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Absolute Permeability Measurement of Water

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ABSTRACT - *The increase in the use of ground water for municipal, industrial, irrigation, air-conditioning, domestic, and other purposes and the attendant lowering of the water levels in wells have caused much concern regarding the quantity of water that can be withdrawn perennially from subterranean sources. As a result, ground-water hydrologists are persistently confronted with the serious problem of determining the safe yield of underground reservoirs. Such quantitative investigations almost always involve the movement of ground water, and to a large degree the success of these studies depends on a reasonably accurate determination of the quantity of underground percolation. The current research is based on the study of finding the permeability of water. The permeability of water may be, determined by laboratory or field test and also check the Darcy's law. In the laboratory the permeability may be determined indirectly by analyses of the size, shape, and arrangement of the grains constituting the material, or directly by observations on the rate of percolation of water through samples.*

Keywords – *Earth, Darcy, permeability, rocks, sediments*

I. INTRODUCTION

Petroleum (from Greek: petra: "rock" + *oleum*: "oil" is a naturally occurring, yellow-to-black liquid found in geological formations beneath the Earth's surface, which is commonly refined into various types of fuels. Components of petroleum are separated using a technique called distillation. Petroleum engineering is a field of engineering concerned with the activities related to the production of hydrocarbons, which can be either crude oil or natural gas. Exploration and Production are deemed to fall within the upstream sector of the oil and gas industry. Exploration, by earth scientists, and petroleum engineering are the oil and gas industry's two main subsurface disciplines, which focus on maximizing economic recovery of hydrocarbons from subsurface reservoirs. Petroleum geology and geophysics focus on provision of a static description of the hydrocarbon reservoir rock, while petroleum engineering focuses on estimation of the recoverable volume of this resource using a detailed understanding of the physical behavior of oil, water and gas within porous rock at very high pressure. The combined efforts of geologists and petroleum engineers throughout the life of a hydrocarbon accumulation determine the way in which a reservoir is developed and depleted, and usually they have the highest impact on field economics. Petroleum engineering requires a good knowledge of many other related disciplines, such as geophysics, petroleum geology, formation evaluation (well logging), drilling, economics, reservoir simulation, reservoir engineering, well engineering, artificial lift systems, completions and oil and gas facilities engineering. Reservoir engineering is a branch of petroleum engineering that applies scientific principles to the drainage problems arising during the development and production of oil and gas reservoirs so as to obtain a high economic recovery. The working tools of the reservoir engineer are subsurface geology, applied mathematics, and the basic laws of physics and chemistry governing the behavior of liquid and vapor phases of crude oil, natural gas, and water in reservoir rock of particular interest to reservoir engineers is generating accurate reserves estimates for use in financial reporting to the SEC and other regulatory bodies. Other job responsibilities include numerical reservoir modeling, production forecasting, well testing, well drilling and work over planning, economic modeling, and PVT analysis of reservoir fluids. Reservoir engineers also play a central role in field development planning, recommending appropriate and cost effective reservoir depletion schemes such as water flooding or gas injection to maximize hydrocarbon recovery. Due to legislative changes in many hydrocarbon producing countries, they are also involved in the design and implementation of carbon sequestration projects in order to minimize the emission of greenhouse gases. Reservoir engineers often specialize in two areas:

- Surveillance (or production) engineering, i.e. monitoring of existing fields and optimization of production and injection rates. Surveillance engineers typically use analytical and empirical techniques to perform their work, including decline curve analysis, material balance modeling, and inflow/outflow analysis.
- Simulation modeling, i.e. the conduct of reservoir simulation studies to determine optimal development plans for oil and gas reservoirs. Also, reservoir engineers perform and integrate well tests into their data for reservoirs in geothermal drilling.

The present understanding of the subsurface processes relevant to reservoir engineering is based on the physical concepts of continuum mechanics. According to these concepts, a porous rock formation saturated with fluids forms a continuum, which means that all the components involved (rock, water, oil and/or gas) are present in every element, or volumetric part, of the reservoir space, even if the elementary volume considered is very small and approaches zero. This conceptual approach allows us to develop a useful theory for the flow of liquid and gas through a porous medium, called the filtration theory.

1.1. SEDIMENTARY ROCKS

Sedimentary rock is one of the three main rock groups (along with igneous and metamorphic rocks) and is formed in four main ways: by the deposition of the weathered remains of other rocks (known as 'clastic' sedimentary rocks); by the accumulation and the consolidation of sediments; by the deposition of the results of biogenic activity; and by precipitation from solution. Sedimentary rocks include common types such as chalk, limestone, sandstone, clay and shale.Four basic processes are involved in the formation of a clastic sedimentary rock: weathering (erosion)caused mainly by friction of waves, transportation where the sediment is carried along by a current, deposition and compaction where the sediment is squashed together to form a rock of this kind. Sedimentary rocks are formed from overburden pressure as particles of sediment are deposited out of air, ice, or water flows carrying the particles in suspension.As sediment deposition builds up, the overburden (or 'lithostatic') pressure squeezes the sediment into layered solids in a process known as lithification ('rock formation') and the original connate fluids are expelled.The term diagenesis is used to describe all the chemical, physical, and biological changes, including cementation, undergone by a sediment after its initial deposition and during and after its lithification, exclusive of surface weathering. The sedimentary rock cover of the continents of the Earth's crust is extensive (73% of the Earth's current land surface, but the total contribution of sedimentary rocks is estimated to be only 8% of the total volume of the crust. Sedimentary rocks are deposited in layers as strata, forming a structure called bedding. The study of sedimentary rocks and rock strata provides information about the subsurface that is useful for civil engineering, petroleum engineering, for example in the construction of roads, houses, tunnels, canals or other structures. Sedimentary rocks are also important sources of natural resources like coal, fossil fuels, drinking water or ores.

Figure 1:- Sedimentary rock sample

1.2 PERMEABILITY

Permeability is a measure of the ability of a porous media to transmit fluids. It is a critical property in defining the flow capacity of a rock sample. The unit of measurement is the Darcy, named after the French scientist who discovered the phenomenon. This chapter will begin with the factors which affect permeability and then lead to the experimental law defining permeability for porous media. The last three sections of this chapter investigate the relationship between porosity and permeability, the distribution of these rock properties and finally lab methods of measuring permeability.

Factors affecting permeability as follows

- Textural properties:-Pore size/ grain size, grain size distribution, shape of grains, packing of grains
- Gas slippage
- Amount, distribution, and type of clay
- Type and amount of secondary porosity
- Overburden pressure
- Reactive fluids
- High velocity flow effects

1.3. ABSOLUTE PERMEABILITY

Absolute permeability is an ability to flow fluid through a permeable rock when only one type of fluid is in the rock pore spaces. The absolute permeability is used to determine relative permeability of fluids flowing simultaneously in a reservoir. A measure of possible flow of a standard liquid under fixed conditions through a porous medium when there is no reaction between the liquid and the solids. This measure is arbitrarily taken for isothermal viscous flow. It can be duplicated with gases if tests are so conducted that extrapolation to infinite pressure can be made; specific permeability.

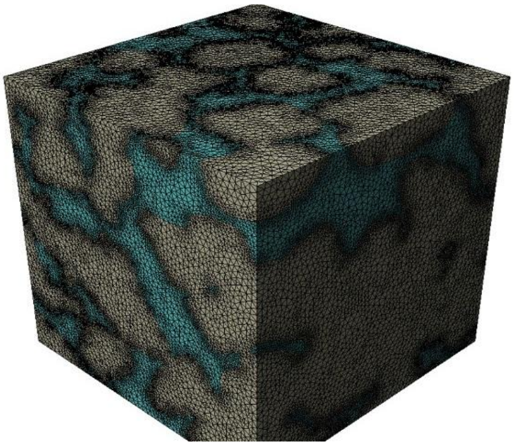


Figure 2:- Absolute permeability of rock sample.

2. DARCY'S LAW

Darcy's law is an equation that describes the flow of a fluid through a porous medium. The law was formulated by Henry Darcy based on the results of experiments on the flow of water through beds of sand, forming the basis of hydrogeology, a branch of earth sciences. Although Darcy's law (an expression of Newton's second law) was determined experimentally by Darcy, it has since been derived from the Navier-Stokes equations via homogenization. It is analogous to Fourier's law in the field of heat conduction, Ohm's law in the field of electrical networks, or Fick's law in diffusion theory. One application of Darcy's law is to analyze water flow through an aquifer; Darcy's law along with the equation of conservation of mass is equivalent to the groundwater flow equation, one of the basic relationships of hydrogeology. Morris Muskat first refined Darcy's equation for single phase flow by including viscosity in the single (fluid) phase equation of Darcy, and this change made it suitable for the petroleum industry. Based on experimental results worked out by his colleagues Wyckoff and Botset, Muskat and Meres also generalized Darcy's law to cover multiphase flow of water, oil and gas in the porous medium of a petroleum reservoir.

Darcy's law can be stated as follows:

"When a fluid flows through a porous medium, the apparent mean velocity of flow is proportional to the hydraulic gradient i.e. "h_f / L", where "h_f" is the head loss between the two sections which are L apart."

This law is valid when inertial forces are less than the viscous forces. In general, the laws considered as valid when the Reynolds number is less than unity.

Beyond Darcy's range the mean velocity is given by

$$V = k\, i\, n$$

2.1. DARCY LAW APPARATUS

The set up consists of a cylindrical test section filled with porous medium. Pressure tapings are provided in the test action to measure the pressure drop with the help of differential manometer. Present set-up is self contained water recirculation unit, provided with a sump tank and a centrifugal pump.

Flow control valve and by - pass valve are fitted in water line to conduct the experiment on different flow rates. Flow rate of water is measured with the help of measuring tank and stop watch.

Figure 2:- Darcy law apparatus

II. PROCEDURE

1.1. STARTING PROCEDURE

a) Clean the apparatus and make all tanks free from Dust.
b) Close the drains valves.
c) Fill Sump tank 3/4th with clean water and ensure that no foreign particles are there.
d) Open By-Pass Valve V2.
e) Ensure that ON/OFF Switch given on the Panel is at OFF position.
f) Now switch ON the main power supply and Switch ON the Pump.

g) Operate the Flow Control Valve V1 and by pass valve V2 to regulate the flow of water in the bed.

h) Open the valves (V5, V6 or V5, V7) for Manometer difference, very slowly to avoid the blow of water on manometer fluid.

i) Now open the Air release Valve V8 & V9 provided on the Manometer, slowly to release the air in manometer.

j) When there is no air in the manometer, close the Air release valves.

k) Adjust water flow rate in testing section with the help of Control Valve V1and by pass valve V2.

l) Record the Manometer readings (h1, h2 by opening valve V5, V6 and h1, h3by opening valve V5, V7)

m) Measure the flow of water, discharged through test section, using Stopwatch and Measuring Tank.

n) Repeat the experiment for different flow rates of water, operating Control Valve V1 and By-Pass Valve V2.

1.2. CLOSING PROCEDURE

When experiment is over,

a) Open the By-Pass V2.

b) Close valve Pressure Taps of the Manometer

c) Switch OFF Pump.

d) Switch OFF Power Supply to Panel.

e) Drain the apparatus by drain valves.

III. OBSEVATION

Si No.	H_1(cm)	H_3(cm)	H_2(cm)	H_3(cm)	R_1(cm)	R_2(cm)	Time(Sec)
1.	12.4	12	12.4	12	8	5	103
2.	12.5	11.4	12.4	12	9	5	64
3.	12.5	11.5	12.6	11.7	10	5	29
4.	13.1	11.3	12.3	11.5	10	5	21

Table 1:- Observed readings

1.1 CALCULATION

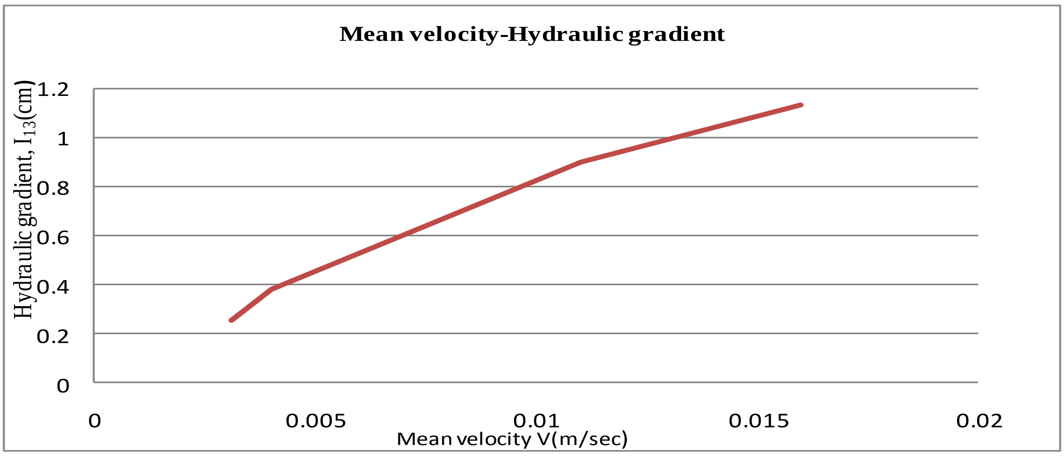
- A, Area of Measuring Tank = 0.77 m^2
- R,Rise of water level in measuring tank = 0.05 m
- I_{12}(cm),Hydraulic gradient

- V(m/sec),Mean velocity
- Q(m^3/sec), Discharge
- K=V/I , K=Coefficient of permeability.

H_{12}(cm)	H_{13}(cm)	H_{f12}(cm)	H_{f13}(cm)	I_{12}(cm)	I_{13}(cm)	Q(m^3/sec)	V(m/sec)
0.004	0.0504	0.0504	0.0504	0.252	0.126	3.5×10^{-5}	0.0031
0.006	0.004	0.075	0.0504	0.378	0.126	6.01×10^{-4}	0.004
0.013	0.009	0.163	0.1134	0.899	0.256	1.3×10^{-3}	0.011
0.018	0.008	0.226	0.1008	1.134	0.277	1.8×10^{-3}	0.016

Table 2:- Calculated readings

1.2. GRAPH



Graph 1:- Mean velocity-Hydraulic gradient

IV. CONCLUSIONS

- Darcy's law is an equation that describes the flow of a fluid through a porous medium. From the observation a graph is plotted i.e. in x-axis the mean velocity and in y-axis the hydraulic gradient. The Darcy's law is verified by the plotting the graph in a straight line manner.
- Absolute permeability of water for K_{13} = 0.03md
- Absolute permeability of water for K_{23} = 0.012md

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