THE EFFECT OF TEMPERATURE ON THE ABSOLUTE PERMEABILITY TO DISTILLED WATER OF UNCONSOLIDATED SAND CORES

A. Sageev, B.D. Gobran, W.E. Brigham, and H.J. Ramey, Jr.
Stanford University

INTRODUCTION

Absolute permeability is an important parameter in the evaluation of the performance of geothermal and hydrocarbon reservoirs. The primary production of oil and gas reservoirs normally is isothermal. This is not the case for geothermal reservoirs or for many enhanced oil recovery projects. In these reservoirs the temperature of the formation changes, and as a result, many of the formation properties change. Absolute permeability is an essential parameter, and it is important to study the effect of temperature on absolute permeability.

Experiments investigating the effect of temperature on absolute permeability have been carried out during the last decade. These experiments covered a range of rock types, fluids, confining pressures, and several other system parameters. It is evident that not all results are in agreement. In some cases the same observation yielded different interpretations. The investigation of the effect of temperature on the permeability to distilled water of Berea sandstones is an example of interpretation disagreement. Certain researchers claim fine sand migration causes an apparent change in the permeability, while others attribute changes to elevated temperature effects.

The work presented herein is a study of the effect of temperature on the absolute permeability to distilled water of unconsolidated sandstones at one confining pressure.

DESCRIPTION OF APPARATUS

Figure 1 presents a schematic diagram of the absolute permeability apparatus. The equipment was designed to produce the absolute permeability of a core at steady-state conditions of temperature, flowrate, and confining pressure. The apparatus consists of a coreholder, a flow system, a confining pressure system, an air bath, and a temperature-pressure-flowrate monitoring system.

The coreholder is a Hassler-sleeve type. The core is placed in a Viton tube supported by a perforated aluminum sleeve. Fine mesh screens were placed at both ends of the core to prevent sand from flowing. The end plugs are designed to ensure linear flow in the core and minimize converging flow stream lines. The pressure taps are located at the sand faces of the core.

The flow system includes an accumulator dampened pulsation pump that generates the flow of distilled water. Flowrate is controlled by a downstream needle valve, and the pore pressure is maintained by an upstream relief valve.

The confining system is pressurized by a hydraulic hand pump. An oil-water pressure vessel transmits the oil pressure to the confining water.

The air bath houses the coreholder. It is a potentiometric-controlled air bath which produces a constant temperature environment with insignificant temperature oscillations.

The monitoring system handles temperature, pressure drop across the core, and the flowrate. Temperature is measured in the flow lines upstream and downstream of the core. The coreholder temperature is measured as well. Effluent temperature is measured to convert room volumetric flowrates to run conditions. The pressure drop across the core is measured and recorded continuously during the run. Volumetric flowrates at room conditions are measured by a graduated cylinder and a timer.

PROCEDURE

The sand is sieved and washed with distilled water. Washing is done to minimize the amount of fines. Then the sand is dried at 60°C-70°C. The coreholder is packed and the dimensions of the core are measured. The core is evacuated while being confined at 2000 psig. The core is flowed after a vacuum of 1 Torr or less is established and maintained for several hours.

Several measurements of the permeability are made at a given temperature. The permeability is calculated for two or three flowrates. Then the average permeability and the errors are calculated. Two temperature cycles are carried out in every run with a run lasting about three days.

The runs are followed by a visual inspection of the core plug to ensure that no damage is evident.

SUMMARY OF RESULTS

Ottawa silica sand was used to construct the cores. In Runs No. 8 and No. 9, 150 mesh sand was used, and in Runs No. 10 and No. 11, 200 mesh sand was used. Every run consisted of two heating cycles to 300°F. A constant confining pressure set at 2000 psig was maintained throughout the runs. There was no evidence of fines migration at the downstream end of the system. In general, there were no problems in establishing steady-state conditions and measuring the absolute permeability.

Figure 2 presents the permeability at various temperatures as obtained in the described experiment. No significant change of the absolute permeability with respect to temperature and time was observed. The permeability at room temperature was reduced by about 5% after one heating and cooling cycle. The permeabilities at 250°F and 300°F were constant during the two temperature cycles. During the first heating cycle, the permeability dropped and then remained fairly constant. This suggests that upon the first heating of the sand, several things can be triggered, such as readjustment of the sand grains or a change in the characteristics of the wetting layer. The packing procedure for the core provides good reproducibility of the permeability. For all practical purposes, the two types of sands, 150 mesh and 200 mesh, produced the same permeability vs temperature behavior. About 200 pore volumes of distilled water were injected in every run, and no dependence of the permeability on time was observed. This is attributed to the initially high permeabilities of the packs, about 2500 md to 5000 md, and to the sieving and washing of the sand prior to packing.

Figure 2 also shows the experimental errors. The experimental errors were in the range of $\pm 2\%$ to 4%. The variations in measurement at a given temperature were in the range of $\pm 1\%$ to 2%.

CONCLUSIONS

The absolute permeability to distilled water of Ottawa silica sand was not dependent on the temperature level. This result agrees with much of the data in the literature. Thus far it is believed that some of the work done at Stanford University in the last few years experienced some mechanical problems that resulted in unreliable results. To expand these conclusions, several experiments will be carried out. These experiments will study a variety of consolidated sandstones as well as a range of confining pressures. The absolute permeability experimental work is leading to a continuing work on the relative permeability dependence on temperature level.

It should be emphasized that temperature level effects on capillary pressure and relative permeabilities for sandstones are still important.

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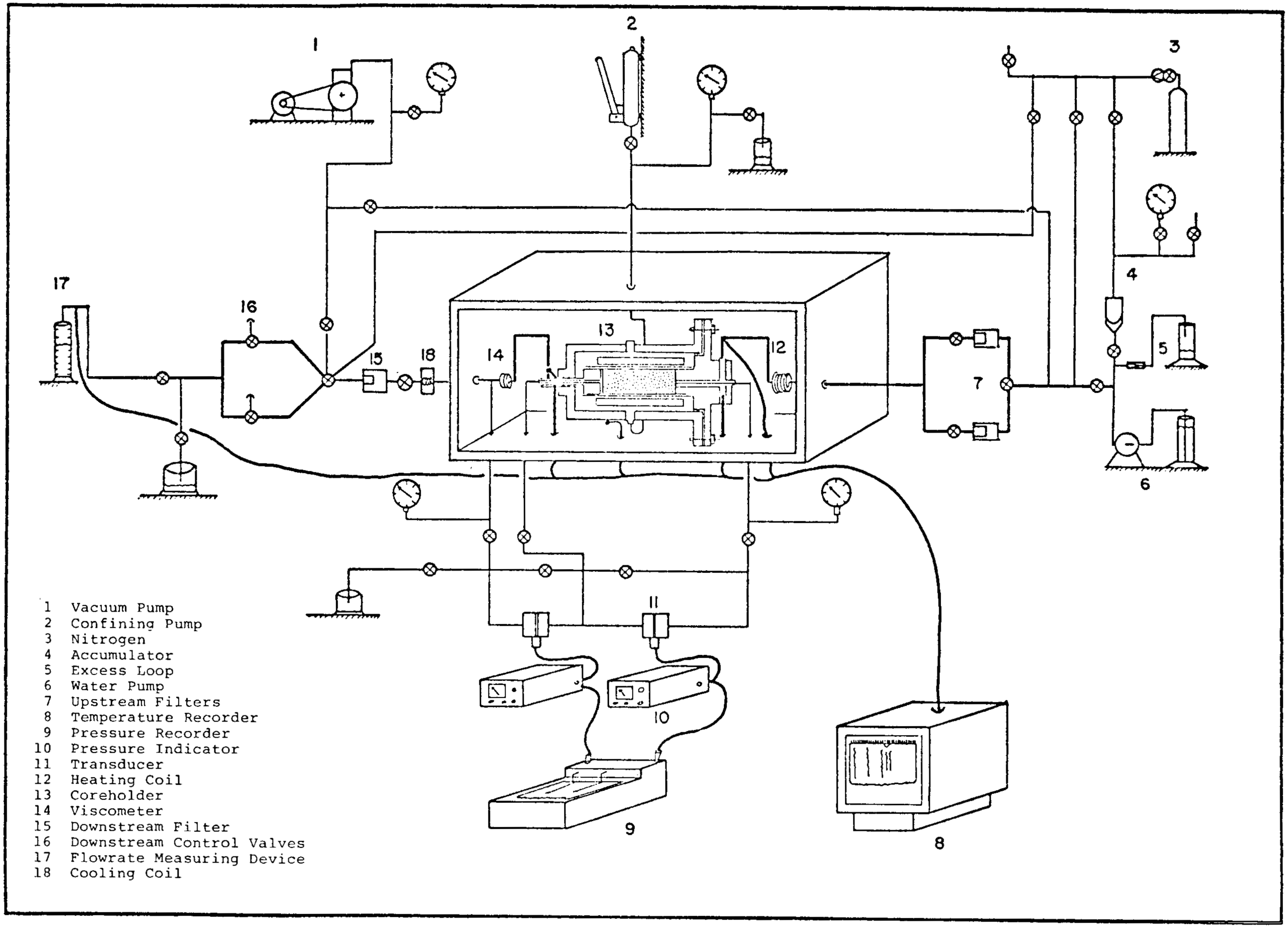

FIG. 1: SCHEMATIC DIAGRAM OF THE APPARATUS-WATER FLOW

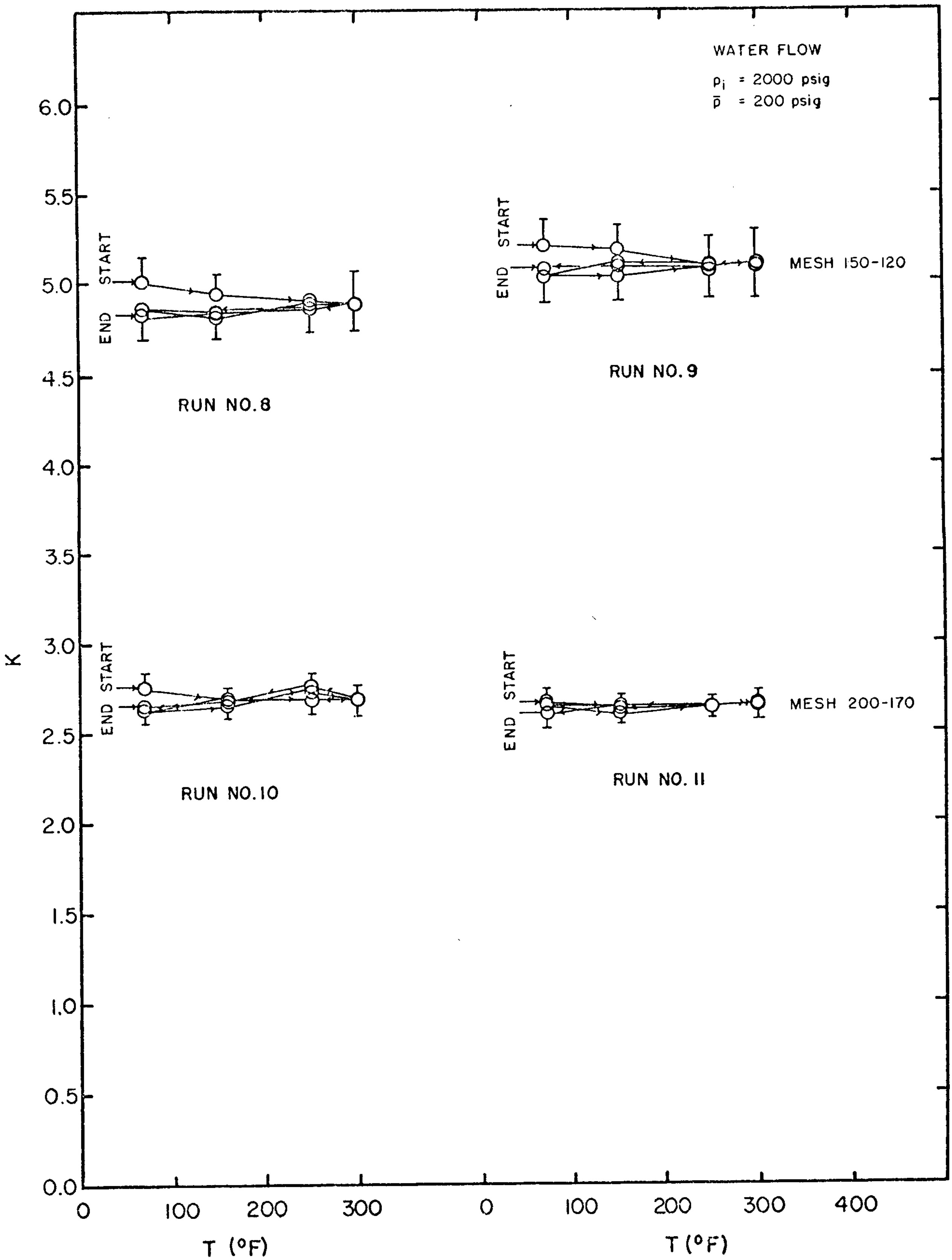

FIG. 2: DISTILLED WATER PERMEABILITY VS TEMPERATURE FOR UNCONSOLIDATED SILICA SAND CORES