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A Formula for the Coefficient of Thermal Expansion of Crude Oils

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Abstract

A new formula for the calculation of the coefficient of world crude oils has been developed. The formula is semi theoretical. The empirical part was obtained by regression calculation of the Formation Volume Factor of the gas free crude oil at reservoir temperature. Comparison of the calculated values of the Formation Volume Factor of the gas free crude oil with experimental values gave a maximum absolute error of 0.189 %. Thus values of the Formation Volume Factor of the gas free crude oil obtained by the new formula are very close to those that can be obtained by laboratory measurement.

1.0 Introduction:

The coefficient of thermal expansion of crude oil is useful in predicting the charge in volume of the crude as a result of temperature increase or Reduction. The volume of a crude oil can change in storage tanks and in transportation pipelines due to change in temperature. The coefficient of thermal expansion is usually measured in the laboratory. Laboratory measurement is time consuming and expensive. This study found a compact formula for the calculation of the coefficient of thermal expansion of a crude oil. The formula was developed with data in the range

$19.8 \leq {}^{o}API \leq 48$

$140 \leq T^{o}F \leq 191$

It was then tested with data in the range

$19.8 \leq {}^{o}API \leq 60$

$140 \leq T^{o}F \leq 200$

The test shows a general validity of the formula.

2. DEVELOPMENT OF THE FORMULA

A unit volume of gas free (dead) crude oil at atmospheric pressure can increase its volume when the temperature is increased. Let BO_1 be the new volume of a unit volume of dead crude oil due to a temperature increase. Then BO_1 is related to the coefficient of thermal expansion of the dead crude oil. Let C_T denote the coefficient of thermal expansion of the crude oil, then,

$$BO_1 = \exp\ [\ C_T\,(T - T_o)] \qquad (1)$$

Where,

T_o = initial temperature

T = new temperature

Equation (1) can be expressed as:

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$$C_T = \frac{\log_e (BO_1)}{(T - T_O)} = \frac{\ln BO_1}{(T - T_O)} \tag{2}$$

If there is an independent source of obtaining an equation for BO_1 in equation (2), it can be used as a formula for the calculation of C_T. [3] used regression on the data of Nigeria crude oil to obtain an equation for the BO_1. The equation is:

$$BO_1 = 0.968065 + 0.004203 \left(\frac{T\ {}^{O}F}{\gamma_O} \right) \tag{3}$$

Where T, is temperature of dead oil in degree Fahrenheit and γ_O is the specific gravity of the crude oil. Equation (3) is very accurate. Some examples of BO_1 calculated by equation (3) are shown in Table (1)

Table1. Comparison of calculated and experimental values of BO_1

S/N	^{O}API	γ_O	T ^{O}F	BO_1 (exp)	BO_1 (calc)	Absolute Error %
1	19.8	0.935	143.6	1.0343	1.033	0.126
2	22.2	0.921	140.0	1.032	1.032	0.000
3	24.8	0.905	142.0	1.034	1.034	0.000
4	21.1	0.927	170.0	1.044	1.045	0.096
5	26.7	0.894	152.0	1.039	1.040	0.096
6	36.9	0.840	183.5	1.060	1.060	0.000
7	38.5	0.832	186.0	1.062	1.062	0.000
8	39.1	0.829	166.0	1.052	1.052	0.000
9	39.3	0.829	175.0	1.057	1.057	0.000
10	40.6	0.822	191.0	1.067	1.066	0.093
11	44.0	0.806	166.0	1.056	1.055	0.095
12	48.0	0.788	168.0	1.060	1.058	0.189

Thus the formula for the calculation of C_T becomes:

$$C_T = \frac{\ln \left[0.968065 + 0.0004203 \left(T\ {}^{O}F / \gamma_O \right) \right]}{(T - T_O)} \tag{4}$$

The oil industry has chosen 60 ^{O}F as a standard value to express T_O. Then equation (4) becomes:

$$C_T = \frac{\ln \left[0.968065 + 0.0004203 \left(T\ {}^{O}F / \gamma_O \right) \right]}{(T - 60\ {}^{O}F)} \tag{5}$$

Example (1)

Calculate the coefficient of thermal expansion of a 19.8 ^{O}API crude oil at atmospheric pressure and 143.6 ^{O}F.

Solution

The specific gravity of a 19.8 ^{O}API crude oil is 141.5 / (131.5 + 19.8) = 0.935. Then,

$$C_T = \frac{\ln\left[0.968065 + 0.0004203\left(143.6\ ^{O}F / 0.935\right)\right]}{(143.6\ ^{O}F - 60\ ^{O}F)} = 3.883635E-4$$

3. COMPARISON OF VALUES OBTAINED FROM EQN. (5) WITH THOSE OF LEVORSEN

[1, 2] has presented a table of the mean value of the coefficient of thermal expansion at 60 ^{O}F, of several oils. (1995) transformed the table into a set of four equations. The equations are as follows.

RANGE OF ^{O}API	EQUATION
0 < 14	C_T = 1.013907E - 5 ^{O}API + 2.0119205E - 4
14 < 34	C_T = 2.0390E - 6 ^{O}API + 3.32362E - 4
34 < 50	C_T = 6.250E - 6 ^{O}API + 1.8750E - 4
50 < 64	C_T = 7.1428571E- 6 ^{O}API + 1.4285714E - 4

These equations present mean values of C_T for a group of crude oils. They are not as accurate as those obtained by the new formula that considers the coefficient of thermal expansion of an individual crude oil.

However, they may be used to check the accuracy of value of C_T calculated by the formula of this study; especially for the crudes that for outside the range of API gravity that is used to develop the new formula. According to the formulas from the table of Levorsen, a 19.8 ^{O}API crude has a coefficient of thermal expansion (C_T) of:

C_T = 2.0390 E - 6 x 19.8 + 3.32362 E - 4 = 3.727342 E - 4

Percentage deviation between the two values of C_T is:

(3.883635 E- 4 - 3.727342 E - 4) / 3.727342 E- 4 = 0.004193 = 4.193 %

Example 2

Calculate the coefficient of thermal expansion of a 60 ^{O}API at 200 ^{O}F with (a) the new formula (b) Guobadia equations for the table of Levorsen. (c) deviation (%) between the value from the formula and the equation of Guobadia.

Solution

(a) Specific gravity of the 60 ^{O}API crude = 141.5 / (131.5 + 60) = 0.7389

Then,

$$C_T = \frac{\ln\left[0.968065 + 0.0004203\left(200.0\ ^{O}F / 0.7389\right)\right]}{(200..0^{O}F - 60\ ^{O}F)} = 5.618061E-4$$

(b) C_T = 7.1428571E-6 x 60 + 1.4285714 E-4 = 5.714286E-4

(c) Deviation = (5.618061E-4 - 5.714286E-4) / 5.714286E-4 = - 0.01684

= - 1.684 %.

This shows that the formula can be used outside the range of ^{O}API that was used to develop the new formula.

4. CONCLUSION

A new formula for calculating the coefficient of thermal expansion of a gas free (dead) crude has been developed. The formula was tested crude oils that have API gravity range 19.8 to 60 and was found accurate.

REFRENCES

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