# Application of Equation of State Based Methods to Correct for Oil Based Drilling Fluid Contamination in Condensates and Near Critical Systems

John Ratulowski

Shell Exploration and Production Technology Company

Houston TX

# Outline

- Sources of Error in Fluid Property Measurement
- Development of EOS models for OBM Contaminants
- Dead Oil Data
- Live Oil Data
- A Field Example for a Condensate
- Conclusions

# Sources of Error from Downhole Samples

- Sampling
  - Phase splits due to drawdown
  - Contamination
- Transfer and Handling
  - Leaks
  - Lack of equilibration
- Laboratory Analysis
  - Poor technique
  - Lack of equilibration
  - Quantification of contamination

# Philosophy of the EOS Approach

- The chemistry of the contaminants is better known than that of the oil
- Develop contaminant EOS description based on the known structure, physical properties, and available VLE data.
  - Actual compounds in the contaminant
  - Model compounds structurally similar
  - Pseudo-components with fixed properties
- Tune oil pseudo-component properties to match measured VLE data of the contaminated system
- This approach reduces the number of adjustable parameters

# Petrofree (Not Petrofree LE)

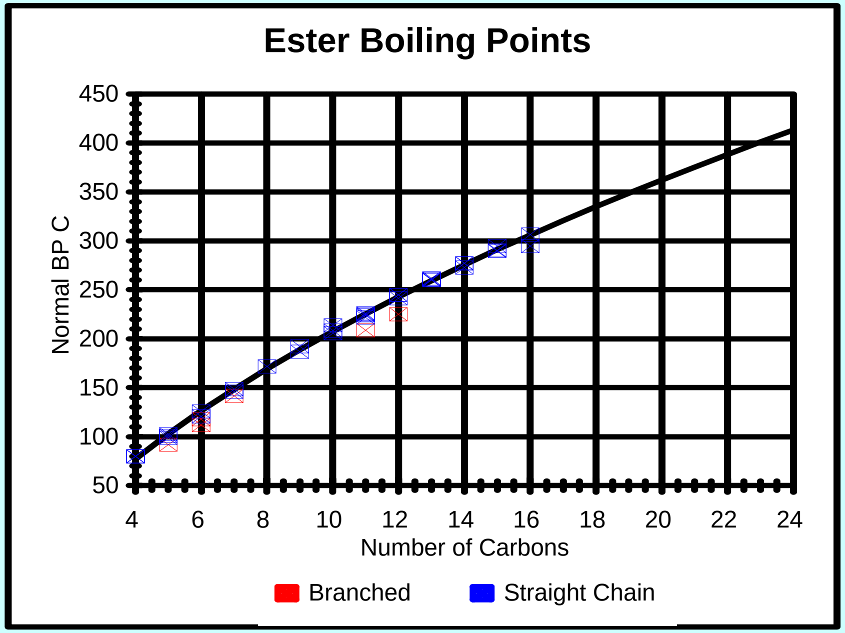
Five fatty acid esters with carbon numbers 16 to 24 and an ethyl side chain

Boiling points extrapolated from known values

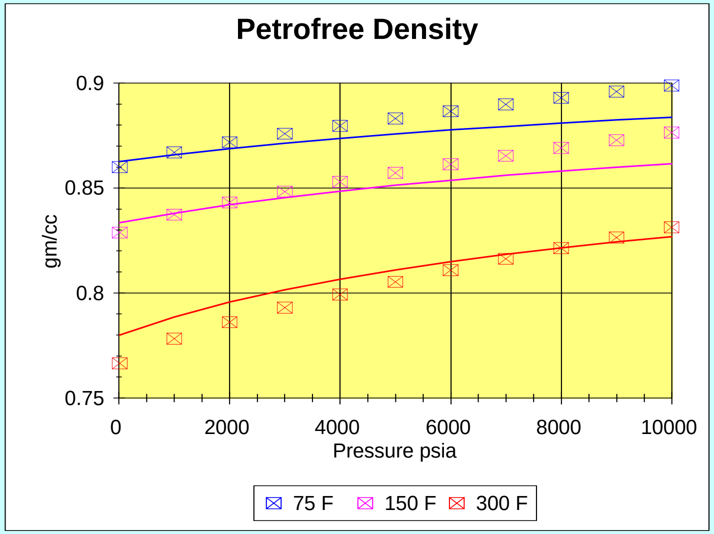
Group contribution techniques used to estimate EOS parameters

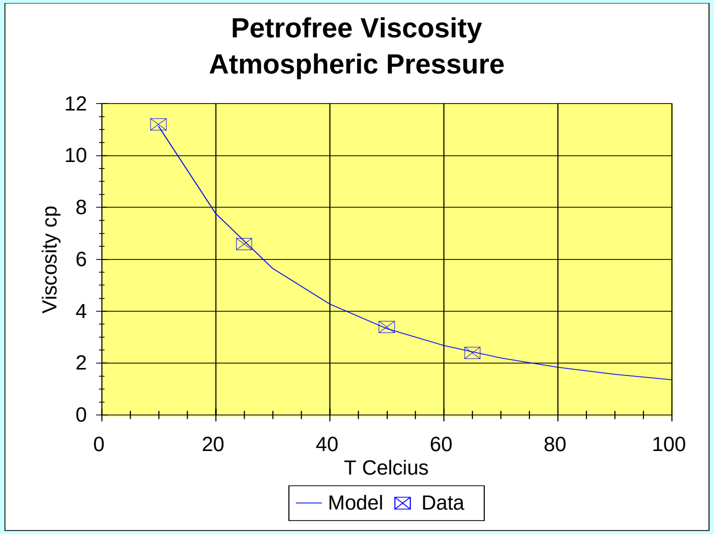
Viscosity model fit to data from 10 C to 65 C

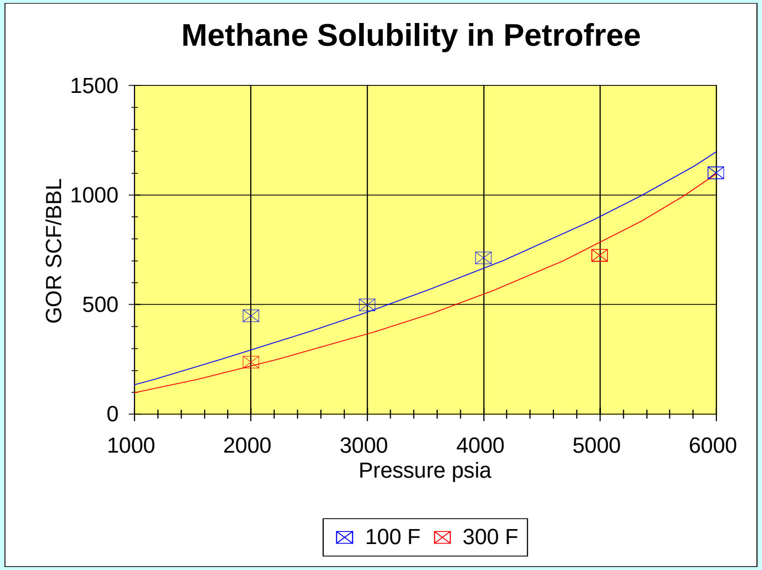
Methane BIP’s fit to gas solubility data



# Petrofree EOS Model Results



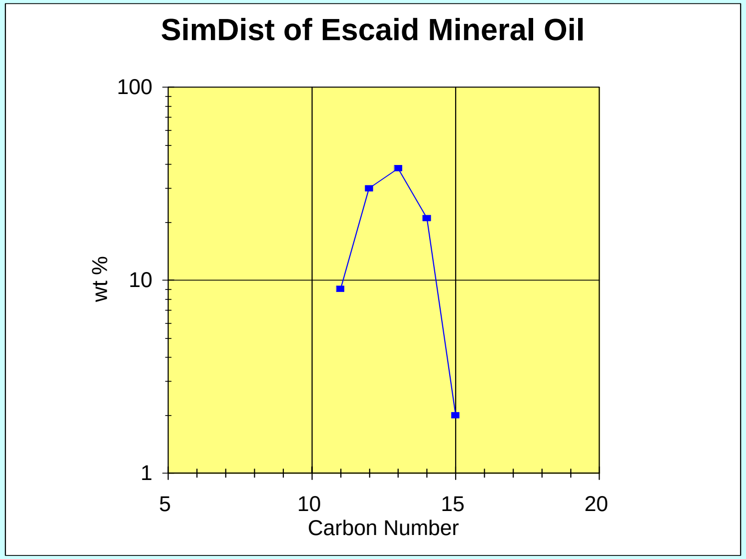
# Escaid Mineral Oil

Refined product with low aromatic content C11 to C15 on SimDist analysis

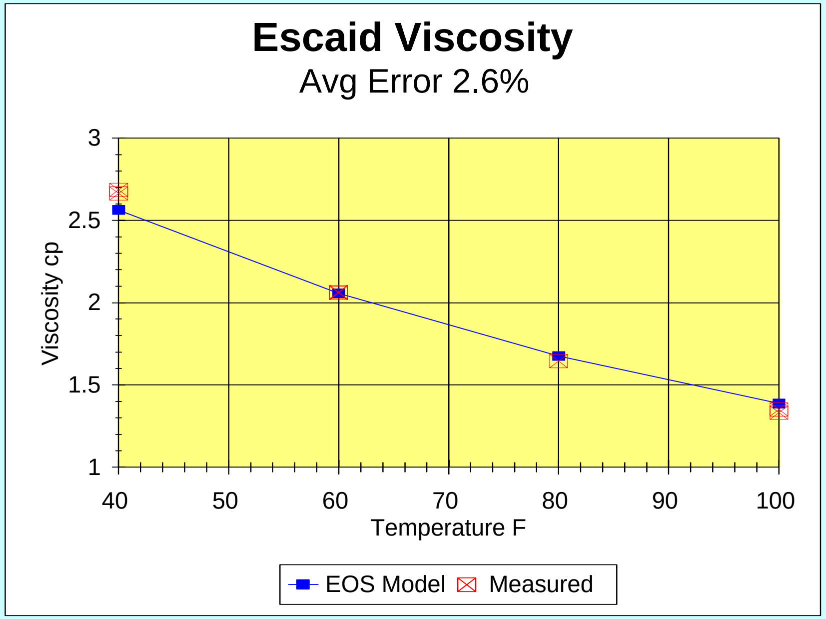
In-house ECHO correlation used to generate pseudo-component properties This was sufficient to match stock tank density

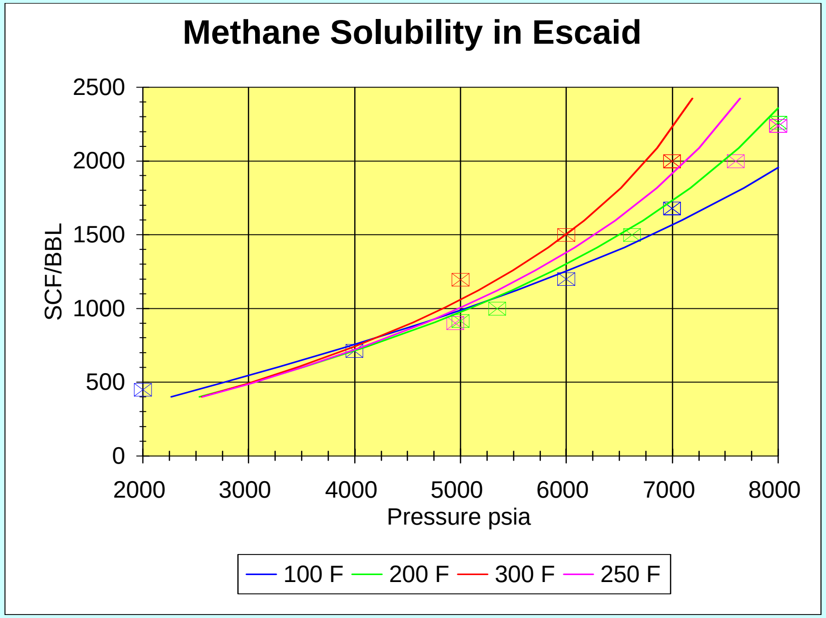
Viscosity model to data between 4 C and 38 C

Methane BIP correlation fit to gas solubility data for mineral oils



# EOS Results for Escaid



# Low Molecular Weight Olefins

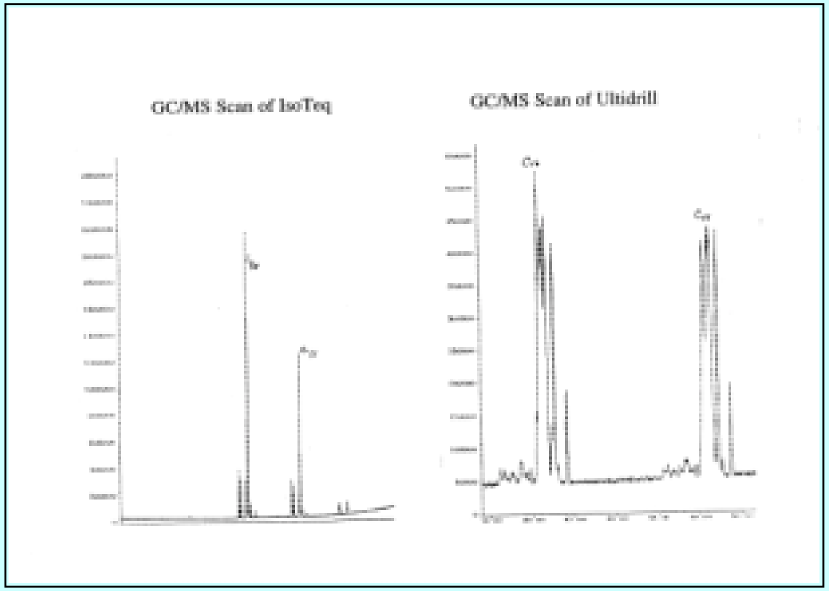
Novaplus, Petrofree LE, IsoTeq, and Ultidrill are all compositionally similar

C14, C16, and C18 alpha or internal olefins. They may be branched or linear and may consist of single compounds or groups of isomers

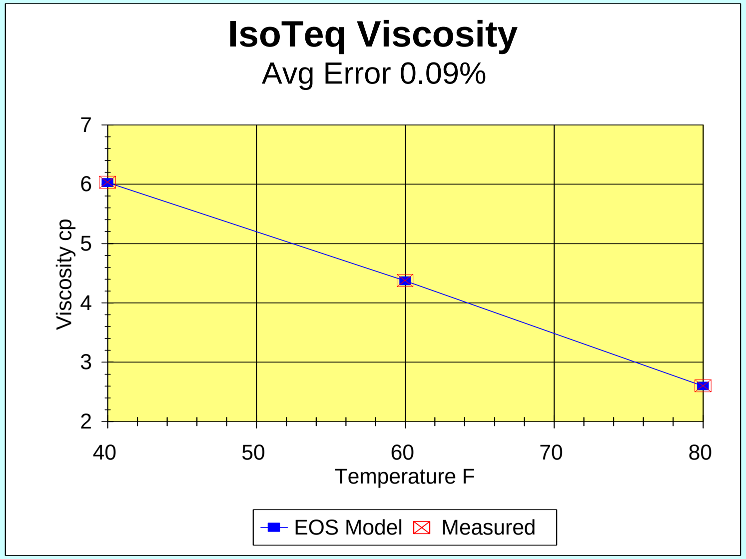
C14, C16, C18 alpha olefins are used as model compounds

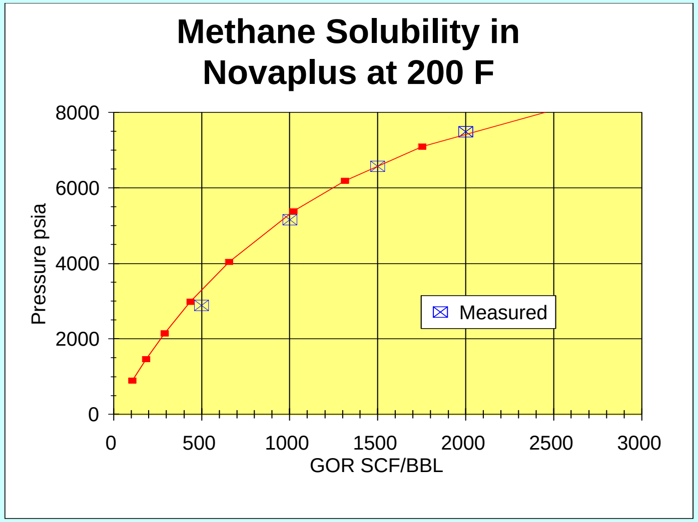
Literature data used to develop EOS description

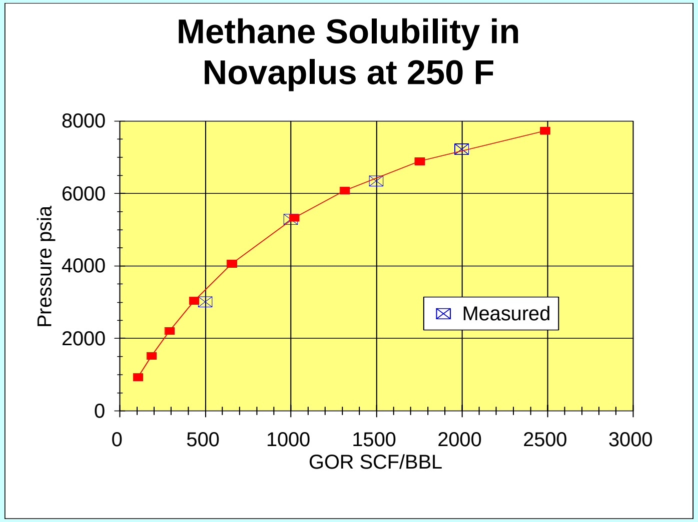
Methane BIP correlation fit to gas solubility data



# EOS Results for the Olefins



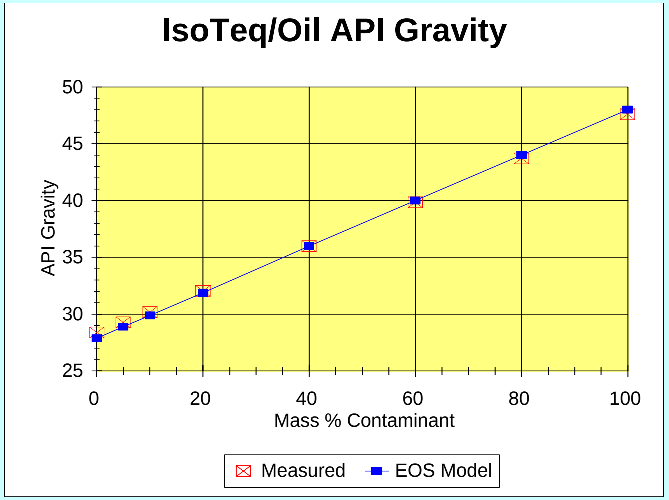



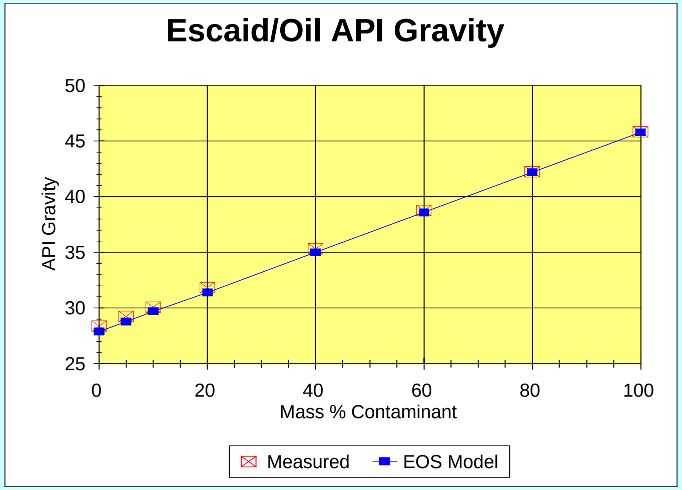
# Other Contaminant Models

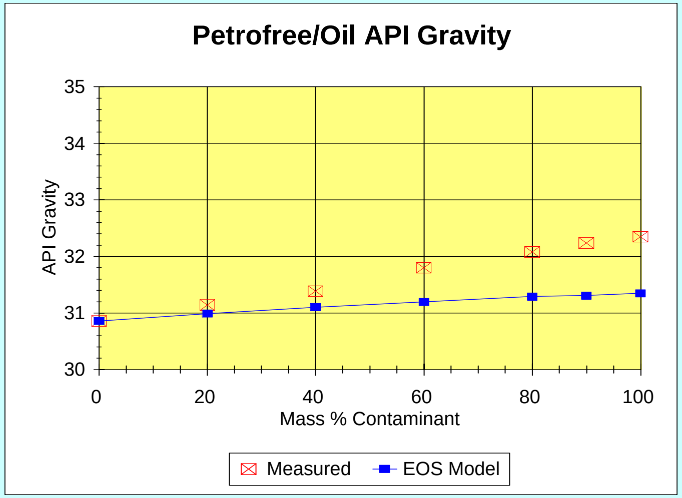
- Aquamul
  - C20 alkyl ether
  - Approach similar to Petrofree esters
  - Limited success matching gas solubility data
- Novasol
  - Alpha-olefin isomers groups one near C20 the other near C30
  - Normal paraffins n-C30 and n-C40
  - Viscosity, density, and gas solubility matched adequately

# Density of Dead Oil Blends

- Linear mixing rule for API gravity.
- Variability in base fluid properties caused some error in the Petrofree trace
- Aquamul and Novasol results similar

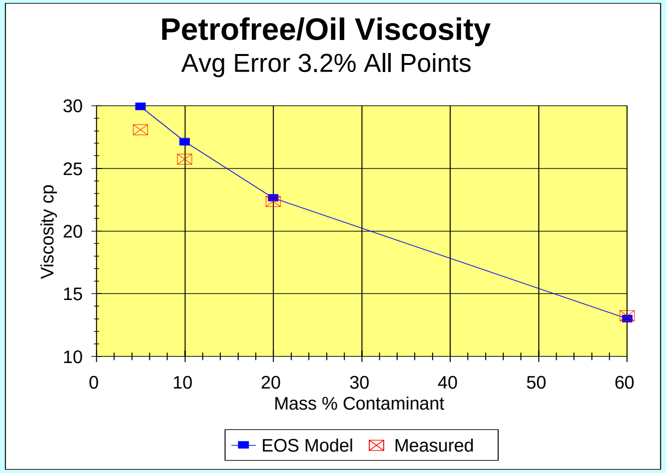


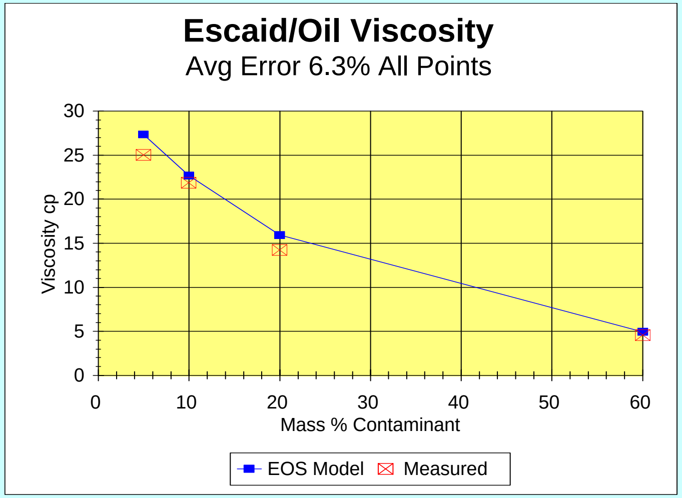



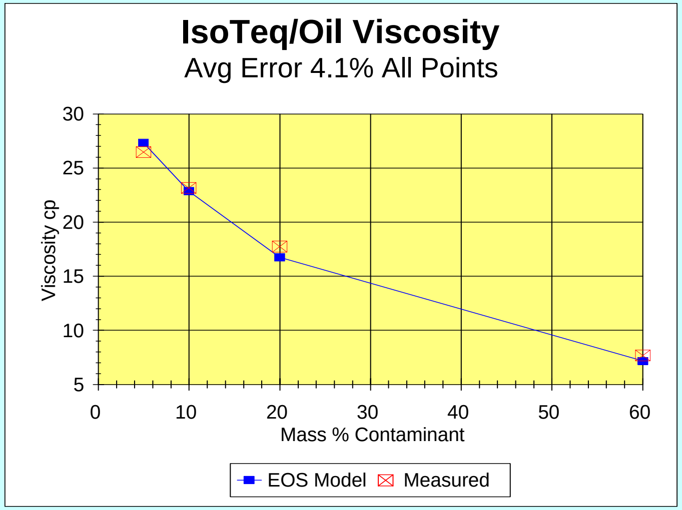



# Viscosity of Dead Oil Blends

- Two oils of different gravity
- Temperature range from 40 to 100 F
- Contamination range from 5 to 60 wt %
- Novasol 3.7 % average error
- Aquamul 2.7 % average error



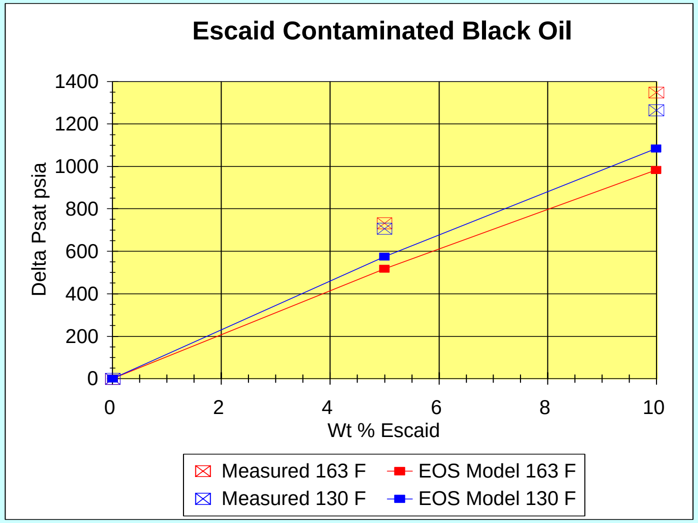



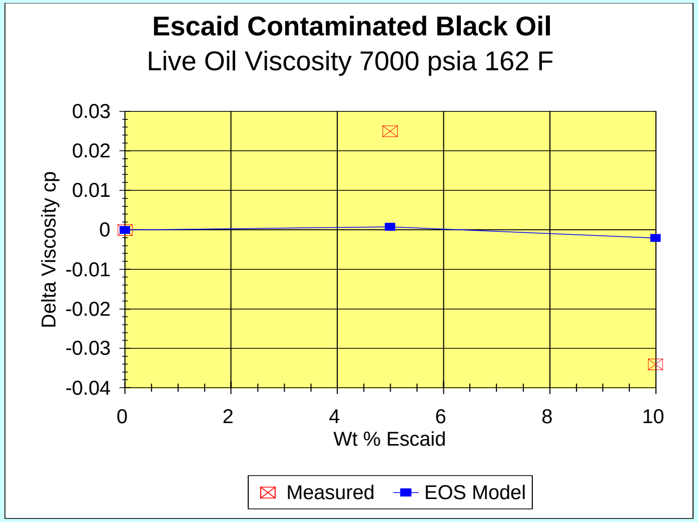



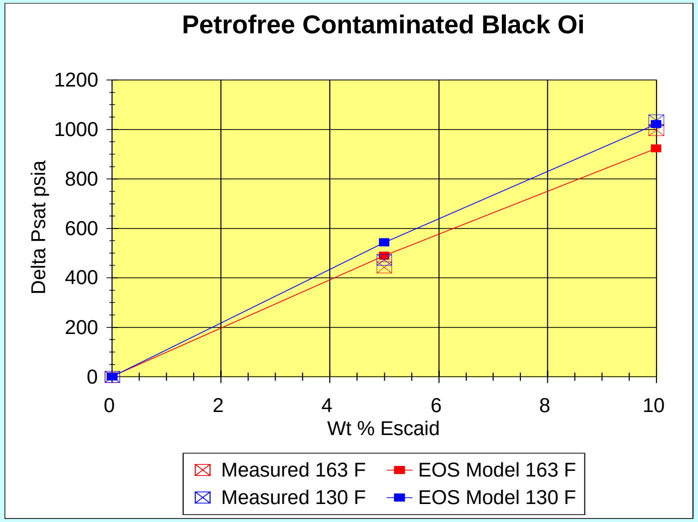
# GOM Black Oil

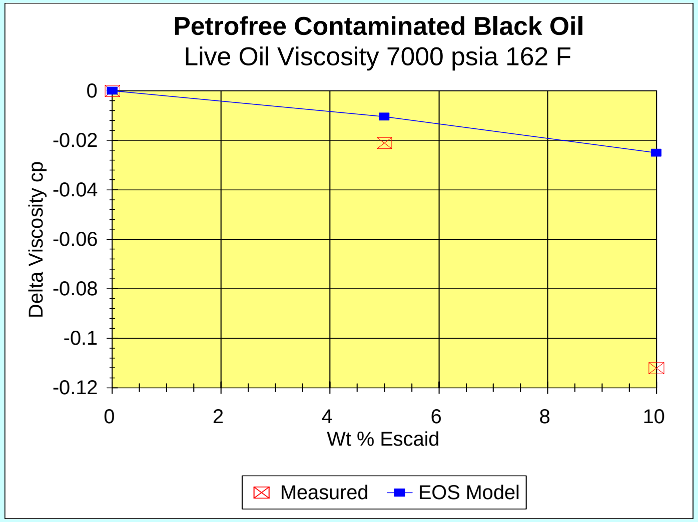
- The oil was a black oil with a GOR of approximately 1200 SCF/BBL and a stock tank gravity of 27 API Gravity
- CCE's at 130 F and 163 F run with 0, 5, and 10 wt % basis dead oil of three contaminates
- Results presented as deviations uncontaminated-contaminated
- Poor quality GOR data
- In general, model and experiments compared favorably

# EOS Results for the Black Oil (Live Oil)

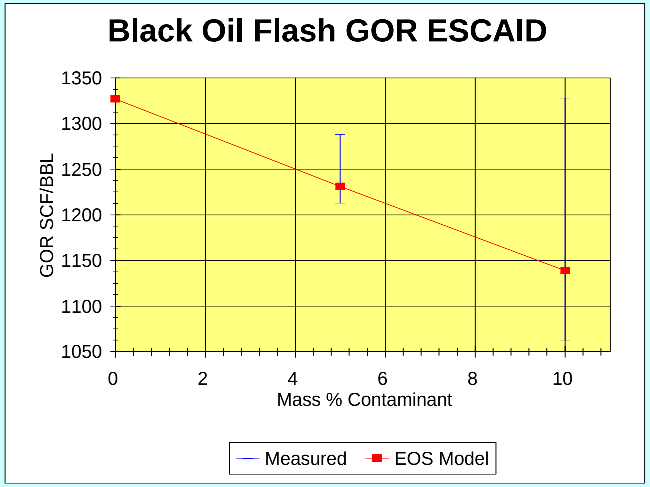


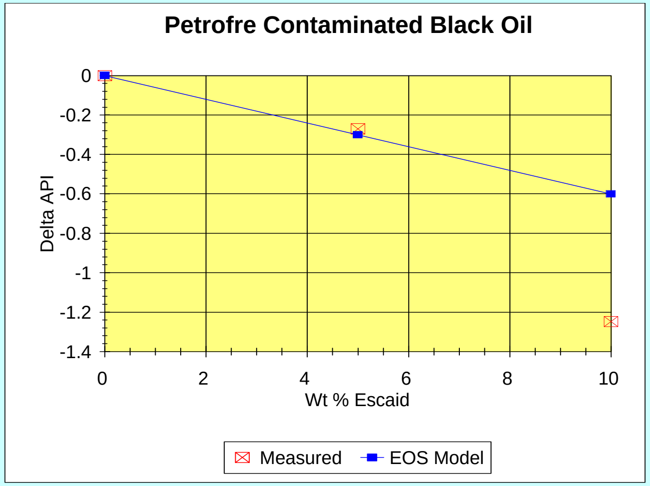



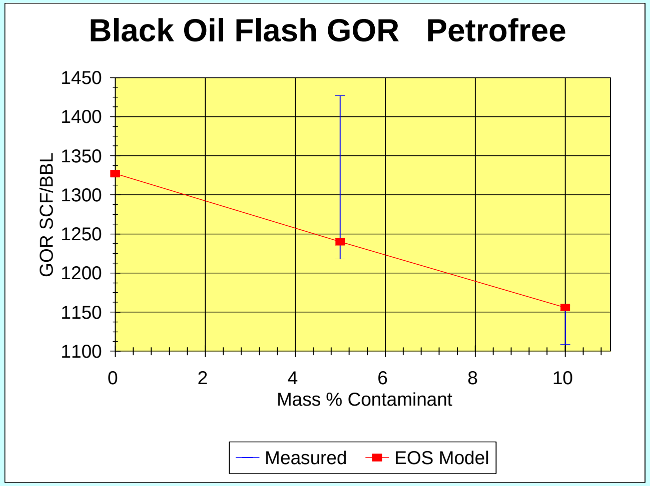



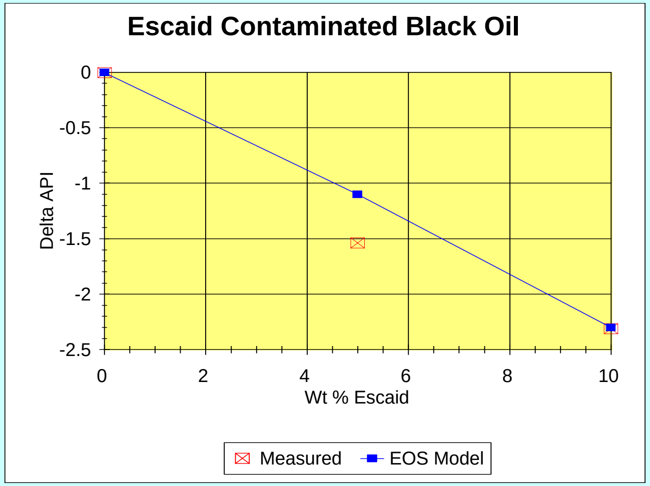



# EOS Results for the Black Oil (Flash Data)



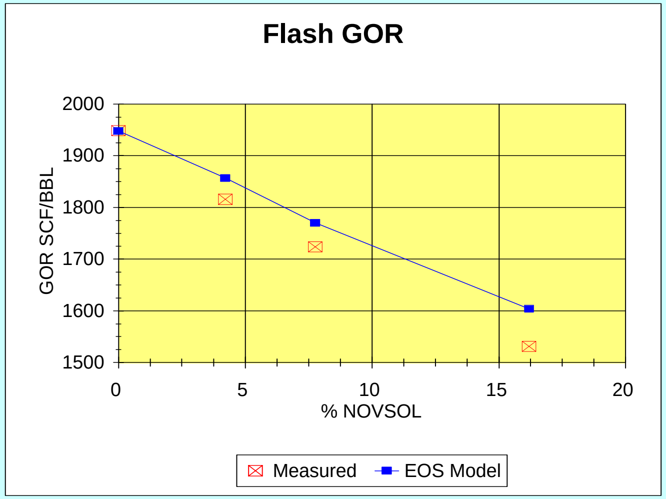



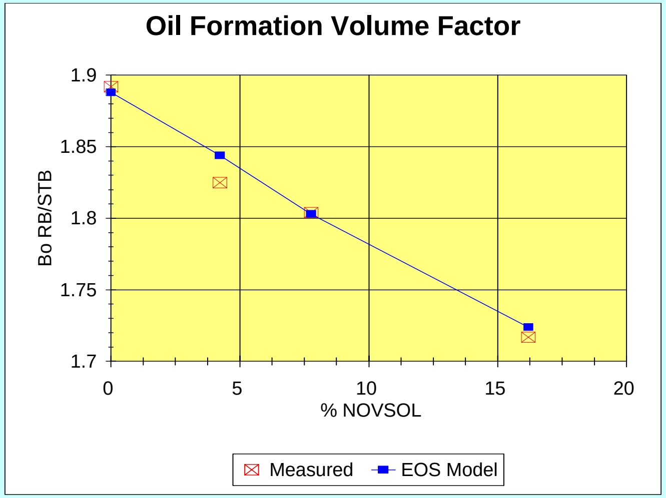
# Gulf of Mexico Volatile oil

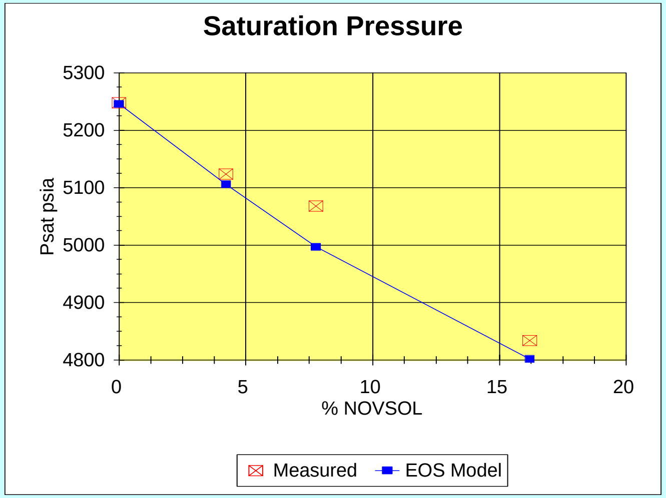
- Volatile oil with a 1950 SCF/BBL GOR and 33.8 API tank gravity
- Mixture of Novasol contaminated and uncontaminated samples available from several wells and zones
- Question: How confident are we in our corrected PVT data from the contaminated samples?
- Minimal PVT rum for three contamination levels up

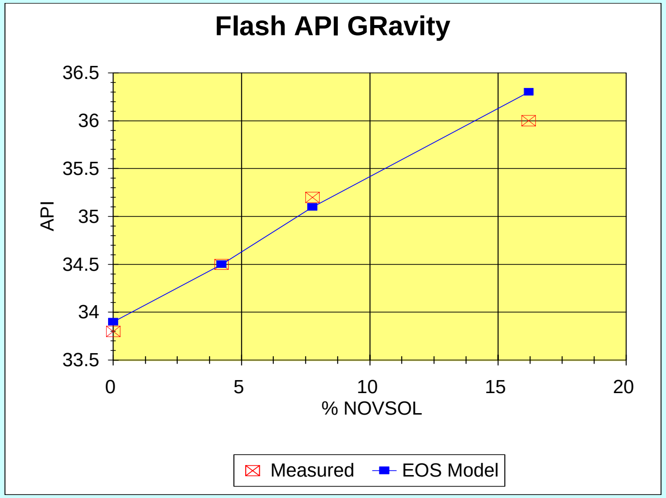
  to 10 %

# EOS Results for a Volatile GOM Oil



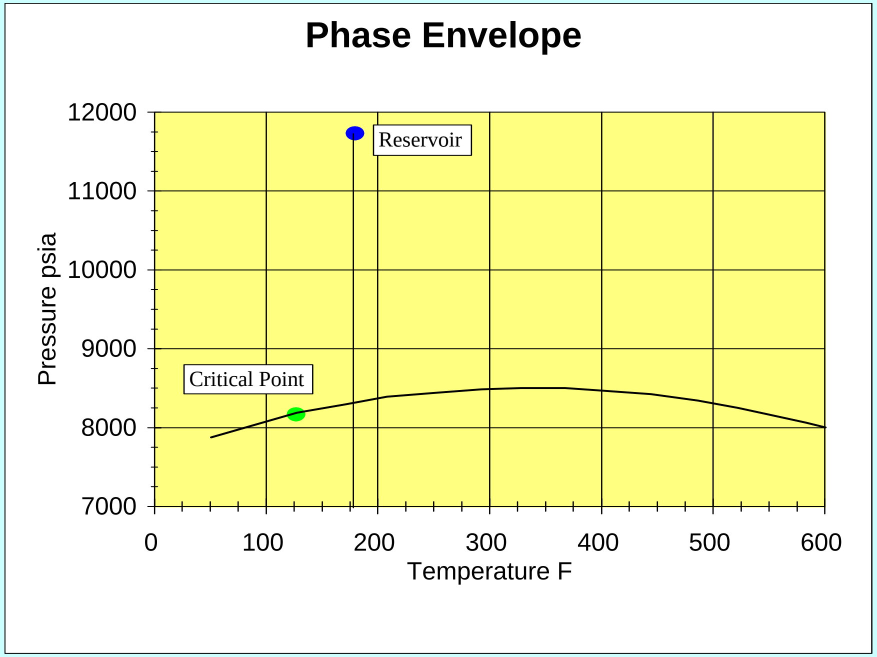



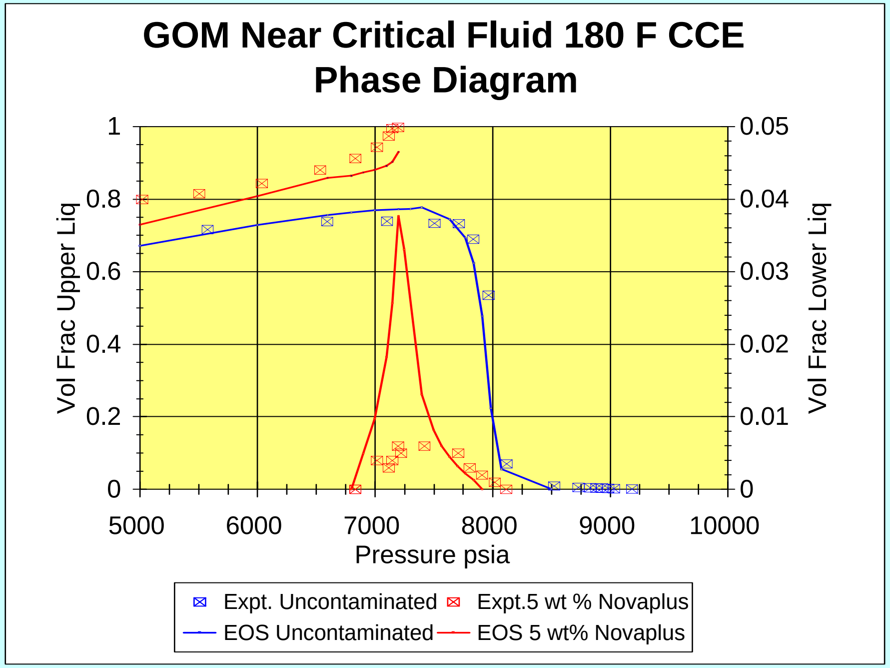



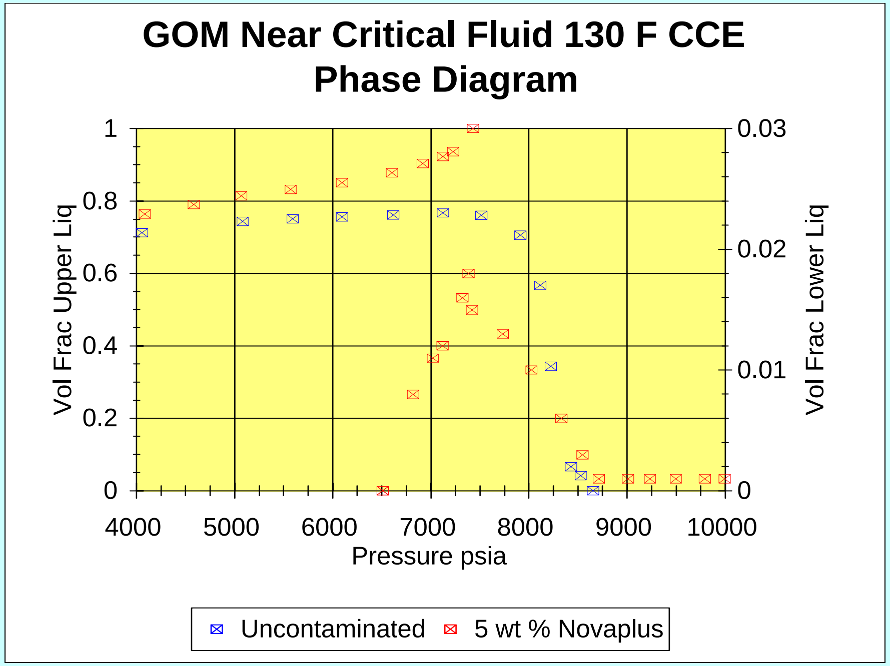
# Near Critical Gas Condensate

- Near critical gas condensate 2300 SCF/BBL or 435 BBL/MMSCF
- 31 API stock tank oil (condensate)
- Retrograde behavior at 130 F and 180 F confirmed in four experiments at two laboratories
- Uncontaminated sample available from first well drilled in water base mud
- Question: Would even small amounts of Novaplus contamination effect the phase behavior?



# EOS Results for GOM Near Critical Fluid

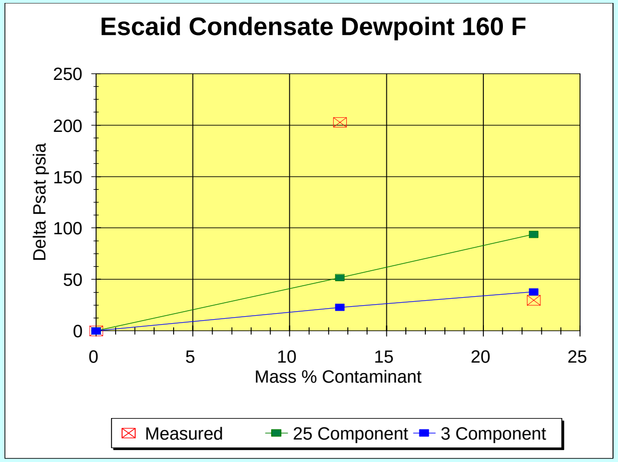


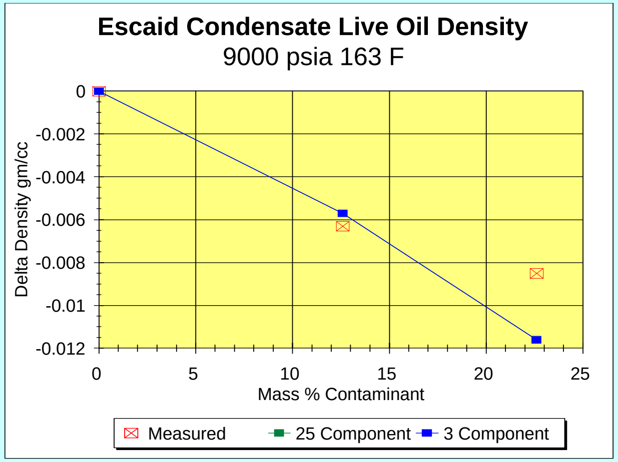



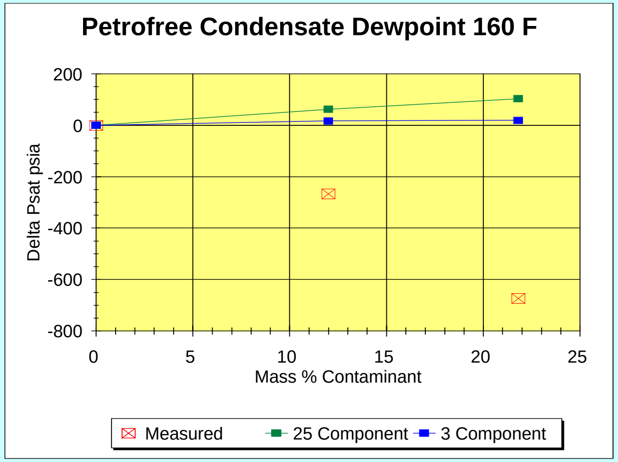
# GOM Lean Gas Condensate

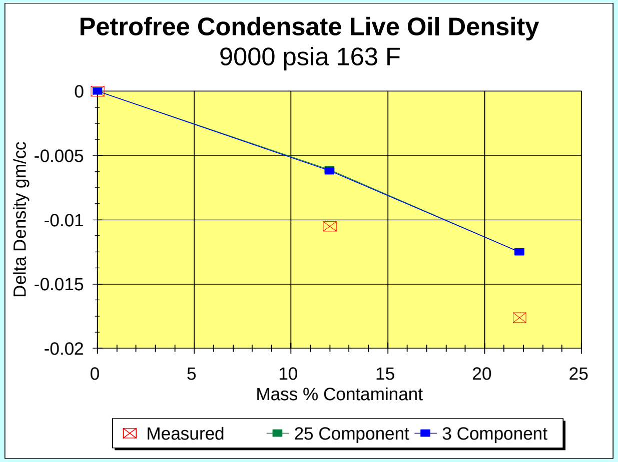
- Single stage flash CGR of 37.8 BBL/MMSCF with a tank gravity of 48.4 API
- Same three contaminants as black oil study
- Two different EOS characterizations were used. Results of the models are sensitive to the detail of EOS characterization
- Reasonably good agreement for flash data between experiment and model
- Contaminant-gas binary interaction parameters should be fit in the retrograde region for accurate prediction of saturation pressure

# EOS results for the Lean Condensate (Live Oil Data)

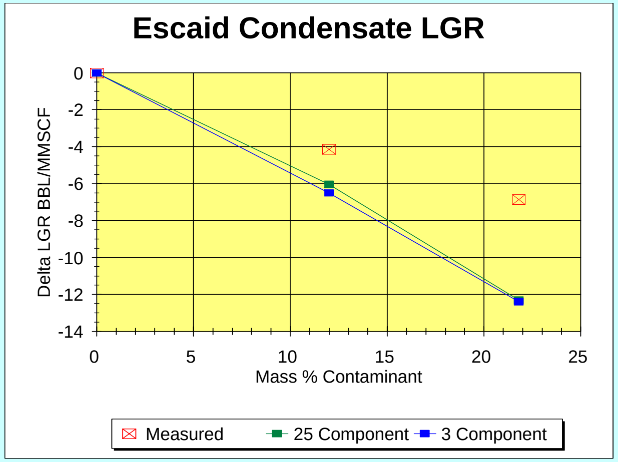


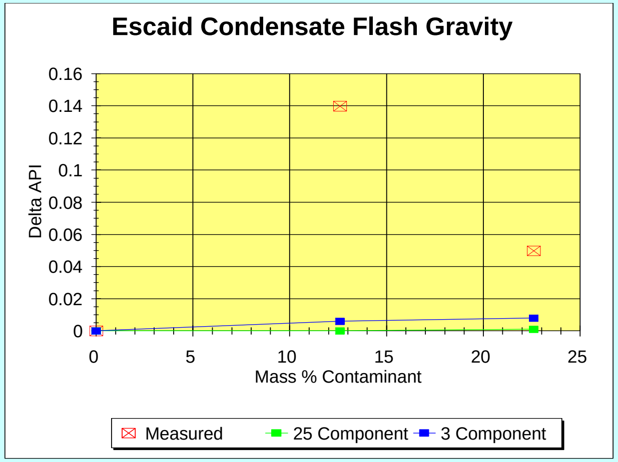



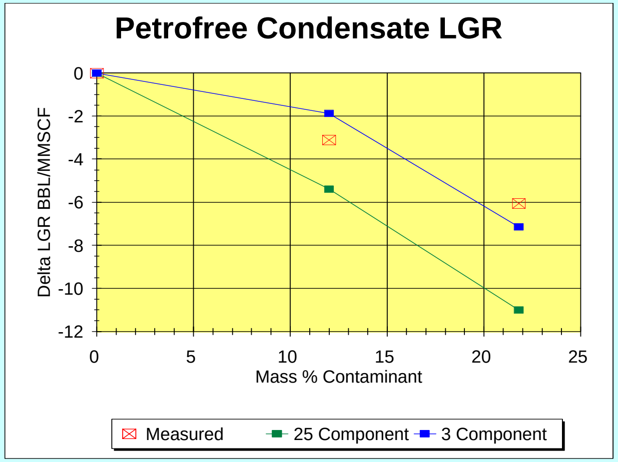



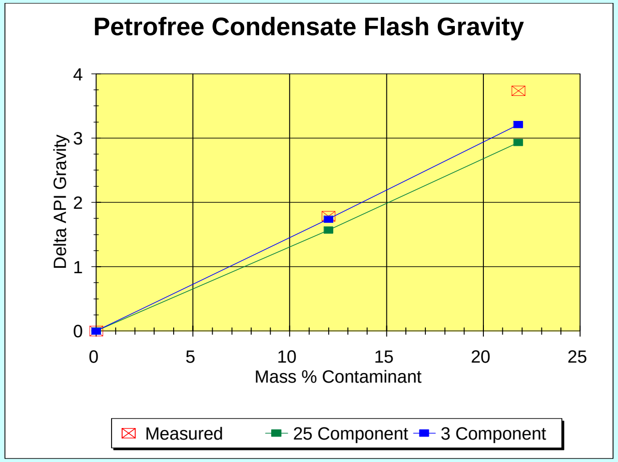



# EOS Results for the Lean Condensate (Flash Data)



# Field Case: Lean Condensate

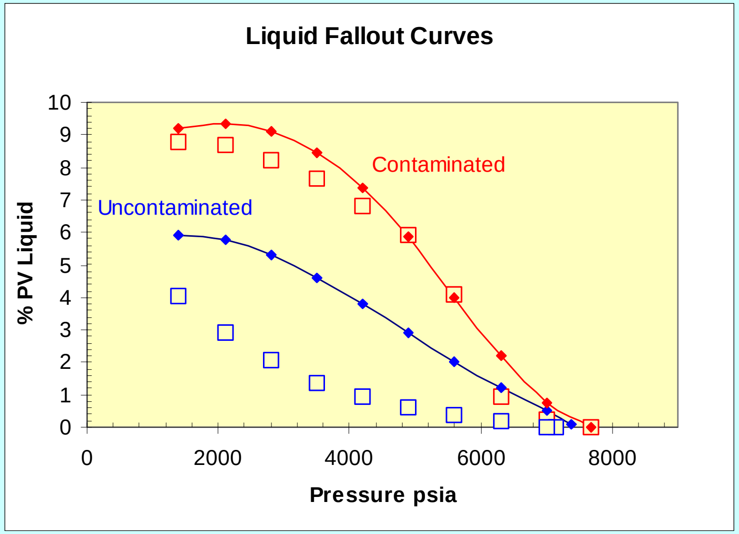
- Small samples of dead contaminated condensate were available (about 33 wt % of Petrofree LE)
- No mud filtrate - uncertainties in mud EOS characterization and in the estimated contamination level
- PVT available on contaminated samples
- The measured saturation pressure is the same as the bottom hole pressure for the contaminated sample

# Results of EOS Correction

Potential Problems

1. Sample handling and transfer
2. Problems in the lab
3. Problems with the EOS model
4. Areal and vertical variation in fluid properties in the reservoir

| | Contaminated | Corrected | Measured |
|---|---|---|---|
| 4-Stage Separator LGR BBL/MMSCF | 55 | 40 | 32 |
| 4-Satge Separator API Gravity | 50 | 49 | 47 |
| Density at reservoir conditions gm/cc | 0.2963 | 0.2947 | 0.2832 |



# Summary

- EOS models for oil based mud contaminants were constructed using chemical, physical, and VLE data from the base fluids
- These models do a reasonable job of correcting black and volatile oil data
- Condensates are difficult to correct. The contaminant model should be fit to the retrograde region for accurate correction of dew points
- In practice, many things can cause differences between data measured on bottom-hole samples and production data these include:
  - Sample handling and transfer
  - Problems in the lab
  - Problems with the EOS model
  - Areal and vertical variation in fluid properties in the reservoir