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# Pressure-Volume-Temperature (PVT) behaviour of Natural Gas According to NX-19 Method in Natural Gas Metering Stations

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## Abstract

Describing the amount of natural gas consumed by an entire country or a single residential appliance can be confusing, since natural gas can be measured in several different ways. Quantities of natural gas are usually measured in cubic feet or cubic meters. Because the pressure, temperature and components of natural gas flow are always differences in several conditions, in custody transfer or fiscal metering it is necessary that the amount of gas flow is calculated in flow conditions and then corrected in standard conditions. So, the correction factor is used to correct the flow amount.

The measurement standards are one of the most accessible methods for calculating the correction factor, and the NX-19 method is one of the simplest and easiest methods, because it has the lower dependence on measurement parameters, such as the components of natural gas compounds. Therefore, major customers at the National Iranian Gas Company have considered this method in measurements of gas consumption. In this research, at first, we will try to describe calculating the correction factor, according to NX-19 method and then we will analyze the effect of temperature, pressure on the amount of supercompressibility, compressibility and correction factors.

**Keywords:** NX-19, Natural Gas, Metering Station, Pressure, Volume, Temperature, Behaviour

## 1. Introduction

The theoretical foundations for flow measurement of complex fluids are the equations used for the conservation of mass and energy. The conservation equations establish theoretical flow rates. In addition to the conservation equations, mathematical correlations and correction factors are required to achieve acceptable measurement accuracy in the field. Mathematical correlations are used to estimate information about the thermophysical and fluid dynamic conditions of many different types of fluids in flow lines. Any measurement application or technology that is concerned with measuring the volume, mass, or energy of a product must use some means to determine fluid density, i.e. the amount of product mass per unit volume. This may be accomplished through direct measurement of the density in the laboratory, measurement in the field and/or using mathematical correlations. The compressibility factor is often defined through its relation to density. It is a particularly important quantity for natural gas and related fluid custody transfer.

Equations of state are mathematical correlations used to relate fluid property behavior, e.g. compressibility or density, to pressure, temperature, and fluid composition. An equation of state correlation can be used in gas measurement applications to estimate the thermophysical properties and the phase condition (e.g. gas, liquid or both) of the fluid being measured [1]. Historical perspective of research is shown in Table 1.

Table 1. Historical perspective on the equation of state and compressibility factor [1].

| Year          | Researcher(s)   | Activities   |
|---------------|---|--|
| 1660          | Robert Boyle & Edme Mariotte                              | They measured the PVT behavior of air at low pressures and established the inverse relationship between pressure and volume at constant temperature, $PV = kT$ (constant). This is known as the Boyle-Mariotte Law.  |
| 1787 to 1803  | Jacques-Alexander Cesar Charles & Joseph Louis Gay-Lussac | They worked independently and established the law of equal thermal expansions of gases at constant pressures, $V/T = k_p$ (constant).  |
| 1834          | Emile Clapeyron   | He recognized that the equations of Boyle-Mariotte and Charles-Gay-Lussac could be combined to create an equation (equation of state) for a perfect gas $PV = R_o T$ where $R_o$ was a gas dependent constant. This equation linked pressure, volume and temperature |
| 1845          | Victor Regnault   | He cast Clapeyron's perfect gas equation into ideal or "perfect" gas equation form. He did this by applying Avagadro's hypothesis on the volume occupied by one mole of an ideal gas, i.e. $PV = nRT$ .  |
| 1873          | Johannes Diderik Van Der Waals                            | He proposed to simply replace $P$ in the ideal gas equation with $(P + a/v^2)$ and $V$ in the ideal gas equation with $(V - b)$ to Regnault's ideal gas equation ( $PV = nRT$ ) to correct the generalized ideal gas equation [2].                                   |
| 1901          | Heike Kamerlingh Onnes                                    | He proposed "Virial Expansion" for "Virial Equation of State" [3].   |
| 1927 and 1928 | James A. Beattie & Oscar C. Bridgeman                     | They Proposed "Beattie-Bridgeman Equation of State" according to "Ones Virial Equation of State" [4], [5].   |
| 1940          | Manson Benedict & George B. Webb & Louis C. Rubin         | They Proposed "Benedict-Webb-Rubin (BWR) Equation of State" according to "Ones Virial Equation of State" [6].  |
| 1949          | Otto Redlich & J. N. S. Kwong                             | They Proposed "Redlich-Kwong Equation of State" according to "Ones Virial Equation of State" [7].  |
| 1972          | Giorgio Soave   | He modified "Redlich-Kwong Equation of State" as a "Soave-Redlich-Kwong (SRK) Equation of State" [8].  |
| 1975          | Byung Ik Lee & Michael G. Kesler                          | They Proposed "Lee-Kesler Equation of State" according to "Pitzer's Correlation" [9].  |
| 1976          | Ding Yu Peng & Donald Robinson                            | The Peng-Robinson (PR) equations are highly successful variations of the original van der Waals formulation [10].  |

Recently, new research has been done on rapidly estimating compressibility factor in natural gas [11]. Also, that shows the intelligent models are very useful for prediction or estimation of natural gas compressibility factor [12], [13]. Some current as well as historical methods and standards for compressibility factor listed as below.

- 1) AGA Report No.8 & API MPMS Chapter 14.2, "Compressibility Factors of Natural Gas and Other Related Hydrocarbon Gases" [14].
- 2) International Standard, 12213 Natural Gas: Calculation of Compression Factor [15].
- 3) Manual for the Determination of Supercompressibility Factors for Natural Gas, NX-19 [16].
- 4) GPA 2172-96, Calculation of Gross Heating Value, Relative Density, and Compressibility Factor for Natural Gas Mixtures from Compositional Analysis [17].
- 5) International Standard, ISO - 20765, Natural Gas – Part 1 and Part 2. Calculation of Thermodynamic Properties [18].

## 2. NX-19 Method

The NX-19 method developed by Zimmerman from Ohio State applied a truncated version of the original BWR [16]. The BWR equation was originally developed at Massachusetts Institute of Technology. This approach extended the ideas of J.D. van der Waals and Kammerlin Onnes by adding higher order density and exponential terms to the virial equation. The functional form of Zimmerman's equation was a mathematical equation truncation of the BWR equation. It used auxiliary fitting functions for different regions of the pressure-temperature surface, i.e. different equations for different operating conditions. The auxiliary fitting functions improved the accuracy of the BWR compressibility factor calculations over specific P-T regions [1].

The NX-19 method, i.e. truncated BWR method, produced reliable supercompressibility factors,  $F^{pv}$ , for high methane natural gas mixtures at typical pipeline conditions. Because of the application at the time and NX-19's improved accuracy, it became an essential part of the natural gas industry's orifice measurement calculation procedure beginning from about 1960 to the mid 1990's. The NX-19 method found widespread use by gas companies throughout the world.

The NX-19 method, although limited, has an important technological legacy in modern measurement practice. One of the significant problems with the NX-19 equation was that the formulation contained discontinuities in the derivatives of the compressibility factor at the boundaries of the auxiliary fitting functions. This limited its engineering utility to supercompressibility factor calculations. The equation could not be used to meet other gas engineering needs including critical flow nozzles calculations, sound speed calculations, or compressor calculations. In addition, the NX-19 method was biased for rich gases and highly dilute content gases. However, it is a very simple and rapid method for calculating of the supercompressibility factor in natural gas. The concern over bias errors caused the industry to initiate the development of a new equation of state method to replace the NX-19 work. The range and applicability of this method are shown in Table 2.

Table 2. The Range and Applicability of NX-19 Method [16].

|                        |                |
|------------------------|----------------|
| Pressure [Psig]        | 0 to 5000      |
| Temperature, [°F]      | -40 to 240     |
| Specific Gravity       | 0.554 to 1.000 |
| Carbon Dioxide [mol %] | 0 to 15        |
| Nitrogen [mol %]       | 0 to 15        |

### 3. Calculation Procedure

Formula for displacement meter volume calculations is:

$$V = q \times \frac{(P_t + 14.7)}{P_b} \times \frac{(T_b + 460)}{(T_t + 460)} \times (F_{pv})^2 \quad (1)$$

Where  $F_{pv}$  is supercompressibility factor,  $P_t$  is absolute pressure of Natural Gas,  $P_b$  is pressure of base condition (14.696 Psi),  $T_t$  is flowing Temperature,  $T_b$  is temperature of base condition (60 °F),  $q$  is measured volume and  $V$  is corrected volume.

The base equation for determining the  $F_{pv}$  Factor is expressed as:

$$F_{pv} = \frac{\sqrt{\frac{B}{D} - D + \frac{n}{3\pi}}}{1 + \left(\frac{0.00132}{\tau^{3.25}}\right)} \quad (2)$$

Where:

$$B = \frac{3 - mn^2}{9m\pi^2} \quad (3)$$

$$m = 0.0330378(\tau)^{-2} - 0.0221323(\tau)^{-3} + 0.0161353(\tau)^{-5} \quad (4)$$

$$n = \frac{0.265827(\tau)^{-3} + 0.0457697(\tau)^{-4} - 0.133185(\tau)^{-1}}{m} \quad (5)$$

$$\pi = \frac{P_{adj.} + 14.7}{1000} \quad (6)$$

$$\tau = \frac{T_{adj.} + 460}{500} \quad (7)$$

$$P_{adj.} = P_t \times F_P \quad (8)$$

$$T_{adj.} = [(T_t + 460) F_T] - 460 \quad (9)$$

$$D = \left[ b + \sqrt{b^2 + B^3} \right]^{1/3} \quad (10)$$

$$b = \frac{9n - 2mn^3}{54m\pi^3} - \frac{E}{2m\pi^2} \quad (11)$$

### 3.1. Alternate Methods

The pseudocritical pressure of a natural gas mixture ( $P_c$ ) can be defined as the sum of the products of the mol fraction ( $X_i$ ) and the critical pressure of each component gas ( $P_i$ ):

$$P_c = \sum P_i X_i \quad (12)$$

Similarly, the absolute pseudocritical temperature of a natural gas mixture ( $T_c$ ) can be defined as the sum of the products of the mol fraction ( $X_i$ ) of any corresponding component natural gas and the absolute critical temperature of any component gas ( $T_i$ ):

$$T_c = \sum T_i X_i \quad (13)$$

For the determination of pseudocritical parameters,  $P_c$  &  $T_c$  (if needed), and adjusting factors,  $F_p$  &  $F_T$ , we have three methods:

#### a) Standard Method or Gravity Method

This method is generally the default method for natural gas with Specific Gravity less than 0.75, mol percent of CO<sub>2</sub> less than 15% and mol percent of N<sub>2</sub> less than 15%. User Inputs are Specific Gravity ( $G$ ), mol% CO<sub>2</sub> ( $X_c$ ) and mol% N<sub>2</sub> ( $X_n$ ). In this method  $F_p$  &  $F_T$  is directly calculated by Eq.14 and Eq.15:

$$F_p = \frac{156.47}{160.8 - 7.22G + 100(X_c - 0.392X_n)} \quad (14)$$

$$F_T = \frac{226.29}{99.15 + 211.9G - 100(X_c + 1.681X_n)} \quad (15)$$

#### b) Methane-Gravity Method

In this method user Inputs are Specific Gravity ( $G$ ), mol percent of CO<sub>2</sub> ( $X_c$ ), mol percent of N<sub>2</sub> ( $X_n$ ) and mol percent of methane ( $X_m$ ). Also, the methane-gravity method is especially applicable where a natural gas has a specific gravity higher than 0.750 due to the heavier hydrocarbon components.

$$P_c = 891.11 - 172.56G + 443.04X_c - 232.23X_n - 122.52X_m \quad (16)$$

$$T_c = 327.77 + 214.82G - 144.12X_c - 319.52X_n - 102.78X_m \quad (17)$$

$$F_p = \frac{671.4}{P_c} \quad (18)$$

$$F_T = \frac{359.46}{T_c} \quad (19)$$

#### c) Heating Value Method

This method is inherently the same as the Standard Method since an exact linear relationship exists between the heating value (wet basis) B.T.U. per cubic foot, 14.73 Psia and 60 °F ( $H$ ) and the specific gravity of the hydrocarbon components of a natural gas. Any difference between the two methods can be attributed to normal uncertainties in determining specific gravity, heating value and diluent content of gas. This method is limited to natural gases of specific gravity less than 0.750.

$$P_c = 693 - 0.02029H + 379.0X_c - 201.0X_n \quad (20)$$

$$T_c = 124.7 + 0.2203H + 384.99X_c + 91.11X_n \quad (21)$$

For determining  $F_p$  and  $F_T$  use Eq.18 and Eq.19.

### 3.2. Equations of Parameter E

Parameter  $E$  appears in Eq.11 which is a definitive relation of the base equation. The following are the equations of  $E$  based on the respective ranges of applicability for pressure and temperature as indicated in Figure 1.

$$E_1 = 1 - 0.00075(\pi)^{2.3} e^{-20(\tau-1.09)} - 0.0011(\tau-1.09)^{0.5} (\pi)^2 \left[ 2.17 + 1.4(\tau-1.09)^{0.5} - \pi \right]^2 \quad (22)$$

PRESSURE– RANGE:  $\pi \rightarrow 0$  to 2 or  $P \rightarrow 0$  to 2000 (Psia)  
TEMPERATURE – RANGE:  $\tau \rightarrow 1.09$  to 1.4 or  $T \rightarrow 85$  to 240 ( $^{\circ}F$ )

$$E_2 = 1 - 0.00075(\pi)^{2.3} \left[ 2 - e^{-20(1.09-\tau)} \right] - 1.317(1.09-\tau)^4 (\pi)(1.69-\pi^2) \quad (23)$$

PRESSURE– RANGE:  $\pi \rightarrow 0$  to 1.3 or  $P \rightarrow 0$  to 1300 (Psia)  
TEMPERATURE – RANGE:  $\tau \rightarrow 0.84$  to 1.09 or  $T \rightarrow -40$  to 85 ( $^{\circ}F$ )

$$E_3 = 1 - 0.00075(\pi)^{2.3} \left[ 2 - e^{-20(1.09-\tau)} \right] + (\pi-1.3) \left( 1.69(2)^{1.25} - \pi^2 \right) \times 0.455[200(1.09-\tau)^6 - \dots - 0.03249(1.09-\tau) + 2.0167(1.09-\tau)^2 - 18.028(1.09-\tau)^3 + 42.844(1.09-\tau)^4] \quad (24)$$

PRESSURE– RANGE:  $\pi \rightarrow 1.3$  to 2.0 or  $P \rightarrow 1300$  to 2000 (Psia)  
TEMPERATURE – RANGE:  $\tau \rightarrow 0.88$  to 1.09 or  $T \rightarrow -20$  to 85 ( $^{\circ}F$ )

$$E_4 = \text{Same as } E_3 \text{ except the exponent } [1.25] \text{ is changed to } [1.25 + 80(0.88-\tau)^2] \quad (25)$$

PRESSURE– RANGE:  $\pi \rightarrow 1.3$  to 2.0 or  $P \rightarrow 1300$  to 2000 (Psia)  
TEMPERATURE – RANGE:  $\tau \rightarrow 0.84$  to 0.88 or  $T \rightarrow -40$  to  $-20$  ( $^{\circ}F$ )

$$E_{5a} = E_4 - Y \quad (26)$$

PRESSURE– RANGE:  $\pi \rightarrow 2.0$  to 5.0 or  $P \rightarrow 2000$  to 5000 (Psia)  
TEMPERATURE – RANGE:  $\tau \rightarrow 0.84$  to 0.88 or  $T \rightarrow -40$  to  $-20$  ( $^{\circ}F$ )

$$E_{5b} = E_3 - Y \quad (27)$$

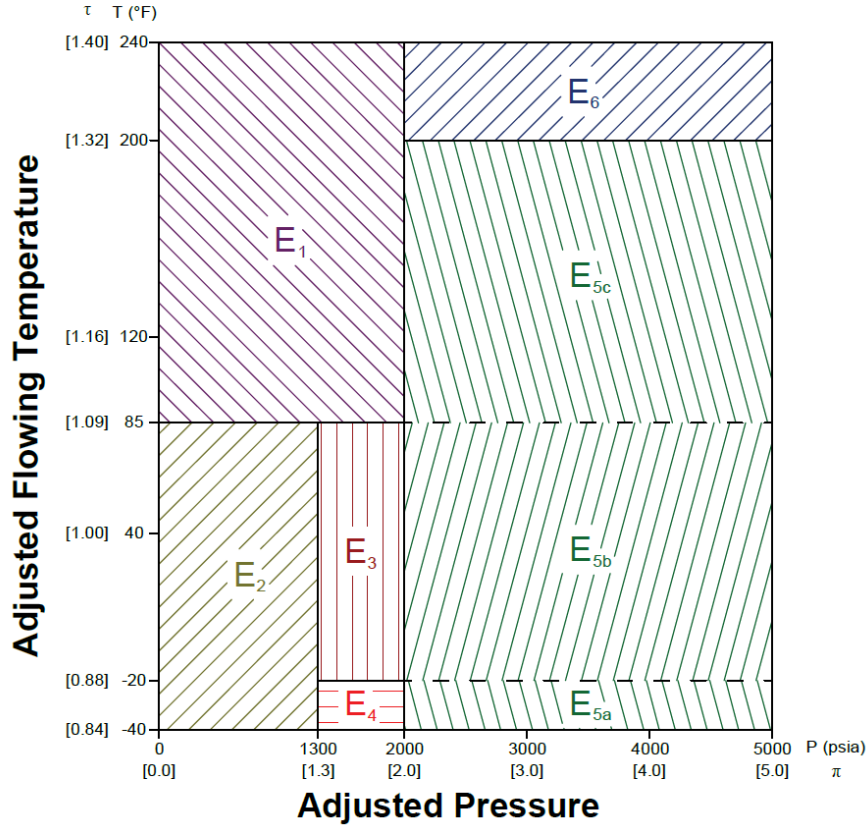
PRESSURE– RANGE:  $\pi \rightarrow 2.0$  to 5.0 or  $P \rightarrow 2000$  to 5000 (Psia)  
TEMPERATURE – RANGE:  $\tau \rightarrow 0.88$  to 1.09 or  $T \rightarrow -20$  to 85 ( $^{\circ}F$ )

$$E_{5c} = E_1 - Y \quad (28)$$

PRESSURE– RANGE:  $\pi \rightarrow 2.0$  to 5.0 or  $P \rightarrow 2000$  to 5000 (Psia)  
TEMPERATURE – RANGE:  $\tau \rightarrow 1.09$  to 1.32 or  $T \rightarrow 85$  to 200 ( $^{\circ}F$ )

$$E_6 = E_{5c} - Y \quad (29)$$

PRESSURE– RANGE:  $\pi \rightarrow 2.0$  to 5.0 or  $P \rightarrow 2000$  to 5000 (Psia)  
TEMPERATURE – RANGE:  $\tau \rightarrow 1.32$  to 1.40 or  $T \rightarrow 200$  to 240 ( $^{\circ}F$ )

Figure 1. Range of applicability of the parameter  $E$ 

Where:

$$Y = A(\pi - 2) + A_1(\pi - 2)^2 + A_2(\pi - 2)^3 + A_3(\pi - 2)^4 \quad (30)$$

$$A = 1.71720 - 2.33123(\tau) - 1.56796(\tau)^2 + 3.47644(\tau)^3 - 1.28603(\tau)^4 \quad (31)$$

$$A_1 = 0.016299 - 0.028094(\tau) + 0.48782(\tau)^2 - 0.728221(\tau)^3 + 0.27839(\tau)^4 \quad (32)$$

$$A_2 = -0.35978 + 0.51419(\tau) + 0.16453(\tau)^2 - 0.52216(\tau)^3 + 0.19687(\tau)^4 \quad (33)$$

$$A_3 = 0.075255 - 0.10573(\tau) - 0.058598(\tau)^2 + 0.14416(\tau)^3 - 0.054533(\tau)^4 \quad (34)$$

$$U = (\tau - 1.32)^2(\pi - 2) \left[ 3 - 1.483(\pi - 2) - 0.10(\pi - 2)^2 + 0.0833(\pi - 2)^3 \right] \quad (35)$$

In Eq.26 to Eq.28 if the value of  $\pi$  is in excess of 2.0, then use 2.0. However, in Eq.30 and Eq.35 use the actual value of  $\pi$  was computed from Eq.6.

#### 4. Analyzing

If we use Table 3 values for analyzing process according to alternate methods we have several charts of natural gas behavior in different conditions. This table contains average values from the gas chromatography of natural gas in Bazargan's metering station in 2010.

Table 3. Natural Gas composition's value according Bazargan's metering station reports average in 2010.

| Composition                               |                           | Component |
|---|---------------------------|-----------|
| Chemical Composition<br>(in mole percent) | Methane (C1)              | 90.307605 |
|   | Ethane (C2)               | 3.442815  |
|   | Propane (C3)              | 0.555435  |
|   | Butane (C4)               | 0.2440425 |
|   | Pentane and heavier (C5+) | 0.13595   |
|   | Nitrogen (N2)             | 4.6275525 |
|   | Carbon Dioxide (CO2)      | 0.677055  |
|   | Oxygen (O2)               | 0.00954   |
|   | Total                     | 100       |
| Sulphur<br>Content<br>(mg/SCM)            | Hydrogen Sulphide (H2S)   | 0.21225   |
|   | Mercaptan Sulphur         | 3.32325   |
|   | Total Sulphur             | 8.50225   |
| Gross Calorific Value (KCal/SCM)          |                           | 8897.738  |
| Water Dewpoint (°C at 45 KGF/CM2)         |                           | -46.602   |
| Hydrocarbon Dewpoint (°C at 45 KGF/CM2)   |                           | -28.04825 |
| Density at standard condition (Kg/SCM)    |                           | 0.74475   |
| Relative Density                          |                           | 0.61235   |

According to Eq.1 compressibility factor,  $Z$  is defined with Eq.36. Also, if we define  $CF$  as a Correction Factor to correct directly measured values to corrected values, we have:

$$Z = F_{pv}^2 \quad (36)$$

$$V = q \times CF \quad (37)$$

$$CF = \frac{(P_t + 14.7)}{P_b} \times \frac{(T_b + 460)}{(T_t + 460)} \times (F_{pv})^2 \quad (38)$$

$$CF = \frac{(P_t + 14.7)}{P_b} \times \frac{(T_b + 460)}{(T_t + 460)} \times Z \quad (39)$$

#### 4.1. Pressure effects

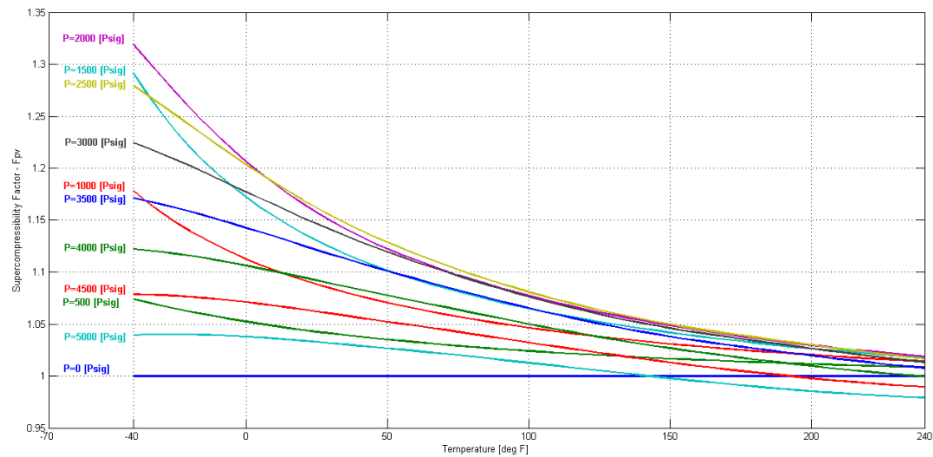


Figure 2. The effect of Pressure on Temperature-Supercompressibility Factor diagram for natural gas with specifications according to Table 3 values.



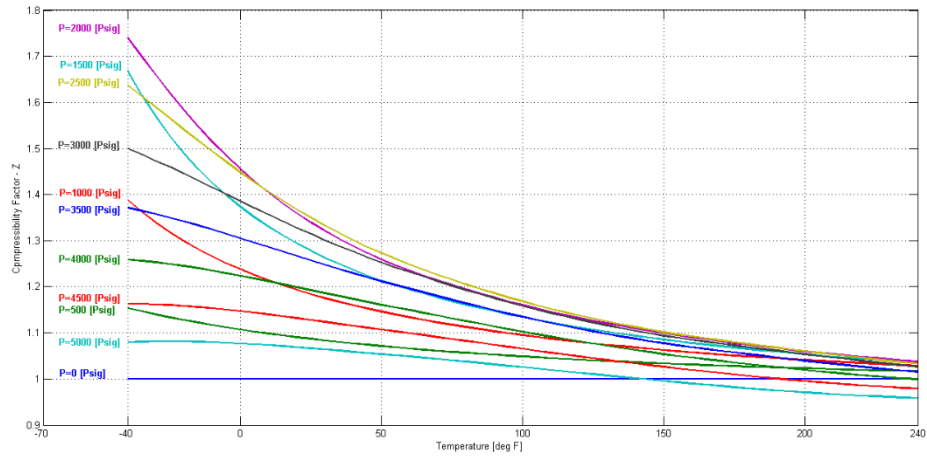


Figure 3. The effect of Pressure on Temperature-Compressibility Factor diagram for natural gas with specifications according to Table 3 values.

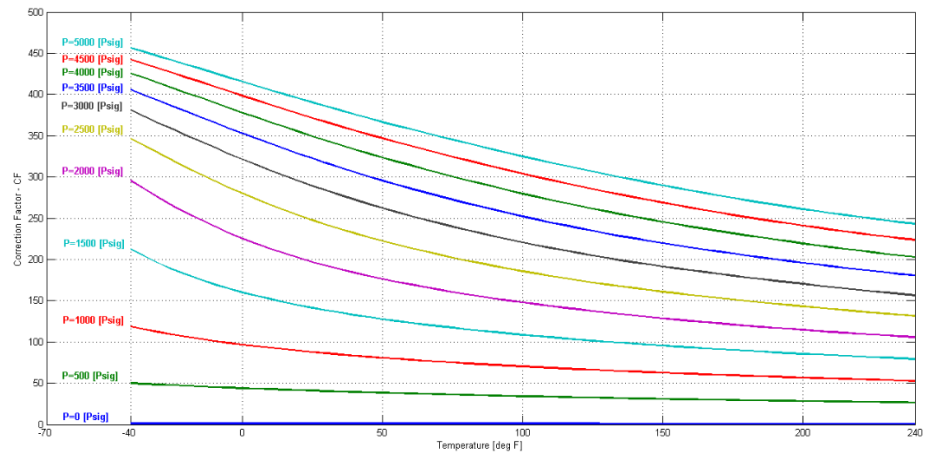


Figure 4. The effect of Pressure on Temperature-Correction Factor diagram for natural gas with specifications according to Table 3 values.

## 4.2. Temperature effects

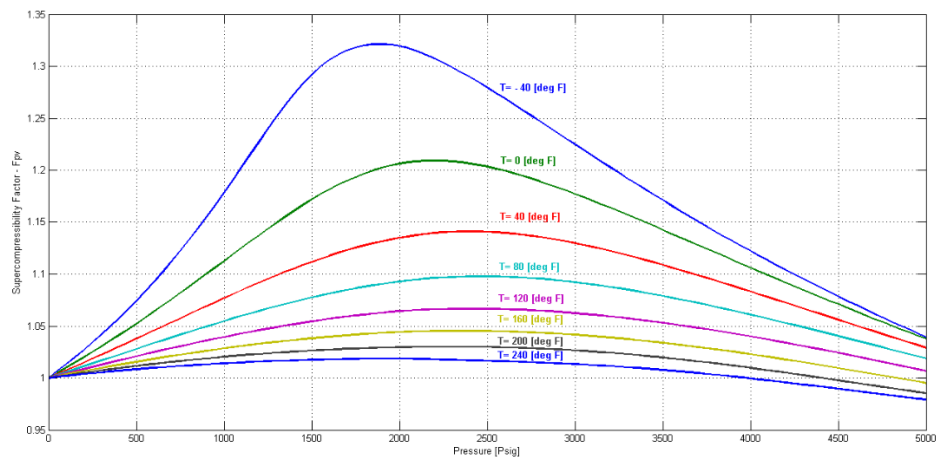


Figure 5. The effect of Temperature on Pressure-Supercompressibility Factor diagram for natural gas with specifications according to Table 3 values.

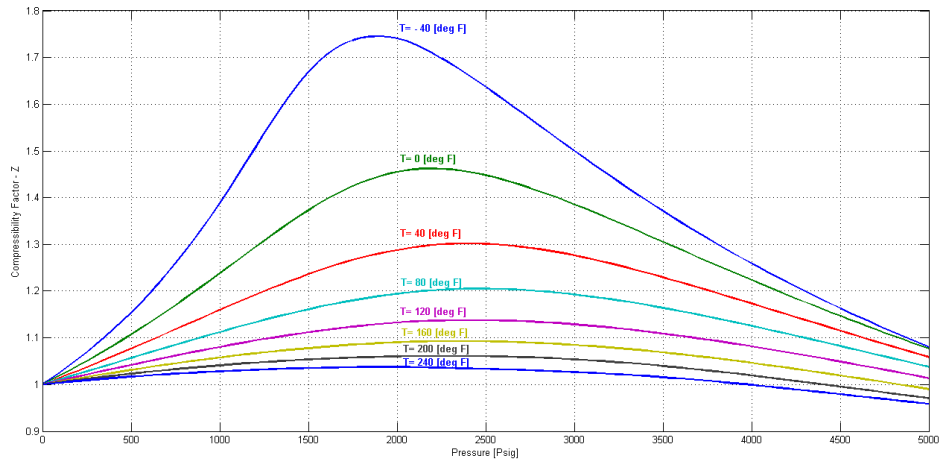


Figure 6. The effect of Temperature on Pressure-Compressibility Factor diagram for natural gas with specifications according to Table 3 values.

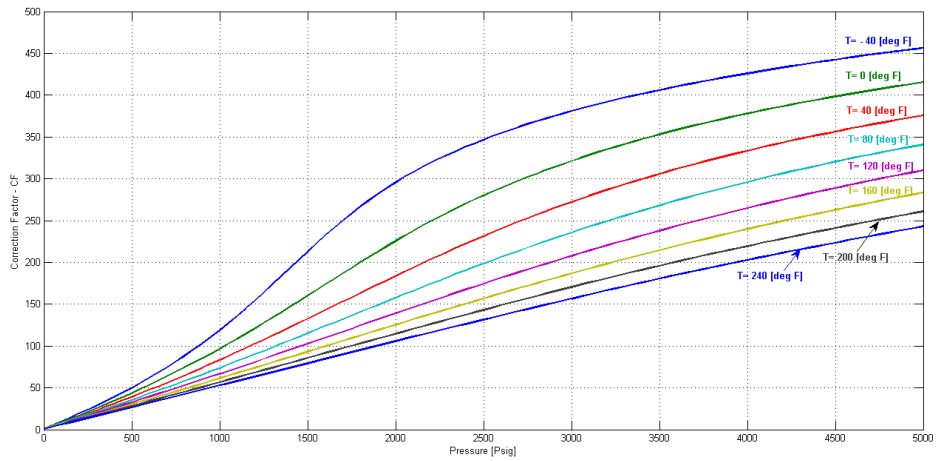


Figure 7. The effect of Temperature on Pressure-Correction Factor diagram for natural gas with specifications according to Table 3 values.

#### 4.3. Pressure-Temperature effects (2D View)

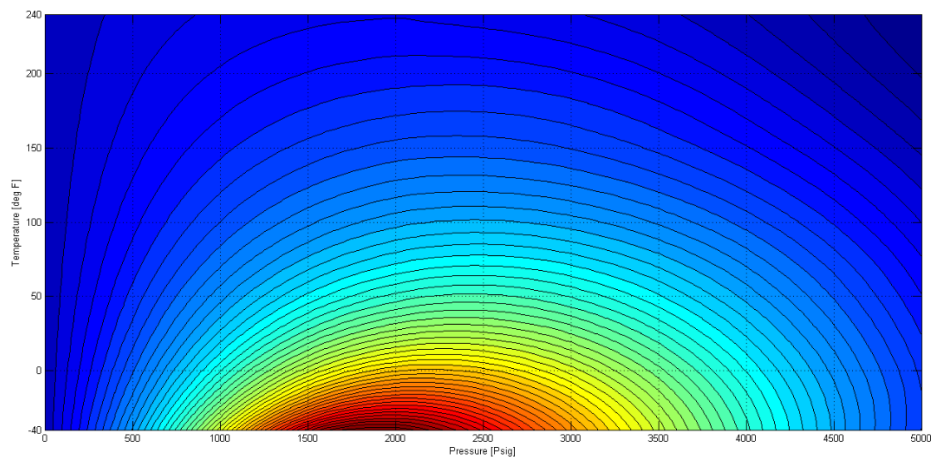


Figure 8. The effects of Pressure-Temperature together on Supercompressibility Factor for natural gas with specifications according to Table 3 values (2D View).

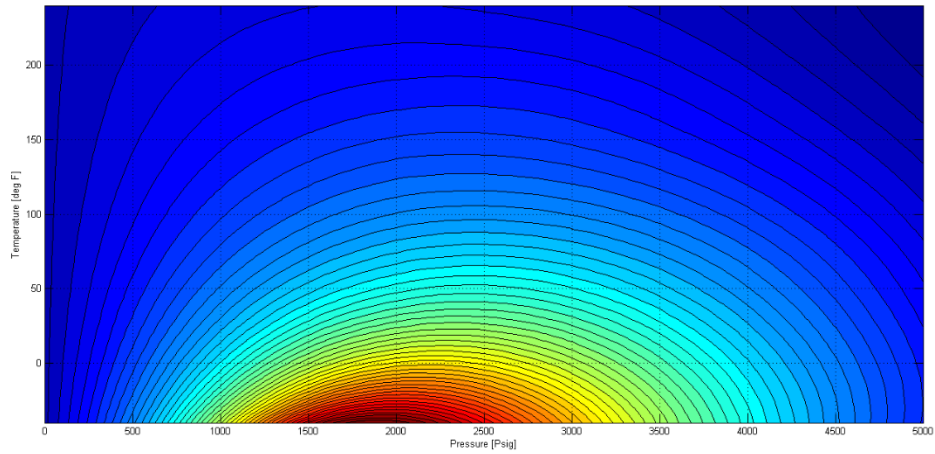


Figure 9. The effects of Pressure-Temperature together on Compressibility Factor for natural gas with specifications according to Table 3 values (2D View).

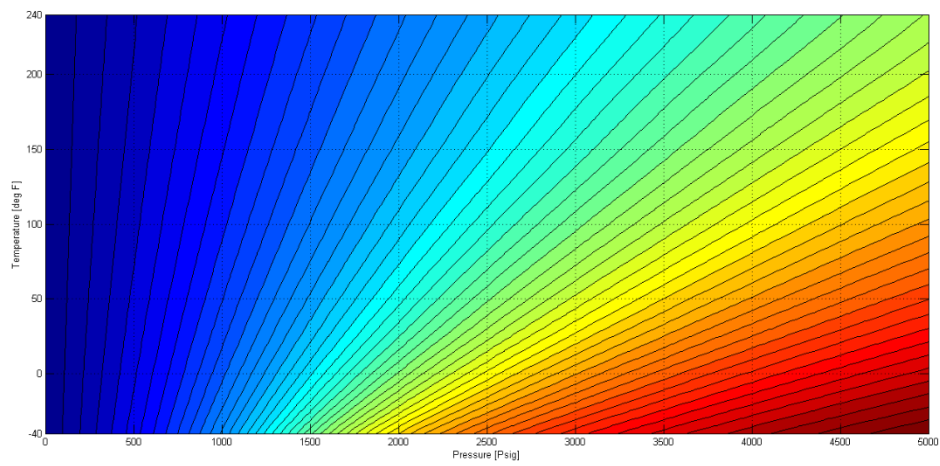


Figure 10. The effects of Pressure-Temperature together on Correction Factor for natural gas with specifications according to Table 3 values (2D View).

#### 4.4. Pressure-Temperature effects (3D View)

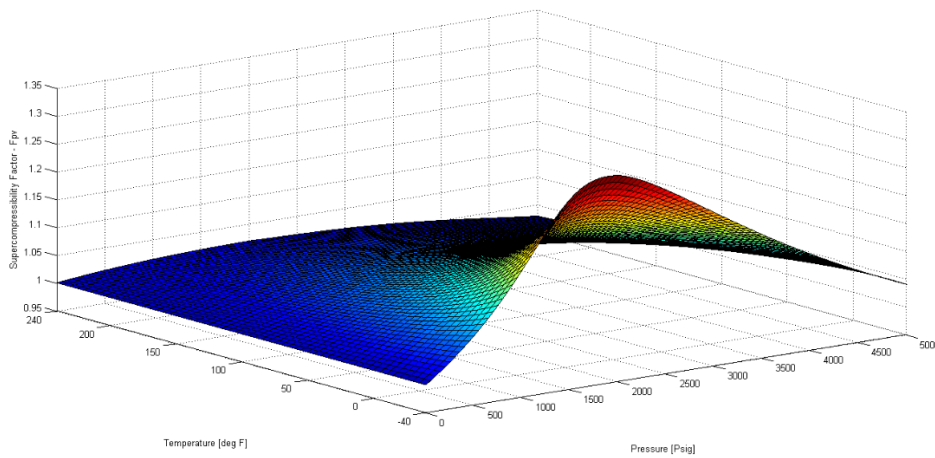


Figure 11. The effects of Pressure-Temperature together on Supercompressibility Factor for natural gas with specifications according to Table 3 values (3D View).

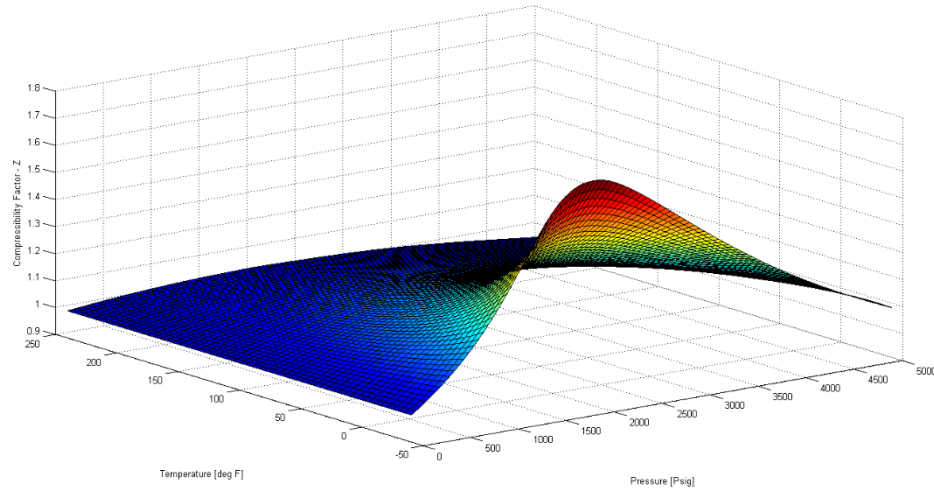


Figure 12. The effects of Pressure-Temperature together on Compressibility Factor for natural gas with specifications according to Table 3 values (3D View).

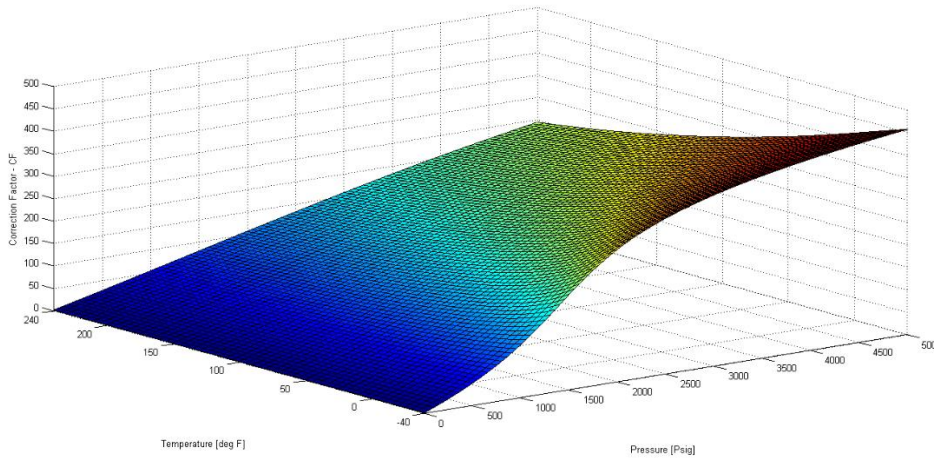


Figure 13. The effects of Pressure-Temperature together on Correction Factor for natural gas with specifications according to Table 3 values (3D View).

## 5. Conclusion

- 1) According to calculating procedures on NX-19 method, this method is one of the simplest and easiest methods.
- 2) As shown in Figure 2, with increasing pressure up to 2,000 psi, variations in supercompressibility factor relative to temperature are reduced more rapidly. At pressures higher than 2,000 Psig, with increasing pressure, the variations of the supercompressibility factor decreases relative to the temperature at a lower rate.
- 3) 3. Like supercompressibility factor behavior and according to Figure 3, with increasing pressure up to 2,000 psi, variations in compressibility factor relative to temperature are reduced more rapidly. At pressures higher than 2,000 Psig, with increasing pressure, the variations of the compressibility factor decreases relative to the temperature at a lower rate.
- 4) 4. Unlike supercompressibility and compressibility factors behaviors, as shown in Figure 4, with increasing pressure, the correction factor changes relative to the temperature are strictly descending.
- 5) As shown in Figure 5, supercompressibility factor behavior relative pressure with constant temperature, has a dome shaped with difference maximum values according to the temperatures. That means the maximum value of supercompressibility factor with constant temperature, -40°F, occurs on 1888 Psig and 1.3212 as a supercompressibility factor value. As well as, this maximum value for 240°F will be on 2039 Psig and 1.0187 as a supercompressibility factor value.

- 6) Like supercompressibility factor behavior and according to Figure 6, also, compressibility factor has a dome shaped with difference maximum values according to the temperatures. That means the maximum value of compressibility factor with constant temperature,  $-40^{\circ}\text{F}$ , occurs on 1888 Psig and 1.7455 as a compressibility factor value. As well as, this maximum value for  $240^{\circ}\text{F}$  will be on 2039 Psig and 1.0377 as a compressibility factor value.
- 7) Unlike supercompressibility and compressibility factors behaviors, as shown in Figure 7, with increasing temperature, the correction factor changes relative to the pressure are strictly ascending.
- 8) As shown in Figure 8, supercompressibility factors are increased around  $-40^{\circ}\text{F}$  and 2000 Psig. It has minimum values on  $240^{\circ}\text{F}$ . As the same way in Figure 11, this factor has a 3D semi-dome shaped with maximum values on 1888 Psig,  $-40^{\circ}\text{F}$  and 1.3212 as a supercompressibility factor value and with minimum values on 5000 Psig,  $240^{\circ}\text{F}$  and 0.9791 as a supercompressibility factor value.
- 9) Like supercompressibility factor behavior and according to Figure 9, compressibility factors are increased around  $-40^{\circ}\text{F}$  and 2000 Psig. It has minimum values on  $240^{\circ}\text{F}$ . As the same way in Figure 12, this factor has a 3D semi-dome shaped with maximum values on 1888 Psig,  $-40^{\circ}\text{F}$  and 1.7455 as a compressibility factor value and with minimum values on 5000 Psig,  $240^{\circ}\text{F}$  and 0.9587 as a compressibility factor value.
- 10) Unlike supercompressibility and compressibility factors behaviors, as shown in Figures 10 and 13, with decreasing temperature and increasing pressure, the correction factor changes are strictly ascending.

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