Journal of Innovation and Development
ISSN: 2958-4752 | Vol. 10, No. 2, 2025

A Brief Discussion on Several Considerations Affecting the Accuracy of Crude Oil Trade Handover Measurement

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Abstract: The precision of crude oil trade handover measurements is of paramount importance, as inaccuracies can result in substantial financial losses for the trading parties. It is therefore imperative to maintain high standards in trade handover measurement processes. This paper provides a comprehensive analysis of the factors that can lead to errors in such measurements and advances viable strategies to mitigate these errors, thereby ensuring the economic viability of the transactions for both parties.

Keywords: Crude oil trade handover; Measurement outcomes; Discrepancies; Contributing factors.

1. Introduction

As China's economy continues to expand, domestic enterprises are increasingly aware of the importance of energy issues in their pursuit of improved operational efficiency and cost reduction [1-6]. The trade of crude oil is a critical element in China's energy sector, instrumental in propelling both social economic growth and corporate advancement. In the context of the market economy, profits from crude oil trade are primarily derived from the price differentials in energy transactions, directly impacting corporate revenues. To safeguard the interests of trading companies, it is imperative to strengthen the scientific and regulatory aspects of crude oil trade handover measurements. For companies engaged in crude oil trade, the ongoing refinement of their measurement systems and the minimization of errors represent a key developmental priority [1, 2-7].

In any measurement activity, errors are an unavoidable aspect, often resulting from a multitude of factors. Given the high priority assigned to economic efficiency by companies, the reduction of errors in crude oil handover measurements is of paramount importance for enhancing accuracy. The primary contributors to measurement errors in crude oil are human involvement, environmental factors, equipment, and methodology. A review of recent measurement inaccuracies indicates that the error rate in crude oil measurements stands at around 1.7%, which is in excess of the internationally accepted standard of ±0.35%. To maintain errors within permissible limits, it is imperative to comply with national standards and pertinent regulations, synthesize practical operational experience, and implement focused enhancements. Key strategies involve augmenting the competencies of supervision and management staff to curtail human-induced errors, advancing the precision of measurement equipment and technology to guarantee dependable operations, and continually refining operational protocols and standards to ensure that measurement practices are both standardized and rational [5-10].

2. Contributory Factors to Discrepancies in Crude Oil Trade Handover Measurement Systems

2.1 Discrepancies in Flow Meter Measurements

The positive displacement flow meter, known for its high precision, is the predominant type utilized in contemporary crude oil trade. However, the accuracy of this device is susceptible to numerous influences during operation. For instance, a discrepancy of more than 0.05mm between the meter's casing and internal cavity can result in oil seeping through the gap during actual fluid flow, thereby inducing measurement discrepancies. To mitigate such errors, it is imperative to conduct calibration of the flow meter in accordance with pertinent standards and regulations prior to crude oil handover, ensuring that the resultant errors are kept within acceptable parameters [11].

Moreover, the positive displacement flow meters employed in crude oil handovers are prone to a frequently overlooked issue of backflow. The quantity of backflow in a specific flow meter is dictated by several factors, including the viscosity of the fluid, the meter's own construction, and the propensity for wax accumulation. Consequently, flow meters designated for crude oil handovers require calibration on a biannual basis. For meters that have been operational over a period, the pattern of wax accumulation tends to stabilize, with minimal variation in wax accumulation for crudes with low wax content. However, viscosity is profoundly influenced by temperature fluctuations; higher temperatures correspond to lower oil viscosities and, consequently, increased backflow in the flow meter, culminating in an inflated estimation of oil volume. In scenarios where the temperature differential between two crude oil sales exceeds 10°C, the measurement error attributable to viscosity variations can be pronounced. Thus, beyond the errors emanating from the flow meter's intrinsic precision, it is crucial to account for the temperature-induced alterations in oil viscosity and the concomitant measurement errors. If the calibrated volume reading of the flow meter is underestimated, elevating the sales temperature will augment backflow, thereby increasing the measured volume and diminishing the measurement error; conversely, a decrease in temperature will amplify the measurement error [12].

2.2 Discrepancies in Sampling Operations

In the crude oil handover procedure, the water content and density of the crude oil are critical parameters, the analysis of which is regulated by national standards. Nonetheless, the fundamental condition for accurate testing is that the oil samples must be representative of the overall condition of the oil being transferred. Any deviation from this can render the testing futile and result in substantial measurement errors. Consequently, the processes of sampling, storage, and analysis of oil samples are of paramount importance. Despite this, there is a widespread issue of insufficient attention being paid to sampling, largely attributed to the limited adoption and high costs associated with automated sampling equipment, which is also known for its high energy consumption. The reliance on manual sampling methods introduces greater errors that are more challenging to control, primarily due to human factors. The responsibility of operators and delays in analyzing samples can compromise the representativeness of the samples, leading to inaccuracies in measured water content and density, and potentially causing unwarranted financial losses for the parties involved in the oil handover. Therefore, ensuring the representativeness of samples is critical. During crude oil measurement handovers, it is standard practice for all three parties to be present during the sampling process: the first party operates, the second party supervises, and the third party oversees. In instances of disagreements, it is imperative to re-sample promptly [2, 4].

To minimize sampling errors, it is crucial to emphasize the importance of dynamic control in actual crude oil trade transactions. Samples should be selected from the outlet of the outgoing flow meter to ensure their representativeness. Moreover, it is necessary to measure parameters such as water content and density for these samples. When manual sampling is employed, errors can arise due to the operator's level of technical expertise or their experience. Thus, the use of automated samplers is recommended for achieving greater accuracy and consistency in sampling results [5].

2.3 Discrepancies in Water Content Measurements

To ensure the precision of water content measurements, the following measures are required: First, the receiver must undergo calibration every six months. If the calibration result exceeds 0.025mL, it must be replaced, and previous measurement results should be re-evaluated. All equipment used in the measurement process should be dried to prevent the adverse effects of external moisture on crude oil water content measurements. Second, during the weighing of crude oil samples, the precision should be maintained within 0.1g. When assembling the instrument, it is crucial to ensure that both liquid and vapor can be sealed in an environment. Attention should also be paid to the water loss caused by boiling, so heating should be conducted slowly in practice. The condensate in the condenser should not exceed 3/4 of the total pipe length. During condensation, the collection should be done at a rate of 2~5 drops per second. If there is no change in the volume of water within five minutes, heating should be stopped immediately, and appropriate measures should be taken for rinsing to ensure that all water is collected in the receiver. Third, after collecting all the water and allowing the temperature to drop, the volume of all collected water should be marked [1-3].

2.4 Discrepancies in Crude Oil Density Measurements

The density of crude oil is determined from samples collected at the outlet of the export flow meter and subsequently measured using analytical methods in a laboratory setting. The current methodology employed is the density meter method, in accordance with the GB/T 1884-80 standard, "Determination of Density of Petroleum and Liquid Products (Density Meter Method)". The potential sources of error in this method include instrumental inaccuracies, procedural measurement errors, and reading discrepancies [7, 11].

In practice, a density meter with a minimum division value of 0.0005g/cm3 is typically utilized, which has been calibrated by a provincial metrology authority and provided with a correction value. The thermometer employed should be a full-immersion mercury type with a minimum division value of 0.2℃ and a maximum scale error of ±0.15%. When the properties of the crude oil sample necessitate density measurement at temperatures other than room temperature, a constant temperature bath is employed to maintain the sample's temperature within a variation of 0.5℃, thereby mitigating the impact of temperature fluctuations on measurement results.

During the density measurement process, it is imperative to minimize human-induced errors. The petroleum density meter should be handled with care, gently pressed down by approximately two divisions, and then released to ensure it promptly returns to its original position. Once the meter reaches a state of static equilibrium, the density of the crude oil is read from the point where the curved edge of the sample aligns with the scale of the density meter, with a precision of 0.0001g/cm^3. The measurement should be replicated twice, and the disparity between the two density values should not exceed 0.0005g/cm^3; otherwise, the test should be repeated. Under stringent management and adherence to standard operating procedures, the uncertainty of density measurement can be maintained within 0.125% [2, 5, 9].

2.5 Influencing Factors of Light Hydrocarbon Components

Crude oil stabilization represents a continuation of conventional oil and gas separation, playing a pivotal role in the gathering and transportation of oil and gas, as well as in reducing crude oil evaporation losses and minimizing oil and gas losses. It is widely accepted that components below C3, due to their high volatility and substantial losses, can introduce measurement errors and should be removed to the extent possible. However, C6, being a constituent of gasoline, is not favored to be removed in large quantities by refining companies, typically limiting its removal rate to within 5% of its content in the crude oil [1-4].

The primary processes for crude oil stabilization include micro-positive pressure distillation and vacuum flash distillation. In the micro-positive pressure distillation process, the crude oil is heated to a higher temperature (＞120℃), resulting in superior stabilization. Conversely, the vacuum flash distillation process involves lower crude oil temperatures (＜80℃), leading to inferior stabilization. Both processes have their respective advantages and disadvantages;

the distillation process offers better stabilization but at a higher cost, whereas the flash distillation process is less costly but less effective. A balance must be struck between investment and output, taking into account environmental and social factors. Currently, vacuum flash distillation is more commonly employed, leading to the main issue of insufficient crude oil stabilization and a higher content of light components [2, 10].

Insufficient crude oil stabilization and a higher content of light components can lead to the release of dissolved gases into free gases during pipeline bends, elevation changes, throttling, or temperature increases of the crude oil. These gases occupy a certain volume in the pipeline and, when they enter the flow meter with the oil flow, the flow meter measures them as part of the crude oil volume. Even with a highly accurate flow meter, this results in incorrect measurement of the actual crude oil volume. Therefore, to remove these gases, a deaerator is typically installed in front of the flow meter to reduce the impact of gases on measurement accuracy. However, the current use of deaerators is not ideal, with issues in management, inspection, and calibration. A more significant problem is that some deaerators used for custody transfer measurement are merely for show and do not function effectively. If the deaerator of a flow meter fails or is ineffective, the flow meter's rotational speed increases, causing the measured value to be greater than the actual oil volume, leading to corresponding errors in the calculated crude oil volume.

Overall, the better the crude oil stabilization, the lower the light component content, the less likely there is to be measurement errors, and the better the crude oil quality can be ensured. A high content of light components can easily volatilize during the loading, transportation, and unloading of crude oil, increasing oil losses, wasting resources, and causing environmental pollution [6, 12].

3. Key Strategies for Enhancing the Precision of Crude Oil Trade Handover Measurement

3.1 Implementing a Routine Self-Inspection Protocol for Crude Oil Pipeline Transmission Measurement Instruments

The terminal station of the crude oil pipeline should employ large-bore scraper flow meters for real-time handover measurement of pipeline crude oil, thereby eliminating the influence of human factors inherent in the previous manual measurement methods. Additionally, the adoption of the standard volume tube real liquid online calibration method addresses the limitation of the offline calibration method, which fails to replicate actual operating conditions. This approach significantly enhances the level of handover measurement technology, improves the accuracy of handover, and eliminates the need for disassembly and inspection, thereby reducing the labor intensity of employees.

In accordance with the calibration procedure regulations, the calibration period for scraper flow meters is six months. During this period, the scraper within the flow meter is in constant operation, and due to wear, the gap increases, causing a continuous decrease in the accuracy of the flow meter until it is calibrated after six months. Given the significant impact of crude oil transportation on the economic interests of petroleum companies, it is imperative to increase the frequency of online calibrations and shorten the self-inspection cycle to minimize the original loss cost caused by measurement discrepancies.

3.2 Improving Flow Meter Selection and Management of Environmental Variables

When measuring the density of crude oil, it is imperative to employ a density meter of higher precision. To ensure measurement accuracy, the density meter must be submitted to a provincial-level or higher metrological verification department for professional calibration prior to use, thereby preventing measurement errors attributable to insufficient precision of the density meter. A full-immersion mercury thermometer should be utilized, with its maximum scale error maintained within 0.15%.

When measuring the density value of crude oil, the sample temperature should be controlled as closely as possible to the actual transmission temperature, with a temperature difference not exceeding 2°C. If, within this temperature range, the crude oil cannot be ensured to have sufficient fluidity, further heating is required until the crude oil has adequate fluidity. Under these temperature conditions, the crude oil can flow and float freely.

3.3 Improving the Efficiency of Crude Oil Stabilization

When considering measurement errors alone, the higher the degree of crude oil stabilization, the smaller the measurement errors caused by light hydrocarbon gases. If a vacuum flash distillation process is employed, improving process parameters and optimizing the process flow, such as increasing the crude oil temperature, enhancing the stripping process and stripping volume, can also improve the stabilization effect to some extent, thereby reducing the measurement errors caused by free gases. At the same time, it ensures the quality of the transferred crude oil: fully extracting components below C3 to reduce the loss during storage and transportation due to oil and gas volatilization, as well as resource wastage and environmental pollution; and controlling the extraction rate of C6 components within the required range to ensure the profitability of refining companies. It is particularly noteworthy that in recent years, due to policy factors, the production units of crude oil and the sales of crude oil stabilization extraction have been separated, and the extraction amount is not included in the production output, which seriously affects the enthusiasm of crude oil production units, resulting in the inability of many crude oil stabilization devices to operate normally. Policies should be actively adjusted to mobilize the enthusiasm of crude oil production units, fully utilize the crude oil stabilization devices, and thus ensure crude oil quality and reduce measurement errors.

Ensuring that the deaerator functions properly allows for the elimination of free gases in the pipeline before they enter the flow meter, reducing the measurement errors caused by gases and ensuring the accuracy of the flow meter.

3.4 Enhancing the Training and Management of Measurement Operators

The training of measurement personnel is essential to adapt to the evolving standards of measurement, the adoption of new methodologies, advancements in measurement technology, and the enhancement of the measurement and testing system. These developments necessitate that measurement personnel update their conceptual frameworks, refine their knowledge structures, and bolster their professional competencies. Consequently, the establishment of a team of measurement personnel characterized by high technical proficiency, experience, and expertise is a crucial step in minimizing measurement errors.

4. Summary

In conclusion, the occurrence of errors in crude oil trade handover measurement is influenced by numerous factors. Practical research indicates that the primary sources of errors are flow measurement inaccuracies, sampling errors, water content measurement discrepancies, and crude oil density errors. To effectively minimize these errors, it is essential to conduct thorough and meticulous analysis of their causes, leverage technological advancements to enhance the precision of measurement equipment, establish comprehensive measurement standards, and implement stringent control measures at each stage that impacts accuracy. This approach will enable companies to achieve favorable economic benefits and maintain a positive market reputation.

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