

Schlumberger Reservoir Laboratories

# Fluid Analysis Report

Heavy Oil

Well: TPTC-002

Field: ITT

Sampling Depth: 4546 ft

For

SINOPEC-PAM

Report No: BRRD2016003.v06

17-Aug-2016



## DISCLAIMER

The following disclaimer applies to this report and any interpretation provided by any of the Laboratories that comprise the Schlumberger Reservoir Laboratories:

Any interpretation, research, analysis, or recommendation furnished with the services or otherwise communicated by Schlumberger Reservoir Laboratories to Customer at any time in connection with the services are opinions based on inferences from measurements and empirical relationships and assumptions, which inferences and assumptions are not infallible, and with respect to which professionals in the industry may differ. Accordingly, Schlumberger Reservoir Laboratories cannot and does not warrant the accuracy, correctness or completeness of any such interpretation or description.

Customer acknowledges that It is accepting the services "as is", that Schlumberger Reservoir Laboratories makes no representation or warranty, express or implied, of any kind or description in respect thereto, and that such services are delivered with the explicit understanding and agreement that any action customer may take based on the services received shall be at its own risk and responsibility and customer shall have no claim against Schlumberger Reservoir Laboratories as a consequence thereof.

Customer confirms that Schlumberger Reservoir Laboratories has made no promise or statement regarding the services that is inconsistent with these terms, or that has created or amounted to a warranty that the services would conform to any such promise or statement, and Schlumberger Reservoir Laboratories disclaims any and all warranties regarding the same.

## Table of Contents

DISCLAIMER .....	2
Quality Assurance Statement .....	6
1. Executive Summary .....	7
1.1 Objectives .....	7
1.2 Introduction .....	7
1.3 Scope of Work .....	7
1.4 Summary of Samples Received .....	8
1.5 Summary of Sample Validation and Quality Check .....	8
1.6 Summary of Fluid Compositional Analysis .....	9
1.7 Results, Findings and Recommendations .....	10
2. Fluid Analysis Results of Bottomhole Sample 22999-IB, 4546 ft (1.2) .....	11
2.1 Summary of Fluid Analysis of Bottomhole Sample 22999-IB (1.2) .....	11
2.2 Compositional Analysis and Single Stage Flash Data of Bottomhole Sample 22999-IB (1.2) .....	13
2.3 Constant Composition Expansion at Tres of Sample 22999-IB (1.2) .....	16
2.4 Differential Liberation at Tres of Sample 22999-IB (1.2) .....	19
2.5 Two-Stage Separator Test of Sample 23000-IB (1.3) .....	24
2.6 Viscosity Test at Tres of Sample 23000-IB (1.3) .....	27
2.7 STO Viscosity Test at 15 psia of Sample 22999-IB (1.2) .....	28
2.8 Wax Content and SARA Analysis of Bottomhole Sample 22999-IB (1.2) .....	29
2.9 Viscosity Test at Tres of Sample 22872-IB (1.1) .....	30
2.10 True Boiling Point (TBP) Distillation on Flashed Liquid from Sample 22872-IB (1.1) .....	31
3. Fluid Analysis Results of Bottomhole Sample 23000-IB, 4546 ft (1.3) .....	34
3.1 Compositional Analysis and Single Stage Flash Data of Bottomhole Sample 23000-IB (1.3) .....	34
Appendix A: Nomenclature and Definitions .....	37
Appendix B: Molecular Weight Data .....	38
Appendix C: Procedure for Sample Restoration and Standard PVT Analyses .....	39

## List of Tables

Table 1: Sample Identification.....	8
Table 2: Initial Sample Validation Results.....	8
Table 3: Bottomhole Sample Properties .....	8
Table 4: Summary of Reservoir Fluid Composition Data .....	9
Table 5: Reservoir Conditions of Bottomhole Sample 22999-IB (1.2).....	11
Table 6: Composition of Bottomhole Sample 22999-IB (1.2).....	11
Table 7: Fluid Properties at Reservoir Conditions of Bottomhole Sample 22999-IB (1.2).....	11
Table 8: Fluid Properties at Saturation Conditions of Bottomhole Sample 22999-IB (1.2).....	11
Table 9: Stock Tank Fluid Properties of Bottomhole Sample 22999-IB (1.2).....	11
Table 10: Data Comparison of PVT Test of Bottomhole Sample 22999-IB (1.2) .....	12
Table 11: Compositional Analysis of Bottomhole Sample 22999-IB (1.2).....	13
Table 12: Single Stage Flash of Bottomhole Sample 22999-IB (1.2) at Standard Conditions <sup>1</sup> .....	14
Table 13: Cn+ Properties of Reservoir Fluid Bottomhole Sample 22999-IB (1.2).....	14
Table 14: Flashed Gas Properties of Bottomhole Sample 22999-IB (1.2) .....	14
Table 15: Constant Composition Expansion at Tres of Sample 22999-IB (1.2) .....	16
Table 16: Differential Liberation at Tres of Sample 22999-IB (1.2) .....	19
Table 17: Differential Liberation at Tres of Sample 22999-IB (1.2) - Vapor Compositions (mole%) .....	23
Table 18: Two-Stage Separator Test of Sample 23000-IB (1.3).....	24
Table 19: Two-Stage Separator Test of Sample 23000-IB (1.3) - Vapor Compositions (mole%) .....	26
Table 20: Viscosity Test at Tres of Sample 23000-IB (1.3).....	27
Table 21: STO Viscosity Test at 15 psia of Sample 22999-IB (1.2) .....	28
Table 22: Stock tank Oil Analysis.....	29
Table 23: Viscosity Test at Tres of Sample 22872-IB (1.1).....	30
Table 24: True Boiling Point (TBP) Distillation Data from Flashed Liquid from Sample 22872-IB (1.1).....	31
Table 25: Compositional Analysis of Bottomhole Sample 23000-IB (1.3).....	34
Table 26: Single Stage Flash of Bottomhole Sample 23000-IB (1.3) at Standard Conditions <sup>1</sup> .....	35
Table 27: Cn+ Properties of Reservoir Fluid Bottomhole Sample 23000-IB (1.3).....	35
Table 28: Flashed Gas Properties of Bottomhole Sample 23000-IB (1.3) .....	35
Table 29: Molecular Weight Data of Katz and Whitson.....	38

## List of Figures

Figure 1: Initial FSW pictures from SSB 2 2999-IB (1.2) and SSB 23000-IB (1.3) .....	10
Figure 2: Gas Chromatogram of Flashed Liquid of Bottomhole Sample 22999-IB (1.2) .....	14
Figure 3: K-Plot Vapor Liquid Equilibrium Check for Bottomhole Sample 22999-IB (1.2) .....	15
Figure 4: Graphs for Constant Composition Expansion at Tres of Sample 22999-IB (1.2) .....	17
Figure 5: Graphs for Differential Liberation at Tres of Sample 22999-IB (1.2) .....	20
Figure 5: Graphs for Differential Liberation at Tres of Sample 22999-IB (1.2) (Cont.) .....	21
Figure 5: Graphs for Differential Liberation at Tres of Sample 22999-IB (1.2) (Cont.) .....	22
Figure 6: Graphs for Two-Stage Separator Test of Sample 23000-IB (1.3) .....	24
Figure 6: Graphs for Two-Stage Separator Test of Sample 23000-IB (1.3) (Cont.) .....	25
Figure 7: Graphs for Viscosity Test at Tres of Sample 23000-IB (1.3) .....	27
Figure 8: Graphs for STO Viscosity Test at 15 psia of Sample 22999-IB (1.2) .....	28
Figure 9: Graphs for Viscosity Test at Tres of Sample 22872-IB (1.1) .....	30
Figure 10: True Boiling Point (TBP) Distillation of Sample 22872-IB (1.1) - %Mass .....	32
Figure 11: True Boiling Point (TBP) Distillation of Sample 22872-IB (1.1) - %Volume .....	33
Figure 12: Gas Chromatogram of Flashed Liquid of SPMC 876 Bottomhole Sample 23000-IB (1.3) .....	35
Figure 13: K-Plot Vapor Liquid Equilibrium Check for Bottomhole Sample 23000-IB (1.3) .....	36

## Quality Assurance Statement

Schlumberger Reservoir Laboratories is committed to providing unsurpassed services in reservoir fluid sampling and fluid property analyses, while maintaining high standards of safety and quality. Our objective is to deliver the most accurate and reliable sampling processes and fluid property measurements available in the industry. This objective requires persistent innovation and ongoing development of state-of-the-art technologies and equipment.

A rigorous program of quality assurance, continuous employee training and enforcement of strict safety standards maintains our compliance with Quality, Health, Safety and Environment (QHSE) requirements. Proactive integration of QHSE objectives and management goals at every level supports the communication and implementation of QHSE policies and standards.

Schlumberger requires that qualified engineering technologists perform all laboratory measurements according to specified analytical procedures designed for obtaining accurate and reliable data. Rigorous quality assurance programs and instrument calibration protocols are in place to ensure and maintain the accuracy of the procedures. Details of these programs are available upon request.

The results of all laboratory work are interpreted and reported by the Project Engineer responsible for supervision of the project. The completion of each project requires that a second Engineer/Manager/Scientist carry out an independent review of all technical data to confirm the consistency and accuracy of the report. Raw data may be adjusted within experimental error tolerances to minimize material balance error. All property measurements and calculation procedures are maintained in company archives for a period of 5 years. This information is available for review by clients upon request.

The file and laboratory records information as listed below, provide access reference to all records related to this project. For answers to any questions, please do not hesitate to contact the undersigned Project Engineer.

### Project Engineer

\_\_\_\_\_  
Bruno Zinani

### Data Quality

\_\_\_\_\_  
Ana Paula Macedo  
Data Quality Engineer

### Overall Report Quality

\_\_\_\_\_  
Diego Rosal  
Field Service Manager – Downhole, WTS

### Overall Report Quality

\_\_\_\_\_  
Joseph Thomas Manakalathil  
Service Quality Team Lead - Houston

## 1. Executive Summary

### 1.1 Objectives

The objective of this study is to evaluate fluid properties of reservoir fluid from well TPTC-002, ITT field, Ecuador. Also, to determine the PVT properties of the selected bottomhole fluid sample from well TPTC-002, in order to obtain essential data for reservoir engineering analysis, simulation and surface facilities design. The various analyses were performed on the selected bottomhole sample to assess the phase behavior of reservoir fluid. The detailed analyses include quality and validity checks of bottomhole sample and Compositional Analysis. Finally PVT study was performed on the more representative samples.

### 1.2 Introduction

Schlumberger Reservoir Laboratories, Rio de Janeiro, conducted a fluid analysis study on bottomhole samples collected at 4546 ft at the well TPTC-002 from ITT field, Ecuador at the request of Sinopec-PAM. The results of de validation samples and PVT study are presented within this report.

### 1.3 Scope of Work

- Measurement of opening pressure of the Bottomhole samples.
- Homogenize Bottomhole samples at the reservoir conditions with rocking during 5 days.
- Conduct preliminary evaluation and validity checks on bottomhole samples.
- Submit bottomhole samples to heating-cooling cycles for water removal.
- Conduct compositional analysis and determine the saturation pressure on the Bottomhole sample in SSB 22999-IB.
- Conduct compositional analysis and determine the saturation pressure on the Bottomhole sample in SSB 23000-IB.
- Individual measurements by gas detection tube for H<sub>2</sub>S.
- Constant Composition Expansion at Tres for sample 1.2 (SSB 22999-IB).
- Differential Liberation for sample for sample 1.2 (SSB 22999-IB).
- Two-Stage Separator Test for sample 1.3 (SSB 23000-IB).
- DL at Tres Data Adjusted to Four-Stage Separators Conditions.
- Measurement of Reservoir Fluid Viscosity at Tres by Electromagnetic Viscometer (EMV) on sample 1.3 (SSB 23000-IB).
- Measurement of stock tank oil viscosity at a range of temperature from 60.0 °F up to 225.0 °F.
- Measurement of atmospheric crude oil analysis on stock tank sample.
- Measurement of Reservoir Fluid Viscosity at Tres by Electromagnetic Viscometer (EMV) on sample 1.1 (SSB 22872-IB).
- Perform TBP analysis on flashed liquid of sample 1.1 (SSB 22872-IB).

## 1.4 Summary of Samples Received

Table 1: Sample Identification

Sample ID	Cylinder ID	Sample Type	Sampling date and time	Reservoir Conditions <sup>1</sup>		
				Pressure	Temperature	Depth
	SSB			psia	°F	ft
1.1	22872-IB	Bottomhole	9-Apr-2016 at 13:15 hrs	1887	159.0	4546
1.2	22999-IB	Bottomhole	9-Apr-2016 at 13:15 hrs	1887	159.0	4546
1.3	23000-IB	Bottomhole	9-Apr-2016 at 13:15 hrs	1887	159.0	4546
1.4	23345-IB	Bottomhole	9-Apr-2016 at 13:15 hrs	1887	159.0	4546

<sup>1</sup>Information supplied by the client.

Table 2: Initial Sample Validation Results

Sample ID <sup>1</sup>	Cylinder ID	Opening Conditions in the Lab	Free Water	BSW <sup>2</sup>	Field Reported Sample Volume
		psia at °F	cm <sup>3</sup>	vol%	cm <sup>3</sup>
1.1	22872-IB	5133 at 71.6	22	NM	225
1.2	SSB 22999-IB	5609 at 72.7	18	11.8	230
1.3	SSB 23000-IB	5588 at 73.2	20	12.7	230

NM: Not Measured

<sup>1</sup>Client selected these two samples for validation and further PVT analyses.

<sup>2</sup>Base sediment and water (BS&W) by centrifuge.

## 1.5 Summary of Sample Validation and Quality Check

Table 3: Bottomhole Sample Properties

Sample ID	Remained sample volume after water removal	Single Stage Flash	Saturation Pressure at Tres <sup>2</sup>	H <sub>2</sub> S Content of Flashed Gas by Gastec Tubes <sup>3</sup>	Molar Mass of Reservoir Fluid	Entrained Water by Karl Fisher
		GOR <sup>1</sup>				
	cm <sup>3</sup>	SCF/STB	psia	ppm	g/mol	wt %
1.1	175	NM	NM	NM	NM	0.9
1.2	130	65.0	214	0.1	358.14	0.8
1.3	155	57.7	174	0.2	369.11	0.8

NM: Not Measured

<sup>1</sup>Flashed gas volume (scf) per barrel of stocktank liquid at 15.6 °C.

<sup>2</sup>Saturation pressure at Tres measured in the PVT cell during initial validation rush analyses.

<sup>3</sup>Gastec Tubes for H<sub>2</sub>S results are from the flashed gas not from the Reservoir fluid.

## 1.6 Summary of Fluid Compositional Analysis

Table 4: Summary of Reservoir Fluid Composition Data

Sample ID	1.2	1.3
Cylinder ID	SSB 22999-IB	SSB 23000-IB
Sample Depth ft	4546	4546
Component	mole %	mole %
CO <sub>2</sub>	0.55	0.60
H <sub>2</sub> S	*	*
N <sub>2</sub>	0.65	0.70
C <sub>1</sub>	5.14	5.22
C <sub>2</sub>	1.38	1.32
C <sub>3</sub>	3.07	2.86
i-C <sub>4</sub>	1.01	0.91
n-C <sub>4</sub>	2.69	2.38
i-C <sub>5</sub>	1.35	1.11
n-C <sub>5</sub>	1.46	1.17
C <sub>6</sub>	1.98	1.61
Mcylo-C <sub>5</sub>	0.60	0.55
Benzene	0.05	0.05
Cyclo-C <sub>6</sub>	0.25	0.23
C <sub>7</sub>	1.78	1.65
Mcylo-C <sub>6</sub>	0.54	0.53
Toluene	0.10	0.11
C <sub>8</sub>	2.11	2.12
C <sub>2</sub> -Benzene	0.12	0.12
m&p-Xylene	0.23	0.23
o-Xylene	0.08	0.08
C <sub>9</sub>	2.24	2.28
C <sub>10</sub>	2.81	2.87
C <sub>11</sub>	2.71	2.78
C <sub>12</sub>	2.79	2.87
C <sub>13</sub>	3.14	3.18
C <sub>14</sub>	3.00	3.06
C <sub>15</sub>	3.06	3.10
C <sub>16</sub>	2.83	2.86
C <sub>17</sub>	2.78	2.82
C <sub>18</sub>	2.71	2.73
C <sub>19</sub>	2.72	2.73
C <sub>20</sub>	2.44	2.46
C <sub>21</sub>	2.27	2.28
C <sub>22</sub>	2.18	2.16
C <sub>23</sub>	2.02	1.99
C <sub>24</sub>	1.86	1.85
C <sub>25</sub>	1.72	1.70
C <sub>26</sub>	1.65	1.61
C <sub>27</sub>	1.58	1.53
C <sub>28</sub>	1.54	1.48
C <sub>29</sub>	1.54	1.46
C <sub>30+</sub>	25.27	26.65
<b>Calculated MW</b>	<b>358.14</b>	<b>369.46</b>

\*H<sub>2</sub>S content below detectable limits by Gas Chromatography.

## 1.7 Results, Findings and Recommendations

The validity of bottomhole samples was initially checked by measuring their opening pressure at room temperature. The opening pressure of these two selected samples was consistent with the closing pressure values presented in field sampling report 2016ECCO-P014-J0001. The two sample bottles were restored under continuous agitation during 5 days at 6015 psia and 159.0 °F. All selected sample cylinders were checked for free water.

During the initial check of samples high oil-water emulsion was found ( figure 1), therefore in good agreement with client, the bottomhole samples were submitted to several heating-cooling cycles until final water content for each samples was less than 1.0 vol%, in order to continue with the validation analysis.

After water removal, a portion of each of the two bottomhole samples was analyzed and individually subjected to a direct flash procedure to measure the composition, GOR, STL density and related data. Due to the heavy oil nature of the samples all fittings and lines were heated to reduce the oil viscosity during the analyses.

Bottomhole samples were consistent between each other, compositions were very similar and API. GOR and Psat values were close but with some differences within the experimental errors. These differences might be due to the heavy oil nature.

As part of initial samples quality checks, H<sub>2</sub>S content was measured on the flashed gas by using Gastec tubes. Very small content of H<sub>2</sub>S was found. However these are below the detectable limits by Gas Chromatography.

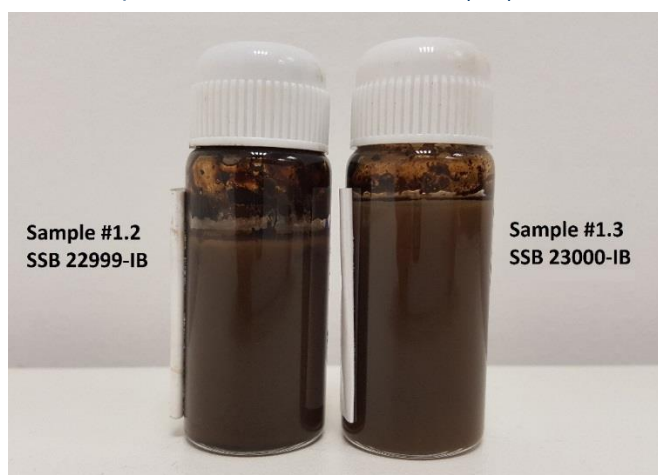
Finally, both validated samples 1.2 (SSB 22999-IB) and 1.3 (SSB 23000-IB) were used in conjunction to perform a PVT study. Both samples were used due to the small amount of clean oil recovered for each sample after dewatering process.

At the request of SINOPEC-PAM, reservoir fluid viscosity at Tres (159.0 °F) was also performed on sample 1.1 (SSB 22872-IB). The validity of sample 1.1 (SSB 22872-IB) was initially checked by measuring opening pressure at room temperature and the sample bottle was restored under continuous agitation during 5 days at 6015 psia and 159.0 °F.

During the initial check of sample 1.1 (SSB 22872-IB) high oil-water emulsion was found, therefore in good agreement with client, the bottomhole sample was submitted to two (2) heating-cooling cycles until final water content was less than 1.0 vol%.

After water removal, a portion of sample 1.1 (SSB 22872-IB) was charged to the Electromagnetic Viscometer (EMV) in which the viscosity of the fluid at Tres (159.0 °F) was measured for a wide range of pressure steps.

Figure 1: Initial FSW pictures from SSB 2 2999-IB (1.2) and SSB 23000-IB (1.3)



## 2. Fluid Analysis Results of Bottomhole Sample 22999-IB, 4546 ft (1.2)

### 2.1 Summary of Fluid Analysis of Bottomhole Sample 22999-IB (1.2)

Table 5: Reservoir Conditions of Bottomhole Sample 22999-IB (1.2)

Reservoir Pressure (Pres)	1887	psia
Reservoir Temperature (Tres)	159.0	°F
Sample Depth	4546	ft

Table 7: Fluid Properties at Reservoir Conditions of Bottomhole Sample 22999-IB (1.2)

Density	0.936	g/cm <sup>3</sup>
Viscosity <sup>1</sup>	225	cP
Formation Volume Factor (Bof) <sup>2</sup>	1.061	bbL/STB
Oil Compressibility (Co)	5.12	10 <sup>-6</sup> /psia

Table 8: Fluid Properties at Saturation Conditions of Bottomhole Sample 22999-IB (1.2)

Bubble Point Pressure	214	psia
Density	0.928	g/cm <sup>3</sup>
Viscosity <sup>1</sup>	180	cP
Formation Volume Factor (Bof) <sup>3</sup>	1.071	bbL/STB
Oil Compressibility (Co)	5.59	10 <sup>-6</sup> /psia
Solution GOR <sup>4</sup>	53.7	SCF/STB

Table 9: Stock Tank Fluid Properties of Bottomhole Sample 22999-IB (1.2)

Density <sup>5</sup>	0.972	g/cm <sup>3</sup>
API Gravity	14.0	API

<sup>1</sup>EMV Viscosity method used to measure viscosity<sup>2</sup>Flash Conditions 15 psia and 140.0 °F, Volume of saturated oil at 1887 psia and 159.0 °F per volume of stock tank oil at standard conditions<sup>3</sup>Flash Conditions 15 psia and 140.0 °F, Volume of saturated oil at 214 psia and 159.0 °F per volume of stock tank oil at standard conditions<sup>4</sup>Flash conditions from DL test stages at Tres cumulative gas volumes at std conditions per DL residual liquid at std conditions<sup>5</sup>Density measured at 15 psia and 104.0 °F and corrected to Standard Conditions 15 psia and 60.0 °F by ASTM method D1250-80

Table 6: Composition of Bottomhole Sample 22999-IB (1.2)

Component	mole %
CO2	0.55
H2S	*
N2	0.65
C1	5.14
C2	1.38
C3	3.07
i-C4	1.01
n-C4	2.69
i-C5	1.35
n-C5	1.46
C6	1.98
Mcylo-C5	0.60
Benzene	0.05
Cyclo-C6	0.25
C7	1.78
Mcylo-C6	0.54
Toluene	0.10
C8	2.11
C2-Benzene	0.12
m&p-Xylene	0.23
o-Xylene	0.08
C9	2.24
C10	2.81
C11	2.71
C12	2.79
C13	3.14
C14	3.00
C15	3.06
C16	2.83
C17	2.78
C18	2.71
C19	2.72
C20	2.44
C21	2.27
C22	2.18
C23	2.02
C24	1.86
C25	1.72
C26	1.65
C27	1.58
C28	1.54
C29	1.54
C30+	25.27
C30+ Mole Wt	875.41
C30+ Density	1.068

\*H2S content below detectable limits by Gas Chromatography.

Table 10: Data Comparison of PVT Test of Bottomhole Sample 22999-IB (1.2)

Experimental Procedure	Total GOR	STO API Gravity	Measured STO Density	Calculated STO MW	FVF at Psat	Avg. Gas Gravity
	SCF/STB	API	g/cm <sup>3</sup>	g/mol	bbI/STB	Air=1
Reservoir Oil Single Stage Flash <sup>1</sup>	65.0	14.0	0.972	425.23	1.071	1.536
Differential Liberation at Reservoir Temperature	53.7	14.6	0.967	411.81	1.059	1.228
Two-Stage Separator Test <sup>2</sup>	45.6	14.7	0.967	404.88	1.055	1.202

<sup>1</sup>Flash Conditions 15 psia and 140.0 °F, Density measured at 15 psia and 104.0 °F and corrected to Standard Conditions by ASTM method D1250-80

<sup>2</sup>Separator test conditions 15 psia and 120.0 °F to 40 psia and 140.0 °F

## 2.2 Compositional Analysis and Single Stage Flash Data of Bottomhole Sample 22999-IB (1.2)

Table 11: Compositional Analysis of Bottomhole Sample 22999-IB (1.2)

Component	MW <sup>1</sup>	Flashed Gas		Flashed Liquid		Reservoir Fluid	
	g/mol	wt %	mole %	wt %	mole %	wt %	mole %
CO2	44.01	3.08	3.11	0.00	0.00	0.07	0.55
H2S	34.08	*	*	*	*	*	*
N2	28.01	2.32	3.68	0.00	0.00	0.05	0.65
C1	16.04	10.53	29.20	0.00	0.00	0.23	5.14
C2	30.07	5.30	7.85	0.00	0.00	0.12	1.38
C3	44.10	16.57	16.72	0.02	0.15	0.38	3.07
i-C4	58.12	6.77	5.18	0.02	0.11	0.16	1.01
n-C4	58.12	17.33	13.26	0.06	0.42	0.44	2.69
i-C5	72.15	9.05	5.58	0.07	0.44	0.27	1.35
n-C5	72.15	9.11	5.62	0.10	0.57	0.29	1.46
C6	84.00	9.60	5.09	0.26	1.32	0.47	1.98
Myclo-C5	84.16	2.12	1.12	0.10	0.49	0.14	0.60
Benzene	78.11	0.17	0.09	0.01	0.04	0.01	0.05
Cyclo-C6	84.16	0.69	0.37	0.04	0.22	0.06	0.25
C7	100.21	4.06	1.80	0.42	1.77	0.50	1.78
Myclo-C6	98.19	0.82	0.37	0.13	0.58	0.15	0.54
Toluene	92.14	0.16	0.08	0.02	0.11	0.03	0.10
C8	114.23	1.64	0.64	0.65	2.42	0.67	2.11
C2-Benzene	106.17	0.03	0.01	0.04	0.14	0.04	0.12
m&p-Xylene	106.17	0.08	0.03	0.07	0.27	0.07	0.23
o-Xylene	106.17	0.01	0.01	0.02	0.10	0.02	0.08
C9	128.26	0.49	0.17	0.81	2.68	0.80	2.24
C10	134.00	0.06	0.02	1.07	3.41	1.05	2.81
C11	147.00	0.01	0.00	1.14	3.29	1.11	2.71
C12	161.00	0.00	0.00	1.28	3.39	1.26	2.79
C13	175.00	0.00	0.00	1.57	3.81	1.53	3.14
C14	190.00	0.00	0.00	1.63	3.64	1.59	3.00
C15	206.00	0.00	0.00	1.80	3.72	1.76	3.06
C16	222.00	0.00	0.00	1.79	3.43	1.75	2.83
C17	237.00	0.00	0.00	1.88	3.38	1.84	2.78
C18	251.00	0.00	0.00	1.94	3.29	1.90	2.71
C19	263.00	0.00	0.00	2.04	3.30	2.00	2.72
C20	275.00	0.00	0.00	1.91	2.96	1.87	2.44
C21	291.00	0.00	0.00	1.88	2.75	1.84	2.27
C22	305.00	0.00	0.00	1.90	2.65	1.86	2.18
C23	318.00	0.00	0.00	1.83	2.45	1.79	2.02
C24	331.00	0.00	0.00	1.76	2.26	1.72	1.86
C25	345.00	0.00	0.00	1.70	2.09	1.66	1.72
C26	359.00	0.00	0.00	1.69	2.00	1.65	1.65
C27	374.00	0.00	0.00	1.69	1.92	1.65	1.58
C28	388.00	0.00	0.00	1.71	1.87	1.67	1.54
C29	402.00	0.00	0.00	1.77	1.87	1.73	1.54
C30+	875.41	0.00	0.00	63.18	30.69	61.80	25.27
Calculated MW		44.49		425.23		358.14	
Mole Ratio		0.1762		0.8238			

<sup>1</sup>Katz and Firoozabadi MW data used; MWs of nC7,nC8 and nC9 are used for C7,C8 and C9\*H<sub>2</sub>S content below detectable limits by Gas Chromatography.

Table 12: Single Stage Flash of Bottomhole Sample 22999-IB (1.2) at Standard Conditions<sup>1</sup>

GOR	STO API Gravity	Measured STO Density	Measured STO MW	Vapor Gravity
SCF/STB	API	g/cm <sup>3</sup>	g/mol	Air=1
65.0	14.0	0.972	425.23	1.536

Table 13: Cn+ Properties of Reservoir Fluid Bottomhole Sample 22999-IB (1.2)

Cn+ Group	mole %	weight %	MW (g/mol)	Density (g/cm <sup>3</sup> )
C7+	80.72	97.52	432.59	0.973
C10+	72.62	95.03	468.59	0.982
C12+	67.10	92.87	495.60	0.988
C20+	44.07	79.24	643.78	1.021
C30+	25.27	61.80	875.41	1.068

Table 14: Flashed Gas Properties of Bottomhole Sample 22999-IB (1.2)

Air Content	0.670	mole %
Gas Specific Gravity	1.536	(Air=1)
Wet Gross Heating Value	2357	BTU/SCF
Dry Gross Heating Value	2399	BTU/SCF

<sup>1</sup>15 psia and 60.0 °F

Figure 2: Gas Chromatogram of Flashed Liquid of Bottomhole Sample 22999-IB (1.2)

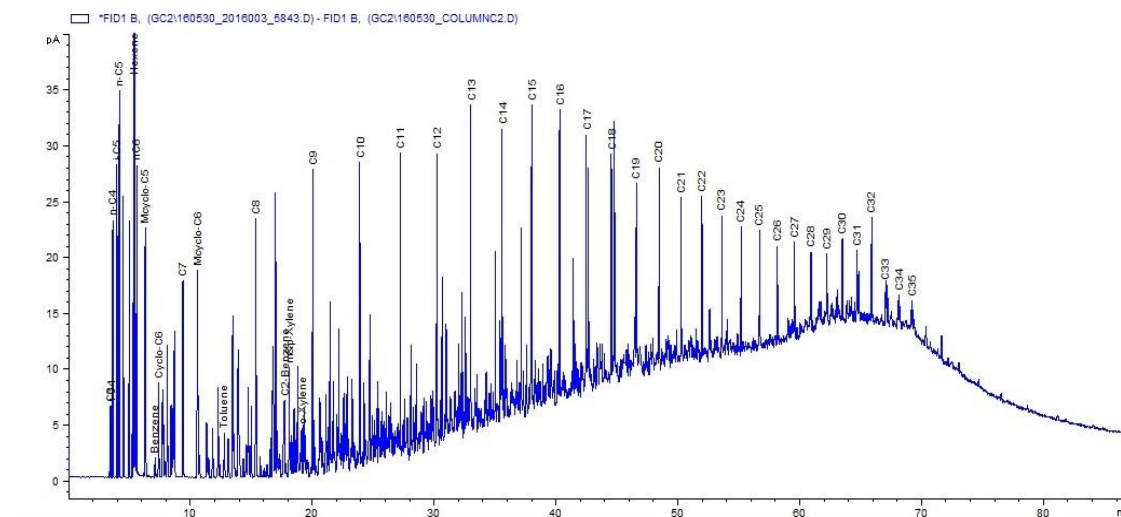
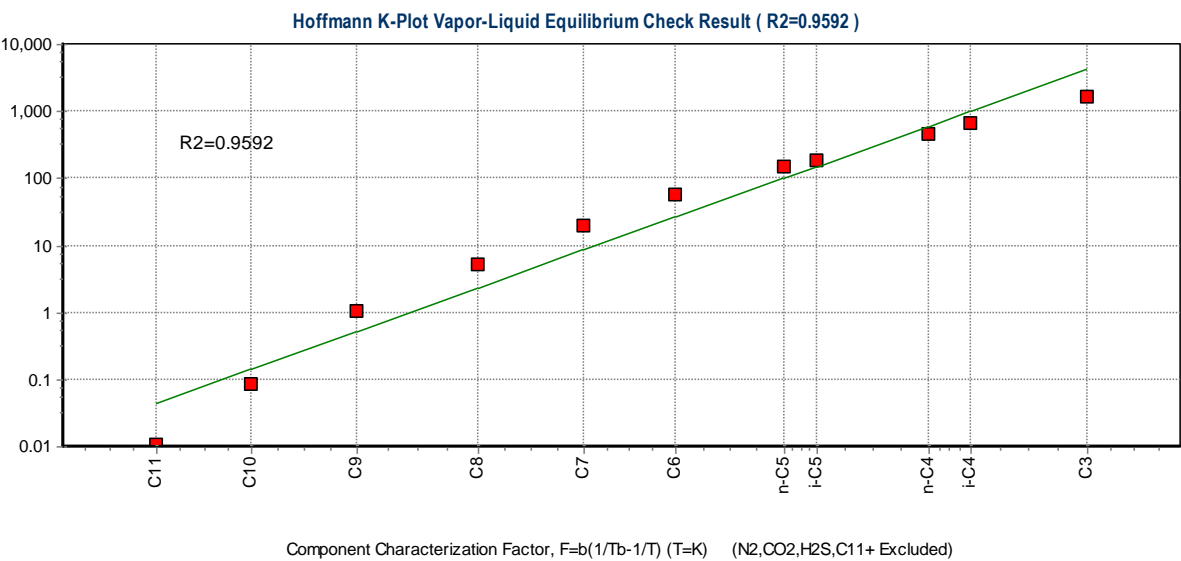


Figure 3: K-Plot Vapor Liquid Equilibrium Check for Bottomhole Sample 22999-IB (1.2)



## 2.3 Constant Composition Expansion at Tres of Sample 22999-IB (1.2)

The Constant Composition Expansion (CCE) experiment was performed by transferring a sub-sample of live reservoir fluid into the PVT cell at reservoir temperature (159.0 °F) and suitable working pressure (6015 psia). Sequential pressure decrease in steps and the corresponding volume changes are presented in Table 15. The intersection of the single-phase and two-phase lines in the P-V plot (Figure 4) along with visual observation was used to define the saturation pressure (214 psia). Fluid density is measured at a suitable working pressure and calculated at other single phase pressures using the measured relative volume.

Table 15: Constant Composition Expansion at Tres of Sample 22999-IB (1.2)

Bottomhole Sample 22999-IB, 4546 ft (1.2)

	Pressure	% Vliq/Vtot <sup>1</sup>	% Vliq/Vsat <sup>2</sup>	Relative Volume <sup>3</sup>	Liquid Density	Compressibility <sup>4</sup>	Y Function
	psia	%	%	Vr=V/Vsat	g/cm <sup>3</sup>	10 <sup>-6</sup> /psia	
	6015	100.00	97.25	0.972	0.954	4.10	
	4015	100.00	98.09	0.981	0.946	4.57	
<b>Pres</b>	<b>1887</b>	<b>100.00</b>	<b>99.11</b>	<b>0.991</b>	<b>0.936</b>	<b>5.12</b>	
	1315	100.00	99.40	0.994	0.933	5.28	
	1015	100.00	99.56	0.996	0.932	5.36	
	815	100.00	99.67	0.997	0.931	5.42	
	615	100.00	99.78	0.998	0.930	5.48	
	515	100.00	99.84	0.998	0.929	5.51	
	415	100.00	99.89	0.999	0.929	5.53	
	315	100.00	99.94	0.999	0.928	5.56	
	265	100.00	99.97	1.000	0.928	5.58	
<b>Psat</b>	<b>214</b>	<b>100.00</b>	<b>100.00</b>	<b>1.000</b>	<b>0.928</b>	<b>5.59</b>	
	210	99.50	99.97	1.005			4.62
	160	92.27	99.62	1.080			4.30
	110	80.02	99.26	1.241			3.96
	67	61.70	98.96	1.604			3.66
	41	47.53	98.81	2.079			3.95

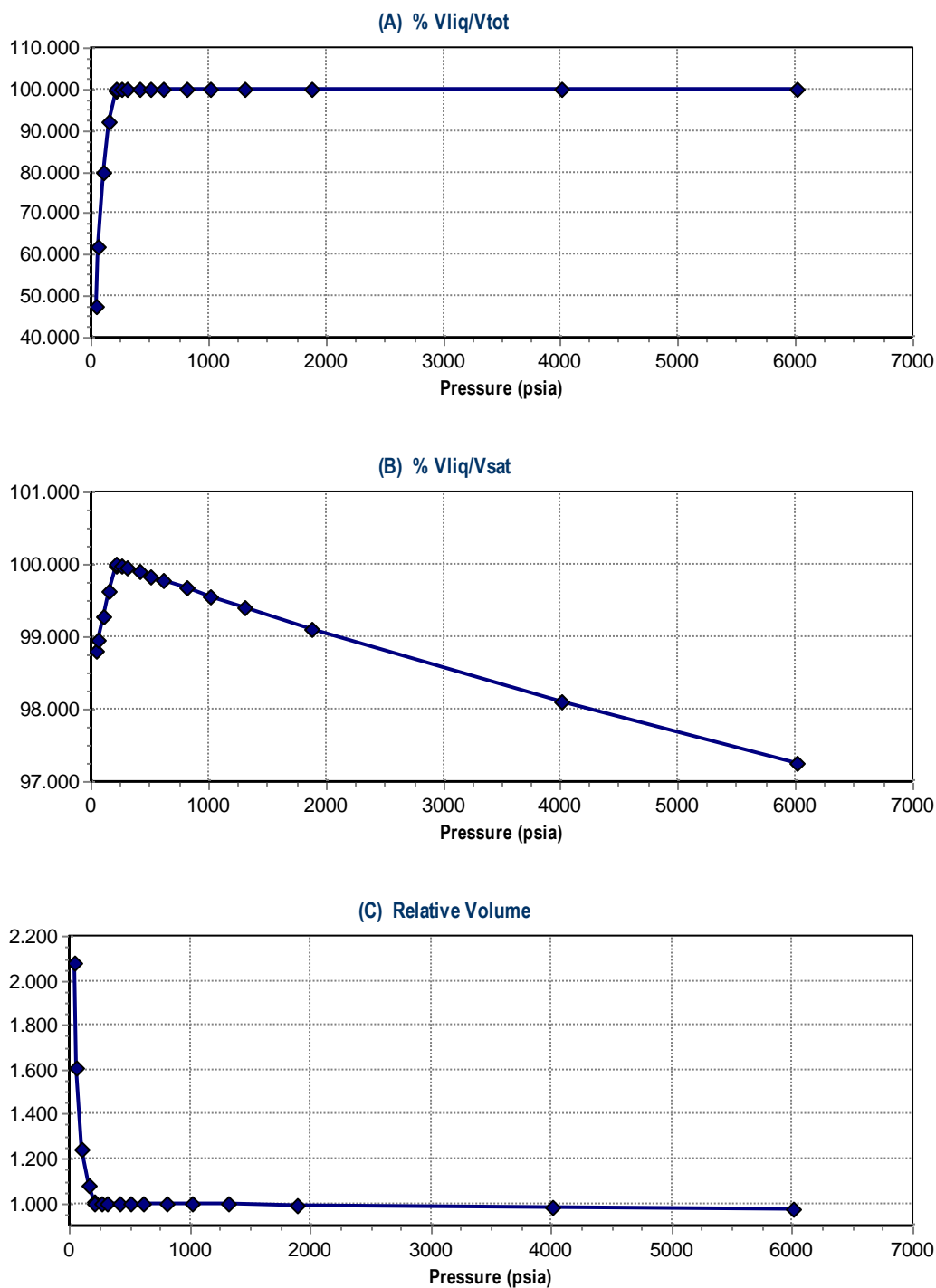
<sup>1</sup>Relative Liquid Volume1 : Liquid volume at indicated pressure per total volume

<sup>2</sup>Relative Liquid Volume2 : Liquid volume at indicated pressure per volume saturation pressure

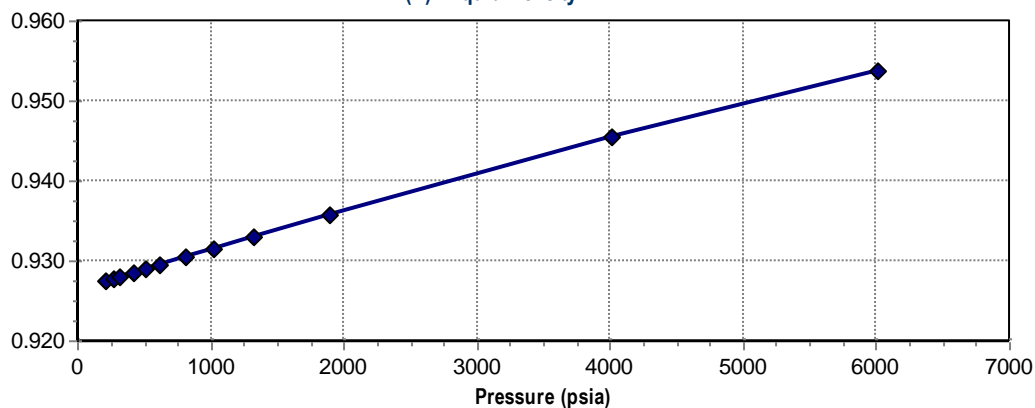
<sup>3</sup>Relative Volume, (Vr=V/Vsat) : Volume at indicated pressure per volume at saturation pressure

<sup>4</sup>Single phase compressibility; Co= -1/V\*dV/dP, V=f(P) is the curve fitting result based on single phase P,V data

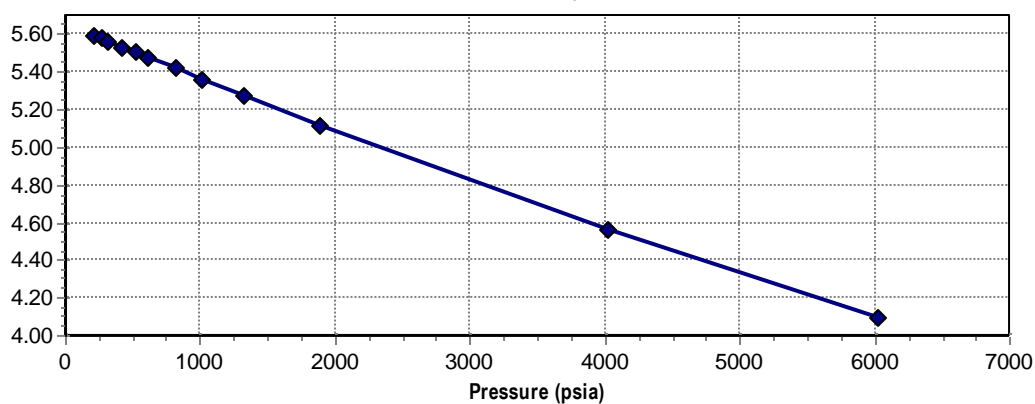
Figure 4: Graphs for Constant Composition Expansion at Tres of Sample 22999-IB (1.2)  
Bottomhole Sample 22999-IB, 4546 ft (1.2)



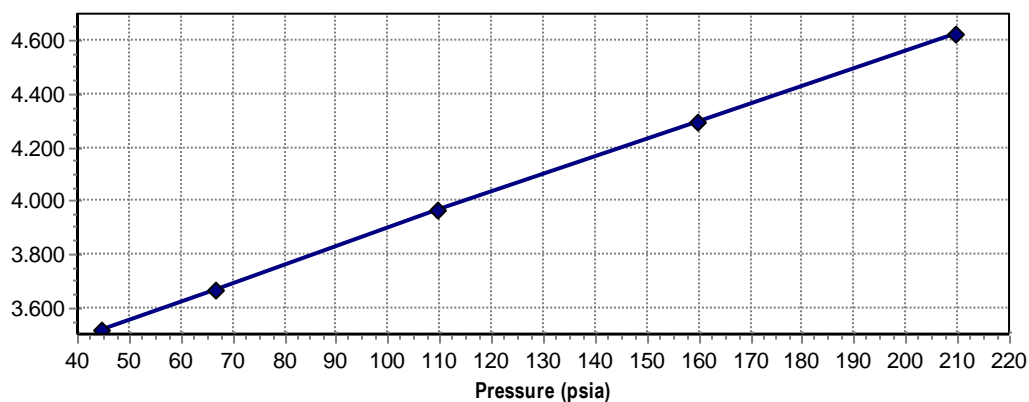
(D) Liquid Density



(E) Compressibility



(F) Y Function



## 2.4 Differential Liberation at Tres of Sample 22999-IB (1.2)

The differential liberation test provides fluid properties such as the oil density, solution gas to oil ratios and oil formation volume factor as a function of pressure depletion (Table 16 and Figure 5). Intermediate oil density values are calculated based on known mass and measured volume. The calculated differentially vaporized gas properties are in Table 16 and in Figure 5, and the measured composition of the differentially liberated gas at each differential pressure along with calculated molecular weights are in Table 16. Composition of the residual oil from the differential vaporization is also presented in Table 17. The API gravity of the residual oil was measured as 14.6.

Table 16: Differential Liberation at Tres of Sample 22999-IB (1.2)

Bottomhole Sample 22999-IB, 4546 ft (1.2)

	Pressure	Solution GOR <sup>1</sup>	Oil FVF <sup>2</sup>	Oil Density	Gas Z Factor <sup>3</sup>	Gas Formation Volume Factor <sup>4</sup>	Incremental Gas Gravity	Gas Viscosity <sup>5</sup>	Total FVF <sup>6</sup>
		Rsd	Bod		Z	Bg			Bt
	psia	SCF/STB	bbI/STB	g/cm <sup>3</sup>		ft <sup>3</sup> /scf	(Air=1)	cP	bbI/STB
	6015	53.7	1.029	0.954					
	4015	53.7	1.038	0.946					
<b>Pres</b>	<b>1887</b>	<b>53.7</b>	<b>1.049</b>	<b>0.936</b>					
	1315	53.7	1.052	0.933					
	1015	53.7	1.054	0.932					
	815	53.7	1.055	0.931					
	615	53.7	1.056	0.930					
	515	53.7	1.057	0.929					
	415	53.7	1.057	0.929					
	315	53.7	1.058	0.928					
	265	53.7	1.058	0.928					
<b>Psat</b>	<b>214</b>	<b>53.7</b>	<b>1.059</b>	<b>0.928</b>					<b>1.059</b>
	115	41.0	1.053	0.930	0.9824	0.150	0.884	0.012	1.393
	69	32.9	1.049	0.932	0.9850	0.251	0.969	0.011	1.981
<b>Residual</b>	<b>15</b>	<b>0.0</b>	<b>1.032</b>	<b>0.937</b>	<b>0.9916</b>	<b>1.181</b>	<b>1.426</b>	<b>0.010</b>	<b>12.330</b>

<sup>1</sup>Volume of gas at standard conditions per volume of residual oil at standard conditions

<sup>2</sup>Volume of oil at indicated pressure and temperature per volume of residual oil at standard conditions. Inaccuracies can be found in liquid measurements due to heavy oil behavior.

<sup>3</sup>Z calculated using equation  $Z = (V \cdot P / T) \cdot [T_{sc} / (V_{sc} \cdot P_{sc})]$

<sup>4</sup>Volume of gas at indicated pressure and temperature per volume of gas at standard conditions

<sup>5</sup>Viscosity calculated using method of Lee, Gonzales, et al. (SPE 75721)

<sup>6</sup>Total Formation Volume Factor

Figure 5: Graphs for Differential Liberation at Tres of Sample 22999-IB (1.2)

Bottomhole Sample 22999-IB, 4546 ft (1.2)

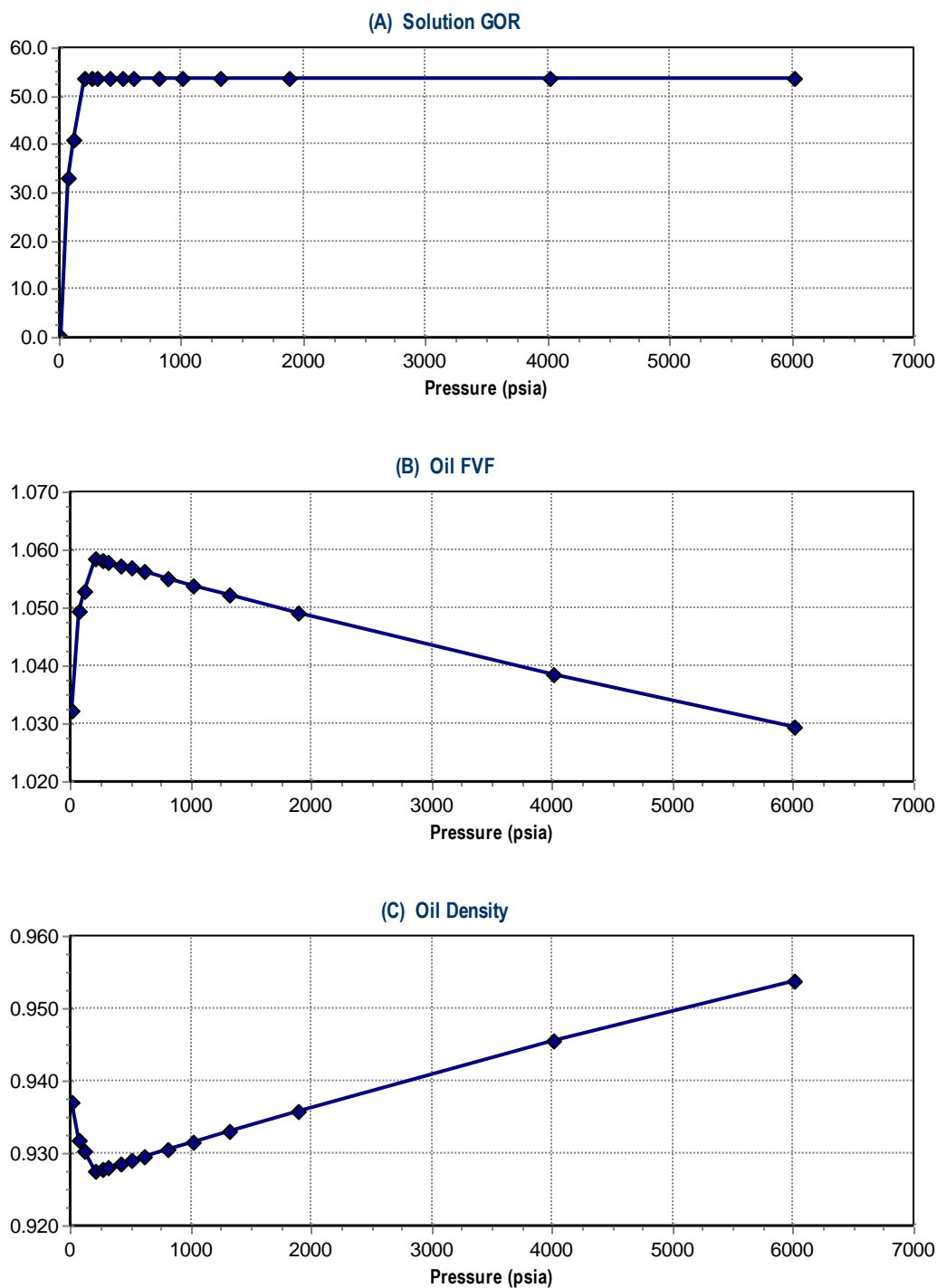


Figure 5: Graphs for Differential Liberation at Tres of Sample 22999-IB (1.2) (Cont.)

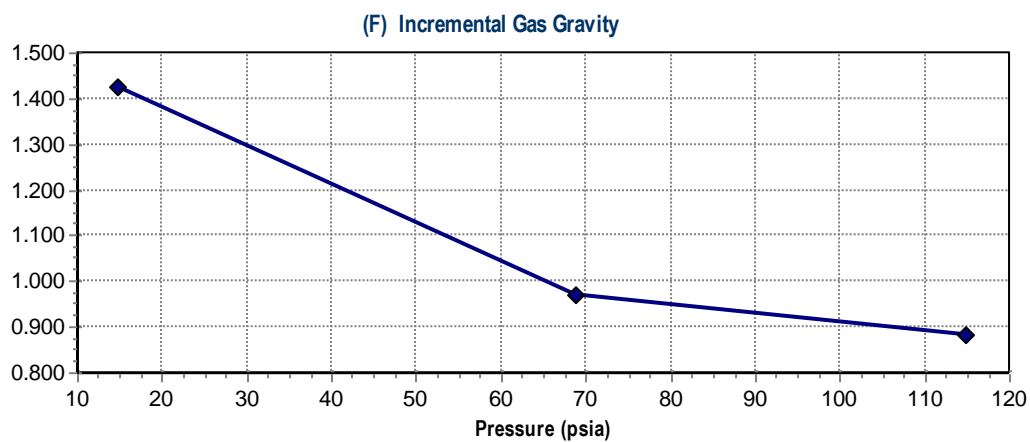
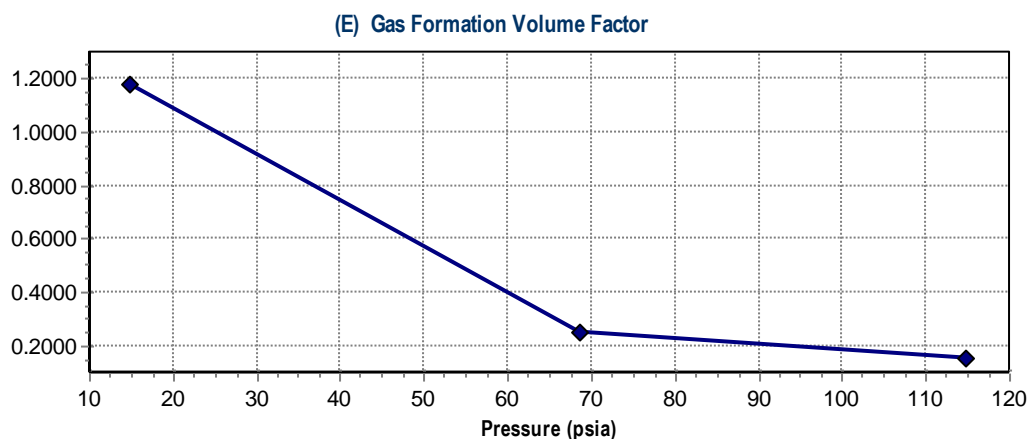
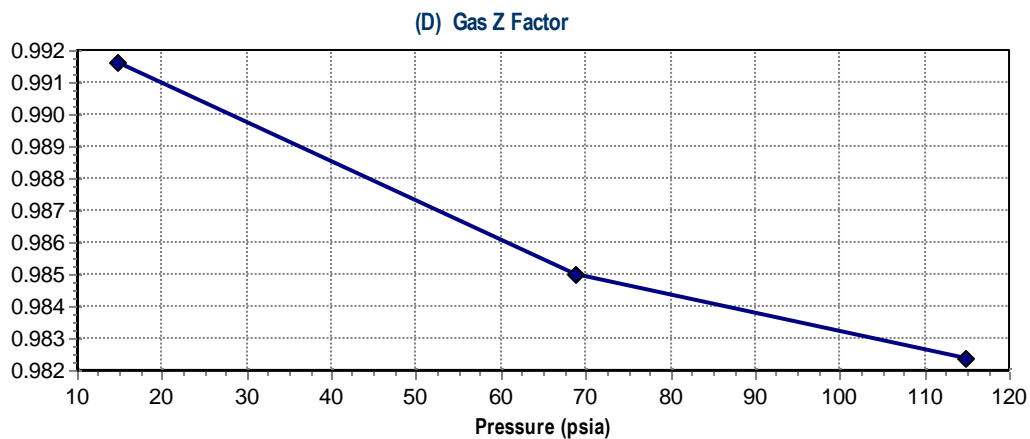


Figure 5: Graphs for Differential Liberation at Tres of Sample 22999-IB (1.2) (Cont.)

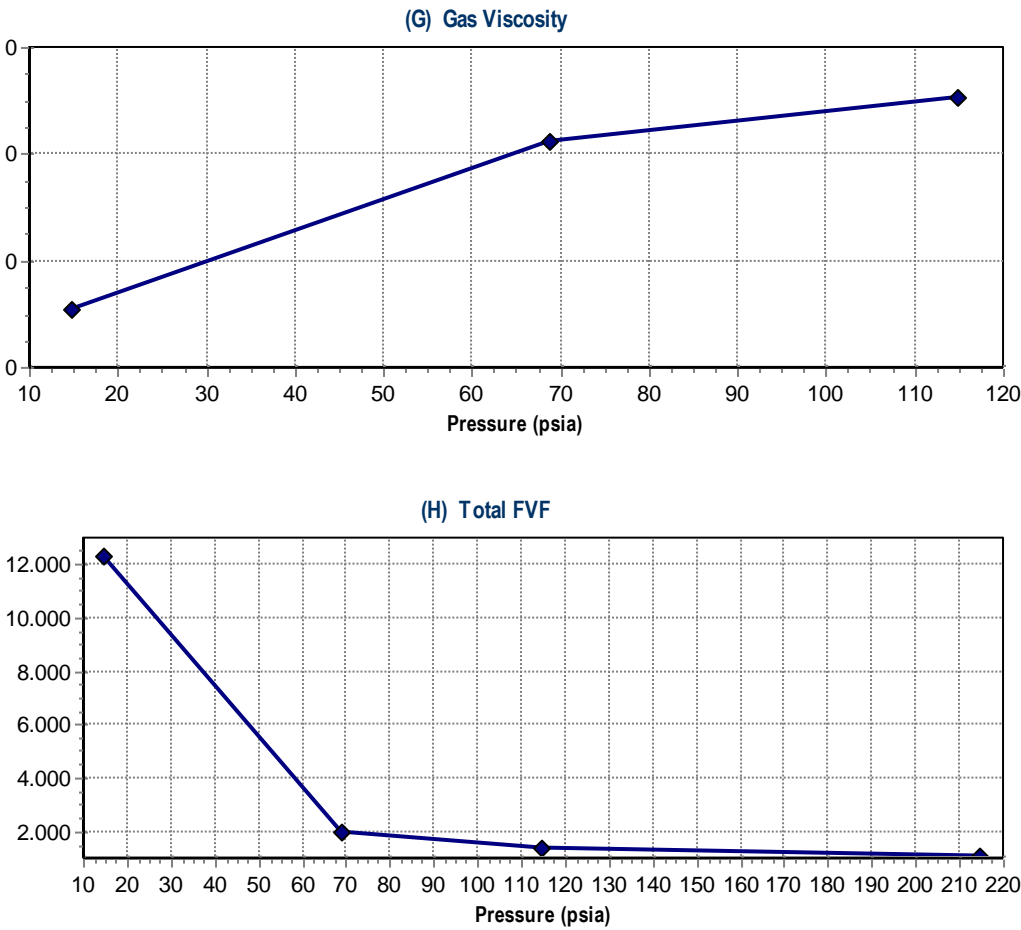


Table 17: Differential Liberation at Tres of Sample 22999-IB (1.2) - Vapor Compositions (mole%)  
Bottomhole Sample 22999-IB, 4546 ft (1.2)

Component	MW <sup>1</sup>	Vapor Compositions at Specified Pressure		Last Stage	
	g/mol	115 psia	69 psia	Vapor	Residual Oil
CO2	44.01	4.63	5.22	3.71	0.00
H2S	34.08	0.00	0.00	0.00	0.00
N2	28.01	11.85	6.15	1.72	0.00
C1	16.04	61.59	58.06	35.97	0.00
C2	30.07	7.37	9.51	8.28	0.00
C3	44.10	7.46	10.37	17.89	0.98
i-C4	58.12	1.29	1.89	4.54	0.52
n-C4	58.12	2.75	4.15	11.24	1.52
i-C5	72.15	0.85	1.30	4.21	0.90
n-C5	72.15	0.82	1.25	3.92	1.06
C6	84.00	0.57	0.85	3.24	1.92
Myclo-C5	84.16	0.15	0.23	0.88	0.60
Benzene	78.11	0.01	0.02	0.07	0.05
Cyclo-C6	84.16	0.05	0.08	0.32	0.26
C7	100.21	0.30	0.45	1.90	2.06
Myclo-C6	98.19	0.08	0.11	0.50	0.61
Toluene	92.14	0.01	0.02	0.08	0.11
C8	114.23	0.22	0.34	1.53	2.47
C2-Benzene	106.17	0.00	0.00	0.00	0.13
m&p-Xylene	106.17	0.00	0.00	0.00	0.24
o-Xylene	106.17	0.00	0.00	0.00	0.09
C9	128.26	0.00	0.00	0.00	2.74
C10	134.00	0.00	0.00	0.00	3.32
C11	147.00	0.00	0.00	0.00	3.14
C12	161.00	0.00	0.00	0.00	3.28
C13	175.00	0.00	0.00	0.00	3.61
C14	190.00	0.00	0.00	0.00	3.44
C15	206.00	0.00	0.00	0.00	3.45
C16	222.00	0.00	0.00	0.00	3.21
C17	237.00	0.00	0.00	0.00	3.15
C18	251.00	0.00	0.00	0.00	3.07
C19	263.00	0.00	0.00	0.00	3.07
C20	275.00	0.00	0.00	0.00	2.77
C21	291.00	0.00	0.00	0.00	2.57
C22	305.00	0.00	0.00	0.00	2.43
C23	318.00	0.00	0.00	0.00	2.26
C24	331.00	0.00	0.00	0.00	2.08
C25	345.00	0.00	0.00	0.00	1.93
C26	359.00	0.00	0.00	0.00	1.82
C27	374.00	0.00	0.00	0.00	1.76
C28	388.00	0.00	0.00	0.00	1.70
C29	402.00	0.00	0.00	0.00	1.72
C30+	875.41	0.00	0.00	0.00	29.96
Calculated MW (g/mol)		25.60	28.07	41.30	411.81
Specific Gravity (Air=1)		0.8838	0.9694	1.4261	
Wet Gross Heating Value (BTU/SCF)		1192	1400	2205	
Dry Gross Heating Value (BTU/SCF)		1213	1425	2245	

<sup>1</sup>Katz and Firoozabadi MW data used; MWs of nC7,nC8 and nC9 are used for C7,C8 and C9

## 2.5 Two-Stage Separator Test of Sample 23000-IB (1.3)

The multi-stage separator test provides fluid properties such as GOR, density and oil formation volume factor at separator test conditions (Table 18). The separator test conditions used are:

Bubble Point: 214 psia at 159.0 °F

Stage 1: 40 psia at 140.0 °F

Last Stage: 15 psia at 120.0 °F

The compositional analyses of the evolved gases and stock tank liquid are reported in Table 19.

Table 18: Two-Stage Separator Test of Sample 23000-IB (1.3)

Bottomhole Sample 22999-IB, 4546 ft (1.3)

	Pressure	Temperature	GOR <sup>1</sup>	GOR <sup>2</sup>	Separator Volume Factor <sup>3</sup>	Specific Gravity of Flashed Gas
			Rsf			
	psia	°F	scf/STB	scf/bbl	bbl/STB	(Air=1)
<b>Psat</b>	<b>214</b>	<b>159.0</b>			<b>1.055</b>	
	40	140.0	35.6	34	1.036	1.109
<b>Residual</b>	<b>15</b>	<b>120.0</b>	<b>10.0</b>	<b>10</b>	<b>1.023</b>	<b>1.532</b>

<sup>1</sup>Volume of gas at standard conditions per volume of stock-tank oil at standard conditions

<sup>2</sup>Volume of gas at standard conditions per volume of oil at indicated pressure and temperature

<sup>3</sup>Volume of oil at indicated pressure and temperature per volume of stock-tank oil at standard conditions

Figure 6: Graphs for Two-Stage Separator Test of Sample 23000-IB (1.3)

Bottomhole Sample 23000-IB, 4546 ft (1.3)

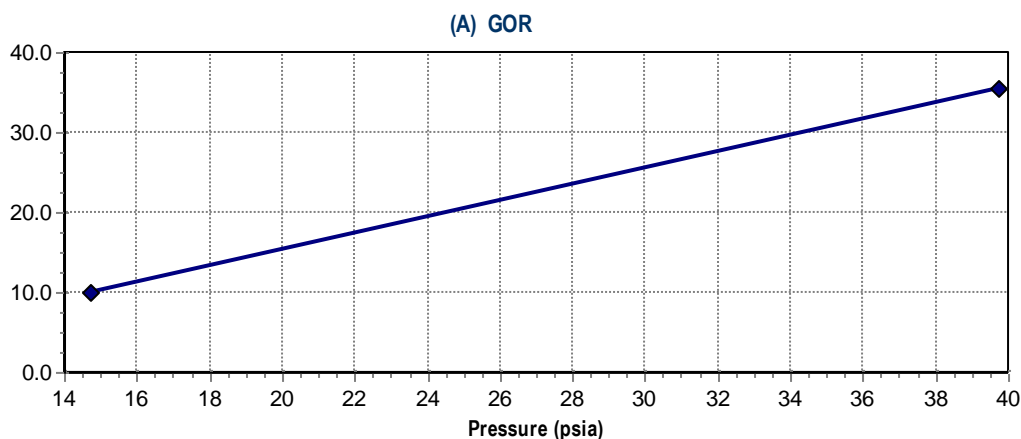


Figure 6: Graphs for Two-Stage Separator Test of Sample 23000-IB (1.3) (Cont.)

Bottomhole Sample 23000-IB, 4546 ft (1.3)

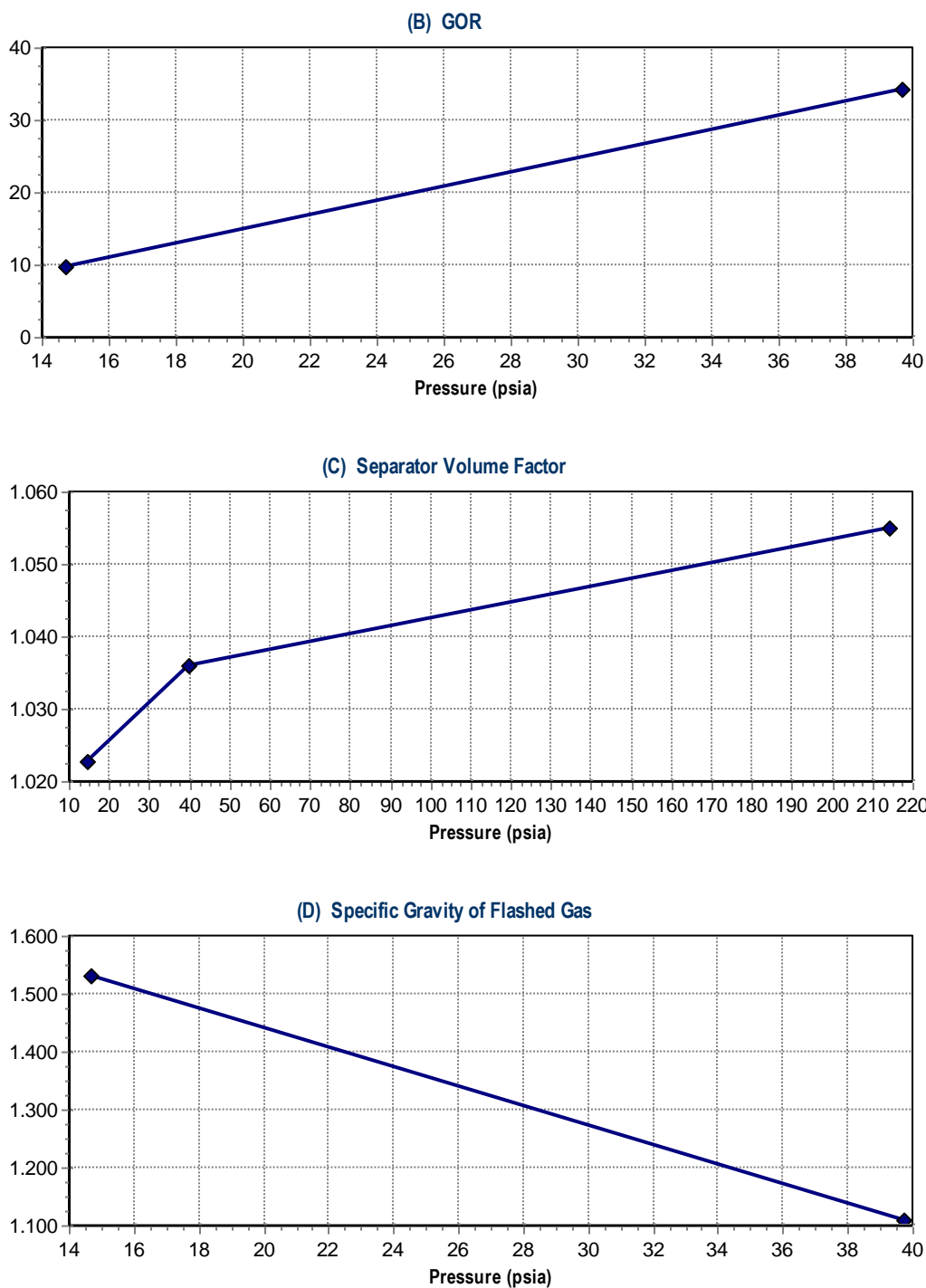


Table 19: Two-Stage Separator Test of Sample 23000-IB (1.3) - Vapor Compositions (mole%)  
Bottomhole Sample 23000-IB, 4546 ft (1.3)

Component	MW <sup>1</sup>	Vapor Compositions at Stage Conditions	Last Stage	
	g/mol	40 psia at 140.0 °F	Vapor	Residual Oil
CO2	44.01	5.21	3.59	0.00
H2S	34.08	0.00	0.00	0.00
N2	28.01	7.18	0.92	0.00
C1	16.04	47.38	25.33	0.00
C2	30.07	9.75	10.18	0.00
C3	44.10	14.07	23.08	1.11
i-C4	58.12	3.06	6.20	0.56
n-C4	58.12	6.55	14.18	1.75
i-C5	72.15	2.01	4.73	0.95
n-C5	72.15	1.88	4.46	1.12
C6	84.00	1.33	3.24	1.84
Mcylo-C5	84.16	0.33	0.81	0.65
Benzene	78.11	0.02	0.06	0.05
Cyclo-C6	84.16	0.10	0.26	0.27
C7	100.21	0.57	1.48	2.09
Mcylo-C6	98.19	0.14	0.38	0.63
Toluene	92.14	0.02	0.06	0.13
C8	114.23	0.40	1.04	2.51
C2-Benzene	106.17	0.00	0.00	0.13
m&p-Xylene	106.17	0.00	0.00	0.25
o-Xylene	106.17	0.00	0.00	0.10
C9	128.26	0.00	0.00	2.73
C10	134.00	0.00	0.00	3.41
C11	147.00	0.00	0.00	3.21
C12	161.00	0.00	0.00	3.25
C13	175.00	0.00	0.00	3.61
C14	190.00	0.00	0.00	3.42
C15	206.00	0.00	0.00	3.47
C16	222.00	0.00	0.00	3.21
C17	237.00	0.00	0.00	3.14
C18	251.00	0.00	0.00	3.09
C19	263.00	0.00	0.00	3.09
C20	275.00	0.00	0.00	2.82
C21	291.00	0.00	0.00	2.56
C22	305.00	0.00	0.00	2.49
C23	318.00	0.00	0.00	2.25
C24	331.00	0.00	0.00	2.11
C25	345.00	0.00	0.00	1.97
C26	359.00	0.00	0.00	1.82
C27	374.00	0.00	0.00	1.76
C28	388.00	0.00	0.00	1.72
C29	402.00	0.00	0.00	1.71
C30+	875.41	0.00	0.00	29.02
Calculated MW (g/mol)		32.11	44.38	404.88
Specific Gravity (Air=1)		1.1089	1.5324	
Wet Gross Heating Value (BTU/SCF)		1597	2385	
Dry Gross Heating Value (BTU/SCF)		1625	2427	

<sup>1</sup>Katz and Firoozabadi MW data used; MWs of nC7,nC8 and nC9 are used for C7,C8 and C9

## 2.6 Viscosity Test at Tres of Sample 23000-IB (1.3)

The viscosity of the reservoir fluid is measured using an EMV at reservoir temperature (159.0 °F). The pressure of the reservoir fluid is reduced in the single phase region and the viscosity measured at predetermined steps. The pressure of the reservoir fluid is then reduced to a predetermined pressure below saturation pressure, the evolved gas removed and the viscosity of the equilibrated oil measured. This process is repeated at selected pressure until atmospheric pressure is reached.

Table 20: Viscosity Test at Tres of Sample 23000-IB (1.3)

Bottomhole Sample 23000-IB, 4546 ft (1.3)

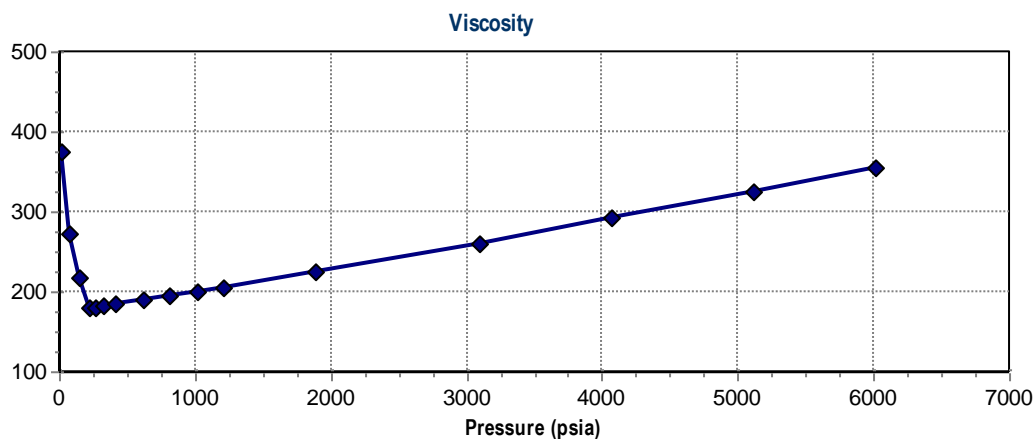
	Pressure	Viscosity
	psia	cP
	6015	356
	5111	326
	4065	292
	3093	261
<b>Pres</b>	<b>1887</b>	<b>225</b>
	1215	205
	1015	200
	818	194
	619	189
	415	184
	325	182
	271	181
<b>Psat</b>	<b>214</b>	<b>180</b>
(1)	145	217
(1)	70	272
<b>Residual<sup>(2)</sup></b>	<b>15</b>	<b>374</b>

<sup>1</sup>Note: The Viscosity results below bubble point for sample 23000-IB (1.3) at Tres (159.0°F) had standard deviation >1%. Hence the viscosity results may not be representative and should be used with caution at end user's discretion.

<sup>2</sup>Note: Stock Tank Viscosity measured by capillary Tube, Live points measured using EMV.

Figure 7: Graphs for Viscosity Test at Tres of Sample 23000-IB (1.3)

Bottomhole Sample 23000-IB, 4546 ft (1.3)



## 2.7 STO Viscosity Test at 15 psia of Sample 22999-IB (1.2)

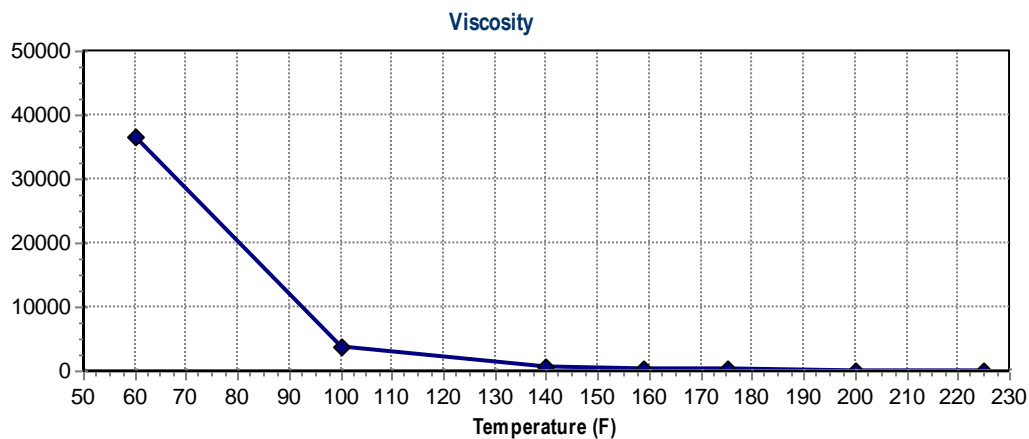
Table 21: STO Viscosity Test at 15 psia of Sample 22999-IB (1.2)

Bottomhole Sample 22999-IB, 4546 ft (1.2)

	Temperature	Viscosity
	°F	cP
	60.0	36629
	100.0	3816
	140.0	744
	159.0	374
	175.0	220
	200.0	104
	225.0	54

Figure 8: Graphs for STO Viscosity Test at 15 psia of Sample 22999-IB (1.2)

Bottomhole Sample 22999-IB, 4546 ft (1.2)



## 2.8 Wax Content and SARA Analysis of Bottomhole Sample 22999-IB (1.2)

As requested by SINOPEC-PAM, atmospheric crude oil analysis were performed on the stock tank oil from bottomhole sample 1.2 (SSB 22999-IB). These analyses were performed by following standard methods as reference.

Table 22: Stock tank Oil Analysis

Sample number	Received number	Wax Content UOP 46-64	SARA ANALYSIS			
			Saturates	Aromatics	Resins	Asphaltenes
		Wt%	Wt%	Wt%	Wt%	Wt%
1.2	SSB 22999-IB	3.08	33.42	30.19	23.89	12.32

## 2.9 Viscosity Test at Tres of Sample 22872-IB (1.1)

The viscosity of the reservoir fluid is measured using an EMV at reservoir temperature (159 °F). The pressure of the reservoir fluid is reduced in the single phase region and the viscosity measured at predetermined steps.

Table 23: Viscosity Test at Tres of Sample 22872-IB (1.1)

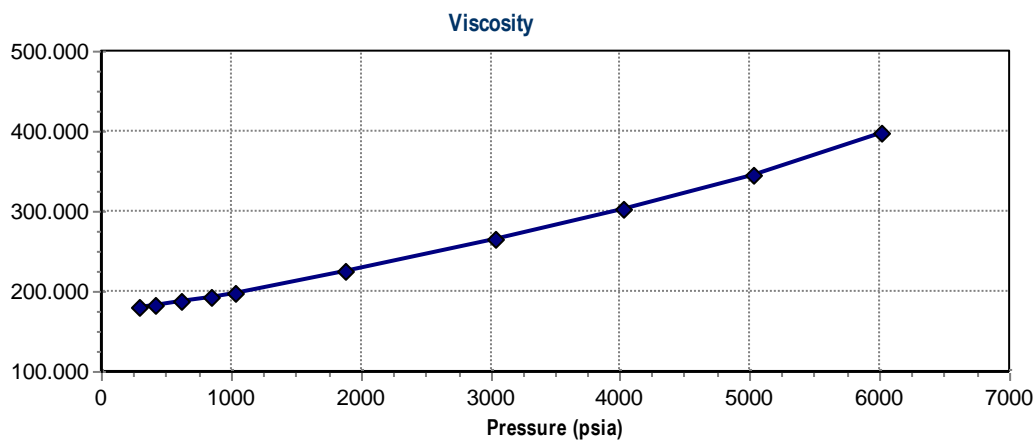
Bottomhole Sample 22872-IB, 4546 ft (1.1)

	Pressure	Viscosity
	psia	cP
	6016	396
	5031	345
	4030	302
	3031	265
<b>Pres</b>	<b>1887</b>	<b>226</b>
	1041	199
	847	193
	619	187
	420	182
	299	180

Note: Due to the heavy oil nature of sample 1.1 (SSB 22872-IB) it was not possible to perform viscosity measurement below bubble point pressure at Tres (159.0 °F).

Figure 9: Graphs for Viscosity Test at Tres of Sample 22872-IB (1.1)

Bottomhole Sample 22872-IB, 4546 ft (1.1)



## 2.10 True Boiling Point (TBP) Distillation on Flashed Liquid from Sample 22872-IB (1.1)

This distillation was performed with system i-Fischer HMS-500 using Spaltrohr column to obtain the boiling points curve from 75°C to 400°C.

In this procedure, a subsample is distilled in the above mentioned system and the fraction are collected every 25°C which are identified according to weight and density; with this data the mass balance is calculated and the boiling points vs %mass and boiling point vs %volume are generated.

The minimum ideal sample volume for TBP is 350cc but only 150cc was available from sample 1.1 (SSB 22872-IB), hence some cuts had insufficient volume to measured density. This ways two cuts were comingle to obtain the volume required for the measurement. This was observed for cut 125°C (comingle with 150°C) and cut 175°C (comingle with cut at 200°C).

Table 24: True Boiling Point (TBP) Distillation Data from Flashed Liquid from Sample 22872-IB (1.1)

Fraction	Temperature (°C)	%Mass	%Volume	%Accum. Mass	%Accum. Volume	Relative Density	
						20/4°C	API
Lights	15.0	0.3	0.4	0.3	0.4	--	--
1	75.0	1.5	2.1	1.8	2.5	0.7001	69.3
2	100.0	1.9	2.5	3.7	5.0	0.7403	58.5
3	150.0	2.2	2.9	5.9	7.9	0.7767	49.7
4	200.0	1.7	2.1	7.6	10.0	0.7958	45.4
5	225.0	2.0	2.4	9.6	12.4	0.8281	38.6
6	250.0	2.0	2.4	11.6	14.8	0.8428	35.6
7	275.0	2.7	3.2	14.3	18.0	0.8586	32.6
8	300.0	3.1	3.6	17.4	21.6	0.8691	30.6
9	325.0	3.9	4.5	21.3	26.1	0.8792	28.7
10	350.0	1.2	1.4	22.5	27.5	0.9048	24.2
11	375.0	4.0	4.5	26.5	32.0	0.9104	23.3
12	400.0	4.1	4.6	30.6	36.6	0.9184	21.9

Figure 10: True Boiling Point (TBP) Distillation of Sample 22872-IB (1.1) - %Mass

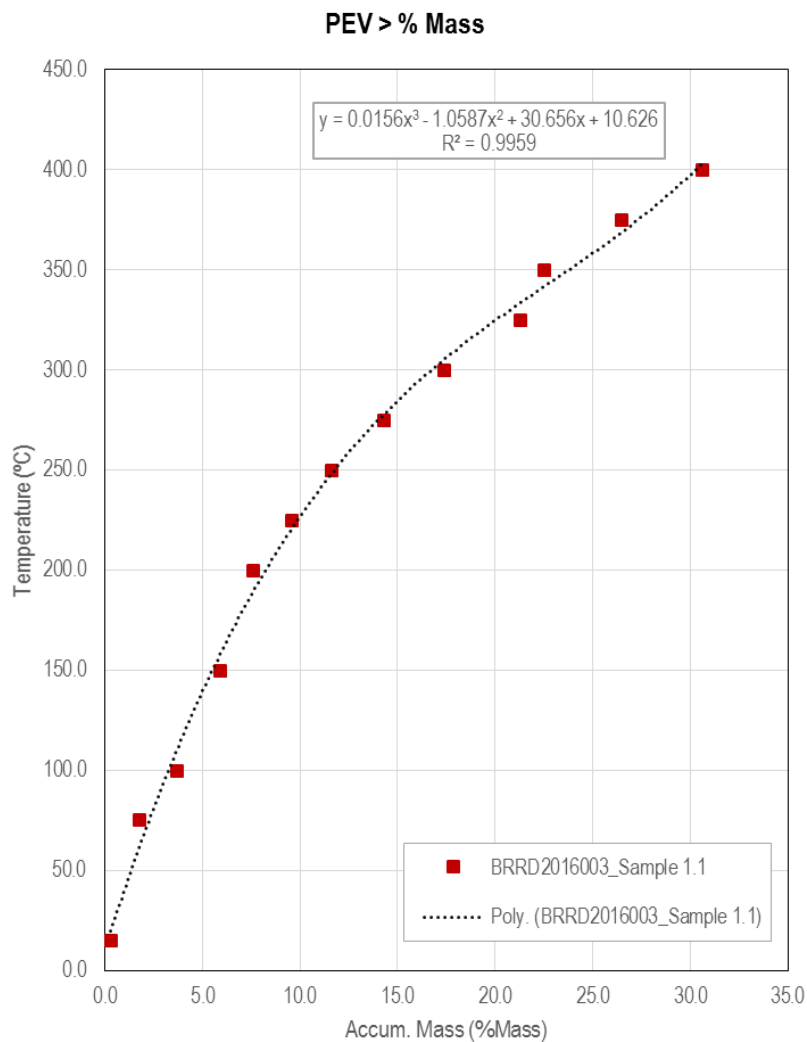
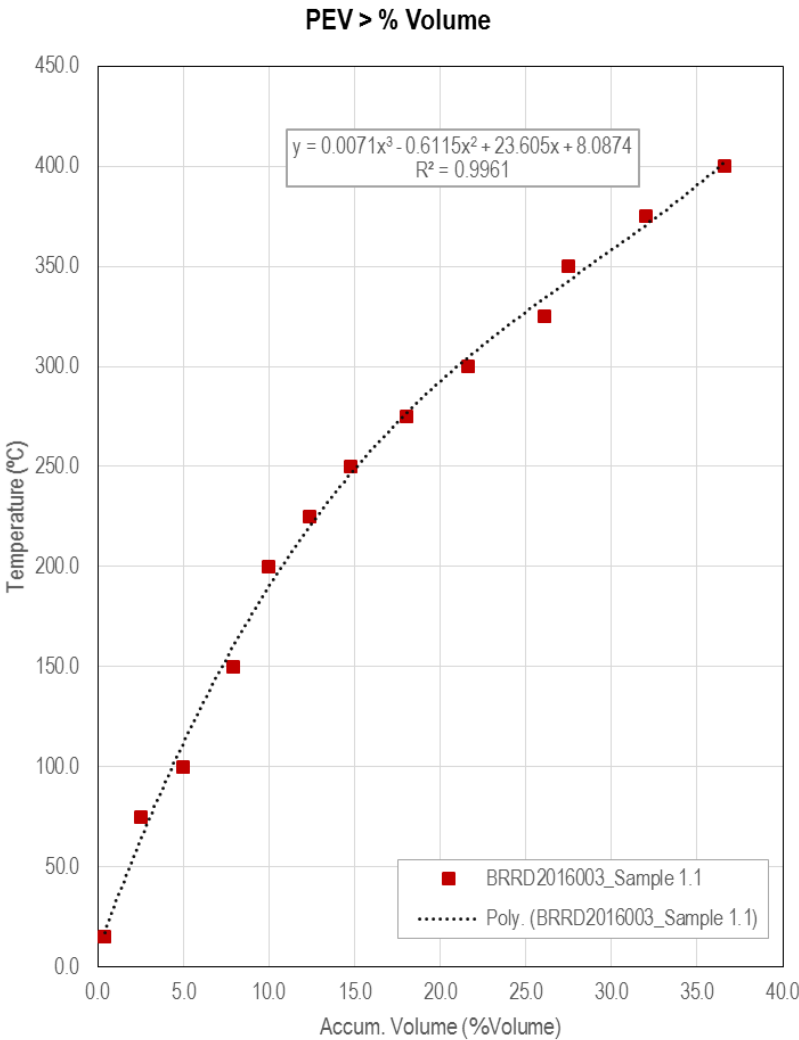


Figure 11: True Boiling Point (TBP) Distillation of Sample 22872-IB (1.1) - %Volume



### 3. Fluid Analysis Results of Bottomhole Sample 23000-IB, 4546 ft (1.3)

#### 3.1 Compositional Analysis and Single Stage Flash Data of Bottomhole Sample 23000-IB (1.3)

Table 25: Compositional Analysis of Bottomhole Sample 23000-IB (1.3)

Component	MW <sup>1</sup>	Flashed Gas		Flashed Liquid		Reservoir Fluid	
	g/mol	wt %	mole %	wt %	mole %	wt %	mole %
CO2	44.01	3.93	3.73	0.00	0.00	0.07	0.60
H2S	34.08	0.00	0.00	0.00	0.00	0.00	0.00
N2	28.01	2.91	4.34	0.00	0.00	0.05	0.70
C1	16.04	12.37	32.27	0.00	0.00	0.23	5.22
C2	30.07	5.87	8.17	0.00	0.00	0.11	1.32
C3	44.10	17.68	16.78	0.02	0.18	0.34	2.86
i-C4	58.12	6.97	5.02	0.02	0.11	0.14	0.91
n-C4	58.12	17.54	12.63	0.05	0.40	0.37	2.38
i-C5	72.15	8.33	4.83	0.06	0.39	0.22	1.11
n-C5	72.15	8.12	4.71	0.08	0.48	0.23	1.17
C6	84.00	7.64	3.81	0.23	1.18	0.37	1.61
Myclo-C5	84.16	1.73	0.86	0.09	0.48	0.12	0.55
Benzene	78.11	0.15	0.08	0.01	0.05	0.01	0.05
Cyclo-C6	84.16	0.58	0.29	0.04	0.22	0.05	0.23
C7	100.21	3.13	1.31	0.40	1.71	0.45	1.65
Myclo-C6	98.19	0.81	0.35	0.13	0.56	0.14	0.53
Toluene	92.14	0.16	0.07	0.02	0.12	0.03	0.11
C8	114.23	1.31	0.48	0.64	2.43	0.65	2.12
C2-Benzene	106.17	0.04	0.02	0.03	0.14	0.03	0.12
m&p-Xylene	106.17	0.10	0.04	0.06	0.26	0.07	0.23
o-Xylene	106.17	0.02	0.01	0.02	0.10	0.02	0.08
C9	128.26	0.51	0.17	0.80	2.69	0.79	2.28
C10	134.00	0.09	0.03	1.06	3.42	1.04	2.87
C11	147.00	0.01	0.00	1.13	3.31	1.11	2.78
C12	161.00	0.00	0.00	1.27	3.42	1.25	2.87
C13	175.00	0.00	0.00	1.54	3.80	1.51	3.18
C14	190.00	0.00	0.00	1.60	3.65	1.57	3.06
C15	206.00	0.00	0.00	1.76	3.69	1.73	3.10
C16	222.00	0.00	0.00	1.75	3.41	1.72	2.86
C17	237.00	0.00	0.00	1.84	3.36	1.81	2.82
C18	251.00	0.00	0.00	1.89	3.26	1.86	2.73
C19	263.00	0.00	0.00	1.98	3.26	1.94	2.73
C20	275.00	0.00	0.00	1.87	2.93	1.83	2.46
C21	291.00	0.00	0.00	1.83	2.72	1.80	2.28
C22	305.00	0.00	0.00	1.82	2.58	1.78	2.16
C23	318.00	0.00	0.00	1.74	2.37	1.71	1.99
C24	331.00	0.00	0.00	1.69	2.20	1.66	1.85
C25	345.00	0.00	0.00	1.62	2.03	1.59	1.70
C26	359.00	0.00	0.00	1.59	1.92	1.56	1.61
C27	374.00	0.00	0.00	1.58	1.82	1.55	1.53
C28	388.00	0.00	0.00	1.59	1.77	1.56	1.48
C29	402.00	0.00	0.00	1.62	1.74	1.59	1.46
C30+	875.41	0.00	0.00	64.53	31.84	63.34	26.65
Calculated MW		41.85		432.22		369.11	
Mole Ratio		0.1617		0.8383			

<sup>1</sup>Katz and Firoozabadi MW data used; MWs of nC7,nC8 and nC9 are used for C7,C8 and C9

Table 26: Single Stage Flash of Bottomhole Sample 23000-IB (1.3) at Standard Conditions<sup>1</sup>

GOR	STO API Gravity	Measured STO Density	Measured STO MW	Vapor Gravity
SCF/STB	API	g/cm <sup>3</sup>	g/mol	Air=1
57.7	13.8	0.973	467.30	1.445

Table 27: Cn+ Properties of Reservoir Fluid Bottomhole Sample 23000-IB (1.3)

Cn+ Group	mole %	weight %	MW (g/mol)	Density (g/cm <sup>3</sup> )
C7+	82.12	97.87	439.56	0.976
C10+	74.17	95.51	474.77	0.985
C12+	68.52	93.36	502.34	0.991
C20+	45.17	79.97	652.54	1.023
C30+	26.65	63.34	875.41	1.068

Table 28: Flashed Gas Properties of Bottomhole Sample 23000-IB (1.3)

Air Content	1.084	mole %
Gas Specific Gravity	1.445	(Air=1)
Wet Gross Heating Value	2192	BTU/SCF
Dry Gross Heating Value	2231	BTU/SCF

<sup>1</sup>15 psia and 60.0 °F

Figure 12: Gas Chromatogram of Flashed Liquid of SPMC 876 Bottomhole Sample 23000-IB (1.3)

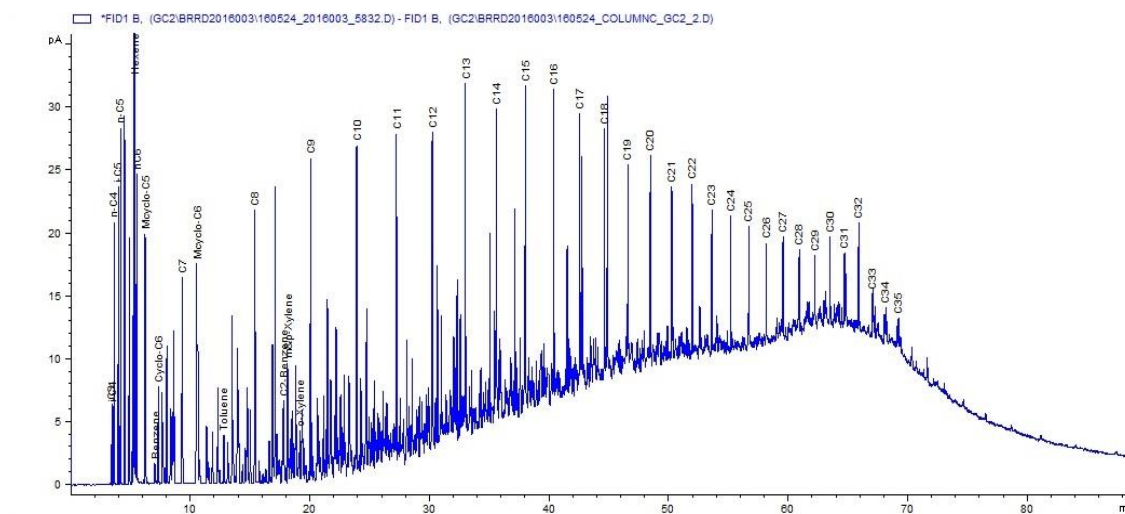
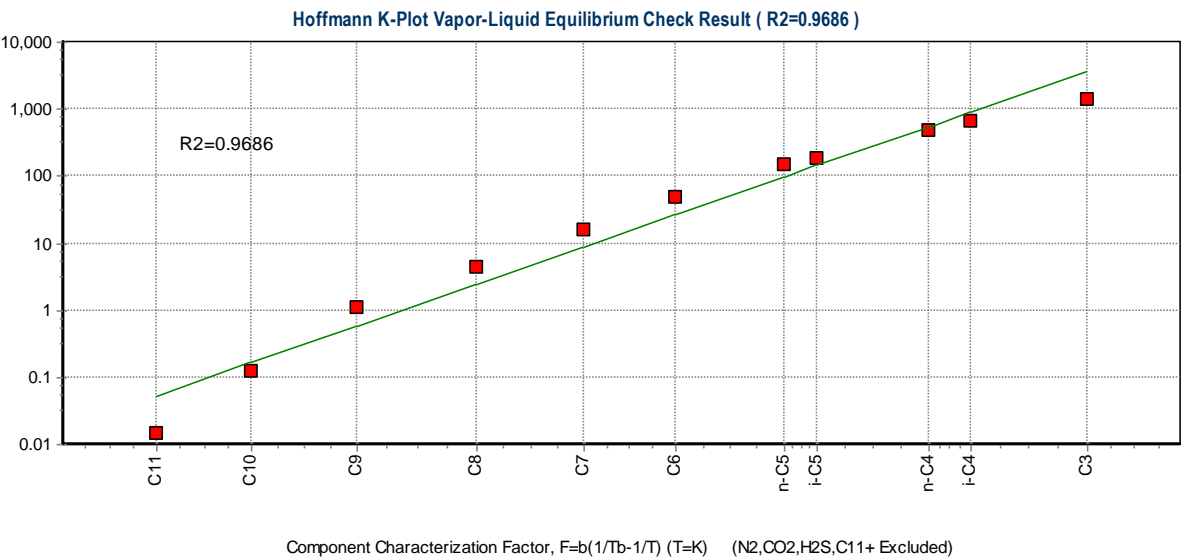


Figure 13: K-Plot Vapor Liquid Equilibrium Check for Bottomhole Sample 23000-1B (1.3)



## Appendix A: Nomenclature and Definitions

API Gravity	American Petroleum Institute Gravity
B <sub>g</sub>	Gas Formation Volume Factor
B <sub>o</sub>	Oil Formation Volume Factor
CCE	Constant Composition Expansion
CGR	Condensate Gas Ratio
CVD	Constant Volume Depletion
DL	Differential Liberation
FS & W	Free Sediment & Water
BS&W	Base Sediment & Water
FVF	Formation Volume Factor
GGR	Gas Condensate Ratio
n	Number of Moles
OBM	Oil Based Mud
P	Absolute Pressure
P <sub>sat</sub>	Bubble Point Pressure
PV	Pressure-Volume Method
P <sub>res</sub>	Initial Reservoir Pressure
R	Universal Gas Constant
RF	Reservoir Fluid
R <sub>s</sub>	Solution Gas Oil Ratio
T	Temperature
V	Volume
V <sub>r</sub>	Relative Volume
SBM	Synthetic Oil Based Mud
STL	Stock Tank Liquid
STO	Stock Tank Oil
WBM	Water Based Mud
Z	Gas Deviation Factor, Gas Compressibility Factor

**Dry Gross Heating Value** is the total energy transferred as heat in an ideal combustion reaction at a standard temperature and pressure in which all water formed appears as liquid.

**Wet Gross Heating Value** is the total energy transferred as heat in an ideal combustion reaction of water saturated gas at a standard temperature and pressure in which all water formed appears as liquid.

Molar masses, densities and critical values of pure components are from CRC handbook of Chemistry and Physics and those of pseudo components are based on corrected MW values proposed by Curtis Whitson in the SPE Journal paper # 12233 of August 1983

**Compressibility** in constant mass study is obtained from mathematical derivation of relative volume.

**Gas gravity** is calculated from composition using the perfect gas equation (Gas deviation factor, Z=1)

## Appendix B: Molecular Weight Data

Table 29: Molecular Weight Data of Katz and Whitson

No	Component	Katz	Whitson	Different
		g/mol	g/mol	
1	CO <sub>2</sub>	44.01	44.01	
2	H <sub>2</sub> S	34.08	34.08	
3	N <sub>2</sub>	28.01	28.01	
4	C <sub>1</sub>	16.04	16.04	
5	C <sub>2</sub>	30.07	30.07	
6	C <sub>3</sub>	44.10	44.10	
7	i-C <sub>4</sub>	58.12	58.12	
8	n-C <sub>4</sub>	58.12	58.12	
9	i-C <sub>5</sub>	72.15	72.15	
10	n-C <sub>5</sub>	72.15	72.15	
11	C <sub>6</sub>	84.00	84.00	
12	Mcylo-C <sub>5</sub>	84.16	84.16	
13	Benzene	78.11	78.11	
14	Cyclo-C <sub>6</sub>	84.16	84.16	
15	C <sub>7</sub>	96.00	96.00	
16	Mcylo-C <sub>6</sub>	98.19	98.19	
17	Toluene	92.14	92.14	
18	C <sub>8</sub>	107.00	107.00	
19	C <sub>2</sub> -Benzene	106.17	106.17	
20	m&p-Xylene	106.17	106.17	
21	o-Xylene	106.17	106.17	
22	C <sub>9</sub>	121.00	121.00	
23	C <sub>10</sub>	134.00	134.00	
24	C <sub>11</sub>	147.00	147.00	
25	C <sub>12</sub>	161.00	161.00	
26	C <sub>13</sub>	175.00	175.00	
27	C <sub>14</sub>	190.00	190.00	
28	C <sub>15</sub>	206.00	206.00	
29	C <sub>16</sub>	222.00	222.00	
30	C <sub>17</sub>	237.00	237.00	
31	C <sub>18</sub>	251.00	251.00	
32	C <sub>19</sub>	263.00	263.00	
33	C <sub>20</sub>	275.00	275.00	
34	C <sub>21</sub>	291.00	291.00	
35	C <sub>22</sub>	305.00	300.00	*
36	C <sub>23</sub>	318.00	312.00	*
37	C <sub>24</sub>	331.00	324.00	*
38	C <sub>25</sub>	345.00	337.00	*
39	C <sub>26</sub>	359.00	349.00	*
40	C <sub>27</sub>	374.00	360.00	*
41	C <sub>28</sub>	388.00	372.00	*
42	C <sub>29</sub>	402.00	382.00	*
43	C <sub>30+</sub>	750.00	750.00	

<sup>1</sup>MW value for C<sub>30+</sub> is industry average which does not reflect the actual MW values of C<sub>30+</sub> measured in this study.

<sup>2</sup>MW values of C<sub>7</sub>, C<sub>8</sub> and C<sub>9</sub> are for pseudo components which include BTEX.

## Appendix C: Procedure for Sample Restoration and Standard PVT Analyses

### Procedure for Sample Restoration and Integrity Check

#### Fluid Sample Restoration

Upon arrival, a sample bottle is connected to a high pressure displacement pump to check the opening pressures at ambient temperature. Next, the sample is conditioned at appropriate pressure and temperature conditions to restore it to its original conditions. For a bottomhole sample, the sample bottle is heated to Tres, pressurized to at least Pres and allowed to equilibrate under continuous rocking for five days unless specified otherwise. This process helps disperse/dissolve any asphaltene or wax particles that may have formed during sample cooling to ambient conditions (if any). Furthermore, if the sample had gone diphasic (vapour-liquid) during cooling, the restoration process will restore the sample to single phase conditions. For separator gas and oil samples, the oil sample is conditioned at the separator temperature and a pressure higher than the separator pressure for 24 hours to restore and homogenize the sample to its sampling conditions. The separator gas sample is heated in excess of separator temperature for a minimum of 24 hours to insure vaporization of any condensed components.

#### Compositional Analyses

Following the sample restoration described above, a sample of each equilibrated live fluid is isobarically displaced, one at a time, into a pre-cleaned and evacuated pycnometer for density, GOR, and C30+ compositional analysis using a flash procedure. In this technique, an accurately measured volume of the single-phase fluid is isobarically displaced into a pycnometer where its mass is measured. The pycnometer is then connected to a GOR single stage flash apparatus where the oil is flashed to ambient pressure and temperature conditions. Next, the evolved gas phase is circulated through the residual liquid for a period of time to achieve equilibrium between phases. Following circulation, the volume of equilibrium vapor and the mass of liquid remaining in the pycnometer are measured. The vapor phase is analyzed to C15, while the residual liquid is analyzed to C30+. From the measured composition and total mass of each phase, the composition of the original live oil may be calculated by mass balance. The test accuracy can also be controlled by mass balance. Alternatively a controlled direct flash process to ambient conditions but not controlling the mass balance is used under certain conditions depending on the measured GOR.

The compositional analysis of gaseous mixtures is performed using two separate gas analysis detectors: one with a natural gas configuration and the other with an extended gas configuration. The natural gas configuration consists of packed columns, a Thermal Conductivity Detector (TCD) detector and uses helium as a carrier gas. The detection range covers N2, CO2, H2S, C1 to nC4. The extended gas configuration consists of a capillary column, a Flame Ionization Detector (FID) detector and uses helium as a carrier gas. The temperature programming is non-isothermal (ramping to 240.0 °C) and the detection range covers C1 to C15 including the associated common isomers.

The compositional analysis of liquid samples is performed on a temperature programmed GC equipped with a different capillary column, an FID detector and uses helium as a carrier gas. The temperature programming is also non-isothermal (ramping to over 300.0 °C), and the detection range covers C3 to C29 and a lumped C30+. The analysis includes the associated common isomers. Identification and quantification of C2 is hampered with the co-elution of C1 and ethylene therefore cannot be guaranteed and is therefore omitted.

The liquid GC utilizes a proprietary technology to determine hydrocarbon liquid carbon number distribution. For low C30+ fraction concentration (< 5 wt %), the GC is calibrated against ASTM D2887 Reference Gas Oil #2. The tuning parameter for this calibration is the C30+ fraction weight percent. A mean value of 2.5 wt % within a deviation of  $\pm 0.4$  wt % is considered acceptable as a control limit. A warning limit is set at  $2.5 \pm 0.6$  wt %, and the GC is completely overhauled and returned to proper operation if the measured ASTM standard C30+ concentration is registered outside these limits.

In much the same way, an internal standard reference crude is used for calibration in the high C30+ region. This standard has a mean C30+ weight percent of 32 wt% and a deviation of 1.8 wt % is considered an acceptable control limit. The warning limit for the reference crude is  $\pm 2.7$  wt %. All of the aforementioned standards are run on a regular basis and detailed records of the GC performance and overhauls are maintained and are provided to clients upon request. Similarly for heavier crude in the region of 52 wt% C30+ there is an additional internal 'heavy crude oil reference'. All compositional details C31 to C35 and C36+ are not controlled quantitatively but C30+ is.

Although the GC is calibrated with "real" crude oils, it cannot differentiate between n-alkanes and other paraffin groups for C6+ components. Only n-alkane peaks are identified and components between these peaks are lumped together into an overall carbon number grouping.

## Procedures for Standard PVT Analyses

### PVT CELL

Figure A.1 is a schematic of the visual PVT Cell employed for all PVT tests. The main body of the cell consists of a Pyrex tube housed inside a steel shell with vertical tempered glass plates to permit visual observation of the entire internal tube contents. The Pyrex glass tube is 15 cm long with an internal diameter of 3 cm. This translates into an effective working volume of approximately 120.0 cm<sup>3</sup>. A specially designed floating piston (described below) and a magnetically coupled impeller mixer are mounted inside the Pyrex tube to allow for mercury-free operation.

The volume, and hence the pressure of the fluids under investigation, are controlled by a variable volume displacement pump which allows for the injection or the removal of the transparent hydraulic fluid. The same transparent displacement fluid is connected to the outer steel shell to maintain a balanced (minimal) differential pressure on the Pyrex tube. Equilibration of the fluid under investigation is achieved by means of a magnetically coupled impeller mixer mounted on the bottom end cap. It should be noted that the bottom end cap is specially designed to achieve two main goals: (i) shield the cell contents from any magnetic effects/flux and (ii) provide for charging and sampling the test fluid.

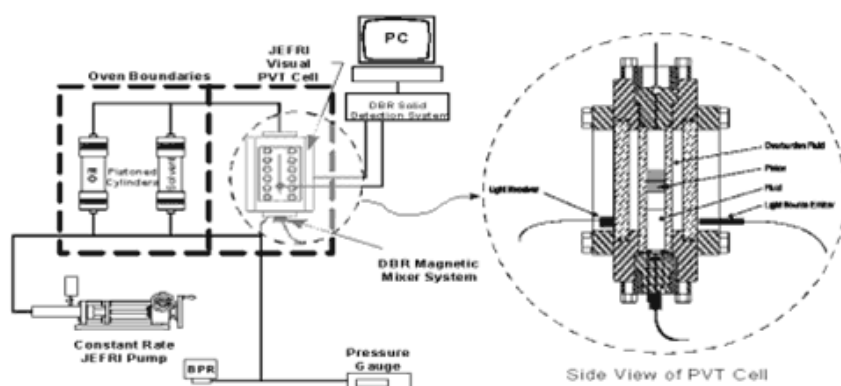


Figure A.1 - Schematic Diagram of Schlumberger PVT Cell Equipped with SDS

The PVT cell is housed inside a temperature controlled, forced air circulation oven. The cell temperature is measured with a platinum RTD and is displayed on a digital indicator with an accuracy of 0.1 °C. The cell pressure is monitored with a calibrated digital pressure gauge accurate to  $\pm 0.1$  % of full scale. The maximum operating pressure and temperature for this PVT system is 15000 psia and 200.0 °C, respectively.

### Constant Composition Expansion (CCE)

The CCE test is initiated by charging a known volume of the equilibrated fluid to the PVT cell at  $T_{res}$  and  $p_{res}$ . At these conditions, the fluid density is measured and the initial mass of the fluid in the cell is calculated. Thereafter, the fluid is expanded isothermally to a lower pressure, which is still in the single-phase region. The total system volume is measured after equilibration at this pressure, and this volume is used to calculate the single-phase density at this pressure. This procedure is repeated at a number of decreasing pressure steps until either a bubble point (formation of a gas phase) or dew point (formation of a liquid phase) is observed. Subsequently, the pressure is reduced further at selected pressure intervals into the two-phase region. At each pressure point, the vapor and liquid phases are equilibrated by mixing the cell contents for a minimum of 30 minutes, phase volumes are then measured and plotted as a function of pressure. The intersection of the single phase and two-phase lines in the p-V plot and the visual observations in the PVT cell are used to define the bubble point pressure. Visual observation and extrapolation of the liquid volume curve to 0% liquid volume are used to define the dew point pressure.

For gas condensate, a CCE test is conducted in the same way as that for black oil except a dew point pressure is determined through visual observation and the liquid drop out is measured.

**Differential Liberation (DL) for Bubble Point fluids**

A known mass of homogenized fluid is transferred into the PVT cell and equilibrated at a pressure in excess of the saturation pressure (bubble or dew point pressure) and reservoir temperature. The fluid is allowed to equilibrate at these conditions for about one hour. The single-phase fluid is then flashed to the first specified pressure condition of the differential liberation study and fully equilibrated. Subsequently, the equilibrium vapor and liquid volumes are measured using the cathetometer. A portion of the liberated vapor phase is isobarically displaced into an evacuated pycnometer for gravimetric density determination and compositional analysis. After collection of the vapor phase sample, the remaining portion of the vapor is isobarically displaced from the cell for a DL test. For the CVD test, the equilibrium volume is displaced until the total cell volume is equal to the original saturated fluid volume. In some case during a DL study, about 5.0 to 6.0 cm<sup>3</sup> of the liquid are charged into the Cambridge electromagnetic viscometer (see below) for viscosity evaluation after the vapor phase is displaced. Whether or not the viscosity is measured, the remaining liquid volume in the PVT cell is measured and this liquid is flashed to the next specified pressure condition. The procedure is then repeated for a series of specified pressure steps down to a predetermined abandonment pressure.

**Constant Volume Depletion (CVD) for Dew Point Fluids (Condensates) and some Volatile oils.**

A Constant Volume Depletion (CVD) test is performed for gas condensate instead of a DL for black oil. The CVD test is initiated by charging a known volume of the equilibrated fluid to the PVT cell at  $T_{res}$  and  $P_{res}$ . This volume is important as it is used to establish the reservoir volume to which the PVT cell contents are returned after each depletion step.

The CVD test involves reducing the system pressure from  $P_{res}$  to the first specified pressure step at which the fluid is equilibrated. Next, the resulting vapor and liquid volumes are determined. In addition, a portion of the equilibrium vapor is displaced from the top of the PVT cell and analyzed for its C30+ composition and density. Finally, additional vapor is displaced to return the fluid system to the initial single-phase reservoir volume as defined above. The system pressure is then reduced to the next specified depletion pressure step and the above measurements are repeated. In all, measurement procedures are completed at 6 to 10 depletion steps.

**Multi-Stage Separator Test (ST)**

A known mass of homogenized fluid is transferred into the PVT cell and equilibrated above the saturation pressure and reservoir temperature. The pressure and temperature are then set to the first specified separator condition and the system is allowed to fully equilibrate. Subsequently, the equilibrium vapor and liquid volumes are measured. A metered sample of equilibrium vapor is isobarically displaced into an evacuated pycnometer for gravimetric density determination and compositional analysis. The remaining portion of the vapor phase is then isobarically displaced from the PVT cell. Next, a metered sample of the liquid is isobarically collected into an evacuated pycnometer for gravimetric density and compositional analysis by the flash procedure.

After measuring the remaining liquid volume in the cell, the system conditions are adjusted to the second specified stage. Again the liquid and vapor phase volumes are measured and a sample of each fluid is taken for density determination and compositional analysis. This procedure is repeated a number of times until the last separator stage has been reached.

**Viscosity Measurements**

For the viscosity measurement of the reservoir fluid at selected pressures in single phase above the saturation pressure, and liquid phase during the DL test, a Cambridge Electromagnetic Viscometer (EMV) is used. In some special cases, a capillary viscometer is also used in addition to the EMV.

**Electromagnetic Viscometer (EMV)** Schlumberger laboratories use an EMV model SPL440 (See Figure A.2).

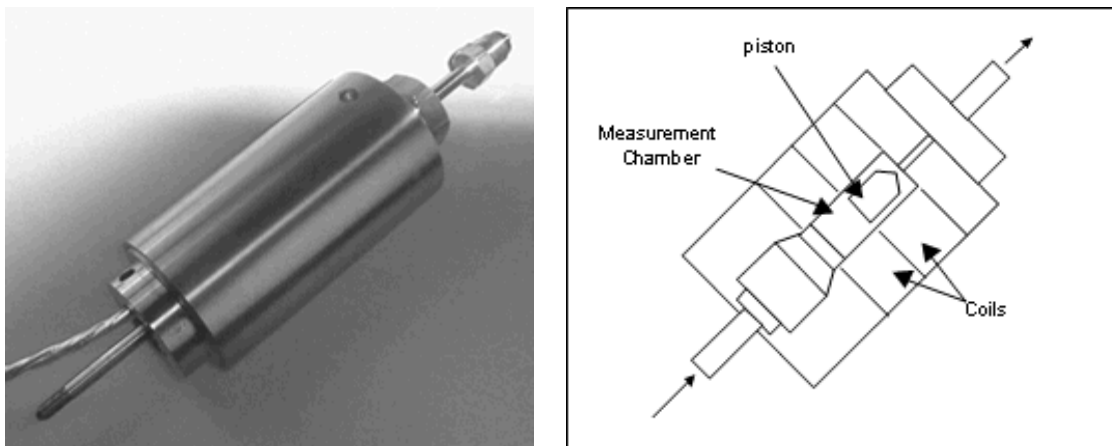


Figure A.2 - Schematic Diagram of Cambridge Electromagnetic Viscometer

Referring to the figure, the test fluid is charged to the pre cleaned and evacuated vessel and the piston is surrounded by fluid. Subsequently, the piston is moved inside the vessel by imparting a force on the piston using two electromagnetic coils inside the sensor body. After traveling the length of the test vessel, the piston is returned to its starting location by reversing the magnetic field of the electromagnet. The motion of the piston inside the vessel is impeded by viscous flow around the annulus between the piston and the measurement chamber wall. Viscosity is determined by measuring the piston transit time for a complete cycle of piston movement and comparing this to times obtained using calibrated standards.

### Capillary Viscometer (CV)

The CV is rated to 10000 psia and 190.0 °C. The CV set-up consists of two high pressure cylinders (50.0 cm<sup>3</sup> each) connected to a 183 m, 0.1 cm diameter capillary coil. A differential pressure transducer is used to monitor the pressure drop across the capillary coil. The fluid sample is pumped from one cylinder to the other through the capillary coil by an opposed pump (See Figure A.3). From the measured fluid flow rate and pressure drop, the viscosity can be determined using the Hagen-Poiseuille relationship for laminar flow in tubes, namely:

$$\mu = \frac{\Delta p}{Q} \left( \frac{\pi r^4}{8 L} \right) = \frac{\Delta p}{Q} k$$

Where  $\mu$  is the fluid viscosity,  $\Delta p$  is the pressure drop across the capillary tube of length,  $L$ , and a radius  $r$ , and  $Q$  is the volumetric flow rate. The tube constant  $k$  is determined by calibrating the viscometer using standards of known viscosity at test pressures and temperatures.

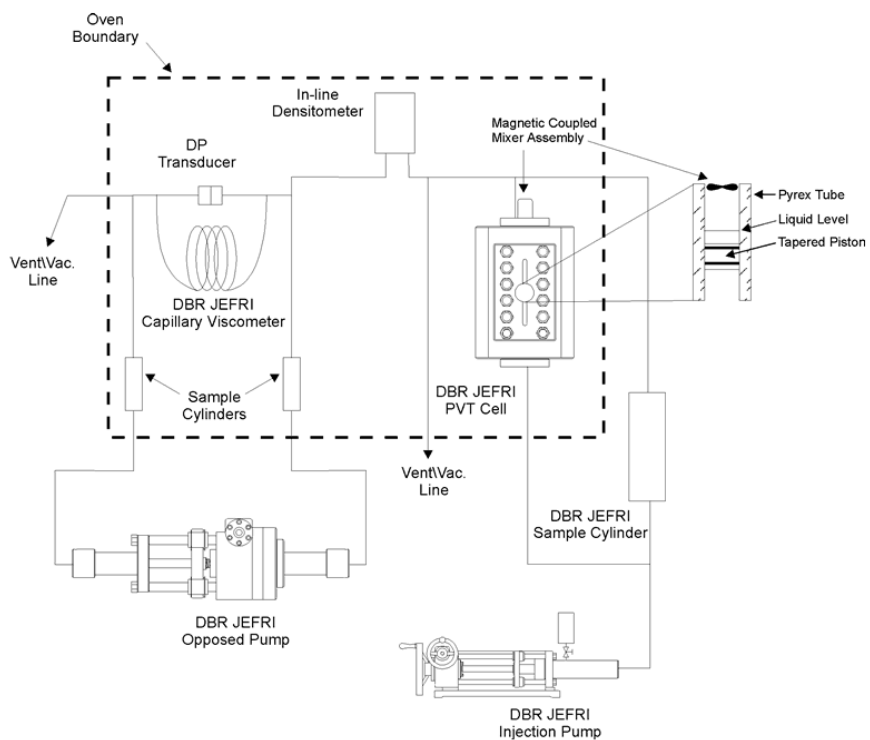


Figure A.3 - Schematic of Capillary Viscometer Setup