MANAGEMENT OF EVAPORATION LOSSES OF GASOLINE'S STORAGE TANKS

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ABSTRACT

Gasoline is a volatile organic compound (VOCs) which consists of different hydrocarbons with different boiling points in the range of 30-200°C. The light compounds that have boiling point of less than 40°C constitute about 10%. Khartoum, Sudan is characterized with an average of 10 hrs of sunshine and solar radiation of 3.05-7.62 kWh/m²/day and average temperature of 32 to 40°C. Under these conditions high evaporation rate is expected from storage tanks. The objective of this study is to evaluate the evaporation loss of gasoline from internal floating roof storage tank. The case study is based on metrological and operation data for the year 2008. The result revealed that the total evaporation loss is 0.5%. This is significantly higher than that set by the ministry of energy [i.e.0.25%]. The results should be of concern to the petroleum industries and government. The reduction of evaporation loss of gasoline will give attractive economic returns as well as reducing air pollution and hazards.

Keywords: Gasoline, Benzene, evaporation loss, storage tank

1. INTRODUCTION

Gasoline is composed of different hydrocarbons with different boiling points in the range of 30-200°C. Some hydrocarbons can be released into the atmosphere at ambient temperature. It contains about 10% of light products that can evaporate at a temperature of about 40 °F as can be seen in Figure 1 [1]. Besides the energy loss due to evaporation, the emission of hydrocarbons give rise to photochemical oxidants when hydrocarbon compounds and oxides of nitrogen react in the presence of sunlight. Resulting health problems include coughs, eye irritation and poor air quality in addition to flammability hazards.

Transportation and handling of gasoline involves many distinct operations each of which represents potential source of evaporation loss. The first operation is the transportation of gasoline from refinery to the main terminal. Then from these terminals to the end fuel consumers sites or distribution services stations. It is final destination is
motor vehicle gasoline tank. Transportation of gasoline can be made by pipelines, rail ways, marine vessels and road tank trucks. In this operation there are basically two types of evaporation losses: loading and transient losses. In the Sudan the most utilized mean of gasoline transportation is pipeline for bulk delivery and exportation, and road tank trucks to service stations and sub-storage facilities. Another Gasoline evaporation factor is the filling of the vehicle tank. This can be considered as handling loss [2].

Evaporation loss of gasoline in storage occurs because of evaporative of the liquid during its storage and as a result of changes in the liquid level. The evaporation loss sources vary with tank design and metrological conditions such as temperature, wind speed and solar radiation. The main types of evaporation loss in fixed roof tanks are standing (also known as breathing) and working losses. Standing storage loss from tanks is evaporative loss of stock vapor resulting from thermal expansion and contraction of air-vapor mixture resulting from the daily temperature cycle. Working loss from a tank is the vapor loss that is expelled from the tank resulting from a change in liquid level in the tank and the combined effect of both filling loss and emptying loss.

In floating roof tanks the main evaporation losses are normal operation and roof landing losses. Normal operation losses are those losses through rim seals, deck fittings, and/or deck seams and withdrawal losses. The roof landing loss includes standing idle loss and filling losses.

Control of losses from the storage tank can be done by methods which are introduced in [2]. However, the standing storage loss from storage tanks is very much lower than the losses from distribution systems. Distribution losses should, therefore, be considered as a priority. A short term modification to reduce displacement loss during loading gasoline was done by connecting a vapor vent line which returns displaced vapor from the headspace back to the storage tank. A future method for controlling evaporative losses is to adapt a vapor recovery system. The cost of this method is quite high because it needs special equipment to convert hydrocarbon vapor to liquid before liquid fuel is sent back to the storage tank [3]. Furthermore during gasoline loading, the splashing of liquid gasoline can cause small droplets to disperse into the vapor within the tank. This emission can be controlled by reducing the amount of turbulence created when the liquid is introduced. With splash loading, liquid is introduced at the top of the container and there is significant turbulence and entrainment of small liquid droplets in the expelled vapor. Using bottom or submerged loading significantly reduces the turbulence lowering the vapor generation [4].

This work is intended to estimate the evaporation loss of gasoline in an external floating roof tank.
2. MATERIALS AND METHODS

2.1 Gasoline
The gasoline is produced in Khartoum refinery. It has an average Reid vapor pressure (RVP) of 8.3 spite true vapor pressure of gasoline at this RVP is given by Antoine equation as:

\[ \ln \frac{P}{T + 460} = -\frac{B}{A - T} \]

Where \( P \) is the true vapor pressure in psi and the temperature in °F and the constants \( A = 1.649 \) and \( B = 1.3225 \).

2.2 Storage tank
The Government of Sudan does not permit the use of storage tank other than internal floating roof tank for gasoline in strategic depots. Table 1 shows the specification of the tank used in this work.

Table 1: Tank technical details

<table>
<thead>
<tr>
<th>Tank type</th>
<th>Internal floating roof tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank height</td>
<td>12.8m</td>
</tr>
<tr>
<td>Tank diameter</td>
<td>12.5m</td>
</tr>
<tr>
<td>Tank roof type</td>
<td>Cone roof</td>
</tr>
<tr>
<td>Tank roof height</td>
<td>0.98m</td>
</tr>
<tr>
<td>( \alpha ) tank paint solar absorptance</td>
<td>0.17</td>
</tr>
<tr>
<td>Rim seal type</td>
<td>Mechanical-shoe seal</td>
</tr>
<tr>
<td></td>
<td>Primary only</td>
</tr>
</tbody>
</table>

2.3 Operation and Metrological data
Khartoum, Sudan is located in semi arid region characterized with high sunshine hours (about 10 h) and solar radiation and temperature. The operation conditions such as the average monthly liquid temperature, outage and etc…is taken from an oil service company located in Khartoum, Sudan. Table 2 shows the operation and metrological data.

2.4 Calculation Procedures
Total floating roof tank emissions are the sum of normal operation losses and roof landing loss. The normal operation losses are the sum of rim seal, withdrawal, deck fitting and deck seam losses as

\[ L_T = L_R + L_{wd} + L_F + L_D \]

Where:
\( L_T = \) total loss, lb/yr
\( L_R = \) rim seal loss, lb/yr
\( L_{wd} = \) withdrawal loss, lb/yr
\( L_F = \) deck fitting loss, lb/yr
\( L_D = \) deck seam loss (internal floating roof tanks only), lb/yr

The roof landing losses is sum of the standing idle losses during roof landing and filling losses during roof landing. These losses are calculated in accordance American Petroleum Institute (API) procedures [5]

Table 2: Operation and metrological data

<table>
<thead>
<tr>
<th>Month</th>
<th>Solar radiation (MJ/m²)</th>
<th>Wind Speed (m/s)</th>
<th>Mean Temp (°C)</th>
<th>Ship Received</th>
<th>In-transit</th>
<th>Stock Balance</th>
<th>Product height (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.45</td>
<td>3.00</td>
<td>26.95</td>
<td>287,944.00</td>
<td>9,255</td>
<td>280,847.40</td>
<td>7.46</td>
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<tr>
<td>2</td>
<td>21.58</td>
<td>3.00</td>
<td>27.88</td>
<td>293,099.14</td>
<td>4,509</td>
<td>680,205.07</td>
<td>18.07</td>
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<tr>
<td>3</td>
<td>22.74</td>
<td>3.50</td>
<td>30.48</td>
<td>276,876.81</td>
<td>-</td>
<td>928,029.55</td>
<td>24.66</td>
</tr>
<tr>
<td>4</td>
<td>24.01</td>
<td>4.00</td>
<td>36.13</td>
<td>210,821.97</td>
<td>47,954</td>
<td>357,324.00</td>
<td>9.49</td>
</tr>
<tr>
<td>5</td>
<td>22.35</td>
<td>3.00</td>
<td>37.35</td>
<td>78,204.84</td>
<td>68,623</td>
<td>462,009.61</td>
<td>12.28</td>
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<tr>
<td>6</td>
<td>20.78</td>
<td>2.50</td>
<td>36.48</td>
<td>353,962.17</td>
<td>352,868.33</td>
<td>-</td>
<td>646,710.23</td>
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<td>7</td>
<td>20.42</td>
<td>3.50</td>
<td>33.23</td>
<td>307,279.48</td>
<td>313,953.10</td>
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<td>755,292.26</td>
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<td>8</td>
<td>20.72</td>
<td>3.50</td>
<td>32.03</td>
<td>328,099.90</td>
<td>337,376.71</td>
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<td>824,617.68</td>
</tr>
<tr>
<td>9</td>
<td>20.52</td>
<td>3.00</td>
<td>34.63</td>
<td>282,032.07</td>
<td>243,849.33</td>
<td>-</td>
<td>599,063.13</td>
</tr>
<tr>
<td>10</td>
<td>19.59</td>
<td>2.50</td>
<td>35.98</td>
<td>360,154.13</td>
<td>370,745.03</td>
<td>-</td>
<td>894,039.23</td>
</tr>
<tr>
<td>11</td>
<td>19.63</td>
<td>3.00</td>
<td>32.25</td>
<td>289,581.60</td>
<td>293,440.97</td>
<td>-</td>
<td>616,361.47</td>
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<tr>
<td>12</td>
<td>18.71</td>
<td>3.00</td>
<td>27.93</td>
<td>324,975.29</td>
<td>339,150.13</td>
<td>-</td>
<td>775,879.68</td>
</tr>
</tbody>
</table>
3. RESULTS

Figure 2 shows the stock per month. The average stock for most of the year is about 350,000 liter per month with exception of April and May. In this period the stock is small. This is due to the Khartoum refinery shutdown.

Figure 2: Stock monthly variation

Figure 3 shows the normal evaporation loss from various sources. It is clear that the evaporation loss due to withdrawal and rim are negligibly small relative to deck fittings. The highest loss occurs in the period between April and June. As indicated above this period is characterized with low stock and hence high vapor space.

Figure 3: Normal Operation losses

Figure 4 shows the roof landing losses. During the months of low level of supply the roof landing losses are very high. Figure 5 shows the total loss as a percent of the total amount received. Clearly during the months of April to June the loss is very high. This is due to low level of stock and large vapor space. If these months are considered as abnormal operation and excluded, the annual average evaporation loss of the 10 months is about 0.52%. This is significantly higher (double) that set by the ministry of energy (0.25%). The ministry recommendation is based on average annual temperature of 31.5°C and for gasoline with high RVP. The specification of gasoline is changing over years while the average ambient temperature for the year 2008 is about 32.61°C.

To validate the result, a number of oil Service Company was interviewed. Almost all the interviewed companies are skeptical to give their own level of losses. Nevertheless, they agreed that the total losses are significant higher than that set by the ministry, taking into account the in-transient, customer service station and filling and emptying losses.

Figure 4: Roof landing losses

Figure 5: Total Loss
The reason for the high loss is attributed to the low RVP of the Sudanese gasoline and metrological conditions of high solar radiation and ambient temperature. In the other hand as can be seen in Figure 1 the gasoline has high percent of volatile components [about 10%] that can evaporate at 30-40°C under atmospheric pressure.

4. EMISSIONS CONTROL

For internal floating roof tank the following measures are generally used for emission control.

- Check condition of existing seals
- Replace vapor mounted primary seal with liquid mounted seal
- Install secondary rim seal
- Install vapor recovery/destruction system

A future method for controlling evaporative losses is to adapt a vapor recovery system. The cost of this method is quite high because it needs special equipment to convert hydrocarbon vapor to liquid before liquid fuel is sent back to the storage tank [6].

5. RECOMMENDATION FOR FUTURE WORK

1. As described, evaporation loss from the storage tank and loss from loading are two of the four common sources of evaporation loss in gasoline. The evaporation loss from intransient and service station should, therefore, be further investigated.
2. Sudanese Gasoline has low RVP and high percent of volatile organic compounds (VOCs). Matching between these specifications and the climatic conditions need to be addressed.

REFERENCES