PVT Lab Manual

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Abstract : Petroleum is a complex mixture of (sulfur, nitrogen, oxygen, helium) the physical and chemical properties of crude oils vary considerably and depend on the concentration of the various types of hydrocarbons and minor constituents present. And in the general there are there tests to measure hydrocarbon reservoir samples (Primary, Routine laboratory, Special laboratory PVT); Pouting laboratory test such as Compositional analysis of the system ,Constant-composition expansion ,Differential liberation ,Separator tests , and Constant-volume depletion.; Special laboratory PVT test such as Slim-tube test and Swelling test.

Introduction

Pressure-Volume-Temperature laboratory offers a comprehensive PVT program for all your reservoir fluid property requirements. Equipped with the latest equipment, PVT laboratory can provide a complete picture of any hydrocarbon sample. This data is essential for the economics and feasibility of any hydrocarbon reservoir. The experienced and specially trained staff can provide you accurate PVT analysis, which is vital for precisely calculating the reserves and also for evaluating the value of the reserve. Good PVT data ensures the reservoir is produced and managed in a controlled way, ultimately leading to maximum recovery. Such as

•Black Oil PVT Analysis

Our PVT laboratory can analyze all types of black oil pressurized samples. Specific services offered include Pressure Volume Relationship's, Differential Vaporization experiments, Pressurized Viscosity determinations and Separator Test analysis.

•Volatile Oil PVT Analysis

Volatile Oil PVT Analysis includes the analysis of volatile oil samples by means of the following techniques; Constant Composition Expansion measurement and Constant Volume Depletion analysis.

•Gas Condensate PVT Analysis

Pressure Volume Temperature laboratory analysis of gas condensate samples includes these services; Constant Composition Expansion measurement and Constant Volume Depletion analysis.

•Gas Compositional Analysis

Extended or basic gas compositional analysis utilizing modified gas chromatographs. Water Analysis

Standard oilfield water analysis utilizing wet chemistry and spectrometric analysis techniques

Table of content:

Preface

Petroleum is a complex mixture of (sulfur, nitrogen, oxygen, helium) the physical and chemical properties of crude oils vary considerably and depend on the concentration of the various types of hydrocarbons and minor constituents present. The properties of primary petroleum engineering include

- Fluid gravity
- Specific gravity of the solution gas
- Oil density
- Gas solubility
- Bubble-point pressure
- Oil formation volume factor
- Isothermal compressibility coefficient of under saturated crude oils
- Under saturated oil properties
- Total formation volume factor
- Crude oil viscosity
- Surface tension

And in the general there are there tests to measure hydrocarbon reservoir samples (Primary, Routine laboratory, Special laboratory PVT)

1. Primary test
Routines tests involving the measurements of the specific gravity and the gas-oil ratio of the produced Hydrocarbons fluids.

2. Routing laboratory test

These are several laboratory tests that are routinely
> Compositional analysis of the system
> ZConstant-composition expansion
> Differential liberation
> Separator tests
> Constant-volume depletion

3. Special laboratory PVT test

Performed for very specific applications
Tests may be performed:
> Slim-tube test
> Swelling test
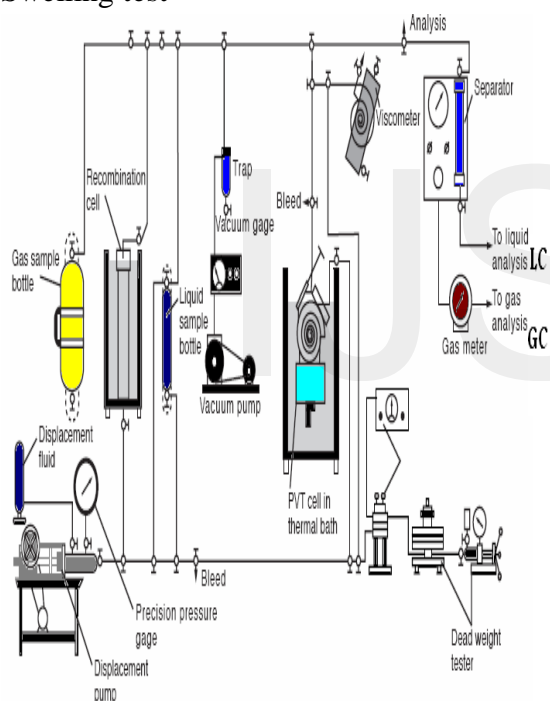
Sampling

- The value to be attached to the laboratory determinations depends on whether the sample investigated is representative of the reservoir contents.

- The taking of samples can be accomplished either by sub-surface sampling or by surface sampling.

1. <u>Subsurface Sampling</u>

- In this case a subsurface sampler is lowered into the well and kept opposite the producing layer for a sufficiently long time, figure in next slide.

- Subsurface samples can only be representative of the reservoir contents when the pressure at the point of sampling is above or equal to the saturation pressure. If this condition is not fulfilled, one should take a surface sample.

Subsurface sampling
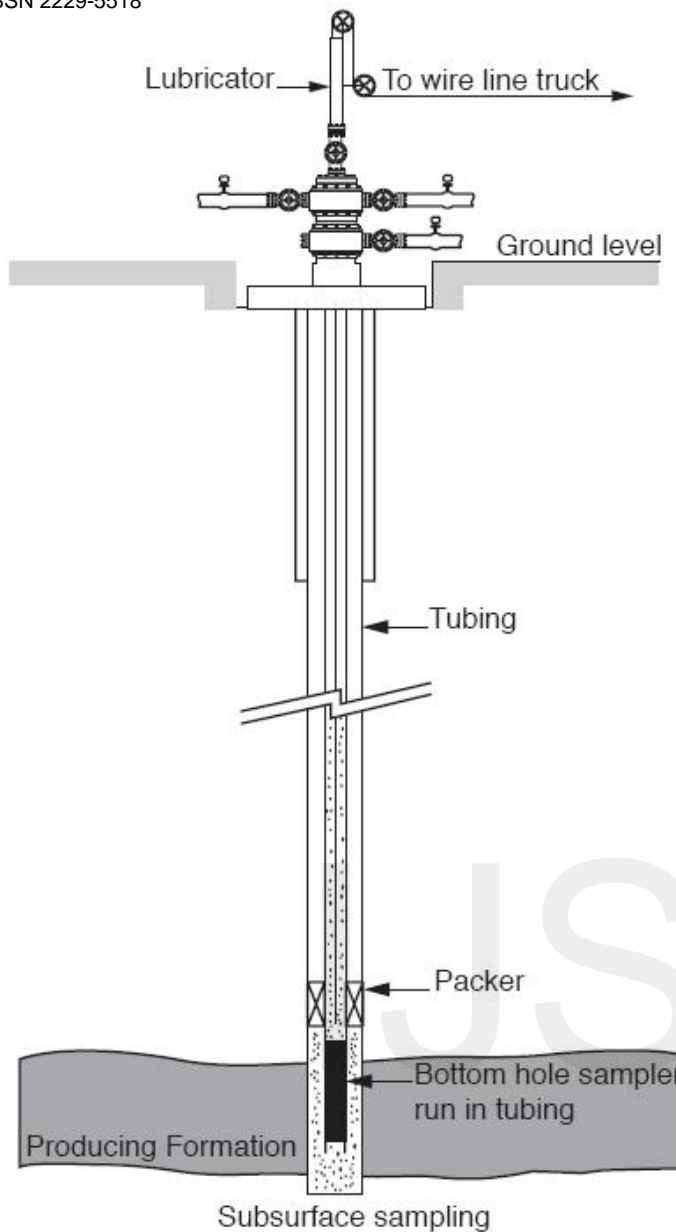
2. Surface Sampling

- In this case a subsurface sampler is lowered into the well and kept opposite the producing layer for a sufficiently long time, figure in next slide.

- Subsurface samples can only be representative of the reservoir contents when the pressure at the point of sampling is above or equal to the saturation pressure. If this condition is not fulfilled, one should take a surface sample.

- A sample of oil and gas is taken from the separator connected with the well (figures in next slides give sketches of vertical and horizontal separators and the arrangement for collecting different fluid samples).

- The surface oil and gas samples are recombined in the laboratory on the basis of the producing GOR.

- Particular care must be exercised in the field to obtain reliable samples and accurate measurement of the GOR and separator conditions. In the case of two or three stage separation the samples are taken from the high pressure separator.
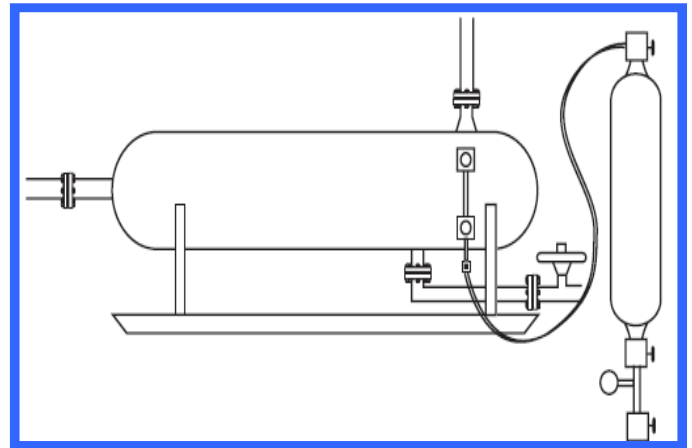
Separator Liquid Sampling by Water Displacement
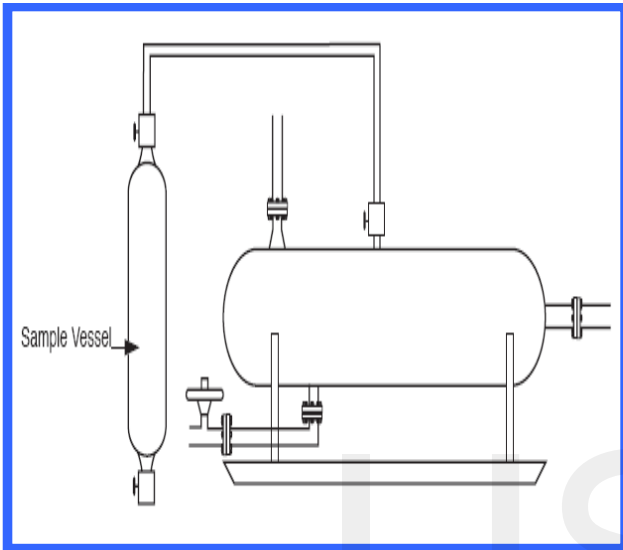
Separator Gas Sampling
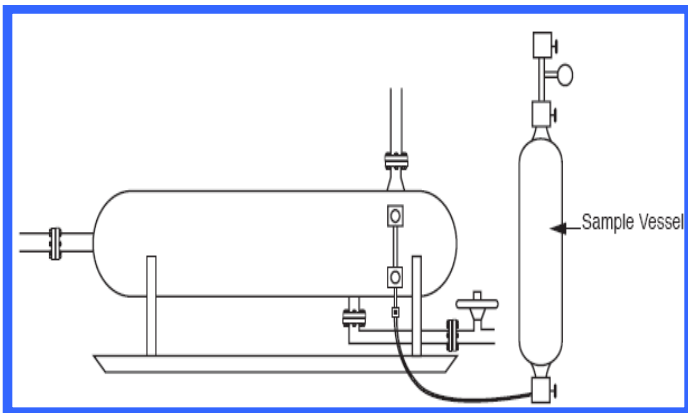
Separator Liquid Sampling by Gas Displacement

EXPERIMENT NO. 1

Fluid Density

Theory

The crude oil density is defined as the mass of a unit volume of the crude at a specified pressure and temperature. The specific gravity of a crude oil is defined as the ratio of the density of the oil to that of water. Both densities are measured at 60°F and atmospheric pressure; although the density and specific gravity are used extensively in the petroleum industry, the API gravity is the preferred gravity scale. This gravity scale is precisely related to the specific gravity.

The American Petroleum Institute gravity, or API gravity, is a measure of how heavy or light petroleum liquid is compared to water. If its API gravity is greater than 10, it is lighter and floats on water; if less than 10, it is heavier and sinks. API gravity is thus an inverse measure of the relative density of a petroleum liquid and the density of water, but it is used to compare the relative densities of petroleum liquids. For example, if one petroleum liquid floats on another and is therefore less dense, it has a greater API gravity. Although mathematically, API gravity has no units (see the formula below), it is nevertheless referred to as being in "degrees". API gravity is gradated in degrees on a hydrometer instrument. The API scale was designed so that

most values would fall between 10 and 70 API gravity degrees.

Test Equipment

The Pycnometer as shown below is used to determine density of reservoir fluid which consists of a constant volume cup with a cover which contains hole in the middel .

Figure 1.1: Typical Pycnometer
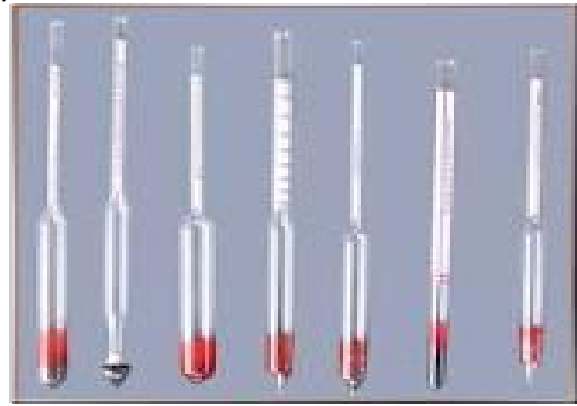
Figure 1.2: Typical Hydrometer

The Pycnometer as shown below is used to determine density of reservoir fluid which consists of a constant volume cup with a cover which contains hole in the middel .

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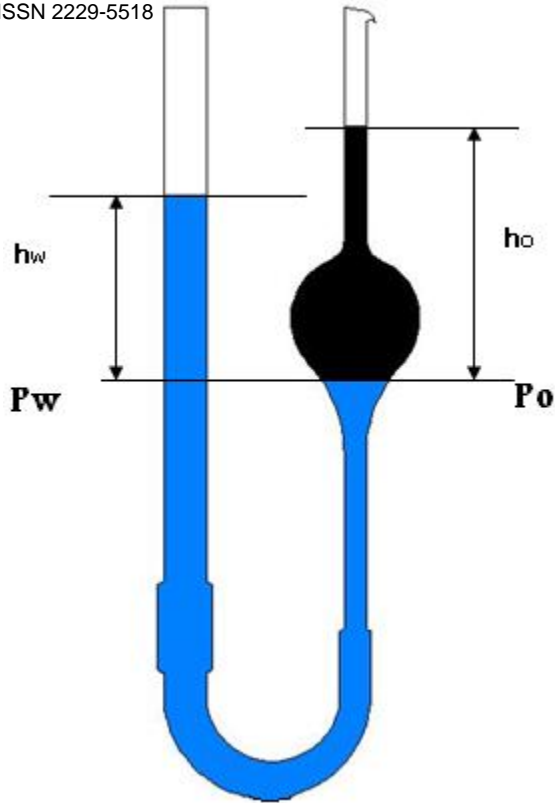
Figure 1.3: Typical U-Tube

At the same level the pressure extracted by the the oil column is equal to the pressure extracted by the water column so:

Po=Pw

Gravity*$Density_w$*$height_w$= Gravity*$Density_o$*$height_o$

$Density_w$*$height_w$= $Density_o$*$height_o$

$Height_w$ /$height_o$= $Density_o$/$Density_w$

$Height_w$ /$height_o$= Sp.gr

$$\text{API gravity} = \frac{141.5}{\text{hw/ho}} - 131.5$$

Measurement of API gravity from its density

To derive the API gravity from the density, the density is first measured using either the hydrometer, detailed in ASTM D1298 or with the oscillating U-tube method detailed in ASTM D4052. Density adjustments at different temperatures, corrections for soda-lime glass expansion and contraction and meniscus corrections for opaque oils are detailed in the Petroleum Measurement Tables, details of usage specified in ASTM D1250. The specific gravity is then calculated from the formula below and the API gravity calculated from the first formula above.

$$\text{SG oil} = \frac{\rho_{\text{oil}}}{\rho_{\text{H}_2\text{O}}}$$

Classifications or grades

Generally speaking, oil with an API gravity between 40 and 45 commands the highest prices. Above 45 degrees the molecular chains become shorter and less valuable to refineries.

Crude oil is classified as light, medium or heavy, according to its measured API gravity.

- Light crude oil is defined as having an API gravity higher than 31.1 °API (less than 870 kg/m^3)
- Medium oil is defined as having an API gravity between 22.3 °API and 31.1 °API (870 to 920 kg/m^3)
- Heavy crude oil is defined as having an API gravity below 22.3 °API (920 to 1000 kg/m^3)
- Extra heavy oil is defined with API gravity below 10.0 °API (greater than 1000 kg/m^3)

Not all parties use the same grading. The United States Geological Survey uses slightly different definitions.

Crude oil with API gravity less than 10 °API is referred to as extra heavy oil or bitumen. Bitumen derived from the oil sands deposits in the Alberta, Canada area has an API gravity of around 8 °API. It is "upgraded" to an API gravity of 31 °API to 33 °API, and the upgraded oil is known as synthetic crude.

Calibration

1. Remove the lid from the cup, and completely fill the device with water after heating it till reach 60°F (make sure the thermometer)
2. Replace the lid and wipe dry.
3. Use the balance in order to get the net weight of the water.
4. Calculate the density by dividing the net weighton the volume which is writen on the device.

API gravity formulas

The formula to obtain API gravity of petroleum liquids, from specific gravity (SG), is:

$$\text{API gravity} = \frac{141.5}{\text{SG}} - 131.5$$

Conversely, the specific gravity of petroleum liquids can be derived from the API gravity value as

$$\text{SG at } 60°\text{F} = \frac{141.5}{\text{API gravity} + 131.5}$$

Thus, a heavy oil with a specific gravity of 1.0 (i.e., with the same density as pure water at 60°F) would have an API gravity of:

$$\frac{141.5}{1.0} - 131.5 = 10.0°\text{API}$$

Procedure:

1. We pick up a pycnometer and wash it very carefully by dry air until we are completely sure that its clean and dry
2. weight the *Bycnometer* empty
3. Make sure that the pycnometer is completely filled until the specific label
4. But volatile oil in it
5. Wight the pycnometer full of volatile
6. Calculate the net weight of the desired fluid by subtracting the empty weight of pycnometer from filled weight of pycnometer
7. But heavy oil in the Bycnometer
8. Wight the heavy oil that in Bycnometer
9. Do these steps for the condensate
10. And do it by using water
11. Calculate the weight of (condensate and volatile oil and the heavy oil)

Results:

$$\text{API} = \frac{141.5}{\gamma} - 131.5$$

RESULTS OF DENSITY TEST

Room Temp........... °F

Fluid Temp……….. °F

Pycnometer volume(ml)	WT of Pycnometer empty(gm)	WT of Pycnometer filled with fluid (gm)	net weight (gm)	Density gm/ml	sp-gr	API	fluid type
							condensate
							volatile
							heavy oil
							water

Comments:

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lot in identifying the type of the oil we are dealing with. As a result we are going to deal with a device rolling ball viscometer. And we will use this device to identify the density of oil according to the sample temperature and pressure

Errors:

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Theory

Error analyses:

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EXPERIMENT NO. 2

Fluid Viscosity

Aim:

The aim of this experiment is to calculate the viscosity of a certain oil sample. Viscosity helps a

Chandler's high pressure viscometer is a manual, time-measuring, instrument that operates on the principle of the measurement of time required for a rolling ball, affected by shear and pressure of the fluid, to travel a pre-determined distance at controlled conditions. It employs a rolling steel ball for determining the dynamic viscosity of liquid-phase samples at constant temperatures and pressures. The ball is positioned inside the measuring barrel with the test fluid sample so that it is limited to only rolling type motion. An electronic timer records the time required for the ball to roll through the barrel.

The Chandler high pressure Rolling Ball Viscometer is a precision instrument used to determine the viscosity of bottom-hole and surface samples of reservoir oils at elevated temperatures and pressures to 10,000 psi at 300°F. Accurate and reproducible engineering data is obtainable, whether the specific application is to determine the viscosity of petroleum fluids at simulated reservoir conditions, or liquid phase viscosities at other predetermined pressures and temperatures. The samples measured must be electrically non-conductive. The viscometer operates on a rolling-ball principle where the roll-time of a ¼-inch-diameter ball is used to obtain viscosity data. Viscosity values are then obtained by correlation of the measured data with curves of fluids with known viscosities and densities.

Safety Requirements

• Operator SHOULD avoid contact with the bare surface of the test assembly jacket when in operation. The instrument control box SHOULD NOT at any time be opened during operation. An unskilled person SHOULD NOT troubleshoot potentially dangerous equipment. Safety SHOULD NOT be assumed. The operator must keep in mind, even the most sophisticated instrument cannot think; (a) insulators do not always insulate, (b) conductors do not always conduct properly, (c) resistors do not always dissipate the required heat. For these reasons, the operator should carefully follow the outlined instructions of this manual and consult the manufacturer when specific questions arise. *CAUTION: Exposure to H2S is potentially fatal. Use adequate safety procedures when handling H2S samples. Consult your safety department for proper procedures for handling H2S.*

Operation

In the rolling-ball viscometer, the time it takes a metal ball to roll from one end of a fluid filled tube to the other is an indication of the viscosity for the fluid. Mathematically this is expressed as:

In the rolling-ball viscometer, the time it takes a metal ball to roll from one end of a fluid-filled tube to the other is an indication of the viscosity for the fluid. Mathematically this is expressed as:

$$\mu = \frac{(\rho_B - \rho_F)gR^2 \sin\theta}{v_\infty}$$

Where,

μ	=	Dynamic Viscosity
ρ_B	=	Density of the ball
ρ_F	=	Density of the fluid
g	=	Acceleration due to gravity
R	=	Diameter of the ball
θ	=	Angle of the measuring barrel
v_∞	=	Velocity normal to the Earth in the down direction
		Defined as distance over time (d/t)

For a given set of tests, the distance variable of the velocity term, along with g, R and θ, remain constant. Therefore, the above equation can be conveniently expressed as follows:

$$\mu = K\,t\,(\rho_B - \rho_F)$$

From the above equation it can be seen that for a constant ball and fluid density ($\rho_B - \rho_F$), the viscosity (μ) is directly proportional to the ball roll-time (t). Effectively, the ball is forced down the tube due to gravitational effects at a rate dependent upon the fluid viscosity and the difference between the density of the ball and that of the fluid. Any increase in fluid density reduces the effect of gravity acting on the ball. The ball will correspondingly fall more slowly (an increase of the t term), and indicates a higher viscosity value. Conversely, as the density term diminishes to zero, the viscosity value also approaches zero.

1. Choose the correct ball size. This can be done by examining the sample fluid. If the fluid viscosity is estimated to be below 25 centipoise (above 25° API), a .252- or .248-inch diameter ball should be used. Above 25 centipoise (below 25° API), the .234-inch diameter ball will be appropriate. The balls are not interchangeable and must be kept separate.

2. Clean the test assembly. Since the barrel, ball and inner chamber must be completely free of dirt and lint, care should be taken to secure a clean test assembly before undertaking any measurements. Light oil, such as kerosene, and thin paper should be used to clean the ball and chamber.

3. Place the ball in the bottom of the empty measuring barrel from the upper end of the assembled test unit.

4. Evacuate the test assembly. This is done by opening the vacuum pump valve at the lower end of the unit and closing the charging valve.

5. Charge the test sample fluid to the viscometer. The vacuum valve should be closed while the high pressure charging valve should now be reopened.

6. Rock the test assembly to obtain a single-phase sample. A mixing device called the "Slip Ring Mixer" is installed to facilitate the effort. Effectively, the task is completed when pressure fluctuations of the sample have ended. Sufficient time afterwards should be allowed to permit the newly liberated gas bubbles to escape from the measuring barrel. Particularly in the case of heavy fluids, a bubble trapped under the ball will sometimes hinder it from free-fall. The surface tension of the oil prevents the bubble from passing

between the confines of the barrel and ball; the bubble thus reduces the weight of the ball and lengthens its roll-time or might prevent electrical contact entirely.

7. Set the temperature of the viscometer to the desired test temperature with the barrel valve open. First, the main power switch (Item #10) must be switched to the **ON** position. Set the desired temperature on the temperature controller (Item #9; this is done by pressing the **UP** and **DOWN** arrows; refer to manufacturers' manual for instructions). The **OP 1** light will illuminate to indicate the proper temperature cycling. During heating, it is very important that the chamber be open to a pressure control system. Allow one hour after the temperature set point has been reached for the test unit and sample to reach thermal equilibrium. Once the desired temperature and pressure has stabilized, rock the test assembly again to homogenize the sample and then close the charging valve.

8. Bring the ball into the **TOP** position at the upper end of the measuring barrel by rotating the receptacle arm handle (Item #49; See Drawing #1602-1). The handle should be rotated towards the upper end of the test unit until the 180° stop assembly (Item #67) engages with the stop lug mounted on the test unit. The **Top** indicator (Item #6) will illuminate when the ball has travelled through the length of the barrel and made contact

with the barrel valve plunger (Item #1 from Drawing #1602-1). At this time, the appropriate resolution of the timer may be determined. The Timer has a 6-digit display with a maximum resolution of 0.001 seconds; this setting yields a maximum test time of approximately 16 minutes and 40 seconds. If the ball takes longer than this to fall from the bottom to the top, adjust the resolution of the Timer (refer to manufacturers' manual for instructions).

9. Energize the solenoid with the **Coil** toggle switch (Item #11) in the **ON** position. Now the ball can be held in the **TOP** position. The test unit is then returned to the operating position.

10. Zero the clock by pushing the **RST** button on the **Timer** (Item #7).

11. Release the ball by pressing the DROP button. The TIMER will start when the ball is no longer in contact with the barrel valve plunger. When the ball makes contact at the end of the roll, the **Timer** stops, the **Alarm** (Item #5) sounds and the **Bottom** light illuminates.

Calibration

As stated previously, operation of the Chandler Rolling Ball Viscometer is based on the following equation:

$$\mu = K\,t\,(\rho_B - \rho_F)$$

Where,

μ	=	Dynamic Viscosity
K	=	Calibration Constant
t	=	Roll Time
ρ_B	=	Density of the Ball
ρ_F	=	Density of the Fluid

Figure 1.4: **Rrolling Ball Viscometer**

The Calibration Constant (K) is dependent upon the size of the ball, the angle of the measuring barrel and the vertical distance traveled. Therefore, everything else being equal, the value of K varies with each ball and roll angle. A calibration should be conducted for each individual ball used at each measuring angle.

Chandler Engineering recommends an annual "spot check" of the Calibration Constant for each ball used, at each angle and at least three (3) temperatures. A simple "spot check" procedure would be to measure the viscosity of a Viscosity Standard. A full calibration should also be performed if any critical component (the ball, measuring barrel, coil assembly, lower contact assembly, control cable or control box) is replaced.

Calibration Procedure

One or more Viscosity Standards (fluids of known density and viscosity at test temperatures) should be used. A roll-time mean is taken from five consistent readings at each desired Roll Angle. All calibrating tests are made at atmospheric pressure.

1. Choose the correct ball size. If the viscosity of the Viscosity Standard is below 25 centipoise (above 25° API), a .252- or .248-inch diameter ball should be used. Above 25 centipoise (below 25° API), the .234-inch diameter ball will be appropriate. The balls are not interchangeable and must be kept separate.
2. Check the diameter and density of the selected ball.
3. Select a minimum of three (3) Test Temperatures from the data sheet of the Viscosity Standard. Typically these are:
a. Ambient (77°F or 25°C)
b. Mid-Range (122°F or 50°C)
c. High Temperature (212°F or 100°C)

WARNING: Select temperatures that are BELOW the Boiling Point of the Viscosity Standard.
4. Clean the test assembly. Since the barrel, ball and inner chamber must be completely free of dirt and lint, care should be taken to secure a clean test assembly before undertaking any measurements. Light oil, such as kerosene, and thin paper should be used to clean the ball and chamber.
5. Place the ball into the empty measuring barrel while in a horizontal position. Slowly raise

the barrel from horizontal and allow the ball to gently roll to the bottom.

6. Fill the viscometer with the Viscosity Standard. Rock the test assembly to obtain a single-phase sample.

7. Set the temperature controller to the first test temperature. Allow one hour after the set point has been reached to allow the temperature to balance throughout the unit.

8. Run several roll tests until at least five (5) consistent roll times are obtained at each measuring angle: 70°, 45°, and 23°.

9. Repeat steps 7 and 8 above for each test temperature.

10. Select as many different Viscosity Standards as required and repeat the above procedure.

11. Compute the mean roll time for each set of roll times (i.e. for each combination of ball, measuring angle, Viscosity Standard and temperature).

12. Divide the known viscosity of the Viscosity Standard by the product of the mean roll time and the difference in density of the selected ball and that of the Viscosity Standard. This is the Calibration Constant. Tables similar to the one below may facilitate this process.

Test Temperature	°F		
Roll Angle	23°	45°	70°
Density of Ball (ρ_B)	g/cc		
Density of Fluid (ρ_F)	g/cc		
$\Delta\rho$ ($\rho_B - \rho_F$)	g/cc		
Viscosity of Standard at Temperature (μ)	cP		
Roll Time 1	s		
2	s		
3	s		
4	s		
5	s		
Mean Roll Time (t)	s		
Calibration Constant K = μ / ($t \Delta\rho$)			

Calibration Fluid					
Test Temperature	77.00	°F	122.00	°F	212.00	°F
Fluid Density (ρ_F)	0.8731	g/mL	0.8575	g/mL	0.8262	g/mL
$\Delta\rho$ ($\rho_B - \rho_F$)	6.8978	g/mL	6.9134	g/mL	6.9447	g/mL
Known Viscosity (μ_C)	104.1	cP	29.77	cP	6.227	cP
Mean Roll Time (t)	4.909	s	1.401	s	0.292	s
Calibration Constant (K) $K = \mu_C / (t\,\Delta\rho)$	3.0743		3.0736		3.0707	

This example viscosity measurement was then performed using the test fluid at the same test conditions of the calibration (0.252 ball, 70° barrel angle, atmospheric pressure). The density of the

test fluid at test temperatures was measured or obtained prior to the test. Again, several roll tests were conducted at each test temperature until consistent results were obtained.

VISCOSITY MEASURMENT

Test Fluid					
Test Temperature	77.00	°F	122.00	°F	212.00	°F
Fluid Density (ρ_F)	0.8728	g/mL	0.8559	g/mL	0.8219	g/mL
$\Delta\rho$ ($\rho_B - \rho_F$)	6.8981	g/mL	6.9150	g/mL	6.9490	g/mL
Mean Roll Time (t)	0.371	s	0.177	s	0.068	s
Measured Viscosity (μ_M) $\mu_M = K\,t\,\Delta\rho$	7.868	cP	3.762	cP	1.451	cP

2- Digital balance.

3- Rolling ball viscometer

Equipment:

1- Oil sample
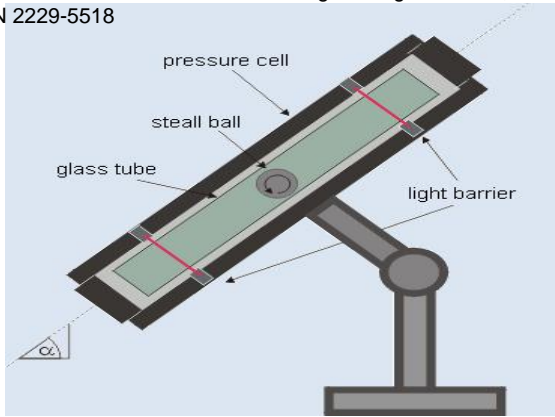
4- Pycnometer

Procedures:

1- Put the sample in the rolling ball viscometer

2- Hold the ball

3- Drop the ball and switch on the device at the same time.

4- The rolling ball viscometer at angle =70

5- Weigh the pycnometer

6- Weight the pycnometer filled with oil

7- Determine the weight of the oil sample.

8- Calculate the density of the sample

9- Calculate the viscosity (μ= K t (ρb - ρf))

Results:

$$\mu = \frac{[(\rho b - \rho f)g\, R^2 \sin\square]}{v}$$

V is the velocity of the ball (v=d/t)
Distance over the time

K is calibration constant → K= $\dfrac{gR^2 \sin\square}{d}$

ρf =   gm. /cc
t=   sec
k=   (cm /sec) ^2

Condition of caliberation (0.252inch ball diameter 70 parrel angle , atmospheric preesure) the density of the test fluid
Test temp =122F
Density of fluid=
Time=   sec
(density ρ_B = 7.7709 g/cc), the Measuring Barrel at and angle of 70° (use thermometer to make sure the fluid`s tempertue is 122 F foe density & viscosity) and at atmospheric pressure

Comments:

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Errors:

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Error analyses:

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EXPERIMENT NO. 3

Pour Point

Theory

The Pour Point test for crude oil is designed to identify difficulties in storage and handling of crude oil with unusually high oil pour point. (Never store fuel near or below the tested oil pour point) where by the Pour Point is the lowest temperature at which fuel can be handled before the viscosity becomes unmanageable even for positive displacement fuel transfer pumps. Fuel is easy to keep warm but once "set" in this way it can be very difficult to re-liquefy with obvious consequences; this really is a very simple test with instructions and equipment provided in the Lab

Error analyses:

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Test Procedure

1- Fetch the oil sample and put it by angle 45 degree.
2- Use water path or oven to begin heating the sample.
3- Insert thermometer into crude to measure the temperature.
4- Observe the sample until the first drop appears.
5- Record the temperature at this point.

Crude oil type	Pour Point Temperature

Comments:

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Errors:

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EXPERIMENT NO. 4

GAS FORMATION VOLUME FACTOR

Theory

The gas formation volume factor is used to relate the volume of gas, as measured at reservoir conditions, to the volume of the gas as measured at standard conditions, i.e., 60°F and 14.7 psia. This gas property is then defined as the actual volume occupied by a certain amount of gas at a specified pressure and temperature, divided by the volume occupied by the same amount of gas at standard conditions.

Assuming that the standard conditions are represented by psc =14.7 psia and Tsc =**520**   Bg =0.02827 ZT/P where Bg = gas formation volume factor, ft3/scf

Z = gas compressibility factor

T = temperature, °R
In other field units, the gas formation volume factor can be expressed in bbl/scf, to give: $B_g = 0.005035 \, ZT/P$

The reciprocal of the gas formation volume factor is called the gas expansion factor and is designated by the symbol Eg, or

$$E_g = 35.37 \, P/ZT$$

scf/ft^3, $E_g = 198.6 \, P/ZT$ scf/bbl

Test Procedure

1. Starting by Gas sample at 60 F & 14.7 psia.
2. Use the oven to heat the sample until reach certain temperature.
3. Use **Jog** mode then increase the volume of the Gas sample**.**
4. Record the new Temperature & Pressure.
5. Calculate Z factor

$$z = \frac{V_R p_R T_{sc}}{V_{sc} p_{sc} T_R}$$
.

6. Calculate **Bg** use the above formula.

Phase Change of Two-Component System at Constant Temperature

Results
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Comments:
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Errors:

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Error analyses:

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EXPERIMENT NO. 5

Gas Density & Specific Gravity
Theory

One of the main gas properties that are frequently of interest to engineers is the apparent molecular weight. If yi represents the mole fraction of the component in a gas mixture, the apparent molecular weight is defined mathematically by the following equation:

$M_a = \sum yi\ Mi$

Where Ma = apparent molecular weight of a gas mixture
Mi = molecular weight of the component in the mixture
yi = mole fraction of component i in the mixture
The density of an ideal gas mixture is calculated by simply replacing the molecular weight of the pure

component with the apparent molecular weight of the gas mixture to give:

$\rho_g = PMa/RT = m/V$

Where ρ_g = density of the gas mixture, lb/ft3
    P = psia
    T = R

The specific gravity is defined as the ratio of the gas density to that of the air. Both densities are measured or expressed at the same pressure and temperature. Commonly, the standard pressure p_{sc} and standard temperature T_{sc} are used in defining the gas specific gravity:

$\gamma = \rho_g / \rho_{air} = Ma/M_{air}$

where γg = gas specific gravity
ρ_{air} = density of the air
M_{air} = apparent molecular weight of the air = 28.96

Test Procedure

1. Starting by Gas sample at 60 F & 14.7 psia.

2. Use the oven to heat the sample until reach certain temperature.

3. Use **Jog** mode then increase the volume of the Gas sample**.**

4. Record the new Temperature, Pressure, and Volume.

5. Calculate Z factor

$$z = \frac{V_R p_R T_{sc}}{V_{sc} p_{sc} T_R}$$.

6. Use **GC** to obtain mole friction**.**

7. Calculate Gas gravity & density use the above formulas.

$$\rho_g = 300 \ * \ 16.5617924/10.7/630 = 0.74 \ lb/cu.ft$$

$$\gamma = \rho_g / \rho_{air} = Ma/M_{air}$$

Results
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....

Comments:
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Errors:
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....

Error analyses:
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EXPERIMENT NO. 6
GAS VISCOSITY

The viscosity of a fluid is a measure of the internal fluid friction (resistance) to flow. If the friction between layers of the fluid is small, i.e., low viscosity, an applied shearing force will result in a large velocity gradient. As the viscosity increases, each fluid layer exerts a larger frictional drag on the adjacent layers and velocity gradient decreases.

The viscosity of a fluid is generally defined as the ratio of the shear force per unit area to the local velocity gradient. Viscosities are expressed in terms of poises, centipoise the gas viscosity is not commonly measured in the laboratory because it can be estimated precisely from empirical correlations. Like all intensive properties.

The Carr-Kobayashi-Burrows Correlation Method

Carr, Kobayashi, and Burrows (1954) developed graphical correlations for estimating the viscosity of natural gas as a function of temperature, pressure, and gas gravity. The computational procedure of applying the proposed correlations is summarized in the following steps:

Step 1. Calculate the pseudo-critical pressure, pseudo-critical temperature, and apparent molecular weight from the specific gravity or the composition of the natural gas. Corrections to these pseudocritical properties for the presence of the nonhydrocarbon gases (CO2, N2, and H2S) should be made if they are present in concentrations greater than 5 mole percent.

Step 2. Obtain the viscosity of the natural gas at one atmosphere and the temperature of interest from Figure 2-5. This viscosity, as denoted by μ1, must be corrected for the presence of nonhydrocarbon components by using the inserts of Figure 2-5. The nonhydrocarbon fractions tend to increase the viscosity of the gas phase. The effect of nonhydrocarbon components on the viscosity of the natural gas can be expressed

mathematically by the following relationships:

$$\mu_1 = (\mu 1)\text{ uncorrected} + (\Delta\mu)_{N2} + (\Delta\mu)_{CO2} + (\Delta\mu)_{H2S}$$

where μ_1 = "corrected" gas viscosity at one atmospheric pressure and reservoir temperature, cp

$(\Delta\mu)_{N2}$ = viscosity corrections due to the presence of N2
$(\Delta\mu)_{CO2}$ = viscosity corrections due to the presence of CO2
$(\Delta\mu)_{H2S}$ = viscosity corrections due to the presence of H2S
(μ_1) uncorrected = uncorrected gas viscosity, cp

Step 3. Calculate the pseudo-reduced pressure and temperature.

Step 4. From the pseudo-reduced temperature and pressure, obtain the viscosity ratio (μ_g/μ_1) from Figure 2-6. The term μg represents the viscosity of the gas at the required conditions.

Step 5. The gas viscosity, μ_g, at the pressure and temperature of interest is calculated by multiplying the viscosity at one atmosphere and system temperature, μ1, by the viscosity ratio.

The following examples illustrate the
use of the proposed raphical
correlations:

$$\mu_g = \frac{\sum\limits_{j} \mu_{gj} y_j M_j^{1/2}}{\sum\limits_{j} y_j M_j^{1/2}}$$

$$\mu_1 = (\mu_1)_{uncorrected} + (\Delta\mu)_{N_2} + (\Delta\mu)_{CO_2} + (\Delta\mu)_{H_2S}$$

where $\mu_1 =$ "corrected" gas viscosity at one atmospheric
pressure and reservoir temperature, cp

$(\Delta\mu)_{N_2} =$ viscosity corrections due to the presence of N_2

$(\Delta\mu)_{CO_2} =$ viscosity corrections due to the presence of CO_2

$(\Delta\mu)_{H_2S} =$ viscosity corrections due to the presence of H_2S

$(\mu_1)_{uncorrected} =$ uncorrected gas viscosity, cp
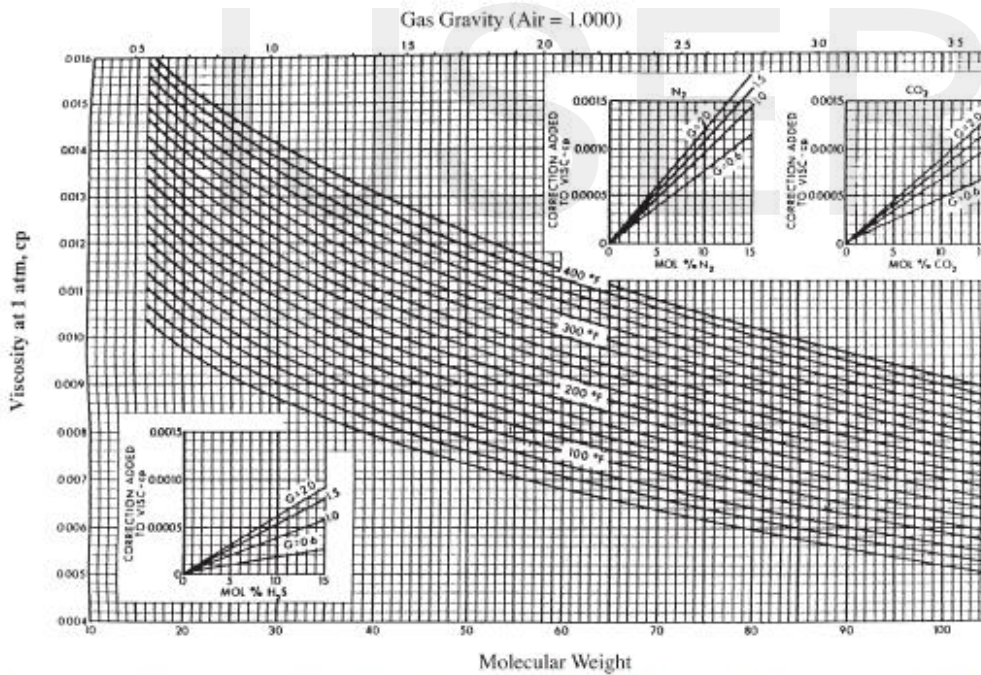
Figure 2-5. Carr's atmospheric gas viscosity correlation. (Permission to publish by the Society of Petroleum Engineers of AIME. Copyright SPE-AIME.)

Viscosity at 1 atm= 0.0093 C.p

 Џ/ Џ1= 1.1 so Viscosity at 1000psia &
170 F
=0.0093*1.1=0.01023 C.P

Gas Composition from Gas Chromo ghaph

Component	Mole %	Yi	Mi	yiMi	Tci R	Pci psia	yiTci	yiPci
Total		**0.99947**		**16.5617924**			**348.7935**	**665.6098**

Sp.gr C7+=   Tr=   Pr=
                   T=   F   P=   Psia

Error analyses:

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Comments:

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Errors:

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- the position of its critical point.

Importance of determination fluid type

☐The following reasons determine the importance of knowing fluid type it determines:

EXPERIMENT NO. 7

Classification of Reservoir Fluids
Five Reservoir Fluids

The petroleum engineer should determine the type of fluid very early in the life of his reservoir ;

the behavior of a reservoir fluid during production is determined by

- the shape of its phase diagram where by The shapes of the phase diagrams can be used in understanding the behavior of multicomponent mixtures

1. The method of fluid sampling,
2. the types and sizes of surface equipment,
3. the calculation procedures for determining oil and gas in place,
4. the techniques of predicting oil and gas reserves,
5. the plan of depletion .
6. the selection of enhanced recovery method are all dependent on the type of reservoir fluid.

Phase Change of Two-Component System at Constant Temperature

10. Repeat the same procedure until the 1st bubble appears.
11. Increase the temperature a little bit afterward repeat the same procedure until get the rest of 1st bubbles point's pressure.
12. Connect between the bubbles point's pressures for drawing bubble point line.
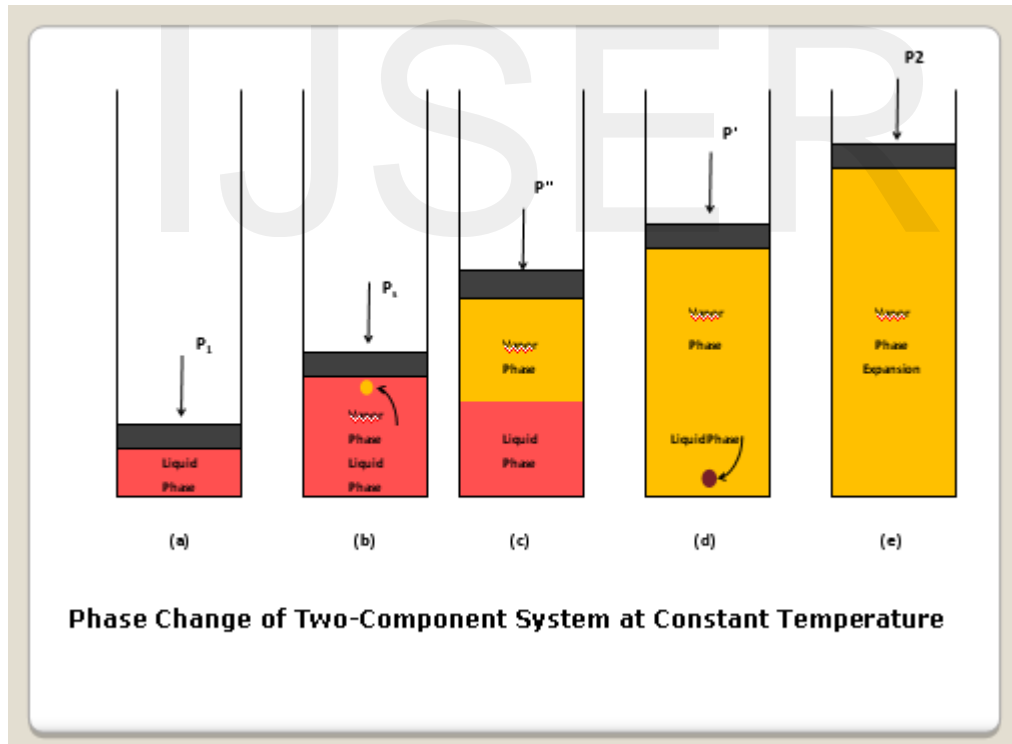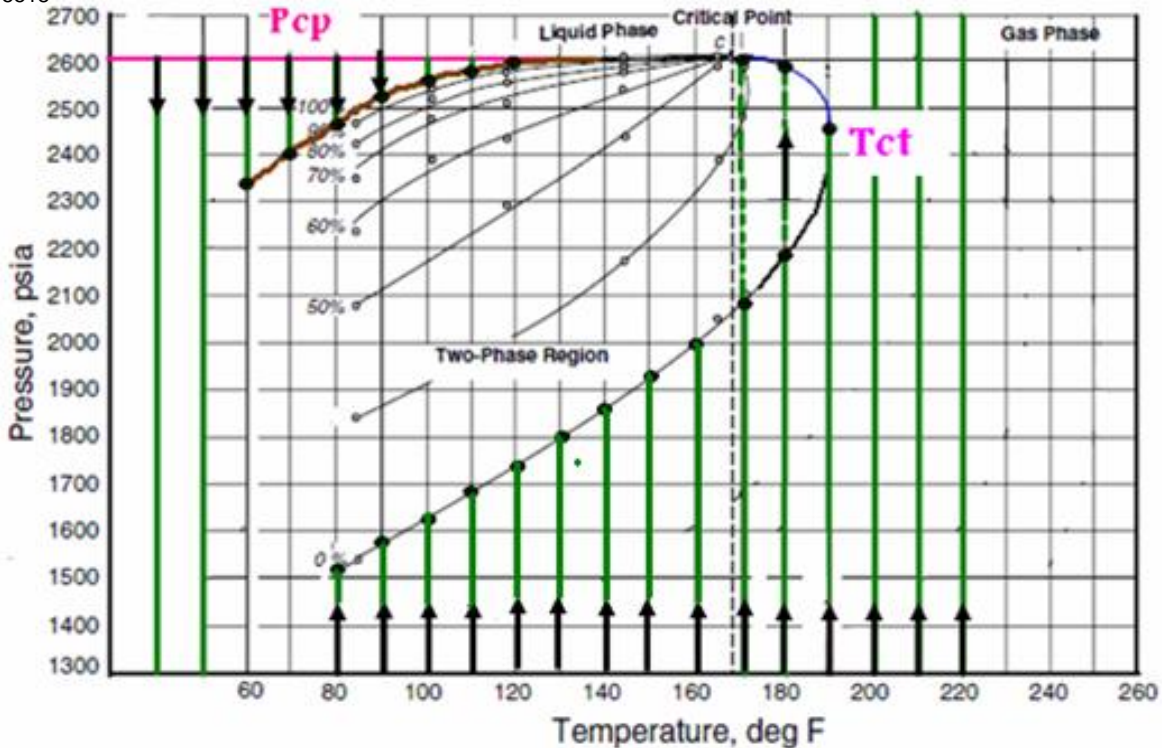
Bubble points line

8. Starting by live crude sample at low temperature & high pressure then decrease the pressure by constant rate until the 1st bubble appears.
9. If the bubble point doesn't appear while step one increase the temperature a little bit and use the pressure value in the step one then decrease the pressure by constant rate .

Dew points line

1. Starting by gas sample at high temperature & low pressure then increase the pressure by constant rate until the 1st gas condense (dew point).
2. If the dew point doesn't appear while step one decrease the temperature a little bit and use the

pressure value in the step one then increase the pressure by constant rate **.**

3. Repeat the same procedure until the 1st bubble appears **(it appears at Tct).**

4. Decrease the temperature a little bit afterward repeat the same procedure until get the 2nd dew point **at this point the volume of gas is 100% meanwhile the volume of condensate is 0%.**

5. Increasing the pressure until the volume of gas will be 0% and the volume of condensate will be 0%.

6. Repeat the same procedure at step 5 & step 6 until get the rest of dew points pressure**.**

7. Connect between the dews point's pressures for drawing dew point line.

Identification of Fluid Type

Reservoir fluid type can be confirmed only by observation in the laboratory; and quick available production information usually will indicate the type of fluid in the reservoir.

Fluid Type	API	GOR SCF/STB	Colour	Bo BBl/STB	Pi Psia	Ps Psia	T
Ordinary black oil	15 to 40	200–700	Brown-dark green		Undersaturated If Pi > Pb		Far Tc
Low-shrinkage crude oil	less than 35°	less than 200	Black-deeply colored	less than 1.2		Inside The envelope	
High-shrinkage	45–55°	2,000–	Greenish	less than 2	Saturated If Pi = Pb		

(volatile)		3,200	to orange				
Near-critical crude oil	Around 50°	excess of 3,000		2.0 or higher	Gas-cap If Pi $<$ Pb		Nearest Tc
Retrograde gas-condensate	above 50°	8,000 and 70,000	water-white				Tc-Tct
Near-critical gas-Condensate	above 60°	60,000 to 100,000	water-white				Near Tc
Wet gas	———	100,000					
Dry gas	———	———	———	———		outside The envelope	Far Tc

IJSER

Example

Pump Cell Press (psia)
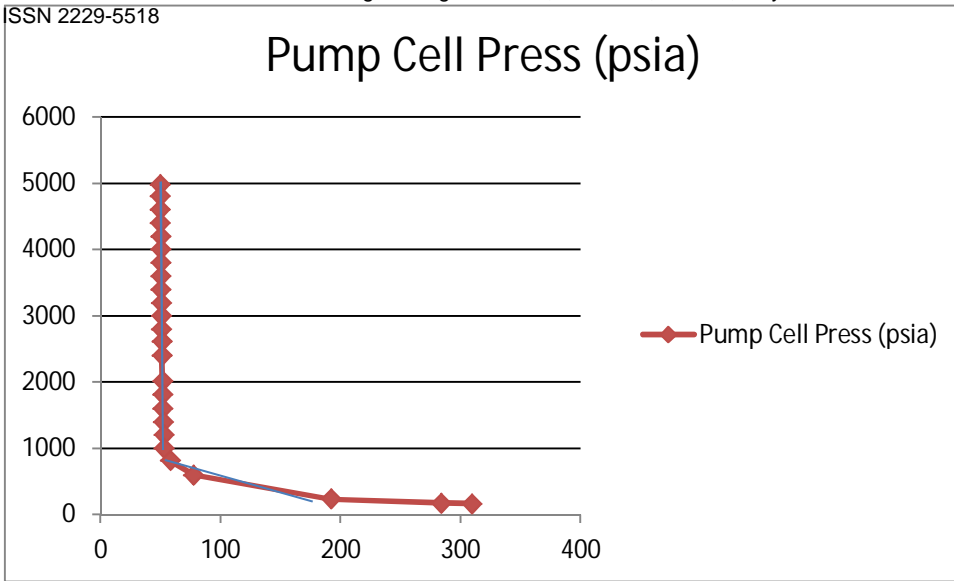
(cc)	(psia)
49.593	4987.3
49.693	4806.8
49.793	4605.7
49.906	4402.2
50.009	4204.6
50.119	4004.5
50.239	3802.1
50.363	3602.1
50.489	3402.1
50.617	3200.8
50.756	3003.2
50.905	2801.9
51.067	2611.6
51.267	2404.2
51.712	2012.6
51.958	1813.8
52.056	1602.8
52.361	1396.7
52.71	1202.7
53.192	1002.6
58.041	816
77.475	601.3
191.94	236.6
283.794	174.4
309.551	163.4

Comments:

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Errors:

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Error analyses:

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Results

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EXPERIMENT NO. 8
Equilibrium Flash Separator Test

Purpose:

The Equilibrium Flash Separator can be used to measure gas oil ratio, relative volume, residual oil gravity, and related information on bottom hole.

Test Procedure:

1. This test simulates flashing from reservoir pressure or well head to separator then stock tank.
2. Close the inlet flash valve and drain valve
3. Open regulator off valve.
4. Close bypass off valve.
5. Adjust the back pressure regulator to desired 1 st stage separator test pressure.
6. Expand the fluid sample into the separator .

7. Close the inlet flash valve and slowly open the drain valve.
8. Record the initial external pump volume reading and initial gasometer volume reading.
9. Weight the 2nd stage tube .
10. Record zero initial gasometer volume reading for the 2nd stage.
11. Carefully open the drain valve to drain receiver tube.
12. **Record the data into the blow table.**

		Pump cell		
		Pressure	Volume	Temp
		psia	*CC*	*°C*
Initial				
Final				
Difference				

Liquid							
First stage sep.				second stage sep.			
Pressure		Volume	Temp	Pressure		Volume	Temp
Psig	*psia*	*CC*	*°C*	*Psig*	*psia*	*CC*	*°C*
Difference							

Gas (as meaured by Gasometer)							
First stage sep.				second stage sep.			
Pressure		Volume	Temp	Pressure		Volume	Temp
Psig	*psia*	*CC*	*°C*	*Psig*	*psia*	*CC*	*°C*
Difference							

	Atmospheric
glass tube wt.	Pressure
gm	*psia*
81.611	14.23
97.117	14.23
Difference 15.5	

**STO= difference Glass tube wt (g)/
difference Liquid Volume (ml)**

**Formation Volume Factor=difference pump
cell volume (cc)/ difference Liquid
Volume (cc)**

Calculated Results

cc/cc	cc/cc	cc/cc	cc/cc	g/cc[1956]

GOR				STO
1st Stage	2nd Stage	Total	FVF	Density

at conditions

Pressure				Temperature			
Reservoir	1st Stage	2nd Stage	atm.	Reservoir	1st Stage	2nd Stage	atm.
psia	psia	psia	psia	℃	℃	℃	℃

Comments:

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Errors:

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Error analyses:

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EXPERIMENT NO. 9

Surface tension

Ai m:

   The tensiometer measures the surface tension at a liquid- air interface at room temperature and atmospheric pressure .

Theory:

   The tensiometer measures the maximum force surface tension relies on the measured of the force acting on a probe by monitoring the weight change on a top-loading analytical balance.

Calibration:

Using the known surface tension of the water as 72.3 mN/m at 23 C .

Measurement Procedures:

1. Turn the tensiometer and the balance on.
2. Remove the draft shield cover.

3. Use the up/down switch to raise the tip up.

4. Fill the sample glass beaker until reach the red line.

5. Put the beaker on the balance .

6. Slid the draft shield cover back in the groove.

7. Tare the balance to get a zero reading.

8. Use the up/down switch to lower the tip down until make a contact with the liquid.

9. Raise the tip while observing the decrease in mass until the mass has begun to increase.

10. At the point where the balance showed lowest reading the measurement tip has lifted the maximum amount of the fluid.

11. Record the data and calculate the surface tension as blow.

Surface tension (air –water)

Please Enter Radius of measuring Tip(mm)	
Please Enter Maximum Balance Readring (g)	
Please Enter Density (g/ml)	
Volume (cubic mm)	
Z	
r/k	
surface Tension(mN/m= dyne/cm)	
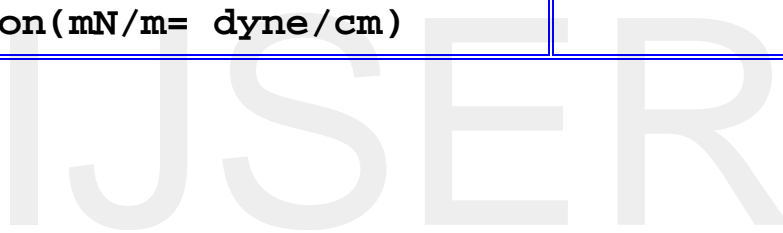
Surface tension (oil –water)

Please Enter Radius of measuring Tip(mm)	
Please Enter Maximum Balance Readring (g)	
Please Enter Density (g/ml)	
Volume (cubic mm)	
Z	
r/k	
surface Tension(mN/m= dyne/cm)	

Comments:

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Errors:

Error analyses:

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2. Bring both of the pistons to the top dead position.

3. Turn both of the three-way valves to closed position.

4. Turn of the two-way valves to closed position.

5. Gas is admitted into the jar by turning the three-way valves to inlet position.

6. Let the gas in the jars come to room temperature.

7. Bring the gas to null pressure by adjusting the knobs.

8. Observe the volumetric reading using the vernier ans scaleor the digital volume display, note the room temperature.

EXPERIMENT NO. 10
Gasometer

Aim:

The gasometer measures the volumetric measurement of atmospheric gas surface tension at a liquid- air interface at room temperature and atmospheric pressure.
Measurement Procedures:

1. Turn both of the three-way valves to the vent position.

Results

Flow rate in CC/ min= total volume/ time

=   cc/ min

Comments:

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Errors:

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Error analyses:

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EXPERIMENT NO. 11

Gas Compressibility

Knowledge of the variability of fluid compressibility with pressure and temperature is essential in performing many reservoir engineering calculations. For a liquid phase, the compressibility is small and usually assumed to be constant. For a gas phase, the compressibility is neither small nor constant.

Test Procedure

1-Starting by Gas sample at constant temperature

2-Record the initial pressure P_1 in psia& initial Volume V_1 in cu.ft .

3-Use **Jog** mode then increase the volume of the Gas sample**.**

4-Record the new volume & Pressure.

5- Calculate Gas Compressibility factor

.

$$C= -\frac{\Delta v}{v} *$$

$$\frac{1}{\Delta p} = \frac{-(v2-v1)}{v(p2-p1)} = \frac{v1-v2}{v(p1-p2)}$$

$$C=$$

$$psi^{-1}$$

Results

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....

EXPERIMENT NO. 12

Comments:

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Dalton's Law of Partial Pressures

The total pressure exerted by a mixture of gases is equal to the sum of the pressures exerted by its components. The pressure exerted by each of the component gases is known as its partial pressure.

Errors:

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Error analyses:

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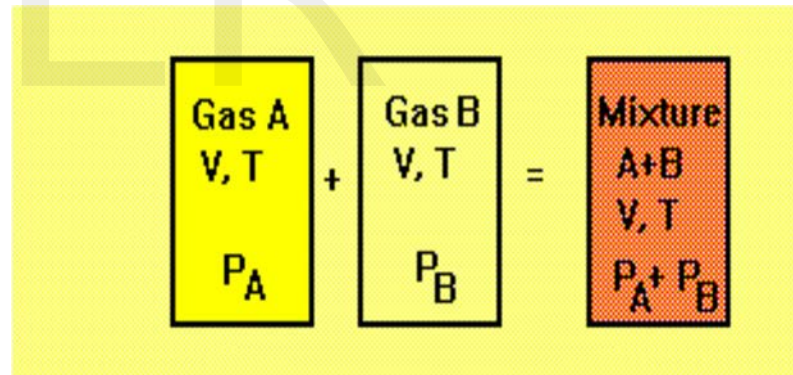
Dalton's law sometimes is called the law of additive pressures. Consider a mixture containing nA moles of component A, nB moles of component B, nC moles of component C, and so on. The partial pressure exerted by each

component of the gas mixture may be determined as:

$$P_A = n_A \frac{RT}{V}, \quad P_B = n_B$$

$$y_j = \frac{P_j}{P} = \frac{n_j}{n}$$

where yj is defined as the mole fraction of the jth component in the gas mixture. Therefore, the partial pressure of a component of a mixture of ideal gases is

$$P = n_A \frac{RT}{V} + n_B \frac{RT}{V}$$

$$P = \frac{RT}{V} \sum_j n_j = \cdot$$

$$\mathbf{Pj = yj* P}$$

The ratio of the partial pressure of component Pj, to the total pressure of the mixture p is:

Component	Mole %	Yi	Pi=Yi*P

Total			

HYDROGEN ION CONCENTRATION (pH):

Comments:

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…………………………………………………………………………………….

Errors:

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……………………………………………………………………………….

Error analyses:

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EXPERIMENT NO. 13

Theory

The acidity and the alkalinity of the drilling fluid can be measured by the concentration of the (H^+) ion in the fluid. As for instance, if H^+ is large (1×10^{-1}), then the (OH^-) hydroxyl concentration is very low (1×10^{-13}), the solution is strongly acidic. If the (OH^-) concentration is (1×10^{-1}) very high then (H^+) concentration is very low then the solution is strongly alkaline. The pH of a solution is the logarithm of the reciprocal of the (H^+) concentration in grams moles per liter, expresses as:

1963

$$pH = \log \left\{ \frac{1}{H^+} \right\} = -\log [H^+]$$

Example: If the solution is neutral then H^+ and OH^- concentrations are the same equal to 1 x 10^{-7}.

$$pH = \log \left(\frac{1}{1 \, x 10^{-7}} \right) = -\log [1 \, x 10^{-7}] = -(-7) = 7.00$$

$$= -\log 10^{-7}$$

Therefore, if the pH of a mixture drops from 7.0 to 6.0, the number of (H^+) increase ten times.

Methods of measuring pH in the laboratory:

1. The PH Paper: The PH paper strips have dyes absorbed into the paper display certain colors in certain pH ranges. It is useful, inexpensive method to determine pH in oil sample. The main disadvantage is that high concentrations of salts (10,000 ppm chloride) will alter the color change and cause inaccuracy.

1. The PH Meter: The PH meter is an electric device utilizing glass electrodes to measure a potential difference and indicate directly by dial reading the pH of the sample. The PH meter is the most accurate method of measuring PH

PH Meter

Error analyses:

....

....

<u>The Laboratory Test:</u>

1. Take 2 samples of crude from each tank.

2. Stir the samples for 2 minutes

3. Insert the electrode into the sample where by

    (a) Use beaker to test (not steal beaker)

    (b) Insert the electrode in the center

    (c) Don`t touch the base of the beaker

Comments:

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Errors:

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EXPERIMENT NO. 14

Acidity No experiment:

Theory

Acidity No: The amount of potassium hydroxide (KOH) in mg required to neutralize on e gm of Crude oil.

Mini Acidity No >0.2 mg KOH/ gm Crude oil

Aim:

Determine acidity no to know if the oil contains organic acid that may react with Alkaline or caustic flooding in order to form surfactant with the aim of reduces the interfacial tension between crude oil and water inside the reservoir hence increase productivity.

PH

The acidity and the alkalinity of the fluid can be measured by the concentration of the (H^+) ion in the fluid. As for instance, if H^+ is large (1 x 10^{-1}), then the (OH^-) hydroxyl concentration is very low (1 x 10^{-13}), the solution is strongly acidic. If the (OH^-) concentration is (1 x 10^{-1}) very high then (H^+) concentration is very low then the solution is strongly alkaline. The pH of a solution is the logarithm of the reciprocal of the (H^+)

concentration in grams moles per liter, [1965] expresses as:

$$PH = \log\left\{\frac{1}{H^+}\right\} = -\log[H^+]$$

Example: If the solution is neutral then H^+ and OH^- concentrations are the same equal to 1 x 10^{-7}.

$$PH =$$
$$\log\left(\frac{1}{1x10^{-7}}\right) = -\log\left[1x10^{-7}\right] = -(-7) = 7.00$$

$$= -\log 10^{-7}$$

Therefore, if the pH of a mixture drops from 7.0 to 6.0, the number of (H^+) increases ten times.

Methods of measuring pH in the laboratory:

The PH Meter: The PH meter is an electric device utilizing glass electrodes to measure a potential difference and indicate directly by dial reading the pH of the sample. The PH meter is the most accurate method of measuring PH

9. Draw a line from PH axis till [1966] intersects with the curve to get the KOH amount.

10. Tabulate the results here below.

PH Meter

The Test Procedures:

1. Fetch oil sample from the well.
2. Pour one mg of crude oil sample into tested tube.
3. Pour 0.05% KOH on the crude oil sample.
4. Stir the sample around 2 minutes
5. Insert the electrode of PH meter into the sample where by

    (a) Use beaker to test (not steal beaker)

    (b) Insert the electrode in the center

    (c) Don`t touch the base of the beaker.

6. Measure PH Value.
7. Repeat the steps from 3 till 6 using the amount (1%, 1.5%,…….5%).
8. Plot a graph between PH on Y axis versus KOH amount on x Axis.

Results

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Comments:

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Sources of errors:

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is dispersed in the other (the continuous [1967] phase)

Error analyses:

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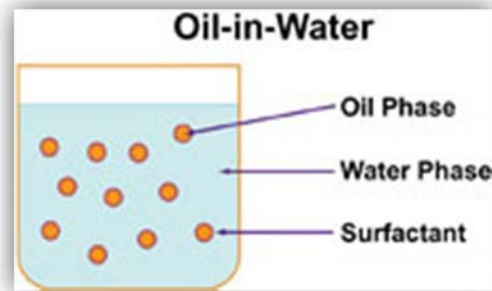
Experiment No.15

Emulsion

Stability Test

Theory

The emulsion is a mixture of two or more liquids that are normally immiscible (non mixable or unbendable). Emulsions are part of a more general class of two-phase systems of matter called colloids. Although the terms colloid and emulsion are sometimes used interchangeably, emulsion should be used when both the dispersed and the continuous phase are liquids. In an emulsion, one liquid (the dispersed phase)

The Laboratory Test:

1. Inspect the electrode probe and cable for any evidence of damage. Ensure that the entire electrode gap is free of deposits and that the connector to the instrument is clean and dry.
2. Clean the electrode body thoroughly by wiping with a clean paper towel, be sure to clean the electrode gap.
3. Pre heat the sample to 120 F.
4. Hand stir the sample with the electrode probe for 10 sec, this will help create a uniform composition and temperature.
5. The position of the electrode probe so that it does touch the bottom or sides of the container. Be sure the electrode surfaces are completely covered by the sample.
6. Push the button to begin the voltage ramp (do not move the electrode during the voltage ramp).
7. Note the ES displayed on the readout.

Comments:

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Errors:

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Error analyses:

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Experiment No.16

<u>Water Content Test</u>

<u>Theory</u>

The emulsion is a mixture of two or more liquids that are normally immiscible (non mixable or unbendable). Emulsions are part of a more general class of two-phase systems

of matter called colloids. Although the terms colloid and emulsion are sometimes used interchangeably, emulsion should be used when both the dispersed and the continuous phase are liquids. In an emulsion, one liquid (the dispersed phase) is dispersed in the other (the continuous phase)

Comments:

....

....

The Laboratory Test:

1. Inspect the electrode probe and cable for any evidence of damage. Ensure that the entire electrode gap is free of deposits and that the connector to the instrument is clean and dry.
2. Clean the electrode body thoroughly by wiping with a clean paper towel, be sure to clean the electrode gap.
3. Pre heat the sample to 120 F.
4. Hand stir the sample with the electrode probe for 10 sec, this will help create a uniform composition and temperature.
5. The position of the electrode probe so that it does touch the bottom or sides of the container. Be sure the electrode surfaces are completely covered by the sample.
6. Push the button to begin the voltage ramp (do not move the electrode during the voltage ramp).
7. Note the ES displayed on the readout.

Errors:

....

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Error analyses:

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....

APPENDIX A
Conversion Tables

To Convert	Multiply By	To Obtain
Acres	43,560	Sq. feet
Acres	0.00405	Sq. kilometer
Acres	4047	Sq. meter
Acres	4840	Sq. yards
Acre-feet	325,851	Sq. feet
Acre-feet	43560	Cu. feet
Acre-feet	1233.5	m (cubed)
Bar	14.5	Lb/sq.in.
Bar	1019.7	g/cm (cubed)
Bar	29.53	inches Hg at 0
Bushels (dry)	0.03524	degrees C
Centimeters	0.03281	msquared
(cm)	0.3937	Feet

971

Centimeters	0.1094	Inches	Kilometers	3281	Centimeters
Centimeters	0.01	Yards	Kilometers	1000	Feet
Centimeters	10	Meters	Kilometers	0.6214	Meters
Centimeters	1.9685	Millimeters (ml)	Kilometers	1094	Miles
cm/sec	0.0223694	ft/min	Km/h	0.62137	Yards
cm/sec	0.0610237	MPH	Km/h	54.6807	MPH
cm (cubed)	0.0283	inch (cubed)	Kilopascals	0.145	ft/min
Cubic feet	7.4805	Cu. meter	(kPa)	0.2642	Pounds/sq.in.
Cubic feet	1728	Gallons	Liters (l)	33.814	(psi)
Cubic feet	0.037	Cubic inches	Liters	2.113	Gallons
Cubic feet	8	Cubic yards	Liters	1.057	Ounces
Cup	30.48	fl oz	Liters	0.2454	Pints
Feet (ft)	0.3048	Centimeters	L/100	0.107	Quarts
Feet	0.01136	Meters	msquared	3.281	gal/1000
Feet per minute	0.433	MPH	Liters/hectare	39.37	ftsquared
Feet head of	10.764	PSI	Meters (m)	1.094	Gallons/acre
water	3.785	Lux	Meters	100	Feet
Foot candle	3785	Liters	Meters	0.001	Inches
Gallons (gal)	128	Millimeters	Meters	1000	yards
Gal	9.354	Ounces (liquid)	Meters	2.2369	Centimeters
Gal	2.938	Liters/hectare	Meters	10.764	Kilometers
Gal/acre	4.0746	Oz/1000	Meters/sec	35.3147	Millimeters
Gal/acre	2.228 x 10 (-3)	ftsquared	Msquared	1.30795	MPH
Gal/1000	0.002205	(liquid)	M (cubed)	160,900	ftsquared
ftsquared	0.035274	L/100 msquared	M (cubed)	5280	ft (cubed)
Gal/minute	0.000893	Cubic	Miles (statute)	1.609	yd (cubed)
Grams (g)	1000	feet/second	Miles	1760	Centimeters
Gram	10	Pounds	Miles	1.467	Feet
G/ha	0.00020481	oz	Miles	88	Kilometers
Grams per liter	0.036127	lbs/a	Miles/hour	1.61	Yards
Grams per liter	62.428	PPM	(mph)	0.447	Feet/second
Grams/sq.meter	2.471	Percent	Miles/hour	0.0338	Feet/minute
G/cm (cubed)	2.540	lb/sq.feet	Miles/hour	0.0002642	Kilometers/hour
G/cm (cubed)	0.0254	lb/in (cubed)	Miles/hour	0.03937	meter/second
Hectares (ha)	25.40	lb/ft (cubed)	Milliliters (ml)	0.13332	Ounces (fluid)
Inches	6.4516	Acres	Milliliters	0.02957	Gallons
Inches	16.3871	Centimeters	Millimeters	29.573	Inches
Inches		Meters	(mm)	28.35	kPa
Insquared		Millimeters	1 mm Hg @ 0	2.719	Liters
In (cubed)		cmsquared	C	0.001	Milliliters
		cm (cubed)	Ounces (fluid)	8.34	Grams
			Ounces (fluid)	1	lb ai/acre foot of
			Ounces	0.013	water
Kilograms (kg)	2.2046	Pounds	(weight)	0.3295	Grams/l
Kg/hectare	0.892	Pounds/acre	Parts per million	8.345	Lb/million gal
Kg/ha	0.02048	lb/1000	(ppm)	10	mg/kg
Kg/L	8.3454	ftsquared	PPM	0.473	Ounces/100 gal
Kilometers (Km)	100,000	lb/gal	PPM	1.1692	of water

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PPM	0.3673	Gal/acre-foot of water
PPM		lbs/million gal of water
PPM		g/kg
PPM		liter
Percent (%)		L/ha
Pint		oz/1000
pt/A		ftsquared
pt/A		
Pounds		
Pounds	0.4536	Kilograms
Pounds/acre	453.6	Grams
Pounds/A	1.12	Kg/hectare
Pounds/sq.ft.	0.02296	lb/1000 ftsquared
Pounds/1000	4883	Grams/sq.meter
ftsquared	43.5597	lb/A
Pounds/yd	0.0005937	G/cm (cubed)
(cubed)	0.12	Kg/liter
Pounds/gallon	6.9	Kilopascals
PSI (lbs/sq.in.)	0.06895	Bar
PSI	0.068046	atm
PSI	2.31	feet head of water
PSI	6.89	kPa
PSI	0.9463	Liters
Quarts	2.3385	L/ha
Qt/A	0.7346	oz/1000 ftsquared
Qt/A	0.001076	Sq. feet
Sq. centimeters	0.1550	Sq. inches
Sq. centimeters	929	Sq. centimeters
Sq. feet	0.0929	Sq. meters
Sq. feet	9.294 x 10 (-6)	Hectares
Sq. feet	6.452	Sq. centimeters
Sq. inch	907	kg
Ton (2000 lbs)	91.44	Centimeters
Yards	0.9144	Meters
Yards	914.4	Millimeters
Yards	27	ft (cubed)
yd (cubed)	0.7645	m (cubed)
yd (cubed)		

Area Equivalents

1 acre = 43,560 ft squared = 4840 yd 2 = 0.4047 hectares = 160 rods squared = 4047 m 2 = 0.0016 sq. mile

1 acre-inch = 102.8 m 3 = 27,154 gal = 3630 ft 3

1 hectare (ha) = 10,000 m 2 = 100 are = 2.471 acres = 107,639 ft squared

1 cubic foot (ft 3) = 1728 in 3 = 0.037 yd 3 = 0.02832 m 3 = 28,320 cm 3

1 square foot (ft 2) = 144 in 2 = 929.03 cm 2 = 0.09290 m 2

1 square yard (yd 2) = 9 ft 2 = 0.836 m 2

1 cubic yard (yd 3) = 27 ft 3 = 0.765 m 3

Liquid Equivalents

1 ft (cubed) of water = 7.5 gal = 62.4 lbs. = 28.3 liters

1 acre-inch of water = 27,154 gal = 3630 ft 3

1 liter (l) = 2.113 pts. = 1000 ml = 1.057 qts. = 33.8 fl.oz. = 0.26 gal

1 US gallon=4 qt.=8 pt. = 16 cups = 128 fl.oz. = 8.337 lbs of water = 3.785 L = 3785 ml = 231 in 3 = 256 tbsp. = 0.1337 ft3

1 quart = 0.9463 liters = 2 pt. = 32 fl. oz. = 4 cups = 64 tablespoons (tbsp.)=57.75 in 3 = 0.25 gal = 946.4 ml

1 pint = 16 fl. oz. = 2 cups = 473.2 ml = 32 level tablespoons = 0.125 gal = 0.5 qt

1 cup = 8 fl. oz. = = ½ pt. = 16 tablespoons = 236.6 ml

1 tablespoon = 14.8 ml = 3 teaspoons (tsp.) = 0.5 fl.oz.

1 milliliter (ml) = 1 cm 3 = 0.34 fl.oz. = 0.002 pts

1 teaspoon = 4.93 ml = 0.1667 fl. oz. = 80 drops

1 US fluid ounce = 29.57 ml = 2 tablespoons = 6 tsp. = 0.03125 qt

Temperature Equivalents

degrees Centigrade = (°F-32)x5/9

degrees Fahrenheit = (°Cx9/5)+32

Pressure Equivalents

1 lb per square inch (PSI) = 6.9 kilopascal (kPa)

1 PSI = 2.31 feet head of water

Units	Dyne	Lb.	Newton
Dyne	1	2.248x10-6	10-5
Lb.	444,823	1	4.448
Newton	100,000	0.2248	1

Mixture Ratios

1 mg/g = 1000 ppm

1 fl.oz./gal = 7490 ppm

1 fl.oz./100 gal = 75 ppm

1 pt/100 gal = 1 teaspoons/1gal

1 qt/100 gal = 2 tablespoons/1 gal

Flow

1 gpm = 0.134 ft 3 /minute

1 ft (cubed) /min. (cfm) = 449 gal/hr. (gph) = 7.481 gal/min.

Weight Equivalents

1 ton (US) = 2000 lb = 0.907 metric tons = 907.2 kg

1 metric ton = 10 6 g = 1000 kg = 2205 lb

1 lb = 16 oz = 453.6 grams (g) = 0.4536 kg

1 oz (weight) = 28.35 g = 0.0625 lb

1 gram = 1000 mg = 0.0353 oz = 0.001 kg = 0.002205 lb

milligrams (mg) = 0.001 grams

1 kilogram (kg) = 1000 grams = 35.3 oz = 2.205 lbs

microgram (mg) = 10 -6 grams = 0.001 mg

nanogram (ng) = 10 -9 grams = 0.001 micrograms (mg)

picogram = 10 -12 grams

1 ppm= 0.0001%= 0.013 fl oz in 100 gal =1 mg/kg=1 mg/L=1 mg/g= 0.379 g in 100 gal water= 8.34 x 10 -6 lb/gal=1ml/l

10 ppm = 0.001% = 10 mg/L 100 ppm = 0.01% = 100 mg/L1000 ppm = 1mg/g = 0.1% = 1000 mg/L

1 ppb = 1 ug/kg or 1 ug/L or 1 ng/g

1 ppt = 1 picogram/g

1 % = 10,000 ppm = 10g/L = 1g/100ml = 10g/kg = 1.33 oz by weight/gal water = 8.34 lbs/

100 gal water

Conclusions

The Pressure Volume Temperature analyses are so important for oil and gas field with the aim of estimate the oil prices leading to significant revenue shortfalls in many energy exporting nations, while consumers in many importing countries are likely to have to pay less to heat their homes or drive their cars.

Energy subsidies, which amount to more than $540 billion per year worldwide, are as common as they are damaging to economies, the poor, and the environment, since they stimulate consumption and undermine efforts to save energy and use it more efficiently.

The price of oil is of critical importance to today's world economy, given that oil is the largest internationally traded good, both in volume and value terms, creating what some analysts have called a hydrocarbon economy. In addition, the prices of energy-intensive goods and services are linked to energy prices, of which oil makes up the single most important share. Finally, the price of oil is linked to some extent to the price of other fuels. Therefore, abrupt changes in the pi-ice of oil have wide-ranging ramifications for both oil-producing and oil-consuming countries. The sharp decline in world oil prices since late 1997 certainly qualify as an abrupt and significant change.

Recommendations

I hope to continue the R&D about this issue.

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