

Analysis of Deviations in the Quantity Calculation During Acceptance Procedures Regarding Coal Bulk Density Measurement Methods

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Abstract

In coal quantity verification, bulk density measurement is a critical factor influencing volume conversion accuracy. Due to variations in coal particle size, moisture content, storage methods, sampling locations, and measurement techniques, bulk density results are prone to deviation, leading to discrepancies between verified quantities and actual quantities. This study analyzes coal bulk density measurement methodologies, focusing on the mechanisms underlying deviations under different conditions and their impact on verification outcomes. It proposes control measures - including standardized sampling procedures, unified measurement protocols, and enhanced verification processes - to enhance measurement accuracy and reduce trade disputes.

Keywords

Coal, Bulk density, Acceptance quantity, Calculation deviation, Measurement error

Introduction

Coal remains the dominant primary energy source supporting China's power generation, chemical raw material processing, steel smelting and other core industrial sectors, and stable, standardized coal trade measurement is the fundamental guarantee for the orderly operation of the national energy supply chain. As thermal power enterprises represented by power plants consume massive amounts of commercial coal every day, the quantity acceptance link runs through the whole process of coal inbound inspection, stockyard storage, monthly inventory reconciliation and handover settlement between suppliers and power plants [1]. The settlement weight of coal directly determines the procurement cost of power generation enterprises and the sales revenue of coal suppliers. Any tiny measurement deviation will be amplified into huge economic losses after long-term and large-volume coal transactions. This easily triggers frequent trade disputes, slows down the efficiency of coal supply chain turnover, and even affects the normal fuel supply guarantee of power units in peak power consumption periods.

In the actual coal acceptance work of thermal power plants, full vehicle weighing by truck scales and rail scales is restricted by site layout, traffic efficiency and

real-time inspection rhythm. The stockyard volume conversion method based on coal bulk density has become the most widely adopted auxiliary and supplementary metering mode for daily inventory, batch spot check and emergency acceptance. The core logic of volume conversion metering is to calculate the actual mass of coal piles through the product of coal pile volume and measured bulk density. Therefore, the accuracy of bulk density measurement is the core bottleneck restricting the reliability of acceptance quantity calculation. Unlike homogeneous solid materials, coal bulk piles belong to heterogeneous granular loose accumulation materials, with complex internal structures including different particle size grades, intergranular voids, surface attached water and internal free water, and uneven compaction formed by stacking gravity and mechanical rolling [2]. Under the combined action of raw coal quality differences, open-air storage environment, artificial sampling operation differences and inconsistent measurement specifications, the measured bulk density value often deviates greatly from the real average bulk density of the whole coal pile. Many power plant acceptance personnel still adopt fixed empirical bulk density values

for long-term settlement calculation in daily work, without timely on-site measurement according to the actual state of coal piles. This further widens the gap between accounting quantity and actual coal stock. It results in long-term unaccountable inventory differences in coal yards [3].

From the perspective of domestic and foreign research status, existing relevant studies mostly focus on single-factor test analysis of coal bulk density. These include the influence of particle size composition on bulk density, the correction method of moisture on bulk density test data, and the accuracy comparison of different measuring containers [4-6]. Some overseas scholars apply unmanned aerial vehicle (UAV) remote sensing, light detection and ranging (LiDAR) point cloud scanning and three-dimensional modeling technology to optimize the measurement accuracy of coal pile volume and quantitatively analyze the error sources of stockpile volume modeling. Domestic researchers have also formed a set of standardized operation specifications for coal sampling and bulk density testing combined with national coal quality inspection standards [7,8]. However, most existing literature separates bulk density

measurement error analysis from coal acceptance quantity settlement, and lacks systematic research on the whole chain deviation transmission mechanism from sampling, testing, volume measurement to final quantity accounting. Few studies combine the actual operation scenarios of thermal power plant open-air coal yards to summarize targeted closed-loop control schemes for the whole acceptance process. There is insufficient research on how to transform empirical approximate measurement into standardized refined metering management to eliminate cumulative calculation deviations.

Against the background of the current national energy cost control policy and the standardized management requirements of coal-fired power fuel procurement, it is urgent to sort out all types of deviation sources in the whole process of coal bulk density measurement and acceptance quantity calculation. It is also necessary to clarify the internal correlation between various influencing factors and settlement errors. Furthermore, operable standardized measurement and data correction schemes applicable to power plant on-site acceptance should be formed. Based on the on-site acceptance data

and operation experience of Anhui Huadian Lu'an Power Plant's coal yard, this paper systematically analyzes the influence mechanism of coal stacking state, sampling mode, environmental humidity and operation specifications on bulk density test results. It sorts out the generation logic of measurement and calculation deviations in each link. It also puts forward targeted deviation correction methods and full-process standardized measurement optimization strategies. The research results can provide reference for thermal power enterprises to standardize coal acceptance metering work. They can also help reduce economic disputes caused by quantity deviation. Moreover, they enable the realization of fine management of coal inventory. In addition, they can provide theoretical support for the formulation of more detailed on-site bulk density measurement operation standards for industrial coal acceptance. The overall structure of this paper is arranged as follows. The first part analyzes the influence of measurement conditions on the accuracy of acceptance calculation. The second part expounds the source of measurement deviation and supporting calculation correction methods. The third part optimizes the standardized measurement process in acceptance accounting. The last part summarizes the full text and puts forward long-term management suggestions for coal bulk density measurement and acceptance control.

Impact of coal bulk density measurement conditions on acceptance calculation accuracy

The measurement conditions for coal bulk density directly determine the reliability of volume-to-mass conversion. Coal piles are not homogeneous materials but rather a dispersed system composed of particles of varying sizes, pore spaces, adhered moisture, and localized compacted layers. Bulk density indicates the mass of coal per unit volume; its measurement results are influenced by factors such as coal type composition, particle size distribution, gangue content, surface moisture, and storage duration. Higher proportions of lump coal increase interparticle voids, potentially reducing specific volume mass; increased amounts of fines and pulverized coal fill pores, enhancing bulk density. Variations in moisture content also affect coal quality and particle adhesion characteristics, leading to differing bulk density values for the same pile under different conditions. Using fixed empirical values for

acceptance calculations may result in significant deviations from actual measurements.

The stacking method significantly impacts the accuracy of bulk density measurement. During coal handling, discharge, transportation, and storage, varying degrees of compaction occur due to elevation differences, mechanical compaction, natural settlement, and slope sliding, resulting in distinct compacted zones. The bottom layer is subjected to higher pressure from upper layers and exhibits greater compaction, whereas the top and edge regions experience lower stress and consequently have relatively higher porosity. If measurement points are concentrated in the surface layer or near slopes, the obtained data cannot accurately represent the overall condition of the pile. Irregular pile shapes also affect volume calculation; particularly when using manual measurements or simplified geometric models, errors in boundary identification, slope angle estimation, and height measurement directly impact the quantitative results [9].

The measurement environment and operational specifications are equally critical to the accuracy of acceptance verification. Open-air coal yards are subject to rainfall, evaporation, wind erosion, and temperature fluctuations, leading to inconsistent moisture distribution between the surface layer and interior of coal piles; variations in sampling timing can cause variability in test results. Without unified standards for sampling equipment specifications, sampling depth, sample storage, weighing calibration, and data recording methods, bulk density measurements are prone to systematic errors. During acceptance procedures, bulk density data is typically used for inventory counts, handover measurements, and settlement verifications; failure to control measurement conditions makes it difficult to ensure traceability of verification results. Enhancing acceptance accuracy requires integrating coal quality characteristics, storage configuration, measurement point placement, and testing protocols into a unified control system, ensuring that bulk density measurements accurately reflect the overall properties of the coal pile.

Sources of deviation in coal bulk density measurement and calculation correction methods

Deviations in coal bulk density measurement primarily

stem from insufficient sample representativeness, distortion of measurement parameters, and inconsistent data processing methods. Acceptance verification relies on the correlation between bulk density and bulk volume. However, particle distribution within coal piles exhibits significant heterogeneity. This makes single measurement points or limited samples inadequate for covering varying compaction levels, particle size ranges, and moisture content zones. Sampling at surface layers, slopes, or material discharge areas often yields localized bulk density readings that fail to reflect overall storage conditions. Measurement instrument limitations - including capacity, weighing accuracy, sampling methods, and leveling procedures - can also introduce deviations, particularly when boundaries between loose and compacted densities are ambiguous, leading to variability due to operator differences. Such deviations directly alter quality conversion results during acceptance verification, creating discrepancies between recorded quantities and actual inventory levels.

Calculation deviations are also closely related to moisture correction, ash content variations, and volume boundary determination. During coal storage, moisture migration occurs surface moisture evaporates rapidly while internal moisture remains relatively stable; localized water accumulation or post-rain infiltration can alter the sample's mass composition. If bulk density measurements do not simultaneously account for total moisture content, calculation results may incorporate quality fluctuations caused by moisture changes, leading to unclear distinctions between dry basis mass and received basis mass [10]. Regarding volume measurement, irregular stack boundaries, slope collapse, mechanical shaping marks, and residual coal at the bottom all affect measurement accuracy. Using approximate geometric models simplifies local irregularities, further amplifying conversion errors. These deviations do not originate from a single parameter but accumulate progressively through interactions among density, volume, moisture content, and weighing processes.

To address measurement deviations, a calculation and correction methodology should be established centered on zonal sampling, parameter calibration, and cross-verification. During sampling, areas should be divided into top, middle, bottom, and edge zones based

on coal pile morphology, with samples collected using grid or layered sampling methods to minimize the impact of local outliers on overall results. Bulk density data should be calculated as a weighted average of multiple measurements, with correction factors adjusted according to coal type, particle size distribution, and storage duration. Moisture testing should be conducted concurrently with bulk density measurement, with separate records kept for moisture content on a wet basis, air-dried basis, and dry basis to prevent confusion in calculation criteria. Volume calculations should be validated using field survey data, site boundary verification, and historical inventory records, with secondary measurements performed for values exceeding permissible error limits. Through controlled measurement conditions, exclusion of anomalous data, and multi-parameter coordinated corrections, quantity verification can transition from empirical estimation to standardized validation, enhancing result accuracy and traceability.

Optimization of the application of standardized measurement procedures in acceptance quantity calculation

The primary focus of applying standardized measurement processes is to shift acceptance quantity calculations from empirical judgment to process control. The coal handling stages - including intake, storage, inventory counting, and handover - should form a continuous measurement chain with clearly defined measurement objects, timing, parameters, and accountability. Prior to bulk density determination, the coal pile's condition must be verified, covering batch type, storage duration, loading or unloading methods, moisture variation, and potential coal blending, to prevent using a single parameter for mixed materials. Field measurements should follow unified operating procedures, specifying limits on sampling container volume, weighing equipment accuracy, sample loading methods, leveling standards, and recording formats to ensure comparability across measurements. The essence of process standardization lies not in adding operational steps, but in minimizing the impact of human judgment variability on calculation results.

In quantity accounting for acceptance purposes, the standardized process must emphasize closed-loop data management. Bulk density measurement results should

not be used in isolation but require cross-verification with volume mapping, coal quality testing, weighing records, and inventory ledgers. If significant discrepancies exist between bulk density conversion values and measurements obtained from rail scales, truck scales, or belt scales, deviation sources must be identified through re-measurement, re-sample collection, and review procedures. Data processing should establish permissible error ranges, marking abnormal high/low values or those significantly deviating from historical ranges to prevent unverified individual results from entering the settlement phase. Accounting forms must retain original measurement points, sample numbers, testing dates, personnel involved, and calculation processes to ensure traceability of acceptance outcomes. This closed-loop approach enables measurement errors to be controlled within identifiable, explainable, and correctable limits.

The optimization of standardized measurement processes requires dynamic adjustments tailored to specific acceptance scenarios. For coal yards with regular stacking patterns, stable coal grades, and low inventory turnover rates, a combination of periodic measurements and sampling verification should be employed to enhance efficiency. For yards with frequent batch changes, significant moisture fluctuations, or complex stacking configurations, measurement point density must be increased and intervals shortened. Digital tools can improve process quality: Three-dimensional (3D) scanning measures stack volume, electronic ledgers record measurement data, and automated systems generate calculation results, reducing errors caused by manual entry and redundant calculations. Once standardized procedures are implemented, quantity verification follows a structured management workflow of "on-site measurement - data validation - deviation correction - result confirmation", ensuring more consistent, transparent, and verifiable coal transfer measurements [11].

Conclusion

Coal bulk density measurement directly impacts the quantity verification during acceptance processes. Measurement conditions, sampling representativeness, data correction methods, and procedural standards all influence the final calculation results. Identifying source of deviations, optimizing zoned sampling, conducting

simultaneous moisture testing, strengthening volume verification, and establishing a closed-loop data management system can effectively reduce measurement errors and enhance the accuracy and traceability of acceptance outcomes. Coal handover management should incorporate bulk density measurement into standardized control systems, facilitating a shift from empirical judgment to refined, standardized management practices in acceptance verification.

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Conflicts of Interest

The author declares no conflict of interest.

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