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Fuel Loss Analysis and Compliance Management in Gas Stations

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Abstract: *As fuel price continues to rise and retail sales of fuel decrease, the profits of gas station owners will continue to decline if they cannot accurately identify and manage fuel loss and meet compliance requirements. For site owners who operate small and medium-sized gas stations, it is even harder to survive in the increasingly fierce competition with big and franchised station owners if they do not stop fuel loss. Many factors and links can lead to the loss of fuel in a service station due to the special physical and chemical properties and storage methods. Accurate analysis and management of every link of fuel dispatch, sales volume and inventory will prevent losses at every node as far as possible, and use scientific means to find out the causes of loss, and then take effective measures to reduce loss and increase efficiency. Based on the practical case of Anzhenmen Gas Station in Beijing, this paper analyzes the physical and chemical characteristics of fuel and the logistics process involving fuel dispatch, sale and inventory of fuel to find out all the elements that caused the incompliance of wet stock. The author helped site owner generate an accurate fuel chart for underground tanks with mathematical modeling algorithm, which improves the precision of metering management of dispatch, sale and inventory, provides reference for the owner of gas station to stop leakage and check mistakes, and greatly improves the profits. The author hopes to use this method to help more gas station owners improve fuel compliance management.*

Keywords: *Loss analysis, Compliance Management, Tank Chart, Fuel logistics, Calibration*

1. Introduction

My uncle operates a gas station near Anzhenmen, a busy street with heavy traffic in downtown Beijing. However, in the last six months, my uncle has found that his monthly profits have been decreasing. I worked there a week as an intern during summer holiday to help find out what caused the fall of profits. I observed the whole fuel logistic process including fuel dispatch from oil depot, sales at the pump and inventory management in the underground tank. My uncle and I analyzed the causes of the losses item by item by consulting professional retail managers from Sinopec, industry experts at the Materials Institute of the Chinese Academy of Sciences and the technical director of a fuel management company. We finally identified the key factors that caused fuel loss and we agreed that an accurate tank chart was critical to achieve fuel compliance. After careful calculation with mathematical modeling, I worked out a new tank chart and help uncle stop losing fuel and gaining profits.

2. The Fuel logistics Chain and Retail Operation Process for a Service Station

Site operator needs to purchase fuel from a fuel depot every day, then unload the fuel to the underground tanks from oil trucks, and sell fuel to customers through dispensers at the forecourt. The remaining fuel will be stored at underground tanks. This is the entire logistic chains in a service station as shown Figure 1.

We can see from the above process that there are too much nodes need to be controlled and managed in fuel logistics.

First, the Fuel dispatch - refers to the unloading of oil from the tank truck to the underground tanks at the gas station when the tank level is lower than the minimum level, which may cause the lack of fuel for sale, the site operator will purchase fuel from oil depot. The oil depot will arrange tank truck and dispatch fuel to the gas station. The tank truck driver will receive and measure fuel in quality with oil depot. The density of different fuel can lead to different oil volumes. [1]（Note:The current domestic trade mode asks for handover in quality. Fuel with the same quality of oil products could lead to

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different volume in handover due to the different density in certain temperature. (excluding the influence of oil flow meter problems)）When fuel arrives at gas station, it is usually measured by volume before filled to the underground tank. There are many factors that can lead to fuel loss during the process including:

No accurate tank chart to measure the exact fuel volume in the tank

Uneven parking place leads to uneven tanker levels

Truck tanks are deformed and tilted which cause the liquid level unstable

Different fuel densities at different temperatures cause different volumes

Fuel theft during transportation

Fuel adheres to the wall of tanks or is not completely downloaded from tank truck

The corresponding dispenser at forecourt did not stop refueling when downloading fuel from tank truck to underground tanks

Next on the logistics chain, is the sale at the pump. Many factors can cause fuel loss, such as meter float drifted, dispenser meter was altered deliberately, meter sensors did not calibrated

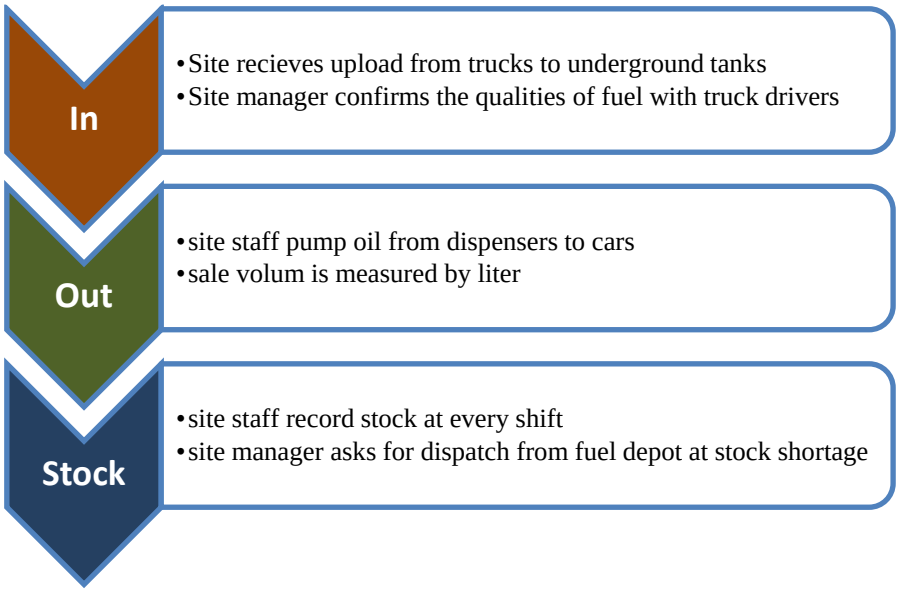

Figure 1: Fuel Logistics Chain in a service station

The last but not least, is the storage measure in the underground tanks. Site staffs need to record storage level at underground tanks for each shift every day. They also need to write down the inventory ledger every day, and check it with the data of fuel dispatch and sales volume at the pump to confirm the daily fuel loss and overflow they will have a comprehensive inventory measure review every month. The losses that can be incurred at this stage include:

No accurate tank chart

The deformation, leak and tilt of underground tanks

The instability of tank level when filling from tank truck

Fuel Evaporation at different temperatures and humidity, meter (dipstick or tank gauge) inaccurate and manual operation errors can lead to data errors. Theoretically, the amount of fuel dispatched from oil depot should be equal to the sales volume at the pump + inventory in storage tanks. However, in reality, since so many factors in the logistics loop can cause fuel loss, it is difficult to monitor fuel compliance accurately. The gap between fuel dispatch volume and the sales volume plus inventory volume can be very big, which lead to big fuel loss and profit loss for gas stations.

Inventory measure is the most difficult part on the logistics chain since tanks are buried and installed deep down under the ground. Therefore, it is critical for site managers to improve wet stock inventory management to achieve compliance.

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3. Objective Factors That Cause Fuel Loss and Over Spill

At room temperature, the fuel sold at the pump is a colorless to pale yellow liquid. Its chemical properties are mainly measured by its evaporation, explosion resistance, oxidation stability and corrosion resistance, the most important of which is its volatility and explosion resistance。The objective factors leading to fuel loss and spillage mainly refer to the characteristics of fuel products that are difficult to measure, hard to store and easy for volatile.

Fuels vary in volume as climatic conditions change. An increase in temperature causes its volatilization to increase, and an increase in humidity reduces its volatilization rate. Different fuel densities have different evaporative properties. In areas with high altitude and hot climate, fuel evaporation is fast, and is prone to vapor lock, that is, the evaporated gas, making it impossible for refueling; blocks the muzzle of the dispenser pump and this high evaporability also makes its loss increase in the storage and dispatch transportation. Fuel explosion resistance refers to the ability of fuel to resist knocking when burning in the engine cylinder, usually featured by octane number, the higher the octane number of gasoline. The higher the fuel label, the better its explosion resistance. These physical characteristics of fuel determine that it is difficult to store and difficult to measure.

Normally speaking, fuel is restored in the oil tanks of refinery facilities and then is dispatched through pipeline or the tank truck to the underground tanks of gas stations. Because fuel tanks are generally buried several meters deep down under the ground, it is hard to observe its inventory level with naked eyes, nor can it accurately monitor whether the oil tank is tilted, deformed and leaked. All these abnormalities can lead to inaccurate fuel measurement. In summary, the objective factors that cause fuel loss and spillage include:

Temperature change

Humidity change

Altitude condition

Tank tilt/deformation/leak

The accuracy of tank chart/manual meters/tank gauge

4. Subjective Factors That Cause Fuel Loss and Over Spill

Despite the objective factors such as the physical and chemical properties of oil products, fuel the loss caused by human factors should not be underestimated. The human factors that cause fuel loss and profit decrease of a gas station mainly include:

When the tank truck driver unloads oil, he colludes with the site staff and they record less unload volumes, or he steals fuel from the tank truck on the road and sells it privately for profit

When refueling, site staff change the fuel dispenser meter without authorization, and refuel less to the customers

The site staffs who refuel the customer’s car collude with the site cashier to collect more money for less fuel. They then split the profit

Technical problems on measurement such as inaccurate readings with manual ruler when measuring the liquid level of underground oil tanks

When tank truck unload fuel to unground tanks, the dispenser pump need to stop refueling, otherwise the liquid level in the tank is unstable and the metering is inaccurate The above subjective human factors can be improved by developing management processes and designing reward and punishment regulations. However, objective factors can lead to big difference in the inventory measurement of fuel. Therefore, an accurate underground tank chart, volume gauge, commonly known as the "tank calibration chart", is the critical and the key for wet stock inventory management.

5. An Accurate Tank Calibration Chart is the Key for Wet Stock Compliance Management

The tank chart is briefly a comparison table of the relationship between the liquid level height and volume of the fuel level of an underground tank. The purpose of making an accurate tank chart is to calculate the corresponding stock volume by measuring the liquid level height. Since the underground

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tank is installed deeply under the ground, it is difficult to be detected with the naked eye. After years' use, it would bear various geological changes such as tank deformation, tank rolling, dripping, soil loose at surround environment and other changes. These changes can lead to measurement errors. Therefore, how to generate an accurate tank calibration chart is a problem to be solved by the owner for wet stock compliance management.

Since the gas station the author worked with had been in operation for six years, and had never monitor the changes on tanks, nor had the tank chart calibrated during the years, the author decided to help the site operator to re-calibrate the tank chart.

6. Generating a New Tank Calibration Chart

An underground oil tank shapes as cylinder in the middle, with semi-elliptical at two ends and oval as the cross-section. Underground fuel tanks are manufactured to meet the relevant national standards and passed the quality inspection before installed in gas stations. Tanks are buried and installed on the horizontally tightened foundation, as shown in Figure 1 below.

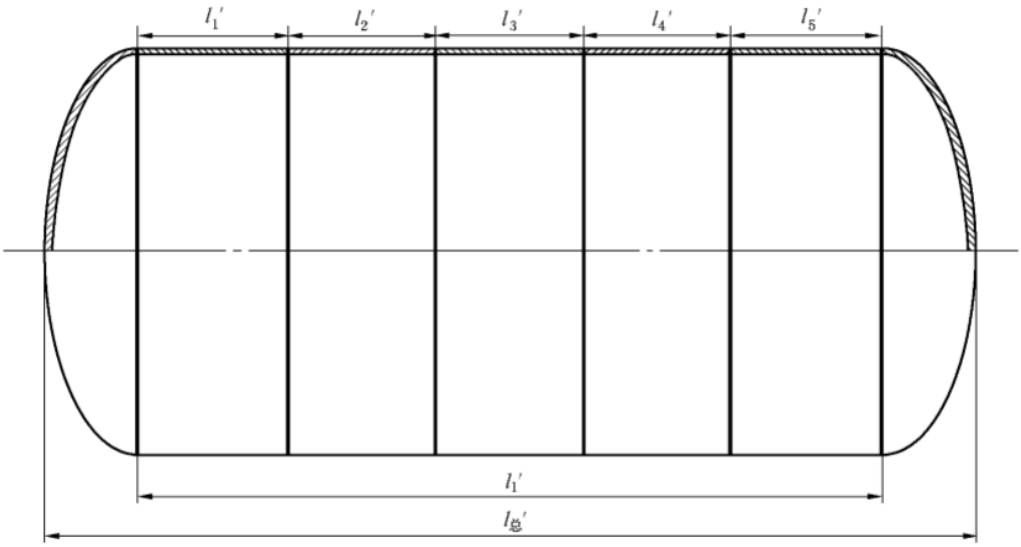

Figure 2: Schematic diagram of a horizontally buried fuel tank

To compile an accurate tank calibration chart, the author consulted the national standards such as the "Horizontal Metal Tank Capacity Verification Regulations" and drafted an action plan. The author worked out a table comparing tank level on tank gauge with the corresponding temperature at the time beforehand. The author discussed with the site owner on calibrating four tans one by one and step by step. They first emptied the tank, asked for dispatch certain amount of fuel from depot, and fill the tank. They recorded the level height and temperature from tank gauge. They pump some fuel out with dispensers to refuel a car and record the tank level and temperature afterwards. After dozens of same operation, they calculated and generated a tank chart for the tank.[2] As shown below:

Calculation formula:

The volume V corresponding to the tank level height h = the initial volume (purchase amount) V' - the amount sold at the pump Vs

For the volume of the liquid level height between the two measuring points, a three-time interpolation algorithm is used to calculate the corresponding volume of the corresponding height (in mm) (in L). Repeat this refueling-recording-counting operation until all the fuel in the tank is pumped out and the tank is empty. At the same time, the author reviewed all the record and shift books for the past six months to collect the data on fuel dispatch from depot, sales volume and inventory data for every shift every day. Compare with the tank calibration chart the author just worked out, they got a very new tank chart as shown below:

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Tank#2 Calibration Chart

CM/CM	0	1	2	3	4	5	6	7	8	9
0	0	16	51	94	145	202	265	334	408	486
10	568	655	745	839	936	1037	1141	1248	1359	1485
20	1614	1747	1882	2020	2161	2304	2450	2599	2750	2903
30	3059	3217	3377	3541	3707	3875	4045	4218	4398	4568
40	4746	4926	5107	5290	5475	5662	5850	6040	6231	6424
50	6622	6822	7023	7226	7431	7636	7843	8052	8261	8472
60	8684	8898	9112	9328	9545	9763	9982	10202	10423	10646
70	10873	11101	11329	11559	11789	12020	12253	12486	12720	12954
80	13190	13426	13664	13902	14140	14380	14620	14860	15102	15344
90	15586	15830	16075	16321	16567	16814	17061	17309	17558	17806
100	18055	18305	18555	18805	19056	19307	19559	19811	20063	20315
110	20568	20821	21074	21327	21581	21835	22090	22346	22602	22858
120	23114	23370	23627	23883	24139	24396	24652	24909	25165	25422
130	25678	25934	26197	26447	26703	26958	27214	27470	27725	27980
140	28235	28490	28745	28999	29253	29507	29760	30014	30266	30519
150	30771	31022	31274	31524	31775	32025	32274	32523	32771	33019
160	33266	33513	33759	34005	34496	34496	34740	34984	35228	35470
170	35712	35953	36193	36433	36909	36909	37146	37382	37617	37851
180	38085	38317	38548	38779	39263	39236	39462	39687	39910	40133
190	40354	40793	40793	41011	41442	41442	41656	41869	42080	42289
200	42493	42694	42894	43092	43486	43486	43681	43875	44068	44258
210	44447	44634	44820	45003	45364	45364	45541	45717	45890	46062
220	46231	46397	46562	46724	47041	47041	47196	47348	47497	47644
230	47788	47929	48067	48201	48461	48461	48586	48707	48825	48938
240	49048	49153	49254	49350	49526	49526	49606	49680	49747	49806
Note:										
1. Reference value for the total height of the measuring rod can in the calibration environment: 3200 mm										
2. The scope of tank level for the chart: 1880 liters - 43,340 liters										
3. The volume in the table is the volume value of 20 degrees of the container, that is, the V standa										
4. The actual volume is corrected according to the following formula: VT=Vs * [1+0.000036 * (TG-20)] TG= 3/4 * TU+ 1/4 * TH Where: Vs - gauge volume at a certain liquid level TU- Average oil temperature in the tank TH- Ambient temperature TG- Tank steel plate temperature										

Figure 3: Calibration Chart for Tank #2

With this accurate tank calibration chart, the site operator managed fuel compliance easily by just comparing sales dispatch, sales volume and inventory with the chart. He could easily control fuel loss and started to gain profits.

7. Conclusion

To sum up, fuel stock management is critical for site operators to improve efficiency and increase profit. An Accurate chart for underground tanks is the key to manage fuel compliance. Results in this paper shows that tank chart reconciliation will help identify and make up fuel losses.

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