Inaccuracy of method of adjusting oil density to normal condition in the measuring and estimating system “MicroTEC”

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This article deals with methods of adjusting oil density to normal conditions according to algorithms, implemented in measuring and estimating system MicroTEC, designed to carry out current and commercial estimating of oil products and gas with minimal overall fractional error.

At the present moment, the adjusting of measured oil density to normal conditions by flow densitometer is very important for estimation in mass units at operating and commercial metering stations, because in most cases conditions of volume and density measuring differ from each other and from normal conditions (normal conditions – temperature 20 C, superpressure: 0 Pa).

There are many methods of adjusting product density to normal conditions. This article touches upon three of them. The first one is density adjustment to API (approximation method), the second one – adjustment by formula (1) MI 2153-2001, the third one - adjustment by table B.1 MI 2153-2001. All these methods are widely applied in various measuring systems, produced in our country and abroad, designed for oil products estimation.

In 2002 SME “Tomsk electronic company” developed and started series production of measuring and estimating system “MicroTEC”, designed for current and commercial estimating of oil products and natural gas. Measuring and estimating system “MicroTEC” is a provided metrological system, with calibrating test, applying basic reference standards and certified technique of measuring process. Measuring and estimating system “MicroTEC” has certificate of measuring equipment approval RU.C.34.000.A №19368 and acceptance certificate MVI № 208/163-03.

For measuring and estimating system “MicroTEC” TEC applied the second method of adjusting density to normal conditions. The comparative analysis of all three methods was carried out in application program “MathCAD 2001i”. The program, estimating density in normal conditions by approximation method is shown in the figure 1.

The program, estimating density in normal conditions by MI 2153 is shown in the Fig.2.

```
.рну1 := | j ← 1
         | kriterii_{j-1} ← 1
         | ρb ← ρ
         | ρ_{j-1} ← ρ
         | t ← t
         | P ← P
         | while  kriterii_{j-1} > 0.01
         |     | CTL_j ← exp[ -613.97226/(ρ_{j-1})^2 · (t − 20) · [1 + 0.8 · 613.97226/(ρ_{j-1})^2 · (t − 20)] ]
         |     | CPL_j ← 1 / (1 − 10^{-4} · exp[ −1.6208 + 0.00021592·t + 870960/(ρ_{j-1})^2 + 4209.2·t/(ρ_{j-1})^2 ] · P · 10)
         |     | ρ_j ← ρb / (CTL_j · CPL_j)
         |     | kriterii_j ← |ρ_j − ρ_{j-1}|
         |     | ρρ_1 ← j
         |     | ρρ_0 ← ρ_j
         |     | j ← j + 1
         | ρρ
```

$$CTL_j \leftarrow \exp\left[\frac{-613.97226}{(\rho_{j-1})^2}\cdot(t-20)\cdot\left[1+0.8\cdot\frac{613.97226}{(\rho_{j-1})^2}\cdot(t-20)\right]\right]$$

$$CPL_j \leftarrow \frac{1}{1-10^{-4}\cdot\exp\left[-1.6208+0.00021592\cdot t+\frac{870960}{(\rho_{j-1})^2}+\frac{4209.2\cdot t}{(\rho_{j-1})^2}\right]\cdot P\cdot 10}$$

$$\rho_j \leftarrow \frac{\rho b}{CTL_j\cdot CPL_j}$$

Fig. 1 – Algorithm of estimating density by approximation method

Initial values for estimating are density in some conditions t and P, temperature and pressure.

The estimating results of first and second methods can be compared using any working value of oil density, temperature and pressure. Comparison with the third method can be carried out only when the oil superpressure equals to zero, as the table contains the dependence of density only from temperature. This is the reason why the third method cannot be applied to adjust density of oil in the pipeline.

The table 1 shows some comparison results of estimating by three methods.

Table 1 – Estimating results.

№	T, °C	P, MPa	ρ, kg/m3	Method 1	Method 2	Method 3	δ1_2, %	δ1_3, %	δ2_3, %
1.	**5**	**0**	**790**	**778,22**	**778,45**	**778,50**	**-0,0303**	**-0,0357**	**-0,0054**
2.			**820**	**808,66**	**808,77**	**809,00**	**-0,0135**	**-0,0419**	**-0,0284**
3.			**850**	**839,07**	**839,16**	**839,40**	**-0,0112**	**-0,0395**	**-0,0283**
4.			**870**	**859,32**	**859,42**	**859,70**	**-0,0107**	**-0,0437**	**-0,0330**
5.	**5**	**0**	**910**	**899,80**	**899,97**	**900,20**	**-0,0185**	**-0,0444**	**-0,0259**
6.	**25**			**913,36**	**913,33**	**913,20**	**0,0042**	**0,0180**	**0,0138**
7.	**45**			**926,65**	**926,52**	**926,10**	**0,0144**	**0,0594**	**0,0450**
8.	**65**			**939,66**	**939,48**	**938,60**	**0,0187**	**0,1129**	**0,0942**
9.	**25**	**0,1**	**910**	**913,31**	**913,27**	**-**	**0,0041**	**-**	**-**
10.		**0,5**		**913,07**	**913,04**	**-**	**0,0038**	**-**	**-**
11.		**1**		**912,78**	**912,75**	**-**	**0,0032**	**-**	**-**
12.		**2**		**912,19**	**912,18**	**-**	**0,0021**	**-**	**-**

Note : δ1_2, %, δ1_3, %, δ2_3, % - Fractional error of the first method relatively the second, the first relatively the third, the second relatively the third.

Temperature1 :=READPRN ("T1.txt") temperature line in the table of coefficients of
Temperature2 :=READPRN ("T2.txt") expansion and compressibility according to MI 2153

ß :=READPRN ("Data1.txt") tables of oil expansion and compressibility coefficient
F :=READPRN ("Data2.txt") according to MI 2153

Plotnost1 :=READPRN ("P1.txt") tables of densities in normal conditions
Plotnost2 :=READPRN ("P2.txt") according to MI 2153

Current_Temperature :=t
Current_Plotnost := p

```
i1 := | r ← 0
      | while  Temperature1_r ≤ Current_Temperature
      |   r ← r + 1
j1 := | r ← 0
      | while  Plotnost1_r ≤ Current_Plotnost
      |   r ← r + 1
```

procedure of column number and line determination, i.e. the cell with the required expansion coefficient

i1 = 2.0000

j1 = 16.0000

```
i2 := | r ← 0
      | while  Temperature2_r ≤ Current_Temperature
      |   r ← r + 1
j2 := | r ← 0
      | while  Plotnost2_r ≤ Current_Plotnost
      |   r ← r + 1
```

procedure of column number and line separation, i.e. the cell with the required compressibility coeffi

i2 = 1.0000

j2 = 8.0000

$\beta_{j1-1,i1-1} = 0.9130$ $\quad F_{j2-1,i2-1} = 0.7520$

$\beta\beta := \beta_{j1-1,i1-1} \cdot 10^{-3}$

$FF := F_{j2-1,i2-1} \cdot 10^{-3}$

$\beta\beta = 9.13 \times 10^{-4}$ oil expansion coefficient depending on its temperature and density

$FF = 7.5200 \times 10^{-4}$ oil compressibility coefficient depending on its temperature and density

$\text{рну2} := p \cdot [1 + \beta\beta \cdot (t - 20)] \cdot (1 - FF \cdot P)$ density calculation in normal conditions according to MI 2153

Figure 2 – Algorithm of density calculation in normal conditions according to MI 2153.

As the table data shows, the reproducibility of all three methods complies with the requirements to the commercial estimation accuracy.

We have already mentioned that the second method by formula (1) MI 2153-2001is implemented in the measuring and estimating system “MicroTEC”. However, it should be noted, that the coefficients of oil thermal expansion and compressibility depend on its density and temperature (dependence of these coefficients is shown in the table A.1 and A.2 respectively in MI 2153-2001). This algorithm is implemented in the measuring and estimating system “MicroTEC”.

This algorithm in “MicroTEC” is applied not only for density adjusting to normal conditions, but also to adjust density to conditions of volume measuring for further estimation of oil mass.

In addition, in order to reduce other errors while estimating oil mass in the measuring and estimating system “MicroTEC”, special software tools are implemented, i.e.:

- automatic adjustment of oil flow according to the current values of temperature, pressure, moisture, density, viscosity;
- automatic estimation of current conversion coefficient of the flow meter as per five calibrating points;
- measure exploitation time of the flow meter;
- control metrological parameters of the flow meter (comparison with the control line mode);
- control flow measurement range;
- possible hook-up of flow densitometer, fluidimeter and oil cut meter.

Consequently, implemented in measuring and estimating system “MicroTEC” algorithm of oil density adjusting to normal conditions is equal in terms of accuracy to American standard API. The overall fractional error of measuring and estimating system “MicroTEC” while measuring and estimating of oil mass and volume does not exceed ± 0,05%, excluding sensors error, which allows to apply the system for oil products estimation. “MicroTEC” is certified with such error.