ABSTRACT

The thermodynamic behaviour of reservoir fluids is a function of temperature and particularly pressure. For gas condensate reservoirs, this data is needed to evaluate gas and condensate reserves and production for field development and surface facility design. The evaluations rely on accurate fluid description and then simulation of actual reservoir depletion experiments on representative samples using a PVT apparatus. Due to the high cost and time required for a complete PVT study, Equations-of-State (EOS), when properly tuned, offer an attractive approach for interpolating between measured points. It is the use of one such equation, the Peng- Robinson EOS (37), to predict the phase behaviour and depletion performance of several Trinidad gas condensates, which forms the heart of this thesis.

Trinidad's gas condensates are described as lean gases with field reported data of under 70 barrels of condensates per million cubic feet of gas and with a methane concentration greater than 85 %. The fourteen local samples studied were recombined from surface separator samples with gas oil ratio GOR, in the range 15, 000 to 75, 000 SCF/STB. The input data for the Equation-of-State predictions were determined from characterization procedures on these samples to obtain mole percent up to C_{20+} by gas chromatography, GC and specific gravity and molecular weight of fractions heavier than C_6 by True Boiling Point, TBP Distillation.

A new distillation apparatus was designed, fabricated and tested for separating the samples into fractions by heating at the respective boiling points of the normal paraffin hydrocarbon concerned. From performance tests, differences less than 6 % before and after distillation were obtained when known mixtures of pure components were separated. No such tests were found in the literature for commercial type apparatus for comparison. Depending on operational conditions, differences of 20 to 30 % between TBP and GC analyses, with reservoir fluids

have been reported. In this study, this difference was less than 10 %, which indicate that the apparatus was adequately designed and can be used for future reservoir characterization studies and further be tested to perform such studies beyond C_{19}, to as high as C_{30+}.

This work has characterized Trinidad condensates in terms of measured specific gravity, molecular weight and weighted average boiling point for the first time. The measured specific gravity and molecular weight of these Single Carbon Number, SCN Fractions were comparable with those published by Katz and Firoozabadi [39] and Whitson [41], with differences of less than 2 %; the latter was used as input data for calculating the EOS tuning parameters.

A new scheme for extending the composition of the C_{7+} (or last fraction) of Trinidad gas condensates with an average absolute deviation of less than 8 % between the predicted and experimental mole % up to C_{20+} is also presented. This scheme is different from those found in the literature in that it takes into account the break in the exponential relationship between mole % and molecular weight at C_{12} as observed with the local samples and does not require a partial analysis as suggested in literature. The proposed scheme was used for splitting the C_{20+} fraction for this study and can be used when extended analysis is not available. The technique used in developing this scheme can be applied to gas condensates in other geographical locations.

A high-pressure mercury injection system was designed and assembled for direct use with the gas condensate cell. This modification to the existing PVT apparatus isolated gas condensate studies from crude oil studies and also reduced the time and effort required for gas condensate studies by one third, in comparison to the previous arrangement. The PVT data used for tuning were dew point pressure, gas compressibility factor, liquid dropout and produced gas which were generated from constant volume depletion, CVD tests. The difficulty in determining dew point pressure from published methods, for these lean gases, led to the development of a novel technique, which does not require the use of a visual cell.

Preliminary studies with all samples indicated that the Peng-Robinson EOS can predict without tuning, dew point pressure, produced gas and relative volume, with a difference of less than 5 % The optimum number of components required for this prediction was determined by trial and error and varies from sample to sample. Gas compressibility factor was predicted with a difference of less than 5 % with an analysis to C_{11+} and beyond. Adjusting Binary Interaction Coefficient, BIC to match dew point pressure resulted in acceptable prediction of dew point pressure, produced gas and gas compressibility factor with differences of less than 10 % For liquid dropout the difference was much higher and other tuning parameters are required. These findings for the local samples are no different from those published.

The Peng-Robinson Equation-of-State has been tuned by regression, to predict the phase behaviour and depletion performance for several Trinidad gas condensate samples. Tuning involved adjustment of Equation of State parameters so as to obtain the best match between predicted and experimental PVT data. In this study the two main groups of tuning parameters investigated were

1) BIC, the criticals and acentric factor;
2) BIC and the omegas, Ω's.

For Trinidad gases an optimum analysis in the range C_{20+} to C_{30+} gave best predictions for both sets of tuning parameters with differences of less than 12 %, using available weight factors. The novel feature is that an appropriate range, for tuning Trinidad gases has never been established. The analysis also revealed that by applying the volume shift parameter improved the prediction of liquid dropout and gas compressibility factor with BIC the criticals and acentric factor but had a negative effect with BIC and the omegas and was not included with the latter when tuning. Application of the volume shift parameter with BIC and the omegas has never been demonstrated before.

New weight factors were used with BIC and the omegas and without the volume shift parameter, improved the prediction of liquid dropout and gas compressibility factor. This proposed thermodynamic model gave excellent prediction of CVD data for the fourteen local and two literature samples, with differences of less than 6 % between the predicted and the experimental. The new weight factors were determined by trial and error and were kept constant for all samples.

The tuned EOS is used in simulators to predict the production performance and economic evaluation of gas condensate reservoirs and is a powerful tool for the reservoir and production engineer. This work has made significant contribution in developing equipment, operational and experimental procedures for future gas condensate characterization and PVT studies, a novel technique for determining dew point pressure and a scheme for splitting the C_{7+} fraction without a partial analysis. Trinidad condensates were characterized for the first time and due to their relative closeness, the data chart of Katz and Firoozabadi and Whitson can be used in the absence of measured data. A thermodynamic model complete with tuning parameters and weight factors was developed for Trinidad lean gases and the range of components required for tuning was narrowed. Tuning parameters compatible with the volume shift parameters were also identified. These innovations provide a major contribution to future gas condensate phase behaviour studies.

KEYWORDS: Raffie Hosein, gas condensate reservoirs, phase behaviour studies, Equation of State, Tuning parameters, characterization of Trinidad lean gases, dew point pressure for lean gases, thermodynamic model for Trinidad lean gases.