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Modeling a Quantifier for Calculating the Net Quantity of Crude Oil in Storage Tanks

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ABSTRACT: The use of the manual calculation procedures, is Nigeria's common mode of calculating the gross and net quantities of crude oil in the major petroleum exportation terminals, refineries and other crude oil storage facilities. This generic use of manual calculation procedures, is time consuming and they are liable to inevitable human errors rising from miscalculation, approximations and field unit conversions. This work is carried out to eliminate the above – mentioned, by modelling a quantifier named: Henry Ekeh Dip Gauge Quantifier using MATLAB graphics user interface, for an easier, faster and reliable way of calculating the net standard quantity of crude oil in several field units without the use of calculators nor oil converters for an on – the – spot oil stock recording after dipping exercise.

KEYWORDS: Calculator, Dip gauge, MATLAB GUI and Oil measurement

I. INTRODUCTION

Calculating the net quantity of crude oil is very important in oil business for stock recording, trading, tax and volume reconciliation purposes at custody of their operators and marketers in determining the exact monetary value of their stock. The quantity of crude oil transferred from separators in flow stations to storage tanks in petroleum exportation terminals and refineries is determined from tanking gauging exercises carried out in these storage tanks followed by the calculation procedures for determining the actual quantity of crude oil transferred to, or stored in these tanks. In gauging of a storage tank, the level of volume is first measured before an onward calculation of the net quantity of crude oil used for inventory control, custody transfers, sales and stock reconciliation.

From gathered studies and research, [7] stated that, Nigeria's petroleum upstream, midstream and downstream sectors rely heavily on the dip gauge method of tank gauging, which is commonly known as manual / hand gauge method for the level of volume measurement of crude oil and liquid petroleum products in which the manual calculation procedures for determining the gross standard quantity and net standard quantity of the crude oil / petroleum products follow suit.

Although, inevitable mistakes arise from this general practice of manually calculating the gross standard quantities and net standard quantities of crude oil in a storage tank due to some human errors resulting from approximations, miscalculations and field unit conversions, which differs from the values of the expected volume or weight of the crude quantified. The main objective of this work is to model a quantifier for calculating the accurate net quantity of crude oil in storage tanks across the sub sectors of Nigeria's petroleum industry since the dip gauge method of tank gauging system is the generally approved standard for tank level of volume measurement. In order to zero out these inevitable human errors in the calculation procedures of this method of level of volume measurement and also reduce the lengthy time taken for calculating the net quantity of crude oil transferred or sold out.

These objectives were realized by modeling a Henry Ekeh Dip Gauge Quantifier using MATLAB graphics user interface, for keying in the input parameters and displaying the calculated result in several field units without hassle in a more convenient and faster way.

II. METHODOLOGY

The materials required for modeling the quantifier are the following:

Department of Petroleum Resources – DPR (2019) publication; Computer system and MATLAB software

A: Calculation Procedure

The calculation procedure of the level of volume measurement for calculating the net quantity of crude oil as stated by [3] is adopted for the modeling of this quantifier and the steps of the calculation procedure is presented below:

Step I: Tank dipping to get the tank level (TL) of petroleum in the tank as measured in meter (m) and use the appropriate tank calibration table (TCT) to determine the total observed volume (TOV) and then subtract the volume of roof displacement (RD) from the total observed volume (TOV) to arrive at gross observed volume (GOV).

Mathematically:

Tank level, TL = TOV (using TCT) (1)

Roof displacement volume, RD (from TCT)

GOV = TOV – RD (2)

Step II: Volume correction factor (VCF) is obtained by establishing the API gravity or specific gravity of the crude oil at 60^{o}F from the ASTM table 5A or 23A respectively derived from the crude oil density at observed temperature (OT). Then the corresponding volume correction factor (VCF) is obtained by referring the API gravity or specific gravity (SG) at 60/60^{o}F from the ASTM table 6A or 24A respectively. However, volume correction factor (VCF) is also determined using density in vacuum at 15^{o}C from ASTM table 54A.

The gross standard volume (GSV) is obtained by multiplying the gross observed volume (GOV) with the volume correction factor (VCF).

Mathematically:

API gravity @ 60^{o}F = Density @ OT (from ASTM table of conversion) or

SG @ 60^{o}F = Density @ OT (from ASTM table of conversion) (3)

Then,

API gravity @ 60/60^{o}F = API gravity @ 60^{o}F (from ASTM table 5A) or

SG @ 60/60^{o}F = SG @ 60^{o}F (from ASTM table 23A) (4)

Therefore;

VCF = API gravity @ 60/60^{o}F (from ASTM table 6A) or

VCF = SG @ 60/60^{o}F (from ASTM table 24A) (5)

Also,

VCF = Density in vacuum @ 15^{o}C (from ASTM table 54A) (6)

Step III: Gross standard volume (GSV) is determined by multiplying the gross observed volume (GOV) by the volume correction factor (VCF)

Mathematically:

GSV = GOV * VCF (7)

Step IV: Gross standard weight (GSW) is determined by multiplying the gross standard volume (GSV) by the Long ton per barrel factor (LTBF)

Mathematically:

GSW = GSV * LTBF (8a)

LTBF is derived from ASTM table of conversion

Or

GSW = GSV * Density in vacuum @15^{o}C (8b)

Density in vacuum @15^{o}C is derived from ASTM table of conversion

Step V: Quantity of water and sediment (BS&W) is determined by multiplying the gross standard volume (GSV) by the percentage of base sediment and water (BS&W) in the given crude oil sample. Thereafter, multiply the quantity of water by a factor of 0.15616 to yield the equivalent weight of water and sediment ($BS\&W_{long\ ton}$).

Mathematically:

$BS\&W_{quantity} = GSV_{quantity} * BS\&W$ (9)

Thereafter;

$BS\&W_{long\ ton} = BS\&W_{barrel} * 0.15616$ (10)

Step VI: Net standard volume (NSV) is obtained by subtracting the quantity of water and sediment ($BS\&W_{quantity}$) from the gross standard volume (GSV), while the Net standard weight (NSW) is obtained by subtracting the weight of water and sediment ($BS\&W_{quantity}$) from the gross standard weight (GSW)

Mathematically:

$NSV = GSV_{quantity} – BS\&W_{quantity}$ (11)

While,

$NSW = GSW_{quantity} – BS\&W_{quantity}$ (12)

B: Calculation Flow Chart

This is a flow chart diagram showing the various pathways of the calculated quantities.

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I) Quantifying Volume

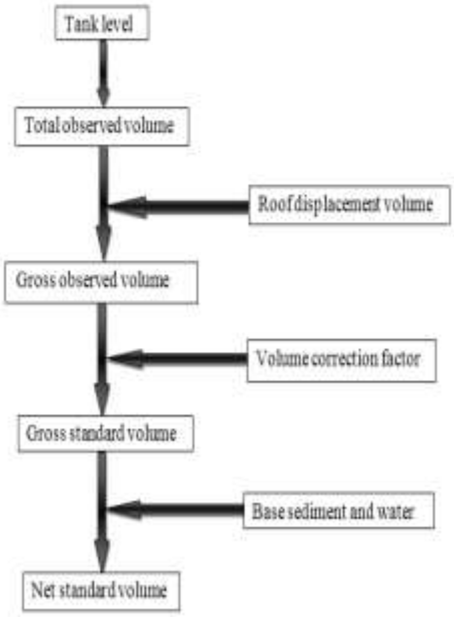

Figure 1: Quantity of volume calculation flow chart

II) Quantifying Mass

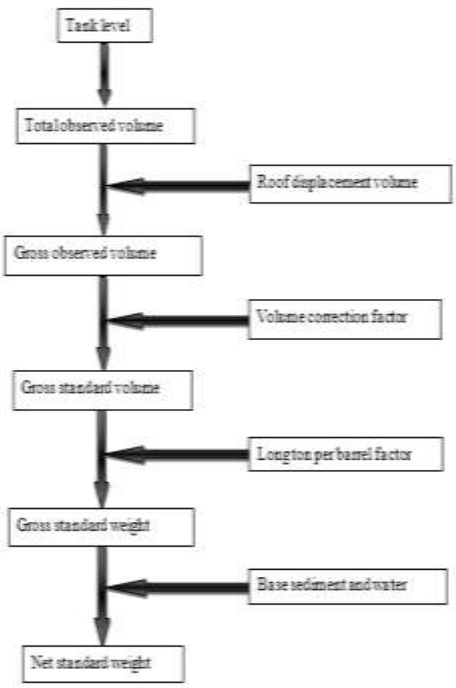

Figure 2: Quantity of mass calculation flow chart

C: Modeling of the Quantifier

The MATLAB R2014b software package was used for the coding of the equations in the calculation procedure of quantifying the net volume and net weight of crude oil going by the guideline provided in [3] to ensure accuracy and reliability of the Quantifier.

The modeling of the Henry Ekeh Dip Gauge Quantifier, starts with the building of the graphics user interface (GUI). The word '**guide**' is entered on the command window in the MATLAB and the software generates a graphics user interface (GUI) development environment for the writing of the figure file.

On writing the function on the GUIDE template for the figure file on which the following functions and data were entered on the graphics user interface development environment (GUIDE) which in turn generates a code file and a figure file. The following files that were automatically generated were named as:

1. Henry_Tank_Calculator.m
2. Henry_Tank_Calculator.fig

The MATLAB code is written on the platform in which the inputted function executes the first file generated (Henry_Tank_Calculator.m).
The MATLAB code for the calculations were inputted for the Henry Ekeh Dip Gauge Quantifier to execute the INPUT PARAMETERS written as;
Enter the Total Observed Volume, cu. metre
Enter the Roof Displacement Volume, cu. metre

Enter the Volume Correction Factor
Enter the Observed Temperature in degree Fahrenheit
Enter the Density in vacuum at 15 degree Celsius
Enter the Long Ton per Barrel Factor
Enter the Base Sediment and Water, %
To process the CALCULATED RESULTS as:
Gross Observed Volume, cu. metre
Gross Standard Volume, cu. metre
Gross Standard Volume, litre
Gross Standard Volume, barrel
Gross Standard Weight, kg
Gross Standard Weight, MT
Gross Standard Weight, LT
Base Sediment and Water, cu. metre
Base Sediment and Water, litre
Base Sediment and Water, barrel
Base Sediment and Water, LT
Base Sediment and Water, kg
Net Standard Volume, cu. metre
Net Standard Volume, litre
Net Standard Volume, barrel
Net Standard Weight, kg
Net Standard Weight, MT

The second file generated (Henry_Tank_Calculator.fig) is clicked once and then right clicked to present the following details in

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which the '**Open in GUIDE**' option is clicked once for the editing of the parameters on the Henry Ekeh Dip Gauge Quantifier template. The '**Open in GUIDE'** option opens a graphics user interface (GUI) in which the Henry Ekeh Dip Gauge Quantifier template is edited for the various input parameters and calculated results as it is listed above.

The editing of the Henry Ekeh Dip Gauge Quantifier was done on the model template. On clicking on the '**Save'** icon, the file is saved and then click on the '**Run**' icon at the top of MATLAB window, to display the Henry Ekeh Dip Gauge Quantifier with the following functions;
CALCULATE (To compute the values of the input parameters)
CLEAR INPUT DATA (To erase the values of the input parameters)
CLEAR CALCULATED RESULTS (To erase the values of the calculated results)
CLOSE (To close the Henry Dip Gauge Quantifier)

Figure 3: Henry Ekeh Dip Gauge Quantifier

The Henry Dip Gauge Quantifier is ready for computation of input parameters by the calculation procedures stated by [3] for determining the net quantity of petroleum and petroleum products.

D: Calculating the Net Quantity of Crude Oil

In calculating the net quantity of crude oil from a dip gauge level of volume measurement in a storage tank with the information provided below:

Table 1: Collected data of Tank dip and Laboratory analysis

Parameter	**Detail(s)**
Tank type	Cylindrical floating roof storage tank
Tank number	XYZ (Tank identification number withheld)
Product	Crude oil
Tank level (Dipping)	12 m 850 mm
Total observed volume	13816.4496 m^3
Observed temperature	23^o C
Observed density	944 kg/m^3
Roof displacement volume	69.16786 m^3
Specific gravity	0.945
API gravity	18.2^o
Base sediment and water	0.50%
Volume correction factor	0.9948 (from ASTM table 6A)
Density in vacuum @ 15^oC	0.9447 (from ASTM table of conversion)
Long ton per barrel factor	0.14756 (from ASTM table of conversion)

III. RESULT AND DISCUSSION

The data provided in **Table 1**, above, is keyed into the Henry Ekeh Dip Gauge Quantifier as the input parameters and presented in the figure below:

Figure 4: Henry Ekeh Dip Gauge Quantifier (with the inputted parameters)

On clicking the CALCULATE button in the Henry Dip Gauge Quantifier, the results are generated according to the calculation guidelines provided by [3] and the values obtained are presented in the calculated results of the quantifier as it is illustrated below:

Figure 5: Henry Ekeh Dip Gauge Quantifier (displaying the calculated results)

The results obtained from the Henry Ekeh Dip Gauge Quantifier (HEDGQ) is matched alongside with the results obtained from the Manual Calculation Procedures (MCP) in the table below.

Table 2: Table of results obtained from the both modes of calculation

Calculated Results	**MCP**	**HEDGQ**
Gross observed volume (GOV), cu. meter (m^3)	13747.2817	13747.2817
Gross standard volume (GSV), cu. meter (m^3)	13675.7958	13675.7959

Gross standard volume (GSV), liter (l)	13675795.8000	13675795.8750
Gross standard volume (GSV), barrel (bbl)	86018.1677	86018.1681
Gross standard weight (GSW), kilogram (kg)	12919524.2900	12919524.3631
Gross standard weight (GSW), Metric ton (MT)	12919.5243	12919.5244
Gross standard weight (GSW), Long ton (LT)	12692.8408	12692.8409
Quantity of Base sediment & water (BS&W), cu. meter (m^3)	68.3790	68.3790
Quantity of Base sediment & water (BS&W), liter (l)	68378.9790	68378.9794
Quantity of Base sediment & water (BS&W), barrel (bbl)	430.0908	430.0908
Quantity of Base sediment & water (BS&W), Long ton (LT)	67.1630	67.1630
Quantity of Base sediment & water (BS&W), kilogram (kg)	64597.6215	64597.6218
Net standard volume (NSV), cu. meter (m^3)	13607.4168	13607.4169
Net standard volume (NSV),liter (l)	13607416.8200	13607416.8956
Net standard volume (NSV), barrel (bbl)	85588.0769	85588.0773
Net standard weight (NSW), kilogram (kg)	12854926.6700	12854926.7413
Net standard weight (NSW), Metric ton (MT)	12854.9267	12854.9267

The speed of determining the net standard volume (NSV) and net standard weight (NSW) of crude oil for the two modes of calculation using a stopwatch, is presented below:

Table 3: Table of time taken for the modes of calculation

Modes of calculation	**Calculation time (sec)**
Manual Calculation Procedures (MCP)	843
Henry Ekeh Dip Gauge Quantifier (HEDGQ)	8.75

IV, CONCLUSION

The Henry Ekeh Dip Gauge Quantifier (HEDGQ), calculates the Gross standard volume (GSV), Gross standard weight (GSW), Net standard volume (NSV) and Net standard weight (NSW) of crude oil in several field units without the use of a conversion table nor calculator as compared to the generic Manual Calculation Procedures (MCP).

This Henry Ekeh Dip Gauge Quantifier has a high level of accuracy as calculated results obtained from this model fell below the range of ±0.05 % benchmark. This shows that, the result values obtained from this model meets the standardized range of accuracy for quantifying crude oil net standard volumes (NSV) and net standard weights (NSW). And also, the time taken to key in the parameters on the quantifier to process the calculation and present the net standard quantity in several field units is less than 10 seconds.

V. RECOMMENDATION

The Henry Ekeh Dip Gauge Quantifier is a good tool and it is recommended for the following purposes:

1. For a smooth calculation of the net standard quantity of crude oil at Nigeria's petroleum exportation terminals and refineries.
2. For an easy calculation of the gross standard quantity and net standard quantity of petroleum products such as; Premium motor spirit (PMS), Aviation turbine kerosene (ATK), Dual purpose kerosene (DPK) and Automotive gas oil (AGO) in storage tanks across airport fuel terminals and petroleum depots in Nigeria.
3. For a wide range of field units in the determination of the gross standard volume (GSV), gross standard weight (GSW), net standard volume (NSV) and net standard weight (NSW) of crude oil and petroleum products.

4. For filling stations and petrochemical plants with large petroleum storage facilities in determining the net quantity of available products in their facilities.
5. For evaluation of oil stock prepared by other modes of calculation to check for errors due to miscalculation or conversion of field units.

VI. CONTRIBUTION TO KNOWLEDGE

This work has been able to establish a relationship for the modeling of a quantifier, using MATLAB graphics user interface for inputting values of the parameter and displaying the calculated results of the accurate gross standard quantity and net standard quantity of crude oil in storage tanks. This research innovation works with the calculation procedures in dip gauge method of quantifying crude oil in storage tanks as being stipulated by the Federal Government of Nigeria through the Department of Petroleum Resources (DPR).

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