Sampling in coal handling and Preparation Plants

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INTRODUCTION :

Sampling is the art of withdrawing a small quantity of material from a large lot in such a manner that the smaller fraction represents proportionally the same specific composition and quality as present in the original entire lot. This is a difficult task and unless due attention is given to the sampling system while designing a plant it is not possible to achieve satisfactory results in our day to day practice. Attempt has been made in the present article to setforth some practical aspects of sampling and sampling procedure. Readers should use their own discretion and judgement to modify these techniques to suit their particular requirements always keeping in mind that the procedure adopted remained reliable and accurate.

Importance of sampling :

Sampling and allied system in a Coal Preparation in a Coal Handling Unit are used to determine process efficiency, plant and individual equipment production efficiency. Indirectly it is used to allocate production costs and finally establish sale prices. Coal being a very heterogeneous mass by nature, is most difficult material to be sampled because of varying composition from combustible to non-combustible in a single seam. In India, this change occurs with depth, length and breadth of the seam in the same mine. Quality control thus becomes a stupendous task for coal preparation personnel. It may not be out of place to mention that quality control is only as effective as the data on which it is based. Information about the material being controlled is the key to successful control and an efficient and correct sampling is the tool for obtaining a reliable result.

In any sampling system the number of stages involved are many before the sample reaches the test laboratory and each stage of sampling contributes to the total error, making reproducibility of results very difficult. At the same time—it has been found that poor reproducibility and inaccuracy in analytical results may be caused just as much by bad sampling as by bad analysis. All too often only lip service is paid to the importance of sampling and sample preparation. It is to be appreciated that lack of care in this important area may invalidate results produced by the most sophisticated and expensive analytical instruments. A simple relation between sample error and analytical error is represented by the formulae given below.

$$\text{Total error} = \sqrt{\text{Sampling error}^2 + \text{Analytical error}^2} \qquad (1)$$

There is no point in carrying out an exacting and expensive analysis if the sample has been taken and prepared in a causal manner with no regards to norms. Hence a good sampling system with strict adherence to procedure is a must for any coal handling and preparation plant.

Purpose of sampling :

Before any sample is collected, a very simple but important question flashes in the mind of everyone involved directly or indirectly with the operation. Why is the sample taken ? Is it simply for quality assessment/monitoring or for equipment/circuit control in a system ? Unless the clear objectives are laid out, sampling does create some sort of confusion in the minds of plant operators, who, invariably think that it would reflect on their efficiency. This coupled

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with not very thoughtful procedure and general attitude of unconcern towards sampling, the results thus obtained become panacea for some and frustrating for others. Therefore sampling should be broadly carried out with two different objectives :

a) For Plant Control

b) For Quality Assessment of Raw Coal and end products

In a Coal Handling and Preparation Plant, samples are taken to conduct one or all the following tests listed below :

1) Sizing Analysis
2) Grindability Test
3) Float and Sink Test
4) Ash Analysis (composite & for each fraction)
5) Moisture Analysis
6) Calorific value/BTU value
7) Sulfur content

It should be known well in advance that the samples drawn are meant for carrying out one or two or all the tests listed above, as this will generally govern the size of sample to be drawn. A table based on the formula given here and own experience of the sampler will be able to guide him about the quantity of gross sample to be drawn :

$$W = KD^a \quad (2)$$

K — Constant depends on nature of materials and amount of precision desired

D — Maximum particle size in the materials to be sampled in inches

a — Constant varying between 2 & 3

If only sizing analysis is to be done the amount of sample drawn could be very small as compared to value computed from the formula (2) but at the same time if the grindability test is also desired then it has to be more than what is required for sizing analysis only. So one has to use his own judgement depending on the total requirement. There are few other sailent points which should also be kept in mind while drawing a sample :

a) Screen analysis above 350 mm size is not generally carried out and only visual estimates are prepared as far as the larger lumps are concerned.

b) General Gradation—Larger the variation from top smallest size, larger is the quantity of sample needed. For example 100×50 mm material will require only 50% sample than that is required for 100×0 mm size material. The percentage of gradation is also important. say, if 90% of the material in a 100×0 mm product is only (—) 6×0 then a larger amount of sample has to be drawn to have proper representation of 100×6 mm fraction in the whole lot.

c) Point at which sample is to be drawn has also an impact on the size of sample.

d) Transportation of sample is always a problem and cost effective as it normally involves manual labour also. Depending on the proximity of laboratory, sample size could be reduced out, but accuracy in obtaining the sample should not be permitted to score down on this account.

e) The purpose of sampling, whether it is for circuit evaluation or for an individual equipment also effects the size of sample drawn.

In-depth knowledge of the above points will help in finally determining the quantity of sample.

Where to take sample :

In most cases the performance evaluation of individual equipment/circuit in a coal handling or preparation plant is not carried out on a day basis but on a charted out time scale basis for which no permanent sampling eqipment installations are generally justified. But due care has to be taken during initial stages of plant design so that suitable sample drawing points are incorporated in the system to facilitate easy withdrawl of sample. On the other hand quality of products such as clean, middlings and the like have to be monitored on a regular basis and thus a sampling system for these become economically justifiable.

If a total circuit is to be evaluated, the sample should be taken from the location that will provide information on all the different operations of the circuit. In a crushing and screening circuit, crusher product, circulating load, crusher feeds, screen oversize and undersize and the final product going out of the system are some of the factors that should be monitored. If a jig performance is in question, then the sample taken of the feed and the reject elevators could provide information for evaluation of the efficiency of operation. The H. M. Cyclone performance can be ascertained by taking sample of the feed and underflow/overflow of depulping and rinsing screen products. Before starting any sampling campaign for performance testing/assessment, a flow sheet for that particular unit has to be separately drawn out showing the points of sampling, the number of increments, the amount of sample per increment and then the final gross sample quantity to be collected. The time span has to be also pre-settled.

Sample could be drawn most conveniently from three places in any coal preparation and handling plant :—

i) Chutes
ii) Belts
iii) Discharge points of belt to belt or belt to any other piece of equipment.

Chute and belt sampling is the most economical method and involves least amount of effort but this generally involves large quantities to be drawn to minimise bias in the sample. Bulk sample thus collected after proper quarter and coning at site itself will provide the optimum size of sample which could be easily transported while the rest of sample could be showelled back on to the belt or in to the chute. This involves manual labour and factor of human error in sampling. Discharge point samples are more accurate and could be made automatic with least amount of human effort but the system need, high initial investment cost.

A typical flow sheet Fig. 1 included as Annexure 1 shows the points of sampling as example.

Chute sampling system :

In normal day to day practice of collecting samples for ascertaining efficiency of crushing system, jig, cyclones or any other system, samples are generally collected manually by means of shovels at the discharge lip of screens or from belt when the material has settled on it. This involves extensive human effort at the same time sample collected this way, may not be very repesentative.

A single but effective system of sampling from chutes and discharge of screen has been shown in Figure 2A, 2B & 2C which could be installed easily without much cost involvement. This will reduce human labour to bare minimum of operating the handle at a regular interval as desired and will also eliminate bias to a large extent. One point has to be kept in mind that at belt discharge point this should be provided only where the tonnage per hour handled is less than 100 tph and also the speed of belt is low (0.5 to 1 mps).

Belt sampling :

Belt sampling is the best as the greatest amount of information can be obtained with least effort. This could be performed two ways. In one case, belt has to be stopped to collect the sample while in other system which is mechanical can collect samples from running belt. Second type has not been very popular in

India but is used in bulk handling/loading systems abroad. Common types are shown in Figure 3C & 3D. Generally the belt samples are large enough to facilitate screen analysis, bulk density measurement, belt capacity measurement or any other desired information. After the belt has been stopped, a measured sample is cut off the belt by one of the two means as shown in Figure 3A & 3B. Sample divider as shown in Figure 3A is fixed frame on the conveyor structure while 3B is made of wood. This is portable and could be used on any belt as desired. This frame is pressed onto material till it touches the bottom. The adjoining material outside the frame is cleared off after which frame is removed from place and remaining material inside the frame is the sample which is removed manually.

The following points should be considered while collecting belt samples :

i) Sample should be taken only when belt is running at full speed.

ii) Sample should be drawn at a minimum distance of $1\frac{1}{2}$ times the coasting distance from the point of loading on the conveyor.

iii) If material is deposited uniformly on the belt, a small length will serve the purpose but if it is in surges, then minimum of two surge peaks should be in sample length.

iv) Belt speed is also to be considered. For lower belt speeds the sample length considered should be less as the material depth is more while on high speed it should be more to get the same quantity of sample.

v) Sample plate divider distance as shown in Figure 3A and 3B should be minimum of 3 times the largest lump in the lot.

Discharge Point Sampling :

Most reliable samples are collected from the dischage point of conveyor belts. These samples can be collected through a manually operated sampling machine or could be made fully automatic as per the pre-set programme. Various types and versions are available in the market from which a most suited one could be picked up. Following general rules must be observed while selecting the sampler :

a) With each sample cut a complete cross section of the stream must be removed by a cutter that has parallel edge.

b) Ideally, the stream should be cut when it is in fully developed free fall.

c) Collector should not overfill and allow material to be lost, even at peak flow rate. No particle should be able to escape by rebound or recochet.

d) Cutter speed, which should be constant through the stream is determined by the size of aperture and the falling rate of the material to ensure that there is no bias against large particles. As per ASTM maximum recommended cutter speed is 18 inches per second but in very high tonnage it has been observed that a speed do 0.8 mps also does not offset the results.

e) No spillage, splatter and/or fine dust should be able to enter the sampler while it is in 'Dwell' or stationary position.

f) Cutter should be arranged and designed in such a way to produce minimum disruption to flow stream.

g) It is recommended to have cutter opening between 2.5 to 4.5 times the largest lump size a factor of 3 has been found satisfactory. But for every fine size this rule may not hold good and a minimum of 10 mm opening is recommended for fines to be sampled.

It has been found that the sample weight per cut can be calculated by formula given below :

$$M = \frac{QS}{V \times 3600} \text{ (Kg.)}$$

Where M = Sample weight from one sampler collector pass

Q = Flow rate tonne/hour.

S = Slit width of sample collector in mm

V = Traversing speed of sample collector in M/Sec.

Knowing this and the lot size, number of passes i.e. frequency of cut can well be computed and cutter could be programmed to collect samples accordingly. This cycle time could easily be varied between 30 seconds to 30 minutes.

A belt scale installed on the conveyor could be used more effectively to give alert signal to the primary sampler but will not operate the sampler untill the main flow has been started and reaches a minimum of belt capacity. This belt weigher could also be used to give signal after a present amount of material has passed over the belt which will actuate the sampler to make a cut/pass. This way the sampling system could be made fully automatic specially in case of high speed loading system. Some common type of primary samplers are shown in Figure 4A, B, C and D.

Selection of sampling system for CHP'S

Collecting samples from chutes and belts as discussed earlier is the most economical means requiring very little in capital investment but a fairly good amount of manual labour and is most suited for the existing and low capacity plants. But with increasing trend towards high capacity plants with computerization in view the automatic samplers are the best suited for the job.

Requirements of a good sampling system are given below :

a) Compact Construction

b) Low wear and tear

c) High machine safety

d) Ease of cleaning

e) Low capital cost

f) Low maintenance cost

g) Low attrition or influence on the particle size and quality of material being sampled.

Installation of a free fall sampling system necessitates some additional elevation to provide for a free fall and to accomodate a sampler. This elevation requires an additional capital expenditure for structural components as well as continuous operating expenditure due to added horse power to drive the conveyor. Attention to these needs during the first stage of plant layout is always advantageous. In addition, placing sample collection point close to preparation room and laboratory both improves efficiency and reduces cost.

As the physical properties i.e. size analysis, moisture content of raw feed and products have to be measured from samples before they are crushed for ash analysis, a complete sampling system including sample feeder, secondary sampler, crusher, and then tertiary sampler are not required to be installed at site. But in case of large capacity plants where large tonnages are handled, secondary sampler may be desired to be introduced for reducing the amount of sample which has to be handled and carried to test laboratory for final sample preparation.

As analysis in most of the cases is done in laboratories involving sophisticated analytical instruments hence it is desired to have secondary sampling crushing and tertiary sampling and final sample preparation by quartering and coning to be done at laboratory. Complete sampling system for units with on-stream analyser has not been included in this paper as it calls for a full discussion/elaboration.

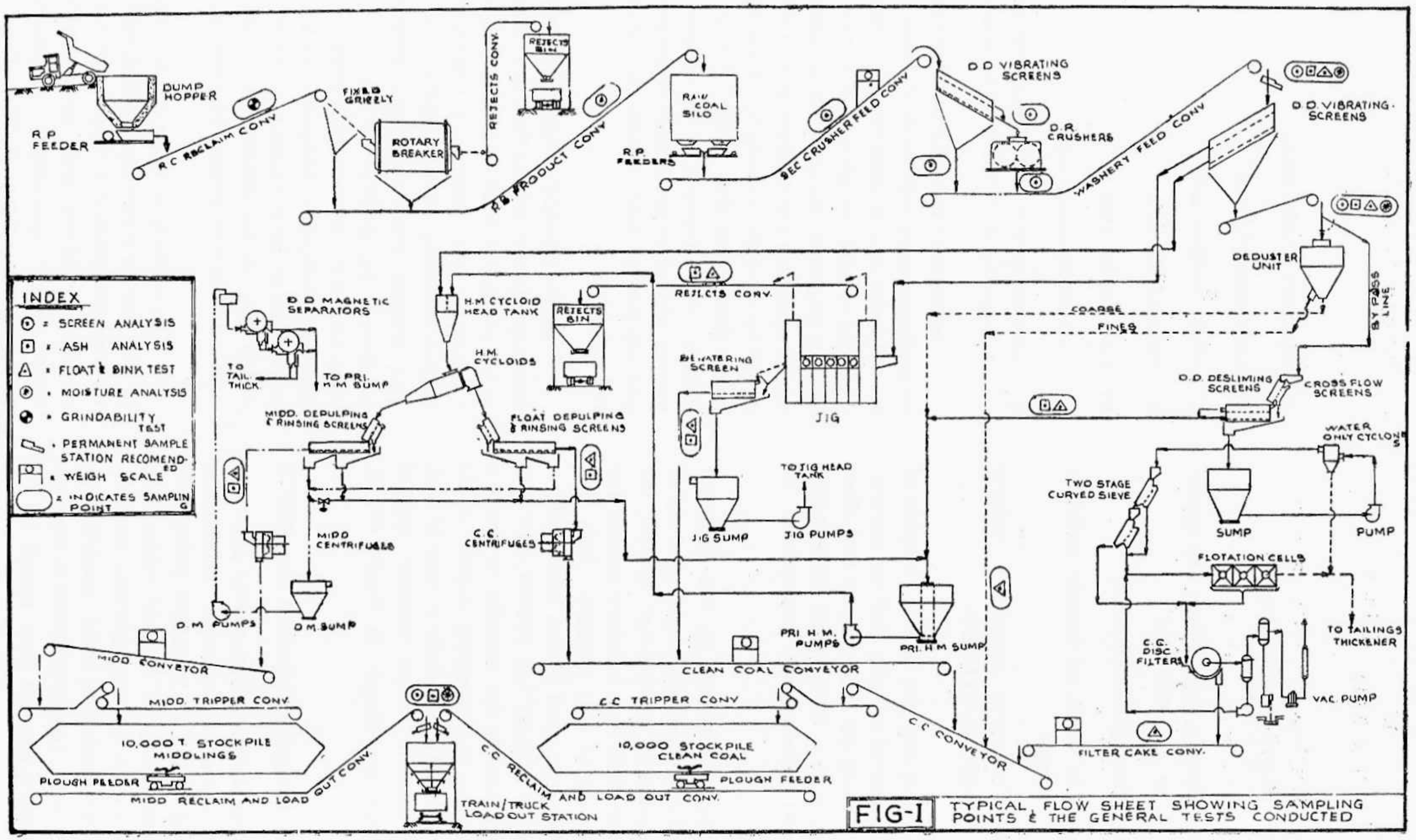


FIG-1 TYPICAL FLOW SHEET SHOWING SAMPLING POINTS & THE GENERAL TESTS CONDUCTED

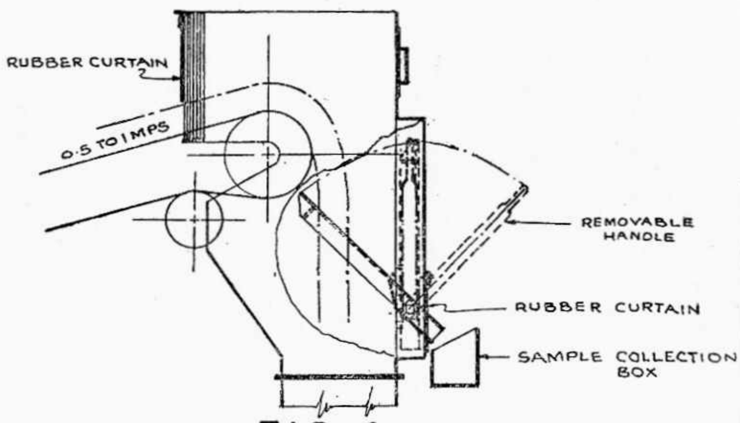


FIG-2A

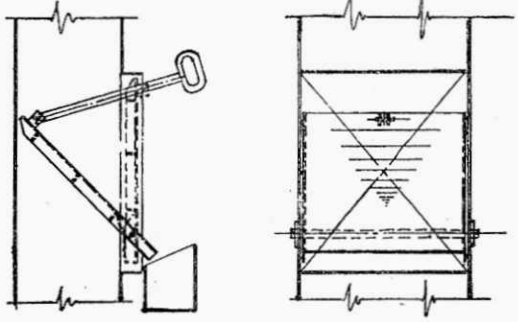


FIG-2B

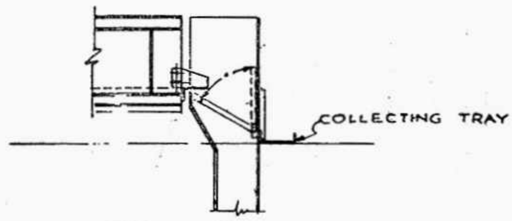
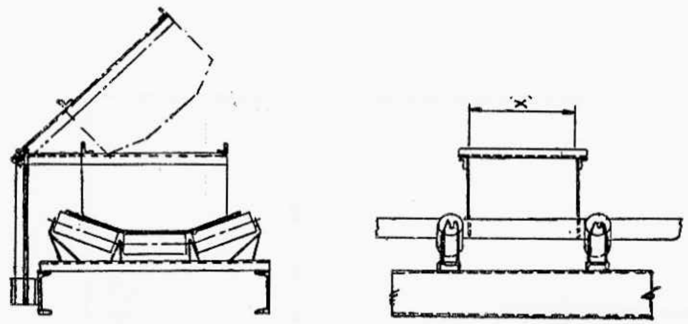


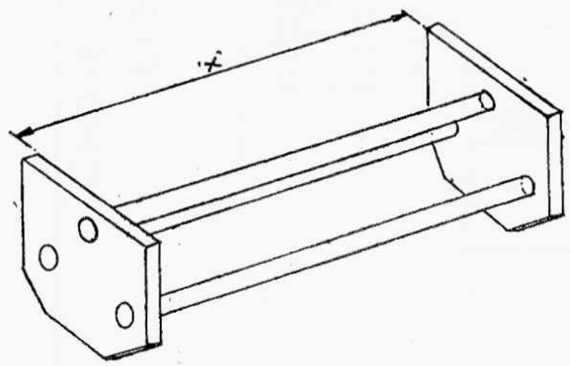
FIG-2C

CHUTE SAMPLING



FIXED TYPE SAMPLE DEVIDER

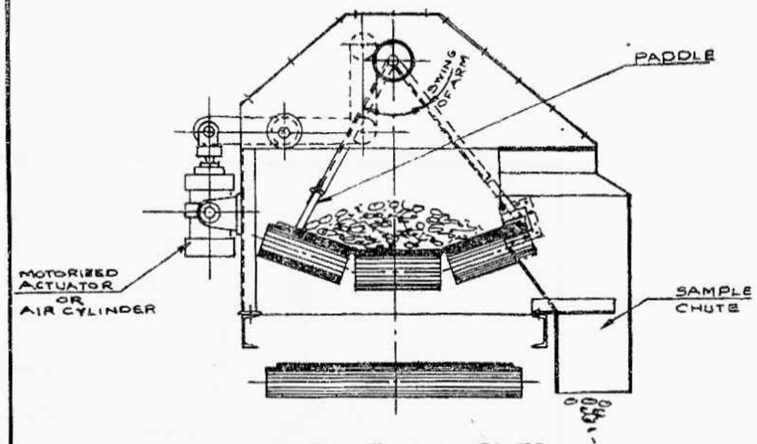
FIG-3A



PORTABLE TYPE SAMPLE DEVIDER

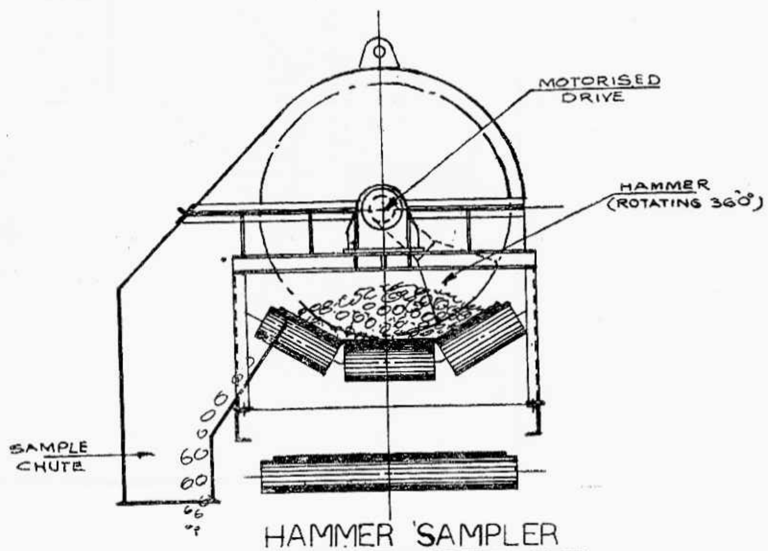
FIG-3B

NOTE - 'X' SHOULD NOT BE LESS THAN THREE TIMES LARGEST LUMP SIZE



PADDLE SAMPLER

FIG-3C



HAMMER SAMPLER

FIG-3D

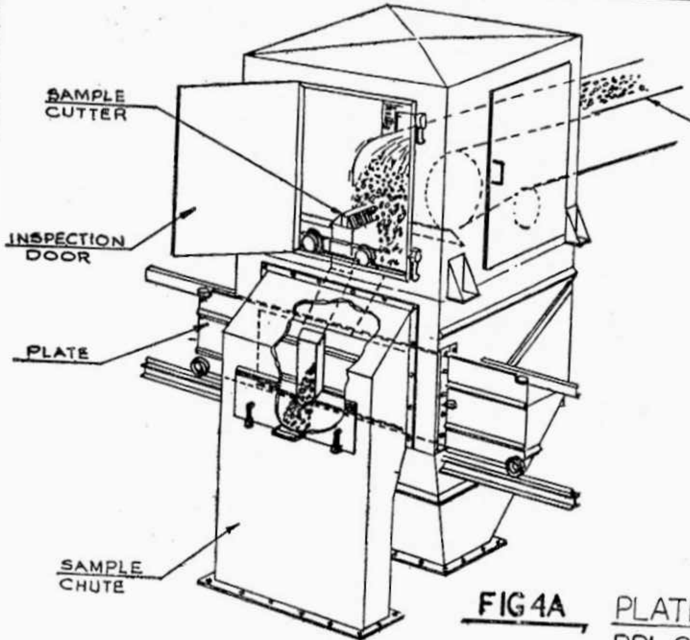


FIG 4A PLATE TYPE PRI. SAMPLER

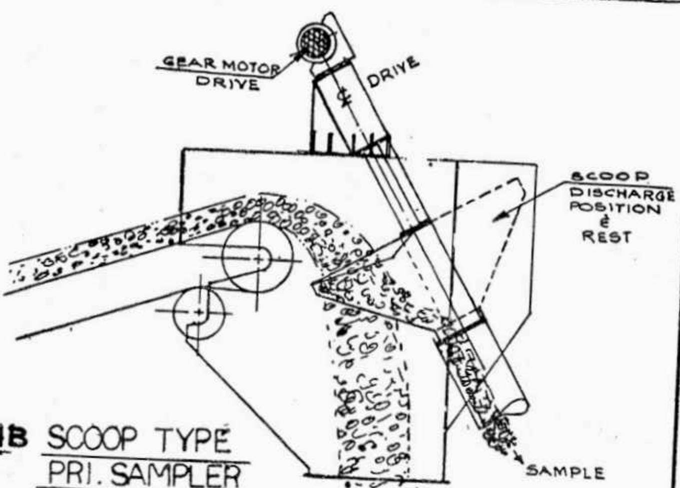
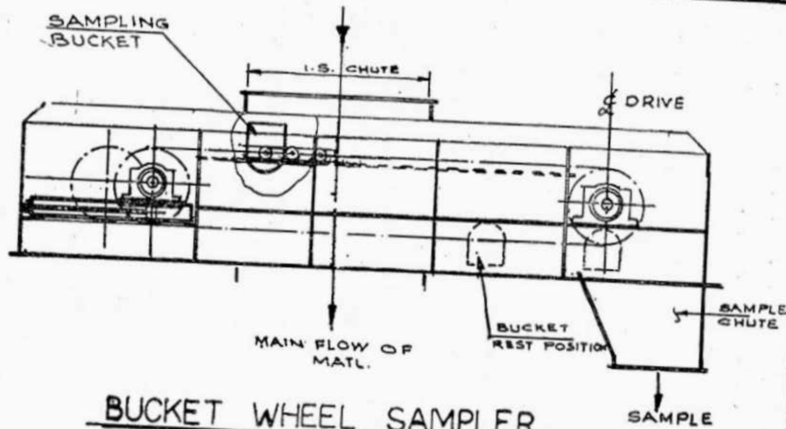
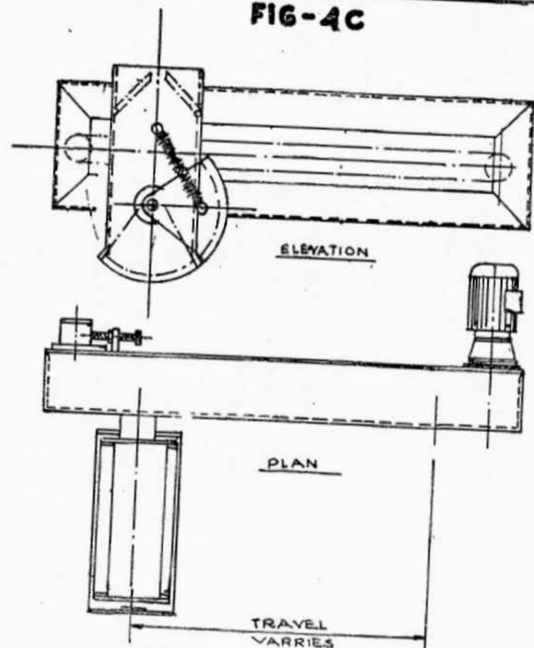


FIG 4B SCOOP TYPE PRI. SAMPLER



BUCKET WHEEL SAMPLER

FIG-4C



SPOON SAMPLER

FIG-4D

Conclusion :

At the end of this subject we would like to mention once again that as there is a limit to amount of money that can be spent for sampling/ sampling equipment just as there are limitations on the amount of analysis equipment that can be afforded. But a better balance between the two is necessary. In selecting sampling system equipment, ample consideration should be given to initial cost, projected maintenance expense and the amount of operator time while producing more reliable and representative sample. It has been seen that the total cost of a sampling system in a coal handling and washing plant is very low in comparision to the overall cost of the plant (less than 1% is either not included in the system and if included is put out of commission for various reasons which could be easily over-come. The most economical and effective sampling system has to be a balance between manual/automatic sampling depending on the size and level of automation/computerization envisaged during the plant design stage itself. Automatic samplers although slightly higher in initial cost can save many hours of costly operator-time while producing reliable and representative sample. In most cases investment in sampling system will still be a fraction of what is expended on the analysis, but the analysis can only be as reliable as the sample delivered to the laboratory.

Acknowledgement :

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DISCUSSION :

D. Basu, CEMPDIL. Ranchi

Question 1 : This is not certainly a question but a suggestion. The undersigned, as a member of PCDC 7 of ISI, who have been formulating the various Indian Standards for coal also including its sampling mode will suggest sending a copy of MBE's proposal to Sri Anjan Kar, Deputy Director, ISI. New Delhi which may be of help for the revision exercise now is on for the prevalent ISI standard.

Author : We have taken note of your valuable suggestion and would be forwarding a copy of the paper on to the address given soon.

S. M. M. Safvi, Tisco, Jamadoba.

Question 2 : What is maximum size and increment of coal samples can collect. ?

Author : Maximum size of coal which could be easily sampled by a primary sampler is 300 mm maximum manufactured by McNally Bharat. As regards increment and gross samples are concerned they have to be governed by I.S. code in principle.

Question 3 : Mechainsm of operation. Say traversing or bucket type ?

Author : Mechanism of operation of samplers i. e. type of drive system used in samplers has not been covered in this paper and being a very wide subject has to be covered separately.

Dr. S. Pattnaik, NINL, Bhubaneswar.

Question 4 : Have you made any attempt to optimize the coal sampling for quality control purpose ?

Author : As regards Number of increment and gross sample to be collected is concerned, I. S. codes IS : 436 and 6345 have covered it in a very elaborate manner. Same could also be computed by the formulae given in the text of this paper.