Analytical Studies of Variations in the Quantities of Petroleum Products during Internal Transfers in a Storage Plant in Côte d'Ivoire

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***Abstract*—This study has been leaded to find the causes of the deviation rates beyond the tolerance. For this study, the mastery of the transfer system was decisive for the resolution of easily identifiable problems and for our guidance in the choice of methods for identifying complex problems. The methods used for this study were the graphical representation method and the ISHIKAWA diagram. The graphical representation of deviation rate (over the period of April to August) enabled us to view 35% discrepancy rates beyond the tolerance limits for the SSP and 20% for GO. Through the ISHIKAWA diagram, we highlighted the root causes of gaps in general and organized these causes into two categories that are the physical gaps and fictive gaps. The estimation of these causes has shown that errors in the temperature measurement are the source of 80% of gap rates beyond tolerance limits and 20% are divided between technical gauging errors and physical gaps (not significant). Solutions have been thereafter proposed to minimize the amount of product gaps during transfers.**

***Index Terms*—Gap, gap rate, oil products, transfer**

I. Introduction

The main objective of an oil terminal is to protect the country holding it from any form of energy shortage in terms of hydrocarbons for at least three months. It is to this end that the State of Côte d'Ivoire thought of setting up a petroleum products storage company [1–2]. For its daily loading activities (tank wagons and tank trucks), the operators of the oil terminal carry out transfers of petroleum products from a storage tank to an operating tank. At the end of these transfers, reports showing the status of the new parameters of the recipient and sender tray are published. On these reports, it can be seen that the quantity of product received is always different from the quantity of product taken out for a given transfer. To this end, a tolerance margin (0.3%) has been set for the management and control of these differences [3–4]. But it has been found that for transfers made under the same conditions as so many others, this margin of tolerance is largely exceeded. Faced with this worrying situation, a series of questions emerge: what are the real causes behind the differences between the quantity of product released and that received? What can justify deviation rates above the set tolerance margin? Are there any solutions to minimize these differences? All of these questions led to the following problem: "what are the reasons for the differences between the quantities of petroleum products received by the receiving tank and those taken out of the shipping tank during transfers?". The objective of this study is to find the causes of deviations in the quantities of petroleum products beyond the tolerance margin in order to minimize them.

II. Materials and Methods

A. Materials

Several materials were used in the realization of this study. These include gauging sheets, transfer sheets, ASTM tables (American Society for Testing Material), gauging tools. This equipment made it possible to carry out analyzes of the various parameters sought.

B. Methodology

The choice of our study fell on transfers of super unleaded (SSP) and diesel (GO). In fact, the depot has five GO bins and four SSP bins. Transfers within the plant generally take place from storage bins to operating bins and a few times between storage bins.

1) Study of transfer circuits

The study of the transfer system consisted in collecting information at the level of the transfer circuits (lines and ferries of GO and SSP). This work lasted five days. The control took place two times a day in the following time intervals 08:00–12:00 and 14:00–16:00. Observation of the system was immediately accompanied by sampling at different levels of leaks. It was carried out over five days using a $1L$ sampler. The purpose of this intake was to quantify the product flow per hour.

2) Method of investigation

a) Graphic representation

The graphical representation of the deviation rates observed will be made using the statgraphics X64 software. The control limits are defined by the tolerance margin set by the structure [5]. They are distributed as follows: VC = 0%, TI = −0.3% and TS = +0.3% with: VC: Central value; TI: Lower tolerance; TS: Upper tolerance.

With this graphical representation, the system will be said to be in control if and only if all the transfer rates are within the defined tolerance limits.

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b) Application of the ISHIKAWA diagram in the search for the causes of discrepancies

The construction of the ISHIKAWA diagram was carried out following a brainstorming which took place through interviews and direct observations. On the ISHIKAWA diagram is represented all the causes generating deviations (in general) during the transfer of petroleum product within the depot. These causes are categorized according to the 5M (equipment; method; labor; environment and matter) [6]. The analysis of the results obtained with the ISHIKAWA method made it possible to introduce the notion of physical difference and fictitious difference. Physical spreads are all spreads related to actual losses. They are materialized by evaporations; tank leaks or overflows. While, the fictitious deviations are all the deviations that are not real, caused by errors in taking the parameters of the bins after the transfer. The causes obtained were therefore distributed between these two gap categories in order to estimate the impact of each category on transfer gaps.

III. Results

A. Transfer System Diagnosis

This operation highlighted sealing problems at the seals at the inlet and outlet of tank C31 as well as at the outlet of tank B21; at outlet valve B33; at the level of the B14 purge and a defective sleeve (2 holes on the sleeve) in the bowl B2. The average of the flows taken during the five days is recorded in Table I.

TABLE I: Product Flow Rates through Leaky Areas

Seals	Average product flow rates (L/h)
Outlet valveB33	0.5
Purge B14	2
Outlet seal B21	2
Entrance seal C31	8
Outlet seal C31	9
Bowl sleeve hole B2	27

Under the influence of heat, the product expands in the line and leaks through leaky joints and valves. These leaks were estimated between 4.5 L and 81 L per day due to a flow of nine hours (09 h to 18 h) per day. The consequence of these leaks on the deviations turns out to be unrepresentative (negligible) compared to the deviations observed, but the correction of these anomalies was necessary for environmental reasons. In order to eliminate the reasons for leaks at the origin of discrepancies during transfers, in the rest of this study, all of these problems and proposed solutions were submitted to the managers of the depot.

B. Graphical Representation of Deviation Rates

The deviations taken into account are the deviations generated by the volumes reduced to the volumes at 15°C. We notice:

- $V15r$: Volume at 15°C of the product received by tank bj;
- $V15e$: Volume at 15°C of the product shipped by tray bi;
- r: Deviation rate;
- bi; bj: Bin number;
- bi/bj: bi transferred product to bj.

On 20 GO and SSP transfers; a total discrepancy of –179,550 L for GO and 38,025 L for SSP is recorded, corresponding respectively to a total discrepancy rate of –3.10% and 1.94%. These quantities are equivalent on average to 8978 L of GO lost per transfer, with a standard deviation of 10802 L. And on average to 1901 L of SSP gained per transfer, associated with a standard deviation of 27672 L. These deviation rates are represented graphically on Figs. 1 and 2 in order to better appreciate the deviations beyond the control limits.

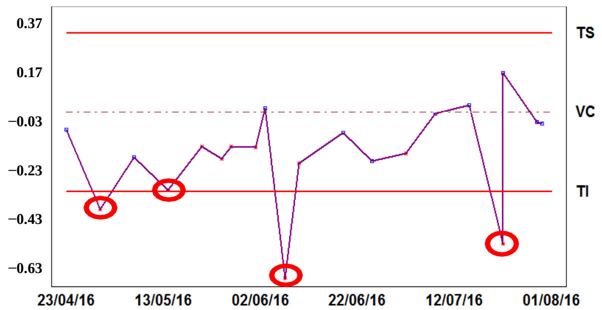

Fig. 1. Graphical representation of deviation rates for GO transfers.

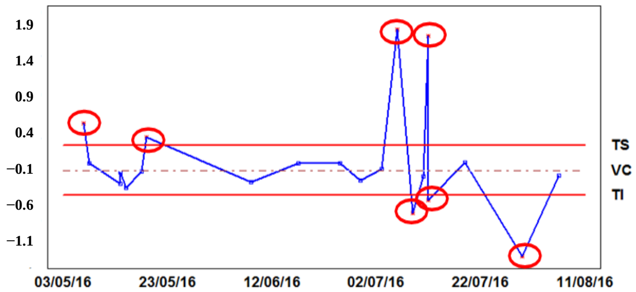

Fig. 2. Graphic representation of deviation rates for PHC transfers.

It appears that out of 20 samples collected (GO, SSP), four transfers are outside the tolerance limits for GO and seven transfers for SSP, i.e., a rate of 20% and 35% respectively. These deviation rates beyond the control limits show that the product quantity transfer system is not under control

C. ISHIKAWA Diagram of the Causes of Deviations

The ISHIKAWA diagram representing the causes generating deviations during petroleum product transfers is given in Fig. 3.

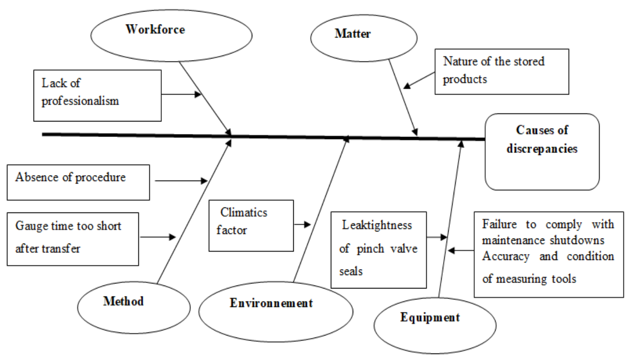

Fig. 3. Diagram of the causes of discrepancies in internal transfers.

The analysis of the results obtained with the ISHIKAWA method made it possible to introduce the notion of physical difference and fictitious difference. Physical spreads are all spreads related to actual losses. They are materialized by evaporations; tank leaks or overflows. While, the fictitious deviations are all the deviations that are not real, caused by errors in taking the parameters of the bins after the transfer. The causes obtained were therefore distributed between these two gap categories in order to estimate the impact of each category on transfer gaps.

D. *Estimation of Transfer Gaps*

1) *Physical deviations*

- Leaks

The product leaks observed during transfers are estimated at 0.5 L/h per leaky area. The quantity of product lost at these different levels depends on the duration of the transfer.

- Evaporation

The total emission (ET) is the sum of the emissions by breathing (ER) and by movement (EM). The average estimates of annual emissions reduced to daily emissions (liter per day (L/j)) of the GO and SSP tanks of the depot are recorded in Tables II and III. These emissions were evaluated using the TANKS software version 4.0.9d.

TABLE II: GO TANK EVAPORATION

	B14	B17	B21	B33
E_R (L/j)	4.14	4.13	5.51	5.75
E_M $(L./j)$	16.36	16.36	31.45	31.45
E_T (L/j)	20.5	20.49	36.96	37.20

TABLE III: SSP PAN EVAPORATION

	C12	C21	C22	C24	C31
E_R (L/j)	19.87	37.63	49.59	51.11	54.97
E_M (L/j)	81.62	17.45	47	38.81	53.69
E_T (L/j)	101.49	55.08	96.59	89.91	108.66

Emissions per movement are estimated to average 47.71L/j for GO bins and at 23.91 L/j for those in the SSP. The average total bin emissions are estimated at 90.35 L/j for the GO and at 28.79 L/j for the SSP. During a transfer lasting 24 hours, the average difference generated by evaporation is of the order of 90.35 L for the GO and of the order of 23.91 L for the SSP.

- Operation

Gauging and sampling activities promote the release of vapors formed by gauge orifices. It can be seen from Tables II and III that the vapors formed by respiration are on average estimated at 42.63 L/j for the GO and at 4.88 L/j for the SSP. The quantities of steam escaped during these activities are a function of the duration of the opening of the valves.

2) *Fictitious spreads*

- Accuracy of measurements

The accuracy of the tape-weight assembly is a class II accuracy tolerance (Table IV).

TABLE IV: TAPE-CARROT UNCERTAINTY

Tape-carrot uncertainty given by the instruction manual		
10 ± 2.3 mm	20 ± 4.3 mm	30 ± 6.3 mm

The absolute error (Δh) made with the scale tables (gauging certificate) is:

Δh = 2 × 3. 10 − 3m Let Δh = 6. 10 − 3m = 6 mm

The formula for the product height will therefore be noted:

$HP = HT - plongée + carotte \pm \Delta$

Δ1= 2.3 + Δh = 8.3 IF DIVING ≤ 10 m

With | Δ2= 4.3 + Δh = 10.3 IF DIVING ≥ 10 m

- Volume at room temperature and uncertainty

The error made on average, with the gauge instruments and the gauge scale, on the volume at ambient temperature is shown in Tables V and VI.

TABLE V: UNCERTAINTY ON THE VOLUME AT ROOM TEMPERATURE OF SSP TANKS

N° bac	B14	B17	B21	B33
VM (L/mm)	1019.6	1019.7	2293.1	2289.1
ΔV_{a1} (L)	8463	8463	19,033	18,999
ΔV_{a2} (L)	87,166	87,174	196,037	195,695

TABLE VI: UNCERTAINTY ON THE VOLUME AT ROOM TEMPERATURE OF GO BINS

N° bac	C12	C21	C22	C24	C31
V_M (L/mm)	1019.5	2292.4	2291.6	2293.9	2296
ΔV_{a1} (L)	8462	19,027	19,020	19,039	19,057
ΔV_{a2} (L)	87,157	195,977	195,909	196,105	196285

- VM: average volume per millimeter of the tank;
- ΔVa_1: Uncertainty on the volume at room temperature with Δ1;
- ΔVa_2: Uncertainty on the volume at room temperature with Δ2.

IV. PROPOSAL OF IMPROVEMENT SOLUTIONS

To achieve all of these objectives, we recommend setting up a team responsible for the annual determination of total emissions, monitoring the quality of its facilities (conditions of tanks, pipeline) and monitoring the reliability of automatic equipment (flow meter, automatic gauge equipment) during installation and to ensure compliance with the hygiene and environment code within the company.

The implementation of a (regularly controlled) system for managing the quality of tank paints will contribute to a 20% reduction in current total annual emissions. These total emissions will therefore increase from an annual average of 32,978 L to 26,382 L for GO bins (fixed roof bin) and from 10,509 L to 8407 L for SSP bins (fixed roof bin equipped with an internal floating screen).

The values of the company's annual emissions associated with actions to control these emissions as well as compliance with the hygiene and environment code will enable the company to participate actively in the sustainable development process.

The gauging of the tanks before or after the transfer must be done using the carrot tape and the gauge bar. The use of the bar in the gauging of the tanks allows a greater precision of the measurements carried out. Indeed, this instrument ensures perpendicularity between the tape and the reference plate which minimizes reading errors.

After the transfer, observe at least one hour of time, for the stabilization of the product in the reception tank, before proceeding to the gauging of the tank.

Bulk operating agents must take part in training sessions to help them better understand the secrets of their trade and to be more efficient in the performance of their duties. These training courses must have as their theme the understanding of: the notions of uncertainties and measurement errors, their roles in the generation of deviations and the means for reducing the deviations resulting from these concepts; the role of temperature in generating fictitious deviations when converting from ambient volume to volume at 15°C; knowledge of the health risks associated with the handling of petroleum products and the behavior to adopt to control these risks.

V. Economic Study

The application of the proposed solutions, especially those concerning the real differences, will thus allow a significant reduction in losses by evaporation and by gauging and sampling activities. Economically, there will be a gain of around five million CFA francs per year (considering that a liter of petroleum products is 590 CFA francs), just for a GO or SSP ferry. So that is 45 million CFA francs per year for the nine (09) ferries (GO and SSP). From an environmental point of view, this action will allow the structure to play an active part in the reduction of greenhouse gases.

VI. Discussion

This study showed that, out of 20 samples collected (GO, SSP), four transfers are outside the tolerance limits for GO and seven transfers for SSP, i.e., a rate of 20% and 35% respectively. These deviation rates beyond the control limits show that the product quantity transfer system is not under control. These results are consistent with those of [7, 8] who showed using a map of averages that operating deviations of quantities of petroleum products are outside the control limits and the variation model is non-random, which shows that the process is not mastered hence the existence of special or assignable causes. The average total bin emissions are estimated at 90.35 L/j for the GO and at 28.79 L/j for the SSP. During a transfer lasting 24 hours, the average difference generated by evaporation is of the order of 90.35 L for the GO and of the order of 23.91 L for the SSP. These results support those of the work of [9–11] who concludes that the total emission is 1610.96 pounds (lbs). This corresponds to an annual mass loss (Mp) of Mp = 730.72 kg in tank R1, i.e., a volume of products (Vp) lost of 859.67L. This study showed that the implementation of a (regularly controlled) quality management system for tank paints will contribute to a 20% reduction in current total annual emissions. These results are consistent with those of the Federal Volatile Organic Compound (VOC) Emission Reduction Program developed in 2017. Indeed, Canada has ratified the Gothenburg Protocol Under the Protocol, Canada has committed to reduce by 20% VOC emissions in 2020 relative to 2005 [12, 13].

VII. Conclusion

It was a question in this study to find the causes of the differences in the quantity of petroleum product during transfers within a storage structure of petroleum products in Côte d'Ivoire. Through the diagnosis of the system, the control charts as well as the ISHIKAWA diagram, we were able to highlight the reasons for the discrepancies in the quantity of petroleum products during transfers and to propose recommendations for the minimization of these discrepancies.

It therefore emerges from this approach that the differences in the quantities of products during transfers are generally due to fictitious differences and physical differences. Fictitious deviations are, however, the main causes of deviation rates beyond tolerance limits in this oil terminal. These differences are divided between technical errors in gauging, errors in the temperatures measured and variations in the volume of product in the line before the transfers. The model established for the determination of the theoretical final temperature of the product in the receiving tank, shows that the temperature determined with the thermo-probe is at the origin of 80% of the deviations beyond the tolerance limits. With regard to physical deviations, they include losses by evaporation, by operating activities and leaks of petroleum product. These discrepancies are insignificant compared to the discrepancies recorded on the transfer sheets. On the other hand, added to the fictitious deviations, the physical deviations considerably increase the deviation rates in absolute value.

The adoption of the established recommendations will make it possible to minimize the discrepancies generated during the transfer of petroleum products and avoid overestimating or underestimating the quantity of products present in its tanks. They will also enable it to further reduce the impact of total emissions on the differences generated and thereby reduce its greenhouse gas emissions and play a key role in the sustainable development process. This study was carried out within a single storage structure for petroleum products in Ivory Coast. Thus, in order to generalize the results obtained, a comparative study must be made with other storage structures for petroleum products. Moreover, these results are only valid for terminals whose storage tanks have the same geometries (cylindrical tanks) as those used in the present study.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Konan Lopez Kouame conducted the research, analyzed the data, wrote the paper and corrected the paper; Ossey Clovis Seka, Lamine Konate, Nogbou Emmanuel Assidjo analyzed the data; Urbain Gnonssoro, Horo Kone, Brou Kouadio read and corrected the paper; all authors had approved the final version.

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