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General Approach to Characterizing Reservoir Fluids for EoS Models Using a Large PVT Database

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Abstract

Fluid characterization is needed when applying any EoS model to reservoir fluids. It is important especially for non-cubic models such as PC-SAFT where fluid characterization is less mature. Furthermore, there is a great interest to apply non-cubic models to high pressure high temperature reservoir fluids as they are believed to give better description of density and compressibility over a wide temperature and pressure range. We proposed a general approach to characterizing reservoir fluids and applied it to PC-SAFT. The approach consists in first, developing the correlations based on the DIPPR database, and then adjusting the correlations based on a large PVT database. The adjustment was made to minimize the deviation in key PVT properties like saturation pressures, densities at reservoir temperature and stock tank oil densities, while keeping the n-alkane limit of the correlations unchanged. The general approach can also be applied to other EoS models for improving their fluid characterization and we showed this for SRK and PR. In addition, we developed a PNA based characterization method for PC-SAFT based on the same general principles. We made a comprehensive comparison in PVT calculation involving 17 EoS-characterization combinations and 260 reservoir fluids. The new characterization methods generally improved the PVT calculation results.

Keywords

Equation of state; Reservoir fluids; C_{7+} characterization; PC-SAFT; PVT database.

1. Introduction

Accurate description of PVT, including phase equilibrium and physical properties, is always needed for development of natural gas and petroleum reservoir fluids. It is especially a crucial problem for reservoirs at high pressure and high temperature (HPHT) conditions, where the importance for density and compressibility in production forecast is more pronounced. Since traditional cubic EoS models have intrinsic problems to provide satisfactory density and compressibility description at high pressures, it is attractive to use non-cubic EoS models such as PC-SAFT, Perturbed-Chain Statistical Association Fluid Theory [1] and Soave-BWR, i.e., Soave's modification of Benedict–Webb–Rubin EoS [2], which are better in accurate density description over a wide temperature and pressure range. PC-SAFT has received more attention due to its rigorous theoretical basis. It has shown promising performance in comparison to cubic EoSs for calculation of complex phase behavior, high pressure density, and second-order derivative properties, such as compressibility and speed of sound [3]–[7].

To apply any cubic or non-cubic EoS model to PVT calculation of a reservoir fluid, we need to represent the reservoir fluid with an appropriate number of pseudo-components and assign appropriate model parameters to these components. Reservoir fluid characterization for cubic EoSs like SRK [8] and PR [9] is relatively mature. For example, the method of Pedersen et al. [10], [11] and that of Whitson et al. [12], [13] are amongst the widely used characterization methods in the upstream oil industry. The model parameters needed for SRK and PR, including T_c, P_c, and ω, can be generated by these methods. For non-cubic models like PC-SAFT, their respective model parameters should be generated for the pseudo components in the C_{7+} fractions but characterization for non-cubics is less mature.

Reservoir fluid characterization for PC-SAFT has been investigated mainly in connection with the recent research on asphaltene precipitation modeling with PC-SAFT [5], [14]–[22]. It is surely important that a specific EoS, such as PC-SAFT, can model phase behavior as complex as asphaltene precipitation with a proper characterization method.

However, the main objective of a characterization method for any EoS should be a reasonable modeling of basic PVT properties. Once the basic PVT properties are satisfactorily described, specific adjustments of the characterization method can be introduced to model particular phase equilibrium phenomena like asphaltene precipitation. Among several recent PC-SAFT characterization methods for basic PVT modeling [23]–[27], some follow Pedersen's or Whitson's method and only use a different set of correlations [23]–[25], [27], whereas the others use a completely different procedure in addition to a new set of correlations [26]. The correlations developed for PC-SAFT model parameters are usually expressed as a function of molecular weight *MW* and/or boiling point T_b and specific gravity *SG* for each SCN (Single Carbon Number) fraction [24]–[27], and some are developed for the PNA content in each fraction [5], [23], [28]. Leekumjorn and Krejbjerg [29] commented that reliable and generally applicable petroleum fluid characterization procedures are still to be developed for the PC-SAFT EoS.

In our previous study [24], a reservoir fluid characterization method for PC-SAFT was proposed by combining Pedersen's method with a new set of correlations for the PC-SAFT model parameters m, $m\varepsilon/k$ and $m\sigma^3$. The correlations were developed based on the properties of 29 normal alkanes and 318 other hydrocarbons from the DIPPR database [30]. In this study, we further improved the characterization method by adjusting the correlations with a large PVT database. We have further improved the correlations and more importantly, we would like to establish a general approach to characterizing reservoir fluids for any EoS. The approach consists in developing correlations of model parameters first with a database for well-defined components and then adjusting the correlations with a large PVT database. Apart from applying the approach to PC-SAFT, we have also shown that the approach can be applied to classical cubic models like SRK and PR. In addition, we discussed how to develop a PNA based characterization for PC-SAFT and also utilize a large PVT database to further improve the characterization. Development of all these new characterization methods is presented in Section 3. Section 4 presents a comprehensive comparison between PC-SAFT, SRK and PR with the new characterization methods and these models with existing characterization methods, i.e.,

traditional characterization methods for SRK and PR and some recent characterization methods [24], [25], [27] for PC-SAFT. In addition, Soave-BWR was used in the comparison.

2. Equations of state

Our study involves two cubic EoSs (SRK and PR) and two non-cubic ones (PC-SAFT and Soave-BWR). The two non-cubic models are briefly described below. PC-SAFT is used here to show how characterization methods can be developed for non-cubic models while Soave-BWR is only used for the purpose of comparison.

2.1. PC-SAFT EoS

The PC-SAFT EoS was proposed by Gross and Sadowski [3] to model asymmetric and highly non-ideal systems and it can be expressed in terms of the reduced Helmholtz energy $\tilde{a}$:

$$\tilde{a} \equiv \frac{A}{NkT} = \tilde{a}^{id} + \tilde{a}^{hc} + \tilde{a}^{disp} + \tilde{a}^{assoc} \tag{1}$$

where $\tilde{a}^{id}$ is the ideal gas contribution, $\tilde{a}^{hc}$ is the contribution of the hard-sphere chain reference system, $\tilde{a}^{disp}$ is the dispersion contribution arising from the square well attractive potential and $\tilde{a}^{assoc}$ is the association contribution based on Wertheim's theory [31]. For reservoir fluid systems consisting only of non-associating components, the $\tilde{a}^{assoc}$ term in Eq. (1) disappears. The remaining three terms have rather complicated forms as compared with SRK or PR. However, there are only three model parameters for a non-associating component, the chain length *m*, the segment diameter σ and the segment energy ε.

von Solms et al. [6] simplified the original PC-SAFT EoS by assuming that all the segments in the mixture have the same mean diameter *d*, which gives a mixture volume fraction identical to that of the actual mixture. This variation of PC-SAFT, called the simplified PC-SAFT EoS, is identical to the original PC-SAFT EoS for pure components. For mixtures, the simplified version and the original version are very similar [6]. The

main motivation to use the simplified version is that it reduces the computation times for non-associating systems and significantly for associating systems. Therefore, it is more suitable to use the simplified version if the model is considered to be used for reservoir simulation in the future. The simplified version of PC-SAFT is used in this study.

2.2. Soave-BWR EoS

The Benedict-Webb-Rubin (BWR) equation of state [32] belongs to the so-called virial type equations of state. Despite its empirical nature, this model provides a highly accurate density description than many other types of EoS models. A recent modification of the BWR EoS is given by Soave in 1999:

$$z = \frac{P}{RT\rho} = 1 + B\rho + D\rho^4 + E\rho^2(1 + F\rho^2)\exp(-F\rho^2) \tag{2}$$

where ρ is the density, and B, D, E, and F are the five model parameters. The Soave-BWR EoS used in this study refers to this version of BWR EoS. This EoS has three parameters for each component, T_c, P_c, and ω. Further details about Soave-BWR EoS can be found elsewhere [2], [24].

3. Characterization

3.1. Considerations in a general characterization approach

Reservoir fluid characterization is to represent the petroleum reservoir fluid with an appropriate number of pseudo-components and to find the equations of state parameters needed for each of them. This procedure normally involves the following steps: (1) estimating the relation between molar composition distribution and carbon number or molecular weight or determining the characteristic parameters of a continuous molar composition distribution function; (2) estimating the required properties or parameters of the chosen equation of state for each pseudo-component (carbon number fraction). For example, T_c, P_c, and ω are needed for SRK and PR and m, σ, and ε for PC-SAFT. In addition, a binary interaction parameter (k_{ij}) is needed for each pair of components; (3) lumping the fractions into a reasonable number of pseudo-components as it is time

consuming to work with all the SCN fractions. Both the method of Pedersen et al. [10], [11] and that of Whitson et al. [13] have the above three steps although they differ in the sequence of these steps and the details involved in each step.

From a pragamatic viewpoint, it is convient to modify only the correlations of model parameters in step (2) when developing a characterization method for an EoS. Since the two other steps are kept unchanged, implementation into the existing codes is straightforward. This also facillitates evaluation of the new method since the existing PVT software needs little change, and a quicker acceptance of the new correlations can be expected if the evaluation results are positive. Modifications of the other two steps may also lead to a further improvement of the characterization results. But such modifications should in principle be effective to cubic models as well and it is better to study the necessity of such modifications in a more general context, not just limited to non-cubic models. For example, one can naturally ask whether those changes are needed for cubic models and whether the widely used procedures such as Pedersen's method and Whitson's method should be updated in the existing software. Those questions are interesting butnot our focus here. Our major interest is non-cubic models where there is no "standard" characterization commonly accepted in the industry. We stick to the principle that the development should be mainly on the correlations for model parameters.

We here propose a general approach to developing the new correlations as illustrated by steps A and B in Fig. 1. In the first step (A), a set of correlations for the model parameters is developed based on a large database for pure components, e.g., the DIPPR database [30]. We prefer correlations developed in a two-step perturbation way because the properties of n-alkanes are expressed with high accuracy and the correction for the aromaticity is given in a separate set of equations. In the second step (B), the correlations accounting for the aromaticity will be adjusted using a large PVT database but the paraffinic limit should be kept unchanged. The general approach is applied to PC-SAFT in Section 3.2 and to SRK and PR in Section 3.3. In Section 3.4 where characterization

using explicit PNA information is tried, we also use the general principles discussed above in the development.

3.2. General characterization approach for PC-SAFT

We use Pedersen's characterization method as the framework and only modify the correlations in step (2) as discussed in Section 3.1. We first develop the correlations using the DIPPR database and then adjust them using a large PVT database. The adjustment is made to minimize the deviation in key PVT properties like saturation pressures, densities at reservoir temperature and Stock Tank Oil (STO) densities from single-stage separation.

The first step was completed in our earlier study [24]. A set of correlations for the PC-SAFT model parameters m, σ, and ε were developed using a two-step perturbation method similar to that used by Twu [33] in the development of correlations of critical properties. In the first step, the properties of the n-alkanes at the T_b of the SCN component were calculated. The molecular weight of the n-alkanes at this T_b, MW_p, was estimated using Twu's correlations [33]. The PC-SAFT model parameters for n-alkanes, m_p, σ_p, and ε_p, were then calculated by the following linear correlations:

$$m_p = 0.02644 MW_p + 0.83500 \tag{3}$$

$$m_p \varepsilon_p / k = 6.90845 MW_p + 139.30870 \tag{4}$$

$$m_p \sigma_p^{\,3} = 1.71638 MW_p + 19.19189 \tag{5}$$

In these correlations m_p is dimensionless, ε_p / k is in Kelvin, and σ_p has the unit of Å. In the second step, the properties of the SCN component were estimated by using the difference in specific gravity $\Delta SG = SG - SG_p$ as the perturbation parameter, where SG_p is the specific gravity of the n-alkane calculated by Soave's correlation [34] as a function of T_b (in Kelvin):

$$SG_p = \left(1.8T_b\right)^{1/3}\left(11.7372 + 3.336\times10^{-3}T_b - 976.3T_b^{-1} + 3.257\times10^{5}T_b^{-2}\right)^{-1} \tag{6}$$

The final correlations suggested for m, ε and σ by Yan et al. [24] are as follows:

$$\sigma = \sigma_p \tag{7}$$

$$\varepsilon = \varepsilon_p(1.1303391\Delta SG + 1) \tag{8}$$

$$m = m_p(1.0460471\Delta SG^2 - 1.6209973\Delta SG + 1) \quad (9)$$

Eqs. (7-9), developed based on the DIPPR database, provide the optimal parameters that can calculate saturation pressure and density for the relevant hydrocarbon components in the DIPPR database. Despite a large number of components are involved, the heavy aromatic and naphthenic components are not well-represented. In the database, the heaviest n-alkane is n-C_{36} with T_b equal to 770.15 K and the heaviest aromatic component is Tetraphenylethylene ($C_{25}H_{20}$) with T_b equal to 760 K. Only around 19% of the components in the database have T_b higher than 600 K and it decreases to around 5% for the components with T_b higher than 700 K. This shows that the majority of the components (around 81%) in the database are light and have T_b lower than 600 K. Furthermore, the naphthenic and aromatic components in the database do not necessarily represent the most probable population in the common reservoir fluids. Therefore, the developed correlations optimal for the database may not be optimal for common reservoir fluids. To address this problem, we suggest further tuning the correlations based on a large PVT database so that the resulting correlations can be representative for common reservoir fluid samples. The tuning is performed only for the Eqs. (7-9) in order to keep the correct n-alkane limit (Eqs. (3-5)). Development of the correlations for model parameters based on a PVT database was used before, e.g., by Pedersen et al. [10]. In their study, the correlations were developed without consideration for the n-alkane limit. As a result, the critical properties and acentric factors generated for n-alkanes by the correlations can be very different from the experimental values. We stress here the importance of keeping the n-alkane limit (Eqs. (3-5)) since the parameters for paraffinic fluids will not be distorted. Besides, the tuning is only made for the coefficients in Eqs. (7) to (9) in order to keep the same functional forms for hydrocarbons other than n-alkanes.

Apparently, a larger database will give more representative results. We have included 260 reservoir fluids in our database (see Section 4.1). Three properties are used in the tuning of the coefficients: saturation pressure, density at reservoir temperature, and Stock Tank Oil (STO) density. The density at reservoir temperature includes liquid density of oils in both single-phase and two-phase regions, and density of gas condensates above dew point

pressure. Selection of these properties is based on two considerations: first, these three properties are usually measured with the lowest uncertainty; second, each property has its particular importance. Saturation pressure is a crucial property for reservoir development since a second phase appears below the saturation pressure, and it is perhaps the most influential property in tuning of a PVT model in phase equilibrium calculation. Density at reservoir temperature is directly related to all the volume related engineering calculations in the reservoir. STO density reflects the volume calculation results at surface conditions and indirectly influences the calculation of formation volume factors and solution gas oil ratios. There is no apparent way to modify Eq. (7) and we only considered tuning of Eqs. (8) and (9). In the tuning, we tried to use as few coefficients as possible and change them as little as possible. Two schemes were tested. In the first scheme, the only coefficient in the ε correlation (Eq. (8)) was regressed to minimize the deviation in saturation pressure, density and STO density. In the second scheme, all the three coefficients in the correlations for m and ε (Eqs. (8) and (9)) were tuned simultaneously. The tuning showed that the saturation pressure was the most influential data for the final values of the regressed coefficients whereas the influence of density at reservoir temperature and STO density was moderate. The final correlations for the two schemes are as follows:

1. Regressing ε coefficient in Eq. (8):
$$\varepsilon = \varepsilon_p \left(0.9533431\Delta SG + 1\right) \tag{10}$$

2. Regressing m and ε coefficients in Eqs. (8) and (9) at the same time:
$$\varepsilon = \varepsilon_p (0.9550243\Delta SG + 1) \tag{11}$$
$$m = m_p (2.4516079\Delta SG^2 - 1.6710480\Delta SG + 1) \tag{12}$$

It should be noted that the above correlations are not proposed to be the ultimate correlations for the PC-SAFT characterization. Instead, they are used as an illustration how the correlations can be developed for an EoS. With a different PVT database, a different set of correlations can be developed by minimizing the deviations of the properties of interest for that database.

The characterization method developed using the general approach can be later applied to PVT calculation (A→B→C→D in Fig. 1). The correlations developed in step B represent

the average performance for the fluids in the database. For any other fluid sample not in the database, the calculation (step C) is still predictive. For the final PVT model for this specific fluid, final tuning in step D can be made. This procedure is compared in Fig. 1 with another procedure (A→B'→C') for improving the characterization results for a specific fluid sample. In step B', the model parameters can be tuned using boiling points and/or specific gravities of SCN fractions for a specific fluid, such as discussed in Yan et al. [24] and Liang et al. [23]. The boiling points and specific gravities are not final PVT data and the calculation based on the tuned model parameters is still predictive. However, since the tuning is directly used for the model parameters, the obtained parameters can only be used for this specific fluid. For the final PVT model, further tuning of model parameters in step C' can be made.

3.3. Application of the general approach to SRK and PR

For cubic EoSs, we still use Pedersen's method as the framework for our development. But instead of using Pedersen's correlations [5], we would like to use a set of correlations similar to Twu's correlations for T_c and P_c [33] where their n-alkane limits are explicitly given. The Lee–Kesler correlations [35], [36] for ω is usually used together with Twu's correlations. This combination gives good estimate of critical properties of hydrocarbons in C_{7+} and has been recommended by Whitson [37].

Twu's correlations estimate the critical properties in two steps. In the first step, the properties of the n-alkanes (T_{cp}, P_{cp}) at the T_b of the SCN component are calculated using the following correlations where T_b and T_{cp} are in R and P_{cp} is in psia.

$$T_{cp} = T_b \left(\begin{array}{l} 0.58327 + 0.19107 \times 10^{-3} T_b + 0.77908 \times 10^{-7} T_b^{\,2} \\ -0.28438 \times 10^{-10} T_b^{\,3} + \dfrac{0.95947 \times 10^{28}}{T_b^{\,13}} \end{array} \right)^{-1} \tag{13}$$

$$\begin{cases} \alpha = 1 - T_b / T_{cp} \\ P_{cp} = \left(3.83354 + 1.19629\alpha^{0.5} + 34.8888\alpha + 36.1952\alpha^2 + 104.193\alpha^4 \right)^2 \end{cases} \tag{14}$$

$$V_{cp} = \left(1 - \left(0.419869 - 0.505839\alpha - 1.56436\alpha^3 - 9481.7\alpha^{14} \right) \right)^{-8} \tag{15}$$

In the second perturbation step, the properties of the SCN component are estimated by using ΔSG as the perturbation parameter. The calculated T_c and P_c are in ^{o}R and psia respectively.

$$\begin{cases} SG_0 = 0.843593 - 0.128624\alpha - 3.36159\alpha^3 - 13749.5\alpha^{12} \\ \Delta SG_T = \exp\left(5\left(SG_0 - SG\right)\right) - 1 \\ f_T = \Delta SG_T\left(-0.362456 / T_b^{0.5} + \left(0.0398285 - 0.948125 / T_b^{0.5}\right)\Delta SG_T\right) \\ T_c = T_{cp}\left((1+2f_T)/(1-2f_T)\right)^2 \\ --- \\ \Delta SG_V = \exp\left(4\left(SG_0^{\,2} - SG^2\right)\right) - 1 \\ f_V = \Delta SG_V\left(0.466590 / T_b^{0.5} + \left(-0.182421 + 3.01721 / T_b^{0.5}\right)\Delta SG_V\right) \\ V_c = V_{cp}\left((1+2f_v)/(1-2f_v)\right)^2 \\ --- \\ \Delta SG_P = \exp\left(0.5\left(SG_0 - SG\right)\right) - 1 \\ f_P = \Delta SG_P\begin{pmatrix}(2.53262 - 46.1955 / T_b^{0.5} - 0.00127885T_b) + \\ (-11.4277 + 252.14 / T_b^{0.5} + 0.00230535T_b)\Delta SG_p\end{pmatrix} \\ P_c = P_{cp}(T_c / T_{cp})(V_{cp} / V_c)\left((1+2f_P)/(1-2f_P)\right)^2 \end{cases} \quad (16)$$

Since the correlations in the second step (Eq. (16)) are complex and difficult to update during the tuning process with a PVT database, we tried to replace them with simpler correlations. Fig. 2 illustrates how T_c/T_{cp} and P_c/P_{cp} change with ΔSG for 318 hydrocarbons in the DIPPR database. Fitting a second order polynomial through the data points for T_c/T_{cp} and a linear function for P_c/P_{cp} give the following correlations for T_c and P_c where T_c is in Kelvin and P_c is in bar:

$$P_c = P_{cp}(3.56179\Delta SG + 1) \quad (17)$$

$$T_c = T_{cp}(-0.39220\Delta SG^2 + 0.50239\Delta SG + 1) \quad (18)$$

In these correlations T_{cp} and P_{cp} are the critical temperature and pressure of n-alkanes calculated by Eqs. (13, 14) and are converted to Kelvin and bar respectively. The difference in the specific gravity $\Delta SG=SG-SG_p$ is calculated using SG_p from Eq. (6). It

should be noted that Eq. (18) has a maximum around ΔSG=0.62, and we keep T_c/T_{cp} constant after its maximum value.

Fig. 3 compares original Twu's method (Eqs. (13-16)) with our simplified version (Eqs. (13-15), (17-18)) in calculation of critical properties of 318 pure components in DIPPR. As can be seen in Fig. 3, the simplified Twu's method gives very close results to that of original Twu's method. The percent average absolute deviations AAD% of the original Twu's method in T_c and P_c are 1.1% and 7.8%, respectively, while those of the simplified version are 1.0% and 7.5%, respectively. It shows that the simplified version of Twu's method (Eqs. (13-15), (17-18)) can be used instead of the original Twu's method for calculation of critical properties.

The new correlations for T_c and P_c can be used together with the Lee-Kesler correlations for ω. For the tuning of Eqs. (17-18) based on the PVT database, two schemes were tested for SRK and PR, similar to that used for PC-SAFT. In the first scheme, the only coefficient in the P_c correlation (Eq. (17)) was regressed to minimize the deviation in saturation pressure, density and STO density. In the second scheme, all the three coefficients in the correlations for P_c and T_c (Eqs. (17) and (18)) were tuned simultaneously. The final correlations for the two schemes are summarized below for SRK and PR:

1. Regressing P_c coefficient in Eq. (17) for SRK:
$$P_c = P_{cp}(4.9242447\Delta SG + 1) \tag{19}$$
2. Regressing P_c and T_c coefficients in Eqs. (17) and (18) at the same time for SRK:
$$P_c = P_{cp}(5.4974598\Delta SG + 1) \tag{20}$$
$$T_c = T_{cp}(-0.7220183\Delta SG^2 + 0.6604209\Delta SG + 1) \tag{21}$$
3. Regressing P_c coefficient in Eq. (17) for PR:
$$P_c = P_{cp}(5.4536065\Delta SG + 1) \tag{22}$$
4. Regressing P_c and T_c coefficients in Eqs. (17) and (18) at the same time for PR:
$$P_c = P_{cp}(5.5119793\Delta SG + 1) \tag{23}$$
$$T_c = T_{cp}(-0.7316782\Delta SG^2 + 0.6181465\Delta SG + 1) \tag{24}$$

Again, the above correlations are examples showing how the general approach can be applied to SRK and PR.

3.4. A PNA based characterization method for PC-SAFT

The aromaticity of a SCN component is sometimes represented by use of the content of paraffinic (P), naphthenic (N) and aromatic (A) components in it. In both Pedersen's method and Whitson's method, PNA distribution is not used explicitly in the characterization. The aromatic content in each SCN component is reflected by the difference in *SG*. It can be advantageous sometimes to account for aromatic content explicitly. For example, when precipitation of asphaltene happens, it is reasonable to assume that the interaction between paraffinic compounds and asphaltenes and that between aromatic compounds and asphaltenes are different. Explicit expression of PNA components might also be useful in composition gradient modeling in petroleum reservoirs since it provides more flexibility.

In principle, if we can find representative chemical compounds to represent P, N and A, and somehow estimate the PNA distribution for each SCN fraction, then we can estimate the model parameters for P, N and A in each SCN fraction separately. In practice, however, there are several challenges. The first challenge is that PNA distribution is usually unavailable. For heavy molecules, it is not easy to classify them into P, N or A, e.g. if they have aromatic rings, naphthenic rings and long paraffinic chains at the same time. There are some correlations for PNA estimation [38], [39] but their accuracy is difficult to evaluate for a wide range of SCN components. We present below a simple trial characterization method which bypasses the first problem: Assuming that there are only P and A classes in each SCN fraction and their specific gravities are known, we can use volume additivity to get the composition of P and A directly from the *SG* for the SCN fraction:

$$\frac{1}{SG_{SCN}} = \sum \frac{w_i}{SG_i} = \frac{w_p}{SG_p} + \frac{w_{A_1}}{SG_{A_1}} + \frac{w_{A_2}}{SG_{A_2}} \tag{25}$$

In this equation w_p, w_{A1}, w_{A2} are the weight fraction of paraffinic, aromatic group 1 and aromatic group 2, respectively, SG_p, SG_{A1}, and SG_{A2} are the specific gravity of each

group, and SG_{SCN} is the specific gravity of each SCN fraction. We assume here two possible aromatic groups: aromatics with one benzene ring A_1, which are essentially linear alkylbenzenes and the aromatics with two benzene rings A_2, which are mainly naphthalene derivatives with alkane chains. The heaviest aromatic component in A_1 group is n-octadecylbenzene ($C_{24}H_{42}$) with T_b equal to 673.15 K and the heaviest component in group A_2 is 1-n-decylnaphthalene ($C_{20}H_{28}$) with T_b equal to 652.15 K. The A_1 group appears after 353.2 K and the A_2 group appears after 491.1 K. There are other possible aromatic compounds but it is difficult to classify them into classes with information as systematic and complete as for the A_1 and A_2 groups selected above. In addition, we assume that w_{A1} is equal to w_{A2} if all three groups exist in the SCN fraction. Hence, knowing the value of SG_{SCN}, we can solve Eq. (25) to find the weight percent of each group.

The model parameters, *MW* and *SG* for P, A_1 and A_2 are readily available and their correlations can be easily developed. It seems that the characterization is straightforward but there is a second challenge. Fig. 4 shows the distribution of *SG* with T_b for n-alkanes and 318 other hydrocarbons. As can be seen, *SG* for the P group increases with T_b while *SG* for the A_1 and A_2 groups decreases with increasing T_b. But we know that the density of SCN fractions increases with the T_b (see Fig. 4). The general perception is that the *SG* for aromatics should also increase with T_b. The opposite trends for A_1 and A_2 groups are because with increasing T_b, the complexity of the aromatics is expected to increase, not just the length of the alkane chain. This is not reflected in the selected aromatic groups. In fact, it would be difficult to select a homologous aromatic family that shows an increase in *SG* with T_b. It should also be noted that the groups A_1 and A_2 are the aromatics groups that we have the most data for. For other groups of aromatics, it can be difficult to find a common trend in their model parameters. The difficulty of finding representative aromatic compounds is another challenge with PNA based characterization methods. Since *SG* for A_1 and A_2 can be far away from the *SG* for the actual aromatic group, it happens often that the density of a SCN fraction cannot be met by combining P, A_1 and A_2 groups. In such case, we have to assume the fraction is completely made up of A_2.

Fig. 5 illustrates the problem for the above test PNA characterization method. Compared with a previous characterization method for PC-SAFT [24], the test PNA method gives a smaller phase envelope for Fluid 7 (31.28% methane and 36.78% C_{7+}) from Jaubert et al. [40]. It is caused by inadequate characterization of heavy fractions because for SCN components with large carbon numbers, their specific gravities can be larger than that of the A_2 group and we had to approximate these SCN components with A_2. Even with this approximation, the obtained fraction will have properties lighter than it should have. This behavior was observed for most of the systems tested.

In order to select the representative aromatic group that shows an increase in *SG* with T_b, we selected some aromatic compounds that capture the upper limit of SG in the aromatic compounds in the DIPPR database. The selection is somewhat arbitrary but we tried to consider the presence of single-ring, double-ring and multiple ring aromatics in the representative aromatic group. The black dashed line in Fig. 4 passes through the representative components from different aromatic groups. The components and their properties are presented in Table 1. The lightest aromatic component in the A group is Benzene (C_6H_6) with T_b equal to 353.24 K which corresponds to C_7 fraction, and the heaviest aromatic component is Tetraphenylethylene ($C_{26}H_{20}$) with T_b equal to 760.0 K corresponding to C_{35} SCN fraction. The aromatic group appears after 353.24 K.

The values of m, $m\varepsilon/k$, $m\sigma^3$ can be estimated as a function of T_b for the representative aromatic group using the following correlations. T_b in the following equations is in Kelvin:

$$m_A = 5.98957\times10^{-6}\times T_b^2 + 2.44045\times10^{-3}\times T_b + 0.807171 \tag{26}$$

$$\left(m\varepsilon/k\right)_A = 2.85713\times10^{-3}\times T_b^2 + 0.661777\times T_b + 107.971 \tag{27}$$

$$\left(m\sigma^3\right)_A = 4.92174\times10^{-4}\times T_b^2 + 0.0938404\times T_b + 30.1198 \tag{28}$$

Using the above correlations in a wide range of T_b (from 300 K to 1000 K), the molar density of the aromatic group ρ_A can be found using PC-SAFT. The correlation for ρ_A as a function of T_b can therefore be written as:

$$\rho_A = 2.03166\times10^{-5}\times T_b^2 - 3.93733\times10^{-2}\times T_b + 21.9838 \tag{29}$$

Assuming that there are only P and A classes in each SCN fraction, we can calculate the composition of P and A by solving the following equation:

$$\frac{MW_{SCN}}{SG_{SCN}} = \frac{x_p MW_p}{SG_p} + \frac{x_A}{\rho_A} \tag{30}$$

where x_p and x_A are the mole fractions of paraffinic and representative aromatic group, respectively. MW_p and MW_A are the molecular weights and SG_p is the specific gravity of the paraffinic group, while MW_{SCN} and SG_{SCN} are the molecular weight and specific gravity of each SCN fraction, the values of which are known from the first step of Pedersen's characterization. The specific gravity of the paraffinic group can be calculated by Eq. (6) while MW_p is calculated by a few iterations using the following correlation as a starting value [33]:

$$MW_p^0 = \frac{T_b}{10.44 - 0.0052T_b} \tag{31}$$

In this correlation T_b is in °R. As all the necessary parameters in Eq. (30) are known, this equation can be solved to find the composition of P and A groups ($x_p = 1 - x_A$).

Given the composition of each group, MW_A can then be found using the following equation:

$$MW_{SCN} = x_p MW_p + x_A MW_A \tag{32}$$

which can later be used in calculation of the specific gravity of the aromatic group, SG_A. In our calculations, instead of applying this methodology to each SCN group and lumping them together to find the final pseudo-components parameters, we used the weighted average T_b (Eq. (33)) for each pseudo-component and found m, $m\varepsilon/k$, $m\sigma^3$ for the pseudo-components directly using $T_{b,\,pseudo}$ instead of T_b in the Eqs. (26-29). In other words, we found the PC-SAFT parameters after lumping the SCN fractions into fewer pseudo-components.

$$T_{b,pseudo} = \frac{\sum_i z_i MW_i T_{b,i}}{\sum_i z_i MW_i} \tag{33}$$

In addition, we further regressed the coefficients in Eq. (27) using the PVT database to minimize the deviation in saturation pressure, density and STO density. To reduce the number of tuned coefficients from three to two, we included T_b of benzene in Eq. (27)

and fixed the last coefficient to make sure the new correlation would reproduce the correct value of $m\varepsilon/k$ for benzene, which is the lightest aromatic compound in our representative aromatic group. As a result, we only tuned the first two coefficients in Eq. (27). The final set of correlations for m, $m\varepsilon/k$, $m\sigma^3$ is given by

$$m_A = 5.98957\times10^{-6}\times T_b^2 + 2.44045\times10^{-3}\times T_b + 0.807171 \quad (34)$$

$$\left(m\,\varepsilon/k\right)_A = 1.7044\times10^{-3}\times\left(T_b - T_{b,benzene}\right)^2 + 3.3024\times\left(T_b - T_{b,benzene}\right) + 711.6350 \quad (35)$$

$$\left(m\sigma^3\right)_A = 4.92174\times10^{-4}\times T_b^2 + 0.0938404\times T_b + 30.1198 \quad (36)$$

The calculation results using the new PNA approach with only two representative groups (P and A) together with other EoSs are presented in Table 2.

4. Results and Discussions

4.1. Petroleum fluid database

In order to investigate and compare the overall performance of different EoSs and different characterization methods in PVT modeling, a petroleum fluids database covering wide composition, temperature and pressure ranges is needed. In this work, 260 petroleum fluids have been collected from different sources in the literature [40], [41], as well as from an internal PVT database [42]. An overview of these fluids including their methane and C_{7+} contents is given in Table A1 in the supplementary information. There are different types of petroleum fluids, from gas condensate to quite heavy oil. The database covers a wide range of methane content from 2.26% to 74.71% while the C_{7+} content changes from 6.39% to 83.21%. The range for the *SG* of C_{7+} is from 0.7597 to 0.9747, and maximum reservoir temperature and saturation pressure are 469.15 K and 427.96 bar, respectively. There are some fluids for which only the saturation pressure data is available [41]. However, various experimental data from different measurements, such as constant mass expansion (CME), differential liberation (DL), and/or separator test, are available for most of the fluids in this database. It should be noted that systems showing deviations larger than 20% in saturation pressure, density and/or STO density using all the EoSs tested were excluded from the final database. The large deviations

could be due to poor quality of the data or the uniqueness of the system (being too heavy or too asymmetric) which may be better treated separately.

4.2. Deviations in saturation pressure, density and STO density

The percent average absolute deviations AAD% of saturation pressure, density, and STO density for the 260 petroleum fluids are listed in Table A2 in the supplementary information where we have compared the performance of PC-SAFT EoS with Yan et al.'s characterization method [24] with SRK, PR, and Soave-BWR EoSs. Compared to the previous study [24], STO density is included in the evaluations. The critical properties for SRK, PR and Soave-BWR were calculated by the original Twu's method [33] and the acentric factor was calculated from the Lee–Kesler correlation [35], [36].

Assareh et al. [27] developed a set of correlations based on *MW* and *SG* for PC-SAFT parameters using a database of 840 pure components from three families (n-alkanes, cycloalkanes and alkylbenzenes). The pure component parameters were generated by the correlations of Tihic et al. [43] and Panuganti et al. [18] in the *MW* range of 70-350. Their correlations are linear functions of *MW* and quadratic functions of specific gravity and were used in this study to compare with our proposed characterization method.

In order to compare the performance of the new general characterization method and several recent methods suggested for PC-SAFT [24], [25], [27], the global deviations in saturation pressure, density and STO density for all 260 fluids were evaluated (Table 2). The results from SRK, PR and Soave-BWR are also presented as references. Since volume translation is commonly used to improve the density calculation by cubic EoSs, we also included SRK and PR with volume translation in the comparison. Furthermore, Table 2 summarizes the performance of the new general characterization method for SRK and PR with/without volume translation and the new PNA approach for PC-SAFT. The binary interaction parameters for all the cases are taken from Yan et al. [24] except for the characterization method suggested by Liang et al. [25] for which the k_{ij} values are taken from Liang et al. [23]. The detailed AAD% of saturation pressure, density and STO

density using the new general characterization for PC-SAFT together with SRK and PR with volume translation are listed in Table A3 in the supplementary information.

Comparison between cubic EoSs without volume translation and non-cubic EoSs shows that all previous versions of PC-SAFT [24], [25], [27] have better performance than SRK, PR, and Soave-BWR in density and stock tank oil density while the cubic ones give slightly lower deviation in saturation pressure. Using volume translation for cubics improves the density and STO density predictions. The change in deviation of density calculation is more significant for SRK than for PR.

Among the existing characterization methods for PC-SAFT tested here, Yan et al.'s [24] method gives the smallest AAD% and maximum deviation in saturation pressure while Assareh et al. [27] method has better performance in density and STO density calculations.

The application of the new general characterization method to SRK and PR (Eqs. 19-24) yields lower deviation in all three properties than SRK and PR with the classical characterization. Actually, the new characterization method for cubics gives the lowest deviation in saturation pressure among all the combinations of EoSs and characterization methods studied in Table 2. However, the deviation in density and STO density for SRK and PR with the new general characterization method is still higher than SRK and PR with the classical characterization and volume translation. Applying volume translation to SRK and PR with the new characterization method further reduces deviations in density and STO density.

Applying the new PNA characterization approach to PC-SAFT gives lower deviation in density and STO density than the previous characterization methods for this EoS. However, the deviation in saturation pressure is poorer than the other models.

Applying the new characterization method developed in this study to Yan et al.'s [24] correlations, yields lower deviations in all three properties. Regressing the coefficient in

the equation for ε (Eq. (11)) mainly influences the saturation pressure deviation while the deviations in density and STO density reduce slightly. Regressing all three coefficients at the same time (Eqs. (11) and (12)) gives even lower deviations in density and STO density but the deviation in saturation pressure slightly increases. In both regression cases, the deviation in saturation pressure is the lowest among the deviations calculated by the previous characterization methods for PC-SAFT and is very close to that of cubic EoSs. For the case where all the three coefficients are regressed, both the average and maximum deviation in density and STO density are very close to that of SRK and PR with volume translation.

In terms of maximum deviation, PC-SAFT with the new characterization method has a slightly higher maximum deviation for saturation pressure than the cubic models. However, it gives the lowest deviation in saturation pressure, density and STO density calculation among other characterization methods for PC-SAFT.

In summary, application of the proposed general characterization method in this study to PC-SAFT makes this model superior to the previous PC-SAFT characterization methods and gives the smallest AAD% and maximum deviation for all three properties. Furthermore, application of the new characterization method to the cubic EoSs yields better performance in saturation pressure calculation in comparison to the original SRK and PR. Using volume translation together with the new characterization approach for SRK and PR gives comparable results for density and STO density to that of SRK and PR with volume translation.

4.3. Simulation of DL and CME tests

The accuracy of our method is tested against the other three characterization methods for PC-SAFT in calculation of oil density, gas compressibility factor, oil formation volume factor, solution gas-oil ratio and compressibility of an oil sample from the book of Pedersen and Christensen [44]. The composition and experimental data for the Constant Mass Expansion (CME) and Differential Liberation (DL) tests can be found in tables 3.7,

3.6 and 3.12 of Pedersen and Christensen's book [44]. This fluid was not used in our regression and the presented results are pure predictions.

Table 3 summarizes the AAD% in calculation of different properties for this oil mixture. It can be seen that our proposed characterization approach gives the lowest deviation in saturation pressure and density while Soave-BWR gives the lowest deviation in STO density. Yan et al.'s [24] method has better performance in calculation of STO density among other PC-SAFT characterization methods.

For the gas compressibility factor, PR with volume translation gives the lowest deviation. Among non-cubic models, Soave-BWR has better performance and PC-SAFT gives the highest deviation for this property.

PC-SAFT with Assareh et al.'s characterization method [27] seems to give the lowest deviation in calculation of Oil Formation Volume Factor (B_o) and solution gas-oil ratio (R_s), while Liang et al.'s method [25] gives the lowest deviation in calculation of compressibility. Our new characterization method for PC-SAFT gives slightly higher deviation in compressibility compared to Liang et al.'s method. For relative volume, the non-cubic models including Soave-BWR seem to have better performance in comparison to the cubic models.

Figures 6-10 show the simulated DL results for the oil mixture from Pedersen and Christensen's book [44] using SRK and PR with and without volume translation, as well as Soave-BWR, and PC-SAFT with different characterization methods. It can be seen from Fig. 6 that SRK and PR under predict the density over the whole pressure range while PC-SAFT with the new characterization method gives the lowest deviation and almost a good match of the experimental data at all pressures. Using volume translation, improves the density prediction of cubic models, however, the final results are not as good as the PC-SAFT prediction.

Fig. 7 illustrates the density prediction results using different characterization methods for PC-SAFT where our developed method gives the lowest deviation especially at higher pressures.

Fig. 8 presents the results for the gas compressibility factor. In general, it seems all the models have some deficiencies in calculation of Z factor especially at higher pressures. PR with volume translation gives the closest predictions to the experimental data. All the characterization methods for PC-SAFT give more or less similar predictions, while Assareh et al.'s method [27] is slightly better than the rest of PC-SAFT characterization methods.

The simulated Oil Formation Volume Factors (B_o) are compared with the experimental data in Fig. 9. The results show that our characterization method for PC-SAFT gives better prediction of B_o than cubics and Soave-BWR in the whole pressure range. SRK and PR without volume translation under predict B_o especially at higher pressures, while using volume translation yields over prediction of the experimental data. This trend is also observed in Fig. 10 where R_s is plotted against pressure. For most of the reservoir fluids in the database it was noticed that using volume translation for cubics might improve the prediction of B_o and R_s for pressures below the saturation pressure, however, it makes the predictions worse for higher pressures or vice versa. In general, it would be difficult to get accurate prediction of B_o and R_s in the whole pressure range using cubic EoSs either with or without volume translation.

Oil compressibility is one of the important properties in HPHT reservoirs as expansion of the reservoir fluid is the main production mechanism from these types of reservoirs. Therefore, accurate prediction of this property is of great importance. Fig. 11 shows the compressibility calculation above saturation pressure for the oil mixture from [44]. Our proposed characterization method for PC-SAFT gives the lowest deviation in compressibility compared to the cubic EoSs and Soave-BWR, and predicts this property almost accurately in the whole pressure range. The cubic models over predict the compressibility even after using volume translation while Soave-BWR seems to give the

correct slope for the experimental data. Although, the deviation is larger at lower pressures, the cubics seem to give better prediction of compressibility at higher pressures. As another example and for slightly heavier reservoir fluid, the compressibility calculation results for reservoir fluid 73 from the database are presented in Fig. 12. The results show almost similar trend as in Fig. 11.

Yan et al. [24] investigated the sensitivity of PC-SAFT to binary interaction parameters (k_{ij}) in calculation of saturation pressure and vapor phase composition for 35 reservoir fluids. They showed that although PC-SAFT gives small absolute average k_{ij} values, it is more sensitive to the change in k_{ij}. Sensitivity to k_{ij} is a possible reason for the large deviations of PC-SAFT when applied to PVT calculation. The current method does not include k_{ij} in the tuning process. Including k_{ij} in the future tuning as an additional parameter could improve the PVT calculation results. Knowing the k_{ij} for the binary mixtures of $C_1/N_2/CO_2$ and C_{7+} is difficult and cannot be completely reflected by the binary VLE systems that we know so far. Use of a large PVT database can make up for this defect.

5. Conclusions

We presented a general approach to characterizing reservoir fluids based on a large PVT database and applied it to non-cubic PC-SAFT as well as cubic SRK and PR. In this approach, the correlations for the EoS model parameters were developed first based on a large pure component database such as DIPPR, and the coefficients in the obtained correlations were further adjusted using a large PVT database. We suggest keeping the n-alkane limit during the adjustment step, which can be readily realized for correlations developed in a two-step perturbation manner. Our final correlations were obtained using a PVT database of 260 reservoir fluids. The developed correlations are not meant to be an ultimate version. They can be constantly improved with a larger PVT database, or even customized to a certain type of reservoir fluid. Repeating the whole procedure for a set of improved correlations is rather straightforward. The obtained correlations can be easily implemented in PVT software.

PC-SAFT with the new general characterization method gives the lowest AAD% and maximum deviation in calculation of saturation pressure, density and STO density, and is superior to the previous characterization methods for PC-SAFT. Furthermore, application of the new characterization method to SRK and PR improves the saturation pressure calculation in comparison to the original characterization method for SRK and PR. Using volume translation together with the new characterization approach for SRK and PR gives comparable results for density and STO density to that of original characterization for SRK and PR with volume translation. The characterization method based on PNA content for PC-SAFT gives accurate results for reservoir fluid density and STO density whereas the deviation in saturation pressure is not as low as other characterization methods for PC-SAFT.

For the PVT database used in this study, cubic EoSs seem to have better performance than PC-SAFT in calculation of saturation pressure; PC-SAFT and cubics with volume translation show comparable results in calculation of density and STO density. For calculation of the derivative properties such as compressibility, PC-SAFT has shown to be superior to cubics for the two reservoir fluids tested. Most of the reservoir fluids in the current PVT database are black oil. For lighter reservoir fluids with higher composition of methane or certain type of reservoir fluids such as volatile oil, PC-SAFT might have better performance than cubics in saturation pressure, density and STO density calculations.

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Figure captions

Fig. 1. The recommended characterization procedure (steps A and B) and its application to PVT calculation

Fig. 2. T_c and P_c correlations as a function of ΔSG for the pure components in DIPPR database

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Fig. 6. Density vs. pressure for the oil mixture from [44] - comparison between cubics with and without volume translation and non-cubic models including PC-SAFT with different characterization methods

Fig. 7. Density vs. pressure for the oil mixture from [44] - comparison between different characterization methods for PC-SAFT

Fig. 8. Gas compressibility factor vs. pressure for the oil mixture from [44]

Fig. 9. Oil formation volume factor vs. pressure for the oil mixture from [44]

Fig. 10. Solution gas-oil ratio vs. pressure for the oil mixture from [44]

Fig. 11. Oil compressibility vs. pressure for the oil mixture from [44]

Fig. 12. Oil compressibility vs. pressure for fluid 73 from the database

Tables

Table 1. Representative aromatic components and their parameters for the new PNA approach

Component	Family	MW (g/mol)	T_b (K)	SG	m (-)	σ (Å)	ε/k (K)	$m.\varepsilon/k$ (K)	$m.\sigma^3$ (Å^3)
Benzene	n-Alkylbenzenes	78.112	353.24	0.883	2.487	3.626	286.104	711.635	118.603
Toluene	n-Alkylbenzenes	92.138	383.78	0.873	2.780	3.727	288.065	800.738	143.859
1,2,3-trimethylindene	Cyclobenzenes	158.240	509.00	1.019	3.893	3.870	311.764	1213.750	225.719
1-phenylindene	Cyclobenzenes	192.256	610.00	1.092	4.756	3.798	340.167	1617.830	260.654
Indane	Cyclobenzenes	118.176	451.12	0.969	3.079	3.839	318.609	980.873	174.230
Ethynylbenzene	Monoaromatics	102.133	416.00	0.934	2.683	3.869	318.811	855.488	155.378
Naphthalene	Naphthalenes	128.171	491.143	1.028	3.013	3.910	353.084	1063.758	180.100
Tetraphenylmethane	Polyaromatics	320.426	743.00	1.350	5.835	3.995	369.840	2158.003	372.009
Tetraphenylethylene	Polyaromatics	332.437	760.00	1.347	6.127	3.985	369.619	2264.786	387.795

Table 2. Summary of AAD% and maximum deviations in the calculated saturation pressures, reservoir fluid densities and STO densities using SRK, PR, Soave-BWR and PC-SAFT with different characterization methods

EoS	Saturation Pressure		Density		STO Density	
	AAD%	Max. Dev.	AAD%	Max. Dev.	AAD%	Max. Dev.
SRK	6.35	21.84	12.62	25.60	16.49	27.11
PR	6.26	22.36	3.95	16.94	6.76	18.61
SRK-VT	6.35	21.84	1.63	7.70	0.66	2.67
PR-VT	6.26	22.36	1.55	7.42	0.80	2.83
Soave-BWR	6.72	31.27	4.46	26.20	6.45	23.52
PC-SAFT Yan et al. (2015)	7.36	28.73	2.82	9.39	2.03	7.41
PC-SAFT Liang et al. (2015)	7.84	42.84	2.71	9.11	2.67	15.57
PC-SAFT Assareh et al. (2016)	7.45	37.54	2.00	8.25	1.87	4.16
SRK This work - Eq. (19)	5.83	27.27	12.18	26.43	16.37	27.96
SRK This work - Eqs. (20-21)	5.76	27.65	10.92	25.08	14.88	26.56
SRK This work - Eqs. (20-21) – With VT	5.76	27.65	1.67	6.08	0.79	2.68
PR This work - Eq. (22)	6.01	29.53	3.92	15.68	4.77	20.88
PR This work - Eqs. (23-24)	5.75	27.33	3.92	16.02	5.01	20.65
PR This work - Eqs. (23-24) – With VT	5.75	27.33	1.66	6.67	0.91	2.92
PC-SAFT New PNA Method - Eqs. (34-36)	9.40	26.76	1.64	7.33	0.77	3.07
PC-SAFT This work - Eq. (11)	6.50	23.99	2.36	7.92	1.75	6.79
PC-SAFT This work - Eqs. (11), (12)	6.51	24.08	1.73	7.73	0.86	2.98

Table 3. AAD% in calculated saturation pressure, density, STO density and other properties of the oil from [44] using SRK, PR, Soave-BWR and PC-SAFT EoS with different characterization methods

EoS	Saturation Pressure	Density	STO Density	Gas Z Factor	B_o	R_s	Compressibility	Relative Volume
SRK	8.07	16.50	21.40	2.63	3.15	14.49	25.56	2.73
PR	9.51	6.85	12.04	1.52	2.70	4.67	21.02	2.10
SRK-VT	8.07	1.18	1.51	1.93	3.45	8.14	9.33	1.95
PR-VT	9.51	1.37	1.74	0.50	3.70	8.73	15.44	2.01
Soave-BWR	3.23	3.47	0.33	1.36	7.70	7.43	9.14	1.41
PC-SAFT Yan et al. (2015)	2.01	0.67	0.93	2.62	1.49	5.20	4.28	1.27
PC-SAFT Liang et al. (2015)	3.53	0.62	2.41	2.68	2.70	6.48	2.65	1.35
PC-SAFT Assareh et al. (2016)	2.94	1.18	3.12	2.43	0.75	3.05	3.69	1.18
PC-SAFT This work - Eqs. (11), (12)	1.69	0.35	1.85	2.57	2.12	6.60	3.21	1.13

Figures

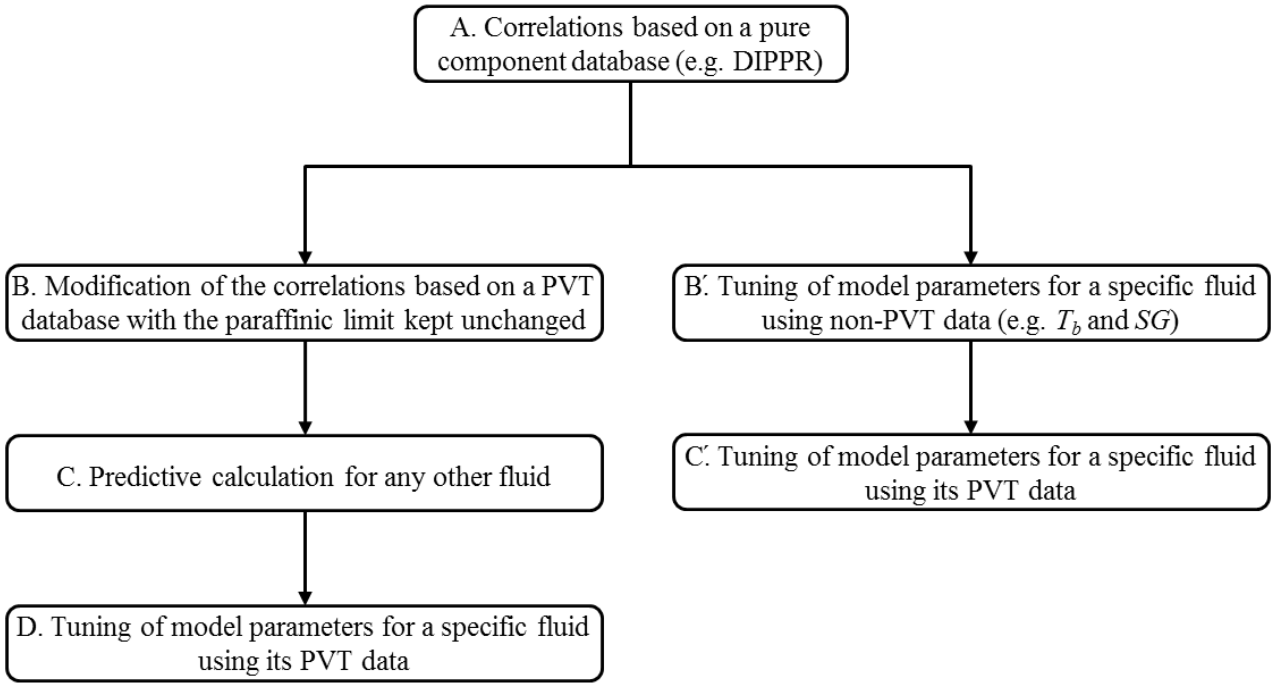
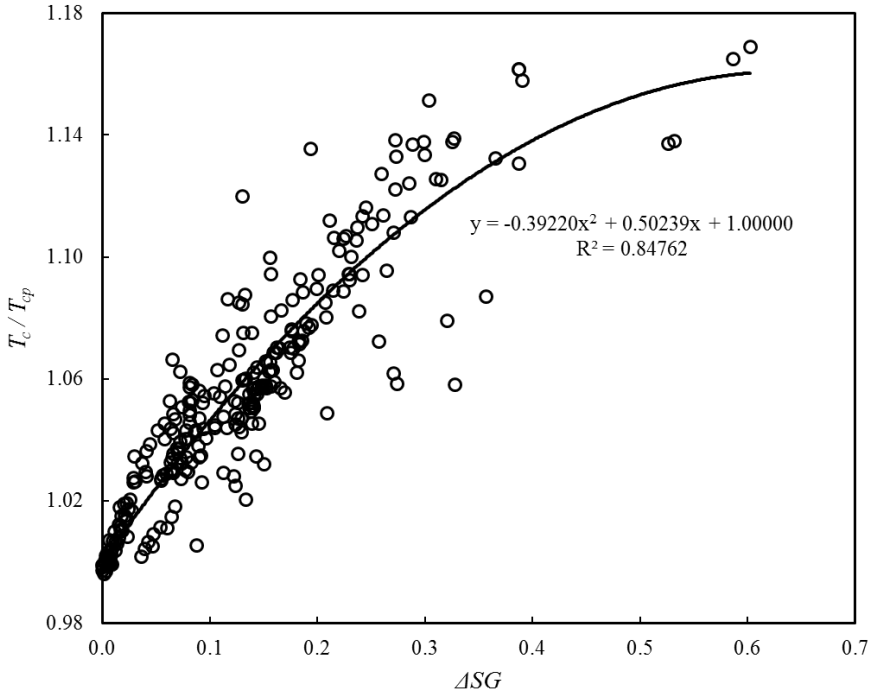
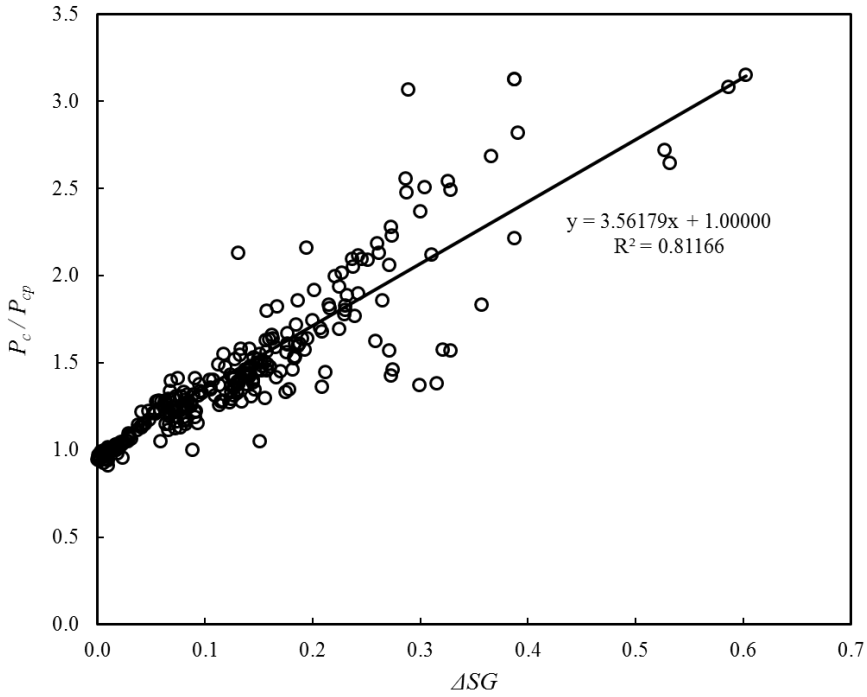


Fig. 1. The recommended characterization procedure (steps A and B) and its application to PVT calculation

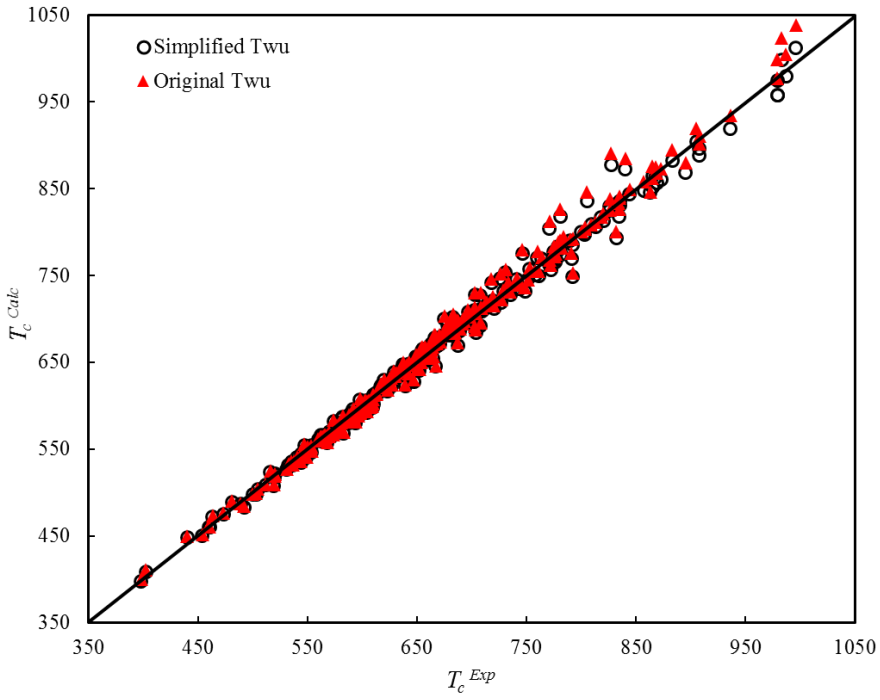

1.18
1.14
1.10
1.06
1.02
0.98
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
T_c / T_{cp}
ΔSG
y = -0.39220x² + 0.50239x + 1.00000
R² = 0.84762

a)

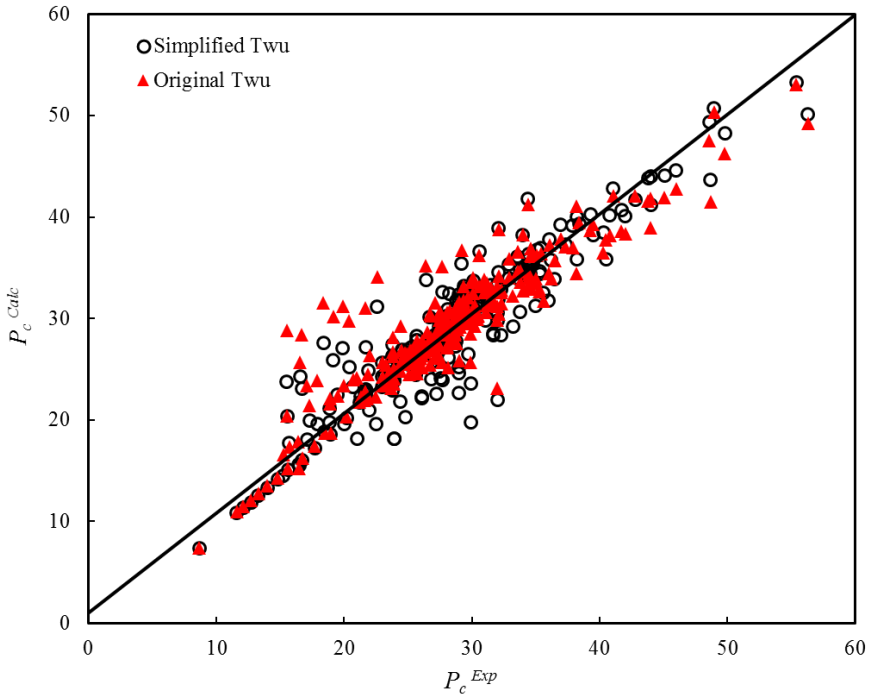


b)

Fig. 2. T_c and P_c correlations as a function of ΔSG for the pure components in DIPPR database

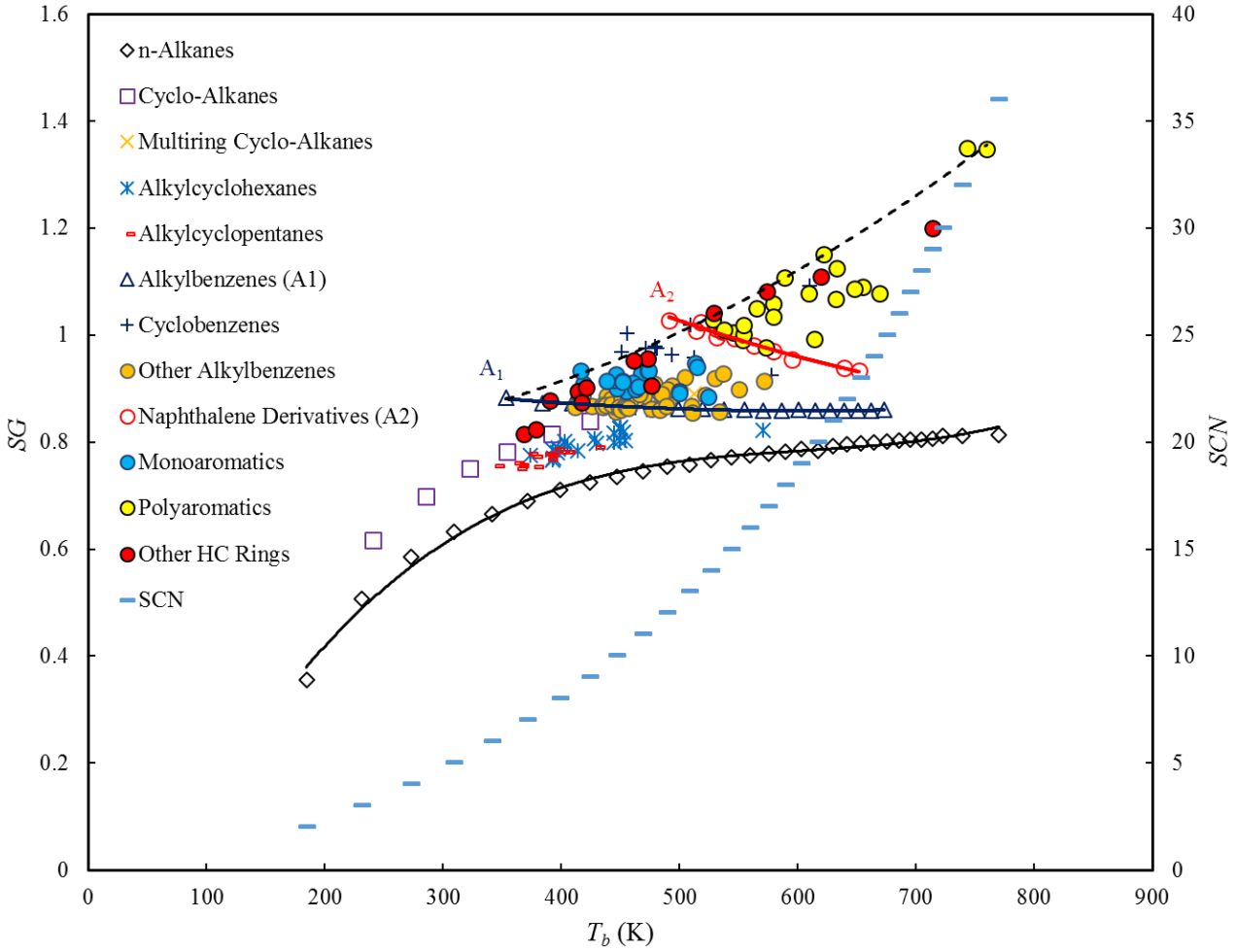

Simplified Twu
Original Twu
1050
950
850
750
650
550
450
350
350
450
550
650
750
850
950
1050
T_c^{Calc}
T_c^{Exp}

a)



b)

Fig. 3. Comparison between original and simplified Twu's method in calculation of critical temperature and pressure vs. experimental data from DIPPR



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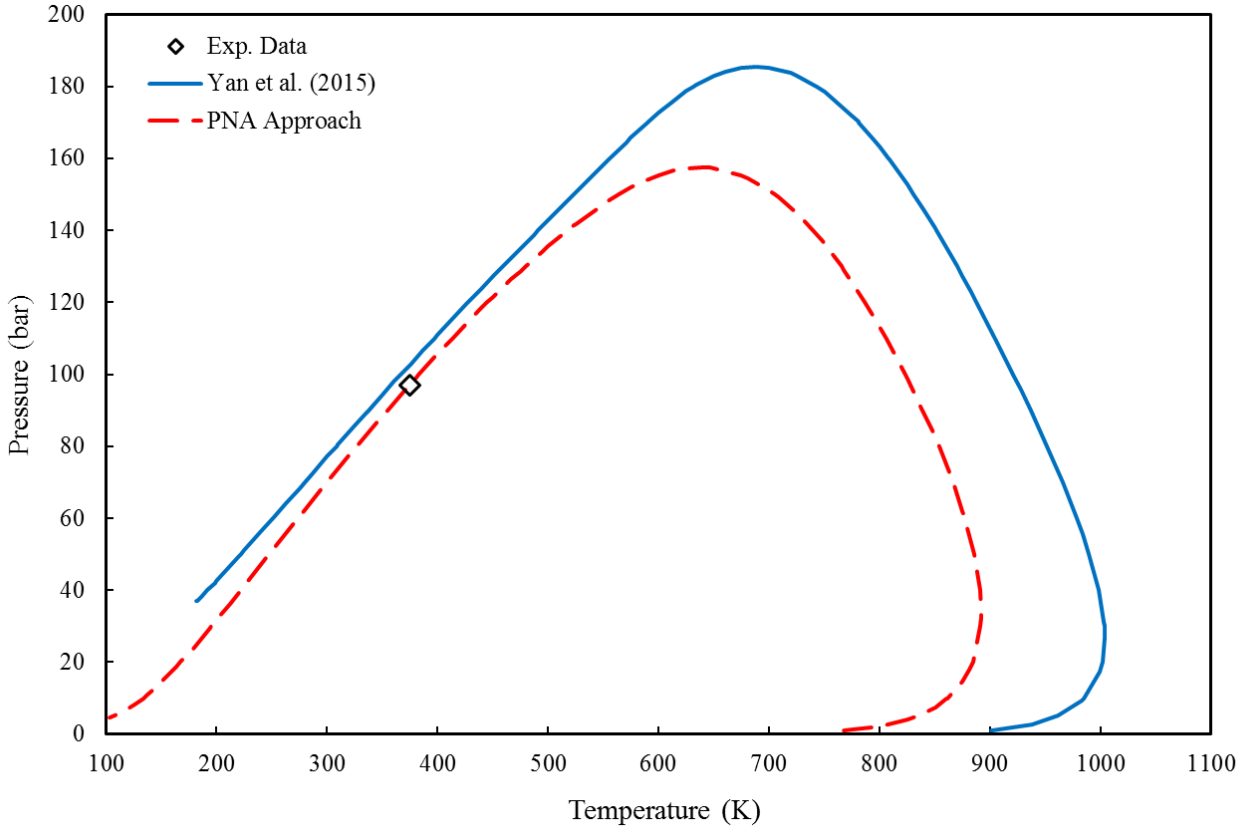


Fig. 5. Phase envelope diagram for Fluid 7 from [40] using PC-SAFT and the “trial” PNA Approach

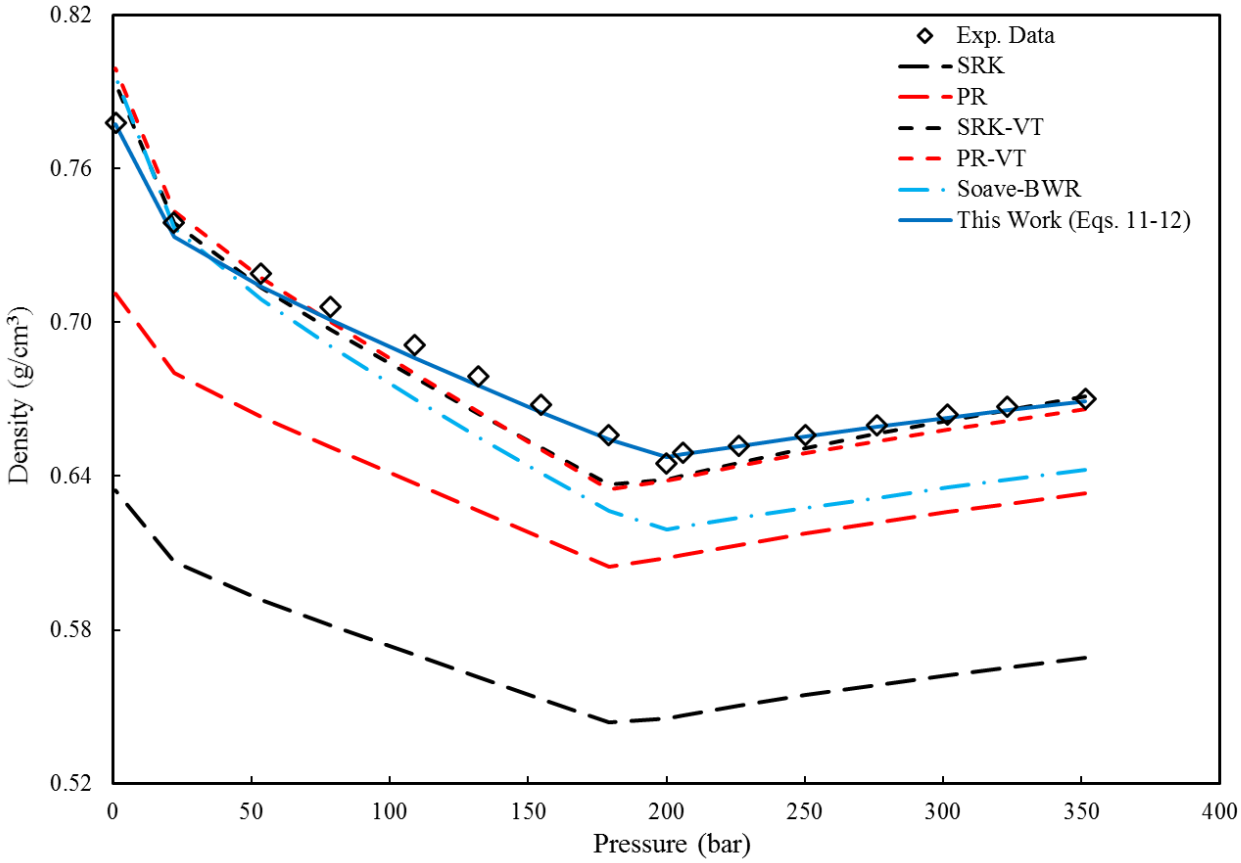


Fig. 6. Density vs. pressure for the oil mixture from [44] - comparison between cubics with and without volume translation and non-cubic models including PC-SAFT with different characterization methods

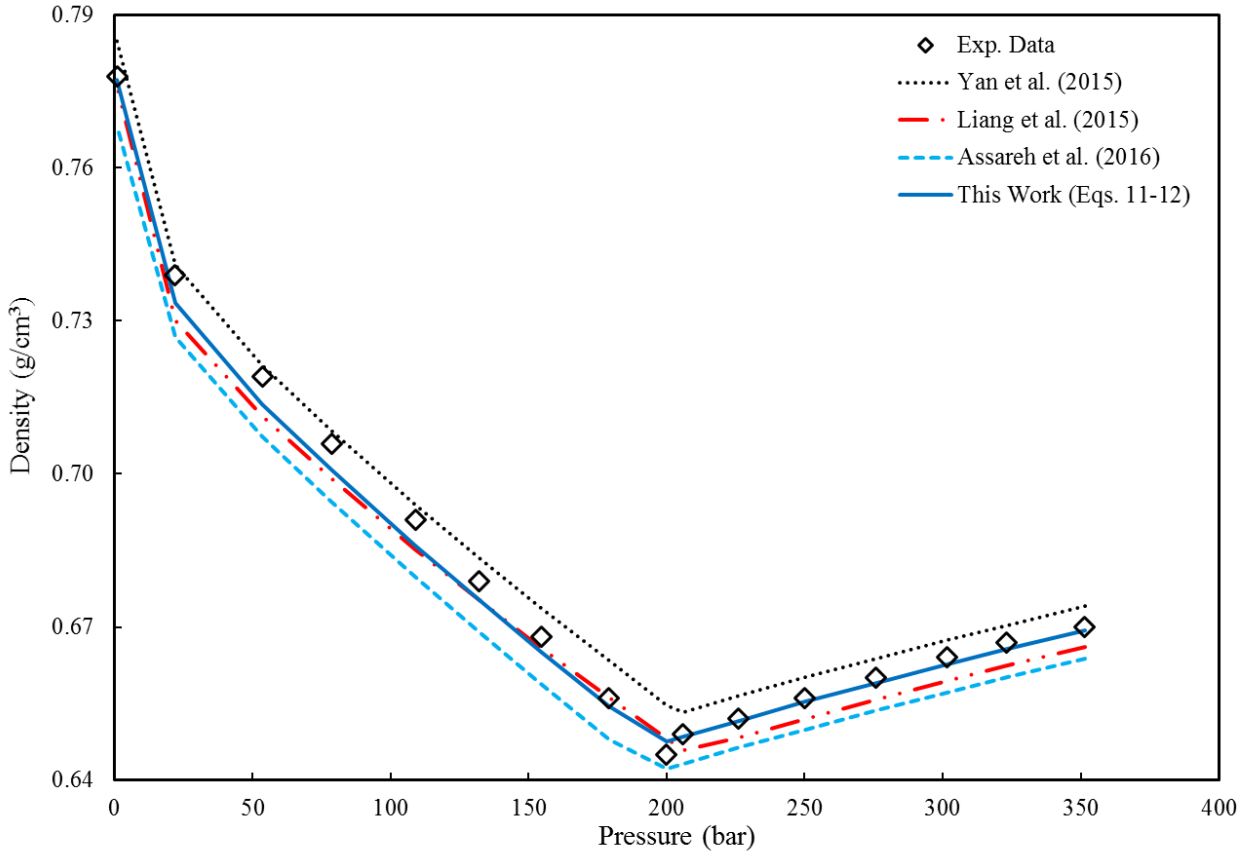


Fig. 7. Density vs. pressure for the oil mixture from [44] - comparison between different characterization methods for PC-SAFT

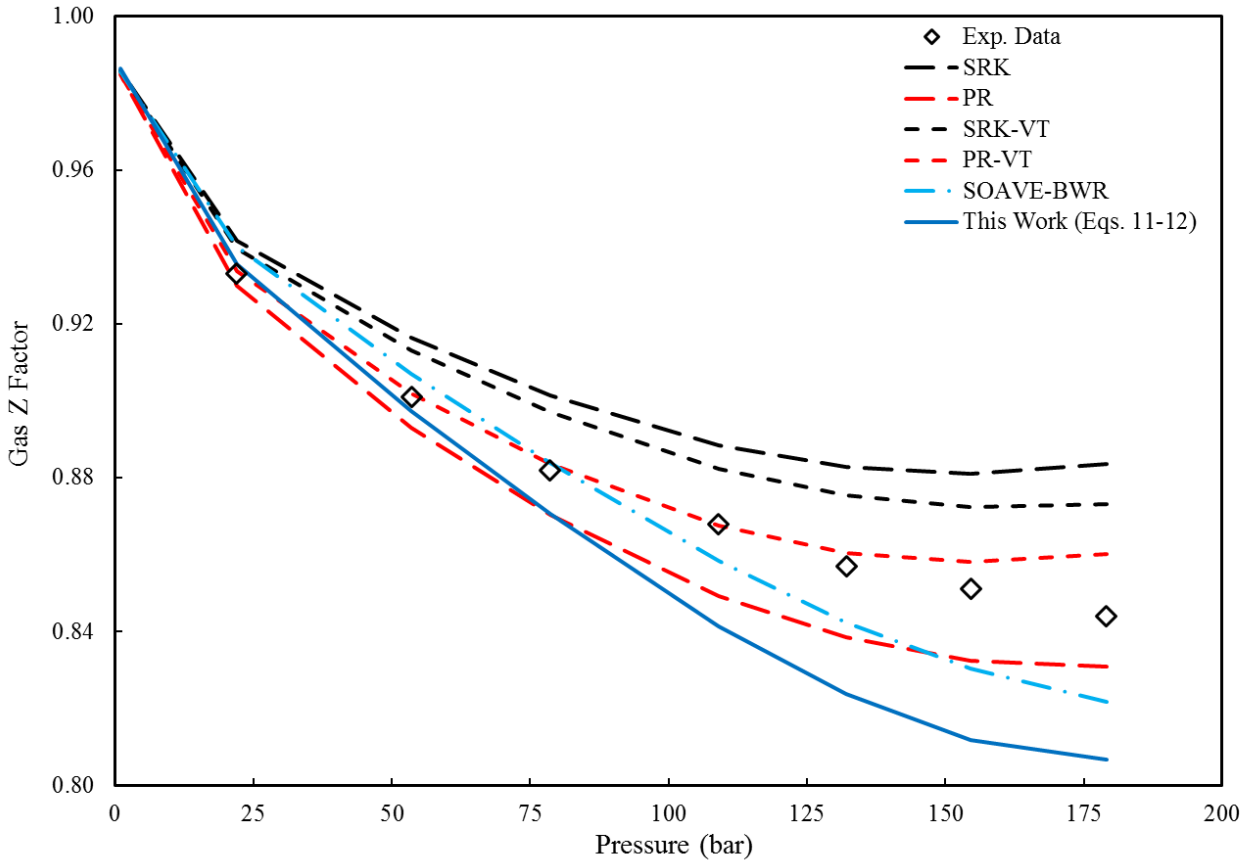


Fig. 8. Gas compressibility factor vs. pressure for the oil mixture from [44]

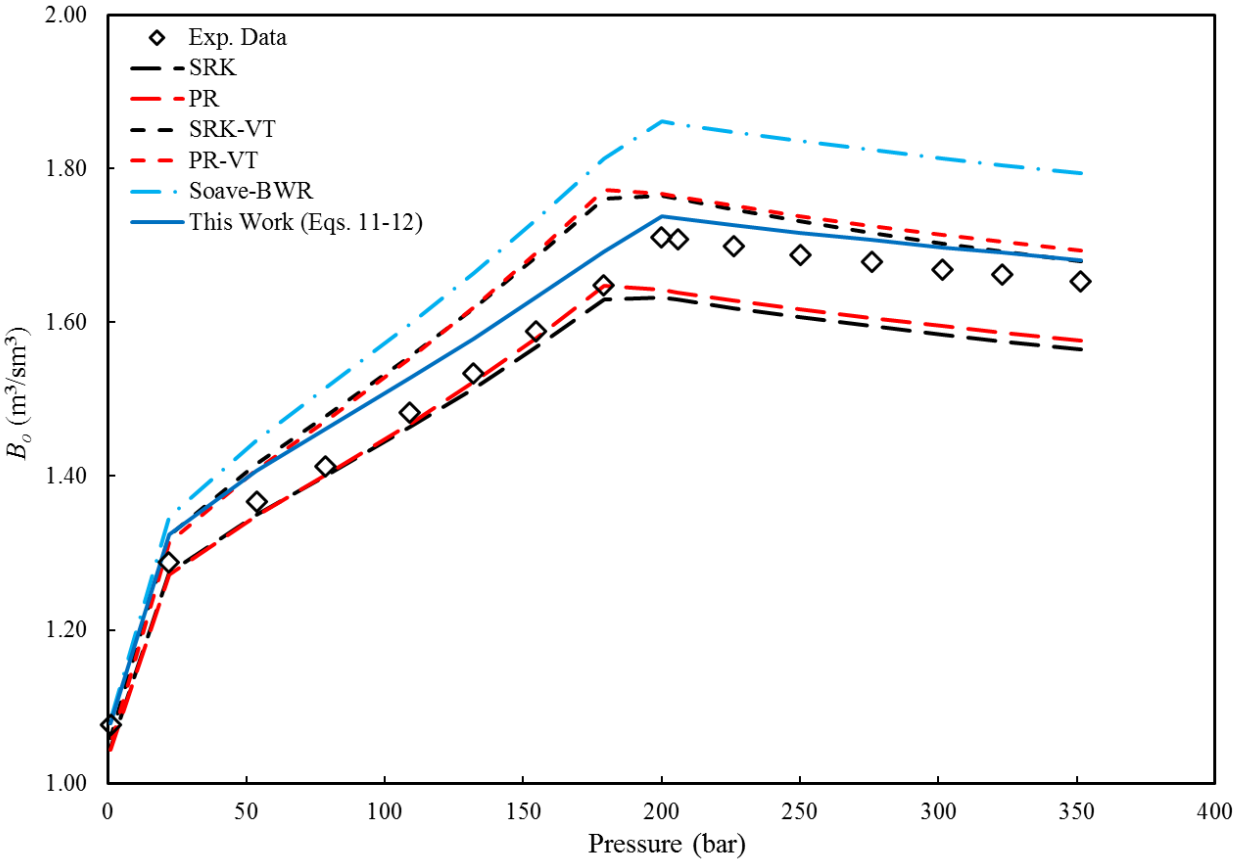


Fig. 9. Oil formation volume factor vs. pressure for the oil mixture from [44]

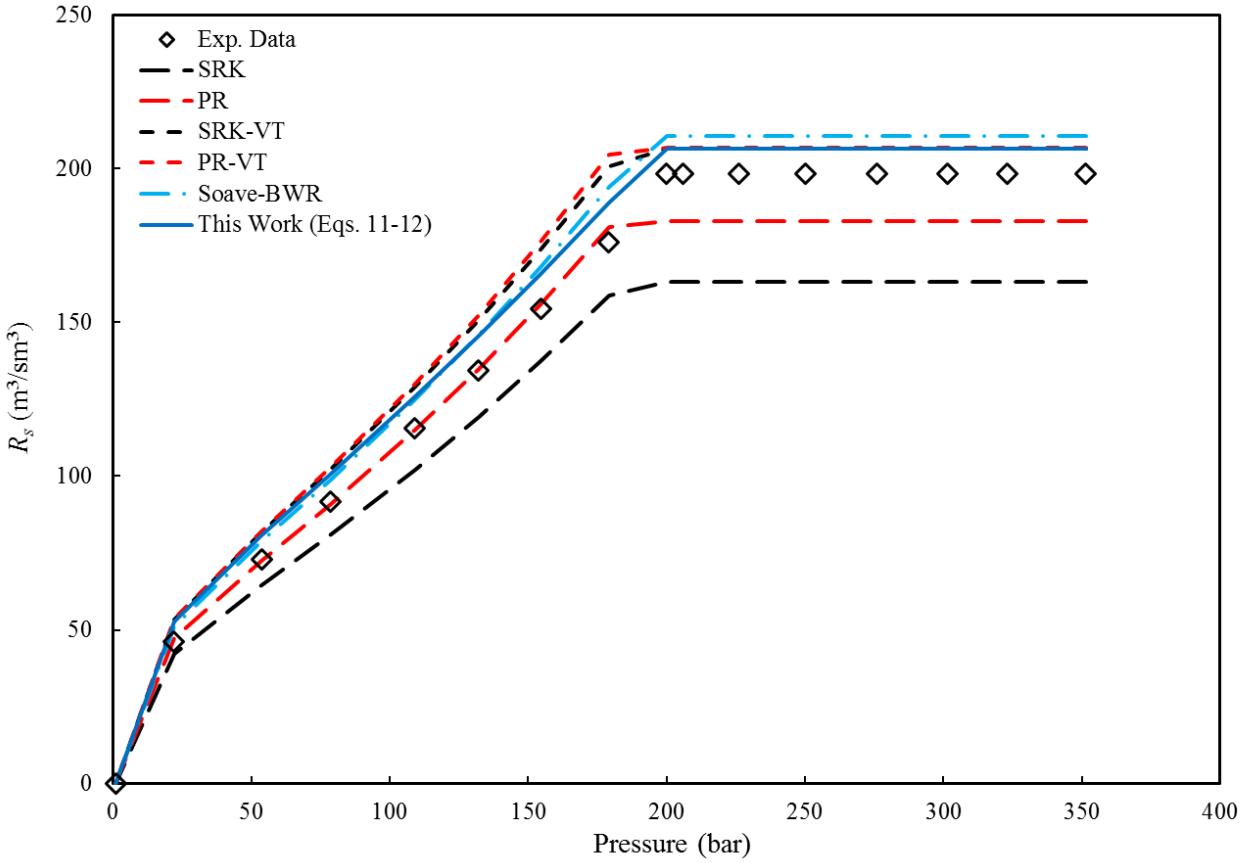
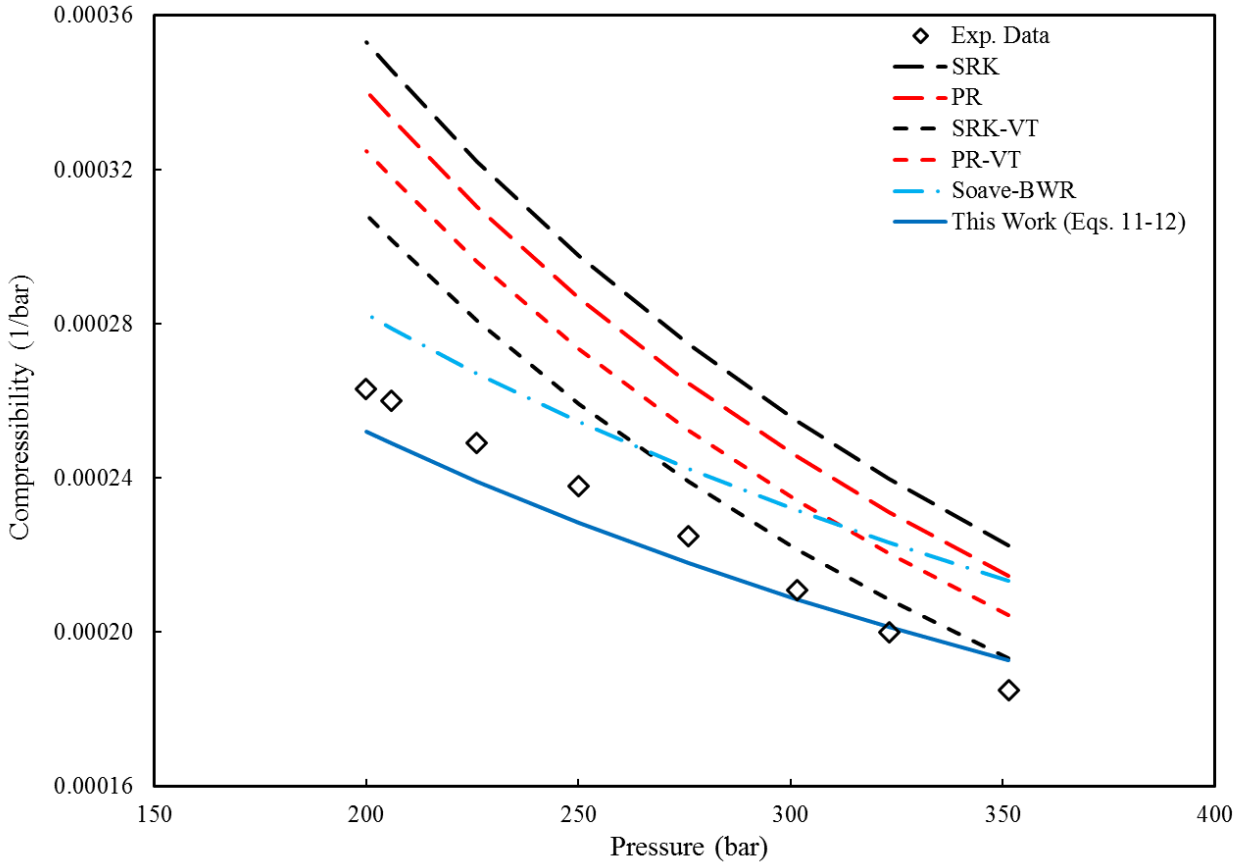


Fig. 10. Solution gas-oil ratio vs. pressure for the oil mixture from [44]



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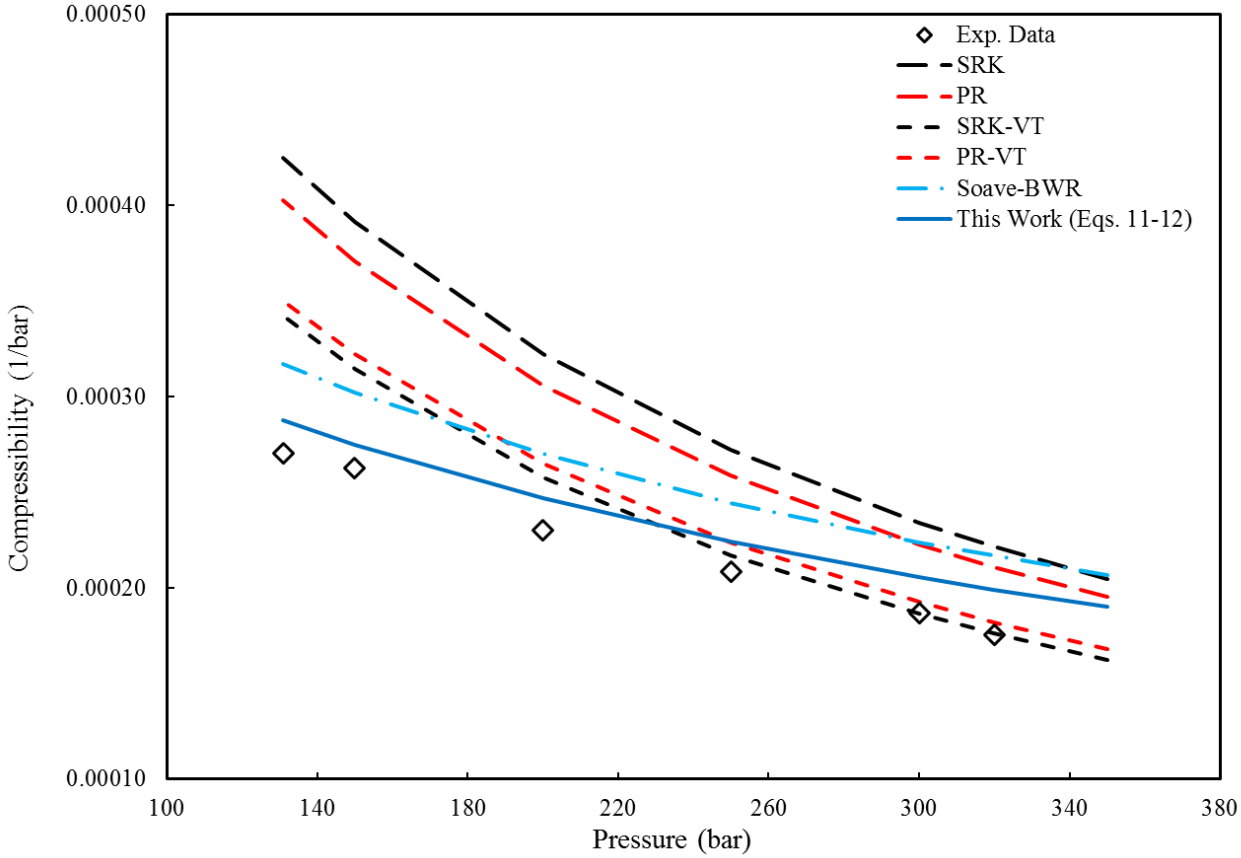

Fig. 12. Oil compressibility vs. pressure for fluid 73 from the database

Supplementary Information

Table A1. An overview of the reservoir fluid systems tested

Fluid no.	$\%N_2$	$\%CO_2$	$\% C_1$	$\% C_{7+}$	MW_{7+}	SG_{7+}	Type	T (K)	P^{sat} (bar)
Fluid 1	0.34	0.84	49.23	31.45	230.34	0.8656	OIL	366.45	274.50
Fluid 2	0.00	1.81	49.83	30.53	227.66	0.8755	OIL	337.25	289.70
Fluid 3	0.08	0.27	49.71	40.22	251.22	0.8853	OIL	337.85	270.40
Fluid 4	0.00	1.43	49.97	44.04	270.86	0.8998	OIL	337.25	282.30
Fluid 5	0.01	1.38	32.10	48.21	212.22	0.8655	OIL	346.15	133.60
Fluid 6	0.02	0.96	32.03	61.38	283.46	0.9174	OIL	333.15	137.80
Fluid 7	0.18	0.82	22.92	44.00	257.71	0.8742	OIL	374.85	96.90
Fluid 8	0.00	0.20	23.64	45.80	254.44	0.8734	OIL	372.05	117.70
Fluid 9	0.00	0.45	45.85	29.02	216.04	0.8527	OIL	387.35	255.60
Fluid 10	0.00	0.35	54.26	21.27	200.91	0.8328	OIL	388.15	320.20
Fluid 11	0.38	0.45	26.58	42.72	245.43	0.8864	OIL	394.25	145.80
Fluid 12	0.00	0.00	36.20	34.40	219.98	0.8568	OIL	383.15	172.90
Fluid 13	0.00	0.00	31.28	36.78	201.48	0.8354	OIL	393.15	153.90
Fluid 14	0.00	0.08	32.16	35.47	208.07	0.8354	OIL	393.15	153.00
Fluid 15	0.00	2.25	44.66	50.45	290.30	0.9185	OIL	322.65	232.20
Fluid 16	0.13	0.09	41.32	53.81	291.72	0.9226	OIL	344.95	198.70
Fluid 17	0.81	0.08	42.14	54.64	299.54	0.9268	OIL	346.05	208.70
Fluid 18	0.16	0.23	39.45	51.13	248.24	0.9170	OIL	346.15	202.30
Fluid 19	0.05	2.25	23.21	72.97	236.22	0.9226	OIL	329.75	105.10
Fluid 20	0.00	2.65	41.99	53.54	288.86	0.9214	OIL	319.55	207.10
Fluid 21	0.07	3.59	35.53	53.76	268.57	0.9185	OIL	339.85	174.80
Fluid 22	0.99	1.41	34.66	33.74	182.36	0.8238	OIL	427.60	186.23
Fluid 23	0.67	1.31	39.55	30.58	194.70	0.8326	OIL	418.10	224.30
Fluid 24	2.18	3.15	74.71	6.39	150.96	0.7932	GC	323.15-469.15	375.20-336.70
Fluid 25	0.70	2.47	63.68	12.47	162.04	0.8036	GC	423.15-455.15	322.31-313.86
Fluid 26	0.81	2.42	63.45	11.13	167.74	0.8070	GC	423.15-460.15	311.27-303.99
Fluid 27	2.66	2.48	63.43	11.46	166.80	0.7986	GC	323.15-460.15	299.40-310.60
Fluid 28	1.13	0.03	27.86	68.15	343.11	0.9400	OIL	345.93	107.85
Fluid 29	0.00	4.70	38.64	53.59	276.63	0.9268	OIL	318.15	185.20
Fluid 30	0.50	0.04	21.50	56.52	317.15	0.9195	OIL	331.15	76.70
Fluid 31	0.15	0.82	32.81	65.83	350.86	0.9747	OIL	329.15	141.20
Fluid 32	2.32	0.25	47.64	25.12	212.74	0.8298	OIL	303.25-417.85	219.20-276.60

Fluid 33	0.36	0.40	47.24	27.18	214.21	0.8451	OIL	394.25	245.70
Fluid 34	0.00	0.67	46.63	28.94	217.29	0.8568	OIL	373.75	245.70
Fluid 35	1.49	0.32	45.29	25.92	222.70	0.8590	OIL	299.85-394.25	212.40-275.00
Fluid 36	0.08	0.27	49.71	40.23	250.15	0.8813	OIL	337.85	270.40
Fluid 37	0.24	2.10	26.13	71.43	260.97	0.8923	OIL	318.35	90.40
Fluid 38	0.09	2.28	30.08	67.33	279.08	0.9096	OIL	318.15	108.60
Fluid 39	0.12	2.08	28.46	69.09	273.23	0.9020	OIL	317.95	94.20
Fluid 40	0.10	3.84	46.77	39.98	256.08	0.8915	OIL	331.15	259.80
Fluid 41	0.07	3.85	45.46	41.67	258.79	0.8900	OIL	331.55	239.90
Fluid 42	0.38	0.14	18.79	50.59	246.49	0.8521	OIL	362.25	72.30
Fluid 43	1.64	1.95	44.40	24.50	209.50	0.8528	OIL	377.95	276.20
Fluid 44	0.01	1.37	32.09	48.21	210.39	0.8725	OIL	346.15	133.60
Fluid 45	0.01	3.87	33.36	55.95	267.64	0.9087	OIL	339.85	155.40
Fluid 46	0.23	0.05	37.62	53.43	257.79	0.9034	OIL	342.15	156.90
Fluid 47	0.00	0.18	36.35	60.22	273.53	0.9094	OIL	335.15	142.60
Fluid 48	0.00	0.14	50.21	34.33	221.50	0.8575	OIL	344.35	267.50
Fluid 49	0.17	0.08	44.72	38.18	235.17	0.8749	OIL	335.25	219.20
Fluid 50	0.23	0.16	35.13	52.20	299.31	0.8659	OIL	318.75	119.50
Fluid 51	0.10	0.09	46.95	38.08	249.18	0.8815	OIL	338.35	260.60
Fluid 52	0.32	0.97	30.18	68.14	314.82	0.9641	OIL	329.15	143.80
Fluid 53	0.00	1.81	49.83	30.53	226.51	0.8616	OIL	337.25	289.70
Fluid 54	0.00	1.43	49.97	44.05	270.11	0.9004	OIL	337.85	282.30
Fluid 55	0.07	3.81	40.24	52.58	280.56	0.9094	OIL	331.15	210.40
Fluid 56	0.24	2.54	40.82	49.53	284.34	0.9029	OIL	323.35	235.80
Fluid 57	3.57	20.78	21.99	36.53	232.93	0.8816	OIL	401.05	233.30
Fluid 58	3.82	21.24	22.99	35.00	239.23	0.8804	OIL	401.05	251.30
Fluid 59	0.00	0.20	36.34	42.31	203.78	0.8550	OIL	347.15	149.60
Fluid 60	0.00	0.45	48.76	30.15	196.37	0.8478	OIL	358.15	264.10
Fluid 61	5.50	33.53	18.58	30.73	200.38	0.8416	OIL	409.15	276.90
Fluid 62	0.43	0.06	25.25	52.97	202.39	0.8249	OIL	395.15	103.77
Fluid 63	0.04	0.06	39.89	42.76	221.79	0.8428	OIL	323.15	150.42
Fluid 64	0.10	0.56	30.65	57.97	183.89	0.8680	OIL	334.80	123.40
Fluid 65	0.55	0.15	61.24	13.04	175.74	0.8156	OIL	347.04	338.86
Fluid 66	0.25	0.01	22.56	38.31	238.00	0.9040	OIL	341.48	96.44
Fluid 67	0.19	0.00	23.10	44.43	207.00	0.8829	OIL	341.48	96.78
Fluid 68	0.07	0.02	33.27	54.95	204.06	0.8498	OIL	323.15	113.76
Fluid 69	0.24	0.02	36.88	51.77	211.46	0.8368	OIL	325.15	116.52
Fluid 70	0.65	0.14	40.77	28.01	203.82	0.8446	OIL	335.15	182.37
Fluid 71	0.02	0.05	34.21	57.61	208.21	0.8372	OIL	321.15	122.02
Fluid 72	1.22	0.01	38.36	26.42	200.00	0.8170	OIL	344.26	181.93
Fluid 73	1.11	0.08	28.50	41.06	189.39	0.8053	OIL	384.85	131.00
Fluid 74	1.17	0.05	28.65	40.86	188.76	0.8048	OIL	384.85	132.00
Fluid 75	0.97	1.46	29.78	40.79	190.80	0.8215	OIL	378.15	148.35

Fluid 76	0.96	0.18	27.56	41.10	187.77	0.8218	OIL	382.04	134.08
Fluid 77	0.00	2.35	47.22	38.15	216.82	0.8381	OIL	355.37	247.29
Fluid 78	0.00	0.00	28.07	60.69	192.00	0.8400	OIL	319.26	103.40
Fluid 79	0.26	8.95	43.32	26.93	224.49	0.8448	OIL	359.26	268.39
Fluid 80	0.15	2.04	44.59	39.17	206.00	0.8410	OIL	353.15	218.82
Fluid 81	0.11	3.35	43.44	34.55	191.00	0.8380	OIL	349.82	214.82
Fluid 82	0.14	0.00	35.85	62.51	226.98	0.8719	OIL	328.15	141.87
Fluid 83	0.29	1.70	45.39	40.04	211.00	0.8400	OIL	352.04	223.78
Fluid 84	0.19	1.82	42.39	44.01	205.00	0.8365	OIL	350.93	209.30
Fluid 85	0.21	1.88	44.80	42.28	208.00	0.8430	OIL	350.93	216.41
Fluid 86	0.10	5.58	42.64	31.63	178.00	0.8290	OIL	347.59	242.74
Fluid 87	0.13	5.13	42.47	33.69	186.00	0.8330	OIL	347.59	232.68
Fluid 88	0.62	0.16	26.67	51.15	195.67	0.8295	OIL	398.15	116.57
Fluid 89	0.21	5.01	45.97	25.89	182.56	0.8202	OIL	357.04	273.77
Fluid 90	0.20	6.51	44.14	27.38	220.00	0.8429	OIL	359.15	257.08
Fluid 91	4.94	0.82	42.41	37.63	228.41	0.8589	OIL	389.82	296.82
Fluid 92	4.14	0.12	42.81	31.23	226.24	0.8665	OIL	381.48	274.83
Fluid 93	3.64	1.17	38.42	32.74	201.20	0.8496	OIL	403.15	251.11
Fluid 94	3.06	0.23	36.02	32.39	181.76	0.8220	OIL	377.59	194.36
Fluid 95	1.42	0.07	9.59	41.89	156.99	0.7840	OIL	364.82	49.16
Fluid 96	1.94	1.11	10.95	44.76	154.00	0.7970	OIL	394.26	80.92
Fluid 97	1.69	0.03	7.50	75.15	229.43	0.8299	OIL	359.26	34.11
Fluid 98	7.18	0.68	40.28	27.00	169.45	0.8145	OIL	398.71	266.83
Fluid 99	1.89	2.26	35.79	25.20	168.00	0.7916	OIL	439.26	198.20
Fluid 100	7.37	2.51	51.58	15.05	164.97	0.8108	OIL	382.04	379.21
Fluid 101	5.82	0.47	42.24	30.52	195.89	0.8366	OIL	402.04	293.72
Fluid 102	0.26	0.01	2.26	44.19	168.40	0.7916	OIL	372.59	15.10
Fluid 103	6.16	0.83	28.88	39.94	184.63	0.8247	OIL	399.82	196.82
Fluid 104	4.94	0.31	35.60	27.99	179.80	0.8376	OIL	386.48	215.19
Fluid 105	2.10	0.03	20.18	36.43	139.91	0.7859	OIL	369.82	101.35
Fluid 106	2.54	0.57	38.96	32.71	206.00	0.8540	OIL	395.93	230.26
Fluid 107	3.72	2.94	48.69	17.95	169.50	0.8220	OIL	402.59	296.20
Fluid 108	3.22	0.95	39.02	28.11	195.26	0.8509	OIL	383.15	244.05
Fluid 109	2.39	0.13	43.63	17.54	145.76	0.7949	OIL	377.59	232.15
Fluid 110	4.89	0.26	32.40	34.52	185.74	0.8307	OIL	390.37	210.61
Fluid 111	6.88	0.13	40.06	27.97	179.26	0.8217	OIL	409.82	284.75
Fluid 112	3.50	0.46	49.96	20.19	188.15	0.8082	OIL	407.59	326.12
Fluid 113	2.00	0.08	10.81	58.57	198.30	0.8430	OIL	382.04	63.29
Fluid 114	3.35	0.32	42.55	23.66	195.75	0.8364	OIL	405.37	257.17
Fluid 115	8.46	7.19	36.77	13.24	126.06	0.7845	OIL	413.15	201.86
Fluid 116	3.44	0.04	37.89	20.96	133.49	0.7792	OIL	379.82	182.02
Fluid 117	7.71	0.97	37.93	16.16	178.67	0.8149	OIL	392.04	230.68
Fluid 118	1.64	0.54	23.24	38.18	190.96	0.8327	OIL	385.93	123.42

Fluid 119	4.86	0.54	44.64	21.65	176.31	0.8205	OIL	414.26	272.94
Fluid 120	7.26	0.48	34.38	29.21	166.40	0.8007	OIL	402.04	191.40
Fluid 121	3.16	0.21	22.75	26.91	160.30	0.7899	OIL	377.59	119.42
Fluid 122	5.82	0.46	41.55	31.39	204.00	0.8545	OIL	393.15	284.18
Fluid 123	6.60	0.09	16.61	59.73	233.07	0.8433	OIL	360.93	128.91
Fluid 124	2.55	0.02	13.50	32.32	157.60	0.7850	OIL	372.04	76.12
Fluid 125	0.28	0.06	33.29	41.32	208.00	0.8349	OIL	316.48	119.88
Fluid 126	3.85	2.67	46.45	26.34	196.83	0.8365	OIL	397.04	294.87
Fluid 127	9.06	0.61	42.73	29.12	153.93	0.7993	OIL	395.37	248.21
Fluid 128	4.42	0.04	44.15	14.23	154.10	0.7866	OIL	379.82	222.63
Fluid 129	4.25	0.00	37.92	25.28	126.95	0.7692	OIL	390.37	195.47
Fluid 130	0.83	0.02	18.16	55.79	256.00	0.8801	OIL	309.82	63.69
Fluid 131	3.11	0.04	17.11	29.53	156.50	0.7842	OIL	372.04	88.46
Fluid 132	4.61	0.70	22.69	38.22	165.64	0.8022	OIL	399.82	133.39
Fluid 133	2.15	0.22	24.77	45.17	196.02	0.8381	OIL	409.26	132.98
Fluid 134	4.95	0.52	43.21	21.31	165.75	0.8128	OIL	400.93	246.47
Fluid 135	3.73	0.00	41.47	28.00	213.81	0.8490	OIL	401.48	263.72
Fluid 136	4.66	2.10	29.26	31.67	149.98	0.7967	OIL	394.26	189.61
Fluid 137	8.28	1.02	48.69	18.57	175.09	0.8150	OIL	397.04	296.34
Fluid 138	3.19	7.13	51.17	14.54	157.07	0.8065	OIL	401.48	305.07
Fluid 139	5.53	3.50	30.92	34.38	181.70	0.8239	OIL	417.59	205.93
Fluid 140	3.60	0.92	45.33	21.18	179.92	0.8269	OIL	395.37	292.34
Fluid 141	4.88	1.86	40.34	27.79	199.25	0.8361	OIL	404.26	298.66
Fluid 142	5.31	0.85	45.91	18.94	170.00	0.8090	OIL	400.37	247.50
Fluid 143	0.30	0.67	24.44	46.59	240.00	0.8703	OIL	300.93	80.23
Fluid 144	2.75	0.10	32.00	30.91	128.29	0.7724	OIL	382.04	156.51
Fluid 145	4.38	0.24	39.08	30.21	183.20	0.8411	OIL	397.59	257.59
Fluid 146	4.51	0.74	50.88	16.32	172.50	0.8264	OIL	395.93	316.75
Fluid 147	4.31	0.13	19.61	59.33	227.12	0.8369	OIL	342.59	109.81
Fluid 148	0.69	2.75	35.24	26.33	182.78	0.8300	OIL	384.00	200.64
Fluid 149	3.37	3.73	54.29	14.78	145.93	0.7926	OIL	397.59	299.92
Fluid 150	14.89	0.18	34.99	27.79	200.80	0.8567	OIL	378.15	427.96
Fluid 151	4.55	0.00	16.31	45.31	213.00	0.8711	OIL	375.37	114.11
Fluid 152	8.22	0.71	15.43	46.64	199.00	0.8540	OIL	398.71	164.01
Fluid 153	7.11	0.63	45.99	16.79	143.00	0.7920	OIL	391.48	239.57
Fluid 154	3.61	1.04	39.27	23.14	203.78	0.8501	OIL	388.00	244.97
Fluid 155	3.59	1.63	49.97	22.57	196.79	0.8259	OIL	388.71	304.06
Fluid 156	5.84	0.43	12.03	53.74	198.87	0.8324	OIL	405.37	120.98
Fluid 157	5.05	0.28	36.83	25.92	126.91	0.7704	OIL	406.00	210.98
Fluid 158	4.79	1.09	46.91	24.66	161.78	0.8068	OIL	395.00	269.59
Fluid 159	5.03	0.33	38.11	33.94	195.00	0.8520	OIL	400.93	260.46
Fluid 160	5.25	0.17	41.63	33.99	218.87	0.8579	OIL	391.48	298.18
Fluid 161	2.47	0.22	22.93	49.67	122.76	0.7597	OIL	405.37	115.47

Fluid 162	0.23	0.63	36.24	52.77	300.00	0.9243	OIL	344.82	160.56
Fluid 163	0.77	0.11	47.34	33.64	214.89	0.8442	OIL	345.95	243.00
Fluid 164	0.69	0.12	47.06	33.86	213.64	0.8436	OIL	345.95	238.00
Fluid 165	0.16	0.91	36.47	33.29	218.00	0.8515	OIL	377.60	181.70
Fluid 166	0.60	0.14	39.21	35.73	247.40	0.8900	OIL	335.93	188.57
Fluid 167	0.36	0.17	27.23	42.38	271.00	0.8790	OIL	327.59	94.11
Fluid 168	0.29	0.48	28.36	42.31	252.00	0.8800	OIL	329.26	112.52
Fluid 169	0.33	0.22	25.56	46.01	222.00	0.8780	OIL	329.26	109.97
Fluid 170	0.35	0.47	26.52	46.57	253.00	0.8920	OIL	330.37	103.42
Fluid 171	0.12	0.51	28.81	47.70	250.00	0.8760	OIL	329.82	111.35
Fluid 172	0.16	0.30	24.66	49.61	239.00	0.8750	OIL	329.82	96.53
Fluid 173	0.21	0.15	27.77	49.94	228.00	0.8630	OIL	329.82	109.63
Fluid 174	0.11	0.28	27.53	48.90	245.00	0.8790	OIL	330.37	106.18
Fluid 175	0.79	0.10	24.79	47.85	227.00	0.8840	OIL	329.82	96.46
Fluid 176	0.04	0.17	31.22	50.44	264.00	0.8890	OIL	330.37	116.52
Fluid 177	0.00	0.17	28.56	44.68	249.00	0.8620	OIL	329.82	106.73
Fluid 178	0.45	0.08	29.35	39.62	227.00	0.8630	OIL	329.82	117.56
Fluid 179	0.56	0.07	29.90	43.10	242.00	0.8770	OIL	329.26	113.97
Fluid 180	0.03	0.30	27.80	44.88	254.00	0.8800	OIL	329.82	113.42
Fluid 181	0.06	0.81	31.34	47.60	270.00	0.8920	OIL	328.71	120.73
Fluid 182	0.00	0.15	19.50	51.22	225.00	0.8490	OIL	328.71	70.67
Fluid 183	0.15	0.19	31.15	40.32	221.00	0.8480	OIL	330.37	113.76
Fluid 184	0.50	0.87	29.72	45.99	271.00	0.8820	OIL	329.82	112.66
Fluid 185	0.68	1.02	25.49	46.03	264.00	0.9020	OIL	329.82	105.70
Fluid 186	0.22	1.37	27.92	52.13	255.00	0.8930	OIL	330.37	106.73
Fluid 187	0.20	1.23	26.54	49.22	290.00	0.9100	OIL	328.71	110.11
Fluid 188	0.44	0.83	27.75	45.72	272.00	0.9020	OIL	329.26	107.90
Fluid 189	0.14	0.54	29.44	44.68	290.00	0.9010	OIL	329.82	108.94
Fluid 190	0.26	1.26	28.27	47.50	274.00	0.9080	OIL	329.82	115.83
Fluid 191	0.20	0.80	31.42	44.91	251.00	0.8890	OIL	328.71	119.83
Fluid 192	0.54	0.50	27.79	46.70	214.00	0.8870	OIL	329.26	114.11
Fluid 193	0.41	0.65	30.21	40.47	247.00	0.8750	OIL	330.37	129.62
Fluid 194	0.20	1.19	32.26	42.16	134.00	0.8790	OIL	329.26	123.28
Fluid 195	0.10	1.16	32.93	41.62	279.00	0.8790	OIL	329.26	124.45
Fluid 196	0.15	0.65	30.48	49.54	239.00	0.8660	OIL	327.59	115.14
Fluid 197	0.45	0.51	30.56	41.10	268.00	0.8920	OIL	330.37	119.62
Fluid 198	0.23	1.06	24.75	46.12	256.00	0.9050	OIL	329.82	105.49
Fluid 199	0.19	0.12	28.62	44.78	274.00	0.9250	OIL	330.37	121.76
Fluid 200	0.08	1.37	35.97	39.71	274.00	0.8980	OIL	348.71	172.71
Fluid 201	0.13	1.45	36.02	37.30	230.10	0.8960	OIL	347.59	198.09
Fluid 202	0.00	1.12	26.95	40.81	249.00	0.8760	OIL	370.93	129.41
Fluid 203	0.00	1.25	33.35	43.29	252.00	0.8510	OIL	383.15	145.48
Fluid 204	0.05	0.85	41.05	29.01	198.00	0.8480	OIL	389.26	229.94

Fluid 205	0.06	0.94	44.44	28.38	195.00	0.8460	OIL	388.71	250.28
Fluid 206	0.04	0.78	40.91	31.34	202.00	0.8450	OIL	389.26	215.12
Fluid 207	0.06	0.85	40.70	31.36	195.00	0.8470	OIL	390.37	219.25
Fluid 208	0.03	0.97	41.64	29.08	208.00	0.8500	OIL	389.26	211.60
Fluid 209	0.03	1.04	41.88	29.07	200.00	0.8480	OIL	385.93	222.98
Fluid 210	0.02	0.99	38.78	33.37	210.00	0.8490	OIL	388.71	208.15
Fluid 211	0.24	0.39	5.82	83.21	304.00	0.9420	OIL	344.26	21.58
Fluid 212	0.06	5.01	23.03	38.82	254.00	0.8770	OIL	365.37	139.35
Fluid 213	0.10	1.32	8.86	68.67	243.00	0.9340	OIL	354.26	46.68
Fluid 214	0.11	2.35	35.21	34.97	213.00	0.8410	OIL	394.26	175.61
Fluid 215	0.30	0.90	53.47	16.92	173.00	0.8360	OIL	353.15	307.51
Fluid 216	0.45	0.44	35.05	48.24	225.00	0.9000	OIL	355.37	173.75
Fluid 217	0.55	1.02	36.25	30.25	200.00	0.8370	OIL	385.37	189.33
Fluid 218	1.64	0.08	28.40	35.97	252.00	0.8430	OIL	328.15	116.80
Fluid 219	0.00	0.00	52.00	36.84	199.00	0.8410	OIL	366.48	264.69
Fluid 220	0.25	0.24	40.91	28.58	182.00	0.8000	OIL	422.04	209.81
Fluid 221	1.67	2.18	60.51	16.29	181.00	0.7890	OIL	392.04	332.53
Fluid 222	0.16	0.91	36.47	33.29	218.00	0.8520	OIL	377.59	180.64
Fluid 223	0.00	0.00	57.52	19.11	203.00	0.8100	OIL	373.15	349.22
Fluid 224	0.56	3.55	45.33	36.11	253.00	0.8360	OIL	365.93	267.86
Fluid 225	1.64	0.08	28.40	35.97	252.00	0.8430	OIL	328.15	117.76
Fluid 226	0.40	1.00	45.40	45.08	250.00	0.8880	OIL	344.26	238.97
Fluid 227	0.67	2.11	34.93	35.15	230.00	0.8550	OIL	387.59	187.81
Fluid 228	0.34	0.84	49.23	31.45	230.00	0.8650	OIL	366.48	274.48
Fluid 229	0.44	0.38	49.10	28.00	231.00	0.8360	OIL	365.93	257.79
Fluid 230	0.90	0.16	47.12	33.00	217.00	0.8500	OIL	347.59	234.01
Fluid 231	0.36	1.06	50.50	39.00	291.00	0.9010	OIL	342.04	254.42
Fluid 232	0.33	0.19	35.42	57.73	255.00	0.9170	OIL	343.71	159.06
Fluid 233	0.41	0.44	40.23	31.23	210.00	0.8450	OIL	370.93	198.98
Fluid 234	0.25	2.19	16.33	52.27	249.00	0.8800	OIL	374.82	86.94
Fluid 235	0.32	3.69	21.55	43.41	243.00	0.8690	OIL	388.15	109.70
Fluid 236	0.21	0.75	6.05	64.81	231.00	0.8570	OIL	337.59	24.27
Fluid 237	0.88	1.34	5.63	67.03	224.00	0.8550	OIL	326.48	25.92
Fluid 238	0.30	0.01	7.14	67.15	233.00	0.8600	OIL	333.15	25.79
Fluid 239	0.31	0.28	6.80	66.76	237.00	0.8580	OIL	335.37	25.79
Fluid 240	0.33	0.35	6.72	71.06	225.00	0.8580	OIL	332.04	24.82
Fluid 241	0.41	0.26	6.14	69.51	225.00	0.8600	OIL	329.82	23.86
Fluid 242	0.53	0.12	22.80	46.04	242.00	0.8640	OIL	342.04	91.36
Fluid 243	0.78	0.10	20.64	47.67	237.00	0.8570	OIL	342.59	83.36
Fluid 244	0.60	0.12	23.71	44.81	238.00	0.8680	OIL	342.04	95.56
Fluid 245	1.13	0.13	25.45	41.02	237.00	0.8510	OIL	342.59	99.70
Fluid 246	0.54	0.18	21.62	47.54	236.00	0.8630	OIL	342.04	86.67
Fluid 247	1.39	0.28	21.32	47.03	257.00	0.8700	OIL	342.04	84.12

Fluid 248	0.68	0.16	22.84	47.90	226.00	0.8640	OIL	342.04	97.01
Fluid 249	0.39	0.14	21.40	50.39	245.00	0.8420	OIL	338.15	77.50
Fluid 250	1.02	0.12	19.76	54.66	247.00	0.8500	OIL	344.54	79.43
Fluid 251	1.67	1.38	26.68	40.41	217.00	0.8550	OIL	372.04	134.72
Fluid 252	0.65	0.02	45.02	22.44	184.00	0.8100	OIL	333.15	206.98
Fluid 253	0.00	0.00	46.79	26.41	158.00	0.7660	OIL	373.15	202.77
Fluid 254	0.00	0.00	36.15	27.79	191.00	0.7720	OIL	373.15	154.30
Fluid 255	0.00	0.00	74.18	10.72	159.00	0.7660	GC	373.15	327.71
Fluid 256	0.00	0.00	73.48	11.20	161.00	0.7670	GC	373.15	326.95
Fluid 257	0.33	3.03	41.33	33.69	200.00	0.8480	OIL	366.48	220.63
Fluid 258	0.31	0.69	47.69	34.64	234.00	0.8690	OIL	384.26	262.00
Fluid 259	0.03	8.39	47.43	18.61	180.00	0.8300	OIL	419.26	275.79
Fluid 260	0.38	7.03	48.73	20.26	181.00	0.8050	OIL	427.04	286.55
Min	0.00	0.00	2.26	6.39	122.76	0.7597	-	299.85	15.10
Max	14.89	33.53	74.71	83.21	350.86	0.9747	-	469.15	427.96

Table A2. Summary of AAD% in predicted saturation pressures, reservoir fluid densities and stock tank oil densities (PC-SAFT Yan et al. [24])

	Saturation Pressure				Density				Stock Tank Oil Density			
Fluid no.	SRK	PR	PC-SAFT	SBWR	SRK	PR	PC-SAFT	SBWR	SRK	PR	PC-SAFT	SBWR
Fluid 1	3.47	5.88	6.15	8.59	13.03	3.00	2.56	2.54	18.55	8.89	0.36	5.66
Fluid 2	7.54	10.42	0.11	7.15	13.26	3.14	1.14	3.31	-	-	-	-
Fluid 3	5.13	8.28	0.54	6.25	13.96	3.94	1.65	4.58	-	-	-	-
Fluid 4	4.02	7.80	2.08	8.57	13.75	3.76	1.39	6.35	-	-	-	-
Fluid 5	3.21	1.31	0.14	1.93	13.16	2.73	1.41	4.26	-	-	-	-
Fluid 6	4.09	0.14	3.14	11.90	11.88	1.58	2.44	11.06	-	-	-	-
Fluid 7	0.49	2.18	6.03	5.53	18.97	9.58	3.18	3.43	20.11	10.70	0.78	4.24
Fluid 8	14.84	16.25	1.88	10.48	16.52	6.85	0.37	0.57	-	-	-	-
Fluid 9	10.02	11.87	11.67	0.45	13.63	4.05	3.50	3.25	20.18	10.71	0.48	2.60
Fluid 10	7.89	10.30	17.84	14.30	10.68	1.16	7.21	2.68	20.98	11.55	0.31	0.73
Fluid 11	5.09	6.40	9.45	0.42	12.37	2.28	1.92	2.13	15.22	5.17	2.64	9.92
Fluid 12	0.66	0.60	8.66	6.77	15.11	5.38	0.87	3.04	18.64	8.95	0.60	4.19
Fluid 13	10.79	11.46	0.58	5.89	-	-	-	-	21.71	12.36	1.81	1.25
Fluid 14	7.14	7.88	5.72	1.44	-	-	-	-	20.41	10.91	0.21	0.88
Fluid 15	0.65	5.33	10.30	19.22	11.43	1.16	4.08	11.45	12.44	2.17	4.85	18.25
Fluid 16	4.99	0.79	5.17	7.27	10.45	0.20	2.93	12.01	11.66	1.29	4.46	19.06
Fluid 17	9.42	4.73	10.47	3.61	9.84	0.58	3.53	13.44	11.74	1.39	4.28	19.66
Fluid 18	1.41	2.24	3.26	8.62	7.49	3.40	4.35	12.28	8.87	1.93	5.74	18.13
Fluid 19	0.13	3.73	6.39	11.07	7.41	3.64	6.31	14.57	8.42	2.46	7.41	17.94
Fluid 20	1.60	3.28	12.28	19.82	10.96	0.64	4.30	11.61	11.89	1.55	5.01	18.83
Fluid 21	4.53	0.58	4.85	7.98	9.34	1.24	3.75	12.21	10.64	0.10	5.02	18.32
Fluid 22	4.88	5.16	0.90	1.94	12.17	2.21	2.83	1.73	18.65	8.83	0.59	0.75
Fluid 23	6.24	7.03	0.37	1.89	11.46	1.54	3.97	1.05	19.65	10.01	0.07	1.03
Fluid 24	8.50	2.48	17.62	11.79	-	-	-	-	18.11	8.16	1.88	0.15
Fluid 25	6.88	1.39	20.20	10.11	-	-	-	-	18.28	8.37	1.87	0.08
Fluid 26	9.94	4.09	22.05	13.42	-	-	-	-	18.01	8.09	2.72	0.87
Fluid 27	11.35	5.81	27.36	18.81	8.95	0.83	4.51	20.77	-	-	-	-
Fluid 28	21.84	16.66	18.18	1.56	-	-	-	-	-	-	-	-
Fluid 29	7.03	1.66	16.07	16.03	8.51	2.09	5.29	14.15	9.00	1.71	6.54	21.13
Fluid 30	16.48	12.36	28.73	0.78	12.74	2.50	3.32	12.17	13.99	3.93	4.25	17.45
Fluid 31	19.66	12.23	24.32	8.78	1.92	9.39	8.61	26.20	-	-	-	-
Fluid 32	8.45	10.44	22.61	7.23	18.28	9.31	2.01	8.40	24.54	15.58	0.74	2.88
Fluid 33	0.38	2.16	21.68	9.48	13.71	4.20	4.99	2.90	19.66	10.10	1.31	2.87
Fluid 34	4.87	6.93	14.29	2.48	12.81	3.03	3.50	2.09	16.96	7.09	3.31	6.24
Fluid 35	4.87	7.37	25.47	12.20	15.24	5.73	1.99	4.18	18.11	8.38	1.44	5.37
Fluid 36	8.09	10.96	1.40	8.06	15.53	5.70	0.92	2.47	16.91	7.09	2.39	9.33
Fluid 37	7.78	4.27	8.52	5.11	14.39	4.42	4.13	7.96	-	-	-	-
Fluid 38	11.34	7.05	14.17	6.78	12.15	1.96	5.20	10.98	-	-	-	-
Fluid 39	16.05	11.89	18.13	0.75	13.33	3.25	4.75	9.51	-	-	-	-

Fluid 40	6.25	9.50	1.94	11.31	13.21	3.16	1.87	2.94	-	-	-	-
Fluid 41	4.91	8.02	2.84	10.65	13.85	3.87	1.87	2.79	-	-	-	-
Fluid 42	1.65	2.93	2.05	1.25	21.06	11.81	1.07	4.29	-	-	-	-
Fluid 43	8.05	9.63	1.35	4.83	15.54	5.67	0.72	3.03	16.77	6.81	2.26	5.32
Fluid 44	5.66	3.59	1.87	0.32	11.95	1.38	2.18	5.42	12.76	2.33	4.17	10.18
Fluid 45	2.61	0.83	2.78	8.85	-	-	-	-	13.43	3.23	3.32	14.90
Fluid 46	11.57	7.94	10.18	1.09	10.92	0.45	3.21	9.92	12.77	2.47	3.89	14.73
Fluid 47	13.45	9.43	11.67	2.42	11.64	1.36	3.53	9.07	12.94	2.69	4.83	16.33
Fluid 48	11.12	13.12	5.22	9.04	16.12	6.30	0.75	2.22	18.11	8.37	1.80	5.33
Fluid 49	4.27	6.83	2.05	6.60	13.90	3.88	1.32	0.59	-	-	-	-
Fluid 50	5.93	8.09	10.19	17.13	25.60	16.94	0.91	3.40	27.11	18.61	0.72	0.26
Fluid 51	12.66	15.25	5.37	12.73	-	-	-	-	16.29	6.39	2.73	9.76
Fluid 52	5.90	0.36	7.72	17.19	4.70	6.40	4.86	7.21	5.35	5.73	6.22	7.86
Fluid 53	15.57	17.76	6.04	13.23	17.77	8.19	1.43	3.82	18.51	8.83	1.12	5.16
Fluid 54	4.21	7.94	2.09	8.14	13.71	3.72	1.81	6.33	15.03	5.03	3.02	13.40
Fluid 55	2.90	6.53	1.39	16.39	12.32	2.07	3.88	10.14	13.57	3.41	5.05	16.21
Fluid 56	19.31	22.36	10.29	31.27	14.85	4.94	1.92	6.84	16.42	6.61	2.44	12.68
Fluid 57	8.73	9.85	7.69	0.53	11.87	1.48	2.49	4.12	13.91	3.67	3.56	10.75
Fluid 58	11.31	12.52	10.16	0.66	12.06	2.04	2.95	0.55	15.11	5.03	3.07	10.01
Fluid 59	1.89	0.26	1.35	1.60	13.91	3.78	0.72	0.63	16.27	6.24	1.55	5.41
Fluid 60	10.58	12.08	7.05	12.62	13.21	3.26	0.23	3.16	16.09	6.02	1.93	5.06
Fluid 61	9.90	10.60	7.47	5.29	16.18	6.22	1.58	1.98	18.34	8.56	1.63	3.28
Fluid 62	6.90	7.28	5.03	0.57	20.54	11.31	0.78	6.16	24.36	15.35	1.34	3.69
Fluid 63	4.29	5.90	1.49	8.98	18.16	8.49	1.80	1.89	21.18	11.81	1.30	1.91
Fluid 64	7.25	5.05	0.85	2.67	9.96	0.88	3.43	5.32	10.78	0.02	5.07	9.64
Fluid 65	8.31	11.16	7.39	3.80	15.27	5.91	1.80	3.03	18.81	9.02	1.65	1.07
Fluid 66	1.43	0.90	1.93	4.74	7.28	3.93	4.66	10.52	9.01	1.86	5.61	14.79
Fluid 67	2.22	0.20	3.34	4.59	7.44	3.81	4.93	9.09	9.17	1.74	5.85	12.87
Fluid 68	1.73	0.38	3.48	6.63	16.16	6.23	0.88	1.06	18.26	8.49	0.61	3.50
Fluid 69	14.37	12.40	14.22	5.54	15.95	6.05	2.08	1.48	18.52	8.80	1.44	4.33
Fluid 70	1.69	3.14	6.52	4.90	12.07	1.99	4.18	1.45	17.57	7.70	2.30	4.22
Fluid 71	8.58	10.30	5.77	15.67	21.03	11.71	1.51	3.88	22.66	13.46	1.17	0.71
Fluid 72	11.60	12.31	6.57	13.48	16.40	6.36	0.61	2.81	19.73	10.09	0.67	1.25
Fluid 73	12.16	12.48	6.74	7.03	20.78	11.46	0.84	7.75	24.49	15.46	0.96	4.87
Fluid 74	12.20	12.54	6.46	7.03	20.86	11.56	0.87	7.88	24.80	15.80	1.29	5.27
Fluid 75	14.27	14.88	9.71	11.13	18.54	8.74	0.29	3.61	21.31	11.88	0.04	1.24
Fluid 76	13.63	14.18	9.91	10.80	18.25	8.37	0.47	3.58	20.84	11.34	0.38	1.29
Fluid 77	13.54	14.61	7.38	6.99	20.23	10.83	0.83	3.85	23.49	14.41	0.65	0.60
Fluid 78	9.30	11.18	12.82	18.01	13.67	3.28	2.48	4.16	14.83	4.60	2.92	6.45
Fluid 79	11.52	12.84	0.28	3.64	17.41	7.87	1.32	3.83	21.61	12.30	1.85	2.01
Fluid 80	0.73	2.19	0.33	0.64	13.54	3.22	3.06	3.33	17.22	7.34	2.12	5.80
Fluid 81	0.02	1.30	0.85	4.64	12.69	2.24	2.22	2.56	15.30	5.13	2.62	6.05
Fluid 82	2.80	0.39	0.91	6.83	14.52	4.40	3.23	4.99	16.95	7.09	2.82	7.57

Fluid 83	3.94	5.35	2.84	3.06	15.67	5.66	1.11	2.07	17.95	8.17	1.88	5.32
Fluid 84	8.19	9.38	8.63	8.92	15.17	5.07	1.65	1.99	18.18	8.41	1.46	4.55
Fluid 85	0.89	2.43	0.92	1.40	14.01	3.79	2.49	2.75	16.63	6.68	2.81	6.74
Fluid 86	12.44	13.41	11.08	19.40	12.86	2.44	1.27	2.64	15.31	5.09	1.96	4.59
Fluid 87	9.22	10.33	7.79	14.56	11.71	1.16	3.33	3.14	15.45	5.27	2.42	5.42
Fluid 88	3.47	3.74	4.61	1.14	16.95	6.82	1.21	1.44	19.98	10.39	0.88	0.77
Fluid 89	18.06	18.82	12.55	21.52	21.66	12.29	5.84	9.78	20.61	11.05	0.54	1.25
Fluid 90	6.93	8.42	3.46	1.25	16.03	6.11	1.14	2.72	18.52	8.82	1.77	5.24
Fluid 91	4.44	6.27	1.85	7.84	12.51	2.62	2.16	0.40	16.60	6.69	2.68	8.22
Fluid 92	3.33	1.24	7.87	12.28	10.23	1.21	4.02	3.78	15.30	5.20	2.54	8.64
Fluid 93	2.74	3.78	0.41	0.53	11.20	1.21	2.39	2.14	15.17	4.99	2.24	6.49
Fluid 94	0.84	1.48	3.00	1.28	14.78	4.75	0.53	3.51	15.66	5.49	3.55	4.56
Fluid 95	5.14	5.00	5.99	4.60	12.97	2.33	1.54	0.84	16.13	5.82	0.23	0.37
Fluid 96	18.05	17.60	3.52	16.84	-	-	-	-	16.94	6.74	1.64	1.43
Fluid 97	1.70	2.73	2.37	3.95	21.17	11.85	1.25	1.39	22.30	13.09	0.11	1.14
Fluid 98	0.30	0.69	4.26	4.29	7.05	3.12	5.35	0.38	16.47	6.33	0.60	1.99
Fluid 99	6.59	7.01	0.25	5.03	-	-	-	-	19.66	9.88	1.54	1.95
Fluid 100	7.19	9.50	0.08	17.01	-	-	-	-	16.02	5.80	1.00	2.22
Fluid 101	2.16	3.58	1.74	0.95	6.65	3.70	7.25	2.80	16.47	6.45	1.91	5.02
Fluid 102	7.41	7.00	6.24	11.32	13.98	3.43	1.23	1.61	17.95	7.87	1.78	2.38
Fluid 103	9.13	9.37	8.22	7.72	12.55	2.22	1.69	1.69	16.60	6.51	1.03	2.84
Fluid 104	1.37	0.78	3.38	2.85	10.28	0.58	2.42	2.06	13.54	3.04	2.46	5.30
Fluid 105	10.43	10.08	12.34	13.85	10.08	0.76	1.78	1.25	13.64	2.94	0.73	0.62
Fluid 106	2.98	1.80	5.25	5.75	10.56	0.24	3.14	2.20	15.06	4.89	2.42	7.17
Fluid 107	1.26	0.45	13.00	6.51	5.72	4.86	9.39	4.08	15.52	5.23	0.74	2.65
Fluid 108	1.70	2.82	1.71	3.91	9.26	1.00	2.58	0.45	14.76	4.50	1.81	6.09
Fluid 109	13.69	13.87	10.98	21.23	9.79	3.73	3.06	4.22	15.74	5.34	1.02	0.71
Fluid 110	4.23	4.79	1.97	4.41	9.66	0.63	3.54	0.13	16.27	6.18	1.34	3.89
Fluid 111	8.32	9.21	4.54	9.85	-	-	-	-	16.85	6.79	0.57	2.31
Fluid 112	15.76	17.02	8.24	15.45	11.62	2.26	1.07	4.88	19.81	10.12	0.55	0.34
Fluid 113	4.69	5.16	7.59	3.05	11.41	0.68	3.54	4.82	15.23	5.03	2.09	5.34
Fluid 114	0.48	1.60	6.55	0.27	-	-	-	-	15.74	5.57	2.11	4.80
Fluid 115	5.68	4.03	26.63	0.17	5.76	4.00	5.04	1.83	13.18	2.35	0.07	0.02
Fluid 116	2.62	2.58	0.78	10.26	-	-	-	-	14.86	4.31	0.57	0.90
Fluid 117	8.72	7.47	26.07	3.51	7.12	2.73	5.31	1.50	17.83	7.85	0.27	0.75
Fluid 118	0.97	1.19	2.80	0.34	9.87	1.97	4.83	2.96	17.05	7.04	0.37	2.77
Fluid 119	3.80	2.25	11.53	0.02	8.14	1.49	3.40	2.08	16.42	6.30	1.12	2.89
Fluid 120	4.17	4.03	6.79	2.11	11.48	1.55	1.05	3.46	16.80	6.63	0.02	0.20
Fluid 121	3.30	2.98	1.01	5.12	11.95	1.27	2.18	2.20	16.12	5.83	0.59	0.26
Fluid 122	4.11	2.31	6.93	7.52	9.59	0.98	4.02	3.42	14.25	3.97	3.16	8.05
Fluid 123	14.46	15.60	10.72	13.88	17.51	7.96	0.79	0.37	19.90	10.39	0.99	3.94
Fluid 124	6.05	4.81	4.03	5.34	12.89	2.19	1.36	2.70	16.62	6.36	0.41	0.95
Fluid 125	0.63	2.30	1.92	7.99	16.65	6.73	0.26	1.87	17.97	8.16	1.73	4.29

Fluid 126	3.00	1.24	12.40	5.83	6.69	3.45	7.66	2.21	16.68	6.68	1.79	4.85
Fluid 127	16.55	15.31	18.13	7.31	6.22	4.00	6.09	0.82	15.79	5.51	0.82	1.38
Fluid 128	2.20	2.84	4.63	9.64	14.95	5.34	3.19	8.19	18.34	8.31	2.12	2.38
Fluid 129	6.05	6.07	5.12	13.26	8.41	1.60	1.87	2.45	15.47	4.97	1.42	2.07
Fluid 130	0.33	2.87	5.97	11.64	14.11	3.91	2.80	7.84	16.33	6.43	1.81	9.36
Fluid 131	1.37	0.97	0.14	2.68	12.09	1.41	1.59	2.41	14.77	4.28	1.72	1.18
Fluid 132	4.31	3.96	3.02	4.33	13.72	3.38	0.45	2.90	15.88	5.62	1.11	1.43
Fluid 133	1.31	1.18	0.05	4.77	10.65	0.37	3.39	1.41	15.43	5.27	2.65	5.73
Fluid 134	5.14	4.06	11.29	1.66	8.16	1.62	3.05	2.21	15.97	5.74	0.72	1.99
Fluid 135	1.66	2.99	4.40	4.00	12.41	2.68	0.76	2.90	17.27	7.37	1.02	4.96
Fluid 136	7.35	7.29	15.00	11.53	7.76	2.69	5.59	0.23	15.92	5.62	0.03	0.32
Fluid 137	13.80	11.38	22.31	6.79	6.62	3.02	6.15	2.07	17.28	7.25	0.36	1.61
Fluid 138	0.59	1.65	27.56	9.24	9.77	0.87	5.02	5.30	15.33	4.98	1.13	2.17
Fluid 139	2.79	3.07	9.66	1.68	12.41	2.59	0.79	3.54	15.44	5.21	2.35	4.20
Fluid 140	7.66	8.78	1.65	12.14	9.77	1.68	3.78	3.11	16.52	6.40	0.39	2.47
Fluid 141	9.91	11.09	2.45	6.77	11.08	1.30	1.85	2.54	17.26	7.33	1.42	4.36
Fluid 142	12.11	10.54	20.96	5.53	7.23	2.41	6.14	2.34	14.50	4.11	3.55	4.44
Fluid 143	2.21	5.15	3.43	15.17	14.38	4.17	2.39	5.65	16.63	6.72	1.36	7.50
Fluid 144	11.15	10.74	12.40	16.76	8.55	1.99	2.17	1.69	15.88	5.41	2.47	2.99
Fluid 145	4.42	5.26	3.13	7.09	11.61	1.88	1.12	2.54	14.27	3.90	2.00	5.34
Fluid 146	2.44	4.18	3.98	10.83	13.45	4.98	3.19	7.08	14.87	4.50	1.18	3.28
Fluid 147	10.73	12.11	7.08	13.43	18.25	8.72	0.75	0.25	20.82	11.40	0.34	2.53
Fluid 148	8.88	9.23	13.40	11.35	9.78	0.61	4.06	1.16	15.54	5.31	1.47	3.79
Fluid 149	3.32	5.19	14.12	13.79	-	-	-	-	15.65	5.29	0.08	0.33
Fluid 150	10.89	13.26	6.33	4.82	-	-	-	-	14.39	4.10	2.16	6.98
Fluid 151	2.94	1.88	2.48	3.59	8.29	2.80	4.92	7.81	11.37	0.74	4.76	10.79
Fluid 152	8.96	9.37	7.51	5.97	10.54	1.92	4.30	6.03	12.84	2.35	3.86	8.34
Fluid 153	6.77	5.76	10.39	3.95	3.86	6.06	6.22	0.65	15.72	5.31	1.03	0.80
Fluid 154	3.03	4.05	3.83	3.92	9.28	0.84	2.57	0.81	15.68	5.51	1.12	4.79
Fluid 155	0.67	1.19	14.67	4.13	11.50	2.16	5.09	1.67	18.51	8.73	0.95	2.85
Fluid 156	13.92	13.89	12.05	8.67	13.55	3.50	1.46	0.15	17.81	7.95	0.86	3.24
Fluid 157	11.46	11.60	10.28	17.02	8.45	1.40	1.12	3.07	15.29	4.78	1.27	1.90
Fluid 158	4.23	3.02	7.77	3.59	-	-	-	-	15.40	5.11	1.76	2.73
Fluid 159	10.24	11.02	7.46	6.77	-	-	-	-	18.33	8.52	0.33	2.65
Fluid 160	4.74	6.46	1.68	3.32	11.34	1.40	2.09	0.29	15.62	5.55	2.79	8.14
Fluid 161	7.62	6.87	9.02	10.70	-	-	-	-	15.30	4.80	0.97	2.11
Fluid 162	11.38	7.18	11.97	2.45	7.95	2.81	5.26	16.05	11.04	0.60	4.65	20.22
Fluid 163	9.26	11.01	0.65	5.58	-	-	-	-	20.11	10.61	1.31	2.81
Fluid 164	8.82	10.54	0.37	5.52	17.55	7.87	1.00	2.44	20.89	11.48	0.28	1.67
Fluid 165	2.03	2.73	0.12	2.02	14.61	4.50	2.31	2.01	17.53	7.67	3.81	5.29
Fluid 166	3.38	0.53	8.32	1.36	11.44	0.92	2.93	8.34	13.46	3.19	3.26	12.28
Fluid 167	12.39	9.66	19.03	4.31	-	-	-	-	17.18	7.40	2.36	9.87
Fluid 168	2.06	0.36	4.95	5.01	-	-	-	-	16.04	6.08	1.80	9.35

Fluid 169	5.39	7.60	7.61	12.93	-	-	-	-	12.71	2.28	3.45	10.53
Fluid 170	7.61	4.69	8.51	1.69	-	-	-	-	13.69	3.46	2.97	12.21
Fluid 171	2.76	0.31	4.99	5.31	-	-	-	-	15.48	5.47	3.30	10.74
Fluid 172	0.68	3.02	0.92	8.37	-	-	-	-	14.79	4.67	3.08	10.32
Fluid 173	1.12	3.20	1.24	8.19	-	-	-	-	15.67	5.64	2.96	8.85
Fluid 174	2.33	0.17	2.70	6.16	-	-	-	-	14.72	4.61	3.19	10.94
Fluid 175	11.51	8.68	9.66	2.24	-	-	-	-	12.39	1.94	3.63	11.53
Fluid 176	9.05	5.98	11.61	2.20	-	-	-	-	14.92	4.88	3.16	12.64
Fluid 177	0.84	2.82	2.19	6.57	-	-	-	-	18.68	9.05	1.39	6.62
Fluid 178	0.47	2.34	0.59	6.10	-	-	-	-	16.33	6.34	1.51	6.77
Fluid 179	10.28	7.67	12.94	2.33	-	-	-	-	15.05	4.97	2.76	10.20
Fluid 180	4.26	6.55	2.38	11.33	-	-	-	-	16.17	6.23	1.85	9.46
Fluid 181	8.07	4.94	12.79	3.05	-	-	-	-	14.72	4.67	3.31	13.31
Fluid 182	4.41	6.15	5.01	9.46	-	-	-	-	18.62	8.93	0.86	4.67
Fluid 183	5.25	3.58	6.91	0.54	-	-	-	-	18.26	8.51	0.90	4.64
Fluid 184	7.59	4.85	13.33	1.27	-	-	-	-	17.09	7.31	2.04	10.13
Fluid 185	5.47	2.33	8.31	4.59	-	-	-	-	12.97	2.67	3.18	13.66
Fluid 186	11.53	8.28	12.57	0.20	-	-	-	-	12.88	2.58	4.31	14.38
Fluid 187	0.50	2.83	4.70	11.94	-	-	-	-	13.50	3.32	3.11	15.55
Fluid 188	11.70	8.29	15.90	0.43	-	-	-	-	13.34	3.10	3.41	14.43
Fluid 189	11.33	7.99	17.69	0.16	-	-	-	-	15.32	5.35	2.34	13.23
Fluid 190	5.42	2.04	8.04	6.40	-	-	-	-	11.95	1.55	4.21	15.96
Fluid 191	14.31	11.09	17.70	3.74	-	-	-	-	13.64	3.42	3.65	13.16
Fluid 192	9.65	6.81	5.82	0.84	-	-	-	-	11.11	0.47	3.90	11.84
Fluid 193	5.27	7.35	2.38	11.08	-	-	-	-	16.54	6.63	1.45	8.14
Fluid 194	19.93	18.07	7.78	2.07	-	-	-	-	7.34	4.09	4.75	5.73
Fluid 195	5.18	2.60	13.64	2.05	-	-	-	-	18.75	9.19	1.21	8.59
Fluid 196	3.52	1.18	5.46	4.87	-	-	-	-	16.62	6.74	2.48	8.78
Fluid 197	8.81	5.88	14.27	0.58	-	-	-	-	15.09	5.05	2.49	11.66
Fluid 198	0.37	2.66	0.41	9.47	-	-	-	-	12.04	1.61	3.38	14.05
Fluid 199	10.52	6.42	12.32	2.68	-	-	-	-	9.62	1.05	4.78	18.75
Fluid 200	4.15	1.42	17.31	2.91	-	-	-	-	14.21	4.10	3.24	13.97
Fluid 201	2.89	5.31	4.58	7.51	-	-	-	-	10.79	0.16	4.51	14.01
Fluid 202	1.44	0.08	4.37	4.56	-	-	-	-	16.22	6.29	2.09	9.28
Fluid 203	5.21	4.22	6.30	14.81	-	-	-	-	21.12	11.81	0.89	4.68
Fluid 204	3.77	4.66	1.30	4.08	-	-	-	-	15.33	5.15	1.81	5.89
Fluid 205	1.94	3.06	0.60	2.75	-	-	-	-	15.07	4.86	2.17	6.16
Fluid 206	0.71	0.22	3.08	2.50	-	-	-	-	16.10	6.04	1.92	5.76
Fluid 207	0.41	1.29	0.61	0.97	-	-	-	-	14.97	4.74	2.12	6.17
Fluid 208	6.96	5.80	11.39	9.79	-	-	-	-	16.08	6.02	1.92	6.23
Fluid 209	0.83	0.19	3.93	0.92	-	-	-	-	15.52	5.37	1.89	5.95
Fluid 210	3.17	4.03	1.14	0.06	-	-	-	-	16.53	6.55	1.72	5.92
Fluid 211	12.35	7.68	4.61	6.87	-	-	-	-	7.96	2.86	5.82	23.52

Fluid 212	16.86	17.91	20.08	14.22	-	-	-	-	16.88	7.02	1.36	8.37
Fluid 213	3.86	7.02	0.92	9.07	-	-	-	-	6.36	4.77	6.65	19.61
Fluid 214	2.56	3.07	0.75	1.61	-	-	-	-	18.59	8.84	0.35	3.28
Fluid 215	3.68	5.72	0.23	12.38	-	-	-	-	13.47	2.98	2.61	5.79
Fluid 216	5.74	3.12	1.06	0.59	-	-	-	-	9.73	1.04	5.04	14.61
Fluid 217	3.34	3.90	0.18	2.41	-	-	-	-	17.56	7.65	0.65	3.42
Fluid 218	5.76	7.34	3.01	7.90	-	-	-	-	23.24	14.16	1.10	0.90
Fluid 219	0.88	0.71	1.08	1.72	-	-	-	-	15.91	5.84	2.67	6.40
Fluid 220	5.14	5.63	0.38	1.95	-	-	-	-	20.52	10.95	0.39	0.59
Fluid 221	0.47	2.32	12.30	4.33	-	-	-	-	21.75	12.35	0.01	1.00
Fluid 222	0.01	0.93	2.06	2.98	-	-	-	-	17.08	7.16	1.32	5.58
Fluid 223	14.89	16.65	3.62	3.98	-	-	-	-	22.09	12.78	0.02	0.01
Fluid 224	20.16	21.29	13.12	7.41	-	-	-	-	24.29	15.38	0.01	1.49
Fluid 225	6.53	8.09	2.17	8.65	-	-	-	-	23.24	14.16	1.10	0.90
Fluid 226	1.63	1.51	3.31	1.60	-	-	-	-	13.06	2.79	4.69	14.42
Fluid 227	4.06	4.93	0.92	1.65	-	-	-	-	18.06	8.30	1.15	5.61
Fluid 228	0.44	1.73	4.57	9.11	-	-	-	-	15.78	5.77	2.75	8.88
Fluid 229	5.57	7.06	3.50	7.04	-	-	-	-	21.49	12.18	0.36	2.58
Fluid 230	1.93	0.06	6.01	3.09	-	-	-	-	17.01	7.11	2.00	6.36
Fluid 231	12.60	8.19	24.59	16.28	-	-	-	-	14.62	4.60	3.64	15.49
Fluid 232	15.26	10.97	9.92	1.55	-	-	-	-	8.10	2.76	6.99	20.67
Fluid 233	0.98	1.97	1.76	0.11	-	-	-	-	17.38	7.49	1.12	4.75
Fluid 234	8.59	9.79	9.71	7.46	-	-	-	-	15.67	5.66	2.01	9.53
Fluid 235	4.12	3.28	13.69	9.76	-	-	-	-	17.18	7.34	1.30	7.38
Fluid 236	3.53	5.39	25.01	5.79	-	-	-	-	18.32	8.58	0.14	4.48
Fluid 237	2.10	0.18	4.11	1.47	-	-	-	-	18.55	8.83	0.45	3.79
Fluid 238	3.83	5.96	6.42	8.39	-	-	-	-	18.01	8.24	0.26	4.96
Fluid 239	5.43	7.40	6.86	9.33	-	-	-	-	18.77	9.10	0.07	4.45
Fluid 240	0.41	2.65	3.05	4.47	-	-	-	-	17.05	7.16	1.27	6.05
Fluid 241	0.93	3.24	2.68	4.86	-	-	-	-	16.85	6.93	1.12	6.03
Fluid 242	0.92	2.65	0.68	4.42	-	-	-	-	18.06	8.32	0.77	6.05
Fluid 243	2.50	4.07	2.44	5.50	-	-	-	-	18.94	9.29	0.08	4.37
Fluid 244	2.86	1.00	2.93	0.98	-	-	-	-	16.82	6.93	1.34	7.28
Fluid 245	5.60	4.06	8.90	3.94	-	-	-	-	19.74	10.20	0.32	4.00
Fluid 246	0.82	2.54	1.39	4.56	-	-	-	-	17.27	7.43	1.28	6.56
Fluid 247	9.22	7.11	12.11	5.12	-	-	-	-	18.61	8.97	0.58	6.44
Fluid 248	2.28	4.00	3.72	6.40	-	-	-	-	15.73	5.67	2.12	7.69
Fluid 249	3.47	4.90	2.10	6.91	-	-	-	-	22.22	13.01	0.19	2.01
Fluid 250	3.03	4.56	2.12	6.48	-	-	-	-	20.99	11.64	0.38	3.83
Fluid 251	6.85	5.81	8.28	8.83	-	-	-	-	16.21	6.21	2.22	7.12
Fluid 252	6.11	7.01	0.38	12.60	-	-	-	-	19.26	9.53	0.29	0.95
Fluid 253	5.78	6.03	3.49	9.80	-	-	-	-	20.87	11.25	1.62	3.01
Fluid 254	8.80	9.02	4.33	5.06	-	-	-	-	25.49	16.56	2.82	5.35

Fluid 255	10.86	6.69	16.80	0.94	-	-	-	-	20.83	11.25	0.52	1.94
Fluid 256	10.44	6.42	17.11	1.82	-	-	-	-	21.11	11.56	0.68	2.14
Fluid 257	1.18	0.16	3.22	0.20	-	-	-	-	14.85	4.65	3.14	7.57
Fluid 258	4.74	2.66	6.38	16.33	-	-	-	-	15.43	5.39	3.05	9.95
Fluid 259	8.45	6.35	20.36	4.55	-	-	-	-	15.49	5.27	1.70	4.28
Fluid 260	3.17	4.92	8.07	2.22	-	-	-	-	19.50	9.79	0.16	0.43
Average	**6.35**	**6.26**	**7.36**	**6.72**	**12.62**	**3.95**	**2.82**	**4.46**	**16.49**	**6.76**	**2.03**	**6.45**

Table A3. Summary of AAD% in predicted saturation pressures, reservoir fluid densities and stock tank oil densities (PC-SAFT with new general characterization Eqs. (12-13))

	Saturation Pressure			Density			Stock Tank Oil Density		
Fluid no.	SRK-VT	PR-VT	PC-SAFT	SRK-VT	PR-VT	PC-SAFT	SRK-VT	PR-VT	PC-SAFT
Fluid 1	3.47	5.88	0.98	1.68	1.55	1.10	0.77	0.97	2.05
Fluid 2	7.54	10.42	5.91	1.57	1.97	1.21	-	-	-
Fluid 3	5.13	8.28	6.12	0.96	1.26	0.84	-	-	-
Fluid 4	4.02	7.80	5.86	0.92	1.20	1.30	-	-	-
Fluid 5	3.21	1.31	4.17	0.84	0.90	0.58	-	-	-
Fluid 6	4.09	0.14	4.84	0.41	0.52	0.80	-	-	-
Fluid 7	0.49	2.18	2.04	2.43	2.59	4.48	0.21	0.53	2.27
Fluid 8	14.84	16.25	5.60	0.77	0.59	1.65	-	-	-
Fluid 9	10.02	11.87	7.20	1.10	0.71	2.32	0.76	0.55	0.58
Fluid 10	7.89	10.30	13.60	1.93	1.25	6.03	0.48	0.63	0.42
Fluid 11	5.09	6.40	4.77	0.73	0.30	0.20	0.17	0.12	0.58
Fluid 12	0.66	0.60	4.69	1.25	1.37	0.97	0.07	0.21	0.70
Fluid 13	10.79	11.46	2.07	-	-	-	1.24	1.55	2.55
Fluid 14	7.14	7.88	2.92	-	-	-	0.15	0.46	0.59
Fluid 15	0.65	5.33	0.26	0.67	0.87	0.64	0.03	0.12	1.46
Fluid 16	4.99	0.79	3.50	0.43	0.47	0.67	0.01	0.11	0.79
Fluid 17	9.42	4.73	0.79	0.86	0.76	0.38	0.39	0.49	0.47
Fluid 18	1.41	2.24	9.76	0.83	0.73	0.51	0.13	0.12	1.45
Fluid 19	0.13	3.73	12.96	0.23	0.31	1.67	0.72	0.79	2.61
Fluid 20	1.60	3.28	1.38	0.66	0.83	0.57	0.26	0.34	1.40
Fluid 21	4.53	0.58	3.00	0.50	0.56	0.21	0.19	0.34	1.15
Fluid 22	4.88	5.16	3.53	2.33	2.00	2.22	0.08	0.39	0.11
Fluid 23	6.24	7.03	3.38	3.22	2.85	3.21	0.76	1.01	0.74
Fluid 24	8.50	2.48	12.91	-	-	-	0.80	0.69	1.52
Fluid 25	6.88	1.39	15.95	-	-	-	0.58	0.35	1.42
Fluid 26	9.94	4.09	17.73	-	-	-	1.32	1.07	2.27
Fluid 27	11.35	5.81	24.08	2.12	1.09	3.15	-	-	-
Fluid 28	21.84	16.66	7.83	-	-	-	-	-	-
Fluid 29	7.03	1.66	5.26	0.88	0.93	1.01	0.61	0.48	2.22
Fluid 30	16.48	12.36	20.22	0.94	0.93	0.49	0.45	0.29	1.28
Fluid 31	19.66	12.23	8.95	2.64	2.45	1.95	-	-	-
Fluid 32	8.45	10.44	18.65	2.61	3.17	1.47	1.07	1.24	1.20
Fluid 33	0.38	2.16	17.34	0.12	0.12	3.74	1.03	0.79	0.39
Fluid 34	4.87	6.93	9.32	0.37	0.68	2.21	0.91	0.69	2.07
Fluid 35	4.87	7.37	19.29	2.50	3.09	1.41	0.80	0.56	0.14
Fluid 36	8.09	10.96	7.67	1.39	1.66	1.07	0.46	0.62	0.48
Fluid 37	7.78	4.27	1.57	0.03	0.16	1.93	-	-	-
Fluid 38	11.34	7.05	5.38	0.39	0.23	2.31	-	-	-

Fluid 39	16.05	11.89	9.72	0.28	0.29	2.21	-	-	-
Fluid 40	6.25	9.50	5.15	0.73	1.18	0.09	-	-	-
Fluid 41	4.91	8.02	4.14	0.72	1.13	0.07	-	-	-
Fluid 42	1.65	2.93	0.92	1.14	1.14	1.84	-	-	-
Fluid 43	8.05	9.63	2.68	2.84	2.71	1.80	0.25	0.07	0.98
Fluid 44	5.66	3.59	2.65	0.63	0.82	0.46	0.57	0.31	1.88
Fluid 45	2.61	0.83	4.34	-	-	-	1.15	1.29	0.16
Fluid 46	11.57	7.94	2.89	0.77	0.77	0.21	0.26	0.44	0.83
Fluid 47	13.45	9.43	3.41	0.36	0.29	0.52	0.10	0.19	1.73
Fluid 48	11.12	13.12	9.73	1.22	1.48	0.90	0.10	0.33	0.50
Fluid 49	4.27	6.83	3.68	1.02	1.42	0.26	-	-	-
Fluid 50	5.93	8.09	4.92	0.95	0.96	1.82	0.73	0.78	1.54
Fluid 51	12.66	15.25	11.15	-	-	-	0.03	0.17	0.78
Fluid 52	5.90	0.36	3.90	0.36	0.32	1.59	0.44	0.54	0.41
Fluid 53	15.57	17.76	10.88	3.49	3.78	2.84	0.84	1.06	0.27
Fluid 54	4.21	7.94	5.80	0.93	1.21	0.89	0.53	0.65	0.40
Fluid 55	2.90	6.53	6.78	0.59	0.73	0.95	0.15	0.22	2.11
Fluid 56	19.31	22.36	17.47	0.85	1.03	0.47	1.26	1.36	0.04
Fluid 57	8.73	9.85	2.65	0.75	0.91	0.91	0.33	0.06	1.31
Fluid 58	11.31	12.52	4.94	0.27	0.10	0.77	0.20	0.05	1.02
Fluid 59	1.89	0.26	2.59	1.27	1.43	0.61	0.64	0.94	0.03
Fluid 60	10.58	12.08	10.74	1.86	2.27	0.74	0.03	0.34	0.56
Fluid 61	9.90	10.60	3.32	1.66	1.17	1.32	0.21	0.39	0.65
Fluid 62	6.90	7.28	7.20	1.38	0.78	1.19	1.39	1.58	1.77
Fluid 63	4.29	5.90	2.35	0.59	0.55	1.00	0.10	0.08	0.55
Fluid 64	7.25	5.05	5.17	0.46	0.50	0.72	0.56	0.34	2.16
Fluid 65	8.31	11.16	3.42	4.17	4.87	1.03	0.84	0.64	1.06
Fluid 66	1.43	0.90	5.43	1.87	1.65	1.37	0.99	0.43	1.84
Fluid 67	2.22	0.20	6.66	2.14	2.08	1.97	1.37	0.92	2.53
Fluid 68	1.73	0.38	0.27	0.77	1.08	1.04	1.15	1.39	1.47
Fluid 69	14.37	12.40	10.31	1.19	0.84	1.09	0.05	0.18	0.27
Fluid 70	1.69	3.14	3.12	2.47	2.03	2.84	0.68	0.41	0.51
Fluid 71	8.58	10.30	9.24	2.37	2.53	2.24	2.34	2.47	1.92
Fluid 72	11.60	12.31	8.62	1.29	1.34	0.47	0.04	0.29	0.05
Fluid 73	12.16	12.48	8.29	2.03	1.45	1.15	0.83	1.07	1.20
Fluid 74	12.20	12.54	8.01	1.94	1.48	1.19	1.10	1.33	1.53
Fluid 75	14.27	14.88	11.86	1.23	1.15	0.60	0.36	0.66	0.58
Fluid 76	13.63	14.18	11.99	1.72	1.36	0.94	0.71	1.07	0.96
Fluid 77	13.54	14.61	10.62	1.01	1.23	0.44	0.12	0.17	0.10
Fluid 78	9.30	11.18	15.88	1.09	1.00	1.07	0.71	0.44	1.35
Fluid 79	11.52	12.84	3.54	1.57	1.40	0.95	0.14	0.25	1.14
Fluid 80	0.73	2.19	3.42	1.73	2.01	1.53	0.04	0.10	0.68
Fluid 81	0.02	1.30	2.69	0.88	1.15	0.66	0.38	0.16	1.08

Fluid 82	2.80	0.39	6.43	0.38	0.40	1.47	1.28	1.33	1.08
Fluid 83	3.94	5.35	6.39	0.91	1.10	0.53	0.17	0.00	0.55
Fluid 84	8.19	9.38	11.82	0.87	1.07	0.52	0.35	0.50	0.18
Fluid 85	0.89	2.43	4.76	1.20	1.44	0.91	0.69	0.54	1.31
Fluid 86	12.44	13.41	13.95	1.35	1.45	1.04	0.12	0.35	0.54
Fluid 87	9.22	10.33	10.90	1.83	2.08	1.85	0.37	0.15	0.99
Fluid 88	3.47	3.74	7.09	0.80	1.45	0.42	0.16	0.41	0.19
Fluid 89	18.06	18.82	15.17	7.70	7.42	6.54	1.84	2.04	1.10
Fluid 90	6.93	8.42	0.40	1.65	1.87	0.52	0.12	0.06	0.47
Fluid 91	4.44	6.27	5.96	0.70	0.38	0.77	0.24	0.06	0.87
Fluid 92	3.33	1.24	3.28	2.24	1.88	2.38	0.36	0.65	0.42
Fluid 93	2.74	3.78	3.81	0.97	1.00	0.80	0.33	0.65	0.46
Fluid 94	0.84	1.48	0.27	1.35	1.38	0.79	2.67	2.35	2.63
Fluid 95	5.14	5.00	7.04	1.97	1.84	1.18	0.61	0.13	0.15
Fluid 96	18.05	17.60	1.84	-	-	-	1.99	2.60	2.32
Fluid 97	1.70	2.73	4.81	0.36	0.17	2.02	0.43	0.69	0.88
Fluid 98	0.30	0.69	1.43	3.69	3.16	4.49	0.64	0.97	0.43
Fluid 99	6.59	7.01	1.65	-	-	-	1.50	1.93	1.99
Fluid 100	7.19	9.50	2.82	-	-	-	0.26	0.56	0.01
Fluid 101	2.16	3.58	1.65	5.41	5.03	6.16	0.05	0.30	0.53
Fluid 102	7.41	7.00	5.32	2.20	1.81	1.03	1.45	2.31	2.15
Fluid 103	9.13	9.37	10.62	1.21	1.26	0.75	0.29	0.70	0.06
Fluid 104	1.37	0.78	0.52	0.98	0.97	0.93	0.31	0.21	0.89
Fluid 105	10.43	10.08	13.64	1.12	0.92	1.26	0.73	0.00	0.12
Fluid 106	2.98	1.80	1.50	0.93	1.10	1.42	0.32	0.61	0.53
Fluid 107	1.26	0.45	9.88	4.32	4.45	7.73	0.85	1.26	0.49
Fluid 108	1.70	2.82	1.68	0.59	0.26	1.29	0.98	1.31	0.11
Fluid 109	13.69	13.87	12.65	3.53	2.92	3.10	1.54	2.12	1.78
Fluid 110	4.23	4.79	4.78	2.35	1.92	2.58	0.47	0.76	0.03
Fluid 111	8.32	9.21	7.21	-	-	-	0.81	1.18	0.51
Fluid 112	15.76	17.02	10.47	0.73	0.77	0.68	0.80	1.26	1.14
Fluid 113	4.69	5.16	10.18	2.88	3.21	2.06	0.12	0.32	0.60
Fluid 114	0.48	1.60	3.34	-	-	-	0.41	0.04	0.81
Fluid 115	5.68	4.03	23.84	1.90	1.57	4.38	0.55	1.03	0.85
Fluid 116	2.62	2.58	2.45	-	-	-	0.64	1.19	1.18
Fluid 117	8.72	7.47	22.87	2.49	1.44	4.52	1.24	1.69	1.14
Fluid 118	0.97	1.19	0.33	3.48	3.51	3.76	1.24	1.65	0.86
Fluid 119	3.80	2.25	8.31	1.47	0.66	2.58	0.43	0.72	0.00
Fluid 120	4.17	4.03	4.70	0.75	0.36	0.53	0.26	0.89	0.63
Fluid 121	3.30	2.98	2.28	1.55	1.30	1.71	0.72	0.04	0.13
Fluid 122	4.11	2.31	2.90	1.95	1.99	2.14	0.30	0.02	1.18
Fluid 123	14.46	15.60	13.61	1.27	0.80	0.28	0.04	0.25	0.13
Fluid 124	6.05	4.81	5.07	2.08	1.54	1.14	0.07	0.84	0.79

Fluid 125	0.63	2.30	1.18	1.13	1.47	0.78	0.29	0.02	0.57
Fluid 126	3.00	1.24	8.62	4.85	4.24	6.39	0.15	0.40	0.42
Fluid 127	16.55	15.31	15.03	4.47	4.05	5.21	0.05	0.32	0.03
Fluid 128	2.20	2.84	2.73	6.25	6.17	3.63	2.10	2.65	2.60
Fluid 129	6.05	6.07	6.78	0.76	0.41	1.48	1.15	1.62	1.94
Fluid 130	0.33	2.87	1.29	0.79	0.53	0.61	0.82	1.11	0.44
Fluid 131	1.37	0.97	0.96	1.60	1.20	1.22	2.08	1.31	1.33
Fluid 132	4.31	3.96	4.82	1.52	0.82	0.69	0.65	0.14	0.43
Fluid 133	1.31	1.18	2.82	2.71	2.51	2.23	0.68	0.37	1.23
Fluid 134	5.14	4.06	8.40	1.00	0.42	2.29	0.54	0.89	0.30
Fluid 135	1.66	2.99	0.79	1.09	1.44	0.42	0.96	1.30	0.52
Fluid 136	7.35	7.29	12.56	2.81	2.68	4.83	0.82	1.17	0.84
Fluid 137	13.80	11.38	18.78	3.06	2.12	5.00	0.83	1.18	0.58
Fluid 138	0.59	1.65	24.05	2.61	3.59	4.36	0.14	0.42	0.11
Fluid 139	2.79	3.07	6.76	0.97	0.96	0.31	0.86	0.50	1.22
Fluid 140	7.66	8.78	4.45	2.13	2.16	2.48	1.27	1.69	0.82
Fluid 141	9.91	11.09	5.62	0.62	0.18	0.97	0.41	0.65	0.09
Fluid 142	12.11	10.54	17.79	2.33	1.74	5.04	2.57	2.19	2.68
Fluid 143	2.21	5.15	0.66	0.27	0.35	0.48	1.12	1.46	0.64
Fluid 144	11.15	10.74	13.72	1.71	1.15	1.75	2.16	2.83	2.98
Fluid 145	4.42	5.26	6.10	2.11	1.93	1.57	0.41	0.81	0.30
Fluid 146	2.44	4.18	1.13	5.62	5.74	3.67	0.51	1.00	0.11
Fluid 147	10.73	12.11	9.90	0.81	0.38	0.29	0.56	0.82	0.65
Fluid 148	8.88	9.23	10.55	0.93	0.54	3.03	0.24	0.67	0.20
Fluid 149	3.32	5.19	11.17	-	-	-	0.62	0.97	0.70
Fluid 150	10.89	13.26	9.96	-	-	-	0.79	1.16	0.11
Fluid 151	2.94	1.88	1.03	3.18	3.34	2.65	1.48	0.99	2.28
Fluid 152	8.96	9.37	10.57	2.87	3.56	2.61	1.12	0.70	1.88
Fluid 153	6.77	5.76	8.02	4.23	3.21	5.43	1.49	2.04	1.78
Fluid 154	3.03	4.05	0.58	0.93	0.28	1.48	1.05	1.57	0.52
Fluid 155	0.67	1.19	11.09	2.01	2.06	3.86	0.34	0.57	0.06
Fluid 156	13.92	13.89	14.44	1.67	1.47	0.43	0.64	0.94	0.31
Fluid 157	11.46	11.60	11.96	1.05	0.61	0.73	1.07	1.52	1.82
Fluid 158	4.23	3.02	4.89	-	-	-	0.66	0.39	0.82
Fluid 159	10.24	11.02	10.21	-	-	-	1.19	1.49	0.80
Fluid 160	4.74	6.46	5.62	0.83	0.17	0.73	0.18	0.04	0.88
Fluid 161	7.62	6.87	10.43	-	-	-	0.49	0.79	1.40
Fluid 162	11.38	7.18	3.47	2.81	2.77	1.09	0.16	0.00	0.46
Fluid 163	9.26	11.01	4.71	-	-	-	0.04	0.22	0.38
Fluid 164	8.82	10.54	4.41	1.09	1.34	0.30	1.09	1.27	0.64
Fluid 165	2.03	2.73	3.54	0.72	0.84	1.31	1.21	0.93	2.81
Fluid 166	3.38	0.53	2.53	0.50	0.55	0.27	0.50	0.80	0.33
Fluid 167	12.39	9.66	13.88	-	-	-	0.34	0.09	0.32

Fluid 168	2.06	0.36	0.46	-	-	-	0.90	1.22	0.49
Fluid 169	5.39	7.60	11.22	-	-	-	0.18	0.56	0.76
Fluid 170	7.61	4.69	3.39	-	-	-	0.54	0.86	0.07
Fluid 171	2.76	0.31	0.30	-	-	-	0.50	0.27	1.08
Fluid 172	0.68	3.02	4.99	-	-	-	0.11	0.17	0.76
Fluid 173	1.12	3.20	5.14	-	-	-	0.28	0.05	0.98
Fluid 174	2.33	0.17	1.85	-	-	-	0.08	0.18	0.78
Fluid 175	11.51	8.68	5.03	-	-	-	0.35	0.69	0.68
Fluid 176	9.05	5.98	5.62	-	-	-	0.02	0.19	0.51
Fluid 177	0.84	2.82	1.61	-	-	-	0.37	0.62	0.21
Fluid 178	0.47	2.34	2.95	-	-	-	0.97	1.33	0.37
Fluid 179	10.28	7.67	8.00	-	-	-	0.27	0.54	0.40
Fluid 180	4.26	6.55	6.60	-	-	-	0.79	1.09	0.43
Fluid 181	8.07	4.94	6.56	-	-	-	0.29	0.08	0.59
Fluid 182	4.41	6.15	7.84	-	-	-	0.91	1.18	0.54
Fluid 183	5.25	3.58	3.49	-	-	-	0.86	1.17	0.50
Fluid 184	7.59	4.85	7.87	-	-	-	0.17	0.41	0.12
Fluid 185	5.47	2.33	2.87	-	-	-	0.70	1.03	0.07
Fluid 186	11.53	8.28	6.60	-	-	-	0.52	0.30	1.27
Fluid 187	0.50	2.83	1.48	-	-	-	0.38	0.63	0.23
Fluid 188	11.70	8.29	9.61	-	-	-	0.23	0.50	0.23
Fluid 189	11.33	7.99	11.11	-	-	-	0.44	0.71	0.47
Fluid 190	5.42	2.04	1.93	-	-	-	0.26	0.05	0.73
Fluid 191	14.31	11.09	11.57	-	-	-	0.02	0.18	0.76
Fluid 192	9.65	6.81	1.30	-	-	-	0.68	1.02	0.47
Fluid 193	5.27	7.35	6.37	-	-	-	1.14	1.48	0.66
Fluid 194	19.93	18.07	6.44	-	-	-	1.26	1.68	0.75
Fluid 195	5.18	2.60	8.18	-	-	-	0.52	0.76	0.71
Fluid 196	3.52	1.18	0.93	-	-	-	0.07	0.14	0.54
Fluid 197	8.81	5.88	8.58	-	-	-	0.61	0.91	0.18
Fluid 198	0.37	2.66	4.46	-	-	-	0.96	1.31	0.18
Fluid 199	10.52	6.42	5.46	-	-	-	0.50	0.81	0.17
Fluid 200	4.15	1.42	10.74	-	-	-	0.08	0.31	0.28
Fluid 201	2.89	5.31	0.39	-	-	-	0.27	0.57	0.85
Fluid 202	1.44	0.08	0.34	-	-	-	0.62	0.89	0.10
Fluid 203	5.21	4.22	2.88	-	-	-	0.02	0.16	0.31
Fluid 204	3.77	4.66	4.53	-	-	-	0.70	1.02	0.06
Fluid 205	1.94	3.06	2.78	-	-	-	0.37	0.66	0.43
Fluid 206	0.71	0.22	0.33	-	-	-	0.38	0.65	0.33
Fluid 207	0.41	1.29	2.69	-	-	-	0.46	0.77	0.35
Fluid 208	6.96	5.80	7.53	-	-	-	0.48	0.76	0.22
Fluid 209	0.83	0.19	0.45	-	-	-	0.61	0.92	0.17
Fluid 210	3.17	4.03	4.44	-	-	-	0.48	0.76	0.11

Fluid 211	12.35	7.68	2.81	-	-	-	0.18	0.05	0.51
Fluid 212	16.86	17.91	15.87	-	-	-	1.06	1.38	0.76
Fluid 213	3.86	7.02	5.99	-	-	-	0.51	0.85	0.58
Fluid 214	2.56	3.07	3.57	-	-	-	1.13	1.47	0.89
Fluid 215	3.68	5.72	2.44	-	-	-	0.04	0.32	0.83
Fluid 216	5.74	3.12	5.97	-	-	-	0.22	0.55	1.03
Fluid 217	3.34	3.90	3.01	-	-	-	1.10	1.44	0.63
Fluid 218	5.76	7.34	0.18	-	-	-	1.44	1.71	2.02
Fluid 219	0.88	0.71	4.79	-	-	-	0.46	0.26	1.13
Fluid 220	5.14	5.63	1.65	-	-	-	0.62	0.85	0.91
Fluid 221	0.47	2.32	9.75	-	-	-	0.24	0.15	0.36
Fluid 222	0.01	0.93	1.30	-	-	-	0.73	1.06	0.27
Fluid 223	14.89	16.65	6.25	-	-	-	0.22	0.38	0.58
Fluid 224	20.16	21.29	15.78	-	-	-	0.14	0.03	0.76
Fluid 225	6.53	8.09	0.63	-	-	-	1.44	1.71	2.02
Fluid 226	1.63	1.51	3.02	-	-	-	0.84	0.69	1.77
Fluid 227	4.06	4.93	4.27	-	-	-	0.81	1.10	0.40
Fluid 228	0.44	1.73	0.16	-	-	-	0.01	0.22	0.73
Fluid 229	5.57	7.06	0.08	-	-	-	0.31	0.50	0.58
Fluid 230	1.93	0.06	1.72	-	-	-	0.12	0.36	0.41
Fluid 231	12.60	8.19	15.24	-	-	-	0.71	0.57	0.72
Fluid 232	15.26	10.97	2.39	-	-	-	1.08	0.94	2.24
Fluid 233	0.98	1.97	1.54	-	-	-	0.79	1.09	0.33
Fluid 234	8.59	9.79	5.72	-	-	-	0.91	1.22	0.34
Fluid 235	4.12	3.28	9.85	-	-	-	1.06	1.36	0.63
Fluid 236	3.53	5.39	21.34	-	-	-	1.66	2.03	1.40
Fluid 237	2.10	0.18	0.70	-	-	-	2.42	2.77	2.02
Fluid 238	3.83	5.96	9.54	-	-	-	1.61	1.99	1.37
Fluid 239	5.43	7.40	9.84	-	-	-	1.61	1.98	1.44
Fluid 240	0.41	2.65	6.36	-	-	-	0.98	1.30	0.44
Fluid 241	0.93	3.24	6.02	-	-	-	1.22	1.56	0.65
Fluid 242	0.92	2.65	4.04	-	-	-	1.24	1.57	0.94
Fluid 243	2.50	4.07	5.47	-	-	-	1.58	1.94	1.41
Fluid 244	2.86	1.00	0.73	-	-	-	1.09	1.40	0.61
Fluid 245	5.60	4.06	5.62	-	-	-	1.07	1.35	1.00
Fluid 246	0.82	2.54	4.70	-	-	-	0.87	1.19	0.48
Fluid 247	9.22	7.11	8.00	-	-	-	1.27	1.59	1.18
Fluid 248	2.28	4.00	7.08	-	-	-	0.53	0.86	0.15
Fluid 249	3.47	4.90	4.70	-	-	-	0.81	1.06	1.15
Fluid 250	3.03	4.56	5.13	-	-	-	0.68	0.91	0.82
Fluid 251	6.85	5.81	4.66	-	-	-	0.28	0.50	0.42
Fluid 252	6.11	7.01	2.14	-	-	-	0.45	0.68	0.44
Fluid 253	5.78	6.03	4.50	-	-	-	0.67	0.95	1.79

Fluid 254	8.80	9.02	4.76	-	-	-	1.41	1.71	2.91
Fluid 255	10.86	6.69	14.68	-	-	-	0.41	0.28	0.69
Fluid 256	10.44	6.42	14.98	-	-	-	0.26	0.12	0.85
Fluid 257	1.18	0.16	0.60	-	-	-	0.39	0.21	1.32
Fluid 258	4.74	2.66	1.59	-	-	-	0.23	0.04	0.87
Fluid 259	8.45	6.35	16.70	-	-	-	0.35	0.64	0.32
Fluid 260	3.17	4.92	5.19	-	-	-	0.40	0.64	0.48
Average	**6.35**	**6.26**	**6.51**	**1.63**	**1.55**	**1.73**	**0.66**	**0.80**	**0.86**