DRY DESHALING OF THERMAL COALS IN INDIA

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ABSTRACT

Beneficiation of thermal coal in India is a relatively new development. For the year 2006, India produced 380 million metric tons of thermal coal, of which only 17 million metric tons were beneficiated coals. One potentially attractive method for upgrading India's coal feed stocks is the air table dry deshaling technology. Dry deshaling offers significant advantages over wet cleaning operations, including reduced surface moisture, enhanced heating value, elimination of processing water and waste slurries, and reduced transportation of large amounts of ash-forming minerals. To evaluate this potential, a pilot-scale air table deshaling unit was tested at three locations in India for the specific purpose of upgrading thermal coals. The field testing confirmed that the separation performance for Indian coals is similar to that which has been achieved at sites in the United States for material in the 50 x 6 mm size range. The data indicate that material with 80% ash and higher can be rejected by the dry deshaler unit with a combustible recovery of more than 90%.

Furthermore, a discreet elemental model was developed using PFC^{3D} to understand the process of segregation on a dry density based vibratory table. Analysis was done to show the effect of different forces on the process efficiency. Also, operating parameters and particle properties such as frequency of vibrations, amplitude of velocity, bed depth, particle size and specific gravity were analyzed in the model. The model results were compared with field testing results of dry deshaling air table and All-Air Jig separator.

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CHAPTER 1 GENERAL INTRODUCTION

1.1 PREAMBLE

Despite the global economic slowdown, India still represents one of the fastest growing economies of the world. This growth rate is underpinned by rapidly increasing demand for energy. Coal has long been considered as the most viable answer to India's burgeoning energy demand. India is the third largest coal producer in the world with production of 512.3 (Ministry of Coal, 2009-10) million metric tons. Coal production is expected to reach 1 billion metric tons by 2020 (Figure 1.1). However, coal has failed to live up to its promise. Although domestic production has increased rapidly over the last few years, demand continues to outstrip domestic supply. The power sector, the largest coal consumer in India (almost 70% of total), continues to report generation losses from coal shortages. As such, India's mining operations are under tremendous pressure to increase the domestic production.

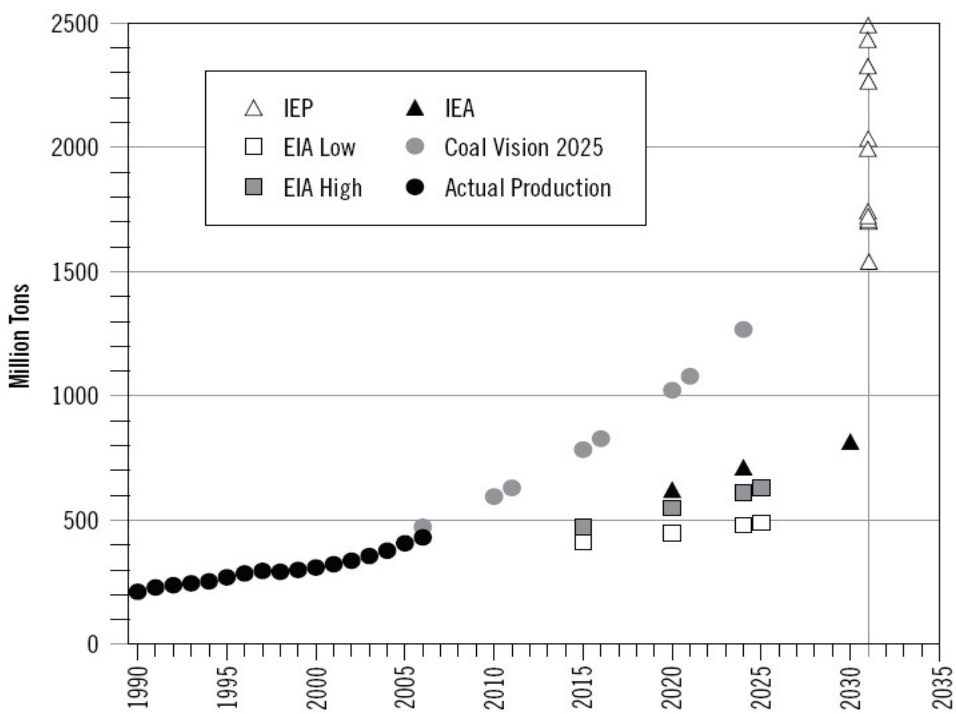


Figure 1.1 Projected future trends in coal production in India (Chikkatur, 2008).

According to the World Energy Outlook 2006, non-Organization of Economic Cooperation and Development (OECD) countries will consume 6.4 billion metric tons of coal in 2030, an increase of 3.7 billion tons over the reference case of 2003. The increased coal use will generate 13.6 billion tons of CO_2, over and above what is being released to the atmosphere today by non-OECD countries. This increment will be twice the amount of the CO_2 generated in North America in 2003 (6.8 billion metric tons).

The Asia Pacific Partnership (APP) on Clean Development and Climate was formed to address this issue, and its approach is to help the developing countries in the region to adopt clean energy technologies and thereby minimize the greenhouse gas (GHG) emissions. This is consistent with the 1997 Kyoto Protocol, which mandates international cooperation to encourage worldwide implementation of GHG abatement technologies. In general, net efficiencies of coal use in non-OECD countries are considerably lower than in developed countries. Therefore, transfer of clean coal (CC) technologies and diffusion of expertise is the key to enable non-OECD countries to reduce GHG emissions from coal combustion.

1.1.1 Need for Dry Processing

Several International Energy Agency (IEA) publications have suggested that increasing the availability of high quality coals in India is an essential step toward the deployment of state-of-the-art clean coal technologies. Unfortunately, Indian coals are poor quality with high ash content and are difficult to clean, due to the ash-forming minerals being finely disseminated in the coal matrices. Much of the coals burned for power generation are raw coals containing 35-50% ash. However, these power plants were designed originally to handle 25-35% ash coal, thus resulting in problems such as low thermal efficiencies, high operating and maintenance costs, erosion, difficulty in pulverization, low radiative transfer, excessive amount of fly ash containing large amounts of unburned carbons, etc. Further, transportation of high-ash coals is energy intensive, which causes shortages of rail cars and trucks.

The washing of thermal coal in India is typically carried out to target less than 34% ash. In 2001, the Ministry of Environment and Forest (MEF) promulgated new regulations mandating coals must be cleaned to less than 34% ash content if transported more than 1,000 km from pit-heads, or if burned in urban areas, environmentally sensitive or critically polluted areas irrespective of their distance from the pit-head (CPCB, 1997). The coals consumed at the pithead and within a rail distance of 1000 km can be burned without washing.

Another potential problem in applying coal cleaning technologies is that conventional processes rely on the use of water as the separating medium. Because wet cleaning adds water to product coal in the form of surface moisture, only the coarse size fractions are cleaned and the un-cleaned fine coal is added back to the cleaned coarse coal. Part of the moisture is drained off during transportation, particularly when the coal is transported over a long distance greater than thousand kilo-meters. On the other hand, the moisture content remains high when the shipping distance is less than 700-800 km. Therefore, the wet-cleaning process is difficult to justify for pithead plants. Further, water is a scarce resource in most of the coal mining regions of India.

It is widely accepted that washing would dramatically improve the calorific value of a coal, its size-consist, and other qualities. The beneficiated coal can reduce erosion rates by 50-60% and maintenance costs by 35% (Couch, 2002). More importantly, use of beneficiated coals can increase thermal efficiencies by 2-3% on existing pulverized coal (PC) boilers, and possibly as much as 4-5%. A change in efficiency from 28 to 33%, for example, can reduce CO_2 emissions by up to 15%. According to Couch (2002), India could reduce CO_2 emissions to nearly 45% of its present level by using state-of-the-art technologies related to coal quality, boiler/generator design, instrumentation and control, and high voltage distribution systems. On the other hand, the ever increasing emphasis on electrification of rural and urban slum areas with diminishing government subsidies makes it difficult to justify the additional costs of installing traditional coal cleaning plants in India. In India, electricity is generated by state-owned companies, and the costs of power generation at the plants operated by State Electricity Boards (SEB) are 2 to 4 times higher than those of the best Indian practice, e.g., at National Thermal Power Corporation (NTPC), also a state-owned company. Thus, in India, building conventional coal cleaning plants is a synonym of additional costs to the already high costs of electricity generation. Thus, there is a dire need to develop (or introduce) non-conventional and low-cost coal cleaning technologies for the Indian coal and power industry.

Dry coal processing can be an effective techno-economical tool for the Indian coal industry. Large quantities of rock are being extracted in order to recover the coal, reportedly resulting in 60-70% of the raw material being rejected as waste. The haulage, processing, and combustion of rock represent a significant waste of energy and have a negative environmental impact (Biswal et al., 2002). The process of removing unwanted rock from ROM coal is referred to as deshaling, which normally involves a high-density separation in a gravity-based process. In contrast to coal cleaning in traditional preparation plants, the separation density in dry deshaling is higher, with a typical target of 2.0 relative density or greater (Honaker et al., 2008). Normally, the most cost-effective approach is to place the deshaling unit as close to the extraction face as possible to reduce transportation and maintenance costs. The dry process also eliminates the use of water for beneficiation.

In light of the potential advantages of dry coal beneficiation, an engineering development project was undertaken to evaluate the potential of dry coal deshaling technology for industrial sites in India. The project was selected by the Asia-Pacific Partnership on Clean Development and Climate (Coal Mining Task Force) under the sponsorship of the U.S. Department of State. Previous work conducted in the U.S. had indicated that the technology could, in particular, efficiently reject undesirable high-ash rock from run-of-mine (ROM) coals in both eastern and western coalfields located in the United States. For the case of Indian coals, this previous work suggested that this low-cost approach to coal quality improvement could:

- Produce lower ash products that can be burned more cleanly and with greater efficiencies.
- Reduce the amounts of fly ash emission and associated hazardous air pollutant precursors.
- Minimize capital, operating and maintenance costs associated with coal beneficiation.
- Reduce the shipping costs and help Indian railway system to ship high calorific value coal to power plants.
- Avoid potential environmental issues concerning slurry impoundments.
- Accommodate coal beneficiation plants in areas where water is not readily available.

Recent studies conducted by Bhattacharya and Maitra (2007) indicate that the dry cleaning of coal in India holds tremendous promise, provided that the total beneficiation costs could be kept below US$1.00-1.50 per ton. Recent studies conducted in the U.S. suggest that the cost of implementing such technology is well below this limit (Honaker and Luttrell, 2007). Increasing the availability of higher-quality coals via removing relatively pure rock from power station feed stocks will help India to increase the net efficiency of coal use, and facilitate implementation of state-of-the-art clean coal technology processes to substantially reduce CO_2 emissions. More importantly, these environmental gains can be realized without financial expenditures, since the application of the deshaling technology can be justified purely on cost benefits resulting from improved boiler efficiencies, reduced coal transportation, and ash handling/disposal requirements.

1.2 PROJECT OBJECTIVE

The primary goal of this engineering project was to develop an effective dry coal deshaling system that can be commercially applied in India for the upgrading of run-of-mine (ROM) coals. To be successful, the system had to be capable of (i) separating rock using a relatively high specific gravity cut-point of around 2.0 RD, (ii) minimizing the amount of valuable carbonaceous material lost with the rejects stream, (iii) operating with lower capital and operating costs than traditional coal cleaning processes,(iv) serving as a mobile cleaning station that can move with the mining operations, and (v) functioning without water to avoid environmental concerns of fine coal slurries and eliminate adverse effects of added moisture on coal transportation and heat value. A promising technology that meets these requirements is the dry deshaling process offered by Eriez Manufacturing for upgrading run-of-mine feed coals. The technology has already found commercial success in the Chinese coal industry (Lu et al., 2003) and in the United States (Honaker and Luttrell, 2007). However, considerable R&D is required prior to implementing this technology for upgrading distinctly different Indian coals, which typically have a greater proportion of middlings and, hence, are more difficult to upgrade. In particular, field testing is required (i) to establish the suitability of the technology for deshaling coals with difficult washabilities, (ii) to define the operational capabilities of the technology in terms of coal recovery and quality for typical Indian coals, and (iii) to determine the economic viability of this approach for the coal markets that currently exist in India.

1.3 ORGANIZATION

This thesis consists of six chapters. The first chapter gives a generic overview to the research. The second chapter provides detailed background information obtained from various literature sources for Indian coal industry, and coal processing techniques in India. The chapter also discusses the air table dry deshaling technology. The third chapter gives the details of on-site pilot-scale test set-up and experimentation in India. The fourth chapter provides the results, conclusions and recommendations of on-site pilot scale testing in India. The fifth chapter discusses the theoretical basis of this research project. Discrete elemental model was developed in order to simulate and study the principles involved in dry density-based separation processes. Finally, the sixth chapter summarizes all the findings of this technology and development project.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

In 2007, the United Nations' Intergovernmental Panel on Climate Change (IPCC) issued the Fourth Assessment Reports (AR4). The report from Working Group I (The Physical Sciences Base) stated that the warming trend, which began since in mid-20th century, is real and is "*very likely*" due to the increase in atmospheric concentrations of the anthropogenic greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and others. Of these, CO_2 accounts for 77% of the greenhouse gases, and is generated largely from burning fossil fuels (IPCC, 2007). The report clearly suggests that there is an urgent need to reduce GHG emissions to a level that can be absorbed by the Earth's system. The atmospheric CO_2 concentration of 379 ppm in 2005 far exceeded the range (180-300 ppm) observed during the last 650,000 years, and the use of fossil fuels was its major source. Working Group III (Mitigation of Climate Change) issued a Summary for Policy Makers, which concluded that the atmospheric GHG concentrations can be stabilized at the range of 445-535 ppm CO_2 equivalent (CO_2e) at a cost less than 3% of the global GDP. The report also suggested that developing appropriate technologies to reduce CO_2 emissions has economic and social benefits that can offset the costs. According to a report released by Sir Nicholas Stern (2007), stabilizing at 450 ppm CO_2 is already out of reach. Delay in taking actions on climate change would imply accepting both more climate changes and higher mitigation costs. Weak actions in the next 10-20 years would put stabilization at 550 ppm CO_2 beyond reach.

The U.S. Congress is continuing to debate the need for addressing this problem by legislation. Moreover, finding ways to engage developing countries, particularly India and China, is a central issue. Although the U.S. is the world's largest GHG emitter, developing countries will soon surpass the U.S. due to their high economic growth rates and large populations. In 2000, the U.S. accounted for 15.56% of the world's CO_2 generation, followed by China (11.89%), EU (11.42%), Brazil (5.37%) and India (4.47%). The top 15 emitters accounted for 80% of the global emissions. Clearly, any U.S. effort to curb CO_2 emissions must engage these major contributors. However, developing countries such as China and India resist to any international negotiations that can obligate them to cut CO_2 emissions significantly, with a fear that it would hurt their economic growth. In the case of India, for example, its reluctance is based on the country's per capita CO_2 emissions (1.8 tons in 2000) and GDP ($2,731 in 2003), which were far below those for the U.S. (i.e., 22.9 tons of CO_2 per person and $35,373 of per capita GDP).

Clearly, it is not possible to coerce these nations into a mandatory agreement. Many energy experts believe that the most viable near-term approach for enticing international cooperation would be to develop sustainable and economical technologies that can help reduce CO_2 emissions without imposing mandatory limits.

2.2 INDIAN COAL INDUSTRY

India has a long history of nearly 235 years of commercial coal mining, starting from 1774 in the Raniganj Coalfield along the western bank of the river Damodar. After a century of sluggish growth, coal production started increasing with the introduction of steam locomotives in 1853. It got a further push with the development of iron and steel industry towards the end of the 19th century, and gradually reached a figure of 30 million metric tons in 1946. After the independence in 1947, India embarked upon five-year development plans. This led to an all around economic growth leading to a gradual increase in coal production.

With the first global energy crisis in the early 1970's, the Government of India made a decision to nationalize private coal mines. In the first phase only coking coal mines were nationalized and, in the second phase in 1973, the non coking coal mines were nationalized. The Coal Mines Authority Ltd. ("CMAL") was set up in 1973 to operate the nationalized non-coking coal mines. In September 1975, the nationalized coal industry was restructured with the establishment of Coal India Limited (CIL). CIL now has eight subsidiary companies. At present, with its monopolistic position, CIL accounts for 85% of coal production, followed by Singareni Coal Company Limited (8.5%), and other captive producers (6.5%).

2.2.1 Coal Resources

India's major workable coal deposits occur in two distinct stratigraphic horizons, i.e., Permian, commonly known as Gondwana coals, and the Tertiary. About 99% of the country's coal resources are found within a great succession of fresh water sediments. These resources are available in sedimentary rocks of older Gondwana formations of peninsular India and younger Tertiary formations of northeastern/northern hilly region of the Himalayas (Ministry of Coal, 2009-10).

The coal resources in India, subdivided by formation and category, as of January 4, 2007, are summarized in Table 2.1. The total coal reserves of the country have been estimated from time to time. The proved reserves are estimated from the dimensions of outcrops, trenches, mine workings and boreholes and a reasonable extension, not exceeding 200 m on geological evidence. Where little or no exploratory work has been done, and the outcrop exceeds one km in length, another line drawn roughly 200 m from outcrop will define a block of coal that may be regarded as proved on the basis of geological evidence.

Table 2.1 Coal resources in India (Million metric tons).

Formation	Proved	Indicated	Inferred	Total
Gondwana Coal	105, 343	123,380	37,414	266,137
Tertiary Coal	477	90	506	1,073
Total	105,820	123,470	37,920	267,210

Table 2.2 Distribution of coal by rank in India (Million metric tons).

Type of Coal	Proved	Indicated	Inferred	Total
Primary Coking	4,614	699	---	5,313
Medium Coking	12,449	12,064	1,880	26,393
Semi-Coking	482	1,003	222	1,707
Sub-total coking	17,545	13,766	2,102	33,413
Non coking	87,798	109,614	35,312	232,724
Tertiary	477	90	506	1,073
Total	105,820	123,470	37,920	267,210

In the case of indicated reserves, the points of observation are 1,000 m apart, but may be 2,000 m for beds of known geological continuity. Thus, a line drawn 1,000 to 2,000 m from an outcrop will demarcate the block of coal to be regarded as indicated. Finally, the inferred reserves refer to coal for which quantitative estimates are based largely on broad knowledge of the geological character of the bed, but for which there are no direct measurements. The estimates are based on an assumed continuity for which there is geological evidence, and more than 1,000 to 2,000 m from the outcrop.

Coals of practically all ranks occur in India except peat and anthracite. The share of lignite, however, is insignificant as compared to sub-bituminous and bituminous coal. Indian bituminous coals are broadly divided into two categories, coking and non-coking. Table 2.2 provides a breakout of the various ranks of coal found in India.

Nevertheless, there are several problems with the Indian coal resource assessments. Detailed drilling and analysis of coal resources seems to be more dependent on the coal industry's views on extraction, rather than on independent assessments of total coal resources, including those at deeper depths (Ministry of Coal, 2006b). For example, Chand (2005) has noted that most of the recent drillings have been limited to 300 m (62% of the explored coal resources is located within 300 m depth), which is the depth accessible through surface (opencast) mining. The coal inventory includes reserves that are already depleted due to mining and resources that cannot be mined due to mining, surface, and geotechnical constraints, as well as resources that cannot be mined using current technology (Ministry of Coal, 2006b). The classification of resources according to borehole density does not take into account geological complexities and coal seam heterogeneities. In many cases, drilling does not even extend to the basement of coal basins, but is limited to arbitrary depths (Ministry of Coal, 2006b).

Another problem in addressing coal resources stems from confusion related to technical terms such as "resources" and "reserves". These two terms are often misused, with geological resources being treated as "reserves" (Chand, 2005). The Indian classification system is primarily based on geological evaluations without assessing the quality, mineability, or extractability of deposits. In contrast, the United Nations Framework Classification denotes reserves as part of the remaining resources that are economically mineable, technically extractable, and geologically proven (UNFC, 2010). Therefore, there is considerable uncertainty as to the exact amount of remaining coal reserves in India.

Depending on the rate of domestic coal production and use, the current Indian coal reserves might last anywhere from 30 to 60 years (Ministry of Coal, 2006b). Without improvements in coal technology and economics, the existing power plants and the new plants added in the next 10 to 15 years might consume most of the currently estimated extractable coal in the country over the course of their 40 to 50 year life spans. The relatively short lifetime projected for India's coal reserves is in sharp contrast to the general assumption that Indian coal will last more than 200 years—an assumption predicated on extracting all of the resources without accounting for technology or economics (Chikkatur, 2005). The amount of coal reserves, and their lifetime, can be increased through more extensive geological surveys, large technological and financial investments in the coal sector, reduced demand for domestic coal, and higher costs for consumers (especially power plants).

Better energy planning and policies require a good understanding of domestic coal reserves, therefore it is important to reduce existing uncertainties about Indian coal by making better reserve assessments. It is likely that much of the uncertainty will be reduced when the current coal resource inventory is reclassified according to the UNFC categories. Furthermore, uncertainty about domestic coal resources will impact India's long term energy supply trajectory, which in turn has significant implications for India's GHG emissions.

2.2.2 Coal Quality and Prices

Coal Quality

The quality of Indian coal is poor and has gotten worse over the past decades. Indian coal has the general properties of the Southern Hemisphere Gondwana coal, whose seams are inter-banded with mineral sediments. Run-of-mine coals typically have high ash content (ranging from 40–50%), high moisture content (4–20%), low sulfur content (0.2–0.7%), and low calorific values (between 2500–5000 kcal/kg) (IEA, 2002). Coals from the U.S. and China have about twice the calorific value and carbon content of Indian coals. The low calorific value implies more coal usage to deliver the same amount of electricity. Indian coal, however, has lower sulfur content in comparison to other coals, although it has relatively high amounts of toxic trace elements, especially mercury (Masto et al., 2007).

Ash is generally well intermixed into the coal structure and hence coal washing using physical methods is difficult, although it might be necessary for industrial use. The high ash content also leads to technical difficulties for utilizing the coal, as well as lower efficiency and higher costs for power plants. Some specific problems with high ash content include high ash disposal requirements, corrosion of boiler walls, fouling of economizers, and high fly ash emissions (IEA, 2002). The high silica and alumina content in Indian coal ash is another problem, as it increases ash resistivity, which reduces the collection efficiency of electrostatic precipitators and increases emissions.

The ash content in Indian coals has been increasing over the past three decades, primarily because of increased surface (opencast) mining and production from inherently inferior grades of coal (Ministry of Coal, 2006b). Current practices have limited coal resource assessments to within 300m, which implies that opencast mining is expected to dominate production over the next 20 to 30 years; thus, coal quality might not improve much without additional washing and beneficiation. Furthermore, the current grading system of coals in India does not provide a proper pricing signal for coal producers to improve coal quality. Nevertheless, there is already some washing of power plant-grade coal in India as power plants aim to meet the environmental regulations on coal-ash content. As stated earlier, the regulations require that power plants must use coal with less than 34% ash if they are located more than 1000 km from the mine-sites or are located in critically polluted areas, urban areas, and ecologically sensitive areas (CPCB, 1997).

Coal Production Cost

The average cost of coal production in India has steadily increased since the 1970s, despite increases in productivity. The productivity of opencast mining in CIL from 1975 to 2009 has gone up from 0.9 to 10.1 tons per man-shift, with the percentage of production from opencast mining increasing from about 25% to 83% in the same period. Although the production cost of opencast mining is about 3 to 4 times cheaper than underground mining, the high cost of production in underground mines has led to higher average production costs. For example, in 1993–94, the cost of underground mining in CIL was about Rs. 710/ton (US $22.5/ton), in contrast to Rs. 240/ton (US $7.6/ton) for opencast mining (CMIE, 1995).

In 2000, a new Colliery Order was passed deregulating the price of all grades of coal (grading system is discussed in the next section). The Ministry of Coal no longer sets the price of coal. Rather, each coal company is allowed to set its own sale price based on prevailing market prices. Nonetheless, the prices fixed by the coal companies still are perceived to be "guided" by the government (Ministry of Coal, 2006b). One issue is that coal consumers do not directly participate in price setting, nor are there any negotiations between consumers and producers (Ministry of Coal, 2007b). Furthermore, there is very little price elasticity for coal (i.e., coal is always in demand regardless of its price) especially since the electricity sector consumes nearly 75% of domestic coal and electricity is in constant demand, even at high prices. Hence, resolving price issues has been a key reason for the push towards having an independent regulatory agency for the coal sector.

The cost of transportation is also a significant part of the final cost of delivered coal to consumers. For example, the cost of coal for power plants in 2005 was estimated to be under US $20/ton (US $5/million kilocalories), including royalty and tax; however, the cost of delivered coal is about US $48 to US $64 per ton, as freight and handling add about US $28 to US $44/ton, depending on distance and mode of transport. Important modes of transport of coal in CIL are railways (56%), road (17%), merry-go-round systems (23%), conveyor belts and the multi modal rail-cum-sea route (CIL, 2008-09).

2.2.3 Coal Grading System

India uses a coal grading system to designate the quality of different mined and washed coals. The gradation of non-coking coal is based on Useful Heat Value (UHV). In the case of coking coal the gradation is based on ash content, and for semi coking / weakly coking coal it is based on ash plus moisture content. In the early sixties, when the high ash content in the domestic coal was considered a deterrent to its gainful utilization particularly in power station boilers, the concept of UHV was introduced. The purpose behind this concept was to promote and popularize the use of coal with high ash content in power plant boilers. UHV differs from the Gross Calorific Value (GCV) by a factor that can be termed as “ash penalty”. Refer to Table 2.3.

For pricing purposes, the thermal coals are graded from 'A' to 'G' based on their ash and moisture content. The government is considering switching over to a gross calorific value based on the grading system of thermal coals because in the present scenario, over 80% of the coal produced is mined from mechanized open pit mines, multiplicity of supply sources, and power plants that are receiving coals of high ash content with inconsistent quality and size distribution causing operational problems.

Table 2.3 Grading of thermal coals in India based on Useful Heat Value.

Grade	Useful Heat Value (Kcal/kg)*	Total Ash Plus Moisture (%)**	Gross Calorific Value (Kcal/kg)***
A	>6200	< 19.5	>6454
B	6200-5600	19.6-23.8	6454-6049
C	5600-4940	23.9-28.6	6049-5597
D	4940-4200	28.7-34.0	5597-5089
E	4200-3360	34.1-40.0	5089-4324
F	3360-2400	40.1-47.0	4324-3865
G	2400-1300	47.1-55.0	3865-3113

Useful Heat Value (UHV) = 8900 - 138 x (Ash+Moisture)
**Percentage ash plus moisture determined at 60% relative humidity and 40^{o}C.*
***Gross Calorific Value (GCV) determined at 5% moisture.*

2.2.4 Major Coalfields in India

The major coalfields in India are represented by isolated basins that occur along prominent river valleys. As such, Indian coal regions are divided into ten "hard coal" sectors and one "soft coal" lignite sector. A map of the major coal producing regions is provided in Figure 2.1. These regions are described in greater detail in the following sections (Ministry of Coal, 2009-10).

Makum Coalfields

The Makum coalfields are situated in the northeastern region of India. They comprise the Assam, Meghalaya, Nagaland, and Arunachal Pradesh. Most of the field has tertiary coal, rich in phosphorous and sulfur and high in moisture content. Four coalfields located in the northern hilly region of Jammu and Kashmir have the same type of coal, but are not part of this coalfield. They cannot be used for metallurgical processes, but are good for conversion fuels. The major player in this region is North-Eastern Coalfields Limited (a subsidiary of CIL), which had a production of 1.10 million metric tons in 2007-08. Coals from this region are characterized by moisture contents of 1.3-3.1%, ash content of 10.3-13.7%, and volatile matter content of 40.1-42.1%.

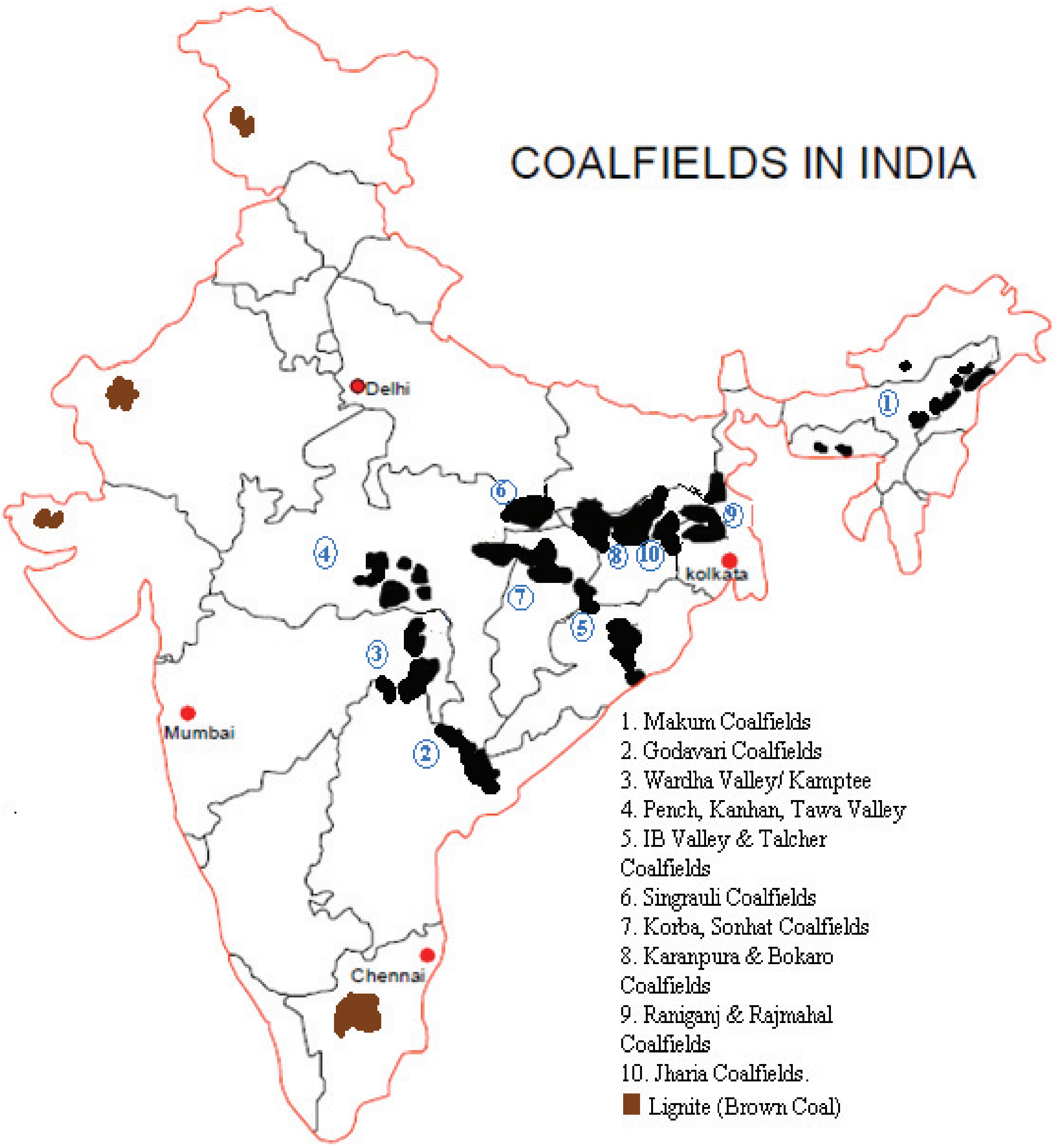


Figure 2.1 Coalfields in India.

Godavari Coalfields

The Godavari coalfields are located in Andhra Pradesh. The major player in this region is Singareni Collieries Company, Ltd., a government undertaking. The total production was 37.71 million metric tons in 2006-07, while the total estimated reserve was 9.16 billion metric tons as of March 2009. Coal mined in this region is entirely non-coking and available in grades from B to G.

Wardha Valley and Kamptee Coalfields

The Wardha Valley and Kamptee coalfields are located in Maharashtra, mainly in the Nagpur and Wardha regions. Western Coalfields (CIL) annual production in the region was 43.51 million metric tons in 2007-08. Coals from this basin are non-coking coal with grade B to F.

Pench Kanhan Tawa valley/Pathkhera Coalfields

The Pench Kanhan Tawa Valley/Pathkhera coalfields are located in the central part of Madhya Pradesh. This area is also part of Western Coalfields, Ltd. The region provides non-coking coal with most grades varying from E and F.

Talcher and IB Valley Coalfields

The Talcher and IB Valley coalfields are located in Orissa and some parts of Chhattisgarh. Mahanadi Coalfields, Ltd. (CIL) produced 88.0 million metric tons of coal from this basin in 2007-08. Other major producers in this region include Jindal Power and Steel, Ltd., Sainik-Aryan Group, and Global Coal Mining, Ltd. The coals generated from this region are non-coking with available grades from B to F.

Singrauli Coalfields

The Singrauli coalfields are located in the eastern part of Madhya Pradesh and some regions in Uttar Pradesh. The basin is one of the major coal producing regions in India. The Northern Coalfields (a subsidiary of CIL) is the major producer in the region, with an annual production of 59.6 million metric tons in 2007-08. The coals from this region are largely non-coking with grades varying from D to G.

Korba-Raigarh, Sohagpur and Sonhat-Bshrampur Coalfields

The Korba-Raigarh, Sohagpur and Sonhat-Bshrampur coalfields are located primarily in Chhattisgarh (87%) and some parts of Madhya Pradesh. South Eastern Coalfields, Ltd. (CIL) produced 93.8 million metric tons of coal from this region in 2007-08. Most of the coal from this region is non-coking with grades varying from A to E. A trace amount of semi-coking coal (approximately 0.16 million metric tons) is also present in this region with a grade of SCG-1.

Karanpura and Bokaro Coalfields

The Karanpura and Bakaro coalfields are mostly located in the region of northern Jharkhand, which is one of the major coal producing regions in India. Central Coalfields, Ltd. (CIL) production in this region was 44.2 million metric tons in 2007-08. The region has both non-coking coal as well as medium-coking coal (around 53% of total production). The rest of the production from this basin is high-grade non-coking coal. Tata Steel is the major coal producer in the Bokaro region with about 4 million metric tons of washed annual coal production that is used for making coke.

Raniganj and Rajmahal Groups Coalfields

The Raniganj and Rajmahal groups of coalfields are located in West Bengal. The region contains primarily high-grade non-coking coal as well as minor amounts (a few percent) of semi-coking coal. Eastern Coalfields, Ltd. (CIL) is the major producer in this region with an annual production of 24.1 million metric tons.

Jharia Coalfields

The Jharia coalfields are located in Dhanbad (Jharia) in Jharkhand. This coalfield is the only source of prime coking coal in India. As such, production from the region includes mostly prime- coking and medium-coking coals. This region accounts for 45% of the total coking coal produced in India. Bharat Coking Coal, Ltd. (CIL) produced 25.2 million metric tons of coal from this region in 2007-08. Tata Steel (TISCO) is the other major coking coal producer in this region.

Lignite Resources

India has significant resources of soft coal (brown coal) as lignite. The total lignite resource is estimated at about 3,500 million metric tons, of which about 2,800 million metric tons are located in Tamilnadu. The remaining lignite deposits are found in Gujrat, Jammu and Kashmir, Pondicherry and Rajasthan. The production in 2006-07 was approximately 31.3 million tons. Major companies working in the lignite deposits include Nevyeli Lignite Corporation and Gujrat Mineral Development Corporation.

2.2.5 Coal Production

Coal mining in India is dominated by opencast extraction and has grown at a 4% average annual rate over the past decade. Through sustained investment programs and greater thrust on application of modern technologies, it has been possible to raise the production of coal from a level of about 70 million metric tons at the time of nationalization of coal mines in the early 1970's to 512.3 million metric tons in 2009-10. Coal India Limited and its subsidiaries are the major producers of coal. 437.4 million metric tons of coal were produced by Coal India Limited and its subsidiaries during 2009-10 as compare to the production of 403.7 million metric tons in the year 2008-09, showing a growth of 8.3%. Singareni Collieries Company Limited (SCCL) is the main supplier of coal for the Southern India region. The company produced 44.54 million metric tons of coal during 2009-10 whereas, the production was 40.604 million metric tons in the year of 2008-09 (Ministry of Coal, 2008-09; 2009-10). Small quantities of coal are also produced by Tata Steel (TISCO), Steel Authority of India Limited (SAIL), Damodar Valley Corporation (DVC) and others. In addition, coal production has been dominated by non-coking coal, as coking coal reserves in the country are quite limited. The increased production of non-coking coal is mainly due to increasing demand from the power sector. Also, the production of lignite (brown coal) has also been increasing—albeit at a much slower rate.

According to the country's 11th Five Year Development Plan, India will produce 629.91 million metric tons of coal in the period of 2011-12, while it may actually need 713 million metric tons. Moreover, India is expected to produce a total of 570 million metric tons of coal in 2010-11 (Planning Commission, 2008).

2.2.6 Coal Consumption

Coal consumption and demand have grown enormously in India, primarily dominated by the electricity sector. Starting in the 1970s, coal-based thermal power plants were installed at a rapid pace, and demand for thermal coal increased accordingly. In 1970, electricity generation consumed about 13 MT (less than 20% of total coal consumption); it consumed about 352 metric tons in 2008 (nearly 70% of total consumption) (Chikkatur, 2008).

Other major coal-consuming sectors include rail transport, iron and steel production, and cement production. Coal consumption by railways has decreased steadily; in fact, direct coal consumption by railways ended by the mid-1990s, as rail transport became entirely based on electricity and diesel. The iron and steel industry, which primarily consumes coking coal and some high-grade non-coking coal, is the second largest consumer of domestic coal, although its consumption has decreased in recent years. Much of India's coal imports are being used by the steel industry as domestic coking coal supply has declined since the mid-1990s. The third largest consumer of coal in India is the cement industry, which accounts for 4 to 5% of total consumption. Other smaller consumers include the fertilizer industry consuming nearly 4–5 metric tons of coal per year since the 1980s (CMIE, 2005); the textile industry (including jute and jute products); the paper industry; the brick industry and other smaller consumers (including domestic consumers).

Despite the global financial crisis, India's energy demand continues to rise. It lacks sufficient domestic energy resources and imports much of its growing energy requirements. India is expected to import 83 million metric tons of coal in 2011-12 (Way2online, 2010) to cope with the rising demand of the domestic market, mainly for power sector and cement industries.

2.2.7 Coal Mining Methods in India

Coal mining in India utilizes both underground extraction and surface mining methods. In underground mining, coal is extracted from the seam without removal of overlying strata. In surface mining, which is also called strip, or opencast mining, the strata overlying the coal seam (overburden) are removed and coal is extracted from the exposed seam.

The type of mining depends on the geo-mining conditions of coal, the thickness and inclination of the seam and overlying strata, the value of surface land and other economic factors. Open cast coal production in India has rapidly increased year after year, whereas underground coal production has been stagnating at approximately 50-60 million metric tons for several years. Its share in total production has fallen to less than 17% in 2003-04. Currently about 83% of India's coal comes from opencast mines, some of them being large, highly mechanized opencast operations (Ministry of Coal, 2009-10). The surface operations require less labor, can be implemented faster and involve lower production costs than underground mines. Productivity in opencast mines is generally much higher than that of underground mines.

The cost of production per metric ton of coal from underground mines could be as high as five times that of opencast mines. Since the coal is priced according to grade and not on a cost plus basis, some of the coal produced from underground mines is sold below their cost of production. (TERI, 2006).

2.3 COAL BENEFICIATION IN INDIA

Beneficiation of thermal coal is a relatively new development in India. Table 2.4 provides a summary of the installed capacities of current washeries. Much of the new cleaning capacity was installed in response to regulations promulgated in 2001 by the Ministry of Environment and Forest (MEF) as mentioned previously.

The Government of India has also established build-own-operate-manage (BOOM) policies to encourage deployment of coal cleaning (beneficiation) technologies by domestic and foreign companies. On the other hand, power plants located near mine sites are still allowed to burn run-of-the-mine (ROM) high ash content raw coals. Even though some coals are being cleaned, the extent of beneficiation is often minimal. Typically, a ROM coal is screened dry to set aside the fines fraction, and only the coarse fraction is cleaned. The raw coal fines are then combined with the cleaned coarse coal to meet the 34% ash requirement. In some cases, the coarse coal cleaning is limited to deshaling by hand picking, which is labor intensive and highly inefficient.

Table 2.4 Installed capacities of washeries operating in India.

Washery Operators	Non-Coking Coal		Coking Coal		Total	
	Numbers	Capacity (MTA)	Numbers	Capacity (MTA)	Numbers	Capacity (MTA)
CIL	7	20.2	11	19.68	18	39.88
Non - CIL	27	69.6	7	11.27	34	80.87
Total	34	89.8	18	30.95	52	120.75

When used, washing plants are typically preceded by single or two-stage crushing to reduce the raw coal to a top size of 100, 75 or 50 mm. The smaller fraction of raw coal (-13, -10 or -6.5 mm) that typically contains low ash (20-30%) is usually not washed. The specific size selected for washing or direct consumption would depend upon the ash content and effectiveness of screening. The coarser fraction is washed by jig, heavy medium bath or heavy medium cyclone to the extent that the combined ash of washed coarse coal and unwashed small and fine coal is within the stipulated limit. In some of the plants, inefficient barrel washers and spirals are used for small (<10 mm) and fine (<3 mm) coal, respectively, in which case the fraction finer than about 0.5 mm would normally be discarded

In 2007, the approximate capacity of beneficiation of thermal coal was 70 million metric tons per annum in (Singh, 2007). For the year 2005-06, India produced 380 million metric tons of thermal coal, of which only 17 million metric tons were beneficiated coals delivered to 12 power stations. The rest were untreated ROM coals. Thus, less than 5% of the coals burned for electricity generation were beneficiated coals. Also, assuming 80% yield as an average, the 17 million metric tons of clean coal should represent 22 million metric tons of feed coal. Thus, the beneficiation plants in India were operating at approximately 44% of the design capacity, despite the fact that beneficiation offers a number of economic and environmental benefits.

Power plants in India have been slow to utilize washed coal because of several reasons including (i) the perception that traditional coal washing adds to the already high cost of supplied coal, (ii) the lack of stringent emission standards (particularly for fly ash) at power stations, and (iii) the absence of a pricing structure that prorates thermal coal value based on variations in gross calorific value (which is standard international practice).

Coal India Limited is going to set up twenty coal washeries (coking and non-coking) on a Build-Own-Operate & Maintain basis with a total capacity of 111 million metric tons (Business Standard, 2011). These washeries are expected to be commissioned by 2015. Nevertheless, the establishment of the build-own-operate policy by the Indian government is expected to encourage more rapid deployment of coal beneficiation practices in India.

2.3.1 Existing Coal Beneficiation Technologies

The current total installed capacity for washing non-coking coal is around 89.8 million metric tons, (see Table 2.4) whereas the requirement by the end of 11th *Five Year Development Plan* is 243 million metric tons. Total production of both coking and non-coking coals was 120.75 million metric tons. Government owned CIL represents approximately 40 million tons of washing capacity, while about twice this amount is available for non-CIL facilities. It is projected that the amount of thermal to be washed by 2025 would be 361 million metric tons. This leaves a huge gap of 271.2 million metric tons of washed coal, posing a need of a large number of high capacity washeries. Some of the various coal preparation techniques used in India are mentioned below.

Lump Washing

Most coals are washed after initial size reduction to improve liberation and coal handleability. However, ROMJIG technology opened the possibility to beneficiate a very large "lump" size coal with top size from 400 mm to bottom size of 30 mm by using only one technologically improved machine and some standard auxiliary equipment. The idea was to ease the process of washing thermal coals by separating coarse refuse, and produce clean coal with desired ash value less than 34%. Due to low water and power consumption and low expenditure, this process is more economical compared to other proven technologies. But, due to the presence of a large amount of minus 30 mm material in Indian coals, the efficiency of the process is reduced because the ash content of the fine material is too high.

Coarse Coal Washing

Most washeries in India treat the coarse coal fraction of 100 mm to 6 mm in jigs or dense medium separators, and mixing the unwashed fraction to achieve the overall desired ash level of less than 34%. In some cases, the top size for washing is reduced to 50 mm, depending on the grain size distribution of impurities contained in the coal. Under pulsated Batac jigs are widely in use. Dense medium cyclone washers are also making impact on coal preparation in India in recent years.

The Batac jig can wash up to 3 mm bottom size without a modification of the flow sheet. The only problem is dry screening at the lower sizes, which can be solved by using the right screening system. Dense medium separators have similar operating results for this size fraction, although the media recovery circuit must be properly designed to avoid high operating costs.

The cost of operation of conventional washeries in India has increased at a rapid rate over the years. A low capital technology called barrel washer has become popular because of its low operation and power cost. The process consists of beneficiation of raw coal with top size 50 mm in a long cylindrical barrel with self generated slurry as the separating dense medium (CMPDI, 2005-06). After initial processing, the barrel float product is crushed and beneficiated in a second stage of cyclones.

Fine Coal Washing

The heart of fine coal circuits is made of dense medium cyclones or under-pulsated jigs. The degree of beneficiation is defined by the raw coal characteristics and product requirements. Washing of smaller size fraction, say less than 3-6 mm, is not common for coal fed to thermal coal as the desired ash level in overall washed product is achieved by coarse coal washing. These products are often used for feeding to sponge iron and cement industry. When washed, non-coking coals of smaller size fraction are typically processed in Batac jigs and dense medium cyclone washeries. Even coking coal washeries utilize Batac jigs and dense medium processes for upgrading coking coals.

2.4 DRY SEPARATION OF COAL

2.4.1 Historical Perspective

The quantities of coal being beneficiated and the levels of beneficiation required are increasing while the quality of raw coals is decreasing. Coal is currently cleaned with the minimum of size reduction; fine particle processing, recovery, and tailings disposal are already major problems. Further, adequate water resources are not always available. Dry beneficiation is an alternative approach. Indeed, pneumatic density separation of coal was widely accepted between 1930 and 1960. The reasons of its downfall in 1960's are the inherent efficiencies of the separators, deterioration of mined coal quality, environmental problems, and higher percentage of fines and moisture in coal. Though wet processes are more efficient, they create two particular problems which promoted significant interest in dry methods in recent years (Osborne, 1988).

- They add moisture to the cleaned coal, hence reduce the coal quality.
- Dewatering and drying costs are more rapidly increasing treatment costs in coal preparation.

It is important to note that dry coal cleaning units were historically most effective for cases involving a high relative density of separation (>2.0 RD). Such separations are referred to as "deshaling" operations since only the high-density high-ash component is removed from the coal feed. Recent studies have indicated significant technical and economical benefits for deshaling coals in a number of different situations (Luttrell et al., 1996; Honaker et al., 2004).

- Removing high density rock from a steam coal that is not being processed through a preparation plant in an effort to improve heating value.
- Reducing rock content from run-of-mine coal prior to loading and transportation. The coal deposits in India are concentrated in the Eastern regions. The setting up of a coal fired power plant in Western India and in the North-west, entails transporting coal over distances exceeding 1000 km. These situations are an ideal application for deshaling.
- Eliminating rock from coal that is not treated and blended with a processed coal to achieve a product having the required quality. The studies have shown that the use of deshaling on the untreated coal to remove one ton of rock will allow the recovery of three additional tons of middling material currently rejected during the processing of the treated coal.

- No moisture penalty to the clean coal product. As the grading is based on ash and moisture percentage, moisture penalty is a major problem for suppliers in India. This advantage is particularly important if the amount of improvement needed is minimal. Also, the processing cost for upgrading coal with dry technology is often low.

2.4.2 Dry Coal Cleaning in India

Interest in dry deshaling has increased significantly in recent years among all the major coal producer countries for cleaning the lignite and sub-bituminous coals. Fortunately, the deshaling is believed to be particularly well suited to Indian coals, which tend to contain a disproportionate amount of middling particles that are intermixed with both carbonaceous matter (coal) and inorganic minerals (rock). The coal feed stocks usually do not contain a large portion of liberated particles of carbonaceous matter that is relatively free of mineral constituents. As such, it is impossible to apply traditional washing practices which typically separate coal from rock at relatively low densities (i.e., 1.4-1.7 RD) without losing large amounts of carbonaceous organic matter. On the other hand, many of the feed coals in India contain a significant portion of liberated rock that is inadvertently added to the coal during the mining process. These particles, which are undesirable from both a cost and environmental perspective, have the potential to be easily removed from ROM coals by low-cost deshaling operations without sacrificing large amounts of carbonaceous organic matter. Honaker et al. (2006) also showed that the treatment of low ash run-of-mine coal to remove the small amount of rock using a dry separator prior to blending with washed coal has significant economical benefits.

Differences in the inherent cleaning characteristics of various coal feeds can be easily illustrated using the washability data plotted in Figure 2.2. This diagram shows the weight and ash distribution of two Indian coals as a function of density. The first coal illustrated in Figure 2.2 (a), which is less common in India, contains only a modest amount of middling particles in the relative density range between 1.60 and 1.85 RD. Traditional coal cleaning plants that make use of dense-medium circuits generally operate with a maximum separation density of about 1.65-1.70 RD. This type of plant circuitry can effectively separate the high-density, high-ash rock (>1.85 RD) from the low-density, low-ash coal in the <1.60 RD range. Unfortunately, many of the coal feed stocks in India have weight distributions that are skewed to the higher density range. These high-middling coals, such as those illustrated in Figure 2.2 (b), typically have large weight percentages in the 1.45 to 1.70 RD range. The high middlings content makes it difficult to produce clean low-ash products without discarding a large proportion of the carbonaceous matter (and heat value) present in these middlings. In addition, the large amount of near-gravity solids in the 1.65-1.70 RD range makes dense medium separators that are traditionally used in modern coal preparation plants much less effective.

For many of the coal feeds in India, a better option for beneficiation is to focus on separating out and discarding only the high-density, high-ash fraction that has the greatest negative impact on the power generation cycle. These high-ash particles contain relatively little heat value, create ash disposal and fly ash emission problems, and unnecessarily consume resources in the transportation infrastructure. For the two coals shown in Figure 2.2, a deshaling plant operating at a high density (e.g., 1.85-2.00 RD) would be ideally suited to remove the high ash (72-76% ash) materials contained in the > 1.85 RD fraction. For these two coals, such a deshaling would reduce the tonnage of materials that would normally have to be transported,

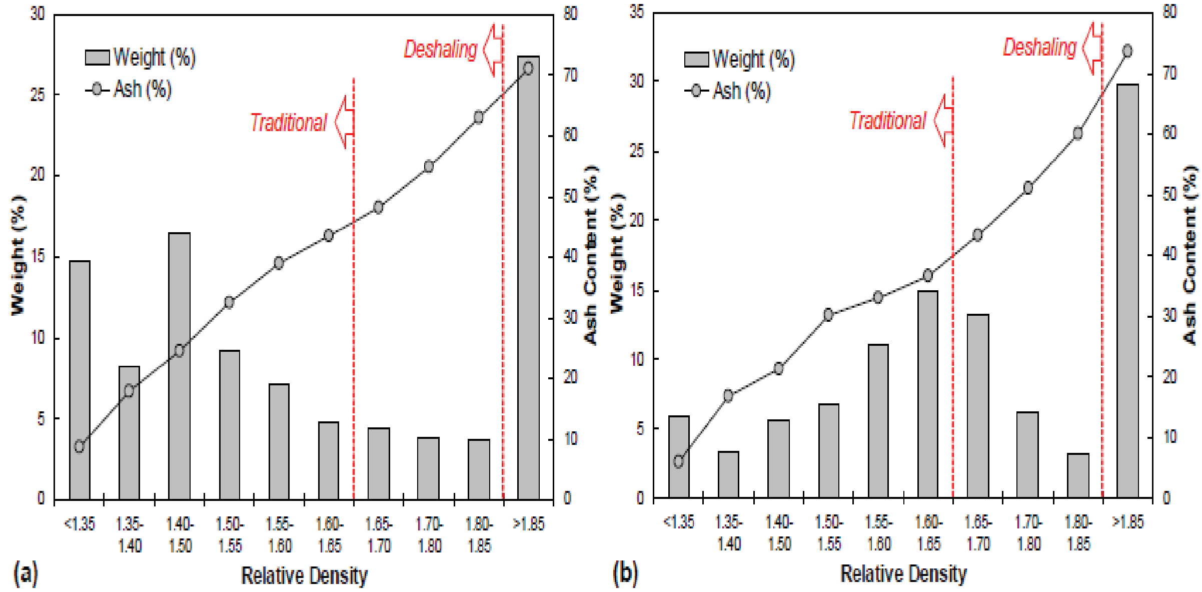


Figure 2.2 Weight and ash distribution (a) low middling (b) high middling Indian coals (Honaker, 2007).

burned and disposed of at the power station by about 25-30%. For the less difficult coal (Figure 2.2a), process simulations indicate that the efficient removal of material higher than 1.85 RD would decrease the feed ash to the power station from about 41% down to below 30%. Likewise, for the more difficult coal (Figure 2.2 b), the same process would decrease the feed ash from 45% down to 34%. Deshaling is expected to provide similar improvements for many of the coals feed stocks that are currently mined and consumed in India. Numbers of projects in recent years are undertaken in India to identify an efficient dry cleaning technology for thermal coal. In 2005, India installed its first dry processing demonstration unit, a 50 TPH capacity All-air Jig for beneficiation of coal at OCL India Ltd, Orissa. Other technologies like Air-dense Medium Fluidized Bed Separators, Magnetic separators, Electrostatic Separators, Optical Sorting process are only tested at laboratory scale (CMPDI, 2005-06).

2.4.3 Dry Beneficiation Methods

The separation (wet or dry) of components in a mixture relies on some difference in the properties of the components. This may be an optical, physical/mechanical, magnetic, electrical, or surface/colloidal property. Mechanical beneficiation of coal is probably effective down to 1 mm particle size, while electrical and magnetic techniques are most applicable to fine coal below 1 mm (Dwari and Rao, 2007).

The effective top size particle for most of the separators was around 2-inches and the effective size ratio for which good separation was achieved was between 2:1 and 4:1. It is noted that this effective particle size range is much smaller than most wet, density based separators. The reported probable error (Ep) values vary due to the particle size ranges treated. For example, within a small particle size range of 4:1, the Ep values ranged from 0.15 – 0.25 whereas a 50:1 ratio provides values around 0.30. These values indicate that the air-based systems are much inferior in separation efficiency as compared to wet coarse coal cleaning units. However, dry coal cleaning devices typically have lower capital and operating costs, no waste water treatment and impoundment requirements, lower product moisture values and less permitting requirements.

If a high density separation provides the desired effect on coal quality, dry cleaning separators are an attractive option. Several processing technologies used during the peak years of dry coal preparation have been recently modified and successfully commercialized. The All-air Jig, for example, is a modification of the Stomp Jig technology and is commercially represented by Alminerals Ltd. (Kelley and Snoby, 2002). The unit has been successfully applied in several applications within and outside the U.S. for coal cleaning (Weinstein and Snoby, 2007). Chinese researchers and manufacturers have applied basic fundamentals including computational fluid dynamics to the redesign of dry particle separators including those employing dense medium and tabling principles.

Various technologies based on material properties that define coal and mineral particles separation are explained below:

Sorting

The sorting operation of coal can be carried out by different techniques such as optical, radioactivity, microwaves, and nuclear magnetic resonance (Riedel and Wotruba, 2004). In sorting the property (appearance or color) usually only “labels” the components, while mechanical deflection, i.e. air jets separates the different labels. Dry sorting has been applied to a variety of minerals, using reflectance, photometric, infra-red, fluorescence, X-ray, radiometric, electrical conductivity, and magnetometric methods. Coal has been sorted by X-ray, gamma-ray, and electrical methods, and this field seems worthy of re-examination in the light of the modem high-speed technology used for sorting mineral ores. There is a significant effort to develop and improve on-line and in- situ ash analysis of coal using X-ray and nuclear techniques, and perhaps this technology could be adapted to reject high ash particles from coarser coal.

Shape and Friability

The Beresford plate separator is designed on the principle of friction and resilience (Mitchell, 1942; Horsfall, 1980). Sized coal particles are fed onto an inclined polished glass plate. Coal has greater resilience or "bounce" and does not remain in contact with the glass as compared to waste minerals. Therefore, coal acquire more speed and thrown further when it reaches to the end of the plate.

Rotary Breaker is based on relative friability of the material. It achieves size reduction by repeatedly raising the coal material and dropping it against strong perforated screen plates around the interior (Bhattacharya et al., 2004). Lumps are broken down and coal passes through screen-sized openings, thus act as a deshaler. Researchers showed its poor efficiency with lower rank coal and Gondwana coals.

Tables and Jigs

The particles settling rates in air are much higher than those in water. Pneumatic jigs or air tables separate particles when material is passes over a porous vibrating bed. The high density material falls to the bottom and is removed by the action of the bed while the less-dense moves by gravity across the direction of vibration of the bed. In case of air jig, material moves in the same direction and separation is achieved by positioning a splitter on the vertically stratified material (Stump, 1932).

Eriez manufactured dry deshaling air table generates a helical motion with air stratification and produces multi products of clean coal, middlings and refuse. The technology is discussed in detail in later section. China has developed FGX dry cleaner separating deck (Gongmin, 2010) based on same principle and it was reported that the unit has been successful on wide range of coal types and implemented in more than 900 plants throughout China, Mangolia, Indonesia, North Korea, Ukraine, United States etc.

Air Dense Medium Fluidized Bed Separator

In the air dense medium fluidized bed separator, the gas-solid fluidized bed must have fluid-like characteristics. The upward air current automatically expands the bed surface to the same level. The bed behaves like a liquid. Particles with density less than the bed density float to the top of the surface of the bed, while particles denser than the bed density sink to the bottom of the container. For efficient separation, stable dispersion fluidization and micro-bubbles must be achieved. The buoyancy of beneficiation materials and the displaced distribution effect play significant role in the fluidized bed (Luo et al., 2002).

When a fluidizing medium is chosen of narrowly sized particles that are appreciably finer than the feed material to be separated, then the segregation seems to depend largely on density. The feed can span a wide size range, the limits being determined by the difficulty of maintaining the air velocity between the minimum needed to fluidize the largest particles and below the terminal settling velocity of the finest particles. Fine particles that are to be separated can themselves combine to form "autogeneous" fluidized medium, and they float or sink according to their size and density. Moisture also affects the fluidizing characteristics of particles, especially for fine particles, but this is a consequence of sticking and aggregation and is not a deficiency of the fluidization technique.

Biswal et al. (2002) and Sahu et al. (2005) designed, developed, fabricated, and successes fully commissioned the unit for high ash non-coking coal of Talcher coalfields, Orissa.

Magnetic Separator

Coal is a weak diamagnetic material. A particle gets magnetized to some extent in presence of magnetic field and act as magnetic dipole. Magnetic separation may be used for coal beneficiation when the gangue minerals contain iron phase. The magnetic susceptibilities are very small for coal separations and strong magnetic field is required. Some of the iron containing minerals in coal are strongly paramagnetic and the major ash forming minerals. Significant ash reduction can be achieved by magnetic separation in the case. Magnetic separation of coal material can be done by two methods namely High-Gradient Magnetic Separation (HGMS) and Open-Gradient Magnetic Separation (OGMS). With the former, the separation is accomplished by applying a large force over a short distance, while in the latter, a smaller force is applied over a much larger distance.

Electro-static Separator

Separation occurs under the influence of very high electric field. Prior to the separation stage, particles have to be electro-statically charged. For the separation of a mineral from the organic phases in coal are based on the differences in the ability of the two phases to develop and maintain charges in different types of separators. There are two such types of electrostatic processes. One uses the difference in electric resistivity while the other uses difference in the electronic surface structure (Kelly and Spottiswood, 1989; Mazumder et al., 1994). Conductive induction, Tribo-electrification and Ion or Corona bombardment are common commercial methods of electric separation.

Coal is generally less conducting than mineral matter, except perhaps in the case of brown coal which has high water content and also often high ion content. Pyrite is the most conducting mineral that is commonly found in coal. Furthermore, vitrain is known to be less conducting than fusain and durain. In corona charging, all particles take the same sign of charge and it is the different rates of loss of this charge, which depend mainly on the relative conductivities, that permits separation while Tirbo-electric separation is based on the deflection of these differently charged particles in opposite directions. When the results of electrical separation experiments are analyzed, it is desirable to determine maceral as well as ash contents in the fractions, because otherwise organic material going into the high ash fraction might be interpreted as poor separation performance (Lockhart, 1984).

2.5 ERIEZ DRY DESHALING AIR-TABLE

The Eriez dry deshaling air table uses the separation principles of autogenous medium and a table concentrator. The separating compartment is comprised of a deck, vibrator, air chamber and hanging mechanism (Figure 2.3). Feed particles introduced into the separating chamber are subjected to upward air flows that pass up through holes in the deck surface at a rate sufficient to transport and fluidize the particles. Particles in the fluidized bed contact the deck surface and are pushed from the discharge baffle plate to the back plate by the vibration- induced inertia forces. Upon striking the back plate, particles move upward and inward towards the discharge side of the table (Figure 2.4).

Low-density particles of coal are lifted up the back plate at a higher elevation than the high-density particles of rock before turning inward toward the discharge point. These lighter particles create an upper layer that is collected along the length of the table as a clean coal and/or middlings. The denser particles of rock are forced by both vibration and the continuous influx of new feed material to transport in a helical transport pattern toward the narrowing end of the table. This action sorts the coal and rock particles along the length of the table. Figure 2.5 provides direct photographic evidence of the selective segregation of coal and rock using the air table separator.

The air table requires several ancillary units to support its operation (see Figure 2.6). During a typical run, the flow of feed to the separating chamber is regulated using a feed bin and vibrating feeder. The separating chamber is totally enclosed in a housing that is connected via duct work to a bag filter and dust cyclones. The filter/cyclones are used to clean and recycle the air and to prevent dust from being emitted to the atmosphere. A draft fan and centrifugal blower are used to circulate air at the required rates.

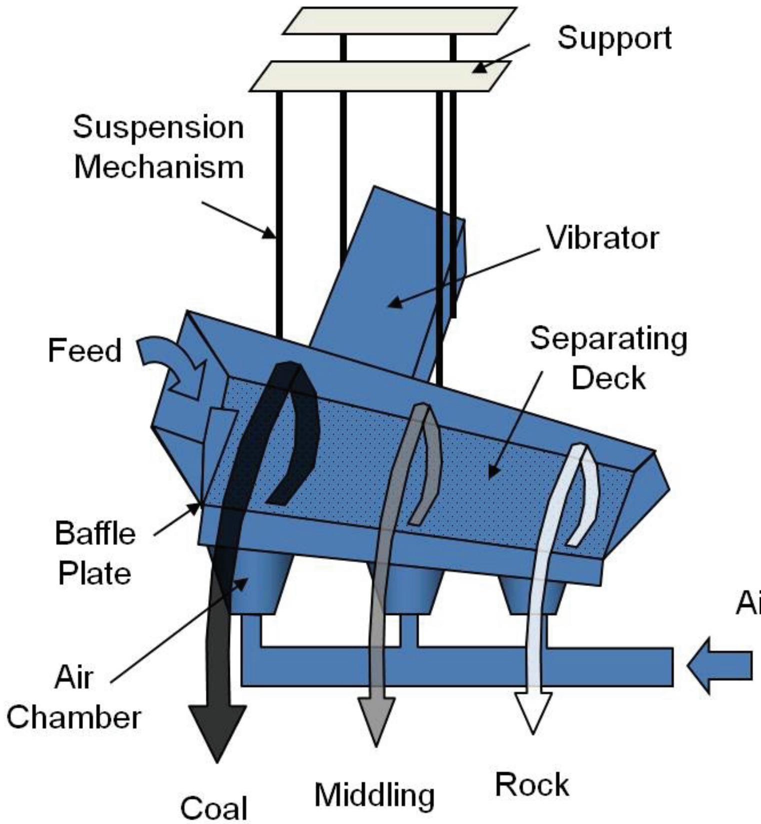


Figure 2.3 The separation chamber of dry deshaling air-table separator.

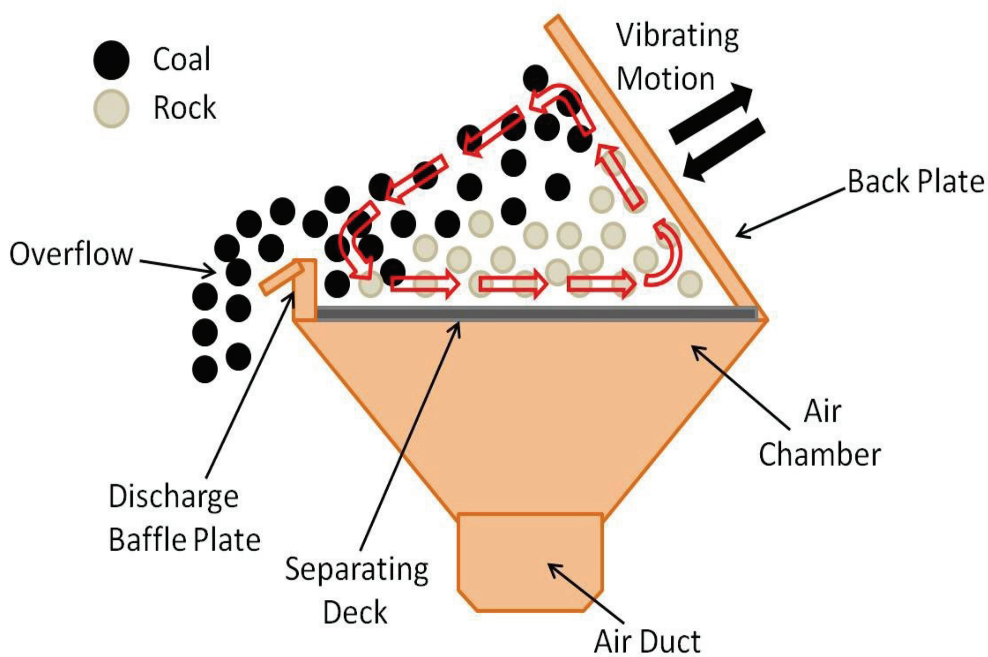


Figure 2.4 Separation mechanism and helical particle motion on air-table.

Figure 2.5 Segregation of coal and rock along the length of the vibrating air table.

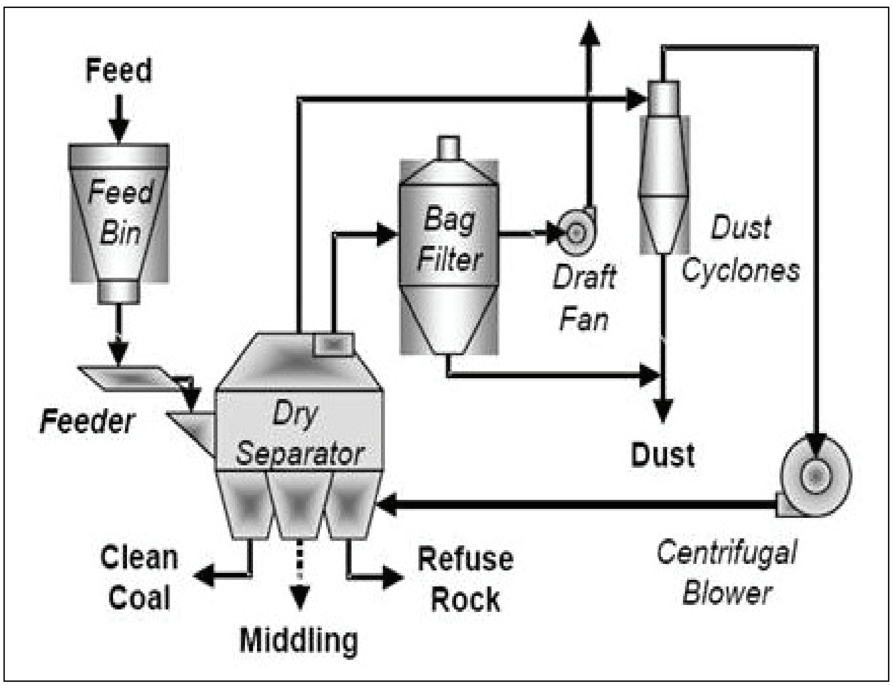


Figure 2.6 Simplified flowsheet of dry deshaling air system.

2.5.1 <u>Previous Works</u>

Prior conducting this project, the performance data for the Eriez dry deshaling air table separator was only limited to tests on Chinese coals and a few pilot-scale tests on the U.S. coals. The separation data collected from these previous studies indicate that this system offers an attractive and cost-effective alternative to traditional wet-coal cleaning processes, particularly for green-field sites where coal cleaning operations are being utilized for the first time like in India, where only 4-5% of the coal is currently being cleaned. The data obtained from studies conducted in China indicate that the unit has the potential to provide an effective separation for particles as coarse as 80 mm to a lower size limit of around 3 mm. The operational data also indicate that the process is relatively insensitive to surface moisture up to a value of about 7-10% by weight.

The previous test data also indicate that the Eriez dry air table separator had the ability to provide a relatively high separation density (RD_{50}) of around 2.0 RD while achieving probable error (Ep) values that range from 0.15 to 0.25 (Lu et al., 2003; Li and Yang, 2006). This level of performance provides high organic efficiencies approaching 97%. The capital cost for a 250 t/hr unit was reported to be less than one fourth (25%) that of a traditional wet-preparation plant design, with operating costs below US $0.30 per ton. These characteristics make the dry deshaling technology ideal for coal cleaning applications in India. The only downside discovered during the course of this field work was that the dry process is not capable of treating particles finer than about 3-6 mm. This finding suggests that additional R&D work is needed to develop other types of dry deshaling processes that can more effectively treat coal fines.

CHAPTER 3 EXPERIMENTATION

3.1 INTRODUCTION

The objectives of the project work at different coal mines were to test advanced dry cleaning technologies on Indian steam coals to produce low ash products that can be more cleanly burned, reduce the amounts of fly ash generated, and minimize maintenance costs. Increasing the availability of high-quality coals will help India increase the net efficiency of coal use and facilitate implementation of state-of-the-art clean coal technologies to substantially reduce CO_2 emissions.

During the past decade, Virginia Tech and University of Kentucky jointly tested a pilot-scale (5 t/hr) dry deshaling unit at various test sites in the United States. The equipment was found to be capable of efficiently removing shale from a coarse coal feed with particles in the size range of 50 x 6 mm. The technology is marketed by Eriez Manufacturing. An inherent advantage of this technology is that it is a dry separator, which does not incur in dewatering costs. The tests results obtained on a bituminous coal sample from Utah reduced ash content from 18 to 11% with a yield of 77%. With a bituminous coal from Virginia, a feed coal assaying 49% ash was cleaned to produce 21% ash clean coal, 74% ash middlings, and 89% rejects. With a Gulf coast lignite coal, the separator was able to reduce 54% of mercury by removing iron sulfide minerals. As a result of the successful test work, the company mining the lignite coal has installed two full-scale Eriez deshaling units, with a total capacity of 240 t/hr (Honaker and Luttrell, 2007).

Virginia Tech served as the prime contractor and the University of Kentucky served as a subcontractor for this project. Eriez Manufacturing provided the pilot-scale unit for cleaning the coarse coal (60 mm x 0). Coal samples were provided by the different private and public sector coal mining industries located in the eastern part of India, which is the richest coal region of the country.

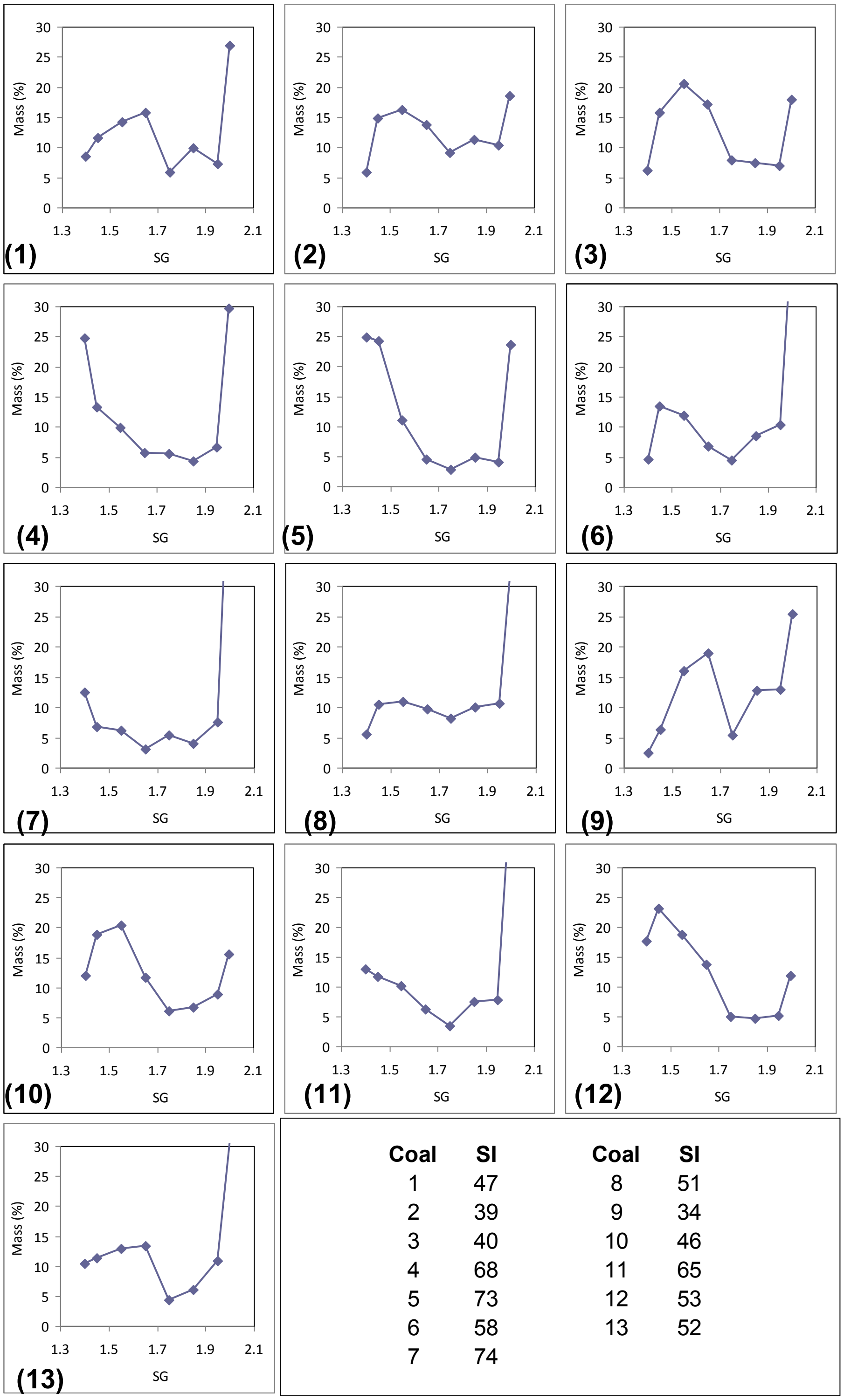
3.2 SAMPLING AND CHARACTERIZATION

Work performed under this subtask has focused on the identification of sites/seams in India that are the best candidates for the application of the dry deshaling technology. Factors considered in the final selection of test sites include (i) cleanability characteristics of the coal, (ii) lack of availability of water for competing processes, (iii) transportation distance between mine and consumption site, and (iv) willingness of producers to implement new technology. For the experimental portions of this work, guidelines were created by the project team for collecting the required characterization data (i.e., standards were established for sampling, sizing, float-sink testing and analytical determinations).

Representative samples of 13 different coals from India were selected by Sharpe International for use in the characterization study. The characterization work for these coals included screening each sample into 50x25, 25x13 and 13x5 mm size fractions followed by float-sink testing of each size fraction at relative densities of 1.4, 1.5, 1.6, 1.7, 1.8, 1.9 and 2.0 RD.

Tables 3.1-3.13 provide detailed listings of the size-by-size washability data for each sample. However, for ease of comparison, the float-sink data for the composite 50x0.5 mm material fraction for each coal is plotted in Figure 3.1. This composite plot shows that, despite washability characteristics that varied considerably from site to site, a significant proportion of high density material was present in nearly every sample. This finding suggests that relatively pure extraneous rock was present to some degree in nearly every coal, and that could be removed by a dry deshaling process.

To better compare the relative cleanabilities of the different coal samples, a separation index (SI) was calculated for each sample. The SI value was computed by summing the amounts of low density (<1.5 RD) and high density (>2.0 RD) fractions. Presumably, a large SI value would indicate that there were larger proportions of liberated coal and rock present in the sample that could be effectively separated, while a low SI value would indicate the presence of large amounts of near-density materials in the 1.6-2.0 RD range that could not be separated due to interlocking. The computed SI values, which are summarized at the bottom of Figure 4.4, ranged from a low value of 34 to a high value of 74. Four coals, which had SI values of 65 or greater, were considered to be excellent candidates for deshaling. Six other coals, with SI values between 46 and 58, were considered as good candidates also suitable for some degree of deshaling. Only three coals with SI values less than 40 were believed to contain inadequate liberated material for effective deshaling. As such, this set of data suggests that considerable potential does indeed exist for the application of dry deshaling technologies for upgrading Indian coals.



Coal	SI	Coal	SI
1	47	8	51
2	39	9	34
3	40	10	46
4	68	11	65
5	73	12	53
6	58	13	52
7	74		

Figure 3.1 Comparison of composite washabilities for various Indian coal samples.

Table 3.1 Size-by-size washability data for coal sample #1.

50-25mm	58.6		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	5.5	15.2	12.8
1.40-1.50	10.9	28.2	11.6
1.50-1.60	14.2	39.0	9.1
1.65-1.70	12.2	50.1	6.8
1.70-1.80	5.1	54.1	5.0
1.80-1.90	10.7	59.7	4.5
1.90-2.00	6.4	65.1	4.2
>2.00	28.7	79.6	2.6
	100.0	54.5	6.3

25-13mm	20.8		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	8.8	13.6	8.6
1.40-1.50	14.2	27.4	7.2
1.50-1.60	15.2	39.5	6.0
1.60-1.70	13.8	48.6	4.6
1.70-1.80	3.9	51.8	6.0
1.80-1.90	12.4	57.5	5.8
1.90-2.00	7.9	65.3	4.8
>2.00	23.8	79.9	3.1
	100.0	51.1	5.4

13-5mm	11.0		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	24.1	8.1	14.0
1.40-1.50	10.6	24.3	8.9
1.50-1.60	13.2	36.8	7.6
1.60-1.70	5.7	44.6	6.7
1.70-1.80	12.6	51.3	6.8
1.80-1.90	1.0	57.0	6.6
1.90-2.00	9.9	61.2	6.7
>2.00	22.9	79.2	3.9
	100.0	43.2	8.2

Table 3.2 Size-by-size washability data for coal sample #2.

50-25mm 60.1

sp.gr	Wt%	Ash%	M%
<1.40	3.8	16.4	9.6
1.40-1.50	14.7	27.9	9.2
1.50-1.60	16.6	39.0	6.7
1.60-1.70	16.1	48.9	5.4
1.70-1.80	6.7	54.0	5.0
1.80-1.90	12.4	58.7	4.4
1.90-2.00	9.8	64.8	4.0
>2.00	19.9	75.3	3.2
	100.0	51.3	5.6

25-13mm 19.8

sp.gr	Wt%	Ash%	M%
<1.40	7.1	13.3	10.2
1.40-1.50	15.8	25.6	8.1
1.50-1.60	16.1	36.8	5.8
1.60-1.70	9.3	44.9	5.2
1.70-1.80	13.2	52.7	4.7
1.80-1.90	11.9	57.1	4.3
1.90-2.00	12.4	67.7	3.5
>2.00	14.2	77.9	2.6
	100.0	48.3	5.4

13-5mm 10.5

sp.gr	Wt%	Ash%	M%
<1.40	14.8	10.5	8.5
1.40-1.50	14.5	24.3	6.9
1.50-1.60	13.8	34.9	6.2
1.60-1.70	8.9	43.5	5.3
1.70-1.80	15.4	51.9	5.2
1.80-1.90	4.3	58.3	4.7
1.90-2.00	9.8	63.4	4.9
>2.00	18.5	75.0	3.3
	100.0	44.4	5.7

Table 3.3 Size-by-size washability data for coal sample #3.

50-25mm 62.6

sp.gr	Wt%	Ash%	M%
<1.40	2.9	15.5	8.1
1.40-1.50	15.6	30.2	6.6
1.50-1.60	21.5	40.2	5.7
1.60-1.70	20.2	49.5	3.7
1.70-1.80	5.5	54.5	4.6
1.80-1.90	7.3	58.5	4.3
1.90-2.00	7.6	64.1	3.6
>2.00	19.4	73.7	2.7
	100.0	50.2	4.6

25-13mm 17.5

sp.gr	Wt%	Ash%	M%
<1.40	7.1	12.3	7.2
1.40-1.50	17.0	25.9	6.0
1.50-1.60	20.0	38.0	4.9
1.60-1.70	12.6	46.8	3.5
1.70-1.80	13.1	53.8	3.3
1.80-1.90	9.1	58.8	2.8
1.90-2.00	4.3	65.9	2.6
>2.00	16.8	75.7	2.0
	100.0	46.7	4.1

13-5mm 11.0

sp.gr	Wt%	Ash%	M%
<1.40	23.4	8.2	11.2
1.40-1.50	14.9	25.3	5.6
1.50-1.60	16.5	36.6	5.1
1.60-1.70	6.7	44.6	4.2
1.70-1.80	13.5	51.5	4.0
1.80-1.90	5.2	57.7	3.5
1.90-2.00	7.5	66.0	2.7
>2.00	12.3	76.2	1.9
	100.0	39.0	5.7

Table 3.4 Size-by-size washability data for coal sample #4.

50-25mm 64

sp.gr	Wt%	Ash%	M%
<1.40	20.7	16.5	10.4
1.40-1.50	13.4	29.3	8.5
1.50-1.60	9.6	40.0	6.6
1.60-1.70	6.8	48.3	5.6
1.70-1.80	5.8	54.3	4.9
1.80-1.90	5.0	58.8	4.5
1.90-2.00	7.1	64.2	4.0
>2.00	31.6	76.0	2.9
	100.0	49.1	6.0

25-13mm 15

sp.gr	Wt%	Ash%	M%
<1.40	32.8	11.8	10.3
1.40-1.50	12.4	26.5	5.8
1.50-1.60	10.1	38.1	4.9
1.60-1.70	4.4	46.6	4.3
1.70-1.80	4.8	53.6	4.0
1.80-1.90	4.4	60.1	4.0
1.90-2.00	5.7	65.7	3.6
>2.00	25.4	77.1	2.5
	100.0	41.6	6.0

13-5mm 12

sp.gr	Wt%	Ash%	M%
<1.40	35.7	8.1	10.9
1.40-1.50	13.8	21.0	7.8
1.50-1.60	11.6	35.8	5.1
1.60-1.70	1.8	44.6	5.1
1.70-1.80	5.9	50.0	5.7
1.80-1.90	0.4	54.7	5.2
1.90-2.00	5.9	58.8	6.9
>2.00	24.9	74.0	4.8
	100.0	35.8	7.6

Table 3.5 Size-by-size washability data for coal sample #5.

50-25mm	63.2		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	21.6	18.9	10.2
1.40-1.50	25.1	30.5	8.7
1.50-1.60	11.1	41.6	6.3
1.60-1.70	5.7	49.3	5.3
1.70-1.80	1.5	53.4	4.8
1.80-1.90	4.9	59.0	4.5
1.90-2.00	4.5	65.9	3.8
>2.00	25.6	80.0	2.4
	100.0	46.3	6.5

25-13mm	16.9		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	26.4	13.0	9.9
1.40-1.50	24.9	27.7	6.7
1.50-1.60	10.7	39.8	5.2
1.60-1.70	2.1	45.8	5.5
1.70-1.80	6.2	50.7	5.4
1.80-1.90	5.4	59.5	4.4
1.90-2.00	3.3	67.2	3.4
>2.00	21.0	80.0	2.5
	100.0	40.9	6.2

13-5mm	12.0		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	39.3	6.5	12.8
1.45-1.50	18.5	22.2	7.4
1.50-1.60	12.1	35.5	5.9
1.60-1.70	1.7	41.5	7.2
1.70-1.80	4.8	47.9	5.0
1.80-1.90	3.4	55.0	5.5
1.90-2.00	2.8	62.5	4.2
>2.00	17.4	78.3	3.1
	100.0	31.2	8.3

Table 3.6 Size-by-size washability data for coal sample #6.

50-25mm	62.6		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	2.0	15.2	9.1
1.40-1.50	13.7	28.3	8.9
1.50-1.60	12.0	38.4	7.2
1.60-1.70	8.4	47.9	5.8
1.70-1.80	2.9	52.9	4.7
1.80-1.90	8.5	58.0	4.7
1.90-2.00	10.8	64.6	3.5
>2.00	41.7	79.6	2.5
	100.0	59.4	4.7

25-13mm	19.4		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	9.2	17.4	9.1
1.40-1.50	12.2	27.4	6.5
1.50-1.60	12.2	36.8	5.5
1.60-1.70	2.3	44.6	5.7
1.70-1.80	8.0	48.5	6.1
1.80-1.90	10.5	59.1	4.2
1.90-2.00	9.3	66.0	3.5
>2.00	36.3	80.8	2.5
	100.0	56.0	4.6

13-5mm	10.7		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	11.5	10.4	10.6
1.40-1.50	13.8	25.0	6.4
1.50-1.60	10.6	36.2	4.5
1.60-1.70	5.5	43.6	4.5
1.70-1.80	7.2	50.8	3.8
1.80-1.90	4.3	58.6	3.7
1.90-2.00	9.2	63.4	3.7
>2.00	37.9	79.2	2.6
	100.0	52.9	4.6

Table 3.7 Size-by-size washability data for coal sample #7.

50-25mm	66.2		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	11.5	14.8	8.9
1.40-1.50	6.1	28.2	6.7
1.50-1.60	5.8	38.3	5.2
1.60-1.70	3.6	46.9	4.1
1.70-1.80	5.9	53.8	3.4
1.80-1.90	4.2	60.6	3.1
1.90-2.00	8.4	66.6	2.8
>2.00	54.4	81.9	1.9
	100.0	63.2	3.5

25-13mm	16.3		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	13.9	12.8	6.4
1.40-1.50	8.6	25.3	4.7
1.50-1.60	6.5	37.7	3.6
1.60-1.70	2.4	46.3	3.5
1.70-1.80	4.4	52.7	3.4
1.80-1.90	3.0	59.3	3.1
1.90-2.00	5.9	65.6	2.6
>2.00	55.3	81.2	2.0
	100.0	60.4	3.1

13-5mm	9.8		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	15.8	8.4	6.3
1.40-1.50	8.3	20.2	4.9
1.50-1.60	7.0	34.2	3.7
1.60-1.70	1.1	40.8	4.7
1.70-1.80	3.3	46.5	4.3
1.80-1.90	4.0	54.0	4.7
1.90-2.00	5.2	61.7	3.7
>2.00	55.4	80.1	2.8
	100.0	57.1	3.8

Table 3.8 Size-by-size washability data for coal sample #8.

50-25mm	64.9		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	4.0	17.5	8.8
1.40-1.50	10.3	29.6	6.9
1.50-1.60	10.8	41.0	4.8
1.60-1.70	12.0	49.2	4.8
1.70-1.80	6.4	54.4	4.5
1.80-1.90	10.6	59.8	4.1
1.90-2.00	10.1	66.5	3.2
>2.00	35.7	80.5	2.2
	100.0	59.4	4.0

25-13mm	17.1		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	5.0	12.3	8.1
1.40-1.50	12.3	26.7	5.4
1.50-1.60	11.6	38.4	4.5
1.60-1.70	3.6	44.7	4.9
1.70-1.80	13.6	48.9	4.4
1.80-1.90	9.6	58.0	4.3
1.90-2.00	13.2	65.6	3.5
>2.00	31.0	79.8	2.0
	100.0	55.6	3.9

13-5mm	10.1		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	16.2	8.4	8.9
1.40-1.50	8.7	25.2	5.3
1.50-1.60	10.8	36.4	4.3
1.60-1.70	5.5	44.8	4.1
1.70-1.80	10.3	52.0	3.5
1.80-1.90	6.2	57.8	5.6
1.90-2.00	9.5	61.8	5.7
>2.00	32.8	78.3	2.3
	100.0	50.5	4.6

Table 3.9 Size-by-size washability data for coal sample #9.

50-25mm	66.8		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	1.8	18.1	8.1
1.40-1.50	6.6	29.8	7.3
1.50-1.60	16.9	41.4	4.9
1.60-1.70	20.3	49.3	4.9
1.70-1.80	1.7	51.2	4.6
1.80-1.90	13.8	56.5	4.2
1.90-2.00	12.7	63.2	3.7
>2.00	26.2	75.4	2.7
	100.0	55.7	4.3

25-13mm	16.9		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	3.6	17.7	6.5
1.40-1.50	5.5	27.8	5.6
1.50-1.60	14.6	38.4	4.7
1.60-1.70	17.8	45.6	4.6
1.70-1.80	10.9	51.7	4.3
1.80-1.90	10.5	58.4	4.0
1.90-2.00	14.9	65.4	4.1
>2.00	22.2	78.1	2.2
	100.0	54.7	4.0

13-5mm	9.8		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	5.5	9.9	8.2
1.40-1.50	5.5	24.2	5.9
1.50-1.60	12.3	36.0	4.7
1.60-1.70	11.1	44.0	4.5
1.70-1.80	20.4	51.1	4.9
1.80-1.90	9.1	58.7	3.4
1.90-2.00	11.3	65.3	3.0
>2.00	24.8	77.2	2.3
	100.0	53.5	4.1

Table 3.10 Size-by-size washability data for coal sample #10.

50-25mm	66.3		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	10.1	16.4	7.4
1.40-1.50	19.8	28.5	6.0
1.50-1.60	20.5	37.9	5.1
1.60-1.70	12.8	47.5	4.1
1.70-1.80	6.2	52.1	3.8
1.80-1.90	6.1	55.0	4.0
1.90-2.00	8.5	60.6	3.5
>2.00	15.9	75.3	2.5
	100.0	44.9	4.7

25-13mm	17.4		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	14.6	16.3	6.0
1.40-1.50	18.7	27.5	5.9
1.50-1.60	19.9	37.7	5.1
1.60-1.70	12.4	47.3	4.2
1.70-1.80	1.9	50.8	4.1
1.80-1.90	9.8	55.9	3.6
1.90-2.00	7.0	62.9	3.4
>2.00	15.8	76.4	2.5
	100.0	43.7	4.6

13-5mm	9.3		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	19.9	10.5	7.3
1.40-1.50	11.7	22.0	5.4
1.50-1.60	21.2	33.4	4.6
1.60-1.70	1.8	40.8	4.9
1.70-1.80	13.5	45.0	5.8
1.80-1.90	5.3	51.4	6.0
1.90-2.00	14.0	59.7	5.1
>2.00	12.7	77.7	2.2
	100.0	39.5	5.2

Table 3.11 Size-by-size washability data for coal sample #11.

50-25mm	61.2		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	11.4	16.9	8.7
1.40-1.50	12.1	28.7	7.4
1.50-1.60	10.3	38.4	5.4
1.60-1.70	8.1	47.4	5.2
1.70-1.80	0.7	46.6	4.3
1.80-1.90	8.1	55.5	3.8
1.90-2.00	7.0	61.0	3.6
>2.00	42.2	76.3	2.6
	100.0	54.5	4.6

25-13mm	19.4		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	13.9	12.5	5.4
1.40-1.50	12.7	25.6	4.5
1.50-1.60	9.9	36.4	4.3
1.60-1.70	2.7	42.2	4.4
1.70-1.80	8.5	49.1	4.3
1.80-1.90	5.7	56.4	3.5
1.90-2.00	11.3	62.7	3.3
>2.00	35.4	78.3	1.8
	100.0	51.9	3.4

13-5mm	11.5		
sp.gr	**Wt%**	**Ash%**	**M%**
<1.40	20.1	10.5	6.1
1.40-1.50	8.1	23.6	4.2
1.50-1.60	10.2	33.7	3.7
1.60-1.70	2.5	40.9	4.4
1.70-1.80	9.5	46.4	4.7
1.80-1.90	7.7	55.5	3.9
1.90-2.00	6.6	62.7	3.8
>2.00	35.3	75.7	3.0
	100.0	48.0	4.1

Table 3.12 Size-by-size washability data for coal sample #12.

50-25mm 64.2

sp.gr	Wt%	Ash%	M%
<1.40	17.0	20.6	4.9
1.40-1.50	24.5	31.7	3.8
1.50-1.60	20.2	40.7	3.4
1.60-1.70	14.1	47.8	3.1
1.70-1.80	4.5	52.6	2.9
1.80-1.90	3.5	56.3	3.0
1.90-2.00	4.6	62.4	2.6
>2.00	11.6	74.8	2.0
	100.0	42.1	3.5

25-13mm 17.8

sp.gr	Wt%	Ash%	M%
<1.40	17.8	17.5	4.3
1.40-1.50	19.9	29.4	3.5
1.50-1.60	16.9	38.1	3.2
1.60-1.70	13.4	46.6	2.7
1.70-1.80	3.9	50.8	3.3
1.80-1.90	9.7	55.2	3.1
1.90-2.00	6.2	63.8	2.5
>2.00	12.2	76.3	1.8
	100.0	42.2	3.2

13-5mm 10.6

sp.gr	Wt%	Ash%	M%
<1.40	21.6	12.9	3.8
1.40-1.50	19.9	26.0	4.1
1.50-1.60	12.6	35.4	3.2
1.60-1.70	12.6	42.5	3.7
1.70-1.80	10.4	48.6	3.6
1.80-1.90	3.7	54.7	2.9
1.90-2.00	6.6	59.9	3.0
>2.00	12.6	74.6	1.7
	100.0	38.2	3.4

Table 3.13 Size-by-size washability data for coal sample #13.

50-25mm 63.5

sp.gr	Wt%	Ash%	M%
<1.40	7.9	17.7	6.9
1.40-1.50	12.5	30.7	5.6
1.50-1.60	13.7	40.7	4.4
1.60-1.70	14.6	48.2	3.7
1.70-1.80	1.8	51.2	3.5
1.80-1.90	5.5	56.0	3.3
1.90-2.00	11.7	60.3	3.1
>2.00	32.3	75.1	1.9
	100.0	53.2	3.6

25-13mm 19.9

sp.gr	Wt%	Ash%	M%
<1.40	14.0	13.4	4.6
1.40-1.50	9.6	27.7	4.0
1.50-1.60	10.8	36.5	3.3
1.60-1.70	12.9	45.2	2.9
1.70-1.80	9.6	52.5	2.5
1.80-1.90	5.8	58.2	2.4
1.90-2.00	9.6	64.1	2.3
>2.00	27.7	75.5	1.6
	100.0	49.8	2.8

13-5mm 9.9

sp.gr	Wt%	Ash%	M%
<1.40	20.1	10.0	6.8
1.40-1.50	8.4	26.5	3.6
1.50-1.60	12.1	36.7	3.1
1.60-1.70	5.7	42.8	3.3
1.70-1.80	10.7	47.8	4.0
1.80-1.90	9.7	56.5	3.2
1.90-2.00	8.7	64.4	2.7
>2.00	24.5	75.5	1.9
	100.0	45.9	3.7

3.3 TEST SITE DESCRIPTIONS

The pilot scale testing in India was done in two sessions: August 2009 and March 2010 respectively,

- In August 2009, the testing was carried in Orissa, India at two big private coal sites namely *Aryan Energy Pvt. Ltd*. in Talcher and *Bhushan Power and Steel Ltd*. in Jharsuguda.
- In March 2010, the testing was done at Kargali Washery, a Coal India Ltd. washery in Bokaro, India. Coal sample from Tata Steel, West Bokaro has also been tested at the same test site.

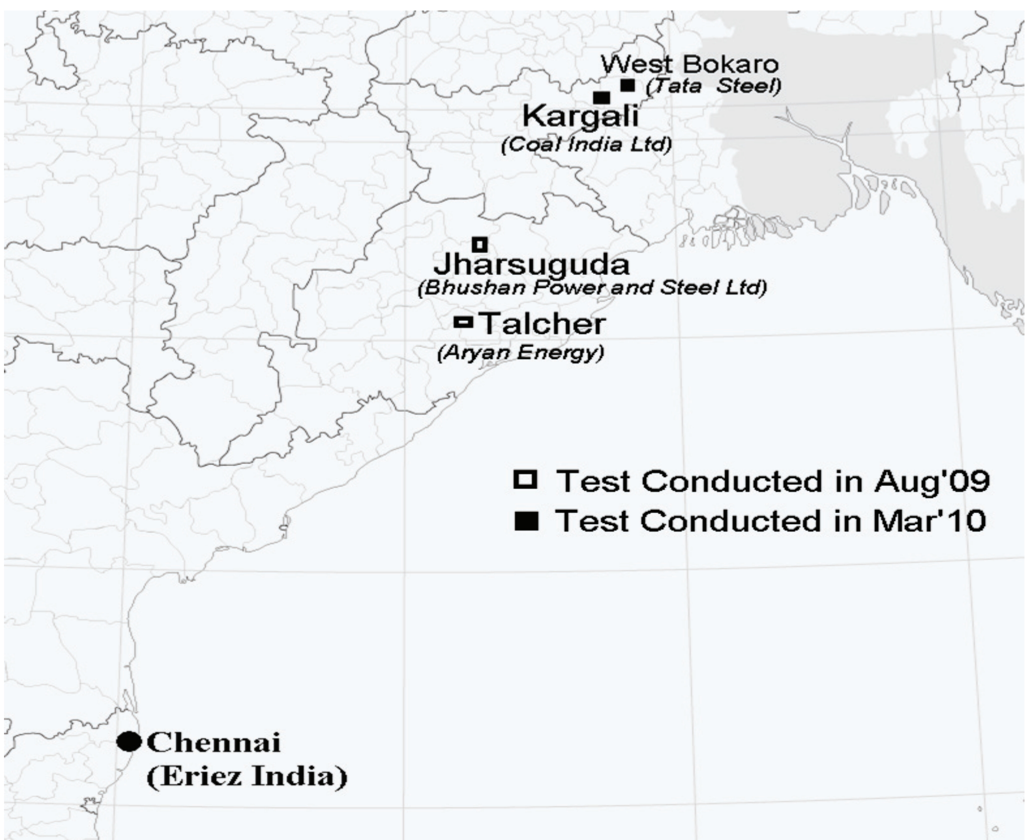


Figure 3.2 Pilot scale dry deshaling field test sites in India.

The pilot-scale Eriez dry coal cleaning unit and associated equipment were shipped from the U.S. in February 2009 and arrived at the Eriez factory in Chennai in May 2009. Following an extensive functional check-out period, the equipment was transferred by truck to Talcher, Orissa, arriving late July, 2009. Map locations of various test sites are shown in Figure 3.2.

3.3.1 Aryan Energy Private Limited

The test site at Aryan Energy Private Limited is located at Talcher, Orissa in India. Typically the facility processes 2 million metric tons annually. The processing facility at Aryan Energy presently utilizes a dense medium vessel to produce a low ash product and uses the water-based barrel washer at times to deshale feed for a high-ash product. The company installed a shaking table technology from China several years ago, but the circuit has only provided an ash reduction of 5% due to inadequacies in the design of the equipment.

The main source of run-of-mine (ROM) coal for the Aryan Energy processing facility was obtained from the Mahanadi coalfields. The beneficiation process includes size reduction and wet processing through barrel washers (280 TPH). The feed size to the washer is 60 mm x 0. The production depends on the market demand and the orders received. The major markets for the washed coal are power plants and sponge iron plants in Orissa. The two major customers are National Thermal and Power Corporation and Vedanta Resources.

The coal received for testing in the dry deshaler unit is from two different seams of Mahanadi Coal fields, that is, Balaram OCP (Test 1 to Test 13) and Hingula OCP (Test 14 and Test 15). The coal contains highly carbonaceous material, less pyrite and mercury, but was high in ash percentage with large amount of near-gravity material. The test sample is soft (high HGI index) and has large amount of fine material (35% to 40%). Due to monsoon season, the percentage of surface moisture is 13%-17%.

The size distribution and washability analyses for the Balram seam are presented in Table 3.14 and Table 3.15. Likewise, the size distribution and washability analyses for the Hingula seam are presented in Tables 3.16 and 3.17, respectively. For convenience, the washability data for the two seams are plotted in Figure 3.3 and Figure 3.4.

3.3.2 Bhushan Power and Steel Limited

Bhushan Power and Steel complex is located at Jharsuguda, Orissa in India. The complex has two washing facilities. Washery I processes coals 250 t/hr with a Batac Jig and Washery II processes 600 t/hr using dense media cyclones. The low ash product is used for four direct reduction iron (DRI) ore kilns, producing 500 metric tons per day (t/day) of iron. In addition to the four kilns, the integrated 1.5 million metric tons per year (t/yr) complex, a compact strip production (CSP) plant, blast furnace, coke oven plant, sinter plant, oxygen plant, steel making facility and lime and dolomite plant. The complex produces hot roll coil, steel billets, alloy steel rounds, tor steel, wire rods, pig iron, sponge iron, cold roll coils, cold roll sheets, precision tubes, cable tapes, black pipe and corrugated sheets. The high-ash product is used at the integrated power generation station.

The main source of run-of-mine coal for the Bhushan's processing facility was obtained from the Mahanadi coalfields and IB Valley coalfields. There are more than 20 sources of different seams from where the coal is received. The feed ash for processing varies from 46-54%. Unfortunately, the research team was unable to obtain any washability data for the coals that were evaluated during the pilot-scale test program.

Table 3.14 Particle size distribution for Balaram seam.

	Individual		Cumulative	
Size (mm)	Weight (%)	Ash (%)	Weight (%)	Ash (%)
50 x 25	36.5	45.2	36.5	45.2
25 x 13	18.7	47.2	55.2	45.9
13 x 6	14.1	45.0	69.3	45.7
6 x 3	6.2	42.2	75.5	45.4
3 x 0.5	19.3	43.8	94.8	45.1
0.5 x 0	5.2	41.3	100.0	44.9

Table 3.15 Washability analysis for the Balaram seam (50 x 0.5 mm).

Float Specific Gravity	Individual		Cumulative	
	Weight (%)	Ash (%)	Weight (%)	Ash (%)
1.4	21.2	18.9	21.2	18.9
1.5	15.0	31.8	36.2	24.2
1.6	13.1	43.3	49.3	29.3
1.7	6.9	46.4	56.2	31.4
1.8	15.6	53.8	71.8	36.3
2.4	28.2	69.7	100.0	45.7

Table 3.16 Particle size distribution for the Hingula seam.

	Individual		Cumulative	
Size (mm)	Weight (%)	Ash (%)	Weight (%)	Ash (%)
50 x 10	74.7	44.8	74.7	44.8
10 x 0	25.3	38.7	100.0	43.1

Table 3.17 Washability analysis for the Hingula seam (50 X 10 mm).

Float Specific Gravity	Individual		Cumulative	
	Weight (%)	Ash (%)	Weight (%)	Ash (%)
1.4	28.9	26.1	28.9	26.1
1.5	13.4	35.7	42.3	29.1
1.6	15.7	43.0	58.0	32.9
1.7	12.0	49.4	70.0	35.7
1.8	11.4	58.8	81.4	38.9
2.4	18.6	70.4	100.0	44.8

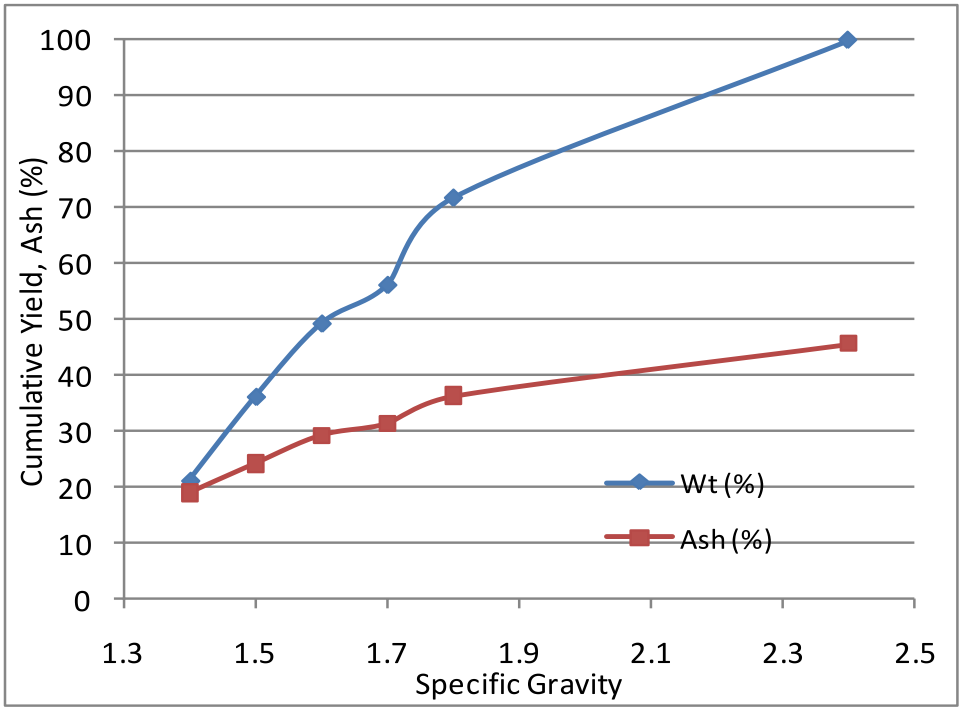


Figure 3.3 Washability of the Balaram Seam.

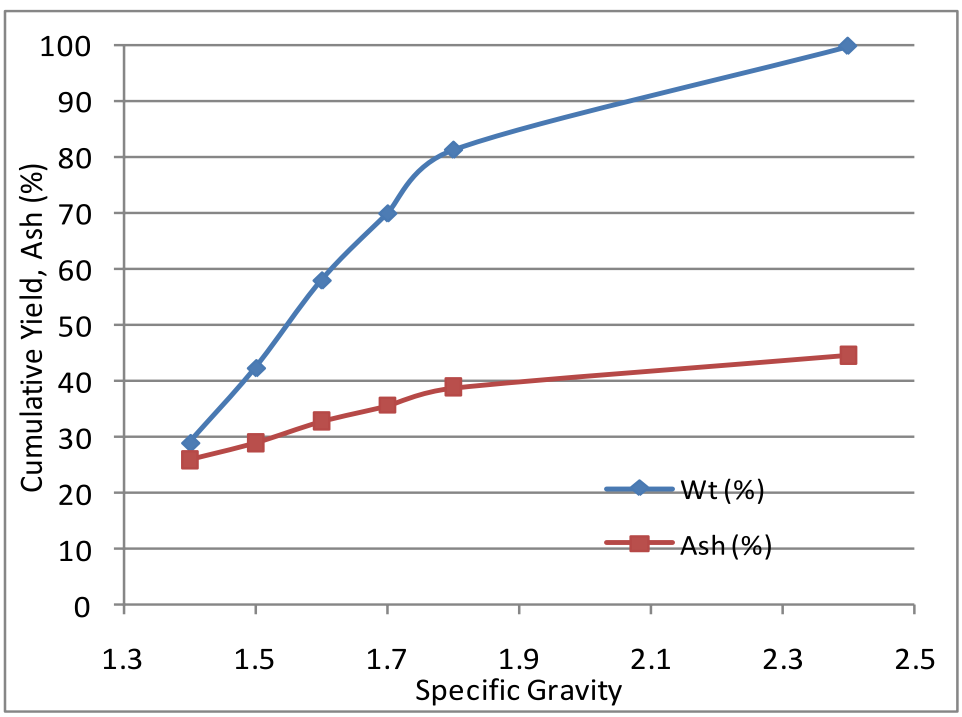


Figure 3.4 Washability of Hingula Seam.

3.3.3 Kargali Washery, Coal India Limited

Kargali Washery, Central Coalfields Limited, a subsidiary of Coal India Limited, is located near Bokaro, Jharkhand, India, and is the largest coal producing company in India. The Kargali testing site typically processes 2.72 million metric tons annually. Commissioned in 1958, the facility is one of the oldest coal washeries in India.

The main source of run-of-mine (ROM) coal for the Kargali Washery processing facility is obtained from open pit mines in the Karanpura and Bokaro coalfields. The beneficiation process includes size reduction, dry screening and wet deshaling through a ROM Jig. The feed size to the washery is 80 mm x 0. The feed is dry screened at 50 mm. The plus 50 mm material reports to the jig which produces a clean coal at 30% yield. The dry minus 50 mm product is mixed with the jig clean coal to produce a 34% ash product at 81% overall yield. The production is transported by rail to a nearby Bokaro Electric Power Corporation generating station.

The ROM coal received for the testing session was from the KMP, Tarmi, and Dhori seams. These coals are a high-ash, low sulfur, moderately-carbonaceous material, and exhibit a high percentage of near-gravity material. The coals have a medium Hardgrove Grindability Index (HGI). The surface moisture will typically be in the 3-7% range, with the moisture increasing to 13-17% during the monsoon (rainy) season. The size distribution and washability analyses for a sample of the three seams are presented in Table 3.18 and Table 3.19, respectively. For convenience, the washability data for the sample is plotted in Figure 3.5.

3.3.4 Tata Steel, West Bokaro

Tata Steel is already operating heavy media washeries at West Bokaro (Washery 2 and Washery 3) for producing coking coal. This company is planning to put up a new 800 t/hr washery at the same location. At present, about 2.4 million t/yr of clean coal at 17% ash is produced from these washeries. Flotation cells have been used with two-stage reagent addition, instead of single stage to reduce oversize material from 18% to less than 6%. The amenability of column flotation for treating the tailings has been established on a pilot scale. Tata Steel sent coal samples to the Kargali washery for pilot scale testing. The ROM coal samples tested were mid-coking coal from West Bokaro.

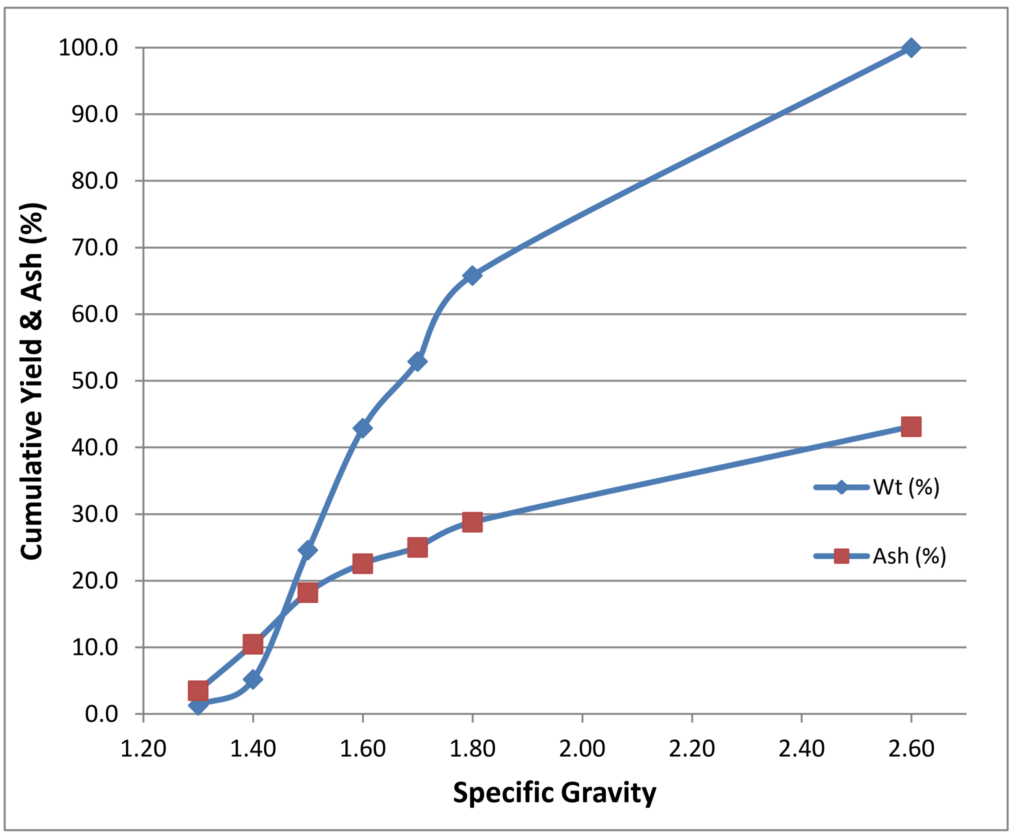


Figure 3.5 Washability of the KMP, Tarmi, and Dhori seams sample.

Table 3.18 Particle size distribution for the KMP, Tarmi and Dhori seams sample.

	Individual		Cumulative	
Size (mm)	Weight (%)	Ash (%)	Weight (%)	Ash (%)
+80	23.4	41.4	23.4	41.4
80 x 50	26.2	44.6	49.6	43.1
50 x 30	11.2	40.8	60.8	42.7
30 x 12.5	12.7	39.7	73.5	42.2
12.5 x 0.5	20.1	40.5	93.6	41.8
0.5 x 0	6.4	31.9	100.0	41.2

Table 3.19 Washability analysis for the KMP, Tarmi and Dhori seams sample (80 x 0.5 mm).

Float Specific Gravity	Individual		Cumulative	
	Weight (%)	Ash (%)	Weight (%)	Ash (%)
1.30	1.3	3.5	1.3	3.5
1.40	3.9	12.8	5.2	10.5
1.50	19.4	20.3	24.6	18.2
1.60	18.3	28.4	42.9	22.6
1.70	10.0	35.5	52.9	25.0
1.80	12.9	44.3	65.8	28.8
2.40	34.2	70.7	100.0	43.1

3.4 PILOT SCALE TESTING

The dry coal cleaning unit is based on a shaking table technology augmented with fluidizing air through the bed of the table. A typical air table circuit arrangement is presented in Figure 2.3. The circuit circulates approximately 90% of the fluidizing air back to the table, leaving about 10% of the air to provide a negative pressure within the unit for dust control. A sketch of the shaking table is presented in Figure 2.4. The pilot-scale Eriez dry coal cleaning unit and associated equipment were shipped from the U.S. in February 2009 and arrived at the Eriez factory in Chennai in May 2009. Following an extensive functional check-out period, the equipment was transferred by truck to Talcher, Orissa, arriving late July, 2009 and to Jharsuguda, Orissa, in August 2009. The equipment was returned to Chennai and again transferred by truck to Kargali, Jharkhand in March 2010 for second phase pilot scale testing.

3.4.1 Pilot Scale Set-up

A 5 t/hr pilot scale air table separator unit utilizing a 1 m^2 air table was used at the various test sites. In all cases, the ROM feed to the unit was supplied directly from the mine or pre-screened to remove the minus 6 mm material from the feed prior to treatment. Underground coal sources required pre-screening due to the relatively large amount of fines and the amount of surface water present due to dust suppression activities. Feed coal was fed to the bin shown in Figure 3.6 by a conveyor or front-end loader. Feed from the feed bin was controlled using a vibratory feeder and transferred via a conveyor belt to a hopper that feeds an internal screw conveyor. The screw conveyor feeds an internal hopper that subsequently feeds the back right corner of the table (Figure 3.7).

Upon entry of the feed onto the table deck, the upward flow of air creates a fluidized-bed of fine reject which causes the light coal particles to migrate to the top of the particle bed. The coal moves toward the right front part of the table due to the downward slope of the table (e.g., typical slope is 8 degree downward from the back of the table to the front). The high-density particles ride on the table surface which is vibrated at a preset frequency. The vibration drives the high density particles to the back of the table where the particles are forced by mass action to travel toward the left side of the table.

The particles that overflow the front of the table are directed into the product, middling or tailing bins by splitters that are adjusted to achieve a clean coal product and high-ash content tailings. The material in each of the three bins is transferred by conveyor away from the dry deshaling unit.

3.4.2 Shakedown Testing

Two rounds of testing were conducted using the pilot-scale test unit. The first round was performed at the Aryan Energy and Bhushan test sites. Several major problems were encountered during equipment setup at the Aryan Energy site due to the long truck transport (approximately 1,400 km) of the pilot-scale test unit from Chennai. One of the main table support cables had broken, the internal feeder supports had detached from the overhead mount, various pieces of chute work had been bent and the electrical controls had to be secured in the control panel. After almost two days of making repairs, the unit was ready to process feed coal. After completing work at the Aryan Energy site, the field research team traveled to the Bhushan test site following the transport of the deshaler unit to the test site. Several delays were encountered during the set up of the unit, including finding an appropriate location at the raw coal stockpile area and heavy monsoon rains for the first two days of testing.

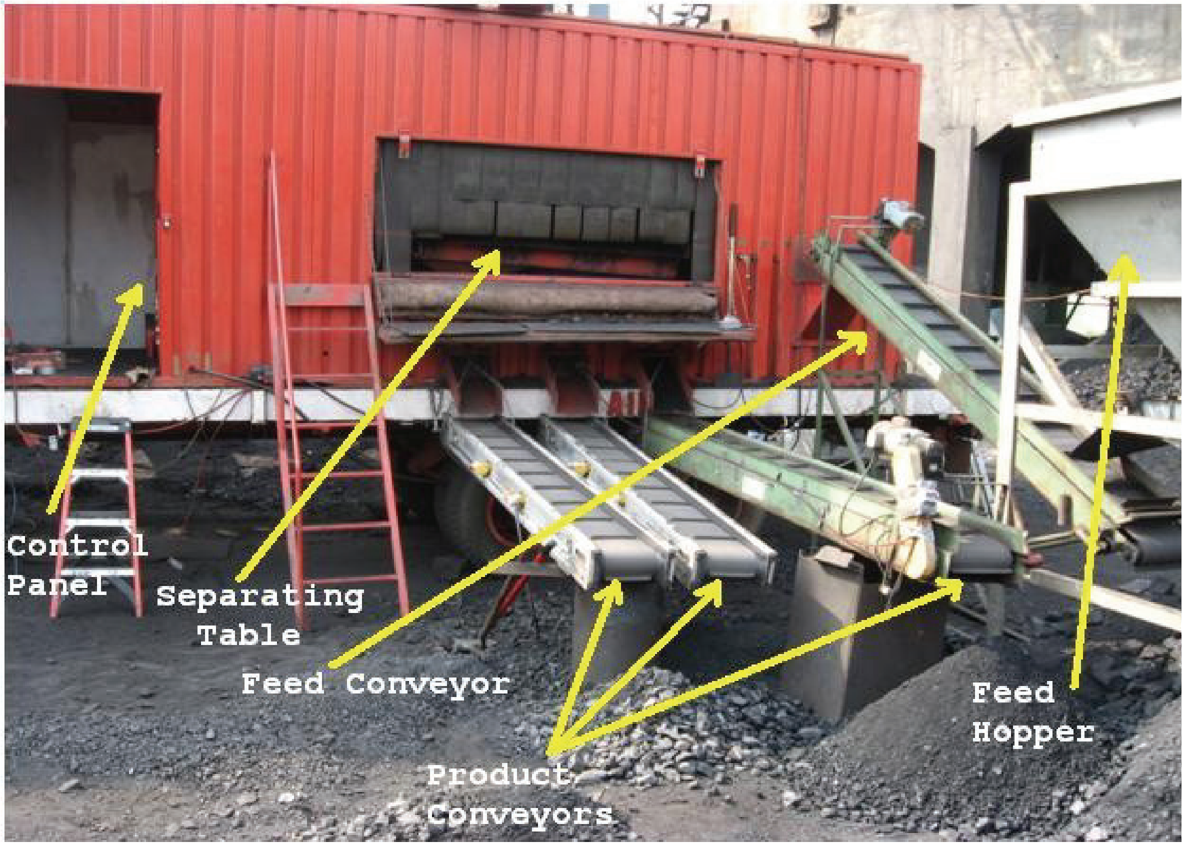


Figure 3.6 Pilot scale dry deshaling set up at Kargali washery, India.

Figure 3.7 Air-table deck (1 m^2) of pilot scale dry deshaling unit.

In the second round of pilot-scale testing, the field research team traveled to the Kargali Washery test site. Several major problems were again encountered during equipment setup at the site due to the long truck transport (approximately 1,900 km) of the pilot-scale unit from Chennai. One of the main table support cables had broken, the internal feeder supports had detached from the overhead mount, various pieces of chute work had been bent, and the electrical cable for the internal feeder had been damaged. All the repairs were accomplished and the unit was fully functional by the end of the first day. Following a complete check and adjustment of the operational parameters, the unit was ready to process the feed coal on the afternoon of the second day.

Figure 3.8 Heavy rain hampering pilot scale testing at Aryan Energy Private Limited.

3.4.3 Detailed Testing

The pilot-scale test unit was operated in continuous mode by filling the feed hopper with material. The main fluidizing air fan and separating table were started and the feeding equipment was started once the fan and table were operating at the specified speed. After the unit was operated for several minutes to attain steady-state conditions, three increments of the feed and table products were collected for each sample. The sampling arrangement provided a method for sampling the table products in six sections using a collection device designed to collect the material exiting the edge of the table into six different splits. The splits allowed the quality of the material exiting the table to be evaluated as a function of table length. After the three increments were collected, the feed, the table, and the fan were stopped while the sample components were weighed and tagged in preparation for laboratory analysis. Each sample was then screened at 6 mm size screen. Separate analysis for plus 6 mm and minus 6 mm was conducted. It should be noted that the results reported in the next chapter are only for plus 6 mm particles, as the pilot scale unit is meant to treat coarse particles only (the fine coal testing results are reported in the U.S. Department of State report, S-OES-07-APS-0001, as a separate study). The dust was collected from the bag-house dust collector after each sample period. The operating parameters were then adjusted for the next sample, and the operating/sampling cycle was repeated.

The major operating variables examined during the testing sessions were the table slope (length-wise angle), the table oscillating frequency, and the main fan motor speed (Honaker and Bratton, 2009). Data obtained from previous testing (Honaker et al., 2008) of the pilot-scale unit indicated that the table cross-wise angle had minimal influence on the separation performance and could be held constant.

CHAPTER 4 RESULTS AND RECOMMENDATIONS

4.1 INTRODUCTION

The dry deshaling technology is popular in various parts of the world because of several reasons mentioned in previous chapters. In the United States, interest in the technology has increased significantly in recent years. Honaker et al. (2006) also showed that the treatment of low ash run-of-mine coal to remove the small amount of rock using a dry separator prior to blending with washed coal has significant economical benefits.

The dry deshaling air-table separator provides a dry, density-based separation that utilizes the combined separating principles of an autogenous fluidized bed and a table concentrator. The dry cleaning process has been evaluated at different mining operations across India for the treatment of run-of-mine coal and coarse coal reject of all ranks. The objectives of the test programs at each site varied and included (1) the production of clean coal having qualities that meet 34% ash specification of feeding thermal power plants and (2) maximization of the amount of high-density rock rejected prior to transportation and processing. A 5 t/hr pilot-scale unit of dry deshaling air-table separator was installed and a detailed parametric study was performed at each site to ensure that optimum performances for each coal were obtained.

The dry deshaling pilot scale test work in India is done in two rounds. In Round – I testing, the unit is tested at two different field sites at *Aryan Energy Private Limited* and *Bhushan Power and Steel Limited.* The coal sample source at the first site was from Mahanadi Coalfields region, while at the second site, the sample source is a mixture of Mahanadi and IB Valley coalfields (mostly sub-bituminous coal, see Figure 2.1). The Round – II testing has been done at

Kargali Washery of Coal India Limited. Coal samples belong to North Karanpura Coalfields. Mid-Coking coal samples from *Tata Steel, West Bokaro* has also been tested at the same site.

4.2 RESULTS AND EVALUATION

4.2.1 Pilot-Scale Testing – Round I

A total of 15 tests were conducted at the Aryan Energy facility using the pilot-scale deshaling unit. The ROM feed ash for all the tests ranged from 48-52%. The test results for plus 6 mm material, which are summarized in Table 4.1, indicate that this particular coal feedstock responded well to dry deshaling technology (Note that the data from tests 1 and 2 could not be reported due to problems associated with laboratory analyses of these particular samples). The minus 6 mm material which represented 11.4% of the feed, and contained 45% ash are not reported in this study. With the exception of the combination of test parameters evaluated in test run 6, the deshaling unit rejected a substantial amount of high-ash (>60% ash) material in all cases with only modest losses of combustible matter. In test run 14, the deshaling unit rejected material as high as 66% ash with a product yield of about 80% and with only about 13% loss in combustible matter (i.e., approximately 87% energy recovery).

A total of 13 tests were conducted at the Bhushan Power & Steel complex. The raw feed ash content for these coal samples ranged from 50-54%. The test results for plus 6 mm material, as shown in Table 4.2, show that the combustible recovery obtained for this particular coal was as low as 80% at 74% yield and as high as almost 93% at 87% yield. The material rejected in these tests was as high as 77% ash with a product yield of about 87% and with only about 6% loss in combustible recovery (test run 10). The minus 6 mm particles which represented 10.9% of the feed with an ash content of 52%, is not included in the study. The variation in performance is due to the different settings for the operating parameters for the unit.

Table 4.1 Pilot scale performance data for Aryan Energy.

Test Run	Combustible Recovery %	Reject Ash %	Reject Yield %
3	91.00	67.67	14.75
4	86.84	60.87	17.74
5	81.13	60.37	24.38
6	88.38	58.92	14.97
7	85.81	64.09	20.35
8	92.67	64.60	10.48
9	91.52	61.60	11.89
10	95.17	62.20	6.83
11	82.31	61.50	23.91
12	86.55	63.05	20.02
13	97.53	64.70	3.53
14	86.69	66.31	20.46
15	85.33	66.76	23.11
Average	88.53	62.69	15.35

Table 4.2 Pilot scale performance data for Bhushan Power & Steel.

Test Run	Combustible Recovery %	Reject Ash %	Reject Yield %
1	90.01	72.59	15.87
2	91.01	72.58	14.54
3	91.64	70.72	13.59
4	88.21	70.19	18.27
5	88.90	69.17	16.55
6	90.41	73.37	15.86
7	81.26	71.36	26.54
8	85.81	72.98	22.21
9	88.19	70.19	19.10
10	93.65	77.37	13.41
11	85.81	70.50	20.60
12	80.63	66.39	26.54
13	87.83	64.02	16.04
Average	87.95	70.88	18.40

The testing sessions at the Aryan Energy and Bhushan Power & Steel complex sites successfully demonstrated that the dry coal cleaning technology from Eriez Manufacturing was capable of removing high-ash material from the raw feed presently being processed by these coal groups. At Aryan Energy, the technology successfully met the original project goals of recovering 85-90% of the coal heating value, while rejecting significant amounts of incombustible high-ash (greater than 65% ash) rock. Similarly, at Bhushan Power & Steel complex, the unit met the original project goals of recovering more than 90% of the coal heating value while rejecting significant amounts of incombustible high-ash (greater than 70% ash) rock.

Composite performance plots of all results from two test sites are summarized in Figures 4.1 and 4.4 for the Aryan Energy and Bhushan Power and Steel sites, respectively. These plots show the combustible recovery as a function of clean coal ash for each series of test runs. The full performance curve was plotted in each case using samples collected at different points along the length of the separating table. In addition, breakout plots for six of the best test runs at each site are summarized in Figures 4.3 and 4.6. These plots provide additional insight into the degree of separation since they show both the combustible recovery versus clean coal ash percent as well as the expected ash rejection versus reject ash content. Finally, Figures 4.2 and 4.5 are included to show the best overall performance levels expected for these two coals. For the Aryan Energy test run 14, it was possible to attain 90% combustible recovery while maintaining a reject ash of about 68% and a yield to reject of about 17%. Likewise, for Bhushan test run 10, the data indicate that a reject ash of over 75% would be produced with about 18% yield to reject at a 90% combustible recovery of coal to the clean product. As such, both sets of results suggest that the dry coal deshaling technology is a viable option for the removal of high-ash impurities while still maintaining high recoveries of valuable combustible matter.

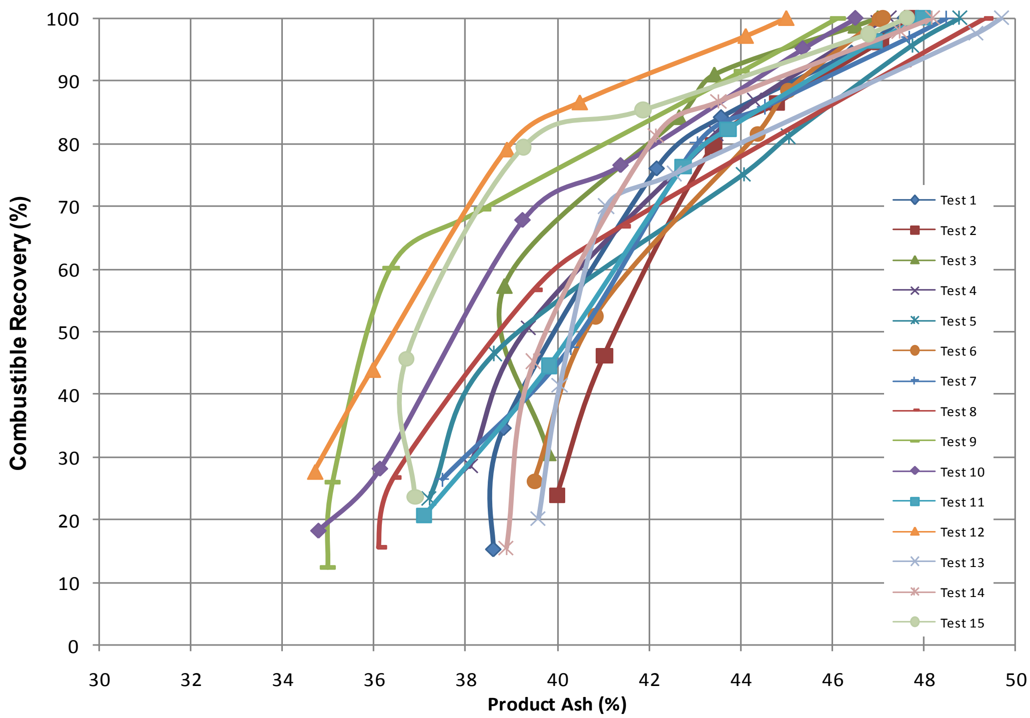


Figure 4.1 Summary of test results for Aryan Energy.

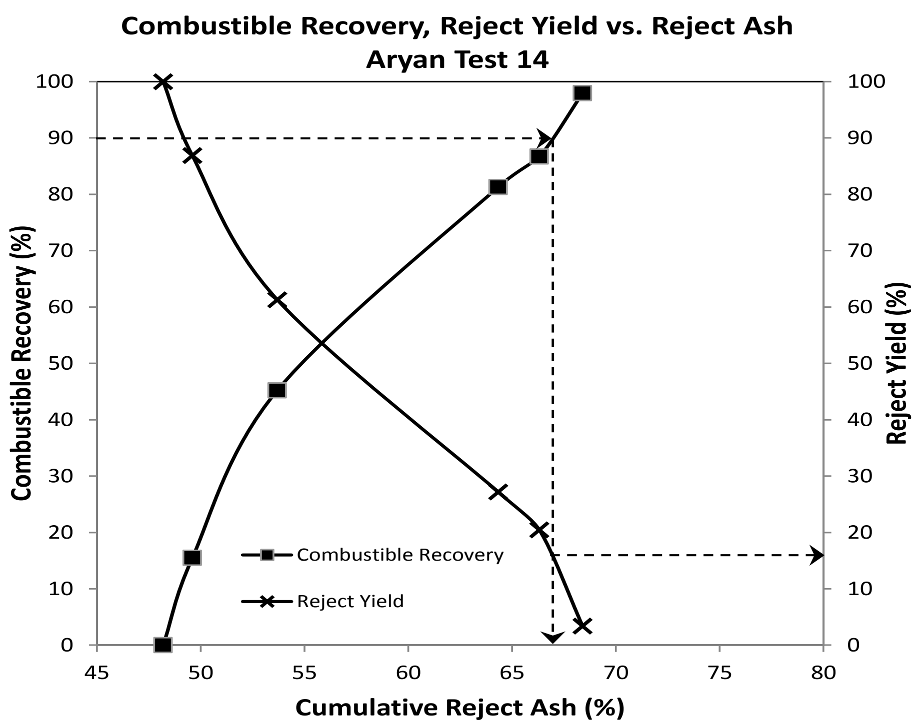


Figure 4.2 Best performance for Aryan Energy.

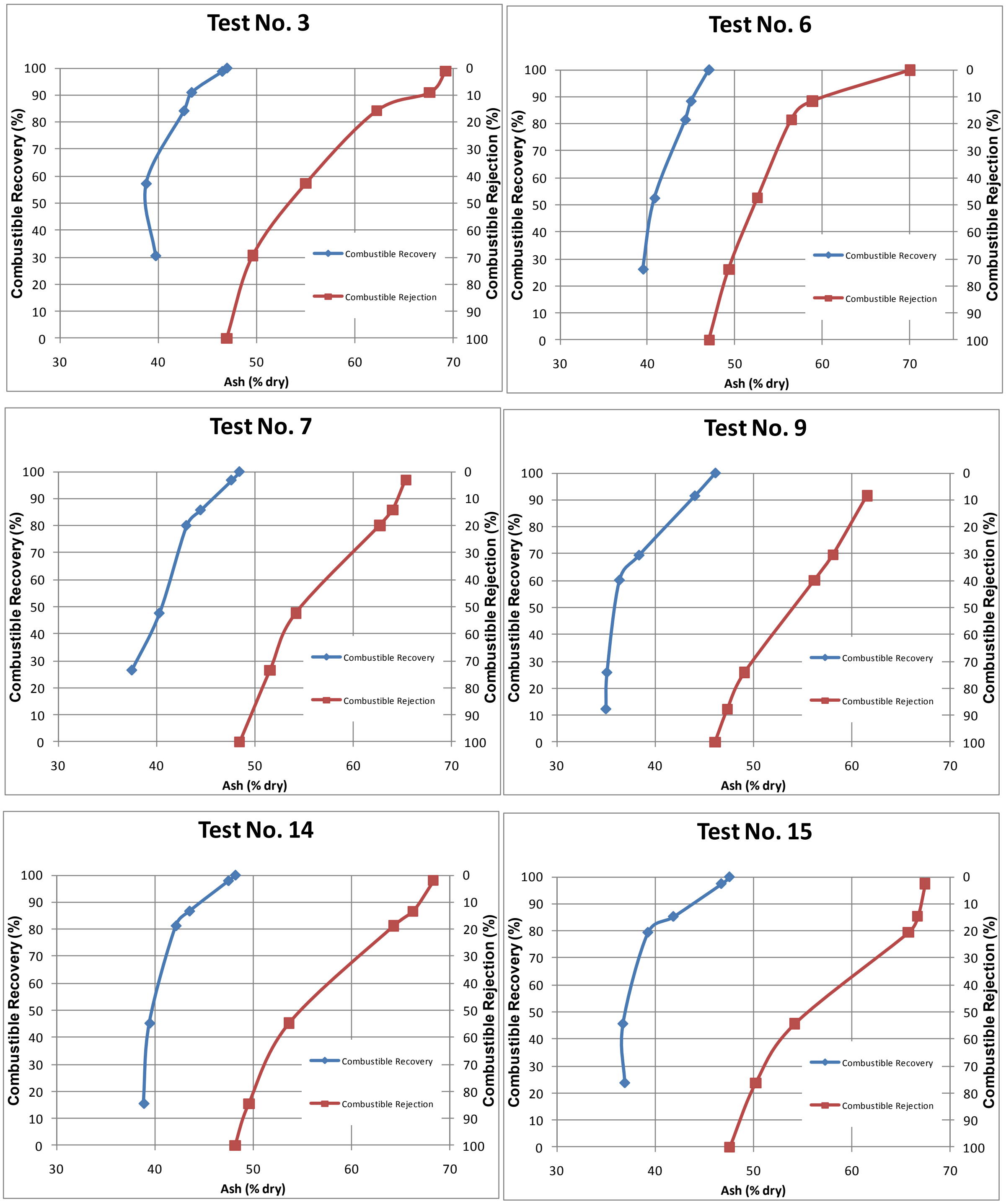


Figure 4.3 Data obtained from the best test runs for Aryan Energy.

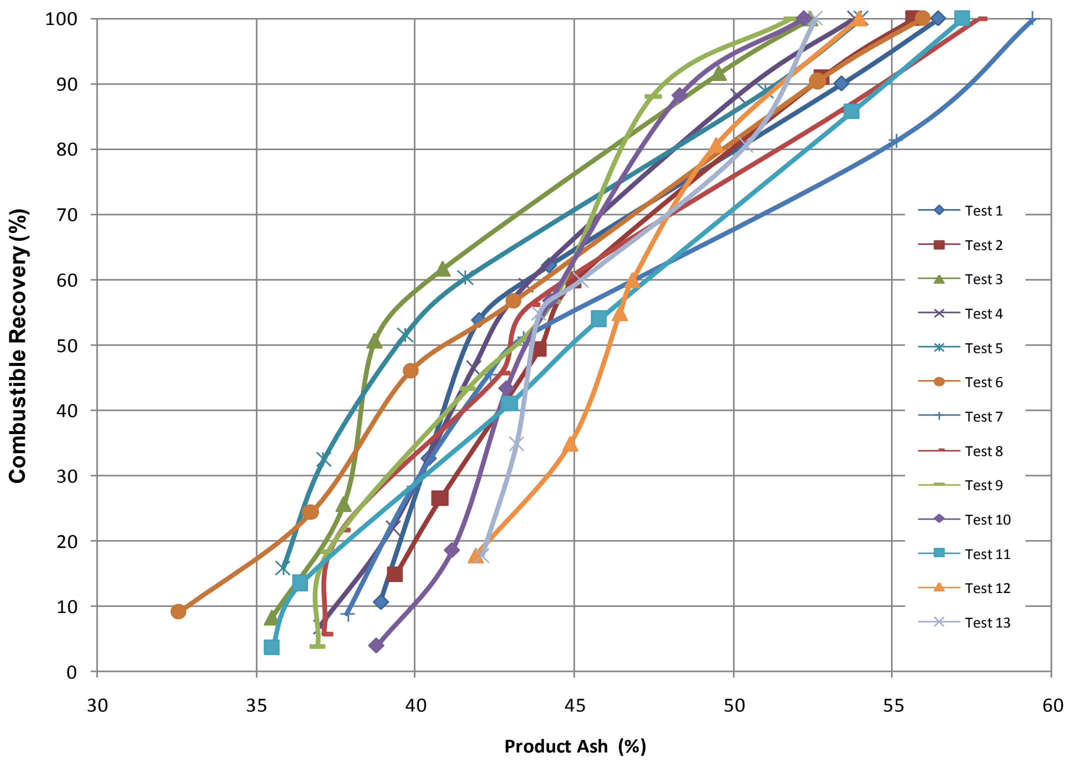


Figure 4.4 Summary of test results for Bhushan Power and Steel.

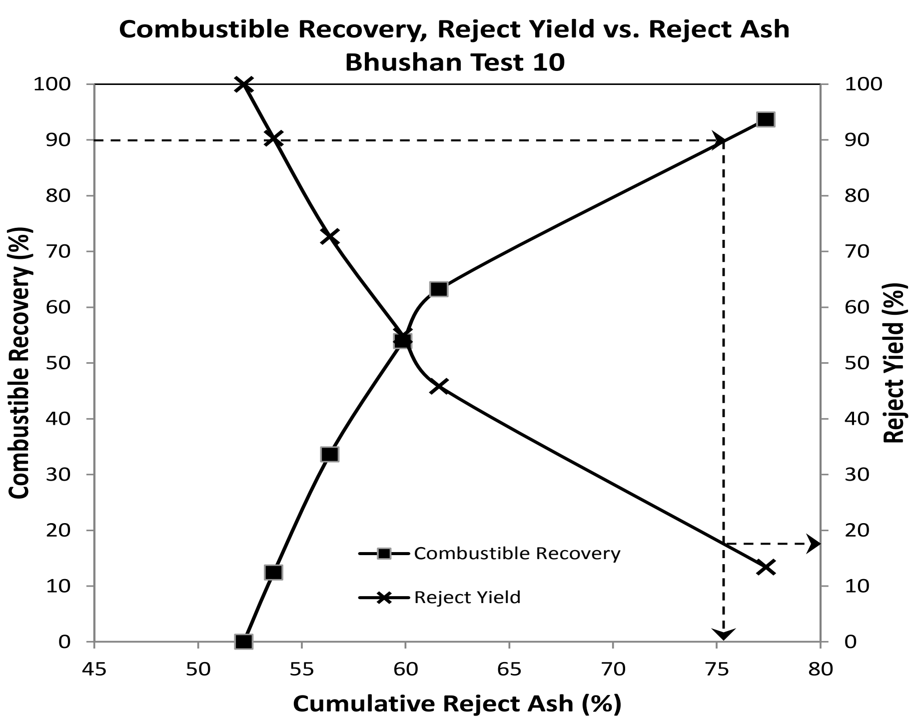


Figure 4.5 Best performance for Bhushan Power and Steel.

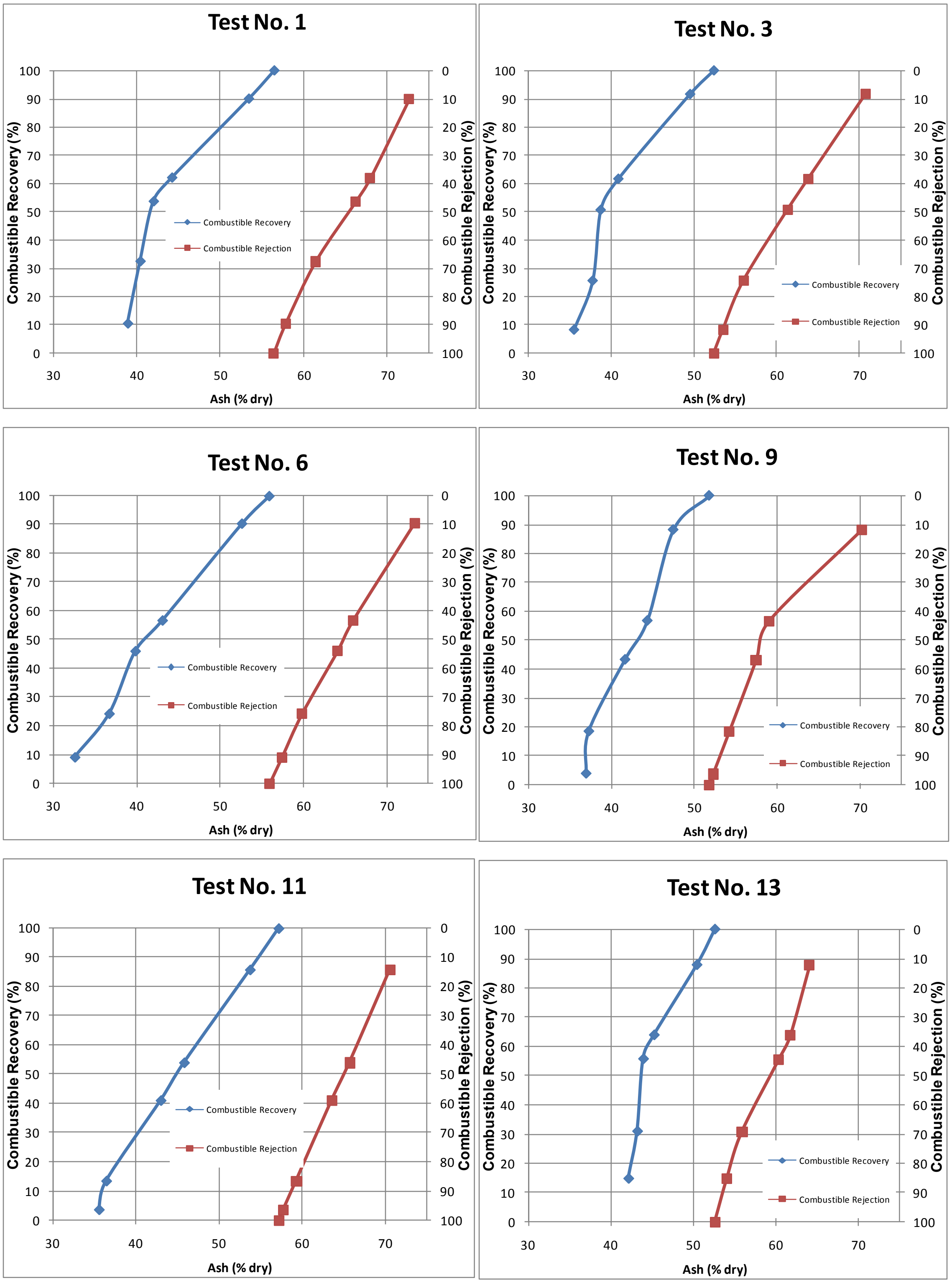


Figure 4.6 Data obtained from the best test runs for Bhushan power and Steel.

4.2.2 Pilot Scale Testing – Round II

A total of 21 tests were conducted to evaluate coals delivered to the Kargali Washery facility, but the corresponding laboratory analysis was obtained for only 14 tests. The 75 mm x 0 feed coal contained 52 to 59% ash, from which minus 6 mm represented 48%; the corresponding ash content was 41%. The results for plus 6 mm material, as shown in Table 4.3, indicate that the combustible recovery for this particular coal ranged from 81% to 94%, with corresponding clean coal yields from 68% to 87%. The data clearly indicate that high-ash (greater than 70% ash) material can be rejected by the dry coal cleaning technology with a minimal loss in combustible recovery. Depending on the settings of the operating variables for the unit, the rejected material could be as high as 86% ash with a clean coal yield of about 80% and only about 7% loss in combustible matter (i.e., approximately 93% energy recovery, test run 11).

Table 4.3 Ash rejection data for Kargali Washery.

Test Run	Combustible Recovery %	Reject Ash %	Reject Yield %
7	89.61	83.40	27.77
8	93.38	79.00	16.17
10	85.89	77.89	27.19
11	92.57	85.92	20.73
12	94.43	84.99	16.15
13	85.65	71.09	25.13
14	89.81	82.87	25.07
15	93.89	81.55	16.64
16	81.26	74.47	31.54
17	95.19	83.10	12.64
18	91.03	78.81	20.07
19	89.48	76.56	21.15
20	92.03	80.00	20.15
21	88.84	79.26	24.74
Average	90.22	79.92	21.80

Figure 4.7 shows a summary of recovery-ash performance curves for all tests run at the Kargali Washery facility, while Figures 4.8 and 4.9 show the breakout plots of recovery-clean ash and rejection-reject ash for the six best runs. The test data for the best overall test run are plotted separately in Figure 4.10. The raw test data indicate substantial variability in the quality of the feed coal, with raw ash values ranging from 48-62%. From these feeds, clean products with ash contents ranging from 35-45% were obtained at reasonable recoveries.

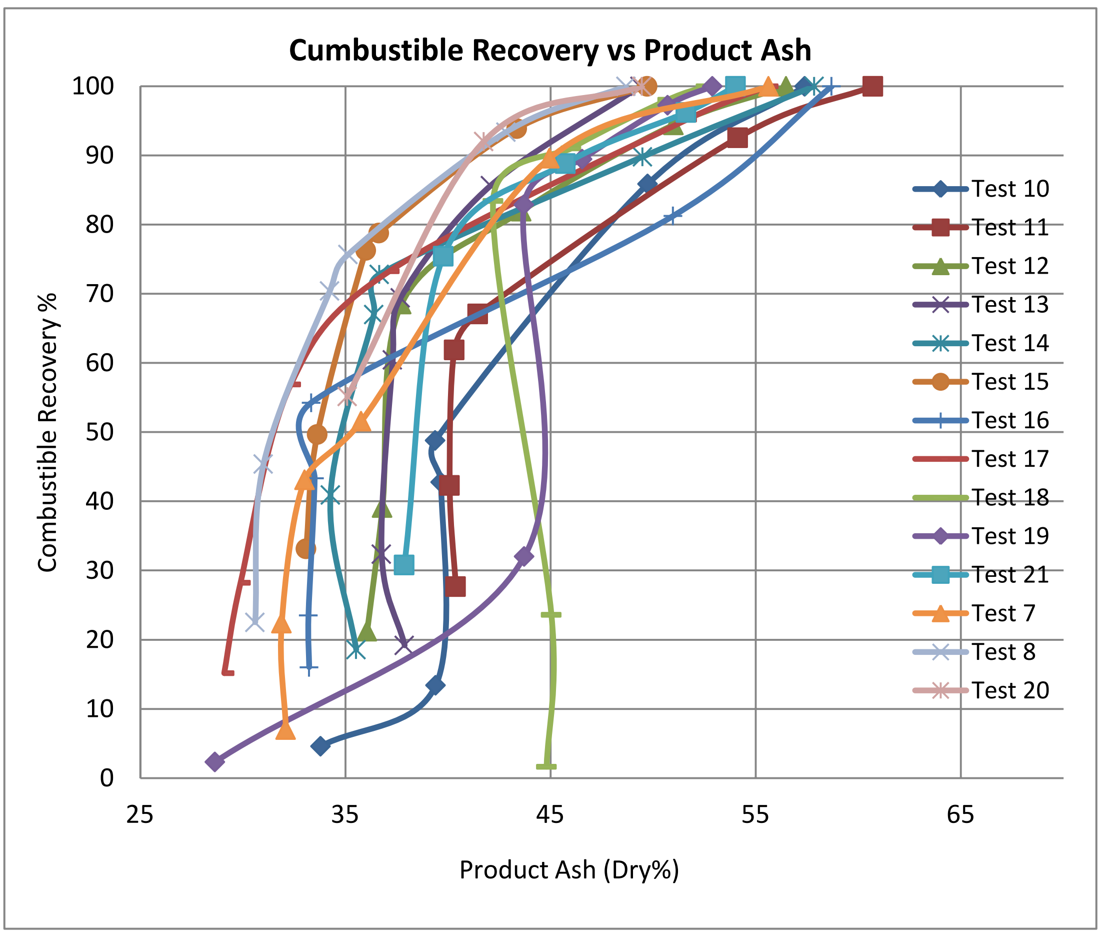


Figure 4.7 Summary of test results for Kargali Washery tests.

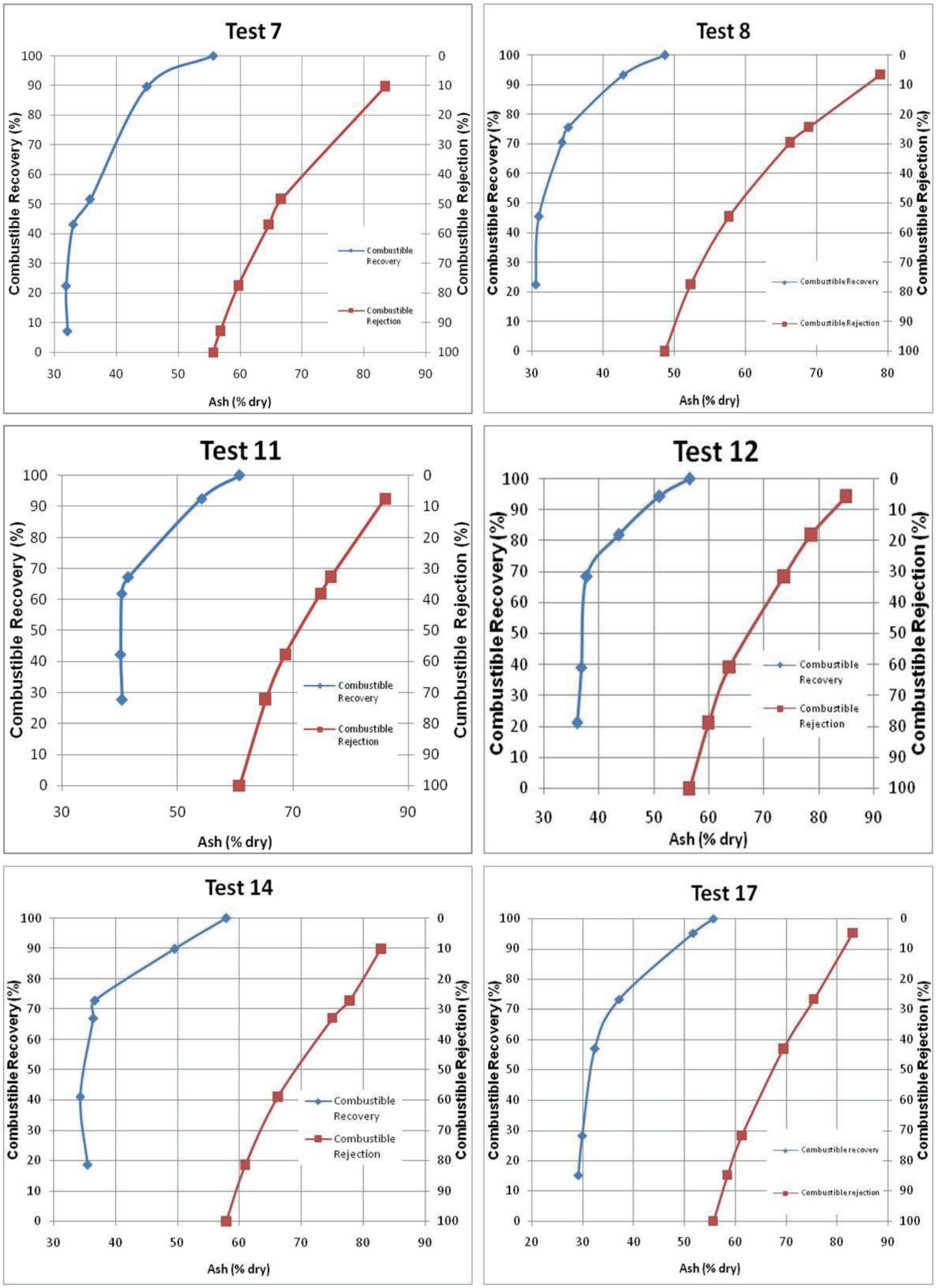


Figure 4.8 Performance data for six tests at Kargali Washery – I.

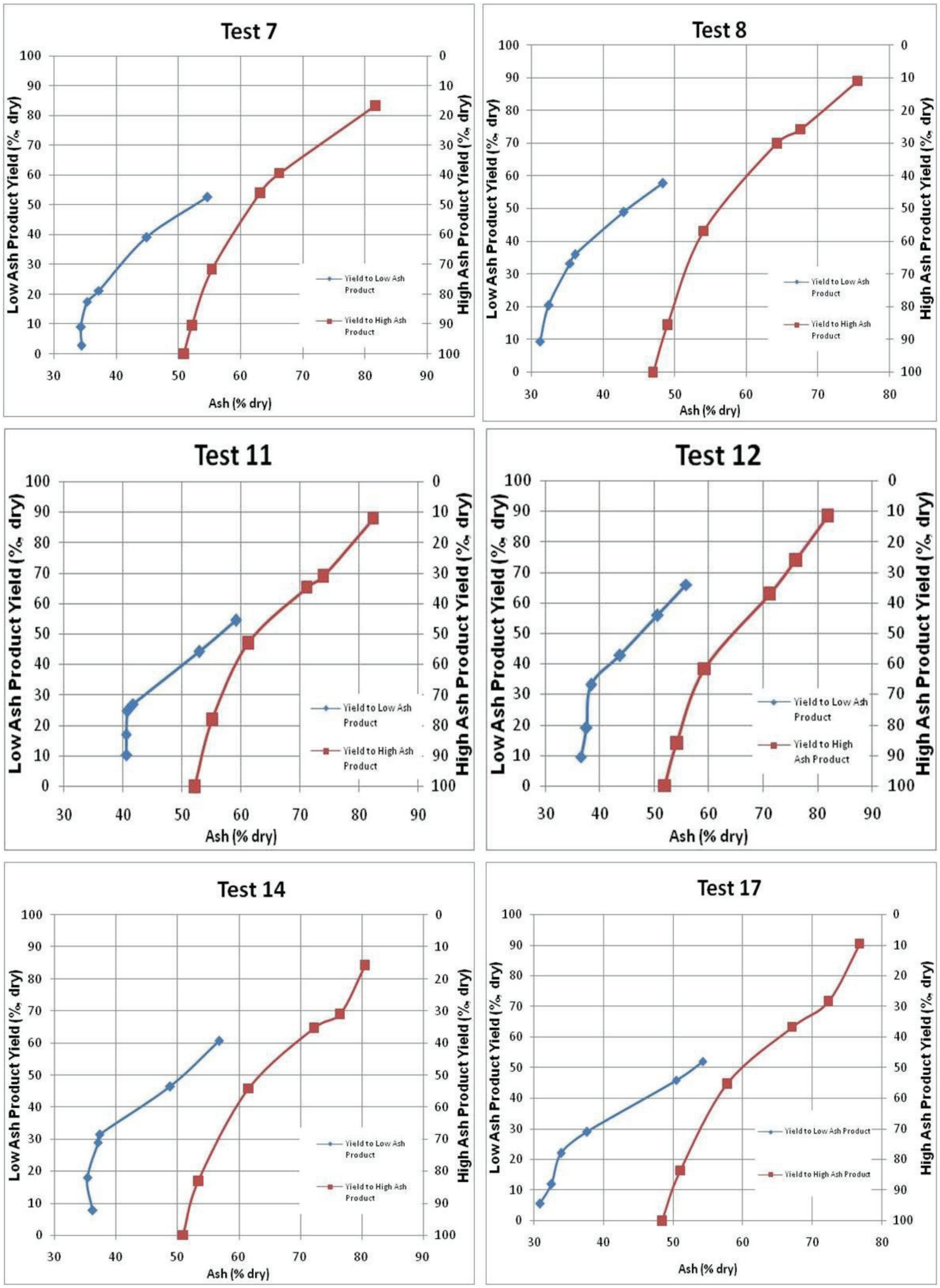


Figure 4.9 Performance data for six tests at Kargali Washery – II.

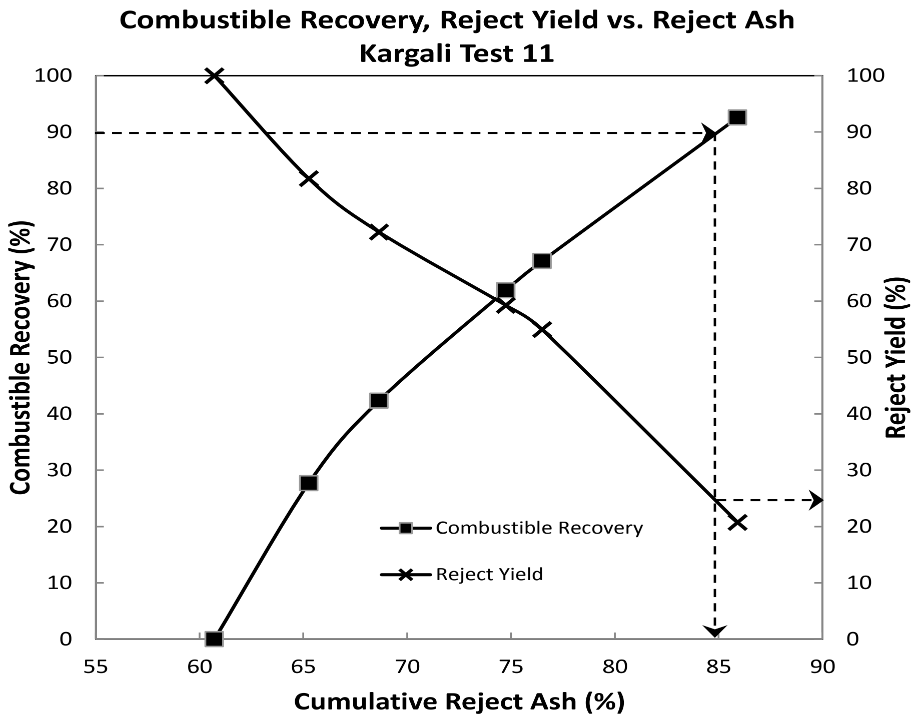


Figure 4.10 Best performance for Kargali Washery.

During the field evaluation at the Kargali Washery facility, six tests were conducted on a semi-coking coal from West Bokaro. Unfortunately, the experimental results for only three of the six tests have been received to date. The feed ash ranged from 27% to 34%. Due to the limited number of test runs, optimum operating conditions for this particular coal failed to be identified. As illustrated in Table 4.4 and Figure 4.11, the best result (test run 6) was a reject containing 53% ash, with a very low loss of combustible material, less than 4%. Additional test work would be required to determine whether an improved level of separation performance could be obtained with this particular coal.

Table 4.4 Ash rejection for semi – coking coal from West-Bokaro.

Test Run	Combustible Recovery %	Reject Ash %	Reject Yield %
1	96.66	41.63	23.80
5	97.46	50.48	19.56
6	96.06	53.06	27.88
Average	96.73	48.39	23.75

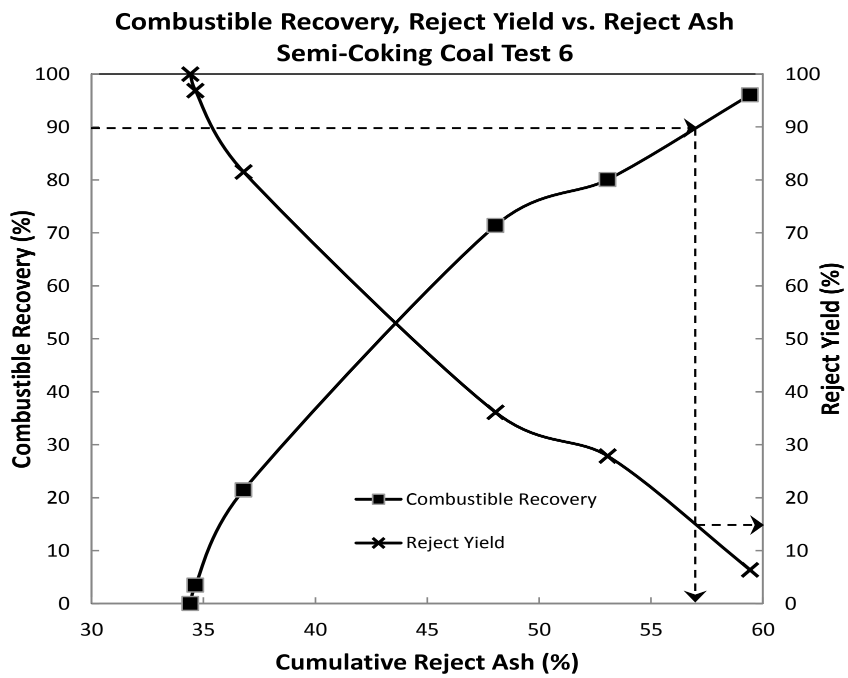


Figure 4.11 Best performance for semi-coking coal from West-Bokaro.

4.2.3 Pilot Scale Testing – Generic Observations

Several generic observations related to the operation of the pilot-scale test unit were made during the on-site testing programs. For example, visual observations revealed that particle shape impacted separation performance. Flat or saucer shaped particles tended to “skate” across the surface of the fluidized bed and report to the clean coal stream regardless of density. Also, some percentage of finer material in the feed stream appeared to aid the separation process by enhancing the fluidization of the bed. Unfortunately, the majority of the finer material reported to the clean coal stream regardless of quality. It was also observed that the longitudinal slope, table frequency, and fluidizing air volume were the most critical operating parameters that control both coal recovery and product grade. When the feed coal contains large amounts of high-density rock, a lower slope angle provided less resistance for the rock to move towards the reject discharge end of the table. The table frequency and fluidizing air volume parameters also required adjustment to provide the proper movement and optimum separation environment for high-ash feed materials (Bratton, 2010).

4.3 FEASIBILITY ASSESSMENT

4.3.1 Technical Feasibility

The testing session at the Aryan Energy and Bhushan complex site successfully demonstrated that the dry coal cleaning technology from Eriez Manufacturing was capable of removing high-ash material from the raw feed presently being processed by these coal groups. At Aryan Energy, the technology successfully met the original project goals of recovering nearly 85-90% of the coal heating value while rejecting significant amounts of incombustible high-ash (greater than 65% ash) rock. Similarly, at Bhushan complex, the unit met the original project goals of recovering more than 90% of the coal heating value while rejecting significant amounts of incombustible high-ash (greater than 70% ash) rock.

In the second round of the pilot scale testing at Kargali washery (CIL), the unit again successfully demonstrated that the dry coal cleaning technology was capable of removing high-ash material from the raw feed presently being processed by the washery. The technology successfully met the original project goals of recovering nearly 85-90% of the coal heating value while rejecting significant amounts of incombustible high-ash (greater than 70% ash) rock. With Tata Steel West Bokaro coking coal, the unit was successful in removing rocks (greater than 40% ash) keeping the combustible substance up to 97% in raw feed coal.

As such, the pre-combustion removal of these impurities increased coal heating value and reduced ash disposal and coal transportation requirements without introducing new issues associated with traditional wet coal processing systems (i.e., slurry disposal, water pollution, etc.). More importantly, the calculated improvement in profitability resulting from the enhanced fuel quality provides an important financial incentive for Indian companies to implement this clean coal technology for other important purposes such as environmental control. Other control measures for reducing downstream emissions of CO_2, particulates and air toxics do not offer a similar financial return and require substantial capital investments that may be difficult to adopt given India's rapidly growing demands for energy infrastructure and other public services. As such, the project team members are very encouraged by these recent developments and are moving ahead with testing of the pilot-scale technology for several other private and governmental coal groups in India.

4.3.2 Economic Feasibility

Preliminary technical and economic analyses indicate that large savings in material handling, processing and storage costs can be gained by applying the dry deshaling approach to many of the coals currently mined in India. These analyses suggest that overall transportation costs may be reduced by up to 30% when compared on an equivalent heat value basis. This value is significant when one considers the fact that many of the railing distances can exceed 1000 km over rail lines in India that are typically overloaded and already operating at full capacity. In addition, the proposed deshaling systems also offer direct cost reductions since the removal of rock reduces grinding demands, improves boiler efficiency, increases carbon burn-out, reduces slagging/fouling problems, decreases erosion rates and lowers bottom ash/fly ash loads.

The economics of deshaling for steam coal applications are understood on the basis of an improved heating value and the fact that utilities pay on the basis of US $/MMBtu (1 million BTU) rather than US $/ton. Consider a situation where a coal with a heating value of 12500 Btu/lb is worth US $50/ton. The total heating value for the coal is 25 MMBtu (= 1 ton x 2000 lb/ton x 12,500 Btu/lb). As such, the monetary value of the coal is US $2 per MMBtu (= $50/25 MMBtu). Thus, improving the heating value through deshaling provides the potential to significantly improve revenue (Honaker and Luttrell, 2007).

4.3.3 Environmental Benefits

It is also important to note that the direct cost benefits provide a significant financial incentive for the implementation of dry coal beneficiation processes that also have positive impacts for the environment. The removal of high-ash rocks will reduce the emissions of many air toxics since potentially hazardous air pollutant precursors typically associate with the mineral components in run-of-mine coals. The disposal of rocks prior to combustion provides a waste that is coarser and substantially less reactive in the environment than the high-surface area ash from the combustion process. Furthermore, the use of a dry process eliminates potential hazards that are commonly associated with wet processes that are traditionally used in modern coal preparation facilities.

The use of beneficiated coals may increase thermal efficiencies by up to 4-5%, which can provide a corresponding reduction in CO_2 emissions by up to 15%. For a longer term perspective, the use of deshaling processes to increase the availability of higher-quality coals will serve as the first logical step in helping India to implement state-of-the-art CCT processes to reduce total CO_2 emissions. Direct cost benefits associated with improved energy efficiency reduced waste handling and lower transportation fees have the potential to pay for the deshaling technologies that make these environmental gains possible. These goals are consistent with those outlined by the APP "Coal Mining Task Force," and also helps to address some of the objectives/goals of other APP Task Force groups such as "Cleaner Fossil Energy Task Force" and "Power Generation and Transmission Task Force."

4.3.4 Specific Site Recommendations

The processing facility at Aryan Energy presently utilizes a dense medium vessel to produce a low ash product and at times uses the water-based barrel washer to deshale feed for a high-ash product. The company installed a shaking table technology from China several years ago, but the circuit has only provided an ash reduction of 5% due to inadequacies in the design of the equipment. The Eriez dry coal cleaning technology could be used to deshale the feed presently being treated in the water-based barrel washers. Processing the material without water would greatly enhance the thermal heating of the clean coal product. The dry coal cleaning technology demonstrated during the testing session almost twice the ash reduction for the feed material. The existing shaking table equipment could be removed and replaced with the technology demonstrated during the testing session.

The dry coal cleaning technology offers a couple options for improving the operation at the Bhushan complex. One option would be to pre-treat the feed to the heavy medium cyclone washery which would either increase the throughput or reduce the required operating time. The dry coal cleaning technology could also be considered as a stand-alone cleaning facility for upgrading a portion of the ROM coal sources that respond favorably to the technology.

Extensive testing would be required to identify the coals that would achieve the best separating efficiency.

The CIL processing facility at Kargali presently utilizes a ROM jig to produce a deshaled low ash product which is combined with the minus 50 mm high ash dry raw product. The Eriez dry coal cleaning technology could be used to deshale the dry raw screen undersize material (minus 50 mm) to remove high ash rock presently in the dry bypassed material. In addition, processing the oversize material (presently treated in the jig) without water would greatly enhance the thermal heating value of the clean coal product. The existing deshaling jig and associated equipment could be replaced with the technology demonstrated during the testing session.

The dry coal cleaning technology could also be used to pre-treat the feed to a conventional coal processing facility by removing high ash rock. Removing high ash rock from the feed will provide a higher clean coal production for the same raw coal feed rate. The deshaling operation can be located at the mine site, which will eliminate transporting the rock and will reduce transportation cost. The deshaled reject material can be used for mine backfilling.

CHAPTER 5 MODELING OF DRY DENSITY BASED SEPARATION METHOD

5.1 INTRODUCTION

Dry Deshaling of coal is a density-based pneumatic separation process. The Eriez manufactured deshaling air table generates a helical motion with air stratification and produces multi products of clean coal, middlings and refuse. The mixture of air and very fine coal particles from the feed act as a medium when suspended by the combined action of shaking and vibrations. The technology is economically beneficial to coal industry and has tremendous scope for future work; therefore, a model of the process would greatly benefit coal producers and researchers.

The separation efficiency of the process is highly depends on many variables such as physical properties of the particles, such as shape and size, and the air table operating parameters which includes the horizontal and vertical angles of the table, table vibration, and the main-fan speed (Honaker and Luttrell, 2007). Because of a large number of particles involved with randomly distributed sizes and shapes, it is impossible to completely describe this complex system from first principle considerations. However, it may be possible to gain useful insight into the operational behavior of the process through the use of process engineering tools if some simplifying assumptions are made.

The model developed in this study uses discrete element modeling to describe the separation behavior of the particles on the density based dry deshaling process. The coupled modeling technique allows relaxation of simplifying assumptions related to the particle-phase tensor. Collisions are treated on a mechanical basis and leads to more realistic reproduction of the actual behavior of the solids. In the method, the motion of individual particle is obtained by solving Newton's second law of motion and mixed air flow by the Navier-Stokes equation.

5.2 MODEL THEORY AND BACKGROUND

The separation of particulate species with respect to specific gravity across the bed height in density based separation methods (e.g. air-jigging, air tabling) is a result of stratification of particles under the influence of air and gravity forces. Various operating parameters affect the stratification process, which include amplitude and frequency of table vibrations, bed thickness, rate of air-flow, and feed characteristics. Several mathematical models have been proposed in the past to correlate the important process variables and they are essentially based on density separation theories or physical concepts. These models have been broadly classified as (Mishra and Mehrotra, 2001):

- Classical theory based on single particle behavior by Gaudin.
- Potential energy theory by Mayer; and Tavares.
- Statistical analysis by Vinogradav et al.
- Energy dissipation theory by Jinnouchi and Kawashima; and Rong and Lyman.
- Empirical analysis by Karantzavelos and Frangicos; Rong and Lyman.
- Dispersion theory of particle suspension by Vetter et al.

A comprehensive description of above theories has been given by Lyman (1992). It is evident from his analysis that these theories only provide a qualitative explanation of the stratification process. The model that can describe motion of every individual particle in constant air flow and vibration is needed to study many sub-processes such as segregation, stratification, dynamic porosity etc.

The density based separation model used in this study is based on a three-dimensional mathematical description of solid-solid and air-solid interactions. In the model, the force balance on the particle is extended to account for the effect of air on the particles. Thus, the force balance on a particle in the air medium is:

$$\mathbf{m}\frac{\mathbf{dv}}{\mathbf{dt}} = \mathbf{f_{pp}} + \mathbf{f_{ap}} + \mathbf{mg} \quad [1]$$

where m is the particle mass, v is the particle velocity, g is the acceleration of gravity and t is time. The total force exerting on each particle is the combination of force of gravity (*mg*), air-particle and apparent fluid- particle interaction force (f_{ap}) and, particle – particle and particle - wall interaction force (f_{pp}). The particle and fluid - particle interaction force $\mathbf{f_{ap}}$ mainly consists of the buoyancy force $\mathbf{f_b}$, which is the force created by surrounding particles (apparent fluid) on an individual particle, and the drag force $\mathbf{f_d}$ generated because of the relative velocities of the particle. The brief account of the model generation leading up to the calculation of the forces acting on a particle due to collisions with other particles and its interaction with the apparent fluid is discussed later. Because of the limitation of this approach, these forces are kept constant (in Z direction only) on the individual particles throughout the model run, i.e.:

$$\mathbf{f_{ap}} = \mathbf{f_b} + \mathbf{f_d} \quad [2]$$

5.2.1 <u>The Linear Contact Model</u>

Cundall (1979) described solid – solid interaction of particles by discrete element method (DEM), in which particles are considered as discrete elements and are indestructible. In the current work, particles interact with each other, and any other element present such as walls, when they make physical contact. The particle trajectory can be determined by applying Newton's second law of motion to the particles and the force displacement law at the contact 'x'

(Figure 5.1). In case of multiple bodies, the approach depends on an efficient scheme for identifying contacts and time tracking.

The force- displacement law relates the relative displacement between two entities in contact to the contact force acting on the entities. The force-displacement law operates at a contact and can be described in terms of a contact point, $x_i^{[C]}$, lying on a contact plane that is defined by a unit normal vector in the *i*th time step, n_i. The contact point is within the interpenetration volume of the two entities. For ball-ball contact, the normal vector is directed along the line between ball centers. For ball-wall contact, the normal vector is directed along the line defining the shortest distance between the ball center and the wall. The contact force is decomposed into normal component acting in the direction of the normal vector and a shear component acting in the contact plane. The force-displacement law relates these two components of force to the corresponding components of the relative displacement via the normal and shear stiffnesses at the contact.

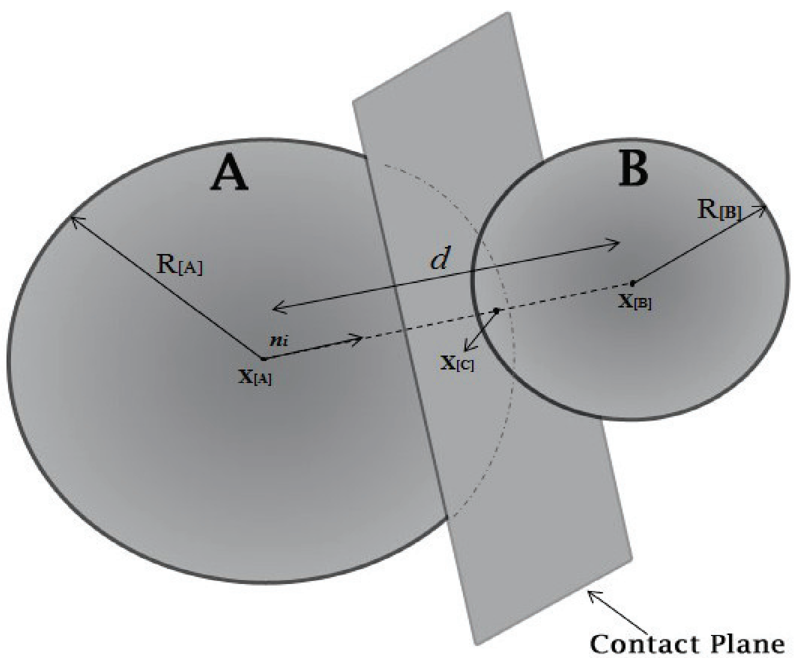


Figure 5.1 Notation used to describe ball-ball contact.

The force-displacement law can be readily described for ball-ball contacts. For ball-ball contact, the relevant equations are presented for the case of two spherical particles, labeled A and B in Figure 5.1. Mathematically, this criterion can be described by:

$$\boldsymbol{n_i} = \frac{\boldsymbol{x_i^{[b]}} - \boldsymbol{x_i^{[a]}}}{\boldsymbol{d}} \quad [3]$$

where $x_i^{[a]}$ and $x_i^{[b]}$ are the position vectors of the centers of spherical particle A and B, and d is the distance between the spherical particle centers:

$$d = |\boldsymbol{x_i^{[b]}} - \boldsymbol{x_i^{[b]}}| \quad [4]$$

The contact force vector F_i (which represents the action of the ball A and ball B for the ball-ball contact) can be resolved into normal and shear components with respect to the contact plane as:

$$F_i = F_i^n + F_i^s \quad [5]$$

where F_i^n and F_i^s denote the normal and shear component vectors, respectively.

The linear contact model is defined by the normal and shear stiffness of the two contact entities. The normal stiffness K^n (force/displacement) at the contact is the secant modulus relates to the total displacement and force. The shear stiffness k^s is the tangent modulus relates incremental displacement and force.

5.2.2 The Fluid Model

Mineral particles differ in size and specific gravity. In the current study, the effect of the apparent fluid on the motion of the particles is computed in a simplified manner. The coupling term between the equations of the particle and fluid motion is the fluid-particle interaction force,

$\mathbf{f_{ap}}$. The two main forces, which include the force of buoyancy due to the apparent fluid (F_b) and effective drag force (F_d), are studied with force of gravity (*mg*) for the segregation of the particles in the model. As stated earlier, these forces are kept constant in the model throughout the simulations because of the limitation associated with the software package employed.

As each particles falls, it displaces the apparent fluid, which in turn must move upward. In concentrated system of high solids content, this causes an upward fluid motion which interferes with the motion of the other particles. The net effect is a slower, hindered settling rate for the group of the particles as compared to free settling terminal velocity of one particle by itself. Maude and Whitmore (1958) modeled the hindered settling process as a power law in the concentration (volume fraction of the fluid phase, $\in$).

$$U_{slip} = U_t \in^n \qquad [6]$$

In this case, U_t is the observed velocity for a single particle relative to stationary fluid falling through a clear fluid (terminal velocity), while U_{slip} is the observed velocity of the particle in hindered settling conditions and $\in^n$ accounts for the hindered settling effect. The parameter *n* is determined experimentally and has dramatic effect on calculated values of hindered settling velocity. For spherical particles, *n* varies from 2.3 to 4.5 depending upon the smoothness of the particle surface. Geankoplis (1993) suggests that, in case of hindered settling conditions, the fluid phase density (ρ) can be replaced with system bulk density (ρ_{bulk}) which is defined in the model as,

$$\rho_{bulk} = \in \rho_{Air} + (1- \in)\, \rho_{app} \qquad [7]$$

where ρ_{Air} is the density of air equal to 1.2 kg/m^3 and ρ_{app} is the apparent density defined as the average density of all the particles and voids present in the system volume.

The drag force F_d (written for the regime where Newton Law is applicable) for turbulent flow is given by:

$$F_D = \frac{1}{2} \text{ x } C_d \text{ x } A_{proj} \text{ x } \rho_{bulk} \text{ x } U_{slip} \quad [8]$$

where C_d is the drag coefficient (for Reynold number > 1, C_d = 0.44, A_{proj} is the projected area of spherical particle over which the drag force is acting (A_{proj}= π $d_p^2/4$, where d_p is particle diameter), ρ_{bulk} is the bulk density of the particle system described in Equation [7], U_{slip} is the slip velocity of the particle described in Equation [6].

The force of buoyancy, F_b, is defined by vertical motion of spherical particle in apparent fluid. The apparent fluid is considered to be the group of particles of different specific gravity surrounding an individual particle. Thus, the force of buoyancy on single spherical particle is given by:

$$F_B = (\rho_p - \rho_{app}) V_p \, g \quad [9]$$

where g is the acceleration of gravity equal to 10 m/sec^2 (- Z direction), V_p is the volume of single particle, ρ_p is the density of individual particle, and ρ_{app} is the average density of all the particles in the system. The latter value is assumed constant throughout the simulation runs.

The variation in potential energy when two particles of different density interchange positions in a settled bed is the driving force for stratification. Consequently, the density difference $(\rho_p - \rho_{app})$ between the particle density and the apparent density of the medium is an important parameter that defines the migration of the particle upward or downward. If $\rho_p > \rho_{app}$ the particle will move downwards, while if $\rho_p < \rho_{app}$ the particle will move upward.

5.3 DISCRETE ELEMENTAL MODELING

Numerical methods for computing the motion of objects are used in many research applications today. Some methods focus on the problem as a holistic, or continuum. Other methods focus on many tiny pieces within the system in order to represent the system in a model. Discrete element method (DEM) is a numerical method for computing the motion of a large number of particles that represent a system.

DEM was first applied by Cundall (1979) in order to address issues in rock mechanics. Cundall's other early studies focused more on microscopic and macroscopic characteristics of many tiny discs. In one paper, the behavior of soil was modeled (Cundall, 1983) using a two dimensional system that mainly determined material behavior after applying many different exterior boundary conditions. The program Cundall used during this time was titled BALL. This program appears to be much like the simpler 2D DEM programs used today.

Williams and Hocking in 1985 explained that DEM was more of a generalized finite element method. This is true in that DEM looks at the individual particles within the system and provides data according to each individual sphere or circle. The finite element method breaks down objects or flows into many small spheres or circles, but only does this to relate to the system as a whole. The finite element method is more of a continuum model, while DEM treats each particle within the model as its own, or as many tiny finite elements (Williams et al., 1985).

While DEM uses spherical or round particles in its models, the method is actually capable of modeling particles with non-spherical shape. This type of modeling is usually done by grouping or bonding many particles together to represent a random mass. This is extremely useful in many flow applications where non-spherical particles are present.

Discrete element models are very detailed models that usually require considerable computational power. Because each particle is treated as its own and has its own set of data, the model is usually limited to a specific number of particles. While advances in software are beginning to take place, some programs with many of thousands of particles still need a fast processor to complete simulations in a timely manner.

There are many commercial and non-commercial DEM software packages that are available today. The original Cundall designed software, BALL, is non-commercial software and is one of the oldest programs available. Particle Flow Code in 3-dimensional, or PFC^{3D}, is one of the popular programs used today. Considering it is in three dimensions, it is the most realistic of the programs and was used to develop the models in this thesis.

5.3.1 Particle Flow Code in Three Dimension (PFC^{3D})

The numerical "Particle Flow Code," or PFC, models sphere particle movement and interaction using the discrete element method. PFC can operate in either 2D or 3D. Calculations in PFC are taken over a series of time steps. This makes it easy on the computer memory in that dynamic equations are performed on every time step, rather than saving and reapplying matrices as in an implicit scheme. However, many thousands of time steps are run and calculations are done on each particle for each step. Considering each step is usually a fraction of a second, the program run time is rather lengthy. This constraint can be an issue considering many applications require a large amount of particles to properly simulate a system (Lorig et al., 1995; Itasca Consulting Group, 2004).

A PFC^{3D} simulation is started by developing a model outline. When first developing a model, the schematics must be inserted. This schematic includes any walls or particles that are necessary in representing the system to be modeled. Information can be inserted into PFC^{3D} either through a command line or through an input file coded for PFC. Once all particles and walls have been properly entered, the program will run a series of cycles. Each cycle performs the specific calculations stated by the programmer and allows the particles to interact accordingly. After each cycle is complete, the computer takes the new particle data and starts a new cycle. The cycling is then repeated until the simulation is complete. Information requested can then be collected for analysis (Itasca Consulting Group, 2004).

5.4 PFC^{3D} SIMULATION DESIGN

The simulation process has been developed in several steps, each steps being described in the following sections.

5.4.1 Development of Geometry and Vibrating Bed

The entire geometry of the unit is designed in PFC^{3D} package. The general wall-logic used in PFC^{3D} illustrates how the force-displacement law is applied at contacts between balls and general walls. If the ball contacts the general wall, the contact force is updated using the law. In the present study, the contact detection procedure for the general wall-logic is described for the case of cylindrical wall.

The cylindrical-vibratory bed structure (Figure 5.2) designed in PFC^{3D} is essentially mimics the perforated vibratory bed of an air table. The programming code was used to construct a virtual three-dimensional cylindrical structure with open faces at both ends. The fixed height of 3.0 m and normal stiffness of 2.25 x 10^7 N/m for the wall was considered. Variable diameters were used to study the effect of bed height in stratification process. To ease the simulation process, the walls were considered smooth with coefficient of friction equal to zero.

The vibratory bed was designed with the combination of number of smooth spherical balls with identical properties attached together by parallel bonds. After fixing the balls, the vibratory bed was driven by several cycles of a sinusoidal wave of given frequency and amplitude of velocity in Z-direction. Further, the frequency and amplitude of velocity varied to study their effect on the density based separation process. The properties of the balls of vibratory bed are given in Table 5.1.

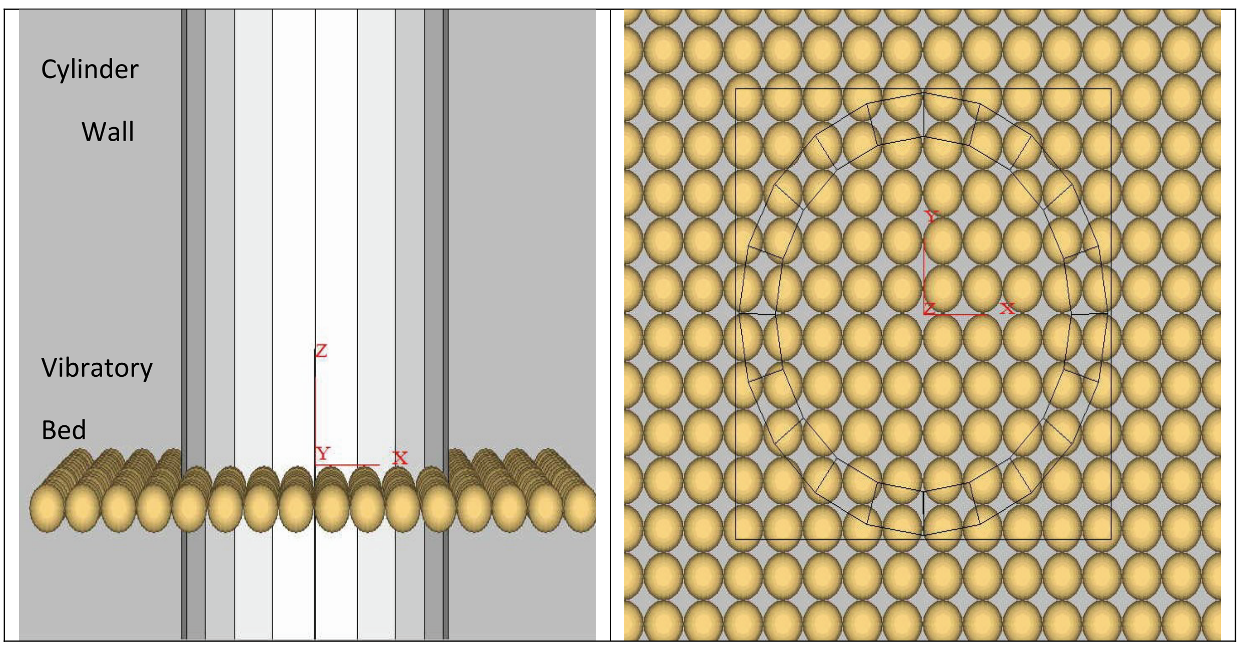


Figure 5.2 The front and top view geometry of the model.

Table 5.1 Ball properties for vibratory bed.

Ball Properties	Values
Density of each ball	4000 kg/m^3
Normal stiffness	1 x 10^8 N/m
Shear stiffness	1 x 10^8 N/m
Parallel bond radius	0.04 m
Parallel bond normal stiffness	1 x 10^4 N/m
Parallel bond shear stiffness	1 x 10^4 N/m
Parallel bond normal strength	1 x 10^2 N/m
Parallel bond shear strength	1 x 10^2 N/m

5.4.2 Generation of Particles

An assembly of 1200 spherical particles was generated inside the cylindrical-vibratory bed region. The locations of the particles were chosen randomly inside the cylinder geometry to make them fall under the force of gravity on the vibratory bed. Each spherical particle was assigned a unique ID number in the model. The particle properties are shown in Table 5.2. The type of particles was assigned in the code as per their density ranges, with each of these ranges assigned specific colors to visualize the separation in the model. Usually, the feed in dry air table separator contains a large percentage of low-density coal mixed with high-density rock material. Similarly, the model simulations were run with similar kind of feed. Mono-size particle of radius 25 mm (0.025 m) was considered in most of the model cases to make the simulations easier. The surface of the particles is considered smooth. Since preliminary tests show that friction increases simulation time and also affects separation efficiency, a zero coefficient of friction was considered to ease the simulation.

5.5 MODEL CALCULATIONS METHOD

In each model case, the simulations were run up to 2.5 million cycles, where each cycle represents a fraction of second in the real world. The results were obtained after every 500,000 cycles to study the process of segregation with time (Figure 5.4). In process of obtaining the results, locations of each particle were traced after every 500,000 cycles in a test (**.txt*) file. Once completed, the particles were then sorted and filtered as per their location in Z direction along the bed height by using Microsoft Excel 2007. Furthermore, the numbers of particles were then counted in a certain level of pre-defined height according to their density ranges. From these values, partition curves are developed to study the efficiency of separation in the model. The pre-defined height levels in the model were intended to represent the six different splits obtained at the discharge end of the dry deshaling air table separator as shown in Figure 5.3.

Table 5.2 Model simulation characteristics for spherical particles.

Type of particles assigned in model	**Color code**	**Number of particles**	**Density of particle (Kg/m^3)**	**Normal stiffness (N/m)**	**Shear stiffness (N/m)**
Coal1_particles	Red	500	1200	10^6	10^6
Coal2_particles	Blue	100	1500	10^6	10^6
Middlings_particles	Green	100	1800	10^6	10^6
Rock_particles	Yellow	500	2400	10^6	10^6

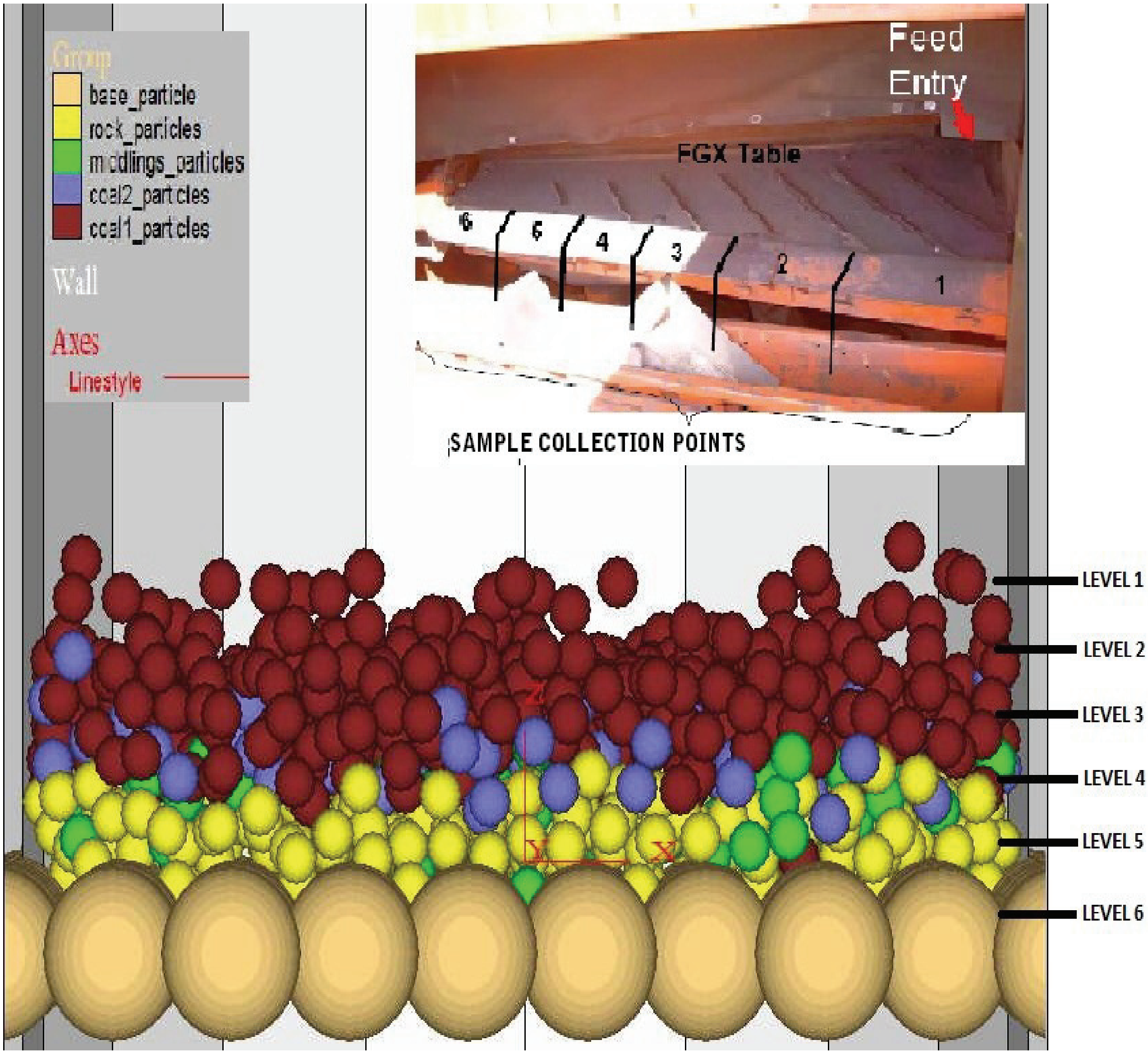


Figure 5.3 Different density particles with different height levels in the model representing six splits on the air table separator.

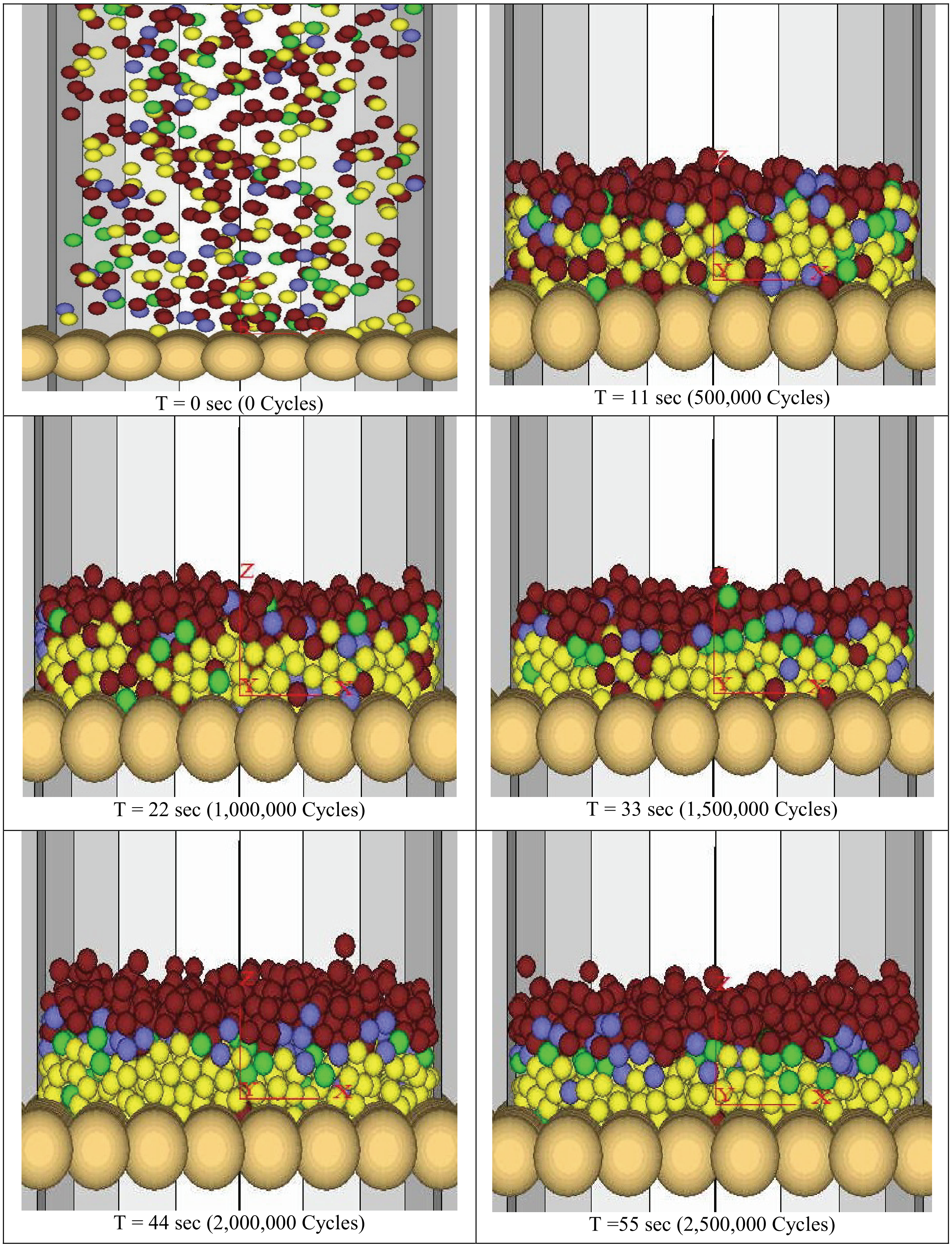


Figure 5.4 Various stages of segregation observed in the model with time.

5.6 RESULTS AND DISCUSSIONS

Several cases were considered for the model simulations to study the effect of different forces in segregation, vibrating bed parameters, size of particles, and bed height in the dry density-based separation process. The simulation results were then compared to experimental separation data obtained by Honaker et al. (2008) using a pilot scale (5 t/hr) dry deshaling air table at different bituminous and sub-bituminous coals from the United States (Figure 5.5). Comparisons were also made to experimental data from an All-Air jig, as shown in Figure 5.6.

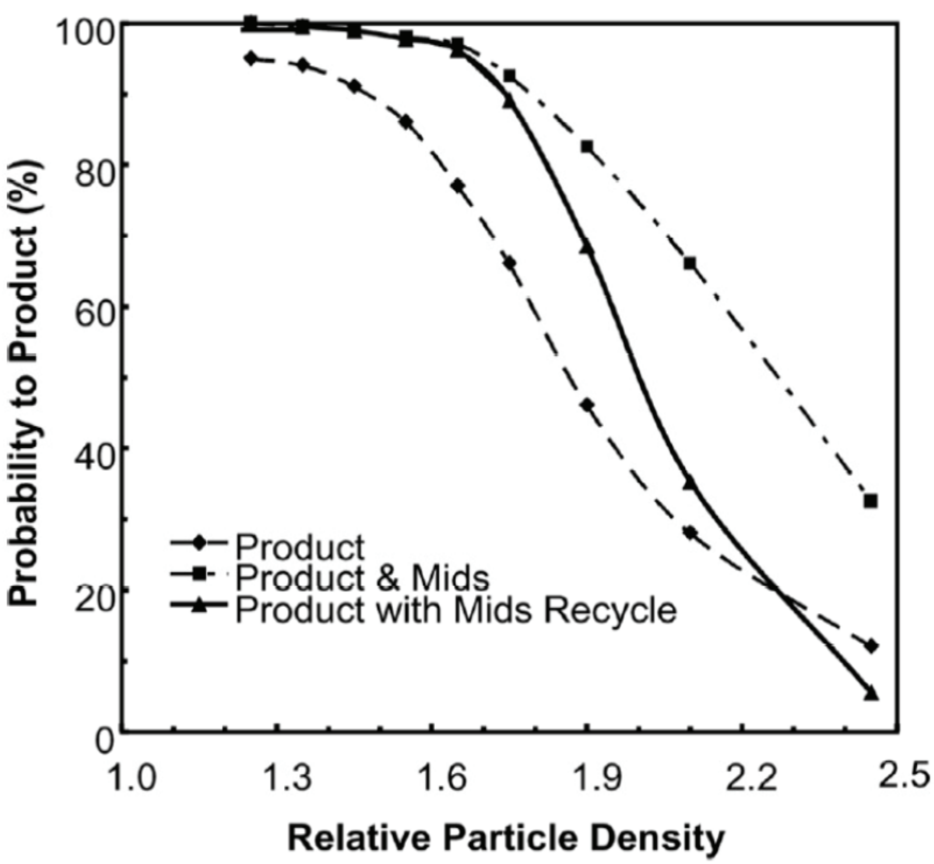


Figure 5.5 Pilot scale testing results for the dry deshaling air table conducted on U.S. coals (Honaker et. al., 2008).

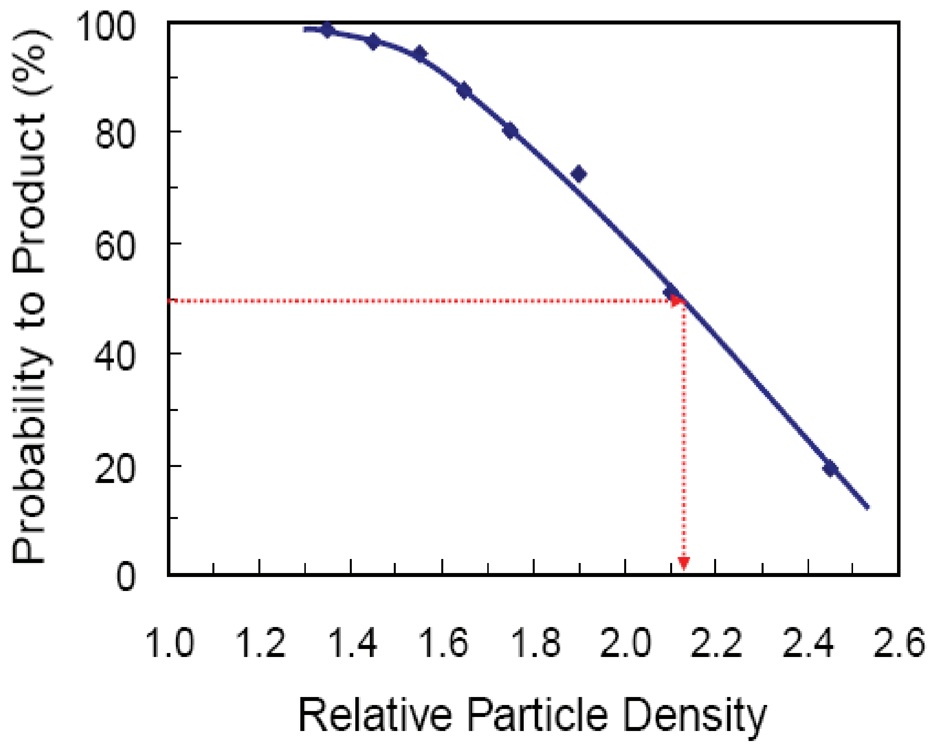


Figure 5.6 All-Air Jig partition curve showing the separation efficiency of the process (Honaker, 2007).

5.6.1 Effect of Forces in Segregation

As mentioned earlier, the three main forces affecting the density-based separation process are the gravity force, force of apparent buoyancy (because of the other particles around one particle) and the drag force (because of the relative velocity of a particle with surrounding particles). Preliminary tests were run to optimize model parameters like viscous damping, frequency of vibrations and amplitude of velocity. Keeping these parameters value optimum, the forces are applied to the spherical mono-size particles. The results achieved show the effect of the forces in the process of segregation.

Figure 5.7 shows the partition curve of separation of different density spherical particles under the effect of different forces. Case 1 is the partition curve developed when all the three forces are implemented in the model. Similarly, partition curves were developed when only buoyancy and gravity force (Case 2), drag and gravity force (Case 3), and only the gravity forces (Case 4) were applied. The E_p (*Ecart Probable*) values have also been calculated based on these partition curves and compared with the real world data. E_p is defined as an index of separation and the value gives an indication of the quantitative errors inherent in the process at a given separation density (Osborne, 1988). The lower the E_p value, higher the separation efficiency. Mathematically, the E_p is defined as half the difference in densities corresponding to partition probabilities of 25% and 75%, i.e.:

$$E_p = (\rho_{25} - \rho_{75}) / 2 \quad [10]$$

Table 5.3 shows a comparison of E_p values of real world data of dry air table and All-Air Jig with the model values. Differences in how air enters the bed (i.e., constant air-flow for the air table and pulsated air-flow for the air jig) was not considered in the model. The E_p value obtained with the model simulation in Case 1 (when all forces are implemented) was close to the experimental values and would be expected to be even better if the air flow is effects were included in the model.

Table 5.3 Ecart Probable (E_p) values for the partition curves based on different forces.

Cases	Forces	Ecart Probable (Ep)
Dry Air table	---	0.17-0.25 [a]
All Air Jig	---	0.29-0.33 [b]
Model-Case 1	Gravity, Buoyancy & Drag	0.30
Model-Case 2	Gravity & Buoyancy	0.35
Model-Case 3	Gravity & Drag	0.59
Model-Case 4	Gravity	0.64

[a] (Honaker and Luttrell, 2007); [b] (Killmeyer and Deurbrouck, 1979; Kelley, 2002)

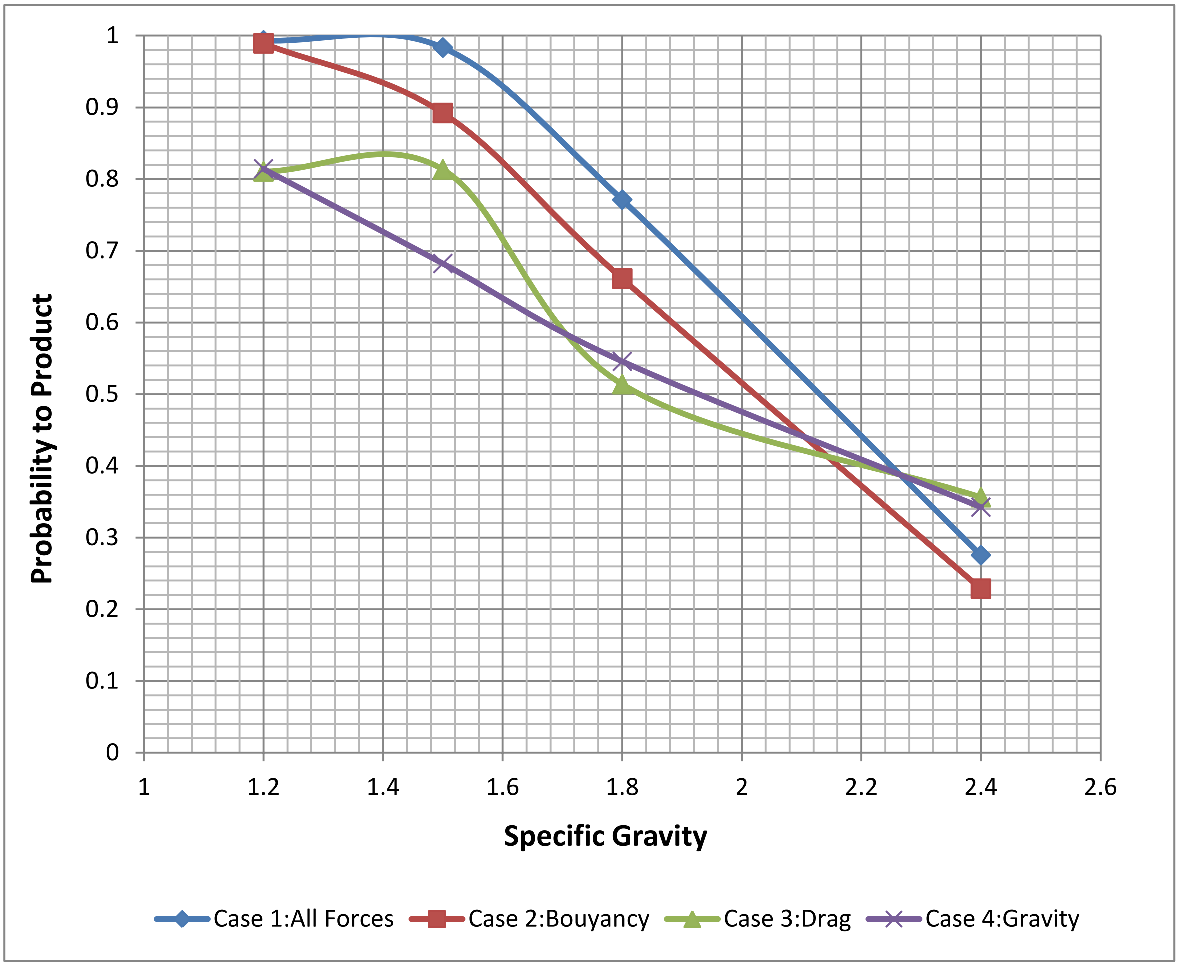


Figure 5.7 Partition curves showing the effect of forces on segregation of spherical particles of different density on the vibratory bed.

5.6.2 Effect of Particle Size in Segregation Process

Partition curves were developed to study the effect of particle size on segregation in the model. Particle diameters of 2, 1, 1/2 and 3/8 inches were used in the model simulations in different runs. Also, variable particle size intervals of 2-1 inches and 1-1/2 inches were also simulated in the model.

The Figure 5.8 shows partition curves for all cases. As should be expected, the results show that the separation efficiency decreased as the particle size decreased. Table 5.4 compares the E_p values obtained in the simulations with real test data from the air-table separator and All-Air jig. The lower Ep for coarse particles clearly indicates that the separation efficiency is higher for large particles compared to smaller ones.

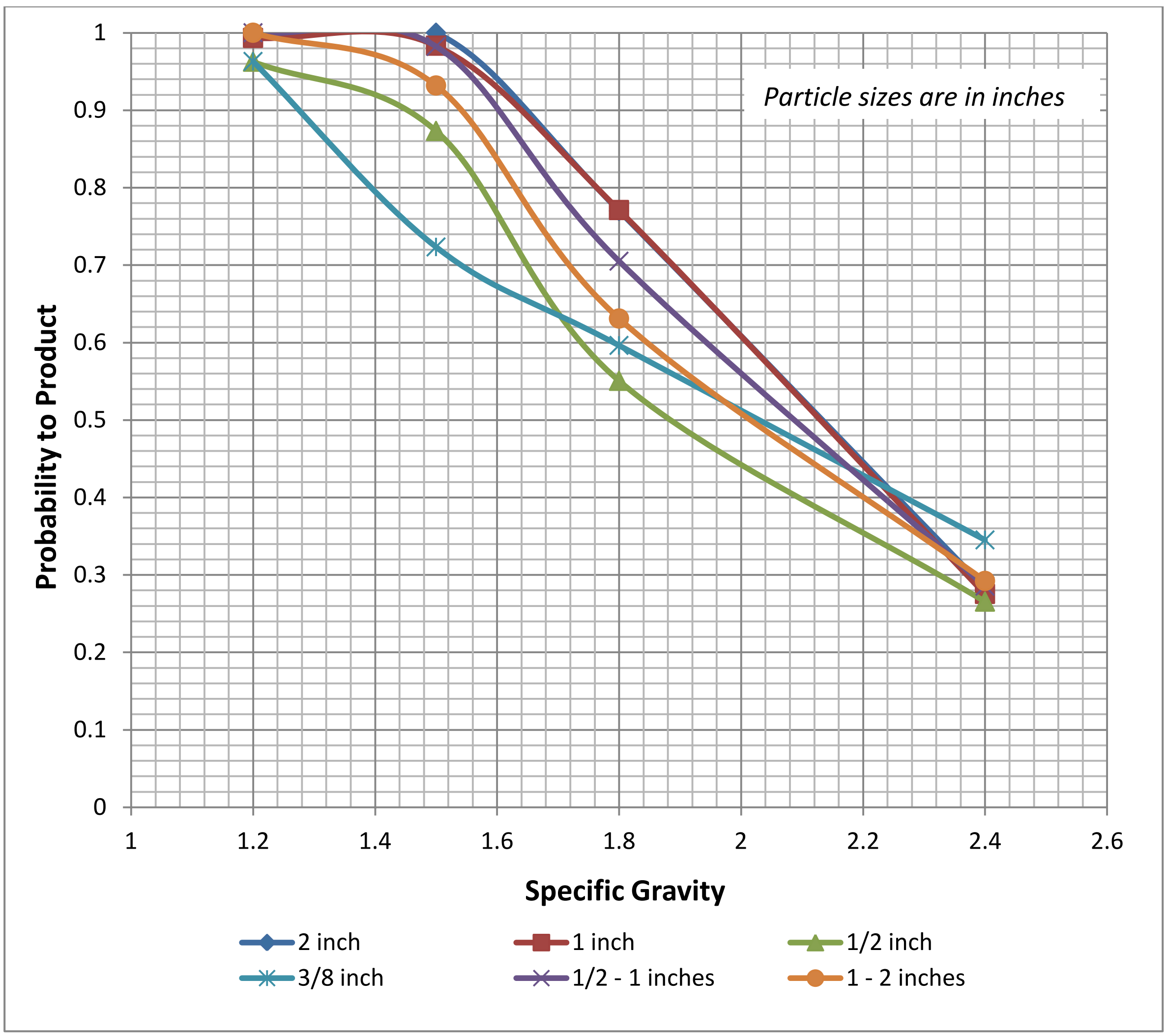


Figure 5.8 Partition curves based on model simulations showing variations in separation efficiency with particle size.

Table 5.4 Variation in Ep with particle size based on model simulations and field tests.

Cases Particle sizes	Ecart Probable (Ep)
Dry Air table	0.17-0.25 [a]
All Air Jig	0.29-0.33 [b]
Mono-size 2 inch	0.31
Mono-size 1 inch	0.31
Mono-size ½ inch	0.40
Mono-size 3/8 inch	0.58
Variable size 1-1/2 inches	0.35
Variable size 2 - 1 inches	0.38

[a] (Honaker and Luttrell, 2007); [b] (Killmeyer and Deurbrouck, 1979; Kelley, 2002)

5.6.3 Effect of Bed Depth

One of the important parameters that affect the separation efficiency is the bed height. Numerous simulations were conducted to show the effect of this variable. Since the number of particles used in the model was held constant, the bed height was increased by reducing the radius of cylindrical geometry. To study the influence of bed height, the other simulation parameters (such as frequency, amplitude of velocity and viscous damping) were kept constant to their optimum values in the model.

Figure 5.9 shows the partition curves obtained for simulation results run with different bed depths that ranged from 1.2 m to 0.12 m. The results show a decrease in separation efficiency when the bed height increased or decreased from a certain limit. The limit was defined for a particular condition only. Also, it was observed that the separation reached steady state at a lower number of cycle runs when the bed height was lower. The results shown in the plot were for a constant number of cycle runs in all the cases.

The simulation showed that the separation efficiency was highly depended upon the bed depth per square area of the vibratory bed. The observed decrease in separation efficiency as the bed height moved from the limit was probably because of this phenomenon. As the bed height increased, over-compaction of the bed was observed, which restricted the diffusion of higher and lower density particle to the bottom and the top of the bed, respectively. As the bed height decreases, it was observed that the numbers of particle on the bed are not enough to segregate on the vibratory bed.

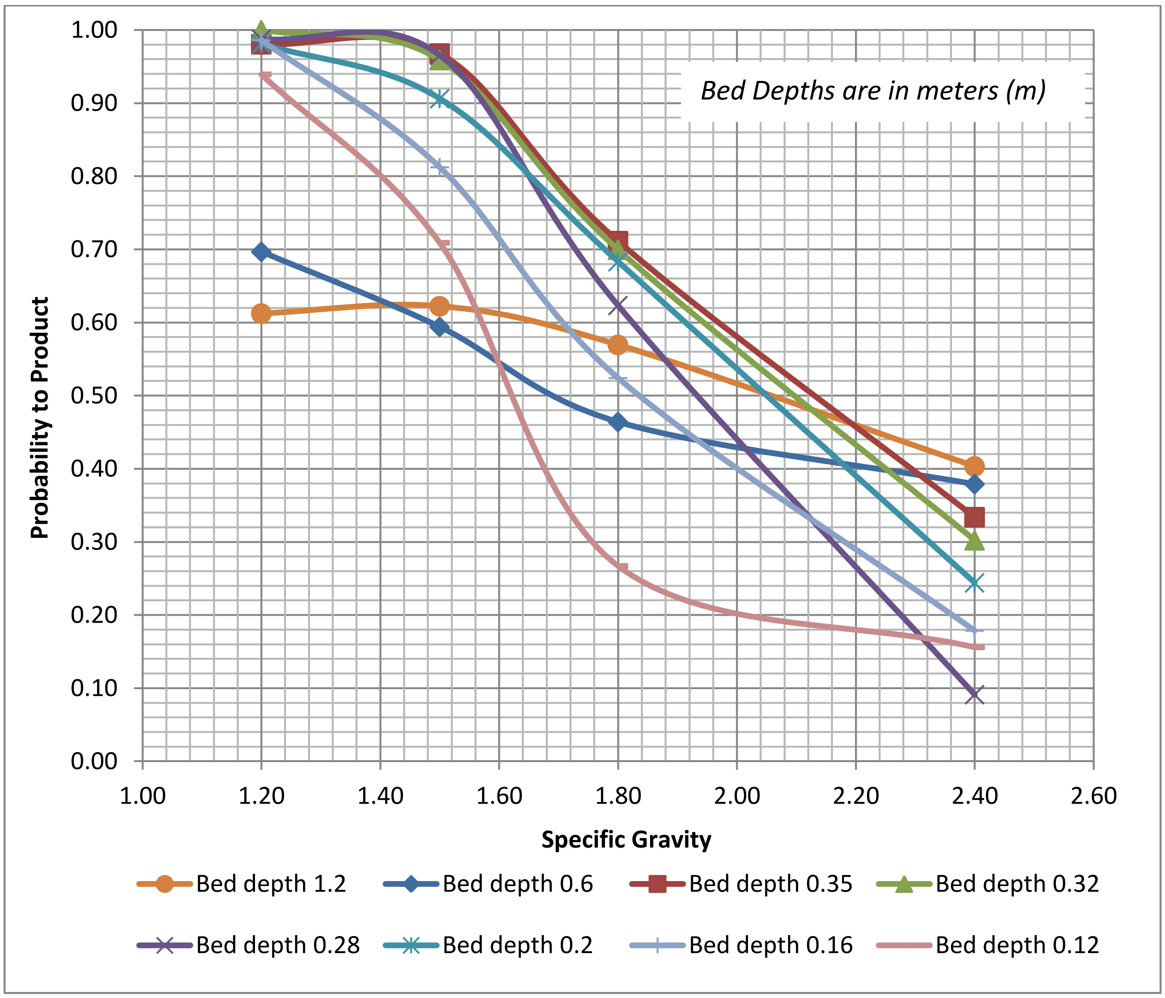


Figure 5.9 Effect of bed height on separation efficiency for different density particles on the vibratory bed.

Table 5.5 Variation in separation efficiency by changing the bed height.

Cases Variable bed depths	Ecart Probable (Ep)
Dry Air table	0.17-0.25 [a]
All Air Jig	0.29-0.33 [b]
Bed depth 1.2 m	>1
Bed depth 0.6 m	>1
Bed depth 0.35 m	0.40
Bed depth 0.32 m	0.37
Bed depth 0.28 m	0.27
Bed depth 0.2 m	0.32
Bed depth 0.16 m	0.37
Bed depth 0.12 m	0.19

[a] (Honaker and Luttrell, 2007); [b] (Killmeyer and Deurbrouck 1979; Kelley 2002)

Table 5.5 shows that E_p values greater than 1 were obtained for a higher bed depths (bed depths equal to 1.2 m, 0.6 m), which indicates no separation occurred. The separation efficiency increased and reached its optimum value, then again decreases as the bed depth decreased. At bed depth of 0.12 m, the value of E_p is much lower. However, the partition curve in Figure 5.9 shows considerable misplacement, or bypass, of low density material in the high-density material for this condition.

5.6.4 Effect of Frequency and Amplitude of Velocity of Vibrating Bed

The model simulations were also run at variable amplitude of velocity and frequency values of the vibratory table to study their effect on the density-based separation process. For variable amplitude of velocity, parameters such as frequency (17.25 Hz) and viscous damping (0.07) were kept constant. Similarly, for variable frequency, the amplitude of velocity (0.5 m/s) and viscous damping were kept constant.

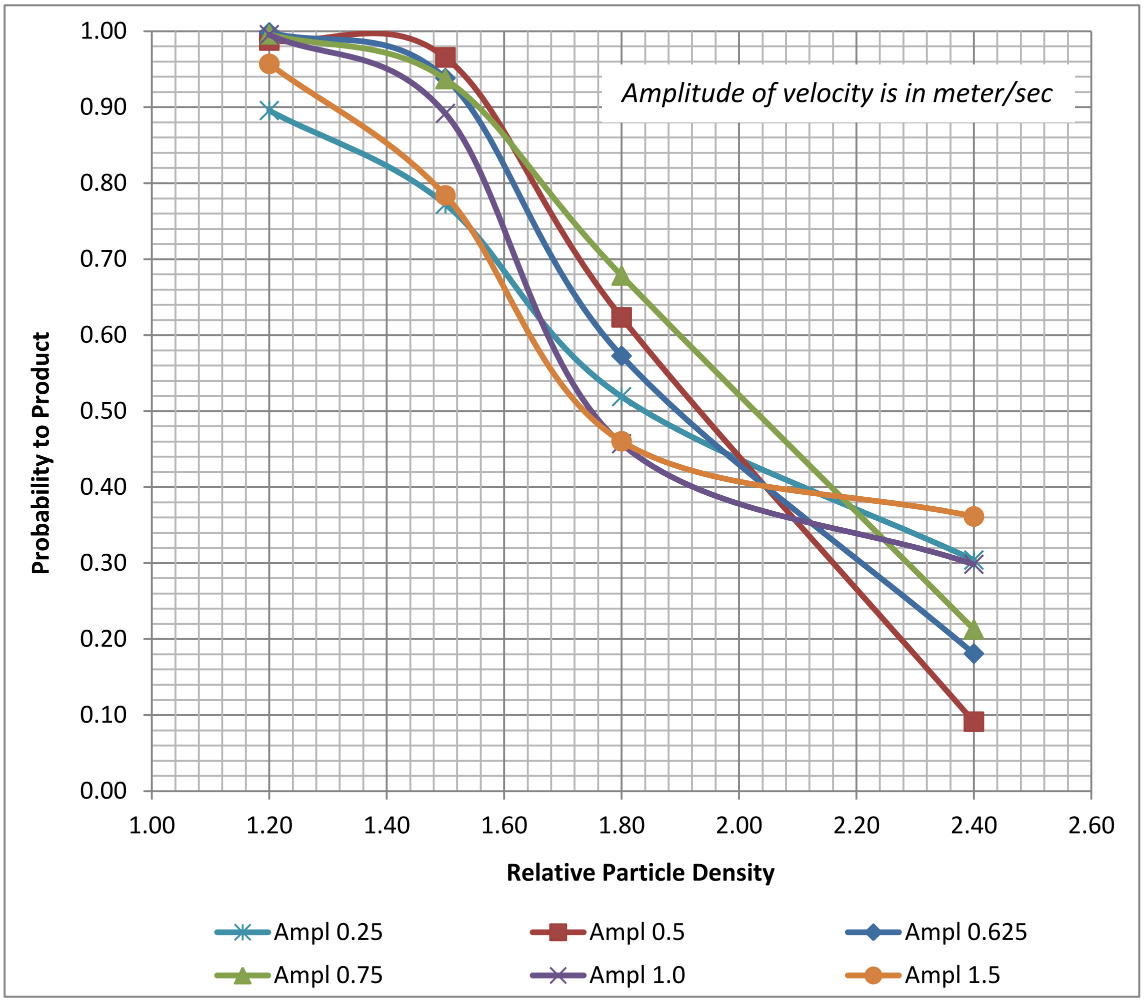


Figure 5.10 Partition curves showing separation efficiency at different values of amplitude of velocity of the vibratory bed.

Figure 5.10 shows the different partition curves obtained at different values of amplitude of velocity of the vibratory bed. The results show the separation was optimum for a specific range of values of amplitude of velocity and it deteriorated with higher or lower values in otherwise identical conditions.

In contrast, frequency variations do not appear to affect the separation process as shown in Figure 5.11. The E_p values varied from 0.26 to 0.30 which is close to the values obtained from the real test data shown in Table 5.6. It is important to note that, the parameter frequency governs the transportation of the material (or retention time of the particle) on the dry deshaling air table. As the model geometry was designed in consideration of batch tests only, it can be expected that the variation in frequency in the model will not show significant effect on the separation efficiency. This statement is based on visual observations and therefore evidences are required for a decisive conclusion.

Work from earlier researches showed that the higher the frequency of the vibratory bed, lower the separation efficiency of the process (Khan and Smalley, 1973). Also, the field test work conducted with dry deshaling air table in the current study indicated that the frequency of the bed, in combination with the air flow through the perforated bed and the horizontal slope of the vibrating bed, have a synergistic effect on the separation efficiency (Honaker and Luttrell, 2007). As the other two parameters are not incorporated in the model, there is a need for further investigations to study the variation of frequency and its effect on the separation process.

Table 5.6 Comparison of Ep values at variable amplitude of velocity and variable frequency of the vibratory bed with dry air table and All-Air jig.

Cases Variable amplitude of velocity	**Ecart Probable (Ep)**	**Cases Variable Frequency**	**Ecart Probable (Ep)**
Dry Air table	0.17-0.25 [a]	Dry Air table	0.17-0.25 [a]
All Air Jig	0.29-0.33 [b]	All Air Jig	0.29-0.33 [b]
0.25 m/s	0.53	5 Hz	0.30
0.5 m/s	0.26	12.5 Hz	0.28
0.625 m/s	0.32	14 Hz	0.28
0.75 m/s	0.33	15.5 Hz	0.29
1.0 m/s	0.56	17.25 Hz	0.26
1.5 m/s	0.58	25 Hz	0.27

[a] (Honaker and Luttrell, 2007); [b] (Killmeyer and Deurbrouck, 1979; Kelley, 2002)

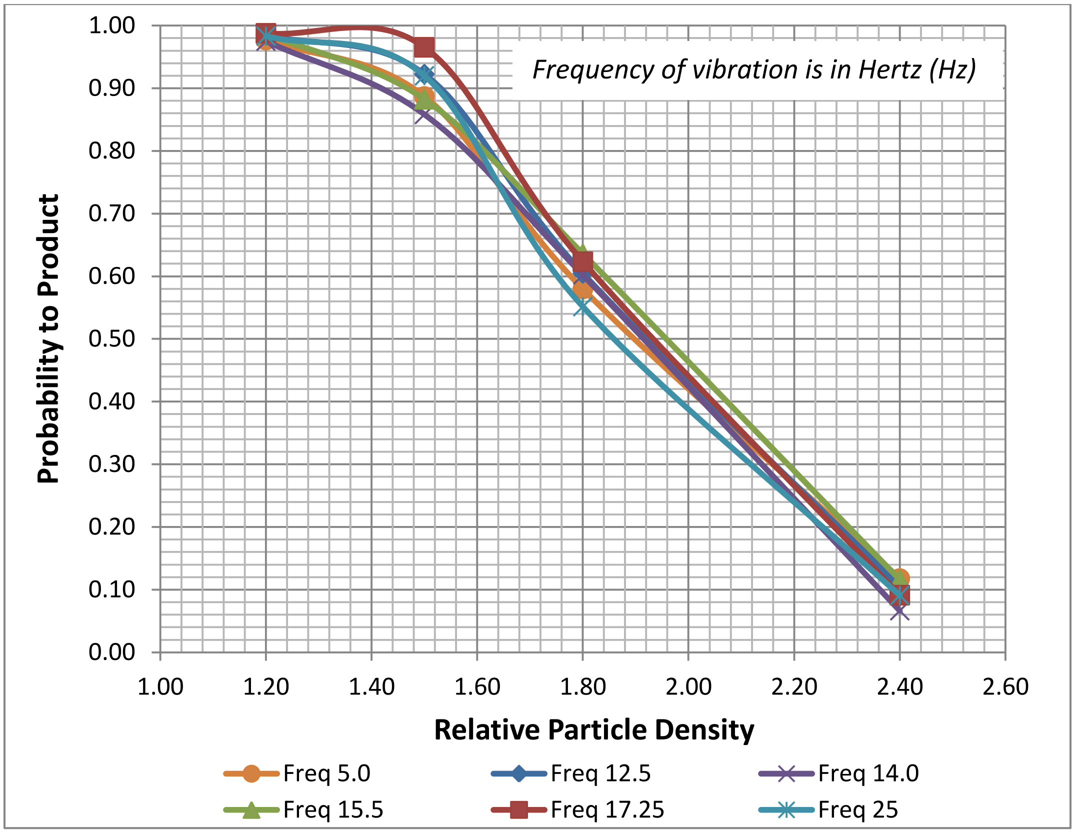


Figure 5.11 Partition curves showing variation in separation efficiency at different values of frequency of the vibratory bed.

5.7 CONCLUSION

The mechanism of segregation of particles under the influence of vibration has been much studied, but not yet completely understood. It is generally agreed that segregation based on particle size and density are the most prevalent in the mining industry. In order to reduce the complexity of the segregation phenomena, the discreet elemental analysis was conducted in order to better understand the effect of some of the critical parameters in a density-based separation process under the influence of sinusoidal vibration. Particle Flow Code in three dimensions (PFC^{3D}), a well known discreet element modeling software package, was used to develop the model for the segregation process. The model was then used to study the separation efficiency of the process under a wide range of different operating conditions. The model results were also compared to real-world separation data obtained from an Eriez air table and All-Air jig.

The three important forces, i.e. force of gravity, force of buoyancy, and drag force are studied in the model. Partition curves were developed to study the separation efficiency of the segregation phenomena. The modeling work showed the importance of the buoyancy force and drag force in the process of segregation.

The model was used to investigate the effects of particle size and density on separation performance. From the results obtained from the model simulations, it is confirmed that coarser particles were segregated with higher separation efficiency. Also, it was observed that denser particles segregated less than lighter particles under similar conditions. Important operating parameters, such as vibration frequency, amplitude velocity and bed height, were also studied using the model. The simulation results showed the selective separation of mono-size particles was optimum only under a certain range of amplitude and bed height. Values lower or higher than this optimum range drastically reduced the separation efficiency of the process. The frequency of vibrations, on the other hand, did not have much of an influence on the separation efficiency. This result contradicts real-world data and, as such, further investigations are required to understand the effect of frequency in the model.

While the modeling exercise did not explain all the paradoxes and puzzles of segregation under vibrations, it successfully provided a platform to establish further work to study the effect of some important parameters like particle shape, horizontal and vertical bed angles, and friction (rough particle surface), which were not considered in the development of the current simulation model.

NOMENCLATURE

A_{proj}:	Projected surface area of a single particle, m^2	g:	Gravitational acceleration, m/sec^2
C_D:	Drag Coefficient	K^n:	Normal stiffness, N/m
d:	Distance between the centers of two spherical particles in contact, m	k^s:	Shear stiffness, N/m
$\frac{dv}{dt}$:	Rate of change of particle velocity, m/sec^2	m:	Mass of a particle, Kg
E_p:	The index of separation for a process	ρ_{Air}:	Density of air, Kg/m^3
$\in$:	Volume fraction of the fluid in the system	P_{app}:	Average density of all the particles in the system , Kg/m^3
f_{ap}:	Apparent fluid particle interaction force, N	ρ_{bulk}:	Bulk density of fluid-particle system, Kg/m^3
F_b:	Force of buoyancy, N	ρ_p:	Density of a particle, Kg/m^3
F_d:	Drag force, N	T:	Time, sec
F_i:	Contact Force, N	U_{slip}:	Slip velocity of the particle, m/sec
F_i^n:	Normal component of the contact force, N	U_t:	Terminal velocity of the particle, m/sec
F_i^s:	Tangential component of the contact force, N	V_p:	Volume of a particle, m^3
f_{pp}:	Particle-particle and wall-particle interaction force, N	$x_i^{[a]}, x_i^{[b]}$:	Position vector of the spherical particles A and B in contact.

CHAPTER 6 FINAL SUMMARY

The air table dry separator technology was evaluated at coal mining sites in India for the treatment of Run-of-Mine (ROM) coals. A (5 t/hr) prototype pilot-scale deshaling unit was installed at three test sites and detailed parametric studies were conducted to evaluate the separation performance for coals at each site. The primary objective of the test program was to produce clean coals having qualities that meet the market specifications while maximizing the amount of high density rock rejected prior to transportation and processing and minimizing the loss of combustible material. Specifically, the work was performed to (i) establish the suitability of the dry deshaling technology for upgrading Indian coals with difficult washabilities, (ii) define the operational capabilities of the technology in terms of coal recovery and quality for typical Indian coals, and (iii) to determine the economic viability of this approach for the coal markets that currently exist in India.

Tests conducted at the Aryan Energy facility in Talcher and the Bhushan complex in Jharsuguda successfully demonstrated that high-ash rock (>60% ash) could be readily rejected from the plus 6 mm ROM coals using the deshaling technology. At Aryan Energy, the technology successfully met the original project goals of recovering nearly 85-90% of the coal heating value while rejecting significant amounts of incombustible high-ash (> 65% ash) rock in the plus 6 mm fraction. Similarly, at the Bhushan complex, the unit met the original project goals of recovering more than 90% of the coal heating value, while rejecting significant amounts of incombustible high-ash (>70% ash) rock in the plus 6 mm fraction. The tests conducted at the Kargali Washery indicated similar results with rejection of 15-25% high ash material (>70% ash) and the loss of only 4-10% of combustible material in the plus 6 mm fraction. The tests conducted on a semi-coking coal indicates the removal of 20-25% of high ash rock (>40% ash) from the ROM coal with a 97% recovery of the combustible material in the plus 6 mm fraction.

As a result of all the on-site testing, it is evident that the air table deshaling technology offers major benefits for improving the quality of coal consumed for electrical power generation and steel manufacturing. Reductions in the amount of high-ash incombustible rock will cut transportation costs, improve utilization efficiency, lower greenhouse gas emissions, and reduce the release of unwanted particulates and elements of environmental concern to the atmosphere.

A discreet elemental model in three dimensions was developed by using Particle Flow Coding (PFC^{3D}) to understand the process of segregation on dry density-based separators. Various important parameters were studied including bed height, frequency of vibrations, amplitude of velocity of the vibratory bed, and particle size. Furthermore, the theoretical basis of the process was studied. Forces such as, gravitational force, drag force and buoyancy force involved in the segregation phenomena were also analyzed. In each case, partition curves were developed to study the separation efficiency of the model process.

The simulation results show the separation efficiency of selective mono-size spherical particles was optimum for a certain range of amplitude of velocity of the vibratory bed and bed height in specific conditions. Variation in frequency of vibrations had not affected the separation efficiency. Furthermore, the results for different size particles evidently confirmed that coarser particles have higher separation efficiency. Although several important parameters of the segregation process have been studied in the model, future work will require further investigation by incorporating parameters and conditions in the model such as, particle shape, air flow through perforated vibratory bed, rough surfaces (friction) and horizontal slope of the vibratory bed.

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APPENDICES

APPENDIX A:
Eriez dry deshaling air table – Setup and Operating Procedure

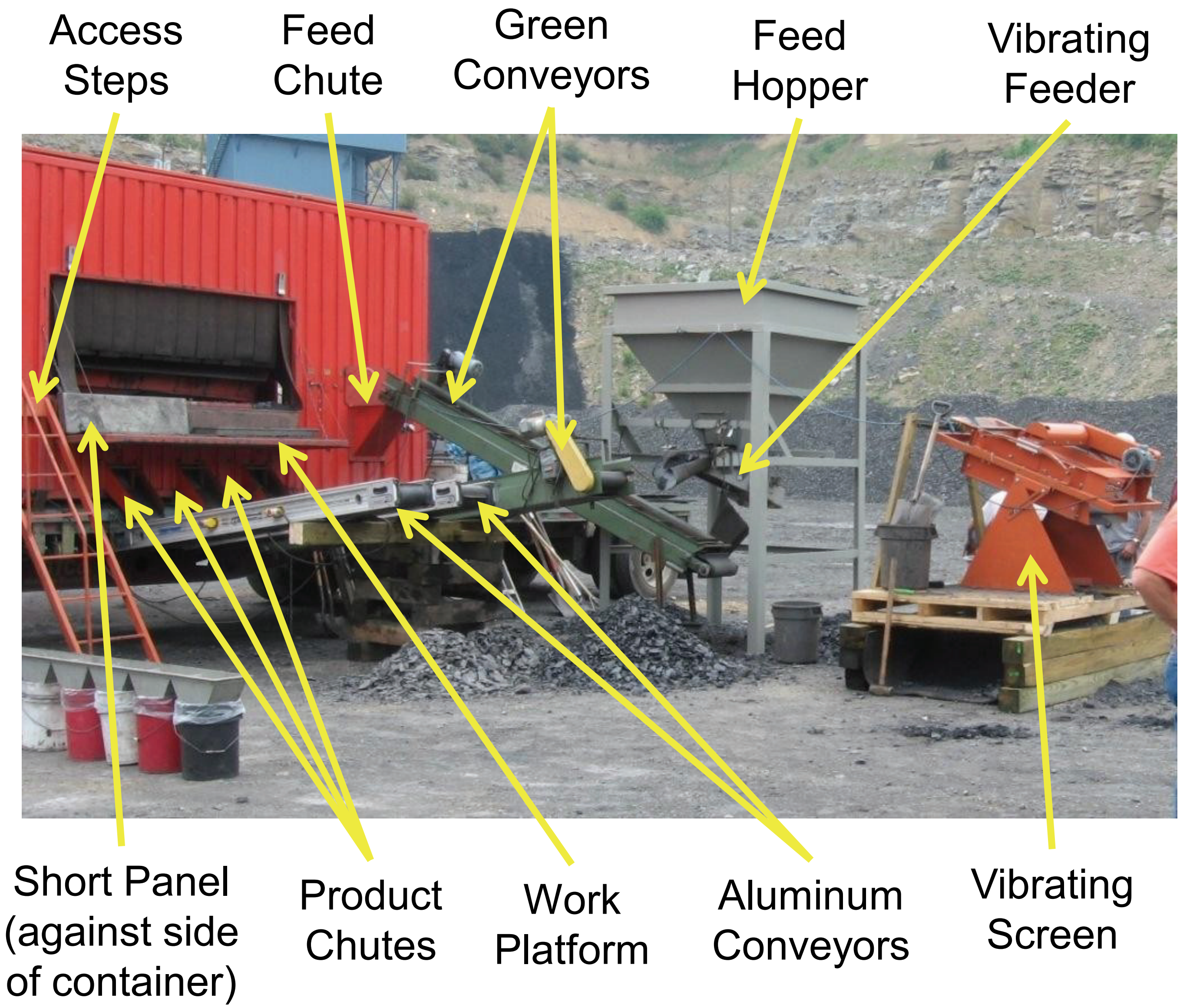
ERIEZ
FGX Compound
Dry Coal Cleaning
Pilot-Scale Unit

Setup and Operating
Procedures

Typical Deshaler Setup

- Typical arrangement of equipment
  - Feed hopper (gray) with vibrating feeder and conveyor to right side of unit
  - Control room on left
  - Products discharge to separate piles in front via conveyors
- Typical (preferred) arrangement of conveyors
  - One green conveyor for feed
  - One green conveyor for clean coal
  - One aluminum conveyor for middlings
  - One aluminum conveyor for reject
- Vibrating screen (right) used to size run-of-mine feed at ¼” x 2”

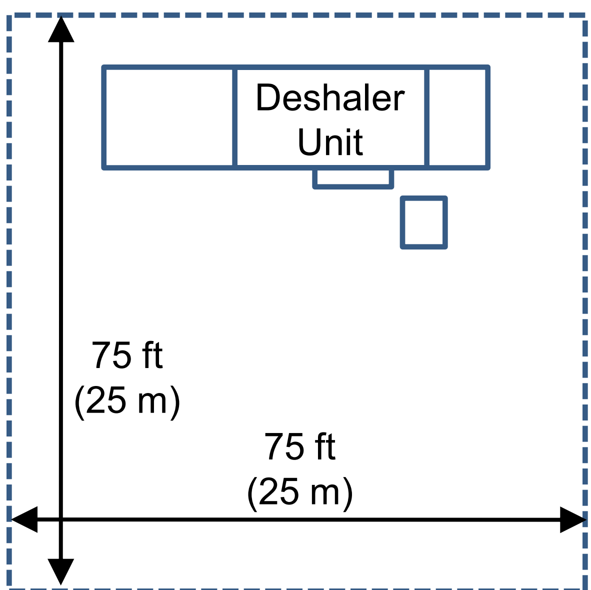
Typical Deshaler Setup



- Arrangement of equipment
  - One green conveyor for feed
  - One green conveyor to collect all products
  - Aluminum conveyors transfer products to one pile or container

Test Site Preparation

- The Deshaler Unit will require an open, level area of approximately 75 feet by 75 feet (25 m by 25 m)
- Position the Unit so that the back of the Unit is near one side of the working area
- The Unit can be operated while mounted on a trailer or it must be supported at least 3 feet (1 m) above the ground



Additional Support Items

- A small fork lift truck is required for unloading and positioning the auxiliary equipment (Feed Hopper, Conveyors, Vibrating Feeder, etc.)
- A small end loader is required to lift the raw coal into the Feed Hopper
  - The top of the Hopper is approximately 12 feet (4 m) above the ground
- The end loader will also be used to move the cleaned and reject products away from the area
- Manpower to operate the lift truck and end loader
- Material to support the discharge end of the product conveyors
  - Metal support stands
  - Wood blocks (such as crib blocks)
  - Wood boards and wedges
- Manpower (2 people) to assist with collecting samples

Equipment Setup

- Locate unit so that the container is level in both directions
- Open horizontal door and insure that work platform is down completely
  - Short panel of door lays against side of container
  - Connect supporting chains at each end of platform
- Support Vibrating Feeder from Feed Hopper using eye bolts
- Remove cover from feed port opening, attach feed chute
- Attach 3 product chutes
- Remove tape from dust discharge port (on back side of unit)
- Remove tape from Exhaust Fan discharge port (on top of unit)
- Remove turnbuckles, tie straps, and/or cables securing Table
- Remove turnbuckles, tie straps, and/or cables securing internal Vibrating Feeder

Equipment Setup

- Position Feed Hopper:
  - On level footing
  - At proper position
- Set Feed Conveyor to transfer raw feed from Vibrating Feeder to the feed chute
- Connect Feed Hopper Vibrating Feeder to outlet near feed chute using cable with selector switch
- Position access steps next to work platform
- Connect 460 VAC, 3 phase power to terminals in electrical control cabinet
  - The entry for the cable is a 2 inch (50 mm) hole on the outside wall at the bottom of the control panel
  - A cable, approximately 45 feet (15 mm) long is available with the unit
  - Turn main circuit breaker OFF before connecting power
  - Check for proper voltage on each phase before turning breaker ON

Pre-Start Checks

- Check rotation of Feed Screw Conveyor
- Check rotation of Dust Discharge Screw Conveyor (on back of unit)
- Check rotation of aluminum conveyors
  - Conveyors are connected in series from control box
  - E-Stop plugs into last conveyor in series
- Insure that table and vibrating feeders are free to move
- Set table angles:
  - Longitudinal – 1.0 degree
  - Horizontal – 8.5 degrees
- Turn main circuit breaker ON
- Press START pushbutton for Main Fan, Table Drives, and internal Vibrating Feeder
- Check control pad for variable frequency drives (VFD)
  - Insure control is "LOCAL"
  - Set Main Fan speed to 55 Hz
  - Set Table Drives speed to 45 Hz
  - Set internal Vibrating Feeder to 60 Hz
- Set Feed Hopper Vibrating Feeder to 45 Hz (small square box beside door under VFDs)

Startup Sequence

- Press Start pushbutton for:
  - Bag House Exhaust Fan
  - Main Fan
  - Table Drives
  - Internal Vibrating Feeder
  - Feed Screw Conveyor
- Start the green and aluminum conveyors
- Press the START button on the VFDs for the:
  - Main Fan
  - Table Drives, after Main Fan is operating at specified speed
  - Internal Vibrating Feeder, after Table is operating at specified speed
- Press Start pushbutton for the Feed Hopper Vibrating Feeder
- Check unit feed rate by collecting a timed sample from the Vibrating Feeder
- Adjust Vibrating Feeder control to set the feed rate at 5 tons per hour

Shutdown Sequence

- Press Stop pushbutton for the Feed Hopper Vibrating Feeder
- Press the STOP button on the VFDs for the:
  - Internal Vibrating Feeder
  - Table Drives
  - Main Fan, after Table has stopped moving
- Press Stop pushbutton for:
  - Feed Screw Conveyor
  - Bag House Exhaust Fan, after Main Fan has stopped
- Remove the dust after each test run by opening the dust port and pressing the START pushbutton (located above the dust port) for the Dust Discharge Screw Conveyor
- For an extended shutdown, stop the green and aluminum conveyors
- Turn the main circuit breaker OFF at the end of the day

APPENDIX B:

Pilot scale dry deshaling test results of Indian coal

India - Deshaler Project - 2009																													
Site -		Aryan Energy Pty																											
Location -		Talcher, Orissa, India																											
												Coal Source #1														Coal Source #2			
	Date -	8/11/09		8/12/09										8/13/09		8/14/09		8/17/09								8/17/09			
	Test No. -	1	2	3		4		5		6		7		8		9		10		11		12		13		14		15	
Table Parameters																													
Tilt	(deg)	8.5	8.5	8.5		8.5		8.5		8.5		8.5		8.5		8.5		8.5		8.5		7.5		7.5		7.5		7.5	
Slope	(deg)	1.0	1.0	1.5		1.5		0.5		0.5		0.5		0.5		0.5		1.0		1.0		1.0		1.0		1.0		1.0	
Fan Speed	(Hz)	55	60	60		60		60		60		55		60		55		50		50		55		50		50		55	
Table Speed	(Hz)	45	45	45		50		50		45		45		55		55		50		45		45		45		45		45	
Feed Rate (kg, AR)		5.49	6.99	5.85		5.88		7.30		6.34		6.30		5.85		5.13		4.63		5.17		6.50		6.85		5.04		4.83	
Feed Rate (kg, dry)		4.89	6.22	5.24		5.33		6.56		5.68		5.62		5.21		4.61		4.22		4.75		5.92		6.24		4.58		4.38	
Total Sample Time (hr:min:sec)		0:10:50	0:05:37	0:10:25		0:06:19		0:07:09		0:06:44		0:06:22		0:04:50		0:07:17		0:09:05		0:05:35		0:06:34		0:05:54		0:09:54		0:06:33	
Sample Data		50 mm x 0	50 mm x 0	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm
Total Dust Collected (kg, AR)		10.32	5.88		10.44		6.36		8.94		7.97		7.32		6.58		3.79		10.68		6.33		7.54		7.24		5.42		4.02
Wt (kg - AR)	Feed	22.88	29.12	17.79	6.58	22.67	1.84	28.07	2.34	23.18	3.23	22.04	4.20	21.30	3.07	18.83	2.56	16.32	2.99	18.19	3.36	23.90	3.18	24.00	4.56	18.83	2.15	18.32	1.80
	Split 1	2.73	5.24	5.16	1.57	5.03	0.93	4.77	0.95	4.22	0.77	4.83	0.04	1.85	0.53	2.11	0.54	2.29	0.66	3.52	0.67	5.01	0.81	4.54	1.78	2.49	0.67	3.06	0.57
	Split 2	3.46	5.07	4.88	1.66	4.45	1.02	4.95	0.76	4.41	0.76	4.27	0.73	1.32	0.75	2.35	0.90	1.31	0.74	4.40	0.87	3.13	0.70	4.82	1.36	4.84	0.72	2.81	0.62
	Split 3	8.13	8.17	5.33	0.44	6.46	0.39	7.35	0.33	5.58	0.23	6.76	0.26	3.82	0.21	6.10	0.40	5.46	0.28	6.28	0.31	7.17	0.31	6.69	0.51	6.42	0.35	4.75	0.23
	Split 4	1.90	2.03	1.38	0.08	1.21	0.18	1.67	0.10	1.37	0.04	1.55	0.04	1.51	0.05	1.96	0.05	1.53	0.05	1.38	0.04	1.89	0.07	1.61	0.06	1.26	0.04	1.28	0.16
	Split 5	2.87	3.22	2.31	0.11	3.32	0.28	4.35	0.07	2.62	0.05	3.35	0.05	4.52	0.08	5.45	0.09	3.49	0.07	3.67	0.05	3.31	0.08	8.07	0.07	3.15	0.08	2.90	0.08
	Split 6	1.30	0.96	0.38	0.03	0.24	0.20	1.50	0.06	0.05	0.05	0.99	0.09	1.48	0.07	2.33	0.14	1.01	0.14	1.14	1.27	0.93	0.06	0.93	0.09	0.62	0.08	0.61	0.06
	Dust	0.24	0.26		0.25		0.25		0.31		0.30		0.29		0.34		0.13		0.29		0.28		0.29		0.31		0.14		0.15
	Products Total	20.60	24.94	19.44	4.12	20.71	3.23	24.58	2.57	18.23	2.18	21.74	1.48	14.50	2.03	20.30	2.24	15.08	2.23	20.38	3.48	21.42	2.30	26.64	4.17	18.76	2.06	15.40	1.86
Total Moist (%)	Feed	11.00	11.00	9.50	12.90	8.60	19.20	10.00	12.00	10.20	11.90	10.30	13.20	10.80	12.30	9.80	13.60	8.90	9.40	7.90	9.60	8.70	9.90	8.70	10.60	8.90	10.80	9.10	10.40
	Split 1	12.00	12.00	10.60	13.10	11.70	13.50	12.00	14.80	11.70	13.90	11.60	12.40	12.10	14.20	12.40	13.80	10.00	11.20	10.90	12.50	9.40	10.50	10.00	14.20	10.20	12.60	10.20	12.40
	Split 2	12.00	12.00	20.50	12.40	19.30	11.60	12.70	14.60	11.20	13.30	12.20	12.40	11.30	13.60	12.60	14.40	10.20	10.70	11.00	12.30	10.20	11.50	10.00	12.90	10.10	11.90	10.10	12.20
	Split 3	11.50	11.50	9.60	10.20	9.40	10.10	10.50	10.80	10.80	12.10	9.50	10.70	10.90	12.70	12.30	13.20	9.80	10.40	10.20	11.90	9.10	10.20	9.60	11.50	9.70	11.20	9.60	11.40
	Split 4	10.00	10.00	7.60	10.00	7.20	10.40	9.50	9.80	9.70	11.30	9.20	10.40	9.80	11.50	9.80	10.60	9.50	10.20	9.80	10.30	8.60	9.80	8.90	10.20	8.80	10.40	8.60	10.30
	Split 5	9.00	9.00	6.40	9.00	9.30	5.80	8.60	9.50	8.80	10.10	8.70	9.80	8.70	10.60	8.80	9.30	8.90	9.40	8.70	9.80	8.10	9.40	8.10	10.20	7.90	9.20	8.10	9.70
	Split 6	9.00	9.00	4.90	4.50	6.30	9.10	7.50	7.6	7.90	9.20	8.10	9.60	7.50	9.30	7.40	7.90	7.70	8.60	9.60	9.60	7.40	8.80	7.80	8.50	7.10	8.60	7.40	8.80
	Dust	8.00	8.00		7.40		7.50		6.9		7.2		7.5		7.00		8.20		9.30		6.4		6.6		6.20		6.80		8.10
	Products Total	10.97	11.13	11.99	11.95	11.91	10.93	10.65	12.79	10.73	12.37	10.29	10.86	9.94	12.24	10.60	13.00	9.49	10.45	10.16	10.78	9.06	10.17	9.18	12.62	9.42	11.42	9.36	11.45
Wt (kg - dry)	Feed	20.36	25.92	16.10	5.73	20.72	1.49	25.26	2.05	20.82	2.85	19.77	3.65	19.00	2.69	16.98	2.21	14.87	2.70	16.75	3.04	21.82	2.86	21.91	4.08	17.15	1.92	16.65	1.61
	Split 1	2.40	4.61	4.61	1.36	4.44	0.80	4.20	0.81	3.72	0.66	4.27	0.03	1.63	0.45	1.85	0.47	2.06	0.59	3.14	0.58	4.53	0.72	4.08	1.53	2.23	0.59	2.74	0.49
	Split 2	3.04	4.46	3.88	1.45	3.59	0.90	4.32	0.65	3.91	0.65	3.75	0.64	1.17	0.65	2.05	0.77	1.17	0.66	3.92	0.76	2.81	0.62	4.33	1.18	4.35	0.63	2.52	0.54
	Split 3	7.19	7.23	4.82	0.39	5.85	0.35	6.58	0.29	4.97	0.20	6.11	0.23	3.40	0.18	5.35	0.34	4.92	0.25	5.64	0.27	6.51	0.28	6.04	0.45	5.79	0.31	4.29	0.20
	Split 4	1.71	1.82	1.27	0.07	1.12	0.16	1.51	0.09	1.23	0.04	1.41	0.03	1.36	0.04	1.77	0.04	1.38	0.04	1.24	0.04	1.72	0.06	1.47	0.05	1.14	0.04	1.17	0.14
	Split 5	2.61	2.93	2.16	0.10	3.01	0.26	3.97	0.06	2.39	0.04	3.06	0.05	4.13	0.07	4.97	0.08	3.18	0.06	3.35	0.05	3.04	0.07	7.41	0.06	2.90	0.07	2.66	0.07
	Split 6	1.18	0.87	0.36	0.02	0.22	0.18	1.38	0.05	0.05	0.04	0.91	0.08	1.37	0.06	2.16	0.12	0.93	0.12	1.03	1.14	0.86	0.05	0.85	0.08	0.58	0.07	0.56	0.05
	Dust	0.22	0.24		0.23		0.23		0.29		0.27		0.27		0.32		0.12		0.27		0.27		0.27		0.29		0.13		0.14
	Products Total	18.34	22.16	17.11	3.62	18.24	2.88	21.96	2.24	16.27	1.91	19.50	1.32	13.06	1.78	18.14	1.94	13.65	2.00	18.31	3.11	19.48	2.07	24.19	3.64	16.99	1.82	13.95	1.65
Wt (% dry)	Split 1	13.10	20.81	26.97	37.53	24.34	27.80	19.12	36.15	22.87	34.69	21.87	2.32	12.45	25.59	10.19	23.94	15.07	29.36	17.13	18.72	23.28	34.84	16.87	41.94	13.13	32.14	19.66	30.00
	Split 2	16.57	20.11	22.68	40.01	19.68	31.33	19.68	28.99	24.04	34.25	19.22	48.40	8.97	36.46	11.30	39.40	8.59	33.11	21.39	24.55	14.41	29.75	17.91	32.53	25.58	34.57	18.07	32.99
	Split 3	39.20	32.63	28.17	10.78	32.08	12.03	29.96	12.95	30.56	10.35	31.34	17.57	26.06	10.32	29.49	17.63	36.06	12.57	30.80	8.79	33.44	13.46	24.98	12.27	34.09	16.82	30.77	12.35
	Split 4	9.30	8.22	7.43	1.86	6.15	5.60	6.86	4.03	7.57	1.86	7.22	2.37	10.43	2.24	9.74	2.30	10.15	2.25	6.77	1.15	8.85	2.84	6.06	1.48	6.74	1.97	8.38	8.70
	Split 5	14.21	13.22	12.64	2.76	16.51	9.00	18.09	2.63	14.68	2.35	15.68	3.41	31.60	4.02	27.39	4.20	23.30	3.18	18.28	1.45	15.62	3.51	30.64	1.60	17.07	3.74	19.07	4.10
	Split 6	6.42	3.92	2.11	0.66	1.23	6.16	6.30	2.27	0.28	2.14	4.66	5.82	10.48	3.57	11.89	6.39	6.83	6.18	5.63	36.80	4.40	2.65	3.53	2.26	3.39	3.76	4.05	3.32
	Dust	1.19	1.09		6.40		8.08		13.00		14.37		20.11		17.80		6.14		13.36		8.54		12.96		7.90		7.00		8.54
	Products Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ash (% dry)	Feed	49.10	48.70	48.20	44.10	48.20	46.00	47.20	47.60	50.30	48.80	47.50	46.80	50.00	46.30	46.40	45.70	49.30	47.10	47.90	45.10	47.50	45.30	49.10	46.20	51.20	46.20	50.50	44.80
	Split 1	38.60	40.00	39.80	39.10	38.10	44.20	37.20	43.80	39.50	44.50	37.50	41.60	36.10	43.10	35.00	42.60	34.80	43.70	37.10	43.10	34.70	43.60	39.60	42.20	38.90	40.50	36.90	40.10
	Split 2	39.00	42.10	37.70	45.20	40.90	43.40	40.00	45.00	42.10	45.40	43.50	43.30	36.90	44.70	35.20	43.00	38.50	42.40	42.00	41.50	38.00	41.40	40.50	44.90	39.80	42.90	36.50	42.10
	Split 3	44.70	46.40	49.40	50.50	49.10	51.10	51.10	47.20	49.80	48.90	46.70	49.80	42.00	46.80	37.30	45.20	41.30	46.90	46.40	50.20	42.20	49.70	42.50	49.50	45.20	48.40	42.40	43.60
	Split 4	54.00	57.10	51.50	60.10	54.80	61.60	54.90	52.00	51.80	50.20	59.10	52.30	50.20	51.00	48.80	46.20	54.00	47.60	53.70	50.50	53.30	50.00	57.10	50.40	58.30	46.70	63.20	50.40
	Split 5	62.10	61.10	67.40	56.50	60.50	60.10	59.00	52.00	58.70	52.50	63.70	52.00	58.80	53.20	56.60	48.10	57.30	47.20	60.30	47.70	62.70	53.20	63.30	49.60	65.90	50.40	66.60	50.60
	Split 6	64.40	63.90	69.30	67.10	65.80	54.80	64.30	59.30	70.10	60.00	65.40	59.80	64.60	58.20	61.60	56.10	62.20	56.80	65.40	55.80	64.30	59.60	64.70	59.20	68.40	52.90	67.50	63.30
	Dust	48.90	48.80		48.90		48.80		49.2		52.00		49.2		47.9		44.8		47.7		48		47.1		47.60		47.20		48.10
	Products Total	47.61	47.74	47.01	44.45	47.25	48.21	48.78	46.19	47.11	46.97	48.51	47.06	49.34	46.04	46.13	44.53	46.52	45.21	47.97	48.57	45.00	45.16	49.69	45.03	48.19	44.09	47.63	43.97
Note -	Total Moisture values estimated, may be updated later																												
	Samples analyzed without screening at 1/4" to obtain quick results for Samples 1 & 2																												

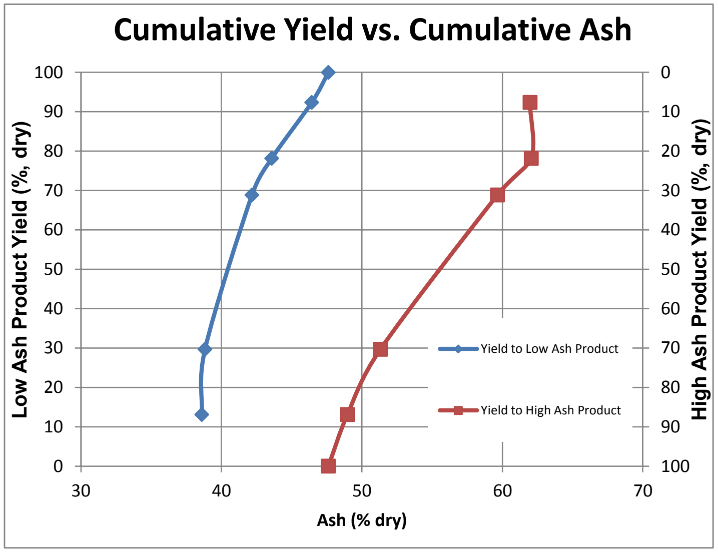
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

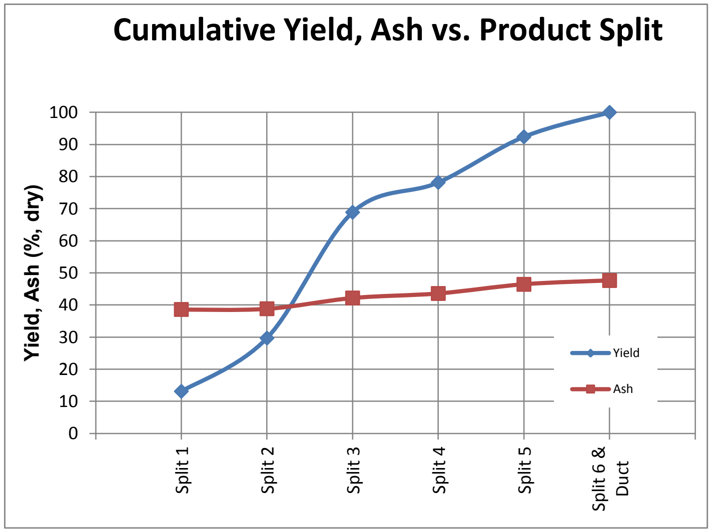
Date 8/11/09 Test - 1

Stream/ Product	Individual					Cumulative			
						Low Ash Product		High Ash Product	
	Weight (kg, AR)	Total Moisture (%)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
Feed	22.88	11.00	20.36		49.10				
Split 1	2.73	12.00	2.40	13.10	38.60	13.10	38.60	100.00	47.61
Split 2	3.46	12.00	3.04	16.57	39.00	29.67	38.82	86.90	48.97
Split 3	8.13	11.50	7.19	39.20	44.70	68.87	42.17	70.33	51.32
Split 4	1.90	10.00	1.71	9.30	54.00	78.17	43.58	31.13	59.65
Split 5	2.87	9.00	2.61	14.21	62.10	92.38	46.43	21.83	62.05
Split 6	1.30	9.00	1.18	6.42	64.40	98.81	47.59	7.62	61.97
Dust	0.24	8.00	0.22	1.19	48.90	100.00	47.61	1.19	48.90
Products	20.60	10.97	18.34	100.00	47.61				

Note - Total Moisture values estimated, may be updated later
Samples analyzed without screening at 1/4" to obtain quick results for Samples 1 & 2
Split 6 and Dust samples combined for final Low Ash Product point and for
first High Ash Product point

Charts Represent Total Sample Composit Values





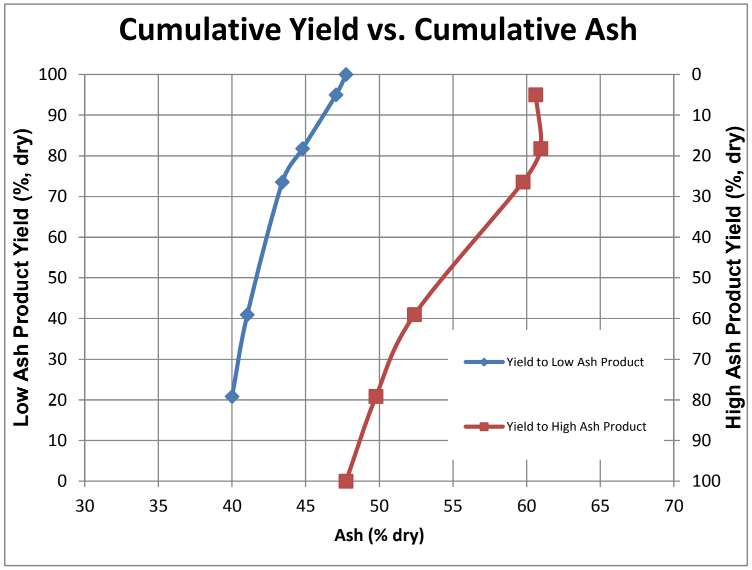
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

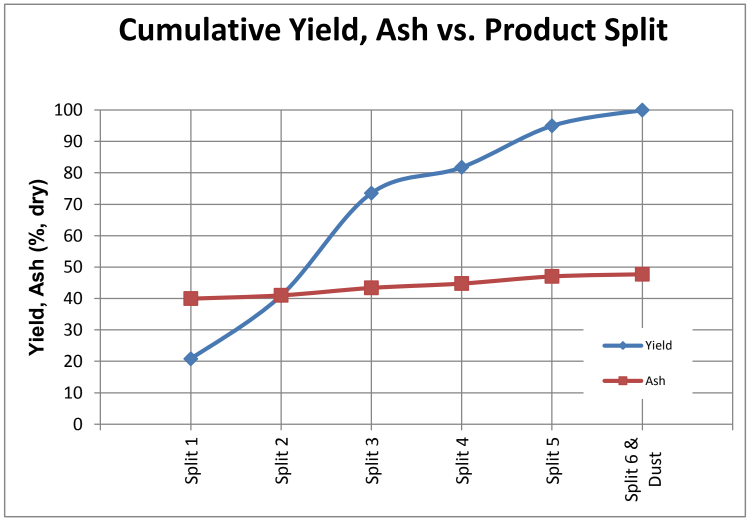
Date 8/11/09 Test - 2

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
Feed	29.12	11.00	25.92		48.70				
Split 1	5.24	12.00	4.61	20.81	40.00	20.81	40.00	100.00	47.74
Split 2	5.07	12.00	4.46	20.11	42.10	40.92	41.03	79.19	49.77
Split 3	8.17	11.50	7.23	32.63	46.40	73.55	43.41	59.08	52.39
Split 4	2.03	10.00	1.82	8.22	57.10	81.77	44.79	26.45	59.77
Split 5	3.22	9.00	2.93	13.22	61.10	94.99	47.06	18.23	60.97
Split 6	0.96	9.00	0.87	3.92	63.90	98.91	47.73	5.01	60.63
Dust	0.26	8.00	0.24	1.09	48.80	100.00	47.74	1.09	48.80
Products	24.94	11.13	22.16	100.00	47.74				

Note - Total Moisture values estimated, may be updated later
Samples analyzed without screening at 1/4" to obtain quick results for Samples 1 & 2
Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values



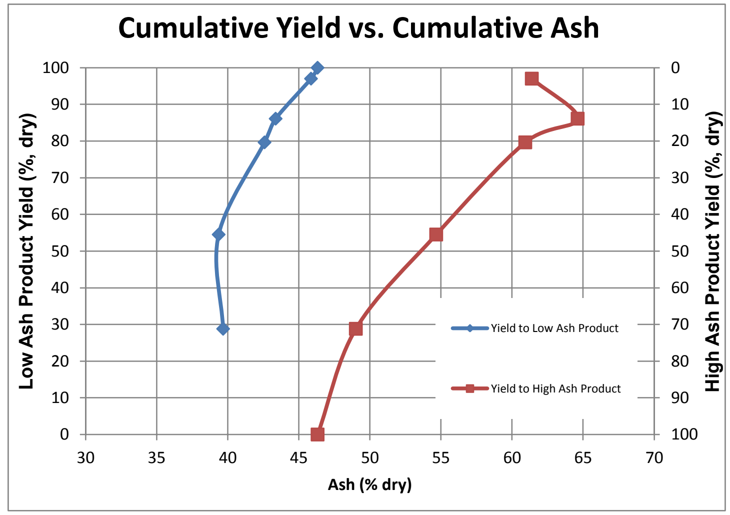


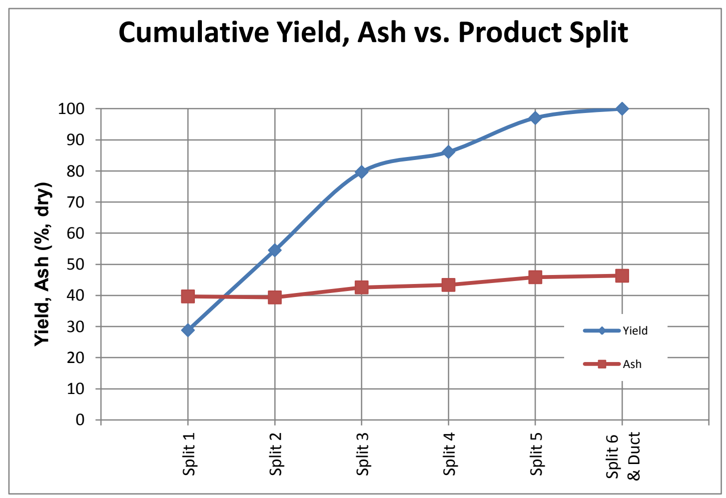
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

Date 8/12/09 Test - 3

Stream/ Product	Individual: Weight (kg, AR)	Total Moisture (%)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative Low Ash Product: Weight (%, dry)	Ash (%, dry)	Cumulative High Ash Product: Weight (%, dry)	Ash (%, dry)
+6 mm			82.52	% of Sample					
Feed	17.79	9.50	16.10		48.20				
Split 1	5.16	10.60	4.61	26.97	39.80	26.97	39.80	100.00	47.01
Split 2	4.88	20.50	3.88	22.68	37.70	49.65	38.84	73.03	49.67
Split 3	5.33	9.60	4.82	28.17	49.40	77.82	42.66	50.35	55.06
Split 4	1.38	7.60	1.27	7.43	51.50	85.25	43.43	22.18	62.26
Split 5	2.31	6.40	2.16	12.64	67.40	97.89	46.53	14.75	67.67
Split 6	0.38	4.90	0.36	2.11	69.30	100.00	47.01	2.11	69.30
Products	19.44	11.99	17.11	100.00	47.01				
-6 mm			17.48	% of Sample					
Feed	6.58	12.90	5.73		44.10				
Split 1	1.57	13.10	1.36	37.53	39.10	37.53	39.10	100.00	44.45
Split 2	1.66	12.40	1.45	40.01	45.20	77.53	42.25	62.47	47.67
Split 3	0.44	10.20	0.39	10.78	50.50	88.31	43.25	22.47	52.06
Split 4	0.08	10.00	0.07	1.86	60.10	90.18	43.60	11.69	53.51
Split 5	0.11	9.00	0.10	2.76	56.50	92.94	43.99	9.82	52.26
Split 6	0.03	4.50	0.02	0.66	67.10	93.60	44.15	7.06	50.60
Dust	0.25	7.40	0.23	6.40	48.90	100.00	44.45	6.40	48.90
Products	4.12	11.95	3.62	100.00	44.45				
Total Sample Composite			100.00	% of Sample					
Feed	24.37	10.42	21.83		47.48				
Split 1	6.73	11.18	5.97	28.81	39.68	28.81	39.68	100.00	46.32
Split 2	6.54	18.45	5.33	25.71	39.01	54.52	39.36	71.19	49.01
Split 3	5.77	9.65	5.21	25.13	49.59	79.65	42.59	45.48	54.67
Split 4	1.45	7.72	1.34	6.45	53.00	86.11	43.37	20.35	60.93
Split 5	2.42	6.52	2.26	10.91	65.49	97.02	45.86	13.89	64.61
Split 6	0.41	4.88	0.39	1.86	68.92	98.88	46.29	2.98	61.39
Dust	0.25	7.40	0.23	1.12	48.90	100.00	46.32	1.12	48.90
Products	23.55	11.98	20.73	100.00	46.32				

Charts Represent Total Sample Composit Values





Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

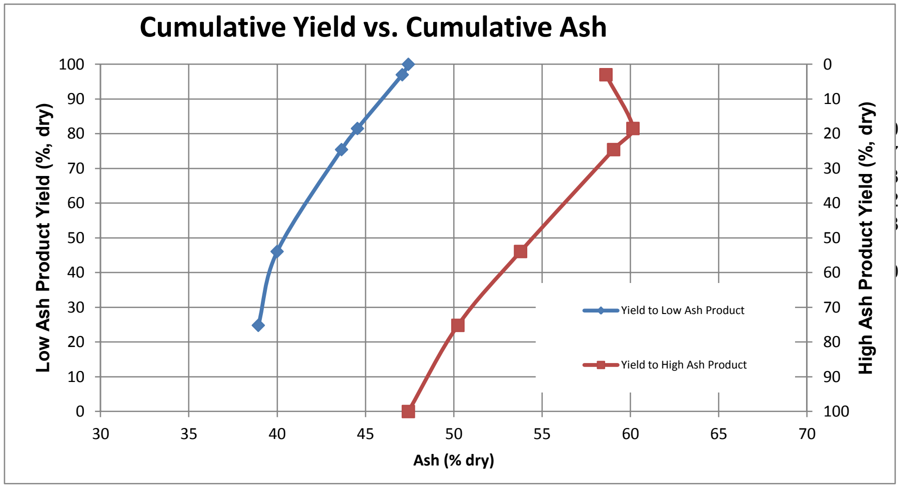
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

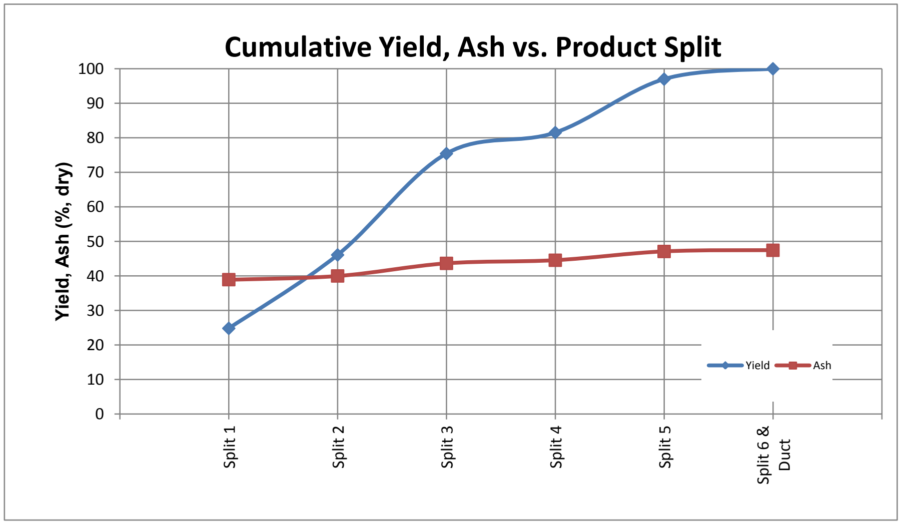
Date 8/12/09 Test - 4

Stream/ Product	Individual					Cumulative			
						Low Ash Product		High Ash Product	
	Weight (kg, AR)	Total Moisture (%)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm			86.37	% of Sample					
Feed	22.67	8.60	20.72		48.20				
Split 1	5.03	11.70	4.44	24.34	38.10	24.34	38.10	100.00	47.25
Split 2	4.45	19.30	3.59	19.68	40.90	44.03	39.35	75.66	50.19
Split 3	6.46	9.40	5.85	32.08	49.10	76.11	43.46	55.97	53.46
Split 4	1.21	7.20	1.12	6.15	54.80	82.26	44.31	23.89	59.31
Split 5	3.32	9.30	3.01	16.51	60.50	98.77	47.01	17.74	60.87
Split 6	0.24	6.30	0.22	1.23	65.80	100.00	47.25	1.23	65.80
Products	20.71	11.91	18.24	100.00	47.25				
-6 mm			13.63	% of Sample					
Feed	1.84	19.20	1.49		46.00				
Split 1	0.93	13.50	0.80	27.80	44.20	27.80	44.20	100.00	48.21
Split 2	1.02	11.60	0.90	31.33	43.40	59.13	43.78	72.20	49.75
Split 3	0.39	10.10	0.35	12.03	51.10	71.15	45.01	40.87	54.62
Split 4	0.18	10.40	0.16	5.60	61.60	76.76	46.22	28.85	56.09
Split 5	0.28	5.80	0.26	9.00	60.10	85.76	47.68	23.24	54.77
Split 6	0.20	9.10	0.18	6.16	54.80	91.92	48.16	14.24	51.39
Dust	0.25	7.50	0.23	8.08	48.80	100.00	48.21	8.08	48.80
Products	3.23	10.93	2.88	100.00	48.21				
Total Sample Composite			100.00	% of Sample					
Feed	24.52	9.40	22.21		47.90				
Split 1	5.96	11.98	5.24	24.82	38.93	24.82	38.93	100.00	47.43
Split 2	5.47	17.86	4.49	21.27	41.24	46.09	40.00	75.18	50.24
Split 3	6.85	9.44	6.20	29.35	49.37	75.43	43.64	53.91	53.78
Split 4	1.39	7.61	1.28	6.08	55.73	81.51	44.55	24.57	59.05
Split 5	3.60	9.03	3.27	15.48	60.45	96.99	47.08	18.49	60.15
Split 6	0.44	7.56	0.40	1.90	64.30	98.90	47.42	3.01	58.62
Dust	0.25	7.50	0.23	1.10	48.80	100.00	47.43	1.10	48.80
Products	23.94	11.77	21.12	100.00	47.43				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





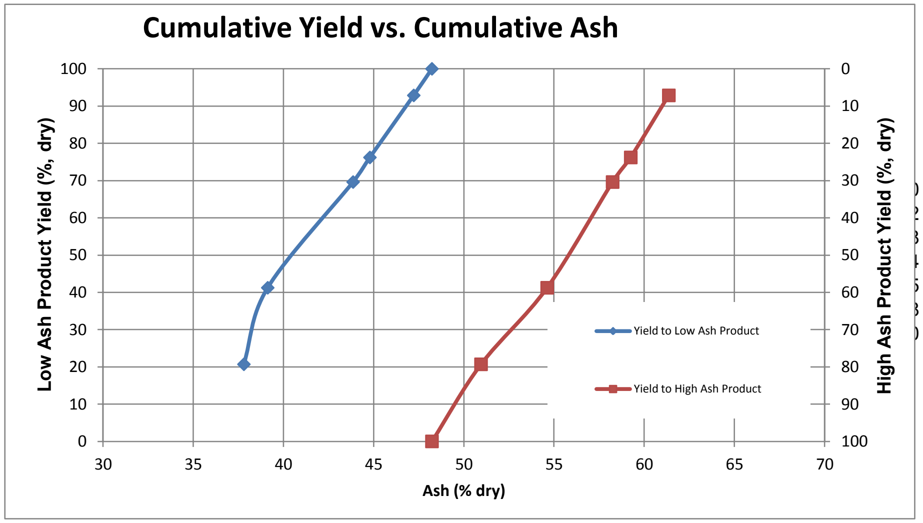
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

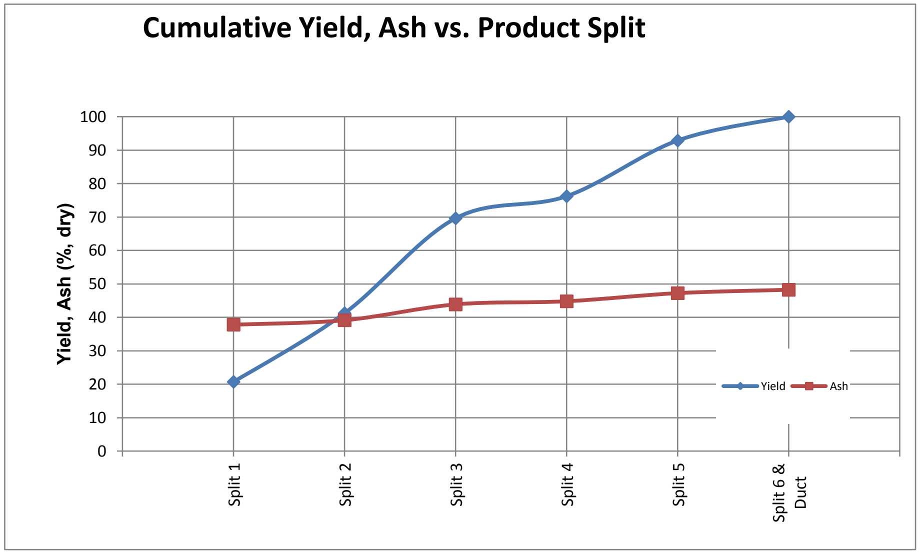
Date 8/12/09 Test - 5

Stream/ Product	Individual					Cumulative			
						Low Ash Product		High Ash Product	
	Weight (kg, AR)	Total Moisture (%)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
<u>+6 mm</u>			90.75	% of Sample					
Feed	28.07	10.00	25.26		47.20				
Split 1	4.77	12.00	4.20	19.12	37.20	19.12	37.20	100.00	48.78
Split 2	4.95	12.70	4.32	19.68	40.00	38.80	38.62	80.88	51.52
Split 3	7.35	10.50	6.58	29.96	51.10	68.75	44.06	61.20	55.22
Split 4	1.67	9.50	1.51	6.86	54.90	75.62	45.04	31.25	59.17
Split 5	4.35	8.60	3.97	18.09	59.00	93.70	47.74	24.38	60.37
Split 6	1.50	7.50	1.38	6.30	64.30	100.00	48.78	6.30	64.30
Products	24.58	10.65	21.96	100.00	48.78				
<u>-6 mm</u>			9.25	% of Sample					
Feed	2.34	12.00	2.05		47.60				
Split 1	0.95	14.80	0.81	36.15	43.80	36.15	43.80	100.00	46.19
Split 2	0.76	14.60	0.65	28.99	45.00	65.13	44.33	63.85	47.54
Split 3	0.33	10.80	0.29	12.95	47.20	78.08	44.81	34.87	49.65
Split 4	0.10	9.80	0.09	4.03	52.00	82.11	45.16	21.92	51.10
Split 5	0.07	9.50	0.06	2.63	52.00	84.73	45.37	17.89	50.89
Split 6	0.06	7.60	0.05	2.27	59.30	87.00	45.74	15.27	50.70
Dust	0.31	6.90	0.29	13.00	49.20	100.00	46.19	13.00	49.20
Products	2.57	12.79	2.24	100.00	46.19				
<u>Total Sample Composite</u>			100.00	% of Sample					
Feed	30.40	10.15	27.31		47.24				
Split 1	5.72	12.47	5.01	20.69	37.81	20.69	37.81	100.00	48.24
Split 2	5.71	12.95	4.97	20.54	40.46	41.23	39.13	79.31	50.96
Split 3	7.68	10.51	6.87	28.38	50.74	69.62	43.86	58.77	54.62
Split 4	1.77	9.52	1.60	6.60	54.63	76.22	44.80	30.38	58.25
Split 5	4.41	8.61	4.03	16.66	58.35	92.87	47.23	23.78	59.26
Split 6	1.55	7.50	1.43	5.92	63.84	98.80	48.22	7.13	61.37
Dust	0.31	6.90	0.29	1.20	49.20	100.00	48.24	1.20	49.20
Products	27.14	10.85	24.20	100.00	48.24				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





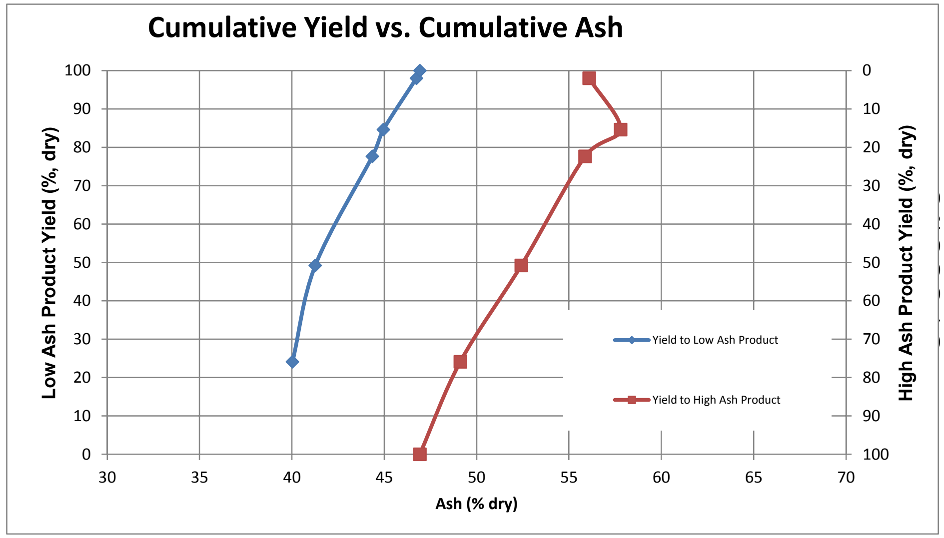
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

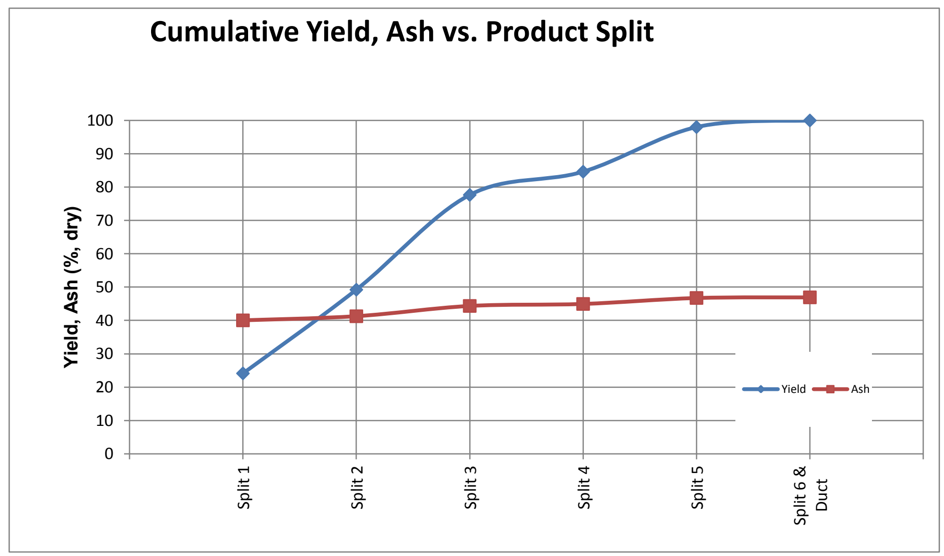
Date 8/12/09 Test - 6

	Individual					Cumulative			
						Low Ash Product		High Ash Product	
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm			89.49	% of Sample					
Feed	23.18	10.20	20.82		50.30				
Split 1	4.22	11.70	3.72	22.87	39.50	22.87	39.50	100.00	47.11
Split 2	4.41	11.20	3.91	24.04	42.10	46.90	40.83	77.13	49.37
Split 3	5.58	10.80	4.97	30.56	49.80	77.46	44.37	53.10	52.65
Split 4	1.37	9.70	1.23	7.57	51.80	85.03	45.03	22.54	56.52
Split 5	2.62	8.80	2.39	14.68	58.70	99.72	47.04	14.97	58.92
Split 6	0.05	7.90	0.05	0.28	70.10	100.00	47.11	0.28	70.10
Products	18.23	10.73	16.27	100.00	47.11				
-6 mm			10.51	% of Sample					
Feed	3.23	11.90	2.85		48.80				
Split 1	0.77	13.90	0.66	34.69	44.50	34.69	44.50	100.00	46.97
Split 2	0.76	13.30	0.65	34.25	45.40	68.94	44.95	65.31	48.28
Split 3	0.23	12.10	0.20	10.35	48.90	79.29	45.46	31.06	51.45
Split 4	0.04	11.30	0.04	1.86	50.20	81.14	45.57	20.71	52.72
Split 5	0.05	10.10	0.04	2.35	52.50	83.49	45.77	18.86	52.97
Split 6	0.05	9.20	0.04	2.14	60.00	85.63	46.12	16.51	53.04
Dust	0.30	7.20	0.27	14.37	52.00	100.00	46.97	14.37	52.00
Products	2.18	12.37	1.91	100.00	46.97				
Total Sample Composite			100.00	% of Sample					
Feed	26.41	10.41	23.66		50.14				
Split 1	4.99	12.04	4.38	24.11	40.03	24.11	40.03	100.00	46.93
Split 2	5.16	11.51	4.57	25.11	42.45	49.22	41.26	75.89	49.12
Split 3	5.80	10.85	5.17	28.43	49.71	77.65	44.35	50.78	52.42
Split 4	1.41	9.75	1.27	6.97	51.63	84.63	44.95	22.35	55.87
Split 5	2.67	8.82	2.43	13.39	58.05	98.01	46.74	15.37	57.80
Split 6	0.10	8.52	0.09	0.48	69.04	98.49	46.85	1.99	56.10
Dust	0.30	7.20	0.27	1.51	52.00	100.00	46.93	1.51	52.00
Products	20.41	10.90	18.19	100.00	46.93				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





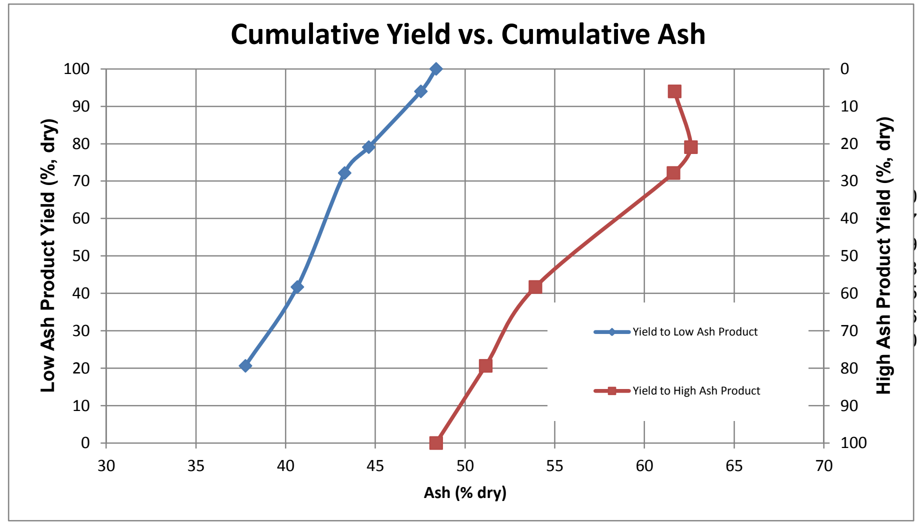
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

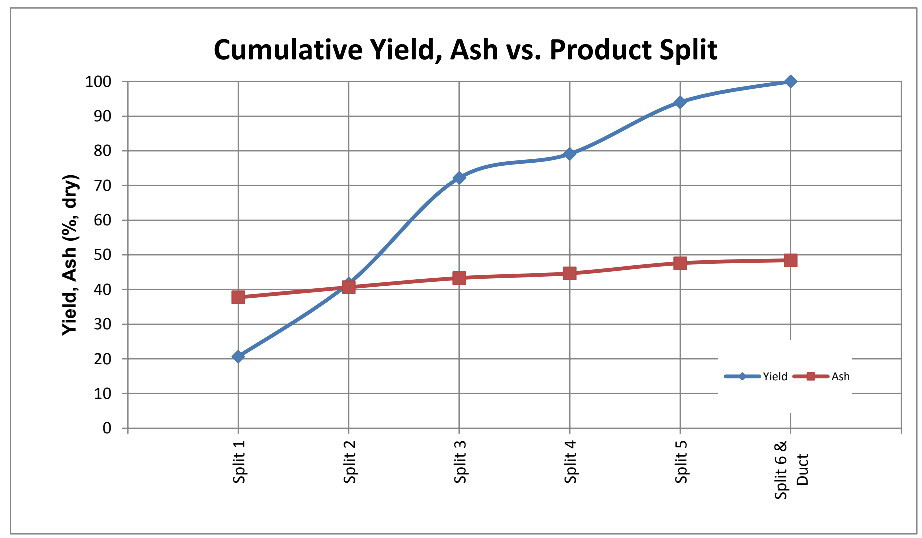
Date 8/12/09 Test - 7

	Individual					Cumulative			
						Low Ash Product		High Ash Product	
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm			93.66	% of Sample					
Feed	22.04	10.30	19.77		47.50				
Split 1	4.83	11.60	4.27	21.87	37.50	21.87	37.50	100.00	48.51
Split 2	4.27	12.20	3.75	19.22	43.50	41.09	40.31	78.13	51.59
Split 3	6.76	9.50	6.11	31.34	46.70	72.44	43.07	58.91	54.23
Split 4	1.55	9.20	1.41	7.22	59.10	79.65	44.53	27.56	62.78
Split 5	3.35	8.70	3.06	15.68	63.70	95.34	47.68	20.35	64.09
Split 6	0.99	8.10	0.91	4.66	65.40	100.00	48.51	4.66	65.40
Products	21.74	10.29	19.50	100.00	48.51				
-6 mm			6.34	% of Sample					
Feed	4.20	13.20	3.65		46.80				
Split 1	0.04	12.40	0.03	2.32	41.60	2.32	41.60	100.00	47.06
Split 2	0.73	12.40	0.64	48.40	43.30	50.72	43.22	97.68	47.19
Split 3	0.26	10.70	0.23	17.57	49.80	68.29	44.91	49.28	51.01
Split 4	0.04	10.40	0.03	2.37	52.30	70.66	45.16	31.71	51.68
Split 5	0.05	9.80	0.05	3.41	52.00	74.08	45.48	29.34	51.63
Split 6	0.09	9.60	0.08	5.82	59.80	79.89	46.52	25.92	51.58
Dust	0.29	7.50	0.27	20.11	49.20	100.00	47.06	20.11	49.20
Products	1.48	10.86	1.32	100.00	47.06				
Total Sample Composite			100.00	% of Sample					
Feed	26.24	10.76	23.41		47.46				
Split 1	4.86	11.61	4.30	20.63	37.76	20.63	37.76	100.00	48.39
Split 2	5.00	12.23	4.39	21.07	43.49	41.70	40.65	79.37	51.15
Split 3	7.02	9.54	6.35	30.47	46.90	72.17	43.29	58.30	53.92
Split 4	1.59	9.23	1.44	6.91	58.67	79.08	44.63	27.83	61.62
Split 5	3.40	8.72	3.10	14.90	62.96	93.99	47.54	20.92	62.59
Split 6	1.08	8.22	0.99	4.74	65.04	98.72	48.38	6.01	61.68
Dust	0.29	7.50	0.27	1.28	49.20	100.00	48.39	1.28	49.20
Products	23.22	10.32	20.82	100.00	48.39				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





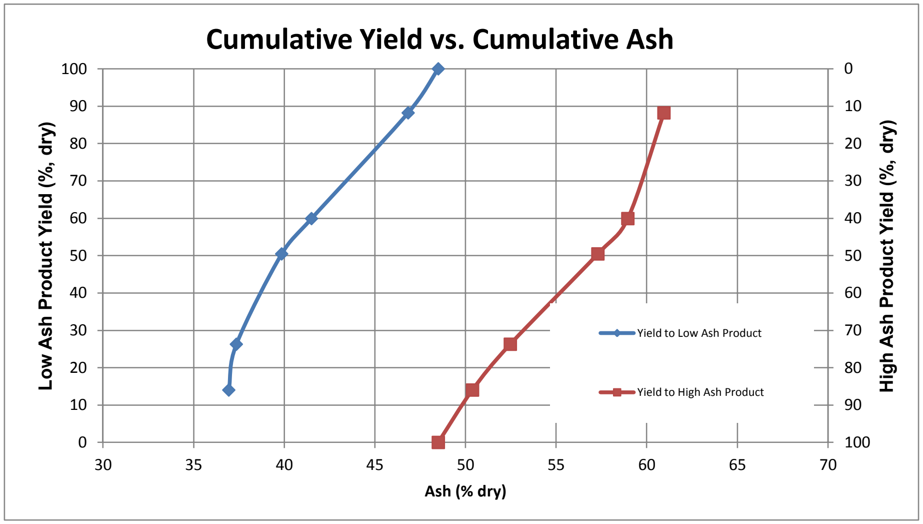
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

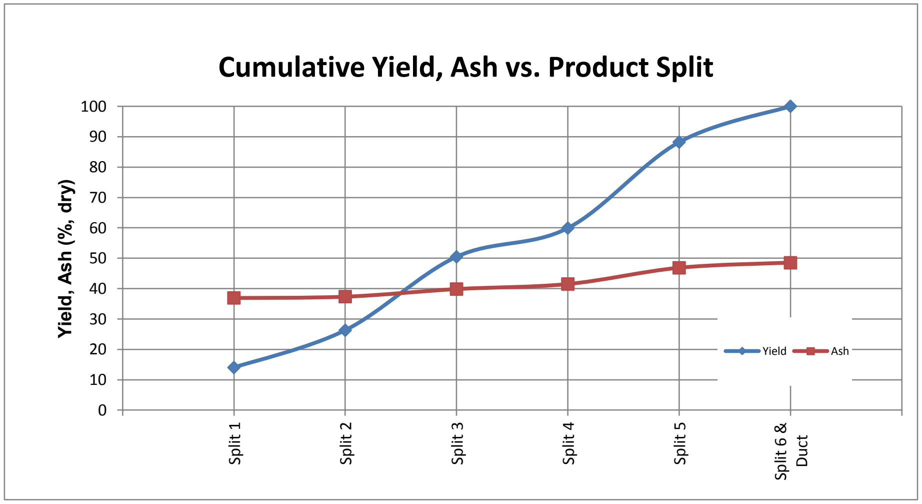
Date 8/13/09 Test - 8

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm			88.02	% of Sample					
Feed	21.30	10.80	19.00		50.00				
Split 1	1.85	12.10	1.63	12.45	36.10	12.45	36.10	100.00	49.34
Split 2	1.32	11.30	1.17	8.97	36.90	21.42	36.43	87.55	51.23
Split 3	3.82	10.90	3.40	26.06	42.00	47.48	39.49	78.58	52.86
Split 4	1.51	9.80	1.36	10.43	50.20	57.91	41.42	52.52	58.25
Split 5	4.52	8.70	4.13	31.60	58.80	89.52	47.55	42.09	60.24
Split 6	1.48	7.50	1.37	10.48	64.60	100.00	49.34	10.48	64.60
Products	14.50	9.94	13.06	100.00	49.34				
-6 mm			11.98	% of Sample					
Feed	3.07	12.30	2.69		46.30				
Split 1	0.53	14.20	0.45	25.59	43.10	25.59	43.10	100.00	46.04
Split 2	0.75	13.60	0.65	36.46	44.70	62.05	44.04	74.41	47.05
Split 3	0.21	12.70	0.18	10.32	46.80	72.37	44.43	37.95	49.32
Split 4	0.05	11.50	0.04	2.24	51.00	74.61	44.63	27.63	50.25
Split 5	0.08	10.60	0.07	4.02	53.20	78.63	45.07	25.39	50.19
Split 6	0.07	9.30	0.06	3.57	58.20	82.20	45.64	21.37	49.62
Dust	0.34	7.00	0.32	17.80	47.90	100.00	46.04	17.80	47.90
Products	2.03	12.24	1.78	100.00	46.04				
Total Sample Composite			100.00	% of Sample					
Feed	24.37	10.99	21.69		49.56				
Split 1	2.38	12.57	2.08	14.03	36.94	14.03	36.94	100.00	48.50
Split 2	2.07	12.13	1.82	12.26	37.83	26.29	37.36	85.97	50.39
Split 3	4.03	10.99	3.59	24.18	42.58	50.46	39.86	73.71	52.47
Split 4	1.56	9.85	1.40	9.45	50.30	59.91	41.50	49.54	57.31
Split 5	4.60	8.73	4.20	28.30	58.13	88.21	46.84	40.09	58.96
Split 6	1.55	7.58	1.43	9.66	63.83	97.87	48.51	11.79	60.95
Dust	0.34	7.00	0.32	2.13	47.90	100.00	48.50	2.13	47.90
Products	16.53	10.22	14.84	100.00	48.50				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





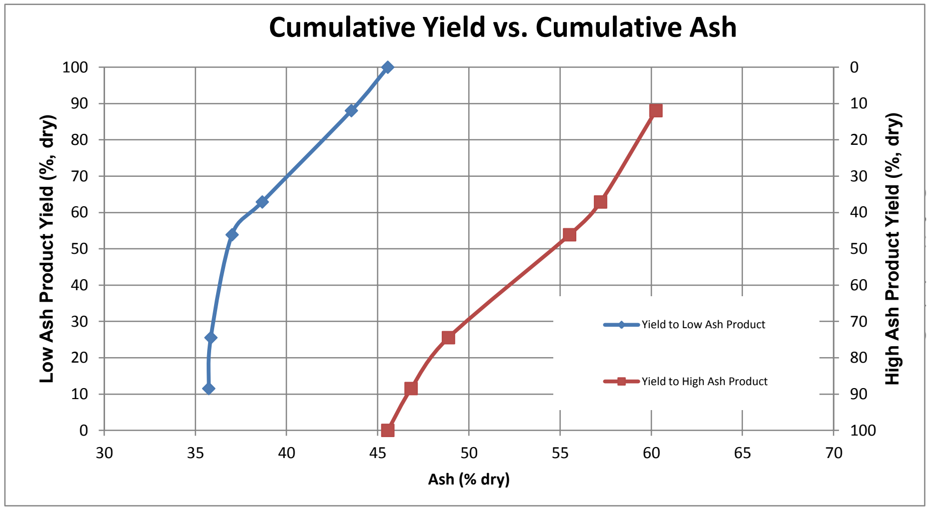
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

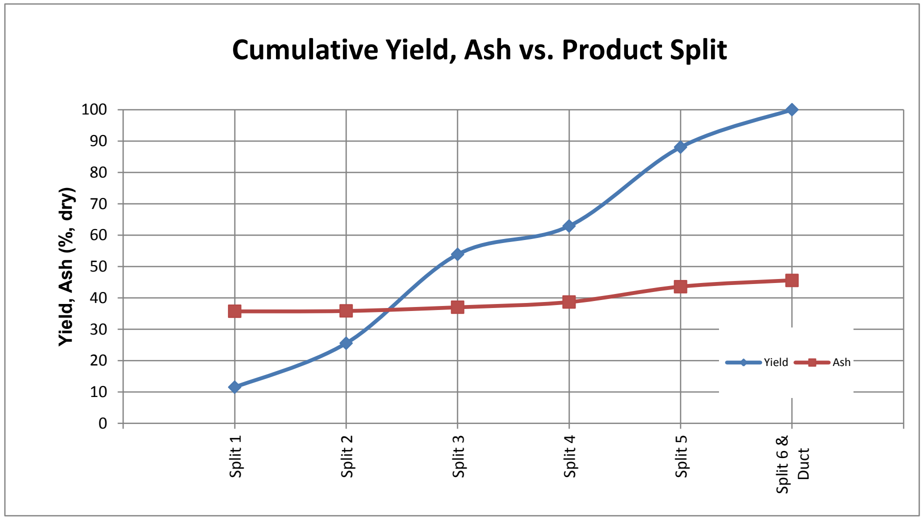
Date 8/14/09 Test - 9

Stream/ Product	Individual					Cumulative			
						Low Ash Product		High Ash Product	
	Weight (kg, AR)	Total Moisture (%)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm			90.32	% of Sample					
Feed	18.83	9.80	16.98		46.40				
Split 1	2.11	12.40	1.85	10.19	35.00	10.19	35.00	100.00	46.13
Split 2	2.35	12.60	2.05	11.30	35.20	21.48	35.11	89.81	47.39
Split 3	6.10	12.30	5.35	29.49	37.30	50.97	36.37	78.52	49.14
Split 4	1.96	9.80	1.77	9.74	48.80	60.71	38.37	49.03	56.26
Split 5	5.45	8.80	4.97	27.39	56.60	88.11	44.04	39.29	58.11
Split 6	2.33	7.40	2.16	11.89	61.60	100.00	46.13	11.89	61.60
Products	20.30	10.60	18.14	100.00	46.13				
-6 mm			9.68	% of Sample					
Feed	2.56	13.60	2.21		45.70				
Split 1	0.54	13.80	0.47	23.94	42.60	23.94	42.60	100.00	44.53
Split 2	0.90	14.40	0.77	39.40	43.00	63.34	42.85	76.06	45.13
Split 3	0.40	13.20	0.34	17.63	45.20	80.97	43.36	36.66	47.43
Split 4	0.05	10.60	0.04	2.30	46.20	83.27	43.44	19.03	49.49
Split 5	0.09	9.30	0.08	4.20	48.10	87.46	43.66	16.73	49.95
Split 6	0.14	7.90	0.12	6.39	56.10	93.86	44.51	12.54	50.56
Dust	0.13	8.20	0.12	6.14	44.80	100.00	44.53	6.14	44.80
Products	2.24	13.00	1.94	100.00	44.53				
Total Sample Composite			100.00	% of Sample					
Feed	21.39	10.25	19.19		46.33				
Split 1	2.65	12.69	2.31	11.52	35.74	11.52	35.74	100.00	45.55
Split 2	3.24	13.10	2.82	14.02	35.96	25.54	35.86	88.48	46.83
Split 3	6.50	12.35	5.69	28.34	38.06	53.87	37.02	74.46	48.88
Split 4	2.01	9.82	1.81	9.02	48.55	62.90	38.67	46.13	55.52
Split 5	5.54	8.81	5.05	25.15	55.78	88.05	43.56	37.10	57.22
Split 6	2.47	7.43	2.28	11.36	61.07	99.41	45.56	11.95	60.26
Dust	0.13	8.20	0.12	0.59	44.80	100.00	45.55	0.59	44.80
Products	22.53	10.84	20.09	100.00	45.55				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





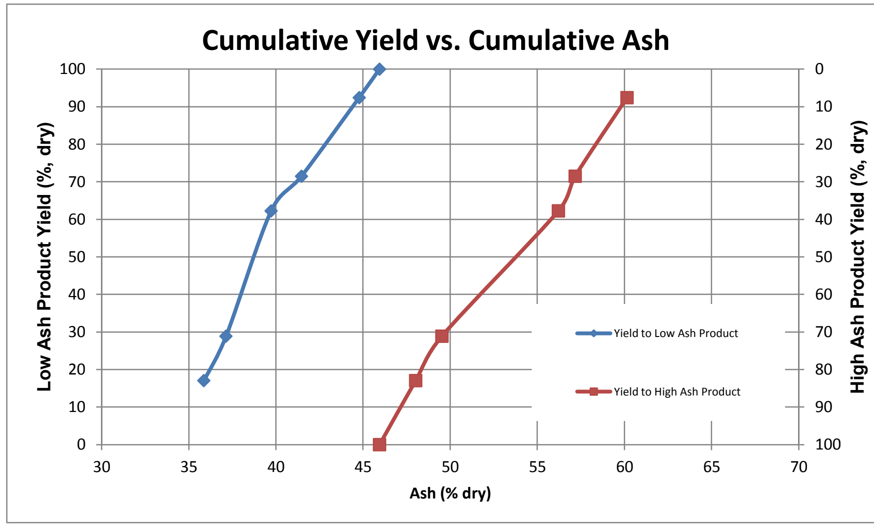
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

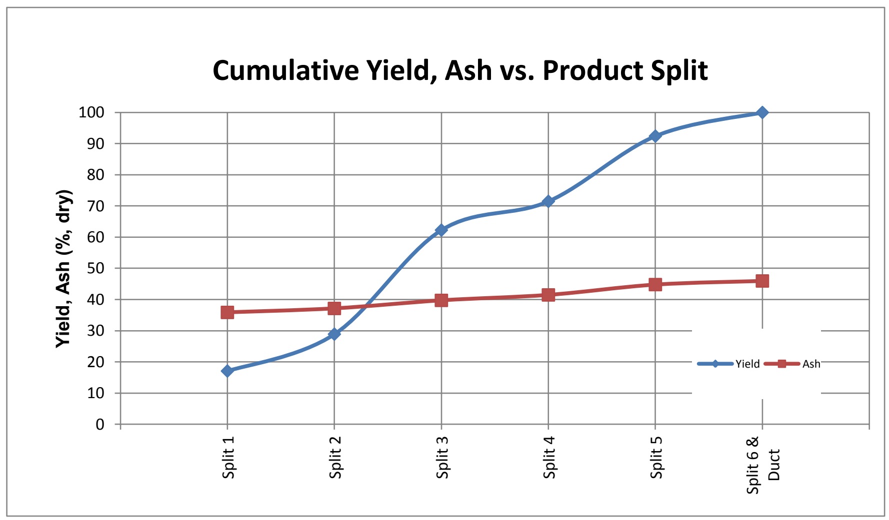
Date 8/17/09 Test - 10

Stream/ Product	Individual					Cumulative			
						Low Ash Product		High Ash Product	
	Weight (kg, AR)	Total Moisture (%)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
<u>+6 mm</u>			88.07	% of Sample					
Feed	16.32	8.90	14.87		49.30				
Split 1	2.29	10.00	2.06	15.07	34.80	15.07	34.80	100.00	46.52
Split 2	1.31	10.20	1.17	8.59	38.50	23.66	36.14	84.93	48.61
Split 3	5.46	9.80	4.92	36.06	41.30	59.72	39.26	76.34	49.74
Split 4	1.53	9.50	1.38	10.15	54.00	69.87	41.40	40.28	57.30
Split 5	3.49	8.90	3.18	23.30	57.30	93.17	45.38	30.13	58.41
Split 6	1.01	7.70	0.93	6.83	62.20	100.00	46.52	6.83	62.20
Products	15.08	9.49	13.65	100.00	46.52				
<u>-6 mm</u>			11.93	% of Sample					
Feed	2.99	9.40	2.70		47.10				
Split 1	0.66	11.20	0.59	31.70	43.70	31.70	43.70	100.00	45.02
Split 2	0.74	10.70	0.66	35.74	42.40	67.44	43.01	68.30	45.63
Split 3	0.28	10.40	0.25	13.57	46.90	81.01	43.66	32.56	49.17
Split 4	0.05	10.20	0.04	2.43	47.60	83.44	43.78	18.99	50.79
Split 5	0.07	9.40	0.06	3.43	47.20	86.87	43.91	16.56	51.26
Split 6	0.14	8.60	0.12	6.67	56.80	93.54	44.83	13.13	52.32
Dust	0.13	8.20	0.12	6.46	47.70	100.00	45.02	6.46	47.70
Products	2.07	10.47	1.85	100.00	45.02				
<u>Total Sample Composite</u>			100.00	% of Sample					
Feed	19.31	8.98	17.57		49.04				
Split 1	2.95	10.27	2.64	17.06	35.86	17.06	35.86	100.00	45.95
Split 2	2.05	10.38	1.83	11.83	38.97	28.88	37.13	82.94	48.02
Split 3	5.74	9.83	5.17	33.38	41.97	62.26	39.73	71.12	49.53
Split 4	1.58	9.52	1.43	9.23	53.24	71.49	41.47	37.74	56.21
Split 5	3.56	8.91	3.24	20.93	56.09	92.42	44.78	28.51	57.17
Split 6	1.15	7.81	1.06	6.81	61.56	99.23	45.93	7.58	60.15
Dust	0.13	8.20	0.12	0.77	47.70	100.00	45.95	0.77	47.70
Products	17.14	9.60	15.49	100.00	45.95				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





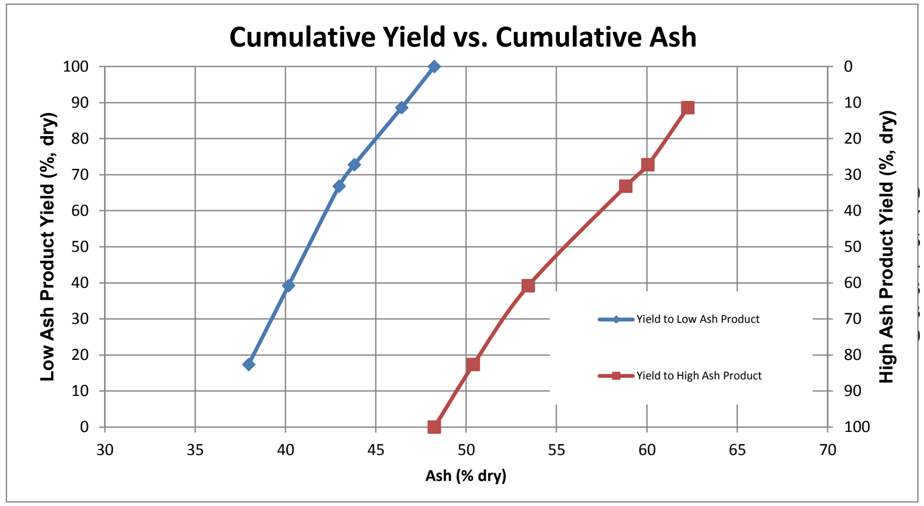
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

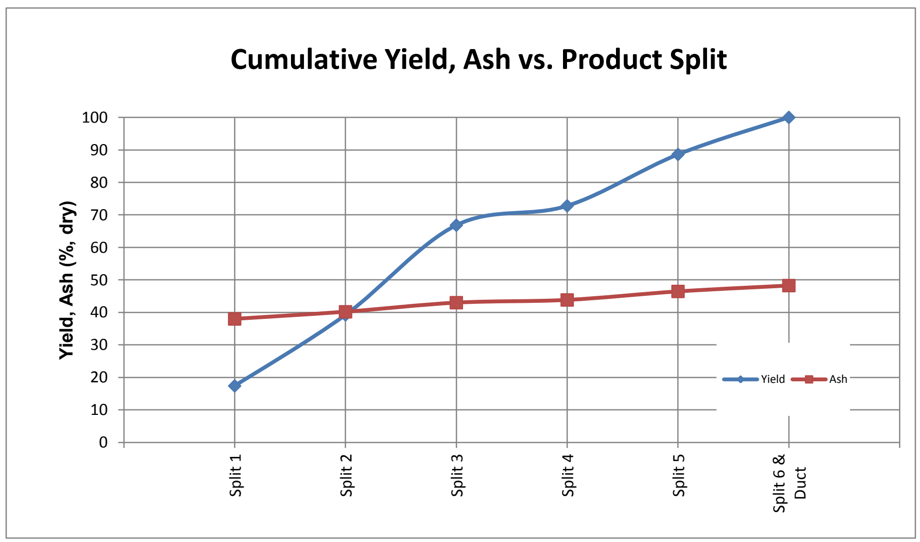
Date 8/17/09 Test - 11

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm			85.49	% of Sample					
Feed	18.19	7.90	16.75		47.90				
Split 1	3.52	10.90	3.14	17.13	37.10	17.13	37.10	100.00	47.97
Split 2	4.40	11.00	3.92	21.39	42.00	38.52	39.82	82.87	50.22
Split 3	6.28	10.20	5.64	30.80	46.40	69.32	42.74	61.48	53.08
Split 4	1.38	9.80	1.24	6.77	53.70	76.09	43.72	30.68	59.78
Split 5	3.67	8.70	3.35	18.28	60.30	94.37	46.93	23.91	61.50
Split 6	1.14	9.60	1.03	5.63	65.40	100.00	47.97	5.63	65.40
Products	20.38	10.16	18.31	100.00	47.97				
-6 mm			14.51	% of Sample					
Feed	3.36	9.60	3.04		45.10				
Split 1	0.67	12.50	0.58	18.72	43.10	18.72	43.10	100.00	48.57
Split 2	0.87	12.30	0.76	24.55	41.50	43.27	42.19	81.28	49.84
Split 3	0.31	11.90	0.27	8.79	50.20	52.06	43.54	56.73	53.44
Split 4	0.04	10.30	0.04	1.15	50.50	53.22	43.69	47.94	54.04
Split 5	0.05	9.80	0.05	1.45	47.70	54.67	43.80	46.78	54.13
Split 6	1.27	9.60	1.14	36.80	55.80	91.46	48.63	45.33	54.33
Dust	0.28	6.40	0.27	8.54	48.00	100.00	48.57	8.54	48.00
Products	3.48	10.78	3.11	100.00	48.57				
Total Sample Composite			100.00	% of Sample					
Feed	21.55	8.17	19.79		47.49				
Split 1	4.19	11.15	3.72	17.36	37.97	17.36	37.97	100.00	48.24
Split 2	5.27	11.21	4.68	21.85	41.93	39.21	40.18	82.64	50.39
Split 3	6.59	10.28	5.91	27.61	46.95	66.82	42.98	60.79	53.44
Split 4	1.42	9.81	1.28	5.96	53.24	72.77	43.82	33.18	58.83
Split 5	3.72	8.71	3.39	15.83	58.47	88.61	46.43	27.23	60.06
Split 6	2.41	9.60	2.17	10.15	64.01	98.76	48.24	11.39	62.27
Dust	0.28	6.40	0.27	1.24	48.00	100.00	48.24	1.24	48.00
Products	23.86	10.25	21.42	100.00	48.24				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





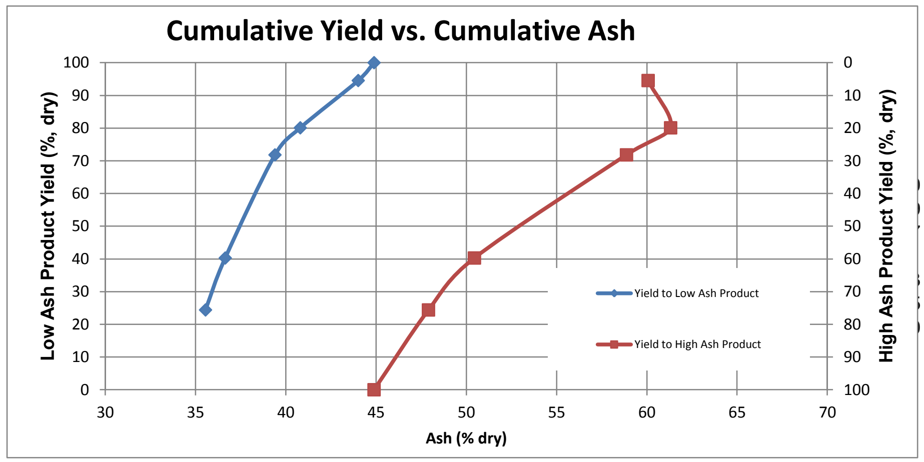
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

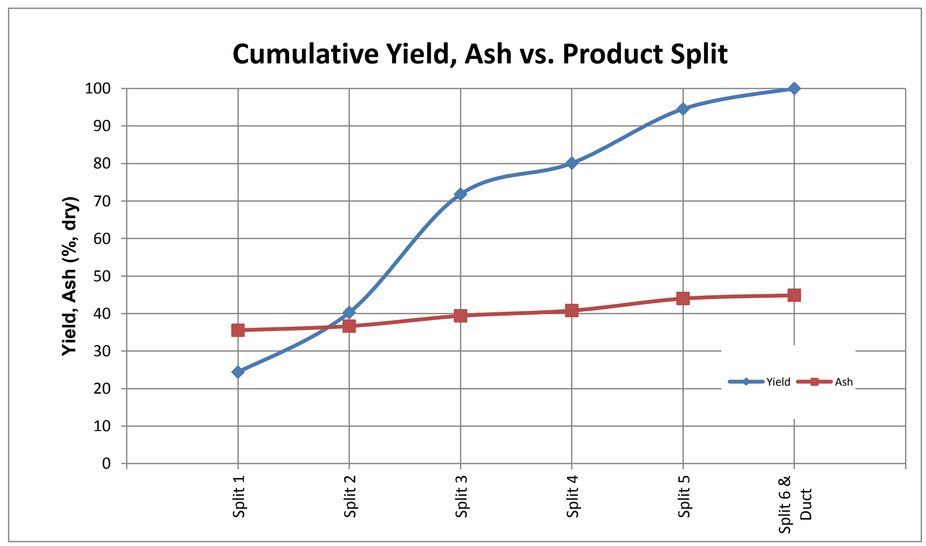
Date 8/17/09 Test - 12

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm			90.41	% of Sample					
Feed	23.90	8.70	21.82		47.50				
Split 1	5.01	9.40	4.53	23.28	34.70	23.28	34.70	100.00	45.00
Split 2	3.13	10.20	2.81	14.41	38.00	37.69	35.96	76.72	48.13
Split 3	7.17	9.10	6.51	33.44	42.20	71.14	38.89	62.31	50.48
Split 4	1.89	8.60	1.72	8.85	53.30	79.98	40.49	28.86	60.06
Split 5	3.31	8.10	3.04	15.62	62.70	95.60	44.12	20.02	63.05
Split 6	0.93	7.40	0.86	4.40	64.30	100.00	45.00	4.40	64.30
Products	21.42	9.06	19.48	100.00	45.00				
-6 mm			9.59	% of Sample					
Feed	3.18	9.90	2.86		45.30				
Split 1	0.81	10.50	0.72	34.89	43.60	34.89	43.60	100.00	45.16
Split 2	0.70	11.50	0.62	29.78	41.40	64.67	42.59	65.11	45.99
Split 3	0.31	10.20	0.28	13.48	49.70	78.15	43.81	35.33	49.87
Split 4	0.07	9.80	0.06	2.84	50.00	80.99	44.03	21.85	49.97
Split 5	0.08	9.40	0.07	3.51	53.20	84.50	44.41	19.01	49.97
Split 6	0.06	8.80	0.05	2.65	59.60	87.15	44.87	15.50	49.24
Dust	0.28	6.40	0.27	12.85	47.10	100.00	45.16	12.85	47.10
Products	2.30	10.15	2.07	100.00	45.16				
Total Sample Composite			100.00	% of Sample					
Feed	27.08	8.84	24.68		47.29				
Split 1	5.81	9.55	5.26	24.40	35.55	24.40	35.55	100.00	44.89
Split 2	3.82	10.44	3.42	15.88	38.33	40.28	36.65	75.60	47.90
Split 3	7.48	9.15	6.79	31.53	42.92	71.81	39.40	59.72	50.45
Split 4	1.95	8.64	1.78	8.27	52.98	80.08	40.80	28.19	58.87
Split 5	3.39	8.13	3.11	14.46	61.79	94.54	44.01	19.92	61.32
Split 6	0.99	7.49	0.91	4.23	63.85	98.77	44.86	5.46	60.07
Dust	0.28	6.40	0.27	1.23	47.10	100.00	44.89	1.23	47.10
Products	23.71	9.16	21.54	100.00	44.89				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





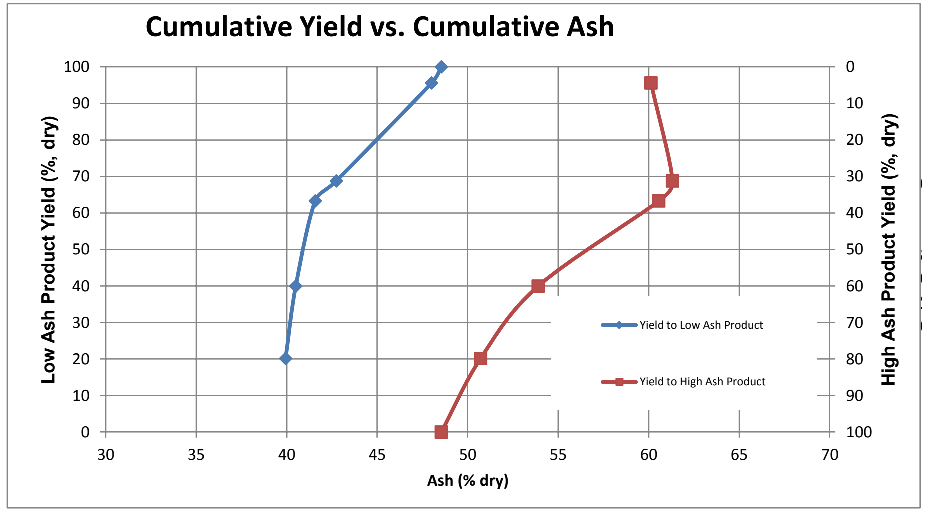
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

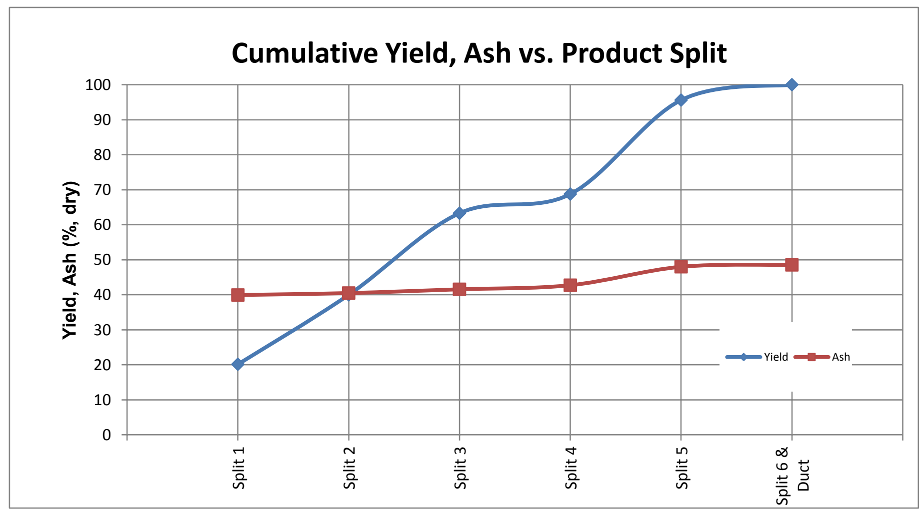
Date 8/17/09 Test - 13

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm			86.92	% of Sample					
Feed	24.00	8.70	21.91		49.10				
Split 1	4.54	10.00	4.08	16.87	39.60	16.87	39.60	100.00	49.69
Split 2	4.82	10.00	4.33	17.91	40.50	34.79	40.06	83.13	51.74
Split 3	6.69	9.60	6.04	24.98	42.50	59.77	41.08	65.21	54.83
Split 4	1.61	8.90	1.47	6.06	57.10	65.83	42.56	40.23	62.49
Split 5	8.07	8.10	7.41	30.64	63.30	96.47	49.15	34.17	63.44
Split 6	0.93	7.80	0.85	3.53	64.70	100.00	49.69	3.53	64.70
Products	26.64	9.18	24.19	100.00	49.69				
-6 mm			13.08	% of Sample					
Feed	4.56	10.60	4.08		46.20				
Split 1	1.78	14.20	1.53	41.94	42.20	41.94	42.20	100.00	45.03
Split 2	1.36	12.90	1.18	32.53	44.90	74.48	43.38	58.06	47.07
Split 3	0.51	11.50	0.45	12.27	49.50	86.75	44.25	25.52	49.83
Split 4	0.06	10.20	0.05	1.48	50.40	88.23	44.35	13.25	50.14
Split 5	0.07	10.20	0.06	1.60	49.60	89.84	44.44	11.77	50.10
Split 6	0.09	8.50	0.08	2.26	59.20	92.10	44.80	10.16	50.18
Dust	0.31	6.20	0.29	7.90	47.60	100.00	45.03	7.90	47.60
Products	4.17	12.62	3.64	100.00	45.03				
Total Sample Composite			100.00	% of Sample					
Feed	28.56	9.00	25.99		48.72				
Split 1	6.32	11.18	5.61	20.15	39.94	20.15	39.94	100.00	48.54
Split 2	6.18	10.64	5.52	19.83	41.08	39.98	40.50	79.85	50.71
Split 3	7.19	9.73	6.49	23.32	43.42	63.30	41.58	60.02	53.90
Split 4	1.67	8.95	1.52	5.46	56.22	68.76	42.74	36.70	60.56
Split 5	8.13	8.12	7.47	26.84	61.51	95.61	48.01	31.24	61.31
Split 6	1.02	7.86	0.94	3.36	63.98	98.97	48.55	4.39	60.13
Dust	0.31	6.20	0.29	1.03	47.60	100.00	48.54	1.03	47.60
Products	30.80	9.65	27.83	100.00	48.54				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





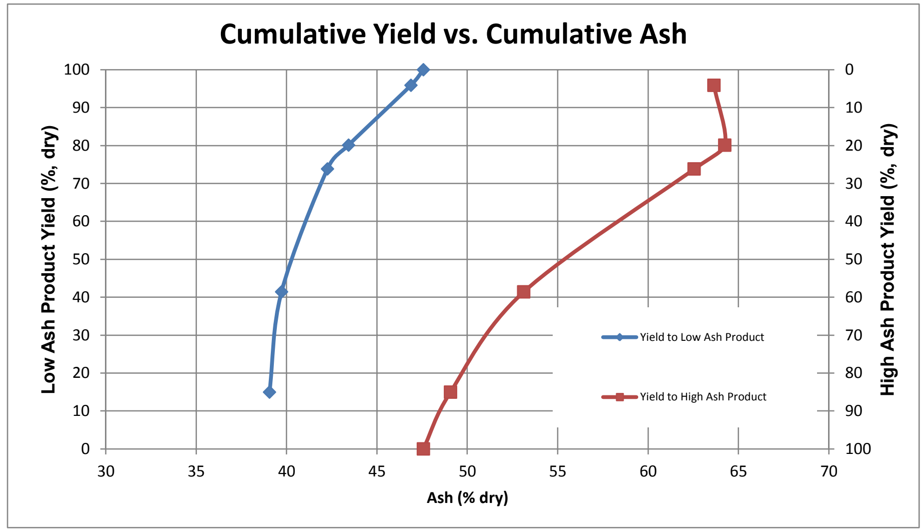
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

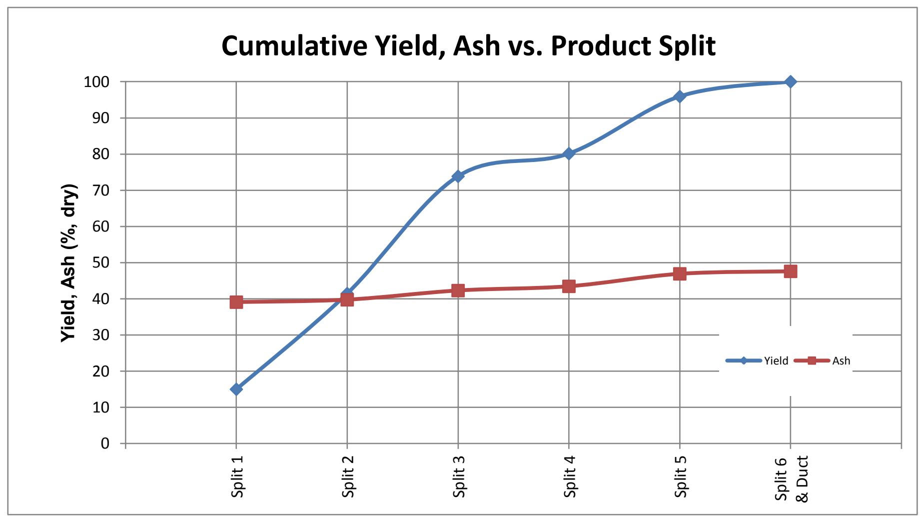
Date 8/17/09 Test - 14

Stream/ Product	Individual					Cumulative			
						Low Ash Product		High Ash Product	
	Weight (kg, AR)	Total Moisture (%)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm			90.32	% of Sample					
Feed	18.83	8.90	17.15		51.20				
Split 1	2.49	10.20	2.23	13.13	38.90	13.13	38.90	100.00	48.19
Split 2	4.84	10.10	4.35	25.58	39.80	38.71	39.49	86.87	49.60
Split 3	6.42	9.70	5.79	34.09	45.20	72.80	42.17	61.29	53.69
Split 4	1.26	8.80	1.14	6.74	58.30	79.54	43.53	27.20	64.33
Split 5	3.15	7.90	2.90	17.07	65.90	96.61	47.49	20.46	66.31
Split 6	0.62	7.10	0.58	3.39	68.40	100.00	48.19	3.39	68.40
Products	18.76	9.42	16.99	100.00	48.19				
-6 mm			9.68	% of Sample					
Feed	2.15	10.80	1.92		46.20				
Split 1	0.67	12.60	0.59	32.14	40.50	32.14	40.50	100.00	44.09
Split 2	0.72	11.90	0.63	34.57	42.90	66.72	41.74	67.86	45.78
Split 3	0.35	11.20	0.31	16.82	48.40	83.53	43.08	33.28	48.78
Split 4	0.04	10.40	0.04	1.97	46.70	85.50	43.17	16.47	49.17
Split 5	0.08	9.20	0.07	3.74	50.40	89.24	43.47	14.50	49.50
Split 6	0.08	8.60	0.07	3.76	52.90	93.00	43.85	10.76	49.19
Dust	0.14	6.80	0.13	7.00	47.20	100.00	44.09	7.00	47.20
Products	2.06	11.42	1.82	100.00	44.09				
Total Sample Composite			100.00	% of Sample					
Feed	20.98	9.09	19.07		50.72				
Split 1	3.16	10.71	2.82	14.97	39.05	14.97	39.05	100.00	47.57
Split 2	5.55	10.33	4.98	26.45	40.10	41.42	39.72	85.03	49.07
Split 3	6.76	9.78	6.10	32.42	45.51	73.84	42.26	58.58	53.12
Split 4	1.30	8.85	1.18	6.27	57.18	80.11	43.43	26.16	62.55
Split 5	3.23	7.93	2.97	15.78	64.40	95.90	46.88	19.89	64.24
Split 6	0.70	7.26	0.64	3.43	66.90	99.32	47.57	4.10	63.64
Dust	0.14	6.80	0.13	0.68	47.20	100.00	47.57	0.68	47.20
Products	20.82	9.62	18.81	100.00	47.57				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





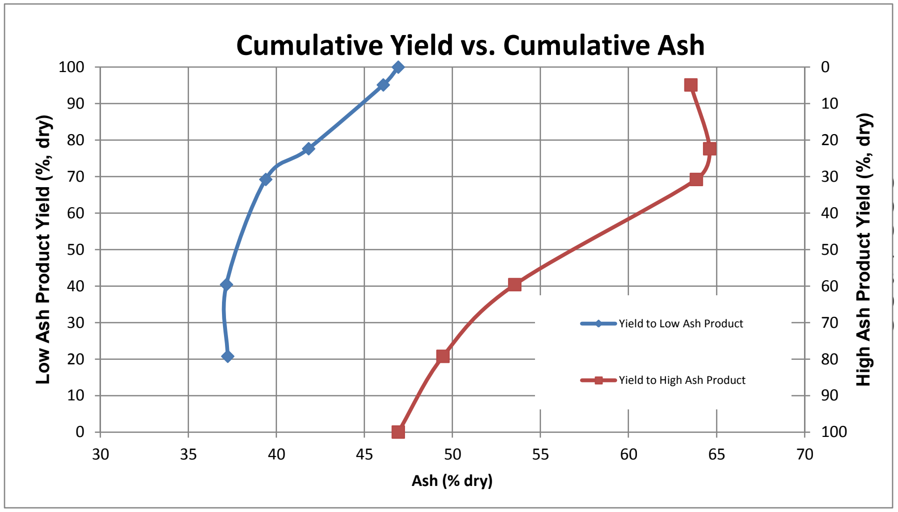
India - Deshaler Project - 2009
Site - Aryan Energy Pty
Location - Talcher, Orissa, India

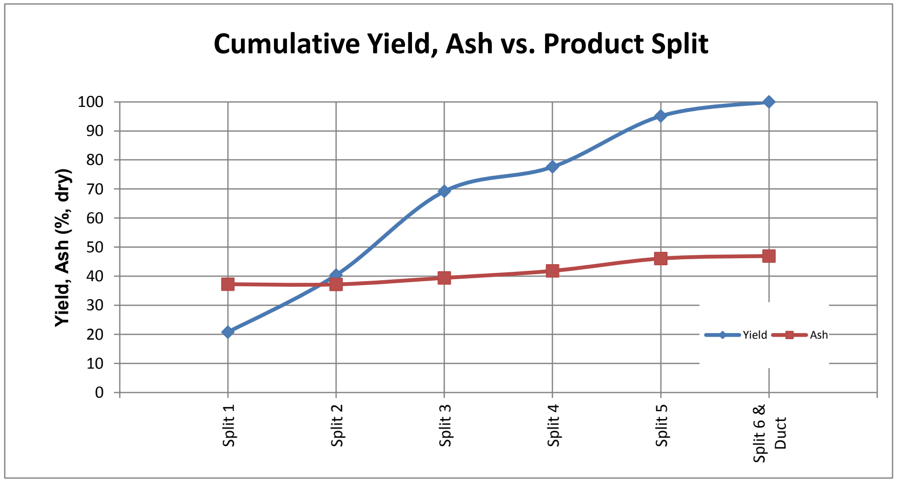
Date 8/17/09 Test - 15

Stream/ Product	Individual Weight (kg, AR)	Total Moisture (%)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Low Ash Product Ash (%, dry)	High Ash Product Weight (%, dry)	High Ash Product Ash (%, dry)
+6 mm			89.43	% of Sample					
Feed	18.32	9.10	16.65		50.50				
Split 1	3.06	10.20	2.74	19.66	36.90	19.66	36.90	100.00	47.63
Split 2	2.81	10.10	2.52	18.07	36.50	37.73	36.71	80.34	50.25
Split 3	4.75	9.60	4.29	30.77	42.40	68.50	39.27	62.27	54.24
Split 4	1.28	8.60	1.17	8.38	63.20	76.89	41.88	31.50	65.81
Split 5	2.90	8.10	2.66	19.07	66.60	95.95	46.79	23.11	66.76
Split 6	0.61	7.40	0.56	4.05	67.50	100.00	47.63	4.05	67.50
Products	15.40	9.36	13.95	100.00	47.63				
-6 mm			10.57	% of Sample					
Feed	1.80	10.40	1.61		44.80				
Split 1	0.57	12.40	0.49	30.00	40.10	30.00	40.10	100.00	43.97
Split 2	0.62	12.20	0.54	32.99	42.10	62.99	41.15	70.00	45.63
Split 3	0.23	11.40	0.20	12.35	43.60	75.34	41.55	37.01	48.78
Split 4	0.16	10.30	0.14	8.70	50.40	84.04	42.47	24.66	51.37
Split 5	0.08	9.70	0.07	4.10	50.60	88.15	42.84	15.96	51.90
Split 6	0.06	8.80	0.05	3.32	63.30	91.46	43.59	11.85	52.35
Dust	0.15	8.10	0.14	8.54	48.10	100.00	43.97	8.54	48.10
Products	1.86	11.45	1.65	100.00	43.97				
Total Sample Composite			100.00	% of Sample					
Feed	20.12	9.22	18.26		49.90				
Split 1	3.62	10.54	3.24	20.75	37.24	20.75	37.24	100.00	46.93
Split 2	3.43	10.48	3.07	19.65	37.09	40.40	37.17	79.25	49.46
Split 3	4.98	9.68	4.50	28.82	42.53	69.23	39.40	59.60	53.54
Split 4	1.44	8.79	1.31	8.42	61.85	77.64	41.83	30.77	63.86
Split 5	2.97	8.14	2.73	17.48	64.91	95.13	46.07	22.36	64.61
Split 6	0.67	7.53	0.62	3.97	67.06	99.10	46.91	4.87	63.55
Dust	0.15	8.10	0.14	0.90	48.10	100.00	46.93	0.90	48.10
Products	17.26	9.58	15.60	100.00	46.93				

Note - Split 6 and Dust samples combined for final Low Ash Product point and for first High Ash Product point

Charts Represent Total Sample Composit Values





India - Deshaler Project - 2009

Site - Bhushan Steel and Power

Location - Jharsuguda, Orissa, India

														Coal Source #1															
	Date -	8/21/09				8/22/09																8/23/09							
	Test No. -	1		2		3		4		5		6		7		8		9		10		11		12		13		14	
Table Parameters																													
Tilt	(deg)	8.5		8.5		8.5		8.5		8.5		8.5		7.5		7.5		7.5		7.5		7.5		8.5		8.5		8.5	
Slope	(deg)	1.0		1.0		0.5		0.5		0.5		0.5		0.5		0.5		1.0		1.0		1.0		1.0		1.0		1.0	
Fan Speed	(Hz)	55		55		55		55		55		60		50		50		50		50		50		50		50		50	
Table Speed	(Hz)	50		45		50		45		55		55		50		55		50		55		45		50		55		45	
														VFD for Main Fan Motor faulted - Remaining tests conducted with motor connected across the line.															
Feed Rate (kg, AR)		4.70		4.04		4.81		3.90		4.25		4.24		2.36		5.79		5.72		4.47		6.11		5.34		5.26		Planned, unable to	
Feed Rate (kg, dry)		4.34		3.73		4.38		3.50		3.77		3.89		2.17		5.32		5.15		3.99		5.45		4.75		4.70		conduct test for	
																												these parameters -	
Total Sample Time		0:08:53		0:06:28		0:08:33		0:06:12		0:06:13		0:06:54		0:06:48		0:06:07		0:06:08		0:06:26		0:07:20		0:06:01		0:06:59		loss of incoming	
(hr:min:sec)																												power and 2-hr	
																												monsoon.	
Sample Data																													
Total Dust Collected (kg, AR)		1.82		1.10		1.58		1.37		1.36		1.37		0.84		1.19		1.25		0.95		2.33		1.78		0.86			
Total Wt (kg - AR)	Feed	19.57		16.82		20.05		16.27		17.71		17.65		9.82		24.11		23.83		18.64		25.47		22.26		21.93			
	Split 1	1.57		2.20		1.27		0.96		2.27		1.30		1.08		1.20		0.94		2.79		0.49		1.98		2.59			
	Split 2	3.37		1.97		2.81		2.13		2.72		2.48		2.45		3.31		2.93		5.40		1.36		2.18		3.02			
	Split 3	3.01		3.41		3.49		3.23		2.72		2.91		1.75		4.59		4.82		4.35		4.03		2.67		4.66			
	Split 4	1.38		1.68		1.77		1.81		1.36		1.64		0.58		1.99		2.85		2.06		2.12		0.68		1.71			
	Split 5	6.06		6.16		6.43		5.32		5.90		6.15		4.69		8.23		6.97		7.01		6.29		2.99		5.84			
	Split 6	2.69		2.45		2.42		2.89		2.72		2.53		3.21		5.12		4.19		3.10		3.61		3.98		3.44			
	Dust	0.05		0.04		0.05		0.06		0.05		0.05		0.03		0.05		0.05		0.04		0.08		0.07		0.03			
	Products Total	18.13		17.91		18.24		16.40		17.76		17.06		13.79		24.49		22.75		24.75		17.98		14.55		21.29			
Total Moist (%)	Feed	7.67		7.69		8.91		10.34		11.21		8.10		8.00		8.11		9.90		10.71		10.85		11.02		10.68			
	Split 1	11.54		11.54		9.66		10.54		10.34		11.54		12.00		10.14		10.00		13.51		13.64		10.17		10.53			
	Split 2	8.00		14.29		10.06		8.00		9.35		14.81		11.54		9.78		9.38		12.12		9.67		9.88		8.33			
	Split 3	9.68		7.14		8.75		7.69		8.81		11.76		10.71		8.06		10.00		9.68		8.00		9.38		9.09			
	Split 4	6.45		11.11		8.17		7.41		8.00		8.57		7.14		8.11		6.90		7.69		8.45		10.00		8.14			
	Split 5	6.90		3.57		9.65		8.70		7.94		5.26		10.71		7.52		10.00		5.41		6.67		10.53		8.11			
	Split 6	3.70		3.85		8.35		6.67		7.55		6.25		3.45		4.88		7.35		4.63		6.00		10.81		7.50			
	Dust	3.85		7.14		7.41		7.25		6.12		8.33		5.00		3.98		3.33		3.95		4.10		4.55		5.15			
	Products Total	7.45		7.16		9.22		8.01		8.54		8.71		9.11		7.54		9.03		8.63		7.45		10.19		8.55			
Wt (kg - dry)	Feed	18.07		15.53		18.26		14.59		15.72		16.22		9.03		22.15		21.47		16.64		22.71		19.81		19.59			
	Split 1	1.39		1.95		1.15		0.86		2.04		1.15		0.95		1.08		0.85		2.41		0.42		1.78		2.32			
	Split 2	3.10		1.69		2.53		1.96		2.47		2.11		2.17		2.99		2.66		4.75		1.23		1.96		2.77			
	Split 3	2.72		3.17		3.18		2.98		2.48		2.57		1.56		4.22		4.34		3.93		3.71		2.42		4.24			
	Split 4	1.29		1.49		1.63		1.68		1.25		1.50		0.54		1.83		2.65		1.90		1.94		0.61		1.57			
	Split 5	5.64		5.94		5.81		4.86		5.43		5.83		4.19		7.61		6.27		6.63		5.87		2.68		5.37			
	Split 6	2.59		2.36		2.22		2.70		2.52		2.37		3.10		4.87		3.88		2.96		3.39		3.55		3.18			
	Dust	0.05		0.04		0.04		0.05		0.05		0.05		0.03		0.05		0.05		0.04		0.08		0.07		0.03			
	Products Total	16.78		16.63		16.55		15.08		16.24		15.57		12.54		22.64		20.70		22.61		16.64		13.07		19.47			
By Size Data		+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm
Wt by Size (% dry)	Feed	93.97	6.03	93.58	6.42	93.57	6.43	96.25	3.75	87.46	12.54	88.84	11.16	88.39	11.61	91.75	8.25	92.49	7.51	90.7	9.30	55.63	44.37	92.99	7.01	91.88	8.12		
	Split 1	83.44	16.56	87.73	12.27	83.46	16.54	84.37	15.63	80.36	19.64	73.08	26.92	66.67	33.33	72.50	27.50	67.02	32.98	79.93	20.07	85.74	14.26	96.47	3.53	94.59	5.41		
	Split 2	81.60	18.40	84.26	15.74	83.99	16.01	86.38	13.62	72.77	27.23	73.79	26.21	69.80	30.20	76.74	23.26	82.59	17.41	73.89	26.11	83.82	16.18	93.12	6.88	90.07	9.93		
	Split 3	94.68	5.32	95.31	4.69	97.42	2.58	98.14	1.86	90.55	9.45	93.47	6.53	92.57	7.43	95.42	4.58	96.89	3.11	90.11	9.89	90.82	9.18	90.64	9.36	91.20	8.80		
	Split 4	97.83	2.17	98.81	1.19	99.44	0.56	99.45	0.55	93.67	6.33	96.95	3.05	96.55	3.45	97.49	2.51	98.25	1.75	95.15	4.85	94.34	5.66	94.12	5.88	94.74	5.26		
	Split 5	98.18	1.82	99.02	0.98	99.53	0.47	99.81	0.19	96.03	3.97	98.37	1.63	98.93	1.07	99.03	0.97	98.85	1.15	97.29	2.71	96.98	3.02	98.00	2.00	97.26	2.74		
	Split 6	95.17	4.83	97.55	2.45	96.28	3.72	98.27	1.73	95.07	4.93	95.26	4.74	96.26	3.74	96.29	3.71	95.94	4.06	90.32	9.68	93.91	6.09	90.96	9.04	91.57	8.43		
	Dust		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		
	Products Total	92.55	7.45	95.03	4.97	94.94	5.06	96.20	3.80	89.06	10.94	91.46	8.54	89.66	10.34	93.24	6.76	94.19	5.81	88.04	11.96	92.97	7.03	93.07	6.93	93.32	6.68		
Ash (% dry)	Feed	54.11	52.11	53.23	49.92	50.31	49.72	53.65	51.87	53.23	52.06	53.64	52.24	52.86	50.69	52.66	51.04	51.03	50.86	53.29	54.36	52.80	51.04	53.87	50.39	53.53	51.80		
	Split 1	38.90	48.60	39.36	47.64	35.50	47.29	37.01	47.64	35.85	50.13	32.56	49.51	37.86	48.36	37.14	47.79	36.91	47.90	38.78	41.82	35.50	48.05	41.89	45.32	42.09	47.74		
	Split 2	41.09	48.49	42.47	46.63	38.77	48.49	40.25	49.09	38.30	50.42	38.93	49.70	40.83	48.56	37.89	47.76	37.33	48.94	42.46	49.71	36.70	49.36	47.65	49.64	44.11	47.35		
	Split 3	44.27	53.71	47.08	54.43	39.69	52.97	43.94	53.28	43.58	53.22	42.98	55.05	45.86	52.89	46.53	52.75	44.50	50.64	45.49	54.63	45.68	49.01	48.94	49.56	44.77	49.52		
	Split 4	55.11	53.82	49.63	53.82	49.06	55.11	48.74	51.93	50.79	55.03	53.84	55.49	50.88	54.63	47.34	52.24	51.50	50.66	51.09	54.24	53.12	50.40	50.76	48.74	52.70	48.76		
	Split 5	65.91	55.78	62.89	53.99	61.25	52.33	59.79	54.24	63.40	53.85	63.07	58.07	66.74	53.45	64.80	52.46	52.29	62.59	55.09	56.94	62.94	50.85	55.79	48.77	60.38	50.54		
	Split 6	72.59	61.90	72.58	63.58	70.72	65.71	70.19	64.01	69.17	69.31	73.37	66.76	71.36	59.32	72.98	62.39	70.19	63.08	77.37	65.90	70.50	63.48	66.39	56.64	64.02	56.63		
	Dust		68.55		65.04		52.78		51.88		60.45		56.92		51.22		52.32		52.64		50.05		53.04		54.26		55.17		
	Products Total	56.45	51.96	55.66	51.06	52.42	50.77	53.81	50.75	54.02	52.96	55.93	52.82	59.43	50.18	57.71	50.62	51.79	51.78	52.20	51.36	57.19	52.25	53.95	52.07	52.58	50.55		

India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

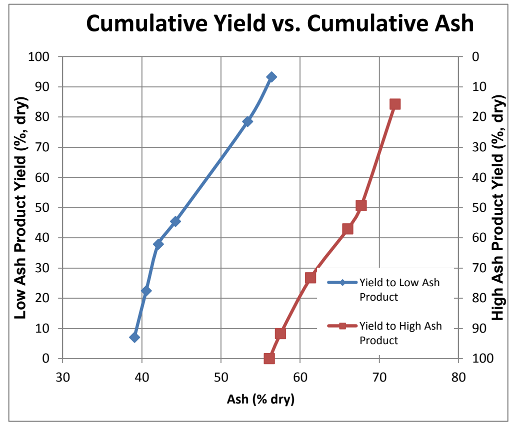
Date 8/21/09 Test - 1

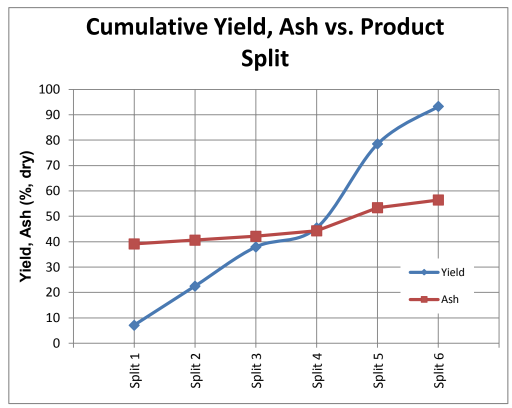
Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			93.97	16.98		54.11				
Split 1			83.44	1.16	7.46	38.90	7.46	38.90	100.00	56.45
Split 2			81.60	2.53	16.29	41.09	23.75	40.40	92.54	57.86
Split 3			94.68	2.57	16.57	44.27	40.33	41.99	76.25	61.44
Split 4			97.83	1.26	8.13	55.11	48.46	44.19	59.67	66.22
Split 5			98.18	5.54	35.67	65.91	84.13	53.40	51.54	67.97
Split 6			95.17	2.47	15.87	72.59	100.00	56.45	15.87	72.59
Products			92.55	15.53	100.00	56.45				
-6 mm										
Feed			6.03	1.09		52.11				
Split 1			16.56	0.23	18.40	48.60	18.40	48.60	100.00	51.96
Split 2			18.40	0.57	45.63	48.49	64.03	48.52	81.60	52.72
Split 3			5.32	0.14	11.57	53.71	75.60	49.32	35.97	58.09
Split 4			2.17	0.03	2.24	53.82	77.84	49.45	24.40	60.17
Split 5			1.82	0.10	8.21	55.78	86.05	50.05	22.16	60.81
Split 6			4.83	0.13	10.01	61.90	96.06	51.28	13.95	63.78
Dust			100.00	0.05	3.94	68.55	100.00	51.96	3.94	68.55
Products			7.45	1.25	100.00	51.96				
Total Sample Composite										
Feed	19.57	7.67	100.00	18.07		53.78				
Split 1	1.57	11.54	100.00	1.39	8.28	40.51	8.28	40.51	100.00	56.11
Split 2	3.37	8.00	100.00	3.10	18.48	42.45	26.75	41.85	91.72	57.52
Split 3	3.01	9.68	100.00	2.72	16.20	44.77	42.95	42.95	73.25	61.32
Split 4	1.38	6.45	100.00	1.29	7.69	55.08	50.65	44.79	57.05	66.02
Split 5	6.06	6.90	100.00	5.64	33.62	65.73	84.27	53.15	49.35	67.73
Split 6	2.69	3.70	100.00	2.59	15.44	72.07	99.71	56.08	15.73	72.01
Dust	0.05	3.85	100.00	0.05	0.29	68.55	100.00	56.11	0.29	68.55
Products	18.13	7.45	100.00	16.78	100.00	56.11				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	7.04	39.09	7.04	39.09	1.23	48.60	1.23	48.60	100.00	56.11
Split 2	15.42	41.25	22.46	40.57	3.06	48.49	4.29	48.52	91.72	57.52
Split 3	15.43	44.32	37.89	42.10	0.78	53.71	5.07	49.32	73.25	61.32
Split 4	7.54	55.11	45.43	44.26	0.15	53.82	5.22	49.45	57.05	66.02
Split 5	33.07	65.89	78.50	53.37	0.55	55.78	5.77	50.05	49.35	67.73
Split 6	14.77	72.54	93.27	56.41	0.67	61.90	6.44	51.28	15.73	72.01
Dust					0.29	68.55	6.73	52.04		
Products	93.27	56.41			6.73	52.04				

Charts Represent Values for Products Screened at 6 mm





Note - Split 6 and Dust samples combined for first High Ash Product point

India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

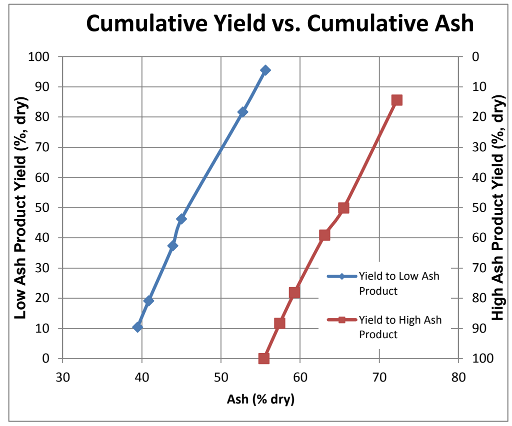
Date 8/21/09 Test - 2

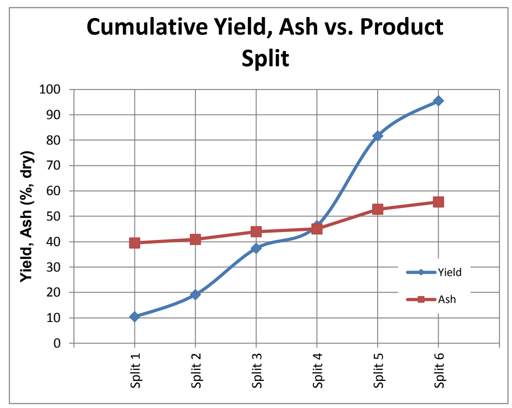
Stream/ Product	Individual: Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative: Low Ash Product Weight (%, dry)	Low Ash Product Ash (%, dry)	High Ash Product Weight (%, dry)	High Ash Product Ash (%, dry)
+6 mm										
Feed			93.58	14.53		53.23				
Split 1			87.73	1.71	10.80	39.36	10.80	39.36	100.00	55.66
Split 2			84.26	1.42	9.00	42.47	19.81	40.77	89.20	57.64
Split 3			95.31	3.02	19.10	47.08	38.90	43.87	80.19	59.34
Split 4			98.81	1.48	9.34	49.63	48.24	44.98	61.10	63.17
Split 5			99.02	5.88	37.22	62.89	85.46	52.78	51.76	65.61
Split 6			97.55	2.30	14.54	72.58	100.00	55.66	14.54	72.58
Products			95.03	15.80	100.00	55.66				
-6 mm										
Feed			6.42	1.00		49.92				
Split 1			12.27	0.24	28.90	47.64	28.90	47.64	100.00	51.06
Split 2			15.74	0.27	32.17	46.63	61.07	47.11	71.10	52.45
Split 3			4.69	0.15	17.97	54.43	79.04	48.77	38.93	57.26
Split 4			1.19	0.02	2.15	53.82	81.19	48.91	20.96	59.69
Split 5			0.98	0.06	7.05	53.99	88.24	49.31	18.81	60.36
Split 6			2.45	0.06	6.99	63.58	95.22	50.36	11.76	64.17
Dust			100.00	0.04	4.78	65.04	100.00	51.06	4.78	65.04
Products			4.97	0.83	100.00	51.06				
Total Sample Composite										
Feed	16.82	7.69	100.00	15.53		52.82				
Split 1	2.20	11.54	100.00	1.95	11.70	40.38	11.70	40.38	100.00	55.43
Split 2	1.97	14.29	100.00	1.69	10.15	43.12	21.86	41.65	88.30	57.43
Split 3	3.41	7.14	100.00	3.17	19.04	47.42	40.90	44.34	78.14	59.29
Split 4	1.68	11.11	100.00	1.49	8.98	49.68	49.88	45.30	59.10	63.11
Split 5	6.16	3.57	100.00	5.94	35.72	62.80	85.60	52.60	50.12	65.51
Split 6	2.45	3.85	100.00	2.36	14.17	72.36	99.76	55.41	14.40	72.24
Dust	0.04	7.14	100.00	0.04	0.24	65.04	100.00	55.43	0.24	65.04
Products	17.91	7.16	100.00	16.63	100.00	55.43				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Ash (%)	Low Ash Product Cumulative Wt (%)	Ash (%)	Screen Undersize & Dust Individual Wt (%)	Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Ash (%)	High Ash Product Cumulative Wt (%)	Ash (%)
Split 1	10.41	39.47	10.41	39.47	1.29	47.64	1.29	47.64	100.00	55.43
Split 2	8.72	42.55	19.13	40.87	1.44	46.63	2.73	47.11	88.30	57.43
Split 3	18.24	47.12	37.36	43.92	0.80	54.43	3.53	48.77	78.14	59.29
Split 4	8.88	49.64	46.25	45.02	0.10	53.82	3.63	48.91	59.10	63.11
Split 5	35.40	62.88	81.65	52.76	0.32	53.99	3.95	49.31	50.12	65.51
Split 6	13.85	72.56	95.50	55.63	0.31	63.58	4.26	50.36	14.40	72.24
Dust					0.24	65.04	4.50	51.13		
Products	95.50	55.63			4.50	51.13				

Charts Represent Values for Products Screened at 6 mm





Note - Split 6 and Dust samples combined for first High Ash Product point

India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

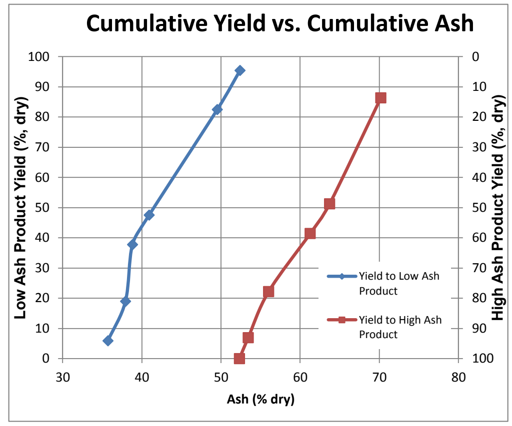
Date 8/22/09 Test - 3

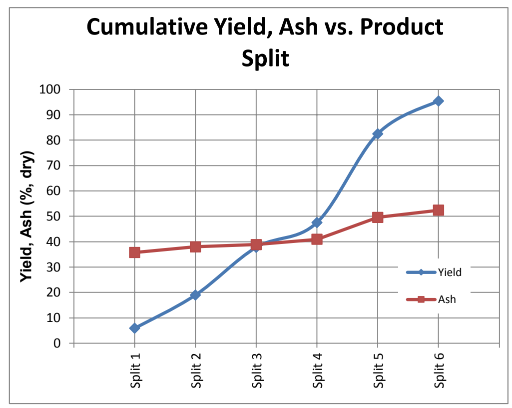
Stream/ Product	Individual: Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative Low Ash Product: Weight (%, dry)	Ash (%, dry)	Cumulative High Ash Product: Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			93.57	17.09		50.31				
Split 1			83.46	0.96	6.09	35.50	6.09	35.50	100.00	52.42
Split 2			83.99	2.12	13.51	38.77	19.60	37.75	93.91	53.52
Split 3			97.42	3.10	19.74	39.69	39.34	38.73	80.40	56.00
Split 4			99.44	1.62	10.28	49.06	49.62	40.87	60.66	61.30
Split 5			99.53	5.78	36.79	61.25	86.41	49.55	50.38	63.80
Split 6			96.28	2.14	13.59	70.72	100.00	52.42	13.59	70.72
Products			94.94	15.72	100.00	52.42				
-6 mm										
Feed			6.03	1.10		49.72				
Split 1			16.54	0.19	22.64	47.29	22.64	47.29	100.00	50.77
Split 2			16.01	0.40	48.27	48.49	70.91	48.11	77.36	51.79
Split 3			2.58	0.08	9.80	52.97	80.71	48.70	29.09	57.26
Split 4			0.56	0.01	1.09	55.11	81.80	48.78	19.29	59.43
Split 5			0.47	0.03	3.26	52.33	85.05	48.92	18.20	59.69
Split 6			3.72	0.08	9.84	65.71	94.90	50.66	14.95	61.30
Dust			100.00	0.04	5.10	52.78	100.00	50.77	5.10	52.78
Products			5.06	0.84	100.00	50.77				
Total Sample Composite										
Feed	20.05	8.91	99.60	18.19		50.21				
Split 1	1.27	9.66	100.00	1.15	6.93	37.45	6.93	37.45	100.00	52.34
Split 2	2.81	10.06	100.00	2.53	15.27	40.33	22.20	39.43	93.07	53.45
Split 3	3.49	8.75	100.00	3.18	19.24	40.03	41.43	39.71	77.80	56.02
Split 4	1.77	8.17	100.00	1.63	9.82	49.09	51.25	41.51	58.57	61.27
Split 5	6.43	9.65	100.00	5.81	35.09	61.21	86.34	49.51	48.75	63.73
Split 6	2.42	8.35	100.00	2.22	13.40	70.53	99.74	52.34	13.66	70.20
Dust	0.05	7.41	100.00	0.04	0.26	52.78	100.00	52.34	0.26	52.78
Products	18.24	9.22	100.00	16.55	100.00	52.34				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Ash (%)	Low Ash Product Cumulative Wt (%)	Ash (%)	Screen Undersize & Dust Individual Wt (%)	Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Ash (%)	High Ash Product Cumulative Wt (%)	Ash (%)
Split 1	5.90	35.73	5.90	35.73	1.03	47.29	1.03	47.29	100.00	52.34
Split 2	13.07	38.95	18.97	37.95	2.20	48.49	3.23	48.11	93.07	53.45
Split 3	18.79	39.73	37.76	38.83	0.45	52.97	3.68	48.70	77.80	56.02
Split 4	9.77	49.06	47.52	40.94	0.05	55.11	3.73	48.78	58.57	61.27
Split 5	34.94	61.25	82.47	49.54	0.15	52.33	3.88	48.92	48.75	63.73
Split 6	12.95	70.70	95.42	52.41	0.45	65.71	4.32	50.66	13.66	70.20
Dust					0.26	52.78	4.58	50.78		
Products	95.42	52.41			4.58	50.78				

Charts Represent Values for Products Screened at 6 mm





Note - Split 6 and Dust samples combined for first High Ash Product point

India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

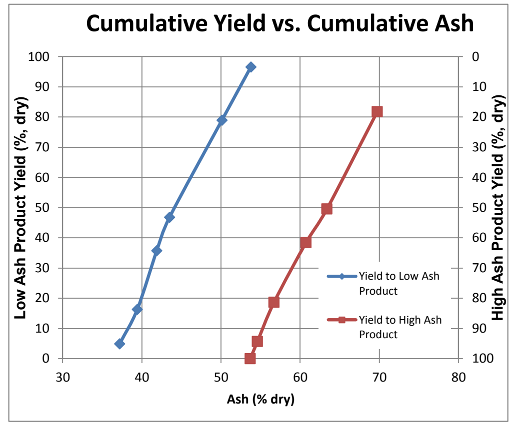
Date 8/22/09 Test - 4

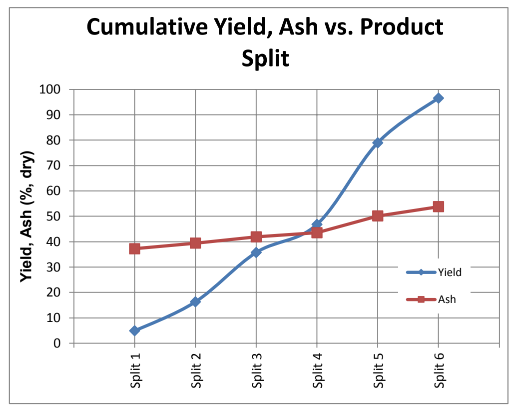
Stream/ Product	Individual: Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative Low Ash Product: Weight (%, dry)	Ash (%, dry)	Cumulative High Ash Product: Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			96.25	14.04		53.65				
Split 1			84.37	0.72	4.99	37.01	4.99	37.01	100.00	53.81
Split 2			86.38	1.69	11.67	40.25	16.66	39.28	95.01	54.69
Split 3			98.14	2.93	20.17	43.94	36.83	41.83	83.34	56.71
Split 4			99.45	1.67	11.49	48.74	48.32	43.47	63.17	60.79
Split 5			99.81	4.85	33.41	59.79	81.73	50.14	51.68	63.47
Split 6			98.27	2.65	18.27	70.19	100.00	53.81	18.27	70.19
Products			96.20	14.51	100.00	53.81				
-6 mm										
Feed			3.75	0.55		51.87				
Split 1			15.63	0.13	23.43	47.64	23.43	47.64	100.00	50.75
Split 2			13.62	0.27	46.58	49.09	70.01	48.60	76.57	51.70
Split 3			1.86	0.06	9.68	53.28	79.69	49.17	29.99	55.76
Split 4			0.55	0.01	1.61	51.93	81.30	49.23	20.31	56.94
Split 5			0.19	0.01	1.61	54.24	82.91	49.32	18.70	57.37
Split 6			1.73	0.05	8.14	64.01	91.06	50.64	17.09	57.66
Dust			100.00	0.05	8.94	51.88	100.00	50.75	8.94	51.88
Products			3.80	0.57	100.00	50.75				
Total Sample Composite										
Feed	16.27	10.34	100.00	14.59		53.37				
Split 1	0.96	10.54	100.00	0.86	5.69	38.67	5.69	38.67	100.00	53.69
Split 2	2.13	8.00	100.00	1.96	12.99	41.45	18.69	40.61	94.31	54.60
Split 3	3.23	7.69	100.00	2.98	19.77	44.11	38.46	42.41	81.31	56.70
Split 4	1.81	7.41	100.00	1.68	11.11	48.76	49.57	43.83	61.54	60.74
Split 5	5.32	8.70	100.00	4.86	32.21	59.78	81.78	50.11	50.43	63.38
Split 6	2.89	6.67	100.00	2.70	17.88	70.08	99.66	53.70	18.22	69.74
Dust	0.06	7.25	100.00	0.05	0.34	51.88	100.00	53.69	0.34	51.88
Products	16.40	8.01	100.00	15.08	100.00	53.69				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Ash (%)	Low Ash Product Cumulative Wt (%)	Ash (%)	Screen Undersize & Dust Individual Wt (%)	Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Ash (%)	High Ash Product Cumulative Wt (%)	Ash (%)
Split 1	4.89	37.20	4.89	37.20	0.80	47.64	0.80	47.64	100.00	53.69
Split 2	11.40	40.39	16.29	39.43	1.59	49.09	2.39	48.60	94.31	54.60
Split 3	19.44	43.96	35.73	41.89	0.33	53.28	2.72	49.17	81.31	56.70
Split 4	11.06	48.74	46.79	43.51	0.06	51.93	2.78	49.23	61.54	60.74
Split 5	32.15	59.79	78.94	50.14	0.06	54.24	2.83	49.32	50.43	63.38
Split 6	17.61	70.18	96.55	53.80	0.28	64.01	3.11	50.64	18.22	69.74
Dust					0.34	51.88	3.45	50.76		
Products	96.55	53.80			3.45	50.76				

Charts Represent Values for Products Screened at 6 mm





Note - Split 6 and Dust samples combined for first High Ash Product point

India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

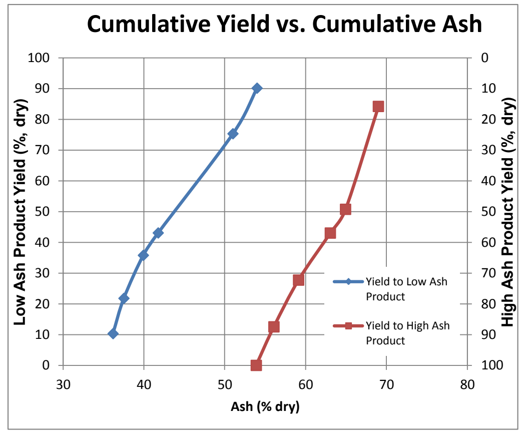
Date 8/22/09 Test - 5

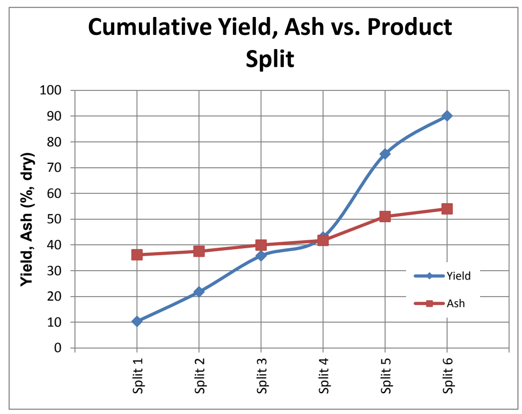
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			87.46	13.75		53.23				
Split 1			80.36	1.64	11.31	35.85	11.31	35.85	100.00	54.02
Split 2			72.77	1.80	12.42	38.30	23.73	37.13	88.69	56.33
Split 3			90.55	2.25	15.55	43.58	39.27	39.68	76.27	59.27
Split 4			93.67	1.17	8.11	50.79	47.39	41.59	60.73	63.29
Split 5			96.03	5.22	36.07	63.40	83.45	51.01	52.61	65.21
Split 6			95.07	2.39	16.55	69.17	100.00	54.02	16.55	69.17
Products			89.06	14.47	100.00	54.02				
-6 mm										
Feed			12.54	1.97		52.06				
Split 1			19.64	0.40	22.49	50.13	22.49	50.13	100.00	52.96
Split 2			27.23	0.67	37.83	50.42	60.32	50.31	77.51	53.78
Split 3			9.45	0.23	13.21	53.22	73.52	50.83	39.68	56.98
Split 4			6.33	0.08	4.46	55.03	77.99	51.07	26.48	58.85
Split 5			3.97	0.22	12.14	53.85	90.12	51.45	22.01	59.62
Split 6			4.93	0.12	6.98	69.31	97.11	52.73	9.88	66.72
Dust			100.00	0.05	2.89	60.45	100.00	52.96	2.89	60.45
Products			10.94	1.78	100.00	52.96				
Total Sample Composite										
Feed	17.71	11.21	100.00	15.72		53.00				
Split 1	2.27	10.34	100.00	2.04	12.53	38.65	12.53	38.65	100.00	53.90
Split 2	2.72	9.35	100.00	2.47	15.20	41.60	27.73	40.27	87.47	56.09
Split 3	2.72	8.81	100.00	2.48	15.29	44.49	43.02	41.77	72.27	59.13
Split 4	1.36	8.00	100.00	1.25	7.71	51.06	50.73	43.18	56.98	63.06
Split 5	5.90	7.94	100.00	5.43	33.45	63.02	84.18	51.06	49.27	64.94
Split 6	2.72	7.55	100.00	2.52	15.50	69.18	99.68	53.88	15.82	69.00
Dust	0.05	6.12	100.00	0.05	0.32	60.45	100.00	53.90	0.32	60.45
Products	17.76	8.54	100.00	16.24	100.00	53.90				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	10.31	36.19	10.31	36.19	2.21	50.13	2.21	50.13	100.00	53.90
Split 2	11.48	38.74	21.79	37.53	3.73	50.42	5.94	50.31	87.47	56.09
Split 3	13.99	43.68	35.78	39.94	1.30	53.22	7.24	50.83	72.27	59.13
Split 4	7.27	50.82	43.05	41.77	0.44	55.03	7.68	51.07	56.98	63.06
Split 5	32.25	63.36	75.31	51.02	1.20	53.85	8.87	51.45	49.27	64.94
Split 6	14.81	69.17	90.12	54.00	0.69	69.31	9.56	52.73	15.82	69.00
Dust					0.32	60.45	9.88	52.98		
Products	90.12	54.00			9.88	52.98				

Charts Represent Values for Products Screened at 6 mm





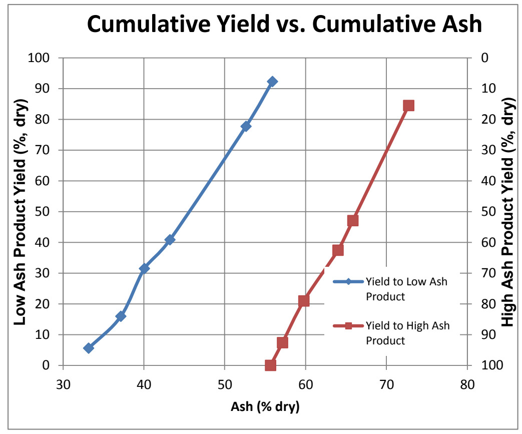
Note - Split 6 and Dust samples combined for first High Ash Product point

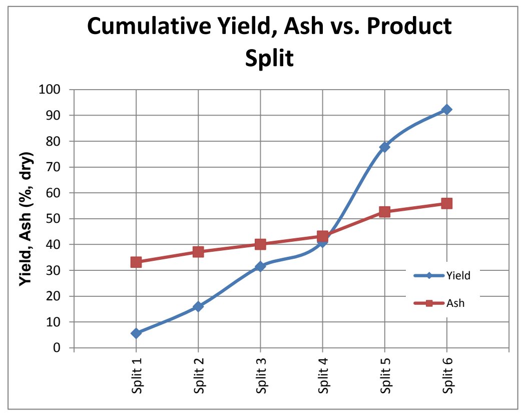
India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

Date 8/22/09 Test - 6

Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			88.84	14.41		53.64				
Split 1			73.08	0.84	5.90	32.56	5.90	32.56	100.00	55.93
Split 2			73.79	1.56	10.94	38.93	16.84	36.70	94.10	57.40
Split 3			93.47	2.40	16.85	42.98	33.69	39.84	83.16	59.83
Split 4			96.95	1.45	10.21	53.84	43.90	43.09	66.31	64.11
Split 5			98.37	5.73	40.24	63.07	84.14	52.65	56.10	65.98
Split 6			95.26	2.26	15.86	73.37	100.00	55.93	15.86	73.37
Products			91.46	14.24	100.00	55.93				
-6 mm										
Feed			11.16	1.81		52.24				
Split 1			26.92	0.31	23.28	49.51	23.28	49.51	100.00	52.82
Split 2			26.21	0.55	41.65	49.70	64.93	49.63	76.72	53.82
Split 3			6.53	0.17	12.61	55.05	77.54	50.51	35.07	58.71
Split 4			3.05	0.05	3.44	55.49	80.98	50.72	22.46	60.77
Split 5			1.63	0.09	7.14	58.07	88.12	51.32	19.02	61.73
Split 6			4.74	0.11	8.46	66.76	96.58	52.67	11.88	63.92
Dust			100.00	0.05	3.42	56.92	100.00	52.82	3.42	56.92
Products			8.54	1.33	100.00	52.82				
Total Sample Composite										
Feed	17.65	8.10	100.00	16.22		53.26				
Split 1	1.30	11.54	100.00	1.15	7.38	37.12	7.38	37.12	100.00	55.67
Split 2	2.48	14.81	100.00	2.11	13.57	41.75	20.95	40.12	92.62	57.15
Split 3	2.91	11.76	100.00	2.57	16.49	43.77	37.44	41.73	79.05	59.79
Split 4	1.64	8.57	100.00	1.50	9.63	53.89	47.07	44.22	62.56	64.01
Split 5	6.15	5.26	100.00	5.83	37.41	62.99	84.48	52.53	52.93	65.85
Split 6	2.53	6.25	100.00	2.37	15.23	73.06	99.71	55.66	15.52	72.75
Dust	0.05	8.33	100.00	0.05	0.29	56.92	100.00	55.67	0.29	56.92
Products	17.06	8.71	100.00	15.57	100.00	55.67				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	5.60	33.16	5.60	33.16	1.79	49.51	1.79	49.51	100.00	55.67
Split 2	10.37	39.30	15.96	37.15	3.20	49.70	4.99	49.63	92.62	57.15
Split 3	15.52	43.06	31.48	40.06	0.97	55.05	5.96	50.51	79.05	59.79
Split 4	9.36	53.85	40.84	43.22	0.26	55.49	6.22	50.72	62.56	64.01
Split 5	36.86	63.06	77.71	52.63	0.55	58.07	6.77	51.32	52.93	65.85
Split 6	14.58	73.34	92.29	55.91	0.65	66.76	7.42	52.67	15.52	72.75
Dust					0.29	56.92	7.71	52.83		
Products	92.29	55.91			7.71	52.83				

India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

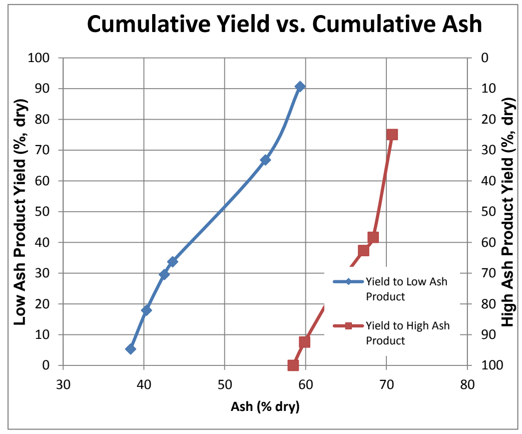
Date 8/22/09 Test - 7

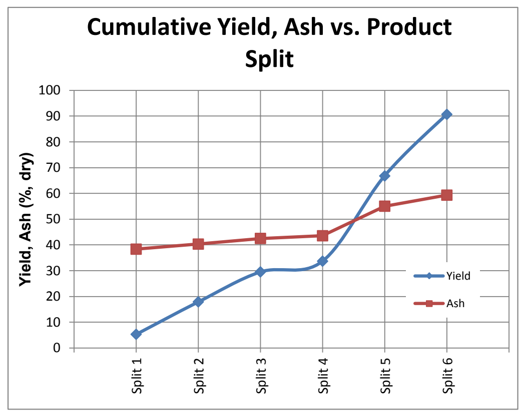
	Individual						Cumulative			
							Low Ash Product		High Ash Product	
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			88.39	7.99		52.86				
Split 1			66.67	0.63	5.64	37.86	5.64	37.86	100.00	59.43
Split 2			69.80	1.51	13.46	40.83	19.10	39.95	94.36	60.72
Split 3			92.57	1.45	12.87	45.86	31.97	42.33	80.90	64.03
Split 4			96.55	0.52	4.63	50.88	36.59	43.41	68.03	67.46
Split 5			98.93	4.14	36.86	66.74	73.46	55.12	63.41	68.67
Split 6			96.26	2.98	26.54	71.36	100.00	59.43	26.54	71.36
Products			89.66	11.24	100.00	59.43				
-6 mm										
Feed			11.61	1.05		50.69				
Split 1			33.33	0.32	24.44	48.36	24.44	48.36	100.00	50.18
Split 2			30.20	0.65	50.50	48.56	74.94	48.49	75.56	50.77
Split 3			7.43	0.12	8.96	52.89	83.90	48.96	25.06	55.21
Split 4			3.45	0.02	1.43	54.63	85.34	49.06	16.10	56.50
Split 5			1.07	0.04	3.46	53.45	88.79	49.23	14.66	56.69
Split 6			3.74	0.12	8.94	59.32	97.74	50.15	11.21	57.68
Dust			100.00	0.03	2.26	51.22	100.00	50.18	2.26	51.22
Products			10.34	1.30	100.00	50.18				
Total Sample Composite										
Feed	9.82	8.00	100.00	9.03		52.14				
Split 1	1.08	12.00	100.00	0.95	7.58	41.36	7.58	41.36	100.00	58.47
Split 2	2.45	11.54	100.00	2.17	17.29	43.16	24.87	42.61	92.42	59.88
Split 3	1.75	10.71	100.00	1.56	12.47	46.38	37.34	43.87	75.13	63.72
Split 4	0.58	7.14	100.00	0.54	4.30	51.01	41.63	44.61	62.66	67.17
Split 5	4.69	10.71	100.00	4.19	33.41	66.60	75.04	54.40	58.37	68.36
Split 6	3.21	3.45	100.00	3.10	24.72	70.91	99.77	58.49	24.96	70.73
Dust	0.03	5.00	100.00	0.03	0.23	51.22	100.00	58.47	0.23	51.22
Products	13.79	9.11	100.00	12.54	100.00	58.47				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	5.31	38.36	5.31	38.36	2.27	48.36	2.27	48.36	100.00	58.47
Split 2	12.59	41.15	17.90	40.32	4.70	48.56	6.97	48.49	92.42	59.88
Split 3	11.63	45.92	29.53	42.53	0.83	52.89	7.81	48.96	75.13	63.72
Split 4	4.16	50.89	33.69	43.56	0.13	54.63	7.94	49.06	62.66	67.17
Split 5	33.09	66.73	66.78	55.04	0.32	53.45	8.26	49.23	58.37	68.36
Split 6	23.89	71.31	90.67	59.33	0.83	59.32	9.09	50.15	24.96	70.73
Dust					0.23	51.22	9.33	50.18		
Products	90.67	59.33			9.33	50.18				

Charts Represent Values for Products Screened at 6 mm





Note - Split 6 and Dust samples combined for first High Ash Product point

India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

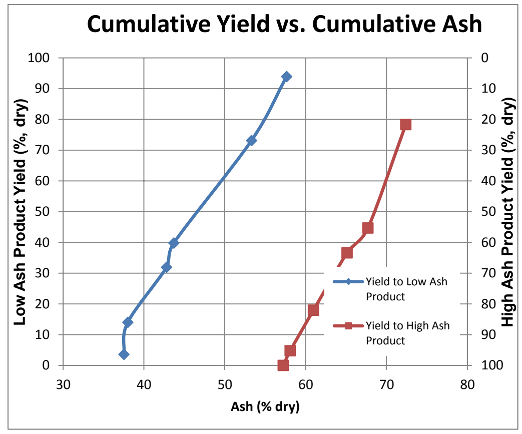
Date 8/22/09 Test - 8

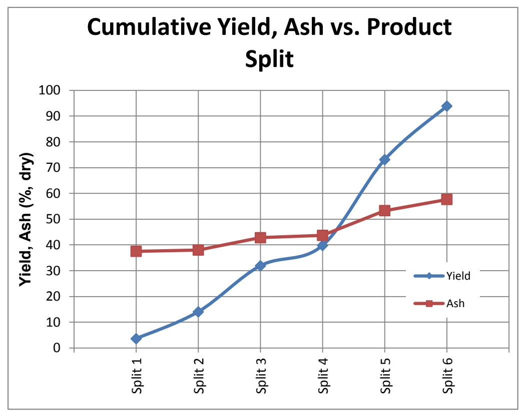
Stream/ Product	Individual Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	High Ash Product Ash (%, dry)
+6 mm										
Feed			91.75	20.33		52.66				
Split 1			72.50	0.78	3.70	37.14	3.70	37.14	100.00	57.71
Split 2			76.74	2.29	10.86	37.89	14.56	37.70	96.30	58.50
Split 3			95.42	4.03	19.08	46.53	33.63	42.71	85.44	61.12
Split 4			97.49	1.78	8.45	47.34	42.08	43.64	66.37	65.32
Split 5			99.03	7.54	35.71	64.80	77.79	53.35	57.92	67.94
Split 6			96.29	4.69	22.21	72.98	100.00	57.71	22.21	72.98
Products			93.24	21.11	100.00	57.71				
-6 mm										
Feed			8.25	1.83		52.11				
Split 1			27.50	0.30	19.36	47.79	19.36	47.79	100.00	50.62
Split 2			23.26	0.69	45.35	47.76	64.72	47.77	80.64	51.30
Split 3			4.58	0.19	12.62	52.75	77.34	48.58	35.28	55.85
Split 4			2.51	0.05	3.00	52.24	80.33	48.72	22.66	57.58
Split 5			0.97	0.07	4.82	52.46	85.15	48.93	19.67	58.39
Split 6			3.71	0.18	11.80	62.39	96.95	50.57	14.85	60.32
Dust			100.00	0.05	3.05	52.32	100.00	50.62	3.05	52.32
Products			6.76	1.53	100.00	50.62				
Total Sample Composite										
Feed	24.11	8.11	100.00	22.15		52.51				
Split 1	1.20	10.14	100.00	1.08	4.76	40.07	4.76	40.07	100.00	57.23
Split 2	3.31	9.78	100.00	2.99	13.19	40.19	17.95	40.15	95.24	58.09
Split 3	4.59	8.06	100.00	4.22	18.64	46.81	36.59	43.55	82.05	60.97
Split 4	1.99	8.11	100.00	1.83	8.08	47.46	44.67	44.26	63.41	65.13
Split 5	8.23	7.52	100.00	7.61	33.62	64.68	78.28	53.03	55.33	67.71
Split 6	5.12	4.88	100.00	4.87	21.51	72.59	99.79	57.24	21.72	72.39
Dust	0.05	3.98	100.00	0.05	0.21	52.32	100.00	57.23	0.21	52.32
Products	24.49	7.54	100.00	22.64	100.00	57.23				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Ash (%)	Low Ash Product Cumulative Wt (%)	Ash (%)	Screen Undersize & Dust Individual Wt (%)	Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Ash (%)	High Ash Product Cumulative Wt (%)	Ash (%)
Split 1	3.58	37.53	3.58	37.53	1.18	47.79	1.18	47.79	100.00	57.23
Split 2	10.43	38.18	14.01	38.01	2.76	47.76	3.94	47.77	95.24	58.09
Split 3	17.87	46.56	31.88	42.80	0.77	52.75	4.71	48.58	82.05	60.97
Split 4	7.89	47.35	39.78	43.71	0.18	52.24	4.89	48.72	63.41	65.13
Split 5	33.32	64.79	73.10	53.32	0.29	52.46	5.18	48.93	55.33	67.71
Split 6	20.79	72.94	93.89	57.66	0.72	62.39	5.90	50.57	21.72	72.39
Dust					0.21	52.32	6.11	50.63		
Products	93.89	57.66			6.11	50.63				

Charts Represent Values for Products Screened at 6 mm





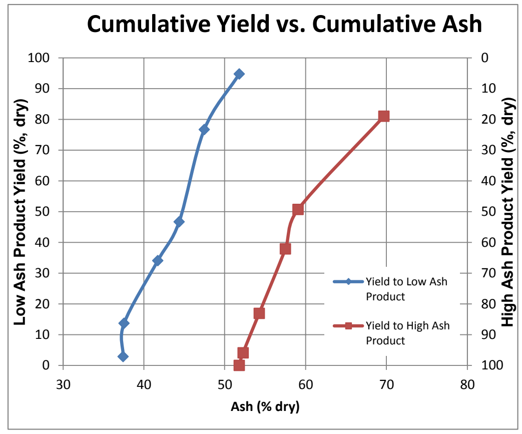
Note - Split 6 and Dust samples combined for first High Ash Product point

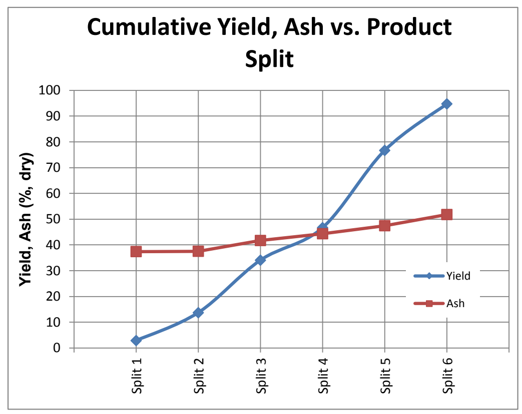
India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

Date 8/22/09 Test - 9

Stream/ Product	Individual						Cumulative			
							Low Ash Product		High Ash Product	
	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			92.49	19.86		51.03				
Split 1			67.02	0.57	2.91	36.91	2.91	36.91	100.00	51.79
Split 2			82.59	2.19	11.25	37.33	14.16	37.24	97.09	52.24
Split 3			96.89	4.20	21.56	44.50	35.72	41.62	85.84	54.19
Split 4			98.25	2.61	13.37	51.50	49.09	44.31	64.28	57.45
Split 5			98.85	6.20	31.81	52.29	80.90	47.45	50.91	59.01
Split 6			95.94	3.72	19.10	70.19	100.00	51.79	19.10	70.19
Products			94.19	19.50	100.00	51.79				
-6 mm										
Feed			7.51	1.61		50.86				
Split 1			32.98	0.28	23.22	47.90	23.22	47.90	100.00	51.78
Split 2			17.41	0.46	38.47	48.94	61.69	48.55	76.78	52.96
Split 3			3.11	0.13	11.23	50.64	72.92	48.87	38.31	56.99
Split 4			1.75	0.05	3.86	50.66	76.78	48.96	27.08	59.62
Split 5			1.15	0.07	6.00	62.59	82.78	49.95	23.22	61.11
Split 6			4.06	0.16	13.12	63.08	95.90	51.74	17.22	60.59
Dust			100.00	0.05	4.10	52.64	100.00	51.78	4.10	52.64
Products			5.81	1.20	100.00	51.78				
Total Sample Composite										
Feed	23.83	9.90	100.00	21.47		50.97				
Split 1	0.94	10.00	100.00	0.85	4.09	40.53	4.09	40.53	100.00	51.79
Split 2	2.93	9.38	100.00	2.66	12.83	39.35	16.92	39.64	95.91	52.27
Split 3	4.82	10.00	100.00	4.34	20.96	44.69	37.88	42.43	83.08	54.27
Split 4	2.85	6.90	100.00	2.65	12.82	51.49	50.70	44.72	62.12	57.50
Split 5	6.97	10.00	100.00	6.27	30.31	52.41	81.01	47.60	49.30	59.06
Split 6	4.19	7.35	100.00	3.88	18.76	69.90	99.76	51.79	18.99	69.69
Dust	0.05	3.33	100.00	0.05	0.24	52.64	100.00	51.79	0.24	52.64
Products	22.75	9.03	100.00	20.70	100.00	51.79				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

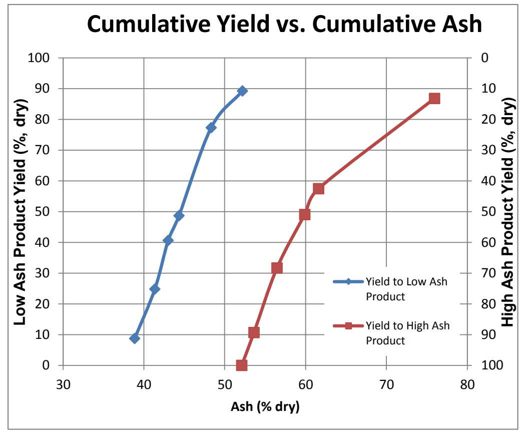
	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	2.87	37.43	2.87	37.43	1.21	47.90	1.21	47.90	100.00	51.79
Split 2	10.82	37.57	13.69	37.54	2.01	48.94	3.22	48.55	95.91	52.27
Split 3	20.37	44.52	34.07	41.71	0.59	50.64	3.81	48.87	83.08	54.27
Split 4	12.62	51.50	46.68	44.36	0.20	50.66	4.01	48.96	62.12	57.50
Split 5	30.00	52.30	76.68	47.47	0.31	62.59	4.33	49.95	49.30	59.06
Split 6	18.07	70.16	94.75	51.79	0.69	63.08	5.01	51.74	18.99	69.69
Dust					0.24	52.64	5.25	51.79		
Products	94.75	51.79			5.25	51.79				

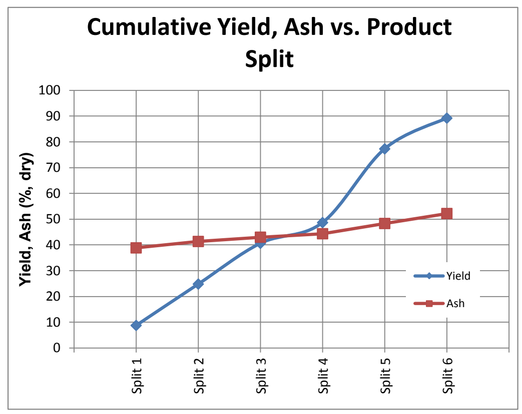
India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

Date 8/22/09 Test - 10

	Individual						Cumulative			
							Low Ash Product		High Ash Product	
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			90.70	15.10		53.29				
Split 1			79.93	1.93	9.69	38.78	9.69	38.78	100.00	52.20
Split 2			73.89	3.51	17.61	42.46	27.30	41.15	90.31	53.64
Split 3			90.11	3.54	17.79	45.49	45.09	42.86	72.70	56.35
Split 4			95.15	1.81	9.09	51.09	54.18	44.24	54.91	59.87
Split 5			97.29	6.45	32.41	55.09	86.59	48.30	45.82	61.61
Split 6			90.32	2.67	13.41	77.37	100.00	52.20	13.41	77.37
Products			88.04	19.91	100.00	52.20				
-6 mm										
Feed			9.30	1.55		54.36				
Split 1			20.07	0.48	17.90	41.82	17.90	41.82	100.00	51.36
Split 2			26.11	1.24	45.80	49.71	63.70	47.49	82.10	53.44
Split 3			9.89	0.39	14.36	54.63	78.06	48.81	36.30	58.13
Split 4			4.85	0.09	3.41	54.24	81.47	49.03	21.94	60.43
Split 5			2.71	0.18	6.64	56.94	88.11	49.63	18.53	61.57
Split 6			9.68	0.29	10.58	65.90	98.69	51.37	11.89	64.15
Dust			100.00	0.04	1.31	50.05	100.00	51.36	1.31	50.05
Products			11.96	2.71	100.00	51.36				
Total Sample Composite										
Feed	18.64	10.71	100.00	16.64		53.50				
Split 1	2.79	13.51	100.00	2.41	10.67	39.39	10.67	39.39	100.00	52.10
Split 2	5.40	12.12	100.00	4.75	20.99	44.35	31.66	42.68	89.33	53.62
Split 3	4.35	9.68	100.00	3.93	17.38	46.39	49.03	44.00	68.34	56.47
Split 4	2.06	7.69	100.00	1.90	8.41	51.24	57.44	45.06	50.97	59.90
Split 5	7.01	5.41	100.00	6.63	29.32	55.14	86.77	48.46	42.56	61.61
Split 6	3.10	4.63	100.00	2.96	13.07	76.26	99.84	52.10	13.23	75.95
Dust	0.04	3.95	100.00	0.04	0.16	50.05	100.00	52.10	0.16	50.05
Products	24.75	8.63	100.00	22.61	100.00	52.10				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	8.74	38.85	8.74	38.85	1.93	41.82	1.93	41.82	100.00	52.10
Split 2	16.06	42.71	24.80	41.35	4.93	49.71	6.86	47.49	89.33	53.62
Split 3	15.83	45.59	40.63	43.00	1.55	54.63	8.41	48.81	68.34	56.47
Split 4	8.04	51.11	48.67	44.34	0.37	54.24	8.77	49.03	50.97	59.90
Split 5	28.61	55.10	77.28	48.32	0.72	56.94	9.49	49.63	42.56	61.61
Split 6	11.94	77.25	89.22	52.19	1.14	65.90	10.63	51.37	13.23	75.95
Dust					0.16	50.05	10.78	51.35		
Products	89.22	52.19			10.78	51.35				

India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

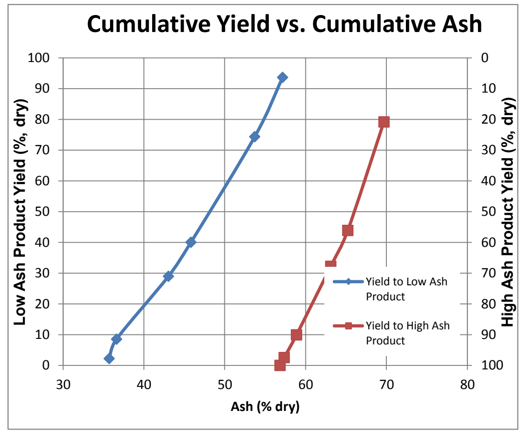
Date 8/23/09 Test - 11

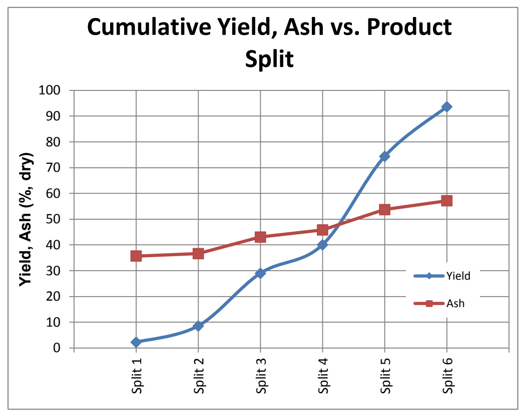
	Individual						Cumulative			
							Low Ash Product		High Ash Product	
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			55.63	12.63		52.80				
Split 1			85.74	0.36	2.35	35.50	2.35	35.50	100.00	57.19
Split 2			83.82	1.03	6.66	36.70	9.00	36.39	97.65	57.71
Split 3			90.82	3.37	21.77	45.68	30.77	42.96	91.00	59.25
Split 4			94.34	1.83	11.84	53.12	42.60	45.78	69.23	63.51
Split 5			96.98	5.69	36.80	62.94	79.40	53.73	57.40	65.65
Split 6			93.91	3.19	20.60	70.50	100.00	57.19	20.60	70.50
Products			92.97	15.47	100.00	57.19				
-6 mm										
Feed			44.37	10.07		51.04				
Split 1			14.26	0.06	5.16	48.05	5.16	48.05	100.00	52.25
Split 2			16.18	0.20	17.00	49.36	22.16	49.05	94.84	52.48
Split 3			9.18	0.34	29.10	49.01	51.26	49.03	77.84	53.16
Split 4			5.66	0.11	9.39	50.40	60.65	49.24	48.74	55.64
Split 5			3.02	0.18	15.16	50.85	75.81	49.56	39.35	56.89
Split 6			6.09	0.21	17.67	63.48	93.49	52.19	24.19	60.67
Dust			100.00	0.08	6.51	53.04	100.00	52.25	6.51	53.04
Products			7.03	1.17	100.00	52.25				
Total Sample Composite										
Feed	25.47	10.85	100.00	22.71		52.55				
Split 1	0.49	13.64	100.00	0.42	2.54	37.29	2.54	37.29	100.00	56.84
Split 2	1.36	9.67	100.00	1.23	7.38	38.75	9.93	38.37	97.46	57.35
Split 3	4.03	8.00	100.00	3.71	22.28	45.99	32.21	43.64	90.07	58.88
Split 4	2.12	8.45	100.00	1.94	11.66	52.97	43.87	46.12	67.79	63.11
Split 5	6.29	6.67	100.00	5.87	35.28	62.57	79.15	53.45	56.13	65.22
Split 6	3.61	6.00	100.00	3.39	20.39	70.07	99.54	56.86	20.85	69.70
Dust	0.08	4.10	100.00	0.08	0.46	53.04	100.00	56.84	0.46	53.04
Products	17.98	7.45	100.00	16.64	100.00	56.84				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	2.22	35.71	2.22	35.71	0.33	48.05	0.33	48.05	100.00	56.84
Split 2	6.31	36.94	8.52	36.62	1.08	49.36	1.40	49.05	97.46	57.35
Split 3	20.44	45.71	28.96	43.04	1.84	49.01	3.24	49.03	90.07	58.88
Split 4	11.07	53.10	40.03	45.82	0.59	50.40	3.84	49.24	67.79	63.11
Split 5	34.32	62.90	74.35	53.71	0.96	50.85	4.80	49.56	56.13	65.22
Split 6	19.28	70.45	93.63	57.15	1.12	63.48	5.91	52.19	20.85	69.70
Dust					0.46	53.04	6.37	52.25		
Products	93.63	57.15			6.37	52.25				

Charts Represent Values for Products Screened at 6 mm





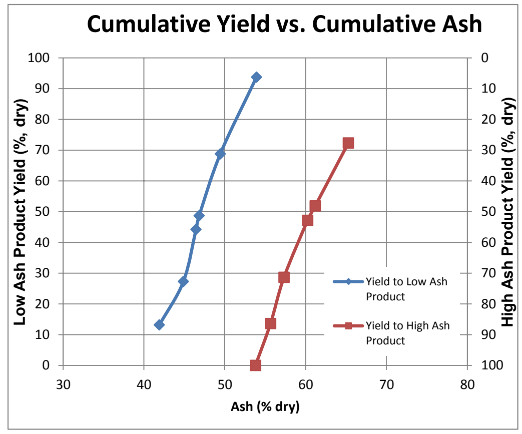
Note - Split 6 and Dust samples combined for first High Ash Product point

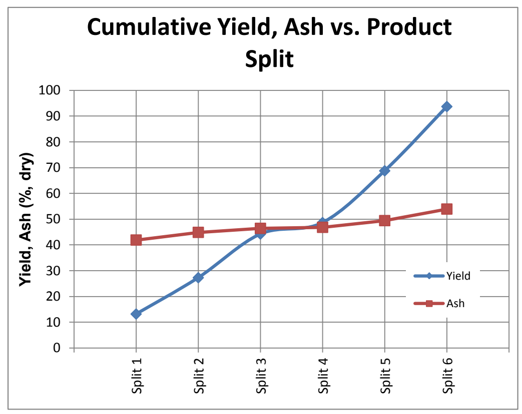
India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

Date 8/23/09 Test - 12

Stream/ Product	Individual: Weight (kg, AR)	Individual: Total Moisture (%)	Individual: Weight (% of Sample)	Individual: Weight (kg, dry)	Individual: Weight (%, dry)	Individual: Ash (%, dry)	Cumulative Low Ash Product: Weight (%, dry)	Cumulative Low Ash Product: Ash (%, dry)	Cumulative High Ash Product: Weight (%, dry)	Cumulative High Ash Product: Ash (%, dry)
+6 mm										
Feed			92.99	18.42		53.87				
Split 1			96.47	1.72	14.10	41.89	14.10	41.89	100.00	53.95
Split 2			93.12	1.83	15.04	47.65	29.14	44.86	85.90	55.93
Split 3			90.64	2.19	18.03	48.94	47.17	46.42	70.86	57.68
Split 4			94.12	0.58	4.74	50.76	51.91	46.82	52.83	60.66
Split 5			98.00	2.62	21.55	55.79	73.46	49.45	48.09	61.64
Split 6			90.96	3.23	26.54	66.39	100.00	53.95	26.54	66.39
Products			93.07	12.16	100.00	53.95				
-6 mm										
Feed			7.01	1.39		50.39				
Split 1			3.53	0.06	6.93	45.32	6.93	45.32	100.00	52.07
Split 2			6.88	0.14	14.93	49.64	21.86	48.27	93.07	52.58
Split 3			9.36	0.23	25.01	49.56	46.88	48.96	78.14	53.14
Split 4			5.88	0.04	3.97	48.74	50.85	48.94	53.12	54.82
Split 5			2.00	0.05	5.91	48.77	56.76	48.92	49.15	55.32
Split 6			9.04	0.32	35.44	56.64	92.20	51.89	43.24	56.21
Dust			100.00	0.07	7.80	54.26	100.00	52.07	7.80	54.26
Products			6.93	0.91	100.00	52.07				
Total Sample Composite										
Feed	22.26	11.02	100.00	19.81		53.75				
Split 1	1.98	10.17	100.00	1.78	13.61	42.01	13.61	42.01	100.00	53.82
Split 2	2.18	9.88	100.00	1.96	15.03	47.79	28.64	45.04	86.39	55.68
Split 3	2.67	9.38	100.00	2.42	18.51	49.00	47.15	46.60	71.36	57.34
Split 4	0.68	10.00	100.00	0.61	4.68	50.64	51.83	46.96	52.85	60.26
Split 5	2.99	10.53	100.00	2.68	20.47	55.65	72.30	49.42	48.17	61.19
Split 6	3.98	10.81	100.00	3.55	27.16	65.51	99.46	53.81	27.70	65.29
Dust	0.07	4.55	100.00	0.07	0.54	54.26	100.00	53.82	0.54	54.26
Products	14.55	10.19	100.00	13.07	100.00	53.82				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	13.18	41.90	13.18	41.90	0.43	45.32	0.43	45.32	100.00	53.82
Split 2	14.10	47.66	27.28	44.88	0.93	49.64	1.36	48.27	86.39	55.68
Split 3	16.95	48.95	44.23	46.44	1.56	49.56	2.92	48.96	71.36	57.34
Split 4	4.43	50.75	48.66	46.83	0.25	48.74	3.17	48.94	52.85	60.26
Split 5	20.10	55.78	68.76	49.45	0.37	48.77	3.54	48.92	48.17	61.19
Split 6	24.95	66.29	93.71	53.93	2.21	56.64	5.75	51.89	27.70	65.29
Dust					0.54	54.26	6.29	52.09		
Products	93.71	53.93			6.29	52.09				

India - Deshaler Project - 2009
Site - Bhushan Steel and Power
Location - Jharsuguda, Orissa, India

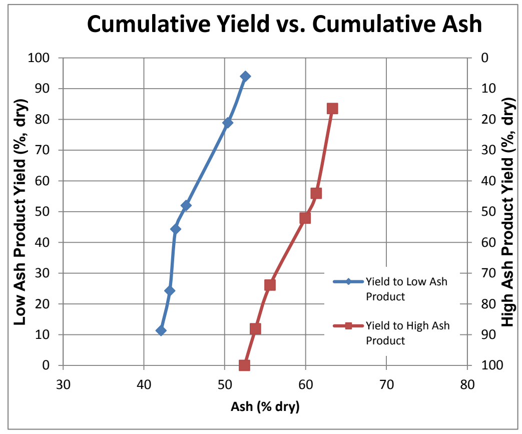
Date 8/23/09 Test - 13

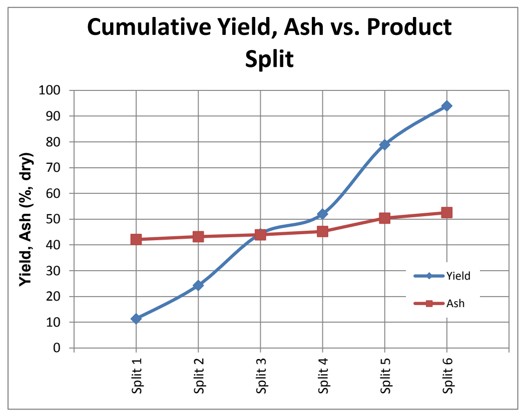
Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			91.88	18.00		53.53				
Split 1			94.59	2.19	12.06	42.09	12.06	42.09	100.00	52.58
Split 2			90.07	2.49	13.72	44.11	25.79	43.17	87.94	54.01
Split 3			91.20	3.86	21.26	44.77	47.05	43.89	74.21	55.85
Split 4			94.74	1.49	8.19	52.70	55.24	45.20	52.95	60.29
Split 5			97.26	5.22	28.72	60.38	83.96	50.39	44.76	61.68
Split 6			91.57	2.91	16.04	64.02	100.00	52.58	16.04	64.02
Products			93.32	18.17	100.00	52.58				
-6 mm										
Feed			8.12	1.59		51.80				
Split 1			5.41	0.13	9.64	47.74	9.64	47.74	100.00	50.55
Split 2			9.93	0.27	21.14	47.35	30.79	47.47	90.36	50.85
Split 3			8.80	0.37	28.67	49.52	59.46	48.46	69.21	51.92
Split 4			5.26	0.08	6.35	48.76	65.81	48.49	40.54	53.62
Split 5			2.74	0.15	11.31	50.54	77.12	48.79	34.19	54.52
Split 6			8.43	0.27	20.63	56.63	97.75	50.44	22.88	56.49
Dust			100.00	0.03	2.25	55.17	100.00	50.55	2.25	55.17
Products			6.68	1.30	100.00	50.55				
Total Sample Composite										
Feed	21.93	10.68	100.00	19.59		53.44				
Split 1	2.59	10.53	100.00	2.32	11.90	42.40	11.90	42.40	100.00	52.44
Split 2	3.02	8.33	100.00	2.77	14.22	44.43	26.12	43.50	88.10	53.80
Split 3	4.66	9.09	100.00	4.24	21.76	45.19	47.88	44.27	73.88	55.60
Split 4	1.71	8.14	100.00	1.57	8.07	52.49	55.95	45.46	52.12	59.95
Split 5	5.84	8.11	100.00	5.37	27.56	60.11	83.51	50.29	44.05	61.31
Split 6	3.44	7.50	100.00	3.18	16.34	63.40	99.85	52.44	16.49	63.32
Dust	0.03	5.15	100.00	0.03	0.15	55.17	100.00	52.44	0.15	55.17
Products	21.29	8.55	100.00	19.47	100.00	52.44				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	11.32	42.12	11.32	42.12	0.58	47.74	0.58	47.74	100.00	52.44
Split 2	12.95	44.15	24.27	43.20	1.27	47.35	1.85	47.47	88.10	53.80
Split 3	20.03	44.82	44.30	43.93	1.72	49.52	3.57	48.46	73.88	55.60
Split 4	7.69	52.68	51.99	45.22	0.38	48.76	3.96	48.49	52.12	59.95
Split 5	26.88	60.35	78.87	50.38	0.68	50.54	4.64	48.79	44.05	61.31
Split 6	15.10	63.95	93.98	52.56	1.24	56.63	5.87	50.44	16.49	63.32
Dust					0.15	55.17	6.02	50.56		
Products	93.98	52.56			6.02	50.56				

Charts Represent Values for Products Screened at 6 mm





Note - Split 6 and Dust samples combined for first High Ash Product point

India - Deshaler Project - 2010

Site - CCL Kargali Washery

Location - Kargali, Bokaro, Jharkhand

		17	10	11	12	13	14	15	16	18	19	21	1	2	3	4	5	6	7	8	9	20		
		Coal Source - Kargali																						
	Date -	3/17/10	3/16/10							3/18/2010		3/19/10	3/15/10						#######			#######		
	Test No. -	17	10	11	12	13	14	15	16	18	19	21	1	2	3	4	5	6	7	8	9	20		
Table Parameters																								
Tilt	(deg)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5		
Slope	(deg)	1.0	1.5	1.5	1.5	1.5	0.5	0.5	0.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5		
Fan Speed	(Hz)	55	55	55	60	50	55	60	60	60	55	60	55	60	60	55	50	60	55	60	60	60		
Table Speed	(Hz)	45	50	40	40	50	45	45	50	45	45	45	45	45	50	50	45	55	45	45	50	45		
Feed Rate (kg, AR)		4.65	4.65	3.89	4.22	3.35	5.30	5.62	3.68	4.54	4.86	6.16	6.27	5.51	6.70	4.65	3.57	4.97	4.54	4.97	3.68	4.97		
Feed Rate (kg, dry)		4.44	4.43	3.72	4.04	3.22	5.07	5.45	3.53	4.47	4.73	6.02	5.96	5.24	6.40	4.44	3.41	4.75	4.34	4.75	3.51	4.75		
Total Sample Time (hr:min:sec)		0:05:57	0:09:24	0:08:43	0:09:01	0:04:49	0:06:30	0:09:27	0:05:31	0:09:20	0:05:36	0:08:36	0:08:48	0:10:52	0:10:02	0:17:05	0:06:47	0:10:54	0:14:30	0:08:44	0:07:24	0:04:32		
Sample Data																								
Total Dust Collected (kg, AR)		5.41	2.70	2.25	2.25	1.36	2.25	3.60	3.15	6.76	5.86	9.46	4.96	4.5	4.50	4.05	2.25	3.15	3.14	3.57	2.25	6.3		
Total Wt (kg - AR)	Feed	19.37	19.37	16.22	17.57	13.96	22.07	23.42	15.32	18.92	20.27	25.68	26.13	22.97	27.93	19.37	14.86	20.72	18.92	20.72	15.32	20.72		
	Split 1	3.60	0.45	2.70	1.80	1.80	3.60	6.31	3.15	0.45	0.45	1.35	4.50	0.90	1.35	1.35	5.41	2.25	1.35	3.15	2.70		Clean	
	Split 2	6.31	1.80	3.15	3.15	2.25	6.31	6.31	4.05	3.15	4.95	4.95	6.31	3.60	4.95	2.25	4.05	2.70	2.70	6.31	4.50	64.41	Coal	
	Split 3	4.05	4.05	2.25	3.15	4.05	4.05	4.05	3.15	7.66	8.11	9.01	3.60	6.76	6.31	4.50	4.05	5.41	3.60	5.86	7.21			
	Split 4	1.80	0.90	0.45	1.35	0.90	0.90	0.45	0.90	1.80	1.80	4.50	1.35	2.70	1.80	0.90	0.90	1.35	0.90	0.90	1.80	53.60	Middling	
	Split 5	4.05	3.15	2.25	1.80	1.35	3.15	2.70	3.15	2.25	2.70	4.05	1.35	2.25	2.25	3.15	2.70	4.05	3.15	3.15	3.60			
	Split 6	1.80	2.25	1.35	1.35	1.80	3.15	2.25	3.15	0.90	1.35	2.25	3.15	4.05	4.05	2.25	2.25	1.80	2.25	2.25	3.15	29.28	Reject	
	Dust	0.23	0.07	0.06	0.06	0.07	0.09	0.10	0.14	0.18	0.26	0.28	0.14	0.10	0.11	0.06	0.08	0.07	0.05	0.10	0.08	0.35		
	Products Total	21.85	12.67	12.23	12.67	12.23	21.26	22.17	17.71	16.40	19.63	26.40	20.41	20.37	20.83	14.47	19.45	17.64	14.02	21.72	23.05	147.64		
Total Moist (%)	Feed	4.50	4.60	4.52	4.13	3.89	4.29	2.99	4.09	1.52	2.79	2.33	5.00	5.00	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50		
	Split 1	4.70	4.72	6.42	5.14	4.80	4.04	3.47	4.82	2.34	2.48	1.72	5.50	5.50	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70		
	Split 2	5.00	7.50	7.24	6.68	6.44	6.35	5.84	5.88	1.14	1.11	1.19	5.80	5.80	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00		
	Split 3	4.00	7.04	5.73	4.91	6.82	4.46	3.27	4.33	1.51	1.09	1.45	5.50	5.50	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00		
	Split 4	2.00	5.25	1.38	1.43	3.02	1.50	1.43	1.47	1.19	1.09	1.05	4.80	4.80	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00		
	Split 5	2.50	3.72	2.40	1.82	2.92	1.00	1.18	1.44	1.09	1.96	1.02	3.30	3.30	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50		
	Split 6	2.00	2.39	1.77	1.53	2.09	1.19	1.56	1.18	1.74	1.11	1.20	3.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00		
	Dust	1.50	1.34	1.12	1.60	1.1	1.24	1.32	1.42	2.41	1.86	2.02	1.4	1.4	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50		
	Products Total	3.77	5.21	5.04	4.20	5.01	3.81	3.58	3.53	1.39	1.26	1.27	4.99	4.70	3.55	3.45	3.86	3.53	3.46	3.87	3.60	3.31		
Wt (kg - dry)	Feed	18.50	18.48	15.49	16.84	13.42	21.13	22.72	14.69	18.63	19.70	25.08	24.82	21.82	26.67	18.50	14.20	19.79	18.07	19.79	14.63	19.79		
	Split 1	3.43	0.43	2.53	1.71	1.72	3.46	6.09	3.00	0.44	0.44	1.33	4.26	0.85	1.29	1.29	5.15	2.15	1.29	3.00	2.58			
	Split 2	5.99	1.67	2.92	2.94	2.11	5.91	5.94	3.82	3.12	4.90	4.90	5.94	3.39	4.71	2.14	3.85	2.57	2.57	5.99	4.28	61.19		145.72
	Split 3	3.89	3.76	2.12	3.00	3.78	3.87	3.92	3.02	7.54	8.02	8.88	3.41	6.39	6.05	4.32	3.89	5.19	3.46	5.62	6.92			
	Split 4	1.77	0.85	0.44	1.33	0.87	0.89	0.44	0.89	1.78	1.78	4.46	1.29	2.57	1.77	0.88	0.88	1.32	0.88	0.88	1.77	52.53		
	Split 5	3.95	3.03	2.20	1.77	1.31	3.12	2.67	3.11	2.23	2.65	4.01	1.31	2.18	2.20	3.07	2.64	3.95	3.07	3.07	3.51			
	Split 6	1.77	2.20	1.33	1.33	1.76	3.12	2.22	3.12	0.89	1.34	2.23	3.06	3.93	3.97	2.21	2.21	1.77	2.21	2.21	3.09	28.69		
	Dust	0.22	0.07	0.06	0.06	0.07	0.09	0.09	0.14	0.18	0.26	0.27	0.14	0.10	0.11	0.06	0.08	0.07	0.05	0.10	0.07	0.34		
	Products Total	21.03	12.01	11.61	12.14	11.62	20.45	21.37	17.09	16.17	19.38	26.07	19.39	19.42	20.09	13.97	18.70	17.02	13.53	20.88	22.22	142.75		

		17		10		11		12		13		14		15		16		18		19		21		1		2		3		4		5		6		7		8		9		20	
By Size Data		+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	52mm X 6mm	
Wt by Size (% dry)	Feed	42.10	57.90	46.15	53.85	43.73	56.27	50.36	49.64	49.16	50.84	50.63	49.37	53.61	46.39	56.77	43.23	94.31	5.69	95.27	4.73	94.79	5.21	59.23	40.77	64.41	35.59	54.68	45.32	48.49	51.51	43.42	56.58	50.48	49.52	57.9	42.10	51	49.00		100.00	100	
	Split 1	27.30	72.70	46.01	53.99	41.57	58.43	64.02	35.98	51.41	48.59	40.43	59.57	48.03	51.97	28.35	71.65	48.61	51.39	64.57	35.43	79.27	20.73	37.50	62.50	45.60	54.40	41.1	58.90	49	51.00	37.04	62.96	49.3	50.70	22.9	77.10	61.5	38.50		100.00		Clean
	Split 2	13.80	86.20	25.79	74.21	18.70	81.30	32.06	67.94	27.49	72.51	27.48	72.52	25.14	74.86	10.42	89.58	91.39	8.61	94.21	5.79	93.98	6.02	22.75	77.25	45.83	54.17	25	75.00	25.1	74.90	17.06	82.94	20	80.00	25	75.00	31.7	68.30		100.00	41.98	Coal
	Split 3	49.30	50.70	36.61	63.39	35.27	64.73	52.87	47.13	34.15	65.85	53.92	46.08	66.71	33.29	35.20	64.80	95.79	4.21	96.87	3.13	97.14	2.86	39.55	60.45	69.34	30.66	28.13	71.87	33.92	66.08	25	75.00	51	49.00	25.9	74.10	41.8	58.20		100.00		
	Split 4	80.50	19.50	31.89	68.11	55.57	44.43	86.95	13.05	48.95	51.05	52.51	47.49	68.41	31.59	64.74	35.26	96.98	3.02	97.28	2.72	98.18	1.82	40.40	59.60	71.17	28.83	39.78	60.22	51.3	48.70	70	30.00	64.52	35.48	51.4	48.60	61.9	38.10		100.00	36.02	Middling
	Split 5	88.90	11.10	84.22	15.78	89.75	10.25	88.29	11.71	79.27	20.73	97.62	2.38	91.48	8.52	96.21	3.79	97.28	2.72	97.28	2.72	99.81	0.19	83.33	16.67	87.70	12.30	81.63	18.37	66.4	33.60	72.41	27.59	76.13	23.87	76.3	23.70	86.4	13.60		100.00		
	Split 6	70.60	29.40	82.15	17.85	89.95	10.05	91.80	8.20	80.28	19.72	92.60	7.40	88.06	11.94	86.87	13.13	96.04	3.96	96.11	3.89	95.63	4.37	85.03	14.97	84.24	15.76	82.3	17.70	73.03	26.97	76.2	23.80	70.5	29.50	80.7	19.30	81.3	18.70		100.00	22	Reject
	Dust		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		
	Products Total	46.92	53.08	55.24	44.76	49.62	50.38	62.29	37.71	48.50	51.50	56.28	43.72	54.89	45.11	50.23	49.77	92.96	7.04	94.22	5.78	95.09	4.91	43.85	56.15	69.14	30.86	45.65	54.35	48.24	51.76	41.42	58.58	54.81	45.19	47.39	52.61	53.13	46.87	0.00	100.00	100.00	
Ash (% dry)	Feed	51.00	41.50	52.14	43.77	53.84	43.43	55.54	44.05	53.51	42.68	54.62	41.91	53.23	41.43	51.72	41.11	54.24	41.90	56.90	39.50	51.60	41.18	55.90	41.80	51.60	43.80	52.40	45.80	56.10	45.10	52.80	42.10	51.20	43.40	50.00	44.20	54.50	45.20			46.5	
	Split 1	29.10	37.40	33.80	41.29	40.38	42.45	36.06	43.03	37.88	41.36	35.53	40.24	33.09	41.07	33.24	39.96	44.81	34.70	28.65	36.80	45.81	37.11	40.40	39.20	25.10	39.20	33.30	42.00	33.80	41.92	39.70	42.30	39.60	34.30	32.10	41.30	30.60	41.90				Clean
	Split 2	30.80	39.10	41.98	41.97	39.51	42.66	37.66	42.65	35.06	42.27	33.20	39.90	34.71	41.23	33.13	38.41	45.06	35.37	44.65	35.81	36.06	37.40	33.20	39.30	32.00	40.80	32.00	41.50	33.60	41.70	37.80	41.40	29.40	40.50	31.80	42.80	31.40	42.60			35.1	Coal
	Split 3	34.60	43.90	39.77	42.14	40.81	43.48	38.93	43.58	37.91	42.43	39.45	44.30	40.00	48.15	33.86	41.91	41.00	36.84	43.70	39.69	41.03	41.46	39.20	39.90	41.10	42.00	37.40	44.20	35.80	43.90	38.90	43.60	35.50	42.30	34.20	43.90	39.40	44.90				
	Split 4	49.60	48.90	37.38	44.00	52.36	43.72	61.87	46.95	40.17	45.08	39.62	45.23	51.31	48.69	32.70	45.17	68.64	45.34	67.31	43.21	65.14	44.67	44.20	43.90	42.70	46.30	37.30	45.90	46.50	43.70	43.50	42.80	37.50	43.60	46.90	42.90	45.10	43.80			49.5	Middling
	Split 5	72.70	48.80	58.97	46.31	70.79	49.67	73.71	53.66	55.51	43.88	72.96	45.60	63.55	44.73	67.99	46.42	76.89	47.76	73.98	47.54	78.99	45.15	60.30	42.60	54.90	46.00	57.00	47.40	55.40	48.50	55.50	47.60	55.60	48.50	53.90	58.10	62.10	58.30				
	Split 6	83.10	72.20	77.89	59.42	85.92	69.04	84.99	68.93	71.09	61.10	82.87	66.58	81.55	65.69	75.47	93.99	83.72	64.15	81.73	69.68	79.76	65.30	80.00		80.00		80.00		80.00		80.00		80.00		83.40	79.60	79.00	68.90			80	Reject
	Dust		52.00		43.25		44.69		41.80		44.17		38.91		40.9		41.51		32.52		36.92		40.18														41.50		40.40				
	Products Total	55.62	42.05	57.39	43.91	60.72	43.73	56.49	44.26	49.37	43.61	57.86	41.83	49.72	42.97	58.70	42.69	52.59	37.22	52.90	39.72	54.03	41.36	53.96	37.63	51.36	37.07	55.48	40.16	52.66	39.91	52.38	40.40	48.24	38.27	55.63	46.75	48.69	45.08	#DIV/0!	0.00	46.02	#DIV/0!

*Colored blocks are not exact data, it is a closest guess

	LB	KG
Feed		0
1		0
2		0
3		0
4		0
5		0
6		0
		0

India - Deshaler Project - 2010

Site - CCL Kargali Washery

Location - Kargali, Bokaro, Jharkhand

Coal Source - Kargali

	Date -	3/17/10		3/16/10														3/18/2010				3/19/10	
	Test No. -	17		10		11		12		13		14		15		16		18		19		21	
Table Parameters																							
Tilt	(deg)			8.5		8.5		8.5		8.5		8.5		8.5		8.5		8.5		8.5		8.5	
Slope	(deg)			1.5		1.5		1.5		1.5		0.5		0.5		0.5		1.5		1.5		1.0	
Fan Speed	(Hz)			55		55		60		50		55		60		60		60		55		60	
Table Speed	(Hz)			50		40		40		50		45		45		50		45		45		45	
Feed Rate (kg, AR)				4.33		3.91		4.24		3.31		5.26		5.56		3.72		4.55		4.88		6.21	
Feed Rate (kg, dry)				4.14		3.73		4.06		3.19		5.04		5.39		3.57		4.48		4.75		6.06	
Total Sample Time (hr:min:sec)				0:09:24		0:08:43		0:09:01		0:04:49		0:06:30		0:09:27		0:05:31		0:09:20		0:05:36		0:08:36	
Sample Data																							
Total Dust Collected (kg, AR)				2.78		2.47		2.20		1.37		2.06		3.83		3.35		6.97		5.88		9.61	
Total Wt (kg - AR)	Feed			18.06		16.28		17.66		13.81		21.93		23.16		15.51		18.97		20.34		25.86	
	Split 1			0.69		2.53		1.85		3.14		3.84		6.31		1.75		0.34		0.62		1.21	
	Split 2			1.85		3.03		3.22		2.11		6.16		6.19		3.83		3.21		5.20		5.04	
	Split 3			3.85		2.38		3.35		3.90		4.02		3.97		3.03		7.56		7.98		9.12	
	Split 4			0.75		0.55		1.30		0.78		0.89		0.51		0.68		1.85		1.95		3.35	
	Split 5			2.94		2.23		1.80		1.57		2.98		2.70		2.98		2.16		2.54		4.01	
	Split 6			2.18		1.29		1.17		1.93		2.98		2.13		3.31		1.11		1.48		2.01	
	Dust	#DIV/0!		0.07		0.07		0.06		0.07		0.08		0.10		0.15		0.19		0.26		0.28	
	Products Total	#DIV/0!		12.33		12.08		12.75		13.50		20.95		21.91		15.73		16.42		20.03		25.02	
Total Moist (%)	Feed			4.60		4.52		4.13		3.89		4.29		2.99		4.09		1.52		2.79		2.33	
	Split 1			4.72		6.42		5.14		4.80		4.04		3.47		4.82		2.34		2.48		1.72	
	Split 2			7.50		7.24		6.68		6.44		6.35		5.84		5.88		1.14		1.11		1.19	
	Split 3			7.04		5.73		4.91		6.82		4.46		3.27		4.33		1.51		1.09		1.45	
	Split 4			5.25		1.38		1.43		3.02		1.50		1.43		1.47		1.19		1.09		1.05	
	Split 5			3.72		2.40		1.82		2.92		1.00		1.18		1.44		1.09		1.96		1.02	
	Split 6			2.39		1.77		1.53		2.09		1.19		1.56		1.18		1.74		1.11		1.20	
	Dust			1.34		1.12		1.60		1.1		1.24		1.32		1.42		2.41		1.86		2.02	
	Products Total	#DIV/0!		5.22		4.99		4.27		4.91		3.84		3.58		3.40		1.39		1.26		1.27	
Wt (kg - dry)	Feed	0.00		17.23		15.54		16.93		13.27		20.99		22.47		14.88		18.68		19.77		25.26	
	Split 1	0.00		0.66		2.37		1.75		2.99		3.68		6.09		1.67		0.33		0.60		1.19	
	Split 2	0.00		1.71		2.81		3.00		1.97		5.77		5.83		3.60		3.17		5.14		4.98	
	Split 3	0.00		3.58		2.24		3.19		3.63		3.84		3.84		2.90		7.45		7.89		8.99	
	Split 4	0.00		0.71		0.54		1.28		0.76		0.88		0.50		0.67		1.83		1.93		3.31	
	Split 5	0.00		2.83		2.18		1.77		1.52		2.95		2.67		2.94		2.14		2.49		3.97	
	Split 6	0.00		2.13		1.27		1.15		1.89		2.94		2.10		3.27		1.09		1.46		1.99	
	Dust	#DIV/0!		0.07		0.07		0.06		0.07		0.08		0.10		0.15		0.18		0.26		0.27	
	Products Total	#DIV/0!		11.69		11.48		12.21		12.84		20.14		21.12		15.20		16.19		19.78		24.70	
By Size Data		+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm
Wt by Size (% dry)	Feed		100.00	46.15	53.85	43.73	56.27	50.36	49.64	49.16	50.84	50.63	49.37	53.61	46.39	56.77	43.23	94.31	5.69	95.27	4.73	94.79	5.21
	Split 1		100.00	46.01	53.99	41.57	58.43	64.02	35.98	51.41	48.59	40.43	59.57	48.03	51.97	28.35	71.65	48.61	51.39	64.57	35.43	79.27	20.73
	Split 2		100.00	25.79	74.21	18.70	81.30	32.06	67.94	27.49	72.51	27.48	72.52	25.14	74.86	10.42	89.58	91.39	8.61	94.21	5.79	93.98	6.02
	Split 3		100.00	36.61	63.39	35.27	64.73	52.87	47.13	34.15	65.85	53.92	46.08	66.71	33.29	35.20	64.80	95.79	4.21	96.87	3.13	97.14	2.86
	Split 4		100.00	31.89	68.11	55.57	44.43	86.95	13.05	48.95	51.05	52.51	47.49	68.41	31.59	64.74	35.26	96.98	3.02	97.28	2.72	98.18	1.82
	Split 5		100.00	84.22	15.78	89.75	10.25	88.29	11.71	79.27	20.73	97.62	2.38	91.48	8.52	96.21	3.79	97.28	2.72	97.28	2.72	99.81	0.19
	Split 6		100.00	82.15	17.85	89.95	10.05	91.80	8.20	80.28	19.72	92.60	7.40	88.06	11.94	86.87	13.13	96.04	3.96	96.11	3.89	95.63	4.37
	Dust		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00
	Products Total	#DIV/0!	#DIV/0!	54.86	45.14	49.62	50.38	61.47	38.53	49.98	50.02	55.66	44.34	54.83	45.17	52.44	47.56	93.23	6.77	93.96	6.04	95.01	4.99
Ash (% dry)	Feed			52.14	43.77	53.84	43.43	55.54	44.05	53.51	42.68	54.62	41.91	53.23	41.43	51.72	41.11	54.24	41.90	56.90	39.50	51.60	41.18
	Split 1			33.80	41.29	40.38	42.45	36.06	43.03	37.88	41.36	35.53	40.24	33.09	41.07	33.24	39.96	44.81	34.70	28.65	36.80	45.81	37.11
	Split 2			41.98	41.97	39.51	42.66	37.66	42.65	35.06	42.27	33.20	39.90	34.71	41.23	33.13	38.41	45.06	35.37	44.65	35.81	36.06	37.40
	Split 3			39.77	42.14	40.81	43.48	38.93	43.58	37.91	42.43	39.45	44.30	40.00	48.15	33.86	41.91	41.00	36.84	43.70	39.69	41.03	41.46
	Split 4			37.38	44.00	52.36	43.72	61.87	46.95	40.17	45.08	39.62	45.23	51.31	48.69	32.70	45.17	68.64	45.34	67.31	43.21	65.14	44.67
	Split 5			58.97	46.31	70.79	49.67	73.71	53.66	55.51	43.88	72.96	45.60	63.55	44.73	67.99	46.42	76.89	47.76	73.98	47.54	78.99	45.15
	Split 6			77.89	59.42	85.92	69.04	84.99	68.93	71.09	61.10	82.87	66.58	81.55	65.69	75.47	93.99	83.72	64.15	81.73	69.68	79.76	65.30
	Dust				43.25		44.69		41.80		44.17		38.91		40.9		41.51		32.52		36.92		40.18
	Products Total	#DIV/0!	#DIV/0!	57.09	43.82	60.54	43.74	55.47	44.15	48.95	43.49	57.22	41.79	49.51	42.95	60.66	43.29	52.97	37.51	52.84	39.64	53.12	41.18

	Date -	3/15/10												3/16/2010						3/18/2010	
	Test No. -	1		2		3		4		5		6		7		8		9		20	
Total Wt (kg - AR)	Split 1																				Clean
	Split 2																				Coal
	Split 4																				Middling
	Split 6																				Reject
	Dust	#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!	
	Products Total	#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!	
Total Moist (%)	Products Total	#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!			
Wt (kg - dry)	Feed	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
	Split 1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00			
	Split 2	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
	Split 3	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00			
	Split 4	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
	Split 5	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00			
	Split 6	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
	Dust	#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!	
	Products Total	#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!		#DIV/0!	
By Size Data		+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm
Wt by Size (% dry)	Feed		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00
	Split 1		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00
	Split 2		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00
	Split 3		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00
	Split 4		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00
	Split 5		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00
	Split 6		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00
	Dust		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00
	Products Total	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash (% dry)	Products Total	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

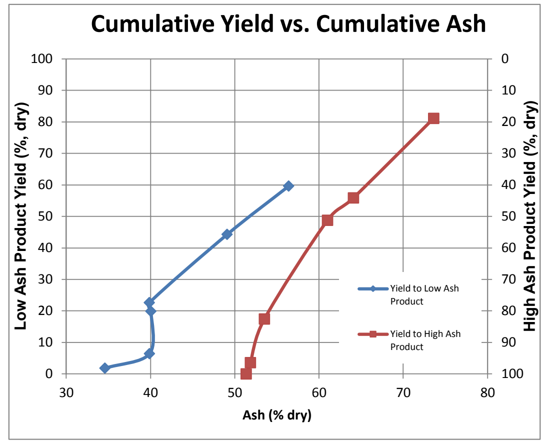
	LB	KG
Feed		0
1		0
2		0
3		0
4		0
5		0
6		0
		0

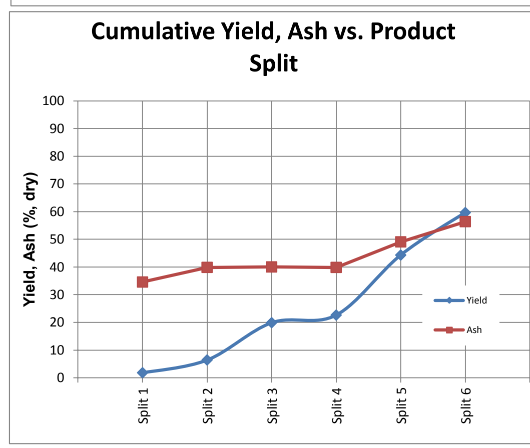
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/16/10 Test - 10

Stream/ Product	Individual						Cumulative			
							Low Ash Product		High Ash Product	
	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			46.15	8.53		52.14				
Split 1			46.01	0.20	2.97	33.80	2.97	33.80	100.00	57.39
Split 2			25.79	0.43	6.47	41.98	9.44	39.41	97.03	58.12
Split 3			36.61	1.38	20.77	39.77	30.22	39.66	90.56	59.27
Split 4			31.89	0.27	4.10	37.38	34.32	39.38	69.78	65.07
Split 5			84.22	2.55	38.49	58.97	72.81	49.74	65.68	66.80
Split 6			82.15	1.80	27.19	77.89	100.00	57.39	27.19	77.89
Products			55.24	6.64	100.00	57.39				
-6 mm										
Feed			53.85	9.95		43.77				
Split 1			53.99	0.23	4.31	41.29	4.31	41.29	100.00	43.91
Split 2			74.21	1.24	22.98	41.97	27.29	41.86	95.69	44.03
Split 3			63.39	2.39	44.39	42.14	71.68	42.03	72.71	44.68
Split 4			68.11	0.58	10.80	44.00	82.49	42.29	28.32	48.66
Split 5			15.78	0.48	8.90	46.31	91.39	42.68	17.51	51.54
Split 6			17.85	0.39	7.29	59.42	98.68	43.92	8.61	56.95
Dust			100.00	0.07	1.32	43.25	100.00	43.91	1.32	43.25
Products			44.76	5.38	100.00	43.91				
Total Sample Composite										
Feed	19.37	4.60	100.00	18.48		47.62				
Split 1	0.45	4.72	100.00	0.43	3.57	37.84	3.57	37.84	100.00	51.36
Split 2	1.80	7.50	100.00	1.67	13.86	41.97	17.43	41.13	96.43	51.86
Split 3	4.05	7.04	100.00	3.76	31.34	41.27	48.78	41.22	82.57	53.52
Split 4	0.90	5.25	100.00	0.85	7.10	41.89	55.88	41.31	51.22	61.01
Split 5	3.15	3.72	100.00	3.03	25.25	56.97	81.13	46.18	44.12	64.09
Split 6	2.25	2.39	100.00	2.20	18.28	74.59	99.41	51.41	18.87	73.61
Dust	0.07	1.34	100.00	0.07	0.59	43.25	100.00	51.36	0.59	43.25
Products	12.67	5.21	100.00	12.01	100.00	51.36				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	1.84	34.59	1.84	34.59	1.73	41.29	1.73	41.29	100.00	51.36
Split 2	4.60	41.98	6.44	39.87	9.26	41.97	10.99	41.86	96.43	51.86
Split 3	13.46	40.12	19.90	40.04	17.88	42.14	28.88	42.03	82.57	53.52
Split 4	2.75	38.55	22.65	39.86	4.35	44.00	33.23	42.29	51.22	61.01
Split 5	21.66	58.74	44.31	49.09	3.59	46.31	36.81	42.68	44.12	64.09
Split 6	15.35	77.50	59.66	56.40	2.94	59.42	39.75	43.92	18.87	73.61
Dust					0.59	43.25	40.34	43.91		
Products	59.66	56.40			40.34	43.91				

India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

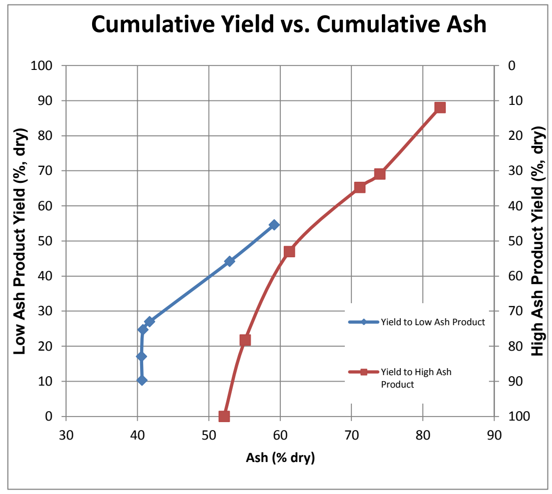
Date 3/16/10 Test - 11

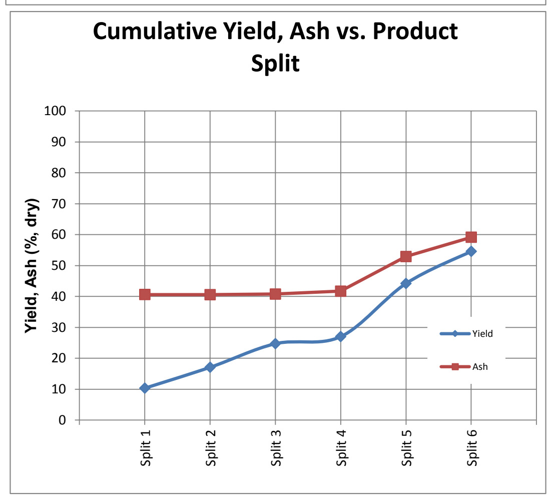
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			43.73	6.77		53.84				
Split 1			41.57	1.05	18.25	40.38	18.25	40.38	100.00	60.72
Split 2			18.70	0.55	9.49	39.51	27.74	40.08	81.75	65.26
Split 3			35.27	0.75	13.00	40.81	40.74	40.31	72.26	68.64
Split 4			55.57	0.25	4.29	52.36	45.03	41.46	59.26	74.75
Split 5			89.75	1.97	34.25	70.79	79.27	54.13	54.97	76.49
Split 6			89.95	1.19	20.73	85.92	100.00	60.72	20.73	85.92
Products			49.62	5.76	100.00	60.72				
-6 mm										
Feed			57.90	8.97		43.43				
Split 1			58.43	1.48	25.26	42.45	25.26	42.45	100.00	43.73
Split 2			81.30	2.38	40.65	42.66	65.91	42.58	74.74	44.16
Split 3			64.73	1.37	23.49	43.48	89.40	42.82	34.09	45.95
Split 4			44.43	0.20	3.37	43.72	92.78	42.85	10.60	51.43
Split 5			10.25	0.23	3.85	49.67	96.63	43.12	7.22	55.03
Split 6			10.05	0.13	2.28	69.04	98.91	43.72	3.37	61.16
Dust			100.00	0.06	1.09	44.69	100.00	43.73	1.09	44.69
Products			50.38	5.85	100.00	43.73				
Total Sample Composite										
Feed	16.22	4.52	101.63	15.74		47.76				
Split 1	2.70	6.42	100.00	2.53	21.78	41.59	21.78	41.59	100.00	52.16
Split 2	3.15	7.24	100.00	2.92	25.19	42.07	46.97	41.85	78.22	55.10
Split 3	2.25	5.73	100.00	2.12	18.29	42.54	65.26	42.04	53.03	61.29
Split 4	0.45	1.38	100.00	0.44	3.83	48.52	69.09	42.40	34.74	71.17
Split 5	2.25	2.40	100.00	2.20	18.93	68.63	88.02	48.04	30.91	73.97
Split 6	1.35	1.77	100.00	1.33	11.43	84.22	99.45	52.20	11.98	82.41
Dust	0.06	1.12	100.00	0.06	0.55	44.69	100.00	52.16	0.55	44.69
Products	12.23	5.04	100.00	11.61	100.00	52.16				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	10.33	40.64	10.33	40.64	11.45	42.45	11.45	42.45	100.00	52.16
Split 2	6.76	40.46	17.09	40.57	18.43	42.66	29.89	42.58	78.22	55.10
Split 3	7.63	41.22	24.72	40.77	10.65	43.48	40.54	42.82	53.03	61.29
Split 4	2.30	51.72	27.02	41.70	1.53	43.72	42.07	42.85	34.74	71.17
Split 5	17.19	70.55	44.20	52.92	1.75	49.67	43.82	43.12	30.91	73.97
Split 6	10.40	85.73	54.60	59.17	1.03	69.04	44.85	43.72	11.98	82.41
Dust					0.55	44.69	45.40	43.73		
Products	54.60	59.17			45.40	43.73				

Charts Represent Values for Products Screened at 6 mm



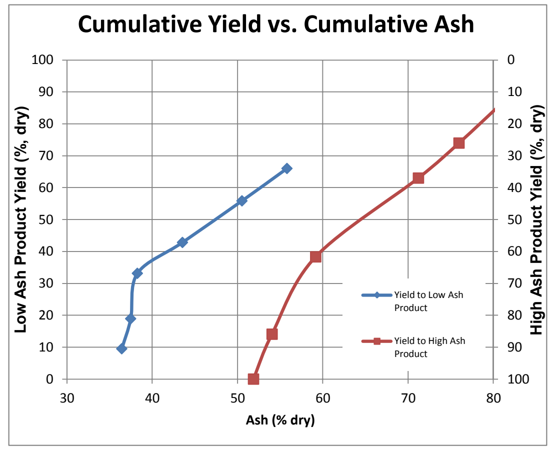


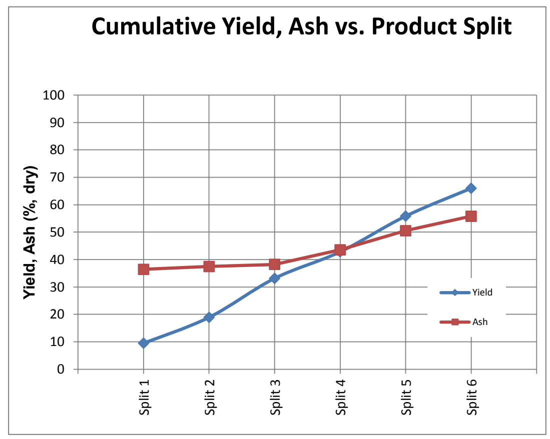
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/16/10 Test - 12

Stream/ Product	Individual Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Low Ash Product Ash (%, dry)	High Ash Product Weight (%, dry)	High Ash Product Ash (%, dry)
+6 mm										
Feed			50.36	8.48		55.54				
Split 1			64.02	1.09	14.47	36.06	14.47	36.06	100.00	56.49
Split 2			32.06	0.94	12.47	37.66	26.94	36.80	85.53	59.94
Split 3			52.87	1.59	20.96	38.93	47.89	37.73	73.06	63.75
Split 4			86.95	1.16	15.31	61.87	63.20	43.58	52.11	73.73
Split 5			88.29	1.56	20.65	73.71	83.85	51.00	36.80	78.66
Split 6			91.80	1.22	16.15	84.99	100.00	56.49	16.15	84.99
Products			62.29	7.56	100.00	56.49				
-6 mm										
Feed			49.64	8.36		44.05				
Split 1			35.98	0.61	13.43	43.03	13.43	43.03	100.00	44.26
Split 2			67.94	2.00	43.66	42.65	57.09	42.74	86.57	44.46
Split 3			47.13	1.41	30.86	43.58	87.96	43.03	42.91	46.29
Split 4			13.05	0.17	3.80	46.95	91.75	43.20	12.04	53.25
Split 5			11.71	0.21	4.52	53.66	96.28	43.69	8.25	56.14
Split 6			8.20	0.11	2.38	68.93	98.66	44.30	3.72	59.16
Dust			100.00	0.06	1.34	41.80	100.00	44.26	1.34	41.80
Products			37.71	4.58	100.00	44.26				
Total Sample Composite										
Feed	17.57	4.13	100.00	16.84		51.41				
Split 1	1.80	5.14	100.00	1.71	14.08	38.57	14.08	38.57	100.00	51.88
Split 2	3.15	6.68	100.00	2.94	24.23	41.05	38.31	40.14	85.92	54.06
Split 3	3.15	4.91	100.00	3.00	24.69	41.12	63.00	40.52	61.69	59.17
Split 4	1.35	1.43	100.00	1.33	10.97	59.92	73.97	43.40	37.00	71.21
Split 5	1.80	1.82	100.00	1.77	14.57	71.36	88.54	48.00	26.03	75.97
Split 6	1.35	1.53	100.00	1.33	10.96	83.67	99.49	51.93	11.46	81.83
Dust	0.06	1.60	100.00	0.06	0.51	41.80	100.00	51.88	0.51	41.80
Products	12.67	4.20	100.00	12.14	100.00	51.88				

Charts Represent Values for Products Screened at 6 mm





Note - Split 6 and Dust samples combined for first High Ash Product point

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Individual Ash (%)	Cumulative Wt (%)	Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Individual Ash (%)	Cumulative Wt (%)	Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	Cumulative Ash (%)
Split 1	9.52	36.43	9.52	36.43	4.56	43.03	4.56	43.03	100.00	51.88
Split 2	9.42	38.53	18.93	37.48	14.82	42.65	19.37	42.74	85.92	54.06
Split 3	14.22	39.31	33.15	38.26	10.47	43.58	29.85	43.03	61.69	59.17
Split 4	9.68	61.65	42.83	43.55	1.29	46.95	31.14	43.20	37.00	71.21
Split 5	13.03	73.45	55.86	50.52	1.54	53.66	32.67	43.69	26.03	75.97
Split 6	10.15	84.85	66.01	55.80	0.81	68.93	33.48	44.30	11.46	81.83
Dust					0.51	41.80	33.99	44.26		
Products	66.01	55.80			33.99	44.26				

India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

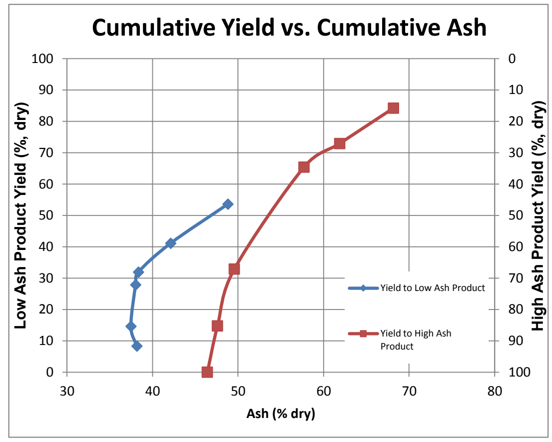
Date 3/16/10 Test - 13

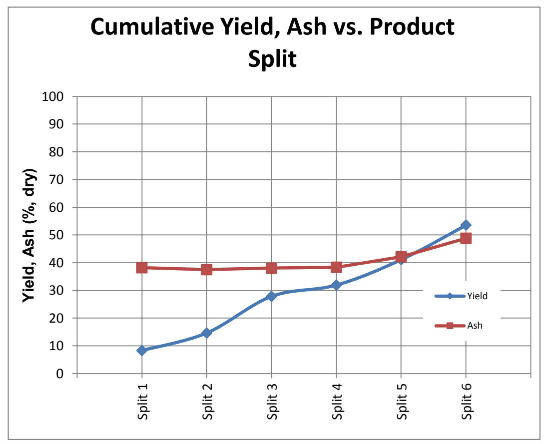
	Individual						Cumulative			
							Low Ash Product		High Ash Product	
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			49.16	6.60		53.51				
Split 1			51.41	0.88	15.65	37.88	15.65	37.88	100.00	49.37
Split 2			27.49	0.58	10.28	35.06	25.93	36.76	84.35	51.50
Split 3			34.15	1.29	22.89	37.91	48.82	37.30	74.07	53.79
Split 4			48.95	0.43	7.59	40.17	56.41	37.69	51.18	60.89
Split 5			79.27	1.04	18.45	55.51	74.87	42.08	43.59	64.49
Split 6			80.28	1.42	25.13	71.09	100.00	49.37	25.13	71.09
Products			48.50	5.64	100.00	49.37				
-6 mm										
Feed			50.84	6.82		42.68				
Split 1			48.59	0.83	13.93	41.36	13.93	41.36	100.00	43.61
Split 2			72.51	1.53	25.53	42.27	39.46	41.95	86.07	43.97
Split 3			65.85	2.49	41.56	42.43	81.02	42.20	60.54	44.69
Split 4			51.05	0.45	7.45	45.08	88.47	42.44	18.98	49.64
Split 5			20.73	0.27	4.54	43.88	93.02	42.51	11.53	52.59
Split 6			19.72	0.35	5.81	61.10	98.83	43.60	6.98	58.27
Dust			100.00	0.07	1.17	44.17	100.00	43.61	1.17	44.17
Products			51.50	5.98	100.00	43.61				
Total Sample Composite										
Feed	13.96	3.89	100.00	13.42		48.25				
Split 1	1.80	4.80	100.00	1.72	14.76	39.57	14.76	39.57	100.00	46.40
Split 2	2.25	6.44	100.00	2.11	18.13	40.29	32.90	39.97	85.24	47.59
Split 3	4.05	6.82	100.00	3.78	32.51	40.89	65.41	40.42	67.10	49.56
Split 4	0.90	3.02	100.00	0.87	7.52	42.68	72.93	40.66	34.59	57.71
Split 5	1.35	2.92	100.00	1.31	11.29	53.10	84.22	42.32	27.07	61.88
Split 6	1.80	2.09	100.00	1.76	15.18	69.12	99.40	46.42	15.78	68.17
Dust	0.07	1.10	100.00	0.07	0.60	44.17	100.00	46.40	0.60	44.17
Products	12.23	5.01	100.00	11.62	100.00	46.40				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	8.31	38.18	8.31	38.18	6.46	41.36	6.46	41.36	100.00	46.40
Split 2	6.30	36.56	14.61	37.48	11.83	42.27	18.29	41.95	85.24	47.59
Split 3	13.24	38.64	27.85	38.03	19.27	42.43	37.56	42.20	67.10	49.56
Split 4	4.06	40.63	31.91	38.36	3.45	45.08	41.01	42.44	34.59	57.71
Split 5	9.18	55.21	41.10	42.13	2.11	43.88	43.12	42.51	27.07	61.88
Split 6	12.49	70.85	53.59	48.82	2.69	61.10	45.81	43.60	15.78	68.17
Dust					0.60	44.17	46.41	43.61		
Products	53.59	48.82			46.41	43.61				

Charts Represent Values for Products Screened at 6 mm





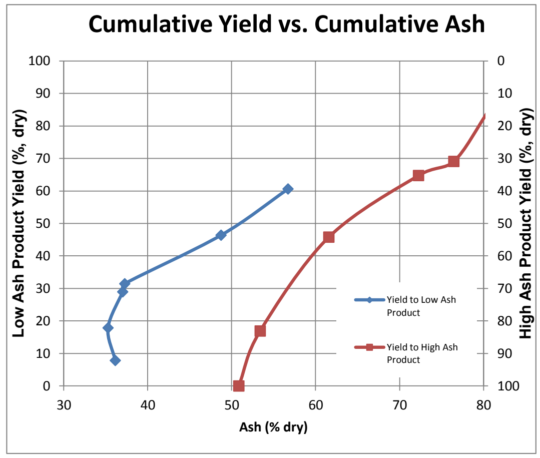
Note - Split 6 and Dust samples combined for first High Ash Product point

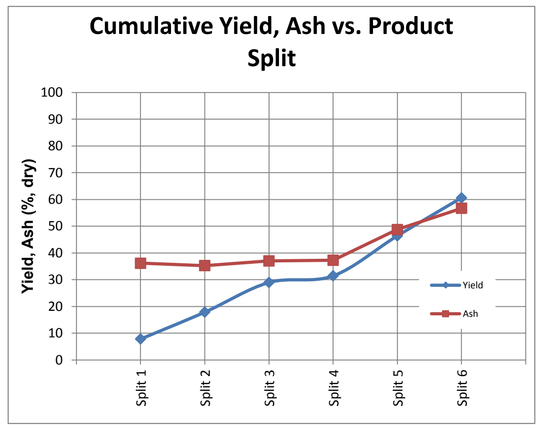
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/16/10 Test - 14

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			50.63	10.70		54.62				
Split 1			40.43	1.40	12.15	35.53	12.15	35.53	100.00	57.86
Split 2			27.48	1.62	14.10	33.20	26.25	34.28	87.85	60.95
Split 3			53.92	2.09	18.15	39.45	44.40	36.39	73.75	66.25
Split 4			52.51	0.47	4.05	39.62	48.45	36.66	55.60	75.00
Split 5			97.62	3.05	26.48	72.96	74.93	49.49	51.55	77.78
Split 6			92.60	2.89	25.07	82.87	100.00	57.86	25.07	82.87
Products			56.28	11.51	100.00	57.86				
-6 mm										
Feed			49.37	10.43		41.91				
Split 1			59.57	2.06	23.04	40.24	23.04	40.24	100.00	41.83
Split 2			72.52	4.28	47.91	39.90	70.95	40.01	76.96	42.31
Split 3			46.08	1.78	19.97	44.30	90.92	40.95	29.05	46.29
Split 4			47.49	0.42	4.71	45.23	95.63	41.16	9.08	50.66
Split 5			2.38	0.07	0.83	45.60	96.46	41.20	4.37	56.53
Split 6			7.40	0.23	2.58	66.58	99.04	41.86	3.54	59.10
Dust			100.00	0.09	0.96	38.91	100.00	41.83	0.96	38.91
Products			43.72	8.94	100.00	41.83				
Total Sample Composite										
Feed	22.07	4.29	100.00	21.13		47.05				
Split 1	3.60	4.04	100.00	3.46	16.91	38.34	16.91	38.34	100.00	50.85
Split 2	6.31	6.35	100.00	5.91	28.88	38.06	45.80	38.16	83.09	53.40
Split 3	4.05	4.46	100.00	3.87	18.94	41.68	64.74	39.19	54.20	61.58
Split 4	0.90	1.50	100.00	0.89	4.34	42.28	69.08	39.39	35.26	72.26
Split 5	3.15	1.00	100.00	3.12	15.27	72.31	84.34	45.35	30.92	76.47
Split 6	3.15	1.19	100.00	3.12	15.24	81.66	99.58	50.90	15.66	80.52
Dust	0.09	1.24	100.00	0.09	0.42	38.91	100.00	50.85	0.42	38.91
Products	21.26	3.81	100.00	20.45	100.00	50.85				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

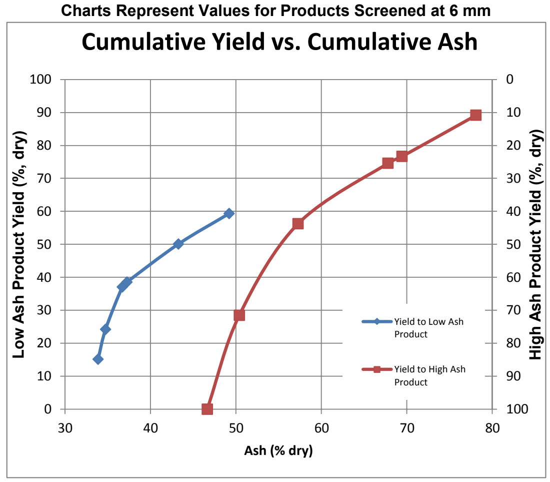
	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	7.84	36.13	7.84	36.13	9.07	40.24	9.07	40.24	100.00	50.85
Split 2	10.03	34.60	17.88	35.27	18.85	39.90	27.92	40.01	83.09	53.40
Split 3	11.09	39.83	28.96	37.02	7.86	44.30	35.77	40.95	54.20	61.58
Split 4	2.48	40.09	31.45	37.26	1.85	45.23	37.63	41.16	35.26	72.26
Split 5	14.94	72.89	46.39	48.74	0.33	45.60	37.96	41.20	30.92	76.47
Split 6	14.22	82.74	60.61	56.72	1.01	66.58	38.97	41.86	15.66	80.52
Dust					0.42	38.91	39.39	41.83		
Products	60.61	56.72			39.39	41.83				

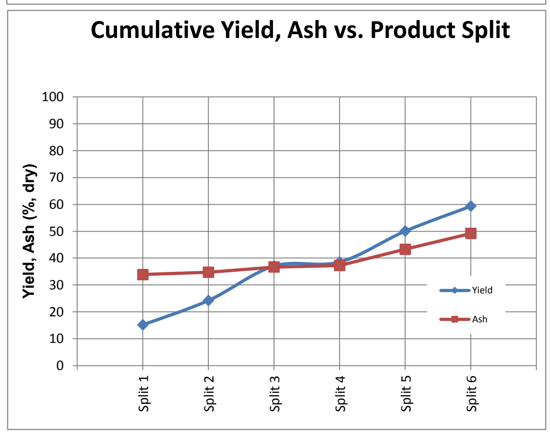
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/16/10 Test - 15

	Individual						Cumulative			
							Low Ash Product		High Ash Product	
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			53.61	12.18		53.23				
Split 1			48.03	2.92	24.92	33.09	24.92	33.09	100.00	49.72
Split 2			25.14	1.49	12.72	34.71	37.65	33.64	75.08	55.24
Split 3			66.71	2.62	22.30	40.00	59.94	36.00	62.35	59.42
Split 4			68.41	0.30	2.59	51.31	62.53	36.64	40.06	70.24
Split 5			91.48	2.44	20.83	63.55	83.36	43.36	37.47	71.54
Split 6			88.06	1.95	16.64	81.55	100.00	49.72	16.64	81.55
Products			54.89	11.73	100.00	49.72				
-6 mm										
Feed			46.39	10.54		41.43				
Split 1			51.97	3.16	32.82	41.07	32.82	41.07	100.00	42.92
Split 2			74.86	4.45	46.11	41.23	78.92	41.16	67.18	43.83
Split 3			33.29	1.31	13.54	48.15	92.46	42.19	21.08	49.51
Split 4			31.59	0.14	1.45	45.17	93.92	42.23	7.54	51.96
Split 5			8.52	0.23	2.36	44.73	96.28	42.29	6.08	53.58
Split 6			11.94	0.26	2.75	65.69	99.03	42.94	3.72	59.19
Dust			100.00	0.09	0.97	40.90	100.00	42.92	0.97	40.90
Products			45.11	9.64	100.00	42.92				
Total Sample Composite										
Feed	23.42	2.99	100.00	22.72		47.10				
Split 1	6.31	3.47	100.00	6.09	28.48	37.24	28.48	37.24	100.00	46.65
Split 2	6.31	5.84	100.00	5.94	27.78	39.59	56.27	38.40	71.52	50.40
Split 3	4.05	3.27	100.00	3.92	18.35	42.71	74.61	39.46	43.73	57.27
Split 4	0.45	1.43	100.00	0.44	2.08	49.37	76.69	39.73	25.39	67.79
Split 5	2.70	1.18	100.00	2.67	12.50	61.95	89.19	42.84	23.31	69.43
Split 6	2.25	1.56	100.00	2.22	10.37	79.66	99.56	46.68	10.81	78.08
Dust	0.10	1.32	100.00	0.09	0.44	40.90	100.00	46.65	0.44	40.90
Products	22.17	3.58	100.00	21.37	100.00	46.65				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

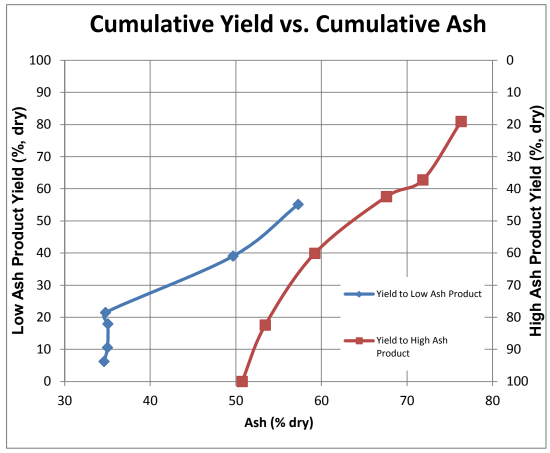
	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	15.16	33.87	15.16	33.87	13.32	41.07	13.32	41.07	100.00	46.65
Split 2	9.06	36.21	24.22	34.74	18.72	41.23	32.04	41.16	71.52	50.40
Split 3	12.85	40.39	37.08	36.70	5.50	48.15	37.54	42.19	43.73	57.27
Split 4	1.49	51.04	38.56	37.25	0.59	45.17	38.13	42.23	25.39	67.79
Split 5	11.54	63.38	50.10	43.27	0.96	44.73	39.09	42.29	23.31	69.43
Split 6	9.26	81.34	59.36	49.21	1.11	65.69	40.20	42.94	10.81	78.08
Dust					0.44	40.90	40.64	42.92		
Products	59.36	49.21			40.64	42.92				

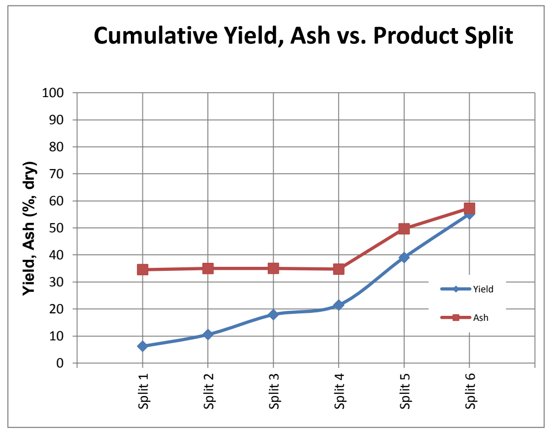
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/16/10 Test - 16

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			56.77	8.34		51.72				
Split 1			28.35	0.85	9.91	33.24	9.91	33.24	100.00	58.70
Split 2			10.42	0.40	4.63	33.13	14.55	33.20	90.09	61.51
Split 3			35.20	1.06	12.37	33.86	26.92	33.51	85.45	63.04
Split 4			64.74	0.57	6.70	32.70	33.62	33.35	73.08	67.98
Split 5			96.21	2.99	34.84	67.99	68.46	50.98	66.38	71.54
Split 6			86.87	2.71	31.54	75.47	100.00	58.70	31.54	75.47
Products			50.23	8.58	100.00	58.70				
-6 mm										
Feed			43.23	6.35		41.50				
Split 1			71.65	2.15	25.29	39.96	25.29	39.96	100.00	42.70
Split 2			89.58	3.42	40.19	38.41	65.48	39.01	74.71	43.62
Split 3			64.80	1.95	22.99	41.91	88.47	39.76	34.52	49.70
Split 4			35.26	0.31	3.68	45.34	92.15	39.99	11.53	65.22
Split 5			3.79	0.12	1.39	46.42	93.53	40.08	7.85	74.54
Split 6			13.13	0.41	4.81	93.99	98.35	42.72	6.47	80.56
Dust			100.00	0.14	1.65	41.51	100.00	42.70	1.65	41.51
Products			49.77	8.50	100.00	42.70				
Total Sample Composite										
Feed	15.32	4.09	100.00	14.69		44.40				
Split 1	3.15	4.82	100.00	3.00	17.57	38.05	17.57	38.05	100.00	50.74
Split 2	4.05	5.88	100.00	3.82	22.33	37.86	39.90	37.95	82.43	53.44
Split 3	3.15	4.33	100.00	3.02	17.66	39.08	57.55	38.29	60.10	59.23
Split 4	0.90	1.47	100.00	0.89	5.20	37.16	62.75	38.20	42.45	67.61
Split 5	3.15	1.44	100.00	3.11	18.19	67.17	80.94	44.71	37.25	71.86
Split 6	3.15	1.18	100.00	3.12	18.24	77.90	99.18	50.81	19.06	76.33
Dust	0.14	1.42	100.00	0.14	0.82	41.51	100.00	50.74	0.82	41.51
Products	17.71	3.53	100.00	17.09	100.00	50.74				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

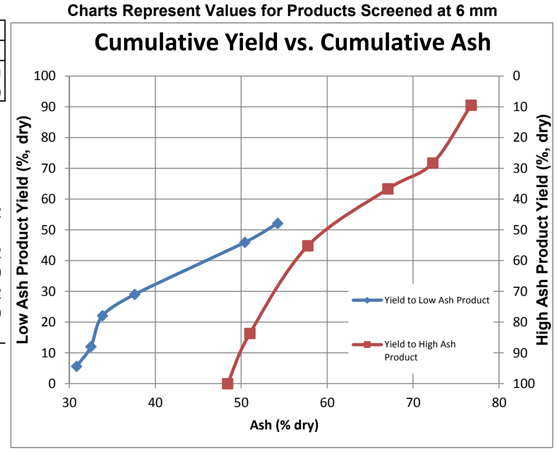
	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	6.24	34.60	6.24	34.60	11.33	39.96	11.33	39.96	100.00	50.74
Split 2	4.33	35.57	10.57	35.00	18.01	38.41	29.33	39.01	82.43	53.44
Split 3	7.36	35.11	17.93	35.04	10.30	41.91	39.63	39.76	60.10	59.23
Split 4	3.55	33.35	21.47	34.76	1.65	45.34	41.28	39.99	42.45	67.61
Split 5	17.57	67.91	39.04	49.68	0.62	46.42	41.90	40.08	37.25	71.86
Split 6	16.08	75.75	55.12	57.28	2.16	93.99	44.05	42.72	19.06	76.33
Dust					0.82	41.51	44.88	42.70		
Products	55.12	57.28			44.88	42.70				

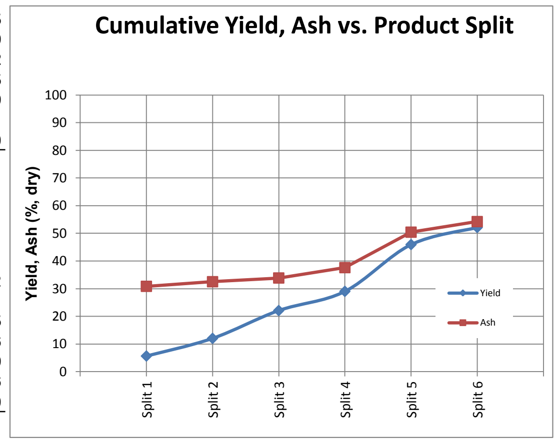
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/17/10 Test - 17

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			42.10	7.79		51.00				
Split 1			27.30	0.94	9.50	29.10	9.50	29.10	100.00	55.62
Split 2			13.80	0.83	8.38	30.80	17.88	29.90	90.50	58.41
Split 3			49.30	1.92	19.45	34.60	37.33	32.35	82.12	61.22
Split 4			80.50	1.42	14.41	49.60	51.74	37.15	62.67	69.49
Split 5			88.90	3.51	35.62	72.70	87.36	51.65	48.26	75.42
Split 6			70.60	1.25	12.64	83.10	100.00	55.62	12.64	83.10
Products			46.92	9.87	100.00	55.62				
-6 mm										
Feed			57.90	10.71		41.50				
Split 1			72.70	2.50	22.37	37.40	22.37	37.40	100.00	42.05
Split 2			86.20	5.16	46.27	39.10	68.64	38.55	77.63	43.39
Split 3			50.70	1.97	17.68	43.90	86.33	39.64	31.36	49.72
Split 4			19.50	0.34	3.09	48.90	89.41	39.96	13.67	57.25
Split 5			11.10	0.44	3.93	48.80	93.34	40.33	10.59	59.69
Split 6			29.40	0.52	4.65	72.20	97.99	41.85	6.66	66.11
Dust			100.00	0.22	2.01	52.00	100.00	42.05	2.01	52.00
Products			53.08	11.16	100.00	42.05				
Total Sample Composite										
Feed	19.37	4.50	100.00	18.50		44.09				
Split 1	3.60	4.70	100.00	3.43	16.33	35.13	16.33	35.13	100.00	48.42
Split 2	6.31	5.00	100.00	5.99	28.49	37.95	44.83	36.93	83.67	51.01
Split 3	4.05	4.00	100.00	3.89	18.51	39.32	63.34	37.62	55.17	57.75
Split 4	1.80	2.00	100.00	1.77	8.40	49.46	71.74	39.01	36.66	67.06
Split 5	4.05	2.50	100.00	3.95	18.80	70.05	90.54	45.46	28.26	72.29
Split 6	1.80	2.00	100.00	1.77	8.40	79.90	98.94	48.38	9.46	76.76
Dust	0.23	1.50	100.00	0.22	1.06	52.00	100.00	48.42	1.06	52.00
Products	21.85	3.77	100.00	21.03	100.00	48.42				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	5.65	30.85	5.65	30.85	10.69	37.40	10.69	37.40	100.00	48.42
Split 2	6.39	33.99	12.04	32.52	22.11	39.10	32.79	38.55	83.67	51.01
Split 3	10.06	35.47	22.10	33.86	8.45	43.90	41.24	39.64	55.17	57.75
Split 4	6.92	49.58	29.02	37.61	1.47	48.90	42.71	39.96	36.66	67.06
Split 5	16.92	72.41	45.95	50.43	1.88	48.80	44.59	40.33	28.26	72.29
Split 6	6.18	82.66	52.12	54.25	2.22	72.20	46.81	41.85	9.46	76.76
Dust					1.06	52.00	47.88	42.07		
Products	52.12	54.25			47.88	42.07				

India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

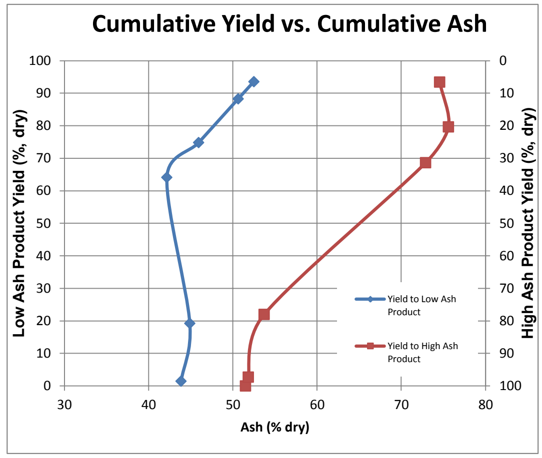
Date 3/18/10 Test - 18

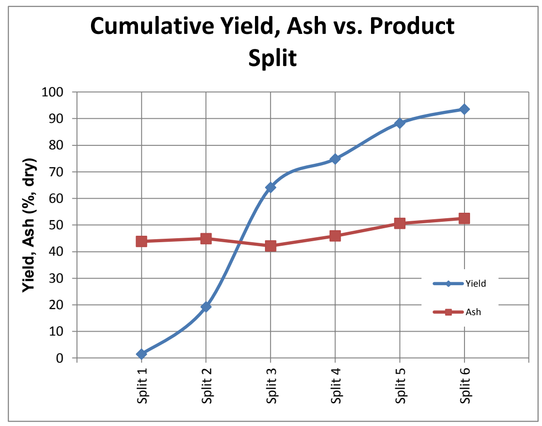
Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			94.31	17.57		54.24				
Split 1			48.61	0.21	1.42	44.81	1.42	44.81	100.00	52.59
Split 2			91.39	2.85	18.95	45.06	20.38	45.04	98.58	52.70
Split 3			95.79	7.22	48.06	41.00	68.44	42.20	79.62	54.52
Split 4			96.98	1.73	11.49	68.64	79.93	46.00	31.56	75.11
Split 5			97.28	2.17	14.42	76.89	94.34	50.72	20.07	78.81
Split 6			96.04	0.85	5.66	83.72	100.00	52.59	5.66	83.72
Products			92.96	15.03	100.00	52.59				
-6 mm										
Feed			5.69	1.06		41.90				
Split 1			51.39	0.23	19.86	34.70	19.86	34.70	100.00	37.12
Split 2			8.61	0.27	23.58	35.37	43.45	35.06	80.14	37.72
Split 3			4.21	0.32	27.90	36.84	71.35	35.76	56.55	38.70
Split 4			3.02	0.05	4.72	43.21	76.07	36.22	28.65	40.51
Split 5			2.72	0.06	5.32	47.76	81.39	36.98	23.93	39.98
Split 6			3.96	0.04	3.08	64.15	84.47	37.97	18.61	37.76
Dust			100.00	0.18	15.53	32.52	100.00	37.12	15.53	32.52
Products			7.04	1.14	100.00	37.12				
Total Sample Composite										
Feed	18.92	1.52	100.00	18.63		47.90				
Split 1	0.45	2.34	100.00	0.44	2.72	39.61	2.72	39.61	100.00	51.50
Split 2	3.15	1.14	100.00	3.12	19.28	44.23	22.00	43.66	97.28	51.83
Split 3	7.66	1.51	100.00	7.54	46.64	40.82	68.64	41.73	78.00	53.71
Split 4	1.80	1.19	100.00	1.78	11.01	67.87	79.65	45.35	31.36	72.89
Split 5	2.25	1.09	100.00	2.23	13.78	76.10	93.43	49.88	20.35	75.60
Split 6	0.90	1.74	100.00	0.89	5.47	82.95	98.91	51.71	6.57	74.55
Dust	0.18	2.41	100.00	0.18	1.09	32.52	100.00	51.50	1.09	32.52
Products	16.40	1.39	100.00	16.17	100.00	51.50				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	1.46	43.84	1.46	43.84	1.26	34.70	1.26	34.70	100.00	51.50
Split 2	17.78	44.97	19.25	44.88	1.49	35.37	2.75	35.06	97.28	51.83
Split 3	44.88	40.98	64.12	42.15	1.77	36.84	4.52	35.76	78.00	53.71
Split 4	10.71	68.56	74.84	45.93	0.30	43.21	4.82	36.22	31.36	72.89
Split 5	13.44	76.81	88.28	50.63	0.34	47.76	5.16	36.98	20.35	75.60
Split 6	5.28	83.64	93.56	52.50	0.20	64.15	5.35	37.97	6.57	74.55
Dust					1.09	32.52	6.44	37.04		
Products	93.56	52.50			6.44	37.04				

Charts Represent Values for Products Screened at 6 mm





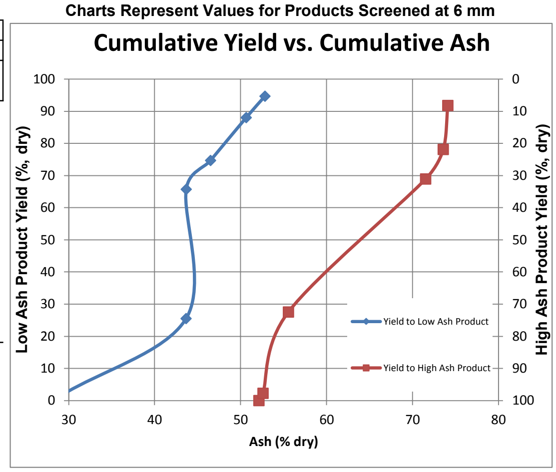
Note - Split 6 and Dust samples combined for first High Ash Product point

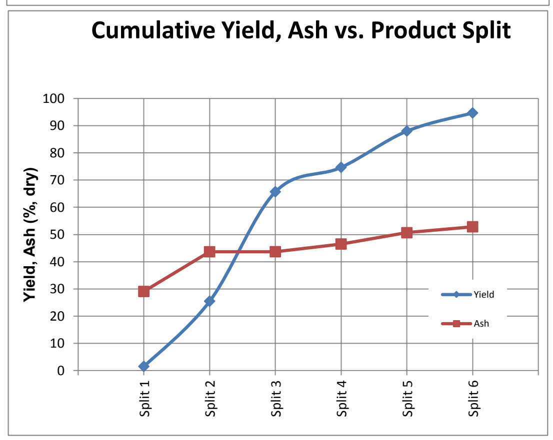
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/18/10 Test - 19

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			95.27	18.77		56.90				
Split 1			64.57	0.28	1.55	28.65	1.55	28.65	100.00	52.90
Split 2			94.21	4.62	25.27	44.65	26.83	43.72	98.45	53.28
Split 3			96.87	7.77	42.53	43.70	69.36	43.71	73.17	56.26
Split 4			97.28	1.73	9.49	67.31	78.85	46.55	30.64	73.69
Split 5			97.28	2.58	14.11	73.98	92.97	50.71	21.15	76.56
Split 6			96.11	1.28	7.03	81.73	100.00	52.90	7.03	81.73
Products			94.22	18.26	100.00	52.90				
-6 mm										
Feed			4.73	0.93		39.50				
Split 1			35.43	0.16	13.90	36.80	13.90	36.80	100.00	39.72
Split 2			5.79	0.28	25.34	35.81	39.24	36.16	86.10	40.19
Split 3			3.13	0.25	22.42	39.69	61.66	37.44	60.76	42.02
Split 4			2.72	0.05	4.33	43.21	65.99	37.82	38.34	43.38
Split 5			2.72	0.07	6.44	47.54	72.43	38.69	34.01	43.40
Split 6			3.89	0.05	4.64	69.68	77.07	40.55	27.57	42.44
Dust			100.00	0.26	22.93	36.92	100.00	39.72	22.93	36.92
Products			5.78	1.12	100.00	39.72				
Total Sample Composite										
Feed	20.27	2.79	100.00	19.70		50.74				
Split 1	0.45	2.48	100.00	0.44	2.27	31.54	2.27	31.54	100.00	52.13
Split 2	4.95	1.11	100.00	4.90	25.28	44.14	27.54	43.10	97.73	52.61
Split 3	8.11	1.09	100.00	8.02	41.37	43.57	68.92	43.39	72.46	55.57
Split 4	1.80	1.09	100.00	1.78	9.19	66.65	78.11	46.12	31.08	71.53
Split 5	2.70	1.96	100.00	2.65	13.67	73.26	91.78	50.17	21.89	73.58
Split 6	1.35	1.11	100.00	1.34	6.89	81.26	98.68	52.34	8.22	74.12
Dust	0.26	1.86	100.00	0.26	1.32	36.92	100.00	52.13	1.32	36.92
Products	19.63	1.26	100.00	19.38	100.00	52.13				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

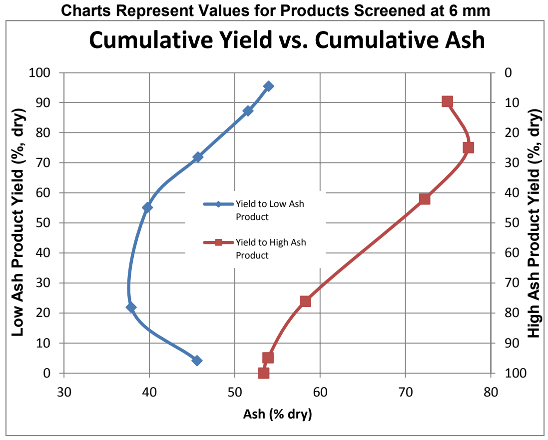
	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	1.54	29.07	1.54	29.07	0.72	36.80	0.72	36.80	100.00	52.13
Split 2	23.96	44.60	25.50	43.66	1.32	35.81	2.04	36.16	97.73	52.61
Split 3	40.21	43.69	65.71	43.68	1.17	39.69	3.21	37.44	72.46	55.57
Split 4	8.97	67.24	74.68	46.51	0.23	43.21	3.43	37.82	31.08	71.53
Split 5	13.34	73.91	88.02	50.66	0.33	47.54	3.77	38.69	21.89	73.58
Split 6	6.65	81.68	94.67	52.84	0.24	69.68	4.01	40.55	8.22	74.12
Dust					1.32	36.92	5.33	39.65		
Products	94.67	52.84			5.33	39.65				

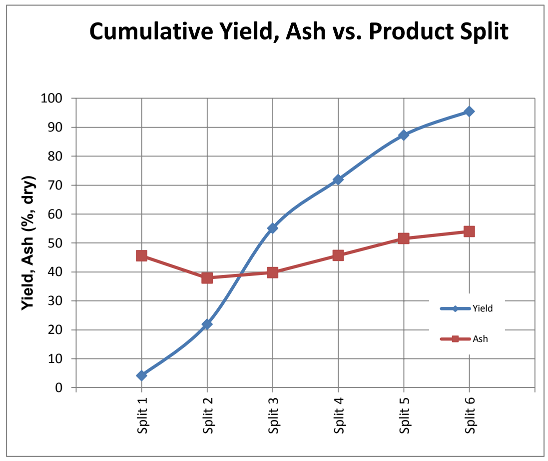
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/19/10 Test - 21

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			94.79	23.77		51.60				
Split 1			79.27	1.05	4.25	45.81	4.25	45.81	100.00	54.03
Split 2			93.98	4.60	18.56	36.06	22.81	37.88	95.75	54.39
Split 3			97.14	8.62	34.79	41.03	57.60	39.78	77.19	58.80
Split 4			98.18	4.38	17.65	65.14	75.26	45.73	42.40	73.38
Split 5			99.81	4.01	16.16	78.99	91.42	51.61	24.74	79.26
Split 6			95.63	2.13	8.58	79.76	100.00	54.03	8.58	79.76
Products			95.09	24.79	100.00	54.03				
-6 mm										
Feed			5.21	1.31		41.18				
Split 1			20.73	0.28	21.52	37.11	21.52	37.11	100.00	41.36
Split 2			6.02	0.29	23.04	37.40	44.56	37.26	78.48	42.52
Split 3			2.86	0.25	19.85	41.46	64.40	38.55	55.44	44.65
Split 4			1.82	0.08	6.34	44.67	70.74	39.10	35.60	46.43
Split 5			0.19	0.01	0.60	45.15	71.34	39.15	29.26	46.81
Split 6			4.37	0.10	7.60	65.30	78.94	41.67	28.66	46.84
Dust			100.00	0.27	21.06	40.18	100.00	41.36	21.06	40.18
Products			4.91	1.28	100.00	41.36				
Total Sample Composite										
Feed	25.68	2.33	100.00	25.08		49.44				
Split 1	1.35	1.72	100.00	1.33	5.09	44.01	5.09	44.01	100.00	53.40
Split 2	4.95	1.19	100.00	4.90	18.78	36.14	23.88	37.82	94.91	53.91
Split 3	9.01	1.45	100.00	8.88	34.06	41.04	57.94	39.71	76.12	58.29
Split 4	4.50	1.05	100.00	4.46	17.10	64.77	75.04	45.42	42.06	72.26
Split 5	4.05	1.02	100.00	4.01	15.39	78.93	90.43	51.13	24.96	77.39
Split 6	2.25	1.20	100.00	2.23	8.54	79.13	98.97	53.54	9.57	74.92
Dust	0.28	2.02	100.00	0.27	1.03	40.18	100.00	53.40	1.03	40.18
Products	26.40	1.27	100.00	26.07	100.00	53.40				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

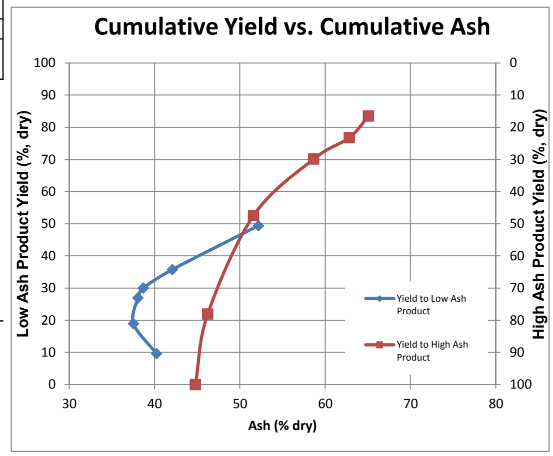
	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	4.14	45.59	4.14	45.59	0.95	37.11	0.95	37.11	100.00	53.40
Split 2	17.76	36.07	21.91	37.87	1.02	37.40	1.97	37.26	94.91	53.91
Split 3	33.18	41.03	55.09	39.77	0.88	41.46	2.84	38.55	76.12	58.29
Split 4	16.82	65.10	71.91	45.70	0.28	44.67	3.12	39.10	42.06	72.26
Split 5	15.37	78.98	87.28	51.56	0.03	45.15	3.15	39.15	24.96	77.39
Split 6	8.20	79.69	95.48	53.98	0.34	65.30	3.49	41.67	9.57	74.92
Dust					1.03	40.18	4.52	41.33		
Products	95.48	53.98			4.52	41.33				

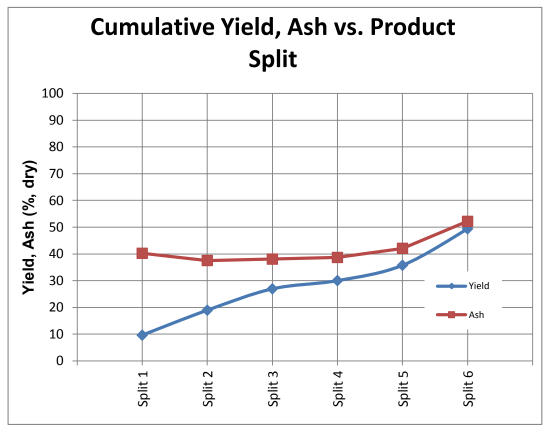
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/15/10 Test - 1

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			59.23	14.70		55.90				
Split 1			37.50	1.60	18.77	40.40	18.77	40.40	100.00	53.96
Split 2			22.75	1.35	15.89	33.20	34.66	37.10	81.23	57.09
Split 3			39.55	1.35	15.84	39.20	50.50	37.76	65.34	62.90
Split 4			40.40	0.52	6.11	44.20	56.61	38.45	49.50	70.48
Split 5			83.33	1.09	12.80	60.30	69.42	42.48	43.39	74.19
Split 6			85.03	2.60	30.58	80.00	100.00	53.96	30.58	80.00
Products			43.85	8.50	100.00	53.96				
-6 mm										
Feed			40.77	10.12		41.80				
Split 1			62.50	2.66	24.43	39.20	24.43	39.20	100.00	37.63
Split 2			77.25	4.59	42.14	39.30	66.57	39.26	75.57	37.12
Split 3			60.45	2.06	18.90	39.90	85.48	39.40	33.43	34.36
Split 4			59.60	0.77	7.04	43.90	92.52	39.75	14.52	27.15
Split 5			16.67	0.22	2.00	42.60	94.52	39.81	7.48	11.39
Split 6			14.97	0.46	4.20	0.00	98.72	38.11	5.48	0.00
Dust			100.00	0.14	1.28	0.00	100.00	37.63	1.28	0.00
Products			56.15	10.89	100.00	37.63				
Total Sample Composite										
Feed	26.13	5.00	100.00	24.82		47.09				
Split 1	4.50	5.50	100.00	4.26	21.95	39.65	21.95	39.65	100.00	44.79
Split 2	6.31	5.80	100.00	5.94	30.63	37.91	52.58	38.64	78.05	46.23
Split 3	3.60	5.50	100.00	3.41	17.56	39.62	70.14	38.88	47.42	51.61
Split 4	1.35	4.80	100.00	1.29	6.63	44.02	76.77	39.33	29.86	58.65
Split 5	1.35	3.30	100.00	1.31	6.74	57.35	83.51	40.78	23.23	62.83
Split 6	3.15	3.00	100.00	3.06	15.77	68.03	99.28	45.11	16.49	65.07
Dust	0.14	1.40	100.00	0.14	0.72	0.00	100.00	44.79	0.72	0.00
Products	20.41	4.99	100.00	19.39	100.00	44.79				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

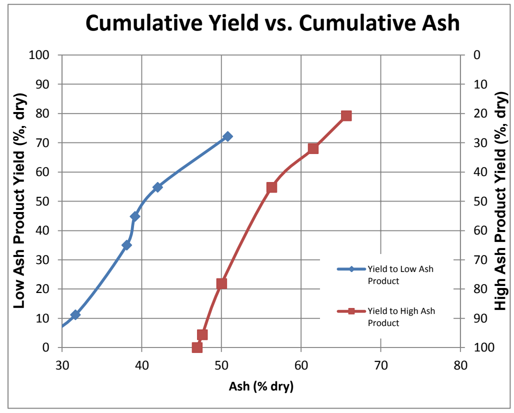
	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	9.60	40.23	9.60	40.23	12.35	39.20	12.35	39.20	100.00	44.79
Split 2	9.34	34.75	18.94	37.53	21.30	39.30	33.64	39.26	78.05	46.23
Split 3	8.01	39.29	26.94	38.05	9.55	39.90	43.20	39.40	47.42	51.61
Split 4	3.08	44.16	30.02	38.68	3.56	43.90	46.75	39.75	29.86	58.65
Split 5	5.73	59.95	35.75	42.09	1.01	42.60	47.77	39.81	23.23	62.83
Split 6	13.65	78.62	49.39	52.18	2.12	0.00	49.89	38.11	16.49	65.07
Dust					0.72	0.00	50.61	37.57		
Products	49.39	52.18			50.61	37.57				

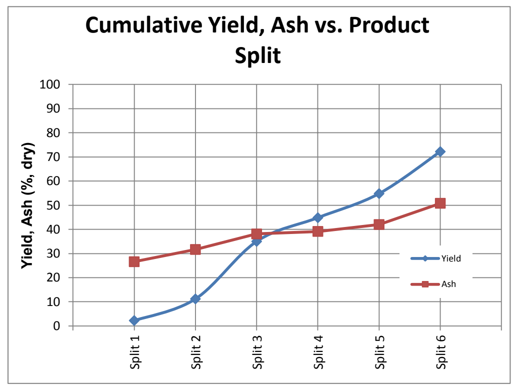
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/15/10 Test - 2

Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			64.41	14.06		51.60				
Split 1			45.60	0.39	2.89	25.10	2.89	25.10	100.00	51.36
Split 2			45.83	1.56	11.59	32.00	14.48	30.62	97.11	52.14
Split 3			69.34	4.43	32.98	41.10	47.46	37.90	85.52	54.87
Split 4			71.17	1.83	13.64	42.70	61.10	38.97	52.54	63.52
Split 5			87.70	1.91	14.23	54.90	75.33	41.98	38.90	70.82
Split 6			84.24	3.31	24.67	80.00	100.00	51.36	24.67	80.00
Products			69.14	13.43	100.00	51.36				
-6 mm										
Feed			35.59	7.77		43.80				
Split 1			54.40	0.46	7.73	39.20	7.73	39.20	100.00	37.07
Split 2			54.17	1.84	30.69	40.80	38.42	40.48	92.27	36.89
Split 3			30.66	1.96	32.68	42.00	71.10	41.18	61.58	34.94
Split 4			28.83	0.74	12.38	46.30	83.48	41.94	28.90	26.95
Split 5			12.30	0.27	4.47	46.00	87.95	42.14	16.52	12.45
Split 6			15.76	0.62	10.34	0.00	98.30	37.71	12.05	0.00
Dust			100.00	0.10	1.70	0.00	100.00	37.07	1.70	0.00
Products			30.86	5.99	100.00	37.07				
Total Sample Composite										
Feed	22.97	5.00	100.00	21.82		47.36				
Split 1	0.90	5.50	100.00	0.85	4.38	32.77	4.38	32.77	100.00	46.95
Split 2	3.60	5.80	100.00	3.39	17.48	36.77	21.87	35.97	95.62	47.60
Split 3	6.76	5.50	100.00	6.39	32.89	41.38	54.75	39.22	78.13	50.03
Split 4	2.70	4.80	100.00	2.57	13.25	43.74	68.00	40.10	45.25	56.31
Split 5	2.25	3.30	100.00	2.18	11.22	53.81	79.22	42.04	32.00	61.52
Split 6	4.05	3.00	100.00	3.93	20.25	67.39	99.47	47.20	20.78	65.69
Dust	0.10	1.40	100.00	0.10	0.53	0.00	100.00	46.95	0.53	0.00
Products	20.37	4.70	100.00	19.42	100.00	46.95				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

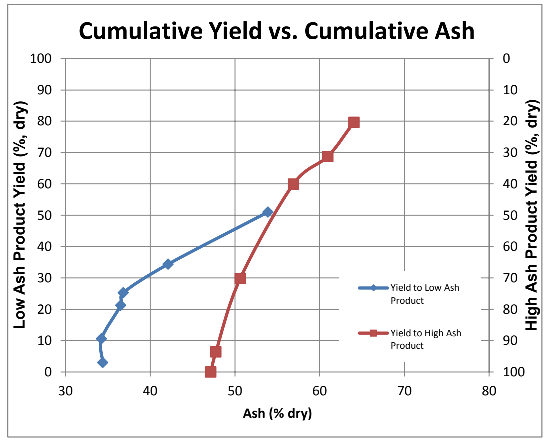
	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	2.24	26.60	2.24	26.60	2.15	39.20	2.15	39.20	100.00	46.95
Split 2	8.96	32.93	11.20	31.67	8.52	40.80	10.67	40.48	95.62	47.60
Split 3	23.81	41.14	35.01	38.11	9.07	42.00	19.74	41.18	78.13	50.03
Split 4	9.81	42.84	44.82	39.14	3.44	46.30	23.18	41.94	45.25	56.31
Split 5	9.98	54.78	54.80	41.99	1.24	46.00	24.42	42.14	32.00	61.52
Split 6	17.38	78.53	72.18	50.79	2.87	0.00	27.30	37.71	20.78	65.69
Dust					0.53	0.00	27.82	37.00		
Products	72.18	50.79			27.82	37.00				

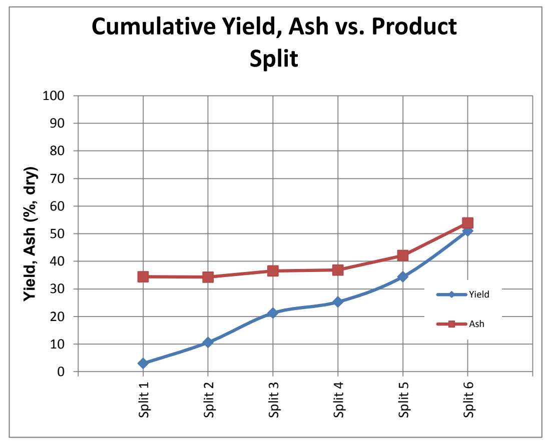
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/15/10 Test - 3

	Individual						Cumulative			
							Low Ash Product		High Ash Product	
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			54.68	14.58		52.40				
Split 1			41.10	0.53	5.77	33.30	5.77	33.30	100.00	55.48
Split 2			25.00	1.18	12.83	32.00	18.60	32.40	94.23	56.83
Split 3			28.13	1.70	18.56	37.40	37.16	34.90	81.40	60.75
Split 4			39.78	0.70	7.66	37.30	44.82	35.31	62.84	67.65
Split 5			81.63	1.79	19.54	57.00	64.36	41.90	55.18	71.86
Split 6			82.30	3.27	35.64	80.00	100.00	55.48	35.64	80.00
Products			45.65	9.17	100.00	55.48				
-6 mm										
Feed			45.32	12.09		45.80				
Split 1			58.90	0.76	6.95	42.00	6.95	42.00	100.00	40.16
Split 2			75.00	3.53	32.33	41.50	39.27	41.59	93.05	40.03
Split 3			71.87	4.35	39.84	44.20	79.12	42.90	60.73	39.24
Split 4			60.22	1.06	9.74	45.90	88.86	43.23	20.88	29.79
Split 5			18.37	0.40	3.69	47.40	92.55	43.40	11.14	15.71
Split 6			17.70	0.70	6.44	0.00	98.99	40.58	7.45	0.00
Dust			100.00	0.11	1.01	0.00	100.00	40.16	1.01	0.00
Products			54.35	10.92	100.00	40.16				
Total Sample Composite										
Feed	27.93	4.50	100.00	26.67		48.51				
Split 1	1.35	4.70	100.00	1.29	6.41	38.42	6.41	38.42	100.00	47.16
Split 2	4.95	5.00	100.00	4.71	23.43	39.13	29.83	38.97	93.59	47.75
Split 3	6.31	4.00	100.00	6.05	30.13	42.29	59.96	40.64	70.17	50.63
Split 4	1.80	2.00	100.00	1.77	8.79	42.48	68.75	40.87	40.04	56.91
Split 5	2.25	2.50	100.00	2.20	10.93	55.24	79.68	42.84	31.25	60.97
Split 6	4.05	2.00	100.00	3.97	19.77	65.84	99.45	47.42	20.32	64.06
Dust	0.11	1.50	100.00	0.11	0.55	0.00	100.00	47.16	0.55	0.00
Products	20.83	3.55	100.00	20.09	100.00	47.16				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	3.01	34.39	3.01	34.39	3.40	42.00	3.40	42.00	100.00	47.16
Split 2	7.61	34.19	10.62	34.25	15.81	41.50	19.21	41.59	93.59	47.75
Split 3	10.64	38.78	21.27	36.52	19.49	44.20	38.70	42.90	70.17	50.63
Split 4	4.02	38.43	25.29	36.82	4.76	45.90	43.46	43.23	40.04	56.91
Split 5	9.12	56.79	34.41	42.11	1.81	47.40	45.27	43.40	31.25	60.97
Split 6	16.62	78.32	51.03	53.91	3.15	0.00	48.42	40.58	20.32	64.06
Dust					0.55	0.00	48.97	40.12		
Products	51.03	53.91			48.97	40.12				

India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

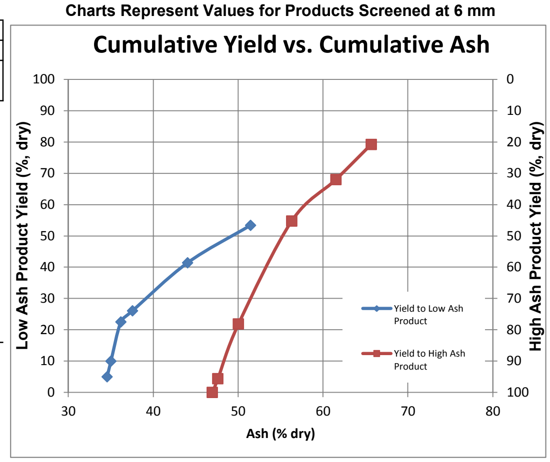
Date 3/15/10 Test - 4

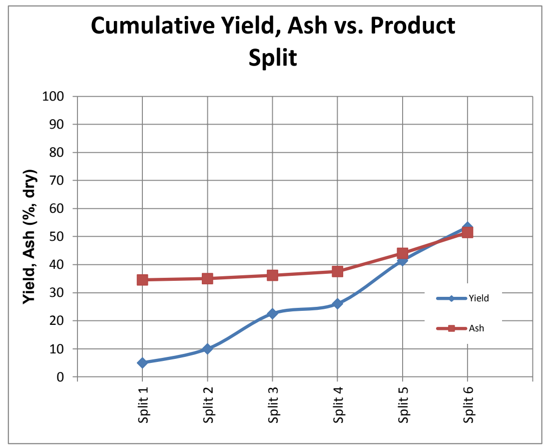
Stream/ Product	Individual Weight (kg, AR)	Individual Total Moisture (%)	Individual Weight (% of Sample)	Individual Weight (kg, dry)	Individual Weight (%, dry)	Individual Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Cumulative Low Ash Product Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Cumulative High Ash Product Ash (%, dry)
+6 mm										
Feed			48.49	8.97		56.10				
Split 1			49.00	0.63	9.36	33.80	9.36	33.80	100.00	52.66
Split 2			25.10	0.54	7.97	33.60	17.33	33.71	90.64	54.61
Split 3			33.92	1.47	21.76	35.80	39.09	34.87	82.67	56.63
Split 4			51.30	0.45	6.72	46.50	45.81	36.58	60.91	64.08
Split 5			66.40	2.04	30.28	55.40	76.09	44.07	54.19	66.25
Split 6			73.03	1.61	23.91	80.00	100.00	52.66	23.91	80.00
Products			48.24	6.74	100.00	52.66				
-6 mm										
Feed			51.51	9.53		45.10				
Split 1			51.00	0.66	9.08	41.92	9.08	41.92	100.00	39.91
Split 2			74.90	1.60	22.16	41.70	31.24	41.76	90.92	39.71
Split 3			66.08	2.86	39.50	43.90	70.74	42.96	68.76	39.07
Split 4			48.70	0.43	5.94	43.70	76.68	43.01	29.26	32.55
Split 5			33.60	1.03	14.28	48.50	90.96	43.88	23.32	29.70
Split 6			26.97	0.60	8.23	0.00	99.19	40.24	9.04	0.00
Dust			100.00	0.06	0.81	0.00	100.00	39.91	0.81	0.00
Products			51.76	7.23	100.00	39.91				
Total Sample Composite										
Feed	19.37	4.50	100.00	18.50		50.49				
Split 1	1.35	4.70	100.00	1.29	9.22	37.94	9.22	37.94	100.00	46.06
Split 2	2.25	5.00	100.00	2.14	15.31	39.67	24.53	39.02	90.78	46.89
Split 3	4.50	4.00	100.00	4.32	30.94	41.15	55.47	40.21	75.47	48.35
Split 4	0.90	2.00	100.00	0.88	6.32	45.14	61.79	40.71	44.53	53.35
Split 5	3.15	2.50	100.00	3.07	22.00	53.08	83.79	43.96	38.21	54.71
Split 6	2.25	2.00	100.00	2.21	15.79	58.42	99.58	46.25	16.21	56.92
Dust	0.06	1.50	100.00	0.06	0.42	0.00	100.00	46.06	0.42	0.00
Products	14.47	3.45	100.00	13.97	100.00	46.06				

Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

	Low Ash Product Individual Wt (%)	Low Ash Product Individual Ash (%)	Low Ash Product Cumulative Wt (%)	Low Ash Product Cumulative Ash (%)	Screen Undersize & Dust Individual Wt (%)	Screen Undersize & Dust Individual Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Screen Undersize & Dust Cumulative Ash (%)	High Ash Product Cumulative Wt (%)	High Ash Product Cumulative Ash (%)
Split 1	4.99	34.57	4.99	34.57	4.23	41.92	4.23	41.92	100.00	46.06
Split 2	4.99	35.46	9.98	35.01	10.32	41.70	14.55	41.76	90.78	46.89
Split 3	12.54	37.12	22.52	36.19	18.40	43.90	32.95	42.96	75.47	48.35
Split 4	3.55	46.26	26.07	37.56	2.77	43.70	35.72	43.01	44.53	53.35
Split 5	15.35	55.07	41.41	44.05	6.65	48.50	42.38	43.88	38.21	54.71
Split 6	11.96	77.15	53.37	51.47	3.83	0.00	46.21	40.24	16.21	56.92
Dust					0.42	0.00	46.63	39.87		
Products	53.37	51.47			46.63	39.87				

Charts Represent Values for Products Screened at 6 mm





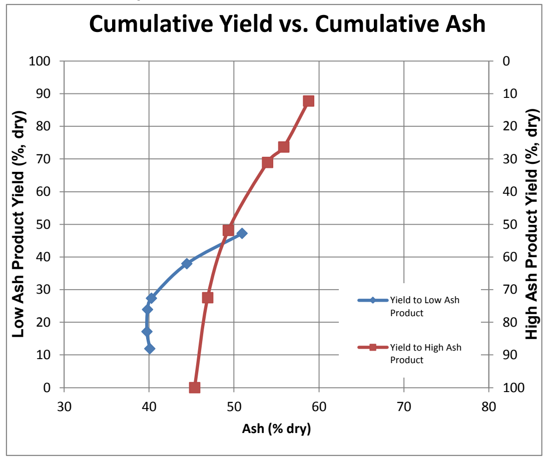
Note - Split 6 and Dust samples combined for first High Ash Product point

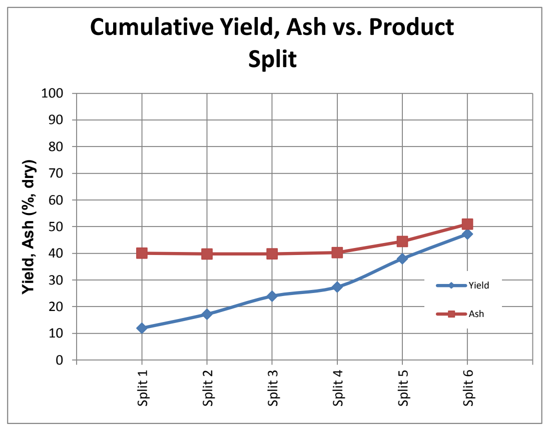
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/15/10 Test - 5

Stream/ Product	Individual: Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative: Low Ash Product Weight (%, dry)	Low Ash Product Ash (%, dry)	High Ash Product Weight (%, dry)	High Ash Product Ash (%, dry)
+6 mm										
Feed			43.42	6.16		52.80				
Split 1			37.04	1.91	24.63	39.70	24.63	39.70	100.00	52.38
Split 2			17.06	0.66	8.48	37.80	33.11	39.21	75.37	56.53
Split 3			25.00	0.97	12.56	38.90	45.68	39.13	66.89	58.90
Split 4			70.00	0.62	7.98	43.50	53.65	39.78	54.32	63.53
Split 5			72.41	1.91	24.63	55.50	78.29	44.72	46.35	66.98
Split 6			76.20	1.68	21.71	80.00	100.00	52.38	21.71	80.00
Products			41.42	7.75	100.00	52.38				
-6 mm										
Feed			56.58	8.03		42.10				
Split 1			62.96	3.24	29.60	42.30	29.60	42.30	100.00	40.40
Split 2			82.94	3.19	29.16	41.40	58.76	41.85	70.40	39.61
Split 3			75.00	2.92	26.64	43.60	85.41	42.40	41.24	38.34
Split 4			30.00	0.26	2.42	42.80	87.82	42.41	14.59	28.73
Split 5			27.59	0.73	6.64	47.60	94.46	42.77	12.18	25.94
Split 6			23.80	0.53	4.80	0.00	99.25	40.71	5.54	0.00
Dust			100.00	0.08	0.75	0.00	100.00	40.40	0.75	0.00
Products			58.58	10.96	100.00	40.40				
Total Sample Composite										
Feed	14.86	4.50	100.00	14.20		46.06				
Split 1	5.41	4.70	100.00	5.15	27.55	41.34	27.55	41.34	100.00	45.37
Split 2	4.05	5.00	100.00	3.85	20.59	40.79	48.14	41.10	72.45	46.90
Split 3	4.05	4.00	100.00	3.89	20.81	42.43	68.95	41.50	51.86	49.32
Split 4	0.90	2.00	100.00	0.88	4.72	43.29	73.67	41.62	31.05	53.95
Split 5	2.70	2.50	100.00	2.64	14.09	53.32	87.76	43.49	26.33	55.86
Split 6	2.25	2.00	100.00	2.21	11.80	60.96	99.56	45.57	12.24	58.78
Dust	0.08	1.50	100.00	0.08	0.44	0.00	100.00	45.37	0.44	0.00
Products	19.45	3.86	100.00	18.70	100.00	45.37				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

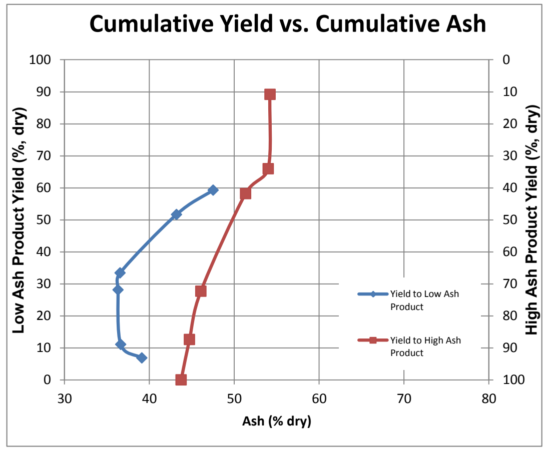
	Low Ash Product: Individual Wt (%)	Individual Ash (%)	Cumulative Wt (%)	Cumulative Ash (%)	Screen Undersize & Dust: Individual Wt (%)	Individual Ash (%)	Cumulative Wt (%)	Cumulative Ash (%)	High Ash Product: Cumulative Wt (%)	Cumulative Ash (%)
Split 1	11.94	40.08	11.94	40.08	15.61	42.30	15.61	42.30	100.00	45.37
Split 2	5.22	38.98	17.16	39.74	15.37	41.40	30.98	41.85	72.45	46.90
Split 3	6.76	39.98	23.92	39.81	14.05	43.60	45.03	42.40	51.86	49.32
Split 4	3.45	43.47	27.37	40.27	1.27	42.80	46.30	42.41	31.05	53.95
Split 5	10.59	55.21	37.96	44.44	3.50	47.60	49.80	42.77	26.33	55.86
Split 6	9.27	77.58	47.23	50.95	2.53	0.00	52.33	40.71	12.24	58.78
Dust					0.44	0.00	52.77	40.37		
Products	47.23	50.95			52.77	40.37				

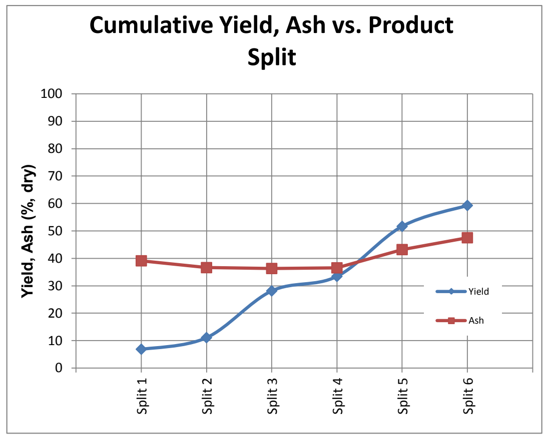
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/15/10 Test - 6

	Individual						Cumulative			
							Low Ash Product		High Ash Product	
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			50.48	9.99		51.20				
Split 1			49.30	1.06	11.35	39.60	11.35	39.60	100.00	48.24
Split 2			20.00	0.51	5.51	29.40	16.85	36.27	88.65	49.34
Split 3			51.00	2.65	28.38	35.50	45.23	35.79	83.15	50.66
Split 4			64.52	0.85	9.16	37.50	54.39	36.07	54.77	58.52
Split 5			76.13	3.01	32.26	55.60	86.65	43.34	45.61	62.74
Split 6			70.50	1.24	13.35	80.00	100.00	48.24	13.35	80.00
Products			54.81	9.33	100.00	48.24				
-6 mm										
Feed			49.52	9.80		43.40				
Split 1			50.70	1.09	14.15	34.30	14.15	34.30	100.00	38.27
Split 2			80.00	2.05	26.71	40.50	40.86	38.35	85.85	38.93
Split 3			49.00	2.54	33.06	42.30	73.92	40.12	59.14	38.21
Split 4			35.48	0.47	6.11	43.60	80.03	40.38	26.08	33.03
Split 5			23.87	0.94	12.27	48.50	92.30	41.46	19.97	29.80
Split 6			29.50	0.52	6.77	0.00	99.07	38.63	7.70	0.00
Dust			100.00	0.07	0.93	0.00	100.00	38.27	0.93	0.00
Products			45.19	7.69	100.00	38.27				
Total Sample Composite										
Feed	20.72	4.50	100.00	19.79		47.25				
Split 1	2.25	4.70	100.00	2.15	12.61	36.91	12.61	36.91	100.00	43.73
Split 2	2.70	5.00	100.00	2.57	15.09	38.28	27.70	37.66	87.39	44.72
Split 3	5.41	4.00	100.00	5.19	30.49	38.83	58.20	38.27	72.30	46.06
Split 4	1.35	2.00	100.00	1.32	7.78	39.66	65.98	38.44	41.80	51.33
Split 5	4.05	2.50	100.00	3.95	23.23	53.91	89.21	42.46	34.02	54.00
Split 6	1.80	2.00	100.00	1.77	10.38	56.40	99.58	43.92	10.79	54.22
Dust	0.07	1.50	100.00	0.07	0.42	0.00	100.00	43.73	0.42	0.00
Products	17.64	3.53	100.00	17.02	100.00	43.73				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

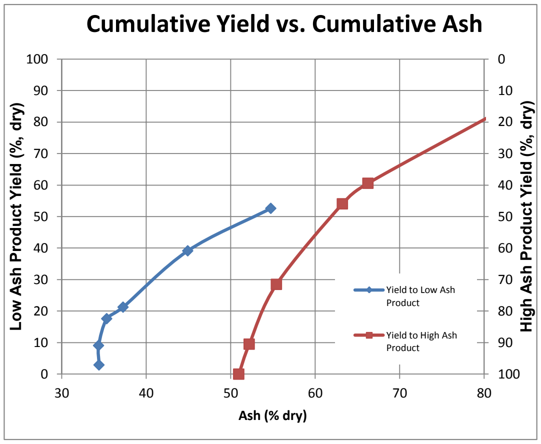
	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	6.86	39.11	6.86	39.11	5.76	34.30	5.76	34.30	100.00	43.73
Split 2	4.22	32.57	11.08	36.61	10.86	40.50	16.62	38.35	87.39	44.72
Split 3	17.05	36.10	28.13	36.30	13.45	42.30	30.07	40.12	72.30	46.06
Split 4	5.30	37.82	33.43	36.54	2.49	43.60	32.55	40.38	41.80	51.33
Split 5	18.24	55.38	51.66	43.19	4.99	48.50	37.54	41.46	34.02	54.00
Split 6	7.62	76.79	59.29	47.51	2.75	0.00	40.30	38.63	10.79	54.22
Dust					0.42	0.00	40.71	38.23		
Products	59.29	47.51			40.71	38.23				

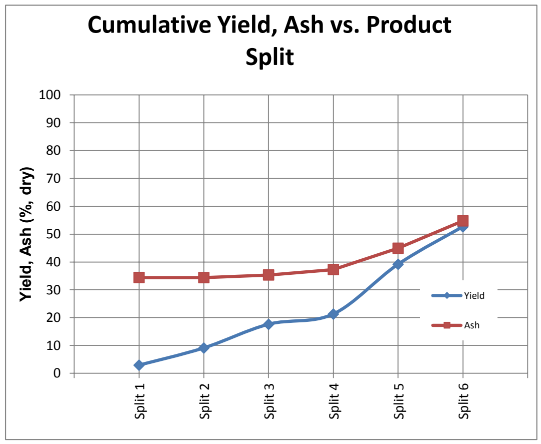
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/16/10 Test - 7

Stream/ Product	Individual Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			57.90	10.46		50.00				
Split 1			22.90	0.29	4.60	32.10	4.60	32.10	100.00	55.63
Split 2			25.00	0.64	10.01	31.80	14.61	31.89	95.40	56.77
Split 3			25.90	0.90	13.97	34.20	28.58	33.02	85.39	59.69
Split 4			51.40	0.45	7.08	46.90	35.65	35.78	71.42	64.68
Split 5			76.30	2.35	36.57	53.90	72.23	44.95	64.35	66.63
Split 6			80.70	1.78	27.77	83.40	100.00	55.63	27.77	83.40
Products			47.39	6.41	100.00	55.63				
-6 mm										
Feed			42.10	7.61		44.20				
Split 1			77.10	0.99	13.95	41.30	13.95	41.30	100.00	46.75
Split 2			75.00	1.93	27.05	42.80	41.00	42.29	86.05	47.63
Split 3			74.10	2.56	36.01	43.90	77.01	43.04	59.00	49.85
Split 4			48.60	0.43	6.03	42.90	83.03	43.03	22.99	59.17
Split 5			23.70	0.73	10.23	58.10	93.27	44.69	16.97	64.95
Split 6			19.30	0.43	5.98	79.60	99.25	46.79	6.73	75.36
Dust			100.00	0.05	0.75	41.50	100.00	46.75	0.75	41.50
Products			52.61	7.12	100.00	46.75				
Total Sample Composite										
Feed	18.92	4.50	100.00	18.07		45.53				
Split 1	1.35	4.70	100.00	1.29	9.52	39.19	9.52	39.19	100.00	50.96
Split 2	2.70	5.00	100.00	2.57	18.97	40.05	28.49	39.76	90.48	52.20
Split 3	3.60	4.00	100.00	3.46	25.56	41.39	54.05	40.53	71.51	55.42
Split 4	0.90	2.00	100.00	0.88	6.52	44.96	60.58	41.01	45.95	63.23
Split 5	3.15	2.50	100.00	3.07	22.72	54.90	83.30	44.80	39.42	66.25
Split 6	2.25	2.00	100.00	2.21	16.31	82.67	99.61	51.00	16.70	81.70
Dust	0.05	1.50	100.00	0.05	0.39	41.50	100.00	50.96	0.39	41.50
Products	14.02	3.46	100.00	13.53	100.00	50.96				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

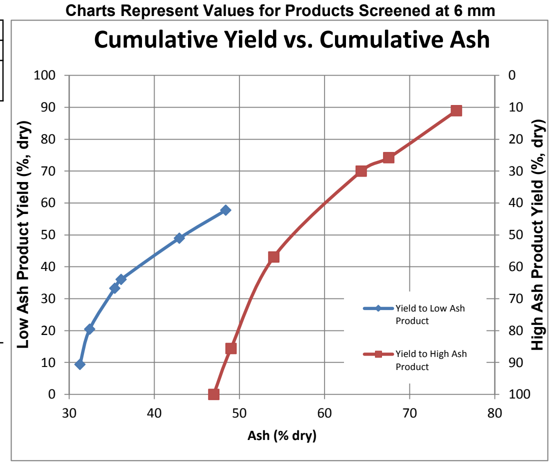
	Low Ash Product Individual Wt (%)	Ash (%)	Low Ash Product Cumulative Wt (%)	Ash (%)	Screen Undersize & Dust Individual Wt (%)	Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Ash (%)	High Ash Product Cumulative Wt (%)	Ash (%)
Split 1	2.91	34.42	2.91	34.42	6.60	41.30	6.60	41.30	100.00	50.96
Split 2	6.17	34.34	9.08	34.36	12.81	42.80	19.41	42.29	90.48	52.20
Split 3	8.52	36.36	17.59	35.33	17.05	43.90	36.46	43.04	71.51	55.42
Split 4	3.67	46.55	21.27	37.27	2.85	42.90	39.31	43.03	45.95	63.23
Split 5	17.87	54.03	39.14	44.92	4.85	58.10	44.16	44.69	39.42	66.25
Split 6	13.48	83.31	52.61	54.75	2.83	79.60	46.99	46.79	16.70	81.70
Dust					0.39	41.50	47.39	46.75		
Products	52.61	54.75			47.39	46.75				

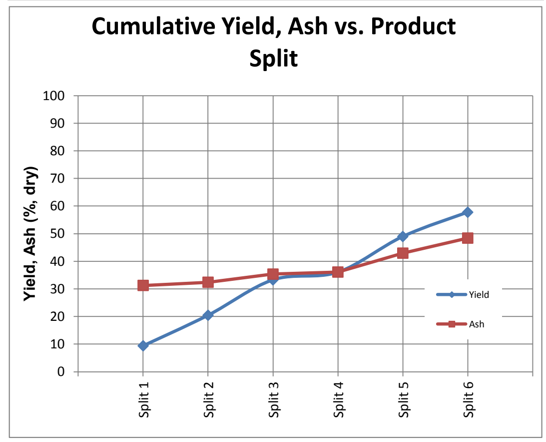
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/16/10 Test - 8

Stream/ Product	Individual						Cumulative			
							Low Ash Product		High Ash Product	
	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			51.00	10.09		54.50				
Split 1			61.50	1.85	16.66	30.60	16.66	30.60	100.00	48.69
Split 2			31.70	1.90	17.12	31.40	33.78	31.01	83.34	52.30
Split 3			41.80	2.35	21.18	39.40	54.96	34.24	66.22	57.70
Split 4			61.90	0.55	4.93	45.10	59.88	35.13	45.04	66.31
Split 5			86.40	2.66	23.94	62.10	83.83	42.84	40.12	68.91
Split 6			81.30	1.79	16.17	79.00	100.00	48.69	16.17	79.00
Products			53.13	11.09	100.00	48.69				
-6 mm										
Feed			49.00	9.70		45.20				
Split 1			38.50	1.16	11.82	41.90	11.82	41.90	100.00	45.08
Split 2			68.30	4.09	41.80	42.60	53.62	42.45	88.18	45.51
Split 3			58.20	3.27	33.42	44.90	87.05	43.39	46.38	48.13
Split 4			38.10	0.34	3.44	43.80	90.48	43.40	12.95	56.48
Split 5			13.60	0.42	4.27	58.30	94.75	44.08	9.52	61.06
Split 6			18.70	0.41	4.22	68.90	98.97	45.13	5.25	63.31
Dust			100.00	0.10	1.03	40.40	100.00	45.08	1.03	40.40
Products			46.87	9.79	100.00	45.08				
Total Sample Composite										
Feed	20.72	4.50	100.00	19.79		50.92				
Split 1	3.15	4.70	100.00	3.00	14.39	34.95	14.39	34.95	100.00	47.00
Split 2	6.31	5.00	100.00	5.99	28.69	39.05	43.08	37.68	85.61	49.02
Split 3	5.86	4.00	100.00	5.62	26.92	42.60	70.00	39.57	56.92	54.05
Split 4	0.90	2.00	100.00	0.88	4.23	44.60	74.23	39.86	30.00	64.32
Split 5	3.15	2.50	100.00	3.07	14.72	61.58	88.95	43.45	25.77	67.56
Split 6	2.25	2.00	100.00	2.21	10.57	77.11	99.52	47.03	11.05	75.51
Dust	0.10	1.50	100.00	0.10	0.48	40.40	100.00	47.00	0.48	40.40
Products	21.72	3.87	100.00	20.88	100.00	47.00				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	9.40	31.27	9.40	31.27	4.99	41.90	4.99	41.90	100.00	47.00
Split 2	11.05	33.39	20.46	32.41	17.64	42.60	22.62	42.45	85.61	49.02
Split 3	12.82	40.07	33.28	35.36	14.10	44.90	36.72	43.39	56.92	54.05
Split 4	2.78	45.02	36.05	36.11	1.45	43.80	38.17	43.40	30.00	64.32
Split 5	12.92	62.04	48.97	42.95	1.80	58.30	39.97	44.08	25.77	67.56
Split 6	8.79	78.77	57.77	48.40	1.78	68.90	41.75	45.13	11.05	75.51
Dust					0.48	40.40	42.23	45.08		
Products	57.77	48.40			42.23	45.08				

India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/18/10 Test - 20

Stream/ Product	Individual						Cumulative			
							Low Ash Product		High Ash Product	
	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
52 X 6mm										
Feed			100.00	19.79		46.50				
Clean Coal			41.98	61.19	42.97	35.10	42.97	35.10	100.00	49.46
Middlings			61.90	52.53	36.88	49.50	79.85	41.75	57.03	60.28
Reject			81.30	28.69	20.15	80.00	100.00	49.46	20.15	80.00
Products			100.00	142.41	100.00	49.46				

India - Deshaler Project - 2010 (TATA WEST BOKARO COAL)
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

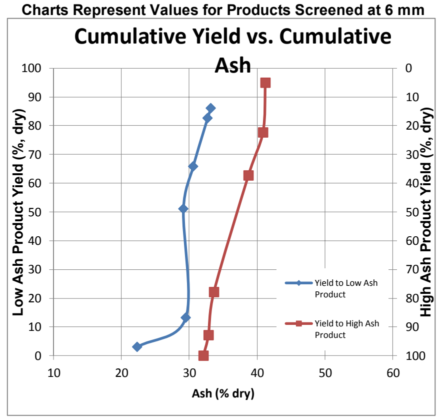
		Coal Source - TATA West Bokaro											
Date -		3/18/10											
Test No. -		1		2		3		4		5		6	
Table Parameters													
Tilt (deg)		8.5		8.5		8.5		8.5		8.5		8.5	
Slope (deg)		1.0		1.0		1		1.5		1.5		1.5	
Fan Speed (Hz)		55		60		60		60		60		55	
able Speed (Hz)		45		45		50		50		45		45	
Feed Rate (kg, AR)		4.83		0.00		0.00		0.00		6.32		4.38	
Feed Rate (kg, dry)		4.62		0.00		0.00		0.00		6.04		4.18	
Total Sample Time (hr:min:sec)		0:12:40		0:05:08		0:06:54		0:11:11		0:08:29		0:08:11	
Sample Data													
Total Dust Collected (k		8.65								6.38		4.35	
Total Wt (k	Feed	20.14								26.34		18.24	
	Split 1	1.09								1.14		0.79	
	Split 2	2.30								3.88		3.49	
	Split 3	6.15								7.73		6.71	
	Split 4	2.22								1.39		0.96	
	Split 5	2.58								1.93		2.48	
	Split 6	0.58								0.50		0.81	
	Dust	0.17		0.00		0.00		0.00		0.19		0.13	
	Products Total	15.08		0.00		0.00		0.00		16.73		15.37	
Total Mois	Feed	4.50		4.60		4.52		4.13		4.50		4.50	
	Split 1	4.70		4.72		6.42		5.14		4.70		4.70	
	Split 2	5.00		7.50		7.24		6.68		5.00		5.00	
	Split 3	4.00		7.04		5.73		4.91		4.00		4.00	
	Split 4	2.00		5.25		1.38		1.43		2.00		2.00	
	Split 5	2.50		3.72		2.40		1.82		2.50		2.50	
	Split 6	2.00		2.39		1.77		1.53		2.00		2.00	
	Dust	1.50		1.34		1.12		1.60		1.50		1.50	
	Products Total	3.55		#DIV/0!		#DIV/0!		#DIV/0!		3.85		3.77	
Wt (kg - dr	Feed	19.23		0.00		0.00		0.00		25.15		17.42	
	Split 1	1.04		0.00		0.00		0.00		1.08		0.75	
	Split 2	2.18		0.00		0.00		0.00		3.68		3.32	
	Split 3	5.90		0.00		0.00		0.00		7.42		6.44	
	Split 4	2.18		0.00		0.00		0.00		1.36		0.94	
	Split 5	2.52		0.00		0.00		0.00		1.88		2.42	
	Split 6	0.57		0.00		0.00		0.00		0.49		0.79	
	Dust	0.17		0.00		0.00		0.00		0.19		0.13	
	Products Total	14.55		0.00		0.00		0.00		16.09		14.79	
By Size Data		+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm	+6 mm	-6 mm
Wt by Size	Feed	85.45	14.55		100.00		100.00		100.00	68.77	31.23	68.2	31.80
	Split 1	36.70	63.30		100.00		100.00		100.00	54.19	45.81	43.04	56.96
	Split 2	64.27	35.73		100.00		100.00		100.00	35.23	64.77	48.14	51.86
	Split 3	92.60	7.40		100.00		100.00		100.00	74.11	25.89	73.10	26.90
	Split 4	98.42	1.58		100.00		100.00		100.00	87.41	12.59	91.15	8.85
	Split 5	96.90	3.10		100.00		100.00		100.00	88.31	11.69	92.34	7.66
	Split 6	87.07	12.93		100.00		100.00		100.00	87.88	12.12	83.85	16.15
	Dust		100.00		100.00		100.00		100.00		100.00		100.00
	Products Total	84.69	15.31	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	66.22	33.78	70.19	29.81
Ash (% dry)	Feed	33.17	24.38							35.08	22.99	33.38	24.00
	Split 1	22.29	22.51							23.55	19.26	47.20	22.35
	Split 2	32.16	22.49							21.87	22.38	23.23	21.76
	Split 3	29.01	28.63							30.55	23.59	27.83	25.58
	Split 4	35.59	32.15							34.84	28.17	31.15	25.98
	Split 5	41.04	32.85							48.63	30.02	51.17	30.26
	Split 6	44.52	44.21							57.68	49.02	59.43	47.95
	Dust		30.29								24.67		23.45
	Products Total	33.31	25.52	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	33.49	23.38	35.04	24.56

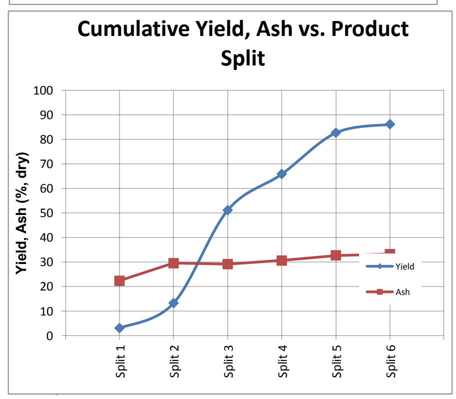
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/18/10 Test - 1

Stream/ Product	Individual: Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative: Low Ash Product Weight (%, dry)	Low Ash Product Ash (%, dry)	High Ash Product Weight (%, dry)	High Ash Product Ash (%, dry)
+6 mm										
Feed			85.45	16.44		33.17				
Split 1			36.70	0.38	3.09	22.29	3.09	22.29	100.00	33.31
Split 2			64.27	1.40	11.37	32.16	14.47	30.05	96.91	33.66
Split 3			92.60	5.46	44.34	29.01	58.81	29.27	85.53	33.86
Split 4			98.42	2.14	17.38	35.59	76.20	30.71	41.19	39.08
Split 5			96.90	2.44	19.79	41.04	95.98	32.84	23.80	41.63
Split 6			87.07	0.49	4.02	44.52	100.00	33.31	4.02	44.52
Products			84.69	12.32	100.00	33.31				
-6 mm										
Feed			14.55	2.80		24.38				
Split 1			63.30	0.66	29.52	22.51	29.52	22.51	100.00	25.52
Split 2			35.73	0.78	34.98	22.49	64.50	22.50	70.48	26.78
Split 3			7.40	0.44	19.60	28.63	84.10	23.93	35.50	31.00
Split 4			1.58	0.03	1.54	32.15	85.65	24.08	15.90	33.92
Split 5			3.10	0.08	3.50	32.85	89.15	24.42	14.35	34.12
Split 6			12.93	0.07	3.30	44.21	92.45	25.13	10.85	34.52
Dust			100.00	0.17	7.55	30.29	100.00	25.52	7.55	30.29
Products			15.31	2.23	100.00	25.52				
Total Sample Composite										
Feed	20.14	4.50	100.00	19.23		27.61				
Split 1	1.09	4.70	100.00	1.04	7.14	22.43	7.14	22.43	100.00	32.11
Split 2	2.30	5.00	100.00	2.18	14.99	28.70	22.13	26.68	92.86	32.86
Split 3	6.15	4.00	100.00	5.90	40.56	28.98	62.69	28.17	77.87	33.66
Split 4	2.22	2.00	100.00	2.18	14.96	35.54	77.64	29.59	37.31	38.74
Split 5	2.58	2.50	100.00	2.52	17.29	40.79	94.94	31.63	22.36	40.89
Split 6	0.58	2.00	100.00	0.57	3.91	44.48	98.84	32.14	5.06	41.24
Dust	0.17	1.50	100.00	0.17	1.16	30.29	100.00	32.11	1.16	30.29
Products	15.08	3.55	100.00	14.55	100.00	32.11				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

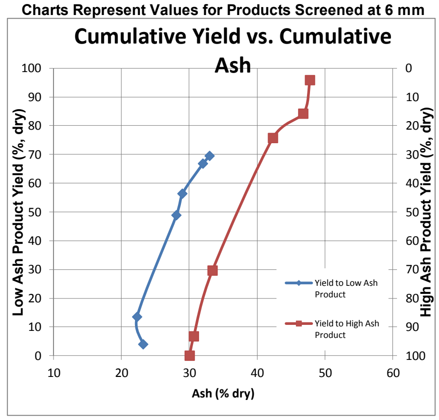
	Low Ash Product Individual Wt (%)	Ash (%)	Low Ash Product Cumulative Wt (%)	Ash (%)	Screen Undersize & Dust Individual Wt (%)	Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Ash (%)	High Ash Product Cumulative Wt (%)	Ash (%)
Split 1	3.07	22.32	3.07	22.32	4.07	22.51	4.07	22.51	100.00	32.11
Split 2	10.17	31.65	13.24	29.49	4.82	22.49	8.89	22.50	92.86	32.86
Split 3	37.85	29.01	51.10	29.13	2.70	28.63	11.59	23.93	77.87	33.66
Split 4	14.74	35.58	65.84	30.58	0.21	32.15	11.80	24.08	37.31	38.74
Split 5	16.81	41.01	82.65	32.70	0.48	32.85	12.28	24.42	22.36	40.89
Split 6	3.45	44.52	86.10	33.17	0.45	44.21	12.74	25.13	5.06	41.24
Dust					1.16	30.29	13.90	25.56		
Products	86.10	33.17			13.90	25.56				

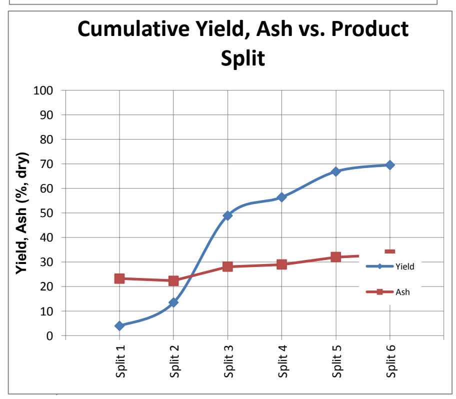
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/18/10 Test - 5

Stream/ Product	Individual Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Cumulative Low Ash Product Weight (%, dry)	Ash (%, dry)	Cumulative High Ash Product Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			68.77	17.30		35.08				
Split 1			54.19	0.59	5.50	23.55	5.50	23.55	100.00	33.49
Split 2			35.23	1.30	12.17	21.87	17.68	22.39	94.50	34.06
Split 3			74.11	5.50	51.59	30.55	69.26	28.47	82.32	35.87
Split 4			87.41	1.19	11.18	34.84	80.44	29.35	30.74	44.79
Split 5			88.31	1.66	15.56	48.63	96.00	32.48	19.56	50.48
Split 6			87.88	0.43	4.00	57.68	100.00	33.49	4.00	57.68
Products			66.22	10.65	100.00	33.49				
-6 mm										
Feed			31.23	7.86		22.99				
Split 1			45.81	0.50	9.12	19.26	9.12	19.26	100.00	23.38
Split 2			64.77	2.38	43.87	22.38	52.99	21.84	90.88	23.79
Split 3			25.89	1.92	35.33	23.59	88.32	22.54	47.01	25.11
Split 4			12.59	0.17	3.16	28.17	91.47	22.74	11.68	29.72
Split 5			11.69	0.22	4.04	30.02	95.51	23.04	8.53	30.29
Split 6			12.12	0.06	1.08	49.02	96.59	23.33	4.49	30.54
Dust			100.00	0.19	3.41	24.67	100.00	23.38	3.41	24.67
Products			33.78	5.43	100.00	23.38				
Total Sample Composite										
Feed	26.34	4.50	100.00	25.15		29.54				
Split 1	1.14	4.70	100.00	1.08	6.72	21.58	6.72	21.58	100.00	30.07
Split 2	3.88	5.00	100.00	3.68	22.88	22.20	29.60	22.06	93.28	30.68
Split 3	7.73	4.00	100.00	7.42	46.10	28.75	75.70	26.13	70.40	33.44
Split 4	1.39	2.00	100.00	1.36	8.47	34.00	84.17	26.92	24.30	42.35
Split 5	1.93	2.50	100.00	1.88	11.67	46.45	95.83	29.30	15.83	46.81
Split 6	0.50	2.00	100.00	0.49	3.02	56.63	98.85	30.14	4.17	47.80
Dust	0.19	1.50	100.00	0.19	1.15	24.67	100.00	30.07	1.15	24.67
Products	16.73	3.85	100.00	16.09	100.00	30.07				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

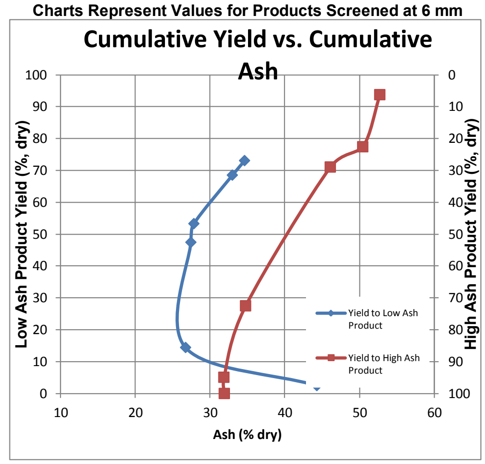
	Low Ash Product Individual Wt (%)	Ash (%)	Low Ash Product Cumulative Wt (%)	Ash (%)	Screen Undersize & Dust Individual Wt (%)	Ash (%)	Screen Undersize & Dust Cumulative Wt (%)	Ash (%)	High Ash Product Cumulative Wt (%)	Ash (%)
Split 1	3.95	23.22	3.95	23.22	2.77	19.26	2.77	19.26	100.00	30.07
Split 2	9.54	21.95	13.49	22.32	13.34	22.38	16.11	21.84	93.28	30.68
Split 3	35.35	30.32	48.85	28.11	10.74	23.59	26.85	22.54	70.40	33.44
Split 4	7.51	34.75	56.36	28.99	0.96	28.17	27.81	22.74	24.30	42.35
Split 5	10.44	48.39	66.80	32.02	1.23	30.02	29.04	23.04	15.83	46.81
Split 6	2.69	57.56	69.48	33.01	0.33	49.02	29.37	23.33	4.17	47.80
Dust					1.15	24.67	30.52	23.39		
Products	69.48	33.01			30.52	23.39				

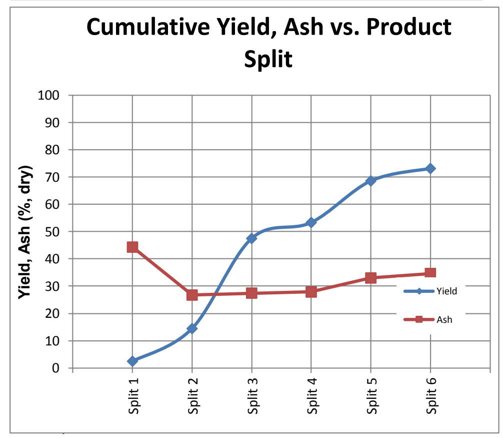
India - Deshaler Project - 2010
Site - CCL Kargali Washery
Location - Kargali, Bokaro, Jharkhand

Date 3/18/10 Test - 6

	Individual						Cumulative			
							Low Ash Product		High Ash Product	
Stream/ Product	Weight (kg, AR)	Total Moisture (%)	Weight (% of Sample)	Weight (kg, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)	Weight (%, dry)	Ash (%, dry)
+6 mm										
Feed			68.20	11.88		33.38				
Split 1			43.04	0.32	3.12	47.20	3.12	47.20	100.00	35.04
Split 2			48.14	1.60	15.38	23.23	18.50	27.28	96.88	34.64
Split 3			73.10	4.71	45.36	27.83	63.86	27.67	81.50	36.80
Split 4			91.15	0.86	8.26	31.15	72.12	28.07	36.14	48.05
Split 5			92.34	2.23	21.51	51.17	93.63	33.38	27.88	53.06
Split 6			83.85	0.66	6.37	59.43	100.00	35.04	6.37	59.43
Products			70.19	10.38	100.00	35.04				
-6 mm										
Feed			31.80	5.54		24.00				
Split 1			56.96	0.43	9.73	22.35	9.73	22.35	100.00	24.56
Split 2			51.86	1.72	39.01	21.76	48.74	21.88	90.27	24.80
Split 3			26.90	1.73	39.31	25.58	88.05	23.53	51.26	27.12
Split 4			8.85	0.08	1.89	25.98	89.94	23.58	11.95	32.17
Split 5			7.66	0.19	4.20	30.26	94.14	23.88	10.06	33.33
Split 6			16.15	0.13	2.89	47.95	97.03	24.60	5.86	35.53
Dust			100.00	0.13	2.97	23.45	100.00	24.56	2.97	23.45
Products			29.81	4.41	100.00	24.56				
Total Sample Composite										
Feed	18.24	4.50	100.00	17.42		28.04				
Split 1	0.79	4.70	100.00	0.75	5.09	33.05	5.09	33.05	100.00	31.91
Split 2	3.49	5.00	100.00	3.32	22.42	22.47	27.51	24.43	94.91	31.85
Split 3	6.71	4.00	100.00	6.44	43.56	27.22	71.07	26.14	72.49	34.76
Split 4	0.96	2.00	100.00	0.94	6.36	30.69	77.43	26.51	28.93	46.10
Split 5	2.48	2.50	100.00	2.42	16.35	49.57	93.78	30.53	22.57	50.44
Split 6	0.81	2.00	100.00	0.79	5.33	57.58	99.11	31.99	6.22	52.72
Dust	0.13	1.50	100.00	0.13	0.89	23.45	100.00	31.91	0.89	23.45
Products	15.37	3.77	100.00	14.79	100.00	31.91				

Charts Represent Values for Products Screened at 6 mm





Low Ash Product - Based on dry screening product at 6 mm and at 90.00 % efficiency

Note - Split 6 and Dust samples combined for first High Ash Product point

	Low Ash Product				Screen Undersize & Dust				High Ash Product	
	Individual		Cumulative		Individual		Cumulative		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)	Wt (%)	Ash (%)
Split 1	2.48	44.30	2.48	44.30	2.61	22.35	2.61	22.35	100.00	31.91
Split 2	11.96	23.09	14.44	26.73	10.46	21.76	13.07	21.88	94.91	31.85
Split 3	33.01	27.75	47.45	27.44	10.55	25.58	23.62	23.53	72.49	34.76
Split 4	5.85	31.10	53.30	27.84	0.51	25.98	24.13	23.58	28.93	46.10
Split 5	15.22	51.00	68.53	32.99	1.13	30.26	25.25	23.88	22.57	50.44
Split 6	4.56	59.21	73.09	34.62	0.78	47.95	26.03	24.60	6.22	52.72
Dust					0.89	23.45	26.91	24.56		
Products	73.09	34.62			26.91	24.56				

APPENDIX C:
PFC^{3D} simulation codes

```
;==============================================================================
;                          VARIATION IN FORCES
; Force of buoyancy and drag force were calculated and the constant value incorporated in the model for each case
;                    CASE 1: All Forces Incorporated
;==============================================================================
new

Set random

set grav 0 0 -10

def make_walls  ; create walls: a cylinder and top plate

  extend = 0.02

  rad_cy = 0.25*width

  w_stiff= 2.25e7

  _z0 = -extend

  _z1 = height*(1.0 + extend)

  command

    wall type cylinder id=1 kn=w_stiff end1 0.0 0.0 -2.0 end2 0.0 0.0 _z1 & rad rad_cy rad_cy

  end_command

 ; _x0 = -rad_cy*(1.0 + extend)

  ;_y0 = -rad_cy*(1.0 + extend)

  ;_z0 = -1.0

  ;_x1 =  rad_cy*(1.0 + extend)

  ;_y1 = -rad_cy*(1.0 + extend)

  ;_z1 = -1.0

  ;_x2 =  rad_cy*(1.0 + extend)

  ;_y2 =  rad_cy*(1.0 + extend)

  ;_z2 = -1.0

  ;_x3 = -rad_cy*(1.0 + extend)

  ;_y3 =  rad_cy*(1.0 + extend)

  ;_z3 = -1.0

  ;command

   ; wall id=5 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &

    ; (_x3,_y3,_z3)

 ;end_command
```

```
  _x0 = -rad_cy*(1.0 + extend)
  _y0 = -rad_cy*(1.0 + extend)
  _z0 = height
  _x1 = -rad_cy*(1.0 + extend)
  _y1 =  rad_cy*(1.0 + extend)
  _z1 = height
  _x2 =  rad_cy*(1.0 + extend)
  _y2 =  rad_cy*(1.0 + extend)
  _z2 = height
  _x3 =  rad_cy*(1.0 + extend)
  _y3 = -rad_cy*(1.0 + extend)
  _z3 = height
  command
    wall id=6 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
     (_x3,_y3,_z3)
  end_command
end
def particle_create
 max_r=0.025
 min_r=0.01
 dens_C1=1200
 dens_C2=1500
 dens_M=1800
 dens_R=2400
 Start_idC1=1
 End_idC1=500
 Start_idC2=501
 End_idC2=600
 start_idM=601
 End_idM=700
 start_idR=701
 End_idR=1200
```

```
 command
  gen id=Start_idC1,End_idC1 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal1_particles range id Start_idC1,End_idC1
  prop dens=dens_C1 ks=1e6 kn=1e6 range group coal1_particles
    prop zforce=0.47 range group coal1_particles
  ;ini rad mul 1.2 range group coal1_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal1_particles

  gen id=Start_idC2,End_idC2 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal2_particles range id Start_idC2,End_idC2
  prop dens=dens_C2 ks=1e6 kn=1e6 range group coal2_particles
    prop zforce=0.3 range group coal2_particles
  ;ini rad mul 1.2 range group coal2_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal2_particles

  gen id=start_idM,End_idM rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group middlings_particles range id Start_idM,End_idM
  prop dens=dens_M ks=1e6 kn=1e6 range group middlings_particles
  prop zforce= - 0.17 range group middlings_particles
  ;ini rad mul 1.2 range group middlings_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group middlings_particles

  gen id=start_idR,End_idR rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group rock_particles range id start_idR,End_idR
  prop dens=dens_R ks=1e6 kn=1e6 range group rock_particles
  prop zforce=-0.62 range group rock_particles
  ;ini rad mul 1.2 range group rock_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group rock_particles
 end_command
end
def ff_cylinder
  ff_cylinder = 0
```

```
  _brad = fc_arg(0)
  _bx   = fc_arg(1)
  _by   = fc_arg(2)
  _bz   = fc_arg(3)
  _rad  = sqrt(_bx^2 + _by^2)
  if _rad + _brad > rad_cy then
    ff_cylinder = 1
  end_if
end
SET height=3.0 width=2.0
make_walls
particle_create
plot set cap size 25
plot set mag 1.5
;plot set rot 30 0 40
plot add group lorange yellow green lblue brown black
plot add wall white
plot add axes red
plot show
; ----- Create the ground
def make_ground
_bid = 5000
_xnum = (balls_per_beam + num_layers + 1)*num_bays_front
_xnum2 = 1.0*_xnum
_y = _yorigin - _xnum*core_radius + core_radius
_z = origin_z - core_radius
loop depth (1,_xnum2)
_x = _xorigin - _xnum*core_radius + core_radius
loop row (1,_xnum2)
command
ball id=_bid x=_x y=_y z=_z rad=core_radius
end_command
```

```
_x = _x + 1.7*core_radius
_bid = _bid + 1
end_loop
_y = _y + 1.7*core_radius
end_loop
Command
group base_particle range id 5000, _bid
prop kn 1e8 ks 1e8 dens 4000 range group base_particle
prop pb_rad=0.04 pb_kn=1e4 pb_ks=1e4 pb_nstren=1e2 pb_sstren=1e2 range group base_particle
fix x y z xspin yspin zspin range group base_particle
End_command
end
DEF variables
origin_x=0.0
origin_y=0.0
origin_z=0.0
core_radius=0.08
num_layers=2
num_bays_front=4
num_bays_depth=1
balls_per_beam=4
num_floors=4
balls_per_col=8
END
variables
make_ground
plot creat structure
plot add cforce black
plot add ball lorange
plot add pbond black
; ----- Install material properties
fix x y z xspin yspin zspin range group base_particle
```

```
set grav 0 0 -10
damp default local 0.0
damp default viscous normal 0.07
;damp default shear normal 0.7
def startup
old_time = time
omega = freq * 2.0 * pi
end
; ----- Apply sinusoidal motion to base of structure
def shake_it
while_stepping
real_time = time - old_time
if real_time < length
ground_vel = ampl * sin(omega*real_time)
else
ground_vel = ampl * sin(omega*real_time)
end_if
command
prop zvel= ground_vel range group base_particle
end_command
end
prop damp=0.0
set time=0.0 freq=17.25 ampl=0.5 length=0.0
startup
set pinterval 100
;plot creat R_Time
;set hist_rep=100
;history id=25 ground_vel
;history id=30 real_time
;plot history 25 vs 30 white
Cycle 800000
;Def _z_position
```

```
;n_count=100
;loop n (1,n_count)
;Sum_zC=0.0
;sum_zR=0.0
;count1= n + 1000
;count2= n + 2000
;bp = ball_head
;loop while bp # null
;if b_id(bp) <= end_idC then
;sum_zc=sum_zc + b_z(bp)
;else
;if b_id(bp) >= start_idR then
;sum_zR=sum_zR + b_z(bp)
;end_if
;end_if
;bp = b_next(bp)
;end_loop
;Cent_zC = sum_zC/(End_idC - Start_idc + 1)
;Cent_zR = sum_zR/(End_idR - start_idR + 1)
;Command
;history id=count1 Cent_zC ;History 1
;history id=count2 Cent_zR ;History 2
;plot add hist count1 count2 25 vs 30 black blue white
cyc 500000
;End_command
;end_loop
;END
;_z_position
Set log on
set logfile R17_Force1_1
print balls position
;print balls velocity
```

```
print balls property
cycle 500000
set logfile R17_Force1_2
print balls position
print balls velocity
save Force1_final_1.sav
cycle 500000
set logfile R17_Force1_3
print balls position
print balls velocity
save Force1_final_2.sav
cycle 500000
set logfile R17_Force1_4
print balls position
print balls velocity
save Force1_final_3.sav
cycle 500000
set logfile R17_Force1_5
print balls position
print balls velocity
save Force1_final_4.sav
;===============================================================================
;                                   VARIATION IN FORCES
; Force of buoyancy and drag force were calculated and the constant value incorporated in the model for each case
;                              CASE 2: Buoyancy and Gravity Forces only
;===============================================================================
new
Set random
set grav 0 0 -10
def make_walls  ; create walls: a cylinder and top plate
  extend = 0.02
  rad_cy = 0.25*width
  w_stiff= 2.25e7
```

```
 _z0 = -extend
 _z1 = height*(1.0 + extend)
 command
   wall type cylinder id=1 kn=w_stiff end1 0.0 0.0 -2.0 end2 0.0 0.0 _z1 & rad rad_cy rad_cy
 end_command
; _x0 = -rad_cy*(1.0 + extend)
 ;_y0 = -rad_cy*(1.0 + extend)
 ;_z0 = -1.0
 ;_x1 =  rad_cy*(1.0 + extend)
 ;_y1 = -rad_cy*(1.0 + extend)
 ;_z1 = -1.0
 ;_x2 =  rad_cy*(1.0 + extend)
 ;_y2 =  rad_cy*(1.0 + extend)
 ;_z2 = -1.0
 ;_x3 = -rad_cy*(1.0 + extend)
 ;_y3 =  rad_cy*(1.0 + extend)
 ;_z3 = -1.0
 ;command
  ; wall id=5 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
   ; (_x3,_y3,_z3)
;end_command
 _x0 = -rad_cy*(1.0 + extend)
 _y0 = -rad_cy*(1.0 + extend)
 _z0 = height
 _x1 = -rad_cy*(1.0 + extend)
 _y1 =  rad_cy*(1.0 + extend)
 _z1 = height
 _x2 =  rad_cy*(1.0 + extend)
 _y2 =  rad_cy*(1.0 + extend)
 _z2 = height
 _x3 =  rad_cy*(1.0 + extend)
 _y3 = -rad_cy*(1.0 + extend)
```

```
  _z3 = height
  command
    wall id=6 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
    (_x3,_y3,_z3)
  end_command
end
def particle_create
 max_r=0.025
 min_r=0.01
 dens_C1=1200
 dens_C2=1500
 dens_M=1800
 dens_R=2400
 Start_idC1=1
 End_idC1=500
 Start_idC2=501
 End_idC2=600
 start_idM=601
 End_idM=700
 start_idR=701
 End_idR=1200
 command
  gen id=Start_idC1,End_idC1 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal1_particles range id Start_idC1,End_idC1
  prop dens=dens_C1 ks=1e6 kn=1e6 range group coal1_particles
    prop zforce=0.38 range group coal1_particles
  ;ini rad mul 1.2 range group coal1_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal1_particles

  gen id=Start_idC2,End_idC2 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal2_particles range id Start_idC2,End_idC2
  prop dens=dens_C2 ks=1e6 kn=1e6 range group coal2_particles
```

```
    prop zforce=0.18 range group coal2_particles
  ;ini rad mul 1.2 range group coal2_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal2_particles

  gen id=start_idM,End_idM rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group middlings_particles range id Start_idM,End_idM
  prop dens=dens_M ks=1e6 kn=1e6 range group middlings_particles
  prop zforce= - 0.02 range group middlings_particles
  ;ini rad mul 1.2 range group middlings_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group middlings_particles

  gen id=start_idR,End_idR rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group rock_particles range id start_idR,End_idR
  prop dens=dens_R ks=1e6 kn=1e6 range group rock_particles
  prop zforce=-0.41 range group rock_particles
  ;ini rad mul 1.2 range group rock_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group rock_particles
 end_command
end
def ff_cylinder
  ff_cylinder = 0
  _brad = fc_arg(0)
  _bx   = fc_arg(1)
  _by   = fc_arg(2)
  _bz   = fc_arg(3)
  _rad  = sqrt(_bx^2 + _by^2)
  if _rad + _brad > rad_cy then
    ff_cylinder = 1
  end_if
end
SET height=3.0 width=2.0
make_walls
```

```
particle_create
plot set cap size 25
plot set mag 1.5
;plot set rot 30 0 40
plot add group lorange yellow green lblue brown black
plot add wall white
plot add axes red
plot show
; ----- Create the ground
def make_ground
_bid = 5000
_xnum = (balls_per_beam + num_layers + 1)*num_bays_front
_xnum2 = 1.0*_xnum
_y = _yorigin - _xnum*core_radius + core_radius
_z = origin_z - core_radius
loop depth (1,_xnum2)
_x = _xorigin - _xnum*core_radius + core_radius
loop row (1,_xnum2)
command
ball id=_bid x=_x y=_y z=_z rad=core_radius
end_command
_x = _x + 1.7*core_radius
_bid = _bid + 1
end_loop
_y = _y + 1.7*core_radius
end_loop
Command
group base_particle range id 5000, _bid
prop kn 1e8 ks 1e8 dens 4000 range group base_particle
prop pb_rad=0.04 pb_kn=1e4 pb_ks=1e4 pb_nstren=1e2 pb_sstren=1e2 range group base_particle
fix x y z xspin yspin zspin range group base_particle
End_command
```

```
end
DEF variables
origin_x=0.0
origin_y=0.0
origin_z=0.0
core_radius=0.08
num_layers=2
num_bays_front=4
num_bays_depth=1
balls_per_beam=4
num_floors=4
balls_per_col=8
END
variables
make_ground
plot creat structure
plot add cforce black
plot add ball lorange
plot add pbond black
; ----- Install material properties
fix x y z xspin yspin zspin range group base_particle
set grav 0 0 -10
damp default local 0.0
damp default viscous normal 0.07
;damp default shear normal 0.7
def startup
old_time = time
omega = freq * 2.0 * pi
end
; ----- Apply sinusoidal motion to base of structure
def shake_it
while_stepping
```

```
real_time = time - old_time
if real_time < length
ground_vel = ampl * sin(omega*real_time)
else
ground_vel = ampl * sin(omega*real_time)
end_if
command
prop zvel= ground_vel range group base_particle
end_command
end
prop damp=0.0
set time=0.0 freq=17.25 ampl=0.5 length=0.0
startup
set pinterval 100
;plot creat R_Time
;set hist_rep=100
;history id=25 ground_vel
;history id=30 real_time
;plot history 25 vs 30 white
Cycle 800000
;Def _z_position
;n_count=100
;loop n (1,n_count)
;Sum_zC=0.0
;sum_zR=0.0
;count1= n + 1000
;count2= n + 2000
;bp = ball_head
;loop while bp # null
;if b_id(bp) <= end_idC then
;sum_zc=sum_zc + b_z(bp)
;else
```

```
;if b_id(bp) >= start_idR then
;sum_zR=sum_zR + b_z(bp)
;end_if
;end_if
;bp = b_next(bp)
;end_loop
;Cent_zC = sum_zC/(End_idC - Start_idc + 1)
;Cent_zR = sum_zR/(End_idR - start_idR + 1)
;Command
;history id=count1 Cent_zC ;History 1
;history id=count2 Cent_zR ;History 2
;plot add hist count1 count2 25 vs 30 black blue white
cyc 500000
;End_command
;end_loop
;END
;_z_position
Set log on
set logfile R17_Force2_1
print balls position
;print balls velocity
print balls property
cycle 500000
set logfile R17_Force2_2
print balls position
print balls velocity
save Force2_final_1.sav
cycle 500000
set logfile R17_Force2_3
print balls position
print balls velocity
save Force2_final_2.sav
```

```
cycle 500000

set logfile R17_Force2_4

print balls position

print balls velocity

save Force2_final_3.sav

cycle 500000

set logfile R17_Force2_5

print balls position

print balls velocity

save Force2_final_4.sav
;==============================================================================
;                                VARIATION IN FORCES
; Force of buoyancy and drag force were calculated and the constant value incorporated in the model for each case
;                          CASE 3: Drag and Gravity forces only
;==============================================================================
new

Set random

set grav 0 0 -10

def make_walls  ; create walls: a cylinder and top plate

  extend = 0.02

  rad_cy = 0.25*width

  w_stiff= 2.25e7

  _z0 = -extend

  _z1 = height*(1.0 + extend)

  command

    wall type cylinder id=1 kn=w_stiff end1 0.0 0.0 -2.0 end2 0.0 0.0 _z1 & rad rad_cy rad_cy

  end_command

 ; _x0 = -rad_cy*(1.0 + extend)

  ;_y0 = -rad_cy*(1.0 + extend)

  ;_z0 = -1.0

  ;_x1 =  rad_cy*(1.0 + extend)

  ;_y1 = -rad_cy*(1.0 + extend)

  ;_z1 = -1.0
```

```
 ;_x2 =  rad_cy*(1.0 + extend)
 ;_y2 =  rad_cy*(1.0 + extend)
 ;_z2 = -1.0
 ;_x3 = -rad_cy*(1.0 + extend)
 ;_y3 =  rad_cy*(1.0 + extend)
 ;_z3 = -1.0
 ;command
  ; wall id=5 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
   ; (_x3,_y3,_z3)
 ;end_command
 _x0 = -rad_cy*(1.0 + extend)
 _y0 = -rad_cy*(1.0 + extend)
 _z0 = height
 _x1 = -rad_cy*(1.0 + extend)
 _y1 =  rad_cy*(1.0 + extend)
 _z1 = height
 _x2 =  rad_cy*(1.0 + extend)
 _y2 =  rad_cy*(1.0 + extend)
 _z2 = height
 _x3 =  rad_cy*(1.0 + extend)
 _y3 = -rad_cy*(1.0 + extend)
 _z3 = height
 command
   wall id=6 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
    (_x3,_y3,_z3)
 end_command
end
def particle_create
 max_r=0.025
 min_r=0.01
 dens_C1=1200
 dens_C2=1500
```

```
dens_M=1800
dens_R=2400
Start_idC1=1
End_idC1=500
Start_idC2=501
End_idC2=600
start_idM=601
End_idM=700
start_idR=701
End_idR=1200
command
 gen id=Start_idC1,End_idC1 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group coal1_particles range id Start_idC1,End_idC1
 prop dens=dens_C1 ks=1e6 kn=1e6 range group coal1_particles
   prop zforce=0.09 range group coal1_particles
 ;ini rad mul 1.2 range group coal1_particles
 prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal1_particles
 gen id=Start_idC2,End_idC2 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group coal2_particles range id Start_idC2,End_idC2
 prop dens=dens_C2 ks=1e6 kn=1e6 range group coal2_particles
   prop zforce=0.12 range group coal2_particles
 ;ini rad mul 1.2 range group coal2_particles
 prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal2_particles
 gen id=start_idM,End_idM rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group middlings_particles range id Start_idM,End_idM
 prop dens=dens_M ks=1e6 kn=1e6 range group middlings_particles
 prop zforce= - 0.15 range group middlings_particles
 ;ini rad mul 1.2 range group middlings_particles
 prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group middlings_particles
 gen id=start_idR,End_idR rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group rock_particles range id start_idR,End_idR
 prop dens=dens_R ks=1e6 kn=1e6 range group rock_particles
```

```
  prop zforce=-0.22 range group rock_particles
  ;ini rad mul 1.2 range group rock_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group rock_particles
 end_command
end
def ff_cylinder
  ff_cylinder = 0
  _brad = fc_arg(0)
  _bx   = fc_arg(1)
  _by   = fc_arg(2)
  _bz   = fc_arg(3)
  _rad  = sqrt(_bx^2 + _by^2)
  if _rad + _brad > rad_cy then
    ff_cylinder = 1
  end_if
end
SET height=3.0 width=2.0
make_walls
particle_create
plot set cap size 25
plot set mag 1.5
;plot set rot 30 0 40
plot add group lorange yellow green lblue brown black
plot add wall white
plot add axes red
plot show
; ----- Create the ground
def make_ground
_bid = 5000
_xnum = (balls_per_beam + num_layers + 1)*num_bays_front
_xnum2 = 1.0*_xnum
_y = _yorigin - _xnum*core_radius + core_radius
```

```
_z = origin_z - core_radius
loop depth (1,_xnum2)
_x = _xorigin - _xnum*core_radius + core_radius
loop row (1,_xnum2)
command
ball id=_bid x=_x y=_y z=_z rad=core_radius
end_command
_x = _x + 1.7*core_radius
_bid = _bid + 1
end_loop
_y = _y + 1.7*core_radius
end_loop
Command
group base_particle range id 5000, _bid
prop kn 1e8 ks 1e8 dens 4000 range group base_particle
prop pb_rad=0.04 pb_kn=1e4 pb_ks=1e4 pb_nstren=1e2 pb_sstren=1e2 range group base_particle
fix x y z xspin yspin zspin range group base_particle
End_command
end
DEF variables
origin_x=0.0
origin_y=0.0
origin_z=0.0
core_radius=0.08
num_layers=2
num_bays_front=4
num_bays_depth=1
balls_per_beam=4
num_floors=4
balls_per_col=8
END
variables
```

```
make_ground
plot creat structure
plot add cforce black
plot add ball lorange
plot add pbond black
; ----- Install material properties
fix x y z xspin yspin zspin range group base_particle
set grav 0 0 -10
damp default local 0.0
damp default viscous normal 0.07
;damp default shear normal 0.7
def startup
old_time = time
omega = freq * 2.0 * pi
end
; ----- Apply sinusoidal motion to base of structure
def shake_it
while_stepping
real_time = time - old_time
if real_time < length
ground_vel = ampl * sin(omega*real_time)
else
ground_vel = ampl * sin(omega*real_time)
end_if
command
prop zvel= ground_vel range group base_particle
end_command
end
prop damp=0.0
set time=0.0 freq=17.25 ampl=0.5 length=0.0
startup
set pinterval 100
```

```
;plot creat R_Time
;set hist_rep=100
;history id=25 ground_vel
;history id=30 real_time
;plot history 25 vs 30 white
Cycle 800000
;Def _z_position
;n_count=100
;loop n (1,n_count)
;Sum_zC=0.0
;sum_zR=0.0
;count1= n + 1000
;count2= n + 2000
;bp = ball_head
;loop while bp # null
;if b_id(bp) <= end_idC then
;sum_zc=sum_zc + b_z(bp)
;else
;if b_id(bp) >= start_idR then
;sum_zR=sum_zR + b_z(bp)
;end_if
;end_if
;bp = b_next(bp)
;end_loop
;Cent_zC = sum_zC/(End_idC - Start_idc + 1)
;Cent_zR = sum_zR/(End_idR - start_idR + 1)
;Command
;history id=count1 Cent_zC ;History 1
;history id=count2 Cent_zR ;History 2
;plot add hist count1 count2 25 vs 30 black blue white
cyc 500000
;End_command
```

```
;end_loop
;END
;_z_position
Set log on
set logfile R17_Force3_1
print balls position
;print balls velocity
print balls property
cycle 500000
set logfile R17_Force3_2
print balls position
print balls velocity
save Force3_final_1.sav
cycle 500000
set logfile R17_Force3_3
print balls position
print balls velocity
save Force3_final_2.sav
cycle 500000
set logfile R17_Force3_4
print balls position
print balls velocity
save Force3_final_3.sav
cycle 500000
set logfile R17_Force3_5
print balls position
print balls velocity
save Force3_final_4.sav
;==========================================================================================
;                                   VARIATION IN FORCES
; Force of buoyancy and drag force were calculated and the constant value incorporated in the model for each case
;                                CASE 4: Only Gravity force included
;==========================================================================================
```

```
new
Set random
set grav 0 0 -10
def make_walls  ; create walls: a cylinder and top plate
  extend = 0.02
  rad_cy = 0.25*width
  w_stiff= 2.25e7
  _z0 = -extend
  _z1 = height*(1.0 + extend)
  command
    wall type cylinder id=1 kn=w_stiff end1 0.0 0.0 -2.0 end2 0.0 0.0 _z1 & rad rad_cy rad_cy
  end_command
 ; _x0 = -rad_cy*(1.0 + extend)
  ;_y0 = -rad_cy*(1.0 + extend)
  ;_z0 = -1.0
  ;_x1 =  rad_cy*(1.0 + extend)
  ;_y1 = -rad_cy*(1.0 + extend)
  ;_z1 = -1.0
  ;_x2 =  rad_cy*(1.0 + extend)
  ;_y2 =  rad_cy*(1.0 + extend)
  ;_z2 = -1.0
  ;_x3 = -rad_cy*(1.0 + extend)
  ;_y3 =  rad_cy*(1.0 + extend)
  ;_z3 = -1.0
  ;command
   ; wall id=5 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
    ; (_x3,_y3,_z3)
 ;end_command
  _x0 = -rad_cy*(1.0 + extend)
  _y0 = -rad_cy*(1.0 + extend)
  _z0 = height
  _x1 = -rad_cy*(1.0 + extend)
```

```
  _y1 =  rad_cy*(1.0 + extend)
  _z1 = height
  _x2 =  rad_cy*(1.0 + extend)
  _y2 =  rad_cy*(1.0 + extend)
  _z2 = height
  _x3 =  rad_cy*(1.0 + extend)
  _y3 = -rad_cy*(1.0 + extend)
  _z3 = height
  command
    wall id=6 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
     (_x3,_y3,_z3)
  end_command
end
def particle_create
 max_r=0.025
 min_r=0.01
 dens_C1=1200
 dens_C2=1500
 dens_M=1800
 dens_R=2400
 Start_idC1=1
 End_idC1=500
 Start_idC2=501
 End_idC2=600
 start_idM=601
 End_idM=700
 start_idR=701
 End_idR=1200
 command
  gen id=Start_idC1,End_idC1 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal1_particles range id Start_idC1,End_idC1
  prop dens=dens_C1 ks=1e6 kn=1e6 range group coal1_particles
```

```
  ;  prop zforce=0.47 range group coal1_particles
  ;ini rad mul 1.2 range group coal1_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal1_particles

  gen id=Start_idC2,End_idC2 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal2_particles range id Start_idC2,End_idC2
  prop dens=dens_C2 ks=1e6 kn=1e6 range group coal2_particles
 ;   prop zforce=0.3 range group coal2_particles
  ;ini rad mul 1.2 range group coal2_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal2_particles

  gen id=start_idM,End_idM rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group middlings_particles range id Start_idM,End_idM
  prop dens=dens_M ks=1e6 kn=1e6 range group middlings_particles
 ;  prop zforce= - 0.17 range group middlings_particles
  ;ini rad mul 1.2 range group middlings_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group middlings_particles

  gen id=start_idR,End_idR rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group rock_particles range id start_idR,End_idR
  prop dens=dens_R ks=1e6 kn=1e6 range group rock_particles
  ; prop zforce=-0.62 range group rock_particles
  ;ini rad mul 1.2 range group rock_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group rock_particles
 end_command
end
def ff_cylinder
  ff_cylinder = 0
  _brad = fc_arg(0)
  _bx   = fc_arg(1)
  _by   = fc_arg(2)
  _bz   = fc_arg(3)
```

```
  _rad  = sqrt(_bx^2 + _by^2)
  if _rad + _brad > rad_cy then
    ff_cylinder = 1
  end_if
end
SET height=3.0 width=2.0
make_walls
particle_create
plot set cap size 25
plot set mag 1.5
;plot set rot 30 0 40
plot add group lorange yellow green lblue brown black
plot add wall white
plot add axes red
plot show
; ----- Create the ground
def make_ground
_bid = 5000
_xnum = (balls_per_beam + num_layers + 1)*num_bays_front
_xnum2 = 1.0*_xnum
_y = _yorigin - _xnum*core_radius + core_radius
_z = origin_z - core_radius
loop depth (1,_xnum2)
_x = _xorigin - _xnum*core_radius + core_radius
loop row (1,_xnum2)
command
ball id=_bid x=_x y=_y z=_z rad=core_radius
end_command
_x = _x + 1.7*core_radius
_bid = _bid + 1
end_loop
_y = _y + 1.7*core_radius
```

```
end_loop
Command
group base_particle range id 5000, _bid
prop kn 1e8 ks 1e8 dens 4000 range group base_particle
prop pb_rad=0.04 pb_kn=1e4 pb_ks=1e4 pb_nstren=1e2 pb_sstren=1e2 range group base_particle
fix x y z xspin yspin zspin range group base_particle
End_command
end
DEF variables
origin_x=0.0
origin_y=0.0
origin_z=0.0
core_radius=0.08
num_layers=2
num_bays_front=4
num_bays_depth=1
balls_per_beam=4
num_floors=4
balls_per_col=8
END
variables
make_ground
plot creat structure
plot add cforce black
plot add ball lorange
plot add pbond black
; ----- Install material properties
fix x y z xspin yspin zspin range group base_particle
set grav 0 0 -10
damp default local 0.0
damp default viscous normal 0.07
;damp default shear normal 0.7
```

```
def startup
old_time = time
omega = freq * 2.0 * pi
end
; ----- Apply sinusoidal motion to base of structure
def shake_it
while_stepping
real_time = time - old_time
if real_time < length
ground_vel = ampl * sin(omega*real_time)
else
ground_vel = ampl * sin(omega*real_time)
end_if
command
prop zvel= ground_vel range group base_particle
end_command
end
prop damp=0.0
set time=0.0 freq=17.25 ampl=0.5 length=0.0
startup
set pinterval 100
;plot creat R_Time
;set hist_rep=100
;history id=25 ground_vel
;history id=30 real_time
;plot history 25 vs 30 white
Cycle 800000
;Def _z_position
;n_count=100
;loop n (1,n_count)
;Sum_zC=0.0
;sum_zR=0.0
```

```
;count1= n + 1000
;count2= n + 2000
;bp = ball_head
;loop while bp # null
;if b_id(bp) <= end_idC then
;sum_zc=sum_zc + b_z(bp)
;else
;if b_id(bp) >= start_idR then
;sum_zR=sum_zR + b_z(bp)
;end_if
;end_if
;bp = b_next(bp)
;end_loop
;Cent_zC = sum_zC/(End_idC - Start_idc + 1)
;Cent_zR = sum_zR/(End_idR - start_idR + 1)
;Command
;history id=count1 Cent_zC ;History 1
;history id=count2 Cent_zR ;History 2
;plot add hist count1 count2 25 vs 30 black blue white
cyc 500000
;End_command
;end_loop
;END
;_z_position
Set log on
set logfile R17_Force4_1
print balls position
;print balls velocity
print balls property
cycle 500000
set logfile R17_Force4_2
print balls position
```

```
print balls velocity

save Force4_final_1.sav

cycle 500000

set logfile R17_Force4_3

print balls position

print balls velocity

save Force4_final_2.sav

cycle 500000

set logfile R17_Force4_4

print balls position

print balls velocity

save Force4_final_3.sav

cycle 500000

set logfile R17_Force4_5

print balls position

print balls velocity

save Force4_final_4.sav
;===========================================================================
;                                VARIATION IN SIZES
;                                MONOSIZE PARTICLES
; Radius of particles changes "max_r" from 0.0045m to 0.025m
; Different simulations run at radius of 0.0045, 0.006, 0.0125, 0.0025 meters
; Force of buoyancy and drag force changes with particle sizes and applied accordingly
;===========================================================================
new

Set random

set grav 0 0 -10

def make_walls  ; create walls: a cylinder and top plate

  extend = 0.02

  rad_cy = 0.25*width

  w_stiff= 2.25e7

  _z0 = -extend

  _z1 = height*(1.0 + extend)

  command

    wall type cylinder id=1 kn=w_stiff end1 0.0 0.0 -2.0 end2 0.0 0.0 _z1 & rad rad_cy rad_cy
```

```
 end_command
; _x0 = -rad_cy*(1.0 + extend)
 ;_y0 = -rad_cy*(1.0 + extend)
 ;_z0 = -1.0
 ;_x1 =  rad_cy*(1.0 + extend)
 ;_y1 = -rad_cy*(1.0 + extend)
 ;_z1 = -1.0
 ;_x2 =  rad_cy*(1.0 + extend)
 ;_y2 =  rad_cy*(1.0 + extend)
 ;_z2 = -1.0
 ;_x3 = -rad_cy*(1.0 + extend)
 ;_y3 =  rad_cy*(1.0 + extend)
 ;_z3 = -1.0
 ;command
  ; wall id=5 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
   ; (_x3,_y3,_z3)
;end_command
 _x0 = -rad_cy*(1.0 + extend)
 _y0 = -rad_cy*(1.0 + extend)
 _z0 = height
 _x1 = -rad_cy*(1.0 + extend)
 _y1 =  rad_cy*(1.0 + extend)
 _z1 = height
 _x2 =  rad_cy*(1.0 + extend)
 _y2 =  rad_cy*(1.0 + extend)
 _z2 = height
 _x3 =  rad_cy*(1.0 + extend)
 _y3 = -rad_cy*(1.0 + extend)
 _z3 = height
 command
   wall id=6 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
    (_x3,_y3,_z3)
```

```
  end_command
end
def particle_create
 max_r=0.025 ; Variable sizes used as mention above
 min_r=0.01
 dens_C1=1200
 dens_C2=1500
 dens_M=1800
 dens_R=2400
 Start_idC1=1
 End_idC1=500
 Start_idC2=501
 End_idC2=600
 start_idM=601
 End_idM=700
 start_idR=701
 End_idR=1200
 command
  gen id=Start_idC1,End_idC1 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal1_particles range id Start_idC1,End_idC1
  prop dens=dens_C1 ks=1e6 kn=1e6 range group coal1_particles
  prop zforce=0.47 range group coal1_particles
  ;ini rad mul 1.2 range group coal1_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal1_particles

  gen id=Start_idC2,End_idC2 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal2_particles range id Start_idC2,End_idC2
  prop dens=dens_C2 ks=1e6 kn=1e6 range group coal2_particles
 prop zforce=0.3 range group coal2_particles
  ;ini rad mul 1.2 range group coal2_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal2_particles
```

```
  gen id=start_idM,End_idM rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group middlings_particles range id Start_idM,End_idM
  prop dens=dens_M ks=1e6 kn=1e6 range group middlings_particles
 prop zforce= - 0.17 range group middlings_particles
  ;ini rad mul 1.2 range group middlings_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group middlings_particles

  gen id=start_idR,End_idR rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group rock_particles range id start_idR,End_idR
  prop dens=dens_R ks=1e6 kn=1e6 range group rock_particles
  prop zforce=-0.62 range group rock_particles
  ;ini rad mul 1.2 range group rock_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group rock_particles
 end_command
end
def ff_cylinder
  ff_cylinder = 0
  _brad = fc_arg(0)
  _bx   = fc_arg(1)
  _by   = fc_arg(2)
  _bz   = fc_arg(3)
  _rad  = sqrt(_bx^2 + _by^2)
  if _rad + _brad > rad_cy then
    ff_cylinder = 1
  end_if
end
SET height=3.0 width=2.0
make_walls
particle_create
plot set cap size 25
plot set mag 1.5
;plot set rot 30 0 40
```

```
plot add group lorange yellow green lblue brown black
plot add wall white
plot add axes red
plot show
; ----- Create the ground
def make_ground
_bid = 5000
_xnum = (balls_per_beam + num_layers + 1)*num_bays_front
_xnum2 = 1.0*_xnum
_y = _yorigin - _xnum*core_radius + core_radius
_z = origin_z - core_radius
loop depth (1,_xnum2)
_x = _xorigin - _xnum*core_radius + core_radius
loop row (1,_xnum2)
command
ball id=_bid x=_x y=_y z=_z rad=core_radius
end_command
_x = _x + 1.7*core_radius
_bid = _bid + 1
end_loop
_y = _y + 1.7*core_radius
end_loop
Command
group base_particle range id 5000, _bid
prop kn 1e8 ks 1e8 dens 4000 range group base_particle
prop pb_rad=0.04 pb_kn=1e4 pb_ks=1e4 pb_nstren=1e2 pb_sstren=1e2 range group base_particle
fix x y z xspin yspin zspin range group base_particle
End_command
end
DEF variables
origin_x=0.0
origin_y=0.0
```

```
origin_z=0.0
core_radius=0.08
num_layers=2
num_bays_front=4
num_bays_depth=1
balls_per_beam=4
num_floors=4
balls_per_col=8
END
variables
make_ground
plot creat structure
plot add cforce black
plot add ball lorange
plot add pbond black
; ----- Install material properties
fix x y z xspin yspin zspin range group base_particle
set grav 0 0 -10
damp default local 0.0
damp default viscous normal 0.07
;damp default shear normal 0.7
def startup
old_time = time
omega = freq * 2.0 * pi
end
; ----- Apply sinusoidal motion to base of structure
def shake_it
while_stepping
real_time = time - old_time
if real_time < length
ground_vel = ampl * sin(omega*real_time)
else
```

```
ground_vel = ampl * sin(omega*real_time)
end_if
command
prop zvel= ground_vel range group base_particle
end_command
end
prop damp=0.0
set time=0.0 freq=17.25 ampl=0.5 length=0.0
startup
set pinterval 100
;plot creat R_Time
;set hist_rep=100
;history id=25 ground_vel
;history id=30 real_time
;plot history 25 vs 30 white
Cycle 800000
;Def _z_position
;n_count=100
;loop n (1,n_count)
;Sum_zC=0.0
;sum_zR=0.0
;count1= n + 1000
;count2= n + 2000
;bp = ball_head
;loop while bp # null
;if b_id(bp) <= end_idC then
;sum_zc=sum_zc + b_z(bp)
;else
;if b_id(bp) >= start_idR then
;sum_zR=sum_zR + b_z(bp)
;end_if
;end_if
```

```
;bp = b_next(bp)
;end_loop
;Cent_zC = sum_zC/(End_idC - Start_idc + 1)
;Cent_zR = sum_zR/(End_idR - start_idR + 1)
;Command
;history id=count1 Cent_zC ;History 1
;history id=count2 Cent_zR ;History 2
;plot add hist count1 count2 25 vs 30 black blue white
cyc 500000
;End_command
;end_loop
;END
;_z_position
Set log on
set logfile R17_Size1_1
print balls position
;print balls velocity
print balls property
cycle 500000
set logfile R17_ Size1_2
print balls position
print balls velocity
save Size1_final_1.sav
cycle 500000
set logfile R17_ Size1_3
print balls position
print balls velocity
save Size1_final_2.sav
cycle 500000
set logfile R17_ Size1_4
print balls position
print balls velocity
```

```
save Size1_final_3.sav

cycle 500000

set logfile R17_ Size1_5

print balls position

print balls velocity

save Size1_final_4.sav




;===================================================================================
;                                            VARIATION IN SIZES
;                                        VARIABLE SIZE PARTICLES
; Radius of particles changes "max_r" from 0.0125m to 0.025m
; Radius of particles changes "min_r" from 0.006m to 0.0125m
; Different simulations run at particle size range of 0.006m-0.0125m and 0.0125m-0.025m
; Force of buoyancy and drag force changes with particle sizes and applied  constantly according to the top size
;===================================================================================
new

Set random

set grav 0 0 -10

def make_walls  ; create walls: a cylinder and top plate

  extend = 0.02

  rad_cy = 0.25*width

  w_stiff= 2.25e7

  _z0 = -extend

  _z1 = height*(1.0 + extend)

  command

    wall type cylinder id=1 kn=w_stiff end1 0.0 0.0 -2.0 end2 0.0 0.0 _z1 & rad rad_cy rad_cy

  end_command

 ; _x0 = -rad_cy*(1.0 + extend)

  ;_y0 = -rad_cy*(1.0 + extend)

  ;_z0 = -1.0

  ;_x1 =  rad_cy*(1.0 + extend)

  ;_y1 = -rad_cy*(1.0 + extend)

  ;_z1 = -1.0
```

```
 ;_x2 =  rad_cy*(1.0 + extend)
 ;_y2 =  rad_cy*(1.0 + extend)
 ;_z2 = -1.0
 ;_x3 = -rad_cy*(1.0 + extend)
 ;_y3 =  rad_cy*(1.0 + extend)
 ;_z3 = -1.0
 ;command
  ; wall id=5 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
   ; (_x3,_y3,_z3)
 ;end_command
 _x0 = -rad_cy*(1.0 + extend)
 _y0 = -rad_cy*(1.0 + extend)
 _z0 = height
 _x1 = -rad_cy*(1.0 + extend)
 _y1 =  rad_cy*(1.0 + extend)
 _z1 = height
 _x2 =  rad_cy*(1.0 + extend)
 _y2 =  rad_cy*(1.0 + extend)
 _z2 = height
 _x3 =  rad_cy*(1.0 + extend)
 _y3 = -rad_cy*(1.0 + extend)
 _z3 = height
 command
   wall id=6 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
    (_x3,_y3,_z3)
 end_command
end
def particle_create
 max_r=0.025 ; Variable sizes used as mention above
 min_r=0.0125; Variable sizes used as mention above
 dens_C1=1200
 dens_C2=1500
```

```
dens_M=1800
dens_R=2400
Start_idC1=1
End_idC1=500
Start_idC2=501
End_idC2=600
start_idM=601
End_idM=700
start_idR=701
End_idR=1200
command
 gen id=Start_idC1,End_idC1 rad=max_r,min_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group coal1_particles range id Start_idC1,End_idC1
 prop dens=dens_C1 ks=1e6 kn=1e6 range group coal1_particles
 prop zforce=0.47 range group coal1_particles
 ;ini rad mul 1.2 range group coal1_particles
 prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal1_particles
 gen id=Start_idC2,End_idC2 rad=max_r,min_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group coal2_particles range id Start_idC2,End_idC2
 prop dens=dens_C2 ks=1e6 kn=1e6 range group coal2_particles
prop zforce=0.3 range group coal2_particles
 ;ini rad mul 1.2 range group coal2_particles
 prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal2_particles
 gen id=start_idM,End_idM rad=max_r,min_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group middlings_particles range id Start_idM,End_idM
 prop dens=dens_M ks=1e6 kn=1e6 range group middlings_particles
prop zforce= - 0.17 range group middlings_particles
 ;ini rad mul 1.2 range group middlings_particles
 prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group middlings_particles
 gen id=start_idR,End_idR rad=max_r,min_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group rock_particles range id start_idR,End_idR
 prop dens=dens_R ks=1e6 kn=1e6 range group rock_particles
```

```
  prop zforce=-0.62 range group rock_particles
  ;ini rad mul 1.2 range group rock_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group rock_particles
 end_command
end
def ff_cylinder
  ff_cylinder = 0
  _brad = fc_arg(0)
  _bx   = fc_arg(1)
  _by   = fc_arg(2)
  _bz   = fc_arg(3)
  _rad  = sqrt(_bx^2 + _by^2)
  if _rad + _brad > rad_cy then
    ff_cylinder = 1
  end_if
end
SET height=3.0 width=2.0
make_walls
particle_create
plot set cap size 25
plot set mag 1.5
;plot set rot 30 0 40
plot add group lorange yellow green lblue brown black
plot add wall white
plot add axes red
plot show
; ----- Create the ground
def make_ground
_bid = 5000
_xnum = (balls_per_beam + num_layers + 1)*num_bays_front
_xnum2 = 1.0*_xnum
_y = _yorigin - _xnum*core_radius + core_radius
```

```
_z = origin_z - core_radius
loop depth (1,_xnum2)
_x = _xorigin - _xnum*core_radius + core_radius
loop row (1,_xnum2)
command
ball id=_bid x=_x y=_y z=_z rad=core_radius
end_command
_x = _x + 1.7*core_radius
_bid = _bid + 1
end_loop
_y = _y + 1.7*core_radius
end_loop
Command
group base_particle range id 5000, _bid
prop kn 1e8 ks 1e8 dens 4000 range group base_particle
prop pb_rad=0.04 pb_kn=1e4 pb_ks=1e4 pb_nstren=1e2 pb_sstren=1e2 range group base_particle
fix x y z xspin yspin zspin range group base_particle
End_command
end
DEF variables
origin_x=0.0
origin_y=0.0
origin_z=0.0
core_radius=0.08
num_layers=2
num_bays_front=4
num_bays_depth=1
balls_per_beam=4
num_floors=4
balls_per_col=8
END
variables
```

```
make_ground
plot creat structure
plot add cforce black
plot add ball lorange
plot add pbond black
; ----- Install material properties
fix x y z xspin yspin zspin range group base_particle
set grav 0 0 -10
damp default local 0.0
damp default viscous normal 0.07
;damp default shear normal 0.7
def startup
old_time = time
omega = freq * 2.0 * pi
end
; ----- Apply sinusoidal motion to base of structure
def shake_it
while_stepping
real_time = time - old_time
if real_time < length
ground_vel = ampl * sin(omega*real_time)
else
ground_vel = ampl * sin(omega*real_time)
end_if
command
prop zvel= ground_vel range group base_particle
end_command
end
prop damp=0.0
set time=0.0 freq=17.25 ampl=0.5 length=0.0
startup
set pinterval 100
```

```
;plot creat R_Time
;set hist_rep=100
;history id=25 ground_vel
;history id=30 real_time
;plot history 25 vs 30 white
Cycle 800000
;Def _z_position
;n_count=100
;loop n (1,n_count)
;Sum_zC=0.0
;sum_zR=0.0
;count1= n + 1000
;count2= n + 2000
;bp = ball_head
;loop while bp # null
;if b_id(bp) <= end_idC then
;sum_zc=sum_zc + b_z(bp)
;else
;if b_id(bp) >= start_idR then
;sum_zR=sum_zR + b_z(bp)
;end_if
;end_if
;bp = b_next(bp)
;end_loop
;Cent_zC = sum_zC/(End_idC - Start_idc + 1)
;Cent_zR = sum_zR/(End_idR - start_idR + 1)
;Command
;history id=count1 Cent_zC ;History 1
;history id=count2 Cent_zR ;History 2
;plot add hist count1 count2 25 vs 30 black blue white
cyc 500000
;End_command
```

```
;end_loop

;END

;_z_position

Set log on

set logfile R17_ VARsize1_1

print balls position

;print balls velocity

print balls property

cycle 500000

set logfile R17_ VARsize1_2

print balls position

print balls velocity

save VARsize1_final_1.sav

cycle 500000

set logfile R17_ VARsize1_3

print balls position

print balls velocity

save VARsize1_final_2.sav

cycle 500000

set logfile R17_ VARsize1_4

print balls position

print balls velocity

save VARsize1_final_3.sav

cycle 500000

set logfile R17_ VARsize1_5

print balls position

print balls velocity

save VARsize1_final_4.sav

;==============================================================================
;                              VARIATION IN BED DEPTH
; Radius of cylinder changes "rad_cy" from 0.2m to 1.0m
; Different simulations run at cylinder radius of 0.2m,0.3m,0.4m,0.5m,0.6m,0.7m,0.8m,1.0m
; Force of buoyancy and drag force changes with bed depth as the volume concentration of particles ;inside the geometry changes
```

```
;==================================================================================
new

Set random

set grav 0 0 -10

def make_walls  ; create walls: a cylinder and top plate

  extend = 0.02

  rad_cy = 0.25*width ;VARIABLE RADIUS MENTIONED ABOVE WERE USED FOR VARIABLE BED Hgt.

  w_stiff= 2.25e7

  _z0 = -extend

  _z1 = height*(1.0 + extend)

  command

    wall type cylinder id=1 kn=w_stiff end1 0.0 0.0 -2.0 end2 0.0 0.0 _z1 & rad rad_cy rad_cy

  end_command

 ; _x0 = -rad_cy*(1.0 + extend)

  ;_y0 = -rad_cy*(1.0 + extend)

  ;_z0 = -1.0

  ;_x1 =  rad_cy*(1.0 + extend)

  ;_y1 = -rad_cy*(1.0 + extend)

  ;_z1 = -1.0

  ;_x2 =  rad_cy*(1.0 + extend)

  ;_y2 =  rad_cy*(1.0 + extend)

  ;_z2 = -1.0

  ;_x3 = -rad_cy*(1.0 + extend)

  ;_y3 =  rad_cy*(1.0 + extend)

  ;_z3 = -1.0

  ;command

   ; wall id=5 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &

    ; (_x3,_y3,_z3)

 ;end_command

  _x0 = -rad_cy*(1.0 + extend)

  _y0 = -rad_cy*(1.0 + extend)

  _z0 = height
```

```
  _x1 = -rad_cy*(1.0 + extend)
  _y1 =  rad_cy*(1.0 + extend)
  _z1 = height
  _x2 =  rad_cy*(1.0 + extend)
  _y2 =  rad_cy*(1.0 + extend)
  _z2 = height
  _x3 =  rad_cy*(1.0 + extend)
  _y3 = -rad_cy*(1.0 + extend)
  _z3 = height
  command
    wall id=6 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
    (_x3,_y3,_z3)
  end_command
end
def particle_create
 max_r=0.025
 min_r=0.01
 dens_C1=1200
 dens_C2=1500
 dens_M=1800
 dens_R=2400
 Start_idC1=1
 End_idC1=500
 Start_idC2=501
 End_idC2=600
 start_idM=601
 End_idM=700
 start_idR=701
 End_idR=1200
 command
  gen id=Start_idC1,End_idC1 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal1_particles range id Start_idC1,End_idC1
```

```
 prop dens=dens_C1 ks=1e6 kn=1e6 range group coal1_particles
 prop zforce=0.47 range group coal1_particles
 ;ini rad mul 1.2 range group coal1_particles
 prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal1_particles

 gen id=Start_idC2,End_idC2 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group coal2_particles range id Start_idC2,End_idC2
 prop dens=dens_C2 ks=1e6 kn=1e6 range group coal2_particles
prop zforce=0.3 range group coal2_particles
 ;ini rad mul 1.2 range group coal2_particles
 prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal2_particles

 gen id=start_idM,End_idM rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group middlings_particles range id Start_idM,End_idM
 prop dens=dens_M ks=1e6 kn=1e6 range group middlings_particles
prop zforce= - 0.17 range group middlings_particles
 ;ini rad mul 1.2 range group middlings_particles
 prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group middlings_particles

 gen id=start_idR,End_idR rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
 group rock_particles range id start_idR,End_idR
 prop dens=dens_R ks=1e6 kn=1e6 range group rock_particles
 prop zforce=-0.62 range group rock_particles
 ;ini rad mul 1.2 range group rock_particles
 prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group rock_particles
end_command
end
def ff_cylinder
 ff_cylinder = 0
 _brad = fc_arg(0)
 _bx   = fc_arg(1)
 _by   = fc_arg(2)
```

```
  _bz   = fc_arg(3)
  _rad  = sqrt(_bx^2 + _by^2)
  if _rad + _brad > rad_cy then
    ff_cylinder = 1
  end_if
end
SET height=3.0 width=2.0
make_walls
particle_create
plot set cap size 25
plot set mag 1.5
;plot set rot 30 0 40
plot add group lorange yellow green lblue brown black
plot add wall white
plot add axes red
plot show
; ----- Create the ground
def make_ground
_bid = 5000
_xnum = (balls_per_beam + num_layers + 1)*num_bays_front
_xnum2 = 1.0*_xnum
_y = _yorigin - _xnum*core_radius + core_radius
_z = origin_z - core_radius
loop depth (1,_xnum2)
_x = _xorigin - _xnum*core_radius + core_radius
loop row (1,_xnum2)
command
ball id=_bid x=_x y=_y z=_z rad=core_radius
end_command
_x = _x + 1.7*core_radius
_bid = _bid + 1
end_loop
```

```
_y = _y + 1.7*core_radius
end_loop
Command
group base_particle range id 5000, _bid
prop kn 1e8 ks 1e8 dens 4000 range group base_particle
prop pb_rad=0.04 pb_kn=1e4 pb_ks=1e4 pb_nstren=1e2 pb_sstren=1e2 range group base_particle
fix x y z xspin yspin zspin range group base_particle
End_command
end
DEF variables
origin_x=0.0
origin_y=0.0
origin_z=0.0
core_radius=0.08
num_layers=2
num_bays_front=4
num_bays_depth=1
balls_per_beam=4
num_floors=4
balls_per_col=8
END
variables
make_ground
plot creat structure
plot add cforce black
plot add ball lorange
plot add pbond black
; ----- Install material properties
fix x y z xspin yspin zspin range group base_particle
set grav 0 0 -10
damp default local 0.0
damp default viscous normal 0.07
```

```
;damp default shear normal 0.7
def startup
old_time = time
omega = freq * 2.0 * pi
end
; ----- Apply sinusoidal motion to base of structure
def shake_it
while_stepping
real_time = time - old_time
if real_time < length
ground_vel = ampl * sin(omega*real_time)
else
ground_vel = ampl * sin(omega*real_time)
end_if
command
prop zvel= ground_vel range group base_particle
end_command
end
prop damp=0.0
set time=0.0 freq=17.25 ampl=0.5 length=0.0
startup
set pinterval 100
;plot creat R_Time
;set hist_rep=100
;history id=25 ground_vel
;history id=30 real_time
;plot history 25 vs 30 white
Cycle 800000
;Def _z_position
;n_count=100
;loop n (1,n_count)
;Sum_zC=0.0
```

```
;sum_zR=0.0
;count1= n + 1000
;count2= n + 2000
;bp = ball_head
;loop while bp # null
;if b_id(bp) <= end_idC then
;sum_zc=sum_zc + b_z(bp)
;else
;if b_id(bp) >= start_idR then
;sum_zR=sum_zR + b_z(bp)
;end_if
;end_if
;bp = b_next(bp)
;end_loop
;Cent_zC = sum_zC/(End_idC - Start_idc + 1)
;Cent_zR = sum_zR/(End_idR - start_idR + 1)
;Command
;history id=count1 Cent_zC ;History 1
;history id=count2 Cent_zR ;History 2
;plot add hist count1 count2 25 vs 30 black blue white
cyc 500000
;End_command
;end_loop
;END
;_z_position
Set log on
set logfile R17_BED1_1
print balls position
;print balls velocity
print balls property
cycle 500000
set logfile R17_ BED1_2
```

```
print balls position

print balls velocity

save BED1_final_1.sav

cycle 500000

set logfile R17_ BED1_3

print balls position

print balls velocity

save BED1_final_2.sav

cycle 500000

set logfile R17_ BED1_4

print balls position

print balls velocity

save BED1_final_3.sav

cycle 500000

set logfile R17_ BED1_5

print balls position

print balls velocity

save BED1_final_4.sav
;==========================================================================
;         VARIATION IN AMPLITUDE OF VELOCITY OF VIBRATING TABLE
;              Amplitude of velocity "ampl" changes from 0.25m/s to 1.5m/s
;Simulations run at variable amplitude of velocity 0.25m/s,0.5m/s,0.625m/s,0.75m/s,1.0m/s,1.5m/s
;==========================================================================
new

Set random

set grav 0 0 -10

def make_walls  ; create walls: a cylinder and top plate

  extend = 0.02

  rad_cy = 0.25*width

  w_stiff= 2.25e7

  _z0 = -extend

  _z1 = height*(1.0 + extend)

  command

    wall type cylinder id=1 kn=w_stiff end1 0.0 0.0 -2.0 end2 0.0 0.0 _z1 & rad rad_cy rad_cy
```

```
 end_command
; _x0 = -rad_cy*(1.0 + extend)
 ;_y0 = -rad_cy*(1.0 + extend)
 ;_z0 = -1.0
 ;_x1 =  rad_cy*(1.0 + extend)
 ;_y1 = -rad_cy*(1.0 + extend)
 ;_z1 = -1.0
 ;_x2 =  rad_cy*(1.0 + extend)
 ;_y2 =  rad_cy*(1.0 + extend)
 ;_z2 = -1.0
 ;_x3 = -rad_cy*(1.0 + extend)
 ;_y3 =  rad_cy*(1.0 + extend)
 ;_z3 = -1.0
 ;command
  ; wall id=5 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
   ; (_x3,_y3,_z3)
;end_command
 _x0 = -rad_cy*(1.0 + extend)
 _y0 = -rad_cy*(1.0 + extend)
 _z0 = height
 _x1 = -rad_cy*(1.0 + extend)
 _y1 =  rad_cy*(1.0 + extend)
 _z1 = height
 _x2 =  rad_cy*(1.0 + extend)
 _y2 =  rad_cy*(1.0 + extend)
 _z2 = height
 _x3 =  rad_cy*(1.0 + extend)
 _y3 = -rad_cy*(1.0 + extend)
 _z3 = height
 command
   wall id=6 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
    (_x3,_y3,_z3)
```

```
  end_command
end
def particle_create
 max_r=0.025
 min_r=0.01
 dens_C1=1200
 dens_C2=1500
 dens_M=1800
 dens_R=2400
 Start_idC1=1
 End_idC1=500
 Start_idC2=501
 End_idC2=600
 start_idM=601
 End_idM=700
 start_idR=701
 End_idR=1200
 command
  gen id=Start_idC1,End_idC1 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal1_particles range id Start_idC1,End_idC1
  prop dens=dens_C1 ks=1e6 kn=1e6 range group coal1_particles
  prop zforce=0.47 range group coal1_particles
  ;ini rad mul 1.2 range group coal1_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal1_particles
  gen id=Start_idC2,End_idC2 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal2_particles range id Start_idC2,End_idC2
  prop dens=dens_C2 ks=1e6 kn=1e6 range group coal2_particles
 prop zforce=0.3 range group coal2_particles
  ;ini rad mul 1.2 range group coal2_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal2_particles
  gen id=start_idM,End_idM rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group middlings_particles range id Start_idM,End_idM
```

```
  prop dens=dens_M ks=1e6 kn=1e6 range group middlings_particles
 prop zforce= - 0.17 range group middlings_particles
  ;ini rad mul 1.2 range group middlings_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group middlings_particles
  gen id=start_idR,End_idR rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group rock_particles range id start_idR,End_idR
  prop dens=dens_R ks=1e6 kn=1e6 range group rock_particles
  prop zforce=-0.62 range group rock_particles
  ;ini rad mul 1.2 range group rock_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group rock_particles
 end_command
end
def ff_cylinder
  ff_cylinder = 0
  _brad = fc_arg(0)
  _bx   = fc_arg(1)
  _by   = fc_arg(2)
  _bz   = fc_arg(3)
  _rad  = sqrt(_bx^2 + _by^2)
  if _rad + _brad > rad_cy then
    ff_cylinder = 1
  end_if
end
SET height=3.0 width=2.0
make_walls
particle_create
plot set cap size 25
plot set mag 1.5
;plot set rot 30 0 40
plot add group lorange yellow green lblue brown black
plot add wall white
plot add axes red
```

```
plot show
; ----- Create the ground
def make_ground
_bid = 5000
_xnum = (balls_per_beam + num_layers + 1)*num_bays_front
_xnum2 = 1.0*_xnum
_y = _yorigin - _xnum*core_radius + core_radius
_z = origin_z - core_radius
loop depth (1,_xnum2)
_x = _xorigin - _xnum*core_radius + core_radius
loop row (1,_xnum2)
command
ball id=_bid x=_x y=_y z=_z rad=core_radius
end_command
_x = _x + 1.7*core_radius
_bid = _bid + 1
end_loop
_y = _y + 1.7*core_radius
end_loop
Command
group base_particle range id 5000, _bid
prop kn 1e8 ks 1e8 dens 4000 range group base_particle
prop pb_rad=0.04 pb_kn=1e4 pb_ks=1e4 pb_nstren=1e2 pb_sstren=1e2 range group base_particle
fix x y z xspin yspin zspin range group base_particle
End_command
end
DEF variables
origin_x=0.0
origin_y=0.0
origin_z=0.0
core_radius=0.08
num_layers=2
```

```
num_bays_front=4
num_bays_depth=1
balls_per_beam=4
num_floors=4
balls_per_col=8
END
variables
make_ground
plot creat structure
plot add cforce black
plot add ball lorange
plot add pbond black
; ----- Install material properties
fix x y z xspin yspin zspin range group base_particle
set grav 0 0 -10
damp default local 0.0
damp default viscous normal 0.07
;damp default shear normal 0.7
def startup
old_time = time
omega = freq * 2.0 * pi
end
; ----- Apply sinusoidal motion to base of structure
def shake_it
while_stepping
real_time = time - old_time
if real_time < length
ground_vel = ampl * sin(omega*real_time)
else
ground_vel = ampl * sin(omega*real_time)
end_if
command
```

```
prop zvel= ground_vel range group base_particle
end_command
end
prop damp=0.0
set time=0.0 freq=17.25 ampl=0.5 length=0.0 ; AMPL values varied as mentioned above in the code
startup
set pinterval 100
;plot creat R_Time
;set hist_rep=100
;history id=25 ground_vel
;history id=30 real_time
;plot history 25 vs 30 white
Cycle 800000
;Def _z_position
;n_count=100
;loop n (1,n_count)
;Sum_zC=0.0
;sum_zR=0.0
;count1= n + 1000
;count2= n + 2000
;bp = ball_head
;loop while bp # null
;if b_id(bp) <= end_idC then
;sum_zc=sum_zc + b_z(bp)
;else
;if b_id(bp) >= start_idR then
;sum_zR=sum_zR + b_z(bp)
;end_if
;end_if
;bp = b_next(bp)
;end_loop
;Cent_zC = sum_zC/(End_idC - Start_idc + 1)
```

```
;Cent_zR = sum_zR/(End_idR - start_idR + 1)
;Command
;history id=count1 Cent_zC ;History 1
;history id=count2 Cent_zR ;History 2
;plot add hist count1 count2 25 vs 30 black blue white
cyc 500000
;End_command
;end_loop
;END
;_z_position
Set log on
set logfile R17_AMPL1_1
print balls position
;print balls velocity
print balls property
cycle 500000
set logfile R17_ AMPL1_2
print balls position
print balls velocity
save AMPL1_final_1.sav
cycle 500000
set logfile R17_ AMPL1_3
print balls position
print balls velocity
save AMPL1_final_2.sav
cycle 500000
set logfile R17_ AMPL1_4
print balls position
print balls velocity
save AMPL1_final_3.sav
cycle 500000
set logfile R17_ AMPL1_5
```

```
print balls position

print balls velocity

save AMPL1_final_4.sav

;==========================================================================================
;                    VARIATION IN FREQUENCY OF VIBRATIONS
;          Frequency of vibrating table "freq" changes from 5 Hz to 25 Hz
;Simulations run at variable Frequency of vibrations 5 Hz, 12.5 Hz, 14.0 Hz, 15.5 Hz, 17.25 Hz, 25 Hz
;Values from 12.5 Hz to 17.25 Hz are same frequencies used in Dry Deshaling Air Table
;==========================================================================================
new

Set random

set grav 0 0 -10

def make_walls  ; create walls: a cylinder and top plate

  extend = 0.02

  rad_cy = 0.25*width

  w_stiff= 2.25e7

  _z0 = -extend

  _z1 = height*(1.0 + extend)

  command

    wall type cylinder id=1 kn=w_stiff end1 0.0 0.0 -2.0 end2 0.0 0.0 _z1 & rad rad_cy rad_cy

  end_command

 ; _x0 = -rad_cy*(1.0 + extend)

  ;_y0 = -rad_cy*(1.0 + extend)

  ;_z0 = -1.0

  ;_x1 =  rad_cy*(1.0 + extend)

  ;_y1 = -rad_cy*(1.0 + extend)

  ;_z1 = -1.0

  ;_x2 =  rad_cy*(1.0 + extend)

  ;_y2 =  rad_cy*(1.0 + extend)

  ;_z2 = -1.0

  ;_x3 = -rad_cy*(1.0 + extend)

  ;_y3 =  rad_cy*(1.0 + extend)

  ;_z3 = -1.0

  ;command
```

```
  ; wall id=5 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
   ; (_x3,_y3,_z3)
 ;end_command
  _x0 = -rad_cy*(1.0 + extend)
  _y0 = -rad_cy*(1.0 + extend)
  _z0 = height
  _x1 = -rad_cy*(1.0 + extend)
  _y1 =  rad_cy*(1.0 + extend)
  _z1 = height
  _x2 =  rad_cy*(1.0 + extend)
  _y2 =  rad_cy*(1.0 + extend)
  _z2 = height
  _x3 =  rad_cy*(1.0 + extend)
  _y3 = -rad_cy*(1.0 + extend)
  _z3 = height
  command
    wall id=6 kn=w_stiff face (_x0,_y0,_z0) (_x1,_y1,_z1) (_x2,_y2,_z2) &
     (_x3,_y3,_z3)
  end_command
end
def particle_create
 max_r=0.025
 min_r=0.01
 dens_C1=1200
 dens_C2=1500
 dens_M=1800
 dens_R=2400
 Start_idC1=1
 End_idC1=500
 Start_idC2=501
 End_idC2=600
 start_idM=601
```

```
 End_idM=700
 start_idR=701
 End_idR=1200
 command
  gen id=Start_idC1,End_idC1 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal1_particles range id Start_idC1,End_idC1
  prop dens=dens_C1 ks=1e6 kn=1e6 range group coal1_particles
  prop zforce=0.47 range group coal1_particles
  ;ini rad mul 1.2 range group coal1_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal1_particles
  gen id=Start_idC2,End_idC2 rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group coal2_particles range id Start_idC2,End_idC2
  prop dens=dens_C2 ks=1e6 kn=1e6 range group coal2_particles
 prop zforce=0.3 range group coal2_particles
  ;ini rad mul 1.2 range group coal2_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group coal2_particles
  gen id=start_idM,End_idM rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group middlings_particles range id Start_idM,End_idM
  prop dens=dens_M ks=1e6 kn=1e6 range group middlings_particles
 prop zforce= - 0.17 range group middlings_particles
  ;ini rad mul 1.2 range group middlings_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group middlings_particles
  gen id=start_idR,End_idR rad=max_r,max_r x=-2.0,2.0 y=-2.0,2.0 z=0.0,height filter ff_cylinder tries 3000000
  group rock_particles range id start_idR,End_idR
  prop dens=dens_R ks=1e6 kn=1e6 range group rock_particles
  prop zforce=-0.62 range group rock_particles
  ;ini rad mul 1.2 range group rock_particles
  prop pb_rad=0.1 pb_kn=0 pb_ks=0 pb_nstren=0 pb_sstren=0 range group rock_particles
 end_command
end
def ff_cylinder
  ff_cylinder = 0
```

```
  _brad = fc_arg(0)
  _bx   = fc_arg(1)
  _by   = fc_arg(2)
  _bz   = fc_arg(3)
  _rad  = sqrt(_bx^2 + _by^2)
  if _rad + _brad > rad_cy then
    ff_cylinder = 1
  end_if
end
SET height=3.0 width=2.0
make_walls
particle_create
plot set cap size 25
plot set mag 1.5
;plot set rot 30 0 40
plot add group lorange yellow green lblue brown black
plot add wall white
plot add axes red
plot show
; ----- Create the ground
def make_ground
_bid = 5000
_xnum = (balls_per_beam + num_layers + 1)*num_bays_front
_xnum2 = 1.0*_xnum
_y = _yorigin - _xnum*core_radius + core_radius
_z = origin_z - core_radius
loop depth (1,_xnum2)
_x = _xorigin - _xnum*core_radius + core_radius
loop row (1,_xnum2)
command
ball id=_bid x=_x y=_y z=_z rad=core_radius
end_command
```

```
_x = _x + 1.7*core_radius
_bid = _bid + 1
end_loop
_y = _y + 1.7*core_radius
end_loop
Command
group base_particle range id 5000, _bid
prop kn 1e8 ks 1e8 dens 4000 range group base_particle
prop pb_rad=0.04 pb_kn=1e4 pb_ks=1e4 pb_nstren=1e2 pb_sstren=1e2 range group base_particle
fix x y z xspin yspin zspin range group base_particle
End_command
end
DEF variables
origin_x=0.0
origin_y=0.0
origin_z=0.0
core_radius=0.08
num_layers=2
num_bays_front=4
num_bays_depth=1
balls_per_beam=4
num_floors=4
balls_per_col=8
END
variables
make_ground
plot creat structure
plot add cforce black
plot add ball lorange
plot add pbond black
; ----- Install material properties
fix x y z xspin yspin zspin range group base_particle
```

```
set grav 0 0 -10
damp default local 0.0
damp default viscous normal 0.07
;damp default shear normal 0.7
def startup
old_time = time
omega = freq * 2.0 * pi
end
; ----- Apply sinusoidal motion to base of structure
def shake_it
while_stepping
real_time = time - old_time
if real_time < length
ground_vel = ampl * sin(omega*real_time)
else
ground_vel = ampl * sin(omega*real_time)
end_if
command
prop zvel= ground_vel range group base_particle
end_command
end
prop damp=0.0
set time=0.0 freq=17.25 ampl=0.5 length=0.0 ; FREQ values varied as mentioned above in the code
startup
set pinterval 100
;plot creat R_Time
;set hist_rep=100
;history id=25 ground_vel
;history id=30 real_time
;plot history 25 vs 30 white
Cycle 800000
;Def _z_position
```

```
;n_count=100
;loop n (1,n_count)
;Sum_zC=0.0
;sum_zR=0.0
;count1= n + 1000
;count2= n + 2000
;bp = ball_head
;loop while bp # null
;if b_id(bp) <= end_idC then
;sum_zc=sum_zc + b_z(bp)
;else
;if b_id(bp) >= start_idR then
;sum_zR=sum_zR + b_z(bp)
;end_if
;end_if
;bp = b_next(bp)
;end_loop
;Cent_zC = sum_zC/(End_idC - Start_idc + 1)
;Cent_zR = sum_zR/(End_idR - start_idR + 1)
;Command
;history id=count1 Cent_zC ;History 1
;history id=count2 Cent_zR ;History 2
;plot add hist count1 count2 25 vs 30 black blue white
cyc 500000
;End_command
;end_loop
;END
;_z_position
Set log on
set logfile R17_FREQ1_1
print balls position
;print balls velocity
```

```
print balls property
cycle 500000
set logfile R17_ FREQ1_2
print balls position
print balls velocity
save FREQ1_final_1.sav
cycle 500000
set logfile R17_ FREQ1_3
print balls position
print balls velocity
save FREQ1_final_2.sav
cycle 500000
set logfile R17_ FREQ1_4
print balls position
print balls velocity
save FREQ1_final_3.sav
cycle 500000
set logfile R17_ FREQ1_5
print balls position
print balls velocity
save FREQ1_final_4.sav
```

Rho (P)	F (wt)	F(Bouy)	F(w)+F(b)	Vs	Us	F(drag)	F(b) + F(d)	Us	F(drag)
1200	-0.785	0.376146	-0.408854	1.927329	0.731621	0.080345	0.456491	1.169226	0.205204
1300	-0.850417	0.310729	-0.539688	2.037255	0.773349	0.089772	0.400501	1.235914	0.229279
1400	-0.915833	0.245313	-0.670521	2.141547	0.812938	0.099198	0.344511	1.299183	0.253355
1500	-0.98125	0.179896	-0.801354	2.24099	0.850687	0.108625	0.288521	1.35951	0.27743
1600	-1.046667	0.114479	-0.932188	2.336204	0.886831	0.118051	0.23253	1.417272	0.301506
1700	-1.112083	0.049063	-1.063021	2.427686	0.921558	0.127478	0.17654	1.472771	0.325581
1800	-1.1775	-0.016354	-1.193854	2.515844	0.955023	-0.136904	-0.153258	1.526253	-0.349657
1900	-1.242917	-0.081771	-1.324688	2.601016	0.987355	-0.146331	-0.228101	1.577923	-0.373732
2000	-1.308333	-0.147188	-1.455521	2.683486	1.01866	-0.155757	-0.302945	1.627954	-0.397807
2100	-1.37375	-0.212604	-1.586354	2.763496	1.049032	-0.165184	-0.377788	1.676492	-0.421883
2200	-1.439167	-0.278021	-1.717188	2.841253	1.07855	-0.17461	-0.452631	1.723664	-0.445958
2300	-1.504583	-0.343438	-1.848021	2.916939	1.10728	-0.184036	-0.527474	1.769579	-0.470034
2400	-1.57	-0.408854	-1.978854	2.99071	1.135284	-0.193463	-0.602317	1.814333	-0.494109
2500	-1.635417	-0.474271	-2.109688	3.062704	1.162613	-0.202889	-0.67716	1.858009	-0.518184
2600	-1.700833	-0.539688	-2.240521	3.133045	1.189315	-0.212316	-0.752003	1.900681	-0.54226
2700	-1.76625	-0.605104	-2.371354	3.201841	1.21543	-0.221742	-0.826846	1.942417	-0.566335
2800	-1.831667	-0.670521	-2.502188	3.269189	1.240995	-0.231169	-0.90169	1.983274	-0.590411

Vol (P)=	6.54E-05	C max	0.67	rho (Peff)=	1775
A (P)=	0.001963		close pak	rho (bulk)	347.6614
r max=	0.025	C min	0.195313		
C drag	0.44				
Gravity=	-10				

FORCE CALCULATIONS FOR MODELING OF DRY DENSITY BASED SEPARATORS

Modeling Parameters Calculations

1) Amplitude of Velocity

Amplitude of velocity used in the model (m/s)	Actual amplitude of bed (mm)
0.25	2
0.5	5
0.625	6
0.75	7
1.0	9
1.5	14

*Ampl = A * Omega*

Omega = 2 pi * Freq , where Freq = 17.25 Hz*

2) Frequency of Vibrations

Frequency of vibrations used in the model (Hz)	Frequency setting on the dry air-table separator
5	18
12.5	45
14	50
15.5	55
17.25	60
25	90

#Dry air table separator runs at 1000 rev/min, therefore if air table runs at '45' frequency setting, then actual frequency can be calculated as,

*(1000/60) *(45/60) = 12.5 Hz*