Laboratory Measurements:-

-Basic Core Analysis Laboratory Measurements:-

* Porosity and Grain Density Measurement

*Permeability Measurement

-Special Core Analysis Laboratory Measurements:-

*Electrical Properties

*Wettability

*Capillary Pressure

* Relative Permeability

Basic Core Analysis Laboratory Measurements:-

Basic core analysis is sometimes referred as routine core analysis. However, in the last few years, the word ‘routine’ has intentionally been replaced by ‘basic’ in order to emphasize that nothing related to core analysis is routine. Instead, for each new reservoir every step requires

extra care and special attention starting from coring and all the way to data reporting.

As the name suggests, basic core analysis includes the measurements of basic physical properties. These are grain density, porosity, permeability and fluid saturation.

Routine core analysis and supplementary measurements.

Data	Application
Routine core analysis	
Porosity	Storage capacity
Permeability	Flow capacity
Saturations	Define the mobile hydrocarbons (productive zones and contacts), type of hydrocarbons
Lithology	Rock type and characteristics (fractures, layering etc.)
Supplementary measurement	
Vertical permeability	Effect of coning, gravity drainage etc.
Core-gamma surface log	Identify lost core sections, correlate cores and logs
Matrix density	Calibrate the density log
Oil and water analysis	Densities, viscosities, interfacial tension, composition etc.

Porosity and Grain Density Measurement:-

Porosity, a measure of space available for hydrocarbon storage, is one of the most important parameters for the development of petroleum reservoirs. It is defined as the void (pore) volume of the sample divided by its bulk volume.

There are several different methods developed for porosity measurements. These methods calculate three critical parameters:

(1) bulk volume, (2) grain volume and (3) pore volume.

Bulk Volume:-

Although the bulk volume may be computed from measurements of the dimensions of a regularly shaped sample, the usual procedure utilizes the observation of the volume of a fluid displaced by the core [4]. This technique is particularly advantageous as it can also be applied to

irregular-shaped samples. However, care should be taken to prevent fluid invasion into the pore space of the rock. This is usually achieved by using mercury as fluid to be displaced.

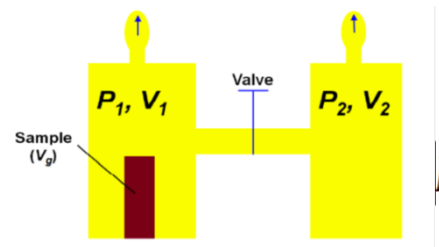
Due to its non-wetting characteristics, mercury tends to stay away from the pore space of the rock.

Grain Volume:-

The most widely used technique is Boyle's law (gas expansion) method. This method involves the expansion of a compressed gas (usually helium is used due to its small molecular size and low adsorption on rock surfaces) into a clean, dry sample. Gas (helium) is initially admitted to the reference cell of known volume at a pre-set reference pressure (V2 and P2 in Figure). The gas in the cell then expands into a connected chamber of known volume and pressure (V1 and P1) which contains the core sample of unknown grain volume. The equilibrium pressure is then measured and grain volume (Vg) can be calculated from the equation below:

where P1 and P2 are the measured pressure values at cell 1 and 2 before the valve is and P is

the equilibrium pressure of the whole system after the valve is opened.



$$P_1(V_1 - V_g) + P_2 . V_2 = P(V_1 + V_2 - V_g)$$

Pore Volume:-

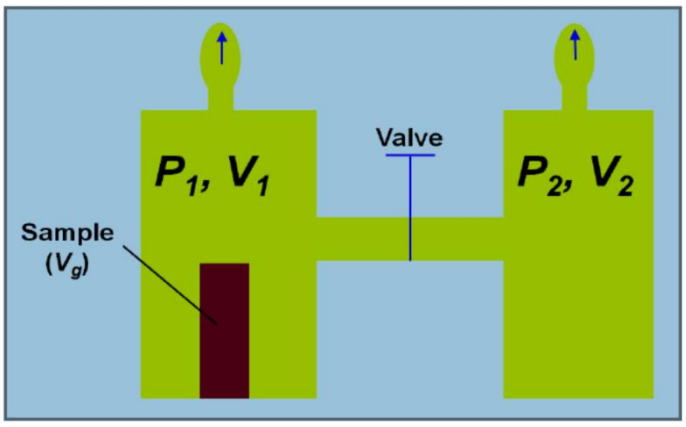
Although it can be measured directly, pore volume is often calculated indirectly by subtracting the grain volume from the bulk volume. All the direct measurement techniques yield effective porosity. The methods are based on either extraction of a fluid from the rock or introduction of .afluid into the pore space of the rock

Grain Density:-

A pycnometer, which is a small glass flask of known weight accurately calibrated for volume,can be used to measure grain (matrix) density. A .dry and clean sample is placed in a pycnometer

After weighing, the pycnometer is filled with toluene or kerosene, and .the solvent is degassed

The weight of pycnometer, sample, and solvent is then determined at a Grain density can then be calculated from weights, .known temperature pycnometer volume and solvent density.



A schematic of the double-cell Boyle's law porosimeter.

Grain density can also be calculated by simply weighing a dry sample on a precise balance and

dividing the measured weight into the grain volume

calculated from Boyle's law (if available):

$$Grain\ Density = \frac{weight\ of\ the\ dry\ sample\ (g)}{grain\ volume\ (cm^3)}$$

Laboratory measurement techniques of porosity have not changed significantly in the last few decades. Accuracy of the measurement may be affected by several factors such as grain volume

measurement accuracy and grain losses in some cases. When comparing experimentally measured porosities with log-derived ones, effects of sample preparation and representativeness of sample volume should be taken into account.

Permeability Measurement:-

Permeability is defined as the ability of a formation to transmit fluids. Darcy's law states that, anincompressible single phase fluid flows

:through the pore space of the rock with a volumetric flow rate of

$$Q = \frac{kA(P_i - P_o)}{\mu L}$$

where Q is the volumetric flow rate (cm3/s) under laminar flow, k is the permeability (Darcy), A is the cross-sectional area (cm2), Pi and Po are inlet and outlet pressures ((atm), μ is viscosity (cp

and L is length (cm). Note that the unit of permeability is termed as Darcy. The Darcy .is used inoil field units and 1 Darcy is approximately 10-12 m2

Accurately predicting permeability and accounting for its heterogeneity are crucial in field development studies. The most direct way of permeability estimation is done by conducting experiments using cores ranging from sidewall plugs to full diameter

cores. Well test analysis also gives information of fluid mobility hence permeability at a larger volume scale if the test is designed properly and the interpretation model is well constrained by geological and geophysical data.

Steady-state Measurement:-

A geometrically regular sample of known length and diameter is placed into a Hassler-type core holder. Gas, which is typically air or nitrogen, is injected from the inlet and flows through the sample by creating a pressure gradient between the inlet and the outlet. Pressure gradient across the core plug and the flow rate are measured with a permeameter. A schematic of a Ruska permeameter is illustrated in Figure 11. The permeability is calculated using a modified form of

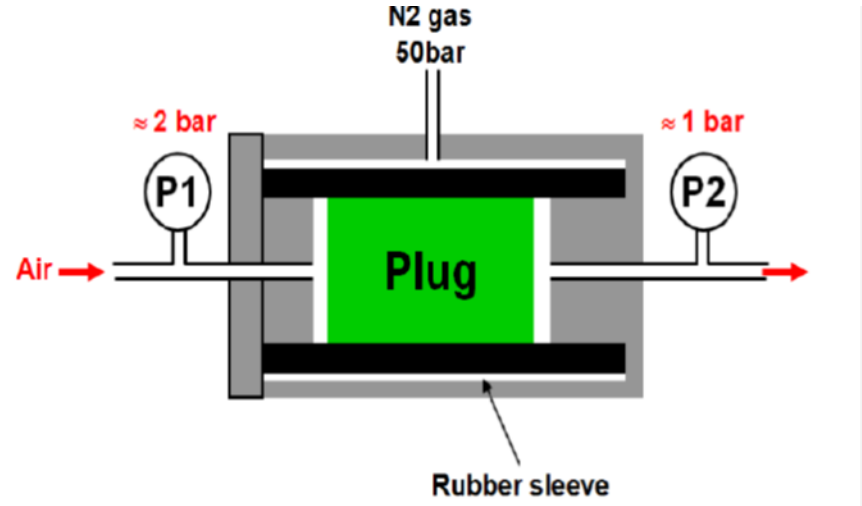
Darcy's equation which takes gas compressibility into account

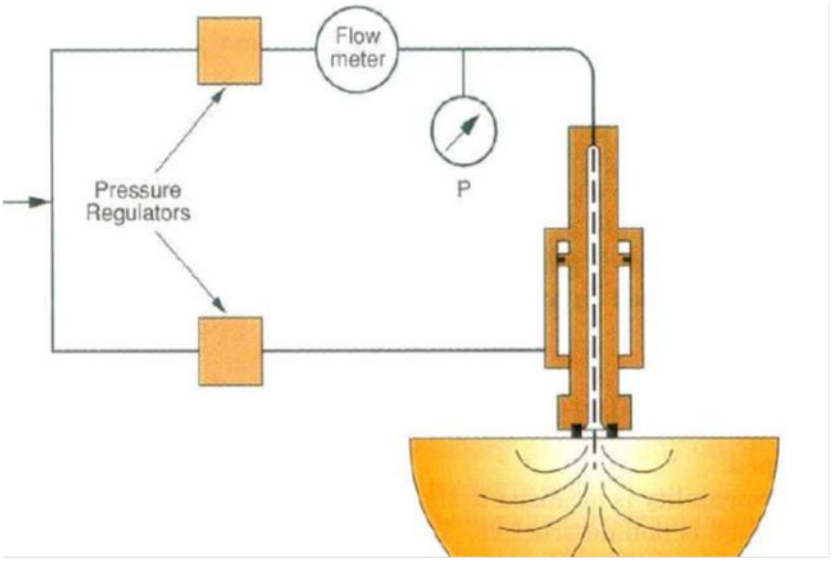
$$K_{gas} = \frac{2000.P_a.\mu.Q.L}{(P_1^2 - P_2^2).A}$$

where Kgas is permeability to gas (mD), Pa is atmospheric pressure (atm), μ is viscosity (cp), Q is the volumetric flow rate (cm3/s), L is the length (cm), P1 and P2 are inlet and outlet pressures

atm) and A is the cross-sectional area (cm2). Note that 1 milidarcy (mD) is equal to) 1/1000 of a Darcy.

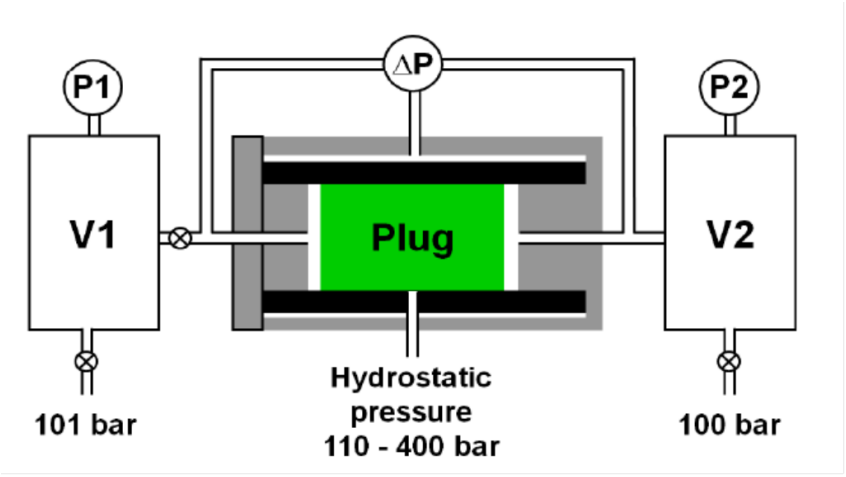
For detailed analysis of spatial permeability variation in the core, a probe permeameter (minipermeameter)can be used. A schematic of a probe permeameter is shown in Figure. In the probe permeameter, gas flows from the end of a small-diameter probe that is sealed against the surface of a slabbed or exposed core. The gas flow rate and the pressure in the probe are measured and used for permeability calculation. As the measured permeability is localized to a small region near the seal, this technique is particularly useful for characterizing small-scale geologicalheterogeneities.Typically the probe permeability measurement results in apermeability profile along the core or a 2-dimensional array across a slabbed core face. Obtaineddata can be calibrated against the core plug permeability measurements.





Unsteady-state Measurement

With the increase in the computational power and the accuracy of pressure transducers, unsteady-state permeability measurements are becoming more common. Figure shows an illustration of the pulse decay permeameter. A dry sample is placed into the core holder. Apressure pulse is introduced by increasing the pressure in the upstream vessel. The system is then allowed to return to equilibrium pressure, and the rate of approaching equilibrium depends on the permeability of the core sample. However, in pulse decay method, it is not necessary to wait until the pressure equilibrium is reached. Therefore, this technique (or one of its variations) is particularly useful for low permeability samples (below 0.1mD) where steady-stat measurement may face the problem of .prohibitively lengthy time to reach pressure/flow equilibrium.

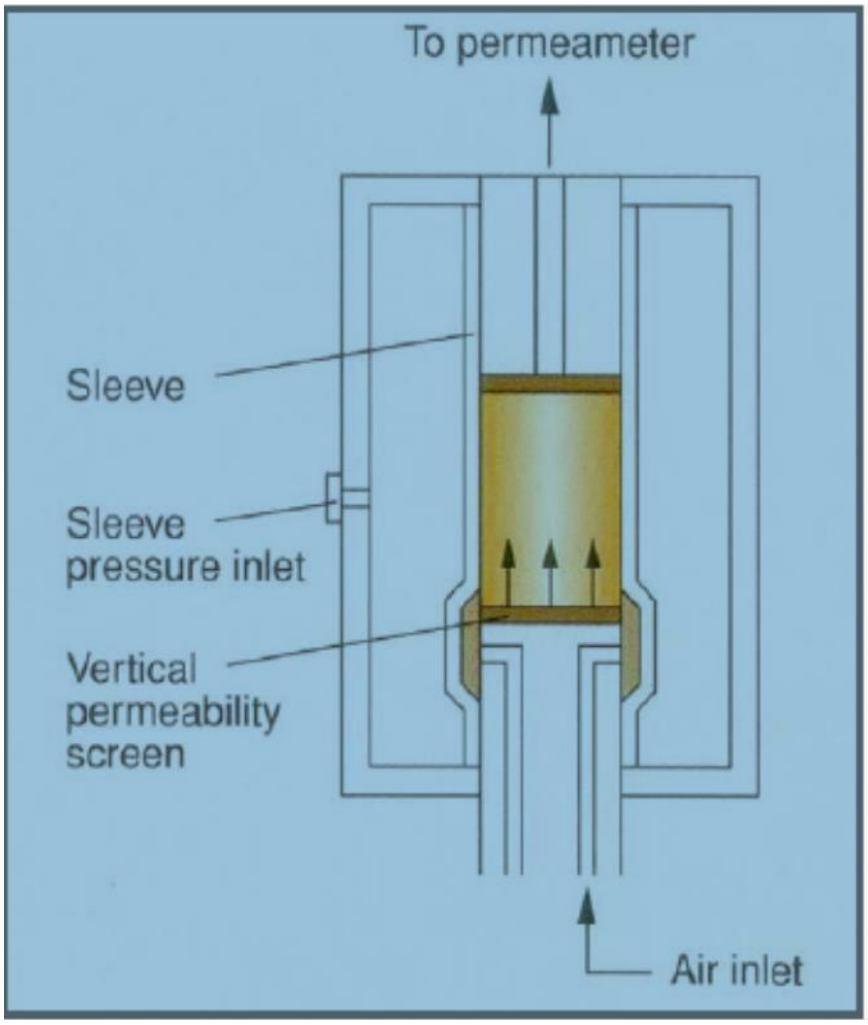


Whole Core Measurement

The whole core is prepared in the same manner as the plugs. It is then placed into a rubber sleeve of a core holder where it is subjected to a confining pressure of around 20 bar. This provides sealing along the sides of the sample. A schematic of a whole core measurement apparatus is shown in the Figure. The principle is the same as the steady-state measurements. Vertical permeability can easily be determined by flowing gas through the length of the core.

Horizontal permeability measurement however is more complex. Gas flows through the cylindrical surface of the sample using an array of permeable screens, which cove opposite quadrants on the surface and are rotated through 90º so that the measurement can be carried out in two perpendicular orientations. The higher of the two horizontal permeabilities is referred to as k max and the lower as k90. Typically a geometric mean permeability is calculated, which is used in

porosity-permeability correlations and in log calibration for permeability estimation.


To permeameter
Sleeve
Sleeve pressure inlet
Vertical permeability screen
Air inlet