Theoretical Development of Thermodynamic Properties of Environmental Friendly Refrigerant RE170 by Using Martin Hou Equation of State

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Theoretical Development of Thermodynamic Properties of an Environmental Friendly Refrigerant RE170 by Using Martin Hou Equation of State

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* Corresponding Author

ABSTRACT

This paper deals with the theoretical development of thermodynamic properties of an environmental friendly refrigerant dimethylether (RE170). Since hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) are going to be phase out and phase down as per Montreal and Kyoto protocol respectively. Refrigerant RE170 has zero ozone depletion potential (ODP) and very low global warming potential (GWP) which is less than two. Hence RE170 is considered as a viable option to replace for the refrigerants with GWP like HFCs. RE170 can be used as blend component with other ecofriendly refrigerant. The main objective of the present study is to compute the thermodynamic properties of RE170 by using Martin Hou equation of state (MH EOS). These properties are useful to do the thermodynamic analysis of a vapour compression refrigeration cycle. The properties computed are saturation vapour pressure, liquid density, vapour specific volume, enthalpy and entropy (both in the saturated liquid and vapour state). In the present study a MATLAB code is developed to compute the above considered thermodynamic properties from the temperature about 131.6K-398.15K and pressure up to 51.3bar. The computed properties of dimethylether is compared with NIST REFPROP database. Since thermodynamic properties of RE170 are not available in ASHRAE hand book and also in the literature. Therefore NIST REFPROP can be considered as a reliable source as that of ASHRAE. The results shows that the absolute average deviation (AAD) of liquid and vapour phase enthalpy from that of NIST REFPROP is 1.01% and 0.319% respectively. Similarly AAD of liquid and vapour phase entropy is 1.05% and 0.25% respectively. Deviation of vapour specific volume and liquid density is 1.49% and 0.25% respectively. AAD of saturation pressure is 0.071%. Overall the computed thermodynamic properties of RE170 by using MHEOS shows good agreement with NIST REFPROP database for wide the temperature range about 131.6K-398.15K and pressure up to 51.3bar.

1. INTRODUCTION

Montreal protocol has been taken the decision to ban the refrigerant R22 completely by the year 2030 (UNEP, 1987, Powell, 2002). Because R22 has adverse ecological impacts like high ozone depletion potential (ODP) and high global warming potential (GWP). Therefore it is necessary to develop the refrigerants which possess zero ODP and low GWP. Thermodynamic properties were required to conduct the performance investigation of any given refrigerants. Hence the present study focuses on development of thermodynamic properties of an ecofriendly refrigerants. Earlier several studies has been carried out to establish the properties of the refrigerants. Barret and Candau were computed the thermodynamic properties of refrigerants like R125 and R143a using MHEOS (Barret and Candau, 1992). Results showed that data obtained from the equation of state for R143a matches well with experimental data of refrigerant R143a. Theoretical thermodynamic properties modeling of two R22 alternatives like R410A and R407C were done by using MHEOS (De Monte, 2002a). Effect of temperature on thermodynamic property of two R22 alternatives like R410A and R407C was established along with the predominant effect of pressure in describing these properties (De Monte, 2002b). Investigation on predicting the liquid density and vapour
pressure of the dimethylether was done based on artificial neural networks with back-propagation algorithm (Moghadassi et al., 2010). Prediction of above properties exhibited good agreement with the experimental data. The thermodynamic property modeling for the RE170 was developed by using the experimental thermodynamic property data (Jiangtao Wu et al., 2011). Investigation of thermodynamic properties of refrigerant R1234yf was estimated by using various cubic equation of state models (Anant Agrawal et al., 2012). The properties obtained from these models were validated against most reliable NIST-REFPROP data base (Lemmon et al., 2013). The present work focuses on the theoretical thermodynamic property modeling and development of properties for the refrigerant RE170 by using Martin-Hou equation of state. The various properties of RE170 are validated with most reliable NIST-REFPROP data base. Because thermodynamic properties of RE170 are not available in ASHRAE hand book and also in the literature. Hence NIST REFPROP can be considered as reliable source as that of ASHRAE.

2. Properties of Dimethylether (RE170)

The basic physical properties and envriomental properties of refrigerant dimethylether (RE170) are shown in table1.

### Table 1: Properties of refrigerant RE170

<table>
<thead>
<tr>
<th>Properties</th>
<th>RE170</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight (kg/kmol)</td>
<td>46.068</td>
</tr>
<tr>
<td>Normal boiling point at 1.01325 bar (°C)</td>
<td>-24.78</td>
</tr>
<tr>
<td>Critical temperature (K)</td>
<td>400.38</td>
</tr>
<tr>
<td>Critical pressure (MPa)</td>
<td>5.336</td>
</tr>
<tr>
<td>ODP</td>
<td>0</td>
</tr>
<tr>
<td>GWP (100 years)</td>
<td>1</td>
</tr>
</tbody>
</table>

From the table 1 it is noticed that RE170 has zero ODP and negligible GWP. Therefore RE170 can be considered as an ecofriendly refrigerant. RE170 can be used as blend component with other ozone friendly HFC refrigerants in order to reduce the GWP of blend and also to improve the performance of the blend. An improvement in COP of the blend depends on the, how much composition of RE170 is going to be mix. For this thermodynamic analysis of various refrigerant blends consists of RE170 as one of the component blends is to be done. In this regard the present authors were computed the theoretical thermodynamic performance of various blends consists of RE170 at air conditioning conditions like $T_d=280K$ and $T_k=328K$ (Sharmas Vali Shaik and T.P. Ashok Babu, 2017). Authors were neglected various losses occurred in the cycle while doing the performance study of various blends. The performance results of various blends are given in the table 2.

### Table 2: Thermodynamic performance results of R22 alternatives (Sharmas Vali Shaik and T.P. Ashok Babu, 2017)

<table>
<thead>
<tr>
<th>Refrigerant Composition (mass %)</th>
<th>COP</th>
<th>Change in COP (%)</th>
<th>$T_d$ (°C)</th>
<th>VRC (kJ/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R22 Pure refrigerant</td>
<td>4.003</td>
<td>0</td>
<td>78.09</td>
<td>3646</td>
</tr>
<tr>
<td>NRM10 (R32/R134a/R290)</td>
<td>17.5/80/2.5</td>
<td>3.437</td>
<td>-14.13</td>
<td>76.64</td>
</tr>
<tr>
<td>NRM20 (R32/R134a/R290)</td>
<td>25/67.5/7.5</td>
<td>3.389</td>
<td>-15.33</td>
<td>79.46</td>
</tr>
<tr>
<td>NRM30 (R134a/R1270/RE170)</td>
<td>55/37.5/7.5</td>
<td>4.217</td>
<td>5.34</td>
<td>66.18</td>
</tr>
<tr>
<td>NRM40 (R134a/R290/RE170)</td>
<td>55/37.5/7.5</td>
<td>4.075</td>
<td>1.79</td>
<td>65.01</td>
</tr>
<tr>
<td>R407C (R32/R125/R134a)</td>
<td>23/25/52</td>
<td>3.231</td>
<td>-19.28</td>
<td>78.07</td>
</tr>
</tbody>
</table>

From the table 2 it is observed that the ternary refrigerant blend consists of R134a, R1270 and RE170 i.e. NRM30 (R134a/R1270/RE170 55/37.5/7.5 by mass %) has 5.34% higher COP compared to base line refrigerant R22. Apart from NRM30 and NRM40 also has considerable increase in COP compared to R22. From these results it is evident
that blending the RE170 as one of the component in small composition enhances the performance of the system. This is the main driving force or basic motivation to study and develop the thermodynamic properties of RE170.

3. METHODOLOGY AND CORRELATIONS

The various correlations used to establish the thermodynamic properties are given in this section. P-h chart used while developing the properties is shown in figure 1. The methodology and step by step procedure followed to develop the properties of given refrigerant (RE170) is explained in below (Arora, 2009).

3.1 Saturation Pressure

Wagner vapour pressure correlation is used to compute the saturation pressure of the given refrigerant RE170.

\[
\ln \left( \frac{P_{sat}}{P_c} \right) = \left( \frac{1}{1 - x} \right) \left[ Ax + B x^{1.5} + C x^{2.5} + D x^5 \right]
\]  

(1)

Where \( x = 1 - \frac{T}{T_c} \); A, B, C and D are constants for a particular refrigerants. These constants for RE170 are available in the literature and they are shown in table 3 (Luis A Forero and Jorge A Velásquez, 2011).

Table 3: Constants for Equation (1)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-6.9798</td>
<td>1.523</td>
<td>-1.6409</td>
<td>-2.7943</td>
</tr>
</tbody>
</table>

3.2 Liquid density

Ried et.al correlation is used to find the liquid density of the given refrigerant RE170 (Reid et al., 1977, Khashayar Nasrifar and Mahmood Moshfeghian, 1999).

\[
\rho_r = \frac{\rho}{\rho_c} = 1 + 0.85 \left( 1 - T_r \right) + \left( 1.6916 + 0.984 \omega \right) \left( 1 - T_r \right)^{1/3}
\]  

(2)
Where \( \omega \) is accentric factor and \( T_r = \frac{T}{T_c} \); \( \omega \), \( \rho_c \), \( T_c \) are constants and they are taken from the literature and given in table 4 (Bruce E Poling et al., 2001).

**Table 4:** Constants for Equation (2)

<table>
<thead>
<tr>
<th>( \omega )</th>
<th>( \rho_c ) (kg/m(^3))</th>
<th>( T_c ) (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.19</td>
<td>273.65</td>
<td>400.38</td>
</tr>
</tbody>
</table>

### 3.3 Specific Volume of Vapour

Specific volume of vapour for the refrigerant RE170 is computed by using Martin-Hou equation of state (Martin Joseph J and Yu-Chun Hou., 1955).

\[
P = \frac{RT}{v-b} + \frac{A_3 + B_3 T + C_3 e^{-5.475T/T_c}}{(v-b)^2} + \frac{A_4 + B_4 T + C_4 e^{-5.475T/T_c}}{(v-b)^3} + \frac{A_5}{v-b} + \frac{B_5 T}{v-b}^5
\]  

(3)

The dimensionless coefficients for the refrigerant RE170 obtained from the above Martin-Hou equation of state are shown in table 5.

**Table 5:** Dimensionless coefficients of RE170 for Equation (3)

| \( A_2 = -498.4594 \) | \( B_2 = 0.3933 \) | \( C_2 = -1.2235 \times 10^4 \) |
| \( A_3 = 2.0780 \) | \( B_3 = -0.0029 \) | \( C_3 = 35.4344 \) |
| \( A_4 = -0.0015 \) | \( B_5 = 2.0087 \times 10^{-9} \) | \( b = 9.2042 \times 10^{-4} \) |

### 3.4 Enthalpy of Vapourization

Clausius-Claperyon equation is used to compute the enthalpy of vapourization of the refrigerant RE170.

\[
\frac{dP_{sat}}{dT} = \frac{h_{fg}}{TV_{fg}^2} = \frac{h_{fg}}{T(v_f - v_g)}
\]  

(4)

Before computing the properties, the reference state for enthalpy and entropy is to be fixed. In this study the reference state for the enthalpy and entropy is \( H_{ref} = 200 \text{ kJ/kg} \), \( S_{ref} = 1 \text{ kJ/kgK} \) for the saturated liquid at 0°C is taken.

### 3.5 Departure Method

The significance of departure function is, to compute the enthalpy and entropy at various points as shown in the P-h diagram (Arora, 2009). To compute the enthalpy at point 3, the enthalpy departure method is used.

The enthalpy departure term \( h_3 - h_2 \) is given by

\[
h_3 - h_2 = (U_3 - U_2) + (P_3V_3 - P_2V_2)
\]  

(5)

\[
U_3 - U_2 = \int \left[ \frac{\partial P}{\partial T} \right]_V - P \right] _v dV
\]  

(6)

By solving the equations (5) and (6) the value of \( h_3 \) can be found.

In order to find the enthalpy \( h_4 \) at point 4, ideal heat capacity correlation and enthalpy difference (\( h_4 - h_3 \)) can be used.

\[
h_4 - h_3 = \int C_{p0} dT
\]  

(7)

In the present work ideal heat capacity \( C_{p0} \) correlation is taken from the literature (Bruce E Poling et al., 2001).

\[
C_{p0} = A_0 + A_1 T + A_2 T^2 + A_3 T^3 + A_4 T^4
\]  

(8)
Where \( A_0 \), \( A_1 \), \( A_2 \), \( A_3 \), and \( A_4 \) are constants for a particular refrigerant. These constants for RE170 are taken from the literature and they are given in table 6 (Bruce E Poling et al., 2001).

**Table 6: Constants for Equation (8)**

<table>
<thead>
<tr>
<th>( A_0 )</th>
<th>( A_1 )</th>
<th>( A_2 )</th>
<th>( A_3 )</th>
<th>( A_4 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.361</td>
<td>6.070\times10^{-3}</td>
<td>2.899\times10^{-5}</td>
<td>-3.581\times10^{-8}</td>
<td>1.282\times10^{-11}</td>
</tr>
</tbody>
</table>

Again enthalpy departure term is used in between the state points 4 and 5 in order to find enthalpy \( h_5 \).

\[
h_5 - h_4 = (U_5 - U_4) + P_5V_5 + P_4V_4
\]

(9)

\[
U_5 - U_4 = \int_4^{5} \left[ T \left( \frac{\partial P}{\partial T} \right)_V - P \right] dV
\]

(10)

By solving the equations (9) and (10) the value of \( h_5 \) can be found.

The saturated liquid enthalpy at state point 6 can be found by using the following relation.

\[
h_5 - h_6 = h_{fg}
\]

(11)

Where \( h_{fg} \) is found by using Clasius-Clayperon equation at a given temperature. Therefore

\[
h_5 = h_6 - h_{fg}
\]

(12)

### 3.6 Liquid Entropy

To compute the thermodynamic properties (enthalpy and entropy) of refrigerant at any given pressure and temperature, the departure method is used and the corresponding saturated liquid enthalpy and saturated liquid entropy is calculated using the Clausius-Clapeyron equations.

Entropy of liquid for the given refrigerant can be calculated as

\[
S_{fg} = S_g - S_f
\]

(13)

\[
S_f = S_g - S_{fg}
\]

### 3.7 Vapour Entropy

Entropy of vapour for the given refrigerant can be computed by

\[
S_{fg} = \frac{h_{fg}}{T_{sat}}, \quad S_f = \frac{h_g}{T_{sat}}
\]

(14)

By following the above methodology the thermodynamic properties are computed for the refrigerant RE170 of wide temperature range from about 131.6K-398.15K and pressure up to 51.3 bar. The computed thermodynamic properties are shown in table 7. The results and discussions on the development of properties of refrigerant RE170 are given below.

### 4. RESULTS AND DISCUSSIONS

#### 4.1 Comparison of Computed \( P_{sat} \) with NIST REFPROP \( P_{sat} \) for RE170

Wagner vapour pressure correlation is used to compute the saturation pressure of the refrigerant RE170. From the figure 2(a) and 2(b) it is noticed that the computed saturation pressure values shows good agreement with NIST REFPROP and percentage error obtained for the computed saturation pressure for RE170 is ranging from -0.150% to -0.114% for the given air conditioner operating temperature range between 280 to328 K. It may also be noted that deviation of saturation pressure varies from -0.61% to -0.03% for the temperature range 131K-363K. Whereas
absolute average deviation (AAD) of saturation pressure is 0.071\% for the wide temperature range about 131.6K-398.15K and wide pressure range about 2.21x10^{-5}-51.3 bar.

4.2 Comparison of Computed $\rho_l$ with NIST REFPROP $\rho_l$ for RE170

Reid method is used to compute the saturated liquid density of the refrigerant RE170. From the figure 3(a) and 3(b) it is noticed that the computed density values shows good agreement with NIST REFPROP data base and percentage error obtained for the computed density for RE170 is ranging from -0.179\% to -0.045\% for the given air conditioner operating temperature range between 280 to328 K. It may also be noted that deviation of saturation pressure varies from -0.19\% to 0.0088\% for the temperature range 131K-363K. Whereas absolute average deviation (AAD) of liquid density is 0.253\% for the wide temperature range about 131.6K-398.15K and wide pressure range about 2.21x10^{-5}-51.3bar.

4.3 Comparison of Computed $V_g$ with NIST REFPROP $V_g$ for RE170

Martin-Hou equation of state is used to compute the specific volume of vapour refrigerant RE170. From the figure 4(a) and 4(b) it is noticed that the computed vapour specific volume values shows good agreement with NIST REFPROP data base and percentage error obtained for the computed vapour specific volume for RE170 is ranging from 0.708\% to 0.108\% for the given air conditioner operating temperature range between 280 to328 K. It may also
be noted that deviation of saturation pressure varies from 0.61% to -2.54% for the temperature range 131K-363K. Whereas absolute average deviation (AAD) of vapour specific volume is 1.49% for the wide temperature range about 131.6K-398.15K and wide pressure range about 2.21x10^{-5}-51.3bar.

4.4 Comparison of Computed $h_f$ with NIST REFPROP $h_f$ for RE170

Enthalpy departure method and latent heat of vaporization is used to compute the liquid enthalpy of the given refrigerant RE170. From the figure 5(a) and 5(b) it is noticed that the computed liquid enthalpy values shows good agreement with NIST REFPROP data base and percentage error obtained for the computed liquid enthalpy for RE170 is ranging from 0.114% to 1.387% for the given air conditioner operating temperature range between 280 to 328 K. It may also be noted that deviation of liquid enthalpy varies from 0.61% to 2.55% for the temperature range 131K-363K. Whereas absolute average deviation (AAD) of liquid enthalpy is 1.01% for the wide temperature range about 131.6K-398.15K and wide pressure range about 2.21x10^{-5}-51.3bar.

4.5 Comparison of Computed $h_g$ with NIST REFPROP $h_g$ for RE170

Enthalpy departure method and latent heat of vaporization is used to compute the vapour enthalpy of the given refrigerant RE170. From the figure 6(a) and 6(b) it is noticed that the computed vapour enthalpy values shows good agreement with NIST REFPROP data base and percentage error obtained for the computed vapour enthalpy for
RE170 is varies from 0.372% to 0.627% for the given air conditioner operating temperature range between 280 to 328 K. It may also be noted that deviation of liquid enthalpy varies from 0.067% to 0.283% for the temperature range 131K-363K. Whereas absolute average deviation (AAD) of vapour enthalpy is 0.319% for the wide temperature range about 131.6K-398.15K and wide pressure range about 2.21x10^{-5}-51.3bar.

4.6 Comparison of Computed $S_f$ with NIST REFPROP $S_f$ for RE170

The departure method and Clasius-Clayperon is used to compute the liquid entropy of the given refrigerant RE170. From the figure 7(a) and 7(b) it is noticed that the computed liquid entropy values shows good agreement with NIST REFPROP data base and percentage error obtained for the liquid entropy for RE170 is varies from 0.082% to 1.032% for the given air conditioner operating temperature range between 280 to 328 K. It may also be noted that deviation of liquid entropy varies from 0.775% to 1.889% for the temperature range 131K-363K. Whereas absolute average deviation (AAD) of liquid entropy is 1.055% for the wide temperature range about 131.6K-398.15K and wide pressure range about 2.21x10^{-5}-51.3bar.
4.7 Comparison of Computed $S_g$ with NIST REFPROP $S_g$ for RE170

The departure method and Clasius-Clayperon is used to compute the vapour entropy of the given refrigerant RE170. From the figure 8(a) and 8(b) it is noticed that the computed vapour entropy values shows good agreement with NIST REFPROP database and percentage error obtained for vapour entropy for RE170 is varies from 0.329% to 0.550% for the given air conditioner operating temperature range between 280 to 328 K. It may also be noted that deviation of vapour entropy varies from 0.078% to 0.305% for the temperature range 131K-363K. Whereas absolute average deviation (AAD) of vapour entropy is 0.262% for the wide temperature range about 131.6K-398.15K and wide pressure range about 2.21x10^{-5}-51.3 bar.

![Figure 8: (a) Comparison of computed $S_g$ with NIST as a function of temperature (b) Deviation of $S_g$ with NIST](image)

6. CONCLUSIONS

In this work an attempt was made to compute and develop the thermodynamic properties of an ecofriendly refrigerant dimethylether (RE170) for the wide temperature range about 131.6-398.15K and pressure up to 51.3 bar. MH EOS was used for this purpose. In this study thermodynamic properties generated were validated against NIST REFPROP database. Martin-Hou equation of state was found to be an appropriate equation of state in the operating temperature region (280-328K) of residential air conditioner. Since the deviation of all the computed and developed properties ($P_{sat}$, $ρ_f$, $V_g$, $h_f$, $h_g$, $S_f$ and $S_g$) were within 1% compared with NIST REFPROP database. It was noticed that for the temperature range (131-363K), the deviation of thermodynamic properties were within 2.5%. This study exhibited there was considerable increase in deviation of properties as the computation approaches to critical point or critical region. Also in this study absolute average deviation (AAD) of above properties were also found. AAD of saturated pressure and liquid density was 0.071% and 0.25% respectively for the entire temperature range 131.6-398.15K and pressure up to 51.3 bar. AAD of saturated vapour phase of both enthalpy and entropy was 0.31% and 0.26% whereas for saturated liquid phase of enthalpy and entropy was 1.01 and 1.05% respectively for the entire temperature and pressure range. AAD of vapour specific volume of RE170 was 1.49% for the wide temperature range 131.6-398.15K and pressure up to 51.3bar. However average absolute deviation (AAD) of all the properties were within 1.05% as the temperature was approaches near to critical region. Hence the developed thermodynamic properties of refrigerant RE170 by using MH EOS were reliable and these properties would be useful and applicable for analyzing and computing the thermodynamic performance characteristics of vapour compression refrigeration system.
Table 7: Refrigerant RE170 (Dimethylether) Properties of Saturated Liquid and Saturated Vapor

<table>
<thead>
<tr>
<th>T (K)</th>
<th>Pressure (Mpa)</th>
<th>Liquid Density (kg/m³)</th>
<th>Vapour Volume (m³/kg)</th>
<th>Enthalpy (kJ/kg)</th>
<th>Entropy (kJ/kgK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>131.66</td>
<td>2.2242E-06</td>
<td>883.86</td>
<td>10682.29356</td>
<td>-107.89</td>
<td>480.34</td>
</tr>
<tr>
<td>133.15</td>
<td>2.9331E-06</td>
<td>882.16</td>
<td>10192.18123</td>
<td>-104.74</td>
<td>481.84</td>
</tr>
<tr>
<td>138.70</td>
<td>7.0676E-06</td>
<td>876.41</td>
<td>3527.48119</td>
<td>-94.17</td>
<td>486.92</td>
</tr>
<tr>
<td>143.15</td>
<td>1.5893E-05</td>
<td>870.62</td>
<td>1625.39118</td>
<td>-83.58</td>
<td>492.07</td>
</tr>
<tr>
<td>148.15</td>
<td>3.3599E-05</td>
<td>864.79</td>
<td>795.67201</td>
<td>-73.97</td>
<td>497.29</td>
</tr>
<tr>
<td>153.60</td>
<td>6.7202E-05</td>
<td>858.936</td>
<td>411.20933</td>
<td>-62.35</td>
<td>502.56</td>
</tr>
<tr>
<td>158.15</td>
<td>0.0012787</td>
<td>853.033</td>
<td>223.13248</td>
<td>-51.72</td>
<td>507.89</td>
</tr>
<tr>
<td>163.15</td>
<td>0.0023261</td>
<td>847.088</td>
<td>126.51628</td>
<td>-41.10</td>
<td>513.28</td>
</tr>
<tr>
<td>168.15</td>
<td>0.00040626</td>
<td>841.100</td>
<td>74.64093</td>
<td>-30.46</td>
<td>518.71</td>
</tr>
<tr>
<td>173.15</td>
<td>0.00068378</td>
<td>835.067</td>
<td>45.64904</td>
<td>-19.83</td>
<td>524.20</td>
</tr>
<tr>
<td>178.15</td>
<td>0.00111282</td>
<td>828.989</td>
<td>28.84503</td>
<td>-9.183</td>
<td>529.72</td>
</tr>
<tr>
<td>183.15</td>
<td>0.00175637</td>
<td>822.862</td>
<td>18.77648</td>
<td>1.47</td>
<td>535.28</td>
</tr>
<tr>
<td>188.15</td>
<td>0.00269547</td>
<td>816.686</td>
<td>12.55792</td>
<td>12.15</td>
<td>540.86</td>
</tr>
<tr>
<td>193.15</td>
<td>0.00403188</td>
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### REFERENCES


