PVT MEASUREMENTS FOR EQUATION OF STATE TUNING

INTRODUCTION

Smart PVT is an analytical program that generates the fluid property data required for Equation of State (EOS) tuning at a reduced cost and turn-around. EOS modeling is commonly used to calculate oil and gas fluid properties at the different temperature and pressure conditions encountered in the reservoir, production and transportation facilities. In addition, EOS models are used to calculate "decontaminated" fluid properties from open-hole samples contaminated with Oil-Based drilling mud.

The Smart PVT program is the result of an industry sponsored examination of the optimum and minimum amount of PVT data required for EOS tuning. These trials demonstrated that a more focused program produces the needed data in less time and at a considerable savings compared to conventional PVT studies which are little changed from the 1950s.

EQUATION OF STATE (EOS) TUNING

Equations of State are used to describe fluid Pressure–Volume–Temperature (PVT) relationships mathematically. While there are hundreds of variations, their use has become much more common as standard versions became available in commercial computer programs.

The most common equations are based on the original "van der Waals" form which takes into account the forces between different molecules as well as the volume of the molecules themselves.

$$\left(P + \frac{a}{v^2}\right)(v - b) = RT$$

where: P – Pressure
T – Temperature
V – Molar Volume
R – Universal Gas Constant
a, b – Adjustable parameters depending on the chemical composition of the fluid

The standard practice in using an Equation of State to mathematically adjust the "a" and "b" parameters to best match a set of laboratory measurements. Once these parameters are "tuned", the EOS can be used to predict phase behavior and fluid properties at other pressure and temperature conditions.

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ADVANTAGES OF SMART PVT

The Smart PVT program determined that certain standard PVT procedures could be omitted from the tuning data set with no overall loss of accuracy in the resulting Equation of State. This allows for a reduced overall experimental program, providing substantial cost and time savings.

This is a key finding in today's Open Hole sampling environment as Equations of State are required to "decontaminate" PVT reports containing Oil and Synthetic Based drilling muds.

TECHNICAL DESCRIPTION

Included in this paper are modeling results for 15 reservoir fluids (8 oils, 7 gases) with widely varying fluid properties. Table 1 contains a summary of the measured PVT data and the blanks represent data not collected in the original PVT reports.

GeoMark ID	Pres *(psia)*	Tres *(°F)*	Psat *(psia)*	GOR *(scf/stb)*	API *(°F)*	Res μ *(cP)*
LA 942	14000	145	2735	759	29.4	0.7
LA 949	8891	189	6675	1947	36.3	
LA 952	6017	157	5150	967	28.1	1.14
LA 974	3308	102	2735	694	38.1	0.684
LA 981	3429	90	2553	833	36.6	0.84
LA 1098	7535	265	6800	1250	29.4	0.346
LA 1103	4736	180	4335	490	23.2	2.15
LA 1108	515	107	430	77	22.1	16.3
LA 915	13390	193	10750	3918	31.9	
LA 918	13203	186	11140	10847	39.1	
LA 926	15077	203	9250	4133	35.6	0.156
LA 927	13203	167	8898		40.8	
LA 995	3307	103	2980		46.9	0.022
LA 999	9552	173	8890		45.1	0.05
LA 1106	5234	206	5234	47444	47.4	0.0293

Table 1. Measured PVT Properties for Selected Reservoir Fluids used in Smart PVT Program

Each reservoir fluid composition and measured PVT data set were entered into Calsep's PVTsim Equation of State program which has an automated regression feature (www.calsep.com). Common to most commercial software packages, this routine automatically adjusts parameters to make EOS predictions match the laboratory measured data.

In this project, regressions were conducted with increasing amounts of PVT data to determine if some optimum suite of PVT tests, short of complete studies, would provide the necessary data for accurate modeling.

Table 2 is a set of percent error ranges between measured data and equation of state predictions for Sample ID LA 974, a black oil from the offshore Gulf of Mexico.

LA 974	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, DL	0 Flash, CCE, DL, ST
Sat. Pressure	15.90	11.08	0.15	0.44	0.29	1.76	2.27
SS GOR	1.44	1.01	0.56	1.44	0.29	1.73	2.31
SS Gas Gravity	6.30	5.83	5.23	5.23	5.23	4.99	5.11
SS Oil Density	0.12	0.12	0.00	0.96	0.36	2.28	2.87
SS FVF	1.23	1.23	0.92	0.69	0.92	1.69	1.84
CCE Rel. Vol.	2.78	2.06	0.42	0.50	0.45	0.50	0.55
CCE Compres.	11.26	9.90	7.57	7.53	7.54	8.83	9.19
CCE Y Function							
DL Oil FVF	0.66	0.64	0.96	0.92	0.92	1.06	1.07
DL Gas FVF	8.07	8.22	8.52	8.51	8.52	8.51	8.50
DL Solution GOR	7.60	4.13	6.08	7.01	5.30	4.17	3.65
DL Gas Gravity	2.16	2.10	1.98	1.99	1.95	17.37	2.01
DL Oil Density	0.54	0.57	0.85	0.81	0.96	2.36	2.85
DL Gas Z	1.50	1.47	1.40	1.40	1.40	1.42	1.40
ST GOR	9.96	9.58	14.18	14.36	13.68	13.85	13.38
ST Gas Gravity	1.57	2.33	3.53	3.56	3.43	3.71	3.66
ST Oil Density	0.98	1.10	1.27	1.17	1.36	2.26	2.79
ST Oil FVF	1.47	1.66	1.93	1.93	1.90	1.81	1.78
DL Oil Viscosity	9.20	15.73	18.03	14.96	24.44	4.80	4.76
DL Gas Viscosity	10.34	10.01	9.57	9.57	9.57	9.57	9.57

Table 2. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 974.

In this table, selected PVT parameters are shown vertically in the first column while the data sets used in tuning are provided across the header row. For example, the error ranges (starting with 15.9% for saturation pressure) in the first column represent EOS predictions with no tuning at all. Moving two columns to the right, the measured data from the “0 Flash” (or “Single-Stage Flash”) including GOR, FVF, API Gravity, etc. have been used to tune the model. In this column we can see most of the errors are reduced, although fairly slightly. Interestingly, the separator test GOR error (ST GOR) has actually increased from 9.96% to 14.18% with the inclusion of the 0-Flash data. This finding is important as it shows that it is not necessarily possible to reduce the errors on all parameters at the same time. Often as one group of predictions become more accurate, others trend in the opposite direction.

In general, as more data is added to the regression effort, we can see the errors are little changed, except for the oil viscosities shown in the second to last row. This suggests that some measured viscosities are required for more accurate tuning.

In summary, little or no benefit is seen in the accuracy of the EOS predictions as the Differential Liberation (DL) and Separator Test (ST) are included in the regression data set so long as some additional viscosities are included.

Tables 3 through 16 contain similar predictions for the remaining 7 oils and 7 gases. As for the first sample, little benefit is achieved in including the additional data sets from the Differential Liberation and Separator Tests. In fact, we're often left with worse overall predictions as the adjustable parameters become over specified with extra data.

LA 942	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, DL	0 Flash, CCE, no DL, ST
Sat. Pressure	5.70	0.00	0.00	2.12	1.65		1.54
SS GOR	3.29	3.43	3.56	2.77	3.43		3.16
SS Gas Gravity	4.99	4.88	4.76	4.99	5.35		5.23
SS Oil Density	0.68	0.68	0.57	0.11	1.14		0.68
SS FVF	0.29	0.36	0.15	0.95	0.80		0.80
CCE Rel. Vol.	1.30	1.14	1.14	1.04	0.99		1.00
CCE Compres.	8.26	8.35	11.11	10.31	9.77		10.22
CCE Y Function							
DL Oil FVF	0.87	0.82	0.84	0.75	0.79		0.76
DL Gas FVF							
DL Solution GOR	5.50	5.56	6.18	6.11	6.38		6.31
DL Gas Gravity	1.10	1.13	1.25	0.93	1.01		1.05
DL Oil Density	0.60	0.58	0.52	0.72	0.78		0.67
DL Gas Z	1.37	1.35	1.32	1.35	1.37		1.37
ST GOR	19.01	18.89	18.65	19.61	19.33		19.34
ST Gas Gravity	1.08	1.15	1.36	0.93	0.72		0.79
ST Oil Density	0.15	0.20	0.24	0.12	0.68		0.36
ST Oil FVF	1.65	1.62	1.71	1.45	1.56		1.48
DL Oil Viscosity	28.37	30.57	41.22	18.92	25.14		19.36
DL Gas Viscosity							

Table 3. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 942.

LA 949	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, DL	0 Flash, CCE, DL, ST
Sat. Pressure	41.90	29.56	0.03	1.78	29.56	1.05	29.56
SS GOR	0.46	0.51	0.46	7.70	0.51	7.50	0.51
SS Gas Gravity	1.22	1.22	0.61	1.52	1.22	1.37	1.22
SS Oil Density	5.46	5.46	5.22	1.90	5.46	1.78	5.46
SS FVF	1.11	0.11	3.72	0.22	0.11	0.11	0.11
CCE Rel. Vol.	11.43	9.45	4.35	4.12	9.45	3.99	9.45
CCE Compres.		43.89	52.71	68.16	43.89	67.40	43.89
CCE Y Function							
DL Oil FVF	7.98	5.24	4.37	0.86	5.24	1.13	5.24
DL Gas FVF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DL Solution GOR	26.56	15.10	15.68	2.70	12.44	5.89	26.46
DL Gas Gravity	2.00	2.77	4.92	2.02	2.63	2.13	2.77
DL Oil Density	15.63	13.37	7.93	3.73	13.37	3.64	13.37
DL Gas Z	3.65	3.58	3.43	3.31	3.25	3.31	3.58
ST GOR	17.97	14.02	4.41	8.53	14.02	6.63	14.02
ST Gas Gravity	0.08	0.16	0.57	0.74	0.16	0.74	0.16
ST Oil Density	5.73	5.48	4.45	1.86	5.48	1.86	5.48
ST Oil FVF	0.87	0.59	0.58	0.08	0.08	0.24	0.59
DL Oil Viscosity							
DL Gas Viscosity							

Table 4. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 949.

LA 952	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, DL	0 Flash, CCE, DL, ST
Sat. Pressure	11.46	2.58	0.00	1.32	2.80	1.53	0.02
SS GOR	3.00	2.79	2.90	20.99	1.55	2.90	2.07
SS Gas Gravity	1.47	1.17	1.47	1.47	1.32	1.17	1.32
SS Oil Density	1.59	1.59	1.48	19.34	2.84	1.59	0.68
SS FVF	0.63	0.21	0.28	5.86	0.70	0.49	0.14
CCE Rel. Vol.	3.35	2.21	1.85	2.87	1.28	1.70	1.83
CCE Compres.	11.85	17.90	15.31	16.35	16.21	14.47	15.12
CCE Y Function	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DL Oil FVF	1.09	0.63	0.77	4.14	0.68	0.82	0.64
DL Gas FVF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DL Solution GOR	8.53	14.08	16.83	37.74	12.49	16.65	12.02
DL Gas Gravity	4.12	4.11	4.11	4.08	3.96	3.77	3.91
DL Oil Density	1.14	0.65	0.48	13.80	3.16	0.52	0.67
DL Gas Z	1.45	1.49	1.47	1.43	1.53	1.51	1.51
ST GOR	48.54	56.18	57.86	75.98	54.89	58.20	55.13
ST Gas Gravity	10.33	10.69	10.54	10.54	10.54	10.54	10.48
ST Oil Density	1.37	1.13	0.98	17.14	3.09	1.05	0.31
ST Oil FVF	1.47	1.72	1.81	2.63	1.69	1.88	1.75
DL Oil Viscosity	40.49	55.32	36.79	31.48	35.36	13.73	12.97
DL Gas Viscosity	3.33	3.31	3.48	3.48	3.40	3.24	3.45

Table 5. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 952.

LA 981	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, DL	0 Flash, CCE, DL, ST
Sat. Pressure	6.15	1.06	0.00	1.06	1.06	0.00	
SS GOR	1.08	0.72	0.60	0.72	0.84	0.60	
SS Gas Gravity	3.69	3.21	3.21	3.21	3.21	3.21	
SS Oil Density	0.09	0.03	0.03	0.03	0.09	0.03	
SS FVF	0.15	0.22	0.15	0.22	0.22	0.22	
CCE Rel. Vol.	1.02	1.35	1.46	1.35	1.35	1.47	
CCE Compres.	20.06	18.22	16.63	17.47	18.22	17.87	
CCE Y Function	14.83	10.48	9.67	10.48	10.48	9.70	
DL Oil FVF	1.39	1.16	1.08	1.16	1.16	1.11	
DL Gas FVF	2.06	2.01	2.01	2.01	2.01	2.00	
DL Solution GOR	11.16	7.02	6.29	7.02	7.02	6.21	
DL Gas Gravity	6.17	5.88	5.87	5.88	5.88	5.86	
DL Oil Density	0.73	0.66	0.61	0.66	0.66	0.63	
DL Gas Z	2.22	2.10	2.10	2.10	2.10	2.09	
ST GOR							
ST Gas Gravity							
ST Oil Density							
ST Oil FVF							
DL Oil Viscosity	26.85	11.34	11.09	11.34	11.34	4.41	
DL Gas Viscosity	3.19	3.23	3.29	3.23	3.23	3.29	

Table 6. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 981.

LA 1098	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, DL	0 Flash, CCE, DL, ST
Sat. Pressure	1.63	0.00	0.00	0.00	0.00	0.00	
SS GOR	1.60	1.60	1.60	1.60	1.60	1.68	
SS Gas Gravity	0.31	0.31	0.31	0.31	0.31	0.46	
SS Oil Density	0.80	0.80	0.91	0.80	0.80	0.68	
SS FVF	3.99	3.81	3.69	3.81	3.81	3.81	
CCE Rel. Vol.	1.96	1.70	1.76	1.70	1.70	1.66	
CCE Compres.	20.37	20.75	22.41	20.75	20.75	19.98	
CCE Y Function	10.13	11.43	12.07	11.43	11.43	11.08	
DL Oil FVF	2.95	3.56	2.42	3.56	3.56	4.61	
DL Gas FVF	0.95	0.95	0.97	0.95	0.95	0.94	
DL Solution GOR	12.37	15.51	9.60	15.51	15.51	19.98	
DL Gas Gravity	26.40	26.83	24.37	26.83	26.83	28.85	
DL Oil Density	3.38	3.11	3.11	3.11	3.11	3.12	
DL Gas Z	1.46	1.43	1.55	1.43	1.43	1.37	
ST GOR							
ST Gas Gravity							
ST Oil Density							
ST Oil FVF							
DL Oil Viscosity	35.86	31.20	57.75	31.20	31.20	21.55	
DL Gas Viscosity	8.32	8.63	7.57	8.63	8.63	9.24	

Table 7. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 1098.

LA 1103	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, DL	0 Flash, CCE, DL, ST
Sat. Pressure	13.68	3.76	0.00	3.76	3.18	0.00	
SS GOR	1.84	1.84	1.63	1.84	1.84	1.84	
SS Gas Gravity	1.79	1.63	1.47	1.63	1.63	1.63	
SS Oil Density	0.44	0.44	0.44	0.44	0.44	0.44	
SS FVF	1.30	0.98	0.73	0.98	1.06	0.81	
CCE Rel. Vol.	2.44	1.26	0.82	1.26	1.15	0.78	
CCE Compres.	1.48	3.67	6.29	3.67	2.92	5.50	
CCE Y Function	3.74	5.83	9.59	5.83	5.86	9.14	
DL Oil FVF	2.57	1.80	1.56	1.80	1.75	1.47	
DL Gas FVF	1.58	1.55	1.58	1.55	1.54	1.55	
DL Solution GOR	16.00	9.16	6.87	9.16	7.81	6.31	
DL Gas Gravity	5.12	5.13	5.12	5.13	5.16	5.16	
DL Oil Density	2.02	1.51	1.28	1.51	1.53	1.31	
DL Gas Z	1.98	1.97	2.02	1.97	1.95	1.96	
ST GOR							
ST Gas Gravity							
ST Oil Density							
ST Oil FVF							
DL Oil Viscosity	15.11	28.35	28.34	28.35	30.82	8.01	
DL Gas Viscosity	1.05	0.98	0.98	0.98	0.98	0.99	

Table 8. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 1103.

LA 1108	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, DL	0 Flash, CCE, DL, ST
Sat. Pressure	17.21	7.91	0.47	1.16	2.33	2.09	
SS GOR	7.79	9.09	7.79	10.39	6.49	10.39	
SS Gas Gravity	3.43	4.14	2.96	4.73	3.79	4.62	
SS Oil Density	0.54	0.43	0.22	0.54	2.82	0.54	
SS FVF	1.96	1.86	1.58	1.77	1.67	1.86	
CCE Rel. Vol.	2.73	1.30	0.37	0.52	0.57	0.56	
CCE Compres.	12.77	6.43	2.50	1.29	1.52	1.26	
CCE Y Function	13.94	5.95	3.27	3.00	3.38	2.96	
DL Oil FVF	1.80	1.67	1.40	1.62	1.54	1.62	
DL Gas FVF	2.14	2.11	2.15	2.08	2.10	2.08	
DL Solution GOR	37.20	33.71	25.62	30.74	28.37	31.10	
DL Gas Gravity	7.32	7.54	10.76	7.55	8.01	7.60	
DL Oil Density	1.23	1.14	1.22	1.02	4.28	1.05	
DL Gas Z	0.51	0.51	0.49	0.54	0.54	0.54	
ST GOR							
ST Gas Gravity							
ST Oil Density							
ST Oil FVF							
DL Oil Viscosity	54.06	72.05	78.13	77.25	71.39	103.46	
DL Gas Viscosity	8.59	8.59	9.49	8.83	8.83	12.30	

Table 9. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 1108.

LA 915	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, CVD	0 Flash, CCE, CVD, ST
Sat. Pressure	25.08	19.92	19.92	19.92	19.92		
SS GOR	12.91	12.91	12.91	12.91	12.91		
SS Gas Gravity	2.63	2.63	2.63	2.63	2.63		
SS Oil Density	5.43	5.43	5.43	5.43	5.43		
SS FVF							
CCE Rel. Vol.							
CCE Liq. Vol.							
CCE Z Factor							
CVD Liq. Vol.							
CVD % Produced							
CVD Z Factor							
CVD 2 Phase Z							
CVD Gas Viscosity							
CVD Gas Gravity							
ST GOR							
ST Gas Gravity							
ST Oil Density							
ST Oil FVF							

Table 10. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 915.

LA 918	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, CVD	0 Flash, CCE, CVD, ST
Sat. Pressure	32.79	26.22	0.16	4.68	3.07		
SS GOR	12.67	13.02	13.75	12.10	8.23		
SS Gas Gravity	1.20	1.35	1.79	1.50	1.50		
SS Oil Density	4.75	4.75	4.63	3.67	0.67		
SS FVF							
CCE Rel. Vol.	10.92	7.99	1.05	1.17	1.19		
CCE Liq. Vol.	23.52	24.94	109.70	38.80	45.70		
CCE Z Factor	1.05	1.64	1.32	1.63	0.66		
CVD Liq. Vol.							
CVD % Produced							
CVD Z Factor							
CVD 2 Phase Z							
CVD Gas Viscosity							
CVD Gas Gravity							
ST GOR							
ST Gas Gravity							
ST Oil Density							
ST Oil FVF							

Table 11. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 918.

LA 926	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, CVD	0 Flash, CCE, CVD, ST
Sat. Pressure	10.02	3.69	0.00	0.08	0.00	5.88	2.84
SS GOR	2.18	2.06	1.96	2.01	1.81	1.89	1.98
SS Gas Gravity	2.73	2.73	2.60	2.73	2.60	2.60	2.60
SS Oil Density	1.06	0.94	0.94	0.94	0.83	0.94	0.94
SS FVF							
CCE Rel. Vol.	2.89	2.16	2.00	1.98	2.00	2.40	2.14
CCE Liq. Vol.	33.46	39.58	39.50	39.52	39.01	38.46	40.67
CCE Z Factor	0.54	0.51	0.93	0.75	0.74	1.03	0.98
CVD Liq. Vol.	21.75	20.87	19.99	20.26	19.88	19.40	20.55
CVD % Produced	16.73	27.56	35.63	35.11	35.23	24.95	30.69
CVD Z Factor	4.05	4.13	4.27	4.20	4.21	4.19	4.24
CVD 2 Phase Z	10.37	13.53	15.21	12.01	14.79	14.83	15.03
CVD Gas Viscosity	34.17	42.15	40.79	40.79	40.79	33.54	40.79
CVD Gas Gravity	9.05	6.63	5.62	5.76	5.80	6.79	5.91
ST GOR							
ST Gas Gravity	0.97	0.88	0.79	0.79	19.34	0.77	0.81
ST Oil Density							
ST Oil FVF	0.85	1.09	1.36	1.29	36.32	1.25	1.27

Table 12. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 926.

LA 927	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, CVD	0 Flash, CCE, CVD, ST
Sat. Pressure	6.33	0.08	0.02	0.08	4.53	0.00	0.00
SS GOR							
SS Gas Gravity	1.60	1.44	1.44	1.44	1.28	1.44	1.44
SS Oil Density	1.44	1.44	1.44	1.44	1.19	1.68	1.56
SS FVF							
CCE Rel. Vol.	3.64	1.41	1.42	1.41	1.38	1.41	2.14
CCE Liq. Vol.	32.75	58.90	59.52	58.90	27.67	51.92	40.67
CCE Z Factor	0.03	0.14	0.08	0.14	0.14	0.14	0.98
CVD Liq. Vol.	47.47	61.20	61.67	61.20	35.24	54.51	51.95
CVD % Produced	21.23	8.76	8.97	8.76	1.56	8.80	8.69
CVD Z Factor	0.69	0.70	0.70	0.70	0.69	0.70	0.67
CVD 2 Phase Z	1.62	1.55	1.38	1.55	1.60	1.55	1.46
CVD Gas Viscosity	6.59	7.58	7.58	7.58	7.58	7.58	7.58
CVD Gas Gravity	7.42	7.82	7.79	7.82	8.26	7.91	7.95
ST GOR	20.08	19.87	19.87	19.87	22.46	19.82	19.72
ST Gas Gravity	4.61	4.61	4.61	4.61	4.47	4.57	4.55
ST Oil Density							
ST Oil FVF	1.44	1.39	1.39	1.39	1.55	1.38	1.43

Table 13. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 927.

LA 995	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, CVD	0 Flash, CCE, CVD, ST
Sat. Pressure	168.76	114.66	0.03	0.74	0.30		
SS GOR							
SS Gas Gravity							
SS Oil Density	29.26	31.78	41.49	28.75	0.00		
SS FVF							
CCE Rel. Vol.	81.89	64.15	1.11	0.85	0.94		
CCE Liq. Vol.	171.26	102.79	64.04	4.40	5.86		
CCE Z Factor	100.00	100.00	6.04	5.86	6.05		
CVD Liq. Vol.							
CVD % Produced							
CVD Z Factor							
CVD 2 Phase Z							
CVD Gas Viscosity							
CVD Gas Gravity							
ST GOR							
ST Gas Gravity							
ST Oil Density							
ST Oil FVF							

Table 14. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 995.

LA 999	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, CVD	0 Flash, CCE, CVD, ST
Sat. Pressure	1.99	0.00	0.00	7.18	5.40	0.00	
SS GOR							
SS Gas Gravity							
SS Oil Density	1.97	1.97	1.22	0.60	1.47	1.97	
SS FVF							
CCE Rel. Vol.	1.17	1.19	1.43	2.01	1.51	1.19	
CCE Liq. Vol.	104.89	115.73	228.40	43.24	55.70	114.62	
CCE Z Factor	1.46	1.43	2.21	1.50	1.59	1.43	
CVD Liq. Vol.	90.02	94.34	189.08	55.51	59.57	93.88	
CVD % Produced	5.39	8.42	9.26	6.60	5.48	8.42	
CVD Z Factor	1.32	1.29	1.72	1.37	1.40	1.29	
CVD 2 Phase Z	1.46	1.51	1.79	1.20	1.16	1.48	
CVD Gas Viscosity	7.46	6.81	6.31	7.87	7.87	6.81	
CVD Gas Gravity	9.41	9.30	7.58	10.05	9.94	9.34	
ST GOR							
ST Gas Gravity							
ST Oil Density							
ST Oil FVF							

Table 15. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 999.

LA 1106	None	Psat	0 Flash	CCE	0 Flash, CCE	0 Flash, CCE, CVD	0 Flash, CCE, CVD, ST
Sat. Pressure	2.27	0.19	0.00	0.19	5.04		
SS GOR	11.11	10.68	0.07	10.68	2.55		
SS Gas Gravity	1.38	1.38	0.31	1.38	0.15		
SS Oil Density	1.38	1.38	0.25	1.38	0.37		
SS FVF							
CCE Rel. Vol.	1.50	0.76	0.69	0.76	3.50		
CCE Liq. Vol.	112.75	103.15	44.18	107.56	15.04		
CCE Z Factor	0.51	0.58	0.55	0.58	0.70		
CVD Liq. Vol.							
CVD % Produced							
CVD Z Factor							
CVD 2 Phase Z							
CVD Gas Viscosity							
CVD Gas Gravity							
ST GOR							
ST Gas Gravity							
ST Oil Density							
ST Oil FVF							

Table 16. Comparison of errors between measured data and EOS predictions with increasing data used in model tuning for Sample LA 1106.

CONCLUSION

The modeling results demonstrate that as more data (including Differential Liberations, Constant Volume Depletions and Separator Tests) are added to the regression effort, errors between measured and predicted parameters are little changed. Other than the inclusion of some measured liquid viscosities, accurate tuning can be achieved with a single-stage flash and a Constant Composition Expansion.

With these findings, the condensed Smart PVT program is an intelligent choice when EOS modeling is applied. As PVT measurements not commonly used in EOS tuning are omitted, cost and time savings are realized. This is particularly useful when analyzing samples containing Oil/Synthetic Based drilling mud, as Equation of State models are required to calculate "contamination-free" fluid properties from laboratory measured data.