Feasible C_{7+} Splitting Methods An Object-Oriented Approach

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Abstract

When using equations of state to predict the phase behavior of hydrocarbon mixtures, problems occur with the C_{7+} fraction that exists in such mixtures. Minimizing such problems requires breaking down (splitting) the C_{7+} fraction into a number of pseudo-components with a single carbon number; e.g. C_7, C_8, C_9…, etc. Extensive compositional analyses of too many reservoir fluids from all over the world have shown exponential molar distributions (mole fraction/molecular weight relation) of the C_{7+} pseudo-components. Hence exponential methods are extensively used by many researchers as a first choice for splitting the C_{7+} fraction. Other researchers are still suggesting improvements and enhancements to such methods. This is due to their feasibility in the sense that they do not contain too many unknown or difficult-to-determine parameters. In addition, C_{7+} characterization represents only a minor portion of the process of compositional reservoir simulation.

This paper revisits the most common splitting methods that were presented in literature and have gotten a wide acceptance in the oil industry. A worthwhile aspect of the paper, however, is that it proposes an improvement to the Katz constant-parameter splitting method. The improved method compared well with other splitting methods for all tested data sets. Another aspect of the paper is that the program has been coded in an object-oriented manner, which offers flexibility in programming and allows the different parts of the code to be described easily and in a natural manner as if they were real world objects. Some examples that were cited in literature are presented.

Keywords: C_{7+} splitting; hydrocarbon plus fractions; phase behavior; equations of state; OOP application

1. Introduction

Hydrocarbon mixtures are often complex for a complete identification of all components that exist in them. In addition, most experimental studies of the hydrocarbon mixtures group components with a carbon number higher than 6; e.g. C_7, C_8, C_9…, etc. in one component referred to as C_{7+}. Molecular weight and specific gravity of the C_{7+} may be the only measured data.

In compositional reservoir simulation, equations of state (EOS) are extensively used for phase behavior calculations of the hydrocarbon mixtures. When using EOS to predict the phase behavior of hydrocarbon mixtures, problems occur with the C_{7+} fraction. Different methods were proposed by several authors to minimize such problems and to enhance EOS predictions when experimental data are lacking.

Minimizing those problems requires either fine-tuning EOS parameters or characterizing the C_{7+} fraction or both. Proper characterization of the plus fraction, however, reduces the need for extensive tuning of the EOS. Thus, C_{7+} characterization is considered the most important step associated with the description of reservoir fluids. Several characterization methods were proposed. Collectively, those methods are grouped into two main categories: *correlation* and *splitting and lumping*.

Splitting refers to the process of breaking down (re-extending) the C_{7+} fraction into a number of pseudo-components with a single carbon number, each having a prescribed set of physical properties.

In this paper, an object-oriented program was developed for applying the most common splitting schemes that were cited in literature and have gotten a wide acceptance in the oil industry. Eight data sets were used to compare those schemes; six gas condensates and two oil systems. It was found that Ahmed, Pedersen, and Whitson methods compare well in almost all cases; bearing in mind that exponential distribution was assumed for all cases; i.e. $\alpha = 1$ for Whitson method. Katz equation, however, with its constant parameters of 1.38205 and -0.25903 did not do a good job; even in some of the gas condensates. A worthwhile aspect of this paper, however, is that it proposes an improvement to the Katz constant-parameter splitting method. When those parameters were replaced with variable ones that account for the C_{7+} molecular weight and specific gravity, it has considerably improved. Another aspect of the paper is that most phase behavior coding, to the best of my knowledge, has been developed using the traditional FORTRAN language, which is a natural choice from the view point of continuity in downstream data processing. Such a natural choice may not necessarily be the optimal choice. In fact, the use of an object-oriented language has allowed the different parts constituting the code to be described easily and in a natural manner.

2. C_{7+} Splitting Methods

Splitting refers to the process of breaking down (re-extending) the C_{7+} fraction into a number of pseudo-components with a single carbon number. The pseudo-components of the extended analysis are assigned the same physical properties used for pure components. Physical properties of pure components are well defined. They were measured and compiled over the years. Katz and Firoozabadi (1978) presented a generalized set of physical properties for pure components C_6 through C_{45}. Whitson (1984) modified the original tabulated physical properties to make their use more consistent. The last fraction of the extended analysis, however, is characterized using one of the characterization methods such as Kesler and Lee (1976) or Riazi and Daubert (1987). Several splitting methods were proposed by different authors. Those methods are based on the observation that lighter hydrocarbon systems such as gas condensates usually exhibit *exponential* molar distribution (mole fraction/molecular weight relation), while heavier systems show *left-skewed* molar distribution.

Extensive compositional analyses of too many reservoir fluids from all over the world have shown exponential molar distributions; Pedersen et al. (1992); Zuo et al. (2000); and Elsharkawy (2003). Hence exponential methods are extensively used by

many researchers as a first choice for splitting the C_{7+} fraction; e.g. Almehaideb et al. (2000); Avaullee et al. (2001); Elsharkawy (2003); Whitson et al. (1990); and Zuo et al. (2000). Other researchers are still suggesting improvements and enhancements to such methods; e.g. Whitson et al. (1990); and Pedersen et al. (1992). This is due to their feasibility in the sense that they do not contain too many unknown or difficult-to-determine parameters. In addition, C_{7+} characterization represents only a minor portion of the process of compositional reservoir simulation.

In most PVT studies, only specific gravity and molecular weight of the C_{7+} fractions are reported. Splitting methods make use of this set of data to satisfy the following requirements:

- $$\sum_{n=7}^{N} z_n = z_{C_{7+}} \tag{1}$$
- $$\sum_{n=7}^{N} MW_n z_n = MW_{C_{7+}} z_{C_{7+}} \tag{2}$$
- $$\sum_{n=7}^{N} \frac{MW_n}{SG_n} z_n = \frac{MW_{C_{7+}}}{SG_{C_{7+}}} z_{C_{7+}} \tag{3}$$

2.1 Katz Splitting Method

Katz (1983) proposed a simple graphical correlation for splitting the C_{7+} fraction. His correlation is represented in a mathematical form as follows:

$$z_n = z_{C_{7+}} 1.38205 e^{-0.25903n} \tag{4}$$

2.2 Lohrenz Splitting Method

Lohrenz et al. (1964) proposed that the C_{7+} fraction could be split into pseudo-components with carbon number that ranges from 7 to 40. Their correlation is represented in a mathematical form as follows:

$$z_n = z_6 e^{A(n-6)^2 + B(n-6)} \tag{5}$$

The parameters A and B are determined in such a way that constraints (1) and (3) are satisfied; i.e. plugging equation (5) into equations (1) and (3) yields:

$$z_6 \sum_{n=7}^{40} e^{A(n-6)^2 + B(n-6)} - z_{C_{7+}} = 0 \tag{6}$$

$$z_6 \sum_{n=7}^{40} \frac{MW_n}{SG_n} e^{A(n-6)^2+B(n-6)} - \frac{MW_{C_{7+}}}{SG_{C_{7+}}} z_{C_{7+}} = 0 \tag{7}$$

Equations (6) and (7) are solved simultaneously for A and B. Once A and B are found, mole fractions of pseudo-components are calculated using equation (5).

2.3 Pedersen Splitting Method

Pedersen et al. (1989) presented an exponential correlation to describe the extended analysis of the C_{7+} fraction that exists in petroleum mixtures. Their correlation is written as:

$$z_n = e^{A+B\,MW_n} \tag{8}$$

Where the parameters A and B are required to satisfy constraints (1) and (3); i.e. plugging equation (8) into equations (1) and (3) yields:

$$\sum_{n=7}^{N} e^{A+B\,MW_n} - z_{C_{7+}} = 0 \tag{9}$$

$$\sum_{n=7}^{N} \frac{MW_n}{SG_n} e^{A+B\,MW_n} - \frac{MW_{C_{7+}}}{SG_{C_{7+}}} z_{C_{7+}} = 0 \tag{10}$$

Equations (9) and (10) are solved simultaneously for A and B. Once A and B are found; mole fractions of pseudo-components are calculated using equation (8).

2.4 Ahmed Splitting Method

Ahmed et al. (1985) devised a simple method for splitting the C_{7+} fraction into a number of pseudo-components. The only input data required are the mole fraction and the molecular weight of the C_{7+}. The authors proposed the following expression for estimating pseudo-component mole fractions:

$$z_n = z_{n+} \left(\frac{MW_{(n+1)+} - MW_{n+}}{MW_{(n+1)+} - MW_n} \right) \tag{11}$$

Where:

$$z_{n+} = z_{(n-1)+} - z_{(n-1)} \tag{12}$$

$$MW_{n+} = MW_{C_{7+}} + S(n-7) \tag{13}$$

S is given by:

	gas condensate system	crude oil system
n ≤ 8	S = 15.5	S = 16.5
n > 8	S = 17.0	S = 20.1

2.5 Whitson Splitting Method

Whitson (1983) proposed that the three-parameter gamma function can be used to model the molar distribution (mole fraction/molecular weight relation) of the C_{7+} fraction. Whitson expressed the mole fraction of each pseudo-component in the extended analysis as follows:

$$z_n = \frac{z_{C_{7+}}}{\Gamma(\alpha)} \sum_{j=0}^{\infty} \frac{y_{n+1}^{\alpha+j} e^{-y_{n+1}} - y_n^{\alpha+j} e^{-y_n}}{\Gamma(\alpha + j + 1)} \tag{14}$$

Where:

$$y_n = \frac{MW_n - \eta}{\beta} \tag{15}$$

$$\eta = \begin{cases} 92 & C_{7+} \\ 14n - 6 & C_{n+} \end{cases} \tag{16}$$

$$\beta = \frac{MW_{C_{7+}} - \eta}{\alpha} \tag{17}$$

The summation in the above equation can be ceased when:

$$\sum_{j+1} - \sum_{j} < 10^{-6} \tag{18}$$

α is an adjustable parameter which can be calculated as follows:

$$\alpha = \frac{0.5000876 + 0.1648852Y - 0.0544174Y^2}{Y} \tag{19}$$

Where:

$$Y = \ln\left[\frac{MW_{C_{7+}} - \eta}{m_G}\right] \tag{20}$$

$$m_G = \left[\prod_{i=n}^{N} (MW_i - \eta)^{z_i}\right]^{\frac{1}{z_{C_{7+}}}} \tag{21}$$

2.6 Improvement to Katz Splitting Method

Direct implementation of Katz splitting method frequently results in poor extended analysis; which does not compare well with other splitting methods. This drawback can basically render the method practically useless for the purpose of PVT predictions and phase behavior calculations. To remedy this problem, the constant parameters of Katz correlation are replaced with variable parameters; i.e. Katz equation is rewritten as:

$$z_n = z_{C_{7+}} A e^{-Bn} \tag{22}$$

Where the parameters A and B are required to satisfy constraints (1) and (3); i.e. plugging equation (22) into equations (1) and (3) yields:

$$A\sum_{n=7}^{N} e^{-Bn} - 1 = 0 \tag{23}$$

$$A\sum_{n=7}^{N} \frac{MW_n}{SG_n} e^{-Bn} - \frac{MW_{C_{7+}}}{SG_{C_{7+}}} = 0 \tag{24}$$

If constraint (2) were used instead of (3), then the equations would consider C_{7+} molecular weight alone. Using constraint (3), however, forces the equations to also consider the C_{7+} specific gravity. Solving equation (23) for A and plug it into equation (24) yields:

$$\frac{\sum_{n=7}^{N} \frac{MW_n}{SG_n} e^{-Bn}}{\sum_{n=7}^{N} e^{-Bn}} - \frac{MW_{C_{7+}}}{SG_{C_{7+}}} = 0 \tag{25}$$

Equation (25) represents a single nonlinear equation; which is solved by the Newton-Raphson method for B, and then equation (23) is directly solved for A. Once A and B parameters are found, mole fractions of the pseudo-components are calculated from equation (22). This modification has changed the correlation to match well with other splitting methods as it can be seen from the presented examples.

3. Program Development

The program in this paper was developed using the C# object-oriented programming (OOP) language, which provides substantial computing and programming advantages and allows the most difficult coding tasks to become truly feasible. OOP is a relatively new approach to creating applications related to the petroleum industry. OOP techniques are firmly rooted in the structure and meaning of data, and the interaction between data and other data. The language has the benefit of extensibility; which is achieved using *objects* as the name of the technology suggests. An *object* is a building block of an OOP application. This building block encapsulates data to the code that operates upon them. Implementation of C_{7+} splitting using C# entailed creating a single class called **PetroleumClassLibrary.Fluid.Compositional.Fraction** or simply **Fraction**. This class includes three constructors as follows:

1. The first constructor is dedicated to pure components, where pure component formula (key) is the only required piece of data. Component properties are obtained from a databank; since physical properties of pure components are well defined. They were measured and compiled over the years. Katz and Firoozabadi (1978) presented a generalized set of physical properties for pure components C_6 through C_{45}. Whitson (1984) modified the original tabulated physical properties to make their use more consistent. For example, the following code snippet creates an object called **Pure** of the class **Fraction**.

```
Fraction Pure = new Fraction(Formula);
```

Once the object has been created, its pertinent data are obtained easily; e.g. the next code snippet displays **Pure** component properties:

```
Console.WriteLine
 (
   Pure.Properties.Name + "     " +
   Pure.Properties.SG.ToString("F6") + "     " +
```

```
   Pure.Properties.MW.ToString("F3") + "     " +
   Pure.Properties.Tb.ToString("F3") + "     " +
   Pure.Properties.Tc.ToString("F3") + "     " +
   Pure.Properties.Pc.ToString("F3") + "     " +
   Pure.Properties.Af.ToString("F6") + "     " +
   Pure.Properties.Zc.ToString("F6") + "     " +
   Pure.Properties.Vc.ToString("F6")
  );
```

That said; the statement `Pure.Properties.Pc` refers to the critical pressure, Pc, of the pure component **Pure**.

2. The second constructor is dedicated to undefined fractions, where fraction specific gravity, molecular weight, and/or true boiling point are the only required data to fully characterize the fraction. There are various correlations for characterizing the undefined fractions. Kesler-Lee (1976) and Riazi and Daubert (1987) methods were implemented. For example, the following code snippet creates an object called **Undefined** of the class **Fraction**.

```
Fraction Undefined = new Fraction(sg, tb, mw, cs);
```

Where `cs` refer to the characterization scheme: either Kesler-Lee or Riazi-Daubert. Once the object has been created, its pertinent data are obtained easily; e.g. the next code snippet displays the **Undefined** fraction properties:

```
Console.WriteLine
 (
   Undefined.Properties.Name + "     " +
   Undefined.Properties.SG.ToString("F6") + "     " +
   Undefined.Properties.MW.ToString("F3") + "     " +
   Undefined.Properties.Tb.ToString("F3") + "     " +
   Undefined.Properties.Tc.ToString("F3") + "     " +
   Undefined.Properties.Pc.ToString("F3") + "     " +
   Undefined.Properties.Af.ToString("F6") + "     " +
   Undefined.Properties.Zc.ToString("F6") + "     " +
   Undefined.Properties.Vc.ToString("F6")
  );
```

That said; the statement `Undefined.Properties.Pc` refers to the critical pressure, Pc, of the undefined fraction **Undefined**.

3. The third constructor is dedicated to C_{7+} fraction, where mole fraction, specific gravity, and molecular weight are the only required data to fully characterize the fraction. For example, the following code snippet creates an object called **Plus** of the class **Fraction**.

```
Fraction Plus = new Fraction(z, sg, mw, last, cs, ss, ls);
```

Where `last` refer to the last component in the split system, `cs` refer to the characterization scheme: either Kesler-Lee or Riazi-Daubert, `ss` refer to the splitting scheme: Katz, Katz Improved, Ahmed, Pedersen, Lohrenz, or Whitson, and finally `ls` refer to the lumping scheme: Whitson or Behrens and Sandler. Once the object has been created, its pertinent data are obtained easily; e.g. the next code snippet displays the **Plus** fraction properties as an undefined fraction:

```
Console.WriteLine
 (
   Plus.Properties.Name + "     " +
   Plus.Properties.SG.ToString("F6") + "     " +
   Plus.Properties.MW.ToString("F3") + "     " +
   Plus.Properties.Tb.ToString("F3") + "     " +
   Plus.Properties.Tc.ToString("F3") + "     " +
   Plus.Properties.Pc.ToString("F3") + "     " +
   Plus.Properties.Af.ToString("F6") + "     " +
   Plus.Properties.Zc.ToString("F6") + "     " +
   Plus.Properties.Vc.ToString("F6")
  );
```

Again; the statement `Plus.Properties.Pc` refers to the critical pressure, Pc, of the plus fraction **Plus**. Similarly the next code snippet displays splitting data of the **Plus** fraction:

```
for (int i=0; i<Plus.Split.Length; i++)
{
 Console.WriteLine
 (
   Plus.Split[i].Name + "     " +
   Plus.Split[i].z.ToString("F6") + "     " +
   Plus.Split[i].SG.ToString("F6") + "     " +
   Plus.Split[i].MW.ToString("F6") + "     " +
   Plus.Split[i].Tb.ToString("F6") + "     " +
   Plus.Split[i].Tc.ToString("F6") + "     " +
   Plus.Split[i].Pc.ToString("F6") + "     " +
   Plus.Split[i].Af.ToString("F6") + "     " +
   Plus.Split[i].Zc.ToString("F6") + "     " +
   Plus.Split[i].Vc.ToString("F6")
  );
}
```

The statement `Plus.Split[i].Pc` refers to the critical pressure (Pc) of component (i) in the split system (Split) of the (Plus) object. Similarly the next code snippet displays lumping data of the **Plus** fraction:

```
for (int i=0; i<Plus.Lump.Length; i++)
{
 Console.WriteLine
 (
   Plus.Lump[i].Name + "     " +
   Plus.Lump[i].z.ToString("F6") + "     " +
   Plus.Lump[i].SG.ToString("F6") + "     " +
   Plus.Lump[i].MW.ToString("F6") + "     " +
   Plus.Lump[i].Tb.ToString("F6") + "     " +
   Plus.Lump[i].Tc.ToString("F6") + "     " +
   Plus.Lump[i].Pc.ToString("F6") + "     " +
   Plus.Lump[i].Af.ToString("F6") + "     " +
   Plus.Lump[i].Zc.ToString("F6") + "     " +
   Plus.Lump[i].Vc.ToString("F6")
  );
}
```

The statement `Plus.Lump[i].Pc` refers to the critical pressure (Pc) of component (i) in the lump system (Lump) of the (Plus) object.

From the above code snippets, it should be so clear how the C# OOP language offers flexibility in programming and allows the different parts of the code to be described easily and in a natural manner as if they were real world objects.

4. Results and Discussion

Eight data sets were used to compare the different splitting methods presented in this work. Table 1 lists four sets of data that were reported by Coats and Smart (1986). Table 2 lists the other four sets of data that were reported by different authors.

Figures 1 to 8 show molar distributions (mole fraction/molecular weight relation). Values of the fitting parameters of the improved Katz splitting method, A and B, are shown on each plot. As it can be seen, the method compares well with Ahmed, Pedersen, and Whitson splitting schemes. Exponential molar distribution was considered in all cases; i.e. the parameter α of Whitson method was set to 1. Pseudo-components were assigned physical properties of pure components. Properties of the last fraction in the extended analysis, however, were generated using Riazi and Daubert correlation (1987).

5. Conclusions

In this paper, the most common splitting schemes, that were cited in literature and have gotten a wide acceptance in the oil industry, were presented. Katz splitting scheme was improved by replacing the constant parameters by variable parameters that account for specific gravity and molecular weight of the plus fraction. Object-oriented development decomposes the code on the basis of objects instead of on the basis of functions. This offers flexibility in programming and increases the computational efficiency. It also allows the different parts of the code to be described easily and in a natural manner as if they were real world objects.

6. Nomenclature

MW_n	molecular weight of the pseudo-component with n carbon atoms, lb/lb-mol
MW_N	molecular weight of last component in the extended system, lb/lb-mol
MW_{C7+}	molecular weight of the C_{7+} fraction in the hydrocarbon system, lb/lb-mol
n	number of carbon atoms of the pseudo-component
N	number of carbon atoms of last component in the extended system
SG_n	specific gravity of the pseudo-component with n carbon atoms
SG_N	specific gravity of last component in the extended system
SG_{C7+}	specific gravity of the C_{7+} fraction in the hydrocarbon system
Z_6	mole fraction of C_6 component in the hydrocarbon system
Z_n	mole fraction of the pseudo-component with n carbon atoms
Z_N	mole fraction of last component in the extended system
Z_{C7+}	mole fraction of the C_{7+} fraction in the hydrocarbon system

Appendix A: Listing of Katz & Improved Katz Splitting Schemes

```
private void KatzSplit()
{
 double Z;
 double RmnZ = z;
 double RmnW = z * MW;
 double RmnG = z * MW / SG;
 string Key;

 SplitTuneParameter = new double[2];
 SplitTuneParameter[0] = 1.38205;
 SplitTuneParameter[1] = 0.25903;
 if (splitscheme == SplitScheme.KatzTuned)
 {
  SplitTuneParameter[1]= PetroleumClassLibrary.Math.RootFinding.Ridder
        (
          0.0,
          1.0,
          1.0e-15,
          KatzSplitFunc
        );
  SplitTuneParameter[0] = 0.0;
  for (int n=7, c=0; n<=45; n++, c++)
     SplitTuneParameter[0] +=
```

```
         System.Math.Exp(-
         SplitTuneParameter[1]*n);
         SplitTuneParameter[0] = 1.0 /
         SplitTuneParameter[0];
 }

 int j;
 for (int n=7, c=0; n<=Last; n++, c++)
 {
  Key = "C" + n.ToString();
  Split[c] = new Component(Key);

  Split[c].z=Z=SplitTuneParameter[0]*z*
        System.Math.Exp(-SplitTuneParameter[1] * n);
         RmnZ -= Z;
         RmnW -= Z * Split[c].MW;
         RmnG -= Z * Split[c].MW / Split[c].SG;
         double RmnWZ = RmnW / RmnZ;
         double RmnWG = RmnW / RmnG;

  if (n==Last || RmnZ<1.0e-4 ||
      RmnWZ>540.0 || RmnWG > 0.94 ||
      RmnWG < SG)
  {
   Key = "C" + n.ToString() + "+";
   RmnZ += Z;
   RmnW += Z * Split[c].MW;
   RmnG += Z * Split[c].MW / Split[c].SG;
   RmnWZ = RmnW / RmnZ;
   RmnWG = RmnW / RmnG;
   Split[c] = new Component(RmnWG, RmnWZ,
   Component.CharacterizationScheme.RiaziDaubertII);
   Split[c].Name = Key;
   Split[c].z = RmnZ;
   j = n - 6;
   Array.Resize(ref Split, j);
   break;
  }
 }
}

private double KatzSplitFunc(double x)
{
 string Key;
 Component Comp;
 double e, Tt = 0.0, Tb = 0.0;
 int n, c;
 for (n = 7, c = 0; n <= 45; n++, c++)
 {
  Key = "C" + n.ToString();
  Comp = new Component(Key);

  e = System.Math.Exp(-x * n);
  Tb += e;
  Tt += (Comp.MW * e / Comp.SG);
 }
 return (Tt / Tb - MW / SG);
}
```

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Table 1: Four C_{7+} fraction data sets that were reported by Coats and Smart (1986).

	Gas 1	**Gas 2**	**Oil 2**	**Oil 3**
C_6 mol %	1.79	0.90	1.51	2.58
C_{7+} mol %	12.20	5.88	16.92	18.51
SG_{C7+}	0.8115	0.8100	0.8364	0.8275
MW_{C7+}	193	153	173	189

Table 2: Four C_{7+} fraction data sets that were reported by Roland (1942), Hoffmann et al. (1953), Donohoe et al. (1981), and Firoozabadi et al. (1978) Mixtures

	Roland	**Hoffmann**	**Donohoe**	**Firoozabadi**
C_6, %	0.63	0.39	1.14	0.72
C_{7+}, %	1.36	1.54	3.48	3.10
SG_{C7+}	0.8268	0.7961	0.7763	0.7740
MW_{C7+}	198	138.78	152.3	132

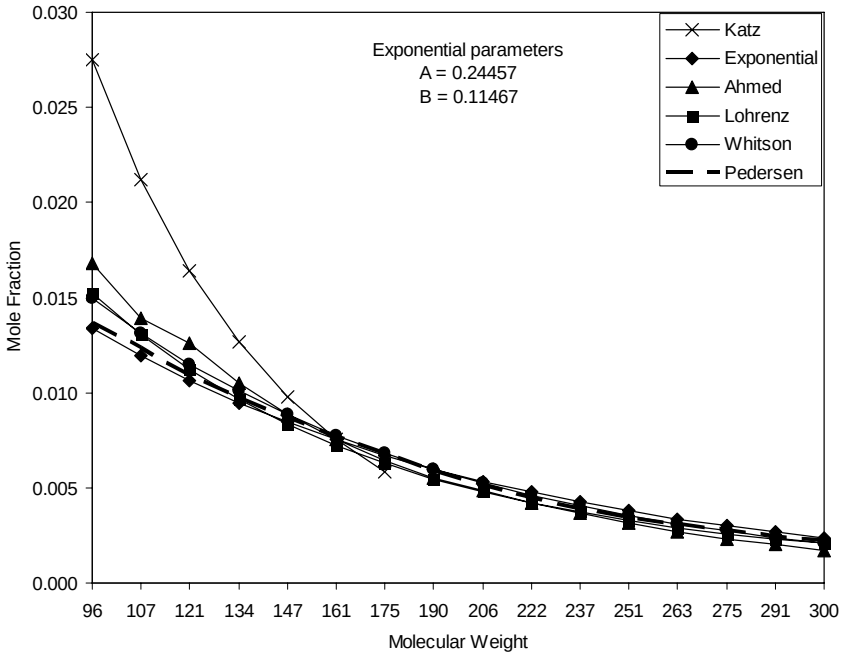

Fig. 1: Mole fractions versus molecular weights of the extended analysis of the C_{7+} fraction of the Gas1 system reported by Coats and Smart (1986)

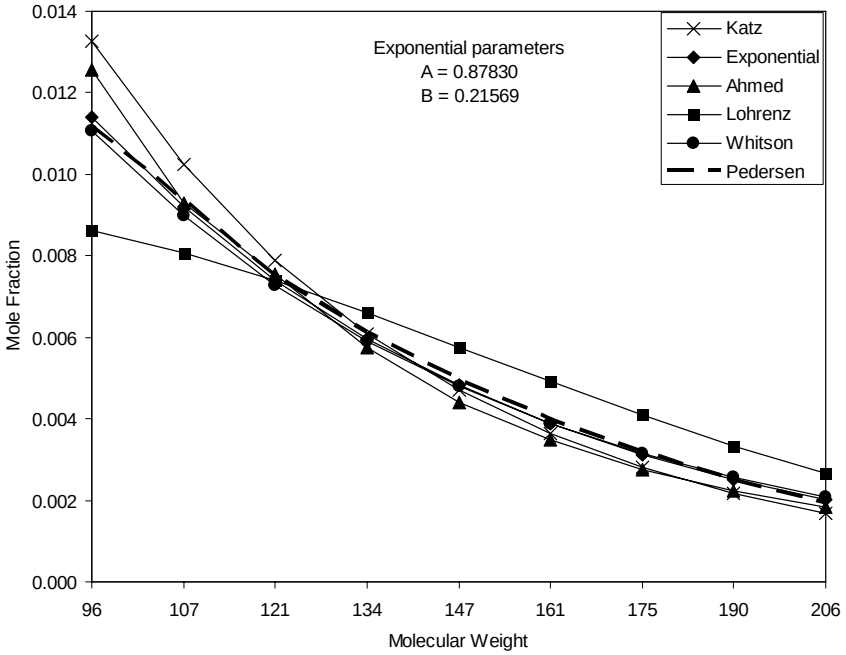

Fig. 2: Mole fractions versus molecular weights of the extended analysis of the C_{7+} fraction of the Gas2 system reported by Coats and Smart (1986)

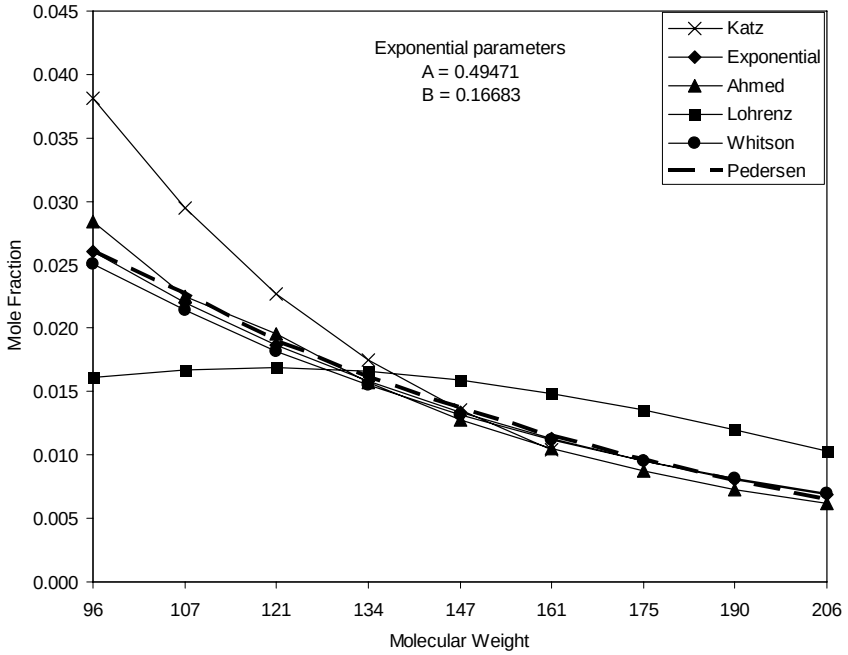

Fig. 3: Mole fractions versus molecular weights of the extended analysis of the C_{7+} fraction of the Oil2 system reported by Coats and Smart (1986)

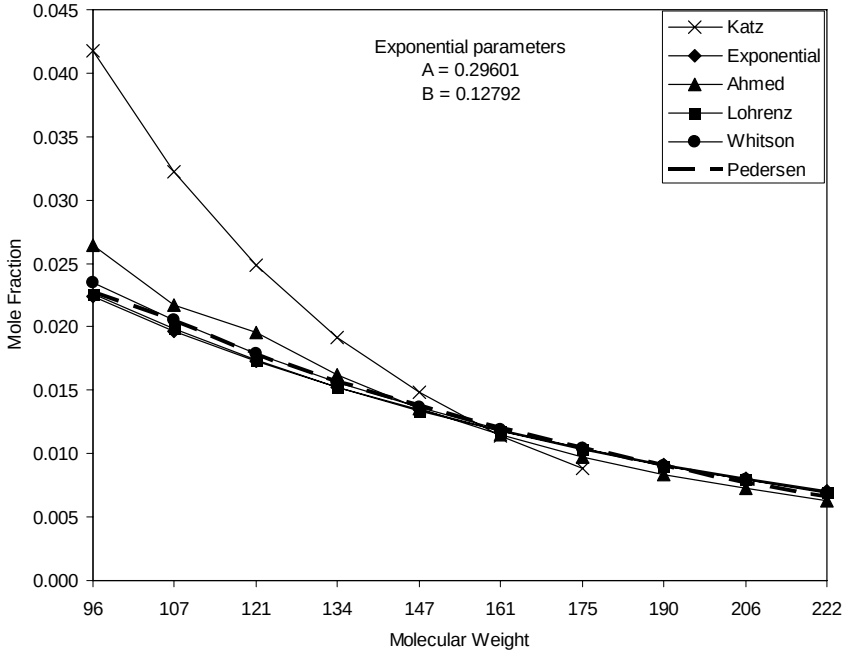

Fig. 4: Mole fractions versus molecular weights of the extended analysis of the C_{7+} fraction of the Oil3 system reported by Coats and Smart (1986)

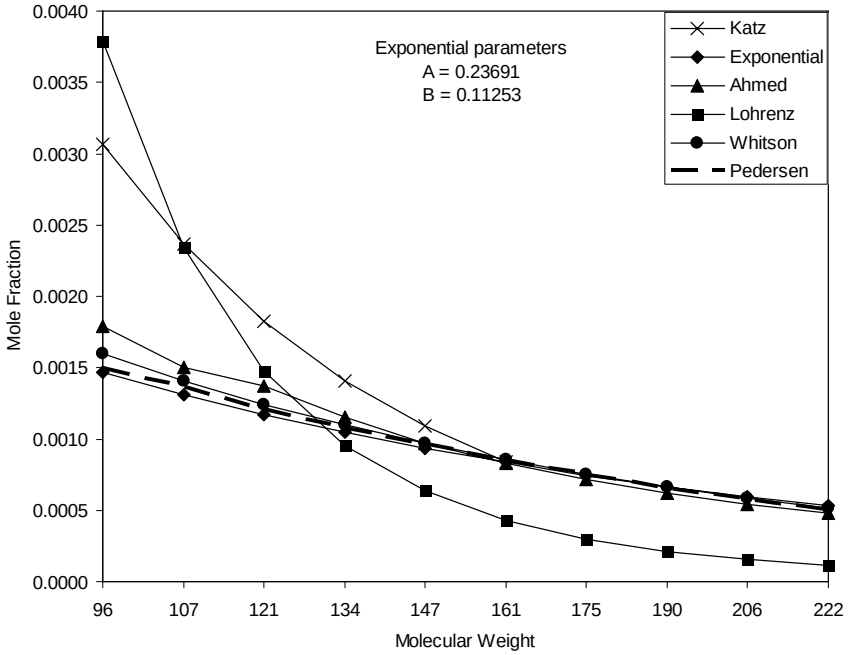

Fig. 5: Mole fractions versus molecular weights of the extended analysis of the C_{7+} fraction of the Mixture1 system reported by Roland (1942)

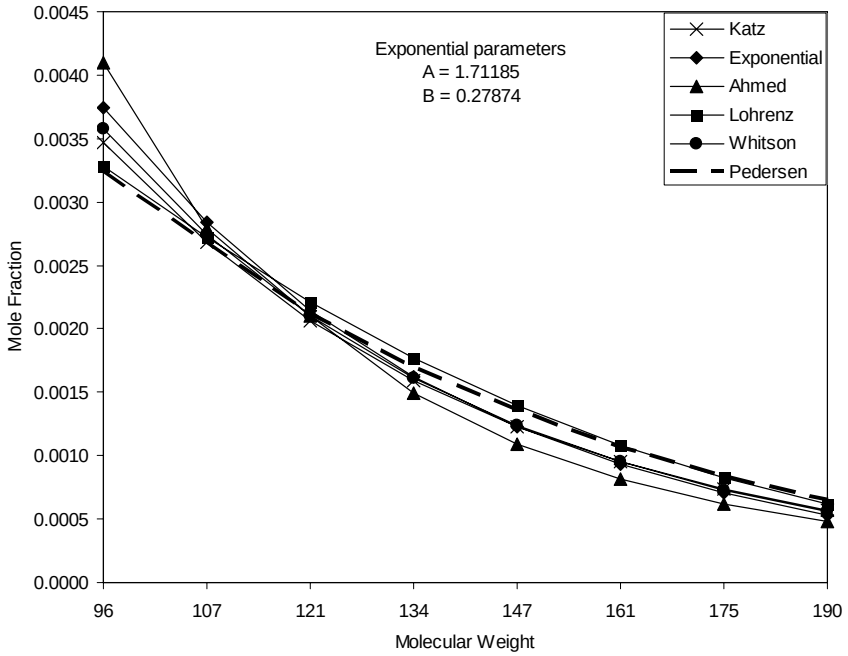

Fig. 6: Mole fractions versus molecular weights of the extended analysis of the C_{7+} fraction of the gas condensate system reported by Hoffmann (1953)

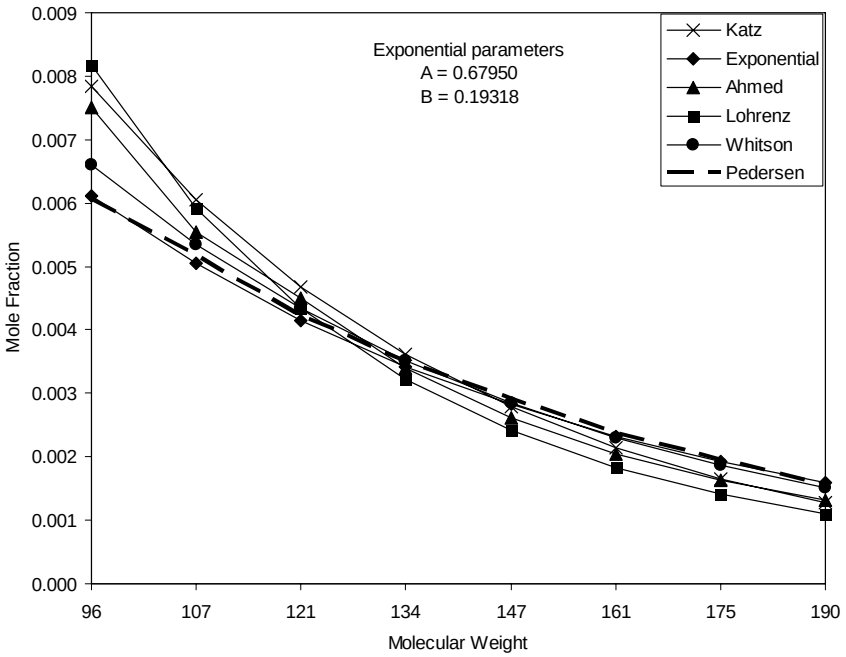

Fig. 7: Mole fractions versus molecular weights of the extended analysis of the C_{7+} fraction of the gas condensate system reported by Donohoe (1981)

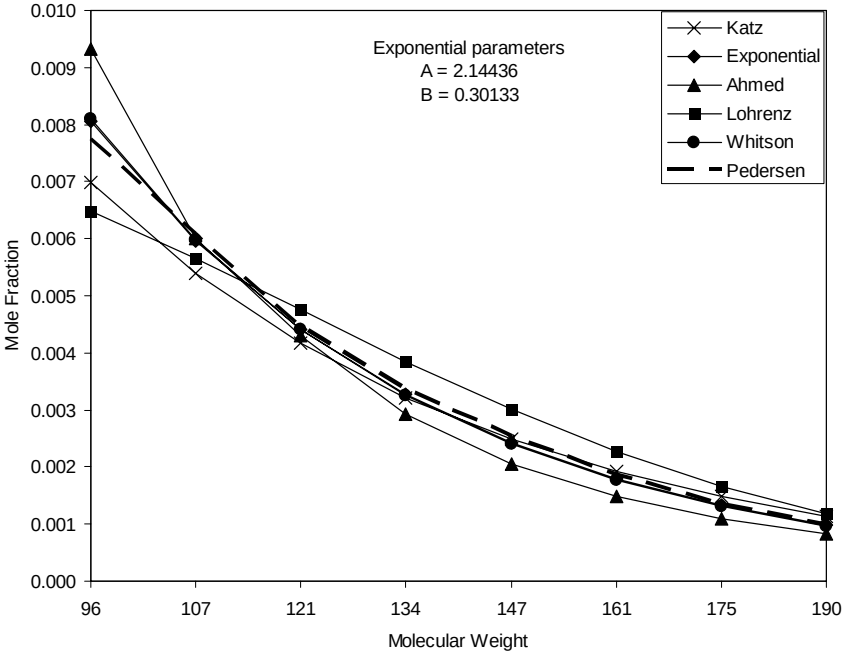

Fig. 8: Mole fractions versus molecular weights of the extended analysis of the C_{7+} fraction of the gas condensate system reported by Firoozabadi (1978)