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Accurate Viscosity Measurement under Extreme Pressure & Temperature

Gulf Coast Conference
October 17, 2012
William A. Small

Agenda

- *Cambridge Viscosity & PAC History*
- *Why High Pressure/Temperature Viscosity measurements required*
- *Viscosity Importance for Reservoir Fluid Analysis*
- *Reservoir Fluid Analysis Overview & Challenges*
- *Cambridge Viscosity Oscillating Piston Viscometer Technology*
- *Operating Characteristics of VISCOlab PVT Viscometer*
- *Pressure & Temperature Standards*
- *Summary*

Cambridge Viscosity & PAC History

- *Founded 1984*
- *Located near Boston/Cambridge, MA*
- *The Leader in Small Sample Viscosity*
- *Developed 1st High Pressure/Temperature Viscometer for Reservoir fluids in 1990*
- *Proprietary Technology*
- *Blue Chip Customer Base*
- *Over 10,000 Systems Installed*
- *Worldwide Reach*
- *Compliance with ASTM D7483 & D445*
- *CVI partnered with PAC in 2012*

About PAC

- *Part of ROPER INDUSTRIES - (NYSE: ROP)*
- *Leading global provider of advanced analytical instruments for industrial laboratories and online process analytics*
- *> 400 employees and over 30,000 instruments installed*
- *11 PAC offices and > 50 distributors Worldwide*
- *> 50 Engineers in Six Countries*
- *Core technologies including:*
  - *Gas chromatography*
  - *Physical properties*
  - *Fuel performance*
  - *Elemental analysis*
  - *Process analytics*
- *Consists of leading, long-established product brands*

Where is HP/HT Viscosity Measurement Required

Upstream

- *Exploration - Fluid Reservoir Analysis*
- *Production Operations*
- *Enhanced Oil Recovery using Polymers (EOR)*
- *Corrosion Inhibitors Analysis*
- *Brine Solutions & CO2 Analysis*

Other Applications

- *Lubricants at "contact bearing pressure" Analysis*
- *R&D applications*
- *Ionic liquids Analysis*

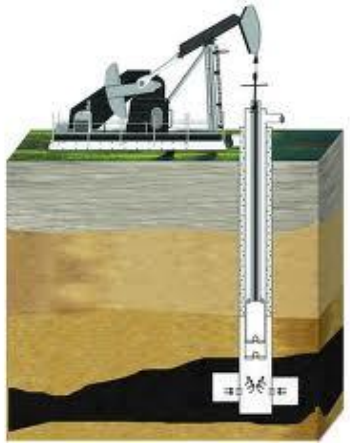
Viscosity Importance for Reservoir Fluid Analysis

Importance of viscosity is two fold:

- *Determining well productivity using Darcy's law (describes flow through a porous medium)*

$$Q = \frac{-kA}{u}\frac{(P_b - P_a)}{L}$$

- *Analyzing displacement in recovery (i.e. – amount of oil recovered vs. water injected)*

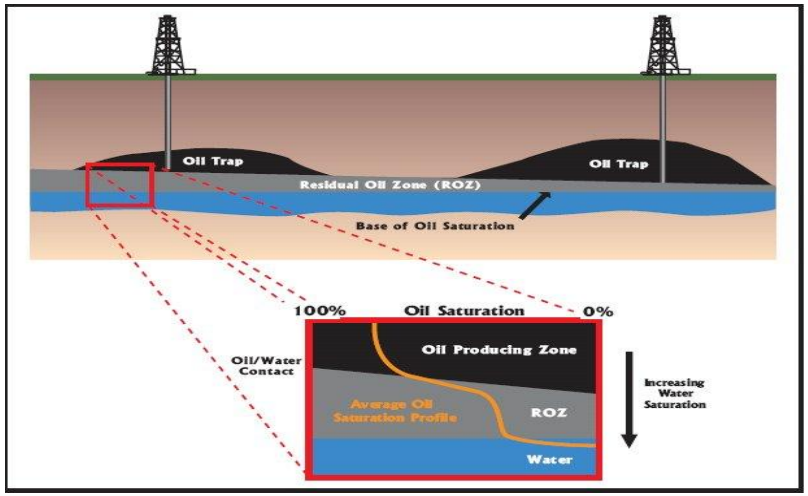


Reference: Kurt Schmidt of Schlumberger, Standards Workshop, 2012

Oil Reservoir Characteristics Drive Economics

Geological characteristics *of the rocks and fluids -* ***control*** *the performance of hydrocarbon reservoirs*

- *Involves numerous properties of the particular rocks and fluids*
- *Including interactions between the rocks and fluids*
- *High quality data are critical for:*
  - *Accurate predictions of reservoir performance for initial investments and analysis over time*
  - *Selection of optimal depletion strategy over time*



The Four Most Critical Production Factors

- ***Original Hydrocarbon in Place**: **Volume** of fluid in the rock formation*
- ***Production/Injection Rates**: **Flow rates** through porous rocks for the hydrocarbon fluids in the particular rock formation*
- ***Fractional Flow**: Rate that water flows through the reservoir rock/fluid combination*
- ***Recovery Factor**: Portion of the hydrocarbon that can be extracted given the rock and fluid characteristics*

Sources:
1) Honarpour, MM, et al, Rock/Fluid Characterization and their Integration – Implications on Reservoir Management", 2006,SPE103358
2) Dindoruk, B., "Reservoir Fluid Challenges: Viscosity", 2010, Cambridge Viscosity-Schlumberger Roundtable Workshop on High Pressure and High Temperature Viscosity Standards

Accurate Viscosity Data: is Vital

Key Reservoir Characteristics	Significant Factors				
	Fluid Viscosity	Rock Permeability	Oil Volume (Formation Volume Factor)	Oil and Water Saturation	Rock Porosity
Hydrocarbon Volume			*b*	*S*	*f*
Production - Injection Rates	*m*	*k*	*b*		
Fractional Flow of Water	*m*	*k*	*b*		
Recovery Factor - Potential	*m*	*k*		*S*	

Viscosity Uncertainties Have a Significant Impact:

Typical Variances without viscosity data -

> 10 % for Light Oil and

> 15% for Heavy Oils

Source: Honarpour, MM, et al, SPE 103358

Reservoir Fluid Analysis Challenges

– Only ***small volumes*** of oil are extracted for evaluation

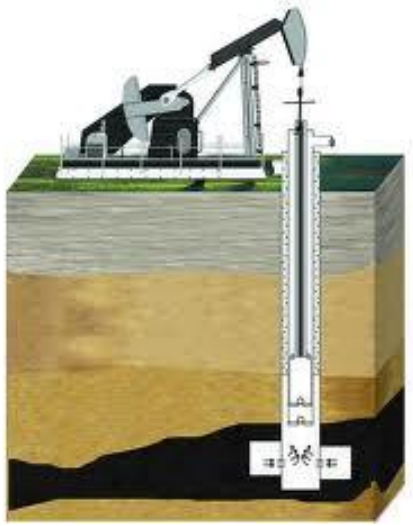
- *Typical "bomb" is 250 ml*

– Material is ***very expensive*** to capture

- *Typical sample costs $250,000*

– Samples Often include:

- ***Corrosive*** fluids (H_2S, brine, drilling muds & contaminants
- ***Excessive Water*** **-** *leaving only 50 ml of oil to analyze*
- *And are under* **-** ***High pressures & temperatures***



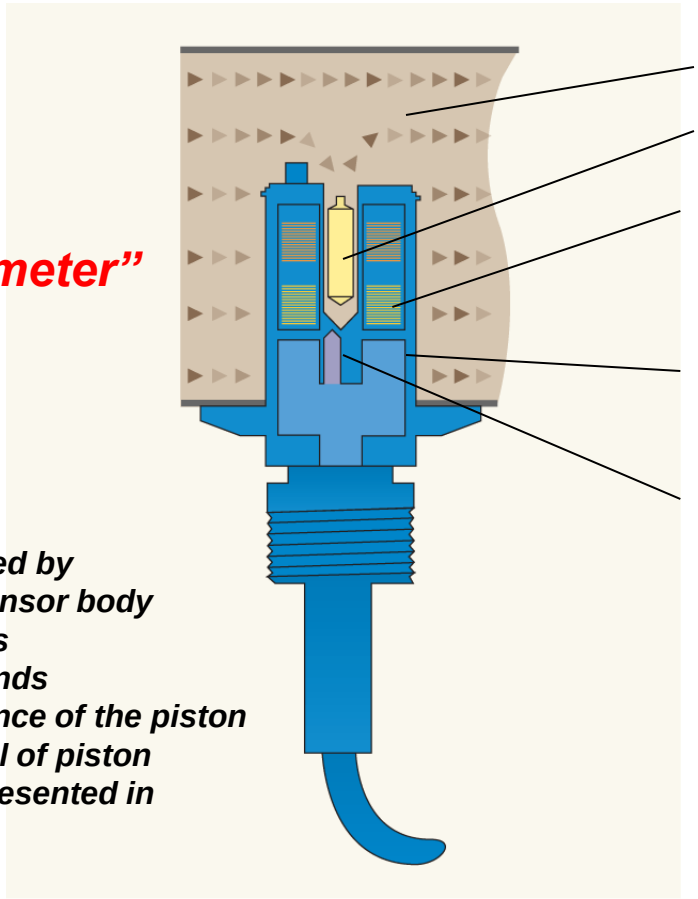
And For Analysis

- Fluid ***sample conditions must be maintained*** from reservoir to lab

Otherwise: gas flashes off, ***irreversibly*** changing fluid viscosity

Cambridge Viscosity Technology

"Electro-Magnetic Viscometer"



- *Piston motion completely controlled by two magnetics around sensor body*
- *Total Piston travel for 1 full cycle is measured in micro-seconds*
- *Calculation is made on the resistance of the piston in the fluid & time of travel of piston*
- *Viscosity is then calculated and presented in centipoise - cP*

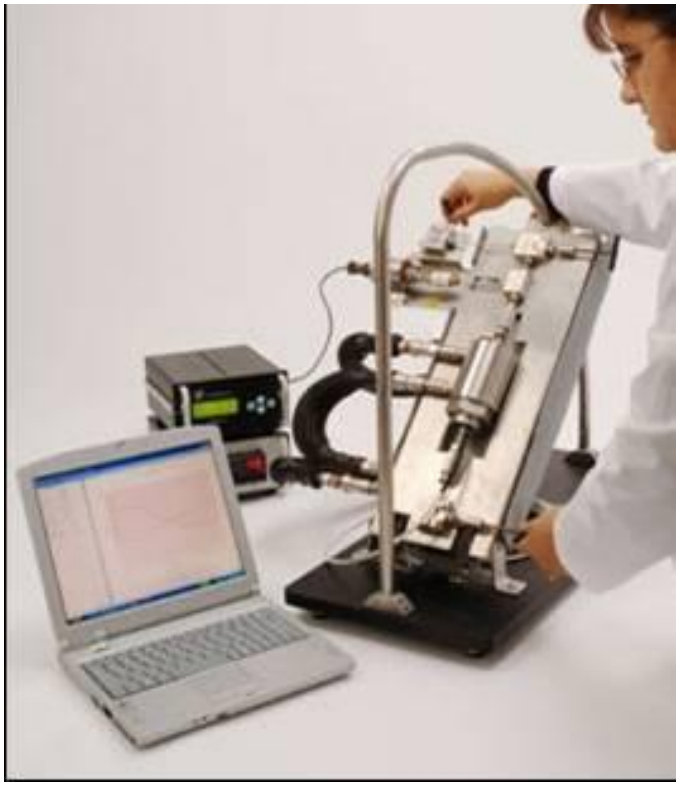
"Sensor shown in a process line"

CVI VISCOLab PVT:

Ideal for Reservoir Fluid Analysis

- *Integrated PVT system:*

  Pressure – Viscosity – Temperature
- *High pressures: up to 40,000 psi*
- *Small Sample size – only 6 ml*
- *High temperatures: up to 315 C*
- *Off-gassing incorporated*
- *Accurate: ± 1%*
- *Easy to use*
- *Manages corrosive fluids: H_2S, brine*
- *The only System that can measure Gas*



VISCOlab PVT has become the industry Gold Standard

VISCOlab PVT:

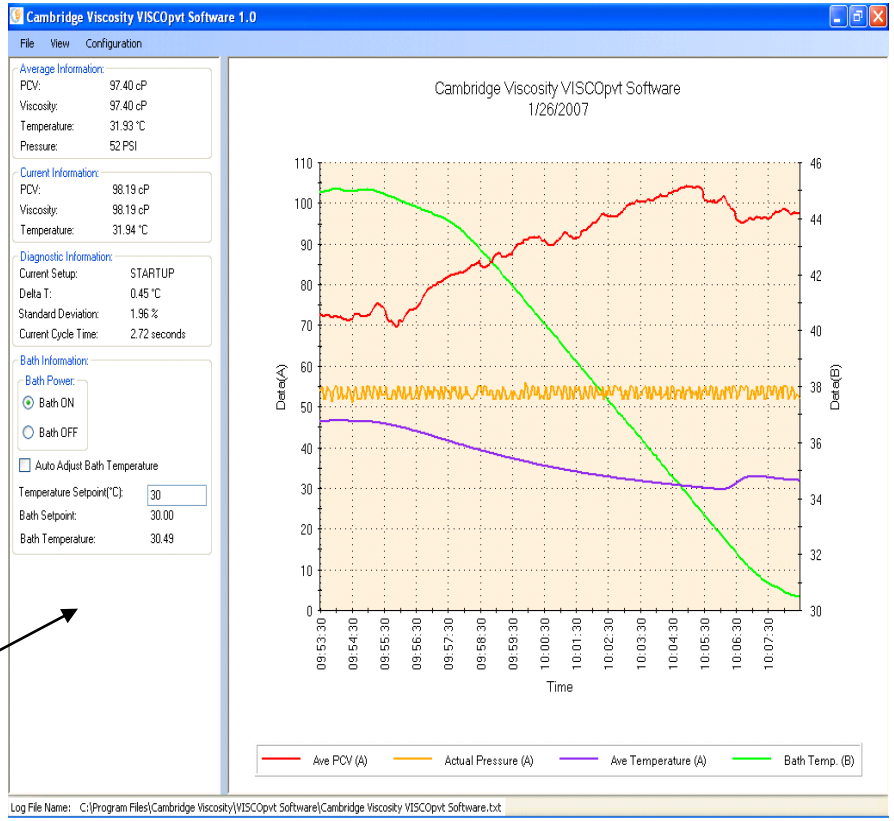
Single Integrated Interface

Traceable Pressure & Temperature (PCV) Compensation

On Screen Statistical Analysis of Test Conditions

Single Click Temperature Set

User configurable Dashboard & Automatic Storage of Test Data



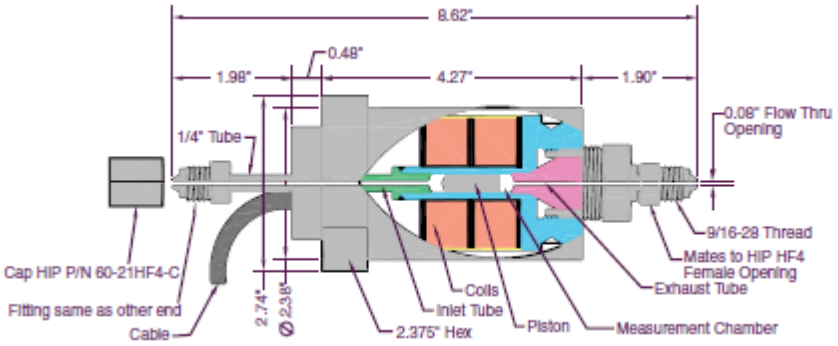
Easy to use……

Pressure & Temperature Compensation

- ***PVT Sensor calibration compensation is necessary***
  - *Critical Sensor Feature: Annular space between piston & chamber wall*
  - *Space to increase with temperature and/or pressure*

- ***Compensation factor based on:***
  - *Published data on fluids characterized by NIST and others*
  - *Data available to 20,000 psi and 150 degC*
  - *depending on fluid and test, but limited by viscosity, temperature and pressure*

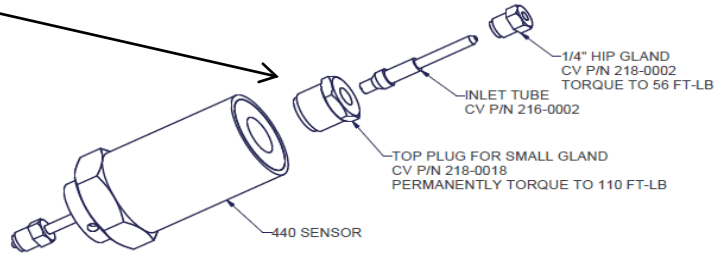
- ***Compensation is based upon best-fit correlations for:***
  - *Temperature and pressure are linear*
  - *Each individual piston range is compensated*



Fluid standards for extended pressures & temperatures are needed ……..

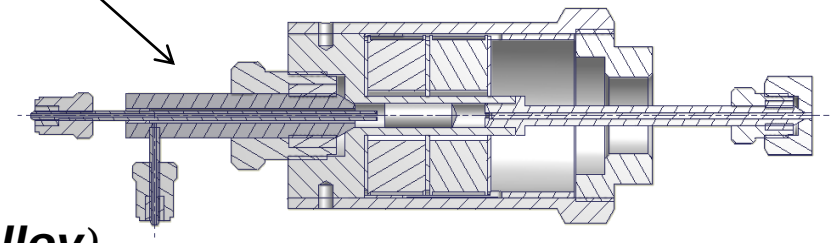
Sensor Enhancements & Options

- *Easy piston change with **low torque** sealing*
  - *to extend the life of sensor*
  - *to prevent seal damage*



Low torque sealing

- *Standard measurement is in <u>static conditions</u>,*
  *New **low flow version** for continuous flow measurements is now available*

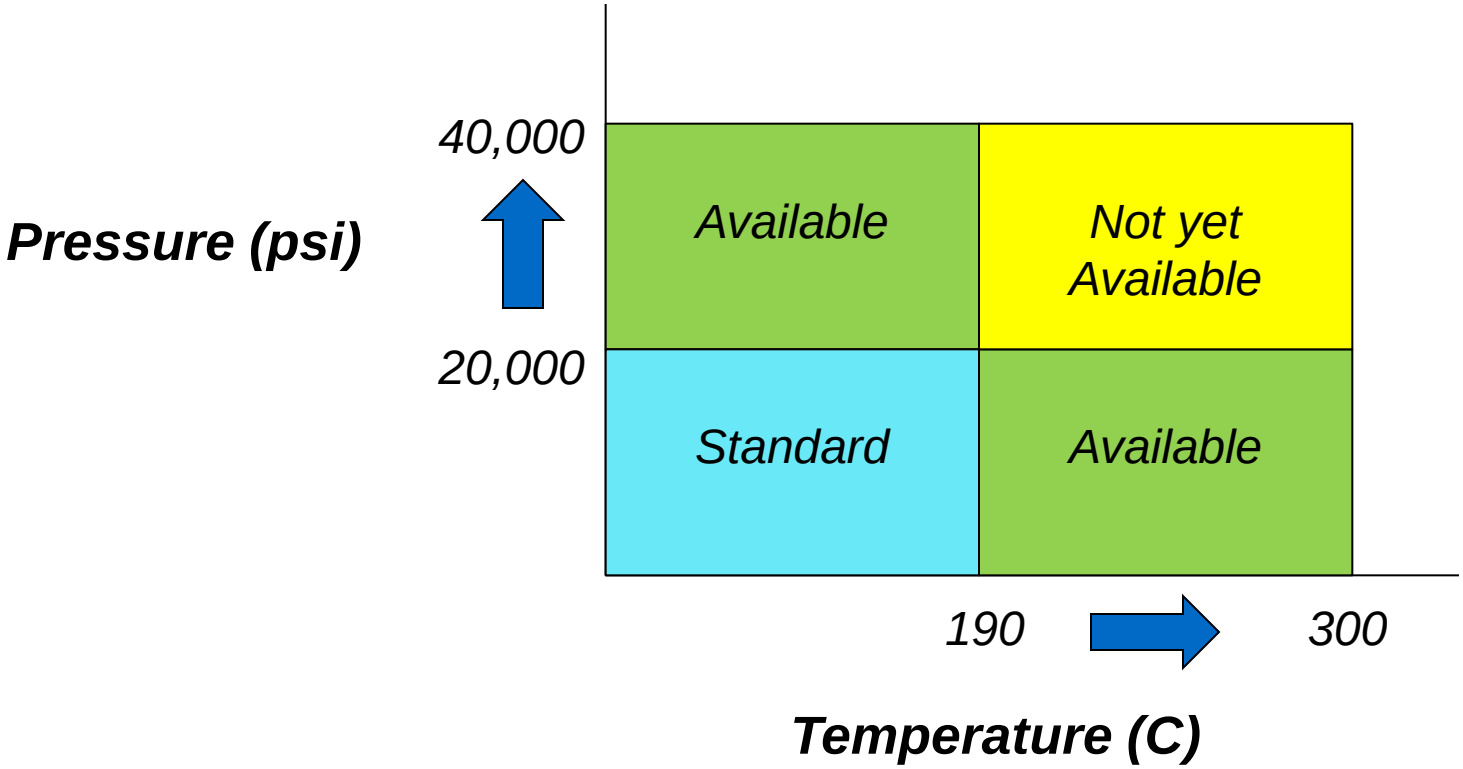


Low flow version

- *New H_2S –friendly materials (**Inconel, Hastelloy**)*

- *<u>Extended</u> Pressure & Temperature*
  Capabilities are ⟶ coming….

Ultra-High Temperature and Pressure Systems



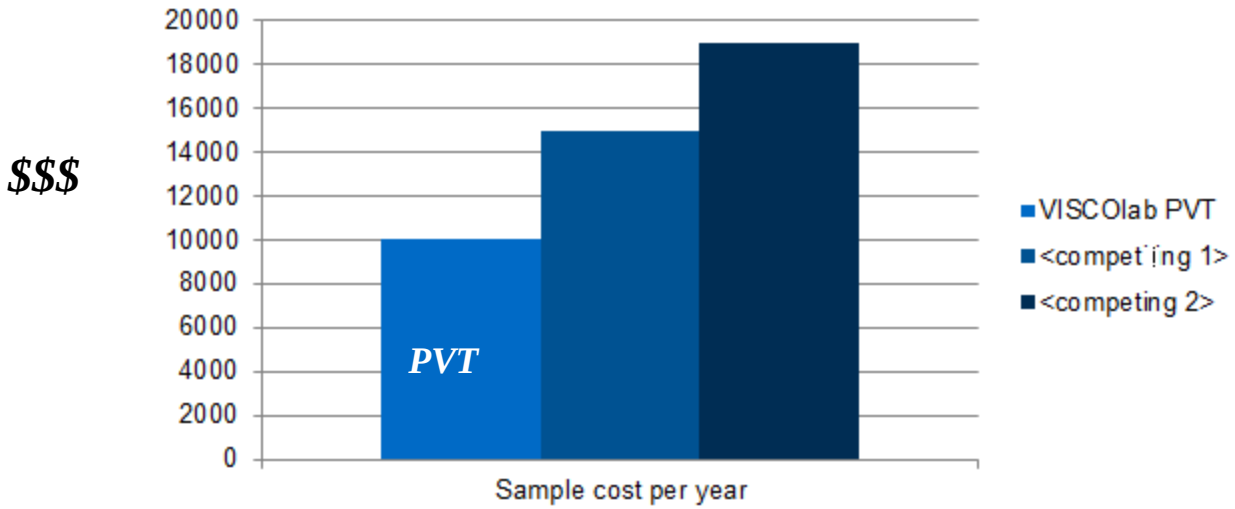
Now available ….

Key Points to remember On CVI PVT Viscometer

- ***Widest*** *operational range with minimal sample volume used - the only system that can measure gas*
- *Unique* ***automated*** *analysis*
- ***Simple*** *cleaning steps - increases lab efficiency*
- ***Robust****, Ergonomic Design Menus - lead to excellent analysis performance*
- ***Delivered*** *completely tested, calibrated and factory assembled for immediate turnkey operation*
- ***Very Cost Effective*** *– accurate results the first tim**e***

High Return on Investment

- *Based on the **sample size** & cost per year - compared to other systems*



- *Based on amount of oil sample available after water is removed - **typically only 50 ml***
- *Achieving accurate results with the first analysis*

Users in the Oil Market today

- ***Global*** *& Independent worldwide Oil Companies*
- *Oil Field Service Companies*
- ***Chemical*** *Manufacturers*
- *Fluid Reservoir Labs*
- *Oil Exploration Companies using Enhanced Oil Recovery* ***(EOR)***

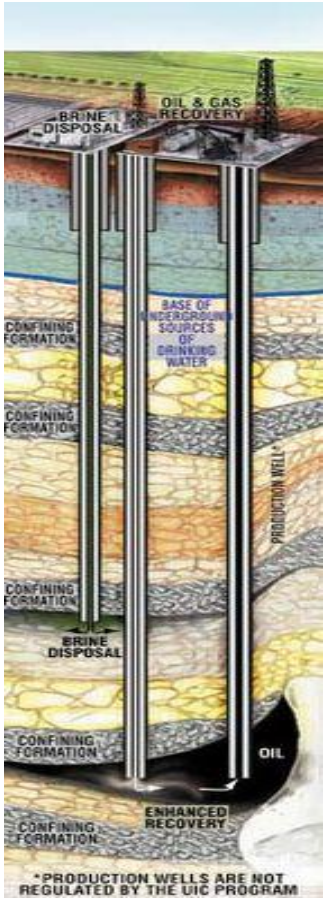
- ***Universities*** *& Scientific Institutes – performing analysis of phase change under extreme conditions for a wide variety of fluids & gasses*

Industry Feedback and Trends

- *Operation under **lower flow** rates*
- *Improved resistance to **H2S & Brine** fluids*
- *Increased Pressure and Temperature required*
- *Improved ease of use and **data collection***
- *Extend the Viscosity measurement of **Gas***
- *Assist in establishing HP/HT **standards***

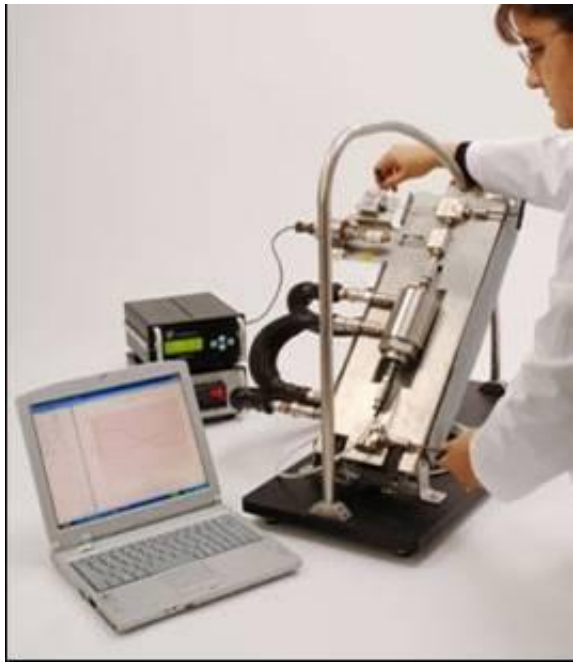
Enhanced Oil Recovery - EOR

- *Oil Exploration Companies now are looking to modify the **OIL Temperature** for easier extraction*
  - *They are now using viscosity analysis to see what changes occur by manipulating the temperatures*
- *CVI Viscometers are now being used to **analyze** oil temperature manipulation*



Summary:

Oil Exploration - Reservoir Analysis



VISCOlab PVT

– ***Industry Gold Standard:***

- *Accuracy*
- *Small sample size requirement*
- *High Pressure & temperature*
- *Ease of use*
- *Small footprint*
- *Wide viscosity range*
- *Fast analysis time*
- *Rugged System design*
- *Turnkey System*
- *Data Management*

- Enhancements Continue ....

State of the Art -

High Pressure/Temperature Viscometer

Contact PAC

- **For any questions, you can contact me at *william.small@paclp.com*. You may also email *PACsales@paclp.com*.**
- **Additional resources can be found at our website, *www.paclp.com*.**
- **Questions…….**

Thank you

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