. Sampling on crushed coal provides the advantage of switching to wagon sampling in case of failure of AMS, involving less manpower, more flexibility and handling of less amount of coal. This will require initial cost involvement but considering the benefits in terms of accuracy of results, lesser maintenance and manpower costs, this will pay in the long run. Adhering to a system which is intrinsically biased when alternatives are known and established may be difficult to justify in the perspective environment.

(89)

Annexure - G

No. Q-15017/40/2007-CPW
Government of India
Ministry of Environment, Forest & Climate Change
C P Division

Indira Paryavaran Bhawan,
Jor Bagh Road,
New Delhi-110003
Dated 26th August, 2015

Office Memorandum

Subject: Protocol for sampling, analysis of coal and reporting of compliance in respect of implementation of the Gazette notification on use & supply of raw or blended or beneficiated coal with ash content not exceeding 34% ash content in coal based thermal power plants

1.0 Purpose:

This protocol presents the protocol for sampling, analysis of coal and reporting of compliance on quarterly basis with respect to ash content in coal to be supplied and used by the thermal power plants covered under the provisions of the Gazette notification GSR 02 (E) dated January 02, 2014 on supply and use of raw or blended or beneficiated coal in thermal power plants. The objective is to ensure compliance of the quality of coal with respect to ash content, supplied and used by thermal power plants in keeping with applicable extant Notification of the Ministry in this regard. The data generated shall help in evaluation of compliance level of the notification.

2.0 The Notification:

In exercise of the powers conferred by Section 3, Section 6 and Section 25 of the Environment (Protection) Act, 1986 (29 of 1986) read with rule 5 of the Environment (Protection) Rules, 1986, the Ministry of Environment, Forest & Climate Change, Government of India made the following rules vide notification No GSR 2 (E) dated January 02, 2014 under the Environment (Protection) Rules, 1986, namely:—

With effect from the date specified hereunder, the following coal based thermal power plants shall be supplied with, and shall use, raw or blended or beneficiated coal with ash content not exceeding thirty-four per cent, on quarterly average basis, namely :—

(a) a stand-alone thermal power plant (of any capacity), or a captive thermal power plant of installed capacity of 100 MW or above, located beyond 1000 kilometres from the pit-head or, in an urban area or an ecologically sensitive area or a critically polluted industrial area, irrespective of its distance from the pit-head, except a pit-head power plant, with immediate effect;

(b) a stand-alone thermal power plant (of any capacity), or a captive thermal power plant of installed capacity of 100 MW or above, located between 750 – 1000 kilometres from the pit-head, with effect from the 1st day of January, 2015;

(c) a stand-alone thermal power plant (of any capacity), or a captive thermal power plant of installed capacity of 100 MW or above, located between 500-749 kilometres from the pit-head, with effect from the 5th day of June, 2016:

Provided that in respect of a thermal power plant using Circulating Fluidised Bed Combustion or Atmosphere Fluidised Bed Combustion or Pressurized Fluidised Bed Combustion or Integrated Gasification Combined Cycle technologies or any other clean technologies as may be notified by the Central Government in the Official Gazette, the provisions of clauses (a), (b) and (c) shall not be applicable.

3.0 Statutory Compliance Requirement and Reporting:

As per the notification, power plants located 750 kilometres from pit head (500 kilometres from June 05, 2016) shall be supplied with, and shall use, raw or blended or beneficiated coal with ash content not exceeding thirty-four per cent, on quarterly average basis. Hence, coal mine or company, as applicable, supplying coal to thermal power plants as well as thermal power plants covered under provisions of the notification shall require to submit compliance report for each quarter with respect to average ash content in coal used by them to respective State Pollution Control Boards (SPCBs), Regional office of the Ministry of Environment, Forest & Climate Change (MoEF&CC) and Central Pollution Control Board (CPCB).

4.0 Amendment in Consent under Air (Prevention and Control of Pollution) Act, 1981 & conditions in Environmental Clearance issued under Environment (Protection) Act, 1986:

In order to implement the provisions made in the notification, the State Pollution Control Board concerned and Ministry of Environment, Forest & Climate Change shall include a condition with respect to specifying ash content in raw or blended or beneficiated coal to be supplied by the coal mine or company, as applicable, and used by thermal power plants, in the existing consent orders issued under Air (Prevention and control of pollution) Act, 1981 and in Environmental Clearance issued under Environment (Protection) Act, 1986 to thermal power plant and coal mine or company, as applicable, under the purview of the notification on supply and use of raw or blended or beneficiatedcoal and shall invariably prescribe to all new thermal power plant and coal mine or company, as applicable, which may otherwise fall under the purview of the said notification.

5.0 Ash content monitoring (sampling and analysis) technique of coal:

Coal is highly heterogeneous in nature consisting of particles of various shapes and sizes each having different physical characteristics, chemical properties and residual ash content. Sampling is further complicated by the sampling equipment available, the quantity to be represented by the sample mass, and the degree of precision required. In addition, the coal to be sampled may be a blend of different coal types and how the coal is blended has a profound effect on the way a representative sample is obtained. National and international standards have been developed to provide guidelines for coal sampling procedures under different conditions, sample preparation and bias test procedures for the purpose of obtaining unbiased samples.

Real Time monitoring using auto mechanical sampling (online) from moving streams shall be used for sampling fuels. This shall be effective from a date not later than 01 September, 2016 in order to enable the Coal Companies and thermal power plants to install and operationalise the real time monitoring system. Manual sampling and analysis may be done so as to verify the online monitoring results.

In case of manual monitoring, coal samples may be taken from a moving conveyor belt since sampling from stationary coal such as a coal storage pile or railcars may be problematic. The analysis of samples shall be carried out by third party appointed by the respective thermal power plant/coal mine or company, as applicable, as per the guidelines of Coal Controller.

6.0 Calibration of auto-mechanical sampler:

It should be ensured that the online ash monitoring instrument is properly calibrated. Measurements should be accepted as valid only if the calibration level showsvariation in ash content is 1.0-2%. The online monitor and calibrator will hold a current calibration certificate traceable to national standards.

7.0 Location of Real-Time monitor:

The best location of real-time monitor for sampling from a moving stream is at the coal discharge point of a conveyor belt to bunker where the complete stream can be intersected at regular intervals.

8.0 Sampling frequency:

The continuous sampling of ash content in coal shall be carried out using real-time coal quality monitoring devices. In case of manual monitoring, minimum one sample from moving conveyor belt leading to bunker at each filling shall be collected. The data generated shall be computed and average for each quarter shall be calculated for reporting to concerned agencies as specified in the para 3.0 of this Office Memorandum.

9.0 Monitoring:

The following criteria will be observed when undertaking the sampling and analysis of coal samples with respect to ash content:

9.1 In case of manual monitoring:

i. Collection of coal samples shall strictly be collected as per the guidelines of Coal Controller/ Bureau of Indian Standards (BIS).
ii. Coal samples shall be collected by the third party appointed by the respective thermal power plant, coal mine or company, as applicable. However, in case of legal sampling a representative of concerned SPCB, thermal power plant, coal mine or company, as applicable shall also be present during sampling.
iii. Preparation of samples and analysis shall be carried out by using standard methodology as given by Coal Controller/ Bureau of Indian Standards (BIS) at the NABL accredited laboratory of either coal company/power plant or third party engaged.

9.2 In case of Real Time monitoring:

Data generated through real time online monitors shall be computed on daily basis an average of 3 months shall be calculated for reporting of compliance.

10.0 Monitoring records:

All power plants and coal mine or company, as applicable shall maintain records of the data generated and reported to SPCBs concerned, CPCB & Regional Office of MoEF&CC in compliance to the provisions of the notification for every quarter.

11.0 Compliance Reporting:

All thermal power plants covered under provisions of the notification shall submit compliance Report for each quarter with respect to average ash content in coal used by them to respective SPCBs, Regional office of the MoEF& CC and CPCB on or before 10th day of next month of each quarter ending on 31st day of March, 30th day of June, 30th day of September and 31st day of December every year. Similarly, all coal mine or company, as applicable, supplying coal to power plants shall also submit the same to agencies as mentioned in para 3 of this Office Memorandum.

In order to improve compliance reporting, the thermal power plants and connected coal mine or company, as applicable, should explore possibility of reporting of compliance on continuous basis (online) by making suitable arrangements with respect to ash content in coal being supplied and used by thermal power plants.

12.0 Verification of data & Compliance:

The SPCB concerned shall verify the sampling and analysis process and calibration of real time monitoring devices at least once a year at each thermal power plant and coal mine. Besides, random sampling and analysis of coal used by the power plant and supplied by coal mine shall also be conducted once in a year to ensure compliance and quality of data reporting by the thermal power plants and coal mines.

26-4-2015

(Dr. Manoranjan Hota)
Director

To

1 PS to MEF&CC
2 PPS to Secretary (EF&CC)
3 Secretary, Ministry of Coal, Shastri Bhawan, New Delhi
4 Secretary, Ministry of Power, Shram Shakti Bhawan New Delhi
5 Secretary, Ministry of Steel, Udyog Bhawan, New Delhi
6 PPS to Addl. Secretary (HKP)/AS (SK)/AS(MMK);
7 JS (MKS), JS(BS)
8 Chairman, CPCB/Member Secretary, CPCB
9 Member Secretary, All the SPCBs/PCCs
10 IT Division, MoEFCC to upload into the website

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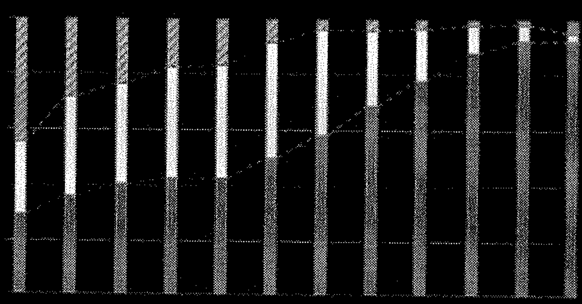
WILEY

Chemical Analysis: A Series of Monographs on Analytical Chemistry and Its Applications
J. D. Winefordner, Series Editor

Handbook of Coal Analysis



JAMES G. SPEIGHT

2 Sampling and Sample Preparation

For homogeneous materials, sampling protocols are relatively simple and straightforward, although caution is always advised lest overconfidence cause errors in the method of sampling as well as introduce extraneous material. On the other hand, the heterogeneous nature of coal (Speight, 1994, and references cited therein) complicates the sampling procedures. In fact, apart from variations in rank (Chapter 1), coal is often visibly heterogeneous and there is strong emphasis on the need to obtain representative samples for testing and analysis (Gould and Visman, 1981).

Thus, the variable composition of coal offers many challenges to analysts who need to ensure that a sample under investigation is representative of the coal. Indeed, the substantial variation in coal quality and composition from the top to the bottom of the seam, from side to side, and from one end to the other, within an unmined bed offers challenges that are perhaps unprecedented in other fields of analytical chemistry: hence the issues that arise during drilling programs designed to determine the size and extent of a coal bed or coal seam. This variability in coal composition and hence in coal quality is often significantly, and inadvertently, increased by mining, preparation, and handling.

Transportation (by belt, rail, or truck) can initiate (due to movement of the coal) processes that result in size and density segregation. Thus, variations from one side of a conveyor belt to the other, from side-to-side, end-to-end, and top-to-bottom locations in individual cars or trucks, and between one location and another in a coal pile, must be anticipated (ASTM D-346; ASTM D-2234; ASTM D-4182; ASTM D-4702; ASTM D-4915; ASTM D-4916; ASTM D-6315; ASTM D-6518; ASTM D-6543; ISO 1988). Therefore, the challenge in sampling coal from a source or shipment is to collect a relatively small portion of the coal that accurately represents the composition of the coal. This requires that sample increments be collected such that no piece, regardless of position (or size) relative to the sampling position and implement, is collected or rejected selectively. Thus, the coal sample must be representative of the composition of the whole coal (i.e., coal in a pile or coal in a railcar or truck) as represented by the properties or quality of the sample.

Handbook of Coal Analysis, by James G. Speight
ISBN 0-471-52273-2

Optimization of coal sampling is a function of the many variable constituents of coal. The effect of fineness on the combustion of pulverized coal is dramatic, and the special problems associated with collection of an unbiased sample of pulverized coal need to be addressed (ASTM D-197). *Operating samples* are often collected from the coal streams to power plants on a regular basis not only for determination of heat balance but also to document compliance with air pollution emission regulations.

Thus, to test any particular coal, there are two criteria that must be followed for a coal sample (1) ensure that the sample is a true representative of the bulk material, and (2) ensure that the sample does not undergo any chemical or physical changes after completion of the sampling procedure and during storage prior to analysis. In short, the reliability of a sampling method is the degree of perfection with which the identical composition and properties of the entire body of coal are obtained in a sample. The reliability of the storage procedure is the degree to which the coal sample remains unchanged, thereby guaranteeing the accuracy and usefulness of the analytical data.

2.1 SAMPLING

Samples submitted for chemical and physical analyses are collected for a variety of reasons, but the collection of each sample should always conform to certain guidelines. The application of precise techniques in sample collection helps to ensure that data from each analysis performed on the samples will be useful. For interpretations and comparisons of elemental compositions of coal beds to be valid, the samples must be collected so that they are comparably representative of the coal bed. Such interpretations and comparisons should never be based on data from different types of samples (Swanson and Huffman, 1976; Golightly and Simon, 1989).

Thus, sampling plays a role in all aspects of coal technology. The usual example given is the determination of coal performance in a power plant. However, an equally important objective relates to exploration and sampling of coal reserves as they exist in the ground. The issues in this case relate not only to determining the extent of the coal resource but also to the quality of the coal so that the amount may be determined. Thus, sampling in connection with exploration is subject to (1) the location, (2) the spacing of the drilled holes, (3) the depth from which the sample is taken, and (4) the size of core drills used. These criteria must be taken into consideration when assessing the quality and quantity of coal in the deposit being explored.

More to the current point, reliable sampling of a complex mixture such as coal is difficult, and handling and quite often the variations in coal-handling facilities make it difficult to generate fixed rules or guidelines that apply to *every* sampling situation. Proper collection of the sample involves an understanding and consideration of the minimum number and weight of increments, the particle size distribution of the coal, the physical character and variability of the constituents of coal, and the desired precision of the method. Thus, preliminary to any laboratory testing of coal, it is imperative that a representative sample of the coal be obtained in as reproducible and repeatable a manner as possible. If not, data derived from the most carefully conducted analysis are meaningless.

A *gross sample* of coal is a sample that represents a quantity, or *lot,* of coal and is composed of a number of increments on which neither reduction nor division has been performed (ASTM D-2234). The recommended maximum quantity of coal to be represented by one gross sample is 10,000 tons [usually, the tonnage shipped in a *unit train*: 100 cars, each of which contains 100 tons of coal (although a unit train may now contain 110 cars or more)]. Mineral matter content (often incorrectly designated as ash content) is the property most often used in evaluating sampling procedures. The density segregation of the mineral matter speaks to the movement of the coal particles relative to each other during transportation. Environmentally, sulfur content has also been applied in the evaluation of sampling procedures.

The sampling procedures (ASTM D-346; ASTM D-2234; ASTM D-4702; ASTM D-4915; ASTM D-4916; ASTM D-6315; ASTM D-6518; ASTM D-6543) are designed to give a precision such that if gross samples are taken repeatedly from a lot or consignment and prepared according to standard test methods (ASTM D-197; ASTM D-2013) and one ash determination is made on the analysis sample from each gross sample, the majority (usually specified as 95 out of 100) of these determinations will fall within $\pm 10\%$ of the average of all the determinations. When other precision limits are required or when other constituents are used to specify precision, defined special-purpose sampling procedures may need to be employed.

Thus, when a property of coal (which exists as a large volume of material) is to be measured, there usually will be differences between the analytical data derived from application of the test methods to a *gross lot* or *gross consignment* and the data from the *sample lot*. This difference (the *sampling error*) has a frequency distribution with a mean value and a variance. *Variance* is a statistical term defined as the mean square of errors; the square root of the variance is more generally known as the *standard deviation* or the *standard error of sampling*.

Recognition of the issues involved in obtaining representative samples of coal and minimization of the *sampling error* has resulted in the designation of methods that dictate the correct manner for coal sampling (ASTM D-346; ASTM D-2234; ASTM D-4702; ASTM D-4915; ASTM D-4916; ASTM D-6315; ASTM D-6518; ASTM D-6543; ISO 1988; ISO 2309).

Every sampling operation consists of either extracting one sample from a given quantity of material or of extracting from different parts of the lot a series of small portions or *increments* that are combined into one gross sample without prior analysis; the latter method is known as *sampling by increments*. In fact, the number of riffling stages required to prepare the final sample depends on the size of the original *gross lot*. Nevertheless, it is possible by use of these methods to reduce an extremely large consignment (which may be on the order of tons, i.e., several thousand pounds) to a representative sample (1 pound or less) that can be employed as the sample for the application of laboratory test methods.

The precision of sampling is a function of the size of increments collected and the number of increments included in a gross sample, improving as both are increased, subject only to the constraint that increment size not be small enough to cause selective rejection of the largest particles present. Recognition of this was evidenced in the specification of minimum number and weight of increments in coal sampling (ASTM D-2234). The manner in which sampling is performed as it relates to the precision of the sample thus depends on the number of increments collected from all parts of the lot and the size of the increments. In fact, the number and size of the increments are operating variables that can, within certain limits, be regulated by the sampler.

Considerations pertinent to the procurement of a representative sample of coal from a gross lot include the following:

1. The *lot* of coal must first be defined (e.g., a single truck, about 20 tons; a barge, about 1500 tons; a unit train, about 10,000 tons; or a ship cargo, about 100,000 tons).
2. The number of increments (e.g., the number of shovelfuls required to constitute the gross sample, which is usually 200 to 500 lb) must be established.
3. For raw, dirty, or poorly cleaned coal, the minimum number of increments is 35.
4. For thoroughly cleaned coal (i.e., maximum practical reduction of ash and sulfur), the minimum number of increments is 15.
5. The precision (ASTM D-2234) is based on one analytical determination falling within one-tenth of the true value 95 times out of 100. To reduce this error by one-half, four times as many gross samples must be used.
6. The weight per increment varies according to the top size of the coal.
7. Increments must be spaced systematically. Stationary sampling employs a grid system, which may be a simple left front–middle center–right rear grid for samples from a railroad car or a surveyed grid system to take samples from a storage pile.
8. Additionally, increments taken from a coal storage pile take into account any variations in the depth of the pile.
9. Increments from a moving coal stream are often collected on a preset interval of time by a mechanical sampling device. The opening of the device must be sufficient to accommodate a full stream cut in both directions without disturbing the coal.

Stream sampling and *flow sampling* are terms usually reserved for the collection of sample increments from a free-falling stream of coal as opposed to the collection of increments from a motionless (stopped) conveyor belt. Coal that passes from one belt to another at an angle tends to become segregated because of the momentum caused by density and particle size differences, with a predominance of coarse particles on one side and a predominance of fine particles on the other side.

Sampling at rest consists of acquiring a coal sample when there is no motion. In such instances, it may be difficult, if not impossible, to ensure that the sample is truly representative of the gross consignment. An example of coal being sampled at rest is when samples are taken from railcars (*car-top sampling*), and caution is advised both in terms of the actual procedure and in the interpretation of data. Again, some degree of segregation can occur as the coal is loaded into hopper cars. In addition, heavy rainfall can cause the moisture content of the coal to be much higher at the top and sides of a railcar than at the bottom. Similarly, the onset of freezing conditions can also cause segregation of the moisture content.

Sampling error is the difference that occurs when the property of the representative sample is compared to the true, unknown value of the gross lot or consignment. The sampling error has a frequency distribution with a mean value and a variance. *Variance* is a statistical term defined as the mean square of errors. Its square root is the more broadly known statistic called the *standard deviation*, or *standard error*, of sampling. Sampling error can thus be expressed as a function of the sampling variance or sampling standard deviation, each of which, in turn, is directly related to the material and the specifics of sample collection.

One aspect of coal sampling materials that has been employed when it is suspected that the gross coal sample (the coal pile or the coal in a railcar after transportation) is nonrandomly distributed is known as *stratified sampling* or *representative sampling*. The procedure consists of collecting a separate sample from each stratum of the gross material lot and determining the properties from each sample so obtained. Incremental sampling has been considered to be a form of stratified sampling in which the strata are imaginary because there is no physical boundary between the imaginary strata, and any such segregation is identified with the portions from which the individual increments are collected. The *within-strata* and *between-strata variances* are a function of the size and number of increments.

Preparation plant performance testing and routine quality control in mining operations and preparation plants require sampling coal both in situ and at various stages of processing following removal from the bed. Other than *channel sampling* for sampling coal in situ, and the sampling of coal slurries, the sampling techniques for quality control purposes and preparation plant are necessary. However, assessing preparation plant performance may require complex sampling programs for the sampling of many coal streams with widely different sampling properties involving the collection of sample increments for which the timing has to be tightly coordinated. Such sampling almost always depends on manual sampling with a variety of sampling implements, often in locations with difficult if not inadequate access.

Storage of laboratory coal samples for subsequent analysis is also a part of proper sample handling. Long-term storage without change is achieved by placing the samples in a plastic bag containing dry ice, sealing them tightly in glass beakers, and storing them under vacuum. Normally, oxidation and deterioration of 60-mesh laboratory samples stored in air increase with decreasing particle size and decreasing rank of coal.

In summary, the precision of sampling improves with the size of each of the increments collected and with the number of increments included in a gross sample; and manual sampling involves the principle of ideal sampling insofar as every particle in the entire mass to be sampled has an equal opportunity to be included in the sample.

2.1.1 Manual Sampling

There are two considerations involved with the principle of manual sampling (that every particle in the entire mass to be sampled have an equal opportunity to be included in the sample): (1) the dimensions of the sampling device, and (2) proper use of the sampling device. The opening of the sampling device must be two to three times the top size of the coal to meet sampling method (ASTM D-2234) requirements, and design criteria have been established for several types of hand tools that can be used for manual sampling (Figure 2.1). The main considerations are that the width is not less than the specified width and the device must be able to hold the minimum specified increment weight without overflowing.

One particular method of sampling (ASTM D-6883) that relates to the standard practice for manual sampling of stationary coal from railroad cars,

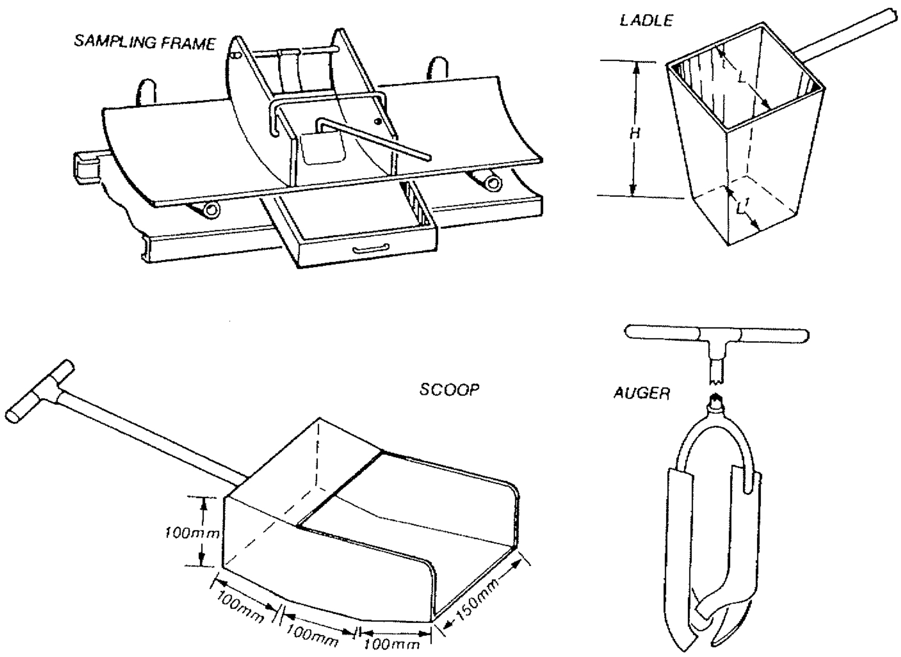


FIGURE 2.1 Sampling tools.

barges, trucks, or stockpiles (ASTM D-6315; ASTM D-6610). These procedures described in this method are to be used to provide gross samples for estimating the quality of the coal. The gross samples are to be crushed, divided, and further prepared for analysis (ASTM D-2013).

The practices described by the method provide instructions for sampling coal from beneath the exposed surface of the coal at a depth (approximately 24 in., 61 cm) where drying and oxidation have not occurred. The purpose is to avoid collecting increments that are significantly different from the majority of the lot of coal being sampled due to environmental effects. However, samples of this type do not satisfy the minimum requirements for probability sampling and, as such, cannot be used to draw statistical inferences such as precision, standard error, or bias. Furthermore, this method is intended for use only when sampling by more reliable methods that provide a probability sample is not possible.

Systematic spacing of increments collected from a stopped belt is accepted universally as the reference method of sampling that is intrinsically bias-free. *Stationary sampling*, that is, sampling coal at rest in piles, or in transit in trucks, railcars, barges, and ships, suffers decreased reliability to an indeterminate degree.

Sampling from coal storage piles (*sampling at rest*) is not as simple as may be perceived and can have serious disadvantages. For example, coal in conical-shaped piles suffers segregation effects that result in fines predominating in the central core (ASTM D-5192) as well as a gradation of sizes down the sides of the pile from generally fine material at the top of the pile to coarser coal at the base of the pile. If at all possible, coal piles should be moved before sampling, which, in turn, determines how the coal is sampled.

Where it is not possible to move a pile, there is no choice but to sample it *as is*, and the sampling regime usually involves incremental spacing of samples over the entire surface. The reliability of the data is still in doubt. However, without any attempt at incremental spacing of the sample locations, any sample taken directly from an unmoved storage pile is a *grab sample* that suffers from the errors that are inherent in the structure of the pile as well as in the method by which the sample is obtained.

Alternatively, sample acquisition from large coal piles can be achieved by core drilling or by use of an auger, or the coal can be exposed at various depths and locations (by means of heavy equipment such as a bulldozer) so that manual sampling can be performed. A wide variety of devices are available for machine sampling (mechanical sampling) and include flow-through cutters, bucket cutters, reciprocating hoppers, augers, slotted belts, fixed-position pipes, and rotating spoons (Figures 2.2 to 2.4). A major advantage of these systems is that they sample coal from a moving stream (ASTM D-6609).

There are numerous situations where coal must be sampled at rest despite the potential for compromising the reliability of the sample(s) acquired. A major problem with sampling coal at rest is that an inevitable and unknown degree of segregation will prevail, and it is not possible to penetrate all parts of the mass such that every particle has an equal opportunity to be included in the sample.

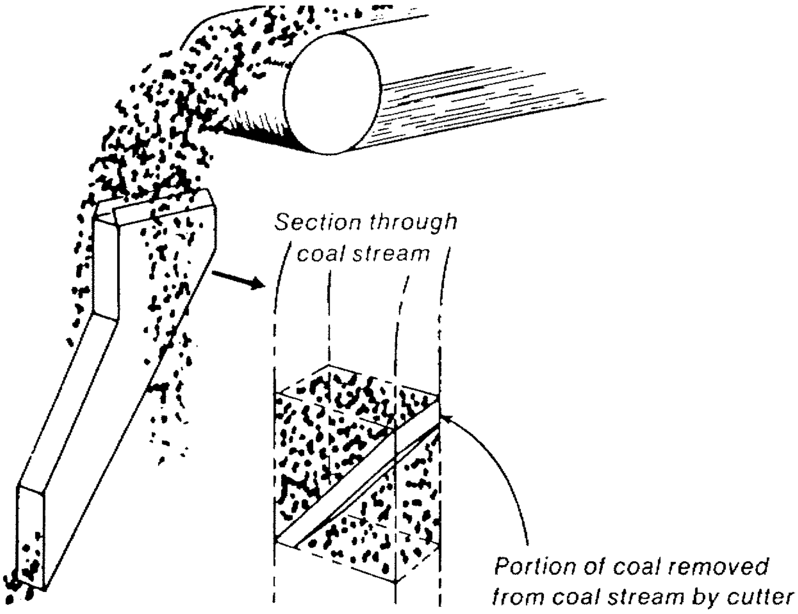


FIGURE 2.2 Cross-cut primary cutter.

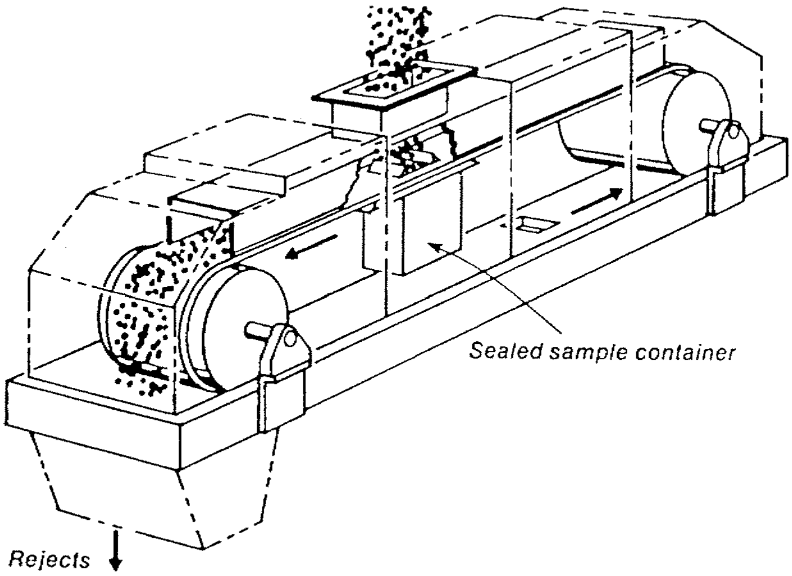


FIGURE 2.3 Slotted-belt secondary cutter.

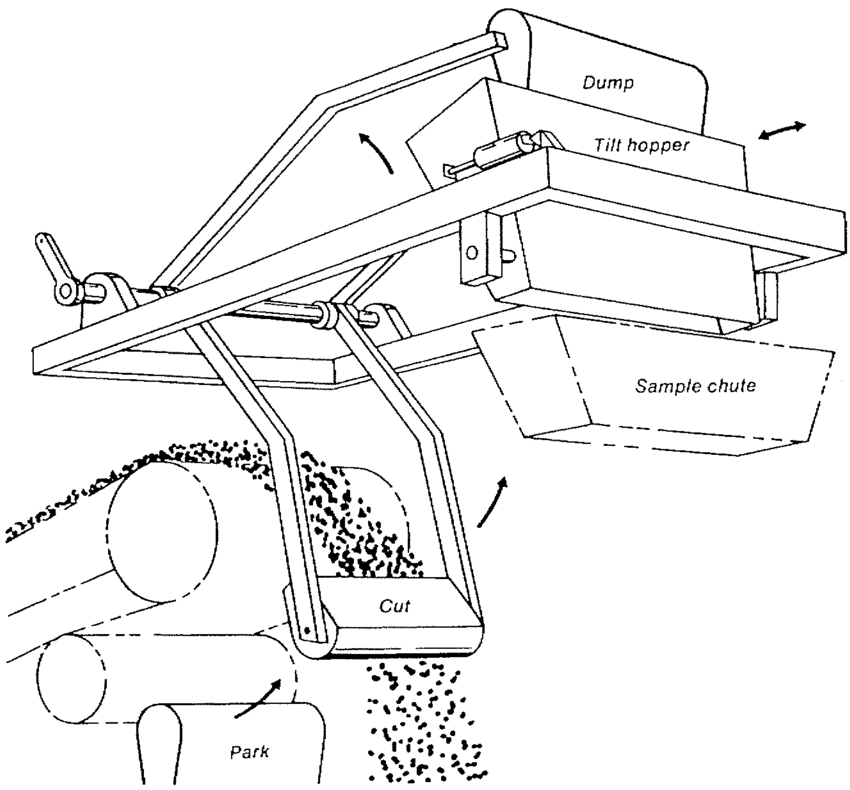


FIGURE 2.4 Swing-arm primary cutter.

The commonest situation where coal must be sampled at rest arises where the coal has to be sampled from railcars. The alternatives for sampling from hopper cars are, top, bottom, and a combination of the two. However, as coal is loaded into hopper cars, it suffers segregation related to the loading process that is not necessarily obvious, and the degree to which it will affect sample results is unpredictable. Sometimes the segregation is clearly evident, such as when cars are loaded from a stream that enters the car from the side, causing the large pieces to be shot to the far side while fines remain at or close to the near side. Having made such a statement, segregation can also occur in a more discreet or subtle manner, and any differences in texture and appearance are not always clearly visible.

In addition, when a significant amount of surface moisture is present, some will begin migrating downward immediately, resulting in a substantially higher moisture content at the bottom of the car than at the top. Furthermore, the difference in moisture at different levels may become more pronounced as time passes, owing to the effects of evaporation and precipitation. Heavy rainfall can cause the moisture content to be much higher at the top and sides than at the bottom, and if freezing conditions prevail (as they often do during Wyoming winters), the outcome will be even more obvious.

In *car-top sampling*, only the coal near the top surface has the potential to be included in the sample, thereby violating the basic tenet of obtaining a representative sample. Thus, the uncertainties regarding the accuracy of the results are increased and any conclusions drawn from the data are highly suspect. Therefore, if car-top sampling is a necessity, the increments must not be collected predominantly from any given location relative to the dimensions of the railcar. Furthermore, if the railcars vary substantially in size, the number of increments per car should be varied proportionately.

An alternative operation to sample the coal is to employ *bottom sampling*, in which coal is sampled as it is discharged from the bottom of hopper cars. Since the coal is *sampled in motion*, bottom sampling is considered to be an improvement over car-top sampling.

Stream sampling (*flow sampling*) is the sampling of coal in motion, usually from one part of the plant to another. However, increment collection must involve cutting across the full stream. The collection of increments from the sides of a moving belt is sometimes loosely called *stream* or *flow sampling*, and this terminology therefore should not be accepted as assurance that increments were collected from a free-falling stream. Such procedures are less reliable because the increments collected are subject to analytical bias caused by any segregation of the coal (including the mineral matter) that has occurred ion the conveyer belt. In fact, coal larger than 1 in. top size, or coal heaped to a depth of more than about 8 in. on a conveyor belt, exhibits a tendency to segregate. Coal that passes from one belt to another at an angle invariably becomes more segregated, with a greater predominance of coarse particles on the far side and a greater predominance of fine particles on the near side.

When the falling stream is more than 1 ft thick or is more than about 2 ft wide, the forces involved tend to be greater than can be resisted with handheld equipment, and simple mechanical devices are often useful. A pivoted scoop with the necessary mechanical advantage is useful, and slide gates (a dropout section at the bottom of a scraper conveyor) or a flop gate in a vertical chute are other possibilities. In the event that such alternatives are not feasible, partial stream cuts are permissible, but the reliability of the sampling is reduced. To combat any reduction in the reliability, partial stream cuts need to be made systematically at different points in the stream so that all parts of the coal stream are represented proportionately.

Despite the potential advantages of the procedure, sampling coal in motion may suffer from disadvantages such as (1) it is not always possible to penetrate the full depth of the coal cascading out of the car; (2) attempts to penetrate the stream result in sample scoop overflow; (3) increment collection is limited to the exposed surface at the sides of the car; (4) moisture is often higher at the sides of the car than for the entire contents of the car; (5) flow rates are highly variable; and (6) disproportionate amounts of coarse coal are often collected because the coarse particles segregate and roll down the exposed surface.

2.1.2 Mechanical Sampling

A wide variety of mechanical devices are now in use and include flow-through cutters, bucket cutters, reciprocating hoppers, augers, slotted belts, fixed-position pipes, and rotating spoons. These systems typically collect the primary increments and perform at least part of the sample preparation by crushing and dividing it down to the 4- or 8-mesh stage of reduction specified (ASTM D-2013).

Conventional design of most mechanical sampling systems for large tonnages of coal use some form of *cross-stream primary cutter* to divert the primary increments from the main stream of coal (Figure 2.2). A major advantage of these systems is that they sample coal from a moving stream, and most of them satisfy the principle that every particle in the entire mass has an equal opportunity to be included in the primary increments.

One of the more innovative primary cutter designs that reduce the component of impact velocity perpendicular to the direction of coal flow in the plane in which the cutter is moving is the *swing-arm cutter* (Figure 2.4). This design achieves this goal by passing through the stream at an obtuse angle instead of at a right angle and can be moved at higher speeds than a cross-stream cutter without causing analytical bias that is associated with disturbance to the coal flow.

A *pipe sampler* is an off-the-belt sampler that collects increments from within the stream cross section by means of one or two pipes. The sampling pipes are mounted at an obtuse angle on a horizontal axle positioned at right angles to the direction in which the coal flows and increments are collected through an orifice that is located in the bottom wall of the sampling pipe.

A *rotary car dumper system* (*tube sampler*) consists of several large-diameter tubes, each with one or two openings that are attached to a rotary car dumper. The openings are located in the path of the coal as it is discharged from the railcar. If, as has been claimed, the tubes collect coal predominantly from the top and far side of the car, the method is susceptible to bias because of the potential segregation of the coal constituents.

A *spoon sampler* consists of one or more pipes, arranged like the spokes of a wheel. Openings located at the tips collect the sample as the device is rotated through coal on a moving belt. This machine can be designed to collect very small primary increments, but the spoon pipes may overflow during increment collection and the sample may be of questionable reliability.

An *auger drill* is also used as a sampling device for penetrating a stationary mass of coal and withdrawing material from its interior. At least two specialized auger-sampling machines, designed for sampling from trucks, are commercially available. One of these uses a 10-in. auger and is intended for sampling uncrushed run-of-mine coal, and a truck-mounted portable version is also used for sampling from railcars.

2.2 SAMPLE PREPARATION

Once a gross sample has been taken, it is reduced in both particle size and quantity to yield a *laboratory sample*. This aspect is known as *coal preparation*.

Sample preparation (ASTM D-2013) includes drying (in air), as well as crushing, dividing, and mixing a gross sample to obtain a sample that is ready for analysis. As written, this test method covers the reduction and division of gross or divided samples up to and including the individual portions for laboratory analysis. Reduction and division procedures are prescribed for coals of the following groups: group A, which includes coals that have been cleaned in all sizes and allows lower-weight laboratory samples to be retained than in group B, which includes all other coals, including unknown coals.

Two processes of sample division and reduction are covered: (1) procedure A, in which manual riffles are used for division of the sample and mechanical crushing equipment for reduction of the sample, and (2) procedure B, in which mechanical sample dividers are used for division of the sample and mechanical crushing equipment for reduction of the sample. A third process that is, in reality, a combination of procedures A and B may be used at any stage.

Other standards are used to collect the gross sample, and one test method allows for one division of the gross sample before crushing. The mass and top size of the gross or divided sample collected using these guides and practices are usually too large for chemical or physical testing. However, any bias in the gross or divided sample before adherence to this practice will remain in the final sample resulting from use of this method. Therefore, the standard to be used to collect the gross sample should be selected carefully. Often, the sample is collected, reduced, and divided (one or more times) by use of a mechanical sampling system, and the remaining sample may be divided further on-site to facilitate transport to the laboratory, where further reduction and division probably occurs before analysis. But division and reduction of a sample may occur at more than one location. Samples are reduced and divided to provide an analysis sample, but some test methods require a sample of different mass or top size. This method can be adapted to provide a sample of any mass and *size consist* (particle size distribution) from a gross or divided sample up to, and including, an analysis sample.

Since moisture losses are a perpetual problem, part of the procedure may include weighing, air drying, and reweighing (ASTM D-3302) before crushing and dividing. This provides a sample in which the moisture loss during the preparation procedure has been determined and has provided a stabilized sample that is not subject to further moisture loss. Thus, sample preparation is not just simply a matter of dividing a gross sample into manageable or usable increments. The task must also be accomplished in a manner that produces an unbiased sample ready for analysis.

When executed improperly, sample preparation is the source of the second-largest component of the overall variance of sampling and analysis. Although it is not specified as a requirement, it is generally recognized that the variance of sample division and analysis is not more than 20% of the total variance of sampling, division, and analysis (ASTM D-2013). The particle size distribution (size consist) of the laboratory sample depends on its intended use in the laboratory and the nature of the test methods to be applied. The minimum allowable

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weight of the sample at any stage of reduction depends on the size consist and the degree of precision desired (ASTM D-2013).

Many issues, including (1) loss or gain of moisture, (2) improper mixing of constituents, (3) improper crushing and grinding, and (4) oxidation of coal, may arise during the sampling and sample preparation processes. To minimize moisture contamination, all standard methods include an air-drying stage in the preparation of the analysis sample. In this manner, all subsequent handling and analysis are made on a laboratory sample of relatively stable moisture content. Be that as it may, all collecting, handling, reducing, and division of the gross sample should be performed as rapidly as possible and in as few steps as possible to guard against further moisture loss or gain in the ambient laboratory conditions.

The distribution of mineral matter in coal presents problems for crushing, grinding, and uniform mixing at each step of the sampling procedure. The densities of the various coal constituents cause segregation, especially if there is a wide particle size distribution. Thus, crushing and/or grinding coal from a large particle to a very small particle should involve a reasonable number of steps that are based on the starting particle size and nature of the coal. At the same time, too many handling steps increase the exposure of the coal to air and increase the chance of moisture variation and coal oxidation. On the other hand, attempting to crush, grind, or pulverize coal from a large to a small particle size in one operation tends to produce a wide range of particle sizes and a high concentration of very fine particles.

Coal is susceptible to oxidation at room temperature, and like the potential for change in the moisture content, the adverse effects of oxidation must be considered in sampling, coal preparation, and coal storage. Again and where possible, the coal preparation steps should be done rapidly, and in as few steps as possible, to minimize oxidation of the coal. Sample containers used should have airtight lids to guard against moisture loss and exposure of the coal to air. In addition, the containers should be selected to hold only the desired amount of sample and to leave a minimum of airspace. Even then, analysis of a sample should be carried out as soon as possible after it is received. Prolonged storage before analysis is often disadvantageous.

The effect of fines content on the combustion of pulverized coal is quite dramatic (Field et al., 1967; Essenhigh, 1981), and the problems associated with collection of an unbiased sample of pulverized coal need attention (ASTM D-197). Operating samples are often collected from the feedstocks to power plant boilers on a shift or daily basis for calculation of heat balances and operating efficiencies. Another objective of operating samples is to document compliance with air pollution emission regulations based on fuel composition.

2.3 WASHABILITY

Coal washing is a process by which mineral matter is removed from coal by the use of any one of several washing processes to leave the coal as near mineral-free as is required by the buyer or by legislation. Mineral matter occurs in coal as in two clearly defined forms, intrinsic mineral matter and extrinsic mineral matter. *Intrinsic mineral matter* is present in intimate association with the pure coal substance itself and originates from inorganic material essential to the growth of the vegetable matter from which the coal was formed originally. Owing to its physical condition, such mineral matter cannot be separated from the coal substance by physical means, but since it seldom exceeds 1% by weight of the coal substance, it does not lead to undue difficulties with ash when the coal is burned in the normal way.

Extrinsic mineral matter, which is purely adventitious, is derived from the roof and floor of the coal seam and from any noncoal or inorganic material that may be associated with the seam itself. It consists generally of pieces of stone, clay, and shale together with infiltrated inorganic salts that have become deposited in the natural fissures in the coal seam (e.g., pyrite, ankeritic material). Such material can be reduced very much in amount by suitable methods of coal cleaning and, indeed, may be separated from the coal completely, provided that it can be broken apart from coal particles.

In simplest terms, the gravimetric separation of light and heavy fractions is used to accomplish coal washing. This involves one or more float–sink tests carried out on predesignated size fractions into which the coal is divided by screening. Solutions or suspensions of different specific gravities are used for the separations. This is performed repetitively with higher and higher specific gravity solutions, separating the size fraction into gravity fractions. The coal is generally of lower density than the mineral matter, and these gravity fractions thus generally exhibit higher and higher ash content. Each size fraction and each gravity fraction is dried, weighed, and analyzed. The analysis is usually made for ash and sulfur content but is frequently extended to include heating value and other variables.

In the test method for determining the washability characteristics of coal (ASTM D-4371), the need for a standard procedure to conduct washability analyses that will serve as an aid to technical communication to coal suppliers and purchaser is recognized. This test method standardizes procedures utilized for performing washability analyses, the data from which can be used for interpreting preparation plant efficiency, for determining preparation plant design, and for determining the potential recovery and quality of coal reserves. This test method describes procedures for determining the washability characteristics of coarse- and fine-coal fractions. Each sample being tested can have more than one coarse-coal size fraction and more than one fine-coal size fraction (ASTM D-4749 provides a test method for the sieve analysis of coal).

In this test method (ASTM D-4371), the specific gravity fractions are obtained by subjecting the material being studied to a series of solutions, each with a discrete specific gravity, that cover the range of specific gravities in question. These solutions are obtained by the mixing of various organic liquids that are relatively inert toward the coal. The distribution, as determined by the analysis, is affected by the physical condition of the sample subjected to the washability analysis (e.g., the moisture content and the size content of the material). Furthermore, this method may not be the most technically correct test method to determine washability characteristics of low-rank coals because of problems relative to the loss of moisture through drying during sample preparation and analysis. Methods that are directly applicable to low-rank coal are not yet available.

The testing procedure consists of washing the coal in a hand jig or subjecting it to a series of various organic liquids of increasing specific gravity. Although certain closely sized portions of a coal sample may show washing characteristics quite different from those of other portions of the same sample, it is customary in practice to have to examine the characteristics of a sample containing all size ranges simply as a whole. A *hand jig*, consisting of a Henry tube, is suitable for moderately small graded coals (Figure 2.5). The jig, or moving portion of the washer, is a brass tube about 30 in. long and 4-to-6 in. in diameter, fitted with handles at the top and having a gauze bottom (about 40 mesh) held in position by two setscrews and a reinforcing disk, all of which form a loose bottom to the jig. The entire apparatus is immersed in an outer vessel containing water. When jigging is complete, the samples are set aside to air-dry in a dust-free atmosphere and then weighed. Each sample is ground, the percentage of

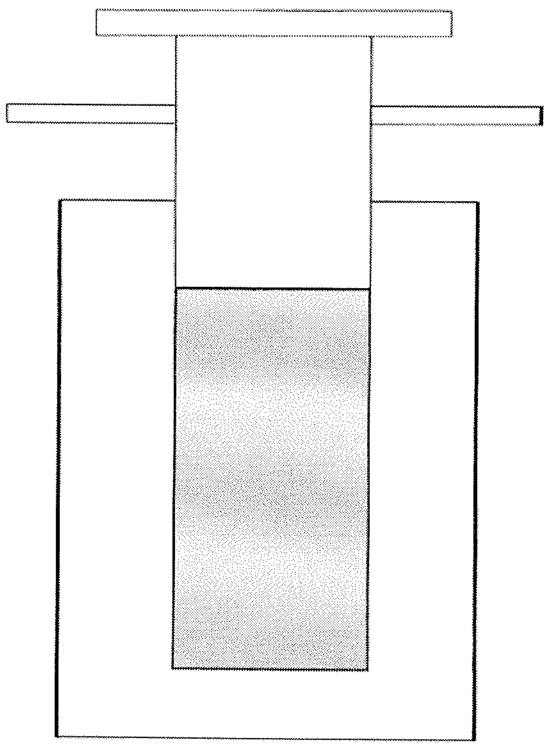

FIGURE 2.5 Henry tube.

moisture and ash is determined, and from the results a set of washability curves can be constructed.

Determination of the washability characteristics of coal by the float and sink (float–sink) method can be applied to coal of any particle size provided suitably large vessels to hold the larger lumps are available. Air-dried coal, not dry coal, should be used since the separation depends partly on the difference in specific gravity of the clean coal and dirt particles, and the specific gravity, in turn, is dependent on the moisture content of the coal. If the coal is dried before the test is carried out, the conditions will then differ from those in commercial washers, and the results will be at variance with those obtained in practice.

The solutions used are generally mixtures of organic liquids such as benzene (specific gravity 0.88), toluene (0.87), carbon tetrachloride (1.60), and bromoform (2.90), and for most purposes a range of liquids from specific gravity 1.20 to 1.60 by increments of 0.05 is adequate. If the coal contains an appreciable quantity of large pieces, it is advantageous to separate the sample into two portions on a 1-in. screen and wash the two fractions separately. The larger fraction may suitably be washed in increments in a tall glass cylinder, the floats removed as soon as separation is complete, and the sinks removed from the bottom of the cylinder from time to time as the occasion demands.

It is customary to start with the lightest liquid and then to treat the sinks with the liquid with the next-higher specific gravity. The various fractions are then set aside to air-dry and are mixed with the corresponding fractions obtained by washing the coal under the 1- or 2-in. screen size. Care should be exercised when taking the original sample to avoid such a wide size range as to preclude obtaining a thoroughly representative sample.

If the coal to be washed has no corresponding fraction over 1 in., the sample is air-dried and a small representative portion is removed for determination of moisture and ash. Weighed portions of the coal are then treated with liquid of specific gravity 1.20, and after the initial separation of floats and sinks has taken place, allowed to stand until separation is complete. The floats are filtered from the solution through a filter paper in a Buchner funnel and set aside to air-dry. The sinks are recovered in a similar manner and allowed to dry. The test is repeated with the other portions of the sample. All the floats are collected together, as are the sinks. The air-dried sinks are subjected to a liquid of specific gravity 1.25, the floats are separated as before, the sinks are subjected to the next liquid, and so on, until finally, the sinks at, say, 1.60 are obtained. All samples are air-dried and weighed (combined with their corresponding samples of coal over 1 in. if necessary), and all or a portion of each sample is crushed for determination of moisture and ash.

If bromoform is used, it is best to wash the fractions after filtration with a little methyl alcohol to dissolve the bromoform since the high boiling point of bromoform [151°C (304°F)] makes it difficult to remove completely by air drying. Furthermore, although it has been recommended that solutions of inorganic salts (e.g., calcium chloride, zinc chloride) in water may be used to replace the more expensive organic solvents, it is almost impossible to remove these salts from various fractions, even by much washing with water, with the result that the ash figures become less reliable.

With decreasing particle size, the practical feasibility of gravity separation diminishes because the efficiency of separation is reduced. Particularly in low-volatile coals, a substantial proportion of the coal may be lost in these fines if other means are not applied for separating them from the slime (clay) and recovering them. *Froth flotation* is one technique that is used for this purpose.

In principle, *froth flotation* consists of bubbling air through a suspension of fine coal and water to which various chemical agents have been added to improve the processes. The separation occurs by reason of a preferential physical attachment of air bubbles to the coal. The coal particles float to the top and are removed. The procedure is sometimes repeated, reprocessing the float fraction several times to simulate multistage full-scale froth flotation.

Selective flotation of one mineral in preference to another is accomplished by depositing on the grains of the first a film of a suitable reagent that will promote flotation of that mineral. Reagents that condition the surface of a material in this manner are known as *collectors*, those inducing the formation of a stable froth in which the material floated can collect are termed *frothers*, and reagents having the property of inhibiting the flotation of one or more constituents of a mixture are called *depressants*.

Coal cleaning by froth flotation is applied essentially to those coals that are inherently soft and are generally obtained in a size range so small as to be difficult to treat by methods of coal cleaning that are based primarily on the differences in specific gravity between the clean coal particles and those of the rejected material. Specially cleaned coking coals for use in the manufacture of coke for electrode carbons are usually prepared by froth flotation, the collectors employed being generally creosote oil fractions from coal tar, essential oils, pine oil, and so on.

The mechanical processes involved in *jig washing* and *float–sink tests* are those that yield a series of increments of the original coal with increasing mineral matter content. As a consequence, it is often found that the integrated ash for the entire sample differs appreciably from the value obtained by direct determination. This difference is the result of the ash being prepared under two sets of conditions. First, each separate increment is ashed (i.e., combusted so that the only residue is mineral ash) under conditions that differ from increment to increment because the mineral matter present on coal can change from one increment to the other. Second, the whole of the coal is ashed to give a certain reproducible ash yield obtainable from any average sample of the original coal. The divergence will be greatest for those coals containing a large percentage of pyrite sulfur, especially if this is also associated with a high alkali or alkaline earth content. The divergence can be minimized, but not eliminated entirely, if the ashing processes are carried out in two stages, as recommended in the proximate analysis.

The net result of the washability test methods is to subdivide coal into fractions having progressively decreasing mineral matter ash content and progressively increasing specific gravities. From the data furnished by the tests, the washability characteristics of the sample can be ascertained. These characteristics are presented most conveniently by construction of *washability curves* for the coal under examination.

Normally, three curves are constructed for each coal: (1) the *instantaneous ash curve* or *coal characteristic curve*, which gives the ash content of any of the individual layers into which the coal has, or can be, separated; (2) the *integrated ash curve for clean coal*, which gives the percentage yield of cleaned coal having an ash content of a certain amount and the ash content of a mixture of any number of consecutive layers of cleaned coal from the top down to a fixed layer, together with the corresponding yield expressed as a percentage of the original coal; and (3) the *integrated ash curve for dirt*, which gives the percentage yield of reject material having an ash content greater than a certain amount or the ash content of a mixture of any number of consecutive layers of dirty coal from the bottom layer up to a fixed layer, together with the yield expressed as a percentage of the original coal.

If the coal contains fusain, this maceral will appear in the lightest fraction. If much is present, its relatively high mineral matter content may have such a weighted effect on the ash yield of the first fraction as to make it greater than the ash yielded by the second, and indeed subsequent, fractions. As a result, the characteristic curve may develop a pronounced curvature up and to the right at the top extremity. Fusain and its disturbing effect should not, however, be ignored because if the sample of coal washed is representative of the main bulk of coal to be washed, the effect of the presence of the fusain must be acknowledged.

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Bulletin 116

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

METHODS OF SAMPLING DELIVERED COAL

AND SPECIFICATIONS FOR THE PURCHASE OF COAL FOR THE GOVERNMENT

BY

GEORGE S. POPE

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1916

exclude these from the mine sample, but they often get into the commercial coal as a result of the character of the roof and floor and of the mining methods employed. The efficiency of the tipple inspection and the means employed in rejecting impurities when the coal is loaded into the railroad car are also factors that often largely account for the difference between mine and commercial samples. Most of the samples collected from the mines by the Government inspectors show a higher moisture content than commercial samples, because of the generally moist atmosphere of the mine and the precaution taken to prevent loss of moisture in the collection, preparation, and analysis of mine samples.

When properly taken, the mine samples are of great value, as they indicate the general character of the coal and the uniformity of the coal bed and enable one to determine its probable value for any designated purpose, provided due consideration is given to the character of the partings, the roof, and the floor, and to the possibility of pieces from these being loaded with the commercial output.

The collection of mine samples by the Bureau of Mines and the Geological Survey is done in a systematic manner, according to a prearranged plan, and the same procedure is always followed where circumstances permit. A special outfit for use in collecting mine samples has been developed. The method followed and a description, with illustrations, of the outfit are published in Bureau of Mines Technical Paper 1, entitled "The Sampling of Coal in the Mine."

THEORY OF SAMPLING.

To determine with utmost accuracy the ash content and heating value of a quantity of delivered coal would require the burning of the entire quantity, and special apparatus arranged to measure the total heat liberated, or would require crushing the whole quantity, and reducing it by an elaborate scheme of successive crushings, mixings, and fractional selections to portions weighing approximately 1 gram, the minute quantity which the chemist requires for each determination. Either of these procedures is obviously impracticable if the coal is to be used for the production of heat and power.

The method actually employed is to select portions from all parts of a consignment or delivery of coal and to systematically reduce the gross sample, obtained by mixing these portions, to quantities that the chemist requires for making ash determinations or that can be burned conveniently in the calorimeter, an apparatus for determining the heating value. The gross sample should be so large that the chance admixture of pieces of slate, bone coal, pyrite, or other impurities in an otherwise representative sample will affect but slightly the final results. Increasing the size of the gross sample tends toward accuracy, but the possible increase is limited by the cost of collection and reduction. In reducing the gross sample by successive crushings and halvings or fractional selections, the object is to procure a small laboratory sample that, upon analysis, will give approximately the same results as the gross sample itself, or, in fact, the entire quantity of coal from which the gross sample was obtained.

THE METHOD OF SAMPLING AS A PART OF COAL SPECIFICATIONS.

The method of sampling because of its importance as a definite commercial procedure, is clearly set forth in the specifications in use by the Government, and is made a part of the contract. In order that there may be uniformity and similarity in specifications used by the different branches of the Federal service for the purchase of coal, the Bureau of Mines has prepared specifications for general use by the Government. These specifications in their present form are the result of development following years of experience and satisfactory use by various Government branches. The specifications printed on pages 46 to 58, are typical of the Federal specifications in use for the fiscal year 1915–16. It is recognized that in general specifications, such as presented, certain requirements have to be of wide application, in order to cover a variety of conditions, not only as to character and quality of coal, but as to type of furnace equipment, size of deliveries, and method of delivering.

PRACTICAL CONSIDERATIONS

MOISTURE.

The specifications that were used for the purchase of coal on the heat-unit basis prior to the fiscal year 1912–13 were on the B. t. u. (British thermal unit) "as received" basis; that is, payment for delivered coal was directly affected by the moisture content of the sample received by the laboratory. This method was based on the assumption that the moisture in the samples collected at the time of weighing and delivery could be preserved with slight loss during the storing and subsequent working down of the gross sample to a quantity convenient for transmittal to the laboratory and in its later treatment in the laboratory. From experiments that have been made and from a large mass of data, it is known that the moisture content of coal does not remain constant, and that the moisture content reported by the laboratory may be as much as 5 to 10 per cent lower than that actually contained in excessively wet or high-moisture coal at the time of weighing.

In one investigation, 254 gross samples were reduced, at the delivery point, to samples weighing approximately 5 pounds each and then the 5-pound samples were divided into two equal parts ("duplicates"), which were placed in mailing cans and sent to the Bureau of Mines for analysis. The moisture contents of the "duplicates" were a longer period. To facilitate accounting, many branches of the Government service order contractors to deliver in certain quantities, usually 100 to 500 tons. In such cases the samples are collected to represent the order without special regard to the period covered, and one or more gross samples of 1,000 pounds or more each are collected, as may be most practical and expedient in view of the facilities for sampling and the other considerations involved.

In sampling cargo deliveries of 5,000 and more tons, the Bureau of Mines collects from 3,000 to 4,000 pounds of coal as a gross sample. In order that the preparation of the samples may proceed while the cargo is being loaded, after approximately 500 pounds has been collected it is reduced to a quantity convenient for mailing to the laboratory, and each succeeding 500 pounds is likewise reduced. This procedure makes unnecessary the accumulation of a quantity of coal that can not be systematically and conveniently handled in the short time and the small space usually available. Two or more of the samples are combined and reduced to one in the laboratory, and four or five analyses are usually made for a cargo, and a report on the cargo is obtained by averaging the analyses. The samples may, however, be mixed in the laboratory and only one analysis made to represent the cargo. Though the experiments which have been made indicate that a sample of approximately 1,000 pounds will give results fairly representative of the cargo, the objection to the 1,000-pound sample is that it is too small to allow of the frequent collection of shovelfuls or portions of any quantity throughout the loading of a large cargo. As it generally happens that coal from a number of mines is loaded into the same cargo, it is desirable to collect a considerable quantity of coal, so that each mine may be well represented in the gross sample. It is obvious that the more frequently the portions are collected and the greater the quantity sampled, the less the probability that the sample will be nonrepresentative; accordingly, the bureau considers that in sampling 5,000-ton cargoes safety lies rather in the larger gross sample.

WHEN TO COLLECT SAMPLES.

The best opportunities for procuring representative samples are afforded while the coal is being loaded into or unloaded from railroad cars, ships, and barges, or while it is being dumped from wagons. Once the coal is stored in piles or bins, or loaded on cars or vessels, the procuring of representative samples is practically impossible unless the whole quantity of coal is immediately handled again and the conditions for sampling become favorable. Samples collected from the coal exposed in piles, bins, barges, cars, or ships can be considered representative only under the condition that the mass of coal is homogeneous throughout. Such a condition is highly improbable and uncertain, and the analysis of samples collected from the surface may give results that are very unreliable as indicating the nature of the entire quantity, and that may be worthless as a basis for determining an equitable price to be paid for the coal.

COLLECTION OF GROSS SAMPLES.

When coal is being loaded into or unloaded from wagons, railroad cars, ships, or barges, a shovel or a specially designed tool may be used for taking portions or increments of 10 to 30 pounds to make up the gross sample of coal. As the size of the increments should be governed by the size and weight of the largest pieces of coal and impurities, increments of more than 30 pounds may be required for coals containing large pieces of coal and impurities.

If one chute or conveyor is used for delivering a considerable quantity of coal to or from wagons, cars, or ships, it may prove expeditious and economical to devise a mechanical means for collecting portions from fractional parts of the discharged coal, or continuously deflecting a portion of the coal as it falls down the chute, or diverting from the conveyor definite portions of coal, and thus mechanically and automatically collecting the gross sample.

The mechanical collection of samples is preferred to shovel sampling, as it eliminates the personal equation. The mechanical sampler does not discriminate for or against taking more or less slate or other impurities. A person should collect samples with a shovel in the main without regard to impurities, leaving the amount of the impurities included in a sample largely to chance, as it is impossible to rate correctly the proportion of the impurities concealed in the coal, however competent the sampler may be. A mechanical sampler should preferably take the whole of the stream of coal flowing down the chute a part of the time rather than a part of the stream all the time, because the sizes and character of the pieces of coal and impurities are not apt to be evenly distributed across the stream. Excellent opportunity is afforded for procuring representative samples if the entire consignment of coal is crushed immediately after it is weighed and delivered, for then the samples can be collected from the crushed coal. If the coal is conveyed from the crusher by a conveyor, means can be devised for mechanically and automatically diverting from the conveyor definite portions of coal to make up the gross sample.

The portions should be regularly and systematically collected, so that the entire quantity sampled will be represented proportionately in the gross sample. The interval at which the portions are collected should be regulated so that the gross sample collected will weigh not less than approximately 1,000 pounds. If the coal contains an

APPENDIX A.

METHOD OF SAMPLING COAL DELIVERIES.

(To be attached to and to become a part of the Specifications and Proposals issued by the Office of the ...., for the purchase of coal for the fiscal year commencing July 1, 191.., and ending June 30, 191...)

NOTE.—As payment for bituminous and the steam sizes of anthracite coal is to be based upon the quality as shown by analyses of representative samples, it is imperative that every sample be collected and prepared carefully and conscientiously and in strict accordance with the method agreed upon herein, for if the sampling is improperly done, a determined price based on the analysis will be in error and it may be impossible or impracticable to take another sample: but if an analysis is in error, another analysis can easily be made of the original sample.

Gross samples of the quantities designated herein must be taken whether the delivery consists of a few tons or several hundred tons, because of the following cardinal principle in sampling coal that must be recognized and understood; that is, the effect of the chance inclusion or exclusion of too many or too few pieces of slate, or other impurities in what, or from what, would otherwise have been a representative sample will cause the analysis to be in error accordingly, regardless of the tonnage sampled. For example, the chance inclusion or exclusion of 10 pounds too much or too little of impurities in or from an otherwise representative sample of 100 pounds would cause the analysis to show an error in ash content and heating value of approximately 10 per cent, whereas for a 1,000-pound sample, the effect would be approximately only 1 per cent, the effect being the same whether the sample is collected from a 1-ton lot or from a lot consisting of several hundred tons.

Time of sampling.

1. The coal shall be sampled when it is being loaded into or unloaded from railroad cars, ships, barges, or wagons, or when discharged from supply bins, or from industrial railway cars, or grab buckets, or from the coal-conveying equipment, as the case may be and as may be mutually agreed upon. If the coal is crushed as received, samples usually can be taken advantageously after the coal has passed through the crusher. Samples collected from the surface of coal in piles or bins, or in cars, ships, or barges, are generally unreliable.

Size of increments.

2. To collect samples, a shovel or specially designed tool or mechanical means shall be used for taking equal portions or increments. For slack or small sizes of anthracite, increments as small as 5 to 10 pounds may be taken, but for run-of-mine or lump coal the increments should be at least 10 to 30 pounds.

Collection of gross sample.

3. The increments shall be regularly and systematically collected, so that the entire quantity of coal sampled will be represented proportionately in the gross sample, and with such frequency that a gross sample of the required amount shall be collected. The standard gross sample shall not be less than 1,000 pounds, except that for slack coal and small sizes of anthracite in which the impurities do not exist in abnormal quantities or in pieces larger than $\frac{3}{4}$ inch, a gross sample of approximately 500 pounds shall be considered sufficient. If the coal contains an unusual amount of impurities, such as slate, and if the pieces of such impurities are very large, a gross sample of 1,500 pounds or more shall be collected. The gross sample should contain the same proportion of lump coal, fine coal, and impurities as is contained in

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IEA CLEAN COAL CENTRE

Coal sampling and analysis standards

Qian Zhu

April 2014

Table 4 – Minimum mass of sample for general analysis and determination of total moisture content (ISO 13909-2:2001)		
Nominal top size of coal, mm	General-analysis samples and common samples, kg	Samples for determination of total moisture content, kg
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	—
1.0	0.10	—

Note:

1. the masses for the general analysis and common samples have been determined to reduce the variance due to the particulate nature of coal to 0.01, corresponding to a precision of 0.2% ash;
2. extraction of the total-moisture sample from the common sample is described in ISO 13909–4:2001.Values in column 3 corresponds to minimum masses of divided samples for total moisture analysis, which are approximately 20% of the minimum masses for general analysis, subject to an absolute minimum of 0.65 kg.

Sampling should be carried out by systematically sampling either on a time-basis or on a mass-basis, or by stratified random sampling. The interval between primary increments depends on the size of the sub-lot and the number of primary increments in the sample, and should be determined in accordance with relevant standards. This interval should not be changed during the sampling of the sub-lot.

3.2 Methods of sampling

Coal samples can be taken at various locations from a moving stream or from a stationary lot either manually or by mechanical sampling systems. The selection of a sampling method depends upon factors such as the sampling purpose, accuracy desired, accessibility of the site and technical, economic and time constraints.

3.2.1 Sampling from moving streams

Sampling from a falling stream

The best location for sampling from a moving stream is at the discharge point of a conveyor belt or chute where the complete stream can be intersected at regular intervals. Sample increments are taken by an automatic mechanical sampler from the whole cross-section of a continuously moving stream at a transfer point. Mechanical cross-stream cutter type is widely accepted as providing a representative primary sample increment and is most commonly used. Various standards recommend that when samples are taken using a cross-stream cutter, the following design criteria should be met in order for representative and correct sampling:

1. the sample cutter should cut a complete cross-section of the stream;
2. the plane or surface of the cutter aperture should preferably be normal to the mean trajectory of the stream to maximise the effective cutter aperture;
3. the speed of the cutter should be constant and not exceed 0.6 m/s;
4. the ratio of cutter aperture to coal top size is a minimum of three, and the cutter opening should be wide enough to prevent bridging;
5. the cutter opening should have parallel edges;
6. the flowing stream to be sampled should be in free fall;
7. the sample cutter should completely retain or entirely pass the increment without loss or spillage and without any part of the cutter aperture ever being blocked or restricted by material already collected.

Depending on the design, there are different types of mechanical cross-stream cutters such as cutter-chute, cutter-bucket and swing-arm.

It is relatively straightforward to ensure that the cutter intercepts the complete stream. Also, it is easy to check visually that cross-stream cutters are operating correctly so the increment delimitation and extraction are correct. As a result, the need for bias tests is reduced.

Sampling from a moving belt

It is preferred to use a sampler which cuts the full width of a falling stream of coal. However, where it is not possible, an alternative method is to scoop the sample from a moving conveyor belt using a cross-belt cutter. Cross-belt cutters are now widely used in the coal industry, partly because they are easier to retrofit than falling-stream samplers. They have a cutter that traverses the full width of the belt in a rotary motion. The leading edges of the cutter cut out an increment of coal being carried on the belt and the back plate pushes it off the belt. For representative and correct sampling the design of a cross-belt cutter should meet the following criteria:

1. the cutter lips should be parallel and cut the stream at a 90 degree angle to the centre-line of the convey being sampled;

2. the cutter should cut through the complete cross-section of the stream during one continuous operation with a uniform velocity and a minimum cutter velocity of 1.5 times the velocity of the belt;
3. the cutting aperture width of the cutter should be at least three times the nominal top size of the coal being sampled;
4. the cutter should have a capacity sufficient to accommodate the increment mass obtained at the maximum flow rate of the material;
5. the belt curvature should be profiled to form an arc which is matched by the cutter side plates to ensure that fines which tend to segregate to the bottom of the coal on the belt are included in the sample, and the gap between belt and side plates and/or back plates should be adjusted to the minimum required to safeguard against direct contact and consequential damage to the belt. In addition, the cutter should be equipped at the rear with an effective and durable wiper that sweeps off the bottom layer of coal cleanly;
6. any flexible blades, brushes or skirts fitted to the cutter should remain in close contact with the surface of the moving conveyor belt to ensure that the complete coal cross-section in the path of the cutter is collected from the belt.

There are two types of mechanical cross-belt samplers that are commonly used and they differ considerably as regards the movement of the cutter relative to the coal on the belt as illustrated in Figure 1. 'Square cutters' or 'hammer samplers' (*see* Figure 1a) have sides which are square to the belt. 'Skew cutters' (*see* Figure 1b) have sides set at an angle to the belt in order to reduce the amount of disturbance to the material on the belt which is near to the cutter but is not intended to be sampled. Both types of cutter are rotated about an axis which is parallel to the belt.

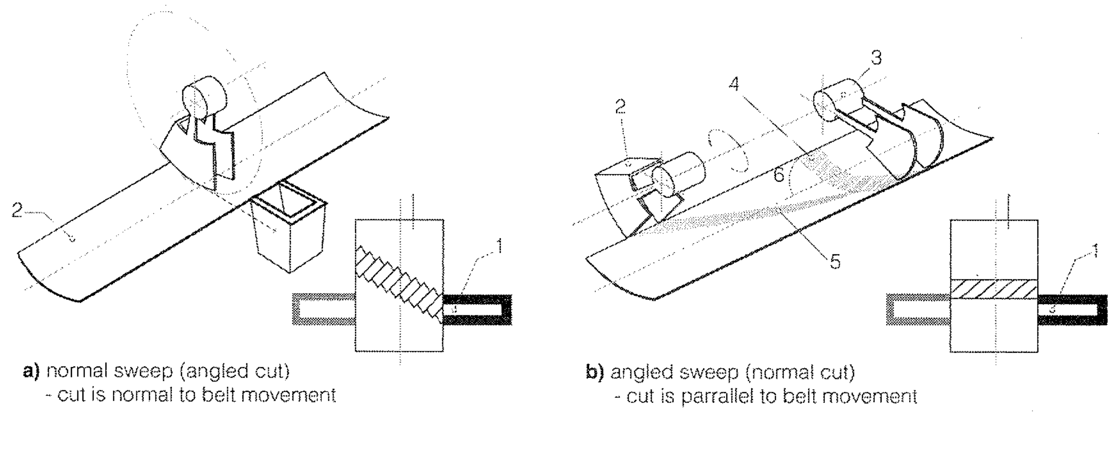

Figure 1 – Cross-belt samplers (Moodley and Minnitt, 2009)

For square cutter type samplers, the stream of coal on the upstream side of the cutters is held back, forming a wave of material which may enter the cutter body during the time the cutter cuts through the stream resulting in over-representation. Consequently, the relationship between belt velocity and cutter velocity relative to the coal is important. Also, the higher the cutter velocity is in relation to the belt velocity, the larger the effective aperture will be and the more favourable will be the sampling conditions.

However, the use of high cutter velocities may result in an unacceptable degree of breakage of sized coal. For these reasons, and also because the density of the material to be sampled is considerably higher than in cases of sampling from falling streams, various standards do not impose as strict limitations on cutter velocities as those applying to falling-stream samplers. The cutter velocity has to be carefully adjusted to avoid taking a biased sample. A commonly used rule is that the cutter speed should be at least 1.5 times belt speed (Robinson and others, 2010).

In order to avoid sampling bias, it is important to make sure the coal fines that tend to segregate and move closest to the conveyor belt are collected. To achieve this, the sampler needs to touch the belt. Understandably, the point of impact is an area of high wear and needs to be constantly adjusted to prevent a gap developing between the edge of the cutter and the conveyor belt.

Stopped-belt sampling

This method collects increments from a complete cross-section of the fuel on the conveyor belt by stopping the belt at intervals. Figure 2a shows a stopped-belt sampler. When properly collected, the stopped-belt increment can be considered as bias free. This method is labour and time consuming. Also, it disturbs plant operation and therefore it is no longer used in routine sampling. Today, stopped-belt sampling is recommended by several standards as a reference sampling method when carrying out a bias test procedure.

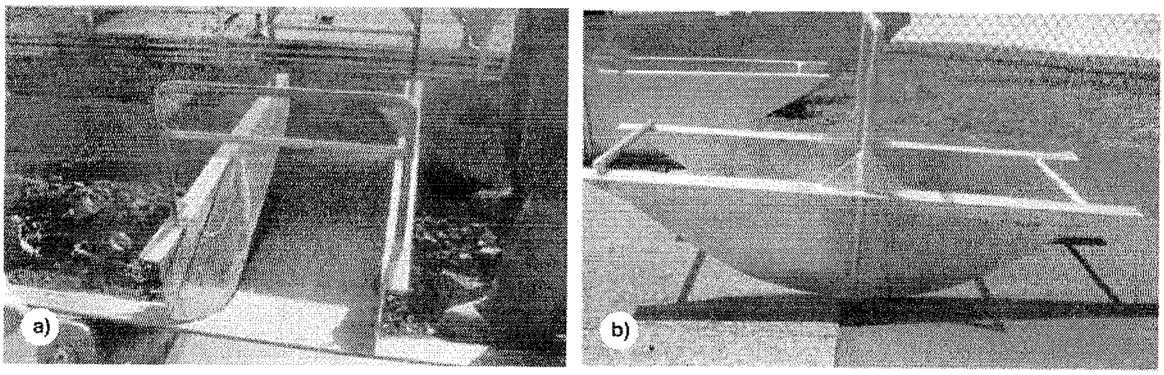

Figure 2 – A stopped-belt sampler (Renner, 2012)

Stopped-belt increments should be taken with a sampler such as a sampling frame (*see* Figure 2b) from a complete cross-section of coal on the belt at a fixed position, for a length along the belt which is at least three times the nominal top size of the coal. The sampler should be placed on the stationary belt at the predetermined position so that the separator plates at each end are in contact with the belt across its full width. All particles lying inside the sampling frame end plates should be swept into the sampling container.

3.2.2 Sampling from stationary coal

Sampling of material that is stationary such as a coal storage pile or railcars, is particularly problematic because in many cases it is not possible to ensure that all parts of the material are accessible and have an equal probability of being collected and becoming part of the final sample for analysis. For large stockpiles, in particular, the material located in the centre of the pile will be inaccessible when conventional sampling techniques are used. Generally, samples taken around the pile will be limited by the depth of penetration of the sampling device into the stationary source.

Sampling from stockpiles

Coal samples can be taken by the methods for sampling of moving streams described above when a stockpile is laid down or picked up. If this is not possible, then increments can be taken regularly using manual probes, augers or scoops, from the working face of the stockpile, from the bucket of a front-end loader, or from a single discrete load delivered to, but before being pushed into, the main stockpile. This method can provide the best available sample, but it is clearly not an accurate or representative sample. The design of the equipment for manual extraction of increments should fulfil the following requirements (ISO 18283:2006):

- the width of the opening of the sampling device, which determines the minimum mass of increment, should be at least three times the nominal top size of the coal being sampled with a minimum dimension of 30 mm;
- the capacity of the device should be sufficiently large to contain at least the required minimum mass during the extraction of a single increment and to ensure it is not over filled;
- if the device is used for falling streams, the length of the entry aperture should be such as to ensure that the whole width of the stream is intercepted.

During the extraction of increments, large and hard pieces of coal or rock should not be pushed aside, and none of the coal should be lost from the device. Wet coal adhering to the devices should be minimised.

Examples of equipment for manually extracting increments are ladles, shovels/scoops, probes, augers, manual cutters, and sampling frames as illustrated in Figure 3. Probes and augers must not be used for coals that require size analysis; they should only be used for coals with a particle size of up to about 25 mm owing to the difficulty of insertion.

6 Summary

With coal being a major source of fuel in many parts of the world and large volumes of coal traded locally and internationally every year, there is a need to understand the fundamental properties of coal so as to establish the price of the coal, and for quality and process control. Also, there is a continued interest in the efficient use of coal and the development of clean coal technologies, making the area of coal evaluation of paramount importance.

Standards

A large number of test methods for evaluation of coal and coal products have been developed and some of the well established test methods are recognised by various standards organisations as standard methods for coal evaluation/characterisation. International and various national standards have been set up to provide procedural guidelines for coal sampling and sample preparation, coal analysis and bias tests for sampling and analytical systems. The ISO Standards are internationally accepted and many national standards are largely based on the ISO Standards. The ASTM Standards are mainly adopted in the USA and Canada, and are widely used in universities and research institutions in the study of coal and in developing new analytical techniques of coal.

Coal sampling

Coal is highly heterogeneous in nature consisting of particles of varied shapes and sizes each having different physical characteristics, chemical properties and residual ash content. Proper sampling and sample preparation are critical for accurate analysis. Obtaining a representative sample implies that every particle has an equal chance of being selected. A correct and representative sample requires that every particle in a lot being sampled is equally represented. A representative sample is collected by taking a definitive number increments, periodically throughout the entire coal lot being sampled. The number and weight of increments required for a desired degree of precision depends on the variability of the coal which increases with increasing impurities. The sampling of coal can take place from either stationary lots or from moving streams. Sampling from stationary lots is particularly problematic because in many cases it is not in compliance with the fundamental sampling principle stipulating that all parts of the lot being sampled must be accessible for physical sampling. Therefore, sampling from moving streams is preferred. The best location for sampling from a moving stream is at the discharge point of a conveyor belt or chute, that is a falling stream where the complete stream can be intersected at regular intervals. However, cross-belt cutters are now more popular and are widely used in the coal industry. The stopped-belt sampling, when properly executed, is considered as bias free and is recommended by several standards as a reference sampling method when carrying out a bias test procedure.

Sampling can be carried out manually or mechanically. Manual sampling is subject to human errors and is known to be incorrect and unreliable. Whenever possible, mechanical sampling from moving streams should be the choice for coal sampling.

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COAL SAMPLING

AND ANALYSIS:

METHODS AND MODELS

Prepared for

Office of Air Quality Planning and Standards

Prepared by

Air and Energy Engineering Research
Laboratory
Research Triangle Park NC 27711

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SECTION 3

ASSESSMENT AND STATISTICAL EVALUATION OF COAL SAMPLING TECHNIQUES AND EQUIPMENT

The purpose of this section is to document industry accepted coal sampling methods and define the specific sampling principles involved. The objectives of coal sampling are discussed, including the procedures and rationale for collecting a representative sample. The development of accepted coal sampling guidelines are presented. Sampling equipment is evaluated according to its effectiveness in obtaining a representative sample according to accepted standard methods. A discussion of sampling considerations and objectives include suggested procedures to achieve the level of accuracy needed to meet specific standards. Coal sampling is presented as a means of predicting SO_2 emission levels.

3.1 OBJECTIVES OF COAL SAMPLING

The sampling of coal, whether performed manually or automatically, must extract a quantity of coal much smaller than the original lot but with proportionately the same characteristic qualities and quantities present in the entire lot. It has long been realized that the properties in coal are not distributed uniformly. The variability of coal makes it difficult to collect a sample that is representative of a large mass of coal. For instance, grab samples of coal from the same source may show different analytical values if tested in different laboratories or by different technicians in the same laboratory.(1)

Besides coal's inherent variability, other factors such as how the coal was handled, or how the samples were obtained, affect the collection of a representative sample. The coal may have become segregated during loading, transport, or unloading operations so that the particles are grouped together by size. When samples are taken from a stationary source, such as a coal storage pile or railroad car, it is difficult to obtain an accurate sample because the material located in the center of the pile will be inaccessible when conventional sampling techniques are used. Generally, samples taken around the pile will be limited by the depth of penetration of the sampling device into the stationary source. Similarly, when samples are taken from a moving stream, such as a conveyor, they should be taken from the entire width of the belt to avoid biasing the sample.

To be effective, a sampling plan must employ measures to reduce the effect of segregated particles, minimize the effect of the variability of the coal properties, and identify any mechanical bias due to the sampling method. Sampling material from a conveyor or a chute through which the coal is flowing provides access to a cross-section cut of the entire stream. This cross-sectional cut will provide a characteristic sample even though the vertical distribution of material on the conveyor may be segregated by particle size.

Mechanical sampling bias may be reduced by the use of automatic equipment which is not dependent on human discretion for operation. These systems are generally elaborate and have been designed for a specific plant's application. Manual sampling methods can be used, but care must be taken to ensure that the sampling technique has been consistently applied.

Sampling personnel must consider the variability between discrete units of coal when attempting to collect a sample which is representative of a specific lot. As an example, a 10,000-ton lot of coal may be made up of 100 discrete units or railroad cars of 100 tons each. If the variability between railroad cars is high because of differences in loading procedures and coal characteristics, a composite made up of one increment collected from every tenth car may be insufficient to represent the entire 10,000-ton lot. In this case, increasing the number of increments or increasing the number of railroad cars sampled, will produce a composite which better characterizes the entire lot. On the other hand, if the variability is expected to be relatively low, then sampling from each car may be an extensive effort with little or no extra benefit.

3.2 SAMPLING GUIDELINES

With all these factors contributing to the inaccuracy of coal sampling, there has been concern over the reliability of coal analysis data. Inaccurate data, whether due to an error in sampling, poor analytical techniques, or some other factor, can result in data misuse. Because of this, there are many opinions concerning guidelines for sampling coal and the establishment of standard methods.

As early as 1914, the United States Bureau of Mines (USBM) presented a procedures, written by A. C. Fieldner, for sampling coal in a mine.[(2)]. The Bureau also developed guidelines for representative sampling for analysis[(3)]. The author, G. S. Pope, points out that it is difficult to obtain a representative sample from a stationary source such as a railcar or storage pile. He further states that the only representative sample that can be collected from a heterogeneous mixture of coal is one from a moving stream of coal as it is being loaded or unloaded. Pope also offers general directions for the number, size, and frequency of sample increments.

Pope states that the conclusion reached by tests run by the USBM indicates that the gross sample should not be less than 1,000 pounds. The increments should be systematically spaced so that the entire quantity is represented in the gross sample. Pope suggests increments of 10 to 30 pounds, but he points out that increment size is governed by the size and weight of the largest pieces of coal; increments of greater than 30 pounds may be necessary.

A more specific guideline was provided by Bertrand A. Landry in another USBM publication[1]. The author applies the theory of random sampling to coal sampling methods. Specifically, Landry used random sampling theories to determine the optimum number of increments to be collected to yield a gross sample of definable quality. The determination of the number of increments is based on the desired representativeness of the gross sample and assumes that the variability of the increments is known. Landry presents an equation for this determination:

$$N = \frac{S_W^2}{S_{(N)W}^2}$$

which states that N, the sufficient number of increments, can be found by dividing the variability of the increments of weight W, S_W^2, by the variability of gross samples of accepted representativeness, $S_{(N)W}^2$. This is based on the premise of the random chance of choosing each increment, and on all increments being the same weight. The total weight of coal being sampled is not considered in determining N for random sampling. The weight of each increment is assumed to be constant, but no specific weight is suggested. Landry then determines that systematic sampling will produce a sample as representative as random sampling when the total lot size is relatively large.

The U.S. Steel Corporation has also written directions for providing representative samples for analysis[4]. They advise removing a full cross sectional cut from a moving stream or stopped belt conveyor, but they discourage sampling from railroad cars and other stationary

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sources. U.S. Steel recommends the collection of one increment every 30 minutes for moving streams and provides guidelines for gross sample requirements using different sampling schemes. A minimum of 1,000 pounds is specified for a gross sample. A sample increment weight of six to eight pounds is recommended when samples are collected from chutes or stationary sources. When sampling from a stopped belt a much larger increment is required. The cross-sectional cut should be a minimum of one foot in length.

To achieve a more uniform, systematic method for collecting coal samples, the USBM published a paper for government employees to use as a guideline in obtaining representative samples[5]. This paper suggests systematic collection of a large number of increments of equal weight. The exact number and size of increments is dependent on the maximum size of the coal. In the case of a coal whose top size is 3/4 inches, 50 increments of 10 pounds each are required. For larger sized coal, the number of increments remains at 50, but the increment weight is increased. For example, a coal whose top size is 8 inches requires increment weights of 20 pounds each. The USBM recommends a full cross-stream cut be taken from a moving stream. They discourage top sampling from railroad cars or barges. If, as a last resort, top sampling is used, increments should be taken from throughout the car or barge.

All of these references give general recommendations for collecting a gross sample of coal, but none is an industry accepted standard method. The most widely regarded standards were established by the American Society for Testing and Materials (ASTM)[6]. The ASTM issued recommended procedures for a variety of sampling situations. The ASTM Method D 2234 details the minimum number and weight of increments and the amount of the gross sample needed to provide a stated level of precision.

utilities that Versar had previously been in contact with. The raw data do not differentiate between even or random increment spacing. However, based on the nature of the sampling equipment and procedure in each case, it is likely that all samples taken with automatic equipment (Type I) are evenly spaced and that those taken manually (Type II) are randomly spaced, unless the utility is extremely rigorous in its application of standard methods.

Versar's experience with power plant operations indicates that stopped-belt, partial-stream cut, and stationary sampling methods are almost never used when automatic sampling equipment is in place. This is reflected in the data collected from Versar contacts, and it indicates that a large percentage of the "undifferentiated" Type I responses shown in Figure 6-1 probably refers to Method IB1. Similarly, the Versar data indicate that if Type II Methods are used, sources C and D are the most common with the emphasis on belt sampling. It can be assumed that a fairly large percentage of "other" sampling methods consist of these sources as well.

6.3 SAMPLING LOCATION

Coal can be sampled at many locations in a power plant depending on the method of coal handling, accessibility, and sampling objective. Most frequently, coal is sampled from a conveyor belt because this affords good accessibility and brings the coal to the sampling equipment rather than vice versa. Some operators, however, take samples from delivery vehicles to monitor incoming coal quality or from bunker storage in the plant. The most important difference between locations is whether the sample represents "as-received" or "as-fired" coal.

As-fired samples are taken at any location after the storage bunker outlet. These samples are frequently taken from the coal feeders or from a clean-out pipe on the bunker line going to the feeders. Samples are usually not taken from the pressurized lines after being pulverized, although one plant contacted did this with the aid of in-line cyclone samplers.

S. No.	Decription
1.	The Director (Comml.) GRIDCO Ltd. 24, Janpath, Bhubaneswar – 751007
2.	The DGM (Regulatory) Madhya Pradesh Power Management COmpany Ltd. Shakti Bhawan, Vidyut Nagar Jabalpur – 482008
3.	The Managing Director Chhatisgarh State Power Distribution Co. Ltd. Sundernagar, Dhagania, Raipur, 492013
4.	The Superintending Engineer (SPA & TC) Uttar Pradesh Power Corp. Limited Shakti Bhawan 14, Ashok Marg Lucknow – 226001
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