EVALUATION OF MOISTURE RETENTION AND HYDRAULIC CONDUCTIVITY CHARACTERISTICS OF UNSATURATED SOILS

George Papageorgiou

A dissertation submitted to the Faculty of Engineering, University of the Witwatersrand, in fulfilment of the requirements for the degree of Master of Science in Engineering

Johannesburg, 1994

DECLARATION

I declare that this Dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

(Signature of candidate)

14 day of March 1994

ABSTRACT

The dissertation describes a modified apparatus, testing and analytical technique for obtaining the relationships between the coefficients of hydraulic conductivity, capillary pressure and water content of unsaturated soils. The apparatus and analytical technique employed in the investigation are aimed at reducing the time duration, and improving the accuracy of testing.

The apparatus used has been based on the design of "The Control Outflow Method", with some modifications. The modified analytical technique, based on the analysis originally developed by W.R. Gardner, is presented with the accompanying developed computer software.

A number of different soils types are tested and the relationships between coefficients of hydraulic conductivity, capillary pressures and water content are determined. An analysis of various curve fitting models used for describing the moisture retention and coefficients of hydraulic conductivity curves using the test data is also conducted.

Keywords : coefficients of hydraulic conductivity, unsaturated, moisture retention curve, capillary pressure, suction.

DEDICATION

To my parents for their endless support and encouragement.

ACKNOWLEDGEMENTS

I am extremely grateful to the following individuals who have contributed in various ways during the research project and drafting of the dissertation:

Prof. A.B. Fourie for his supervision, guidance, reading of the draft dissertation and words of encouragement when nothing seemed to be going right.

Prof. G.E. Blight for providing the financial assistance enabling me to carry out the research on a full time basis.

Mr. S.N. Alexander for his precious technical advice and suggestions.

Finally the University of the Witwatersrand for providing the facilities and equipment necessary for the research project.

CONTENTS | | Page

CONTENTS Page

CONTENTS Page

CONTENTS Page

CONTENTS

CHAPTER 1

OUTLINE OF DISSERTATION

1.1 INTRODUCTION

Soil is a material consisting of weathered rock, air and water forming a three phase system. As the ratio of water and air present in the soil fluctuates with changing environmental conditions so the soil's behaviour changes. It is therefore of great importance to engineers to firstly, understand what affect certain changes have on the soil's behaviour, and secondly to predict or determine how the soil will respond to these changes and loading conditions.

One of the soil's properties which is highly sensitive to any change in the water\air ratio is the coefficient of hydraulic conductivity. The coefficient of hydraulic conductivity is a "constant" which indicates the rate or velocity at which a specific fluid flows through a soil. The coefficient is dependent on a number of soil parameters besides the water\air ratio, namely: size of soil grains, properties of the pore fluid, void ratio, the shape and arrangement of the soil grains.

A very wide spectrum of geotechnical problems require the coefficient of hydraulic conductivity as part of their solution. Among the problems where the coefficient may play quite a prominent role is in:

(1) quantity of leakage through and under dams

(2) rate of consolidation and related settlements

(3) infiltration into de-watering of deep excavations

(4) stability of slopes, embankments, and hydrostatic uplift evaluation

(5) seepage velocity through the soil which may create erosion.

(6) movement of contaminants through the sub surface

One of the issues receiving much attention in recent years is the environment and in particular what impact certain engineering projects have on it. It is in this area that the coefficient of hydraulic conductivity has a vital role to play.

Increasing pressure is being placed on engineers to be able to calculate and predict the movement, rate and concentration at which water and pollutants enter the soil and water-table. The migration of pollutants via the soil water is particularly applicable to waste dumps and landfills. The migration of rain water into the soil and water-table is important to hydrologists, who determine how ground water should be utilized so as not to deplete the reserves, as well as in agriculture where water management measures are employed. In all the above mentioned areas the computer models used for forecasting the migration of water and pollutants require the relationships that exist between the coefficients of hydraulic conductivity, capillary pressures and water content as part of their input data.

The coefficient of hydraulic conductivity for saturated soils is regarded as a constant and can be determine fairly easily, using relatively unsophisticated equipment and in a short period of time. The problem in using the "saturated" coefficient of hydraulic conductivity in geotechnical problems is that the situation of soil being completely saturated is hardly ever encountered. It is therefore far more appropriate to use a coefficient of hydraulic conductivity which is more closely related to actual soil conditions encountered in geotechnical problems - namely the "unsaturated" coefficients of hydraulic conductivity.

There are however a number of practical problems associated with determining the "unsaturated" coefficients of hydraulic conductivity of a soil. The coefficient is no longer a constant but becomes a function of the water content or capillary pressures of the soil. The equipment required to determine these relationships are very sophisticated and the duration of testing is time consuming, which makes it costly. In addition to the above mentioned problems, the equipment and techniques used to measure the various soil variables are not always sufficiently accurate, leading to dubious results.

The research project therefore concentrated on addressing the problem of improving the accuracy with which the various soil variables may be monitored, reducing the time duration of testing, and improving the analytical technique used in determining the "unsaturated" coefficients of permeability.

1.2 PROBLEM STATEMENT

The problem encountered with most testing procedures involved in determining the "unsaturated" coefficients of hydraulic conductivity are listed below:

(1) The time duration of the test, which may vary from a couple of days to a few weeks or months depending on the soil type and testing technique used. - Bear (1972) p. 455.

(2) The accuracy with which certain soil variables are monitored is unsatisfactory eg. a measuring cylinder or burette and a stop watch to monitor very small flow rates.

(3) The type of technique used to determine when capillary equilibrium is established in the soil sample is not always accurate, for eg. establishing equilibrium by monitoring outflow at a fixed applied pressure appears to be slower and less accurate when compared to monitoring capillary pressures at a fixed saturation - Lorentz et al (1992).

There are also certain problems associated with the analytical techniques used to calculate the coefficients of hydraulic conductivity:

(1) In most analytical techniques the ultimate outflow obtained from applying a certain capillary pressure to the sample is required. This makes the testing procedure extremely time consuming and in some cases may result in inaccurate data due to factors such as evaporation losses from the system, temperature affects, leaks and in extreme cases the breakdown of membranes or equipment resulting in no data at all.

(2) The technique of using the "eye ball" approach, of superimposing experimental outflow graphs onto a "family" of theoretical graphs and obtaining certain required values is not accurate.

Finally there are a number of models which can be used to fit the experimental data, describing the moisture retention curve and the coefficients of hydraulic conductivity. Which model best fits the experimental data is not always very clear.

The objectives of the research project are therefore:

(1) To reduce the duration of the test to a few days or a couple of weeks depending on the soil type being tested.

(2) To improve the accuracy with which the various soil parameters are monitored.

(3) To convert the analytical technique used from an "eye ball" graphical approach to a computer based selection process.

(4) To determine which models best describe the experimental data, and what the advantages and disadvantages of the various models are.

1.3 OUTLINE OF SUBSEQUENT CHAPTERS

Chapter 2 provides a brief literature survey of existing testing and analytical techniques for determining the coefficients of hydraulic conductivity and moisture retention curves of soils.
Chapter 3 describes the testing apparatus used in the research project and the equipment it comprises of.
Chapter 4 details the manner in which the various equipment was calibrated.
Chapter 5 explains the testing procedure followed to obtain the moisture retention and hydraulic conductivity data.
Chapter 6 deals with the analytical technique used to determine the coefficients of hydraulic conductivity. It also details the modifications which have been introduced to the analytical technique by the author.

Chapter 7 briefly describes the computer programmes which have been developed for analysing the test data.

Chapter 8 describes the selection process which was used to find a suitable mathematical model for describing the moisture retention and coefficients of hydraulic conductivity curves of the soil samples tested.

Chapter 9 details the procedures followed in processing the test data to obtain the moisture retention and coefficients of hydraulic conductivity curves.

Chapter 10 provides the soil parameters and properties used to describe and classify the soils used in the research project.

Chapter 11 presents the results obtained from the tests conducted including the moisture retention and hydraulic conductivity curves for the tested soils. It also contains results on the curve fitting analysis performed, in which the van Genuchten model was fitted to the experimentally obtained moisture retention curves and the calculated coefficients of hydraulic conductivity of the tested soils.

Chapter 12 lists the conclusions drawn from the research project and recommendations for improving the testing apparatus and analytical technique used to determine the coefficients of hydraulic conductivity. It also highlights problem areas encountered in the research project ~~which require~~ further investigation.

CHAPTER 2

REVIEW OF LABORATORY TECHNIQUES USED TO DETERMINE THE COEFFICIENTS OF HYDRAULIC CONDUCTIVITY AND CAPILLARY PRESSURES OF SOILS

2.1 INTRODUCTION

The following chapter serves as a brief overview of the different laboratory techniques available for determining the coefficients of hydraulic conductivity and capillary pressures of a soil, as well as the relationship that exist between these parameters and water content. The chapter is not written with the intention of describing all the techniques available, but to highlight those methods which are most commonly used.

The chapter is divided into three sections:

Section 2.2 : describes methods used for obtaining the "saturated" coefficient of hydraulic conductivity.

Section 2.3 : describes methods used to determine the moisture retention relationship, (water content - capillary pressure curve), of a soil sample.

Section 2.4 : deals with the methods used to obtain the "unsaturated" coefficients of hydraulic conductivity.

2.2 LABORATORY TECHNIQUES USED TO DETERMINE THE SATURATED COEFFICIENTS OF HYDRAULIC CONDUCTIVITY

2.2.1 Constant Head Test

The test is suitable for soils of relatively high permeability eg. sands.

A constant head of water is applied to the saturated soil sample, housed in a cylindrical container. Water flowing out at the opposite end of the sample is collected into a measuring cylinder over a monitored time period.
Using Darcy's Law, the coefficient of hydraulic conductivity is determined as

follows :

$$k = \frac{QL}{hAt} \quad 2.1$$

where

- Q = total volume of water collected during time t (cm^3)
- t = time period over which water is collected (sec)
- h = constant head applied to sample (cm)
- A = cross-sectional area of sample (cm^2)
- L = length of the sample in direction of water flow (cm)
- k = coefficient of hydraulic conductivity (cm/s)

Refer to figure 2.1

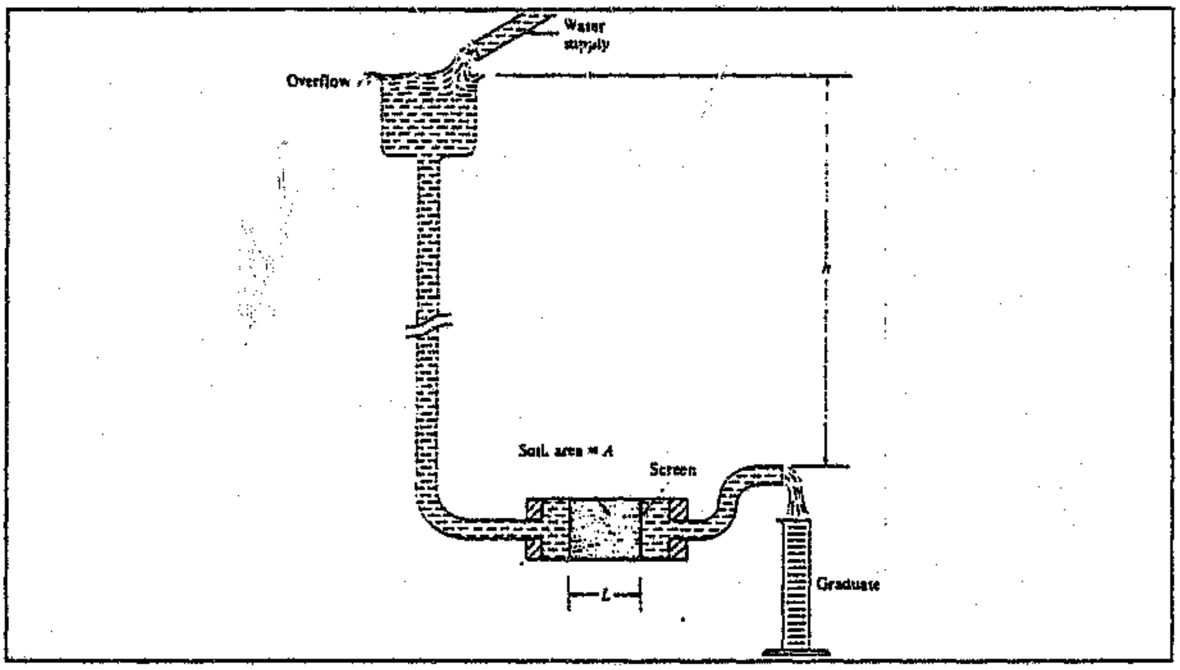


Figure 2.1 Constant Head Permeameter

Cernica (1982) p. 98 "Geotechnical Engineering"

2.2.2 Falling Head Test

The test is more appropriate for soils of lower permeability ie. fine grained soils.

A stand-pipe is attached to the top of the sample, housed in a cylindrical container. The water in the stand-pipe is allowed to flow through the sample, and its level and time is recorded at a minimum of two points along the stand-pipe, although three points are suggested.

Equation :

$$k = \frac{aL}{A(t_f - t_0)} * \ln\frac{h_0}{h_f} \qquad 2.2$$

where

- h_0 = water head at time t_0 (cm)
- h = water head at time t (cm)
- h_f = water head at time t_f (cm)
- t_0 = time at start of test (sec)
- t = intermediate time (sec)
- t_f = time at end of test (sec)
- A = cross-sectional area of sample (cm^2)
- L = length of the sample in direction of water flow (cm)
- a = cross-sectional area of stand-pipe (cm^2)

Refer to figure 2.2

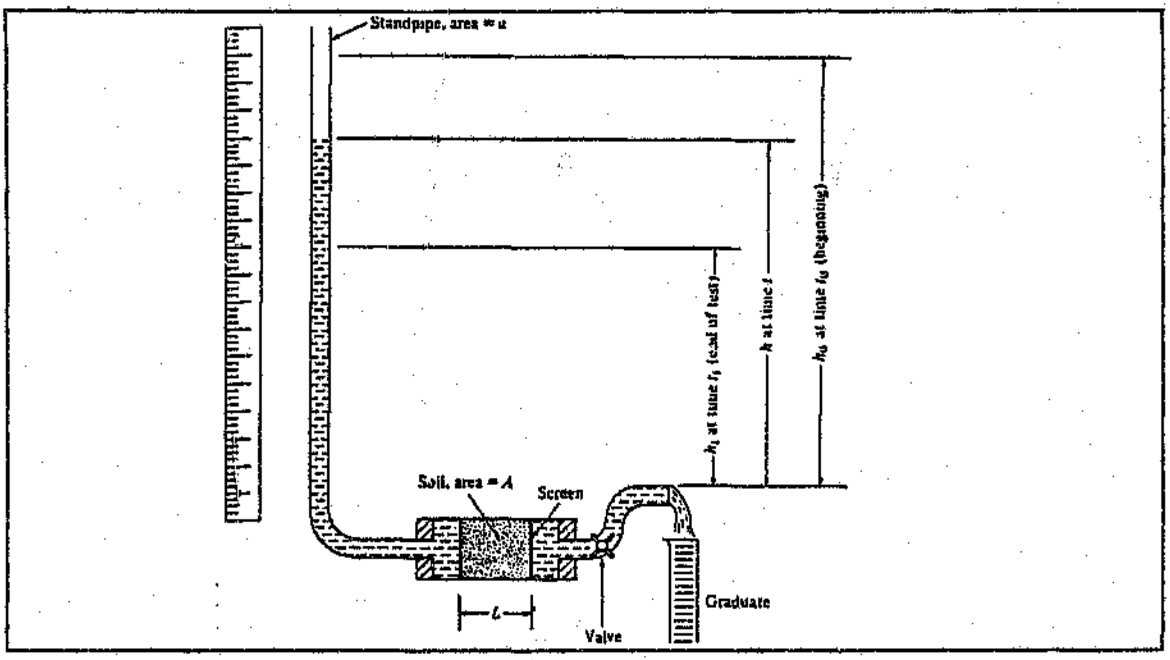


Figure 2.2 Falling Head [illegible]eameter

Cernica (1982) p. 99 "Geotechnical Engineering"

<u>2.2.3 Consolidation Test</u>

The test is performed on a saturated soil sample submerged in water at all times. The sample lies in a metal ring between two porous plates. A load is applied to the sample, via a lever arm, and its compression is monitored. The load is doubled every 24 hours until the test is completed. For each load increment the sample deformation and corresponding time is plotted on semi-logarithmic paper, from which the consolidation coefficient is determined.

Consolidation Equation :

$$T_v = \frac{C_v t}{H^2} \qquad 2.3.1$$

where

- T_v = time factor
- C_v = coefficient of consolidation (cm^2/s)
- H = length of average drainage path (cm)
- t = time (sec)

$$k - C_v \gamma_w m_v \qquad 2.3.2$$

where

- k = coefficient of hydraulic conductivity (cm/s)
- γ_w = unit weight of water (g/cm^2s^2)
- m_v = volume coefficient of compressibility (cms^2/g)

$$m_v - \frac{\Delta e}{\Delta P(1+e)} \qquad 2.3.3$$

where

- Δe = change of void rate for incremental loading
- ΔP = incremental pressure applied (g/cms^2)
- e = initial void ratio

Refer to figures 2.3 & 2.4

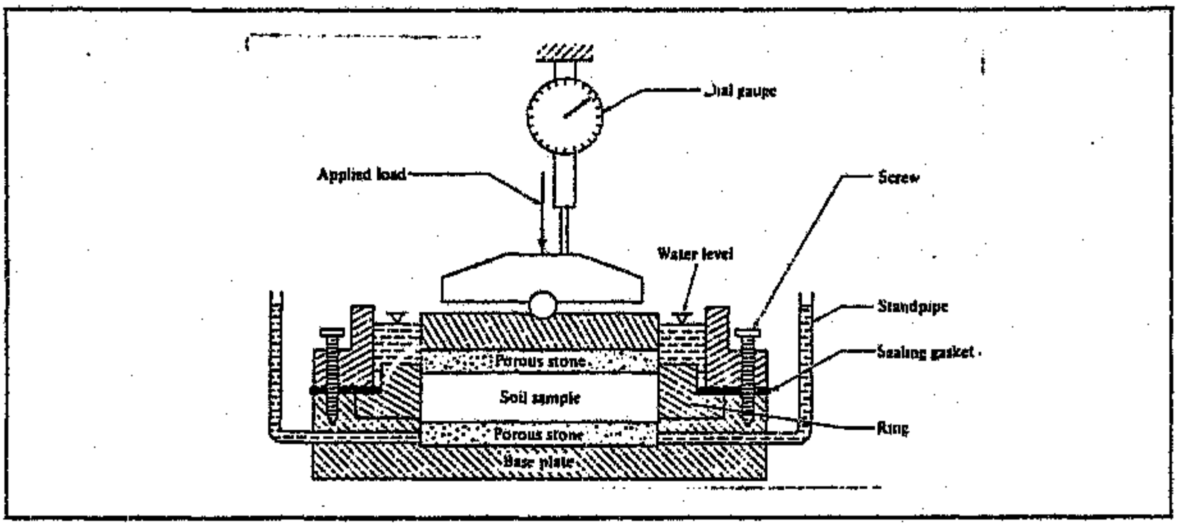


Figure 2.3 Fixed Ring Oedometer

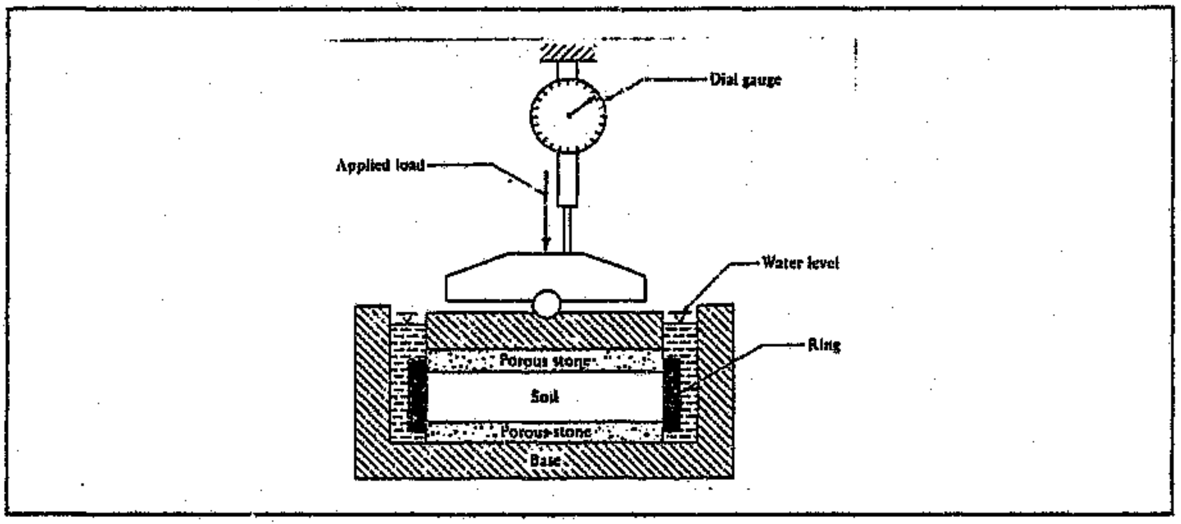


Figure 2.4 Floating Ring Oedometer

Cernica (1982) p. 216 "Geotechnical Engineering"

2.3 LABORATORY TECHNIQUES USED TO DETERMINE THE MOISTURE RETENTION RELATIONSHIP OF SOILS

Although there are numerous techniques and apparatus developed for obtaining the moisture retention relationship, many are just modified variations of certain basic methods. The various techniques can be classified into two main categories:

(1) Displacement\Unsteady Flow Method :

These techniques are based on establishing successive states of hydrostatic equilibrium.

(2) Dynamic\Steady Flow Method :

These techniques are based on establishing successive states of steady flow of wetting and non-wetting fluids.

2.3.1 Displacement Techniques

2.3.1.1 Porous Plate\Suction Plate\Pressure Plate Method

The technique is based on measuring the amount of wetting fluid displaced from a sample at different applied capillary pressures.

A soil sample saturated with wetting fluid (water) is placed into a pressure chamber containing only non-wetting fluid (air). The sample rests on a porous disc which is also saturated with wetting fluid. The disc is manufactured so as to be only permeable to the wetting fluid, up to a certain pressure, after which non-wetting fluid penetrates into the disc.

The pressure of the non-wetting fluid is increased, or a suction is applied below the porous disc, resulting in a certain amount of wetting fluid draining out of the sample, which is collected in a measuring cylinder. Once the flow of wetting fluid ceases for a particular applied pressure, equilibrium is achieved. The pressure of the non-wetting and wetting fluids is then measured to determine the capillary pressure. The non-wetting fluid pressure or suction is then increased and the process is repeated.

Once the sample is fully saturated by non-wetting fluid, or no more wetting fluid can be drained out of the sample for any significant increase in pressure or suction, the test is terminated. From the measured amounts of wetting fluid drained out at each pressure or suction increment, the corresponding saturation of the sample can be determined. Plotting the corresponding saturations and capillary pressures of the sample, produces the moisture retention curve.

A major disadvantage of this method is the time required to run the test, due to the decreasing pressure difference that results in flow as equilibrium is reached. The time required to obtain the entire moisture retention curve varies from 1 week to a month or more, depending on the type of soil tested - Bear (1972) p. 455, and Lorentz et al (1992).

With minor modifications to the apparatus the test can be performed for a sample initially saturated by non-wetting fluid and gradually saturated with wetting fluid.

Refer to figure 2.5 for an illustration of a typical Pressure Plate Apparatus.

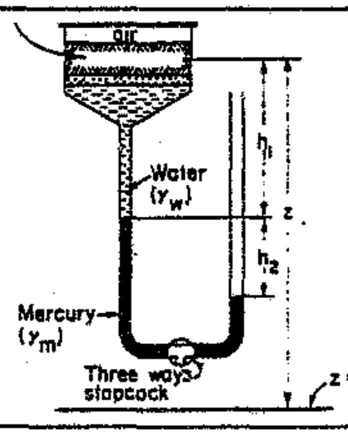


Figure 2.5 Pressure Plate Apparatus

Bear (1972) p. 478 "Dynamics of fluids in porous media"

2.3.1.2 Centrifuge Method

This is an indirect method of obtaining the moisture retention relationship of a sample.

A sample saturated with wetting fluid is placed in a centrifuge and subjected to rotations at various constant angular velocities. Due to the rotation, the fluids in the sample are subjected to centrifugal forces which produce a pressure gradient directed outwards from the axis of rotation. This causes wetting fluid to drain out of the outer radius of the sample, and non-wetting fluid to enter from the inner radius.

The drained wetting fluid is collected into a measuring cylinder for determining the saturation of the sample. Once drainage ceases for a certain angular velocity, equilibrium is established. The angular velocity is then increased and the process is repeated until the sample is completely saturated by the non-wetting fluid.

The total volume of wetting fluid collected at each angular velocity is used to determine the saturation of the sample. The corresponding capillary pressure is determined by the following equation :

$$p_c(r_1) = \frac{(r_2^2 - r_1^2)\omega^2 \Delta\rho}{2} \qquad 2.4$$

where

p_c = capillary pressure (g/cms^2)

$\Delta\rho$ = density difference of fluids (g/cm^3)

ω = angular rate of rotation (rad/s)

r_2 = outer radius of rotation of sample (cm)

r_1 = inner radius of rotation of sample (cm)

An advantage of this method is the time required to run the entire test ranges from a few hours to a few days - Bear (1972) p. 456. Availability and cost are, however, a major disadvantage.

2.3.1.3 Controlled Outflow Method

This method has recently been developed, and offers a number of advantages over existing methods. Figure 2.6 illustrates the arrangement of the apparatus.

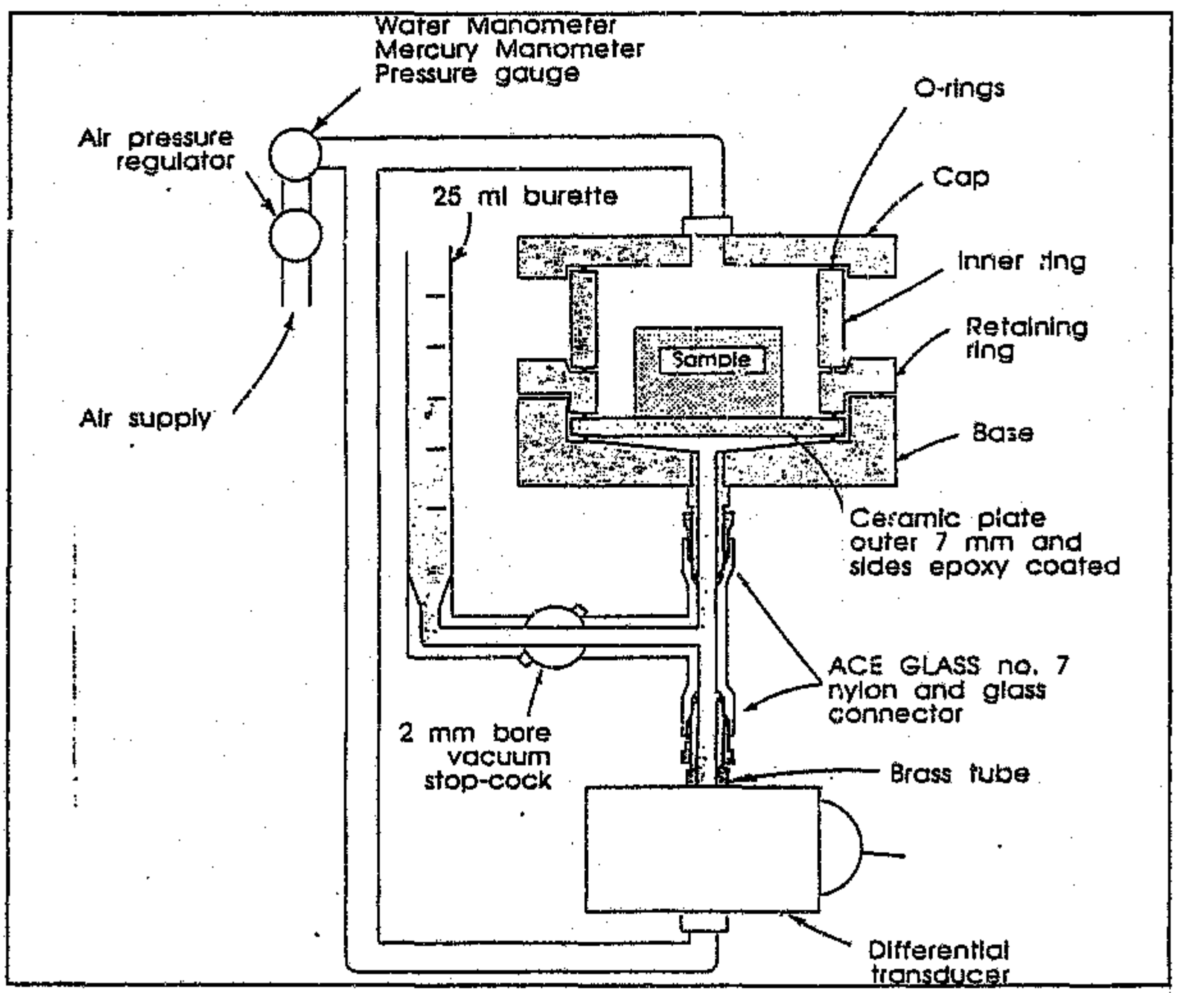


Figure 2.6 Control Outflow Apparatus

Lorentz et al (1992) - Draft

The main components are a base, a retaining ring, an inner ring that houses the sample, the cap and the outflow burette and T-piece. Additional items for the system consist of a differential null transducer to measure the difference in pressure of air and water, and tubing.

A ceramic plate is clamped between the O-rings in the base and the retaining ring. The sides and outer edges of the plate are covered in epoxy to form an impervious surface. The cap clamps the inner ring to the retention ring and seals the compartment in which the sample rests on the ceramic plate.

The sample initially saturated by wetting fluid lies on the ceramic plate. The space below the ceramic plate and tubes leading to the burette and "wet port" of the pressure transducer are filled with wetting fluid. The "dry port" of the transducer and the inlet to the cell are connected to the non-wetting fluid pressure source.

Testing commences by increasing the non-wetting fluid pressure in the cell. Wetting fluid is allowed to drain out of the sample and into the burette, so as to determine the degree of saturation of the sample. After a predetermined amount of wetting fluid has drained from the sample, the outlet port leading to the burette is closed. The capillary pressure within the sample is then monitored, via the transducer, until it stabilizes. At this point equilibrium is established in the sample for that particular saturation.

Additional points on the moisture retention curve are obtained by increasing the non-wetting fluid pressure and reducing the saturation of the sample.

The wetting cycle of the sample (starting with a dry sample and ending with a wet one) can also be obtained without modifying the apparatus.

As a result of monitoring the capillary pressure of the sample at a fixed saturation, instead of outflow at a fixed applied pressure, the point of equilibrium is established more rapidly and with greater accuracy. Equilibrium time varies from 10 minutes to 36 hours, - Lorentz et al (1992), depending on the type of material, degree of saturation and volume of wetting fluid removed during each loading step.

2.3.2 Dynamic Techniques

The apparatus most commonly used by this approach is based on the Hassler principle, - Bear (1972) p. 456, and is the same apparatus used to determine relative permeability. Figure 2.7 illustrates an apparatus based on Hassler's principle.

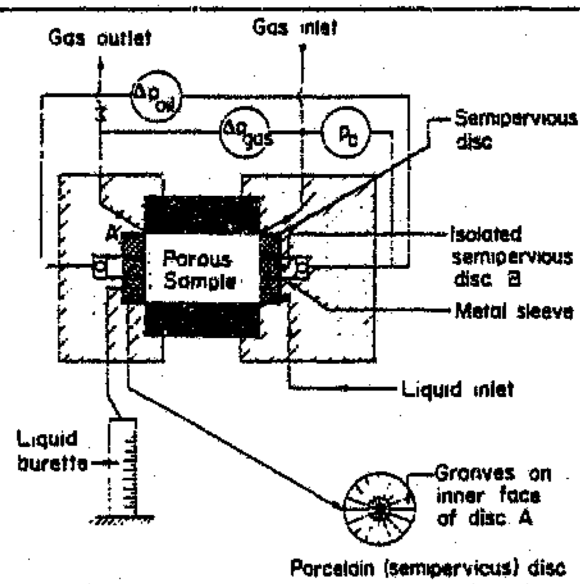


Figure 2.7 Hassler Apparatus

Bear (1972) p. 457 "Dynamics of fluids in porous media"

A test sample initially saturated by wetting fluid is placed between two porous plates permeable to the wetting fluid only. The plates are divided into an outer ring "A" and inner disc "B".

At the inflow end wetting fluid is introduced through ring "A" and non-wetting fluid through disc "B". At the outflow end wetting fluid exits through the porous plate while the non-wetting fluid escapes through an outlet port. The pressures of both fluids and the capillary pressures at both ends of the sample are monitored.

Both fluids pass through the sample at rates such that the capillary pressure at both ends of the sample is equal. Once this is achieved, equilibrium is attained and the sample is removed and it's saturation determined for the particular capillary pressure.

2.3.3 Other Methods

The following methods are mentioned for the sake of completeness.

(1) Gravity Method *
(2) Back Pressure Method *
(3) Field Tensiometer
(4) Rapid Method *
(5) Oedometer Test
(6) Freezing Point Depression Method
(7) Vacuum Desiccator
(8) Sorption Test

The above mentioned methods are not described in detail as, those marked with a "*", are techniques based on one or another of those described previously, while the remaining tests are not commonly used. The Back Pressure and Rapid method are modified techniques of the Outflow method, with the aim of reducing the duration of the test by applying a back pressure on the wetting fluid after a pre-determined water content is reached in the sample. The pressure required to stop the outflow is recorded and subtracted from the pressure of the non-wetting fluid to determine the capillary pressure.

Other techniques are more applicable for measuring the vapour capillary pressures of a sample, which is more common in chemical applications than geotechnical, eg. Sorption and Freezing point depression methods. The Field Tensiometer Test is more applicable for field testing.

For further information on these techniques refer to Corey et al (1961).

2.4 LABORATORY TECHNIQUES USED TO DETERMINE THE UNSATURATED COEFFICIENTS OF HYDRAULIC CONDUCTIVITY

Most methods are based on solving a one-dimensional continuity equation for steady or unsteady flow.

2.4.1 Steady State Method

The permeameters used in this approach are based on the Hassler, Hafford and Dispersed Feed principles. The techniques differ from each other mainly in the manner in which the wetting and non-wetting fluids are introduced into the sample, and determining the degree of saturation. The permeameters used are very similar to the apparatus described in the section 2.3.2 Dynamic Techniques and illustrated in figure 2.7.

A sample is placed into a plexiglass tube or pressurizing chamber. The wetting and non-wetting fluids are introduced simultaneously, but through separate openings, at a certain ratio, into the sample at the inflow end of the apparatus. Once the same ratio is established at the outflow end of the apparatus a steady state (equilibrium) is reached. The time duration to establish a steady state varies between 2 and 40 hours, - Bear (1972) p. 474, according to the method used, the degree of saturation, and permeability of the sample.

The pressures and rate of flow of the two fluids at either end of the sample is measured, and the degree of saturation determined. By using the following equation the coefficient of hydraulic conductivity of the sample with regard to either fluid can be obtained, for the corresponding saturation:

$$k = \frac{qL}{\Delta pA} \tag{2.5}$$

where

q = outflow rate (cm^3/s)

k = coefficient of hydraulic conductivity (cm/s)

Δp = pressure drop of fluid (cm)

A = cross-sectional area of sample (cm^2)

L = length over which pressure drop measured (cm)

The ratio at which the two fluids are introduced into the sample is then changed, (either gradually increasing or decreasing the amount of wetting fluid present in the sample), and the procedure is repeated.

The major disadvantage of this technique is the availability of such apparatus and the cost. The degree of saturation of the sample is also not easily determined. The sample has to either be removed after each equilibrium point is established to determine the degree of saturation, resulting in a re-disturbed sample been tested for each equilibrium point, or use an altogether new sample for the next test point. Alternatively, expensive electronic equipment can be used to determine the degree of saturation of the sample during testing.

2.4.2 Unsteady State Method

2.4.2.1 Outflow Method

This technique was originally developed by Richards and then further developed by Gardner (1956), Miller and Elrick (1958), Ritjema (1959), Kunze and Kirkham (1962) and Richards (1965).

The method is based on measuring the volume of outflow from a sample at a fixed applied air pressure. The sample, initially saturated with wetting fluid, rests on a porous plate inside a pressure chamber. The non-wetting fluid pressure in the chamber is increased and the outflow of wetting fluid is measured as a function of time. Once the outflow terminates for a particular applied non-wetting fluid pressure, equilibrium is attained. The non-wetting fluid pressure is then increased and the process is repeated.

The outflow data for each pressure increment is then used to solve the unsteady, one-dimensional continuity equation. This results in determining the coefficients of hydraulic conductivity for the corresponding degrees of saturation of the sample. For details on the apparatus and unsteady state equations refer to Gardner (1956), Miller and Elrick (1958), Ritjema (1959), Kunze and Kirkham (1962) and Richards (1965).

CHAPTER 3

DESCRIPTION OF APPARATUS

3.1 SET-UP OF APPARATUS BEFORE START OF RESEARCH PROJECT

The initial apparatus was developed by G. Mc Phail. It consisted of a Triaxial Cell (76 mm diameter sample), base plate with a ceramic plate, Outflow Gauge, data logger, 10 volt excitation supply, double burette volume gauge, air-water cylinder, de-aired water supply and an air pressure source. Figure 3.1 shows the set-up of the apparatus.

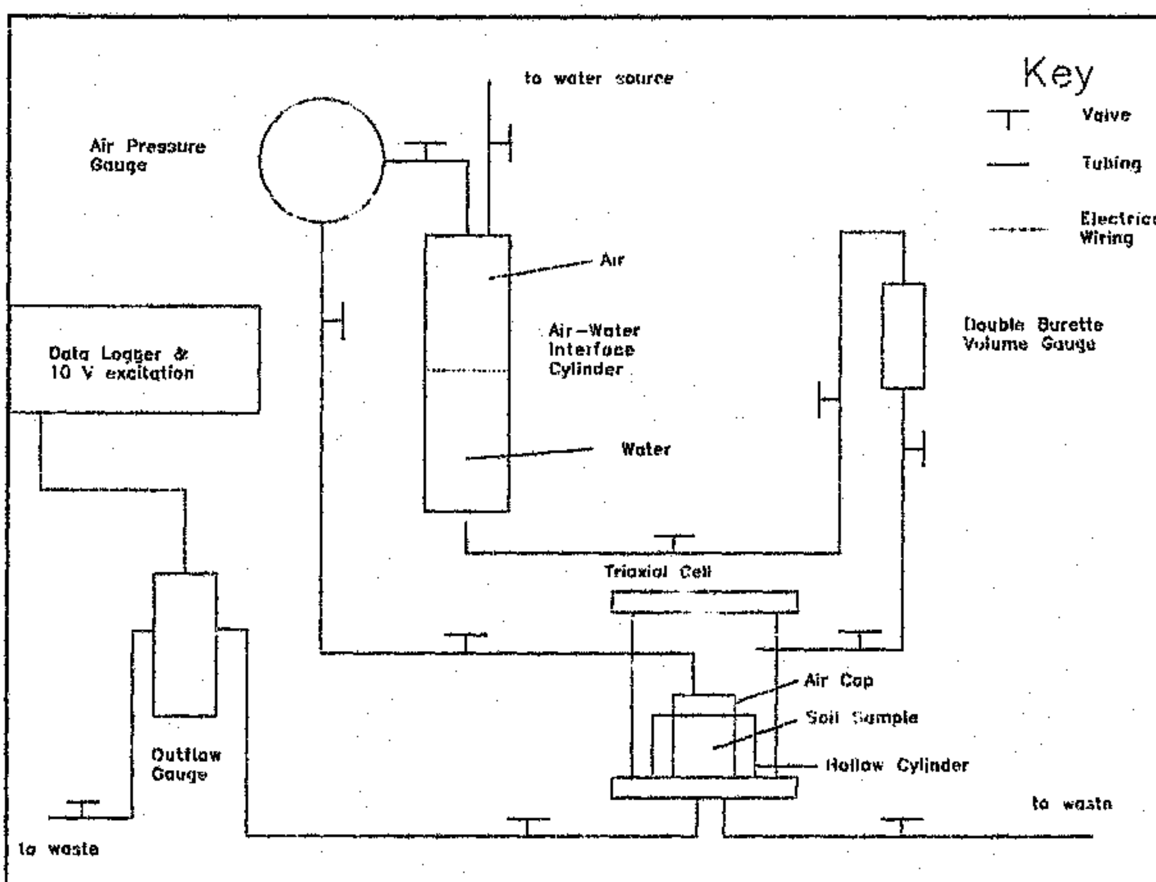


Figure 3.1 Apparatus set-up at start of research

3.2 SET-UP OF EXSISTING APPARATUS

Figure 3.2 shows a schematic arrangement of the apparatus used. The apparatus consists of a Triaxial Cell (76 mm diameter sample), Screw Control Cylinder, modified base plate with ceramic plate, bubble trap, Outflow Gauge, Volume Gauge, Differential Pressure Transducer, Data Logger, 10 volt excitation supply, air-water interface cylinder, de-aired water supply and an air pressure source.

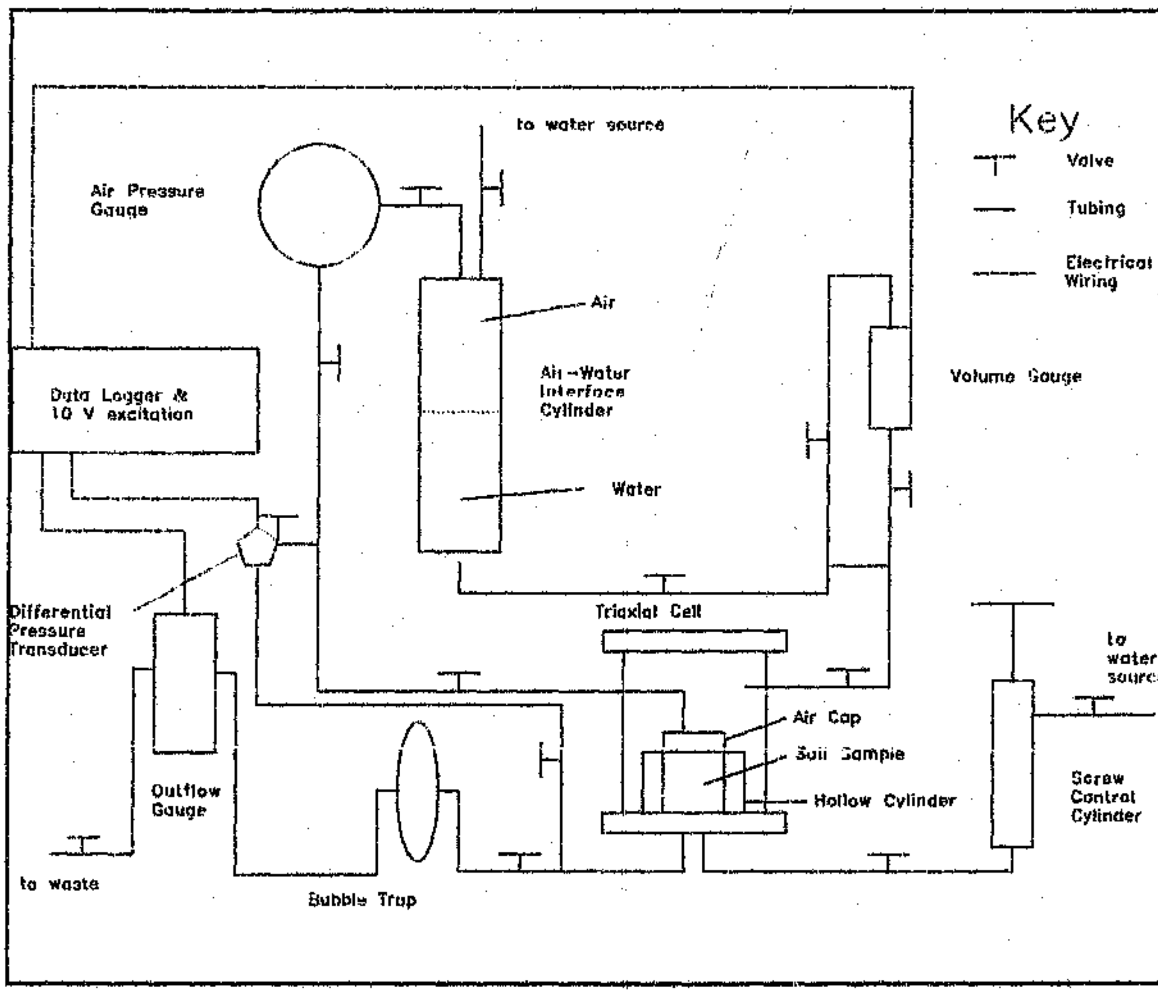


Figure 3.2 Apparatus set-up

The Triaxial Cell has four valve connections at its base. Two of the valves lead into the interior of the Cell, here from referred to as water-inflow and air-inflow valves. The remaining two valves lead to the flushing channel of base plate with the ceramic plate. These two valves are referred to as base-inflow and base outflow valves hereafter.

The base-inflow valve is connected to a Screw Control Cylinder which in turn is connected to a de-aired water supply source. The base-outflow valve leads to the wet\pore water port of the Differential Pressure Transducer and the bubble trap. An in-line ball valve is present in the tube connecting the base-outflow valve to the bubble trap. The bubble trap in turn is connected to the Outflow Gauge which leads to waste. The air-inflow valve is connected to the air pressure source, and to the air cap on the internal side of the cell. The water-inflow interior valve is connected to the Volume Gauge and a de-aired water supply source. The Volume Gauge is connected to the air-water interface cylinder, which is connected to the air pressure source. The dry\air port of the Differential Pressure Transducer is connected to the air pressure source. The Outflow Gauge, Volume Gauge and Differential Pressure Transducer are linked to the data logger and the 10 volt excitation supply.

3.2.1 Description of equipment comprising the apparatus

3.2.1.1 Differential Pressure Transducer

The Differential Pressure Transducer is a low cost transducer manufactured by Omega Engineering. Three models are currently available. All three models have a maximum mode pressure of 60 psi (413,7 kPa). The three models differ only in the differential pressure range that they can measure, which is 0-5 psi (0-34,5 kPa), 0-15 psi (0-103,4 kPa) and 0-30 psi (0-206,8 kPa).

The 0-30 psi transducer was used in the apparatus as it allows for a greater range of capillary pressures to be measured. The wet\pore water pressure port of the Differential Pressure Transducer is connected to the base-outflow valve which leads to the base plate with the ceramic plate and ultimately to the bottom end of the soil sample. This enables monitoring of the pore water pressure in the soil sample. The dry\air pressure port of the Differential Pressure Transducer is connected to the air supply source. In this manner the

Differential Pressure Transducer determines the capillary pressure of the soil sample at a fixed saturation. The Differential Pressure Transducer also indicates when equilibrium is established in the soil sample via the stabilization of the capillary pressure reading.

3.2.1.2 Outflow Gauge

The Outflow Gauge consists of a Bellow Diaphragm which moves vertically up and down as water passes through the device. A Linear Variable Displacement Transducer is attached to the bellows and monitors its vertical movement.

The Outflow Gauge is used to monitor the volume of the water discharged from a soil sample at a certain applied air pressure. It also enables the determination of the flow rate of the water released during each step interval of the test.

3.2.1.3 Volume Gauge

The Volume Gauge consists of a hollow cylinder with Bellowfram rolling seals attached to a "floating" frictionless piston. The Volume Gauge is able to measure a volume change of up to 25 cm^3. A Linear Variable Displacement Transducer is attached externally onto the cylinder and to a lever which is attached to the piston. In this manner the movement of the piston is monitored and the amount of water entering or leaving the Volume Gauge is determined.

The Volume Gauge inflow port is connected to the air-water interface cylinder. The outflow port is connected to the base-inflow valve which leads to the interior of the Triaxial Cell. The Volume Gauge therefore is able to monitor the change in volume of the soil sample during testing, by monitoring the amount of water passed in or out of the Triaxial Cell, so as to maintain the applied cell pressure.

3.2.1.4 Modified Base Plate

The original base plate of the Triaxial Cell was modified so as to allow for the flushing out of trapped air bubbles between the ceramic plate and base plate during testing. The modification is a 3 mm deep and wide "S" shaped channel from the base-inflow to the base-outflow hole of the base plate. The "S" shaped pattern was selected as it allows for the maximum coverage of the surface area of the base plate and ceramic plate. The pattern also restricts water and air bubbles to move along only one path and to one destination. Refer to figure 3.3

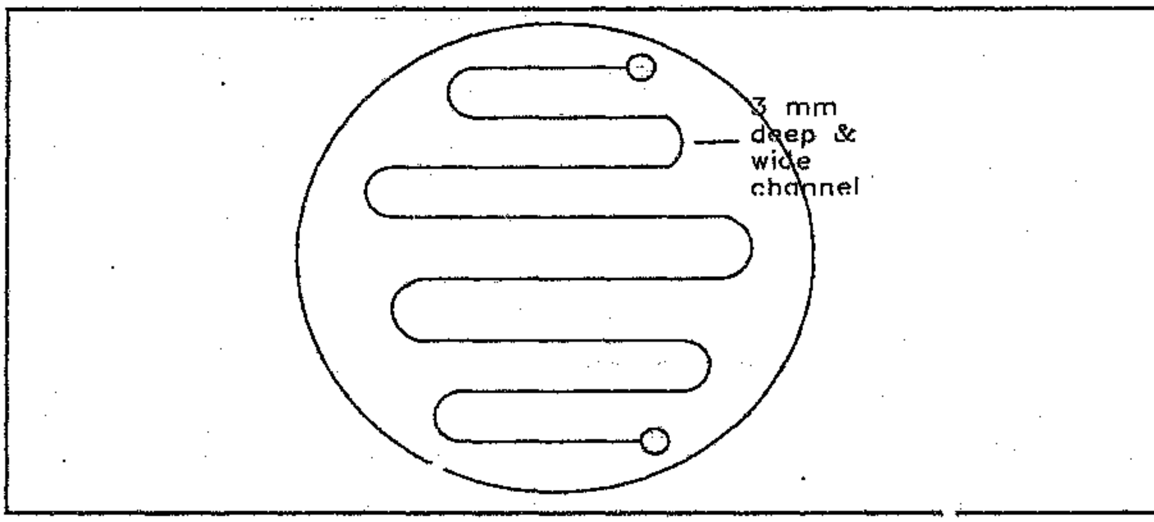


Figure 3.3 Modified Base Plate

3.2.1.5 Ceramic Plate

The porous ceramic plates used in the apparatus, are manufactured by Soilmoisture Equipment Corporation. The 5 bar ceramic discs that were used have a bubbling pressure\air entry value greater than 552 kPa, and a saturated coefficient of hydraulic conductivity of $1.21*10^{-7}$cm/s. - according to the manufacturers specifications. The dimensions of the disc are as follows: diameter = 6.668 cm, thickness of disc = 0.714 cm.

3.2.1.6 Data Logger

The Data Logger used, allowed for up to 8 channels for monitoring. In the apparatus set-up that was used only 3 channels were utilized. The 1^{st} channel was linked to the Differential Pressure Transducer, the 2^{nd} to the Outflow Gauge and the 3^{rd} to the Volume Gauge. The Data Logger was able to monitor any time interval required and to record the data onto paper. The Data Logger also displayed the readings of the monitored channels continuously.

3.2.1.7 Screw Control Cylinder

This device is a standard piece of equipment consisting of a hollow cylinder containing a plunger attached to a threaded shaft and handle. The Screw Control Cylinder was connected to a de-aired water supply source and to the base-inflow valve of the Triaxial Cell.

The Screw Control Cylinder was used for flushing out any air bubbles that may become trapped during testing between the ceramic plate and base plate.

3.2.1.8 Bubble Trap

The main objective of the bubble trap is to prevent any flushed out air bubbles from entering the Outflow Gauge. The reason for this precaution is so as to measure only the amount of water displaced from the soil sample, thereby introducing no errors due to gas volume.

An air-release valve is present at the top of the bubble trap to allow trapped air bubbles to escape at various times during testing.

3.2.1.9 Tubing

A 0.635 cm semi-stiff polyurethane tubing was used. The tubing is transparent to allow for the checking of air-bubbles in the system. The tubing is also sufficiently stiff so that it does not expand under the pressures it is subjected to.

CHAPTER 4

CALIBRATION OF EQUIPMENT

4.1 CALIBRATION OF DIFFERENTIAL PRESSURE TRANSDUCER

The wet\pore water pressure port of the Differential Pressure Transducer was connected to a tube filled with de-aired water. The dry\air pressure port was connected to a tube with an in-line ball valve. Both tubes were connected to a common air pressure source. The Differential Pressure Transducer was linked to the data logger and the 10 volt excitation supply.

Starting with a zero common pressure the in-line ball valve on the dry\air pressure port side was closed, ensuring that the pressure on this side of the Differential Pressure Transducer was kept at zero. The common air pressure source was then increased, in increments of 20 kPa, resulting in an increase in pressure on the wet\pore water pressure port side of the Differential Pressure Transducer, and in the differential pressure between the two ports. The corresponding volt reading for each 20 kPa differential pressure increment was recorded until a maximum differential pressure of 200 kPa was attained. The common pressure source was then decreased in 20 kPa intervals until a zero differential pressure was re-established. At the zero differential pressure the in-line ball valve was opened, to ensure that the differential pressure was zero, and the corresponding voltage reading was taken.

This procedure was repeated three times before the zero differential pressure was increased by 10 kPa. The calibration procedure was then repeated until a zero differential pressure of 210 kPa was reached.

A linear regression curve was then fitted to the corresponding voltage and differential pressure readings for each zero differential increment. Figure 4.1 shows the linear regression curve determined for the zero differential pressure of 20 kPa.

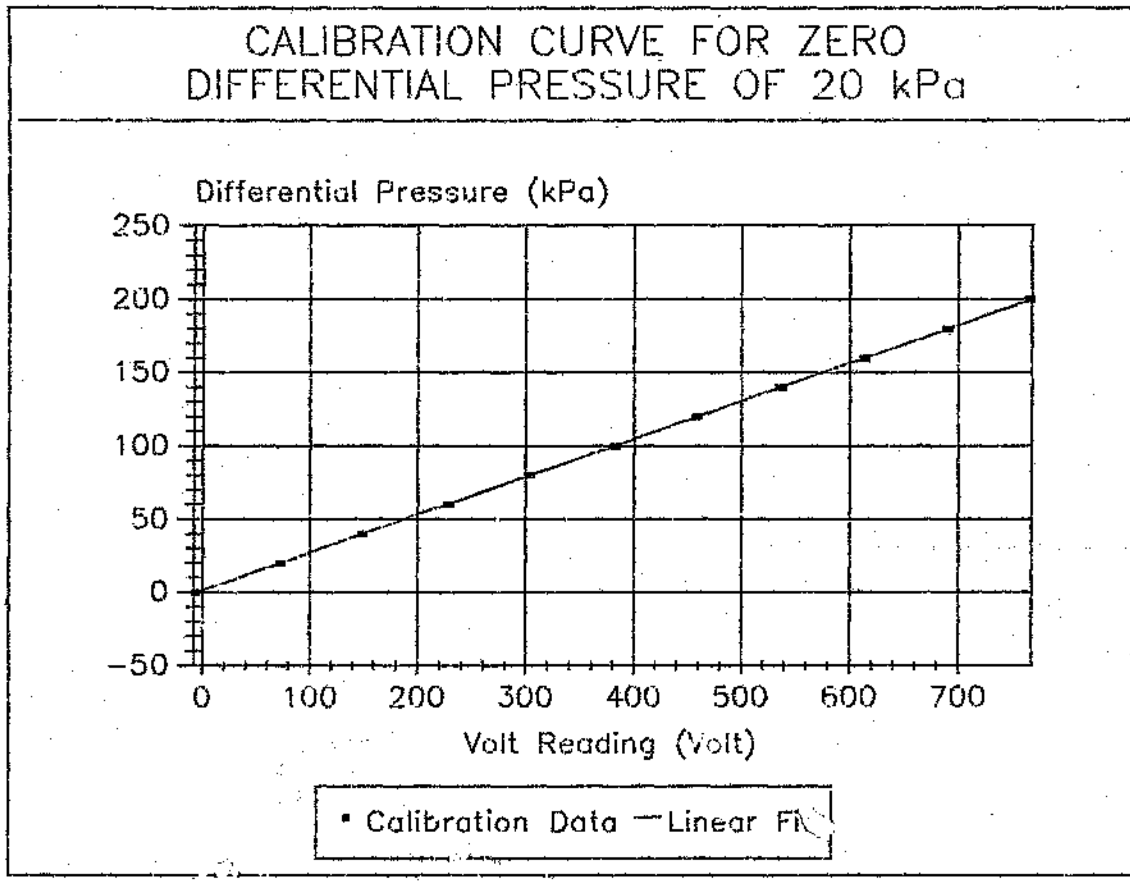


Figure 4.1 Calibration curve of Differential Pressure Transducer - at 20 kPa zero pressure

Once the slopes for the various zero differential pressures were determined, an average slope value for the entire spectrum of linear regression curves was calculated. This average slope value was used to convert the differential voltage readings during testing to capillary pressures. Table 4.1 lists the slope values for the various zero differential pressures as well as the average slope and the standard deviation.

Zero Differential Pressure (kPa)	Slope	Zero Differential Pressure (kPa)	Slope
0	3.875398	110	3.852500
10	3.859545	120	3.856136
20	3.860341	130	3.854091
30	3.860682	140	3.857784
40	3.859205	150	3.855455
50	3.860455	160	3.853920
60	3.858409	170	3.858523
70	3.861818	180	3.854773
80	3.855000	190	3.851250
90	3.863077	200	3.856477
100	3.856250	210	3.855455

Average slope = 3.858066
Standard Deviation = 0.00799

Table 4.1 Slope values determined for the differential pressure transducer

Due to the fact that the corresponding zero voltage readings for the various zero differential pressures decreased slightly, as the zero differential pressure was increased, it had to be accounted for. A linear regression curve was fitted to the constants determined from the linear ragression curves for the various zero differential pressures. The slope determined from the regression was then used to correct the zero pressure volt reading during testing, based on the dry\air pressure side of the Differential Pressure Transducer. Figure 4.2 shows the linear regression curve determined for the adjustment to the zero pressure voltage reading. The equation for zero pressure adjustment is as follows :

$$\text{Zero Pressure} = -0.0357x - 4.6821 \qquad 4.1$$

where

x = applied air pressure (kPa)

For the comprehensive data on the calibration of the Differential Pressure Transducer refer to Appendix 1.

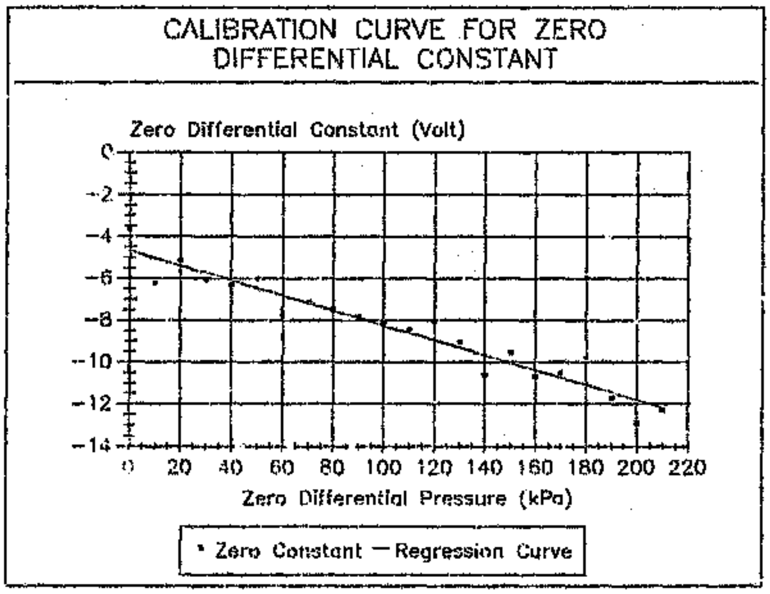


Figure 4.2 Calibration curve for adjusted zero pressure value

4.2 CALIBRATION OF VOLUME GAUGE

The inlet port of the Volume Gauge was connected to the Screw control cylinder which in turn was connected to a de-aired water source. The outlet port leads to a measuring cylinder. The Linear Variable Differential Transducer which was attached on the side of the gauge was linked to the data logger and the 10 volt excitation supply source.

The Volume Gauge was adjusted to the zero volume position and the corresponding voltage reading recorded. Water was then pushed into the Volume Gauge by the Screw control cylinder and the amount of discharge out of the gauge was collected in the measuring cylinder. Water was discharged out of the Volume Gauge until a voltage reading of a multiple of a hundred was reached. The outflow was then stopped and the mass of the water discharged was measured to three decimal places. The cumulative mass of the water collected at each interval was converted to a volume using the density of water (1 g = 1 cm^3). The procedure was then continued until the maximum displacement of the Volume

Gauge was reached.

The Volume Gauge was then refilled with water from the inlet outlet port so as to return it to its zero displacement position. The entire calibration procedure was then repeated, for a total of three times.

A plot of the cumulative volume discharged versus volt readings indicated that a non-linear relationship existed between the two variables. Using a least squares curve fitting program a 4[th] order polynomial was fitted to the data. Figure 4.3 shows the polynomial fitted to the calibration data.

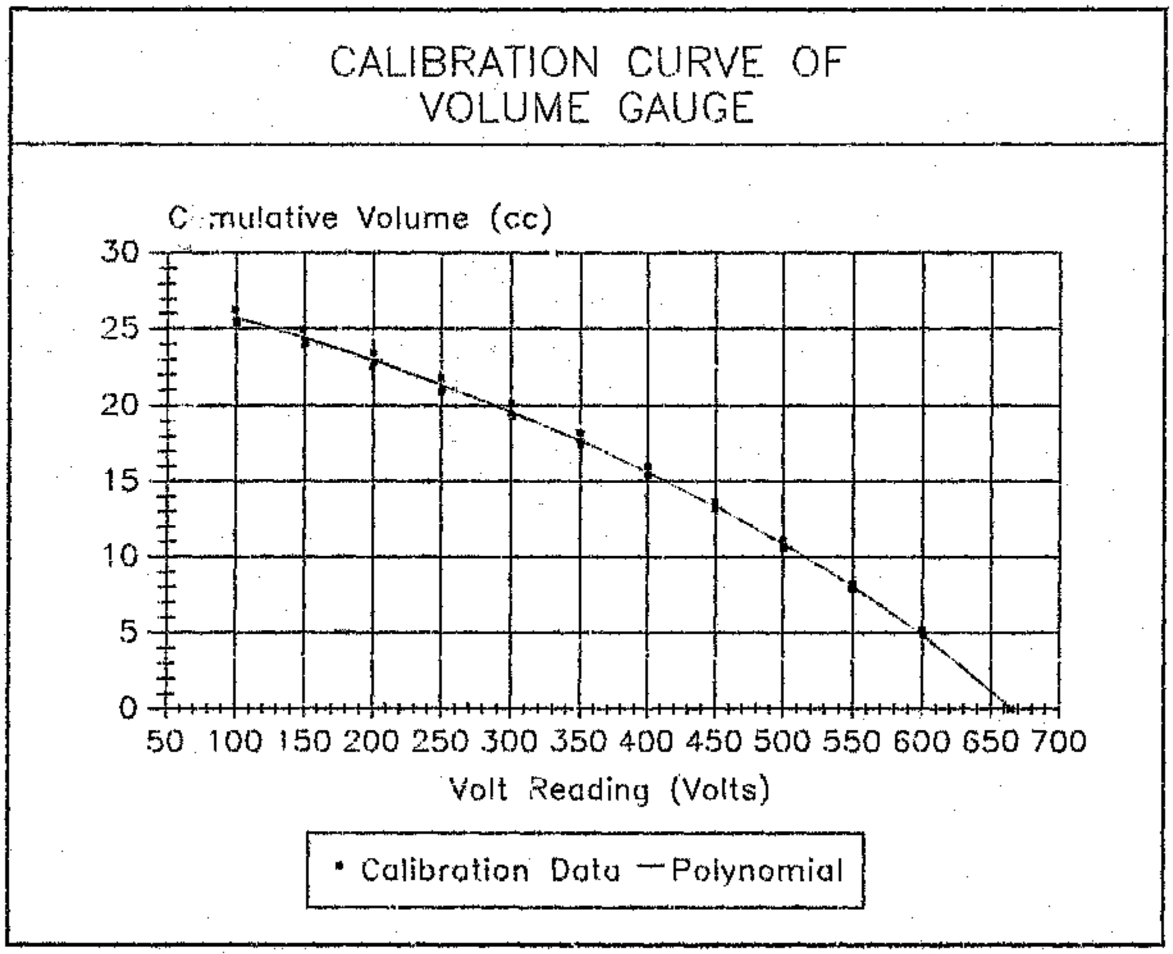


Figure 4.3 Calibration curve of Volume Gauge

The polynomial equation is as follows :

$$V = -8.65981E-11*x^4+8.50705E-8*x^3-5.84998E-5*x^2+2.771321E1 \quad 4.2$$

where :

V = volume discharged (cm^3)

x = volt reading (volts)

For the comprehensive data regarding the calibration of the Volume Gauge refer to Appendix 1.

4.3 CALIBRATION OF OUTFLOW GAUGE

The inlet port of the Outflow Gauge was connected to the Screw control cylinder which in turn was connected to a de-aired water source. The outlet port leads to a measuring cylinder. The Linear Variable Differential Transducer was connected to the Bellows Diaphragm of the Outflow Gauge which was linked to the data logger and the 10 volt excitation supply.

The Bellows Diaphragm of the Outflow Gauge was adjusted to its maximum\minimum position of displacement and the corresponding voltage reading was recorded. Water was pushed into the Outflow Gauge, with the aid of the Screw control cylinder, and the discharged water was collected in the measuring cylinder. After every ten revolutions of the Screw control cylinder handle the water collected in the measuring cylinder was weighed to three decimal places and the corresponding voltage reading was recorded. The cumulative mass of the water discharged was then converted to a volume using the density of water (1 g = 1 cm^3). This procedure was repeated until the maximum\minimum displacement of the Outflow Gauge was reached.

The direction of movement of the Bellows Diaphragm was then reversed and the calibration procedure was repeated. The Outflow Gauge was calibrated twice in both directions of movements of the Bellows Diaphragm.

A separate linear regression curve was determined for the two directions of movement of the Bellows Diaphragm. The reason for this was that the Bellows Diaphragm was moving with or against gravity. This results in a slight difference in the amount of water discharged out of the Outflow Gauge depending on the direction of movement of the Diaphragm. The slopes determined from the linear regression curves were then used to determine the amount of water discharged from the soil sample during testing. The slopes obtained from the linear regression were as follows:

(1) Bellows Diaphragm moving from positive to negative volt readings : 0.013218 ml/volt

(2) Bellows Diaphragm moving from negative to positive volt readings : -0.013150 ml/volt

Figures 4.4 & 4.5 show the linear curves fitted to the calibration data of the Outflow Gauge.

For the comprehensive data regarding the calibration of the Outflow Gauge refer to Appendix 1.

NB! It should be noted that although all the equipment was initially calibrated at the beginning of the research project, they were re-calibrated periodically, although not as thoroughly as initially. In all cases the changes in the calibration constants were very small, resulting in insignificant changes to the results. The calibration constants were therefore not adjusted at any time during the research project.

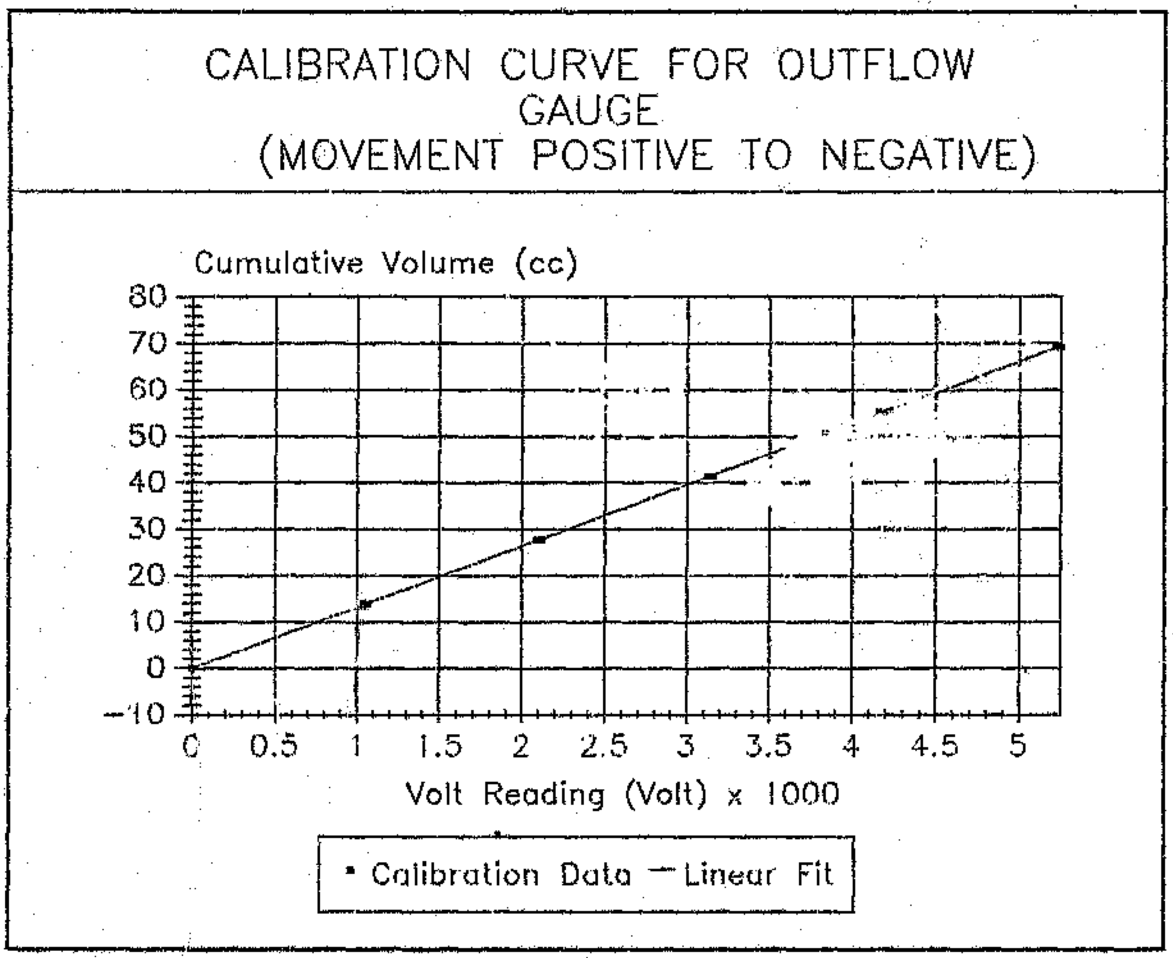


Figure 4.4 **Calibration curve of Outflow Gauge**

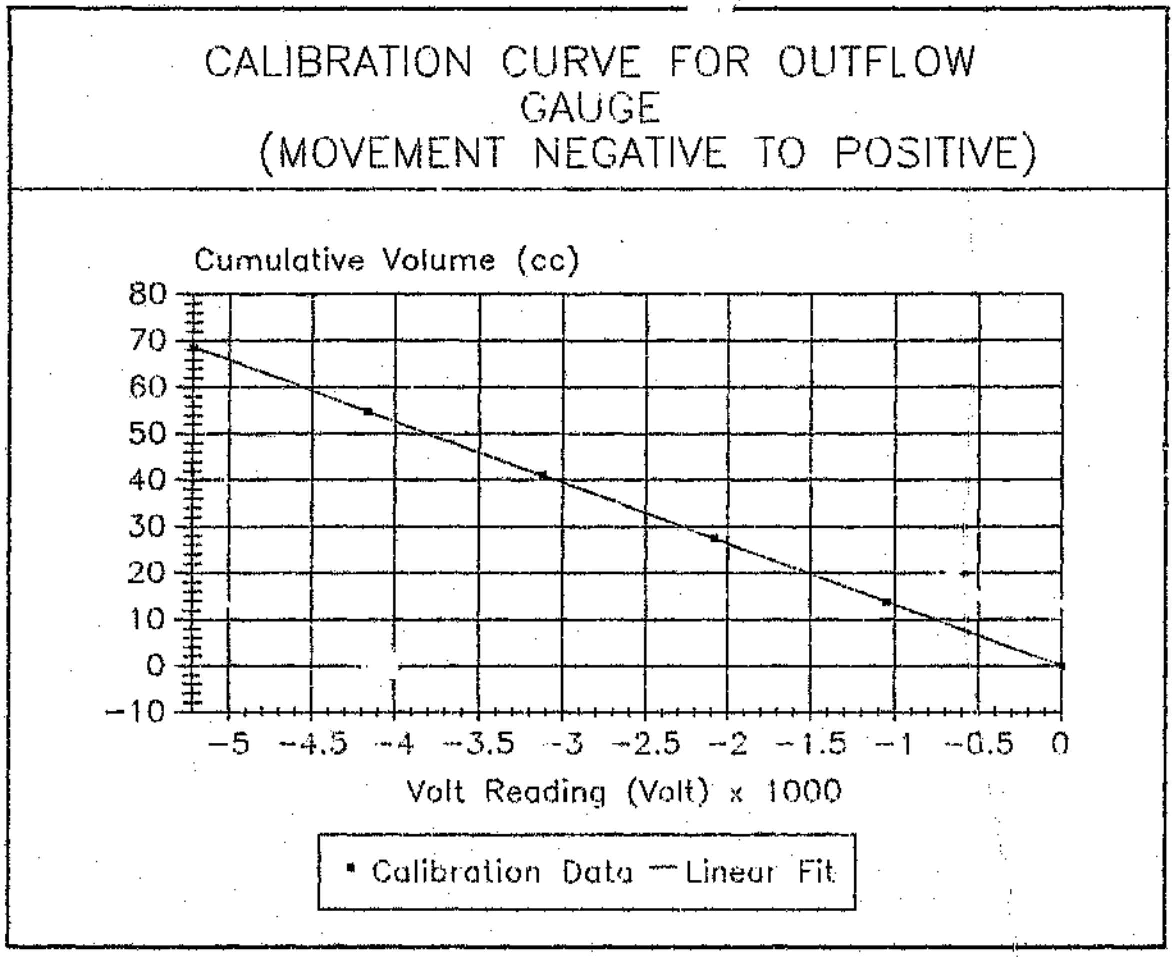


Figure 4.5 **Calibration curve of Outflow Gauge**

CHAPTER 5

TESTING PROCEDURE

5.1 PREPARATIONS BEFORE TESTING COMMENCED

5.1.1 Preparation of Soil Sample

Once a sample of the soil to be tested had been obtained, any clods were broken down. A sufficient amount of soil for the test was placed into a beaker and submerged with de-aired, distilled water. The submerged sample was placed into a vacuum chamber for 24 hours with an applied suction of 40 kPa. This removed most of the air within the sample, allowing a high degree of saturation to be obtained. Once the de-airing process was completed, any surface water was carefully drained off.

5.1.2 Preparation of Ceramic Plate

The base plate and ceramic plate was first cleaned of any soil or grit from the previous test. The ceramic plate was then inspected for any defects. If any were found, the ceramic plate was replaced, otherwise it was reused. The ceramic plate was fixed onto the base plate with epoxy, along its circumference. The epoxy used was manufactured by Bostik and was waterproof, unaffected by pressure and did not shrink. Once the epoxy had set, the base plate was immersed into a beaker of de-aired, distilled water, and placed into a vacuum chamber for 24 hours, with an applied suction of 40 kPa.

Once the de-airing process was completed, the base plate was mounted onto the Triaxial Cell, and the cell was filled with de-aired, distilled water. Half of the water in the cell was allowed to drain out, through the base plate, under a pressure of 200 kPa. This flushed out any air present in the flushing channel or base plate connection passages. The base-outflow valve was then closed, isolating the cell from all other equipment, and the cell pressure was increased to 800 kPa for 24 hours. This allowed any air still present in the ceramic plate to dissolve into the water below the ceramic plate. At random intervals the base-outflow valve was opened to allow the dissolved air bubbles to escape out of the cell. After the 24 hour period, the remaining water and air bubbles (if any) were flushed out of the cell.

NB! Caution should be taken when draining out the cell, that the pressure used to force the water out, must be well below the air entry level of the ceramic, so as to prevent any air form being forced into the saturated ceramic plate.

5.1.3 Preparation of Latex Membranes

The latex membranes which surround the soil sample during testing were prepared just before testing commenced. Two membranes were used with a thin layer of vaseline applied on the outer surface of the inner membrane. The double membrane and vaseline layer acted as additional preventative measures against water diffusing into the soil sample.

5.2 SETTING-UP PROCEDURE

The double membrane was placed around the base plate with two O-Rings around the membranes and base plate. The O-Rings prevented water from seeping into the soil sample from the interface between the membranes and the base plate. A hollow steel cylinder (6 cm high) was slid over the membranes and base plate, resting on the O-Rings. Care had to be taken at this stage that the membranes were not pinched between the hollow cylinder and the base plate or that the membrane were not twisted by the cylinder. A helpful technique in making the sliding of the cylinder easier and smoother, was to smear some vaseline on the inner side of the cylinder.

With the hollow cylinder in position the soil sample was placed into the membranes and tamped carefully until it stood approximately 3-5 mm below the upper lip of the cylinder.

A circular filter paper was placed on the bottom surface of the air cap to prevent any fine soil particles from entering into the air way and blocking it. The air cap was then placed on top of the soil sample with the double membrane around its circumference. Care had to be taken at this stage to ensure that the air cap rested firmly and as far as possible evenly over the soil sample. The air cap also had to be about 3-5 mm within the cylinder so as to ensure that it slid further into the hollow cylinder as the soil volume decreased. Two O-Rings were placed around the double membrane and air cap. The air cap had two grooves around its circumference into which the membranes were clamped fast by the O-Rings. These grooves ensured that the interface between the air cap and membranes was sealed off and that no water could penetrate into the soil sample.

The Triaxial Cell was then sealed and filled with de-aired water.

5.2.1 Testing Procedure

A zero voltage reading was taken of the Outflow Gauge, Differential Pressure Transducer and Volume Gauge. When taking the zero reading for the Differential Pressure Transducer, the base-outflow valve and the in line ball valve to the bubble trap were kept open, so as to ensure atmospheric pressure below the pressure plate.

The air pressure source was then increased to the pre-determined level. The required time interval of recording the outflow of water and volume change of the sample was entered into the data logger.

Once the required amount of water had drained out of the sample, or outflow had ceased, the in-line ball valve was closed, isolating the bubble trap and Outflow Gauge from the Triaxial Cell. This prevented the release of any additional water from the soil sample. The capillary pressure was then monitored by the Differential Pressure Transducer on an hourly basis, as well as the volume changes in the sample. The monitoring was continued until the capillary pressure in the soil sample stabilized.

Once the capillary pressure reading had stabilized, the in-line ball valve was re-opened, and the area below the base plate flushed of any air bubbles. Once this was completed a new zero volt reading was taken of the Outflow Gauge. The air pressure source was increased and the process was repeated.

The testing procedure was repeated until one of the following three conditions were achieved:

(1) no more water could be drained out of the sample for any significant increase in air pressure.

(2) a sufficient amount of data points were obtained for determining the required curves.

(3) the air pressure or capillary pressure exceeded the limitations of the Differential Pressure Transducer.

5.2.2 Guidelines to running the various soils tests

The following section describes the guidelines that were used when performing the tests.

5.2.2.1 Testing procedure for determining only the moisture retention curve of a soil

The testing procedure for determining the moisture retention curve of a sample is the same as is mentioned above in section 5.2.1, with only a few modifications :

(1) The rate of outflow from the sample did not need to be monitored - only the total amount of water drained out at each interval of the test was required.

(2) The ultimate outflow of water corresponding to the applied air pressure did not need be attained - ie. drainage did not have to cease or approach ultimate outflow before closing the in-line ball valve and beginning capillary pressure monitoring.

The following guidelines were also used when performing the test:

(1) Pressure increments of the air pressure source:

The magnitude of the increments in the air pressure source at each interval of the test was dependant on two main factors:

(i) The soil type - If the soil sample tested was a clay, the magnitude of the incremental increase of the air pressure source during testing was larger than for sandy soil samples.

(ii) The degree of saturation of the soil - The magnitude of the incremental increase of the air pressure source, increased as the degree of saturation of the soil sample decreased.

The air pressure should be high enough to allow relatively rapid drainage of the required volume of water, but not high enough to induce a large water pressure gradient in the sample. As a rough guideline the initial increment in the air pressure source should not be higher than 30 kPa for a clay and 10-15 kPa for a sand. The magnitude of the air pressure source increments for the proceeding intervals of the test can then be gradually increased.

(2) Determining when to terminate the outflow from the sample

The decision as to when to close the in-line ball valve, so as to begin monitoring the capillary pressures of the sample, rests purely on the operator. The valve should be closed as soon as possible so as to reduce the duration of the test, but at the same time allowing for a sufficient amount of water to drain out of the sample, so as to change the degree of saturation of the sample.

A useful guide is to refer to existing moisture retention curves and to observe how the capillary pressure changes for a specific change in saturation. The amount of water initially drained out of the sample should be of small amounts, which can later be increased as the test progresses.

The number of points required for a particular curve should also be considered. If a large number of experimental data points are required, so as to have a relatively accurate representation of the curve, small amounts of water should be drained out at each interval of the test. The increase in the air pressure source should then also be of a smaller magnitude.

5.2.2.2 Testing procedure for determining the coefficients of hydraulic conductivity of a sample

The testing procedure for obtaining the relationship between the coefficients of hydraulic conductivity and suction or water content, is the same as mentioned above in section 5.2.1, with only a few modifications :

(1) The rate of outflow from the sample needed to be monitored. The intervals used for monitoring the outflow of water from the sample were as follows: the first 20 minutes of outflow were monitored at 1 minute intervals, the following 40 minutes at 20 minute intervals, and the remaining duration of drainage at hourly intervals.

(2) The ultimate outflow of water corresponding to the applied air pressure did not need be attained. However, the outflow had to approach ultimate outflow before the in-line ball valve could be closed and capillary pressure monitoring commenced.

The guideline pertaining to the air pressure increments in section 5.2.2.1 also applied here.

5.2.2.3 Determining when to begin capillary pressure monitoring

Monitoring of the capillary pressures could commence once one of the following two conditions were met:

(1) Outflow from the sample had ceased after a reasonable time duration. A reasonable time duration was dependant on two factors:

   (i) The type of soil tested - a clay soil required a longer outflow period than a sand for the same applied air pressure.

(ii) The magnitude of the air pressure increment - the greater the magnitude, the longer the outflow period.

(2) Outflow had started to tend towards an ultimate outflow value.- This was determined by plotting outflow (cm^3) against time (minutes or hours). Once the outflow curve began to flatten out, drainage could be stopped, and capillary pressure monitoring commenced.

It should also be noted that the total amount of water discharged during each interval of the test was known, therefore enabling one to simultaneously determine the moisture retention curve of the sample.

CHAPTER 6

METHOD USED TO DETERMINE THE COEFFICIENTS OF HYDRAULIC CONDUCTIVITY

6.1 INTRODUCTION

The following chapter describes the development of the analytical technique used to determine the unsaturated coefficients of hydraulic conductivity. It includes modifications which the author has introduced to the technique as well as the assumptions used.

The saturated coefficients of hydraulic conductivity for the various soils tested were determined using the Constant Head Test, which is described in section 2.2.1.

The unsaturated coefficients of hydraulic conductivity for the various soils tested were determined by a modified analytical technique based on a procedure proposed by Richards (1965).

6.2 DEVELOPMENT OF THE TECHNIQUE USED TO DETERMINE THE COEFFICIENTS OF HYDRAULIC CONDUCTIVITY IN UNSATURATED SOILS

Numerous graphical-analytical methods for determining the coefficients of hydraulic conductivity of unsaturated soils have been proposed over the years. The following section provides a brief overview of some of these techniques and the developments that have taken place.

The original method for determining the unsaturated coefficients of hydraulic conductivity, from the flow properties of a soil, using pressure plate outflow data, was developed by Gardner (1956). Gardner made the following assumptions:

(1) The slope (diffusivity) of the moisture retention curve and the coefficient of hydraulic conductivity is constant for small pressure or suction increments.

(2) The impedance of the membrane or plate and the contact impedance is negligible ie. the resistance to flow that the plate and contact surface between the plate and soil provides is very small compared to that of the soil sample.

The latter assumption however,is not valid in most cases, especially at low suctions, resulting in the calculated coefficients of hydraulic conductivity being lower than the true values.

Miller & Elrick (1958) improved on Gardner's method by taking the impedance of the porous stone into account. The technique's drawback however is that the impedance is determined experimentally. To quote the authors "...the major limitation of the method resides in the uncertainty of determining the impedance of the porous plate. Unless good contact is established between the soil and the porous plate or membrane, an unknown impedance will exist, possibly of significant magnitude compared to the impedance of the plate. The value of the impedance of the porous plate itself may also change with time due to plugging of the larger pores by dirt, bacterial growth, or air bubbles; perhaps also with changes of tension due to swelling and shrinking or partial air entry."

Ritjema (1959) extended the technique further by taking the membrane and other impedances into account without experimentally determining them. The total impedance occurring at the lower boundary of the sample was determined from the experimental outflow data for each applied pressure increment.

Kunze & Kirkham (1962) also extended Miller & Elrick's method. By taking extreme care in placing the soil sample onto the pressure plate, ensuring that the entire lower part of the soil sample was completely in contact with the plate and accurate monitoring during the initial stage of outflow, the total boundary impedance was accounted for and did not need to be measured. This offered two advantages:

(1) Plate impedance need not be measured experimentally. Likewise the contact impedance value is automatically incorporated in the calculations of the coefficients of hydraulic conductivity.

(2) The initial outflow period is a period when diffusivity, although changing, can be determined in a systematic manner from the theory. Due to the relatively short time span in which the outflow of interest occurs, the errors arising from air bubbles diffusing through thHxplate, temperature changes, and consequently changes in the plate and contact impedance are considerably minimal.

The major disadvantage of all of the above mentioned techniques is that they require the experimental determination of the total, final or ultimate outflow (Q_∞) for the particular applied pressure increment. This makes the tests very time consuming.

Richards (1965) modified Kunze & Kirkham's method so as to estimate Q_∞ from the early outflow data and the theoretical outflow curves. The relevant theory and procedure is described in the following paragraphs.

Unsaturated flow is described by Darcy's law :

$$V = -k_\theta \frac{d\Phi}{dz} \qquad 6.1$$

where

V = volumetric flow velocity (cm/s)

$d\Phi/dz$ = potential gradient

θ = volume of water per unit volume of soil (cm^3/cm^3)

k_θ = coefficient of hydraulic conductivity as a function of θ (cm/s)

Combining Darcy's law with the law of conservation of mass gives :

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial z}\left(k_\theta \frac{\partial\Phi}{\partial z}\right) \qquad 6.2$$

Consider a sample of soil having a volume V, a cross-sectional area A and a height l, which is placed in a pressure plate apparatus. Suppose the initial pressure in the chamber is P_i and the moisture in the soil is in equilibrium with the atmospheric air-pressure outside the chamber. At time t = 0 the pressure in the chamber is increased by a small amount ΔP, the final pressure being $P_f = P_i + \Delta P$. Due to the increment of the pressure, water will flow out of the soil sample until equilibrium is attained again. The differential equation for the one-dimensional vertical flow under discussion is :

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} k_\theta \left(\frac{\partial P}{\partial z} + 1\right) \qquad 6.3$$

In general this equation is non-linear and difficult to solve analytically. Assuming that between P_i and $P_i + \Delta P$ the coefficient of hydraulic conductivity is constant and that there exists a linear relationship between P and θ in this range of pressure, provided that the increments of ΔP are sufficiently small.

Now the relation between the soil moisture content and the pressure is given by :

$$\theta_p = a+bP \tag{6.4}$$

where

a,b = constants

Neglecting gravity and substituting 6.4 into 6.3 gives :

$$\frac{\partial P}{\partial t} = D\frac{\partial^2 P}{\partial z^2} \tag{6.5}$$

where

D = k/b

As no flow exists across the upper boundary of the sample, the potential gradient must vanish at this plane, thus :

$$\frac{\partial P}{\partial z} = 0 \qquad z = 0 \tag{6.6}$$

Assuming that the flow of water through the cross-sectional area at z = l equals the flow through the disk at each time, the lower boundary condition will be :

$$k\frac{\partial P}{\partial z}+\frac{k_p}{l_p}P = 0 \qquad z = l \tag{6.7}$$

where

P = pressure drop through plate (cm)

k_p = coefficient of hydraulic conductivity of plate (cm/s)

l_p = thickness of plate (cm)

By applying all of the above assumptions and conditions the equation describing the outflow of water from a soil sample at any time t is as follows :

$$\frac{Q_t}{Q_\infty} = 1-2\sum_{n=1}^{\infty} \frac{h^2l^2}{\alpha_n^2[hl(hl+1)+\alpha_n^2]} * \exp^{\frac{-D\alpha_n^2 t}{l^2}} \qquad 6.8$$

where

Q_t	= outflow at time t (cm^3)
Q_∞	= ultimate outflow at $t = \infty$ (cm^3)
hl	= relative impedance of sample to membrane or plate
l	= length of sample (cm)
α_n	= solution of, $hl = \alpha_n \tan \alpha_n$
D	= diffusivity (cm^2/minute)
t	= time (minutes)
h	= $k_p/l_p k$ (1/cm)

Kunze & Kirkham (1962) plotted the above equation for varying values of "a", impedance factor, (= 1/hl), in the form :

$$\log\left(\frac{Q_t}{Q_\infty}\right) \text{ against } \log\left(\alpha_1^2 \frac{Dt}{l^2}\right) \qquad 6.9$$

resulting in a family of theoretical outflow curves. Refer to figure 6.1

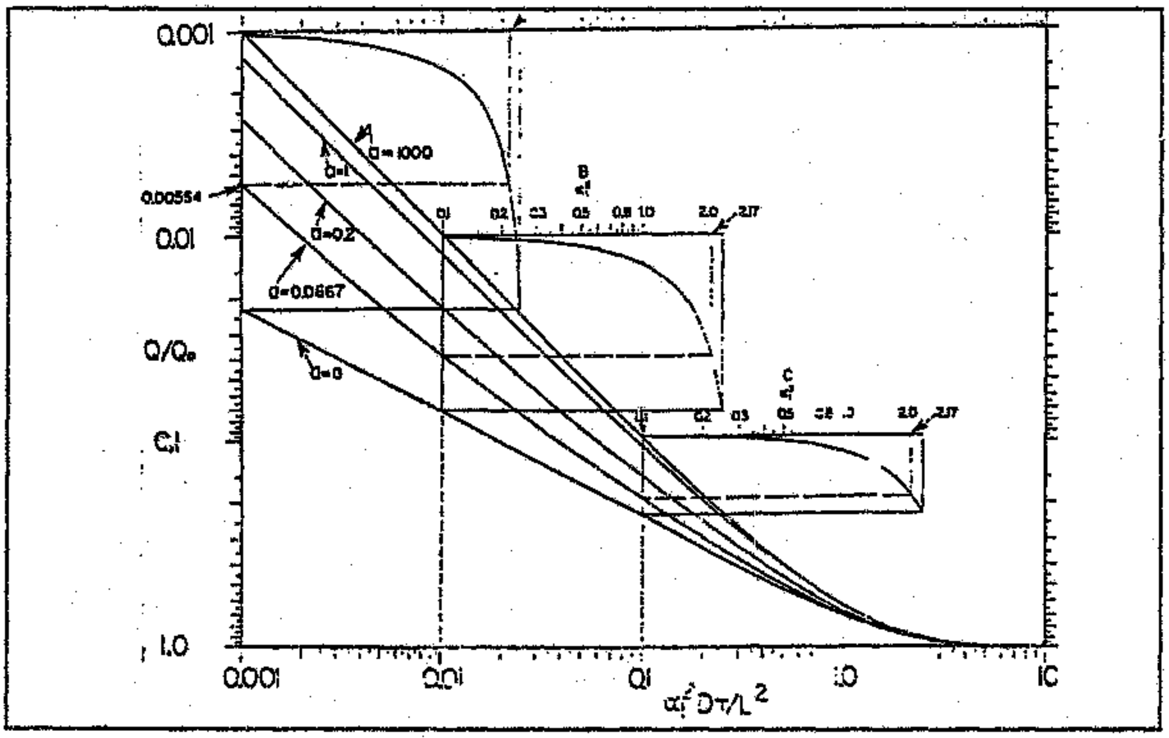


Figure 6.1 Theoretical outflow curves

Kunze & Kirham (1962)

An overlay of the experimental outflow data is made by plotting it in the format of:

$$\log\left(\frac{Q_t}{Q_\infty}\right) \text{ against } \log(t) \qquad 6.10$$

By shifting the experimental outflow curve horizontally until it matches a theoretical outflow curve, with particular emphasis on the initial stage of outflow, an estimate of "a" and t_{mp} (real time t corresponding to dimensionless reduced time, $(\alpha_1^2 Dt/l^2 = 1)$ can be made. Refer to figure 6.2.

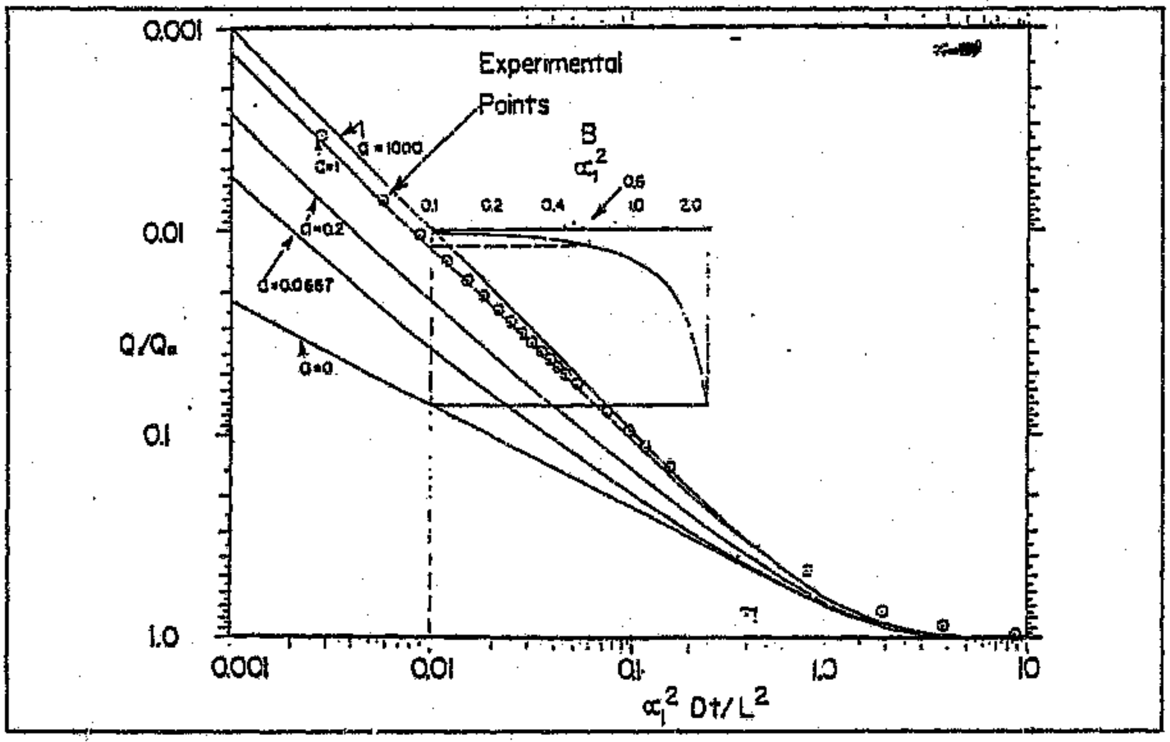


Figure 6.2 Experimental outflow curve superimposed onto theoretical outflow curve

Kunze & Kirkham (1962)

With "a" and t_{TR} known, α_1^2 and D can be calculated using the following formulas :

$$hl = \alpha_n \tan\alpha_n$$

OR

$$a\alpha_n = \cot\alpha_n \qquad 6.11$$

where

a = ratio of impedance of the plate to impedance of the soil (1/hl)

$$D = \frac{l^2}{\alpha_1^2 t_{TR}} \qquad 6.12$$

The coefficient of hydraulic conductivity can then be determined by the following equation :

$$k = D\frac{\partial\theta}{\partial P} = \frac{DQ_\infty}{V\Delta P} \qquad 6.13$$

where

$\partial\theta$ = change in volumetric water content (cm^3/cm^3)

∂P = pressure or suction increment (ΔP) (cm)

V = volume of sample (cm^3)

The modification that Richards (1965) introduced is that the overlay plotted for the experimental outflow curve is in the format of $\log(Q_t)$ against $\log(t)$. By shifting the experimental outflow curve horizontally and vertically until it matches a theoretical outflow curve, "a" and t_{ap} can be determined. As the family of theoretical outflow curves coalesce at dimensionless reduced time greater than 2.5, Q_∞ does not have to be experimentally determined. Referring to figure 6.1, at dimensionless reduced time 2.5 and greater all the theoretical curves merge into one curve. Q_t values need only be measured for values of t giving part of the coalesced curve. An important point to bear in mind here is that Q_t needs to be monitored for a period of time sufficient to obtain the "transitional" stage of the outflow curve from a linear to a "constant" relation. If this "transitional" period is not obtained t_{ap} and thus the coefficient of hydraulic conductivity cannot be determined.

6.2.1 Modifications introduced by the author

Using Richard's (1965) approach in conjunction with that of Kunze & Kirkham's (1962) the following modifications were introduced by the author:

(1) The theoretical outflow curve for any value of "a" was generated by a computer programme.

(2) The slope of the linear part (initial stage) of the experimental outflow curve was determined using a linear regression analysis.

(3) The slope obtained from the regression analysis was used in a computer programme to select the theoretical outflow curve with the same slope, during the initial stage of outflow. As the slope of the theoretical outflow curve is uniquely associated with an "a" value, the impedance factor could be determined, and thus α_1^2.

(4) The overlay of the experimental outflow curve and the corresponding theoretical curve was done graphically on a computer spreadsheet, so as to determine time t_{mp}. A minor modification which was made here, was that the axes used were not log axes (as used by Gardner and Kunze & Kirkham). Instead the log value of the numbers were plotted on normal axis. In addition, the discharge (Q_t) values were all divided by the last discharge value, for the considered pressure increment, resulting in a reduction of the range of the outflow values, ranging from 1 to zero (or in log values: 0 to minus infinity). The reason for these minor modifications were purely for convenience, so as to manage the overlay of the curves on the spreadsheet easier.

(5) Once all the required values had been determined or calculated a computer programme was used to calculate the average coefficient of hydraulic conductivity for the soil sample, for the particular pressure increment and volumetric water content. The entire monitored outflow data for the particular pressure increment was used to determine the average value.

6.2.2 Assumptions used in the technique

The following assumptions and equations were used to determine the parameters needed to calculate the coefficients of hydraulic conductivity.

(1) In determining the height and thus also the diameter of the soil sample during testing, from the change in volume readings of the sample, the sample was assumed to behave in an isotropic manner.

(2) The volume and thus the height of the sample which were used in equations 6.8 & 6.13, to calculate the coefficient of hydraulic conductivity, for a particular pressure increment were determined as follows :

The volume, height and thus the volumetric water content of the sample (indirectly), as determined at the end of the considered pressure increment was used. These values were associated with the stable capillary pressure and coefficient of hydraulic conductivity for the considered pressure increment.

Although this approach was not entirely correct - a mean value between the initial and final volume, height and volumetric water content, of each pressure increment, might be used - it provides a simple and workable approach.

6.2.3 Equations used to determine the volume of the sample during testing

As mentioned before, the change in volume of the sample was monitored throughout the test. Using the assumptions mentioned above the following equations for determining the volume, height and diameter of the sample were developed.

Referring to figure 6.3 :

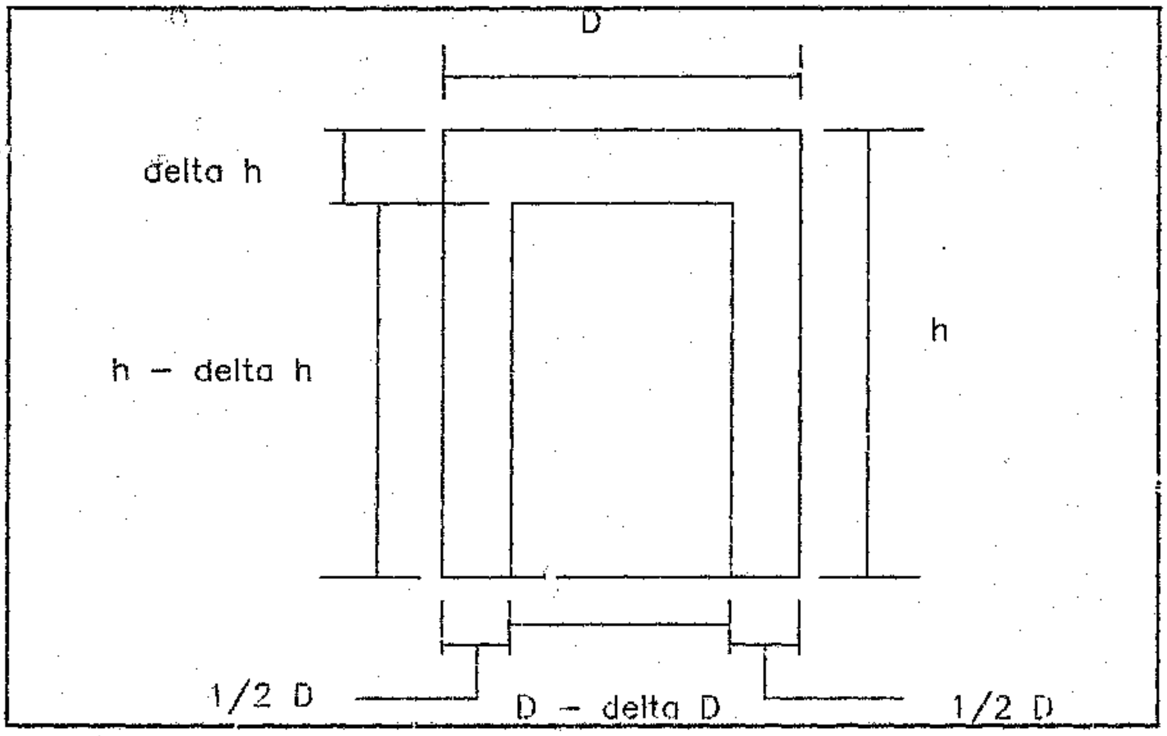


Figure 6.3 Change in sample volume

$$V = \frac{\pi D^2 h}{4} \qquad 6.14$$

$$\Delta V = \frac{\pi}{4}[((D+\Delta D)^2(h+\Delta h)-D^2h)] \qquad 6.15$$

Using the assumption of an isotropic material, and therefore isotropic strain

$$\frac{\Delta D}{D} = \frac{\Delta h}{h} \qquad 6.16$$

Substituting equation 6.16 into equation 6.15 the change in diameter of the sample can be determined from :

$$\Delta V = \frac{\pi}{4}[(D+\Delta D)^2 (h(1+\frac{\Delta D}{D})) - D^2 h] \qquad 6.17$$

In the same manner as above, the change in height of the sample can be determined from :

$$\Delta V = \frac{\pi}{4}[(D+\Delta h\frac{D}{h})^2 (h+\Delta h) - D^2 h] \qquad 6.18$$

where

V = volume of sample (cm^3)

ΔV = change in volume of sample (cm^3)

D = diameter of sample (cm)

ΔD = change in diameter of sample (cm)

h = height of sample (cm)

Δh = change in height of sample (cm)

CHAPTER 7

COMPUTER PROGRAMMES DEVELOPED AND USED FOR DATA ANALYSIS

7.1 PROGRAMMES DEVELOPED

The programmes described in this chapter were developed so as to aid in the analysis of the test data, using the analytical technique and equations described in chapter 6. Most of the programmes used for analyzing the test data were developed using Turbo Pascal Six. The programmes were however run directly from Dos. Due to the nature of the programmes, the large amount of numerical generation and manipulation required, a maths co-processor is strongly recommended.

7.1.1 Programme 1 - AlphaX.exe

This programme determines the theoretical outflow curve that has the same slope as the experimental outflow curve, during the initial stage of outflow.

The programme requires the slope of the experimental outflow curve and a number, pertaining to roots as input. The slope of the experimental outflow curve is determined beforehand. The number of roots pertains to the number of solutions to equation 6.11. Quoting Kunze & Kirkham (1962) "... For large values of "a" (small values of h1) only a few α_n values are required to make the right hand side of equation 6.8 converge. For "a" = 0.0473 and reduced dimensionless time = 0.001, 34 values of α_n were needed". During analysis of test data, 80 roots were used so as to ensure that convergence was achieved.

The programme begins by solving equation 6.11 for "a" = 1, and for the number of solutions specified by the user. The Bisection (or Interval-Halving) method is used to obtain the roots, which are then stored in a matrix.

The programme then solves equation 6.8 for a range of reduced dimensionless time values. The corresponding reduced dimensionless time and Q_t/Q_∞ values are logged (to the base 10) and stored in matrices. The matrices describe a theoretical outflow curve. A linear regression analysis is performed on these matrices values, over a specific range of dimensionless reduced time. The range of the dimensionless reduced time values considered for the linear regression analysis is dependant on the alphaX programme selected - refer to table 7.1 for details.

Programme	Range of dimensionless reduced time considered by regression analysis	Ultimate slope of outflow curve
Alpha0.exe	0.001 to 0.5	0.93745
Alpha1.exe	0.001 to 0.3	0.96127
Alpha2.exe	0.001 to 1.0	0.88147
Alpha3.exe	0.01 to 1.0	0.87048
Alpha4.exe	0.01 to 0.5	0.92835
Alpha5.exe	0.01 to 0.3	0.95346
Alpha6.exe	0.1 to 1.0	0.82012
Alpha7.exe	0.1 to 0.5	0.88468

Table 7.1 Details regarding AlphaX.exe programmes

Once the slope of the theoretical outflow curve is determined it is compared to the slope of the experimental outflow curve. By dividing the slope of the theoretical outflow curve by the experimental one, the ratio indicates how close the theoretical and experimental outflow curve slopes are. If the ratio of the slopes is less than one, the entire procedure is repeated by increasing the first significant digit of the "a" value by 1 (ie from 1 to 2). Once a ratio greater than one is obtained for a particular "a" value, the preceding "a" value's first significant digit is fixed. The entire procedure is then repeated from the beginning, but this time determining the second significant digit of "a". This procedure is repeated until the slope of the theoretical and experimental outflow curve are identical for the number of significant digits the experimental outflow slope is required by the user.

The programme displays the following information on the screen for each "a" value it considers :

(1) The correlation coefficient of the linear regression performed on the theoretical outflow curve.

(2) The constant and the slope of the line determined by the linear regression.

(3) The "a" value for the considered theoretical outflow curve.

(4) The slopes of the theoretical and experimental outflow curves, to the same number of significant digits.

(5) The ratio of the slopes of the theoretical and experimental outflow curves.

A printout of a briefer format is also provided for each "a" value considered. The following information is printed :

(1) The slope of the theoretical outflow curve being considered.

(2) The "a" value of the considered theoretical outflow curve.

(3) The ratio of the slopes of the theoretical and experimental outflow curves.

7.1.2 Programme 2 - Curve.exe

This programme is a modification of programme 1. The programme determines the Q_t/Q_∞ values corresponding to reduced dimensionless time values ranging from 0.001 to 3 for a specific "a" value.

The programme requires an "a" value and a number, pertaining to roots as its input. The "a" value is determined beforehand by programme 1, and the number of roots pertains to the number of solutions to equation 6.11. The same value used in programme 1, for the number of roots should also be used here.

The programme solves equation 6.11 for the "a" value, and the number of solutions specified by the user. The Bisection (or Interval-Halving) method is used to obtain the roots, which are then stored in a matrix.

The programme then solves equation 6.1 for values of reduced dimensionless time ranging from 0.001 to 3 and stores the corresponding reduced dimensionless time and Q_t/Q_∞ values into separate files. The reduced dimensionless time values are stored in an existing file named Fugfile.prn and the corresponding Q_t/Q_∞ values in a file named Outflow.prn. These files are imported into a spreadsheet at a later stage, to aid in the analysis of test data.

7.1.3 Programme 3 - Attempt.exe

This programme determines the unsaturated coefficient of hydraulic conductivity for a particular pressure increment.

The programme requires the following information a input :

(1) The "a" value determined by programme 1.

(2) A number, pertaining to the number of roots.

(3) The real time value that corresponds to t_{sp} (minutes).

(4) The height of the sample at the end of the considered pressure increment (cm).

(5) The volume of the sample at the end of the considered pressure increment (cm^3).

(6) The applied air pressure for the considered pressure increment (cm - of water).

In addition to the above mentioned input values two files containing the following information must be created. The corresponding time (minutes) and outflow values (cm^3), monitored during the entire outflow stage of the considered pressure increment must be saved in files named Time.prn and Flow.prn respectively.

The programme solves equation 6.11 for the "a" value, and the number of solutions specified by the user. It then solves equation 6.8 for Q_{∞} after which equation 6.13 can be solved for k (unsaturated coefficient of hydraulic conductivity). This procedure is repeated for each corresponding time and outflow value saved in files Time.prn and Outflow.prn. The corresponding Q_{∞} and k values for each monitored outflow value are saved into existing files named Ultimate.prn and Perm.prn respectively.

The programme then determines an average k and Q_{∞} for the entire outflow stage of the considered pressure increment and displays them on the screen.

Note : All computer programmes developed for analysing the data are enclosed in the sleeve attached to the back cover.

7.2 PROGRAMME PACKAGE USED

7.2.1 Least Squares Curve Fitting programme

Various models which describe the moisture retention curve and the coefficients of hydraulic conductivity - water content\suction relationship of a soil, were fitted to experimentally determined points. A least squares program, which was developed for the University of the Witwatersrand was utilised for this purpose.

The programme uses the Levenberg-Marques least squares method, and optimises the various variables of the models considered, so as to obtain the best fitting curve to the experimental points.

The running of the programme will not be discussed here as the programme is user friendly and information on how to operate it is available within the programme itself. It should be noted however that other curve fitting programmes are available within the package, so the user should ensure that the correct programme is selected - Levenberg-Marques method is option 4.

CHAPTER 8

MODELLING

8.1 INTRODUCTION

Numerous theoretical models have over the years been developed to describe the moisture retention curve and the unsaturated coefficients of hydraulic conductivity relationship of soils.

The experimental data points obtained from these tests are not of much use, if presented as just a few points, for describing the moisture retention curve or the unsaturated coefficients of hydraulic conductivity relationship of a soil. By fitting an equation to the experimental data points, the entire curve or relationship can be described, which is far more attractive for use in computer modelling than numerical tables.

8.2 SELECTION OF MODEL TO BE USED IN RESEARCH PROJECT

Numerous models were considered for describing the moisture retention curve and unsaturated coefficients of hydraulic conductivity relationship of the soil samples tested.

In selecting an appropriate model, the following criteria had to be met :

(1) The model must describe the moisture retention curve and unsaturated coefficients of hydraulic conductivity relationship of all soil types fairly accurately.

(2) The equations used by the model should be "relatively" simple.

(3) The equation must be continuously differentiable (smooth). - ie. one equation must describe the entire soil relationship without any discontinuity.

(4) The equations used to describe the moisture retention curve and the unsaturated coefficients of hydraulic conductivity relationship, must

be related or linked to one another in some manner.

Due to the above selection criteria various models were not considered, one of which was the Brooks & Corey model. The main drawback of this model is that it is not a continuous model (criterion 3). The model also does not describe all soil types accurately - " The Brook-Corey equation has been shown to produce fairly accurate results for many coarse textured soils characterized by relatively narrow pore - or particle size distributions (large values of λ).

Results have generally been less accurate for fine textured and undisturbed, structured field soils because of the absence of a well defined air-entry value for these soils," van Genuchten et al (1992) p.2.

Three models were finally selected which met all of the above criteria namely : the van Genuchten, Fermi and Brutsaert models. A comparison of the three models was conducted to select the " best " model. Experimental data obtained from Ash Test 2 was used for the analysis. Only the capillary pressure - volumetric content and capillary pressure - water content relationships were investigated. The reasons for not considering the unsaturated coefficients of hydraulic conductivity relationships as well were:

(1) A larger discrepancy is usually obtained between the unsaturated coefficients of hydraulic conductivity experimental data points and the model curve fitted.

(2) Experimental data points obtained for unsaturated coefficients of hydraulic conductivity are far more scattered than for the moisture retention relationships, thereby making curve fitting more difficult.

(3) The moisture retention relationship of a soil is far easier to obtain, as well as far more accurately measured, than the unsaturated coefficients of hydraulic conductivity relationship.

Using the least squares program mentioned in section 7.2.1 the three models were fitted to the experimental data. Using the sum of squares error as the judging parameter for the models, the van Genuchten model was found to fit the finally the Brutsaert model. Table 8.1 summarizes the results of the analysis and figures 8.1 & 8.2 show how the models fit the experimental data. For further information on the model analysis conducted refer to Appendix 2.

	van Genuchten	Fermi	Brustaert
Capillary pressure - volumetric content relationship			
Sum of squares errors	1.076679e-4	1.225461e-4	6.531577e-4
Estimated standard deviation	1.037631e-2	7.827711e-3	1.807149e-2
Capillary pressure - water content relationship			
Sum of squares errors	7.944538e-5	8.155605e-5	3.716130e-4
Estimated standard deviation	8.913214e-3	6.385767e-3	1.363108e-2

Table 8.1 Results of the analysis done on the models considered

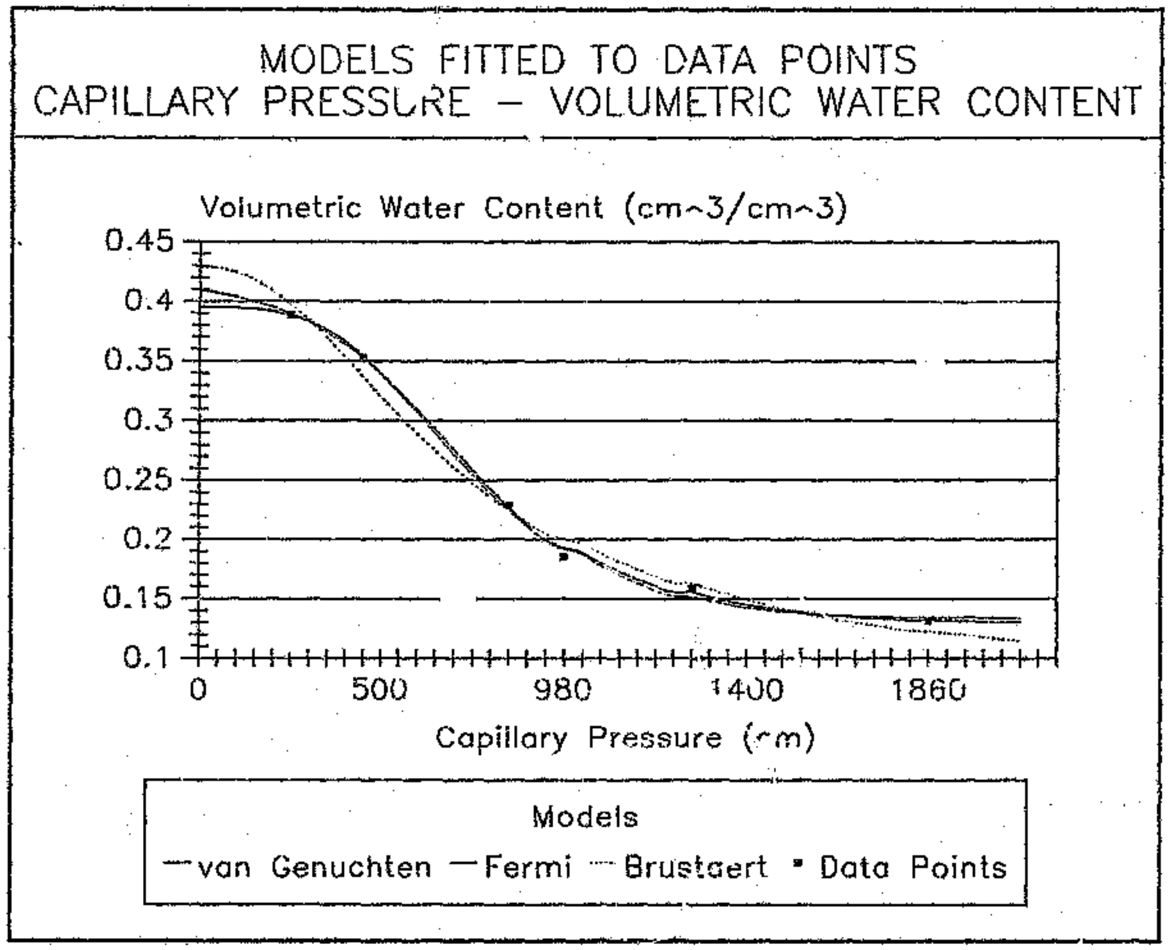


Figure 8.1 Models fitted to data points - capillary pressure - volumetric water content relationship

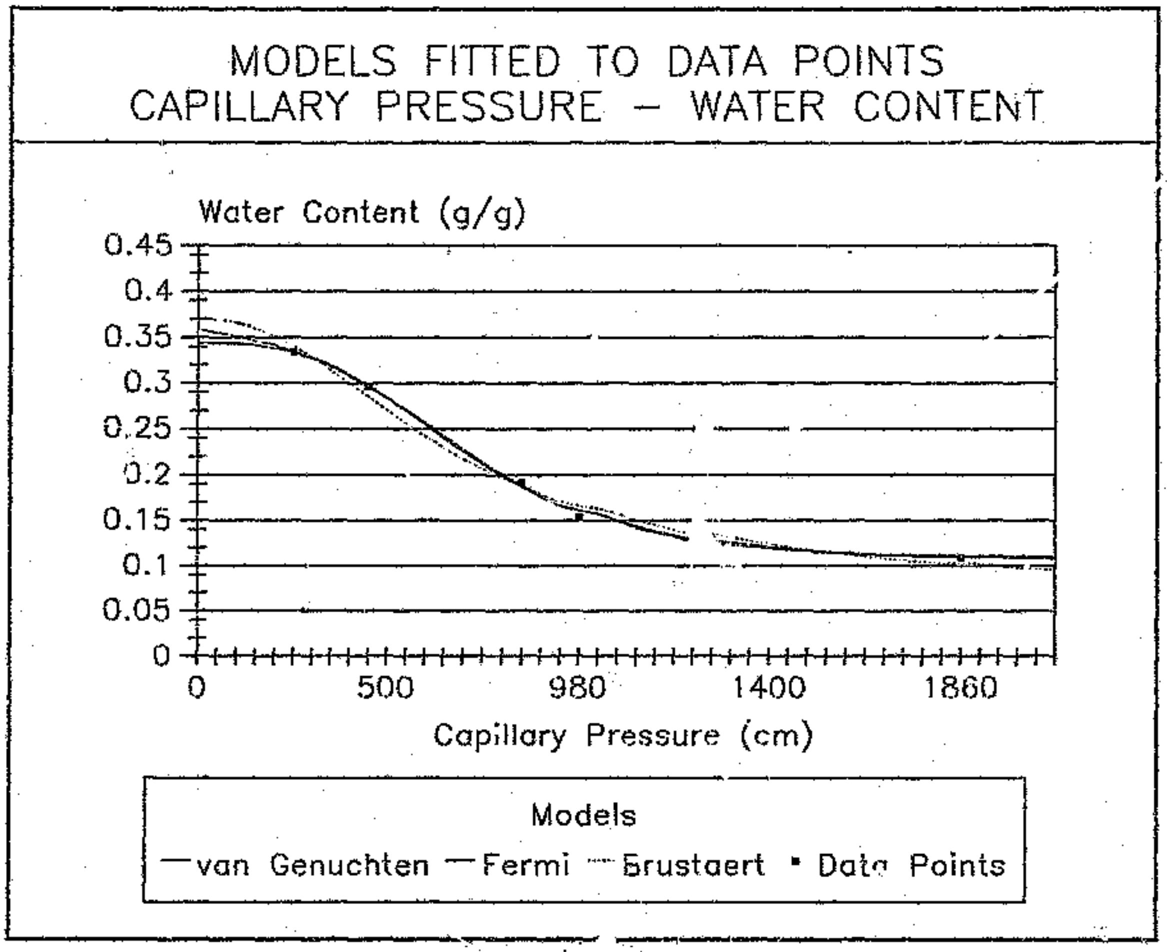


Figure 8.2 Models fitted to data points - capillary pressure - water content relation

8.3 VAN GENUCHTEN MODEL

Equation 8.1 describes the equation for the moisture retention curve of a soil sample :

$$S_e = [1+(\alpha h)^n]^{-m} \quad \text{where} \quad S_e = \frac{\theta-\theta_r}{\theta_s-\theta_r} \qquad 8.1$$

where :

S_e = effective degree of saturation or reduced water content

θ = volumetric (cm^3/cm^3) or water content (g/g)

θ_r = residual volumetric (cm^3/cm^3) or water content (g/g)

θ_s = saturated volumetric (cm^3/cm^3) or water content (g/g)

h = capillary pressure without the negative sign (cm)

n,m,α = empirical constants affecting shape of the curve

Equation 8.1 was fitted to the experimental data, with the capillary pressure treated as the independent variable and the volumetric or water content treated as the dependant variables.

Equation 8.1 can be simplified further by applying the restriction m=1-1/n to the empirical constants. Quoting van Genuchten et al. (1992) p.3. " From these results, and many other examples not further discussed here, it can be concluded that equation 8.1 with variable m,n gives an excellent fit to observed retention data for most soils.....Of the three cases with restricted m values, m=1-1/n seems to perform best for many but not all soils..."

Equation 8.2 describes the unsaturated coefficients of hydraulic conductivity relationship of a soil sample :

$$k(S_e) = k_s S_e^l [1-(1-S_e^{1/m})^m]^2 \quad \text{where} \quad S_e = \frac{\theta-\theta_r}{\theta_s-\theta_r} \qquad 8.2$$

where :

S_e = effective degree of saturation or reduced water content

k = coefficients of hydraulic conductivity (cm/s)

k_s = saturated coefficient of hydraulic conductivity (cm/s)

l,m = empirical constants affecting shape of the curve, where "m" is the same as in equation 8.1

Equation 8.2 uses the restriction $m=1-1/n$, as the general case of m and n independent results in a far too complex expression.

Equation 8.2 was fitted to the experimental data with the volumetric or water content treated as the independent variable and the coefficients of hydraulic conductivity treated as the dependant variable.
The least squares curve fitting program described in section 7.2.1 was used to determine the constants to the above equations. In both cases none of the equation variables were fixed ie. θ_s, θ_r, α, m and n were allowed to vary in the case of equation 8.1 and θ_s, θ_r, m, l and k_s in the case of equation 8.2.

CHAPTER 9

PROCEDURE USED TO OBTAIN THE REQUIRED RELATIONSHIPS

9.1 INTRODUCTION

This chapter describes the methodology used to obtain the required relationships of the soil samples tested using the computer programmes, techniques and monitored test data described in the preceding chapters.

9.2 MOISTURE RETENTION RELATIONSHIP

During testing the following parameters were monitored :

(1) The amount of water discharged from the sample during each pressure increment.

(2) The change in volume of the sample.

(3) The capillary pressure in the sample.

With the final water content (by mass) of the sample known, the water content at any pressure increment can be determined by back-calculation, using the recorded outflow data. The total mass of water released for the entire test is calculated and added to the final water mass, thereby determining the initial water content of the sample. The water content at any pressure increment of the test can then be obtained by subtracting the mass of water released, up to and including the pressure increment considered, from the initial water mass.

The corresponding capillary pressures and water contents are then plotted to produce the sample's water retention curve. The corresponding capillary pressure is considered to be the stabilized capillary pressure for the particular water content. Figure 9.1 shows the a typical graph of the behaviour of the capillary pressure during monitoring.

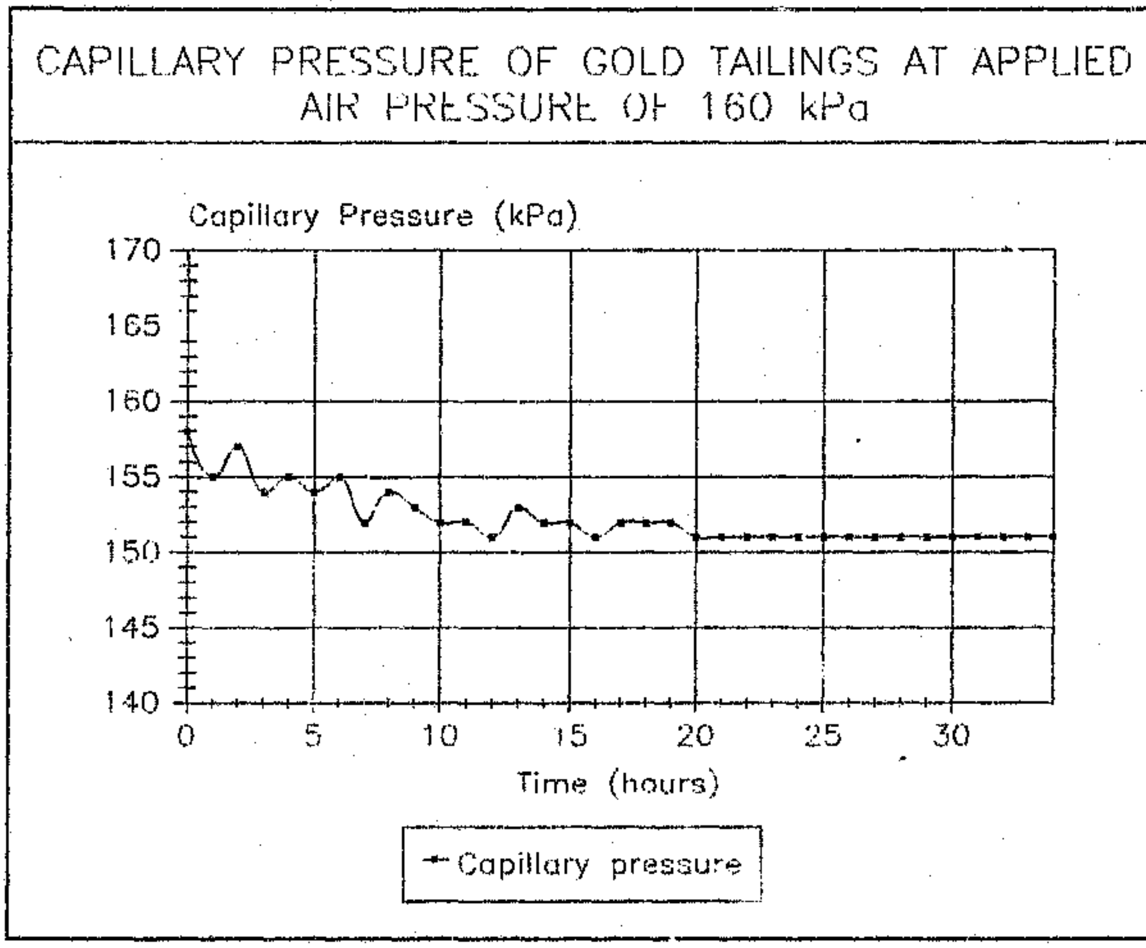


Figure 9.1 Graph showing the behaviour of the capillary pressure during monitoring

The capillary pressure-volumetric water content relationship of the sample can also be obtained with minor modifications to the procedure described above. Volumetric water content is defined as the volume of water in the sample divided by the total volume of the sample. Using the density of water, the final water mass of the sample is converted to a volume (1 cm^3 = 1 g). From the recorded data, the volume of water released during each pressure increment is known. This enables determination of the volume of water present in the sample at any time during the test. With the final volume of the sample determined, and the change in volume monitored during the entire test, we can back-calculate the volume of the sample, for any specific pressure increment. With these values determined for each pressure increment the volumetric water content of the sample can be calculated for each pressure increment.

The corresponding capillary pressures and volumetric water contents are then plotted to produce the sample's water retention curve.

Once the water retention plot is done, a model curve developed by van Genuchten is fitted to the data, using a least squares curve fitting program. For more details on the van Genuchten model curve refer to section 8.3.

9.3 COEFFICIENTS OF HYDRAULIC CONDUCTIVITY-WATER CONTENT RELATIONSHIP

During testing the following parameters were monitored :

(1) The rate of discharge of water from the sample during each pressure increment. Refer to section 5.2.2.2 for the exact monitoring procedure.

(2) The change in volume of the sample.

(3) The capillary pressures of the sample.

The method and equations used to obtain the following relationship are described in chapter 6.

From the recorded data, the flow rate of the water discharged from the sample for each pressure increment is known. The entire experimental outflow curve is obtained by plotting $\log(Q_t)$ - discharge (cm^3), against $\log(t)$ - time (minutes). A linear regression analysis is performed on the initial stage of the outflow curve - the linear part of the outflow curve. Refer to figure 9.2.

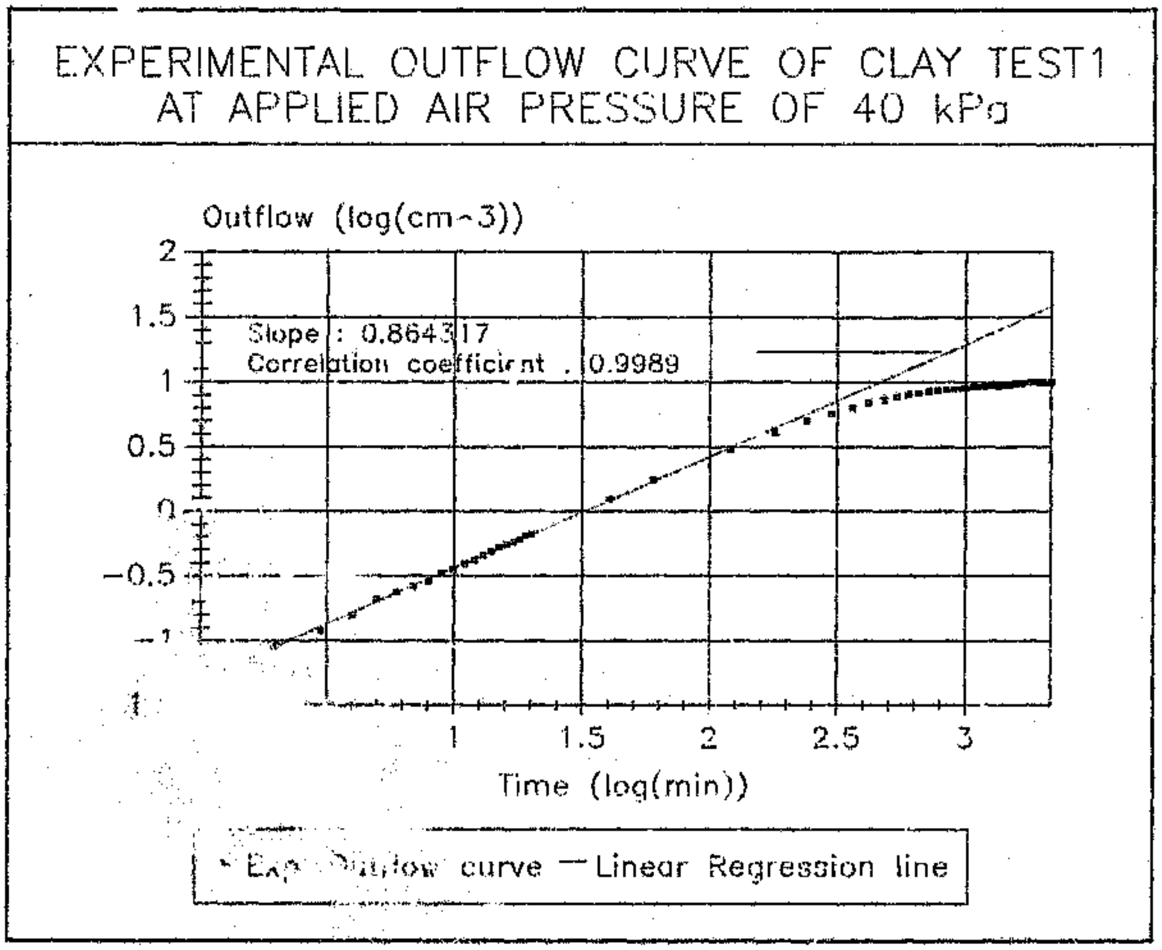


Figure 9.2 Linear regression analysis done on an outflow curve

The slope which is determined from the analysis is then used in the AlphaX.exe computer programme to select the theoretical outflow curve, with the same slope during its initial stage of outflow. As the "a" and α_1^2 values are uniquely related, refer to equation 6.11, they are also determined by the computer programme.

NB! It should be noted that the suitable AlphaX.exe programme to be used in the analysis is not initially clear, and therefore an iterative approach is required. A few of the AlphaX.exe programmes are initially run. The theoretical outflow curves from the different AlphaX.exe programmes are superimposed onto the experimental outflow curve. The AlphaX.exe programme that produces the theoretical outflow curve, with the initial outflow slope that best fits the experimental outflow curve should then be used throughout the particular test.

A spreadsheet was then used to plot the theoretical and experimental outflow curves. By dividing the experimental discharge values of a particular pressure increment by its final discharge value, the outflow values fall within a specific range (in log values - between 0 and minus infinity). This results in the experimental and theoretical outflow curves plotting over the same range along the discharge axis (Y-axis). Refer to figure 9.3.

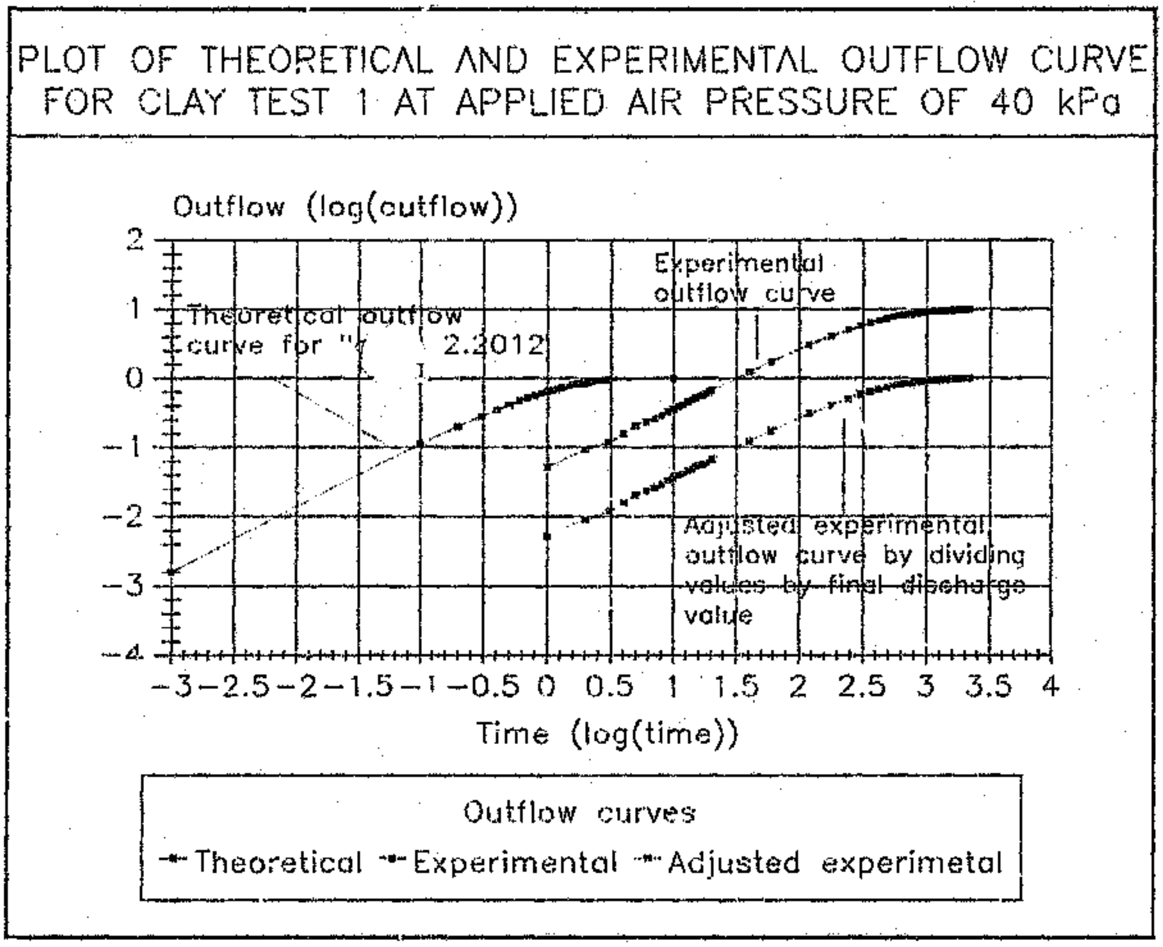


Figure 9.3 Adjustment to outflow curve so as to fall over a specific range

The real time values are then modified by adding or subtracting a "time adjustment" value so as to shift the experimental outflow curve horizontally until it was superimposed over the theoretical curve. The real time which coincided with the reduced dimensionless time value of one (0 in log values) is read off as the t_w value, refer to figure 9.4.

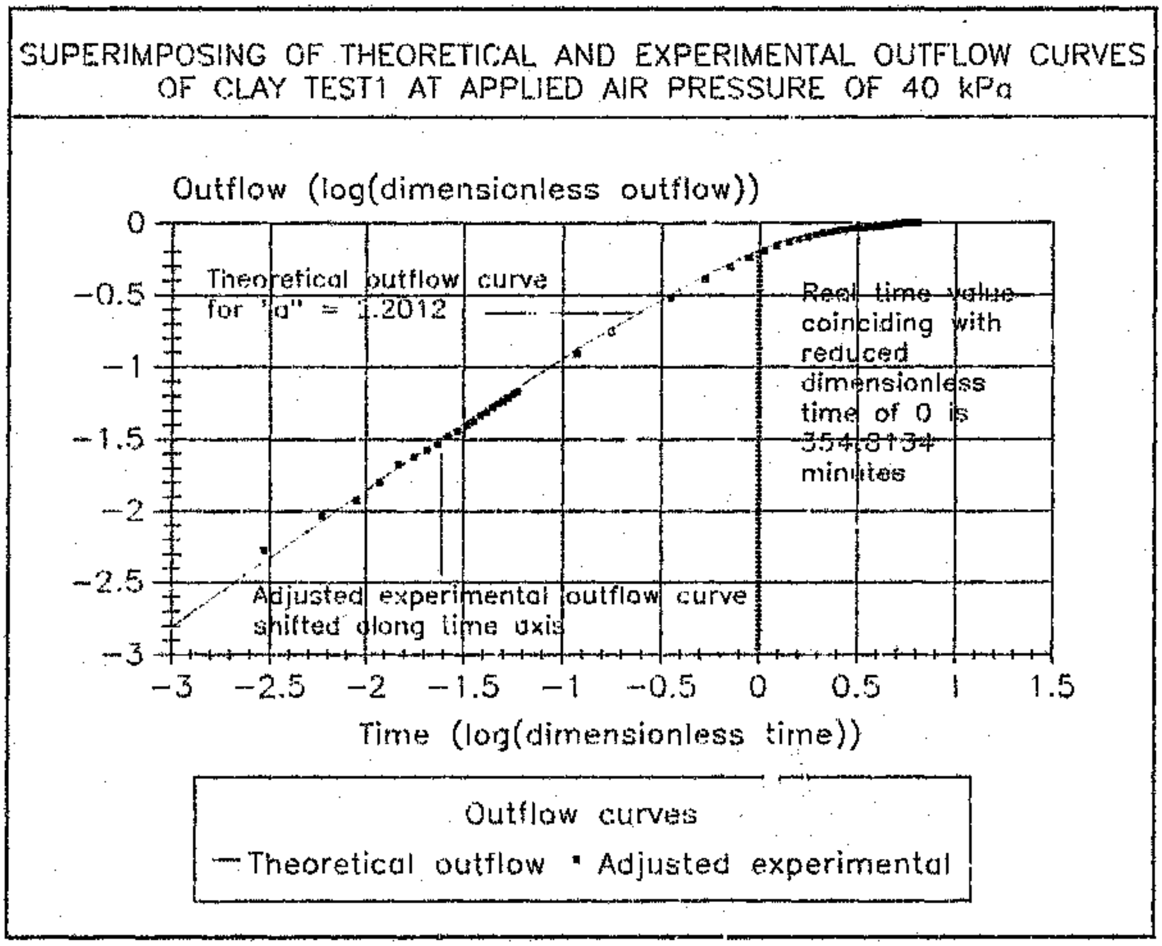


Figure 9.4 Superimposing adjusted experimental outflow curve onto theoretical outflow curve by shifting along X-axis

The t_{sp},"a" and α_1^2 values, the entire experimental outflow curve, the applied air pressure, volume and length of the sample, for the particular pressure increment, are entered into the Attempt.exe computer programme. The programme determines the diffusivity and the average coefficient of hydraulic conductivity for the particular pressure increment (or volumetric\water content), as outlined in Section 7.1.3.

The corresponding coefficients of hydraulic conductivity and water contents or volumetric water contents were then plotted. A model developed by van Genuchten was then fitted to the data points using a least squares curve fitting programme.

CHAPTER 10

DESCRIPTION OF SOIL SAMPLES TESTED

10.1 INTRODUCTION

The following chapter describes the soils that were tested in the research project. Three soils were tested namely : Letaba Ash Tailings, Gold Tailings and Estcourt Clay. The various soil parameters and properties are described in the following pages.

10.2 LETABA ASH TAILINGS

The sieve analysis curve for the Ash is shown in figure 10.1.

The Atterberg Limits for the Ash were as follows :

(1) Liquid Limit = 29.8 %

(2) Plastic Limit = could not be determined due to nature of soil

The specific gravity of the Ash was : 2.18
The saturated coefficient of hydraulic conductivity for the Ash (from constant head test) was : 9.631E-5 cm/s.

10.3 GOLD TAILINGS

The sieve analysis curve for the Gold is shown in figure 10.1.

The Atterberg Limits for the Gold were as follows :

(1) Liquid Limit = 34.2 %

(2) Plastic Limit = could not be determined due to nature of soil

The specific gravity of the Gold was : 2.64
The saturated coefficient of hydraulic conductivity for the Gold was : 4.846E-5 cm/s.

10.4 ESTCOURT CLAY

The sieve analysis curve for the Clay is shown in figure 10.1. The soil is classified as :

(1) Unified Classification : CL (Lean Clay)

(2) AASHO Classification : A-7-6 (Clayed soils)

The Atterberg Limits for the Clay were as follows :

(1) Liquid Limit = 42.7 %

(2) Plastic Limit = 20.4 %

(3) Plasticity Index = 22.3 %

(4) Shrinkage Limit = 14.8 %

The specific gravity of the soil was : 2.61
The saturated coefficient of hydraulic conductivity for the Clay was : 1.442E-6 cm/s.

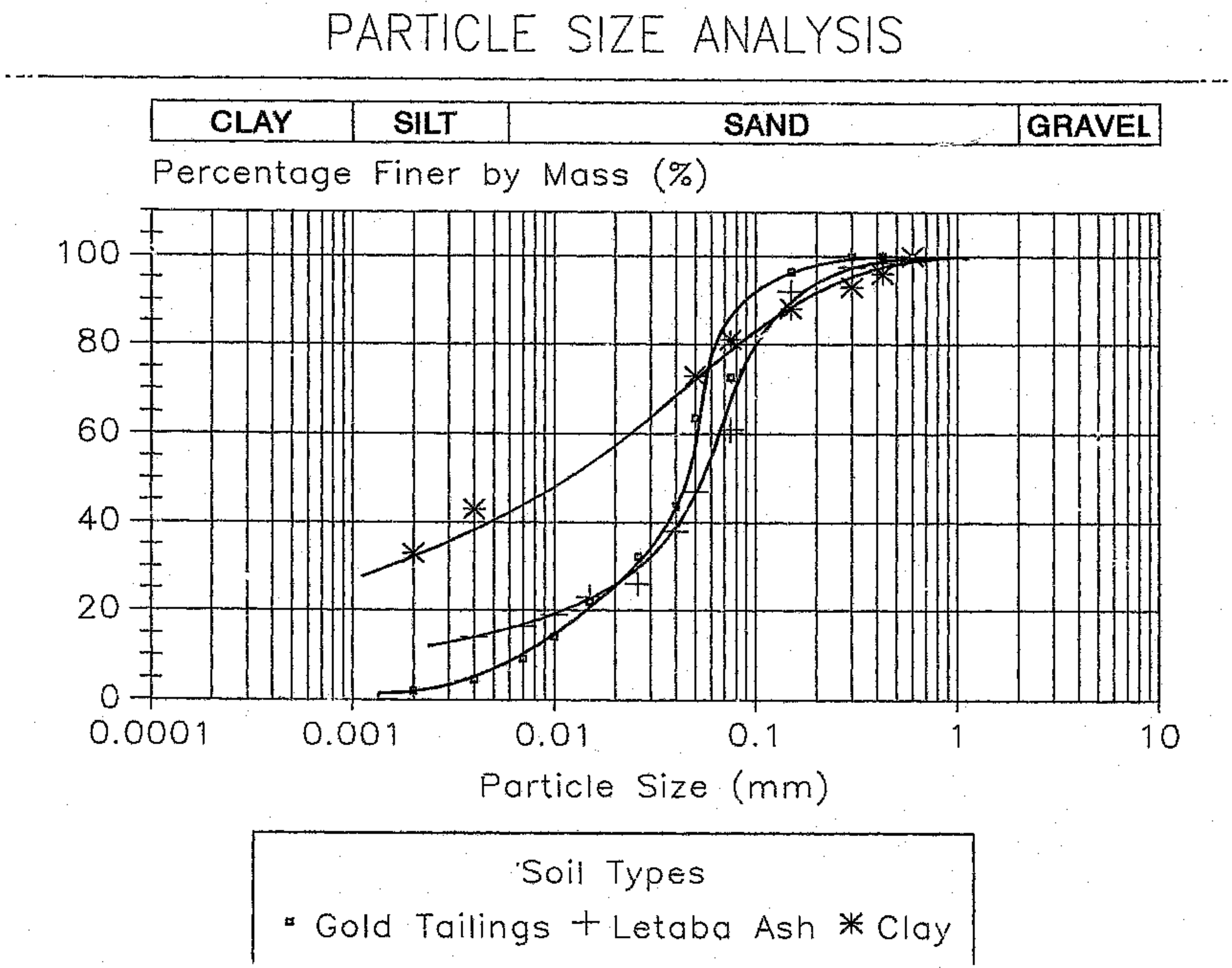


Figure 10.1 Sieve analysis of soils tested

CHAPTER 11

RESULTS

11.1 INTRODUCTION

The following chapter presents the results obtained from the various tests. The chapter is sub-divided into four sections :

Section 11.2 : details the moisture retention curves obtained for the various soils tested.

Section 11.3 : deals with the fitting of the van Genuchten model to the moisture retention curves for the various soils tested.

Section 11.4 : shows the results obtained from using the modified analytical technique for determining the unsaturated coefficients of hydraulic conductivity for the various soils tested.

Section 11.5 : deals with the fitting of the van Genuchten model to the coefficients of hydraulic conductivity - volumetric/water content relationship for the various soils tested.

11.2 MOISTURE RETENTION CURVES

11.2.1 Letaba Ash Test Results

Three tests were conducted using this soil. The three tests are referred to as Ash Test 1, Ash Test 2 and Ash Test 3. The tests differ from one another only in terms of the applied air pressure increments. It should be noted that the test sample used in each test was not the same, although all the test samples came from the same soil sample bag.

Tables 11.1, 11.2 & 11.3 summarize the results obtained from the individual tests.

ASH TEST 1				
Applied air pressure (kPa)	Suction (kPa)	Water content (g/g)	Volumetric water content (cm^3/cm^3)	Degree of saturation
0	-	0.391445	-	-
30	15	0.33917	0.362552	0.710983
80	42	0.272665	0.298887	0.602183
110	67	0.210149	0.233407	0.476657
140	109	0.165441	0.185784	0.383829
190	140	0.150664	0.172322	0.36318
250	-	0.121585	0.141745	0.30526

Table 11.1 Summary of test results from Ash Test 1.

ASH TEST 2				
Applied air pressure (kPa)	Suction (kPa)	Water content (g/g)	Volumetric water content (cm^3/cm^3)	Degree of saturation
0	–	0.380714	–	
30	25	0.334253	0.38889	0.865561
60	45	0.296216	0.353236	0.781353
90	85	0.191217	0.229665	0.512485
110	98	0.15411	0.185156	0.413326
130	126	0.131975	0.15862	0.353961
160	–	0.11942	0.143524	0.320517
200	185	0.108911	0.130935	0.29252

Table 11.2 Summary of test results from Ash Test 2.

ASH TEST 3				
Applied air pressure (kPa)	Suction (kPa)	Water content (g/g)	Volumetric water content (cm^3/cm	Degree of saturation
0	–	0.352083	–	–
30	28	0.231246	0.280324	0.632768
60	59	0.168464	0.20937	0.488087
110	108	0.124326	0.158958	0.385314
160	155	0.111257	0.148447	0.383643
200	190	0.096546	0.136999	0.393669

Table 11.3 Summary of test results from Ash Test 3.

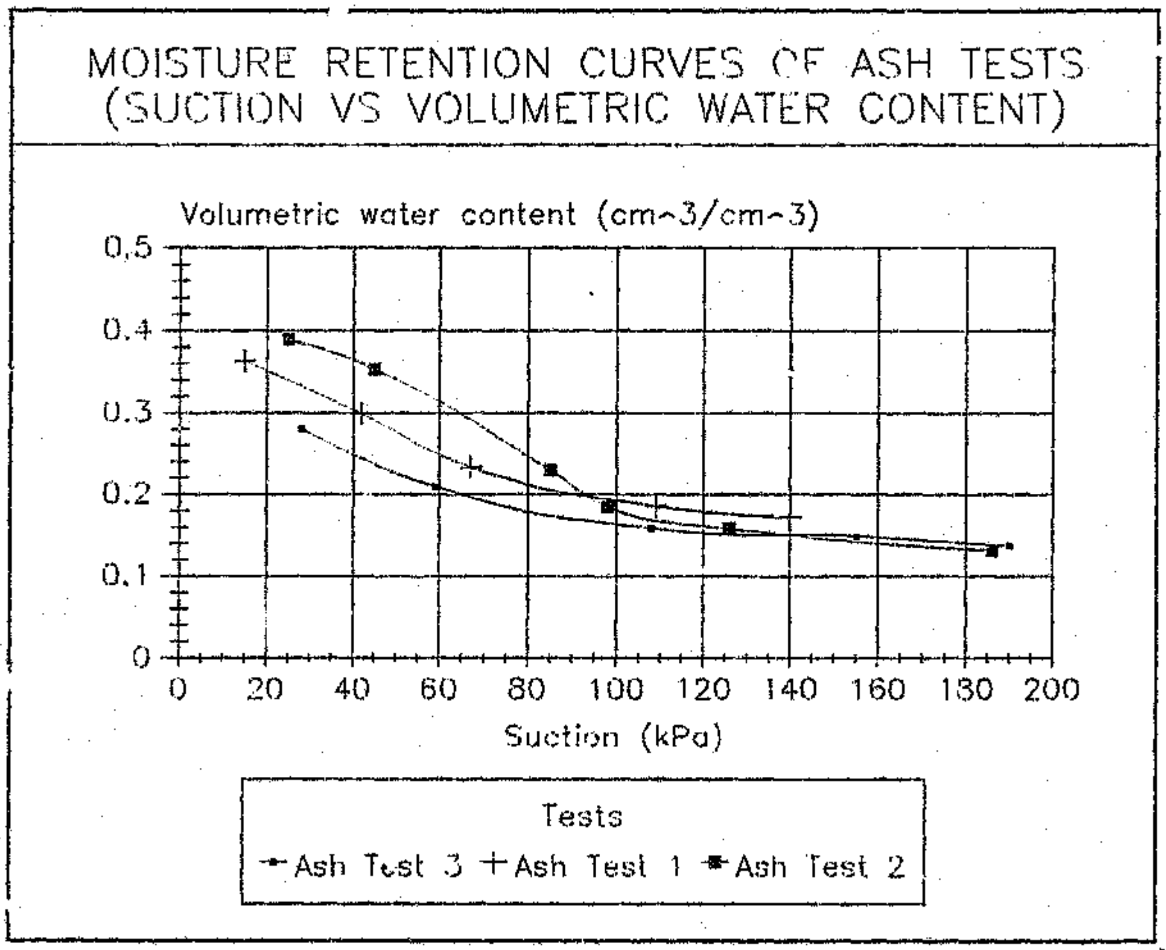


Figure 11.1 **Moisture Retention Curves obtained from Letaba Ash tests - Suction versus Volumetric water content**

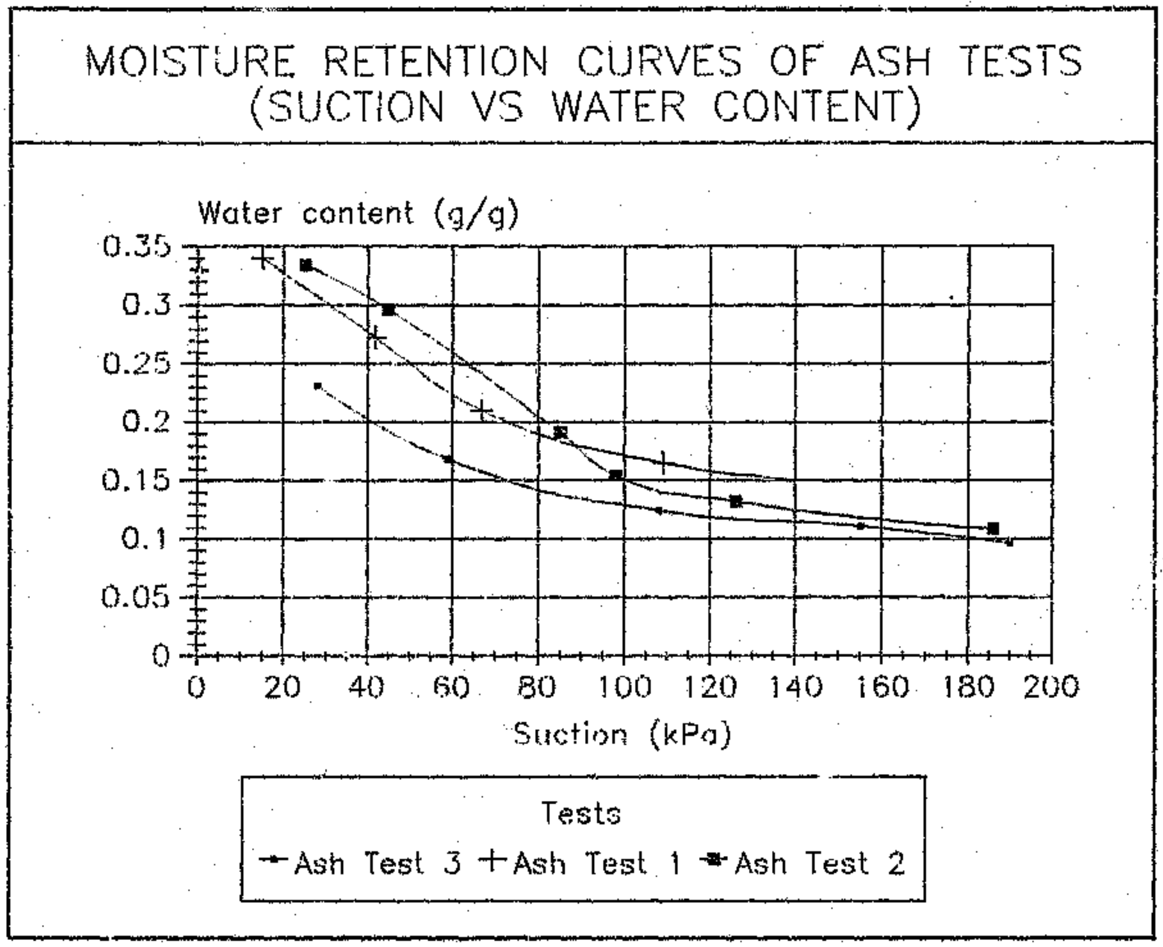


Figure 11.2 Moisture Retention Curves obtained from Letaba Ash tests - Suction versus water content

It is evident from the curves that at low suctions the data points for the three tests plot over a relatively large region. As the suction increases the region over which the three tests plot narrows considerably. Although the general trend and overall shape of the curves from the three tests is similar, there is some difference between the tests. This indicates that the test may be sensitive to the applied air pressure increments, or that the variation is due to differences between the test samples themselves.

11.2 Gold Tailings Test Results

Only one test was conducted using this soil. The reasons for this were :

(1)The time duration of the test was longer than for the Ash.

(2)The time limitation on the research project.

(3) Using the results of the Ash tests as a guide, the only additional mation that would be obtained from running more than one test on the Gold Tailings, would be the region or band within which the moisture retention curves occur.

Table 11.4 summarizes the results obtained from the test and figures 11.3 & 11.4 show the moisture retention curve of the soil.

The time duration for testing the gold was found to be the following for each point obtained :

(1) Drainage or outflow stage 24 to 48 hours.

(2) Capillary pressure equilibrium 24 to 48 hours.

Refer to Appendix 4 for the comprehensive results of the gold tests.

GOLD TEST				
Applied air pressure (kPa)	Suction (kPa)	Water content (g/g)	Volumetric water content (cm^3/cm^3)	Degree of saturation
0	-	0.29598	-	-
20	19	0.22806	0.37513	0.9939
40	33	0.20199	0.33698	0.91429
69	66	0.14585	0.24398	0.66499
99	96	0.11831	0.19876	0.54587
130	128	0.09969	0.16821	0.46547
156	151	0.08714	0.14722	0.40829

Table 11.4 Summary of test results from Gold Test

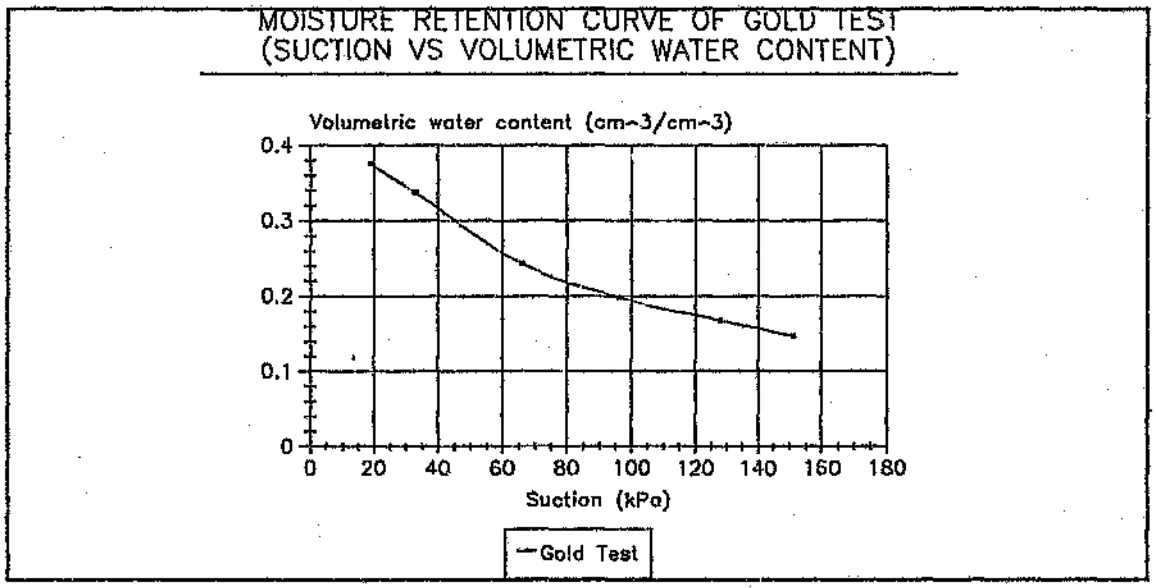


Figure 11.3 Moisture Retention Curve from Gold test - Suction versus Volumetric water content

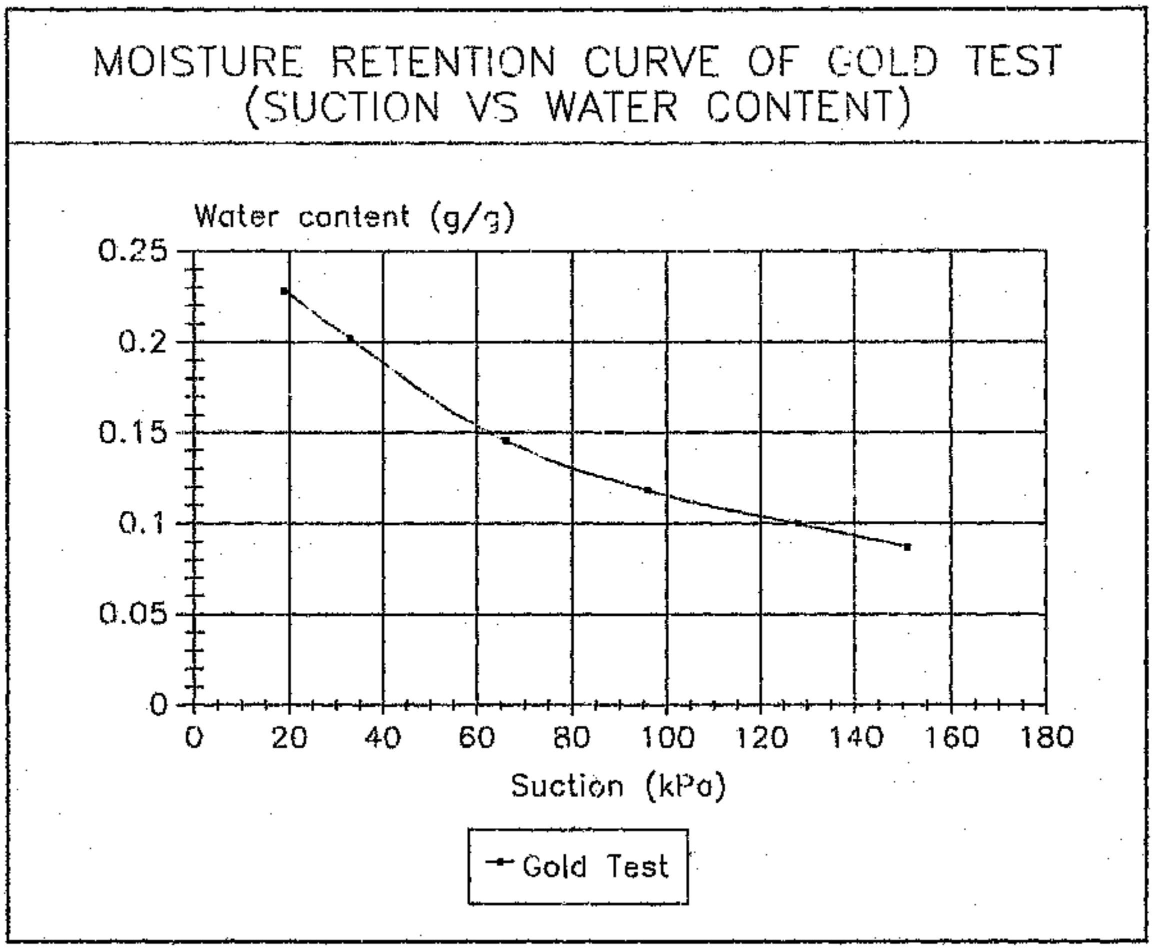


Figure 11.4 Moisture Retention Curve obtained from Gold test - Suction versus Water content

11.2.3 Clay Test Results

Only one test was conducted using this soil. The reasons for this are the same as stated for the Gold test in section 11.2.2.

Table 11.5 summarizes the results obtained from the test and figures 11.5 & 11.6 show the moisture retention curves of the soil.

The time duration for testing the clay was found to be the following for each point obtained :

(1) Drainage or outflow stage 24 to 48 hours.

(2) Capillary pressure equilibrium 24 to 48 hours.

Refer to Appendix 5 for the comprehensive results of the clay tests.

CLAY TEST				
Applied air pressure (kPa)	Suction (kPa)	Water content (g/g)	Volumetric water content (cm^3/cm^3)	Degree of saturation
0	-	0.471367	-	-
20	13	0.394063	0.473879	0.879234
41	34	0.330367	0.426382	0.843969
63	54	0.331438	0.42937	0.910724
81	68	0.304456	0.429701	0.936328
125	102	0.285779	0.419006	0.956835
160	135	0.27989	0.415667	0.965196

Table 11.5 Summary of test results from Clay Test.

Referring to figure 11.5 and table 11.5 the volumetric water content of the clay test sample appears to increase slightly (instead of decrease) with an increase in suction at applied air pressures of 60 and 80 kPa. The reason for this is thought to have resulted from having to re-zero the volume gauge at the beginning of the 60 kPa air pressure increment, as its maximum measuring capacity had been reached. It is thought that two things may have occurred during the re-zeroing of the volume gauge :

(1) A sample volume change may have taken place during the re-zeroing of the volume gauge which could not be measured.

(2) The volume gauge may behave in a slightly "hysteretic" manner after re-zeroing.

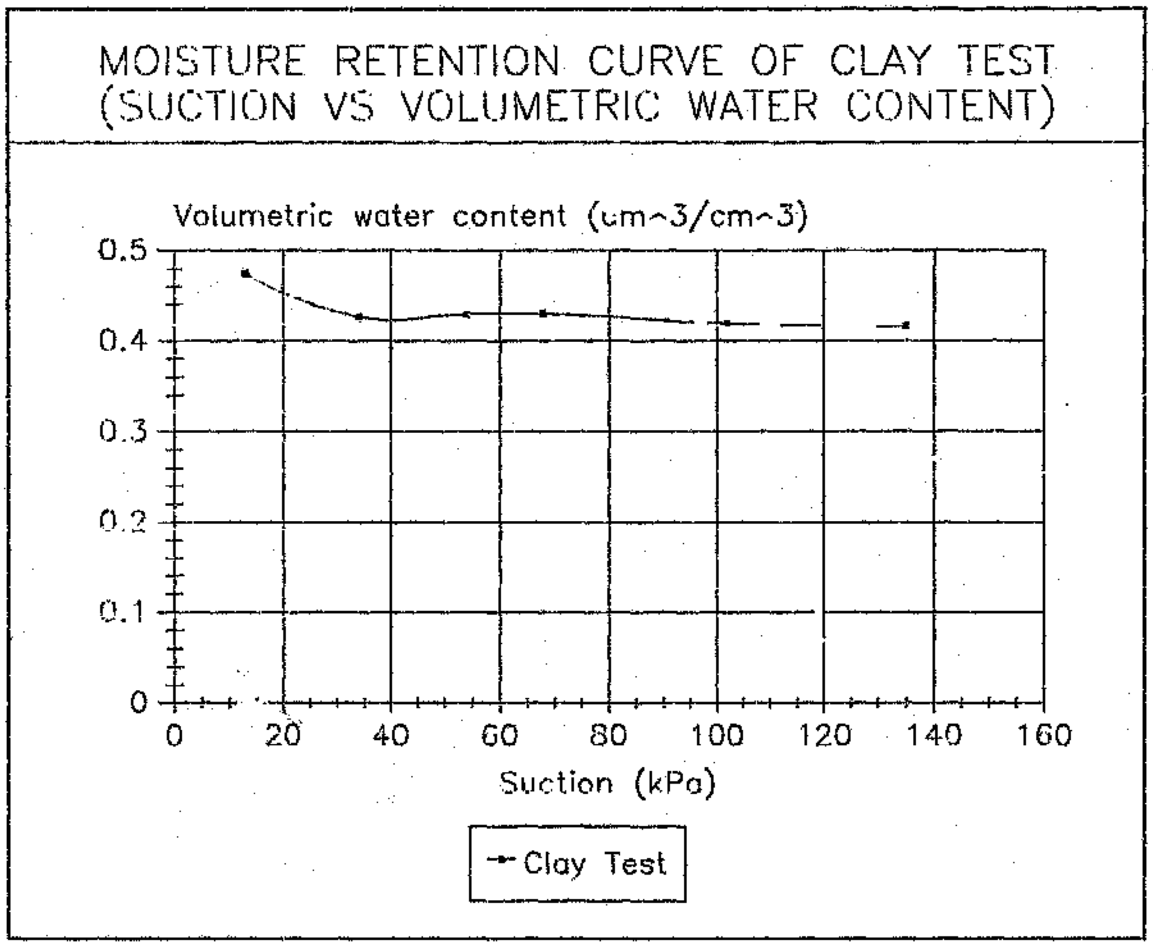


Figure 11.5 Moisture Retention Curve obtained from Clay test - Suction versus Volumetric water content

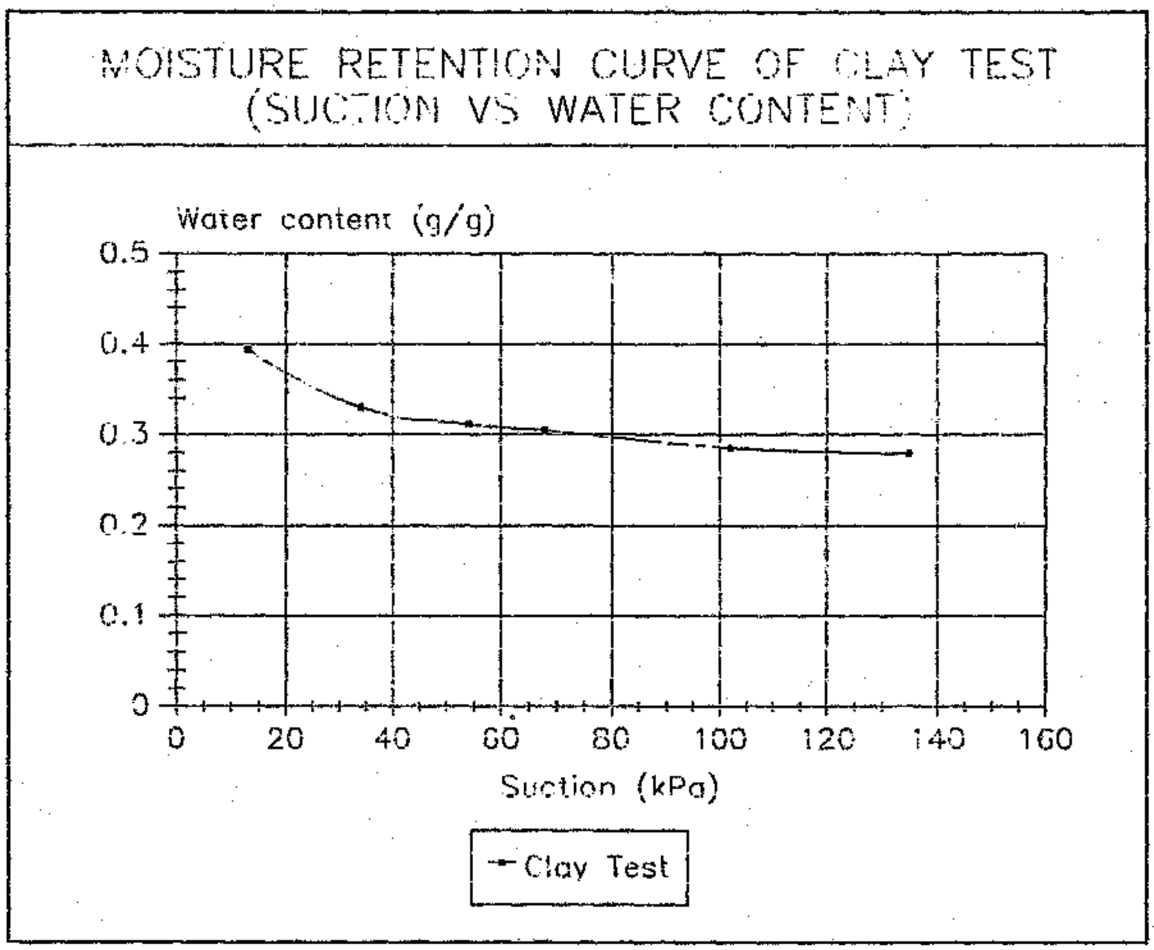


Figure 11.6 Moisture Retention Curve obtained from Clay test - Suction versus Water content

11.2.4 General Comments

The shape of the curves for the individual tests are almost identical whether plotted as suction versus volumetric water content (cm^3/cm^3) or suction versus water content (g/g).

The curves obtained for the three soils display the "typical" moisture retention curve, as reported in the literature.

11.3 MODEL FITTING OF MOISTURE RETENTION CURVES

The van Genuchten model was fitted to the experimental points describing the moisture retention curves of the soils tested using the curve fitting programme mentioned in section 7.2.1. The model was fitted to both the suction -volumetric water content and suction - water content curves of the soils. Throughout the curve fitting analysis, all the constants of the model were varied.

11.3.1 Letaba Ash

Table 11.6 highlights the most important results obtained from the curve fitting analysis. It should be noted that the van Genuchten model using the restriction m=1-1/n was fitted to all the ash moisture retention curves. The van Genuchten model using m & n as independent constants could only be fitted to the Ash Test 2 results. The reason for this is that the least squares curve fitting programme required a minimum of 6 data points and Ash Test 1 & 3 only had 5 data points.

	ASH TEST 1	ASH TEST 2		ASH TEST 3
	Suction	versus content	volumetric	water
	m=1-1/n	m=1-1/n	m & n	m=1-1/n
SSE	6.7596E-9	1.3274E-3	1.0768E-4	3.4421E-5
SD	8.2217E-5	2.5762E-2	1.0377E-2	5.8669E-3
	Suction	versus	water	content
	m=1-1/n	m=1-1/n	m & n	m=1-1/n
SSE	9.2725E-7	9.9883E-5	7.9445E-5	4.9178E-5
SD	9.6294E-4	7.0669E-3	8.9132E-3	7.0127E-3

SSE : Sum of the Squares Error
SD : Standard Deviation

Table 11.6 Summary of curve fitting analysis for Letaba Ash.

Referring to table 11.6 and in particular to the curve fitting analysis of Ash Test 2 the restriction of m=1-1/n appears to a good assumption. The SSE, using the restriction m=1-1/n, increases by an order of magnitude, when compared to the SSE for m & n independently. In the case of suction versus water content however, the SSE is almost the same for the two cases. Referring to figure 11.10 it is evident that the model using m & n independently fits the data points better, although the restriction m=1-1/n is considered adequate.

Figures 11.7 to 11.12 illustrate how the model fits the experimental data points for each ash test. From the graphs it is apparent that the model fits the experimental data points extremely well. One thing to note however is that the constants for the model are different for each ash test.

Refer to Appendix 6 for the values of the constants to the model for each test and particular moisture retention curve.

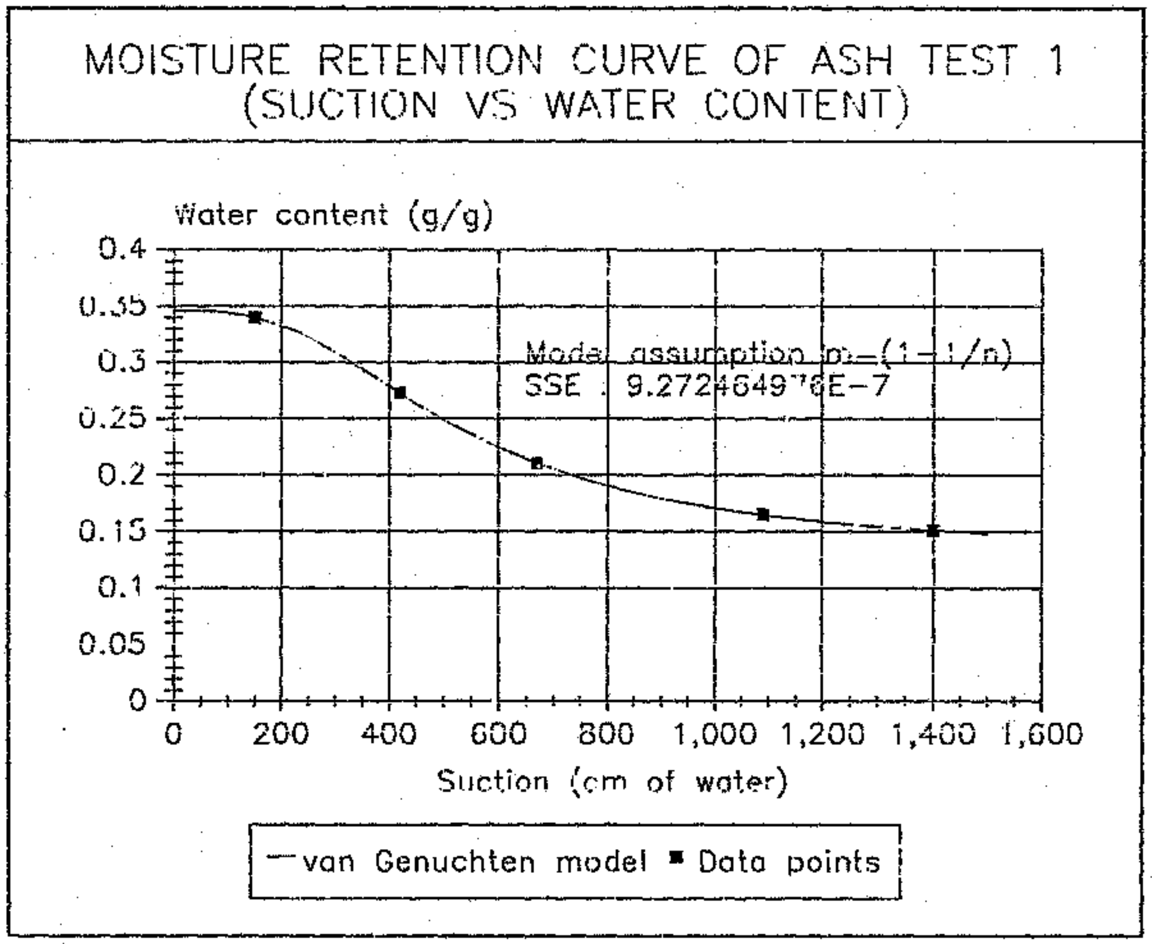


Figure 11.7 Model fitted to Moisture Retention Curve of Ash Test 1 - Suction versus Water Content

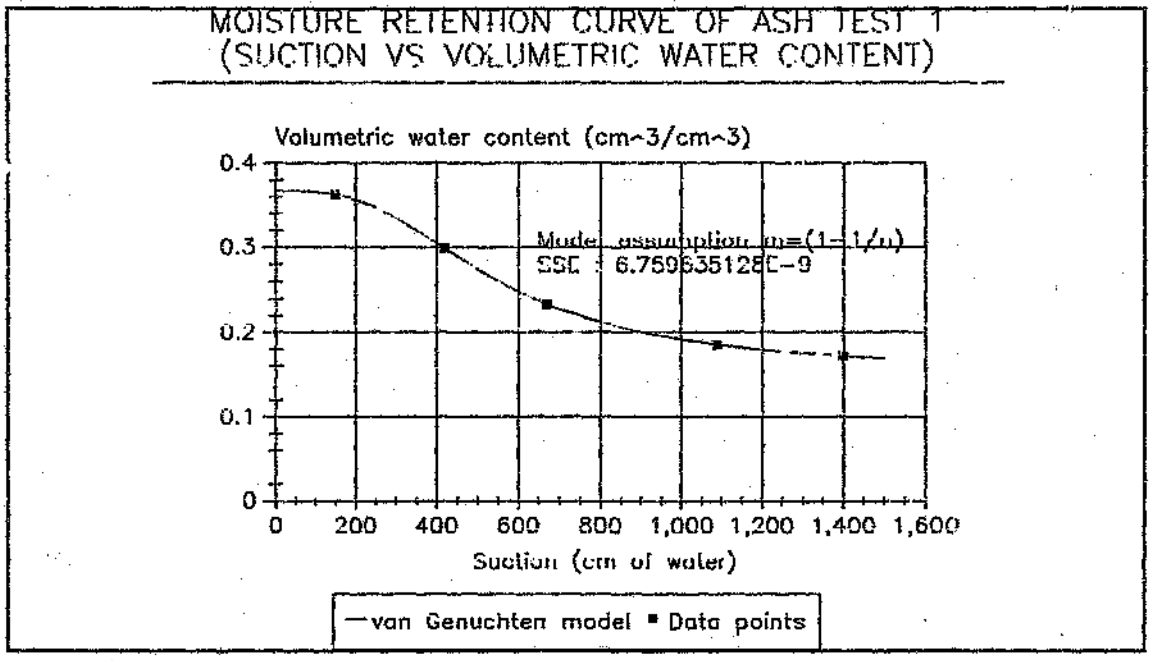


Figure 11.8 Model fitted to Moisture Retention Curve of Ash Test 1 - Suction Versus Volumetric water content

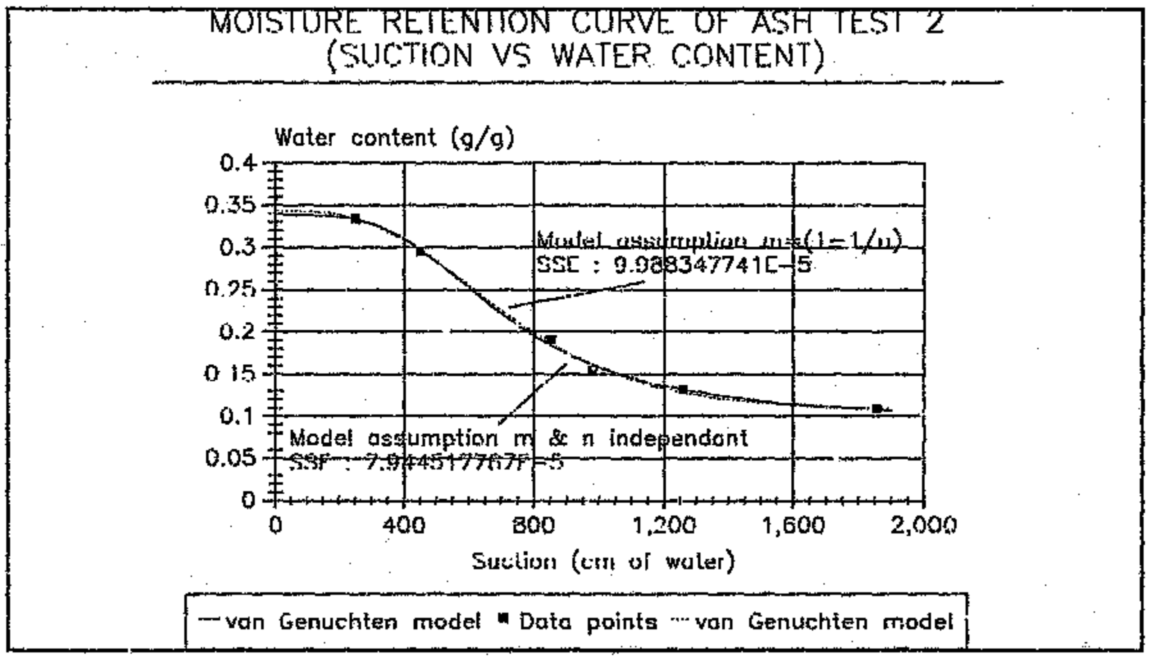


Figure 11.9 Model fitted to Moisture Retention Curve of Ash Test 2 - Suction versus Water content

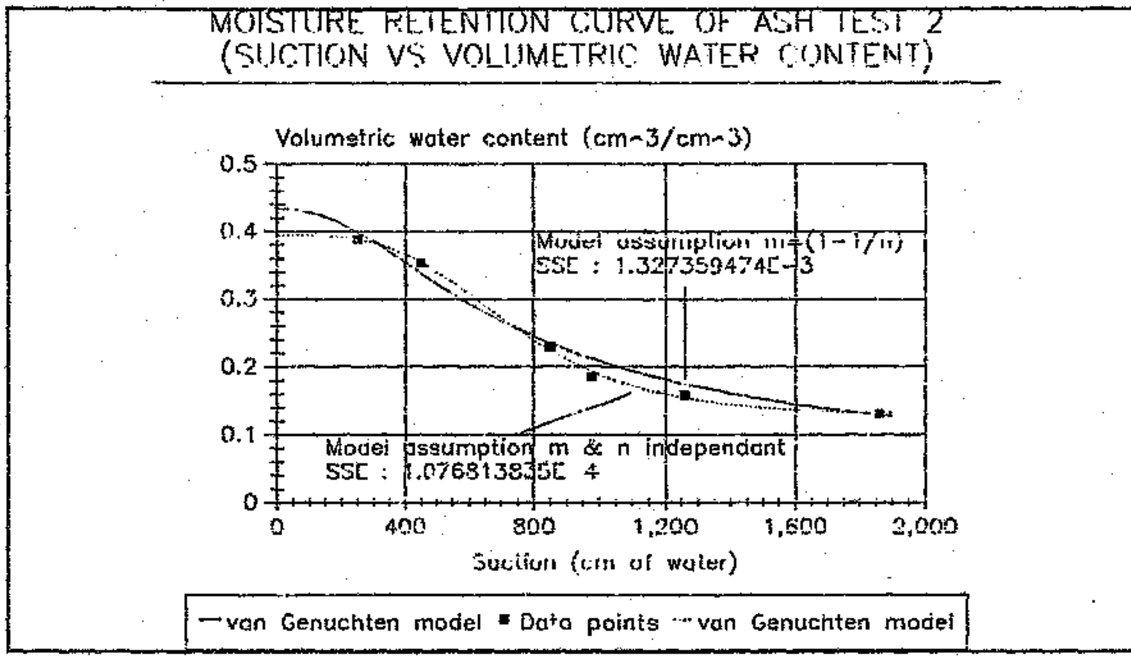


Figure 11.10 Model fitted to Moisture Retention Curve of Ash Test 2 - Suction versus Volumetric water content

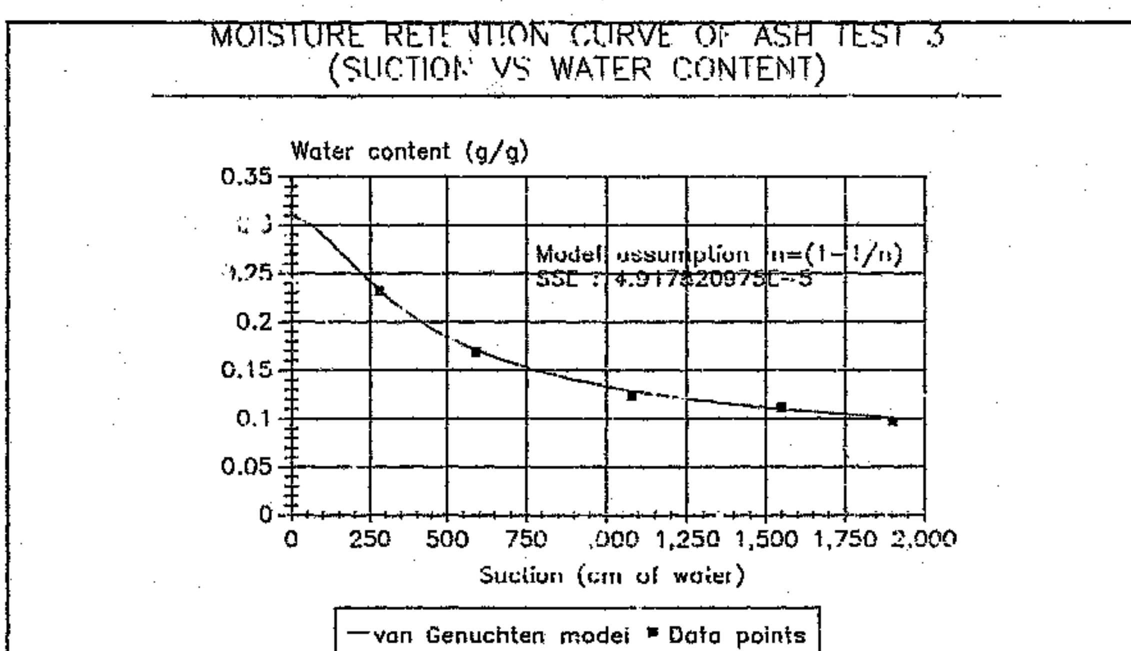


Figure 11.11 Model fitted to Moisture Retention Curve of Ash Test 3 - Suction versus Water content

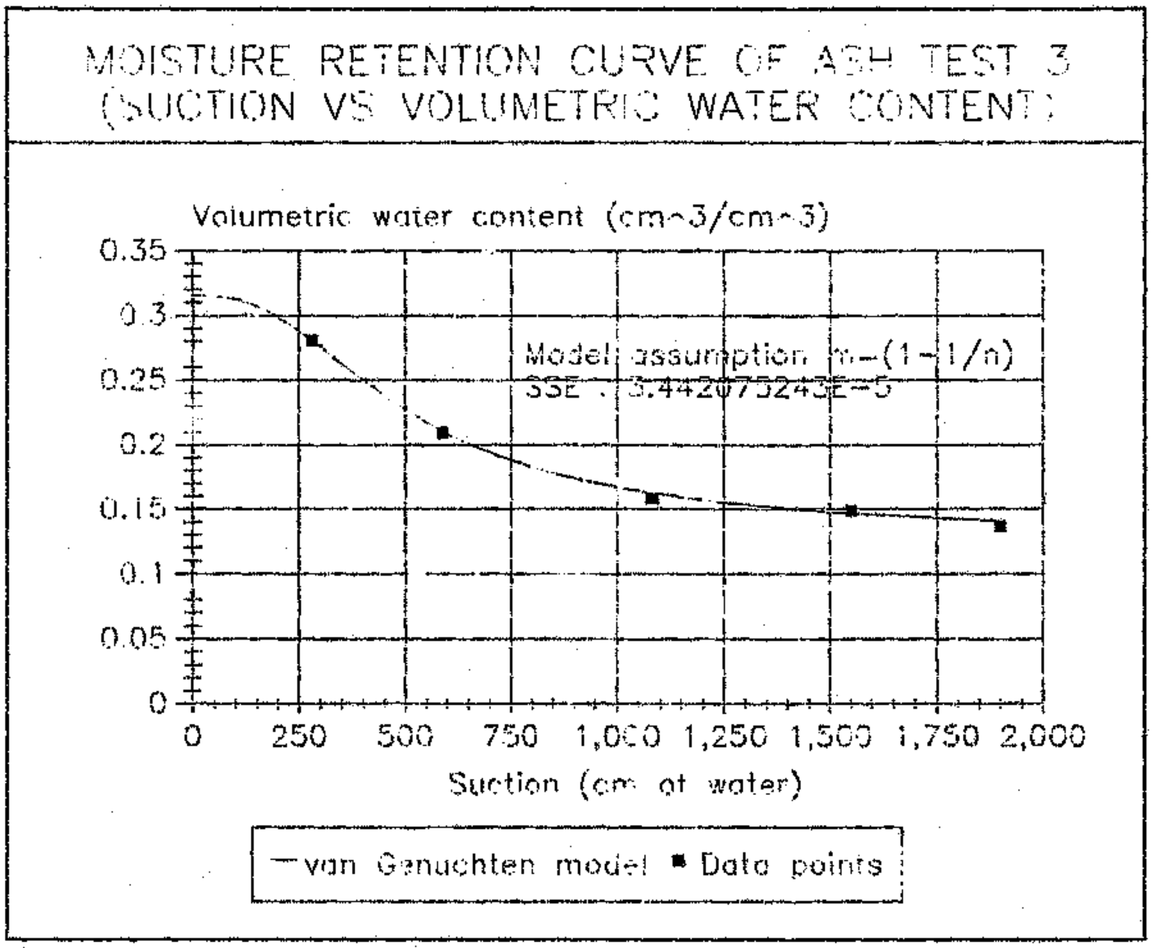


Figure 11.12 Model fitted to Moisture Retention Curve of Ash Test 3 - Suction versus Volumetric water content

11.3.2 Gold Tailing

Table 11.7 highlights the most important results obtained for the curve fitting analysis. Both of the van Genuchten models, using the restriction m=1-1/n and m & n independent, were fitted to all the gold moisture retention curves.

	GOLD TEST	
Suction versus volumetric water content		
	m=1-1/n	m & n
SSE	2.891643617E-5	5.168411471E-6
SD	3.802396361E-3	2.273414056E-3
Suction versus water content		
	m=1-1/n	m & n
SSE	7.667640334E-6	1.547340531E-6
SD	1.958014343E-3	1.243921433E-3

SSE : Sum of the Squares Error
SD : Standard Deviation

Table 11.7 Summary of curve fitting analysis for Gold Tailings.

Referring to table 11.7 the restriction m=1-1/n appears to be a good assumption. The SSE, using the restriction m=1-1/n, in both the cases of suction versus volumetric water content and suction versus water content, is slightly higher than for the SSE of m & n independently.

Figures 11.13 & 14 illustrate how the model fits the experimental data points for the gold test. From the graphs it is apparent that there is only a marginal difference between the two models in terms of fitting the experimental data points. Both models however fit the data points extremely well. For the complete data on the curve fitting analysis refer to Appendix 7.

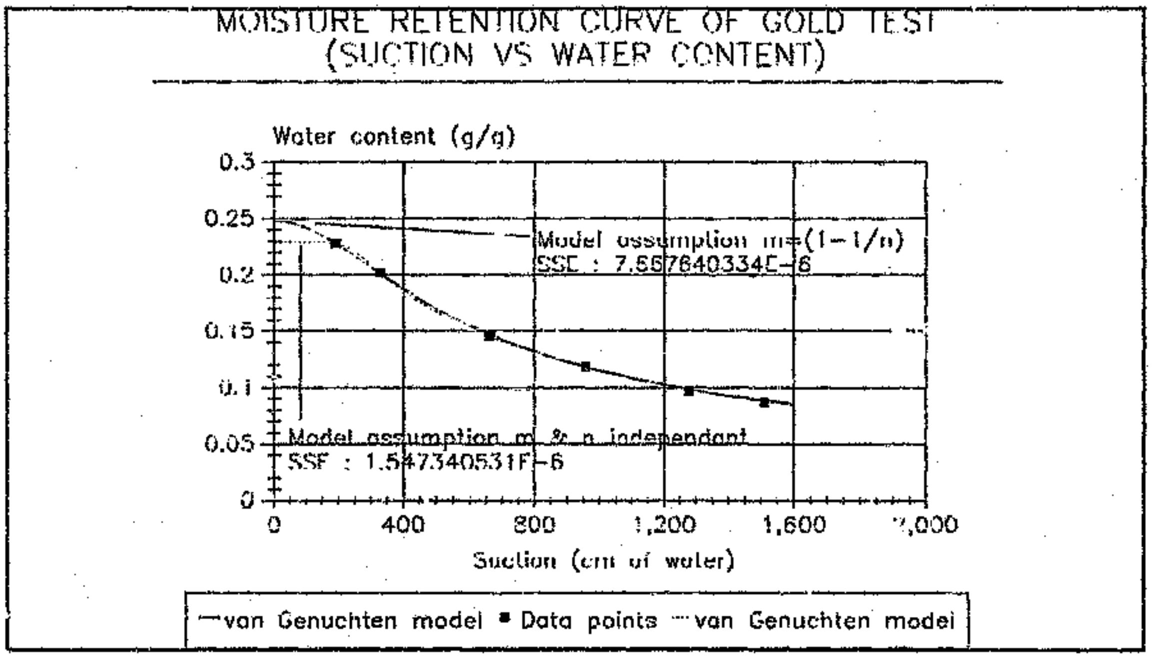


Figure 11.13 Model fitted to Moisture Retention Curve of Gold Test - Suction versus Water content

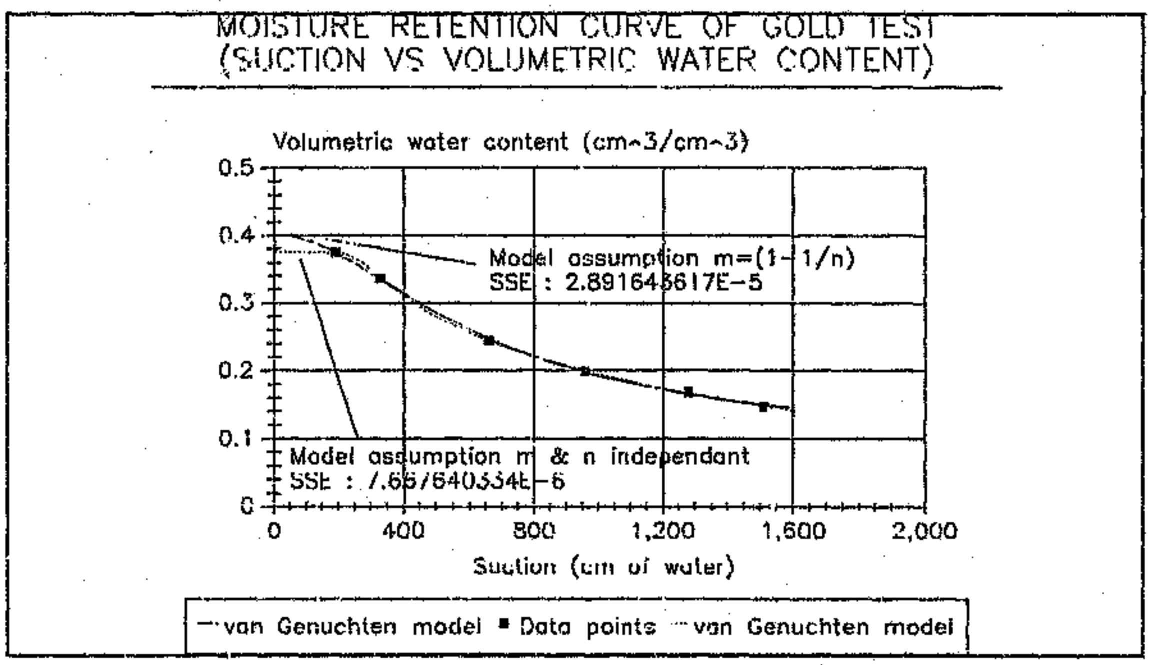


Figure 11.14 Model fitted to Moisture Retention Curve of Gold Test - Suction versus Volumetric water content

11.3.3 Clay

Table 11.8 highlights the most important results obtained for the curve fitting analysis. Both of the van Genuchten models, using the restriction m=1-1/n and m & n independently, were fitted to all the clay moisture retention curves.

	CLAY TEST	
Suction versus volumetric water content		
	m=1-1/n	m & n
SSE	1.131980481E-4	1.130924857E-4
SD	7.523232288E-3	1.063449508E-2
Suction versus water content		
	m=1-1/n	m & n
SSE	1.573695590E-5	1.622040887E-5
SD	2.805080738E-3	4.027456874E-3

SSE : Sum of the Squares Error
SD : Standard Deviation

Table 11.8 Summary of curve fitting analysis for Clay

Referring to table 11.8 the restriction m=1-1/n appears to be a very good assumption. The SSE, using the restriction m=1-1/n, in both the cases of suction versus volumetric water content and suction versus water content, is almost identical as for the SSE of m & n independently.

Figures 11.15 & 16 illustrate how the model fits the experimental data points for the clay test. From the graphs it is apparent that there is almost no difference between the two models in terms of fitting the experimental data points. Both models fit the data points extremely well. For the complete data on the curve fitting analysis refer to Appendix 8.

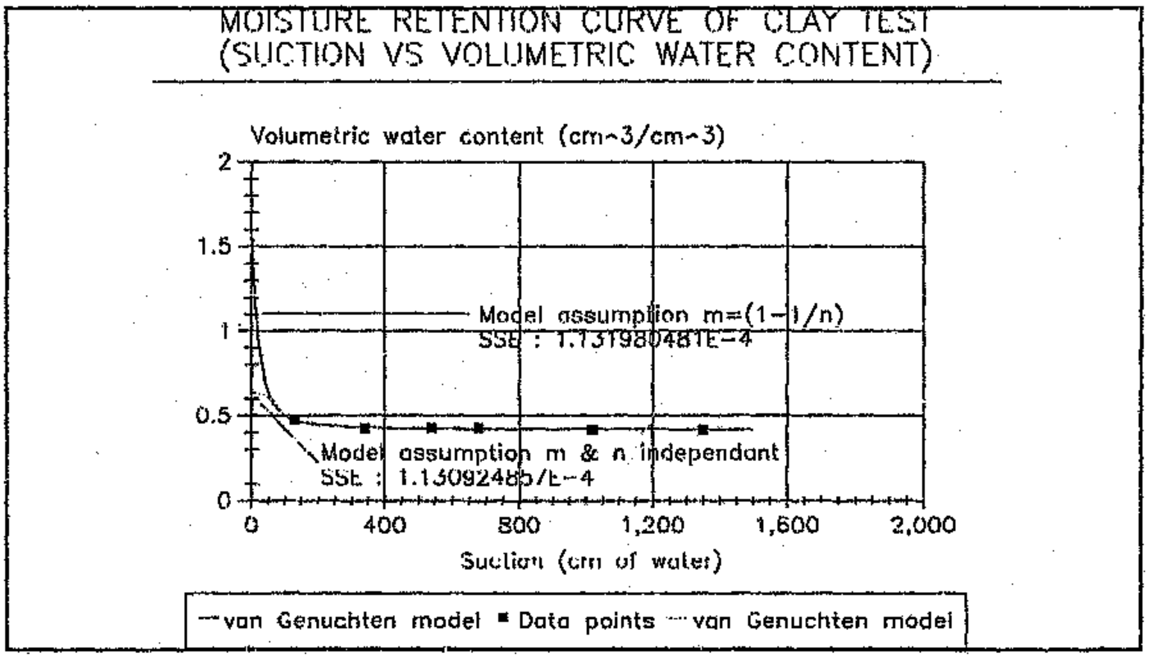


Figure 11.15 Model fitted to Moisture Retention Curve of Clay Test - Suction versus Volumetric water content

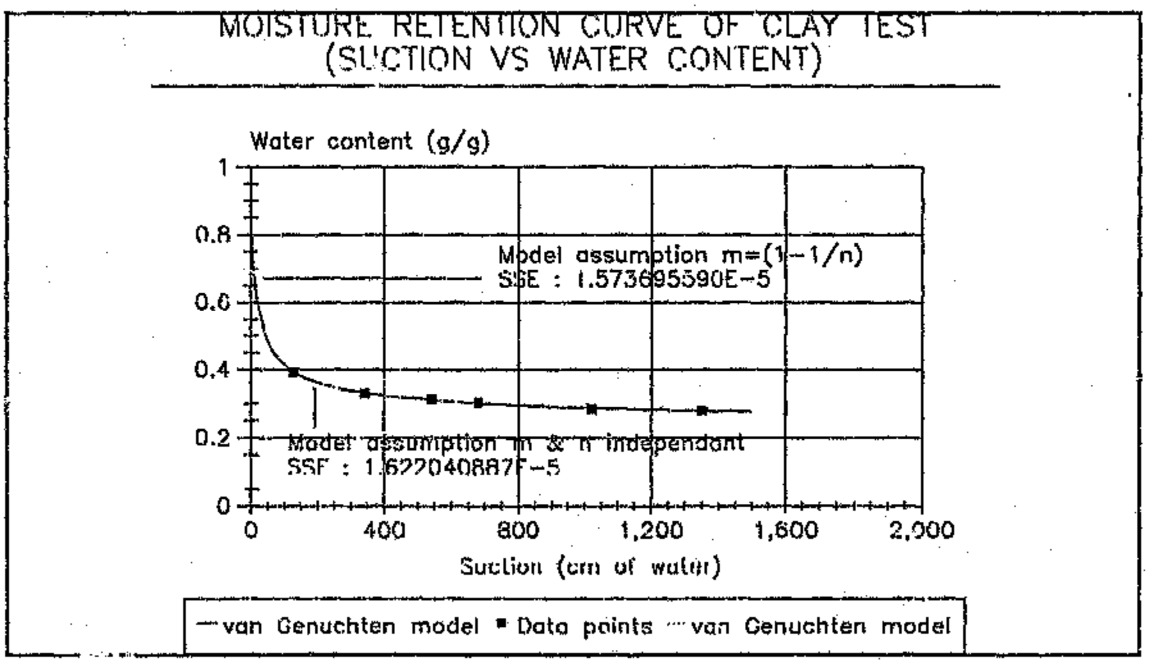


Figure 11.16 Model fitted to Moisture Retention Curve of Clay Test - Suction versus Water content

11.3.4 General Comments

The van Genuchten model fitted extremely well to the experimental data points for the moisture retention curves of all the soils tested. The restriction of $m=1-1/n$ appears to be a very good assumption and can certainly be used in place of the model treating m & n as independent constants. The model using the restriction $m=1-1/n$ produced almost identically the same moisture retention curves as the model treating m & n independently in the case of the clay tests.

With reference to Appendices 6,7 & 8 which show the constants that were determined for the models describing the various moisture retention curves the following should be noted. The values corresponding to θ_s and θ_r do not necessarily represent the saturated and residual water content of the soil sample respectively. In some cases, namely in the clay and gold tailings tests, θ_s is above 100 % and θ_r is less than 0 %. It is therefore felt that the constants to the model should be viewed as curve fitting constants, instead of constants related to soil parameters. This however would not apply in cases where θ_s, θ_r or any other constants of the model were determined experimentally.

11.4 COEFFICIENTS OF HYDRAULIC CONDUCTIVITY CURVES

The saturated coefficients of hydraulic conductivity for the three soils were determined independently of the unsaturated coefficients of hydraulic conductivity, using the Constant Head Permeameter approach. Throughout the curve fitting analysis all the constants of the van Genuchten model were allowed to vary.

11.4.1 Letaba Ash

In the case of the Ash tests it was not possible to determine the unsaturated coefficients of hydraulic conductivity. In the case of Ash Test 1 the "transitional" period of outflow from a linear curve to a horizontal curve was not obtained, as capillary pressure monitoring was started too early. In the case of Ash Test 2 & 3 although the entire outflow curves were obtained, the slopes of the linear section of the outflow curves in most cases were steeper than what the AlphaX.exe programmes and thus the theory could account for. However some important practical lessons were obtained from these tests. Referring to tables 11.8 to 11.10 which summarize the results of the three tests certain deductions can be made. In the case of Ash Test 1 only three slopes could be used in the Alpha5.exe programme to determine coefficients of hydraulic conductivities. In the case Ash Test 2 only one slope and Ash Test 3 two slopes. The difference between Ash Test 1 and the other two tests was that the porous plate used in Ash Test 1 had a lower air entry value and thus a higher coefficient of hydraulic conductivity that the plate used in Ash Test 2 & 3. It is therefore felt that the steepness of the linear part of the outflow curves could be governed by two possible factors :

(1) The magnitude of the applied air pressure increments - although it is thought that this is unlikely.

(2) The ratio of the coefficient of hydraulic conductivity of the plate to that of the soil sample, ie. in the case of the Ash tests the coefficient of hydraulic conductivity of the plate to that of the ash was very small resulting in a very large "a" value which the theory, and thus the slope of the theoretical curves could not account for. This becomes apparent when referring to equations 6.8 & 6.11 which shows how the impedance factor, and therefore the ratio of the coefficient of hydraulic conductivity of the plate and the soil sample, are related to the "a" value and therefore to the slope of the theoretical outflow curves.

ASH TEST 1					
Applied air pressure (kpa)	Volumetric water content (cm^3/cm^3)	Water content (g/g)	Slope of linear section of outflow curve	"a" value	Coefficient of hydraulic conductivity (cm/s)
0	_	_	_	_	9.631E-5
30	0.362552	0.339917	0.908931	_	_
80	0.298887	0.272665	1.004725	_	_
110	0.233407	0.210149	0.861392	_	_
140	0.185784	0.165441	1.091624	_	_
190	0.172322	0.150664	0.706172	_	_
250	0.141745	0.121585	1.227554	_	_

Table 11.8 Table summarizing results of Ash Test 1

ASH TEST 2					
Applied air pressure (kPa)	Volumetric water content (cm^3/cm^3)	Water content (g/g)	Slope of linear section of outflow curve	"a" value	Coefficient of hydraulic conductivity (cm/s)
0	_	_	_	_	9.6312E-5
30	0.38889	0.334253	0.96275	_	_
60	0.353236	0.296216	1.018601	_	_
90	0.229665	0.191217	1.273666	_	_
110	0.185156	0.15411	1.10157	_	_
130	0.158562	0.131975	1.110192	_	_
160	0.143524	0.11942	0.961978	_	_
200	0.130935	0.108911	0.906486	_	_

Table 11.9 Table summarizing results of Ash Test 2

ASH TEST 3					
Applied air pressure (kPa)	Volumetric water content (cm^3/cm^3)	Water content (g/g)	Slope of linear section of outflow curve	"a" value	Coefficient of hydraulic conductivity (cm/s)
0	–	–	–	–	9.6312E-5
30	0.280324	0.231246	1.131574	–	–
60	0.20937	0.167464	0.769193	–	–
110	0.158958	0.124326	1.736061	–	–
160	0.148447	0.111257	0.911587	–	–
200	0.13699	0.096546	1.279425	–	–

Table 11.10 Table summarizing results of Ash Test 3

For further information on the Ash test results refer to Appendix 3.

11.4.2 Gold Tailings

Table 11.11 summarizes the results obtained from the Gold Test. Figures 11.17 & 11.18 show the coefficients of hydraulic conductivity as a function of volumetric water content and water content.

GOLD TEST					
Applied air pressure (kPa)	Volumetric water content (cm^3/cm^3)	Water content (g/g)	Slope of linear section of outflow curve	"a" value (0.01 to 0.[illegible]) (Alpha5)	Coefficient of hydraulic conductivity (cm/s)
0	–	–	–	–	4.8464E-5
20	0.37513	0.22806	0.96777	–	–
40	0.33698	0.20199	1.10191	–	–
69	0.24398	0.14585	0.90221	1.12856	1.2E-7
99	0.19875	0.11831	0.92935	2.3358	1.2E-7
130	0.16821	0.09969	0.88750	0.85239	2.5E-8
156	0.14722	0.08714	0.77996	0.22978	4.8E-9
188	0.12447	0.07355	0.79882	0.27579	3.8E-9

Table 11.11 Table summarizing results of Gold Test

It is important to note that the calculated coefficients of hydraulic conductivity are the average values from using the entire outflow curve for the particular air pressure increment as input to equation 6.8 and 6.13 to determine the coefficient of hydraulic conductivity.

For further information on the Gold test results refer to Appendix 4.

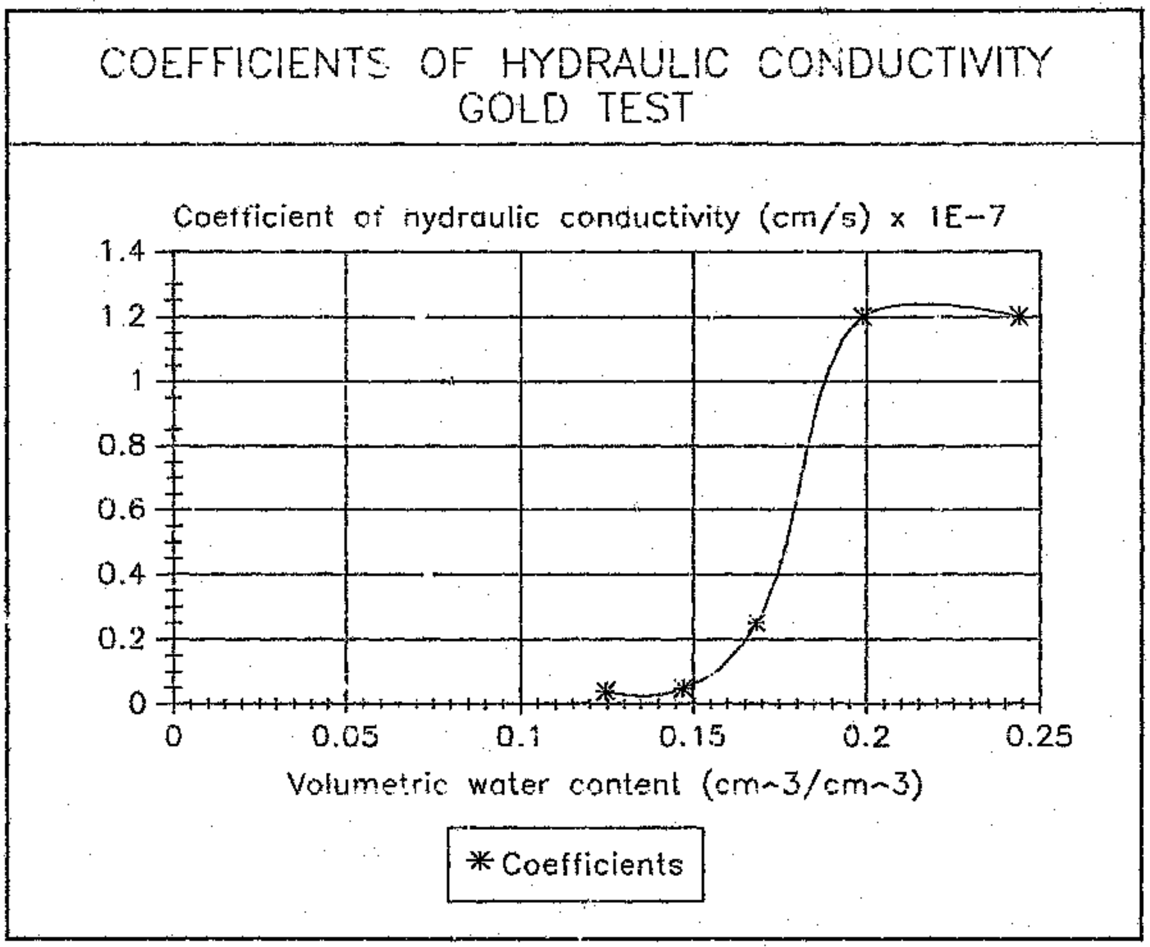


Figure 11.17 Coefficients of hydraulic conductivity for Gold Test as a function of volumetric water content

25X

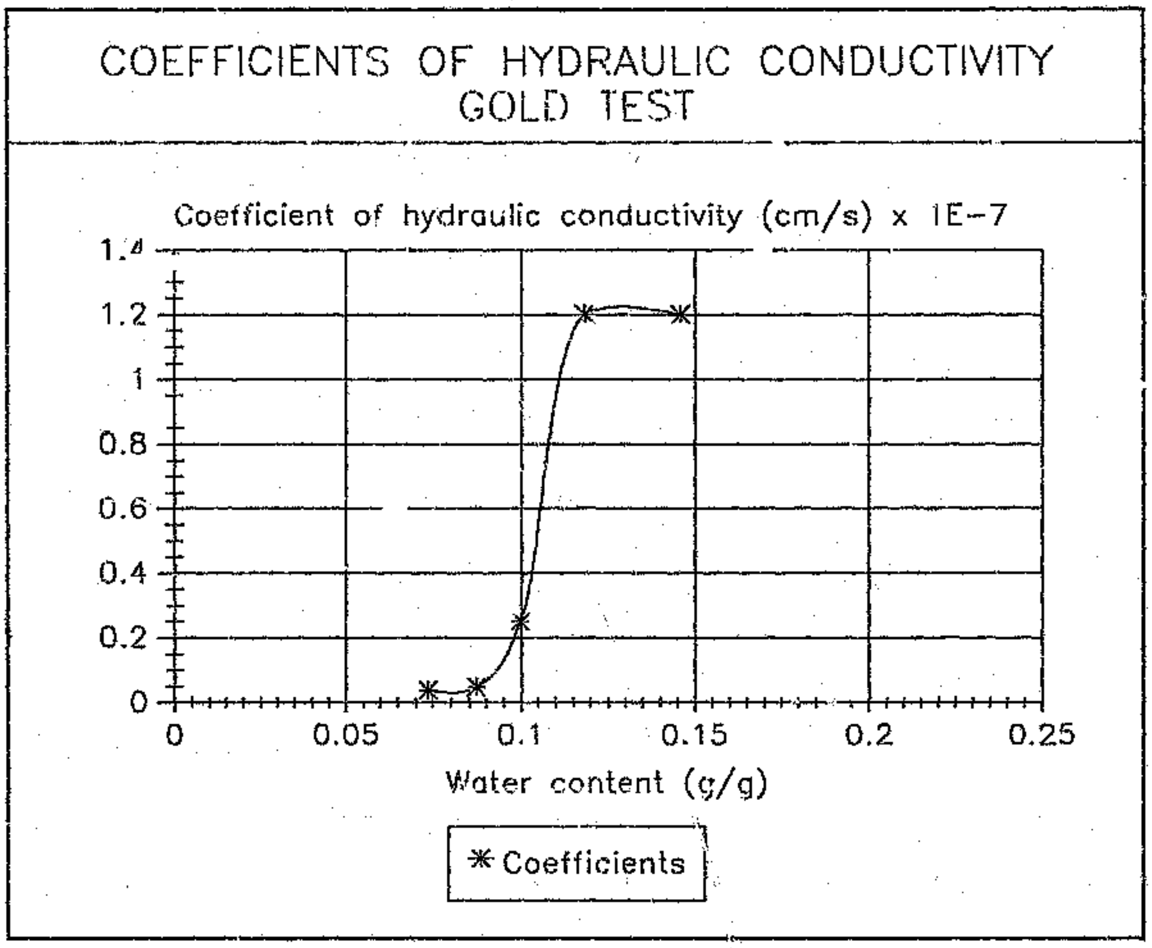


Figure 11.18 Coefficients of hydraulic conductivity for Gold Test as a function of water content

Referring to figures 11.17 & 18, with the exception of one of the points at a permeability of 1.2E-7 cm/s the coefficient of hydraulic conductivity curves for the Gold Tailing test display the classical curve for this type of relation ie. as the water content decreases initially there is a steep "linear" decrease in the coefficient of hydraulic conductivity. As the water content approaches the residual content there is a "flattening" of the curve to a horizontal line.

11.4.3 Clay

Table 11.12 summarizes the results obtained from the Clay Test. Figures 11.19 & 11.20 show the coefficients of hydraulic conductivity as a function of volumetric water content and water content.

CLAY TEST					
Applied air pressure (kPa)	Volumetric water content (cm^3/cm^3)	Water content (g/g)	Slope of linear section of outflow curve	"a" value (0.01 to 0.3) Alpha5	Coefficients of hydraulic conductivity (cm/s)
0	–	–	–	–	1.442E-6
20	0.473879	0.394053	0.92766	2.2012	9.92E-7
41	0.426382	0.330367	0.864317	0.59244	9.83E-8
63	0.42937	0.331438	0.977753	–	–
81	0.429701	0.304456	0.700395	0.113146	3.60E-9
125	0.419006	0.285779	0.710158	0.123239	6.85E-9
160	0.415667	0.27989	0.584356	0.034015	1.62E-9
204	0.404608	0.265084	0.783254	0.237051	2.48E-9

Table 11.11 Table summarizing results of Clay Test

For further information on the Clay test results refer to Appendix 5.

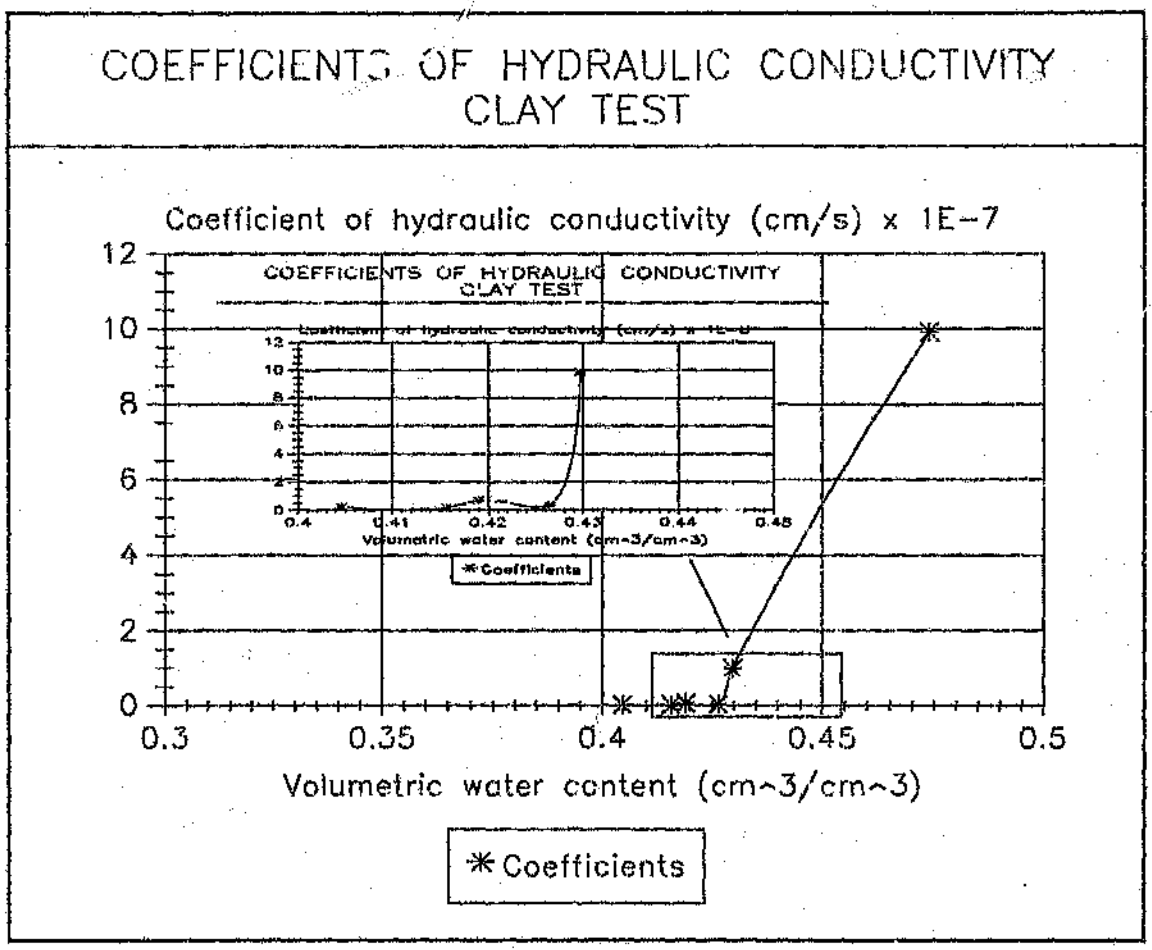


Figure 11.19 Coefficients of hydraulic conductivity for Clay Test as afunction of volumetric water content

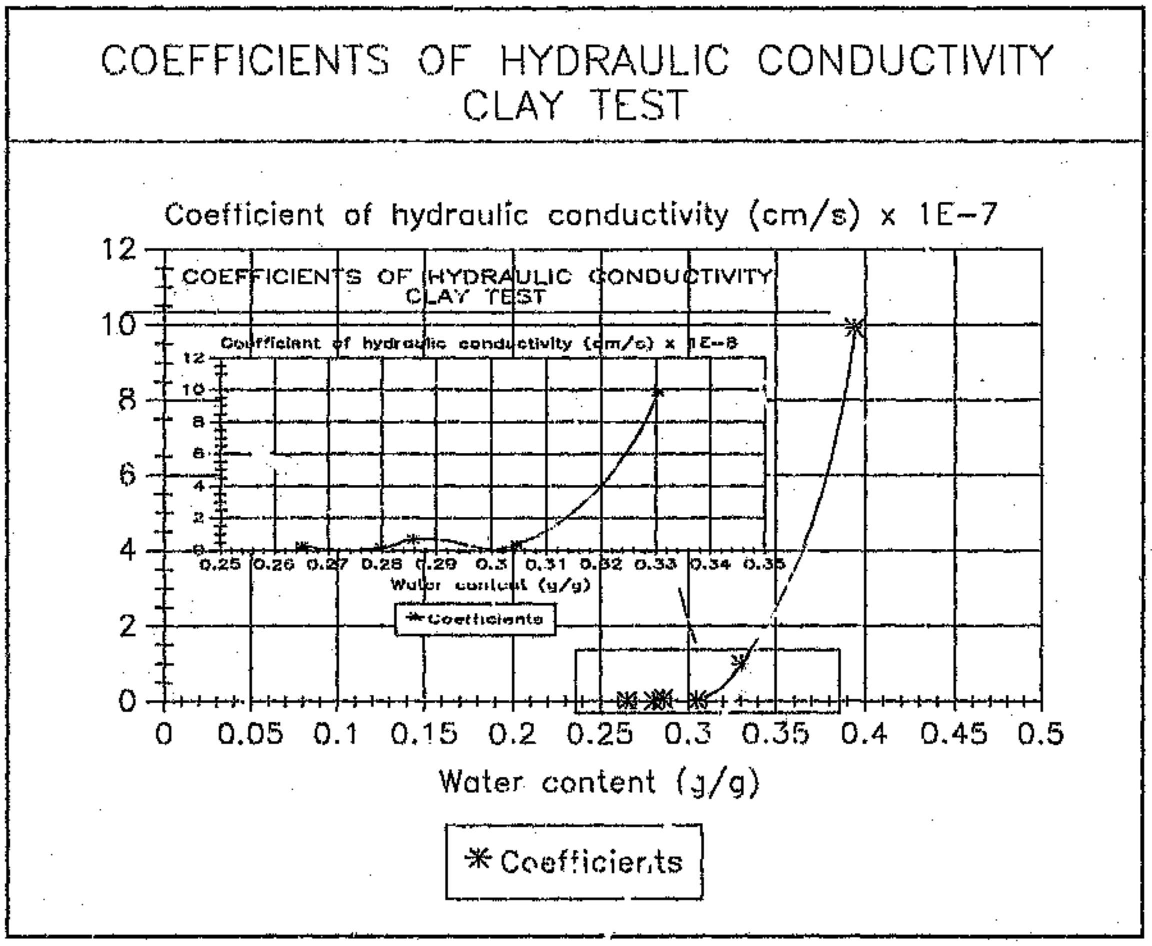


Figure 11.20 Coefficients of hydraulic conductivity for Clay Test as a function of water content

Referring to figures 11.19 & 20 the classical curve for the coefficient of hydraulic conductivity relationship is obtained. An interesting observation when comparing the two figures is that in the case of plotting the coefficient of hydraulic conductivity against water content (g/g) the transition from the linear part of the curve to the horizontal part, is smoother and not as sharp and sudden as in the case for the volumetric water content (cm^3/cm^3) plot.

11.4.4 General Comments

The curves obtained for the Gold Tailings and Clay have the typical expected shape. There is a slight variation of the coefficient of hydraulic conductivity at the horizontal part of the curve.

One problem which was encountered during the determination of the coefficients of hydraulic conductivity was which outflow values (Q_t) and time (t) values from the outflow curves should be used in equations 6.8 & 6.13. No clarification could be found in the literature and it was therefore decided to use the entire outflow curve and determine the average coefficient of hydraulic conductivity. It is however felt that this is not entirely correct as certain Q_t values of the outflow curves when entered into the mentioned equations, produce ultimate outflow values (Q_∞) less than outflow values (Q_t) measured at later times. This in turn affects the coefficient of hydraulic conductivity as it is directly proportional to the ultimate outflow value. Refer to figures 11.21 to 24 for a graphical description of the variation of the ultimate outflow values determined using an entire outflow curve.

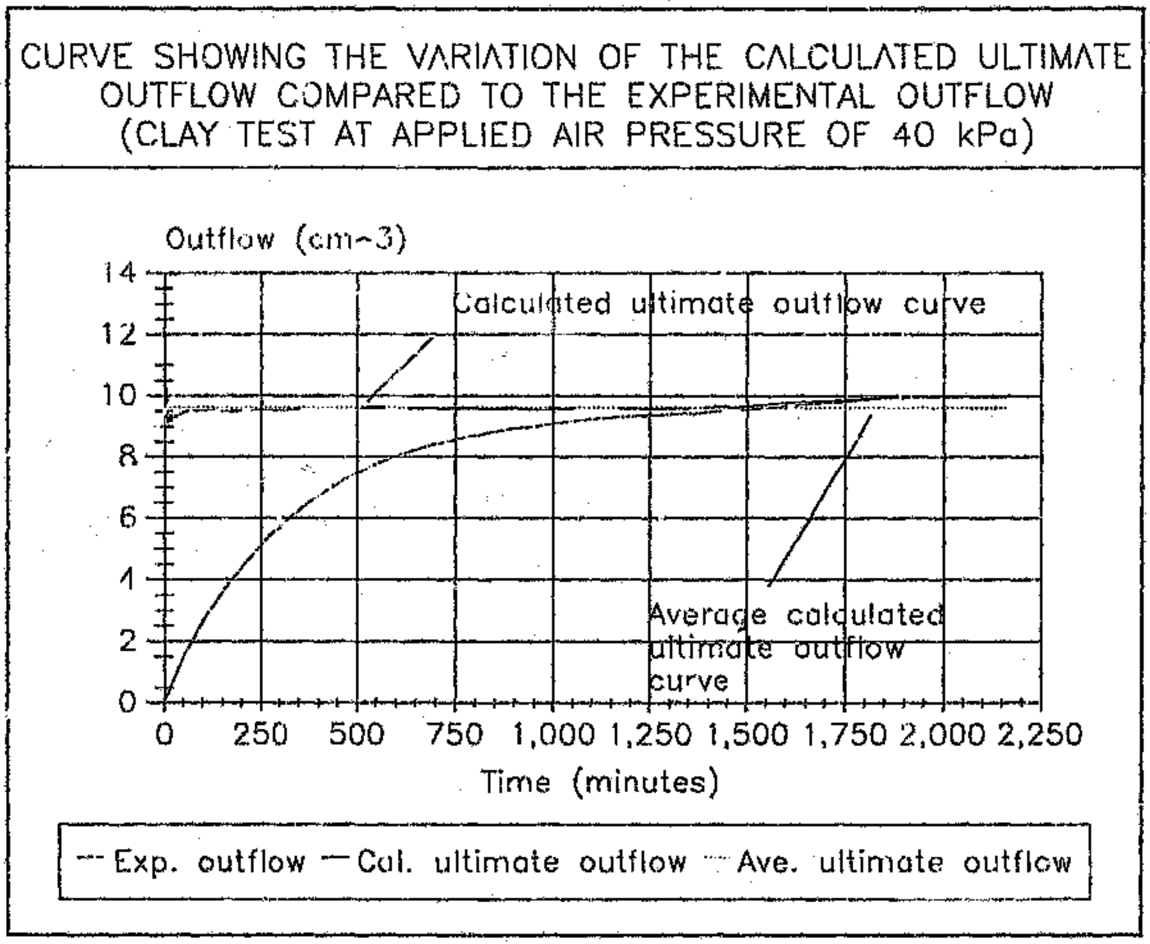


Figure 11.21 Graph comparing the calculated ultimate outflow to the experimental outflow curve

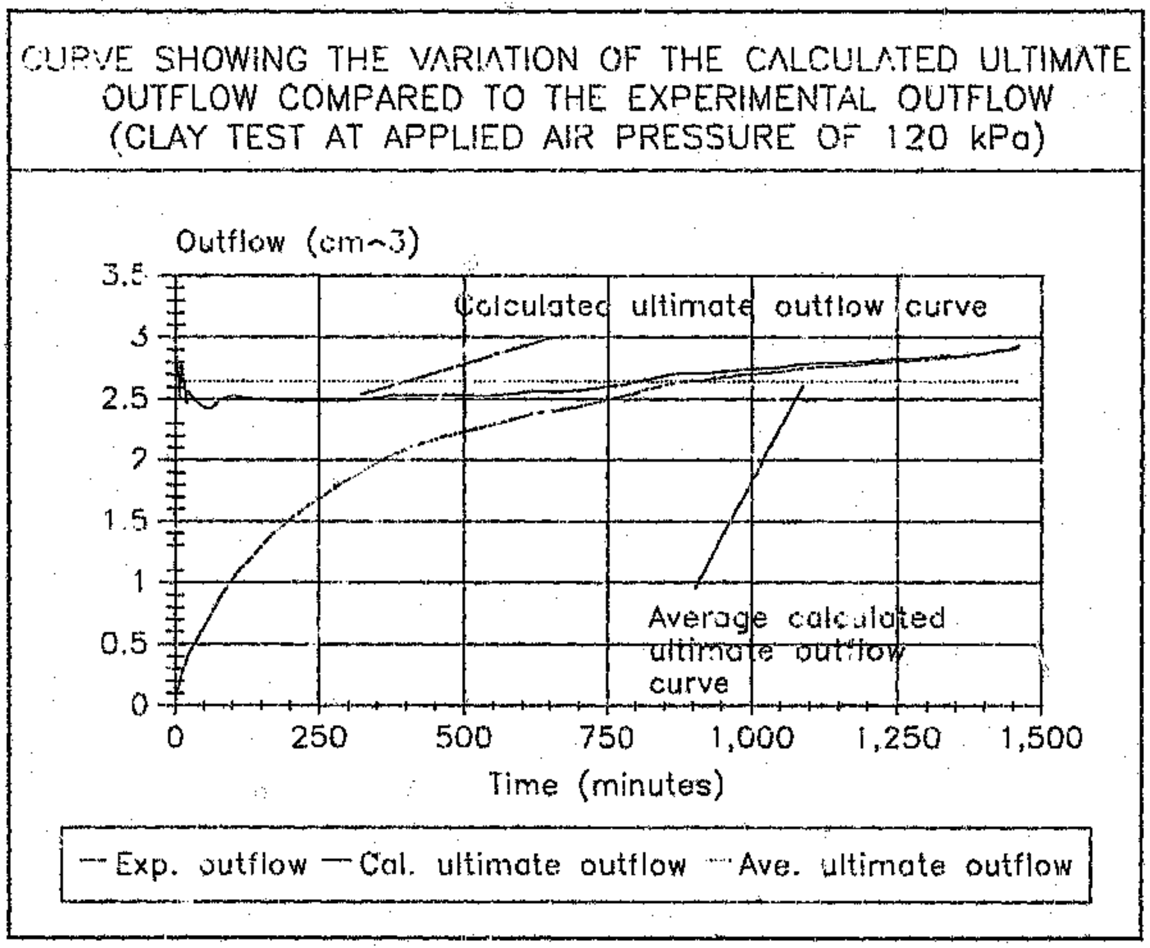


Figure 11.22 Graph comparing the calculated ultimate outflow curve to the experimental outflow curve

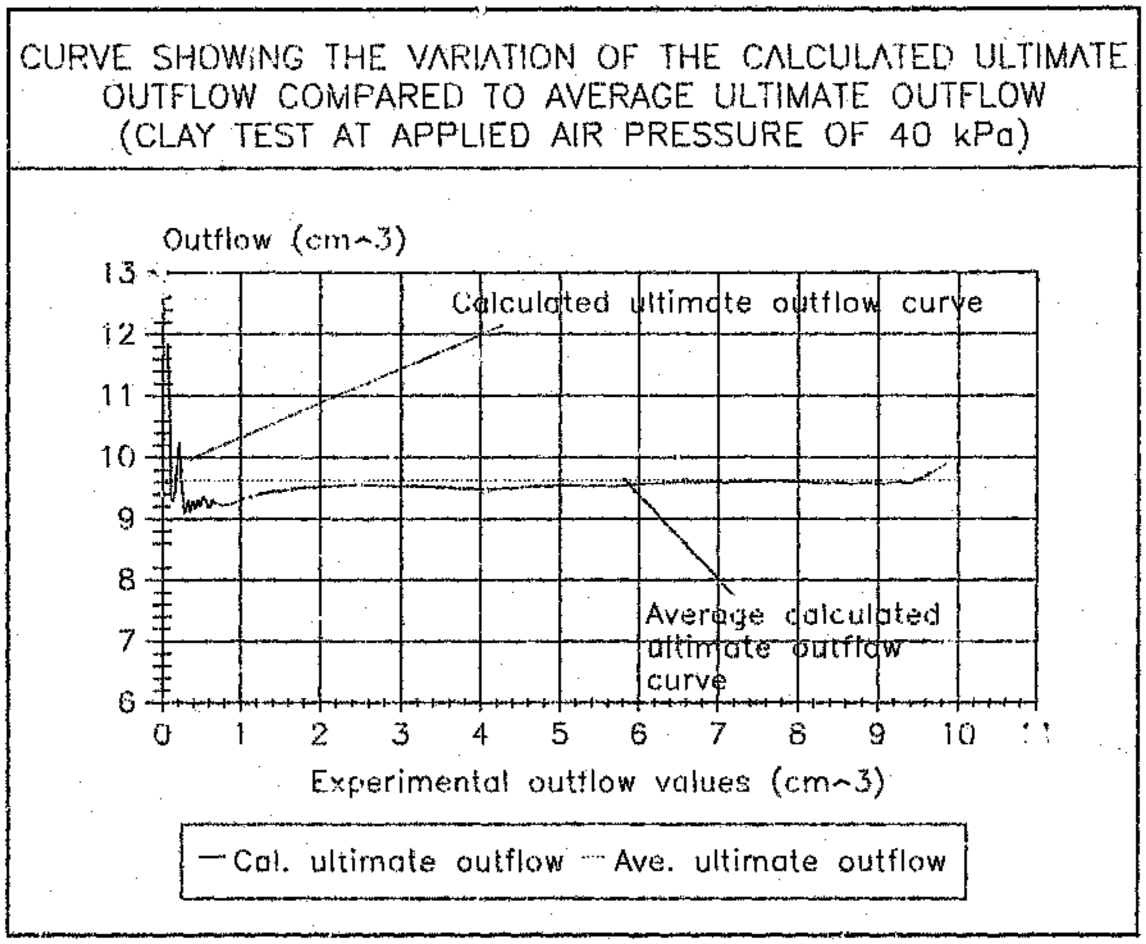


Figure 11.23 Graph comparing the calculated ultimate outflow curve to the averge calculated ultimate outflow

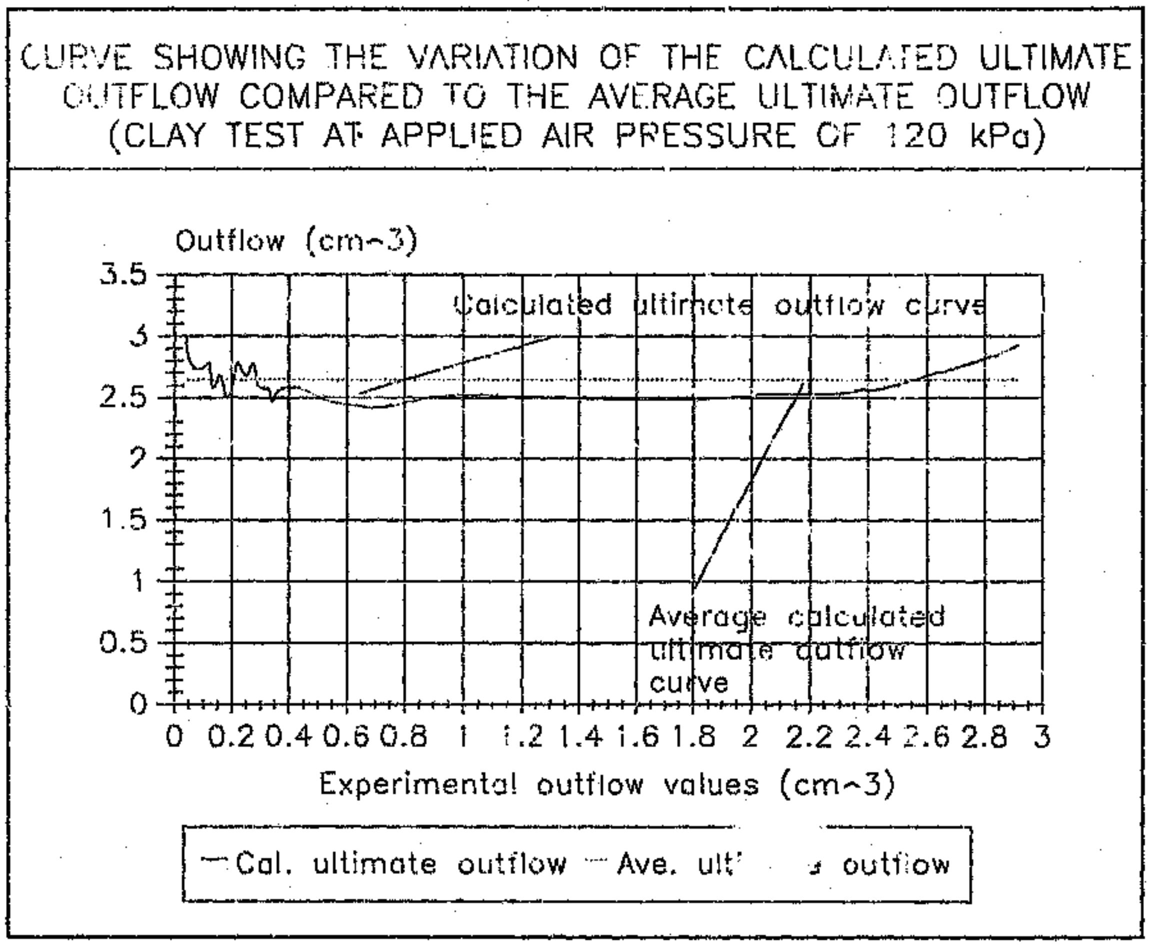


Figure 11.24 Graph comparing the calculated ultimate outflow curve to the averge calculated ultimate outflow

11.5 MODEL FITTING OF COEFFICIENTS OF HYDRAULIC CONDUCTIVITY CURVES

The van Genuchten model was fitted to the coefficients of hydraulic conductivity determined in section 11.3. The curve fitting programme mentioned in section 7.2.1 was used to fit the model to the experimental points.

11.5.1 Gold Tailings

In the case of the Gold Tailing test the number of points determined experimentally were too few to be able to determine the constants to the van Genuchten model. The least squares curve fitting programme required a minimum of six experimental points and only five point were obtained in the case of the Gold Tailings test.

11.5.2 Clay

In the case of the Clay test the van Genuchten model was fitted to the experimental points. Only the van Genuchten model using the restriction $m = 1-1/n$ was used for reasons explained in section 8.3. Table 11.12 highlights the most important results from the curve fitting analysis and figure 11.25 shows graphically how the model fits the experimental points.

It was only possible to fit the model to the curve of coefficients of hydraulic conductivity against volumetric water content. In the case of the curve of coefficients of hydraulic conductivity against water content (g/g) the curve fitting programme could not determine the constants to the van Genuchten model. The following reasons may have been the cause of the constants not being determined for the van Genuchten model :

(1) The nature of the least squares curve fitting programme and the type of mathematical procedure used to determine the constants.

(2) The experimental data points may be numerically not suitable for the curve fitting programme ie. they may cause the least squares programme to compute values that are too small or large for it.

(3) The variation (scatter) of the experimental points may be to large.

CLAY TEST	
	Suction versus volumetric water content
	m=1-1/n
SSE	6.031747139
SD	2.466119855

SSE : Sum of the Squares Error
SD : Standard Deviation

Table 11.12 Summary of curve fitting analysis for Clay.

Referring to figure 11.25 it appears that the model fits the experimental data reasonably well. This is however not totally correct. Referring to Appendix 8 with the detailed results of the curve fitting analysis it becomes apparent that there is a fairly large difference between the experimentally obtained coefficients of hydraulic and the values predicted by the model. One important factor to note here is that the model could only be fitted to the experimental points once they were converted to cm/year. The reason for this is not clear but it is thought it may be due to one of the first two reasons mentioned on the previous page. Most of the experimentally obtained points were also concentrated at the bottom "horizontal" part of the curve.

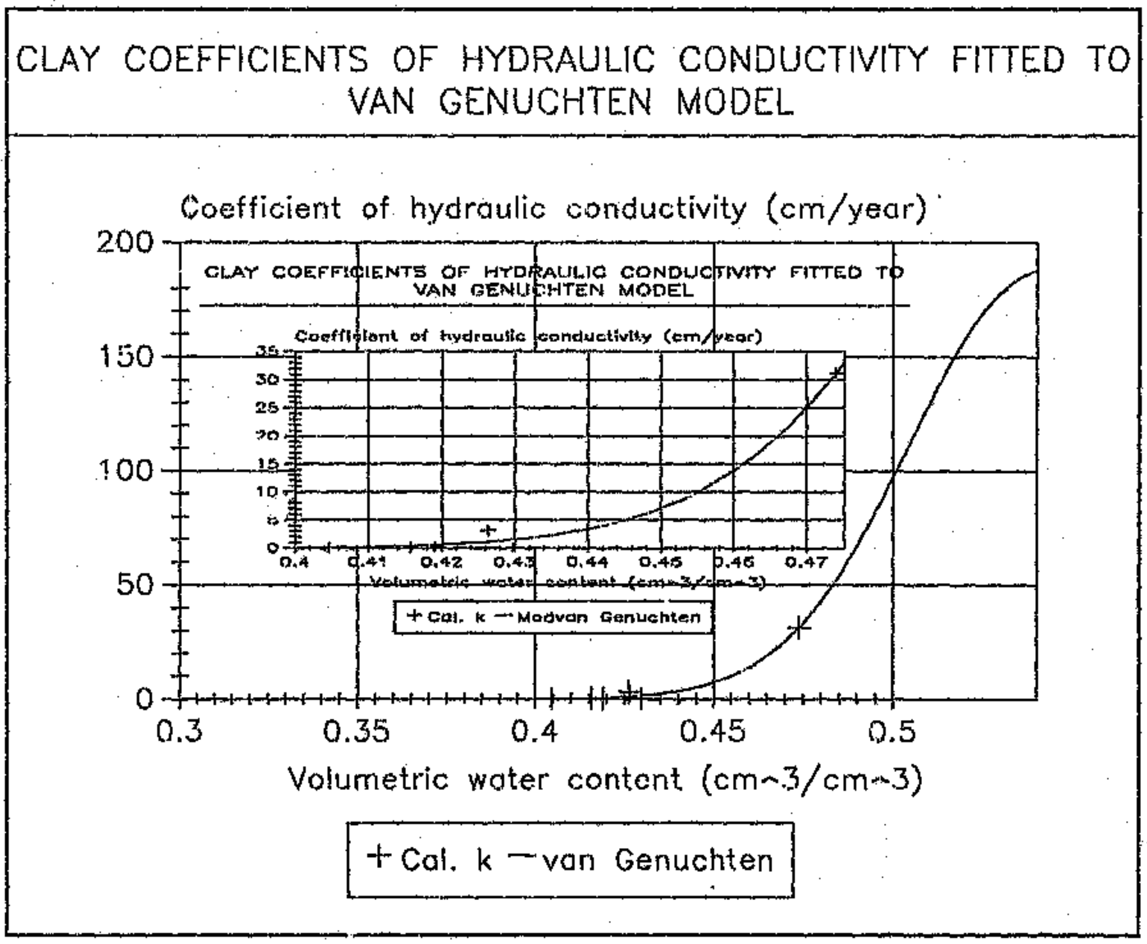


Figure 11.25 van Genuchten model fitted to Coefficients of hydraulic conductivity of Clay - volumetric water content

11.5.3 General Comments

In general the fitting of the model to the experimental values was not very satisfactory. It is thought that one of the problems may have been the curve fitting programme used. Other problems may have been the greater degree of variation or scatter in the data points, too few points obtained and that not a good spread of data points was obtained.

A point which becomes apparent when comparing the curve fitting constants of the van Genuchten model, for the coefficients of hydraulic conductivity function to that of the moisture retention curve of the clay, is that the constants which appear in both models are not numerically close at all. This may largely be due to the change in units of the coefficients of hydraulic conductivity, from cm/s to cm/year. It is however thought that a portion of this difference in the constants must be due to the curve fitting analysis. Refer to Appendix 8.

11.4.3 General Comments

In general the fitting of the model to the experimental values was not very satisfactory. It is thought that one of the problems may have been the curve fitting programme used. Other problems may have been the greater degree of variation or scatter in the data points, too few points obtained and that not a good spread of data points was obtained.

An point which becomes apparent when comparing the curve fitting constants of the van Genuchten model, for the coefficients of hydraulic conductivity function to that of the moisture retention curve of the clay, is that the constants which appear in both models are not numerically close at all. This may largely be due to the change in units of the coefficients of hydraulic conductivity, from cm/s to cm/year. Refer to Appendix 8 for further information on the curve fitting analysis.

CHAPTER 12

CONCLUSIONS AND RECOMMENDATIONS

(1) The manner in which the soil variables were monitored significantly improved the accuracy and convenience of testing. This was evident in:

- (i) the monitoring of the outflow rates, where extremely small outflows over small time intervals were required so as to accurately obtain the all important initial linear part of the outflow curves.
- (ii) the determination of equilibrium by monitoring the capillary pressure of the sample at a fixed saturation as opposed to monitoring outflow rates at a fixed applied air pressure, resulted in the point of equilibrium been identified with greater ease and certainty. Equilibration of the liquid pressure at a fixed saturation appears to be more rapid than equilibration by continuous drainage at a fixed applied pressure.
- (iii) as a result of the equipment used and the testing procedure adopted, test data could be recorded continuously and the time spent by the operator on actual testing was appreciably reduced.

(2) A possible disadvantage of the apparatus could be the initial cost of setting-up. However, with the exception of the differential pressure transducer, ceramic pressure plate and data logger, all the remaining equipment, or equally suitable alternatives, are available in most geotechnical laboratories.

(3) It is recommended that the apparatus be modified so as to be able to obtain a complete drying and wetting cycle of the soil sample using one set-up and the same soil sample throughout the test.

(4) The modifications introduced to Richards' (1965) analytical technique, greatly improves the accuracy of selecting the appropriate theoretical outflow curve for a particular experimental outflow curve.

However a possible drawback is the longer time period required to obtain the curve in terms of computer time. Although this could be improved with better programming techniques and hardware.

(5) Although the modified analytical technique used to calculate the coefficients of hydraulic conductivity provides an estimated value, from the results obtained it appears to produce the type of curves expected and mentioned in the literature. The major advantage of the technique over other traditional methods is the significant reduction in testing time and therefore cost.

(6) Clarification needs to be obtained as to which Q_t and time values of the experimental outflow curves should be substituted into equations 6.8 & 6.13 so as to obtain Q_∞ and k. Using the entire outflow curve and obtaining the average however appears to be acceptable as indicated by figures 11.21 to 11.24.

(7) The selection of the type of ceramic plate to be used in terms of its coefficient of hydraulic conductivity seems to be of critical importance, as mentioned in section 11.4.1. The ratio of coefficient of hydraulic conductivity of the plate to that of the soil sample tested affects the "a" value and slope of the outflow curve.

However, it is not clear whether it is this factor, or the magnitude of the applied air pressure increments, or both that affect the steepness of the outflow curve, which results in an "a" value too large for the theory to account for. It is therefore recommended that an investigation be conducted for determining which factors affect the slope of the outflow curves, and what suitable ratio of the coefficient of hydraulic of conductivity of plate to soil sample should be used.

(8) Due to the variation occurring between separate tests conducted on the same soil type, it is recommended that a statistical approach be implemented to describe the moisture retention curve and coefficients of hydraulic conductivity of a sample. Preferably an upper bound and lower bound curve should be obtained enclosing the region within which a certain percentage of the curves occur.

(9) It is suggested that a computer programme and technique be developed to superimpose the experimental and theoretical outflow curves, thereby determining t_{m} in a quicker and more accurate manner, than is currently done.

However, the technique currently used for superimposing the curves is superior in accuracy and clarity to the previous technique, as only one isolated theoretical curve is considered during superimposing, as opposed to a family of curves and interpolation between curves.

(10) The obtained curves appear to conform to the "typical" kind of curves expected, as mentioned in the literature. The curves should however be compared and tested with other testing techniques.

(11) The van Genuchten model was found to fit the moisture retention experimental data extremely well for the three soil samples tested. The approximation of m=1-1/n is acceptable. However the difference between the approximation of m=1-1/n and using m & n as independent constants appears to increase as the soil type moves from a clay to a gravel.

(12) No conclusion could be drawn about the van Genuchten model used to fit the coefficients of hydraulic conductivity relationship. It is however thought that a possible reason for not being able to fit the model to the experimental points could be the type of least squares curving fitting method (programme) used.

(13) It is recommended that where both moisture retention curve data and coefficients of hydraulic conductivity data are available a simultaneous fit of the van Genuchten model constants be performed. It should be noted that such a programme is available, and is described in van Genuchten (1992).

APPENDIX 1

CALIBRATION OF EQUIPMENT

DIFFERENTIAL PRESSURE TRANSDUCER CALIBRATION SUMMARY

ZERO PRESSURE (kPa)	SLOPE	ZERO CONSTANT	CONSTANT CALCULATED FROM REGRESSION ANALYSIS
0	3.875398	-3.64205	-4.6820692490119
10	3.859545	-6.22727	-5.0388979785432
20	3.860341	-5.125	-5.3957267080745
30	3.860682	-6.06818	-5.7525554376059
40	3.859205	-6.30682	-6.1093841671372
50	3.860455	-6.02273	-6.4662128966685
60	3.858409	-7.79545	-6.8230416261999
70	3.861818	-7.15909	-7.1798703557312
80	3.855	-7.47727	-7.5366990852626
90	3.863977	-7.82955	-7.8935278147939
100	3.85625	-8.10227	-8.2503565443252
110	3.8525	-8.45455	-8.6071852738566
120	3.856136	-8.04545	-8.9640140033879
130	3.854091	-9.06818	-9.3208427329193
140	3.857784	-10.608	-9.6776714624506
150	3.855455	-9.54545	-10.034500191982
160	3.85392	-10.6989	-10.391328921513
170	3.858523	-10.5341	-10.748157651045
180	3.854773	-9.79545	-11.104986380576
190	3.85125	-11.7386	-11.461815110107
200	3.856477	-12.8977	-11.818643839639
210	3.855455	-12.2909	-12.17547256917

AVERAGE SLOPE 3.85806564

LINEAR REGRESSION ANALYSIS OF ZERO POINTS

Regression Output:

Constant	-4.6820692490119
Std Err of Y Est	0.671683750172
R Squared	0.92590041670661
No. of Observations	22
Degrees of Freedom	20

X Coefficient(s)	-0.0356829
Std Err of Coef.	0.0022572

CALIBRATION OF DIFFERENTIAL PRESSURE TRANSDUCER

ZERO PRESSURE 0 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 10 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 20 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 30 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 40 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 50 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)
0	-7	0	-8	0	-7	0	-7	0	-7	0	-7
20	74	20	69	20	72	20	73	20	72	20	70
40	154	40	148	40	151	40	148	40	149	40	150
60	230	60	225	60	227	60	228	60	225	60	227
80	307	80	303	80	304	80	304	80	303	80	303
100	384	100	379	100	380	100	382	100	379	100	382
120	462	120	456	120	459	120	460	120	457	120	459
140	539	140	535	140	534	140	536	140	534	140	537
160	616	160	612	160	612	160	611	160	612	160	614
180	693	180	689	180	688	180	683	180	688	180	689
200	769	200	764	200	766	200	767	200	760	200	766
0	-8	0	-7	0	-8	0	-8	0	-8	0	-8
20	75	20	70	20	73	20	74	20	71	20	71
40	153	40	149	40	150	40	149	40	150	40	151
60	229	60	224	60	228	60	229	60	226	60	226
80	309	80	302	80	306	80	305	80	304	80	302
100	385	100	380	100	381	100	381	100	380	100	381
120	463	120	457	120	457	120	458	120	459	120	458
140	539	1 70	534	140	535	140	537	140	535	140	536
160	617	160	611	160	613	160	612	160	611	160	613
180	694	180	690	180	689	180	689	180	687	180	689
200	769	200	763	200	766	200	766	200	764	200	767
0	-7	0	-7	0	-7	0	-7	0	-7	0	-7
20	74	20	72	20	72	20	70	20	72	20	72
40	152	40	149	40	150	40	149	40	150	40	150
60	230	60	226	60	227	60	227	60	225	60	228
80	308	80	303	80	304	80	304	80	303	80	306
100	385	100	380	100	382	100	382	100	379	100	383
120	430	120	457	120	459	120	460	120	459	120	460
140	538	140	535	140	535	140	537	140	535	140	539
160	615	160	611	160	614	160	613	160	611	160	613
180	695	180	689	180	688	180	690	180	689	180	688
200	759	200	765	200	766	200	764	200	765	200	766
0	-8	0	-8	0	-8	0	-8	0	-8	0	-8
20	73	20	71	20	73	20	71	20	71	20	71
40	153	40	149	40	151	40	149	40	151	40	151
60	231	60	224	60	228	60	228	60	228	60	229
80	309	80	302	80	303	80	303	80	304	80	305
100	384	100	381	100	383	100	383	100	380	100	384
120	461	120	458	120	459	120	461	120	459	120	459
140	539	140	534	140	534	140	536	140	536	140	537
160	616	160	610	160	615	160	619	160	[illegible]	160	612
180	694	180	690	180	688	180	691	180	[illegible]	180	689
200	770	200	766	200	767	200	766	200	764	200	767
0	-7	0	-7	0	-7	0	-7	0	-7	0	-7
20	74	20	71	20	72	20	71	20	69	20	69
40	153	40	149	40	148	40	148	40	148	40	148
60	229	60	226	60	226	60	225	60	226	60	226
80	309	80	303	80	302	80	303	80	301	80	302
100	385	100	380	100	380	100	379	100	381	100	380
120	461	120	457	120	459	120	[illegible]	120	458	120	456
140	539	140	534	140	537	140	[illegible]	140	536	140	533
160	616	160	610	160	613	160	612	160	611	160	610
180	695	180	688	180	689	180	698	180	687	180	688
200	770	200	764	200	765	200	764	200	766	200	763
0	-9	0	-8	0	-8	0	-8	0	-8	0	-9
20	73	20	72	20	71	20	70	20	69	20	69
40	152	40	146	40	149	40	147	40	147	40	147
60	230	60	226	60	227	60	226	60	227	60	227
80	310	80	304	80	303	80	304	80	302	80	301
100	384	100	381	100	381	100	380	100	380	100	378
120	460	120	456	120	466	120	456	120	457	120	457
140	538	140	533	140	535	140	533	140	537	140	532
160	617	160	611	160	612	160	611	160	610	160	611
180	694	180	687	180	690	180	687	180	688	180	686
200	769	200	765	200	764	200	766	200	767	200	762
0	-7	0	-8	0	-6	0	-7	0	-8	0	-7
20	76	20	71	20	73	20	71	20	70	20	70
40	161	40	149	40	151	40	146	40	149	40	146
60	229	60	220	60	228	60	226	60	224	60	225
80	308	80	304	80	304	80	301	80	308	80	301
100	386	100	382	100	382	100	379	100	380	100	381
120	463	120	458	120	460	120	457	120	458	120	457
140	540	140	535	140	537	140	533	140	534	140	535
160	617	160	611	160	613	160	611	160	611	160	612
180	694	180	689	180	690	180	688	180	688	180	688
200	770	200	766	200	767	200	765	200	764	200	764
0	-8	0	-7	0	-7	0	-8	0	-7	0	-8
20	76	20	72	20	74	20	70	20	69	20	71
40	161	40	148	40	150	40	147	40	148	40	147
60	230	60	227	60	229	60	226	60	223	60	228
80	309	80	303	80	305	80	302	80	303	80	302
100	387	100	381	100	383	100	379	100	381	100	382
120	462	120	459	120	459	120	458	120	458	120	456
140	541	140	536	140	539	140	534	140	533	140	535
160	616	160	612	160	612	160	612	160	610	160	611
180	693	180	689	180	691	180	687	180	687	180	687
200	769	200	765	200	766	200	766	200	763	200	766

ZERO PRESSURE 60 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 70 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 80 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 90 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 100 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 150 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)
0	-9	0	-9	0	-9	0	-8	0	-9	0	-11
20	68	20	70	20	69	20	70	20	70	20	66
40	146	40	148	40	146	40	148	40	147	40	148
60	224	60	223	60	223	60	227	60	223	60	225
80	300	80	303	80	301	80	303	80	301	80	300
100	377	100	379	100	376	100	379	100	380	100	379
120	455	120	455	120	455	120	457	120	454	120	456
140	532	140	534	140	530	140	534	140	532	140	531
160	609	160	606	160	608	160	612	160	608	160	607
180	688	180	687	180	687	180	687	180	685	180	684
200	761	200	763	200	761	200	765	20C	763	200	761
0	-8	0	-10	0	-10	0	-9	0	-10	0	-12
20	67	20	71	20	68	20	71	20	69	20	67
40	146	40	149	40	144	40	147	40	146	40	147
60	225	60	224	60	222	60	226	60	224	60	226
80	300	80	304	80	302	80	302	80	302	80	301
100	378	100	380	100	377	100	380	100	381	100	380
120	454	120	454	120	454	120	456	120	455	120	457
140	533	[illegible]	533	140	531	140	535	140	533	140	532
160	610	[illegible]	609	160	607	160	613	160	609	160	608
180	667	180	686	180	688	180	683	180	686	180	685
200	762	200	764	200	762	200	766	200	762	200	762
0	-9	0	-10	0	-9	0	-8	0	-9	0	-11
20	70	20	69	20	69	20	72	20	70	20	68
40	148	40	147	40	147	40	149	40	148	40	146
60	225	60	224	60	224	60	228	60	225	60	222
80	303	80	300	80	300	80	303	80	302	80	300
100	380	100	377	100	377	100	380	100	379	100	378
120	456	120	456	120	457	120	459	120	455	120	454
140	533	140	534	140	533	140	536	140	534	140	531
160	609	160	608	160	610	160	612	160	610	160	609
180	686	180	687	180	685	180	687	180	687	180	684
200	764	200	763	200	763	200	766	200	764	200	761
0	-10	0	-11	0	-10	0	-9	0	-9	0	-12
20	69	20	68	20	68	20	73	20	71	20	69
40	149	40	146	40	146	40	149	40	147	40	147
60	225	60	225	60	226	60	227	60	226	60	223
80	304	80	301	80	301	80	304	80	303	80	301
100	381	100	378	100	378	100	379	100	379	100	379
120	456	120	456	120	456	120	460	120	456	120	455
140	534	140	535	140	532	140	535	140	533	140	532
160	608	160	609	160	600	160	613	160	609	160	610
180	686	180	689	180	686	180	689	180	686	180	686
200	763	200	764	200	762	200	767	200	763	200	762
0	-9	0	-8	0	-9	0	-10	0	-9	0	-10
20	70	20	70	20	70	20	67	20	67	20	66
40	144	40	147	40	147	40	144	40	145	40	143
60	225	60	226	60	224	60	223	60	223	60	220
80	302	80	302	80	302	80	300	80	299	80	299
100	377	100	380	100	380	100	378	100	379	100	376
120	455	120	456	120	456	120	456	120	453	120	453
140	534	140	534	140	534	140	533	140	532	140	529
160	609	160	612	160	610	160	609	160	610	160	606
180	687	180	688	180	686	180	687	180	686	180	679
200	763	200	766	200	762	200	762	200	760	200	759
0	-10	0	-9	0	-9	0	-9	0	-10	0	-11
20	71	20	71	20	71	20	68	20	68	20	67
40	145	40	149	40	148	40	146	40	146	40	144
60	224	60	227	60	225	60	222	60	221	60	221
80	301	80	303	80	303	80	301	80	300	80	300
100	378	100	379	100	381	100	379	100	378	100	378
120	464	120	459	120	459	120	464	120	454	120	464
140	533	140	533	140	536	140	534	140	531	140	530
160	610	160	613	160	609	160	607	160	609	160	606
180	686	180	687	180	687	180	686	180	686	180	680
200	764	200	764	200	761	200	761	200	761	200	760
0	-9	0	-9	0	-9	0	-9	0	-9	0	-10
20	69	20	72	20	70	20	69	20	69	[illegible]	66
-0	147	40	147	40	149	40	144	40	146	40	142
60	224	60	227	60	225	60	223	60	222	60	221
80	302	80	304	80	304	80	300	80	302	80	296
100	378	100	380	100	380	100	379	100	377	100	377
120	456	120	459	120	456	120	456	120	454	120	453
140	534	140	536	140	534	140	532	140	533	140	529
160	610	160	613	160	611	160	606	160	609	160	607
180	687	180	689	180	689	180	687	180	685	180	683
200	763	200	766	200	762	200	764	200	762	200	759
0	-10	0	-9	0	-8	0	-10	0	-10	0	-11
20	70	20	71	20	71	20	68	20	68	20	66
40	148	40	149	40	146	40	145	40	146	40	143
60	225	60	229	60	224	60	222	60	223	60	222
80	303	80	305	80	303	80	301	80	301	80	297
100	379	100	381	100	381	100	370	100	376	100	379
120	455	120	457	120	457	120	454	120	453	120	454
140	533	140	536	140	533	140	531	140	532	140	530
160	609	160	612	160	610	160	609	160	610	160	608
180	688	180	688	180	687	180	686	180	689	180	684
200	762	200	763	200	763	200	763	200	761	200	760

ZERO PRESSURE 160 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 170 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 180 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 190 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 200 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)	ZERO PRESSURE 210 kPa DIFFERENTIAL PRESURE (kPa)	VOLTS (Volts)
0	-11	0	-11	0	-11	0	-11	0	-13	0	-13
20	60	20	64	20	66	20	64	20	64	20	62
40	145	40	144	40	144	40	142	40	141	40	141
60	221	60	222	60	223	60	221	60	220	60	219
80	299	80	301	80	299	80	297	80	296	80	296
100	377	100	377	100	376	100	372	100	373	100	371
120	464	120	462	120	462	120	462	120	450	120	450
140	530	140	530	140	529	140	523	140	525	140	525
160	605	160	609	160	604	160	605	160	604	160	603
180	692	180	694	180	693	180	632	180	681	180	692
200	769	200	761	200	759	200	756	200	767	0	-14
0	-12	0	-12	0	-12	0	-12	0	-14	20	63
20	67	20	65	20	69	20	65	20	63	40	149
40	146	40	146	40	146	40	143	40	142	60	220
60	222	60	223	60	224	60	222	60	221	80	290
80	300	80	302	80	300	80	299	80	296	100	379
100	376	100	378	100	377	100	373	100	374	120	451
120	465	120	463	120	463	120	463	120	451	140	526
140	531	140	531	140	530	140	529	140	528	160	604
160	607	160	609	160	606	160	606	160	605	180	683
180	683	180	685	180	684	180	693	180	682	0	-13
200	760	200	762	200	760	200	757	200	758	20	65
0	-11	0	-11	0	-12	0	-12	0	-14	40	142
20	67	20	67	20	67	20	63	20	63	60	218
40	144	40	144	40	144	40	142	40	141	80	298
60	222	60	224	60	220	60	220	60	216	100	373
80	299	80	299	80	298	80	297	80	296	120	451
100	375	100	377	100	377	100	372	100	373	140	525
120	465	120	465	120	452	120	451	120	450	160	603
140	532	140	532	140	531	140	528	140	527	180	682
160	607	160	609	160	607	160	603	160	605	0	-14
180	683	180	683	180	683	180	680	180	680	20	66
200	769	200	761	200	759	200	756	200	767	40	143
0	-12	0	-12	0	-13	0	-13	0	-15	60	219
20	68	20	68	20	69	20	64	20	64	80	299
40	146	40	146	40	146	40	143	40	142	100	374
60	223	60	225	60	221	60	221	60	219	120	452
80	302	80	300	80	299	80	298	80	297	140	526
100	376	100	378	100	378	100	373	100	374	160	604
120	459	120	463	120	463	120	462	120	451	180	683
140	533	140	533	140	532	140	527	140	528	0	-12
160	608	160	610	160	609	160	604	160	606	20	64
180	684	180	684	180	684	180	681	180	681	40	143
200	760	200	762	200	760	200	757	200	759	60	220
0	-11	0	-11	0	-11	0	-11	0	-14	80	298
20	64	20	64	20	67	20	66	20	63	100	373
40	141	40	143	40	143	40	141	40	140	120	451
60	220	60	219	60	223	60	219	60	217	140	526
80	297	80	298	80	298	80	296	80	298	160	605
100	375	100	375	100	377	100	373	100	372	180	680
120	450	120	450	120	463	120	451	120	461	0	-14
140	527	140	527	140	632	140	527	140	526	20	65
160	605	160	604	160	600	160	604	160	604	40	144
180	682	180	681	180	683	180	681	180	681	60	221
200	763	200	759	200	760	200	758	200	757	80	297
0	-12	0	-12	0	-12	0	-12	0	-15	100	373
20	65	20	66	20	68	20	66	20	64	120	452
40	142	40	144	40	144	40	142	40	141	140	527
60	221	60	220	60	224	60	220	60	218	160	606
80	299	80	299	80	299	80	297	80	299	180	681
100	376	100	376	100	379	100	374	100	373	0	-13
120	451	120	451	120	454	120	452	120	452	20	59
140	526	140	528	140	533	140	529	140	527	40	142
160	605	160	605	160	610	160	605	160	605	60	219
180	683	180	682	180	684	180	682	180	682	80	298
200	757	200	760	200	761	200	759	200	758	100	373
0	-13	0	-11	0	-11	0	-12	0	-13	120	452
20	63	20	65	20	67	20	65	20	64	140	526
40	142	40	144	40	143	40	140	40	141	160	604
60	220	60	221	60	222	60	219	60	219	180	680
80	296	80	296	80	296	80	295	80	297	0	-14
100	374	100	373	100	378	100	372	100	372	20	67
120	451	120	451	120	452	120	451	120	451	40	143
140	527	140	529	140	529	140	529	140	528	60	220
160	606	160	606	160	605	160	604	160	603	80	299
180	680	180	683	180	683	180	681	180	679	100	374
200	759	200	760	200	760	200	759	200	757	120	453
0	-14	0	-12	0	-12	0	-13	0	-14	140	529
20	64	20	60	20	66	20	66	20	65	160	605
40	143	40	146	40	144	40	141	40	142	180	681
60	221	60	222	60	223	60	220	60	220		
80	297	80	297	80	299	80	296	80	298		
100	376	100	374	100	370	100	373	100	373		
120	452	120	452	120	453	120	452	120	452		
140	529	140	530	140	530	140	529	140	527		
160	606	160	605	160	606	160	605	160	604		
180	681	180	664	180	694	180	682	180	680		
200	757	200	760	200	761	200	759	200	759		

LINEAR REGRESSION ANAYSIS OF DIFFERENTIAL PRESSURE TRANSDUCER

ZERO PRESSURE 0 kPa

Regression Output:		
Constant		-3.64205
Std Err of Y Est		1.852164
R Squared		0.999944
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.8753977272727	
Std Err of Coef.	0.003121821 1297	

ZERO PRESSURE 10 kPa

Regression Output:		
Constant		-6.22727
Std Err of Y Est		1.019472
R Squared		0.999963
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.8595454545455	
Std Err of Coef.	0.0017183199604	

ZERO PRESSURE 100 kPa

Regression Output:		
Constant		-8.10227
Std Err of Y Est		1.303861
R Squared		0.999972
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.85625	
Std Err of Coef.	0.0021976568 45	

ZERO PRESSURE 150 kPa

Regression Output:		
Constant		-9.64545
Std Err of Y Est		1.860005
R Squared		0.999943
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.8554545454545	
Std Err of Coef.	0.0031350381732	

ZERO
PRESSURE 20 kPa

Regression Output:

Constant		-5.125
Std Err of Y Est		1.336569
R Squared		0.999971
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.8603409090909	
Std Err of Coef.	0.002252786463	

ZERO
PRESSURE 30 kPa

Regression Output:

Constant		-6.06818
Std Err of Y Est		1.569463
R Squared		0.99996
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.8606818181818	
Std Err of Coef.	0.0026453290366	

ZERO
PRESSURE 160 kPa

Regression Output:

Constant		-10.6989
Std Err of Y Est		1.76301
R Squared		0.999949
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.8539204545455	
Std Err of Coef.	0.0029715633905	

ZERO
PRESSURE 170 kPa

Regression Output:

Constant		-10.5341
Std Err of Y Est		1.743835
R Squared		0.99995
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.8585227272727	
Std Err of Coef.	0.0029392339878	

ZERO
PRESSURE 40 kPa

Regression Output:

Constant		-6.30682
Std Err of Y Est		1.260629
R Squared		0.999973
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.8592045454545	
Std Err of Coef.	0.0021584996965	

ZERO
PRESSURE 50 kPa

Regression Output:

Constant		-6.02273
Std Err of Y Est		1.821965
R Squared		0.999946
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.8604545454545	
Std Err of Coef.	0.00307092117943	

ZERO
PRESSURE 180 kPa

Regression Output:

Constant		-9.79545
Std Err of Y Est		1.442997
R Squared		0.999966
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.8547727272727	
Std Err of Coef.	0.0024321713403	

ZERO
PRESSURE 190 kPa

Regression Output:

Constant		-11.7386
Std Err of Y Est		1.132571
R Squared		0.999979
No. of Observations		88
Degrees of Freedom		86
X Coefficient(s)	3.85125	
Std Err of Coef.	0.00190894775714	

ZERO
PRESSURE 60 kPa

Regression Output:	
Constant	-7.795455
Std Err of Y Est	1.3247522
R Squared	0.9999712
No. of Observations	88
Degrees of Freedom	86
X Coefficient(s)	3.8584090909091
Std Err of Coef.	0.0022328693115118

ZERO
PRESSURE 70 kPa

Regression Output:	
Constant	-7.159091
Std Err of Y Est	1.5950173
R Squared	0.9999583
No. of Observations	88
Degrees of Freedom	86
X Coefficient(s)	3.8618181818182
Std Err of Coef.	0.0026884011904818

ZERO
PRESSURE 200 kPa

Regression Output:	
Constant	-12.89773
Std Err of Y Est	1.1600512
R Squared	0.9999779
No. of Observations	88
Degrees of Freedom	86
X Coefficient(s)	3.8564772727273
Std Err of Coef.	0.0019552659201178

ZERO
PRESSURE 210 kPa

Regression Output:	
Constant	-12.29091
Std Err of Y Est	1.3442444
R Squared	0.9999641
No. of Observations	80
Degrees of Freedom	78
X Coefficient(s)	3.8554545454545
Std Err of Coef.	0.0026162321152822

ZERO PRESSURE 80 kPa			ZERO PRESSURE 90 kPa		
	Regression Output:			Regression Output:	
Constant		-7.47727	Constant		-7.82955
Std Err of Y Est		1.490881	Std Err of Y Est		1.838929
R Squared		0.999963	R Squared		0.999945
No. of Observations		88	No. of Observations		88
Degrees of Freedom		86	Degrees of Freedom		86
X Coefficient(s)	3.855		X Coefficient(s)	3.863977	
Std Err of Coef.	0.002512880044034		Std Err of Coef.	0.0031	

CALIBRATION OF VOLUME GAUGE

VOLUME GAUGE READING (VOLTS)	INDIVIDUAL WATER DISPLACED (cm^3)	CUMULATIVE WATER DISPLACED (cm^3)
665	56.251	0
600	61.42	5.169
550	64.507	8.256
500	67.308	11.057
450	69.925	13.674
400	72.282	16.031
350	74.439	18.188
300	76.343	20.092
250	78.043	21.792
200	79.695	23.444
149	81.187	24.936
99	82.497	26.246
665	82.497	0
601	87.319	4.822
550	90.36	7.863
500	93.113	10.616
450	95.623	13.126
400	97.875	15.378
350	99.943	17.446
301	101.765	19.2[illegible]
250	103.4	20.[illegible]
200	105.042	22.545
150	106.504	24.007
101	107.853	25.356
664	107.853	0
601	112.74	4.887
549	115.803	7.95
501	118.513	10.66
450	121.044	13.191
400	123.349	15.496
350	125.444	17.591
300	127.309	19.456
251	128.951	21.098
201	130.639	22.786
150	132.104	24.251
100	133.426	25.573

CALIBRATION OF VOLUME GUAGE

Least-squares polynomial curve fit

Coefficients in least-squares approximation:

Order of polynomial: 4
  Coefficient 0: 2.7713161891803E+0001
  Coefficient 1: -1.4896207161354E-0002
  Coefficient 2: -5.8499845556095E-0005
  Coefficient 3: 8.5070490343384E-0008
  Coefficient 4: -8.6599056642955E-0011

Variance : 3.1173686E+0000
Standard deviation : 3.1711240E-0001

	volts	volume (cm^3) obs	calc	obs - calc
1	6.6500000E+0002	0.0000000E+0000	1.9216352E-0002	1.9216352E-0002
2	6.0000000E+0002	5.1690000E+0000	4.8676110E+0000	-3.0137903E-0001
3	5.5000000E+0002	8.2560000E+0000	8.0533841E+0000	-2.0261592E-0001
4	5.0000000E+0002	1.1057000E+0001	1.0861530E+0001	-1.9547033E-0001
5	4.5000000E+0002	1.3674000E+0001	1.3364637E+0001	-3.0936318E-0001
6	4.0000000E+0002	1.6031000E+0001	1.5622305E+0001	-4.0869513E-0001
7	3.5000000E+0002	1.8188000E+0001	1.7681143E+0001	-5.0685651E-0001
8	3.0000000E+0002	2.0092000E+0001	1.9574773E+0001	-5.1722738E-0001
9	2.5000000E+0002	2.1792000E+0001	2.1323823E+0001	-4.6817749E-0001
10	2.0000000E+0002	2.3444000E+0001	2.2935934E+0001	-5.0806633E-0001
11	1.4900000E+0002	2.4936000E+0001	2.4433598E+0001	-5.0240203E-0001
12	9.9000000E+0001	2.6246000E+0001	2.5739306E+0001	-5.0669437E-0001
13	6.6500000E+0002	0.0000000E+0000	1.9216352E-0002	1.9216352E-0002
14	6.0100000E+0002	4.8220000E+0000	4.7994778E+0000	-2.2522193E-0002
15	5.5000000E+0002	7.8630000E+0000	8.0533841E+0000	1.9038408E-0001
16	4.5000000E+0002	1.3126000E+0001	1.3364637E+0001	2.3863682E-0001
17	5.0000000E+0002	1.0616000E+0001	1.0861530E+0001	2.4552967E-0001
18	4.0000000E+0002	1.5378000E+0001	1.5622305E+0001	2.4430487E-0001
19	3.5000000E+0002	1.7446000E+0001	1.7681143E+0001	2.3514349E-0001
20	3.0100000E+0002	1.9268000E+0001	1.9538364E+0001	2.7036423E-0001
21	2.5000000E+0002	2.0903000E+0001	2.1323823E+0001	4.2082251E-0001
22	2.0000000E+0002	2.2545000E+0001	2.2935934E+0001	3.9093337E-0001
23	1.5000000E+0002	2.4007000E+0001	2.4405757E+0001	3.9875693E-0001
24	1.0100000E+0002	2.5356000E+0001	2.5690525E+0001	3.3452483E-0001
25	6.6400000E+0002	0.0000000E+0000	1.0080494E-0001	1.0080494E-0001
26	6.0100000E+0002	4.8870000E+0000	4.7994778E+0000	-8.7522193E-0002
27	5.4900000E+0002	7.9500000E+0000	8.1129845E+0000	1.6298445E-0001
28	5.0100000E+0002	1.0660000E+0001	1.0808577E+0001	1.4857658E-0001
29	4.5000000E+0002	1.3191000E+0001	1.3364637E+0001	1.7363682E-0001
30	4.0000000E+0002	1.5496000E+0001	1.5622305E+0001	1.2630487E-0001
31	3.5000000E+0002	1.7591000E+0001	1.7681143E+0001	9.0143491E-0002
32	3.0000000E+0002	1.9456000E+0001	1.9574773E+0001	1.1877262E-0001
33	2.5100000E+0002	2.1098000E+0001	2.1290188E+0001	1.9218754E-0001
34	2.0100000E+0002	2.2786000E+0001	2.2905047E+0001	1.1904662E-0001
35	1.5000000E+0002	2.4251000E+0001	2.4405757E+0001	1.5475693E-0001
36	1.0000000E+0002	2.6573000E+0001	2.5714953E+0001	1.4195340E-0001

CALIBRATION OF OUTFLOW GAUGE

BELLOWS DIAPHRAGM MOVEMENT

POSITVE TO NEGATIVE VOLTS / NEGATIVE TO POSITVE

TURNS OF SCREW CYLINDER	VOLT READING	INDIVIDUAL VOLTS READING	CUMULATIVE VOLT READING	CUMULATIVE VOLUME (cm^3)	TURNS OF SCREW CYLINDER	VOLT READING	INDIVIDUAL VOLTS READING	CUMULATIVE VOLT READING	CUMULATIVE VOLUME (cm^3)
0	2222	0	0	0	0	-2990	0	0	0
10	1152	1070	1070	13.823	10	-1923	-1067	-1067	13.70313
20	102	1050	2120	27.646	20	-893	-1030	-2097	27.40626
30	-934	1036	3156	41.469	30	144	-1037	-3124	41.10939
40	-1966	1032	4188	55.292	40	1192	-1048	-4172	54.81252
60	-3032	1066	5254	69.115	0	-2956	0	0	0
0	1948	0	0	0	10	-1908	-1048	-1048	13.70313
,0	896	1052	1052	13.823	20	-874	-1034	-2082	27.40626
20	-148	1044	2096	27.646	30	164	-1038	-3120	41.10939
30	-1179	1031	3127	41.469	40	1208	-1044	-4164	54.81252
40	-2217	1038	4165	55.292	50	2261	-1053	-5217	68.51565
0	2243	0	0	0	0	-2977	0	0	0
10	1202	1041	1041	13.823	10	-1930	-1047	-1047	13.70313
20	153	1049	2090	27.646	20	-894	-1036	-2083	27.40626
30	-884	1037	3127	41.469	30	145	-1039	-3122	41.10939
40	-1914	1030	4157	3..732	40	1187	-1042	-4164	54.81252
60	-2974	1060	5217	69.115	50	2232	-1045	-5209	68.51565

CALIBRATION OF SCREW CONTROL CYLINDER

No. OF TURNS	CUMULATIVE OUTFLOW (cm^3)				No. OF TURNS	CUMULATIVE OUTFLOW (cm^3)
0	0				0	0
10	13.967				10	13.678
20	27.996				20	27.053
30	41.613				30	41.124
40	55.041				40	54.66

LINEAR REGRESSION ANALYSIS OF SCREW CONTROL CYLINDER

Regression Output:

Constant		0
Std Err of Y Est		0.236560774
R Squared		0.999862005
No. of Observations		6
Degrees of Freedom		4
X Coefficient(s)	1.3632	
Std Err of Coef.	0.004316369	

Regression Output:

Constant		0
Std Err of Y Est		0.073257195
R Squared		0.999986609
No. of Observations		5
Degrees of Freedom		4
X Coefficient(s)	1.370213333	
Std Err of Coef.	0.001337487	

LINEAR REGRESSION ANALYSIS OF OUTFLOW GAUGE

Regression Output:

Constant		0
Std Err of Y Est		0.20495604
R Squared		0.999923336
No. of Observations		17
Degrees of Freedom		16
X Coefficient(s)	0.013219	
Std Err of Coef.	1.65646E-05	

Regression Output:

Constant		0
Std Err of Y Est		0.070041069
R Squared		0.99999089
No. of Observations		17
Degrees of Freedom		16
X Coefficient(s)	-0.0131604	
Std Err of Coef.	5.69079E-06	

APPENDIX 2

DETERMINATION OF A SUITABLE MATHEMATICAL MODEL

MATHEMATICAL MODELS CONSIDERED

BRUTSAERT MODEL

$$S_e = \frac{A}{A+h^{\beta}}$$

where :

S_e	= effective degree of saturation or reduced water content
h	= capillary pressure without the negative sign (cm)
β,A	= empirical constants affecting shape of the curve

For further details on the model refer to El-Kadi (1984).

FERMI MODEL

$$S_e = \frac{1}{1+\exp[\frac{(P_c-P_{c1/2})}{\beta}]}$$

where :

S_e	= effective degree of saturation or reduced water content
P	= capillary pressure without the negative sign (cm)
β,A	= empirical constants affecting shape of the curve

For further details on the model refer to Bumb et al. (1992)

VAN GENUCHTEN MODEL

$$S_e = [1+(\alpha h)^n]^{-m} \quad \text{where} \quad S_e = \frac{\theta-\theta_r}{\theta_s-\theta_r}$$

where :

S_e = effective degree of saturation or reduced water content

θ = volumetric (cm^3/cm^3) or water content (g/g)

θ_r = residual volumetric (cm^3/cm^3) or water content (g/g)

θ_s = saturated volumetric (cm^3/cm^3) or water content (g/g)

h = capillary pressure without the negative sign (cm)

n,m,α = empirical constants affecting shape of the curve

For further details on the model refer to van Genuchten et al. (1992)

CURVE FITTING ANALYSIS - CAPILLARY PRESSURE VS VOLUMETRIC WATER CONTENT

	CONSTANTS B1	B2	B3	B4
VAN GENUCHTEN MODEL	0.3948857	0.12599954	0.001161	3.325624
FERMI MODEL	0.41910357	0.13318345	699.1574	208.5074
BRUSTAERT MODEL	0.42912787	0.084550762	1708371	2.183507

VOLUMETRIC WATER CONTENT				
CAPILLARY PRESSURE (cm)	VAN GENUCHTEN MODEL	FERMI MODEL	BRUSTAERT MODEL	DATA POINTS
0	0.3948867	0.409442	0.42912787	
50	0.3948356051	0.406935	0.4280968	
100	0.3945542244	0.403814	0.424493	
150	0.3936665688	0.399948	0.41810454	
200	0.3917611559	0.395191	0.40902996	
250	0.388412699	0.389384	0.39756731	0.38[illegible]
300	0.3832273261	0.382365	0.3841482	
350	0.3756947738	0.37398	0.36927464	
400	0.3652413906	0.364104	0.35346142	
450	0.3542727587	0.352663	0.33719[illegible]	
500	0.3401932872	0.339661	0.32087893	
550	0.3243938666	0.325203	0.30486589	
600	0.3074068924	0.30951	0.28940749	
650	0.2898379114	0.292918	0.27468328	
700	0.2722903184	0.275855	0.26[illegible]80669	
750	0.2552990157	0.2588	0.24783768	
800	0.2392868553	0.242231	0.23579504	
850	0.2245446344	0.226575	0.22466758	0.229665
900	0.2112366622	0.212163	0.21442335	
950	0.19[illegible]17435	0.199212	0.205[illegible]707	
980	0.1930311577	0.19219	0.19975364	0.186158
1000	0.18905812	0.187825	0.1963957	
1050	0.1800729746	0.178	0.18850258	
1100	0.1723424301	0.169664	0.18128031	
1150	0.1657312946	0.162688	0.17467276	
1200	0.1601017257	0.15692	0.16862628	
1250	0.1553216523	0.152195	0.16309046	
1260	0.1544566703	0.151362	0.16204039	0.158562
1300	0.1512696316	0.148357	0.15801853	
1350	0.1478371483	0.145258	0.15336749	
1400	0.1449292056	0.14277	0.14909804	
1450	0.1424638677	0.14078	0.14517448	
1500	0.1403712206	0.139195	0.14156448	
1550	0.138592069	0.137934	0.13823881	
1600	0.1370765648	0.136935	0.13517114	
1650	0.1357828954	0.136143	0.13233776	
1700	0.1346760223	0.135517	0.12971732	
1750	0.1337287074	0.135023	0.12729062	
1800	0.1329104812	0.134633	0.12504037	
1850	0.1322068977	0.134325	0.12295102	
1860	0.1320781408	0.134272	0.1225512	0.130935
1900	0.1315988524	0.134082	0.12100856	
1950	0.1310720192	0.133891	0.11920037	
2000	0.130614381	0.133741	0.11751506	
2050	0.1302158401	0.133622	0.11594237	
2100	0.1298678953	0.133529	0.11447299	

CURVE FITTING ANALYSIS - CAPILLARY PRESSURE VS WATER CONTENT

	CONSTANTS			
	B1	B2	B3	B4
VAN GENUCHTEN MODEL	0.34392381	0.10616672	0.001018	2.844257
FERMI MODEL	0.37256766	0.10960869	654.0574	228.125
BRUSTAERT MODEL	0.37013261	0.071449111	1435454	2.1702

WATER CONTENT				
CAPILLARY PRESSURE (cm)	VAN GENUCHTEN MODEL	FERMI MODEL	BRUSTAERT MODEL	DATA POINTS
0	0.34392381	0.358419	0.37013261	
50	0.343817694	0.355182	0.35912369	
100	0.343162578	0.351266	0.36584467	
150	0.341524111	0.346562	0.35953786	
200	0.338535593	0.340956	0.35094247	
250	0.333909038	0.334336	0.34018597	0.334253
300	0.327450893	0.326604	0.32771462	
350	0.319092607	0.317691	0.31402776	
400	0.308891638	0.307568	0.29962056	
450	0.297036359	0.296262	0.2849413	0.296216
500	0.283828239	0.28387	0.2703656	
550	0.269651856	0.270566	0.25618819	
600	0.254935724	0.256594	0.24261459	
650	0.240110719	0.242257	0.22979008	
700	0.225572844	0.227893	0.21779213	
750	0.211855437	0.21384	0.20665384	
800	0.198613262	0.200409	0.19637399	
850	0.186618253	0.187856	0.18692756	0.191217
900	0.175764675	0.176365	0.17827403	
950	0.166080518	0.166046	0.17036373	
980	0.160823121	0.160435	0.16595185	0.15411
1000	0.157541905	0.156937	0.1631425	
1050	0.15008789	0.149018	0.15655493	
1100	0.143633877	0.142223	0.1505466	
1150	0.138082709	0.136459	0.14506543	
1200	0.133333152	0.131617	0.14006257	
1250	0.129285891	0.127581	0.13549276	
1260	0.128552354	0.126861	0.13462704	0.131975
1300	0.125847427	0.124241	0.1313145	
1350	0.122932312	0.121491	0.12749001	
1400	0.120464166	0.119238	0.12398508	
1450	0.118375855	0.117399	0.12076886	
1500	0.116609128	0.115902	0.11781356	
1550	0.11511394	0.114687	0.11509426	
1600	0.113847628	0.113703	0.11258858	
1650	0.112774017	0.112909	0.11027646	
1700	0.111862589	0.112265	0.10813992	
1750	0.111087657	0.111746	0.10616285	
1800	0.110427659	0.111328	0.10433078	
1850	0.109864516	0.110992	0.102[illegible]3076	
1860	0.109762131	0.110933	0.10230655	0.108911
1900	0.109383083	0.110721	0.10105111	
1950	0.108970672	0.110503	0.09958138	
2000	0.108616654	0.110327	0.09821212	
2050	0.108312119	0.110186	0.09693486	
2100	0.1[illegible]804959	0.110073	0.0957419	

RESULTS FROM CURVE FITTING ANALYSIS USING VAN GENUCHTEN MODEL
CAPILLARY PRESSURE- VOLUMETRIC WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(b5)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations =1000
Number of data points = 6
Total number of parameters = 5
Number of parameters to be varied = 5

Initial estimates:
b 1 = 4.00000000E-0001 b 2 = 1.00000000E-0001 b 3 = 1.00000000E-0003
b 4 = 4.00000000E+0000 b 5 = 1.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 4
Number of data points = 6
Sum of squares of errors = 1.076679376E-0004
Total number of parameters = 5
Number of parameters varied = 5
Estimated standard deviation = 1.037631619E-0002

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 3.9486670E-0001 (1.735E-0002) b 2 = 1.2699954E-0001 (2.307E-0002)
b 3 = 1.1607187E-0003 (9.837E-0004) b 4 = 3.3256239E+0000 (1.644E+0000)
b 5 = 1.5055140E+0000 (3.231E+0000)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC WATER CONTENT (cm^3/cm^3)

	x	y obs	calc	obs - calc
1	2.5000000E+0002	3.8889000E-0001	3.8841270E-0001	4.7729727E-0004
2	4.5000000E+0002	3.5323600E-0001	3.5427276E-0001	-1.0367594E-0003
3	6.5000000E+0002	2.2966500E-0001	2.2454463E-0001	5.1203669E-0003
4	9.8000000E+0002	1.8515800E-0001	1.9303116E-0001	-7.8731559E-0003
5	1.2600000E+0003	1.5856200E-0001	1.5445667E-0001	4.1053315E-0003
6	1.8600000E+0003	1.3093500E-0001	1.3207814E-0001	-1.1431390E-0003

RESULTS FROM CURVE FITTING ANALYSIS USING VAN GENUCHTEN MODEL
CAPILLARY PRESSURE - WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(b5)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations =1000
Number of data points = 6
Total number of parameters = 5
Number of parameters to be varied = 5

Initial estimates:
b 1 = 4.00000000E-0001 b 2 = 1.00000000E-0001 b 3 = 1.00000000E-0003
b 4 = 3.00000000E+0000 b 5 = 2.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 4
Number of data points = 6
Sum of squares of errors = 7.944538408E-0005
Total number of parameters = 5
Number of parameters varied = 5
Estimated standard deviation = 8.913214015E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 3.4392381E-0001 (1.920E-0002) b 2 = 1.0616672E-0001 (1.942E-0002)
b 3 = 1.0179548E-0003 (1.320E-0003) b 4 = 2.8442668E+0000 (1.510E+0000)
b 5 = 2.1315353E+0000 (6.079E+0000)

x = CAPILLARY PRESSURE (cm)
y = WATER CONTENT (g/g)

	x	y obs	calc	obs - calc
1	2.5000000E+0002	3.3425300E-0001	3.3390804E-0001	3.4496305E-0004
2	4.5000000E+0002	2.9621600E-0001	2.9703636E-0001	-8.2035909E-0004
3	8.5000000E+0002	1.9121700E-0001	1.8661826E-0001	4.5987432E-0003
4	9.8000000E+0002	1.5411000E-0001	1.6082313E-0001	-6.7131252E-0003
5	1.2600000E+0003	1.3197500E-0001	1.2855236E-0001	3.4226415E-0003
6	1.8600000E+0003	1.0891100E-0001	1.0976214E-0001	-8.5113521E-0004

RESULTS FROM CURVE FITTING ANALYSIS USING FERMI MODEL
CAPILLARY PRESSURE - VOLUMETRIC WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

FUNCTION:
(b1-b2)*(1/(1+exp((x-b3)/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations = 100
Number of data points = 6
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 4.19103553E-0001 b 2 = 1.33183453E-0001 b 3 = 6.99157463E+0002
b 4 = 2.08507367E+0002

Step length = 1.000000000E-0003
Number of iterations = 4
Number of data points = 6
Sum of squares of errors = 1.225461421E-0004
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 7.827711739E-0003

(Not converging further)

Final set of parameters (and estimated standard deviations):

b 1 = 4.1910357E-0001 (2.358E-0002) b 2 = 1.3318345E-0001 (7.608E-0003)
b 3 = 6.9915744E+0002 (5.227E+0001) b 4 = 2.0850739E+0002 (3.600E+0001)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC WATER CONTENT (cm^3/cm^3)

	x	y obs	calc	obs - calc
1	2.5000000E+0002	3.8889000E-0001	3.8938403E-0001	-4.9402870E-0004
2	4.5000000E+0002	3.5323600E-0001	3.5266331E-0001	5.7268911E-0004
3	8.5000000E+0002	2.2966500E-0001	2.2657524E-0001	3.0897606E-0003
4	9.8000000E+0002	1.8515800E-0001	1.9219008E-0001	-7.0320832E-0003
5	1.2600000E+0003	1.5856200E-0001	1.5136171E-0001	7.2002909E-0003
6	1.8600000E+0003	1.3093500E-0001	1.3427163E-0001	-3.3366303E-0003

RESULTS FROM CURVE FITTING ANALYSIS USING BRUSTRAET MODEL
CAPILLRY PRESSURE - VOLUMETRIC WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

FUNCTION:
(b1-b2)*(b3/(b3+(x)^b4))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations =1000
Number of data points = 6
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 5.63342313E-0001 b 2 =-5.75906662E-0002 b 3 = 6.50150629E+0002
b 4 = 9.88748764E-0001

Step length = 1.000000000E-0003
Number of iterations = 244
Number of data points = 6
Sum of squares of errors = 6.531577816E-0004
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 1.807149387E-0002

(Not converging further)

Final set of parameters (and estimated standard deviations):

b 1 = 4.2912787E-0001 (2.884E-0003) b 2 = 8.4550762E-0002 (3.035E-0003)
b 3 = 1.7083707E+0006 (6.265E+0005) b 4 = 2.1836074E+0000 (5.544E-0002)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC WATER CONTENT (cm^3/cm^3)

	x	y obs	calc	obs - calc
1	2.5000000E+0002	3.8889000E-0001	3.9756731E-0001	-8.6773149E-0003
2	4.5000000E+0002	3.5323600E-0001	3.3719021E-0001	1.6045786E-0002
3	6.5000000E+0002	2.2966500E-0001	2.2466760E-0001	4.9974021E-0003
4	9.8000000E+0002	1.8515800E-0001	1.9975366E-0001	-1.4595664E-0002
5	1.2600000E+0003	1.5856200E-0001	1.6204041E-0001	-3.4784077E-0003
6	1.8600000E+0003	1.3093500E-0001	1.2255121E-0001	8.3837931E-0003

RESULTS FROM CURVE FITTING ANALYSIS USING BRUSTRAET MODEL
CAPILLARY PRESSURE - WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

FUNCTION:
(b1-b2)*(b3/(b3+(x)^b4))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations =1000
Number of data points = 6
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 4.89996744E-0001 b 2 =-3.41534880E-0002 b 3 = 6.95343814E+0002
b 4 = 1.01835724E+0000

Step length = 1.000000000E-0003
Number of iterations = 250
Number of data points = 6
Sum of squares of errors = 3.716130590E-0004
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 1.363108688E-0002

(Not converging further)

Final set of parameters (and estimated standard deviations):

b 1 = 3.7013261E-0001 (2.356E-0003) b 2 = 7.1449111E-0002 (2.243E-0003)
b 3 = 1.4354541E+0006 (4.648E+0005) b 4 = 2.1702003E+0000 (4.896E-0002)

x = CAPILLARY PRESSURE (cm)
y = WATER CONTENT (g/g)

	x	y obs	calc	obs - calc
1	2.5000000E+0002	3.3425300E-0001	3.4018596E-0001	-5.9329641E-0003
2	4.5000000E+0002	2.9621600E-0001	2.8494129E-0001	1.1274712E-0002
3	6.5000000E+0002	1.9121700E-0001	1.8692754E-0001	4.2894610E-0003
4	9.8000000E+0002	1.5411000E-0001	1.6595183E-0001	-1.1841935E-0002
5	1.2600000E+0003	1.3197500E-0001	1.3462703E-0001	-2.6520298E-0003
6	1.8600000E+0003	1.0891100E-0001	1.0230554E-0001	6.6054582E-0003

APPENDIX 3

COMPLETE TEST RESULTS OF ASH TEST 1,2 & 3

ASH TEST 1

SUMMARY OF RESULTS

SAMPLE: ASH TAILINGS TEST1

DIMENSIONS IN cm AND g

								AVERAGE
DIAMETER		7.03	7.075	6.91				7.005
LENGTH		3.085	3.115	3.07				3.09
S GRAVITY		2.192239	2.199338	2.199721	2.126009	2.164744		2.17641

FINAL VOLUME T	119.0871
VOLUME SOIL	63.78991

BOWL	189.835
WET SOIL & BOWL	345.548
DRY SOIL & BOWL	328.668
WATER CONT.	0.12158492577
VOLM CONT.	0.14174501762

APPLIED PRESSURE kPa	VOLUME volts	VOLUME cm^3	TOTAL VOLUME cm^3	FLOW INITIAL volts	FINAL volts	ACTUAL FLOW cm^3	TOTAL FLOW cm^3
0	667	-0.1446730587	12.44141			0	37.46548
30	650	1.2186315514	11.0761	-1281	-737	7.153816	30.31166
80	602	4.7311590590 8	7.565574	-379	331	9.336782	20.97488
110	577	6.3851216169 3	5.911611	358	1018	6.679262	12.29562
140	555	7.75311025261	4.543622	-1478	-1006	6.206987	6.088634
190	516	9.99932507858	2.297408	-2347	-2191	2.051462	4.037172
250	472	12.2967326555	0	-2205	-1898	4.037172	0

APPLIED PRESSURE kPa	SUCTION kPa	VOLUMETRIC CONTENT cm^3/cm^3	WATER CONTENT g/g	DEGREE SATURATION	SLOPE
0	-	0.41318411473	0.391445	0.802282556	-
30	15	0.36255214057	0.339917	0.71098259	0.908931
80	42	0.2[illegible]388740735	0.272665	0.602183084	1.004725
110	67	0.23340741518	0.210149	0.476657418	0.861392
140	109	0.18578422315	0.165441	0.383829016	1.091624
190	140	0.17232162455	0.150664	0.363179513	0.706172
250		0.14174501762	0.121585	0.305259727	1.227554

ASH TEST 1 APPLIED AIR PRESSURE 30 kPa

30

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1281	0	ERR	ERR	
10	-1228	0.56545	1	-0.24761	-0.23033445
20	-1195	1.1909	1.30103	0.053424	0.04328116
30	-1156	1.64375	1.477121	0.215836	0.203226032
40	-1120	2.11715	1.60206	0.325762	0.316896771
50	-1086	2.56425	1.69897	0.40896	0.404981323
60	-1052	3.01135	1.778151	0.478761	0.476961643
70	-1020	3.43216	1.845098	0.535566	0.537801681
80	-989	3.8338	1.90309	0.584309	0.590512381
90	-960	4.22115	1.954243	0.625491	0.637006514
100	-932	4.58935	2	0.661751	0.678596924
110	-907	4.9181	2.041393	0.691797	0.716220044
120	-884	5.22055	2.079181	0.717716	0.750567283
130	-863	5.4967	2.113943	0.740102	0.782163623
140	-844	5.74655	2.146128	0.759407	0.811417291
150	-827	5.9701	2.176091	0.775982	0.838651805
160	-804	6.27265	2.20412	0.797444	0.864127992
170	-777	6.6276	2.230449	0.821356	0.888059191
180	-755	6.9169	2.255273	0.839911	0.910622125
190	-737	7.1636	2.278754	0.854526	0.93195433

Regression Output:

Constant		-1.13927
Std Err of Y Est		0.010905
R Squared		0.99871
No. of Observations		9
Degrees of Freedom		7
X Coefficient(s)	0.908931	
Std Err of Coef.	0.012343	

OUTFLOW VOLTAGE

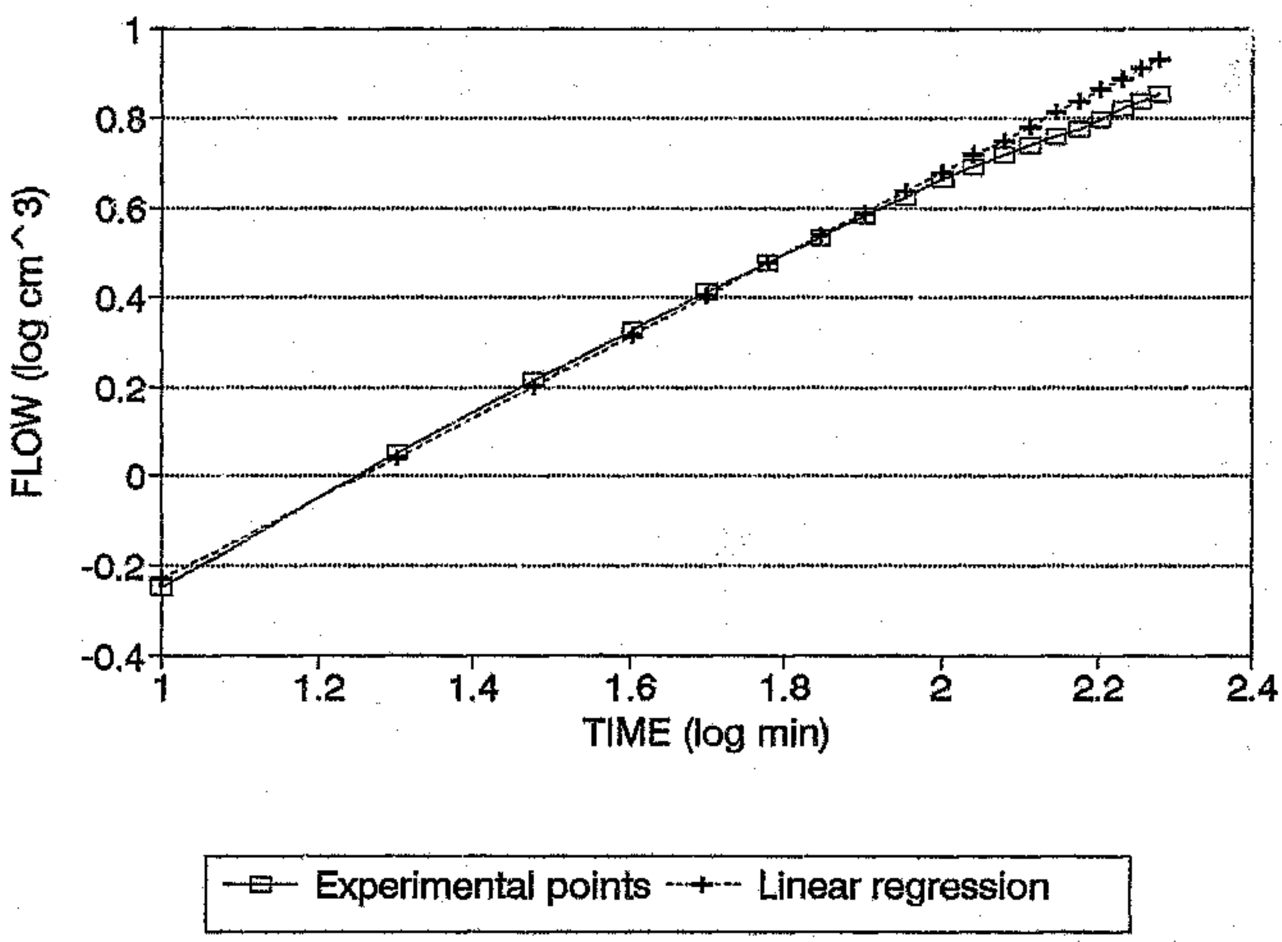
INITIAL	-1281
FINAL	-737

VOLUME VOLTAGE

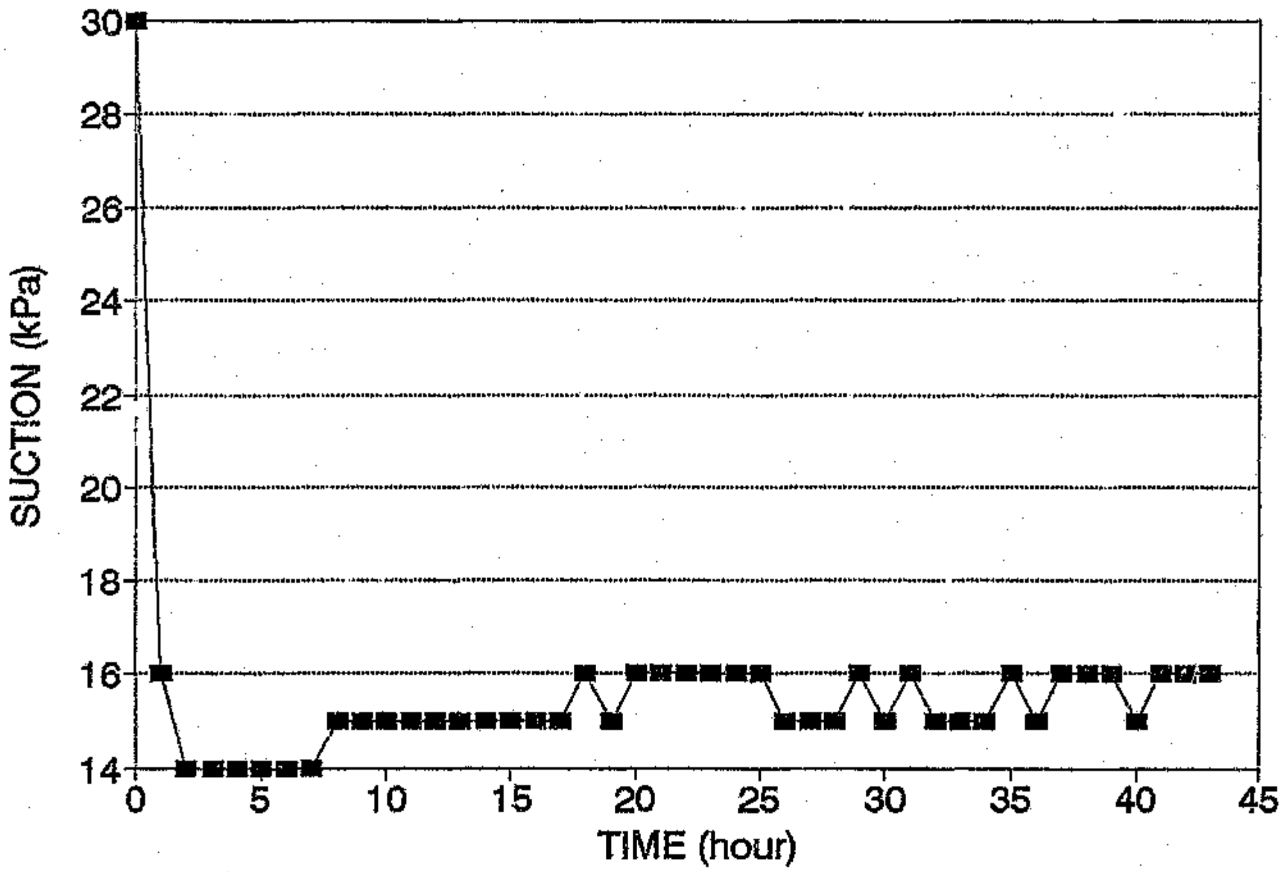
INITIAL	-667
FINAL	-649

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	124	29.56673	30
1	70	15.67008	16
2	65	14.27409	14
3	63	13.7557	14
4	64	14.0149	14
5	64	14.0149	14
6	64	14.0149	14
7	65	14.27409	14
8	66	14.53329	15
9	66	14.53329	15
10	67	14.79249	15
11	67	14.79249	15
12	67	14.79249	15
13	67	14.79249	15
14	66	14.53329	15
15	69	15.31088	15
16	69	15.31088	15
17	69	15.31088	15
18	71	15.82928	16
19	69	15.31088	15
20	71	15.82928	16
21	72	16.08848	16
22	71	15.82928	16
23	73	16.34767	16
24	70	15.67008	16
25	70	15.67008	16
26	69	15.31088	15
27	69	15.31088	15
28	69	15.31088	15
29	70	15.67008	16
30	69	15.31088	15
31	70	15.67008	16
32	69	15.31088	15
33	69	15.31088	15
34	69	15.31088	15
35	70	15.67008	16
36	69	15.31088	15
37	70	15.67008	16
38	70	15.67008	16
39	70	15.67008	16
40	69	15.31088	15
41	70	15.67008	16
42	70	15.67008	16
43	70	15.67008	16

OUTFLOW AT 30 kPa



CAPILLARY PRESSURE AT 30 kPa



ASH TEST 1 APPLIED AIR PRESSURE 80 kPa

80

TIME min.sec	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-287	0	ERR	ERR	ERR
10	-239	0.6312	1	-0.19983	-0.19224224
20	-191	1.2624	1.30103	0.101197	0.104210051
30	-145	1.8673	1.477121	0.271214	0.2811223
40	-92	2.56425	1.60206	0.40896	0.406562342
50	-40	3.24805	1.69897	0.511623	0.504030232
60	10	3.90565	1.778151	0.591682	0.583586591
70	59	4.5499	1.845098	0.658002	0.650948688
80	108	5.19425	1.90309	0.715623	0.709114634
90	155	5.8123	1.954243	0.764348	0.76050884
100	201	6.4172	2	0.807346	0.806482523
110	245	6.9958	2.041393	0.844837	0.848070778
120	288	7.56125	2.079181	0.878594	0.886037882
130	331	8.1267	2.113943	0.909914	0.920964231

Regression Output:

Constant		-1.20297
Std Err of Y Est		0.006969
R Squared		0.999601
No. of Observations		13
Degrees of Freedom		11
X Coefficient(s)	1.004726	
Std Err of Coef.	0.006051	

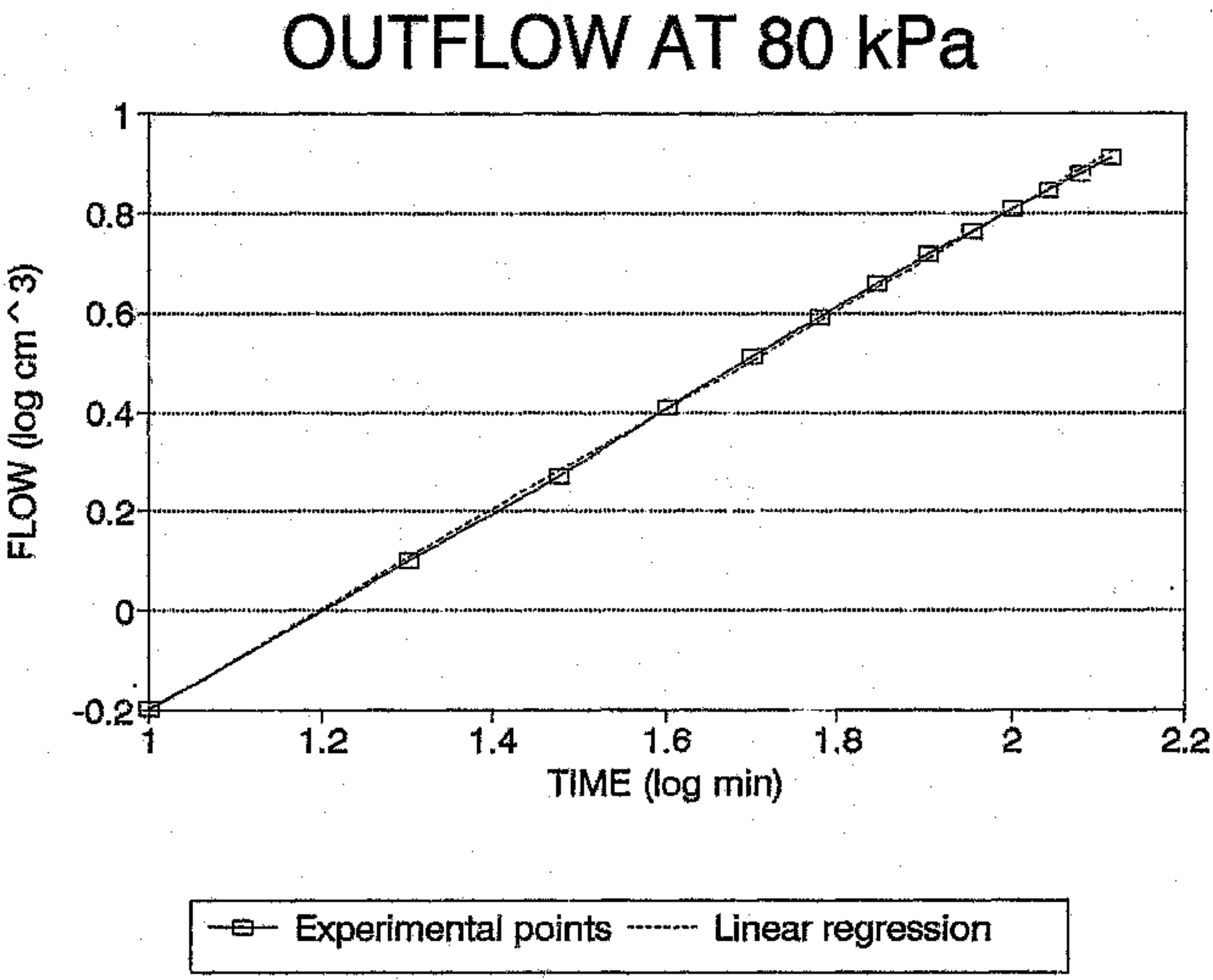
OUTFLOW VOLTAGE

INITIAL	-379
FINAL	231

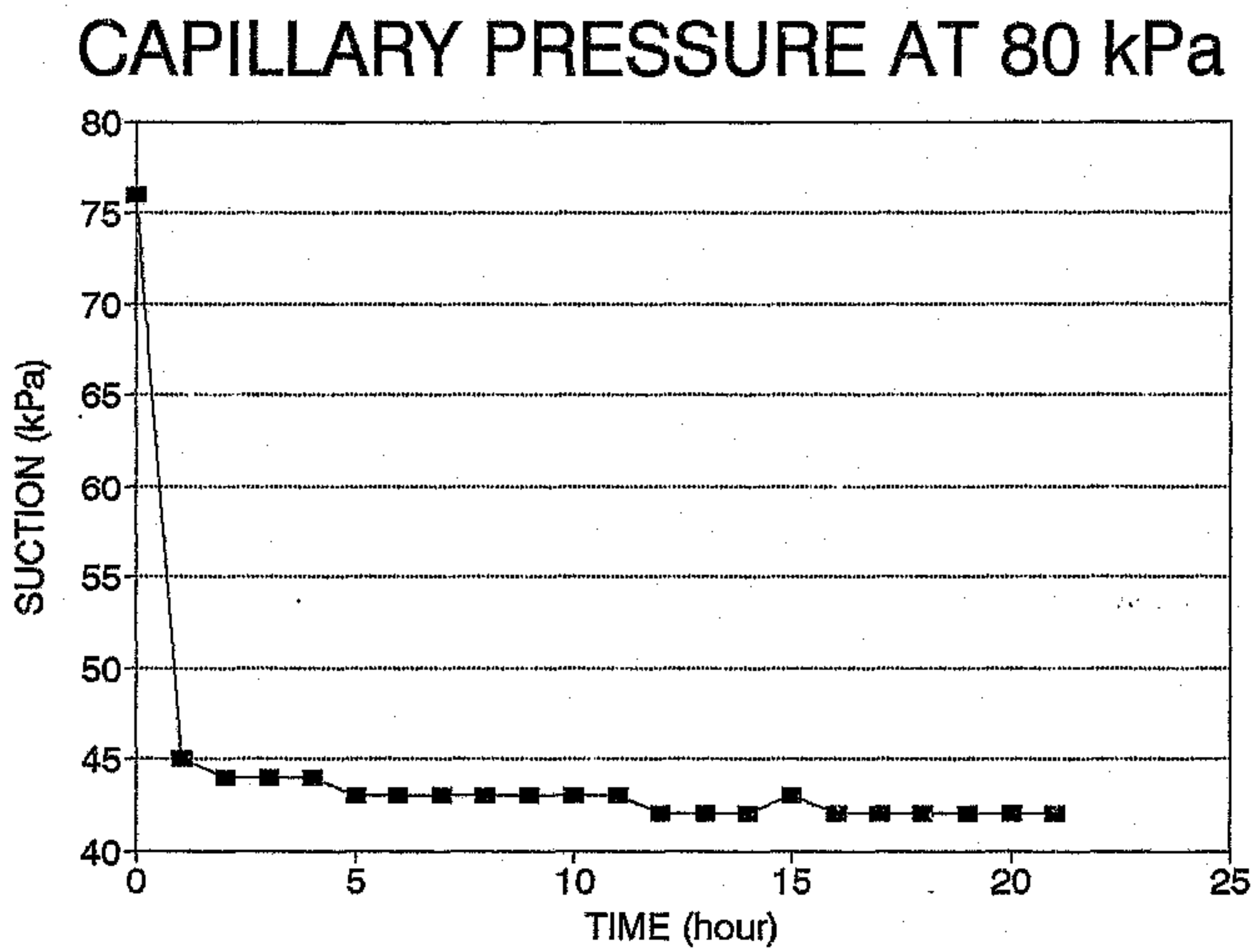
VOLUME VOLTAGE

INITIAL	-650
FINAL	-602

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	303	78.42544	78
1	182	45.06258	45
2	179	44.28499	44
3	177	43.76659	44
4	177	43.76659	44
5	175	43.2482	43
6	174	42.989	43
7	174	42.989	43
8	174	42.989	43
9	173	42.7298	43
10	173	42.7298	43
11	173	42.7298	43
12	172	42.47061	42
13	172	42.47061	42
14	171	42.21141	42
15	173	42.7298	43
16	172	42.47061	42
17	171	42.21141	42
18	172	42.47061	42
19	172	42.47061	42
20	171	42.21141	42
21	172	42.47061	42



OUTFLOW AT 80 kPa
FLOW (log cm ^ 3)
1
0.8
0.6
0.4
0.2
0
-0.2
1
1.2
1.4
1.6
1.8
2
2.2
TIME (log min)
Experimental points
Linear regression



CAPILLARY PRESSURE AT 80 kPa
SUCTION (kPa)
80
75
70
65
60
55
50
45
40
0
5
10
15
20
25
TIME (hour)

ASH TEST 1 APPLIED AIR PRESSURE 110 kPa
110

TIME minutes	FLOW volts	FLOW volts	LOG TIME	LOG FLOW	PREDICTED FLOW
0	358	0	ERR	ERR	ERR
10	450	1.2098	1	0.082714	0.083148376
20	524	2.1829	1.30103	0.339034	0.34245323
30	595	3.11655	1.477121	0.492874	0.494136845
40	663	4.01075	1.60206	0.603226	0.601758083
50	730	4.8918	1.69897	0.689469	0.685235601
60	793	5.72025	1.778151	0.757416	0.753441699
70	853	6.50925	1.845098	0.812531	0.811109133
80	911	7.27195	1.90309	0.861651	0.861062937
90	966	7.9952	1.954243	0.902829	0.905125314
100	1018	8.679	2	0.93847	0.944540464

Regression Output

Constant		-0.77824
Std Err of Y Est		0.003469
R Squared		0.999858
No. of Observations		10
Degrees of Freedom		8
X Coefficient(s)	0.867392	
Std Err of Coef	0.003633	

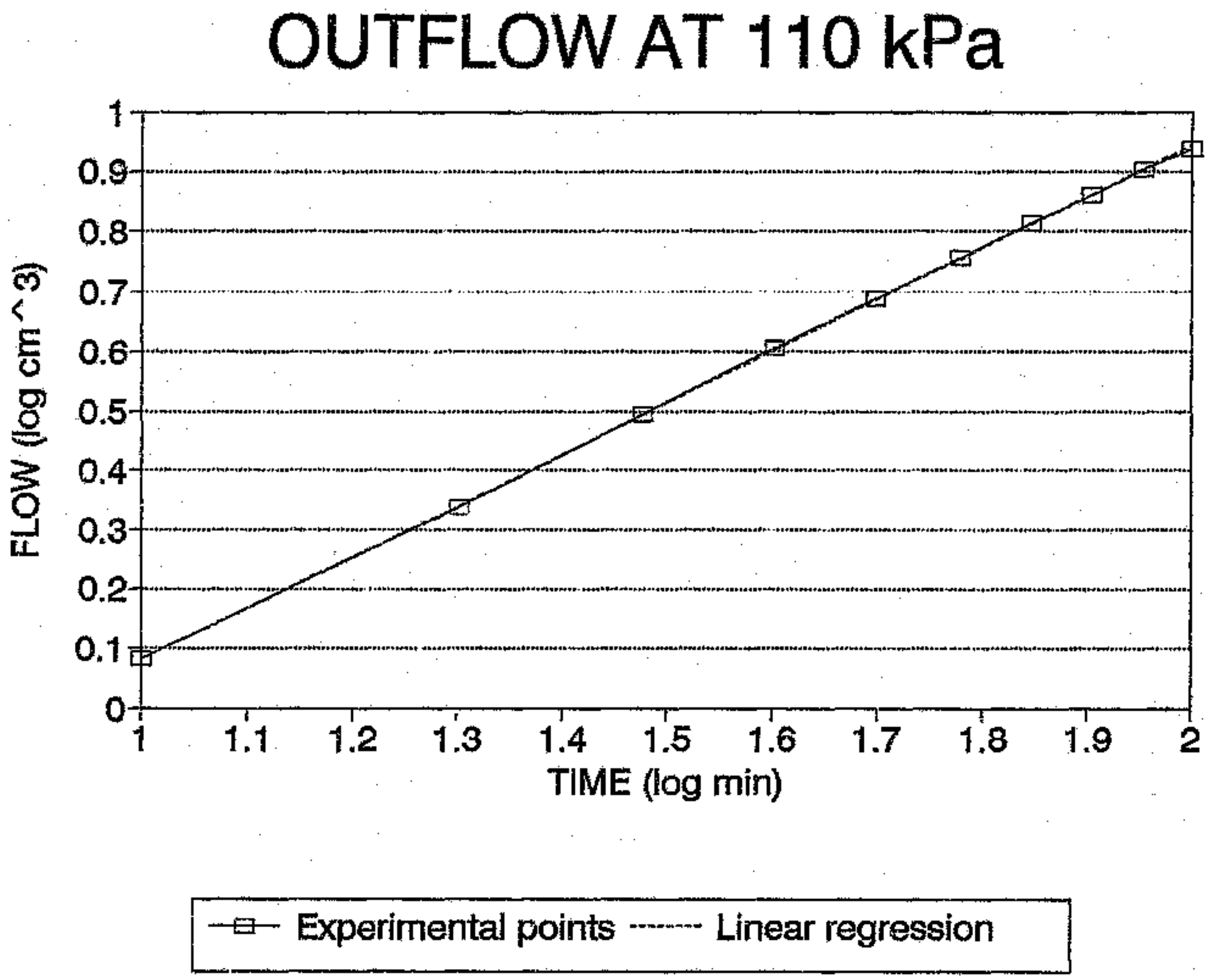
OUTFLOW VOLTAGE

INITIAL	358
FINAL	1018

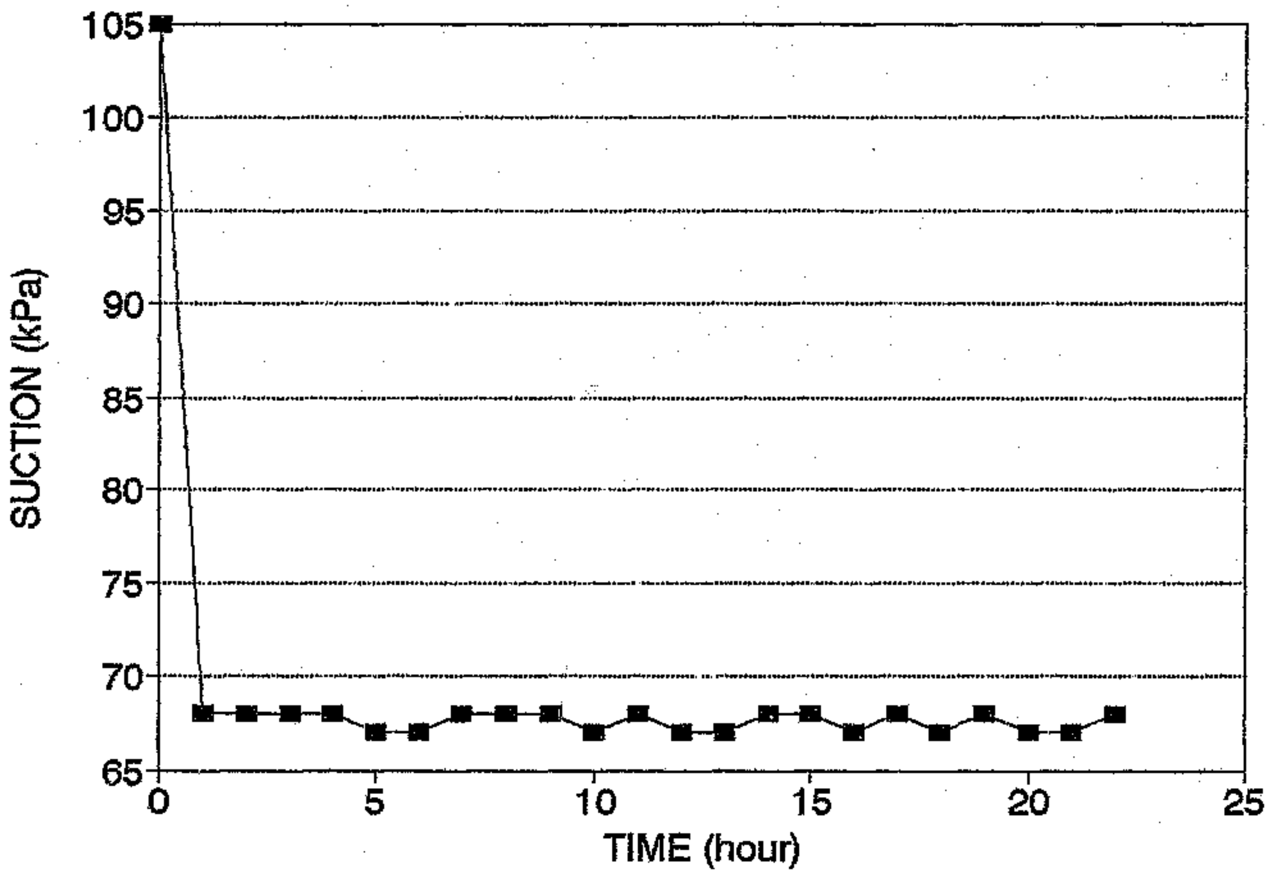
VOLUME VOLTAGE

INITIAL	-602
FINAL	377

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	413	105.2146	105
1	271	68.40858	68
2	269	67.89018	68
3	271	68.40858	68
4	270	68.14938	68
5	267	67.37179	67
6	267	67.37179	67
7	269	67.89018	68
8	268	67.63098	68
9	270	68.14938	68
10	267	67.37179	67
11	268	67.63098	68
12	267	67.37179	67
13	267	67.37179	67
14	268	67.63098	68
15	268	67.63098	68
16	267	67.37179	67
17	269	67.89018	68
18	266	67.11259	67
19	268	67.63098	68
20	267	67.37179	67
21	265	66.85339	67
22	268	67.63098	68


OUTFLOW AT 110 kPa
FLOW (log cm^3)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
TIME (log min)
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
Experimental points
Linear regression

CAPILLARY PRESSURE AT 110 kPa



ASH TEST 1 APPLIED AIR PRESSURE 140 kPa

140

TIME minutes	FLOW Volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1478	0	ERR	ERR	ERR
10	-1424	0.7101	1	-0.14868	-0.13692649
20	-1354	1.6305	1.30103	0.212347	0.191695204
30	-1291	2.46905	1.477121	0.390767	0.383910723
40	-1235	3.19545	1.60206	0.504532	0.520296899
50	-1186	3.8398	1.69897	0.584309	0.626086236
60	-1140	4.4447	1.778151	0.647842	0.712522417
70	-1107	4.87965	1.845098	0.6883	0.785603168
80	-1076	5.2863	1.90309	0.723152	0.848909593
90	-1049	5.64135	1.954243	0.751388	0.904747936
100	-1028	5.9438	2	0.774064	0.95469793
110	-1006	6.2058	2.041393	0.792868	0.999583166

Regression Output.

Constant		-1.22855
Std Err of Y Est		0.020744
R Squared		0.996491
No. of Observations		4
Degrees of Freedom		2
X Coefficient(s)	1.091624	
Std Err of Coef.	0.045973	

OUTFLOW VOLTAGE

INITIAL -1478

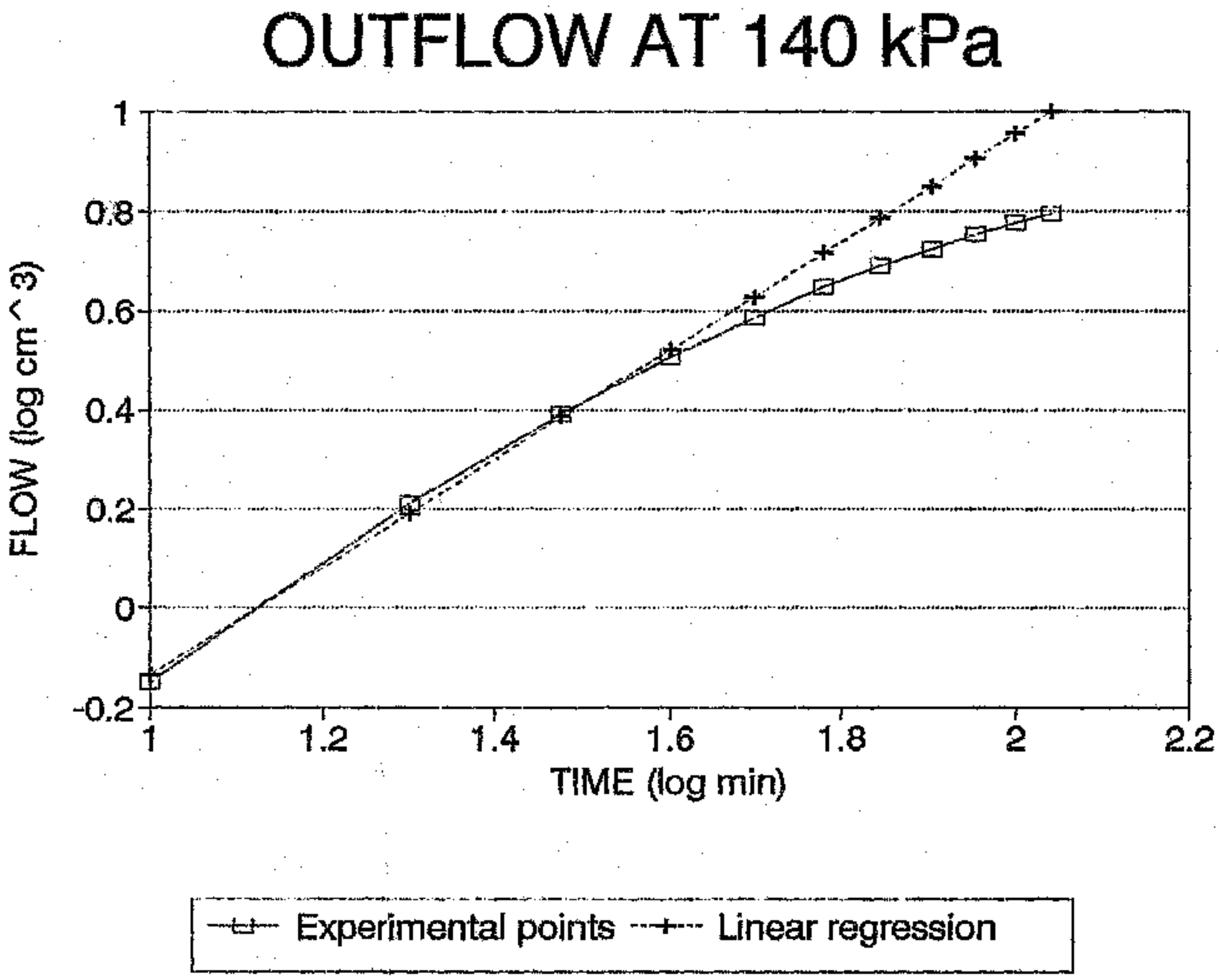
FINAL -1006

VOLUME VOLTAGE

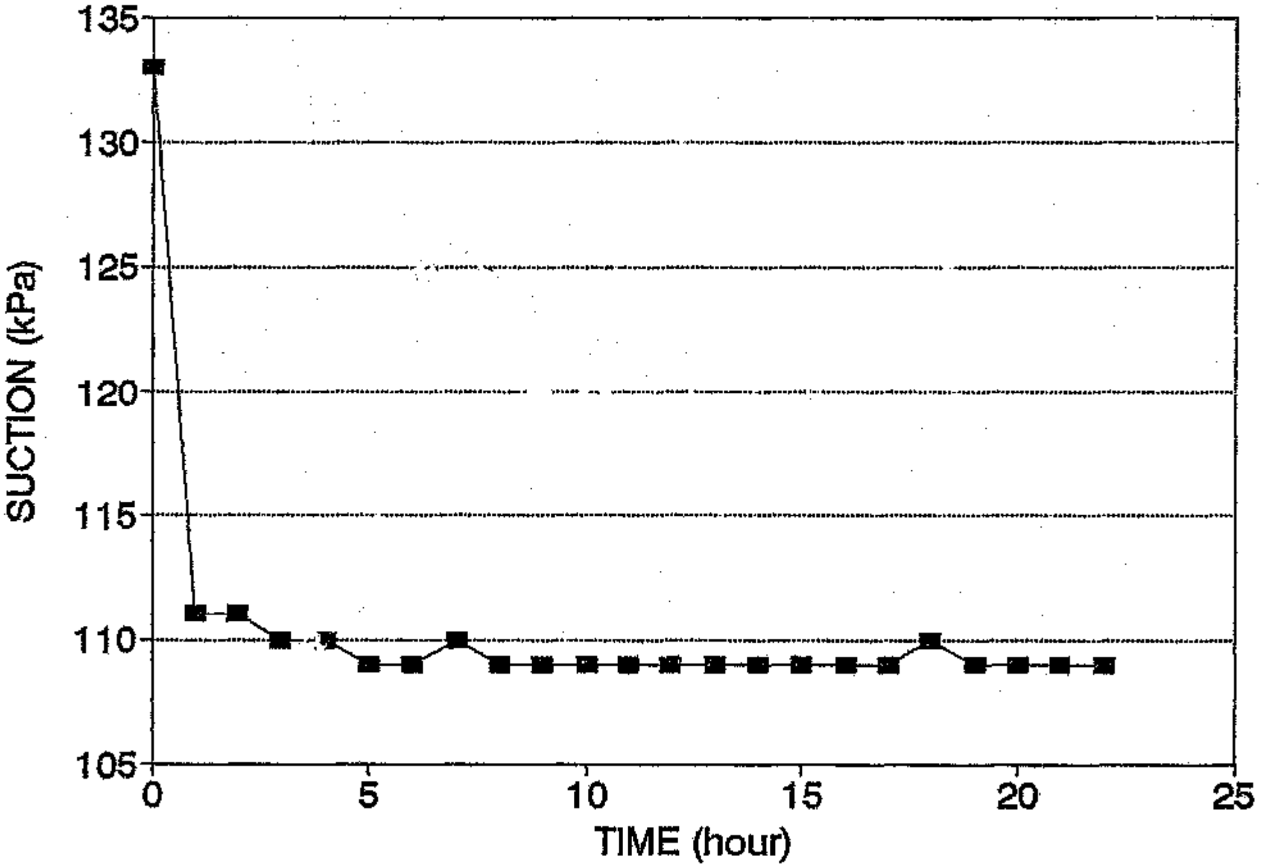
INITIAL -577

FINAL -555

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	518	132.9669	133
1	434	110.9352	111
2	436	111.1944	111
3	431	110.1576	110
4	430	109.8984	110
5	428	109.38	109
6	427	109.1208	109
7	429	109.6392	110
8	427	109.1208	109
9	426	108.8616	109
10	425	108.6024	109
11	427	109.1208	109
12	428	109.38	109
13	426	108.8616	109
14	428	109.38	109
15	426	108.8616	109
16	425	108.6024	109
17	425	108.6024	109
18	429	109.6392	110
19	425	108.6024	109
20	426	108.8616	109
21	425	108.6024	109
22	426	108.8616	109


OUTFLOW AT 140 kPa
FLOW (log cm ^ 3)
TIME (log min)
1
0.8
0.6
0.4
0.2
0
-0.2
1
1.2
1.4
1.6
1.8
2
2.2
Experimental points
Linear regression

CAPILLARY PRESSURE AT 140 kPa



ASH TES 1 APPLIED AIR PRESSURE 190 kPa

190

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-2248	0	ERR	ERR	ERR
10	-2232	0.2104	1	-0.67695	-0.37254246
20	-2221	0.35505	1.30103	-0.44971	-0.46096359
25	-2218	0.3946	1.39794	-0.40393	-0.39252842
30	-2213	0.46025	1.477121	-0.33701	-0.33561285
35	-2208	0.51285	1.544068	-0.29001	-0.28933691
40	-2204	0.5786	1.60206	-0.23762	-0.24838463
45	2201	0.61805	1.653213	-0.20899	0.21236216
50	-2198	0.6575	1.69897	-0.182	-0.1799495
55	-2195	0.69695	1.740363	-0.1568	-0.16071915
60	-2191	0.74955	1.778151	-0.1252	-0.12403890

Regression Output

Constant		-1.37971
Std Err of Y Est		0.007408
R Squared		0.998258
No. of Observations		10
Degrees of Freedom		8
X Coefficient(s)	0.706172	
Std Err of Coef.	0.0104	

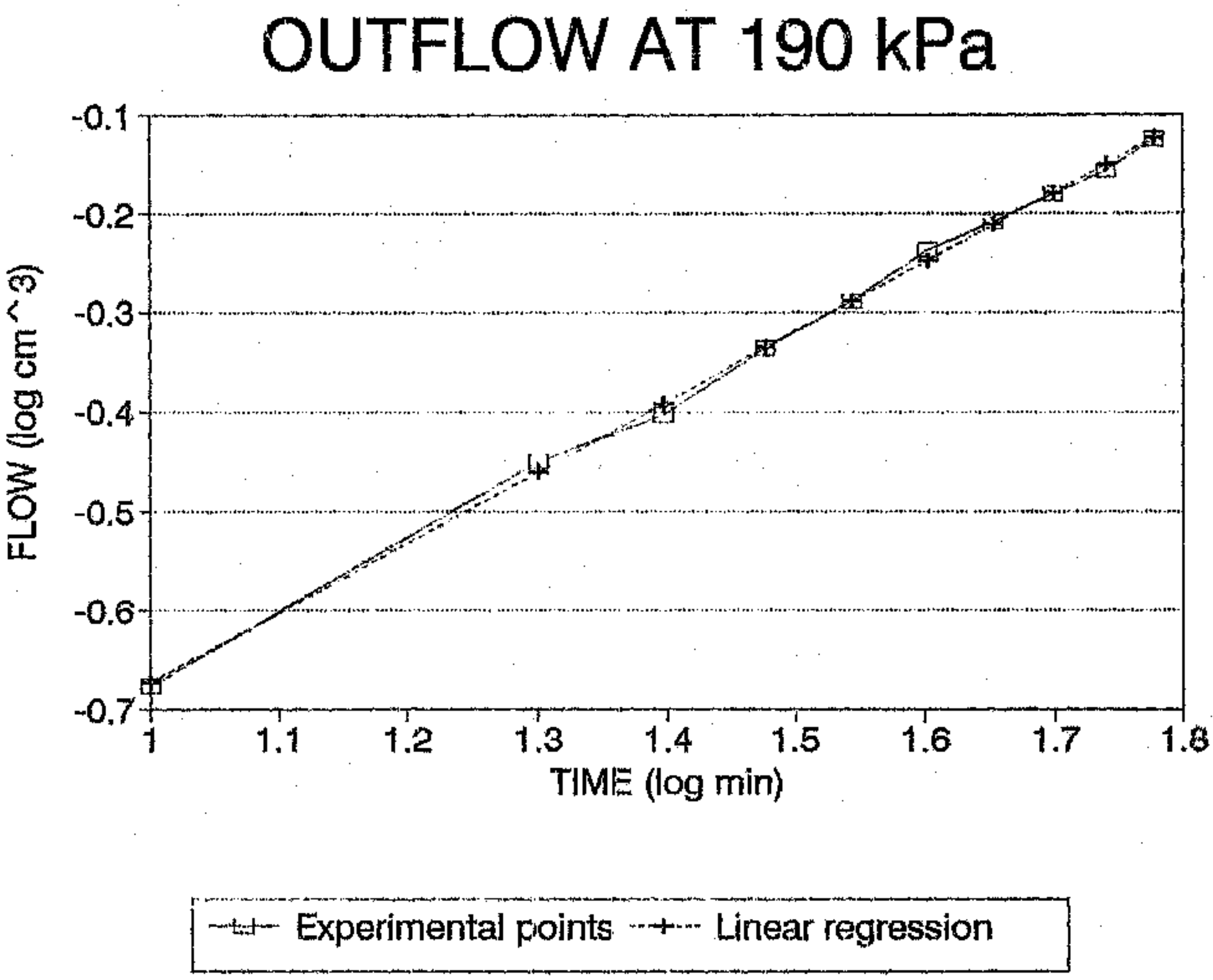
OUTFLOW VOLTAGE

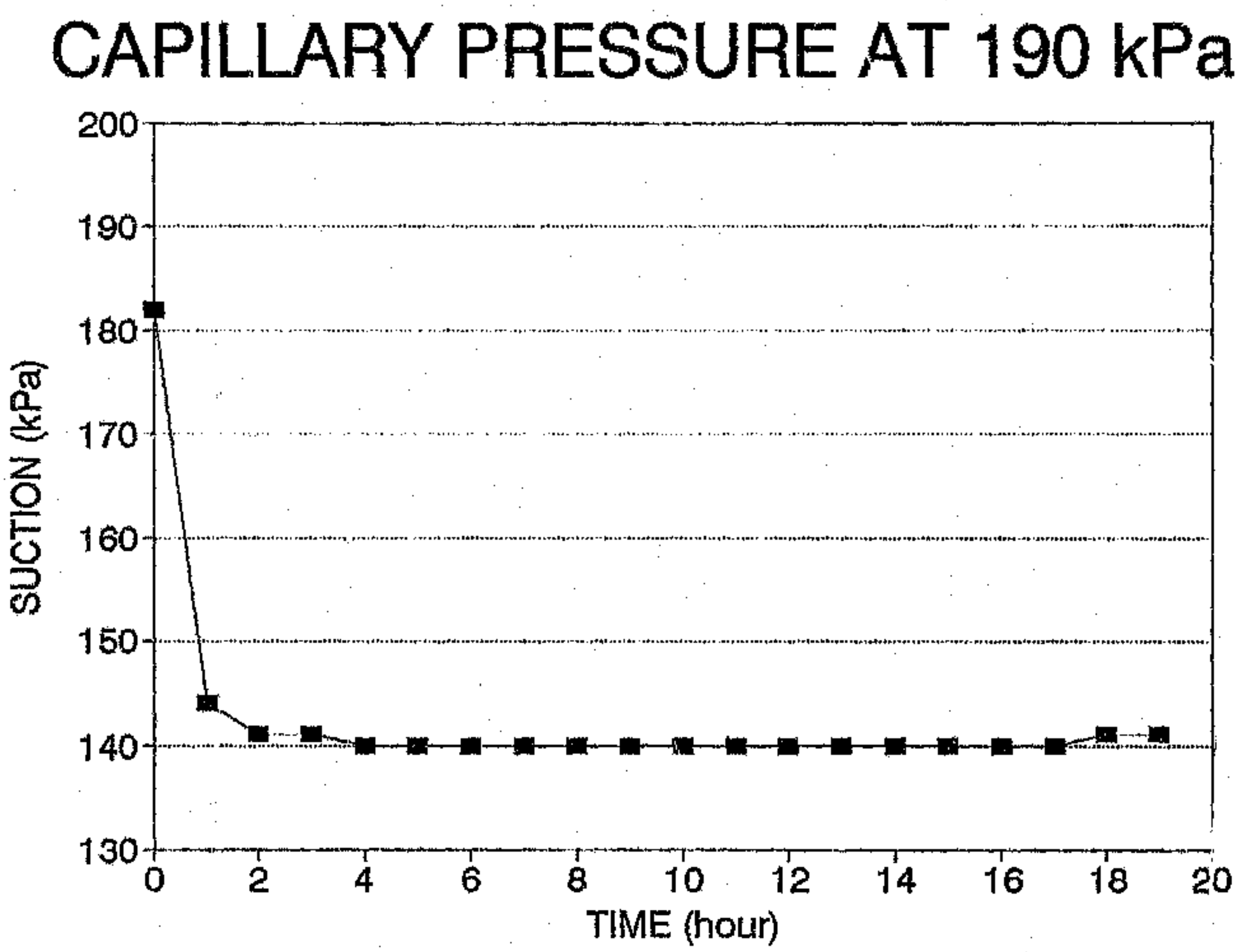
INITIAL	-2347
FINAL	-2191

VOLUME VOLTAGE

INITIAL	-665
FINAL	-516

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	706	181.6992	182
1	559	143.7972	144
2	549	141.2059	141
3	547	140.6869	141
4	546	140.4277	140
5	546	140.4277	140
6	545	140.1685	140
7	545	140.1685	140
8	545	140.1685	140
9	545	140.1685	140
10	544	139.9093	140
11	545	140.1685	140
12	546	140.4277	140
13	545	140.1685	140
14	545	140.1685	140
15	545	140.1685	140
16	545	140.1685	140
17	546	140.4277	140
18	549	141.2053	141
19	548	140.9461	141


OUTFLOW AT 190 kPa
FLOW (log cm ^3)
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
TIME (log min)
Experimental points
Linear regression


CAPILLARY PRESSURE AT 190 kPa
SUCTION (kPa)
200
190
180
170
160
150
140
130
TIME (hour)
0
2
4
6
8
10
12
14
16
18
20

ASH TEST 1 APPLIED AIR PRESSURE 250 kPa

250

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-2205	0	ERR	ERR	ERR
10	-2189	0.2104	1	-0.67695	-0.8226868
20	-2176	0.38135	1.30103	-0.41868	-0.4531561
30	-2160	0.59175	1.477121	-0.22786	-0.2369946
40	-2141	0.8416	1.60206	-0.07489	-0.0836255
50	-2121	1.1046	1.69897	0.043205	0.03533676
60	-2103	1.3413	1.778151	0.127526	0.13253603
70	-2084	1.59115	1.845098	0.201711	0.21471684
80	-2060	1.90675	1.90309	0.280294	0.28590509
90	-2040	2.16975	1.954243	0.33641	0.34869758
100	-2010	2.56425	2	0.40896	0.40486738
110	-1987	2.8667	2.041393	0.457382	0.45567914
130	-1930	3.61625	2.113943	0.558258	0.54473901

Regression Output:

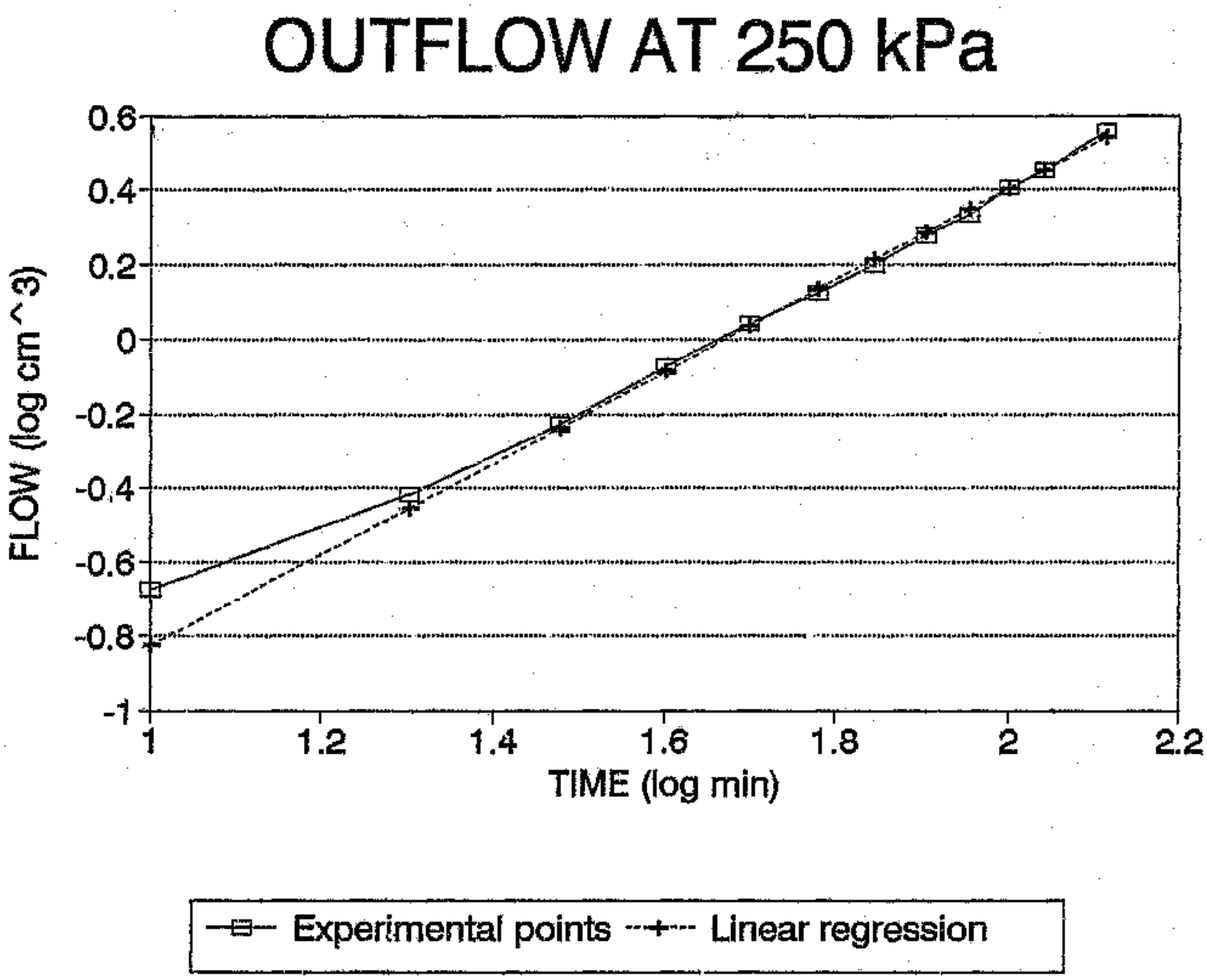
Constant		-2.05024
Std Err of Y Est		0.010123
R Squared		0.997868
No. of Observations		9
Degrees of Freedom		7
X Coefficient(s)	1.227554	
Std Err of Coef.	0.021446	

OUTFLOW VOLTAGE

INITIAL	-2205
FINAL	-1898

VOLUME VOLTAGE

INITIAL	-516
FINAL	-472


OUTFLOW AT 250 kPa
FLOW (log cm ^3)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
1.2
1.4
1.6
1.8
2
2.2
TIME (log min)
Experimental points
Linear regression

ASH TEST 2

SUMMARY OF RESULTS

SAMPLE: ASH TAILINGS TEST2

DIMENSIONS IN cm AND g

								AVERAGE
DIAMETER		7.135	7.31	7.33				7.258333
LENGTH		2.855	2.83					2.8425
S GRAVITY		2.192239	2.199338	2.199721	2.126009	2.164744		2.17641

FINAL VOLUME T	117.6154
VOLUME SOIL	64.96937

BOWL	176.4
WET SOIL & BOWL	333.2
DRY SOIL & BOWL	317.8
WATER CONT.	0.1089108911
VOLM CONT.	0.1309352399

APPLIED PRESSURE kPa	VOLUME volts	VOLUME cm^3	TOTAL VOLUME cm^3	FLOW INITIAL volts	FINAL volts	ACTUAL FLOW cm^3	TOTAL FLOW cm^3
0	662	0.2632742499	16.53468			0	36.43296
30	417	14.879072122	3.91888	-242	-739	6.569537	31.86341
60	346	17.838357619	0.959594	-214	195	5.378512	26.4849
90	324	18.684840368	0.113111	184	1313	14.8468	11.6381
110	323	18.722604657	0.075347	-1431	-1032	5.247008	6.391093
130	323	18.722604657	0.075347	-315	-77	3.129794	3.261298
160	322	18.760308376	0.037643	450	585	1.775304	1.485995
200	321	18.797951706	0	-403	-290	1.485995	0

APPLIED PRESSURE kPa	SUCTION kPa	VOLUMETRIC CONTENT cm^3/cm^3	WATER CONTENT g/g	DEGREE SATURATION	SLOPE
0	-	0.3953941912	0.380714	0.7562857061	-
30	25	0.3888895642	0.334253	0.835560697	0.96275
60	45	0.3532355277	0.296216	0.7813527681	1.018601
90	85	0.2296648607	0.191217	0.5124816733	1.273666
110	98	0.1851555386	0.15411	0.4133256002	1.10157
130	126	0.1585621605	0.131975	0.3539607869	1.110192
160	-	0.1435236609	0.11942	0.3205166862	0.961978
200	186	0.1309352399	0.108911	0.29251971	0.906486

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG cm FLOW	PREDICTED FLOW
0	242	0	ERR	ERR	ERR
1	246	0.052872	0	-1.27677	1.23113083
2	-250	0.105744	0.30103	-0.97574	-0.94132305
3	-255	0.171834	0.477121	-0.76489	-0.77179122
4	-259	0.224706	0.60206	-0.64839	-0.65190648
5	263	0.277578	0.69897	-0.55661	0.65820028
6	-267	0.33045	0.778151	-0.48089	-0.48197465
7	-272	0.39654	0.845098	-0.40171	-0.41762164
8	-276	0.449412	0.90309	-0.34738	-0.3616899
9	-280	0.502284	0.954243	-0.29905	-0.31244292
10	-284	0.555156	1	-0.25558	-0.26838591
11	-288	0.608028	1.041393	-0.21608	-0.228539
12	-292	0.6609	1.079181	-0.17986	-0.19216807
13	-295	0.700554	1.113943	-0.15456	-0.15869003
14	-299	0.753426	1.146128	-0.12296	-0.12770506
15	-303	0.806298	1.176091	-0.0935	-0.09885798
16	-307	0.85917	1.20412	-0.06592	-0.07187333
17	311	0.912042	1.230449	-0.03903	0.04662516
18	-315	0.964914	1.255273	-0.01551	0.02263826
19	-318	1.004568	1.278754	0.001979	-1.9825E-05
20	-323	1.070658	1.30103	0.029651	0.02142977
40	402	2.11483	1.60206	0.325286	0.311243244
60	-474	3.066576	1.778151	0.486654	0.480775173
120	-616	4.930314	2.079181	0.692876	0.770591747
180	-673	5.696958	2.255273	0.755643	0.940123676
240	-696	6.000972	2.380211	0.778222	1.060408322
300	-727	6.41073	2.477121	0.806907	1.15370842
360	-722	6.47682	2.556303	0.811362	1.229940161
420	-734	6.503298	2.623249	0.813131	1.29439316
480	-735	6.516474	2.681241	0.814013	1.350224097
540	-736	6.529692	2.732394	0.814893	1.399471979
600	-735	6.516474	2.778151	0.814013	1.443524995
660	-736	6.529692	2.819544	0.814893	1.483376796
720	-736	6.529692	2.857332	0.814893	1.519756726
780	-736	6.529692	2.892095	0.814893	1.553223937

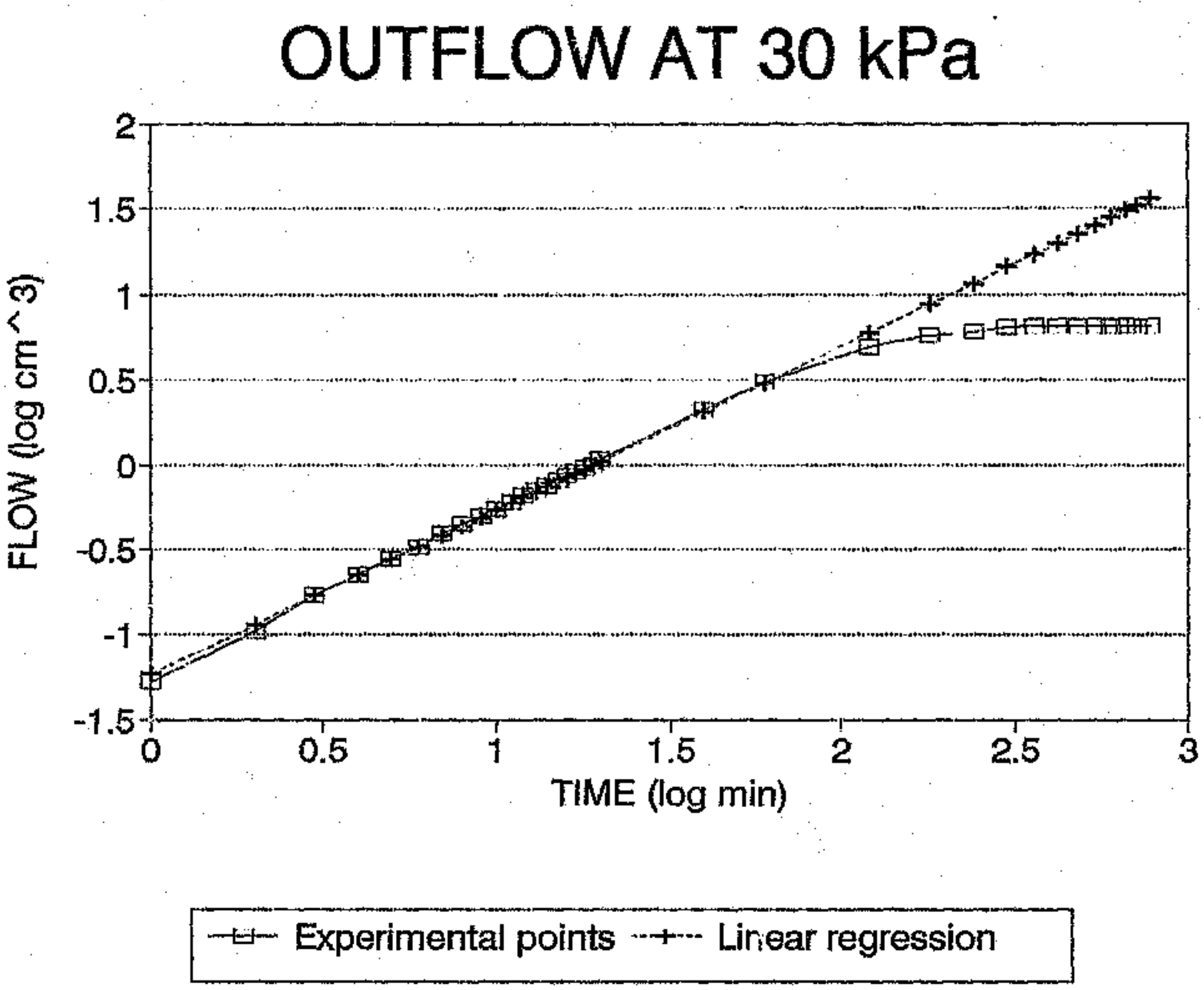
Regression Output

Constant		-1.23114
Std Err of Y Est		0.02286
R Squared		0.997432
No. of Observations		23
Degrees of Freedom		21
X Coefficient(s)	0.96275	
Std Err of Coef	0.01066	

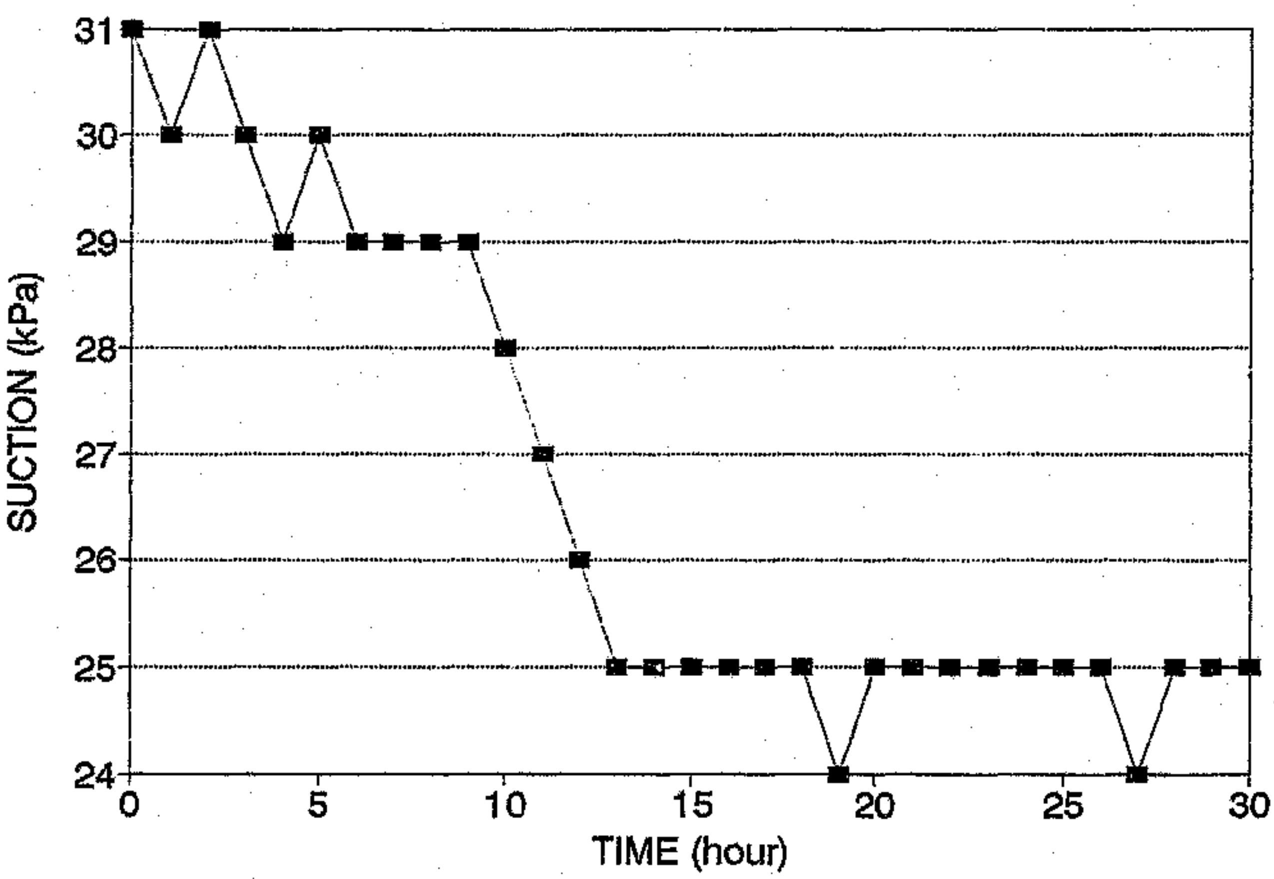
OUTFLOW VOLTAGE
INTIAL -242
ENDED -739

VOLUME CHANGE VOLTAGE
VOLUME INITIAL -662 V
VOLUME FINAL -418 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	140	30.86272	31.0
1	137	20.08512	30.0
2	139	30.60352	31.0
3	136	29.82593	30.0
4	134	29.30753	29.0
5	135	29.56673	30.0
6	132	28.78314	29.0
7	131	20.62994	29.0
8	131	28.52994	28.0
9	133	29.04834	29.0
10	130	28.27074	28.0
11	126	27.23390	27.0
12	123	26.45630	26.0
13	119	25.41950	25.0
14	117	24.90118	25.0
16	117	24.90118	26.0
16	116	24.64198	25.0
17	117	24.90118	26.0
18	116	24.64198	25.0
19	115	24.38279	24.0
20	116	24.64198	25.0
21	116	24.64198	25.0
22	116	24.64198	26.0
23	117	24.90118	25.0
24	117	24.90118	25.0
25	116	24.64198	25.0
26	116	24.64198	25.0
27	115	24.38279	24.0
28	117	24.90118	26.0
29	117	24.90118	25.0
20	116	24.64198	25.0


OUTFLOW AT 30 kPa
FLOW (log cm ^ 3)
TIME (log min)
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.5
1
1.5
2
2.5
3
Experimental points
Linear regression

CAPILLARY PRESSURE AT 30 kPa



ASH TEST 2 APPLIED AIR PRESSURE 60 kPa
60

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-214	0	ERR	ERR	ERR
1	-212	0.0263	0	-1.58004	-1.63138724
2	-210	0.0526	0.30103	-1.27901	-1.22475769
3	-207	0.09205	0.477121	-1.03598	-1.0463909
4	-205	0.11835	0.60206	-0.92683	-0.91812814
5	203	0.14465	0.69897	-0.83968	0.81941547
6	-201	0.17095	0.778151	-0.76713	-0.73876135
7	-198	0.2104	0.845098	-0.67695	-0.67056926
8	-195	0.24985	0.90309	-0.60232	-0.61149858
9	-193	0.27615	0.954243	-0.55885	-0.55939458
10	-190	0.3156	1	-0.50085	-0.51278592
11	-187	0.35505	1.041393	-0.44971	-0.47062327
12	-184	0.3946	1.079181	-0.40395	-0.43213179
13	-181	0.43395	1.113943	-0.36256	-0.39372397
14	-178	0.46025	1.146128	-0.33701	-0.36393971
15	-176	0.4997	1.176091	-0.30129	-0.33341913
16	-174	0.520	1.20412	-0.27901	-0.20486903
17	-171	0.56545	1.230449	-0.24761	0.27805034
18	-169	0.59175	1.255273	-0.22786	-0.252765
19	-166	0.6312	1.278754	-0.19983	-0.22884713
21	-162	0.6838	1.322219	-0.16507	-0.18467292
41	-115	1.30185	1.612784	0.114581	0.111203082
61	-69	1.90675	1.78533	0.280284	0.287152094
121	4	2.8667	2.082785	0.457382	0.590140697
181	43	3.37955	2.257679	0.528859	0.768287147
241	66	3.682	2.382017	0.566084	0.[illegible]308475
301	96	4.0765	2.478566	0.610287	0.993283876
361	109	4.24746	2.557507	0.628128	1.073692984
421	118	4.3658	2.624282	0.640064	1.141709979
491	124	4.4447	2.682145	0.647842	1.200349283
541	127	4.48415	2.733197	0.65168	1.252651115
601	130	4.5236	2.778874	0.655484	1.299177978
661	135	4.58935	2.820201	0.661751	1.341273704
721	138	4.6208	2.857935	0.665480	1.379709407
781	141	4.66825	2.892651	0.669154	1.415070935
841	143	4.69455	2.924796	0.671594	1.447813836
901	145	4.72085	2.954725	0.67402	1.478299348
961	147	4.74716	2.982723	0.676433	1.506818754
1021	149	4.77345	3.009026	0.678832	1.533610367
1081	155	4.85235	3.033826	0.685952	1.558871631
1141	165	4.98385	3.057286	0.697585	1.582767858
1201	182	5.2074	3.079543	0.716621	1.605439347
1261	199	5.29945	3.100715	0.724731	1.627005255
1321	193	5.35205	3.120903	0.72862	1.647568505
1381	195	5.37835	3.140194	0.730649	1.667218201

Regression Output:

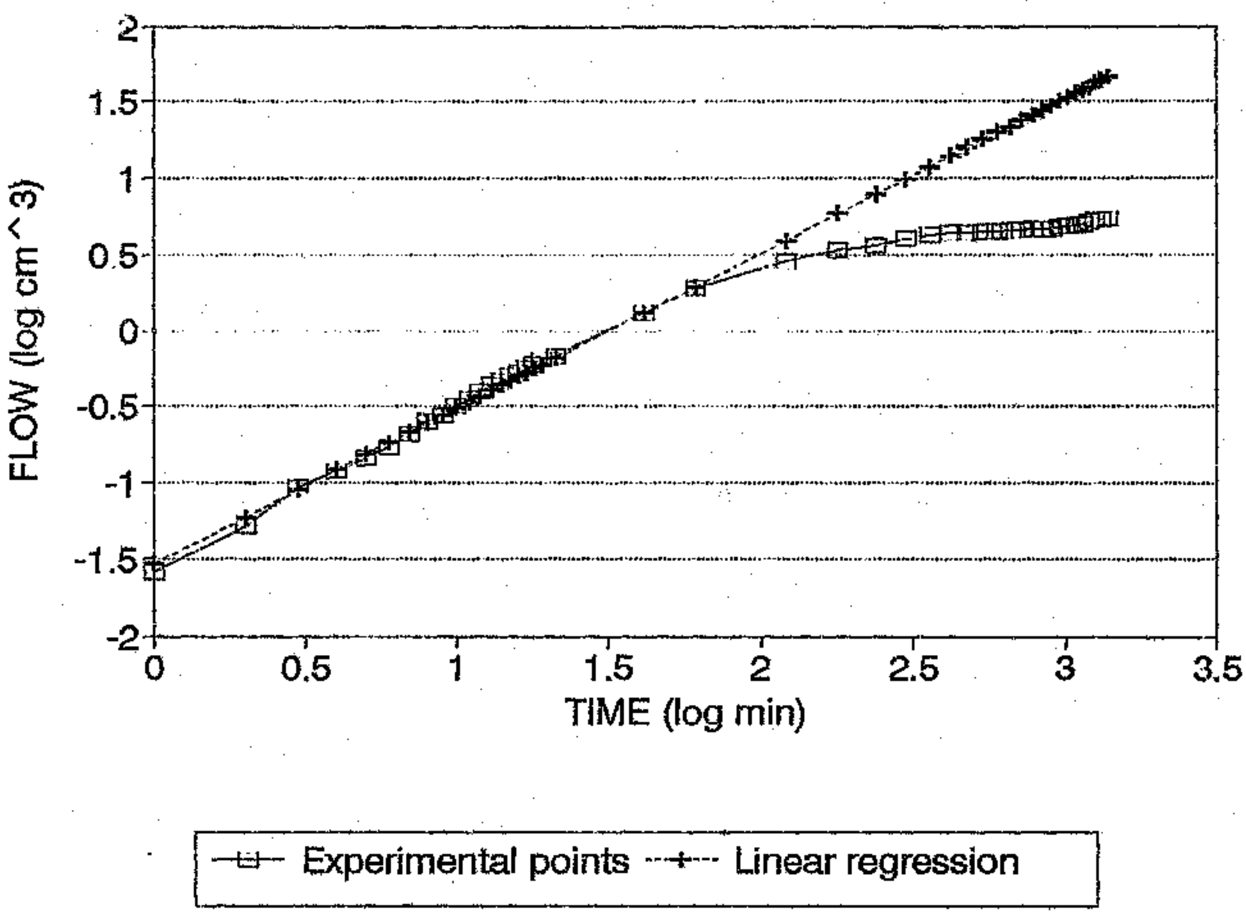
Constant		-1.63139
Std Err of Y Est		0.039170
R Squared		0.99335
No. of Observations		23
Degrees of Freedom		21
X Coefficient(s)	1.018601	
Std Err of Coef.	0.018187	

OUTFLOW VOLTAGE
INTIAL -214
ENDED 195

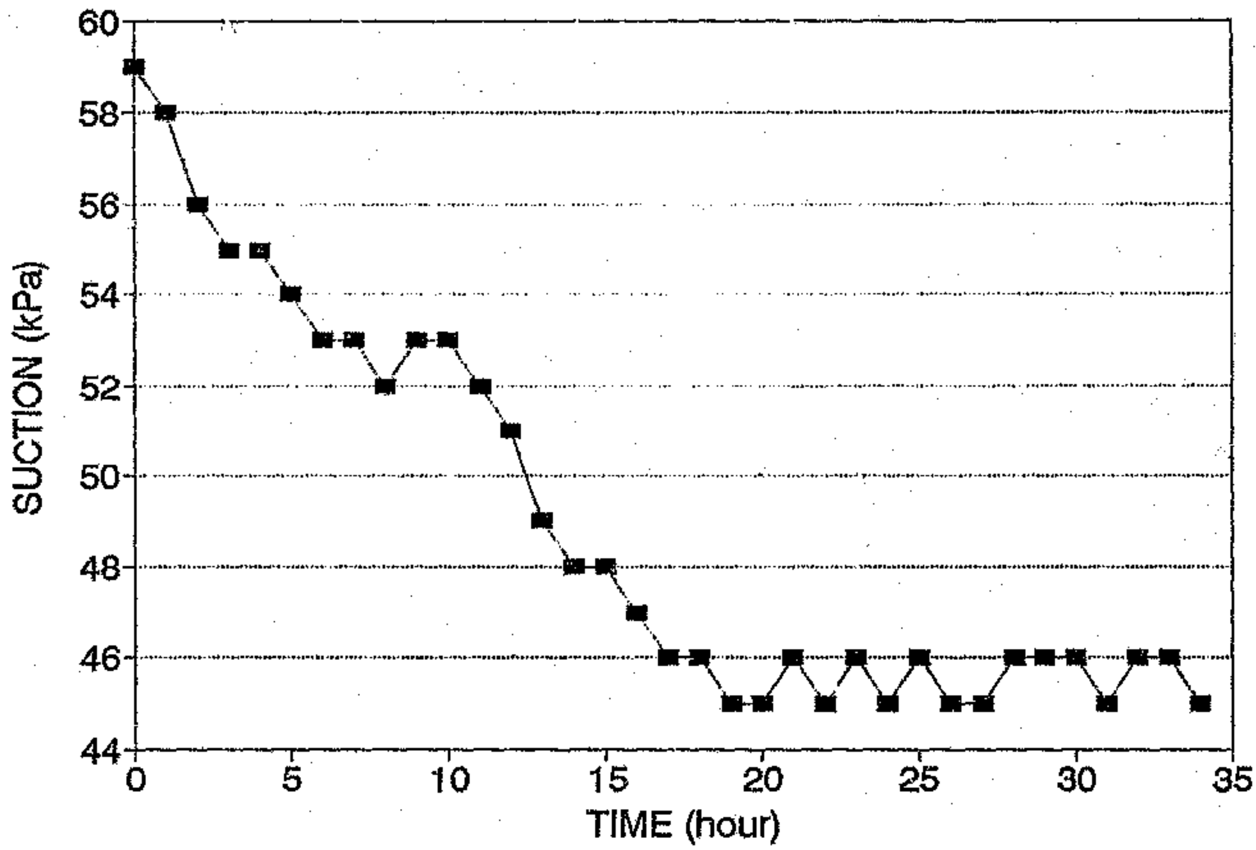
VOLUME CHANGE VOLTAGE
VOLUME INITIAL -417 V
VOLUME FINAL -246 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	246	58.61607	59.0
1	242	57.57828	58.0
2	235	55.7639	56.0
3	231	54.72711	55.0
4	231	54.72711	55.0
5	227	53.69032	54.0
[illegible]	224	52.91273	53.0
7	223	52.65353	53.0
8	222	52.39433	52.0
9	223	52.65353	53.0
10	224	52.91273	53.0
11	220	51.87594	52.0
12	216	50.57985	51.0
13	210	49.28397	49.0
14	205	47.98798	48.0
15	206	48.24718	48.0
16	200	46.692	47.0
17	198	46.1728	46.0
18	196	45.65521	46.0
19	194	45.13681	45.0
20	194	45.13681	45.0
21	196	45.65521	46.0
22	195	45.39601	45.0
23	196	45.65521	46.0
24	195	45.39601	45.0
25	196	45.65521	46.0
26	195	45.39601	45.0
27	195	45.39601	45.0
28	196	45.65521	46.0
29	196	45.65521	46.0
30	196	45.65521	46.0
31	195	45.39601	45.0
32	196	45.65521	46.0
33	196	45.65521	46.0
34	195	45.39601	45.0

OUTFLOW AT 60 kPa



CAPILLARY PRESSURE AT 60kPa



ASH TEST 2 APPLIED AIR PRESSURE 90 kPa
90

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	184	0	ERR	ERR	ERR
1	185	0.01316	0	1.88107	1.76284344
2	186	0.0263	0.30103	-1.58004	-1.37923073
3	188	0.0526	0.477121	-1.27901	-1.16494926
4	191	0.09205	0.60206	-1.03598	-0.99581902
5	194	0.1315	0.69897	-0.88107	0.87238802
6	196	0.1578	0.778151	-0.80189	-0.77163766
7	199	0.19725	0.845098	-0.70490	-0.68626869
8	203	0.24985	0.90309	-0.60292	-0.61240731
9	206	0.2893	0.954243	-0.53865	-0.54725627
10	209	0.32875	1	0.48313	-0.48897631
11	213	0.38135	1.041393	-0.41868	-0.43626556
12	216	0.4208	1.079181	-0.37592	-0.38812684
13	220	0.4734	1.113943	-0.32477	-0.34389052
14	223	0.51285	1.146128	-0.29001	-0.30285798
15	227	0.56545	1.176091	-0.24761	-0.26469484
16	230	0.6049	1.20412	-0.21832	-0.2289956
17	234	0.6576	1.230449	-0.1821	-0.19540132
18	238	0.7101	1.255273	-0.14868	-0.16384437
19	242	0.7627	1.278754	-0.11765	-0.13393729
20	245	0.80216	1.30103	-0.09574	-0.1065848
40	323	1.82735	1.60206	0.261041	0.277847111
60	397	2.80096	1.778151	0.447306	0.502128583
120	610	5.6019	2.079181	0.748335	0.885540294
180	766	7.5218	2.255273	0.876322	1.109821737
240	848	8.7316	2.380211	0.941094	1.268952004
300	972	10.3622	2.477121	1.015462	1.392283006
360	1059	11.60625	2.556303	1.060934	1.493233477
420	1109	12.16375	2.623249	1.085067	1.578501336
480	1137	12.53195	2.681241	1.098019	1.652360715
540	1162	12.7299	2.732394	1.104801	1.71761495
600	1167	12.79495	2.778151	1.107032	1.776794716
660	1211	13.50505	2.819544	1.130456	1.828916177
720	1273	14.33035	2.857332	1.166954	1.878346100
780	1304	14.728	2.892095	1.168144	1.920920505
840	1318	14.9121	2.924279	1.173530	1.961913046
900	1324	14.991	2.954243	1.175891	2.000078189
960	1326	15.0173	2.982271	1.176693	2.035775425
1020	1325	15.00415	3.0086	1.176211	2.069309703
1080	1325	15.00415	3.033424	1.176211	2.10092566
1140	1324	14.991	3.056905	1.175831	2.130833737
1200	1323	14.97780	3.079181	1.175449	2.169306427
1260	1321	14.95155	3.100371	1.174685	2.186191519
1320	1317	14.89895	3.120574	1.173156	2.211920888
1380	1313	14.84635	3.139879	1.17162	2.23651621

Regression Output:

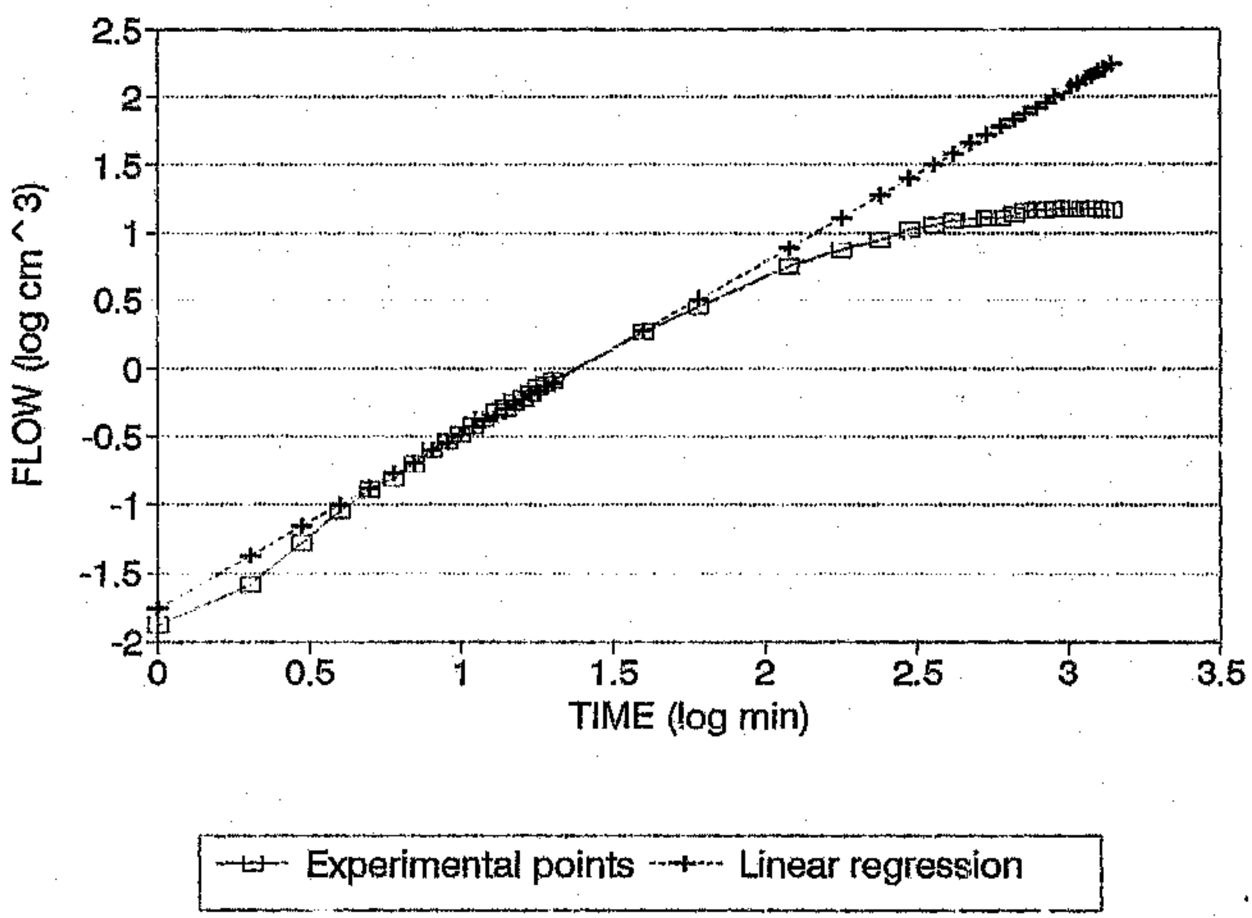
Constant		-1.76284
Std Err of Y Est		0.022481
R Squared		0.99847
No. of Observations		19
Degrees of Freedom		17
X Coefficient(s)	1.273666	
Std Err of Coef	0.016385	

OUTFLOW VOLTAGE
INTIAL 184
ENDED 1313

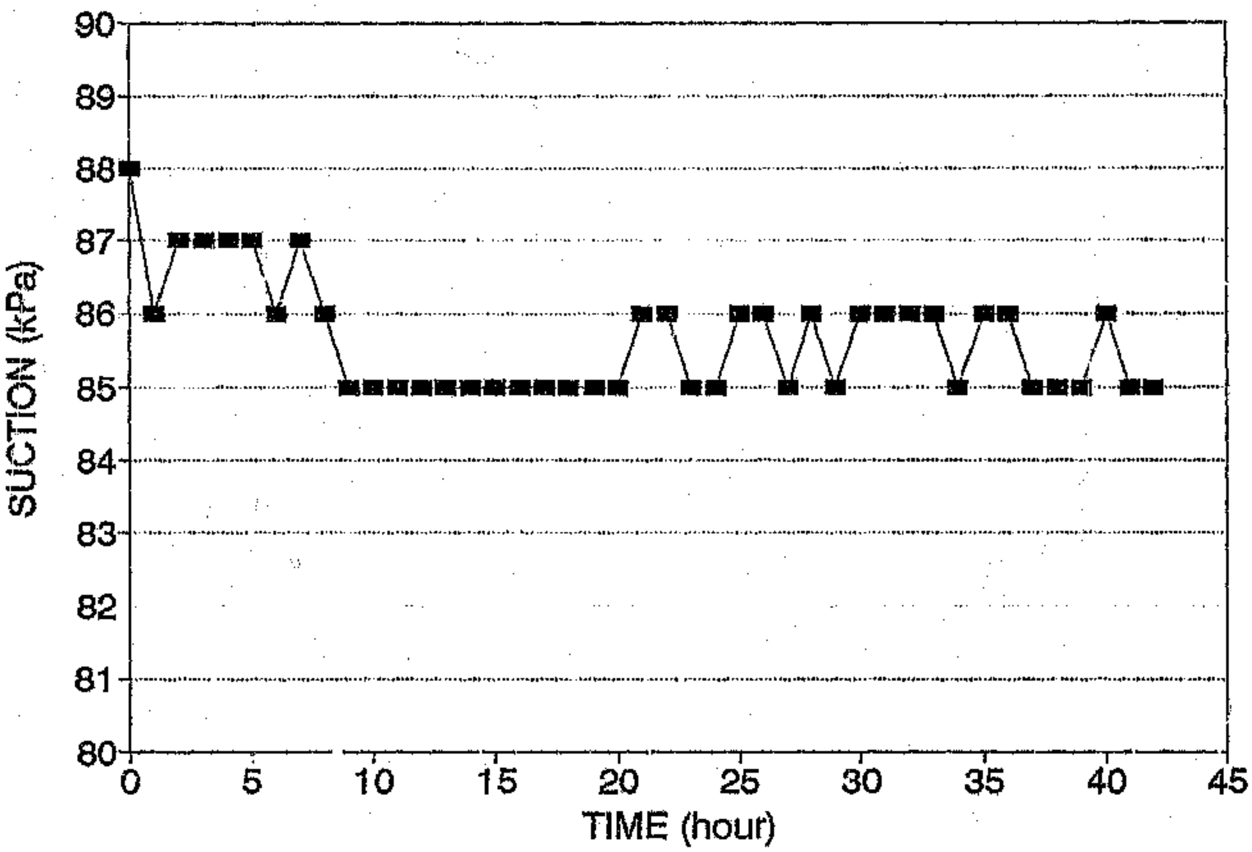
VOLUME CHANGE VOLTAGE
VOLUME INITIAL -346 V
VOLUME FINAL -324 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	357	87.88354	88.0
1	350	85.84916	86.0
2	353	86.62675	87.0
3	353	86.62675	87.0
4	354	86.88595	87.0
5	353	86.62675	87.0
6	350	85.84916	86.0
7	353	86.62675	87.0
8	350	85.84916	86.0
9	348	85.33076	85.0
10	345	84.55317	85.0
11	345	84.55317	85.0
12	346	84.81237	85.0
13	348	85.33076	85.0
14	345	84.55317	85.0
15	346	84.81237	85.0
16	348	85.33076	85.0
17	345	84.55317	85.0
18	346	84.81237	85.0
19	348	85.33076	85.0
20	345	84.55317	85.0
21	349	85.58996	86.0
22	350	85.84916	86.0
23	348	85.33076	85.0
24	347	85.07156	85.0
25	350	85.84916	86.0
26	349	85.58996	86.0
27	348	85.33076	85.0
28	350	85.84916	86.0
29	347	85.07156	85.0
30	349	85.58996	86.0
31	351	86.10835	86.0
32	349	85.58996	86.0
33	349	85.58996	86.0
34	347	85.07156	85.0
35	350	85.84916	86.0
36	349	85.58996	86.0
37	347	85.07156	85.0
38	347	85.07156	85.0
39	347	85.07156	85.0
40	349	85.58996	86.0
41	347	85.07156	85.0
42	347	85.07156	85.0

OUTFLOW AT 90 kPa



CAPILLARY PRESSURE AT 90 kPa



AGH TEST 2 APPLIED AIR PRESSURE 110 kPa
110

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1431	0	ERR	ERR	ERR
1	-1430	0.01316	0	1.88107	1.72813842
2	-1428	0.03946	0.30103	1.40390	1.39653279
3	-1427	0.0526	0.477121	-1.27901	-1.20265593
4	-1424	0.09205	0.60206	-1.03590	-1.06492716
5	-1422	0.11835	0.69897	-0.92683	0.35817399
6	-1421	0.1315	0.778151	-0.88107	-0.8709503
7	-1419	0.1578	0.845098	-0.80189	-0.78720372
8	-1417	0.1841	0.90309	-0.73495	-0.73332153
9	-1415	0.2104	0.954243	-0.37695	-0.67697344
10	-1413	0.2367	1	-0.6258	-0.62856836
11	-1411	0.263	1.041393	-0.58004	-0.58097141
12	-1410	0.27615	1.079181	-0.55885	-0.53934407
13	-1408	0.30245	1.113943	-0.51935	-0.50103177
14	-1406	0.32875	1.146128	-0.48319	-0.46559809
15	-1404	0.35505	1.176091	-0.44971	-0.4325915
16	-1401	0.3945	1.20412	-0.40395	-0.4017169
17	-1400	0.40765	1.230449	-0.33971	-0.37271273
18	-1397	0.4471	1.255273	-0.3499	-0.34578781
19	-1395	0.4734	1.278754	-0.32477	-0.31960174
20	-1392	0.51285	1.30103	-0.29001	-0.29496273
21	-1390	0.53916	1.322219	-0.26820	0.27162123
22	-1388	0.56545	1.342423	-0.24761	-0.24936578
23	-1386	0.59175	1.361728	-0.22786	-0.2280998
24	-1383	0.6312	1.380211	-0.19983	-0.20773904
25	-1381	0.6575	1.39794	-0.1821	-0.18820956
26	-1379	0.6838	1.414973	-0.16507	-0.16944614
27	-1376	0.7384	1.431364	-0.16289	-0.15139095
28	-1374	0.74955	1.447158	-0.1252	-0.13399246
29	-1371	0.789	1.462398	-0.10292	-0.11720457
30	-1369	0.8153	1.477121	-0.09868	-0.10098587
60	-1320	1.45965	1.69897	0.164249	0.143366072
70	-1273	2.0777	1.845098	0.317583	0.304366341
71	-1272	2.09085	1.851258	0.320323	0.311162353
131	-1163	3.6557	2.117271	0.562971	0.604184251
191	-1082	4.58835	2.281033	0.661761	0.784579648
251	-1048	5.03646	2.399674	0.702126	0.916270308
311	-1034	5.22056	2.49276	0.717719	1.017811794
371	-1028	5.29945	2.569374	0.724231	1.102208954
431	-1024	5.35205	2.634477	0.72852	1.173922867
491	-1023	5.3652	2.691081	0.729586	1.236276383
551	-1022	5.37835	2.741152	0.730649	1.291432113
611	-1023	5.3652	2.786041	0.729576	1.340881165
671	-1024	5.35205	2.826723	0.72852	1.385694478
731	-1024	5.35205	2.863917	0.72852	1.42666.219
791	-1025	5.3389	2.898178	0.727452	1.464406025
851	-1026	5.32575	2.92993	0.726381	1.499384264
911	-1024	5.35205	2.959518	0.72852	1.531978418
971	-1025	5.3389	2.987219	0.727462	1.562492849
1031	-1025	5.3389	3.013259	0.727462	1.591177111
1091	-1026	5.32575	3.037825	0.726381	1.618238375
1151	-1026	5.32576	3.061075	0.726381	1.64285051
1211	-1027	5.3126	3.083144	0.725307	1.668160861
1271	-1029	5.2863	3.104146	0.723152	1.691296383
1331	1020	5.27316	3.124178	0.72307	1.713356269
1391	-1032	5.24685	3.143327	0.719899	1.734456637
1451	-1032	5.24686	3.161627	0.719899	1.754659743

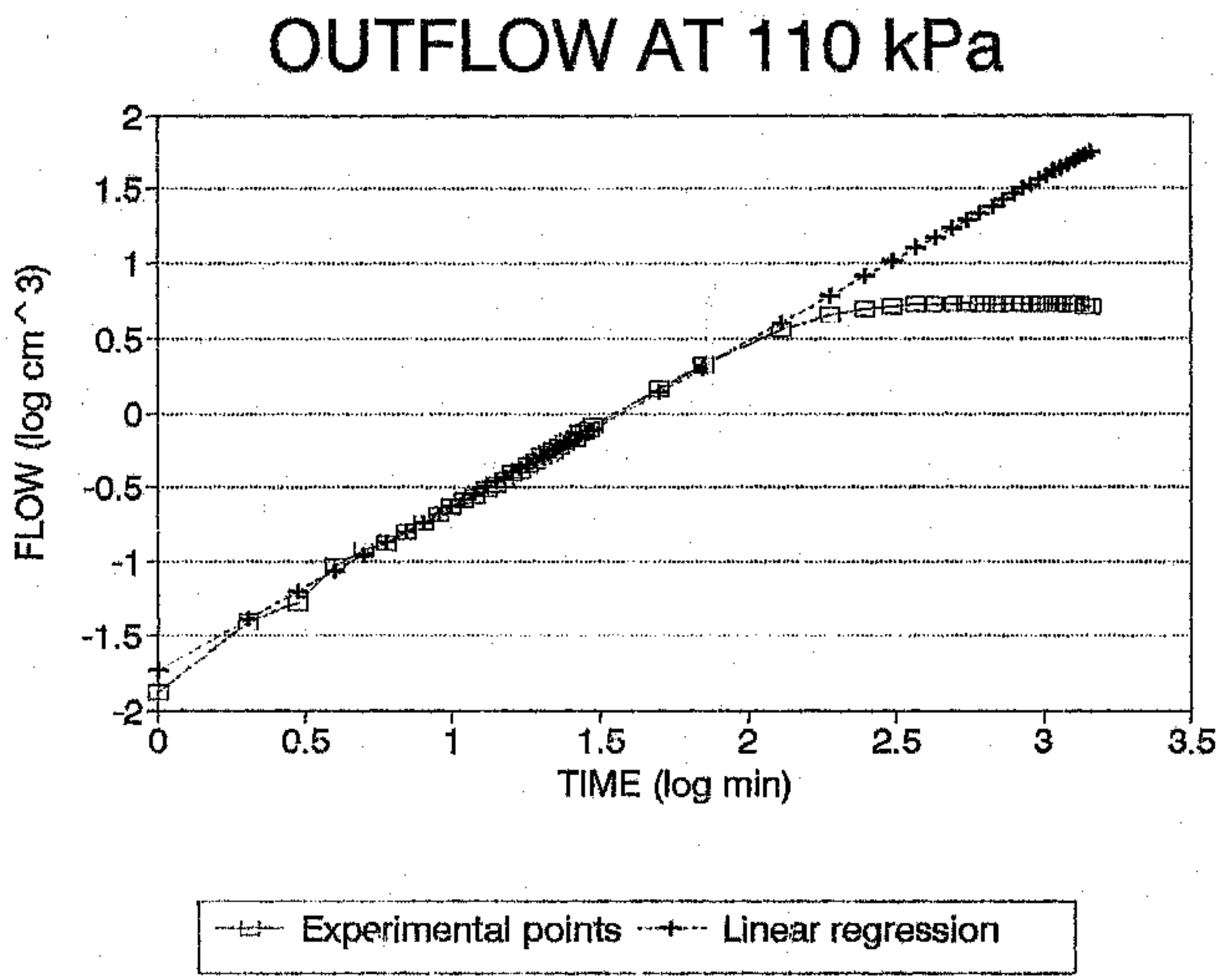
Regression Output.

Constant		-1.72814
Std Err of Y Est		0.01475
R Squared		0.998311
No. of Observations		30
Degrees of Freedom		28
X Coefficient(s)	1.10157	
Std Err of Coef.	0.008563	

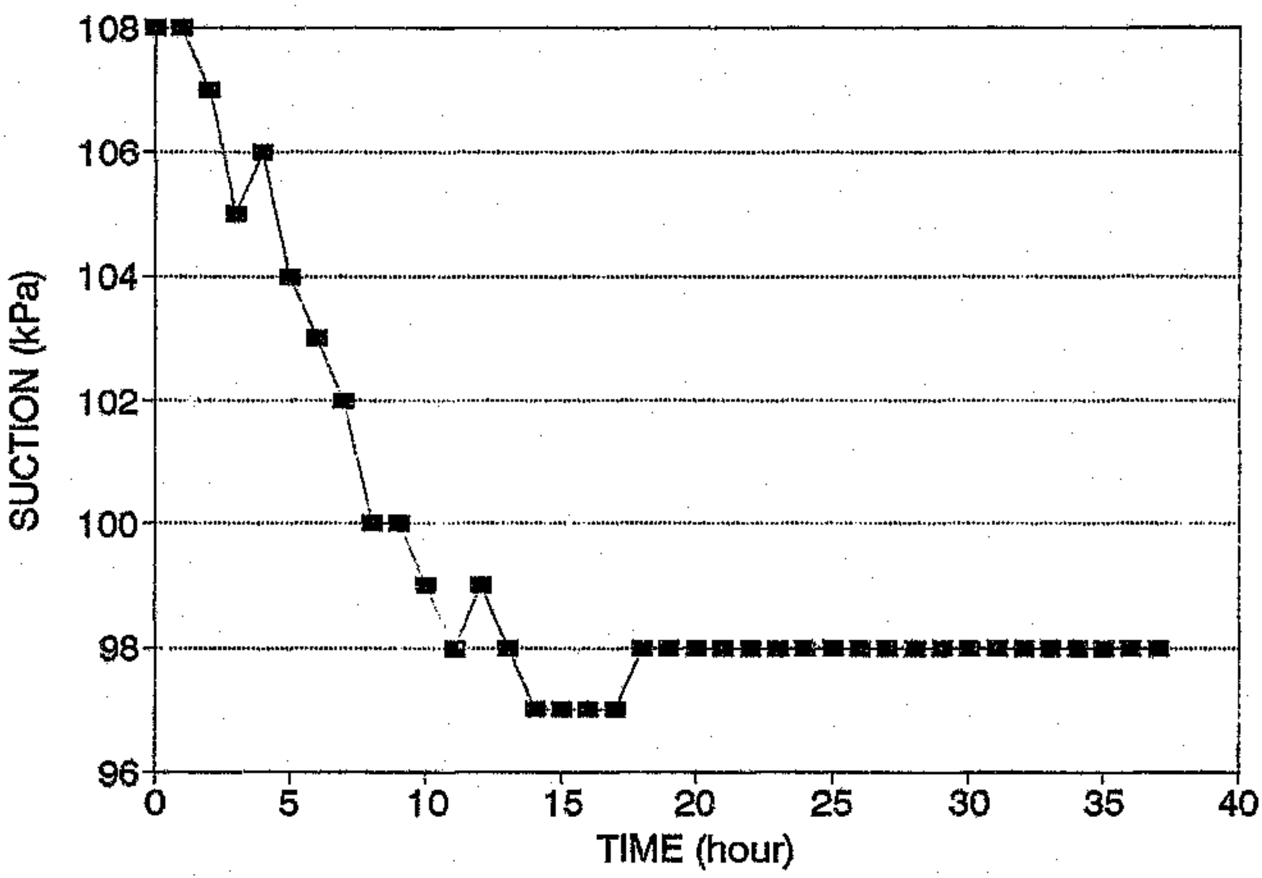
OUTFLOW VOLTAGE
INTIAL -1431
ENDED -1032

VOLUME CHANGE VOLTAGE
VOLUME INITIAL -324 V
VOLUME FINAL -323 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	434	107.8056	108.0
1	433	107.5474	108.0
2	429	106.5106	107.0
3	425	105.4739	105.0
4	426	105.733	105.0
5	420	104.1778	104.0
6	416	102.8918	103.0
7	410	101.5858	102.0
8	405	100.2898	[illegible]
9	402	99.51224	[illegible]
10	400	98.99385	99.0
11	398	98.47545	98.0
12	400	98.99385	99.0
13	398	98.47545	98.0
14	392	96.92027	97.0
15	392	96.92027	97.0
16	393	97.17947	97.0
17	394	97.43883	97.0
18	395	97.69786	98.0
19	395	97.69786	98.0
20	397	98.21626	98.0
21	396	97.95706	98.0
22	396	97.95706	98.0
23	395	97.69706	98.0
24	395	97.69786	98.0
25	395	97.69783	98.0
26	396	97.95706	98.0
27	395	97.69786	98.0
28	397	98.21626	98.0
29	396	97.95706	98.0
30	397	98.21626	98.0
31	395	97.69788	98.0
32	395	97.69786	98.0
33	395	97.69783	98.0
34	397	98.21626	98.0
35	395	97.69786	98.0
36	395	97.69785	98.0
37	396	97.95706	98.0


OUTFLOW AT 110 kPa
FLOW (log cm ^ 3)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5
2
2.5
3
3.5
TIME (log min)
Experimental points
Linear regression

CAPILLARY PRESSURE AT 110 kPa



A3H TEST 2 APPLIED AIR PRESSURE 130 kPa
130

TIME min	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-316	0	ERR	ERR	ERR
1	-314	0.01016	0	-1.88107	-1.80002357
2	-313	0.0263	0.30103	-1.68004	-1.55672248
3	-312	0.03945	0.477121	-1.40395	-1.36122738
4	-311	0.0526	0.60206	-1.27901	-1.22252139
5	-310	0.06575	0.69897	-1.1821	-1.11403267
6	-308	0.09205	0.778151	-1.03598	-1.02702629
7	-307	0.1052	0.845098	-0.97798	-0.9527026
8	-306	0.11835	0.90309	-0.92668	-0.8883203
9	-304	0.14465	0.954243	-0.83968	-0.83153110
10	-302	0.17095	1	-0.76713	-0.78073168
11	-301	0.1841	1.041393	-0.73495	-0.73477776
12	-299	0.2104	1.079181	-0.67695	-0.6928252
13	-298	0.22355	1.113943	-0.65063	-0.65123259
14	-296	0.24985	1.146128	-0.60232	-0.61850141
15	-294	0.27616	1.176091	-0.55885	-0.58522648
16	-293	0.2893	1.20412	-0.53865	-0.55411931
17	-291	0.3156	1.230449	-0.50086	-0.52488003
18	-289	0.3419	1.255273	-0.4661	-0.49733009
19	-288	0.35505	1.278754	-0.44971	-0.47126157
20	-286	0.38136	1.30103	-0.41868	-0.44653049
40	-252	0.82840	1.60206	-0.08173	-0.1123394
60	-220	1.24925	1.778151	0.096649	0.083165705
120	-154	2.11716	2.079181	0.325752	0.417356796
180	-119	2.5774	2.255273	0.411182	0.612861901
240	-100	2.82725	2.380211	0.451364	0.751567085
300	-90	2.95876	2.477121	0.471108	0.859156606
360	-84	3.03765	2.556303	0.482538	0.947062991
420	-80	3.09025	2.623249	0.489994	1.021386781
480	-79	3.1034	2.681241	0.491838	1.085768976
540	-79	3.1034	2.732394	0.491838	1.142558097
600	-80	3.09025	2.778151	0.489994	1.193357697
660	-80	3.09025	2.819544	0.489994	1.239311624
720	-80	3.09025	2.857332	0.489994	1.281264082
780	-80	3.09025	2.892095	0.489994	1.319856594
840	-79	3.1034	2.924279	0.491838	1.355587872
900	-79	3.1034	2.954243	0.491838	1.388852902
960	-79	3.1034	2.982271	0.491838	1.419970057
1020	-78	3.11655	3.0085	0.493674	1.449200243
1080	-78	3.11655	3.033424	0.493674	1.476769187
1140	-77	3.1297	3.056905	0.495503	1.502827712
1200	-77	3.1297	3.079181	0.495503	1.527558787
1260	-77	3.1297	3.100371	0.495503	1.551082977
1320	-77	3.1297	3.120574	0.495503	1.573512614

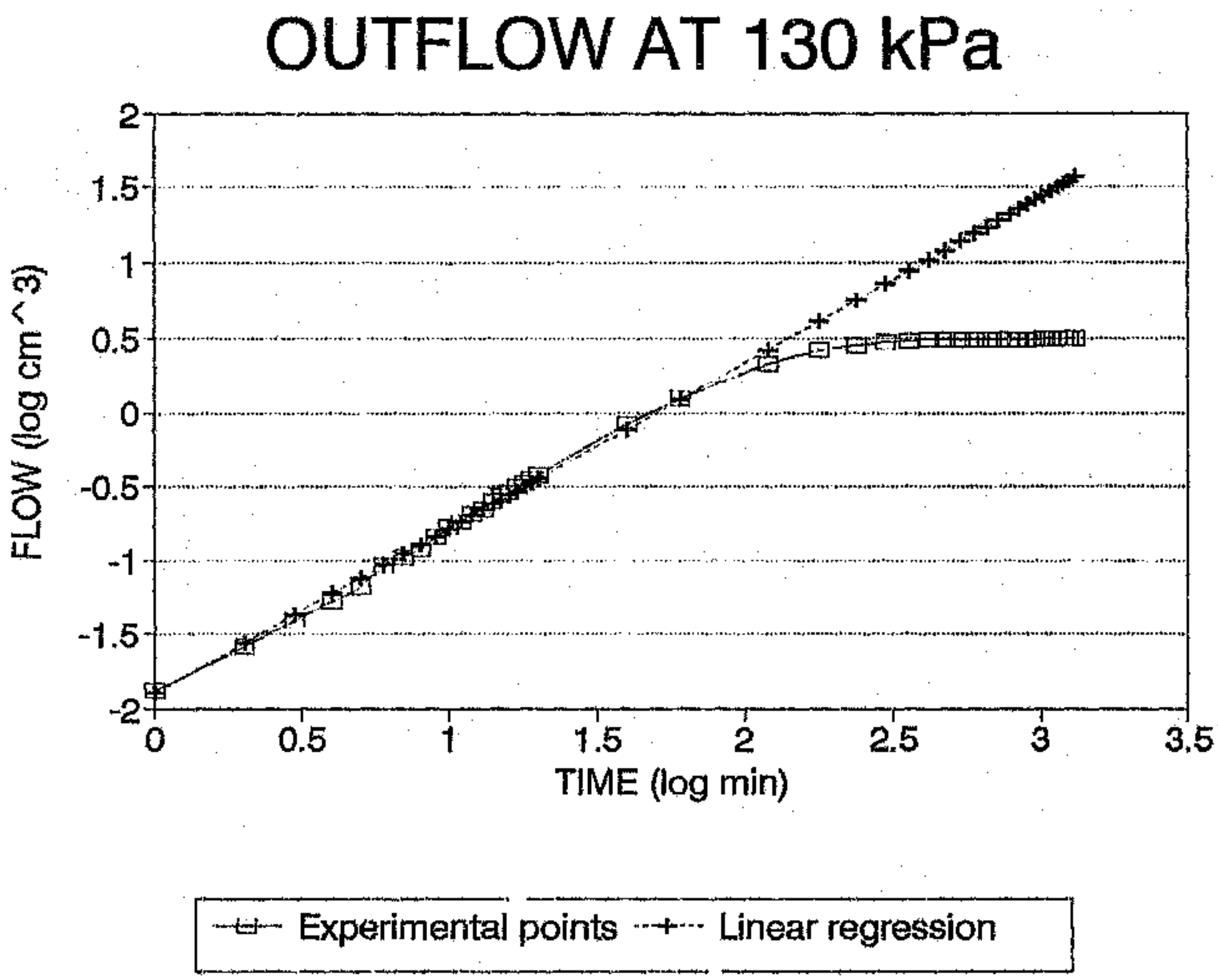
Regression Output:

Constant		-1.88092
Std Err of Y Est		0.034922
R Squared		0.991969
No. of Observations		19
Degrees of Freedom		17
X Coefficient(s)	1.110192	
Std Err of Coef.	0.024228	

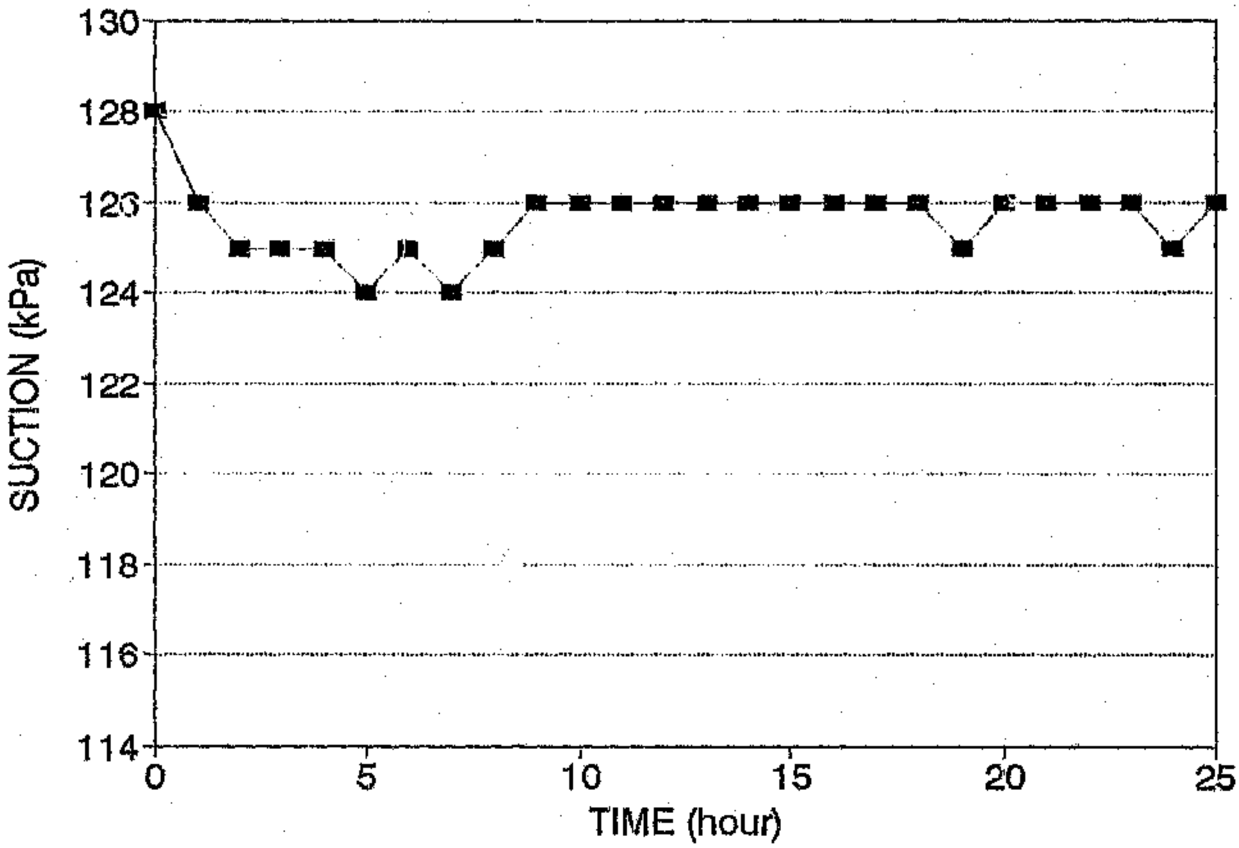
OUTFLOW VOLATGE
INTIAL -316
ENDED -77

VOLUME CHANGE VOLATGE
VOLUME INITIAL -329 V
VOLUME FINAL -324 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	610	127.8905	128
1	605	126.3945	126
2	501	125.3577	125
3	498	124.5801	126
4	498	124.5801	126
5	495	123.8025	124
6	498	124.5801	125
7	495	123.8025	124
8	500	125.0985	125
9	505	126.3945	126
10	503	125.8761	126
11	502	125.6169	126
12	504	126.1353	126
13	505	126.3945	126
14	503	125.8761	126
15	504	126.1353	126
16	505	126.3945	126
17	505	126.3945	126
18	502	125.6169	126
19	498	124.5801	125
20	502	125.6169	126
21	502	125.6169	126
22	503	125.8761	126
23	502	125.6169	126
24	498	124.5801	125
25	502	125.6169	126


OUTFLOW AT 130 kPa
FLOW (log cm ^3)
TIME (log min)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5
2
2.5
3
3.5
Experimental points
Linear regression

CAPILLARY PRESSURE AT 130 kPa



ASH TEST 2 APPLIED AIR PRESSURE 160 kPa
160

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	450	0	ERR	ERR	ERR
1	451	0.01915	0	-1.88107	-1.85908873
2	452	0.0263	0.30103	-1.58004	-1.56950459
3	453	0.03945	0.477121	-1.40395	-1.40010874
4	454	0.0526	0.60206	-1.27901	-1.27992046
5	455	0.06575	0.69897	-1.1821	-1.18660519
7	457	0.09205	0.845098	-1.03598	-1.04612329
9	458	0.1052	0.954243	-0.97798	-0.94112874
10	459	0.11635	1	-0.92563	-0.89711106
11	460	0.1315	1.041393	-0.88107	-0.85729223
12	462	0.1578	1.079181	-0.80189	-0.82094047
13	463	0.17095	1.113943	-0.76712	-0.7875001
14	464	0.1841	1.146128	-0.73495	-0.75653916
16	465	0.19725	1.20412	-0.70496	-0.7007522
17	466	0.2104	1.230449	-0.67695	-0.67542434
18	467	0.22355	1.255273	-0.65063	-0.65164461
19	469	0.24985	1.278754	-0.60232	-0.62895622
40	488	0.4997	1.60206	-0.30129	-0.3170428
60	503	0.69695	1.778151	-0.1568	-0.14854694
61	504	0.7101	1.78533	-0.14868	-0.1416413
121	554	1.3676	2.082785	0.135959	0.14504283
181	574	1.6306	2.257679	0.212347	0.31274764
241	584	1.7621	2.382017	0.246031	0.432358468
301	588	1.8147	2.478566	0.258805	0.525236886
361	591	1.85416	2.557507	0.268146	0.601176082
421	592	1.8673	2.624282	0.271214	0.665412039
481	591	1.85416	2.682145	0.268146	0.721074934
541	590	1.841	2.733197	0.265054	0.770185999
601	588	1.8147	2.778874	0.258805	0.814126452
661	586	1.7884	2.820201	0.252465	0.853882091
721	584	1.7621	2.857935	0.246031	0.890181169
781	583	1.74895	2.892651	0.242777	0.923576963
841	580	1.7095	2.924796	0.232869	0.954499699
901	578	1.6832	2.954725	0.226136	0.983290531
961	578	1.6832	2.982723	0.226136	1.010224556
1021	579	1.69635	3.009026	0.229516	1.035526834
1081	577	1.67005	3.033826	0.222729	1.059383033
1141	576	1.64375	3.057286	0.215836	1.081951782
1201	577	1.67005	3.079543	0.222729	1.103362858
1261	582	1.7358	3.100715	0.2395	1.123729936
1321	584	1.7621	3.120903	0.246031	1.143150082
1381	586	1.77625	3.140194	0.24926	1.161707459

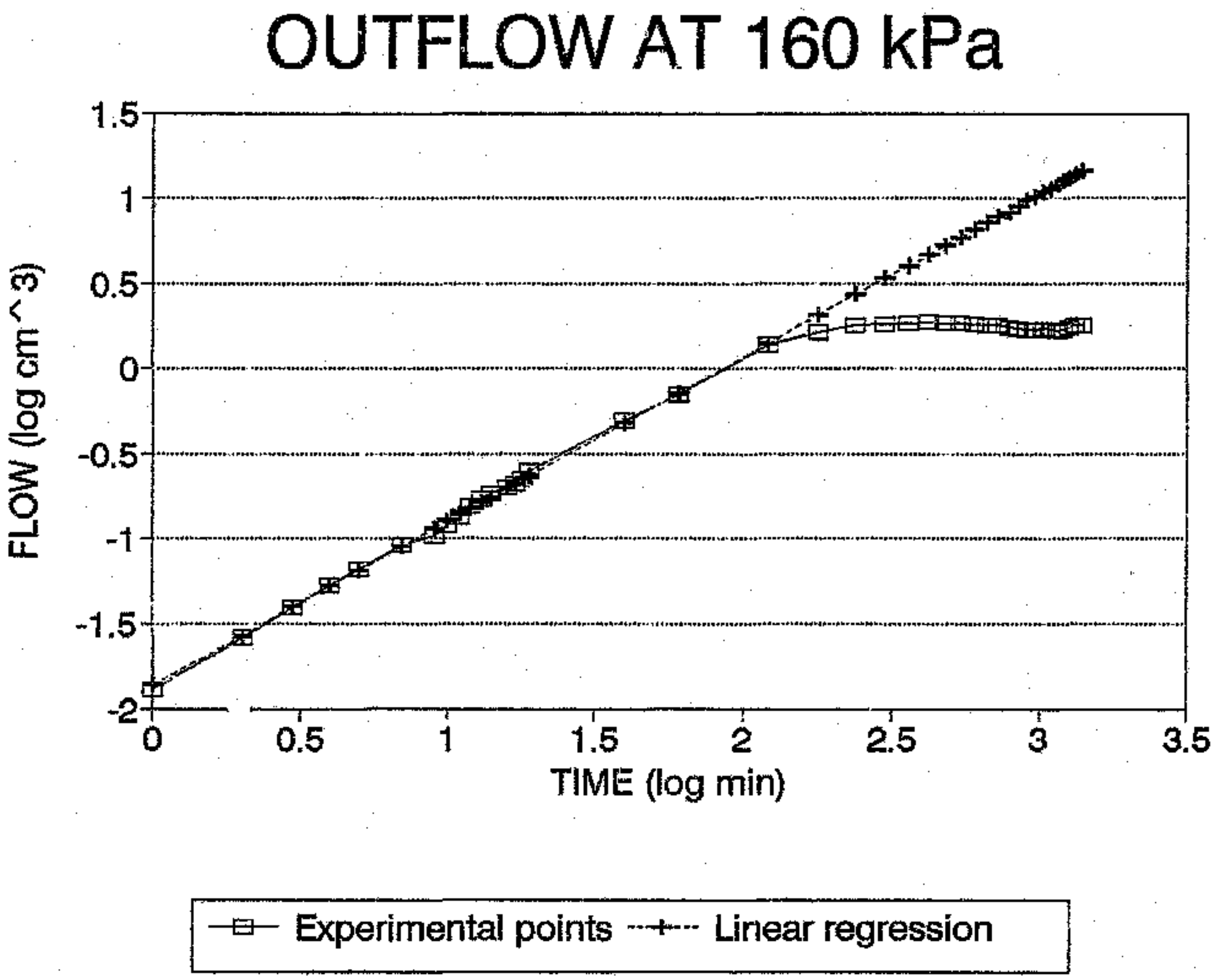
Regression Output:

Constant		-1.85909
Std Err of Y Est		0.019592
R Squared		0.997249
No. of Observations		16
Degrees of Freedom		14
X Coefficient(s)	0.961978	
Std Err of Coef	0.013503	

OUTFLOW VOLTAGE
INTIAL 450
ENDED 586

VOLUME CHANGE VOLTAGE
VOLUME INITIAL -324 V
VOLUME FINAL -322 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	618	165.4429	165.0
1	616	165.4429	155.0
2	607	153.1101	153.0
3	610	153.8877	164.0
4	612	154.4061	154.0
5	609	153.6285	154.0
6	607	153.1101	163.0
7	618	165.9613	166.0
8	628	167.2572	167.0
9	622	156.999	157.0
10	624	157.5184	158.0
11	623	167.2572	167.0
12	626	168.0248	158.0
13	629	158.8121	159.0
14	628	168.5532	159.0
15	630	159.0716	159.0
16	632	159.59	160.0
17	633	159.8492	160.0
18	634	160.1084	160.0
19	633	159.8492	160.0
20	635	160.3676	160.0
21	638	161.1452	161.0
22	637	160.886	161.0
23	631	159.3308	159.0
24	627	158.294	158.0
25	639	161.4044	161.0
26	633	159.8492	160.0
27	628	158.6532	159.0
28	638	161.1452	161.0
29	631	159.3308	159.0
30	630	159.0716	159.0
31	635	160.3676	160.0
32	639	161.4044	161.0
33	640	161.6636	162.0
34	643	162.4412	162.0
35	640	161.6636	162.0
36	642	162.182	162.0
37	643	162.4412	162.0
38	642	162.182	162.0
39	644	162.7004	163.0
40	645	162.9596	163.0
41	647	163.478	163.0
42	630	159.0716	159.0
43	628	158.6532	159.0
44	626	167.7768	168.0
45	626	168.0348	168.0
46	624	157.5184	158.0
47	618	165.9613	156.0
48	620	165.4796	166.0
49	623	167.2572	167.0


OUTFLOW AT 160 kPa
FLOW (log cm^3)
TIME (log min)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5
2
2.5
3
3.5
Experimental points
Linear regression

ASH TES2 APLLIED AIR PRESSURE 200 kPa
200

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-403	0	ERR	ERR	ERR
5	-400	0.03945	0.69897	-1.40305	-1.42962467
10	-399	0.0526	1	-1.27901	-1.16674501
15	-397	0.0789	1.176091	-1.10292	-1.0071207
20	-394	0.11835	1.30103	-0.92683	-0.89386546
25	391	0.1578	1.39794	-0.80189	0.80601785
30	-389	0.1841	1.477121	-0.73495	-0.73424114
35	-387	0.2104	1.544068	-0.67695	-0.67355479
40	-385	0.2367	1.60206	-0.6258	-0.62098589
45	-382	0.27315	1.653213	-0.56085	-0.57461693
50	-380	0.30246	1.69897	-0.51935	-0.53313829
55	-378	0.32875	1.740363	-0.48313	-0.49561699
61	-375	0.3682	1.78533	-0.43392	-0.45485429
121	-353	0.6575	2.082785	-0.1821	-0.18521493
181	-336	0.88105	2.257679	-0.055	-0.02867664
241	-323	1.052	2.382017	0.022016	0.086034478
301	-314	1.17025	2.478566	0.068316	0.173555233
361	312	1.19660	2.557507	0.077967	0.2461139
421	-310	1.22295	2.624282	0.087409	0.305644425
481	-307	1.2624	2.682145	0.101197	0.358096423
541	-304	1.30185	2.733197	0.114561	0.404374531
601	301	1.3413	2.778874	0.127626	0.445780292
661	-299	1.3676	2.820201	0.135959	0.483242639
721	-297	1.3939	2.857935	0.144232	0.517447816
781	-295	1.4202	2.892651	0.15235	0.548917185
841	-293	1.4465	2.924796	0.160318	0.578056151
901	-292	1.45965	2.954725	0.164249	0.605186194
961	-291	1.4728	2.982723	0.168144	0.630566637
1021	-290	1.48595	3.009026	0.172004	0.654409251
1081	-290	1.48595	3.033826	0.172004	0.676890077
1141	-290	1.48595	3.057286	0.172004	0.6981662
1201	-290	1.48595	3.079543	0.172004	0.718332194
1261	-290	1.48595	3.100715	0.172004	0.737524393

Regression Output

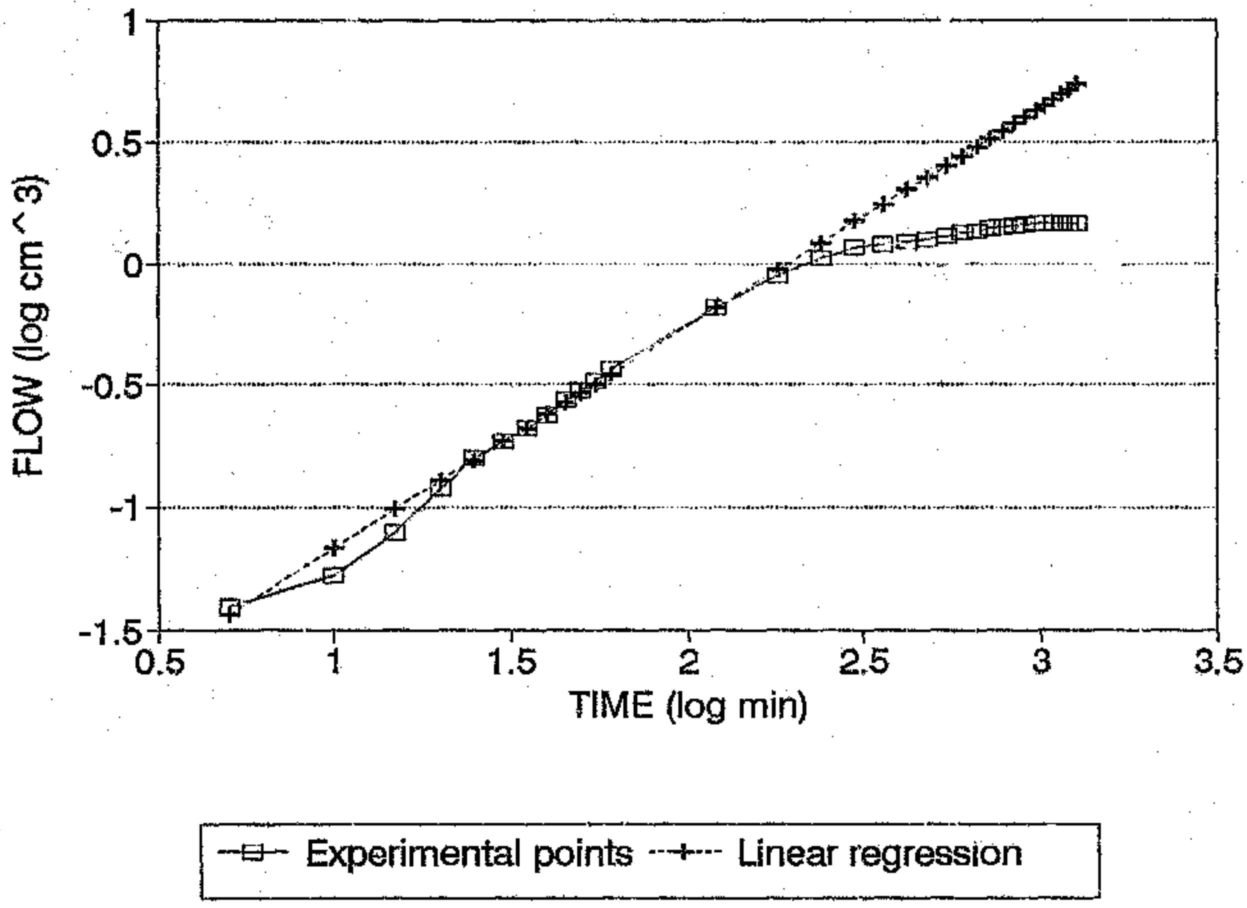
Constant		-2.07329
Std Err of Y Est		0.018208
R Squared		0.995483
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.906486	
Std Err of Coef	0.020353	

OUTFLOW VOLTAGE
INTIAL -403
ENDED -290

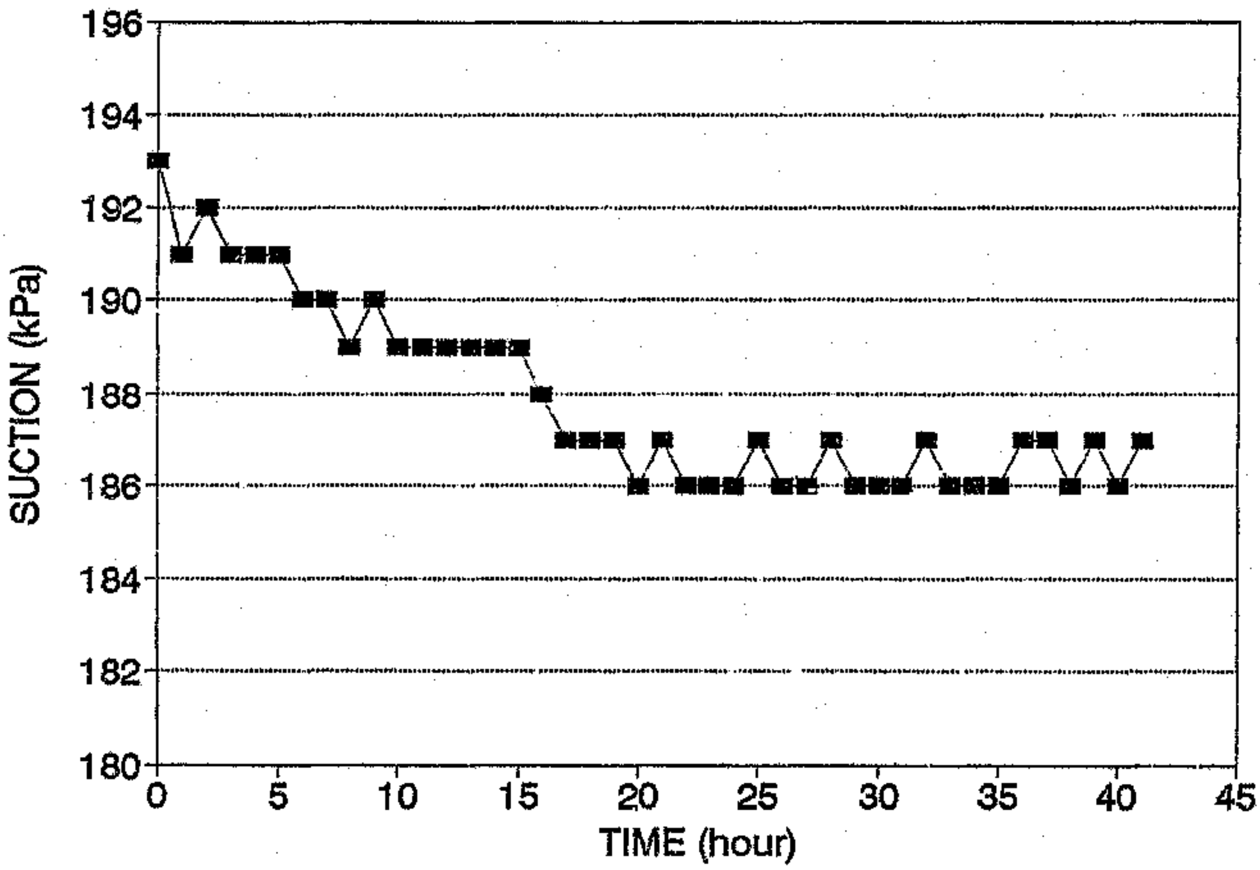
VOLUME CHANGE VOL
VOLUME INITIAL -322 V
VOLUME FINAL -321 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	769	192.876	193.0
1	760	190.6452	191.0
2	766	192.1004	192.0
2	762	191.0836	191.0
4	760	190.5452	191.0
5	762	191.0636	191.0
6	749	190.0258	190.0
7	746	189.6084	190.0
8	746	189.2492	189.0
9	748	190.0259	190.0
10	745	189.2492	189.0
11	743	188.7308	189.0
12	744	188.99	189.0
13	745	189.2492	189.0
14	744	188.99	189.0
15	743	188.7308	189.0
16	740	187.9532	188.0
17	736	186.6573	187.0
18	737	187.1756	187.0
19	735	186.6573	187.0
20	733	186.1389	185.0
21	736	186.6573	187.0
22	733	186.1389	186.0
23	731	185.6205	186.0
24	733	186.1289	185.0
25	735	186.6573	187.0
26	731	185.6205	186.0
27	732	185.8797	186.0
28	735	186.6573	187.0
29	731	185.6205	186.0
30	732	185.8797	186.0
31	732	185.8797	186.0
32	735	186.6573	187.0
33	731	185.6205	186.0
34	732	185.8797	186.0
35	732	185.8797	186.0
36	735	186.6573	187.0
37	736	186.6073	187.0
38	732	185.8797	186.0
39	738	187.4348	187.0
40	732	185.8797	186.0
41	735	186.6573	187.0

OUTFLOW AT 200 kPa



CAPILLARY PRESSURE AT 200 kPa



ASH TEST 3

SUMMARY OF RESULTS

SAMPLE: ASH TAILINGS TEST3

DIMENSIONS IN cm AND g

								AVERAGE
DIAMETER		7.24	7.15	6.98	6.96			7.0825
LENGTH		3.63	3.12	3.03	2.99	3.06		3.166
S GRAVITY		2.192239	2.199338	2.199721	2.126009	2.164744		2.17641

FINAL VOLUME T	124.7309
VOLUME SOIL	81.32382

BOWL	174.656
WET SOIL & BOWL	368.738
DRY SOIL & BOWL	351.65
WATER CONT.	0.09654564562
VOLM CONT.	0.136998962 13

	666	-0.06260936
RESET VOLUME GAUGE	-1	27.72799951

APPLIED PRESSURE kPa	VOLUME volts	VOLUME cm^3	TOTAL VOLUME cm^3	FLOW INITIAL volts	FINAL volts	ACTUAL FLOW cm^3	TOTAL FLOW cm^3
0	666	0.01921635172	38.57997			0	45.22849
30	359	17.3235493543	21.27564	364	1254	21.38734	23.84115
60	262	20.9166119134	17.68257	-1124	-279	11.11209	12.72906
110	132	24.8969298389	13.70228	335	926	7.812065	4.916996
160	628	30.6778734925	7.921312	-916	-1091	2.313217	2.603779
200	501	38.599185454	0	-1077	-879	2.603779	0

APPLIED PRESSURE kPa	SUCTION	VOLUMETRIC CONTENT cm^3/cm^3	WATER CONTENT	DEGREE SATURATION	SLOPE
0	-	0.38158208092	0.352083	0.760077544	-
30	28	0.20032411872	0.231246	0.632768202	1.131574
60	59	0.20936970088	0.168464	0.48808717	0.769193
110	108	0.15895758543	0.124326	0.395313676	1.736061
160	155	0.14644669699	0.111257	0.383643245	0.911587
200	190	0.1369989621 3	0.096546	0.393668789	1.279425

ASH TEST 3 APPLIED AIR PRESSURE 30 kPa
32

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	364	0	ERR	ERR	ERR
1	361	0.039654	0	-1.40171	-1.39874211
2	358	0.079308	0.30103	-1.10058	-1.0561044
3	354	0.13218	0.477121	-0.87882	-0.85684412
4	350	0.185052	0.60206	-0.73271	-0.7164667
5	345	0.251142	0.69897	-0.60006	-0.60580585
6	341	0.304014	0.778151	-0.51711	-0.51620641
7	336	0.370104	0.845098	-0.43168	-0.44045117
8	331	0.436194	0.90309	-0.36032	-0.37482909
9	326	0.502284	0.954243	-0.29905	-0.31634613
10	321	0.568374	1	-0.24537	-0.26515815
11	317	0.621246	1.041393	-0.20674	-0.21832826
12	312	0.687336	1.079181	-0.16283	-0.17556871
13	307	0.753426	1.113943	-0.12296	-0.13623202
14	302	0.819516	1.146128	-0.08644	-0.09981347
15	297	0.885606	1.176091	-0.05276	-0.06590786
16	292	0.951696	1.20412	-0.0216	-0.03419128
17	287	1.017786	1.230449	0.007606	-0.00439816
18	282	1.083876	1.255273	0.03498	0.023891672
19	277	1.149966	1.278754	0.060685	0.050262169
20	272	1.216056	1.30103	0.084954	0.076459567
40	179	2.44338	1.60206	0.388337	0.41610725
60	98	3.615988	1.778151	0.646047	0.615367544
180	-169	6.913014	2.255273	0.839667	1.155255591
300	-287	8.604918	2.477121	0.934747	1.406303799
420	-403	10.13021	2.623249	1.003961	1.571650479
540	-587	12.57032	2.732394	1.099348	1.695163618
660	-718	14.30188	2.819544	1.155393	1.793780387
780	-819	15.63589	2.892095	1.19416	1.875876833
900	-901	16.72077	2.954243	1.223256	1.946201786
1020	-963	17.54029	3.0086	1.244097	2.007711501
1140	-1009	18.14831	3.056905	1.258836	2.062371818
1260	-1047	18.6506	3.100371	1.270693	2.111556466
1380	-1080	19.08379	3.139879	1.280733	2.156263302
1500	-1110	19.48233	3.176091	1.289563	2.197240053
1620	-1137	19.84022	3.209515	1.297646	2.235061505
1740	-1165	20.21032	3.240549	1.305673	2.270179030
1860	-1190	20.54077	3.269513	1.312617	2.3029636
1980	-1207	20.76548	3.296665	1.317342	2.333678374
2100	-1217	20.89765	3.322219	1.320098	2.362594733
2220	-1224	20.99018	3.346353	1.322016	2.389903777
2340	-1231	21.08271	3.369216	1.323928	2.41577482
2460	-1235	21.1488	3.390935	1.325288	2.440351757
2580	-1241	21.21489	3.41162	1.326641	2.463757911
2700	-1246	21.28098	3.431364	1.327992	2.486099773
2820	-1254	21.38672	3.450249	1.330144	2.507469936

Regression Output:

Constant		-1.99674
Std Err of Y Est		0.023302
R Squared		0.997657
No. of Observations		22
Degrees of Freedom		20
X Coefficient(s)	1.131574	
Std Err of Coef.	0.012532	

OUTFLOW VOLTAGE

INTIAL +364

ENDED -1264

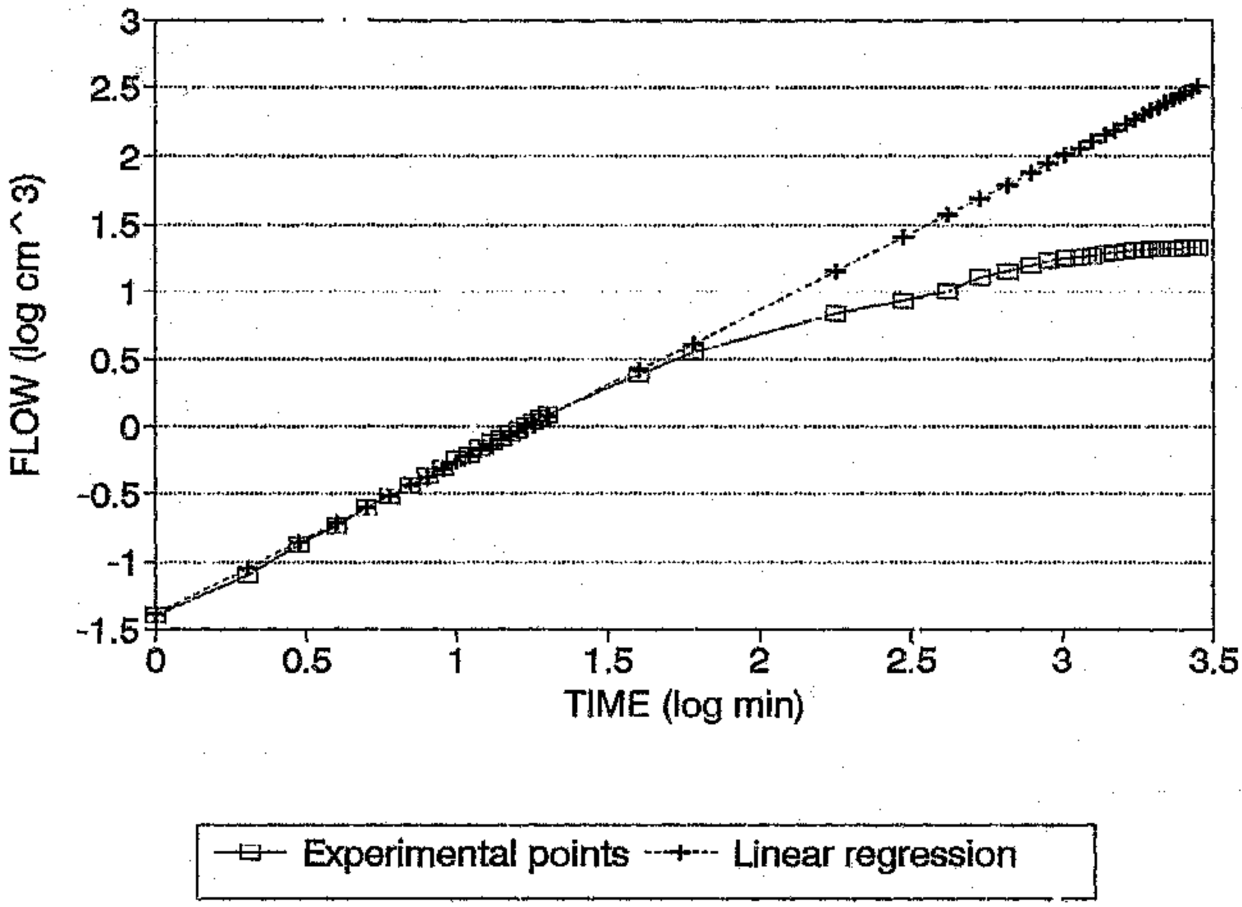
VOLUME CHANGE

VOLUME INITIAL -665 V

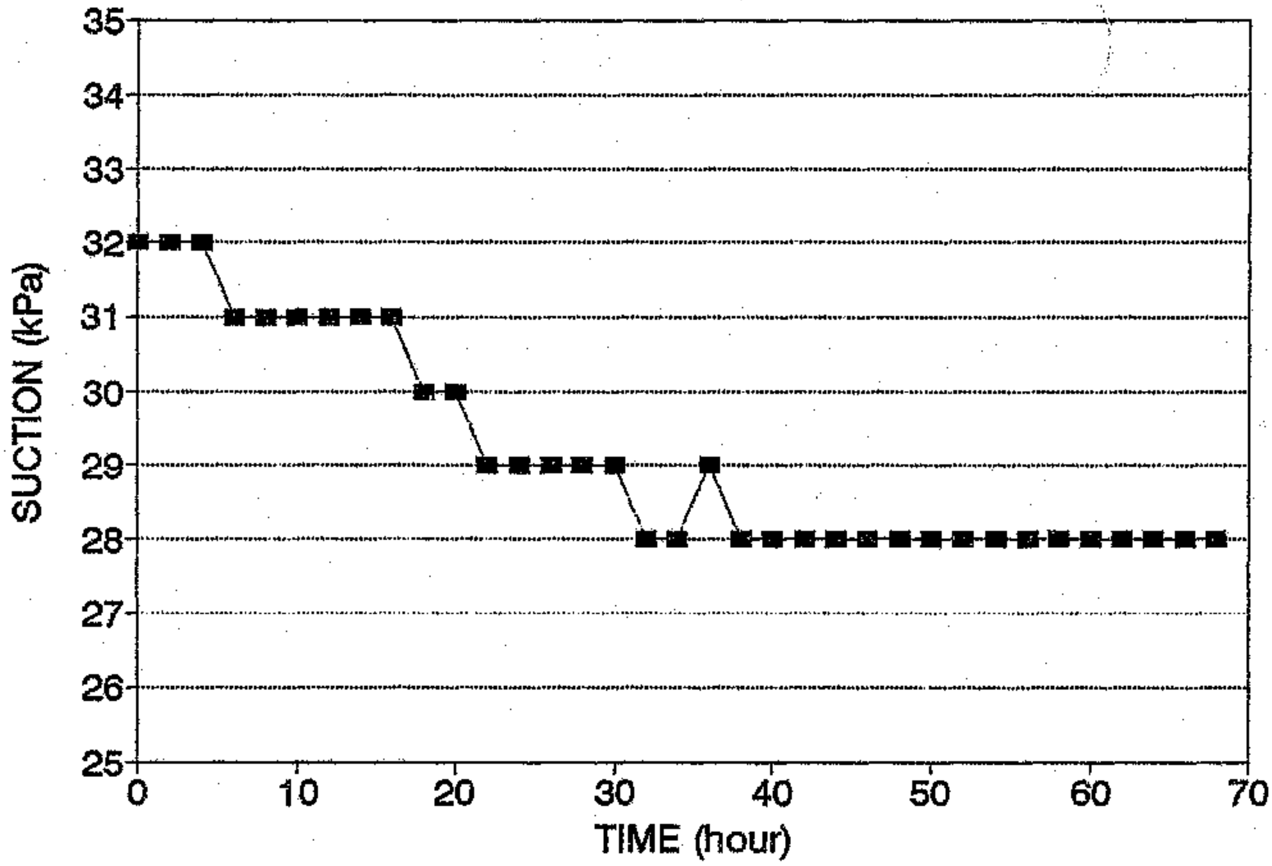
VOLUME FINAL -359 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	139	32.4364	32.0
2	138	32.1772	32.0
4	136	31.65881	32.0
6	135	31.39951	31.0
8	133	30.88121	31.0
10	133	30.88121	31.0
12	134	31.14041	31.0
14	134	31.14041	31.0
16	133	30.88121	31.0
18	128	29.58523	30.0
20	128	29.58523	30.0
22	127	29.32603	29.0
24	126	29.06683	29.0
26	125	28.80764	29.0
28	127	29.32603	29.0
30	126	29.06683	29.0
32	122	28.03004	28.0
34	122	28.03004	28.0
36	125	28.80764	29.0
38	123	28.28924	28.0
40	123	28.28924	28.0
42	123	28.28924	28.0
44	121	27.77085	28.0
46	120	27.51165	28.0
48	121	27.77085	28.0
50	120	27.51165	28.0
52	120	27.51165	28.0
54	120	27.51165	28.0
56	122	28.03004	28.0
58	122	28.03004	28.0
60	120	27.51165	28.0
62	121	27.77085	28.0
64	122	28.03004	28.0
66	120	27.51165	28.0
68	121	27.77085	28.0

OUTFLOW AT 30 kPa



CAPILLARY PRESSURE AT 30 kPa



ASH TEST { APPLIED AIR PRESSURE 60 kPa
60'

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1124	0	ERR	ERR	ERR
1	-1118	0.0789	(	-1.10292	-0.88960584
2	-1111	0.17095	0.30103	-0.76713	-0.65540824
3	-1104	0.263	0.477121	-0.58004	-0.51995023
4	-1098	0.3418	0.60206	-0.4661	-0.42385827
5	-1092	0.4208	0.69897	-0.37602	0.3493159
6	-1086	0.4997	0.778151	-0.30129	-0.28841017
7	-1081	0.56545	0.845098	-0.24751	-0.23691519
8	-1076	0.6312	0.90309	-0.19983	-0.19230821
9	-1071	0.69695	0.954243	-0.1568	-0.15296206
10	-1066	0.7627	1	-0.11765	-0.11775574
11	-1062	0.8153	1.041393	-0.08868	-0.08592879
12	-1057	0.88106	1.079181	-0.055	-0.0566601
13	-1053	0.93385	1.113943	-0.02982	-0.03012135
14	-1049	0.98625	1.146128	-0.00601	-0.00536512
15	-1044	1.052	1.176091	0.022016	0.017582367
16	-1040	1.1040	1.20412	0.043205	0.039241865
17	-1036	1.1672	1.230449	0.063408	0.059493882
18	-1032	1.2098	1.255273	0.082714	0.078588
19	-1029	1.24926	1.278754	0.096649	0.096649487
20	-1025	1.30185	1.30103	0.114561	0.113784326
21	-1021	1.35445	1.322219	0.131763	0.120082970
22	-1017	1.40705	1.342423	0.14831	0.145623276
23	-1014	1.4465	1.361728	0.160318	0.160472659
24	-1010	1.4891	1.380211	0.175831	0.174689969
25	-1006	1.5517	1.39794	0.190808	0.189326797
45	-945	2.35385	1.653210	0.371779	0.384680534
60	-902	2.9193	1.778151	0.465279	0.480782494
180	-640	8.3646	2.255273	0.903771	0.847780682
300	-478	8.4949	2.477121	0.929168	1.018426092
420	-379	9.79675	2.623249	0.991082	1.130825704
540	-324	10.62	2.732394	1.022316	1.214778829
660	-295	10.8882	2.819544	1.036956	1.281814108
780	-281	11.08546	2.892095	1.044753	1.337619543
900	-271	11.21695	2.954243	1.049875	1.38542325
1020	-264	11.309	3.0086	1.053424	1.42723477E
1140	-260	11.3616	3.056905	1.055439	1.46439038
1260	-266	11.2827	3.100371	1.052413	1.497923872
1380	-273	11.19065	3.139879	1.048855	1.528213552
1500	-279	11.11175	3.176091	1.045782	1.55608769

Regression Output:

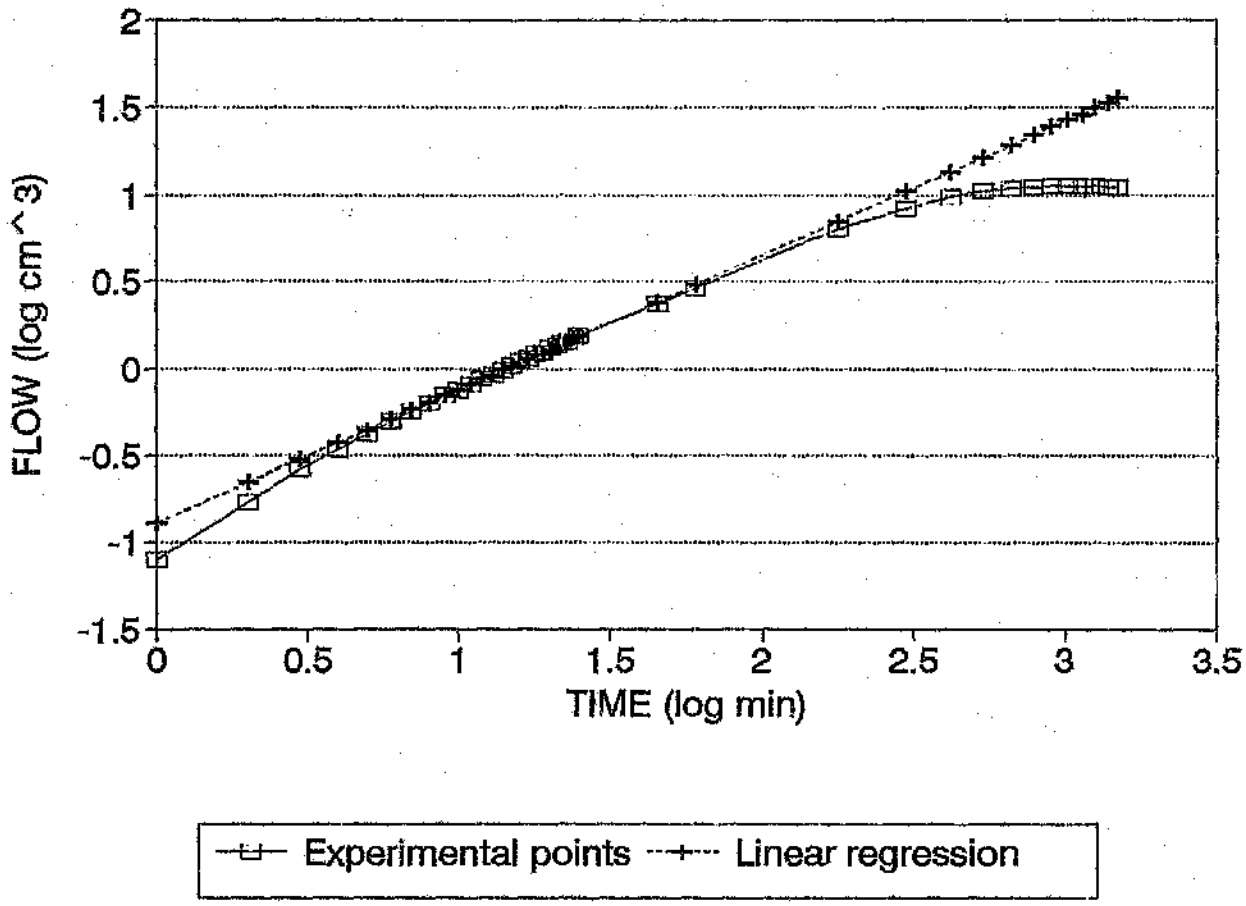
Constant		-0.88696
Std Err of Y Est		0.112103
R Squared		0.937556
No. of Observations		28
Degrees of Freedom		26
X Coefficient(s)	0.769193	
Std Err of Coef.	0.038928	

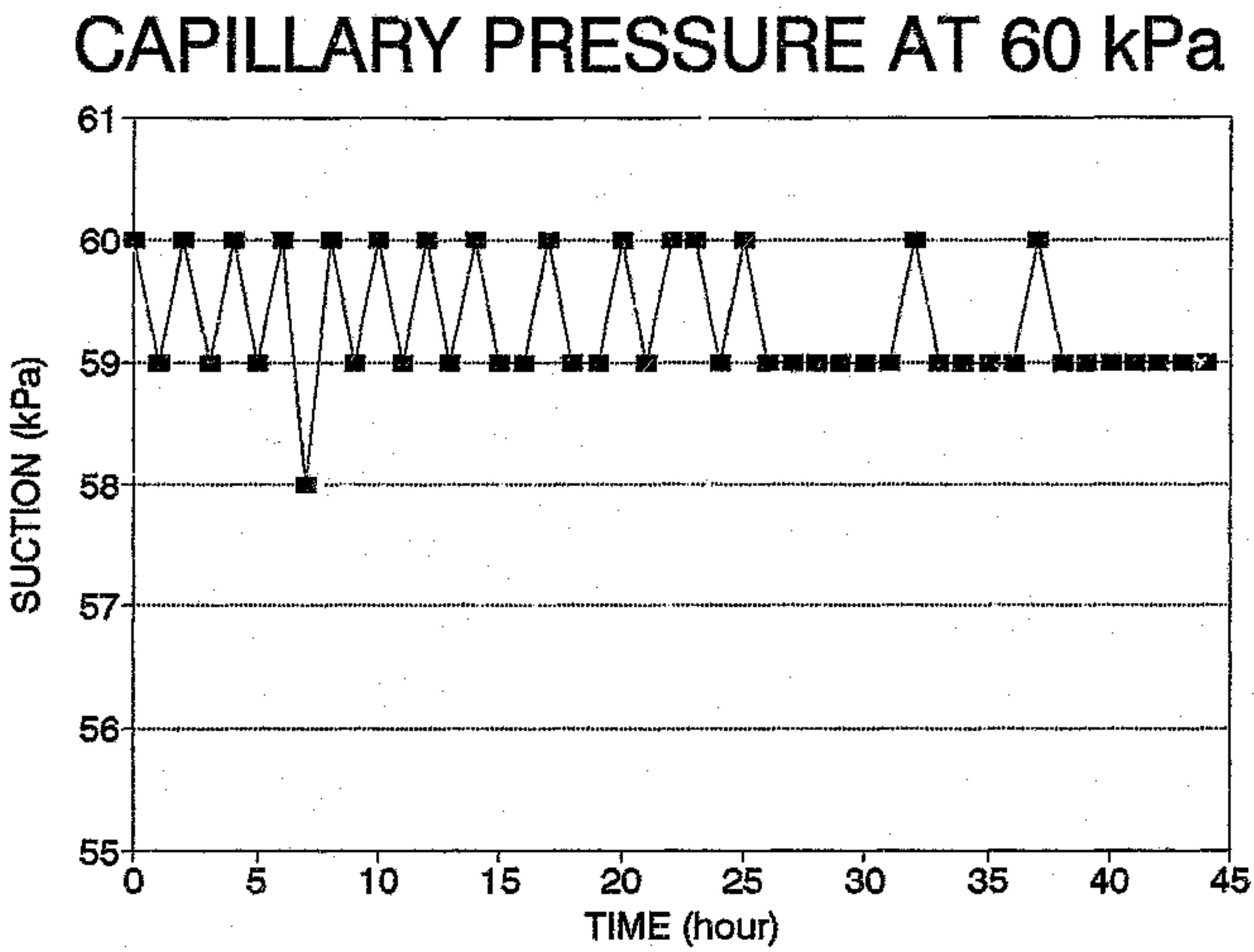
OUTFLOW VOLTAGE
INTIAL -1124
ENDED -279

VOLUME CHANGE VOLTAGE
VOLUME INITIAL -859 V
VOLUME FINAL -262 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	230	60.42945	60.0
1	223	58.61507	59.0
2	230	60.42945	60.0
3	226	59.39266	59.0
4	230	60.42945	60.0
5	224	58.87426	59.0
6	230	60.42945	60.0
7	222	58.35587	58.0
8	230	60.42945	60.0
9	223	58.61507	59.0
10	230	60.42945	60.0
11	225	59.13346	59.0
12	230	60.42945	60.0
13	225	59.13346	59.0
14	230	60.42945	60.0
15	223	58.61507	59.0
16	225	59.13346	59.0
17	227	59.65186	60.0
18	224	58.87426	59.0
19	223	58.61507	59.0
20	230	60.42945	60.0
21	225	59.13346	59.0
22	228	59.91105	60.0
23	228	59.91105	60.0
24	225	59.13346	59.0
25	227	59.65186	60.0
26	224	58.87426	59.0
27	223	58.61507	59.0
28	225	59.13346	59.0
29	223	58.61507	59.0
30	223	58.61507	59.0
31	223	58.61507	59.0
32	229	60.17025	60.0
33	226	59.39266	59.0
34	225	59.13346	59.0
34	226	59.39266	59.0
35	226	59.39266	59.0
36	223	58.61507	59.0
37	228	59.91105	60.0
38	225	59.13346	59.0
39	223	58.61507	59.0
40	225	59.13346	59.0
41	223	58.61507	59.0
42	224	58.87426	59.0
43	225	59.13346	59.0
44	226	59.39266	59.0

OUTFLOW AT 60 kPa




CAPILLARY PRESSURE AT 60 kPa
61
60
59
58
57
56
55
SUCTION (kPa)
0
5
10
15
20
25
30
35
40
45
TIME (hour)

ASH TEST 3 APPLIED AIR PRESSURE 110 kPa
110

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-335	0	ERR	ERR	ERR
14	-349	0.185052	1.146128	-0.73271	-0.79989735
16	-351	0.211488	1.20412	-0.67471	-0.69920979
17	-352	0.224706	1.230449	-0.64839	-0.65350114
18	-354	0.251142	1.255273	-0.60008	-0.61040589
19	-356	0.277578	1.278754	-0.55661	0.65964127
20	-357	0.290796	1.30103	-0.53641	-0.53096809
21	-359	0.317232	1.322219	-0.49862	-0.49418217
22	-361	0.343668	1.342423	-0.46386	-0.45910706
23	-363	0.370104	1.361728	[illegible]	-0.43559293
24	-366	0.409758	1.380211	[illegible]	-0.39350461
25	-368	0.436194	1.39794	-.36032	-0.26272629
26	-370	0.46263	1.414973	-0.33477	-0.33315648
27	-372	0.489066	1.431364	-0.31093	-0.30170071
28	-375	0.52872	1.447158	-0.27677	-0.2772809
29	-378	0.568374	1.462398	-0.24537	-0.25382339
30	-380	0.59481	1.477121	-0.22562	-0.2252 '282
31	383	0.634464	1.491362	-0.19760	0.20054064
32	-385	0.6609	1.50515	-0.17989	-0.17550334
33	-388	0.700554	1.518514	-0.15468	-0.15340289
34	-391	0.740208	1.531479	-0.13065	-0.1308947
35	-394	0.779862	1.544068	-0.10798	0.1090392
36	-397	0.819516	1.556303	-0.08644	-0.08779944
96	-565	3.04014	1.982271	0.482894	0.651708282
156	-682	4.586546	2.193125	0.661495	1.017782595
216	-760	5.61765	2.334454	0.749596	1.253118601
276	-812	6.304986	2.440909	0.799684	1.447931584
336	-850	6.80727	2.526339	0.832973	1.596243617
396	-878	7.177374	2.597695	0.855968	1.72012183
456	-898	7.441734	2.658965	0.871674	1.828489594
516	-913	7.640004	2.71265	0.883094	1.919689887
576	-925	7.79862	2.760422	0.892018	2.002626352
636	-931	7.877928	2.803457	0.896412	2.0773371
696	-934	7.917582	2.842609	0.898593	2.145307677
756	-938	7.970454	2.878522	0.901483	2.207653967
816	-938	7.970454	2.91169	0.901483	2.26523627
876	-939	7.983672	2.942504	0.902203	2.318731164
936	-936	7.944018	2.971276	0.90004	2.368680665
996	-934	7.917582	2.998259	0.898593	2.41652566
1056	-933	7.904364	3.023664	0.897867	2.459629561
1116	-932	7.891146	3.047664	0.89714	2.501295498
1176	-931	7.877928	3.070407	0.896412	2.640776963
1236	-930	7.86471	3.092018	0.895683	2.578297227
1296	-928	7.838274	3.112605	0.89422	2.614036701
1356	-926	7.811838	3.13226	0.892753	2.648158439
1416	-926	7.811838	3.151063	0.892753	2.680802574

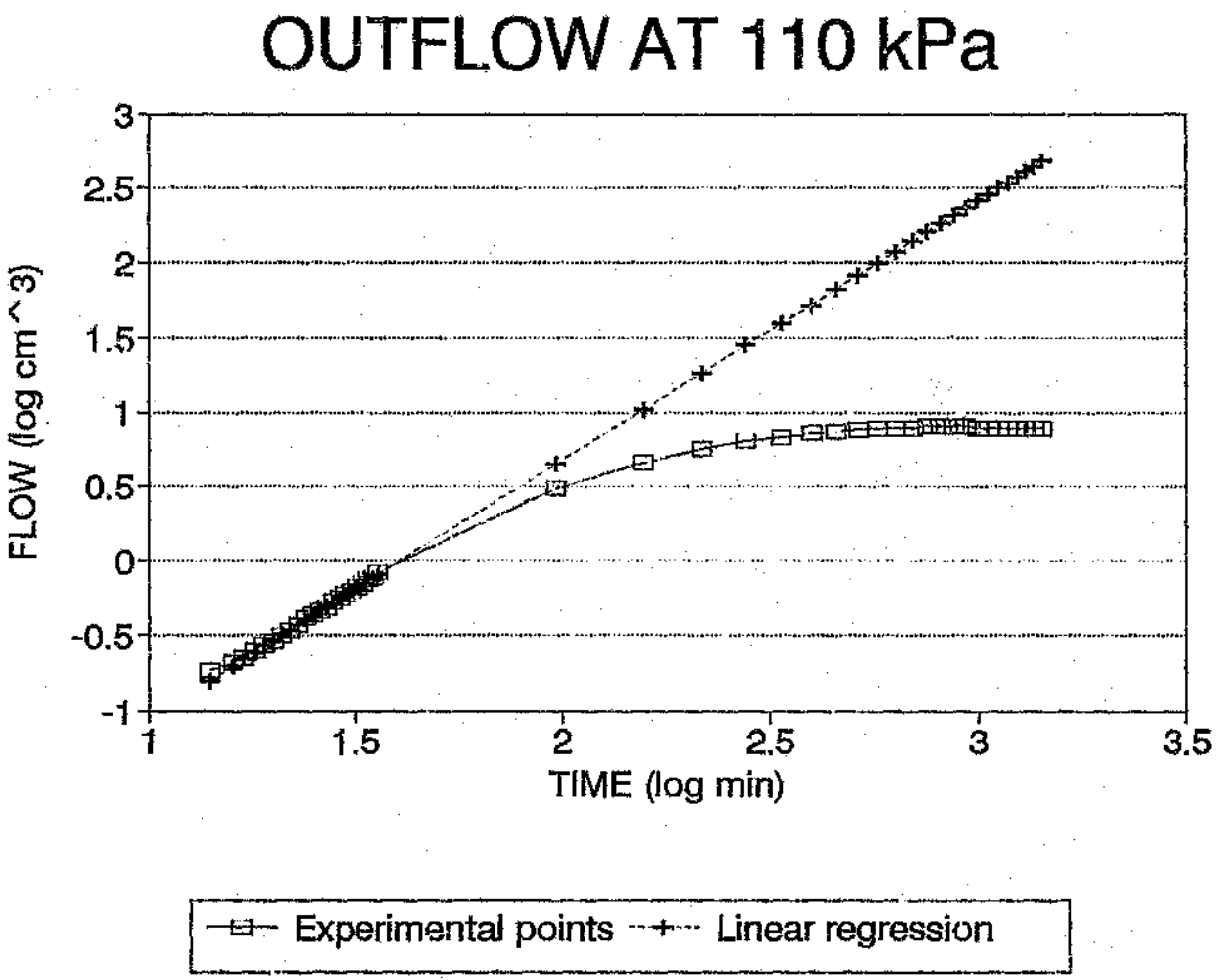
Regression Output:

Constant		-2.78964
Std Err of Y Est		0.005077
R Squared		0.998926
No. of Observations		18
Degrees of Freedom		16
X Coefficient(s)	1.736061	
Std Err of Coef.	0.014234	

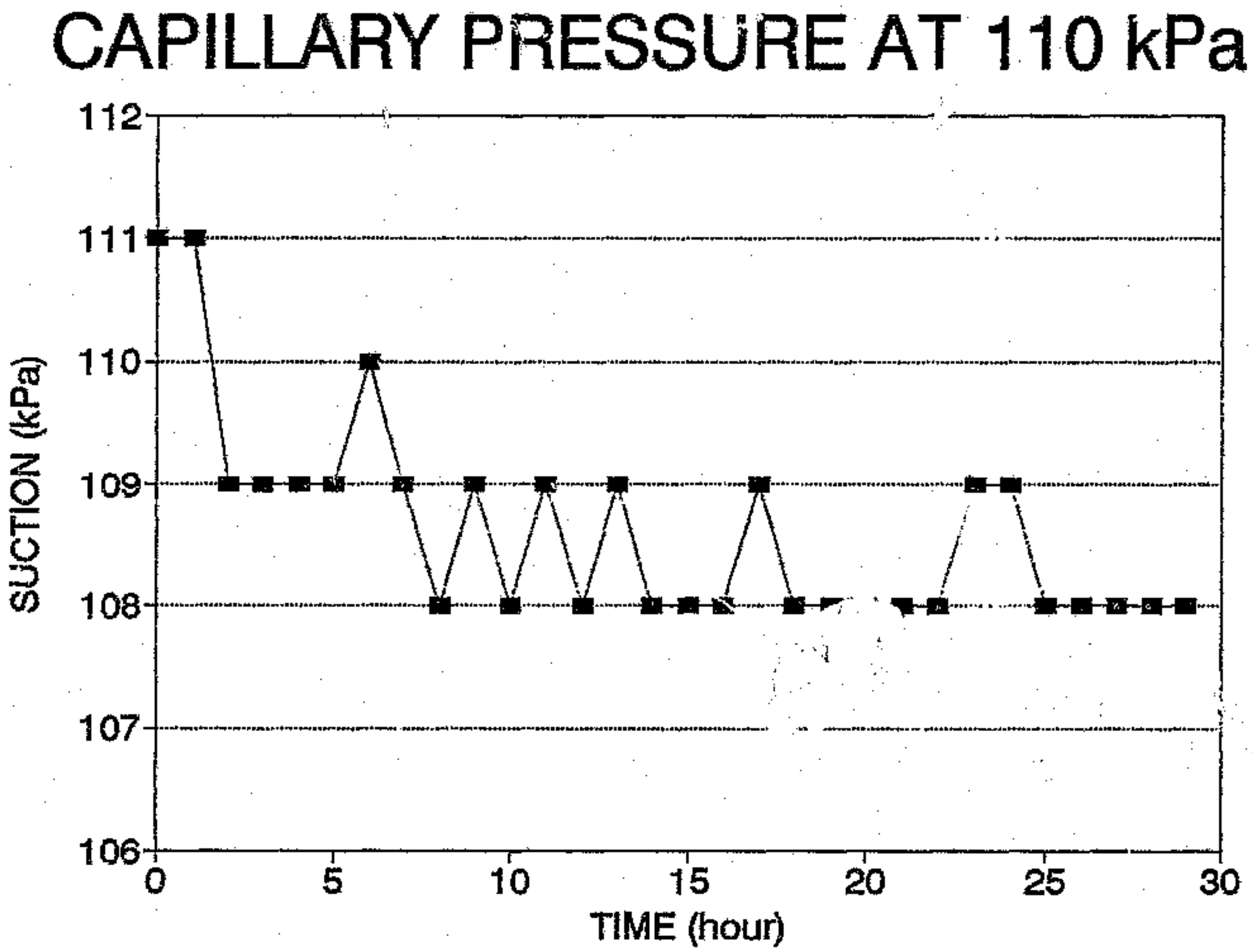
OUTFLOW VOLTAGE
INTIAL -335
ENDED -926

VOLUME CHANGE VOLTAGE
VOLUME INITIAL -262 V
VOLUME FINAL -132 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	422	110.6577	111.0
1	424	111.1761	111.0
2	416	109.1025	109.0
3	415	108.8433	109.0
4	417	109.3617	109.0
5	417	109.3617	109.0
6	418	109.6209	110.0
7	415	108.8433	109.0
8	413	108.3249	108.0
9	417	109.3617	109.0
10	411	107.8066	109.0
11	415	108.8433	109.0
12	410	107.5474	108.0
13	416	109.1025	109.0
14	410	107.5474	108.0
15	413	108.3249	108.0
16	413	108.3249	108.0
17	414	108.5841	109.0
18	413	108.3249	108.0
19	410	107.5474	108.0
20	413	108.3249	108.0
21	410	107.5474	108.0
22	413	108.3249	108.0
23	414	108.5841	109.0
24	414	108.5841	109.0
25	412	108.0658	108.0
26	411	107.8066	108.0
27	410	107.5474	108.0
28	413	108.3249	108.0
29	412	108.0658	108.0



OUTFLOW AT 110 kPa
FLOW (log cm^3)
TIME (log min)
3
2.5
2
1.5
1
0.5
0
-0.5
-1
1
1.5
2
2.5
3
3.5
Experimental points
Linear regression


CAPILLARY PRESSURE AT 110 kPa
SUCTION (kPa)
TIME (hour)
112
111
110
109
108
107
106
0
5
10
15
20
25
30

ASH TEST 3 APPLIED AIR PRESSURE 160 kPa
130

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-922	0	ERR	ERR	ERR
20	-934	0.158616	1.30103	-0.79965	-0.78341322
40	-945	0.304014	1.60206	-0.51711	-0.51492807
60	-956	0.449412	1.778151	-0.34728	-0.25447549
80	-966	0.581692	1.90309	-0.23538	-0.24058291
100	-976	0.713772	2	-0.14644	-0.15224096
120	-986	0.845952	2.079181	-0.07265	-0.08006033
140	-995	0.964914	2.146128	-0.01566	-0.01903248
160	-1006	1.097094	2.20412	0.040244	0.03932255
180	-1013	1.202838	2.255273	0.080207	0.080482252
200	-1022	1.3218	2.30103	0.121188	0.122174206
220	-1029	1.414326	2.342423	0.15065	0.159907258
240	-1037	1.52007	2.380211	0.181964	0.194354835
260	-1043	1.599378	2.414973	0.203951	0.226042525
280	-1049	1.678686	2.447158	0.224969	0.255382688
300	-1055	1.757994	2.477121	0.245017	0.282696786
320	-1061	1.837302	2.50515	0.264161	0.308247418
340	-1065	1.903392	2.531479	0.279528	0.332248548
360	-1070	1.956264	2.556303	0.291427	0.354877415
380	-1075	2.022354	2.579784	0.305857	0.376282487
400	-1079	2.075226	2.60206	0.317066	0.396589259
420	-1083	2.128098	2.623249	0.327992	0.415905263
440	-1085	2.154534	2.643453	0.333353	0.434322421
460	-1087	2.18097	2.662758	0.33965	0.451920759
[illegible]	-1088	2.194188	2.681241	0.341274	0.468769898
500	-1089	2.207406	2.69897	0.343882	0.48493132
520	-1088	2.194188	2.716003	0.341274	0.500458696
540	-1089	2.207406	2.732394	0.343882	0.515399995
560	-1089	2.207406	2.748188	0.343882	0.529797651
580	-1090	2.220624	2.763428	0.346475	0.543690413
600	-1089	2.207406	2.778151	0.343882	0.557111949
620	-1089	2.207406	2.792392	0.343882	0.570093354
640	-1088	2.194188	2.80618	0.341274	0.582662581
660	-1088	2.194188	2.819544	0.341274	0.594845001
680	-1089	2.207406	2.832509	0.343882	0.606663711
700	-1091	2.233842	2.845098	0.349052	0.618139801
720	-1091	2.233842	2.857332	0.349052	0.629292578
740	-1091	2.233842	2.869232	0.349052	0.640139761

Regression Output:

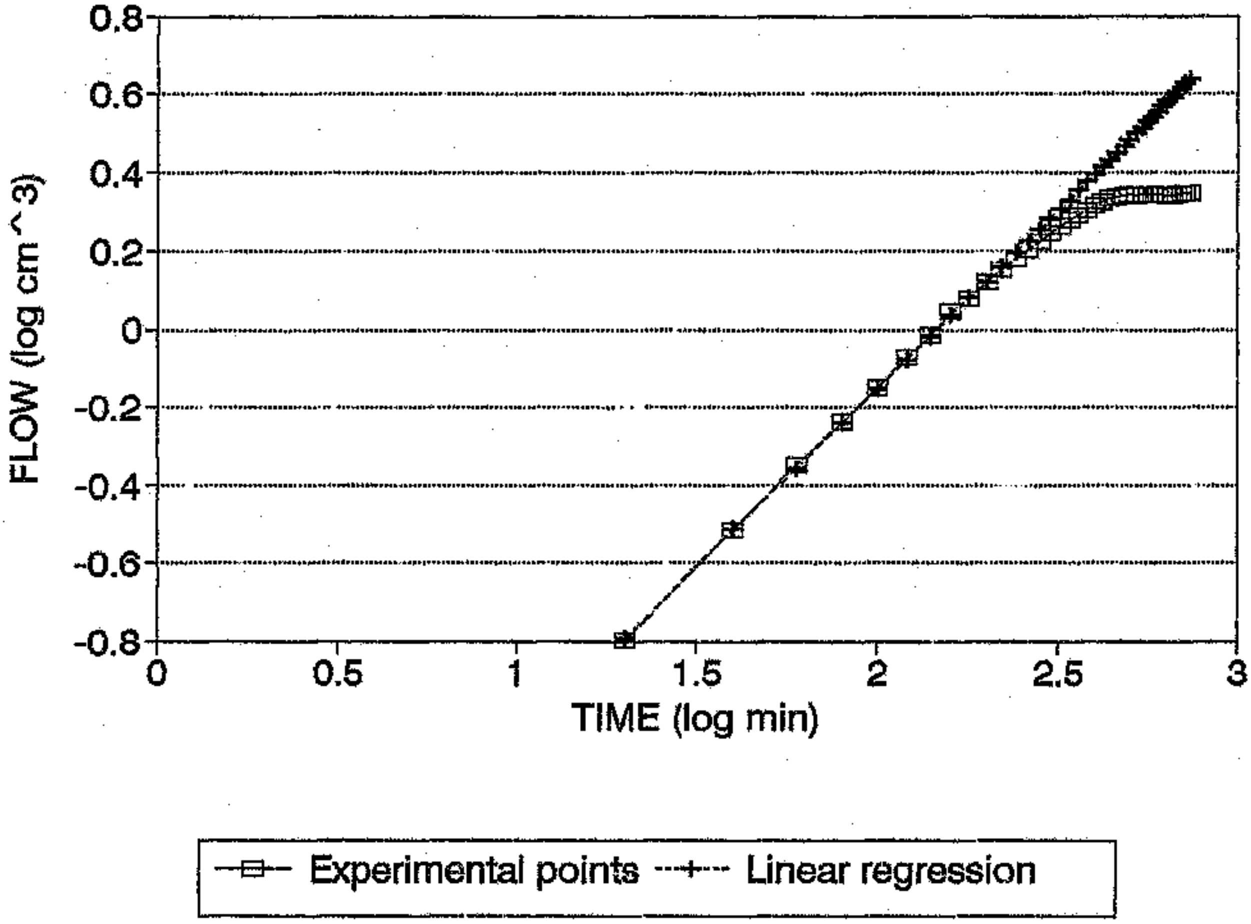
Constant		-1.97542
Std Err of Y Est		0.027574
R Squared		0.999418
No. of Observations		12
Degrees of Freedom		10
X Coefficient(s)	0.911567	
Std Err of Coef.	0.005957	

OUTFLOW VOLTAGE
INTIAL -916
ENDED -1091

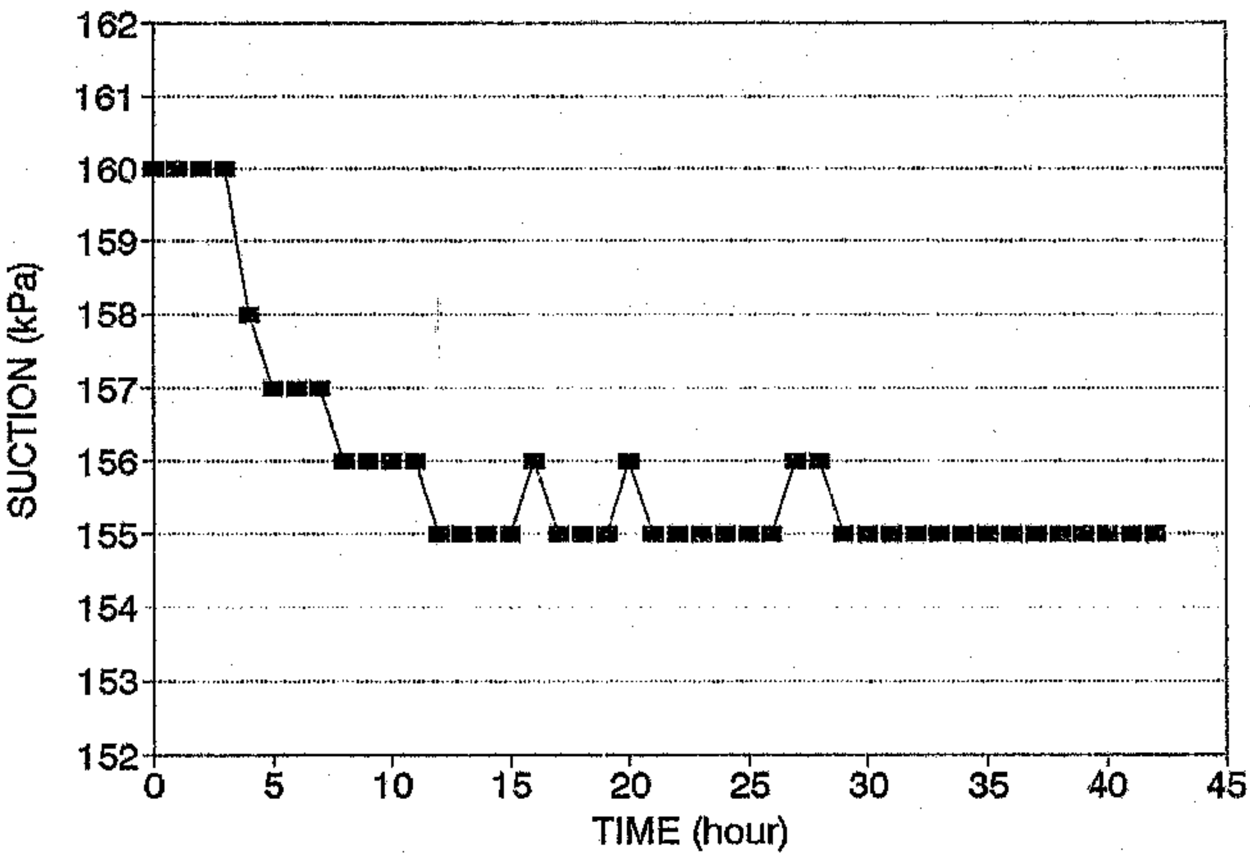
VOLUME CHANGE VOLATEG
VOLUME INITIAL -132 V
VOLUME FINAL -628 (-666) V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	613	160.3484	160
1	612	160.0902	160
2	610	159.5718	160
3	612	160.0902	160
4	605	158.2758	158
5	600	156.9798	157
6	599	156.7206	157
7	600	156.9798	157
8	596	155.6838	156
9	527	156.2022	156
10	597	156.2022	156
11	595	155.6838	156
12	593	155.1654	155
13	594	155.4246	155
14	593	155.1654	155
15	593	155.1654	155
16	595	155.6838	156
17	593	155.1654	155
18	594	155.4246	155
19	593	155.1654	155
20	595	155.6838	156
21	[illegible]	155.1654	155
22	592	154.9062	155
23	593	155.1654	155
24	594	155.4246	155
25	593	155.1654	155
26	593	155.1654	155
27	595	155.6838	156
28	595	155.6838	156
29	592	154.9062	155
30	594	155.4246	155
31	593	155.1654	155
32	594	155.4246	155
33	592	154.9062	155
34	594	155.4246	155
35	592	154.9062	155
36	593	155.1654	155
37	594	155.4246	155
38	593	155.1654	155
39	593	155.1654	155
40	592	154.9062	155
41	592	154.9062	155
42	593	155.1654	155

OUTFLOW AT 160 kPa



CAPILLARY PRESSURE AT 160 kPa



ASH TEST 3 APPLIED AIR PRESSURE 200 kPa
200

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1077	0	ERR	ERR	ERR
20	-1076	0.01315	1.30103	-1.88107	-1.0508399
40	-1074	0.03945	1.60206	-1.40396	-1.4716446
60	-1073	0.0526	1.778151	-1.27901	-1.240549
80	-1071	0.0789	1.90309	-1.10292	-1.0265093
100	-1069	0.11835	2	-0.92683	-0.9097102
120	-1067	0.1315	2.079181	-0.88107	-0.8814037
140	-1065	0.1578	2.146128	-0.80189	-0.7767503
160	-1062	0.19725	2.20412	-0.70498	-0.701654
180	-1063	0.2367	2.255273	-0.6253	-0.6331031
200	-1057	0.263	2.30103	-0.58004	-0.5775049
220	-1054	0.30245	2.342423	-0.51935	-0.524506
240	-1052	0.32875	2.380211	-0.48316	-0.4762584
260	-1049	0.3682	2.414973	-0.43392	-0.4317820
280	-1046	0.40765	2.447158	-0.38971	-0.390625
300	-1043	0.4471	2.477121	-0.3496	-0.3522593
320	-1040	0.48655	2.50515	-0.31287	-0.3164080
340	-1037	0.526	2.531479	-0.27901	-0.2827247
360	-1034	0.56545	2.556303	-0.24761	-0.2509623
380	-1031	0.6049	2.579784	-0.21832	-0.2209205
400	-1029	0.64435	2.60206	-0.19089	-0.1924195
420	-1025	0.6838	2.623249	-0.16507	-0.1653094
440	-1023	0.7101	2.643453	-0.14869	-0.1394507
460	-1021	0.7364	2.662758	-0.13289	-0.1147512
480	-1018	0.77585	2.681241	-0.11022	-0.0911131
500	-1015	0.8153	2.69897	-0.08869	-0.0684304
520	-1013	0.8416	2.716003	-0.07499	-0.0466379
540	-1010	0.88105	2.732394	-0.055	-0.0256672
560	-1005	0.90735	2.748188	-0.04223	-0.0054597
580	-1006	0.92365	2.763428	-0.02062	0.01403974
600	-1003	0.9731	2.778151	-0.01184	0.03287605
620	-1002	0.98625	2.792392	-0.00601	0.05109502
640	-999	1.0257	2.80618	0.01102	0.0687357
660	-997	1.052	2.819544	0.022016	0.08583489
680	-995	1.0783	2.832509	0.03274	0.1024225
700	-993	1.1046	2.845098	0.043205	0.11852945
720	-991	1.1309	2.857332	0.053424	0.13418262
740	-989	1.1572	2.869232	0.063408	0.14940658
760	-987	1.1835	2.880814	0.073168	0.16422482
780	-985	1.2098	2.892095	0.082714	0.17865603
800	-983	1.2361	2.90309	0.092054	0.1927258
820	-981	1.2624	2.913814	0.101197	0.20644613
840	-979	1.2887	2.924279	0.110152	0.21983592
860	-977	1.315	2.934498	0.118926	0.23291059
880	-976	1.32815	2.944483	0.123247	0.24568464
900	-974	1.35445	2.954243	0.131763	0.25817152
920	-971	1.3939	2.963788	0.144233	0.27038414
940	-970	1.40705	2.973128	0.14831	0.282334
960	-969	1.4202	2.982271	0.15236	0.29403227
980	-967	1.4465	2.991226	0.160318	0.30548932
1000	-965	1.4728	3	0.168144	0.3167149
1020	-963	1.4991	3.0086	0.175831	0.32771810
1040	-962	1.51225	3.017033	0.179624	0.33850778
1060	-960	1.53855	3.025306	0.187119	0.34909188
1080	-959	1.5517	3.033424	0.190808	0.35947809
1100	-957	1.578	3.041393	0.198107	0.36967374
1120	-955	1.60115	3.049218	0.201711	0.37968587
1140	-955	1.6043	3.056905	0.205296	0.3895204
1160	-954	1.61745	3.064458	0.208831	0.39918407
1180	-952	1.64375	3.071882	0.215836	0.40868255
1200	-951	1.6569	3.079181	0.219296	0.41802137
1220	-950	1.67005	3.08636	0.222729	0.42720584
1240	-949	1.6832	3.093422	0.226135	0.43624095
1260	-947	1.7095	3.100371	0.232869	0.4451318
1280	-947	1.7095	3.10721	0.232869	0.45388203
1300	-946	1.72265	3.113943	0.236197	0.46249589
1320	-945	1.7358	3.120574	0.2395	0.47098021
1340	-944	1.74895	3.127105	0.242777	0.47923597
1400	-942	1.77525	3.146128	0.24926	0.50367478
1460	-939	1.81785	3.164353	0.261941	0.52660207
1520	-934	1.88045	3.181844	0.274252	0.54927010
1580	-930	1.93306	3.198657	0.286243	0.57088176
1640	-927	1.9725	3.214844	0.295017	0.59159161
1700	-922	2.03895	3.230449	0.309357	0.61155701
1760	-919	2.0777	3.245513	0.317583	0.63082997
1820	-915	2.1303	3.260071	0.328441	0.64945676
1880	-913	2.1566	3.274158	0.33377	0.66747933
1940	-908	2.22235	3.287802	0.346812	0.68493580
2000	-904	2.27495	3.30103	0.356972	0.70186023
2060	-901	2.3144	3.313867	0.364439	0.7182345
2120	-899	2.3407	3.326336	0.369346	0.73423719
2180	-897	2.367	3.338456	0.374198	0.74974463
2240	-895	2.3933	3.350248	0.378997	0.764931
2300	-892	2.43275	3.361728	0.386097	0.77951057
2360	-890	2.45905	3.372912	0.390767	0.79382787
2420	-888	2.48535	3.383815	0.395388	0.80777701
2480	-885	2.5248	3.394452	0.402227	0.82136829
2540	-884	2.53795	3.404834	0.404483	0.83466932
2600	-882	2.56425	3.414973	0.40896	0.84764221
2660	-880	2.59055	3.424882	0.413392	0.86031913
2720	-879	2.6037	3.434569	0.415591	0.87271329

Regression Output

Constant		-3.52156
Std Err of Y Est		0.023256
R Squared		0.997367
No. of Observations		18
Degrees of Freedom		16
X Coefficient(s)	1.279425	
Std Err of Coef.	0.015822	

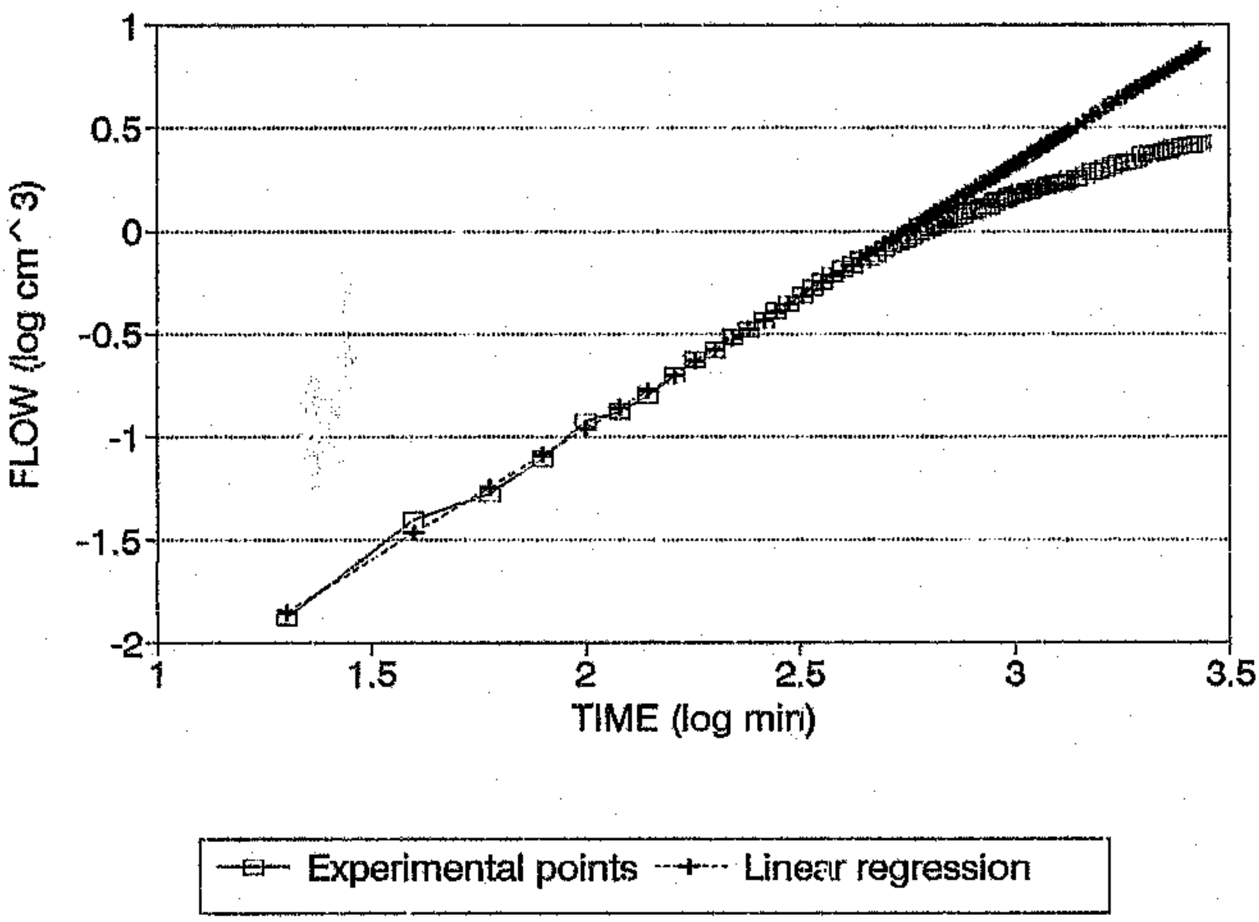
OUTFLOW VOLATGE
INITIAL -1077

ENDED -879

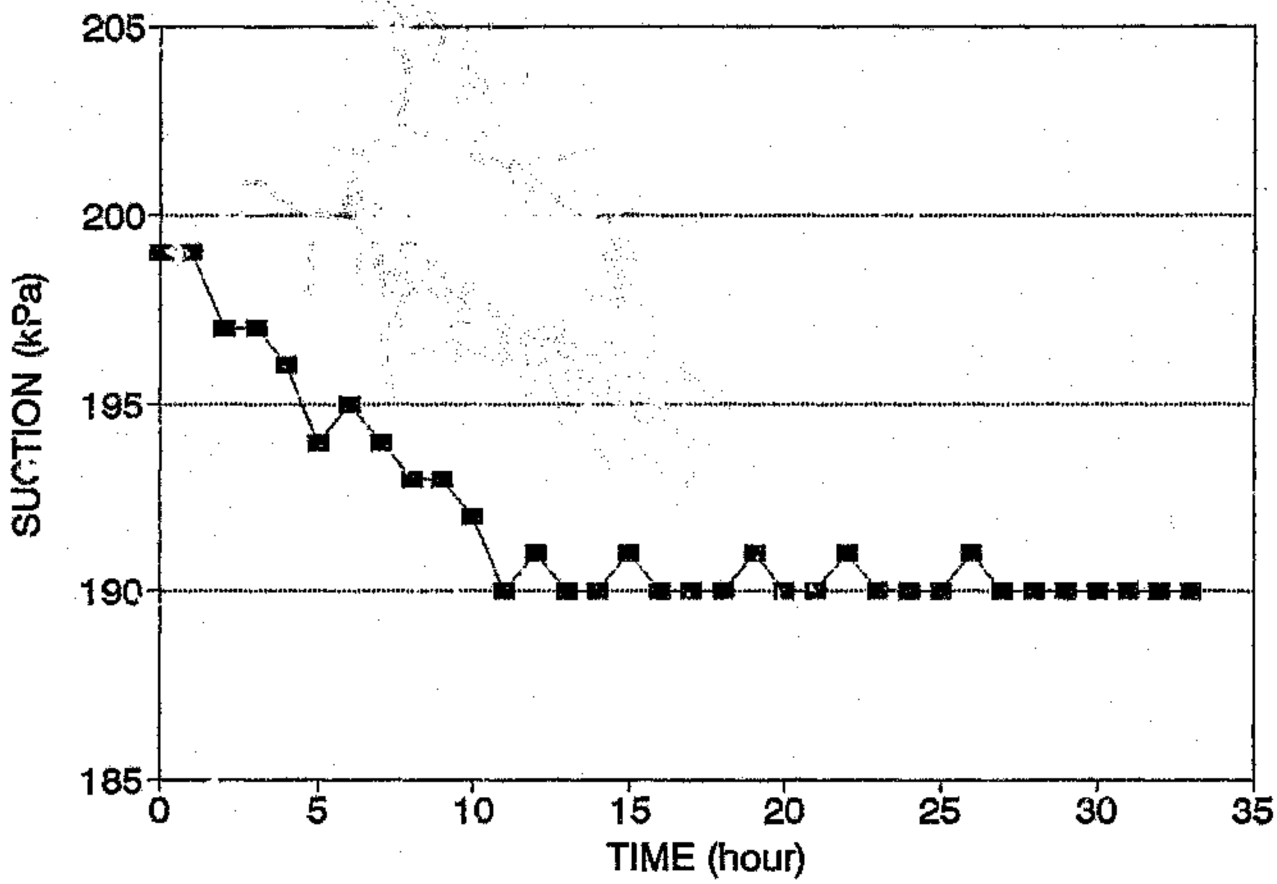
VOLUME CHANGE VOLATGS
VOLUME INITIAL -828 V
VOLUMG FINAL -801 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	760	199.0997	199.0
1	758	198.5803	199.0
2	750	196.5067	197.0
3	753	197.2843	197.0
4	747	195.7292	196.0
5	740	193.9146	194.0
6	743	194.6924	195.0
7	742	194.4332	194.0
8	738	193.3964	193.0
9	736	192.8188	192.0
10	731	191.583	192.0
11	726	190.286	190.0
12	728	190.8044	191.0
13	724	189.7676	190.0
14	726	190.286	190.0
15	727	190.5452	191.0
16	724	189.7676	190.0
17	725	190.0268	190.0
18	724	189.7676	190.0
19	727	190.5452	191.0
20	725	190.0268	190.0
21	726	190.286	190.0
22	728	190.8044	191.0
23	724	189.7676	190.0
24	726	190.286	190.0
25	725	190.0268	190.0
26	727	190.5452	191.0
27	725	190.0268	190.0
28	724	189.7676	190.0
29	726	190.286	190.0
30	725	190.0268	190.0
31	725	190.0268	190.0
32	724	189.7676	190.0
33	725	190.0268	190.0

OUTFLOW AT 200 kPa



CAPILLARY PRESSURE AT 200 kPa



APPENDIX 4

COMPLETE TEST RESULTS OF GOLD TEST

SUMMARY OF RESULTS

SAMPLE: GOLD TAILINGS TEST1

DIMENSIONS IN cm AND g

								AVERAGE
DIAMETER		7.02	7.235	6.85				7.035
LENGTH		2.93	2.44	2.75				2.706667
S GRAVITY		2.760357	2.544476	2.682764	2.577899	2.685928	2.601391	2.642136

FINAL VOLUME T	106.209
VOLUME SOIL	67.38828

BOWL	176.476
WET SOIL & BOWL	367.62
DRY SOIL & BOWL	354.525
WATER CONT.	0.0735471696
VOLM CONT.	0.1244665476

APPLIED PRESSURE kPa	VOLUME volts	VOLUME cm^3	TOTAL VOLUME cm^3	FLOW INITIAL volts	FINAL volts	ACTUAL FLOW cm^3	TOTAL FLOW cm^3
0	668	-0.226975626	15.10605			0	39.06983
20	481	11.845129274	3.033943	1184	305	11.5592	27.51063
40	450	13.364636016	1.514435	-298	55	4.64209	22.86854
70	444	13.647477052	1.231595	-1329	-569	9.994301	12.87424
100	434	14.111301895	0.76777	-1382	-1009	4.905098	7.96914
130	424	14.566003876	0.313068	-1548	-1296	3.3139	4.65524
160	421	14.700693044	0.178379	-1641	-1471	2.235567	2.419673
200	417	14.879072122	0	-780	-596	2.419673	0

APPLIED PRESSURE kPa	SUCTION kPa	VOLUMETRIC CONTENT cm^3/cm^3	WATER CONTENT g/g	DEGREE SATURATION	SLOPE	"a" VALUE	IRP	PERM cm/s
0	-	0.4335686438	0.29298	0.9856041231	-	-	-	-
20	19	0.3751342291	0.228059	0.9939047121	0.96777	-	-	-
40	33	0.3369788695	0.201987	0.9142852148	1.101912	-	-	-
70	66	0.2439787218	0.145854	0.6649860928	0.902208	1.12856	194.3345	3.249742
100	96	0.1987618792	0.118305	0.5458660569	0.929346	2.3358	112.202	1.870033
130	128	0.1682135508	0.099633	0.4654729278	0.887498	0.85239	141.2538	2.35423
160	151	0.1472156753	0.087137	0.4082906781	0.779963	0.229781	197.2423	3.287372
200	-	0.1244665476	0.073547	0.346238892	0.798816	0.27579	239.8833	3.998055

GOLD TEST APPLIED AIR PRESSURE 20 kPa

20

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1015	0	ERR	ERR	ERR
1	1011	0.0526	0	-1.27901	1.27999163
2	-1007	0.1052	0.30103	-0.97789	-0.98866379
3	-1003	0.1578	0.477121	-0.80189	-0.81824793
4	-1000	0.18725	0.60206	-0.70498	-0.69733595
5	996	0.24985	0.69897	-0.60232	-0.60554033
6	-993	0.2893	0.778151	-0.53865	-0.52692000
7	-989	0.3419	0.845098	-0.4661	-0.46213098
8	-985	0.3945	0.90309	-0.40396	-0.4060081
9	-982	0.43395	0.954243	-0.36256	-0.35650422
10	-978	0.48655	1	-0.31287	-0.31222149
11	-975	0.526	1.041393	-0.27901	-0.27216288
12	-971	0.5786	1.079181	-0.23762	-0.23559224
13	-967	0.6312	1.113943	-0.19983	-0.20195051
14	-964	0.67065	1.146128	-0.1735	-0.17080314
15	-960	0.72325	1.176091	-0.14071	-0.14180562
16	-957	0.7627	1.20412	-0.11765	-0.11468026
17	-954	0.80215	1.230449	-0.09574	-0.0891890
18	-950	0.85475	1.255273	-0.06818	-0.06517638
19	-946	0.90735	1.278754	-0.04223	-0.04245200
20	-943	0.9468	1.30103	-0.02374	-0.02089385
40	-874	1.85416	1.60206	0.268145	0.270434106
60	-793	2.9193	1.778151	0.465279	0.440860069
120	-690	5.58875	2.079181	0.747316	0.73217790
180	-428	7.71905	2.255273	0.887564	0.902693764
240	-360	8.61325	2.380211	0.935167	1.023305743
300	-334	8.95515	2.477121	0.952073	1.117292361
360	-323	9.0998	2.556303	0.959032	1.193921606
420	-318	9.16555	2.623249	0.962159	1.258710711
480	-316	9.208	2.681241	0.964024	1.314833585
540	-313	9.2313	2.732394	0.965263	1.364337469
600	-310	9.27075	2.778151	0.967116	1.408620203
660	-309	9.29705	2.819544	0.968345	1.448678807
720	-306	9.32335	2.857332	0.969572	1.485249449
780	-305	9.3365	2.892095	0.970184	1.518891177
840	-304	9.34965	2.924279	0.970795	1.550038553
900	-304	9.34965	2.954243	0.970795	1.579036068
960	-303	9.3628	2.982271	0.971406	1.606161427
1020	-303	9.3628	3.0086	0.971406	1.631641788
1080	-304	9.34965	3.033424	0.970795	1.655665311
1140	-304	9.34965	3.056905	0.970795	1.678389615
1200	-305	9.3365	3.079181	0.970184	1.699948046
1260	-305	9.3365	3.100371	0.970184	1.720454416
1320	-305	9.3365	3.120574	0.970184	1.740006649

Regression Output:

Constant		-1.27999
Std Err of Y Est		0.009113
R Squared		0.999676
No. of Observations		24
Degrees of Freedom		22
X Coefficient(s)	0.96777	
Std Err of Coef.	0.003714	

OUTFLOW VOLTAGE

INITIAL -1184

ENDED -305

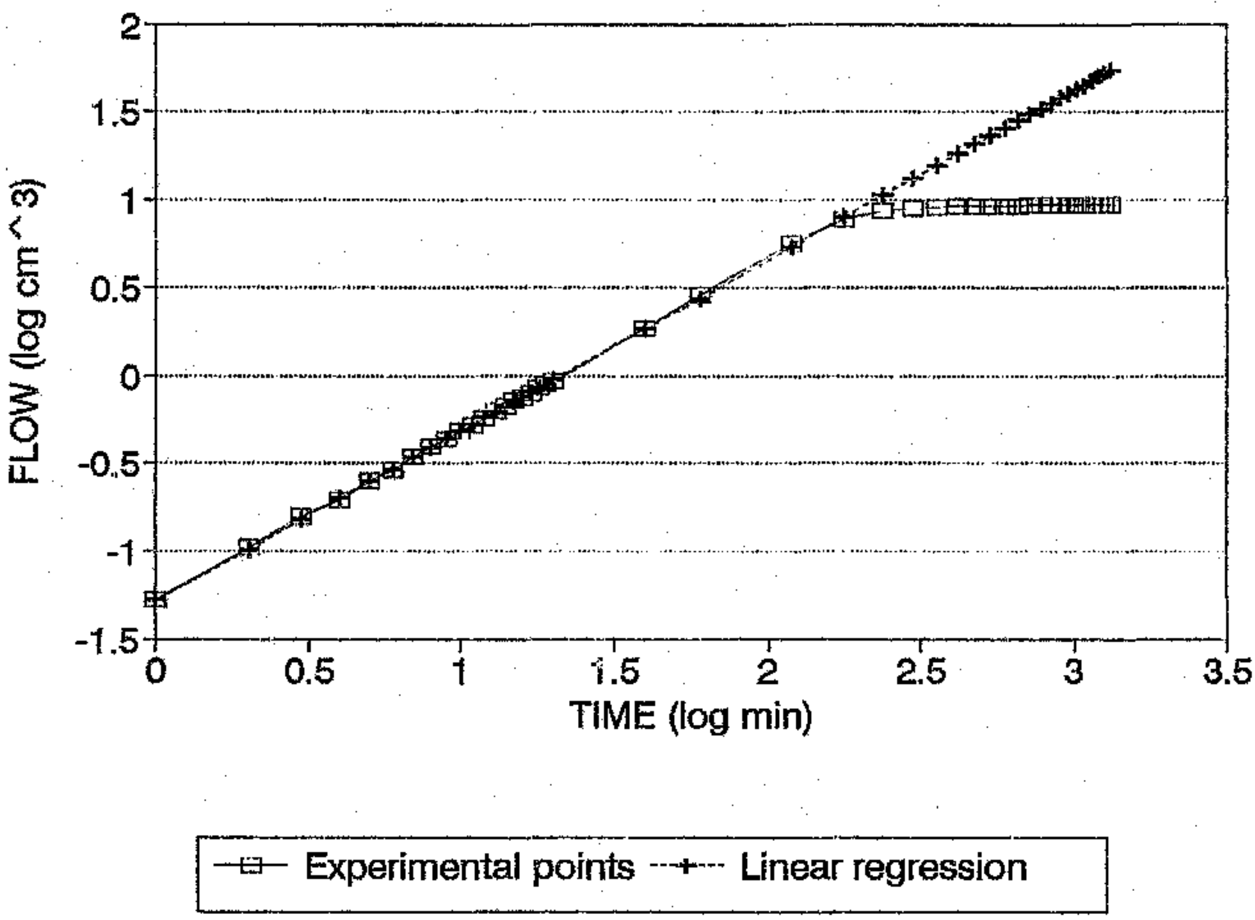
VOLUME CHANGE VOLTAGE

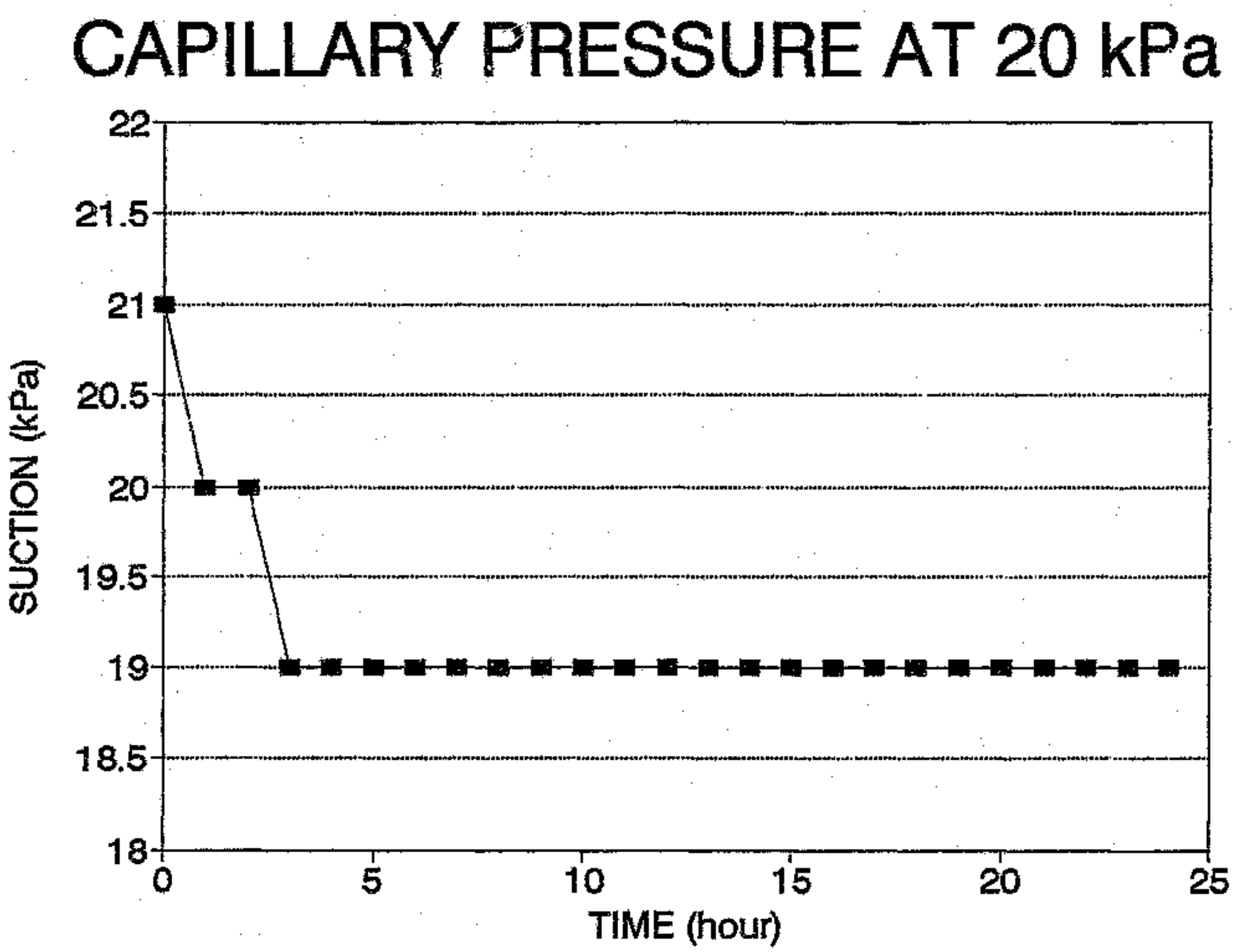
VOLUME INITIAL -668 V

VOLUME FINAL -491 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	74	20.68154	21.0
1	72	20.14315	20.0
2	70	19.62476	20.0
3	69	19.36556	19.0
4	68	19.10636	19.0
5	68	19.10636	19.0
6	69	19.36556	19.0
7	68	19.10636	19.0
8	66	18.58797	19.0
9	67	18.84716	19.0
10	67	18.84716	19.0
11	66	18.58797	19.0
12	66	18.58797	19.0
13	66	18.58797	19.0
14	67	18.84716	10.0
15	66	18.58797	19.0
16	66	18.58797	19.0
17	67	18.84716	19.0
18	66	18.58797	19.0
19	67	18.84716	19.0
20	67	18.84716	19.0
21	66	18.58797	19.0
22	67	18.84716	19.0
23	66	18.58797	19.0
24	66	18.58797	19.0

OUTFLOW AT 20 kPa





CAPILLARY PRESSURE AT 20 kPa
SUCTION (kPa)
22
21.5
21
20.5
20
19.5
19
18.5
18
0
5
10
15
20
25
TIME (hour)

GOLD TEST APPLIED AIR PRESSURE 40 kPa
40

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-298	0	ERR	ERR	ERR
1	-295	0.01316	0	-1.88107	1.87643661
2	-294	0.0263	0.30103	-1.58004	-1.5437282
3	-293	0.03945	0.477121	-1.40395	-1.34969122
4	-292	0.0526	0.60206	-1.27901	-1.21201979
5	290	0.0789	0.69897	-1.10292	1.10523353
6	-289	0.09205	0.778151	-1.03598	-1.01798281
7	-287	0.11835	0.845098	-0.92683	-0.94421337
8	-285	0.14465	0.90309	-0.83968	-0.88031158
9	-284	0.1578	0.954243	-0.80189	-0.82394583
10	-282	0.1841	1	-0.73496	-0.77352812
11	-280	0.2104	1.041393	-0.67695	-0.72791405
12	-279	0.22355	1.079181	-0.65063	-0.6862744
13	-277	0.24985	1.113943	-0.60232	-0.64790933
14	-276	0.263	1.146128	-0.58004	-0.61250496
15	-276	0.27615	1.176091	-0.55885	-0.57948814
16	-273	0.30245	1.20412	-0.51935	-0.54860297
36	-249	0.61805	1.556303	-0.20898	0.10352901
56	-229	0.88105	1.748188	-0.055	0.05091186
116	-185	1.45955	2.064458	0.164249	0.399413365
176	-154	1.8673	2.245513	0.271214	0.598019595
236	-129	2.19605	2.372912	0.341642	0.738302385
296	-108	2.4722	2.471292	0.393084	0.847708117
356	-89	2.72206	2.55145	0.434896	0.936035464
416	-73	2.93245	2.619093	0.467231	1.010572419
476	-59	3.11665	2.677607	0.493674	1.075049252
536	-46	3.2876	2.729165	0.516856	1.131861425
596	-34	3.4463	2.775246	0.537227	1.182639128
656	-23	3.58995	2.816904	0.555088	1.228542001
716	-13	3.72145	2.854913	0.570712	1.270424847
776	-2	3.8661	2.889862	0.587273	1.30893572
836	5	3.95816	2.922206	0.597492	1.344576058
896	13	4.06335	2.952308	0.608884	1.377746502
956	21	4.16866	2.980458	0.619985	1.408764181
1016	27	4.24745	3.006894	0.628128	1.43789411
1076	34	4.3395	3.031812	0.63744	1.465352161
1136	40	4.4184	3.055378	0.645266	1.491319874
1196	46	4.49416	3.077731	0.65168	1.515950734
1256	49	4.53675	3.09899	0.656745	1.539375675
1316	55	4.61665	3.119256	0.664233	1.561707289

Regression Output:

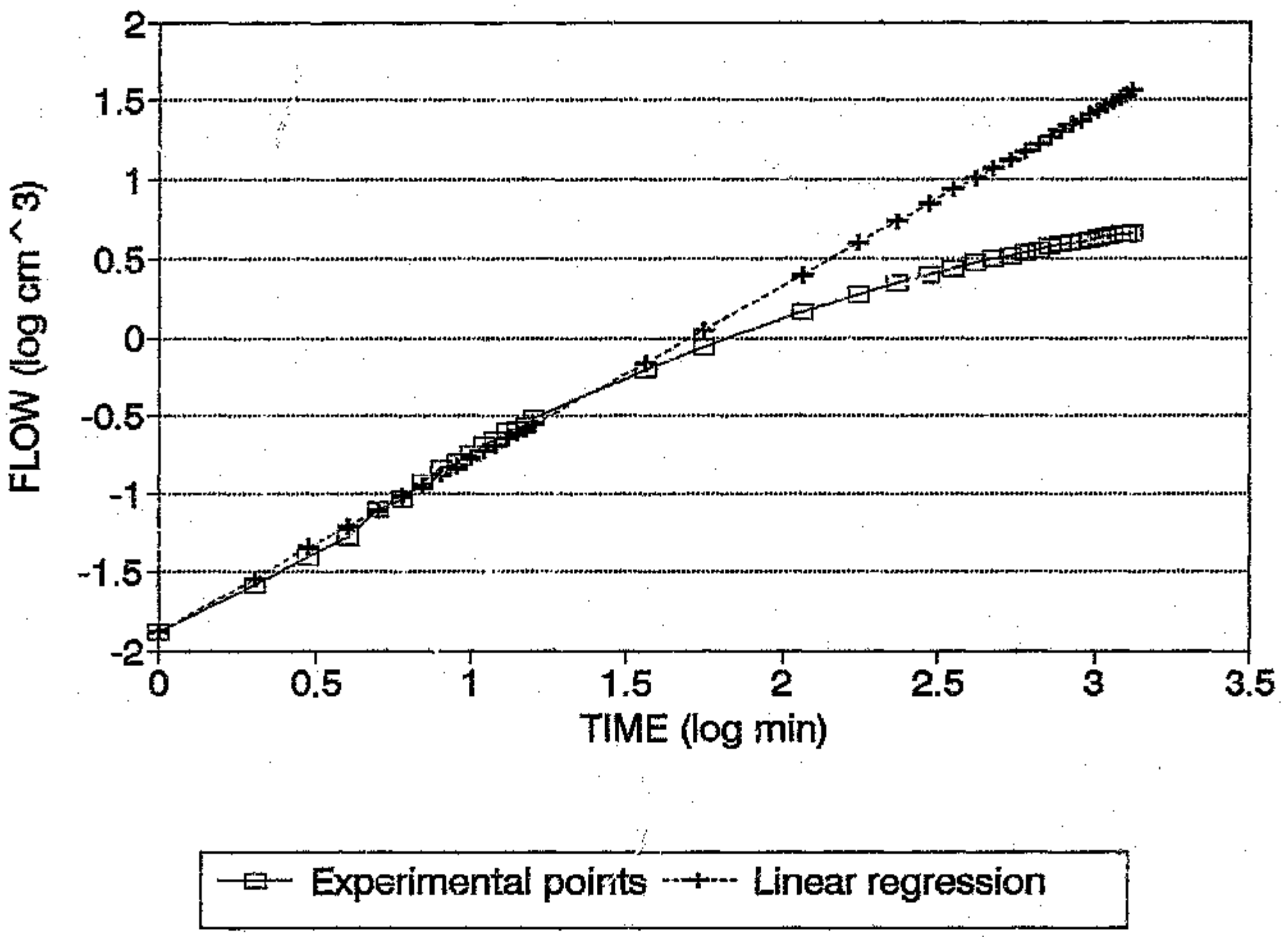
Constant		-1.87544
Std Err of Y Est		0.046608
R Squared		0.990433
No. of Observations		18
Degrees of Freedom		16
X Coefficient(s)	1.101911	
Std Err of Coef	0.027075	

OUTFLOW VOLTAGE
INTIAL -298
ENDED +55

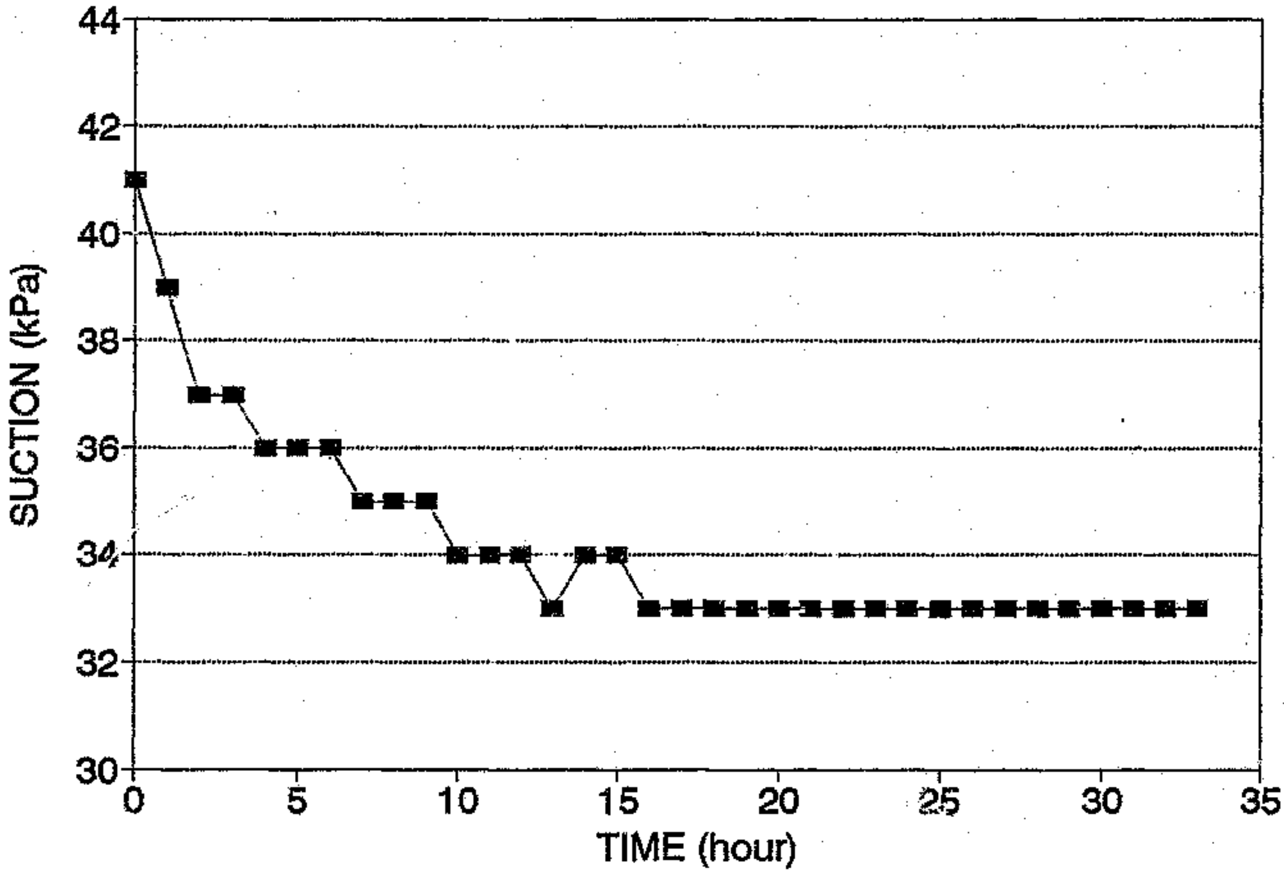
VOLUME CHANGE VOLTAGE
VOLUME INITIAL -481 V
VOLUME FINAL -450 V

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	150	40.5455	41.0
1	143	39.73112	39.0
2	137	37.17593	37.0
3	137	37.17593	37.0
4	133	35.13914	35.0
5	133	35.13914	35.0
6	132	35.87995	35.0
7	130	35.36155	35.0
8	130	35.36155	35.0
9	129	35.10235	35.0
10	125	34.06557	34.0
11	125	34.06557	34.0
12	124	33.80637	34.0
13	122	33.28797	33.0
14	123	33.54717	34.0
15	124	33.80637	34.0
16	122	33.28797	33.0
17	121	33.02878	33.0
18	122	33.28797	33.0
19	122	33.28797	33.0
20	122	33.28797	33.0
21	120	32.76958	33.0
22	121	33.02878	33.0
23	120	32.76958	33.0
24	122	33.28797	33.0
25	122	33.28797	33.0
26	120	32.76958	33.0
27	121	33.02878	33.0
28	120	32.76958	33.0
29	121	33.02878	33.0
30	120	32.76958	33.0
31	121	33.02878	33.0
32	121	33.02878	33.0
33	121	33.02878	33.0

OUTFLOW AT 40 kPa



CAPILLARY PRESSURE AT 40 kPa



GOLD TEST APPLIED AIR PRESSURE 70 kPa
70

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1330	0	ERR	ERR	ERR
1	-1325	0.06575	0	-1.1821	-1.17090984
2	-1320	0.1315	0.30103	-0.88107	-0.89931802
3	-1316	0.1841	0.477121	-0.73495	-0.74744699
4	-1312	0.2367	0.60206	-0.6258	-0.6277262
5	-1308	0.2893	0.69897	-0.53865	-0.54029317
6	-1305	0.32875	0.778151	-0.48313	-0.46885518
7	-1301	0.38135	0.845098	-0.41868	-0.40845522
8	-1298	0.4208	0.90309	-0.37592	-0.35613489
9	-1294	0.4734	0.954243	-0.32477	-0.30928415
10	-1290	0.526	1	-0.27901	-0.26870135
11	-1286	0.5786	1.041393	-0.23762	-0.23135652
12	-1282	0.6312	1.079181	-0.19983	-0.19726396
13	-1278	0.6838	1.113943	-0.16507	-0.16590069
14	-1274	0.7364	1.146128	-0.13289	-0.1368534
15	-1270	0.789	1.176091	-0.10292	[illegible]83032
16	-1265	0.85475	1.20412	-0.06816	[illegible]
17	-1262	0.8942	1.230449	-0.04857	[illegible]8838
18	-1258	0.9468	1.255273	-0.02374	-0.03839233
19	-1255	0.98625	1.278754	-0.00601	-0.01720749
20	-1251	1.03885	1.30103	0.016553	0.002890464
60	-1122	2.7262	1.778151	0.435569	0.433353309
120	-963	4.82605	2.079181	0.683592	0.704945125
180	-841	6.43025	2.255273	0.808226	0.863816153
240	-765	7.66125	2.380211	0.878694	0.976626942
300	-694	8.3634	2.477121	0.922383	1.063963979
360	-654	8.8894	2.556303	0.948872	1.13540797
420	-628	9.2313	2.623249	0.965263	1.195807931
480	-613	9.42855	2.681241	0.974446	1.248128759
540	-603	9.56005	2.732394	0.98046	1.294278998
600	-596	9.6521	2.778151	0.984622	1.335561794
660	-592	9.7047	2.819544	0.986982	1.372906626
720	-587	9.77045	2.857332	0.989915	1.406999786
780	-583	9.82305	2.892095	0.992246	1.438362453
840	-580	9.8625	2.924279	0.993987	1.467399748
900	-577	9.90195	2.954243	0.995721	1.494432622
960	-576	9.92825	2.982271	0.996873	1.519720574
1020	-574	9.9414	3.0086	0.997448	1.543474766
1080	-573	9.95455	3.033424	0.998022	1.565870814
1140	-572	9.9677	3.056905	0.998595	1.587055658
1200	-571	9.98085	3.079181	0.999162	1.60715361
1260	-570	9.994	3.100371	0.999739	1.626270776
1320	-570	9.994	3.120574	0.999739	1.644498442
1380	-570	9.994	3.139879	0.999739	1.661915717
1440	-569	10.00715	3.158362	1.00031	1.679591603

Regression Output:

Constant		-1.17091
Std Err of Y Est		0.012336
R Squared		0.999124
No. of Observations		22
Degrees of Freedom		20
X Coefficient(s)	0.902208	
Std Err of Coef.	0.005973	

OUTFLOW VOLTAGE
INTIAL -1329
ENDED -569

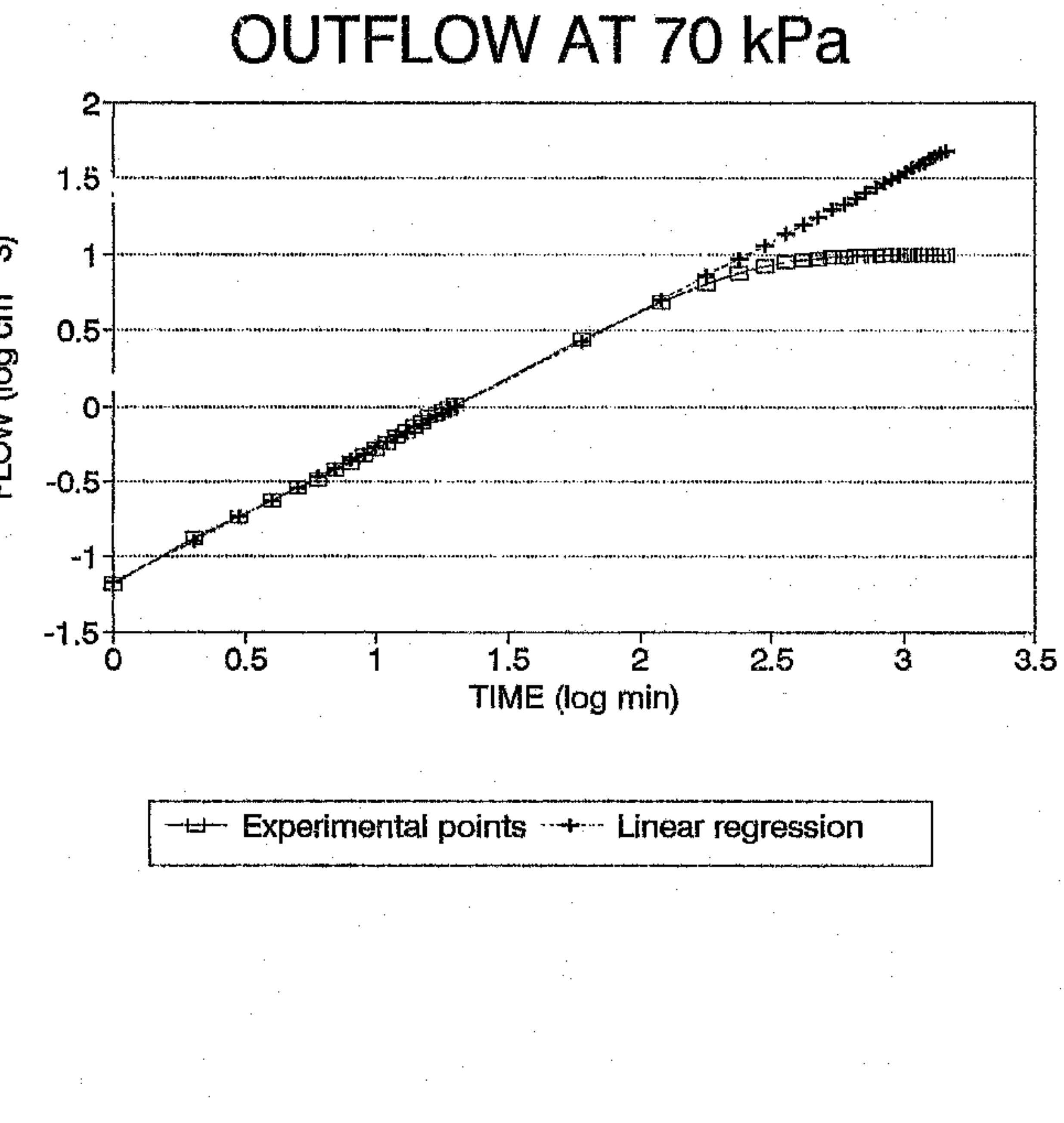
VOLUME CHANGE VOLTAGE
VOLUME INITIAL -450 V
VOLUME FINAL -444 V

ALPHA
1.12856 (0.01-0.3)

TIME TRP
2.29

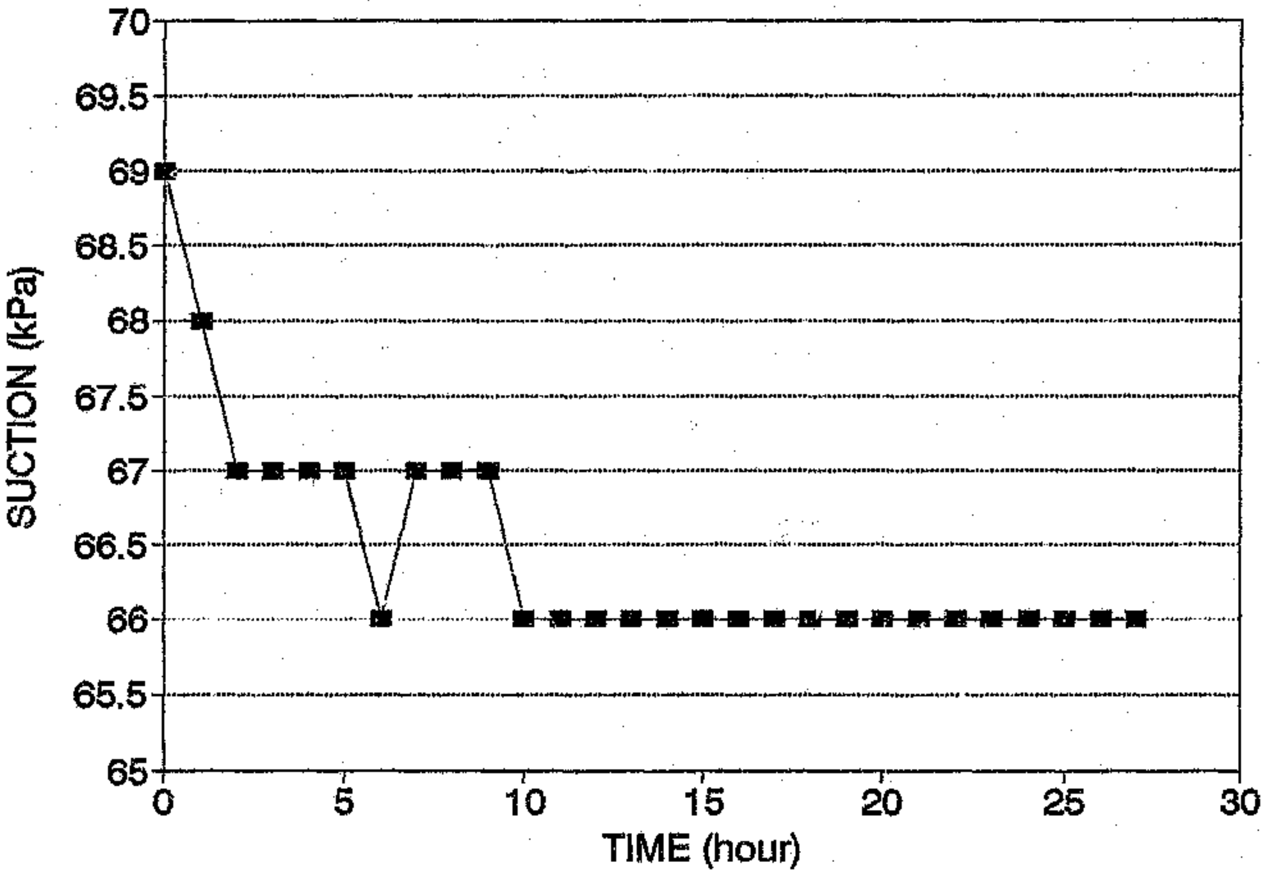
TIME minutes
194.9845

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	257	68.65704	69.0
1	256	68.29765	68.0
2	250	66.74256	67.0
3	252	67.26106	67.0
4	252	67.26106	67.0
5	250	66.74256	67.0
6	249	66.48347	66.0
7	251	67.[illegible]196	67.0
8	250	66.74256	67.0
9	252	67.26106	67.0
10	247	65.96507	66.0
11	246	65.70587	66.0
12	247	65.96507	66.0
13	246	65.70587	66.0
14	248	66.22427	66.0
15	249	66.48347	[illegible].0
16	248	66.22427	[illegible]0
17	246	65.70587	66.0
18	247	65.96507	66.0
19	246	65.70587	66.0
20	248	66.22427	66.0
21	247	65.96507	66.0
22	247	65.96507	66.0
23	247	65.96507	66.0
24	249	66.48347	66.0
25	247	65.96507	66.0
26	247	65.96507	66.0
27	248	66.22427	66.0



OUTFLOW AT 70 kPa
FLOW (log cm ^ 3)
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.5
1
1.5
2
2.5
3
3.5
TIME (log min)
Experimental points
Linear regression

CAPILLARY PRESSURE AT 70 kPa

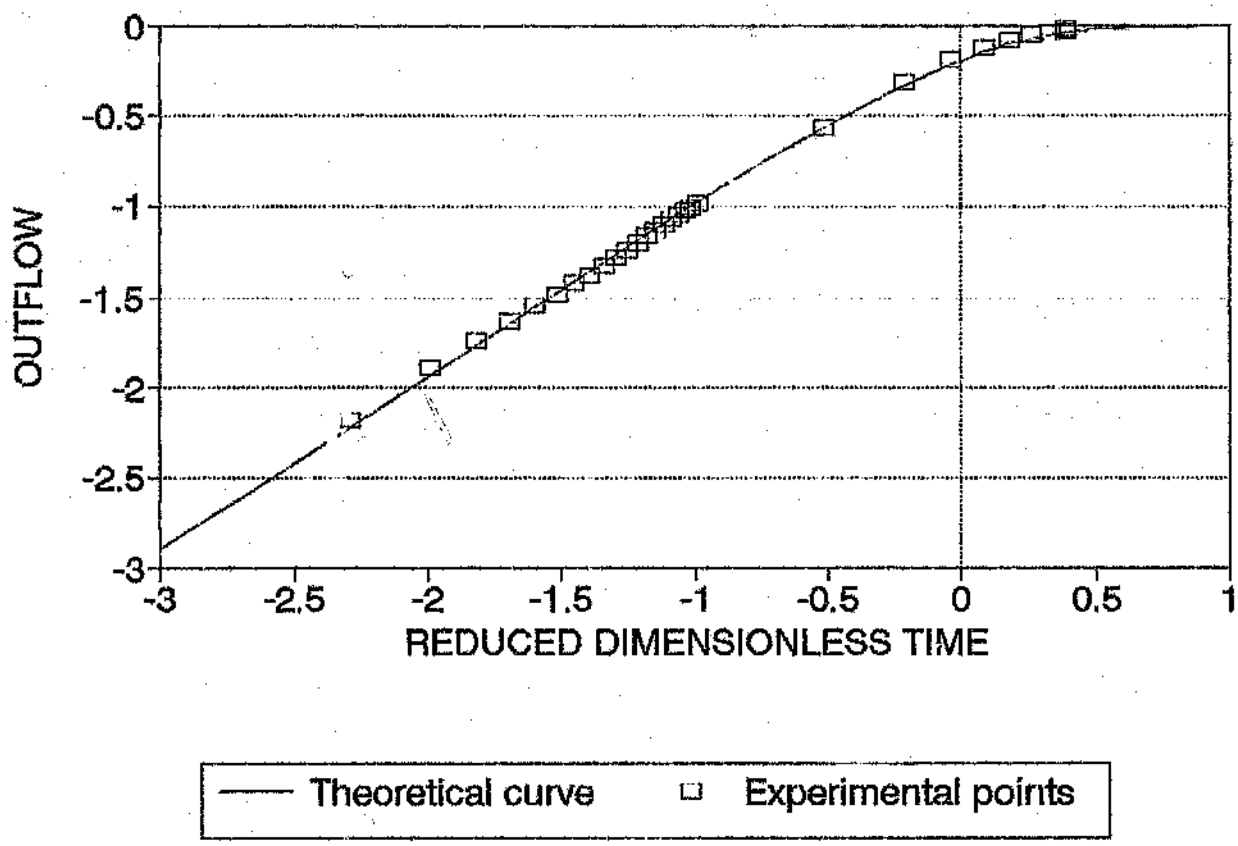


TIME hours	SUCTION Volts	SUCTION kPa	SUCTION kPa
0	257	68.55704	69.0
1	256	68.29785	68.0
2	250	66.74256	67.0
3	252	67.26106	67.0
4	252	67.26106	67.0
5	250	66.74266	67.0
6	249	66.48347	66.0
7	251	67.00186	67.0
8	250	66.74266	67.0
9	252	67.26106	67.0
10	247	65.96507	66.0
11	246	65.70587	66.0
12	247	65.96507	66.0
13	246	65.70587	66.0
14	248	66.22427	66.0
15	249	66.48347	66.0
16	248	66.22427	66.0
17	246	65.70587	66.0
18	247	65.96507	66.0
19	246	65.70587	66.0
20	248	66.22427	66.0
21	247	65.96507	66.0
22	247	65.96507	66.0
23	247	65.96507	66.0
24	249	66.48347	66.0
25	247	65.96507	66.0
26	247	65.96507	66.0
27	248	66.22427	66.0

GOLD TEST APPLIED AIR PRESSURE 70 kPa

TIME	THEORETICAL Qo/Qt	EXPERIMENTAL Qt	LOG TIME	LOG Qo/Qt	LOG Qt	ADJUSTED Qt	ADJUSTED TIME
0.001	0.0012767907		-3	-2.89388			-3
0.1	0.1036910893		-1	-0.98426			-1
0.2	0.1903418629		-0.69897	-0.72047			-0.69897
0.3	0.2676370559		-0.52288	-0.57245			-0.522879
0.4	0.3373753134		-0.39794	-0.47189			-0.39794
0.5	0.4004408514		-0.30103	-0.39746			-0.30103
0.6	0.4574976191		-0.22185	-0.33961			-0.221849
0.7	0.5091738147		-0.1549	-0.29318			[illegible]
0.8	0.5558369087		-0.09691	-0.25505			-0.09691
0.9	0.5981046241		-0.04576	-0.22322			-0.045757
1	0.6363500274		0	-0.1963			0
1.1	0.670955898		0.041393	-0.17331			0.0413927
1.2	0.7022685844		0.079181	-0.1535			0.0791812
1.3	0.7306014746		0.113943	-0.13632			0.1139434
1.4	0.7562381339		0.146128	-0.12134			0.146128
1.5	0.7794351424		0.176091	-0.10822			0.1760913
1.6	0.8004246038		0.20412	-0.09668			0.20412
1.7	0.8194167581		0.230449	-0.0865			0.2304489
1.8	0.8366015347		0.255273	-0.07748			0.2552725
1.9	0.8521509545		0.278754	-0.06948			0.2787536
2	0.8662208514		0.30103	-0.06237			0.30103
2.1	0.[illegible]9514397		0.322219	-0.05604			0.3222193
2.2	0.8904707392		0.342423	-0.05039			0.3424227
2.3	0.9007893821		0.361728	-0.04533			0.3617278
2.4	0.9105290209		0.380211	-0.0408			0.3802112
2.5	0.9168687235		0.39794	-0.03675			0.39794
2.6	0.92[illegible]5803368		0.414973	-0.03312			0.4149733
2.7	0.93[illegible]5671416		0.431364	-0.02985			0.4313638
2.8	0.9398890539		0.447158	-0.02692			0.447158
2.9	0.9456093768		0.462398	-0.02429			0.462398
3	0.9507705328		0.477121	-0.02192			0.4771213
10	1		1	0			1
1		0.06576	0		-1.1821	-2.182416	-2.29
2		0.1315	0.30103		-0.88107	-1.881386	-1.98897
3		0.1841	0.477121		-0.73495	-1.735767	-1.812879
4		0.2367	0.60206		-0.6258	-1.626112	-1.68794
5		0.2893	0.69897		-0.53865	-1.538982	-1.59103
6		0.32876	0.778151		-0.48313	-1.483445	-1.511849
7		0.38135	0.845098		-0.41868	-1.418987	-1.444902
8		0.4208	0.90309		-0.37592	-1.376235	-1.38691
9		0.4734	0.954243		-0.32477	-1.325082	-1.335757
10		0.526	1		-0.27901	-1.279326	-1.29
11		0.5786	1.041393		-0.23762	-1.237932	-1.248607
12		0.6312	1.079181		-0.19983	-1.200143	-1.210819
13		0.6838	1.113943		-0.16507	-1.165381	-1.176057
14		0.7364	1.146128		-0.13289	-1.133197	-1.143872
15		0.789	1.176091		-0.10292	-1.103233	-1.113909
16		0.85476	1.20412		0.06816	-1.068471	1.08008
17		0.8942	1.230449		-0.04857	-1.048876	-1.059551
18		0.9468	1.255273		-0.02374	-1.024052	-1.034727
19		0.98626	1.278754		-0.00601	-1.006323	-1.011246
20		1.03885	1.30103		0.016553	-0.983758	-0.98897
60		2.7352	1.778151		0.436989	-0.563321	-0.511849
120		4.82505	2.079181		0.683492	-0.316719	-0.210819
180		6.43035	2.255273		0.808235	-0.192076	-0.034727
240		7.58125	2.380211		0.878594	-0.121717	0.0902112
300		8.3634	2.477121		0.922383	-0.077928	0.1871213
360		8.8894	2.556303		0.948872	-0.051438	0.2663025
420		9.2313	2.623249		0.965263	-0.035048	0.3332493
480		9.42855	2.681241		0.974445	-0.025866	0.3912418
540		9.56005	2.732394		0.98046	-0.01985	0.4423938
600		9.6521	2.778151		0.984622	-0.015689	0.4881518
660		9.7047	2.819544		0.986982	-0.013328	0.5295430
720		9.77046	2.857332		0.989915	-0.010396	0.5673326
780		9.82305	2.892095		0.992246	-0.008031	0.6020946
840		9.8625	2.924279		0.993987	-0.006323	0.6342793
900		9.90195	2.954243		0.995721	-0.00459	0.6642426
960		9.92026	2.982271		0.996873	-0.003438	0.6922712
1020		9.9414	3.0086		0.997448	-0.002863	0.7186002
1080		9.95450	3.033424		0.998022	-0.002289	0.7434238
1140		9.9677	3.056905		0.998596	-0.001716	0.7669049
1200		9.98085	3.079181		0.999168	-0.001143	0.7891812
1260		9.994	3.100371		0.999739	-0.000571	0.8103706
1320		9.994	3.120574		0.999739	-0.000571	0.8305739
1380		9.991	3.139879		0.999739	-0.000571	0.8498791
1440		10.00716	3.158362		1.00031	0	0.8683626

SUPERIMPOSING OF OUTFLOW CURVES
AT 70 kPa



GOLD TEST APPLIED AIR PRESSURE 100 kPa
100

TIME minutes	FLOW VOLTS	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1376	0	ERR	ERR	ERR
1	-1373	0.03045	0	-1.40396	-1.34697252
2	-1370	0.0789	0.30103	-1.10292	-1.06721137
3	-1367	0.11835	0.477121	-0.92683	-0.90356169
4	-1364	0.1578	0.60206	-0.80189	-0.78745022
5	-1361	0.19725	0.69897	-0.70498	-0.69738724
6	-1358	0.2367	0.778151	-0.6258	-0.62380043
7	-1354	0.2893	0.845098	-0.53865	-0.56158367
8	-1351	0.32875	0.90309	-0.48313	-0.50766907
9	-1349	0.35505	0.954243	-0.44971	-0.46019035
10	-1345	0.40765	1	-0.38971	-0.41762609
11	-1343	0.43395	1.041393	-0.36258	-0.37916795
12	-1340	0.4734	1.079181	-0.32477	-0.34403928
13	-1337	0.51285	1.113943	-0.29001	-0.31173324
14	-1335	0.53915	1.146128	-0.26829	-0.28182262
15	-1331	0.59175	1.176091	-0.22786	-0.25397631
16	-1329	0.6312	1.20412	-0.19985	-0.22792791
17	-1327	0.64435	1.230449	-0.19096	-0.20346021
18	-1324	0.6838	1.255273	-0.16507	-0.1803895
19	-1322	0.7101	1.278754	-0.14868	-0.15866743
20	-1319	0.74955	1.30103	-0.1252	-0.13785494
40	-1270	1.3939	1.60206	0.144232	0.141898212
60	-1229	1.93305	1.778151	0.286243	0.305545996
120	-1148	3.0245	2.079181	0.480654	0.585307147
180	-1096	3.682	2.255273	0.566084	0.74895893
240	-1066	4.09965	2.380211	0.611696	0.865069299
300	-1047	4.32635	2.477121	0.636122	0.955131274
360	-1035	4.48415	2.556303	0.65168	1.028716082
420	-1027	4.58935	2.623249	0.661751	1.090934842
480	-1021	4.66825	2.681241	0.669154	1.144829461
540	-1017	4.72085	2.732394	0.67402	1.192367865
600	-1016	4.74715	2.778151	0.676433	1.234892425
660	-1016	4.74715	2.819544	0.676433	1.27338057
720	-1014	4.7603	2.857332	0.677634	1.308479234
780	-1013	4.77345	2.892095	0.678832	1.340785273
840	-1013	4.77345	2.924279	0.678832	1.370695994
900	-1012	4.7866	2.954243	0.680027	1.398542208
960	-1012	4.7866	2.982271	0.680027	1.424590603
1020	-1011	4.79975	3.0086	0.681219	1.449059308
1080	-1010	4.8129	3.033424	0.682407	1.472129017
1140	-1010	4.8129	3.056905	0.682407	1.493951089
1200	-1010	4.8129	3.079181	0.682407	1.514653677
1260	-1010	4.8129	3.100371	0.682407	1.534345777
1320	-1010	4.8129	3.120574	0.682407	1.553121721
1380	-1009	4.82605	3.139879	0.683592	1.571062898

Regression Output:

Constant		-1.34697
Std Err of Y Est		0.032444
R Squared		0.994465
No. of Observations		23
Degrees of Freedom		21
X Coefficient(s)	0.929346	
Std Err of Coef.	0.015129	

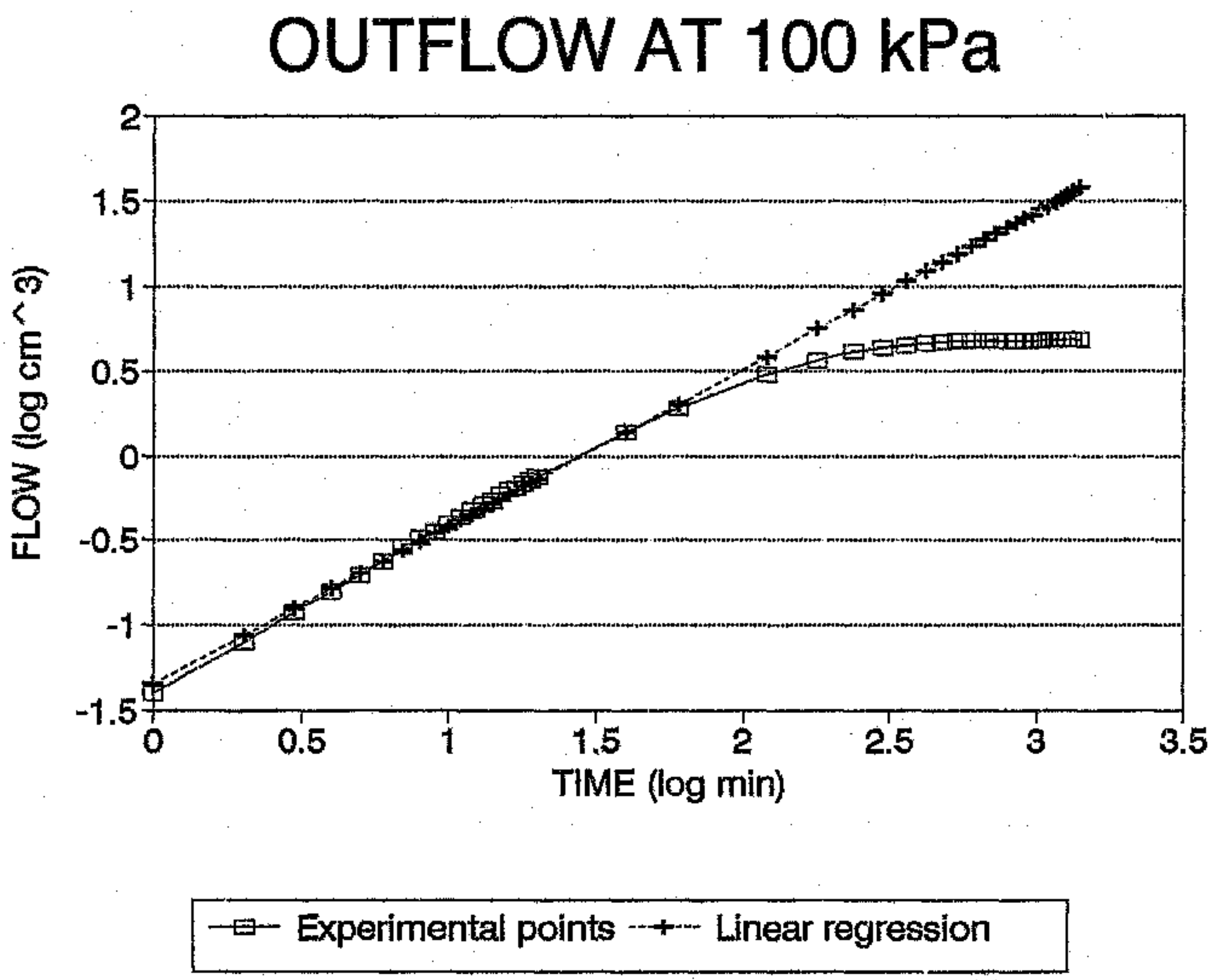
OUTFLOW VOLTAGE
INTIAL -1282
ENDED -1009

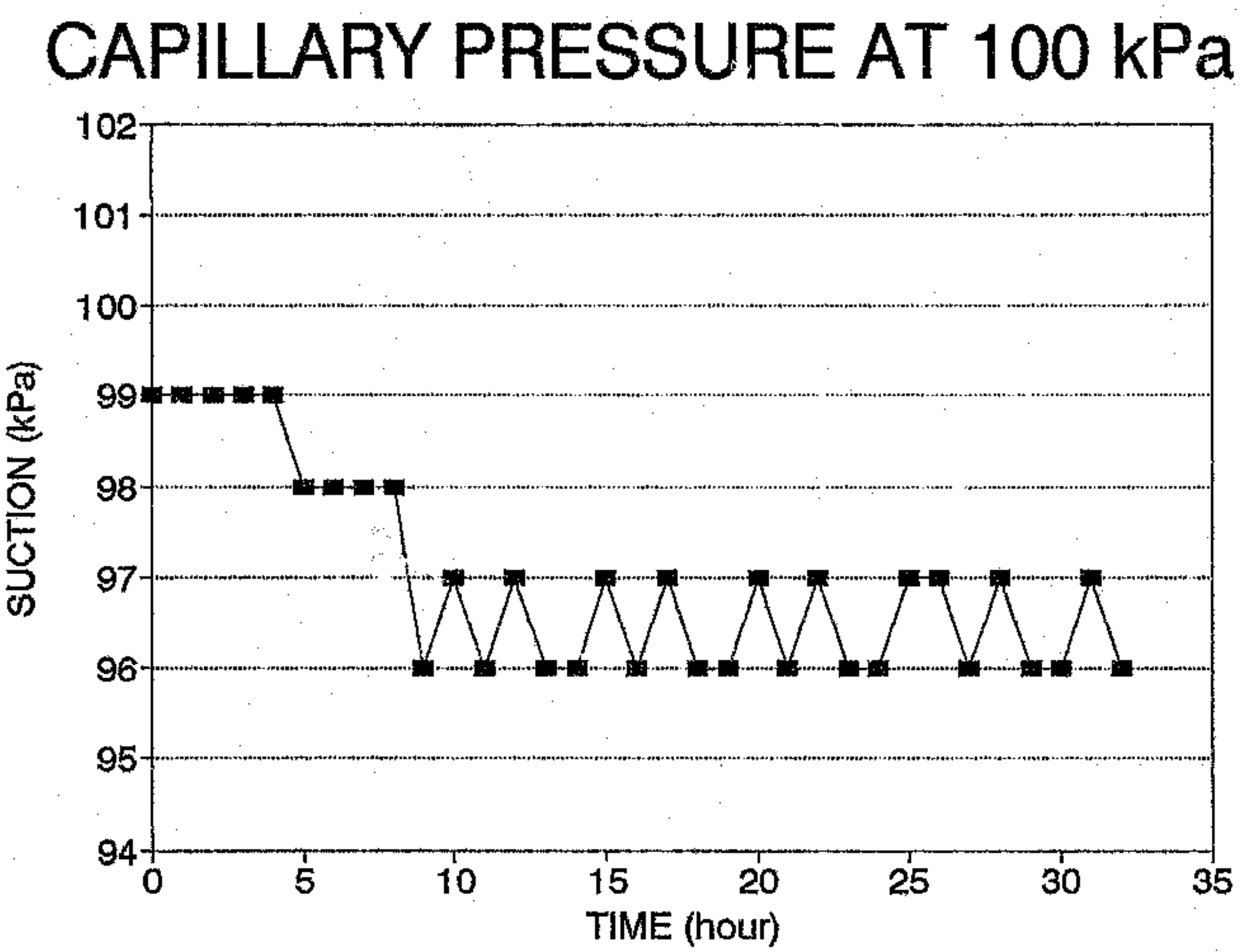
VOLUME CHANGE VOLTAGE
VOLUME INITIAL -444 V
VOLUME FINAL -434 V

ALPHA
2.3358 (0.01-0.3)

TIME TRP
2.09
TIME minutes
112.202

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	372	98.64239	99.0
1	372	98.64239	99.0
2	375	99.41997	99.0
3	372	98.64239	99.0
4	374	99.16077	99.0
5	371	98.38318	98.0
6	369	97.86479	98.0
7	371	98.38318	98.0
8	370	98.12398	98.0
9	362	96.0504	96.0
10	364	96.5688	97.0
11	360	95.53201	96.0
12	366	97.08719	97.0
13	363	96.3095	96.0
14	362	96.0504	96.0
15	366	97.08719	97.0
16	360	95.53201	96.0
17	365	96.828	97.0
18	360	95.53201	96.0
19	363	96.3096	96.0
20	364	96.5688	97.0
21	362	96.0504	96.0
22	364	96.5688	97.0
23	360	95.53201	96.0
24	362	96.0504	96.0
25	364	96.5688	97.0
26	364	96.5688	97.0
27	362	96.0504	96.0
28	364	96.5688	97.0
29	363	96.3095	96.0
30	362	96.0504	96.0
31	364	96.5688	97.0
32	363	96.3095	96.0

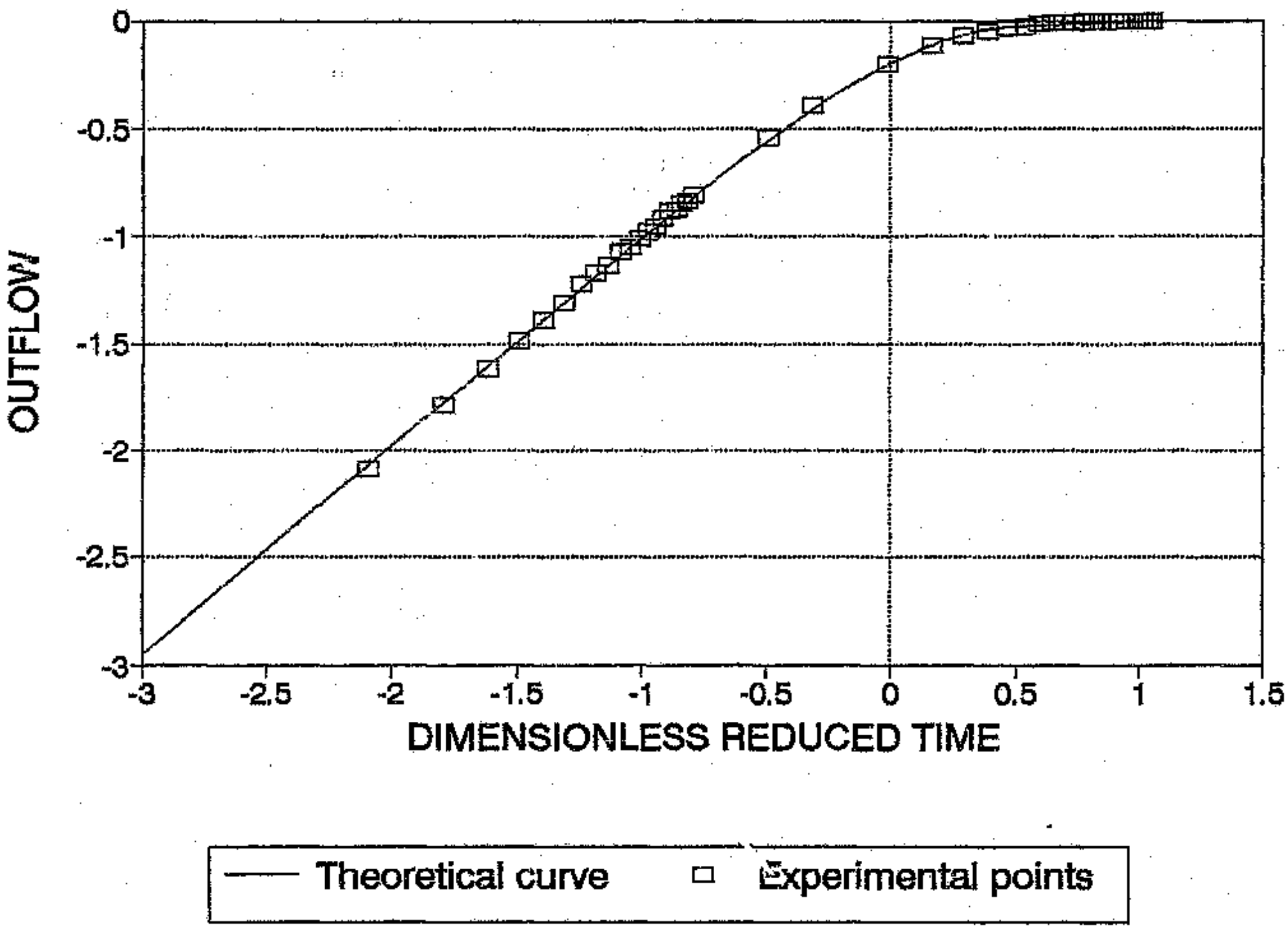

OUTFLOW AT 100 kPa
2
1.5
1
0.5
0
-0.5
-1
-1.5
FLOW (log cm ^ 3)
0
0.5
1
1.5
2
2.5
3
3.5
TIME (log min)
Experimental points
Linear regression


CAPILLARY PRESSURE AT 100 kPa
SUCTION (kPa)
TIME (hour)
102
101
100
99
98
97
96
95
94
0
5
10
15
20
25
30
35

GOLD TEST APPLIED AIR PRESSURE 100 kPa

TIME	THEORETICAL Qo/Qt	EXPERIMENTAL Qt	LOG TIME	LOG Qo/Qt	LOG Qt	ADJUSTED Qt	ADJUSTED TIME
0.001	0.0011275632		-3	-2.94785			-3
0.1	0.0979958455		-1	-1.00879			-1
0.2	0.1839789397		-0.69897	-0.73523			-0.69897
0.3	0.2616419223		-0.52288	-0.58229			-0.522879
0.4	0.3319064564		-0.39794	-0.47898			-0.39794
0.5	0.3954839899		-0.30103	-0.40287			-0.30103
0.6	0.4530112958		-0.22185	-0.34389			-0.221849
0.7	0.5050941533		-0.1549	-0.29655			-0.154902
0.8	0.5521636264		-0.09691	-0.25793			-0.09691
0.9	0.5947808016		-0.04576	-0.22564			-0.045757
1	0.6333425037		0	-0.19836			0
1.1	0.6682345305		0.041393	-0.17507			0.0413927
1.2	0.6998062344		0.079181	-0.15502			0.0791812
1.3	0.7283734482		0.113943	-0.13765			0.1139434
1.4	0.7542221322		0.146128	-0.1225			0.146128
1.5	0.7776109887		0.176091	-0.10924			0.1760913
1.6	0.7987741012		0.20412	-0.09758			0.20412
1.7	0.8179232772		0.230449	-0.08729			0.2304489
1.8	0.8352501693		0.255273	-0.07818			0.2552725
1.9	0.8509281877		0.278754	-0.07011			0.2787536
2	0.8651142463		0.30103	-0.06293			0.30103
2.1	0.8779503229		0.322219	-0.05653			0.3222193
2.2	0.8895648952		0.342423	-0.05082			0.3424227
2.3	0.9000741769		0.361728	-0.04572			0.3617278
2.4	0.9095833763		0.380211	-0.04116			0.3802112
2.5	0.9181876548		0.39794	-0.03707			0.39794
2.6	0.9259731266		0.414973	-0.0334			0.4149733
2.7	0.932017717		0.431364	-0.03011			0.4313638
2.8	0.939391924		0.447158	-0.02715			0.447158
2.9	0.9451169545		0.462398	-0.02449			0.462398
3	0.9503783043		0.477121	-0.0221			0.4771213
10	1		1	0			1
1		0.03945	0		-1.40395	-2.087545	-2.09
2		0.0789	0.30103		-1.10292	-1.786516	-1.78897
3		0.11835	0.477121		-0.92683	-1.610424	-1.612879
4		0.1578	0.60206		-0.80189	-1.485485	-1.48794
5		0.19725	0.69897		-0.70498	-1.388575	-1.39103
6		0.2207	0.778151		-0.6250	-1.309394	-1.311849
7		0.2893	0.845098		-0.53865	-1.222243	-1.244902
8		0.32875	0.90309		-0.48313	-1.166728	-1.18691
9		0.36605	0.954243		-0.44971	-1.133302	-1.135757
10		0.40765	1		-0.38971	-1.073304	-1.09
11		0.43395	1.041393		-0.35255	-1.048152	-1.048607
12		0.4734	1.079181		-0.32477	-1.008364	-1.010819
13		0.51285	1.113943		-0.29001	-0.973601	-0.976057
14		0.53915	1.146128		-0.26829	-0.951882	-0.943872
15		0.59175	1.176091		-0.22786	-0.911454	-0.919909
16		0.6312	1.20412		-0.19933	-0.883426	-0.88588
17		0.64435	1.230449		-0.19038	-0.87447	-0.859551
18		0.6838	1.255273		-0.16507	-0.848659	-0.834727
19		0.7101	1.278754		-0.14868	-0.832272	-0.811246
20		0.74955	1.30103		-0.1252	-0.808791	-0.78897
40		1.3939	1.60206		0.144232	-0.53938	-0.48794
60		1.93305	1.778151		0.286243	-0.397349	-0.311849
120		3.0245	2.079181		0.480654	-0.202928	-0.010819
180		3.682	2.255273		0.566084	-0.117508	0.1662735
240		4.08966	2.380211		0.611686	-0.071906	0.2902112
300		4.32635	2.477121		0.636122	-0.04747	0.3871213
360		4.48416	2.556303		0.65168	-0.031912	0.4663025
420		4.58635	2.623249		0.661751	-0.021841	0.5332493
480		4.66825	2.681241		0.669154	-0.014438	0.5912412
540		4.72085	2.732394		0.67402	-0.009572	0.6423938
600		4.74715	2.778151		0.676433	-0.007159	0.6881513
660		4.74715	2.819544		0.676433	-0.007159	0.7295439
720		4.7603	2.857332		0.677634	-0.005957	0.7673325
780		4.77345	2.892095		0.678832	-0.004759	0.8020946
840		4.77345	2.924279		0.678832	-0.004759	0.8342793
900		4.7866	2.954243		0.680027	-0.003565	0.8642425
960		4.7866	2.982271		0.680027	-0.003565	0.8922712
1020		4.79975	3.0086		0.681219	-0.002373	0.9186002
1080		4.8129	3.033424		0.682407	-0.001185	0.9434239
1140		4.8129	3.056905		0.682407	-0.001185	0.9669049
1200		4.8129	3.079181		0.682407	-0.001185	0.9891812
1260		4.8129	3.100371		0.682407	-0.001185	1.0103705
1320		4.8129	3.120574		0.682407	-0.001185	1.0305739
1380		4.82605	3.139879		0.683592	0	1.0498791

SUPERIMPOSING OF OUTFLOW CURVES



GOLD TEST APPLIED AIR PRESSURE 130kPa
120

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1548	0	ERR	ERR	ERR
1	1546	0.0263	0	-1.58004	1.49241272
2	-1544	0.0526	0.30103	-1.27901	-1.22524934
3	-1542	0.0789	0.477121	-1.10292	-1.06896879
4	-1539	0.11835	0.60206	-0.92683	-0.95808597
5	1538	0.1315	0.69897	-0.88107	0.87207857
6	-1536	0.1578	0.778151	-0.80189	-0.80180541
7	-1534	0.1841	0.845098	-0.73495	-0.7423903
8	-1532	0.2104	0.90309	-0.67695	-0.69092269
9	-1530	0.2367	0.954243	-0.6258	-0.64552485
10	-1529	0.24985	1	-0.60232	-0.60491519
11	-1527	0.27615	1.041393	-0.55885	-0.56817029
12	-1525	0.30245	1.079181	0.51935	0.53464903
13	-1523	0.32875	1.113943	-0.48313	-0.50379075
14	-1521	0.35505	1.146128	-0.44971	-0.47522692
15	[illegible]	0.38136	1.176091	-0.41868	-0.44863464
16	-1519	.3945	1.20412	-0.40395	-0.42376921
17	1517	0.42766	1.230449	-0.36871	0.40030235
18	-1516	0.43395	1.255273	-0.36256	-0.37836149
19	-1513	0.46025	1.278754	-0.33701	-0.35752206
20	-1512	0.4734	1.30103	-0.32477	-0.33776182
21	-1510	0.4997	1.322219	-0.30129	0.31894637
22	-1508	0.526	1.342423	-0.27901	-0.30101691
23	-1507	0.63915	1.361728	-0.26829	-0.28388263
24	-1506	0.6523	1.380211	-0.25782	-0.26747868
25	-1504	0.5786	1.39794	-0.23762	-0.25174442
45	-1473	0.98625	1.653213	-0.00601	-0.0251907
60	-1455	1.22295	1.778151	0.087409	0.085692116
120	-1397	1.98585	2.079181	0.297903	0.352855492
180	-1350	2.4722	2.255273	0.393084	0.609136049
240	-1339	2.74835	2.380211	0.439072	0.620018869
300	-1325	2.93245	2.477121	0.467231	0.706026265
360	-1316	3.06395	2.556303	0.486282	0.776299425
420	-1309	3.14283	2.623249	0.497324	0.835714535
480	-1304	3.2089	2.681241	0.506316	0.887182245
540	-1303	3.22175	2.732394	0.508092	0.932679982
600	-1301	3.24805	2.778151	0.511623	0.973189542
660	-1300	3.2612	2.819544	0.513377	1.009925547
720	-1300	3.2612	2.857332	0.513377	1.043462801
780	-1298	3.2875	2.892095	0.516866	1.074314085
840	-1298	3.2875	2.924279	0.516866	1.102877912
900	-1298	3.2875	2.954243	0.516866	1.129470198
960	-1298	3.2875	2.982271	0.516866	1.154315621
1020	-1297	3.30065	3.0085	0.518599	1.177712469
1080	-1297	3.30065	3.033424	0.518599	1.199743358

Regression Output

Constant		-1.49241
Std Err of Y Est		0.036137
R Squared		0.993038
No. of Observations		29
Degrees of Freedom		27
X Coefficient(s)	0.887498	
Std Err of Coef	0.014301	

OUTFLOW VOLTAGE
INTIAL -1548
ENDED -1296

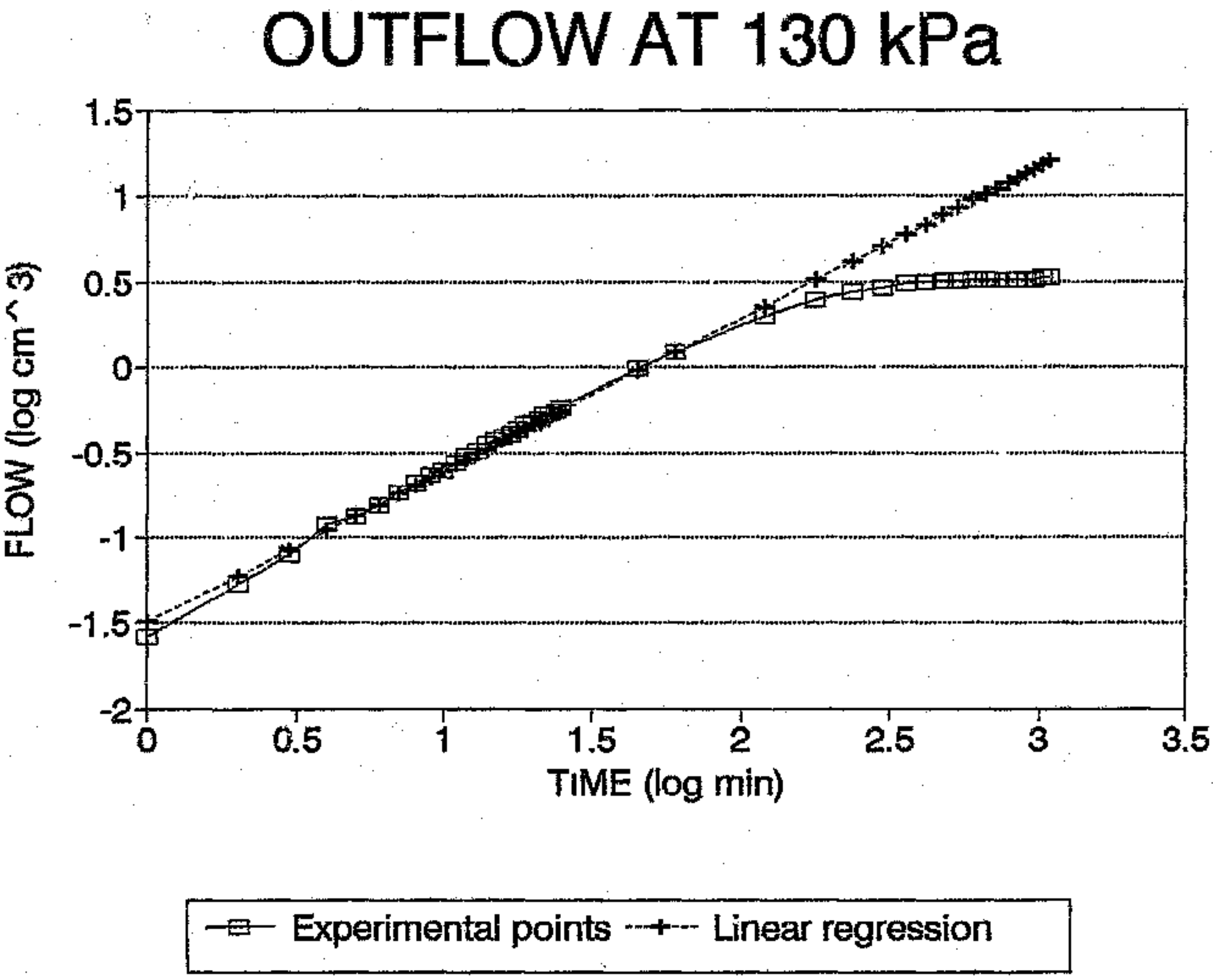
VOLUME CHANGE VOLATGE
VOLUME INITIAL -434 V
VOLUME FINAL -424 V

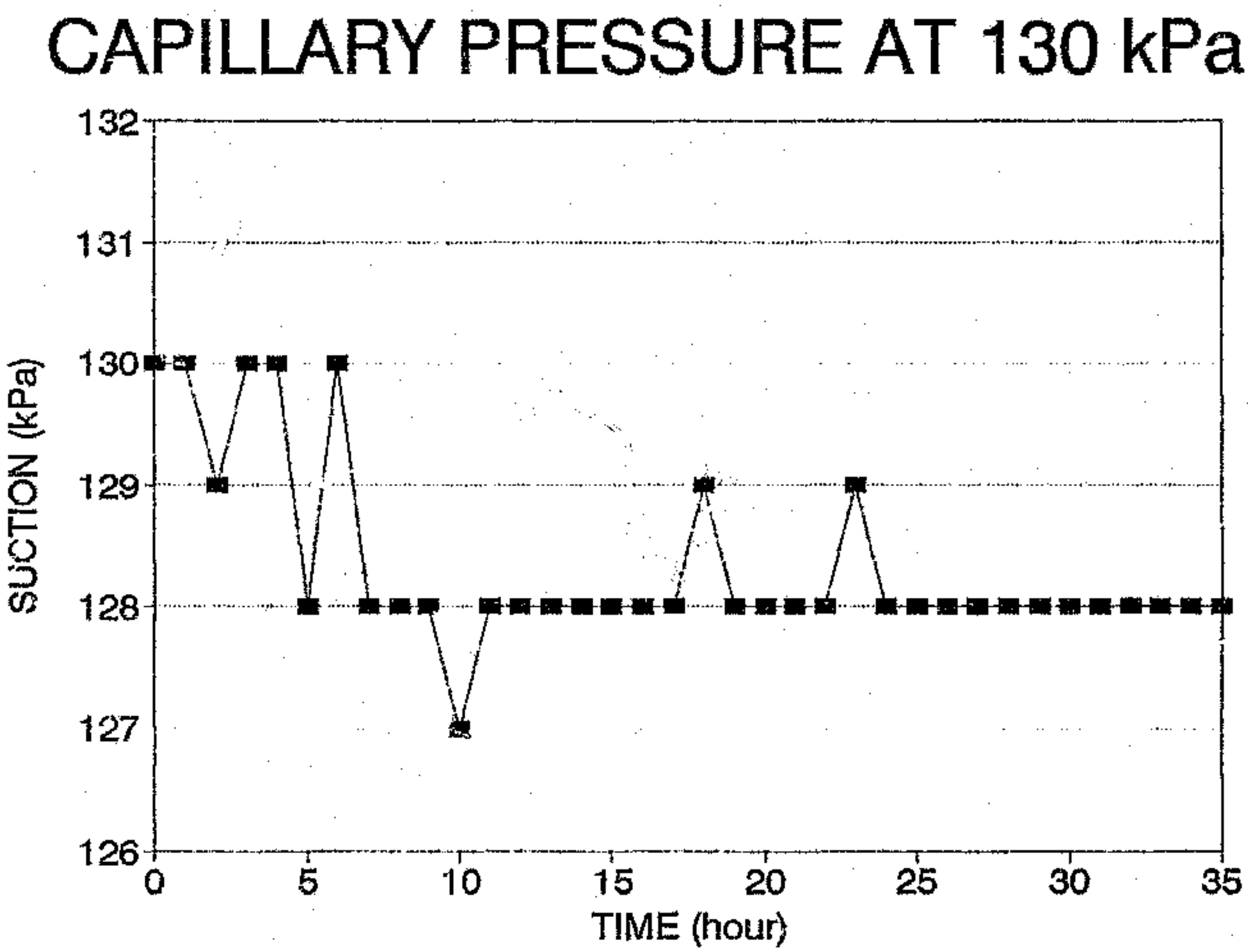
ALPHA
0.85239 (0.01-0.3)

TIME TRP
2.15

TIME minutes
141.2638

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	490	129.5049	130.0
1	493	130.2825	130.0
2	489	129.2457	129.0
3	492	130.0233	130.0
4	491	129.7641	130.0
5	485	128.2089	128.0
6	492	130.0233	130.0
7	484	127.9497	128.0
8	484	127.9497	128.0
9	486	128.4681	128.0
10	479	126.6537	127.0
11	484	127.9497	128.0
12	485	128.2089	128.0
13	485	128.2089	128.0
14	485	128.2089	128.0
15	486	128.4681	128.0
16	485	128.2089	128.0
17	484	127.9497	128.0
18	487	128.7273	129.0
19	486	128.4681	128.0
20	485	128.2089	128.0
21	484	127.9497	128.0
22	484	127.9497	128.0
23	487	128.7273	129.0
24	486	128.4681	128.0
25	486	128.4681	128.0
26	485	128.2089	128.0
27	486	128.4681	128.0
28	486	128.4681	128.0
29	484	127.9497	128.0
30	486	128.4681	128.0
31	485	128.2089	128.0
32	486	128.4681	128.0
33	485	128.2089	128.0
34	485	128.2089	128.0
35	486	128.4681	128.0


OUTFLOW AT 130 kPa
FLOW (log cm ^ 3)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5
2
2.5
3
3.5
TIME (log min)
Experimental points
Linear regression



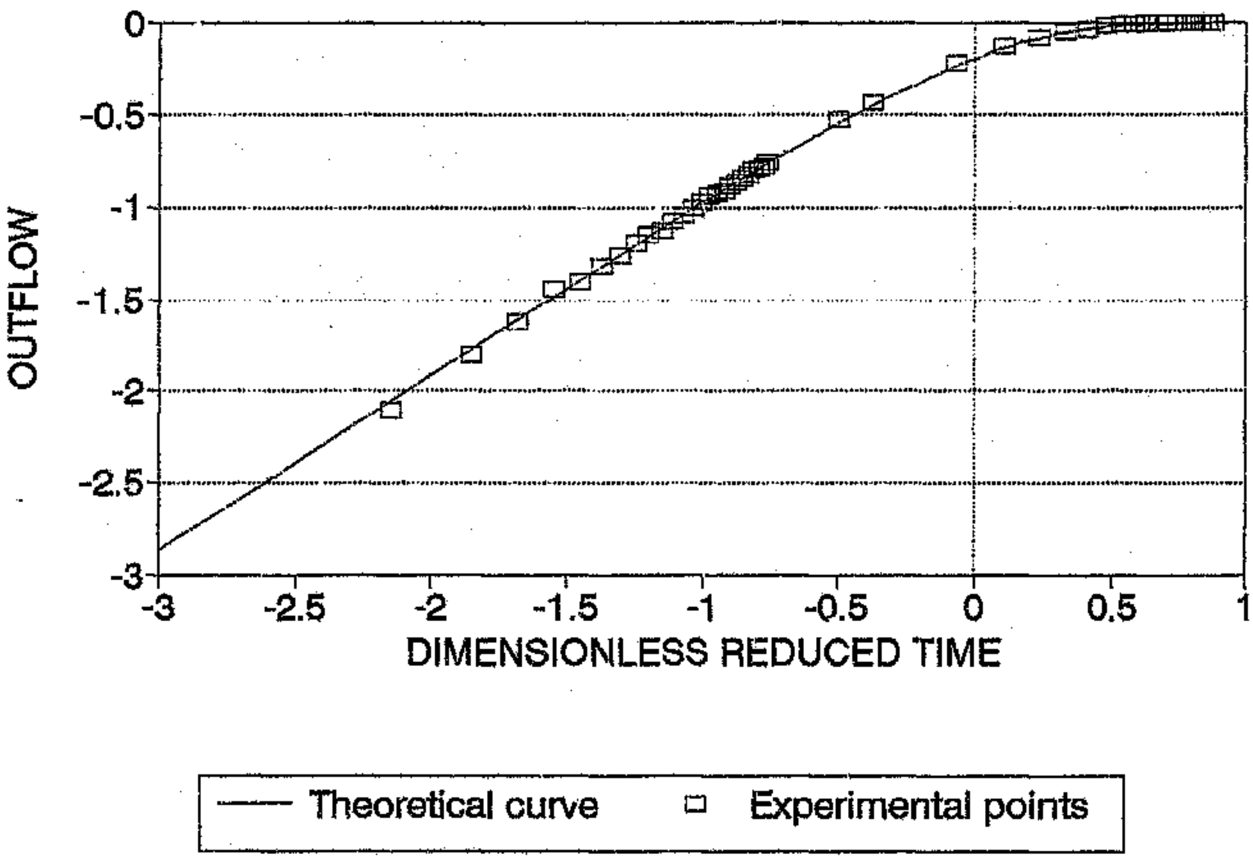
CAPILLARY PRESSURE AT 130 kPa
132
131
130
129
128
127
126
SUCTION (kPa)
0
5
10
15
20
25
30
35
TIME (hour)

GOLD TEST APPLLIED AIR PRESSURE 130 kPa

TIME	THEORETICAL Qo/Qt	EXPERIMENTAL Qt	LOG TIME	LOG Qo/Qt	LOG Qt	ADJUSTED Qt	ADJUSTED TIME
0.001	0.0019723394		-3	-2.80254			-3
0.1	0.1075013596		-1	-0.96859			-1
0.2	0.1949116983		-0.69897	-0.7* 116			-0.69897
0.3	0.2721052389		-0.52288	-0.56525			-0.522879
0.4	0.3416094488		-0.39794	-0.4665			-0.39794
0.5	0.4042043801		-0.30103	-0.3934			-0.3010[illegible]
0.6	0.4609098484		-0.22185	-0.33638			-0.221849
0.7	0.5122128128		-0.1549	-0.29055			-0.154902
0.8	0.5526923124		-0.09691	-0.25287			-0.09691
0.9	0.6006340576		-0.04576	-0.22139			-0.045757
1	0.6353288107		0	-0.19474			0
1.1	0.6730258798		0.041393	-0.17197			0.0413927
1.2	0.7041424874		0.079181	-0.15234			0.0791812
1.3	0.7322970525		0.113943	-0.13531			0.1139434
1.4	0.7577723582		0.146129	-0.12046			0.146128
1.5	0.7808233642		0.176091	-0.10746			0.1760913
1.6	0.8016807788		0.20412	-0.096			0.20412
1.7	0.8205533479		0.230449	-0.08589			0.2304489
1.8	0.8376299547		0.255273	-0.07695			0.2552725
1.9	0.8530816074		0.278754	-0.06901			0.2787536
2	0.8670626505		0.30103	-0.06195			0.30103
2.1	0.8797133119		0.322219	-0.05566			0.3222193
2.2	0.8911601037		0.342423	-0.05004			0.3424227
2.3	0.9015176893		0.361728	-0.04503			0.3617278
2.4	0.9108894299		0.380211	-0.04053			0.3802112
2.5	0.9193694217		0.39794	-0.03651			0.39794
2.6	0.9270424357		0.414973	-0.0329			0.4149733
2.7	0.9339852359		0.431364	-0.02966			0.4313638
2.8	0.9402673995		0.447158	-0.02675			0.447158
2.9	0.9469517071		0.462398	-0.02413			0.462398
3	0.9510950822		0.477121	-0.02178			0.4771213
10	1		1	0			1
1		0.0263	0		-1.58004	-2.098644	-2.15
2		0.0526	0.30103		-1.27901	-1.797614	-1.84897
3		0.0789	0.477121		-1.10292	-1.621522	-1.672879
4		0.11835	0.60206		-0.92683	-1.44543	-1.54794
5		0.1316	0.69897		-0.88107	-1.399574	-1.45103
6		0.1578	0.778151		-0.80189	-1.320492	-1.371849
7		0.1841	0.845098		-0.73495	-1.257548	-1.304902
8		0.2104	0.90309		-0.67695	-1.195554	-1.24691
9		0.2367	0.954243		-0.6258	-1.144401	-1.195757
10		0.24985	1		-0.60232	-1.12092	-1.15
11		0.27615	1.041393		-0.55885	-1.077454	-1.108607
12		0.30245	1.079181		-0.51935	-1.037946	-1.070819
13		0.32875	1.113943		-0.48319	-1.001734	-1.036057
14		0.35505	1.146128		-0.44971	-0.96831	-1.003872
15		0.38135	1.176091		-0.41868	-0.937270	-0.973909
16		0.3945	1.20412		-0.40395	-0.922552	-0.94588
17		0.40765	1.230449		-0.38971	-0.908312	-0.919551
18		0.43395	1.255273		-0.36256	-0.88116	-0.894727
19		0.46025	1.278754		-0.33701	-0.855606	-0.871246
20		0.4734	1.30103		-0.32477	-0.843371	-0.84897
21		0.4997	1.322219		-0.30129	-0.81[illegible]	-0.827781
22		0.526	1.342423		-0.27901	-0.797614	-0.807577
23		0.53915	1.361728		-0.26829	-0.78689	-0.788272
24		0.5523	1.380211		-0.25782	-0.776424	-0.769789
25		0.5786	1.39794		-0.23762	-0.756221	-0.75206
45		0.99623	1.653213		-0.00501	-0.524612	-0.496787
60		1.22295	1.778151		0.087409	-0.431191	-0.371849
120		1.98565	2.079181		0.297903	-0.220697	-0.070819
180		2.4722	2.255273		0.393084	-0.125516	0.1052729
240		2.74835	2.380211		0.439072	-0.079527	0.2302112
300		2.93245	2.477121		0.467231	-0.051369	0.3271213
360		3.06395	2.556303		0.486282	-0.032318	0.4063025
420		3.14285	2.623249		0.497234	-0.021275	0.4732493
480		3.2086	2.681241		0.506318	-0.012284	0.5312412
540		3.22175	2.732394		0.508092	-0.010508	0.5823938
600		3.24805	2.778151		0.511623	-0.006977	0.6281510
660		3.2612	2.819544		0.513377	-0.005222	0.6695439
720		3.2612	2.857332		0.513377	-0.005222	0.7073026
780		3.2875	2.892095		0.516866	-0.001734	0.7420946
840		3.2875	2.924279		0.516866	-0.001734	0.7742793
900		3.2875	2.954243		0.516866	-0.001734	0.8042425
960		3.2875	2.982271		0.516866	-0.001734	0.8322712
1020		3.30065	3.0086		0.518599	0	0.8586052
1080		3.30065	3.033424		0.518599	0	0.8834238

SUPERIMPOSING OF OUTFLOW CURVES

AT 130 kPa



GOLD TEST APPLIED AIR PRESSURE 160 KPa
160

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1638	0	ERR	ERR	ERR
1	1637	0.01315	0	1.88107	1.65380179
2	-1535	0.03945	0.30103	-1.40395	-1.31900951
3	-1633	0.06575	0.477121	-1.1871	-1.10166487
4	1632	0.0709	0.60206	-1.10292	-1.0843173
6	1630	0.1052	0.778151	-0.97793	0.94687266
7	-1629	0.11835	0.845098	-0.92683	-0.88465665
8	-1627	0.14465	0.90309	-0.83968	-0.84942608
9	-1626	0.1578	0.954243	-0.80189	-0.80952801
10	-1625	0.17095	1	-0.76713	-0.77383207
11	-1624	0.1841	1.041393	-0.73495	-0.74159411
12	-1623	0.19725	1.079181	-0.70498	-0.71208044
13	-1622	0.2104	1.113943	-0.67695	-0.68496729
14	-1621	0.22355	1.146128	-0.65063	-0.65988113
15	-1620	0.2367	1.176091	-0.6258	-0.63649423
16	-1619	0.24985	1.20412	-0.60232	-0.61463287
17	-1618	0.263	1.230449	-0.58004	-0.59409727
18	1617	0.27616	1.278754	-0.55885	-0.55642143
20	-1616	0.2893	1.30103	-0.53865	-0.53904666
40	-1599	0.51285	1.60206	-0.29001	-0.30425444
60	-1584	0.7101	1.778151	-0.14868	-0.1669098
120	1549	1.17026	2.079181	0.068316	0.067882417
180	-1527	1.45965	2.255273	0.164249	0.205227059
240	-1512	1.6549	2.380211	0.219256	0.302674633
300	-1501	1.80166	2.477121	0.255646	0.37856084
360	-1494	1.8936	2.556303	0.277208	0.440019275
420	-1488	1.9726	2.62324	0.295017	0.492235284
480	-1486	1.9988	2.68124	0.300769	0.537466849
1380	-1472	2.1829	3.139879	0.339084	0.895107336
1440	-1473	2.16975	3.158362	0.33641	0.909503706
1500	-1473	2.16975	3.176091	0.33641	0.923431485
1560	-1471	2.19605	3.193125	0.341642	0.936716868

Regression Output

Constant		-1.6338
Std Err of Y Est		0.017959
R Squared		0.997265
No. of Observations		19
Degrees of Freedom		17
X Coefficient(s)	0.779963	
Std Err of Coef	0.009907	

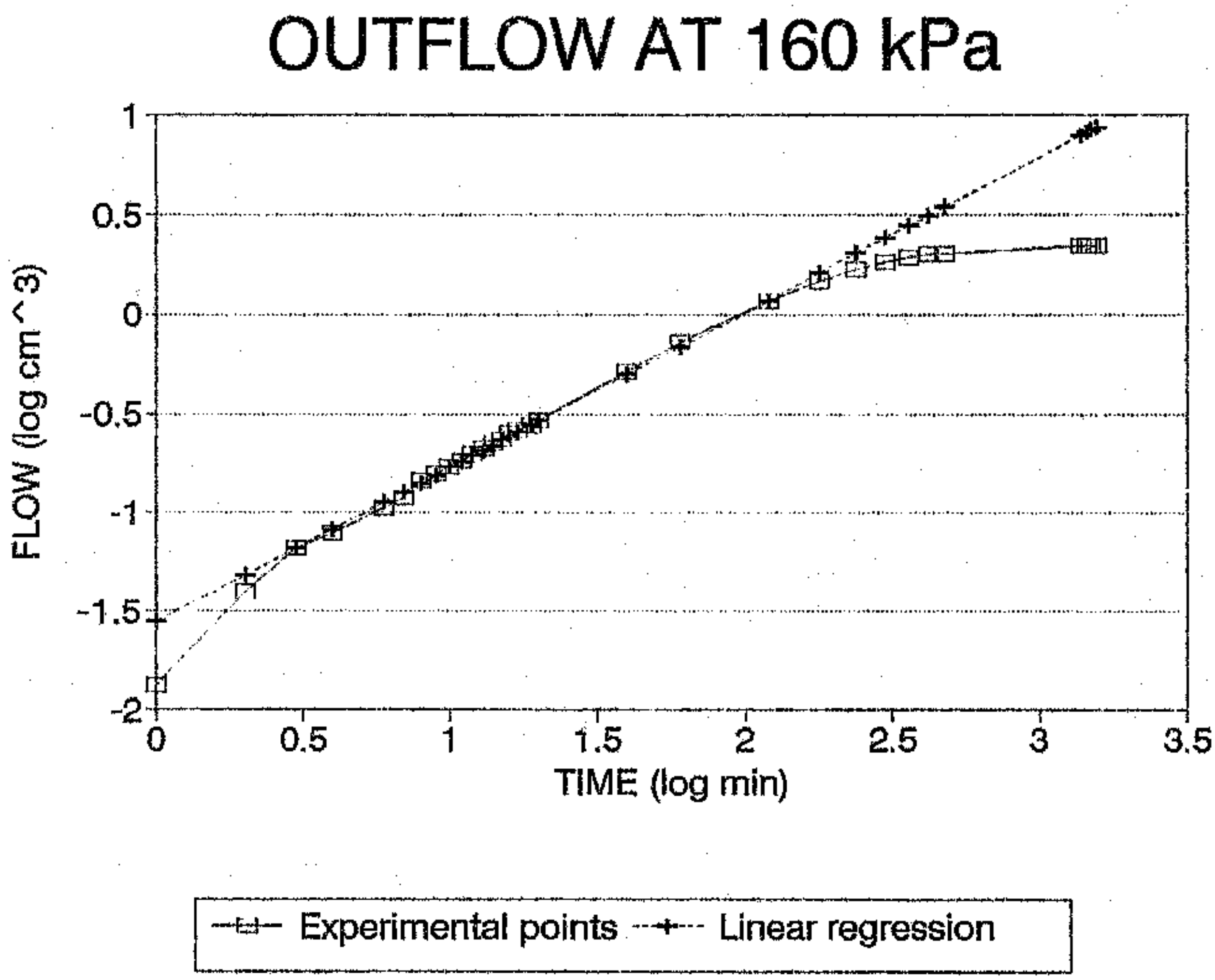
OUTFLOW VOLTAGE
INTIAL -1641
ENDED -1471

VOLUME CHANGE VOLATGE
VOLUME INITIAL -424 V
VOLUME FINAL -421 V

ALPHA
0.229781 (0.01-0.3)

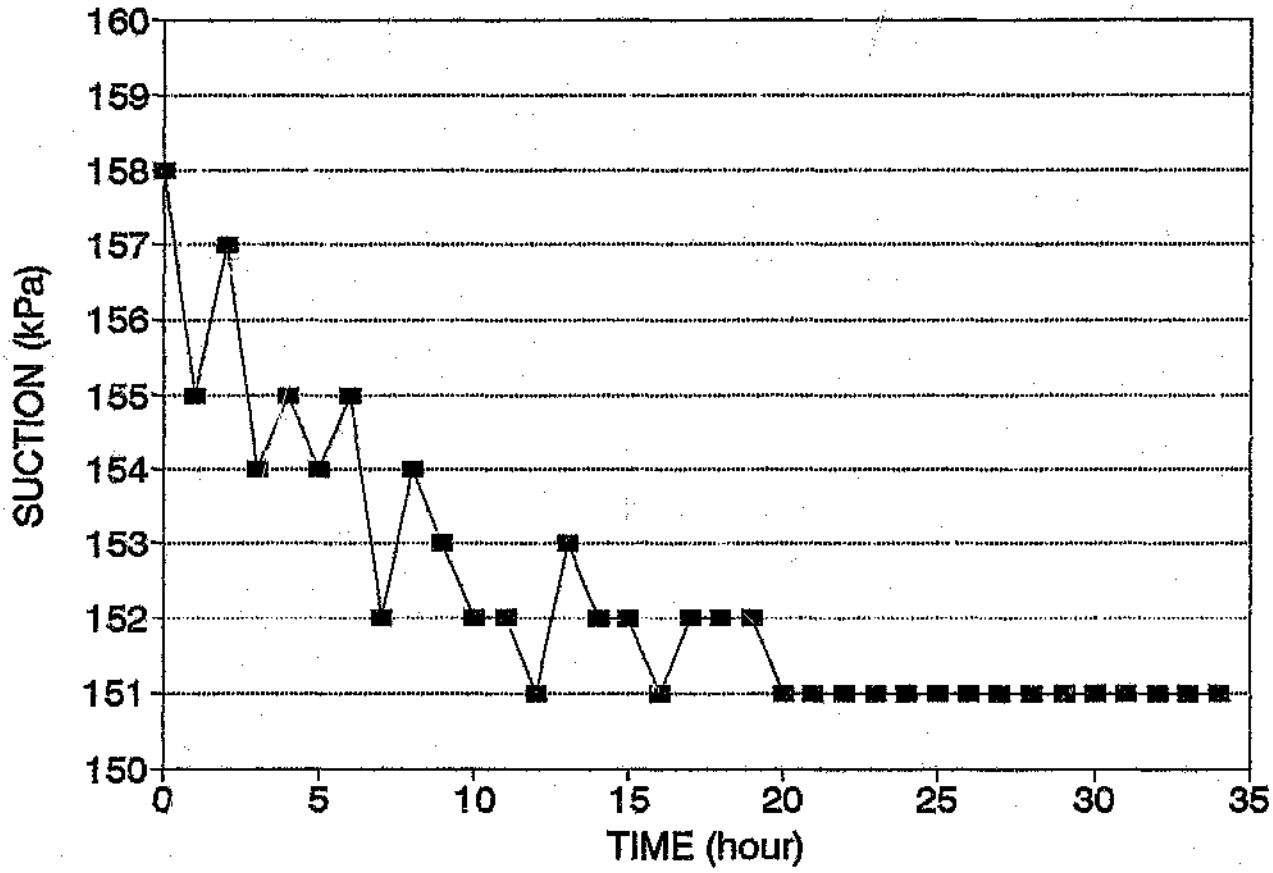
TIME TRP
2.295
TIME minutes
197.2423

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	600	168.294	158.0
1	587	154.9246	155.0
2	594	166.7389	157.0
3	585	154.4061	154.0
4	588	165.1837	155.0
5	582	163.6285	154.0
6	586	164.6652	165.0
7	577	162.3326	162.0
8	582	163.6285	154.0
9	580	163.1101	153.0
10	575	151.8141	152.0
11	574	161.5549	152.0
12	571	160.7773	151.0
13	579	152.5917	153.0
14	577	162.3326	162.0
15	577	162.3326	152.0
16	572	151.0365	151.0
17	576	162.0732	162.0
18	577	162.3326	152.0
19	575	161.8141	162.0
20	573	151.2957	161.0
21	570	160.5181	161.0
22	573	151.2957	161.0
23	572	161.0365	151.0
24	570	150.5181	151.0
25	573	161.2957	151.0
26	570	160.5181	161.0
27	572	161.0365	161.0
28	571	160.7773	161.0
29	572	161.0365	161.0
30	572	161.0365	151.0
31	570	160.5181	161.0
32	573	161.2957	161.0
33	571	160.7773	151.0
34	572	161.0365	151.0



OUTFLOW AT 160 kPa
FLOW (log cm ^ 3)
TIME (log min)
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5
2
2.5
3
3.5
Experimental points
Linear regression

CAPILLARY PRESSURE AT 160 kPa

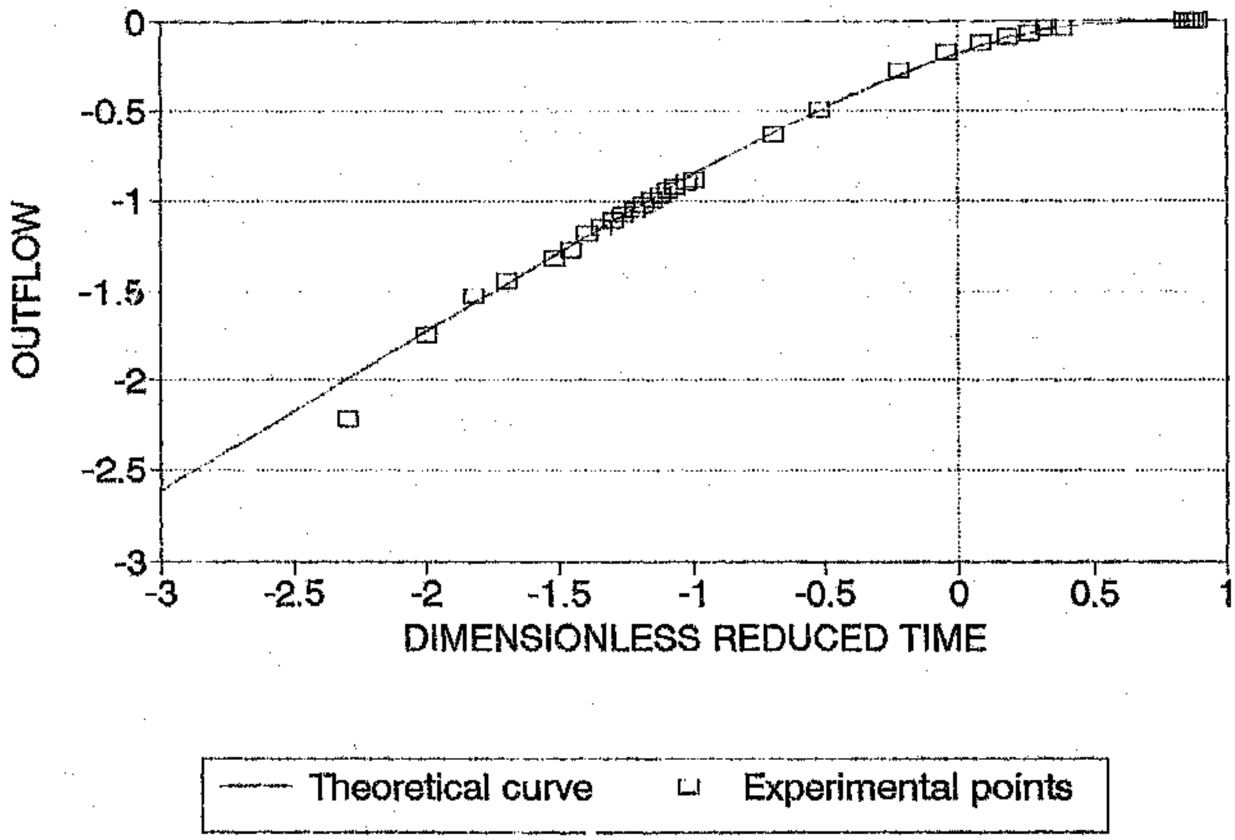


GOLD TEST APPLIED AIR PRESSURE 160 kPa

TIME	THEORETICAL Qo/Qt	EXPERIMENTAL Qt	LOG TIME	LOG Qo/Qt	LOG Qt	ADJUSTED Qt	ADJUSTED TIME
0.001	0.0024414236		-3	-2.61236			-3
0.1	0.1420525509		-1	-0.84755			-1
0.2	[illegible]		-0.69897	[illegible]			-0.69897
0.3	0.3135575568		-0.52288	-0.50313			-0.522879
0.4	0.3810558351		-0.39794	-0.41901			-0.39794
0.5	0.4408514632		-0.30103	-0.3559			-0.30103
0.6	0.4941474153		-0.22185	-0.30614			-0.221849
0.7	0.5423881185		-0.1549	-0.26569			-0.154902
0.8	0.5859749845		-0.09691	-0.23212			-0.09691
0.9	0.6253897763		-0.04576	-0.20385			-0.016757
1	0.6610444505		0	-0.17977			0
1.1	0.6933025617		0.041393	-0.15908			0.0413927
1.2	0.7224895364		0.079181	-0.14117			0.0791812
1.3	0.7489984707		0.113943	-0.12558			0.1139434
1.4	0.7727840718		0.146128	-0.11194			0.146128
1.5	0.794415823		0.176091	-0.09995			0.1760913
1.6	0.8139795817		0.20412	-0.08939			0.20412
1.7	0.8316817722		0.230449	-0.08004			0.2304489
1.8	0.8476993721		0.255273	-0.07176			0.2552725
1.9	[illegible]		0.278754	-0.0644			0.2787536
2	0.8753007905		0.30103	-0.05704			0.30103
2.1	0.8871799212		0.322219	-0.05199			0.3222193
2.2	[illegible]		0.342423	-0.04677			0.3424227
2.3	0.9076250009		0.361728	-0.04209			0.3617278
2.4	0.9164166443		0.380211	-0.03791			0.3802112
2.5	0.9240697474		0.39794	-0.03415			0.39794
2.6	0.9315669175		0.414973	-0.03078			0.4149733
2.7	0.9380791883		0.431364	-0.02776			0.4313638
2.8	0.9439717308		0.447158	-0.02504			0.447158
2.9	0.9493035266		0.462398	-0.02259			0.462398
3	0.9541279933		0.477121	-0.02039			0.4771213
10	1		1	0			1
1		0.01315	0		-1.88107	-2.222716	-2.295
2		0.03945	0.30103		-1.40395	-1.745625	-1.99397
3		0.06575	0.477121		-1.1821	-1.523746	-1.817879
4		0.0789	0.60206		-1.10292	-1.444565	-1.69294
6		0.1052	0.778151		-0.97798	-1.319626	-1.516949
7		0.11635	0.845098		0.93283	1.280474	-1.449902
8		0.14465	0.90309		-0.83968	-1.181324	-1.39191
9		0.1578	0.954243		-0.80189	-1.143535	-1.340757
10		0.17095	1		-0.76713	-1.108773	-1.295
11		0.1841	1.041393		-0.73495	-1.076589	-1.253607
12		0.19725	1.079181		-0.70498	-1.046626	-1.215819
13		0.2104	1.113943		-0.67695	-1.018596	-1.181057
14		0.22355	1.146128		-0.65063	-0.992268	-1.148872
15		0.2367	1.176091		-0.6258	-0.967444	-1.118909
16		0.24985	1.20412		-0.60232	-0.943963	-1.09088
17		0.263	1.230449		-0.58004	-0.921686	-1.064551
19		0.27615	1.278754		-0.55885	-0.900497	-1.016246
20		0.2893	1.30103		-0.53865	-0.880294	-0.99397
40		0.51285	1.60206		-0.29001	-0.631052	-0.69294
60		0.7101	1.778151		-0.14866	-0.490323	-0.516849
120		1.17035	2.079181		0.068316	-0.273326	-0.215819
180		1.46065	2.255273		0.164249	-0.177393	-0.039727
240		1.6560	2.380211		0.219226	0.122046	0.0852112
300		1.80155	2.477121		0.255646	-0.085996	0.1821213
360		1.8936	2.556303		0.277298	-0.064354	0.2613025
420		1.9726	2.623249		0.295017	-0.046625	0.3282493
480		1.9988	2.681241		0.300769	-0.040873	0.3862412
1380		2.1829	3.139879		0.339034	-0.002608	0.8448791
1440		2.16976	3.158362		0.33641	-0.005233	0.8633625
1500		2.16976	3.176091		0.33641	-0.005233	0.8810913
1560		2.19605	3.193125		0.341642	0	0.8981248

SUPERIMPOSING OF OUTFLOW CURVES

AT 160 kPa



GOLD TEST APPLIED AIR PRESSURE 200 kPa
200

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-776	0	ERR	ERR	ERR
1	-774	0.0263	0	-1.58004	-1.6386601
2	-773	0.03946	0.30103	-1.40385	-1.3981827
3	-772	0.0526	0.477121	-1.27901	-1.2579182
4	-771	0.06576	0.60206	-1.1831	-1.1677182
5	-770	0.0789	0.69897	-1.10292	-1.080302
6	-769	0.09205	0.778151	-1.03598	-1.0170506
7	-768	0.1052	0.845098	-0.97798	-0.9635726
8	-767	0.11835	0.90309	-0.92683	-0.9172477
9	-766	0.1315	0.954243	-0.88107	-0.8763362
10	-765	0.14465	1	-0.83968	-0.8398348
11	-764	0.1578	1.041393	-0.80189	-0.8067094
12	-763	0.17095	1.079181	-0.76713	-0.7765833
14	-761	0.19725	1.146128	-0.70498	-0.7231062
15	-760	0.2104	1.20412	-0.67695	-0.6757903
17	-759	0.22355	1.230449	-0.65063	-0.6557483
18	-758	0.2367	1.255273	-0.6258	-0.6358169
20	-757	0.24985	1.30103	-0.60232	-0.5993571
40	-748	0.4471	1.60206	-0.3496	-0.3580096
60	-723	0.61806	1.778151	-0.20895	-0.2182262
120	-699	1.01255	2.079181	0.005415	0.02223229
180	-677	1.30185	2.255273	0.114561	0.16289874
240	-660	1.5254	2.380211	0.193384	0.26269976
300	-649	1.67005	2.477121	0.222729	0.34011299
360	-630	1.80155	2.556303	0.255645	0.40335419
420	-633	1.88045	2.623249	0.274262	0.45684923
480	-629	1.93305	2.681241	0.286243	0.5031672
540	-627	1.95935	2.732394	0.292119	0.54402964
600	-625	1.98565	2.778151	0.297903	0.58058043
660	-624	1.9988	2.819544	0.300769	0.61364555
720	-623	2.01195	2.857332	0.303617	0.64333105
780	-623	2.01195	2.892095	0.303617	0.67160019
840	-623	2.01195	2.924279	0.303817	0.69730979
900	-622	2.0251	2.954243	0.306446	0.72124498
960	-622	2.0251	2.982271	0.306446	0.74363466
1020	-621	2.03825	3.0086	0.309257	0.76466962
1080	-620	2.0514	3.033424	0.31205	0.78449609
1140	-620	2.0514	3.056905	0.31205	0.80325316
1200	-620	2.0514	3.079181	0.31205	0.82104769
1260	-620	2.0514	3.100371	0.31205	0.83797423
1320	-620	2.0514	3.120574	0.31205	0.85411301
1380	-620	2.0514	3.139879	0.31205	0.86953437
1440	-620	2.0514	3.158362	0.31205	0.8842991
1500	-618	2.0777	3.176091	0.317583	0.89846119
1560	-616	2.104	3.193125	0.323046	0.91206761
1620	-615	2.11715	3.209515	0.325752	0.92516064
1680	-613	2.14345	3.225309	0.331113	0.93777724
1740	-611	2.16975	3.240549	0.33641	0.94995118
1800	-610	2.1829	3.255273	0.339034	0.96171233
1860	-610	2.1829	3.269513	0.339034	0.97308792
1920	-610	2.1829	3.283301	0.339034	0.98410211
1980	-610	2.1829	3.296665	0.339034	0.99477745
2040	-611	2.16975	3.30963	0.33641	1.00513406
2100	-610	2.1829	3.322219	0.339034	1.01519047
2160	-611	2.16975	3.334454	0.33641	1.02496395
2220	-610	2.1829	3.346353	0.339034	1.03446963
2280	-610	2.1829	3.357935	0.339034	1.04372081
2340	-610	2.1829	3.369216	0.339034	1.05273206
2400	-609	2.19605	3.380211	0.341642	1.06151534
2460	-609	2.19605	3.390935	0.341642	1.07008173
2520	-609	2.19605	3.401401	0.341642	1.07844169
2580	-609	2.19605	3.41162	0.341642	1.08660491
2640	-609	2.19605	3.421604	0.341642	1.09458047
2700	-609	2.19605	3.431364	0.341642	1.10237679
2760	-609	2.19605	3.440909	0.341642	1.11000173
2820	-609	2.19605	3.450249	0.341642	1.11746268
2880	-609	2.19605	3.459392	0.341642	1.12476656
2940	-607	2.2092	3.468347	0.344235	1.13191983
3000	-606	2.2235	3.477121	0.346976	1.13892857
3060	-604	2.2518	3.485721	0.354464	1.14579852
3120	-602	2.2881	3.494155	0.359475	1.15253507
3180	-601	2.30125	3.502427	0.361964	1.15914329
3240	-600	2.3144	3.510545	0.364438	1.16562799
3300	-600	2.3144	3.518514	0.364438	1.1719037
3360	-600	2.3144	3.526339	0.364438	1.1782447
3420	-600	2.3144	3.534026	0.364438	1.18438506
3480	-600	2.3144	3.541579	0.364438	1.19041862
3540	-600	2.3144	3.549003	0.364438	1.19634904
3600	-600	2.3144	3.556303	0.364438	1.20217979
3660	-599	2.32755	3.563481	0.366899	1.20791416
3720	-599	2.32755	3.570543	0.366899	1.21355527
3780	-599	2.32755	3.577492	0.366899	1.21910613
3840	-598	2.3407	3.584331	0.369346	1.22456957
3900	-598	2.3407	3.591065	0.369346	1.2299462
3960	-597	2.35385	3.597695	0.371779	1.23524491
4020	-597	2.35385	3.604226	0.371779	1.24046187
4080	-597	2.35385	3.61066	0.371779	1.24560164
4140	-600	2.3144	3.617	0.364438	1.25066617
4200	-599	2.32755	3.623249	0.366899	1.25565703
4260	-598	2.367	3.62941	0.374199	1.26057866

Regression Output:

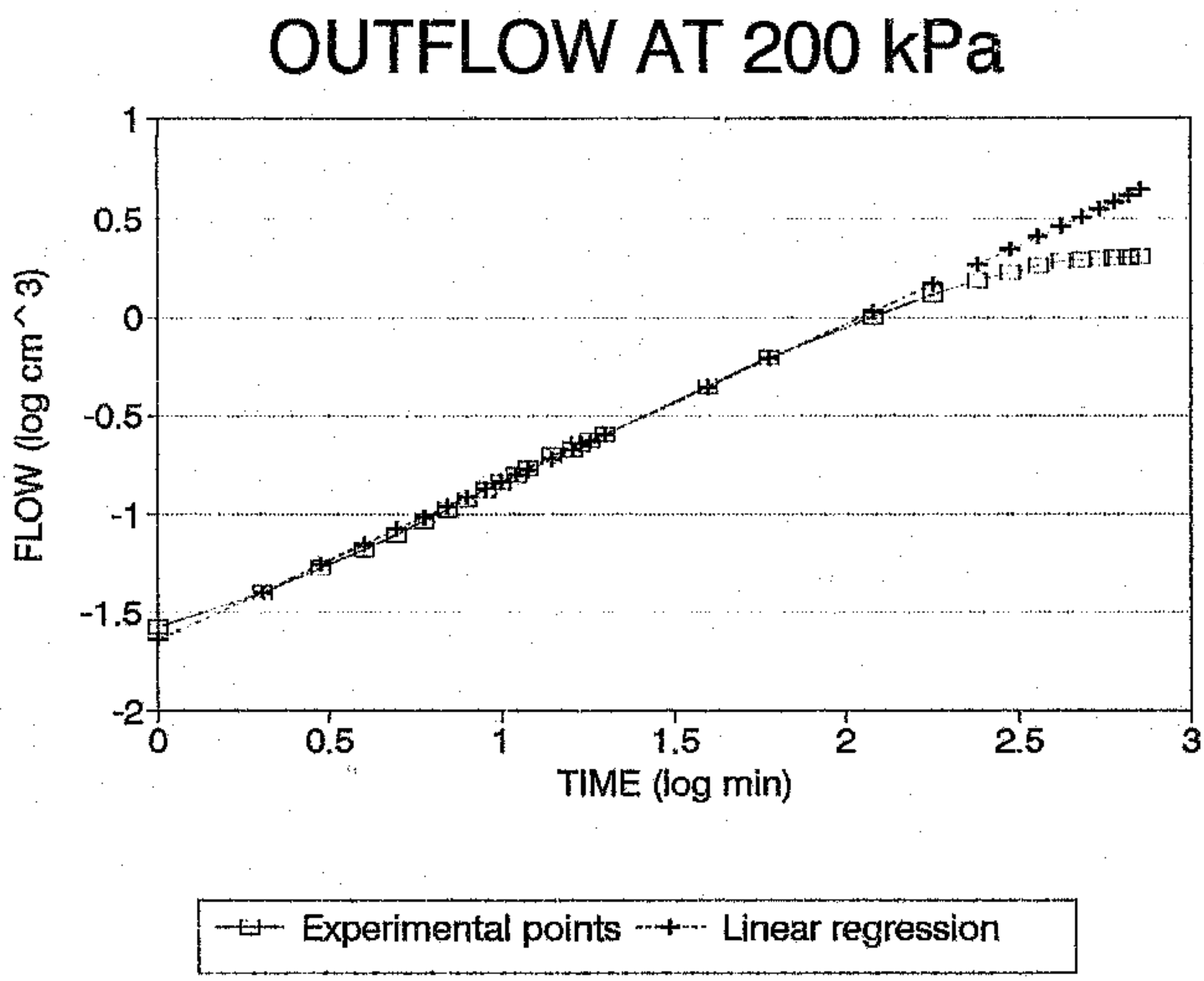
Constant		-1.63865
Std Err of Y Est		0.012505
R Squared		0.998947
No. of Observations		19
Degrees of Freedom		17
X Coefficient(s)	0.798816	
Std Err of Coef.	0.010721	

OUTFLOW VOLTAGE
INITIAL -760
ENDED -598

VOLUME CHANGE VOLTAGE
VOLUME INITIAL -421 V
VOLUME FINAL -417 V

ALPHA
0.27679 (0.01-0.3)

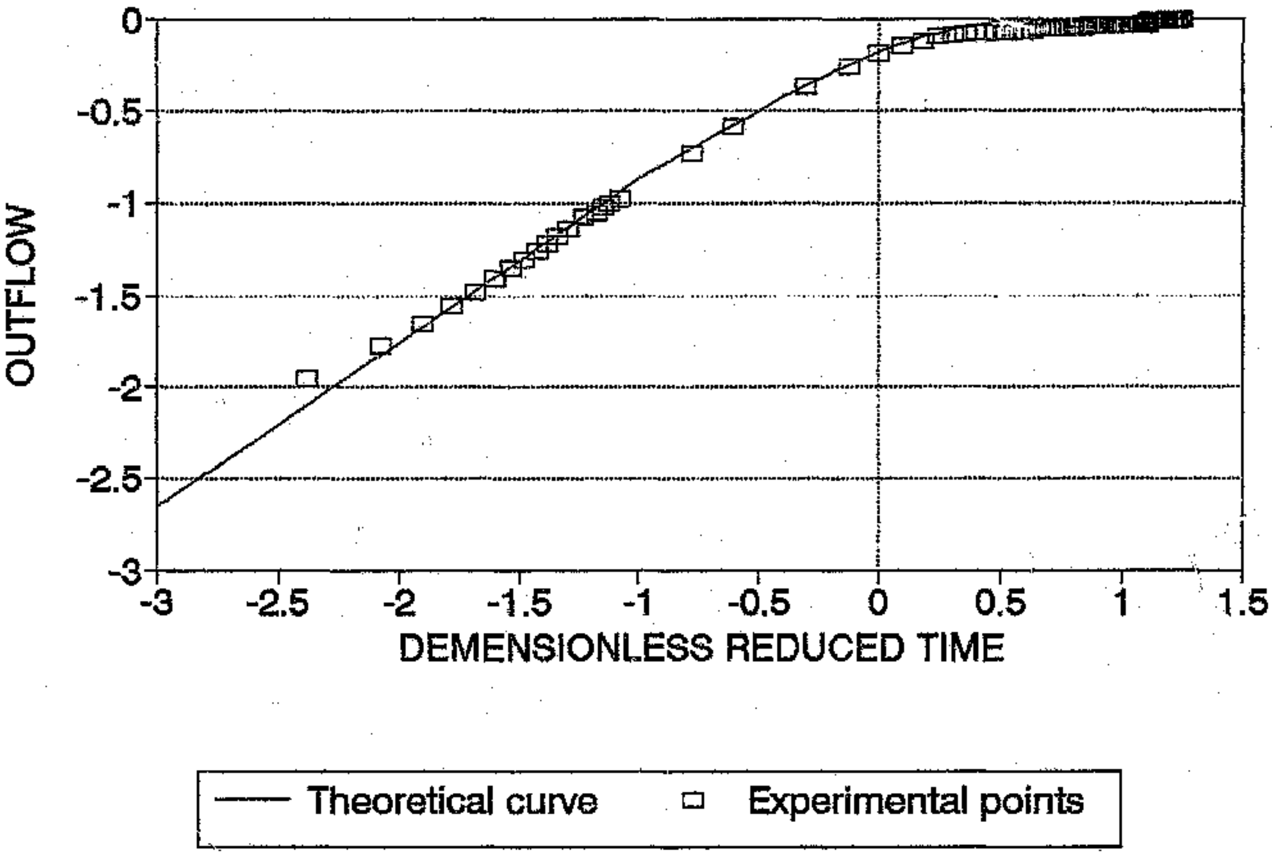
TIME TRP
2.39
TIME minutes
239.8833


OUTFLOW AT 200 kPa
FLOW (log cm^3)
TIME (log min)
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5
2
2.5
3
Experimental points
Linear regression

COLD TEST APPLIED AIR PRESSURE 200 kPa

TIME	THEORETICAL Qt/Qr	EXPERIMENTAL Qt	LOG TIME	LOG Qt/Qr	LOG Qt	ADJUSTED Qt	ADJUSTED TIME
0.004	0.0022600482		-3	-2.6575			-3
0.1	0.135844606		-1	-0.8676			-1
0.2	0.229089641		-0.699	-0.64			-0.69897
0.3	0.306520409		-0.5229	-0.5135			-0.52288
0.4	0.374022449		-0.3979	-0.4271			-0.39794
0.5	0.43416045		-0.301	-0.3623			-0.30103
0.6	0.485216908		-0.2218	-0.3114			-0.22185
0.7	0.537000162		-0.1549	-0.27			-0.1549
0.8	0.581690604		-0.0969	-0.2353			-0.09691
0.9	0.620965825		-0.0458	-0.2069			-0.04576
1	0.667038857		0	-0.1554			0
1.1	0.686678191		0.04139	-0.1634			0.041393
1.2	0.7182096		0.07918	-0.1437			0.079181
1.3	0.746930797		0.11394	-0.1273			0.113943
1.4	0.770108705		0.14613	-0.1134			0.146128
1.5	0.791966735		0.17609	-0.1013			0.176091
1.6	0.811760969		0.20412	-0.0906			0.20412
1.7	0.829849237		0.23045	-0.0811			0.230449
1.8	0.845869234		0.25527	-0.0727			0.255273
1.9	0.860065918		0.27876	-0.0655			0.278754
2	0.873830014		0.30103	-0.0586			0.30103
2.1	0.885500333		0.32222	-0.0528			0.322219
2.2	0.896705208		0.34242	-0.0474			0.342423
2.3	0.906533198		0.36173	-0.0426			0.361728
2.4	0.915645774		0.38021	-0.0384			0.380211
2.5	0.923475605		0.39794	-0.0346			0.39794
2.6	0.93075600		0.41497	-0.0312			0.414973
2.7	0.937347529		0.43136	-0.0281			0.431364
2.8	0.943308918		0.44716	-0.0253			0.447158
2.9	0.948704331		0.4624	-0.0228			0.462398
3	0.95359876		0.47712	-0.0206			0.477121
10	1		1	0			1
1		0.0263	0		-1.58	-1.95404	-2.04
2		0.03945	0.30103		-1.404	-1.77916	-2.07687
3		0.0526	0.47712		-1.279	-1.65321	-1.50265
4		0.06576	0.60206		-1.1821	-1.5563	-1.27794
5		0.0789	0.69897		-1.1029	-1.47722	-1.65407
6		0.08206	0.77815		-1.058	-1.41917	-1.60965
7		0.1052	0.8451		-0.978	-1.35216	-1.6344
8		0.11836	0.90309		-0.9268	-1.30103	-1.47831
9		0.1316	0.95424		-0.8811	-1.25527	-1.40670
10		0.14471	1		-0.8397	-1.21396	-1.38
11		0.1578	1.04139		-0.8018	-1.17609	-1.33961
12		0.17096	1.07918		-0.7671	-1.14133	-1.30947
14		0.19735	1.14613		-0.705	-1.07936	-1.22587
16		0.2504	1.20412		-0.677	-1.05105	-1.17646
17		0.22356	1.23045		-0.6506	-1.02482	-1.14656
18		0.2367	1.25527		-0.6263	-1	-1.12473
20		0.26306	1.30103		-0.5823	-0.95602	-1.07887
40		0.4471	1.60206		-0.3496	-0.72579	-0.72794
60		0.61805	1.77815		-0.209	-0.54347	-0.66186
120		1.01266	2.07918		0.00542	-0.36875	-0.30062
180		1.30165	2.25527		0.11458	-0.25904	-0.12473
240		1.6284	2.38021		0.18356	-0.19061	0.000211
300		1.67006	2.47712		0.22273	-0.15147	0.067126
360		1.80656	2.5563		0.25684	-0.11695	0.378365
420		1.86045	2.62325		0.26960	-0.09962	0.343323
480		1.90306	2.68124		0.28604	-0.06796	0.416491
540		1.95975	2.73235		0.29231	-0.08203	0.362494
600		1.96685	2.77815		0.2979	-0.0763	0.396797
660		1.9969	2.81954		0.30077	-0.07343	0.429324
720		2.01195	2.85733		0.30362	-0.07059	0.477332
780		2.01195	2.89209		0.30362	-0.07059	0.494691
840		2.01195	2.92428		0.30362	-0.07059	0.544879
900		2.0261	2.95424		0.30646	-0.06775	0.576962
960		2.0257	2.98227		0.30645	-0.06776	0.605271
1020		2.03625	3.0086		0.30888	-0.06486	0.6349
1080		2.0614	3.03342		0.31206	-0.06216	0.660494
1140		2.0514	3.0569		0.31206	-0.06215	0.679608
1200		2.0514	3.07918		0.31206	-0.06213	0.700707
1260		2.0514	3.10037		0.31206	-0.06214	0.718971
1320		2.0514	3.12057		0.31205	-0.06215	0.746594
1380		2.0514	3.13988		0.31206	-0.06214	0.759879
1440		2.0514	3.15836		0.31205	-0.06215	0.775302
1500		2.0777	3.17609		0.31758	-0.05662	0.796091
1560		2.104	3.19312		0.32305	-0.05116	0.815196
1620		2.11715	3.20952		0.32575	-0.04845	0.836575
1680		2.14746	3.22531		0.33111	-0.04309	0.865366
1740		2.15775	3.24055		0.33041	-0.04379	0.880684
1800		2.1626	3.25527		0.33503	-0.03916	0.876373
1860		2.1626	3.26951		0.33503	-0.03916	0.890673
1920		2.1626	3.2833		0.33503	-0.03916	0.903301
1980		2.1626	3.29667		0.33503	-0.03916	0.916648
2040		2.16876	3.30963		0.33641	-0.03779	0.92664
2100		2.1626	3.32222		0.33503	-0.03916	0.942219
2160		2.16875	3.33445		0.33641	-0.03779	0.954454
2220		2.1626	3.34635		0.33503	-0.03916	0.966351
2280		2.1626	3.35793		0.33503	-0.03916	0.977928
2340		2.1626	3.36922		0.33503	-0.03916	0.989218
2400		2.19605	3.38021		0.34164	-0.03256	1.000211
2460		2.19605	3.39094		0.34164	-0.03256	1.010939
2520		2.19605	3.4014		0.34164	-0.03256	1.021401
2580		2.19605	3.41162		0.34164	-0.03256	1.03162
2640		2.19605	3.4216		0.34164	-0.03256	1.041604
2700		2.19605	3.43136		0.34164	-0.03256	1.051356
2760		2.19605	3.44091		0.34164	-0.03256	1.060905
2820		2.19605	3.45025		0.34164	-0.03256	1.070254
2880		2.19605	3.45939		0.34164	-0.03256	1.079383
2940		2.2082	3.46835		0.34424	-0.02996	1.088347
3000		2.2135	3.47712		0.34507	-0.02906	1.097121
3060		2.2619	3.48572		0.35448	-0.01974	1.104721
3120		2.2661	3.49415		0.35346	-0.01472	1.114154
3180		2.30125	3.50243		0.36185	-0.01225	1.122422
3240		2.3144	3.51055		0.36444	-0.00976	1.130545
3300		2.3144	3.51851		0.36444	-0.00976	1.138494
3360		2.3144	3.52634		0.36444	-0.00976	1.146329
3420		2.3144	3.53403		0.36444	-0.00976	1.154028
3480		2.3144	3.54158		0.36444	-0.00976	1.161576
3540		2.3144	3.549		0.36444	-0.00976	1.168003
3600		2.3144	3.5563		0.36444	-0.00976	1.176305
3660		2.32756	3.56348		0.3669	-0.0073	1.183481
3720		2.32765	3.57054		0.3669	-0.0073	1.190543
3780		2.32765	3.57749		0.3669	-0.0073	1.197491
3840		2.3407	3.58433		0.36935	-0.00485	1.204331
3900		2.3407	3.59106		0.36935	-0.00485	1.211063
3960		2.35385	3.5977		0.37178	-0.00242	1.217696
4020		2.35385	3.60423		0.37178	-0.00242	1.224229
4040		2.35385	3.61066		0.37178	-0.00242	1.23066
4140		2.3144	3.617		0.36444	-0.00976	1.237
4200		2.32765	3.62325		0.3669	0.0073	1.24325
4260		2.367	3.62941		0.3742	0	1.24941

SUPERIMPOSING OF OUTFLOW CURVES
AT 200 kPa



APPENDIX 5

COMPLETE TEST RESULTS OF CLAY TEST

SAMPLE: CLAY TEST1

DIMENSIONS IN cm AND g

								AVERAGE
DIAMETER		6.41	6.56	6.43	6.49			6.4725
LENGTH		3.06	3.26	3.08	3.05			3.1125
S GRAVITY		2.649946	2.492408	2.704072	2.724195	2.608055	2.472609	2.608448

FINAL VOLUME T	102.4102
VOLUME SOIL	59.92568

BOWL	167.74
WET SOIL & BOWL	365.49
DRY SOIL & BOWL	324.054
WATER CONT.	0.2650835183
VOLM CONT.	0.4046079993

ADJUSTMENT TO VOLUME DUE TO ZEROING DURING TEST

665 0.0192163517

APLLIED PRESSURE kPa	VOLUME volts	VOLUME cm^3		TOTAL VOLUME cm^3	FLOW INTIAL volts	FINAL volts	ACTUAL FLOW cm^3	TOTAL FLOW cm^3
0	664	0.1008049428	0	43.3922133642			0	32.24477
20	393	15.921604543	15.8208	27.571414042	-779	140	12.08521	20.15956
41	136	24.78963028	24.68883	18.703388305	-1722	-965	9.95485	10.20471
63	555	7.7531102526	32.42272	10.969494404	-1473	-1248	2.958839	7.245869
81	509	10.380510857	35.05012	8.3420938	-857	-774	1.091483	6.154386
125	425	14.52093318	39.19054	4.2016714772	-1283	-1061	2.919388	3.234998
160	394	15.879080637	40.54869	2.8435240194	-125	-55	0.920528	2.31447
204	323	18.722604657	43.39221	0	1489	1313	2.31447	0

APPLIED PRESSURE kPa	SUCTION kPa	VOLUMETRIC CONTENT cm^3/cm^3	WATER CONTENT g/g	DEGREE SATURATION	SLOPE	a" VALUE	IRP	PERM cm/s
0		0.5053466094	0.471367	0.8579826385				1.44E-06
20	13	0.4730788816	0.394063	0.8792336031	0.92766	2.2012	354.8134	9.92E-07
41	34	0.4263823230	0.330367	0.8439687433	0.864317	0.59244	338.8442	9.83E-08
63	54	0.4293701277	0.311438	0.9107237562	0.977753	-	-	-
81	68	0.4297009957	0.304456	0.9363275166	0.700395	0.113146	269.1535	3.6E-09
125	102	0.419005713	0.285779	0.9568347079	0.710158	0.123259	245.4709	6.85E-09
160	135	0.4156665807	0.27989	0.9651958585	0.584356	0.034015	199.5262	1.62E-09
204		0.4046079993	0.265084	0.9753192511	0.783254	0.237051	426.5795	2.48E-09

90 CLAY TEST AT APPLIED AIR PRESSURE 20 kPa

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	779	0	ERR	ERR	ERR
1	784	0.056092	0	-1.17085	1.1770449
2	789	0.112101	0.30103	-0.87802	0.89779143
3	792	0.171839	0.477121	-0.76488	-0.73443068
4	-797	0.237931	0.60206	-0.62355	0.61863806
5	801	0.290805	0.69897	-0.5361	0.53??
6	805	0.343678	0.778151	-0.46385	-0.46518531
7	-809	0.396552	0.845098	-0.4017	-0.39308148
8	-814	0.462644	0.90309	-0.33475	-0.33278469
9	-818	0.515518	0.954243	-0.28775	-0.29103356
10	-822	0.568321	1	-0.24535	-0.24930519
11	-826	0.621265	1.041393	-0.20672	-0.21098607
12	830	0.674138	1.079181	-0.17125	-0.17593194
13	-833	0.712791	1.113943	-0.14643	-0.14329154
14	-838	0.779806	1.146128	-0.10797	-0.11302811
15	841	0.819541	1.176091	0.08649	-0.08603244
16	-846	0.885633	1.20412	-0.05279	0.06008132
17	850	0.938606	1.230449	-0.02755	0.03060703
18	-853	0.978162	1.255273	-0.00959	-0.01257919
19	-858	1.044254	1.278754	0.018806	0.009203969
20	-861	1.083909	1.30103	0.034993	0.029860181
40	937	2.088507	1.60206	0.319896	0.30912155
60	-1005	2.987359	1.778151	0.475297	0.4724743
77	-1068	3.820118	1.886491	0.582077	0.572974455
120	-963	5.200868	2.079181	0.716075	0.761727609
180	818	7.107618	2.255273	0.851724	0.915080418
240	-691	8.777660	2.380211	0.943379	1.030801028
300	-580	10.23732	2.477121	1.010186	1.130880543
360	-482	11.52602	2.556303	1.061679	1.194333768
420	-395	12.67007	2.623249	1.102779	1.25643702
480	-321	13.64317	2.681241	1.134916	1.310734408
540	257	14.48477	2.732394	1.160912	1.357686637
600	-203	15.19487	2.778151	1.181697	1.400133913
660	-157	15.79977	2.819544	1.19865	1.438532205
720	[illegible]	15.68142	2.857332	1.196285	1.473687157
780	85	16.73607	2.892095	1.224948	1.505031559
840	53	17.16737	2.924279	1.234704	1.53562099
900	26	17.52242	2.954243	1.243594	1.563486682
960	4	17.81172	2.982271	1.250756	1.589487777
1020	14	18.04842	3.0086	1.256439	1.61391307
1080	30	18.25882	3.033424	1.261473	1.636939906
1140	44	18.44292	3.056905	1.26583	1.65872237
1200	55	18.60072	3.079181	1.26953	1.679397287
1260	67	18.74537	3.100371	1.272894	1.699042739
1320	77	18.87687	3.120574	1.27593	1.717705604
1380	87	19.00837	3.139879	1.278945	1.73559217
1440	97	19.13987	3.158362	1.281939	1.752810596
1500	107	19.27137	3.176091	1.284913	1.769286787
1560	117	19.40287	3.193125	1.287866	1.785087928
1620	126	19.52122	3.209515	1.290507	1.800292655
1680	134	19.62642	3.225309	1.292841	1.81914959
1740	141	19.71847	3.240549	1.294873	1.829091861

Regression Output

Constant		-1.17704
Std Err of Y Est		0.012406
R Squared		0.999257
No. of Observations		24
Degrees of Freedom		22
X Coefficient(s)	0.92166	
Std Err of Coef	0.005394	

OUTFLOW VOLTAGE

INITIAL -779

ENDED 140

VOLUME CHANGE VOLTAGE

VOLUME INITIAL 604 V

VOLUME FINAL 393 V

ALPHA

2.2012 (0.01-0.3)

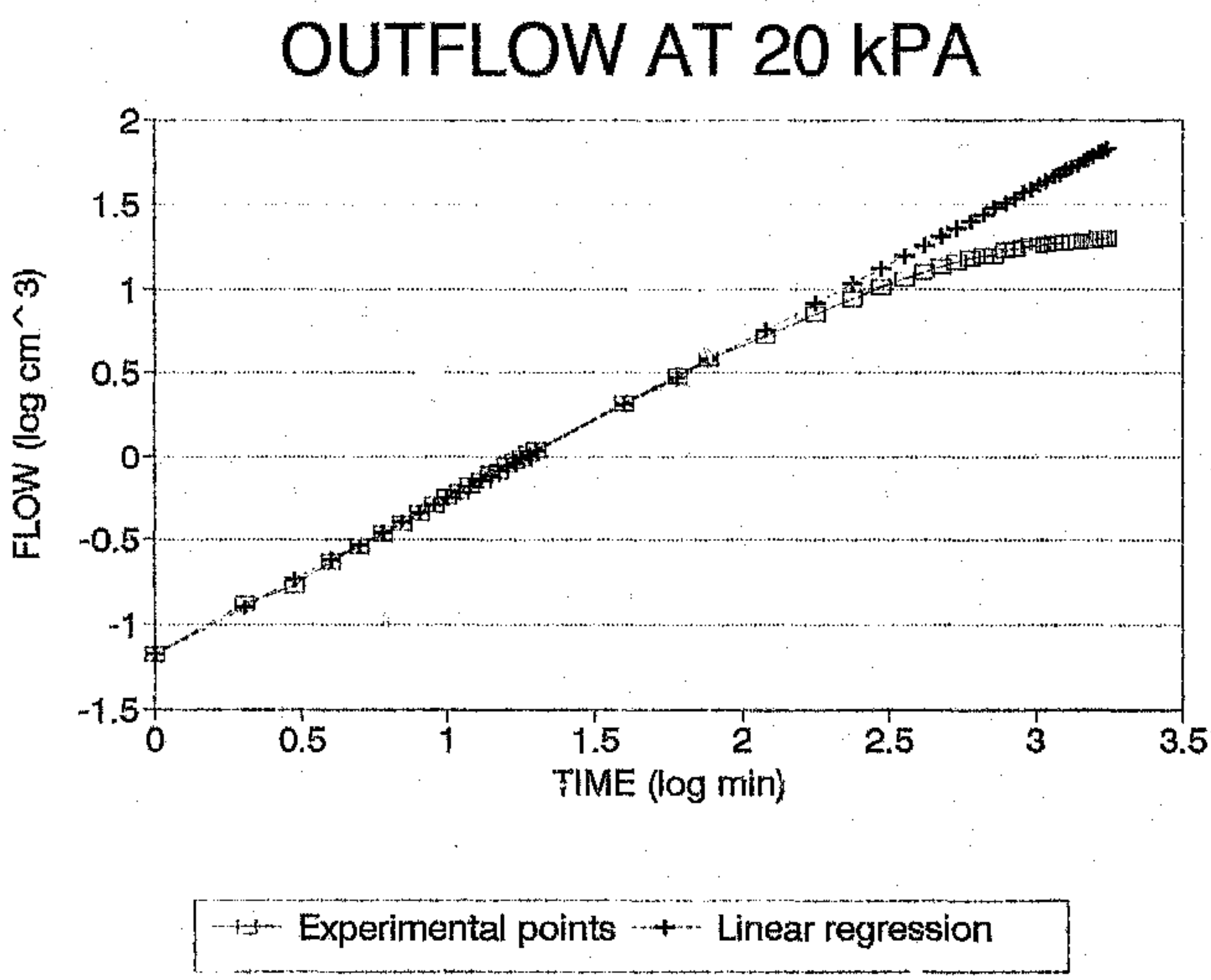
TIME TRP

2.65

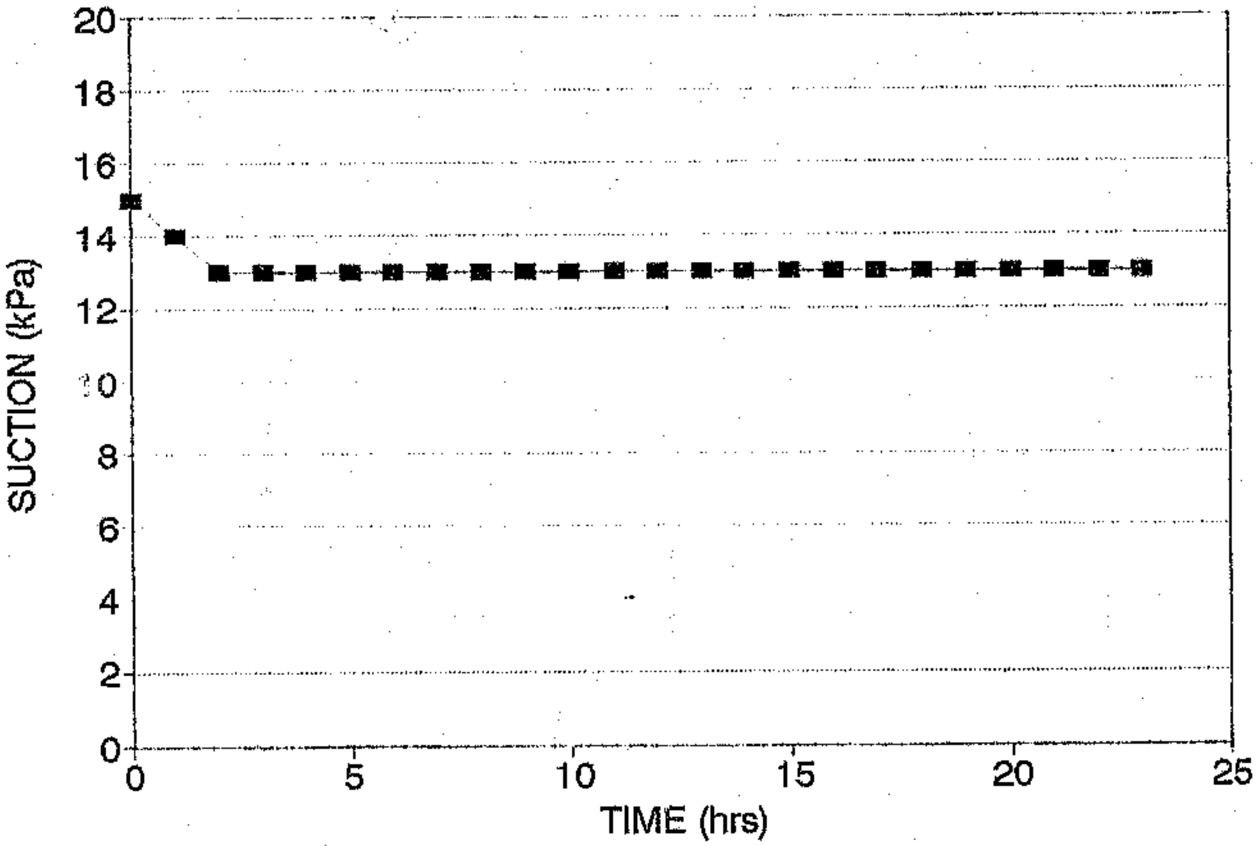
TIME

354.3134

TIME hours	SUCTION volts	SUCTION kPa	SUCTION KPA
0	48	15.4776	150
1	43	14.19164	140
2	40	13.40402	130
3	40	13.40402	130
4	39	13.14482	130
5	40	13.40402	130
6	39	13.14482	130
7	39	13.14482	130
8	39	13.14482	130
9	38	12.88563	130
10	38	12.88563	130
11	38	12.88563	130
12	38	12.88563	130
13	38	12.88563	130
14	39	13.14482	130
15	39	13.14482	130
16	40	13.40402	130
17	38	12.88563	130
18	39	13.14482	130
19	39	13.14482	130
20	39	13.14482	130
21	38	12.88563	130
22	38	12.88563	130
23	38	12.88563	130


OUTFLOW AT 20 kPA
FLOW (log cm ^ 3)
TIME (log min)
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.5
1
1.5
2
2.5
3
3.5
Experimental points
Linear regression

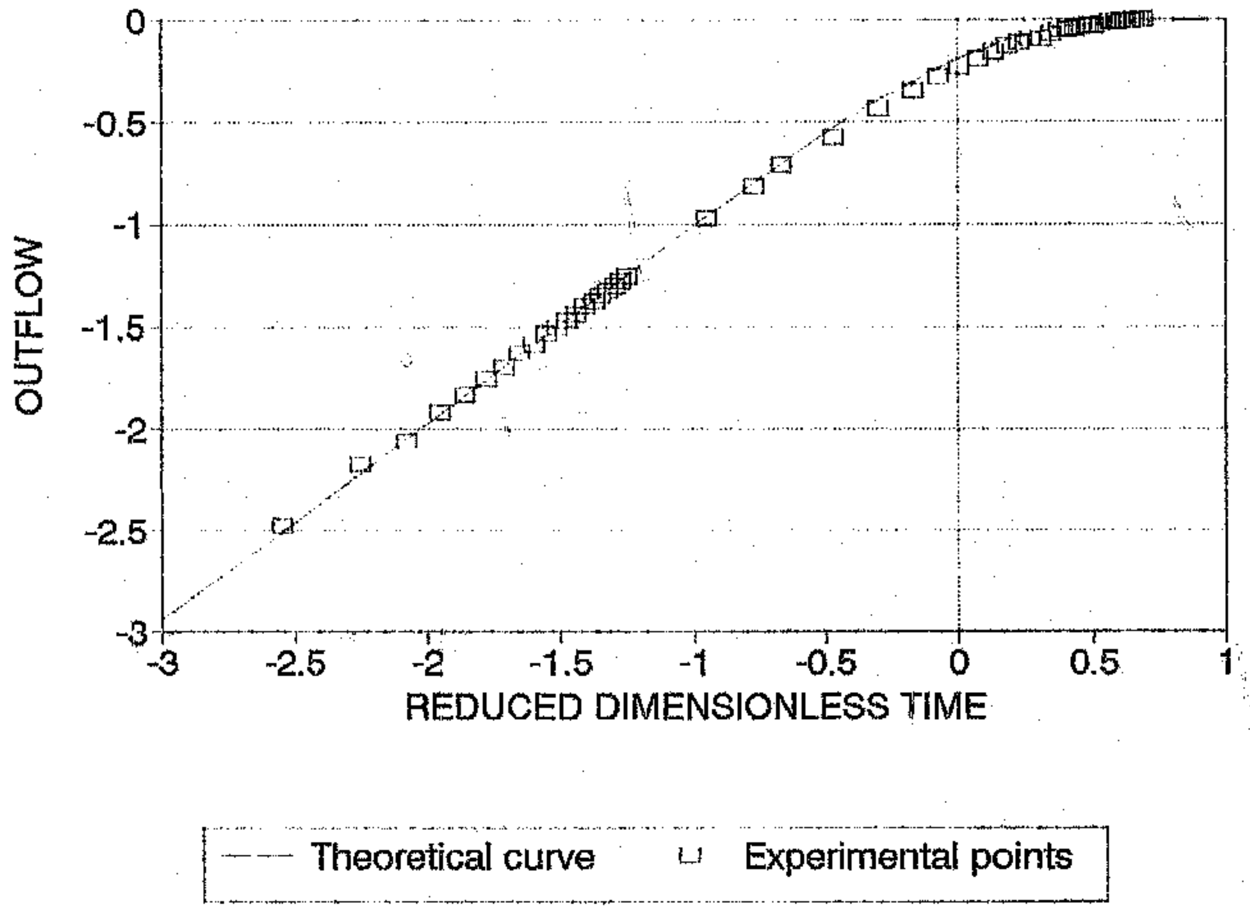
CAPILLARY PRESSURE AT 20 kPa



[illegible] TEST AT APPLIED AIR PRESSURE [illegible]

TIME	THEORETICAL avg d	EXPERIMENTAL d	LOG TIME	LOG avg d	LOG d	ADJUSTED d	ADJUSTED TIME
0.001	[illegible]		-3	-0.041645			-3
0.1	0.09320704067		-1	1.007504			-1
0.2	0.15427984659		-0.69897	-0.234523			-0.69897
0.3	[illegible]		-0.52288	[illegible]			-0.5228787
0.4	[illegible]		-0.39794	[illegible]			-0.39794
0.5	[illegible]		-0.30103	[illegible]			-0.30103
0.6	[illegible]		-0.221849	-0.342095			-0.2218487
0.7	0.50524913091		-0.154902	-0.296434			-0.154902
0.8	[illegible]		-0.09691	-0.257801			-0.09691
0.9	0.59493026852		-0.045757	-0.225592			-0.0457575
1	0.63547957254		0	-0.196907			0
1.1	0.66905050019		0.0413927	-0.17499			0.04139269
1.2	0.69901645952		0.0791812	-0.154892			0.07918125
1.3	0.72947499353		0.1139434	-0.137085			0.11394335
1.4	0.75431401421		0.146128	-0.122440			0.14612804
1.5	0.77709112597		0.1760913	-0.109491			0.17609126
1.6	[illegible]		0.20412	-0.097535			0.20411998
1.7	[illegible]		0.2304489	-0.087063			0.23044892
1.8	0.82553117097		0.2552725	-0.078151			0.25527251
1.9	0.85093391606		0.2787536	-0.070070			0.2787536
2	0.85616407917		0.30103	-0.069901			0.30103
2.1	0.87790595011		0.3222193	-0.056507			0.32221929
2.2	0.88860617651		0.3424227	-0.050102			0.34242268
2.3	0.90041153035		0.3617278	-0.045704			0.36172784
2.4	0.90961717004		0.3802112	-0.041141			0.38021124
2.5	[illegible]		0.39794	[illegible]			0.39794001
2.6	0.92800060313		0.4149733	-0.032399			0.41497335
2.7	0.93204279777		0.4313638	-0.030099			0.43136376
2.8	0.93941450102		0.447158	-0.027143			0.44715803
2.9	0.94518064654		0.462398	-0.024495			0.462398
3	0.95030095496		0.4771213	-0.022095			0.47712125
10	1		1	0			1
1		0.060092	0		-1.179951	-2.4747943	-2.95
2		0.132164	0.30103		-0.876921	-2.1740943	-2.94297
3		[illegible]	0.4771213		[illegible]	-2.0567509	[illegible]
4		0.2373312	0.60206		-0.623649	-1.9184218	-1.99794
5		0.2603048	0.69897		-0.556398	-1.8318716	-1.90103
6		[illegible]	0.7781513		-0.483540	-1.7537709	-1.7218487
7		0.396512	[illegible]		0.4017	1.[illegible]	1.704[illegible]
8		0.402944	[illegible]		0.394703	1.6290[illegible]	[illegible]
9		0.5175178	0.9542425		0.317757	1.5[illegible]	[illegible]
10		0.5083912	1		-0.245353	-1.5402850	-1.55
11		0.6212048	1.0413927		-0.20[illegible]	-1.5015[illegible]	-1.5[illegible]
12		0.6741364	1.0791812		-0.171251	-1.4567241	-1.4708188
13		0.7117930	1.1139434		-0.148427	-1.4418005	-1.3860566
14		0.7703390	1.146128		-0.1[illegible]	-1.4025423	-1.403872
15		0.6105493	1.1760913		-0.036420	-1.3013020	-1.3739087
16		0.6260320	1.20412		-0.052740	-1.3470195	-1.34588
17		0.9105054	1.2304489		0.027552	1.[illegible]	1.2190511
18		0.9701050	1.2552725		-0.00[illegible]	1.3044000	1.2947275
19		1.0440530	1.2787536		0.018600	-1.2760072	-1.2712464
20		1.0939023	1.30103		0.0340927	-1.2099394	-1.24897
40		2.0835072	1.60206		0.319835	-0.5750379	-0.44794
60		2.9873594	1.7781513		0.4752073	-0.0195[illegible]	-0.7718487
77		3.8901176	1.8864907		0.5890767	-0.7127904	0.66[illegible]
120		5.2008076	2.0791812		0.7160758	0.5727974	0.4708193
180		7.1976176	2.2552725		0.8517241	0.4431401	0.2942276
240		[illegible]	2.3802112		0.9433794	0.351494	0.1697836
300		10.2375176	2.4771213		1.0101052	0.284607	0.0720787
330		11.9250176	2.5797025		1.0640793	0.2231909	0.6063065
420		12.6708676	2.6232493		1.1027291	0.1920042	[illegible]
450		13.0431676	2.6532125		1.1340152	0.1502670	0.13194124
540		13.4817070	2.7323938		1.1000115	-0.1373616	0.122[illegible]
600		15.1949070	2.7781513		1.1010075	0.1151282	0.22815183
650		15.7997676	2.8129133		1.1956007	0.0162295	0.25954394
720		15.6214176	[illegible]		1.1073543	-0.0011079	[illegible]
780		16.7380176	2.8920946		1.2240477	0.0680255	0.3430446
800		17.1073676	2.9030900		1.2342037	0.0001085	0.37427023
900		17.5224176	2.9542425		1.243594	-0.0512781	0.40424251
960		17.9111178	2.9822712		1.2507458	-0.0441674	0.43227121
1020		18.0484176	3.0086002		1.2564641	-0.033942	0.45860017
1080		18.2598176	3.0334238		1.2614727	-0.0334005	0.48342376
1140		18.4489176	3.0569049		1.2659246	0.0287436	0.50690485
1200		18.6807176	3.0791812		1.2695297	0.0253495	0.52918125
1260		18.7453670	3.1003705		1.272894	-0.0210792	0.55037055
1320		18.9760676	3.1205739		1.2750239	-0.0109432	0.57057393
1380		19.0002676	3.1398791		1.2709445	-0.0150503	0.58987913
1440		19.1399076	3.1583625		1.2819309	-0.0129342	0.60836249
1500		19.2713676	3.1760913		1.2849185	-0.0099506	0.62609126
1560		19.4023076	3.1931246		1.2878000	-0.0070073	0.6431246
1620		19.5212176	3.209515		1.2905069	-0.0043083	0.65951501
1680		19.6804176	3.2253093		1.292341	-0.0020321	0.67530929
1740		19.7831676	3.2405492		1.2943735	0	0.69054925

SUPERIMPOSING OF OUTFLOW CURVES



41 CLAY TEST AT APPLIED AIR PRESSURE 41 kPa

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1722	0	ERR	ERR	ERR
1	1719	0.0526	0	-1.27001	1.30337571
2	-1716	0.09205	0.30103	-1.03598	-1.0431904
	-1713	0.11925	0.477121	-0.92683	0.89099176
4	1710	0.1578	0.60206	-0.80189	0.7830051
5	1706	0.2104	0.69897	0.67595	0.69724414
6	-1704	0.2367	0.778151	-0.6250	-0.63080645
7	-1702	0.263	0.845098	-0.58004	-0.57294321
8	-1700	0.2893	[illegible]90309	-0.53865	-0.52281979
9	-1697	0.32075	[illegible]4243	-0.49313	-0.4706078
10	-1695	0.36505	1	-0.44971	-0.43905883
11	-1692	0.3945	1.041393	-0.40395	-0.40329244
12	-1690	0.4208	1.079181	-0.37592	-0.37062114
13	-1687	0.46095	1.113943	-0.29701	-0.31057567
14	1685	0.48655	1.146128	0.31287	0.31227579
15	1682	0.526	1.176091	-0.27901	-0.28616018
16	-1680	0.5523	1.20412	-0.25782	-0.20263449
17	1678	0.5780	1.230449	-0.23762	0.23987794
18	-1676	0.6049	1.255273	-0.21832	-0.2184225
19	-1673	0.64435	1.278754	-0.19088	-0.19812739
20	-1671	0.67065	1.30103	-0.1735	-0.17887353
40	1628	1.2361	1.60206	0.092054	0.07101178
60	-1589	1.74895	1.778151	0.242777	0.233510428
120	-1491	3.03765	2.079181	0.482538	0.493695734
180	-1412	4.0765	2.255273	0.610287	0.64689381
240	1343	4.98386	2.380211	0.697565	0.76328104
300	-1287	5.72025	2.477121	0.757415	0.857642
360	-1237	6.37775	2.556303	0.804667	0.906079588
420	-1197	6.90375	2.623249	0.839085	0.953942928
480	-1163	7.35085	2.681241	0.866308	1.014060047
540	-1135	7.71905	2.732394	0.887564	1.06827895
600	-1112	8.0215	2.778151	0.904266	1.097827307
660	1094	8.2582	2.819544	0.916885	1.132603703
720	1077	8.48175	2.857332	0.928465	1.166264004
780	-1064	8.6527	2.892095	0.937162	1.196310469
840	-1052	8.8105	2.924279	0.945001	1.22412834
900	-1043	8.92885	2.954243	0.950796	1.250026954
960	-1036	9.0209	3.982271	0.95526	1.274251063
1020	-1028	9.1261	3.0086	0.960295	1.297008199
1080	1021	9.21815	3.033424	0.964641	1.318463541
1140	-1016	9.2839	3.056905	0.96773	1.338758749
1200	-1013	9.32395	3.079181	0.969672	1.358012613
1260	-1010	9.3629	3.100371	0.971406	1.376326892
1320	-1007	9.40225	3.120574	0.973232	1.393789009
1380	-1003	9.45485	3.139879	0.975655	1.410474781
1440	-998	9.5206	3.158362	0.978664	1.4264503
1500	-995	9.5469	3.176091	0.979862	1.441773573
1560	-989	9.63095	3.193125	0.98403	1.456495776
1620	-984	9.7047	3.209515	0.986982	1.470662289
1680	-980	9.7573	3.225309	0.98933	1.484312541
1740	-976	9.8099	3.240549	0.991665	1.497485701
1800	-971	9.87565	3.255273	0.994566	1.51021126
1860	-968	9.9151	3.269513	0.996297	1.52251951
1920	-966	9.95465	3.283301	0.998022	1.534436959
1980	-964	9.9677	3.296665	0.998595	1.545987657
2040	964	9.9677	3.30963	0.998595	1.557193505
2100	-964	9.9677	3.322219	0.998595	1.5680745
2160	-964	9.9677	3.334454	0.998595	1.578648948

Regression Output

Constant		-1.30338
Std Err of Y Est		0.01242
R Squared		0.9999
No. of Observations		23
Degrees of Freedom		21
X Coefficient(s)	0.864317	
Std Err of Coef.	0.006258	

OUTFLOW

INITIAL -1722

ENDED -965

VOLUME CHANGE VOLTAGE

VOLUME INITIAL 392 V

VOLUME FINAL 136 V

ALPHA

0.69244 (0.01-0.3)

TIME TEP

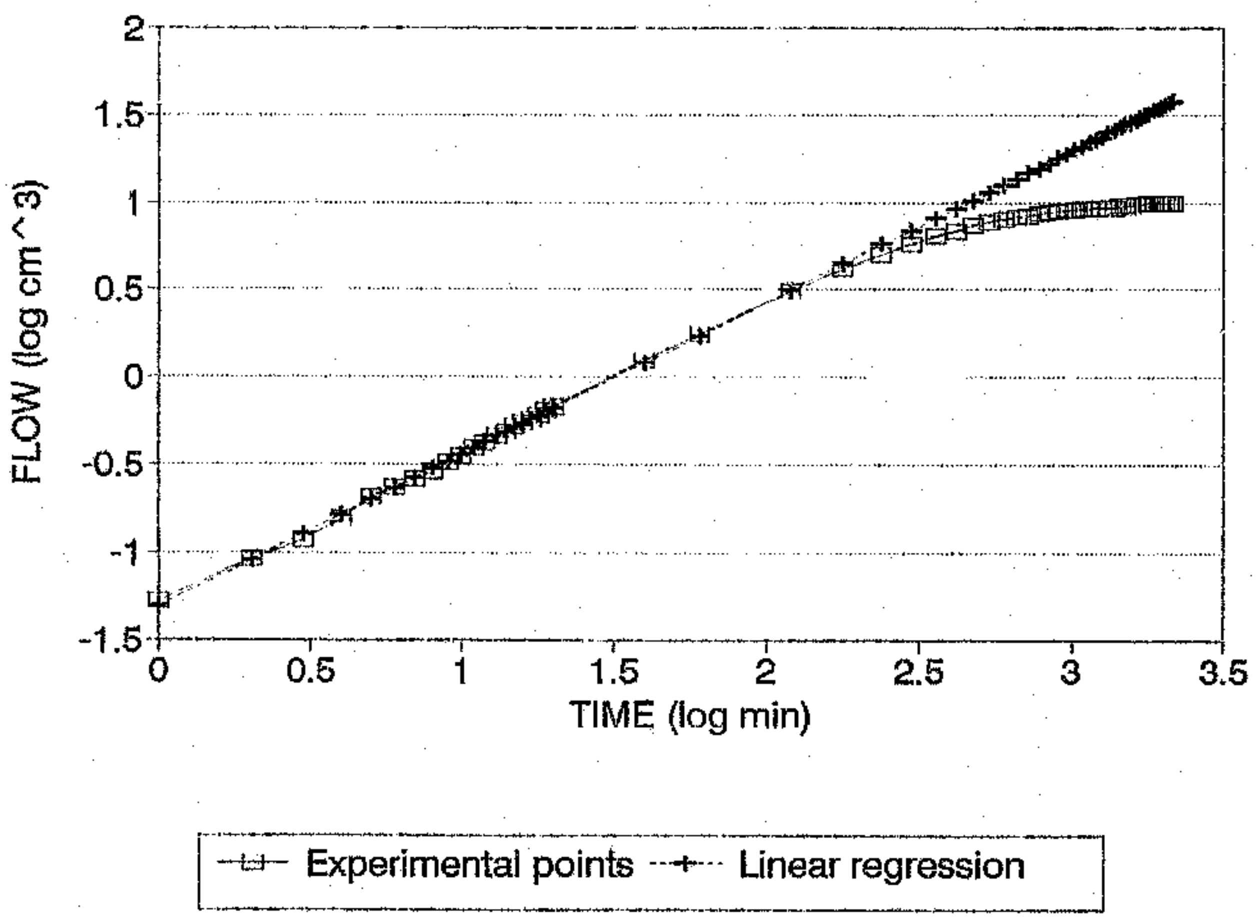
2.53

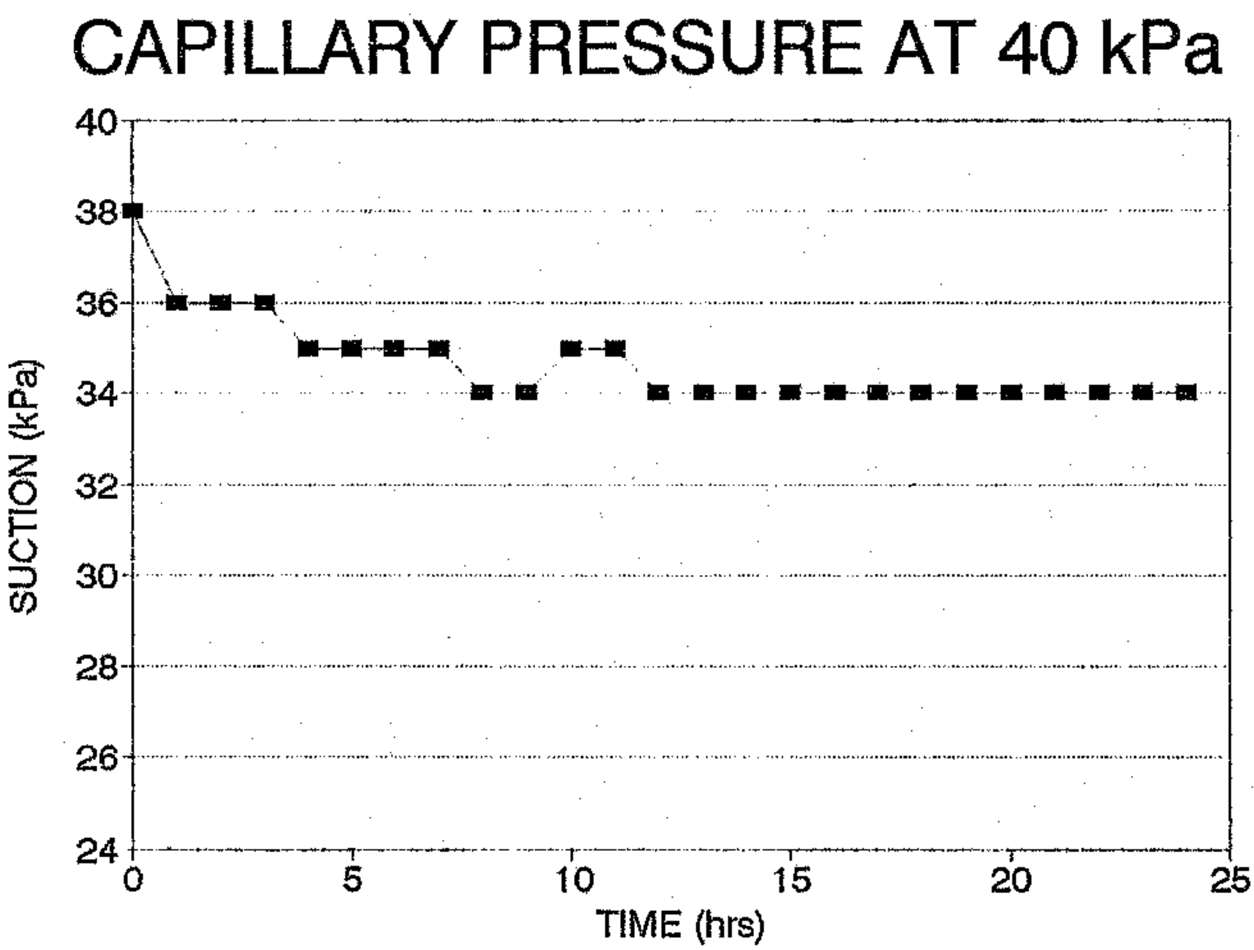
TIME

338.8449

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	136	33.48117	38.0
1	127	36.14839	36.0
2	126	35.88919	36.0
3	125	35.63	36.0
4	124	35.3708	35.0
5	122	34.85241	35.0
6	121	34.69321	35.0
7	121	34.69321	35.0
8	119	34.07481	34.0
9	120	34.33401	34.0
10	121	34.69321	35.0
11	121	34.69321	35.0
12	118	33.81562	34.0
13	117	33.55612	34.0
14	118	33.81562	34.0
15	118	33.81562	34.0
16	118	33.81562	34.0
17	119	34.07481	34.0
18	120	34.33401	34.0
19	119	34.07481	34.0
20	117	33.55642	34.0
21	118	33.81562	34.0
22	119	34.07481	34.0
23	119	34.07481	34.0
24	118	33.81562	34.0

OUTFLOW AT 40 kPa

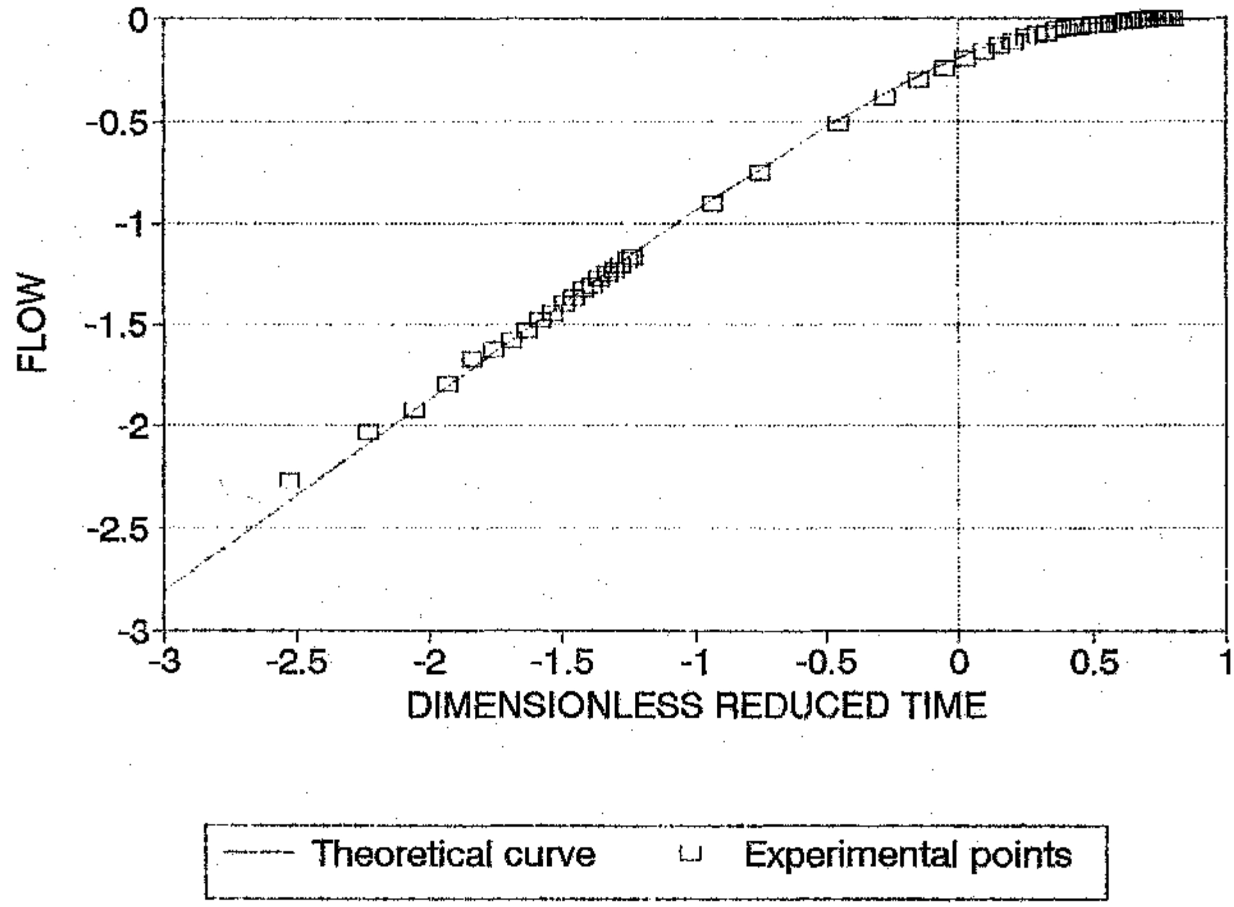



CAPILLARY PRESSURE AT 40 kPa
SUCTION (kPa)
TIME (hrs)
40
38
36
34
32
30
28
26
24
0
5
10
15
20
25

[illegible] TEST AT APPLIED AIR PRESSURE [illegible] MPa

TIME	THEORETICAL Qt/Q∞	EXPERIMENTAL Qt	LOG TIME	LOG Qt/Q∞	LOG Qt	ADJUSTED Qt	ADJUSTED TIME
0.001	0.0016466474		-3	-2.81039			-3
0.1	0.114226103		-1	-0.94096			-1
0.2	0.2031559681		-0.69897	-0.69217			-0.69897
0.3	0.2500488715		-0.52288	-0.56231			-0.522879
0.4	0.3492273256		-0.39794	-0.45692			-0.39794
0.5	[illegible]		[illegible]	[illegible]			[illegible]
0.6	0.4073[illegible]		-0.22185	-0.33937			-0.221849
0.7	0.5160340087		-0.1549	-0.29604			-0.154902
0.8	[illegible]		[illegible]	[illegible]			[illegible]
0.9	[illegible]		-0.04576	-0.21796			-0.045757
1	0.6429541395		0	-0.19185			0
1.1	0.6769312551		0.041393	-0.16946			0.0413927
1.2	[illegible]		0.079181	-0.15037			0.0791812
1.3	0.7354945[illegible]		0.113943	-0.13342			0.1139434
1.4	[illegible]		0.146128	[illegible]			[illegible]
1.5	0.7734400751		0.176091	-0.10693			0.1760913
1.6	0.8040192934		0.20412	-0.09479			0.20412
1.7	0.825096465		0.230449	-0.08476			0.2304489
1.8	[illegible]		0.255273	-0.07594			0.2552725
1.9	0.8548361452		0.278754	-0.06812			0.2787536
2	0.8826580167		0.30103	-0.06410			0.30103
2.1	0.8811480003		0.322219	-0.05495			0.3222193
2.2	0.89245937		0.342423	-0.04941			0.3424227
2.3	0.9025937580		0.361728	-0.04448			0.3617278
2.4	0.9119935792		0.380211	-0.04005			0.3802112
2.5	[illegible]		0.39794	[illegible]			0.39794
2.6	0.9279137691		0.414973	-0.03249			0.4149733
2.7	0.9347730746		0.431364	-0.02929			0.4313638
2.8	[illegible]		0.447158	[illegible]			0.447158
2.9	0.9458972015		0.462398	-0.02383			0.462398
3	[illegible]		0.477121	-0.02151			0.4771213
10	1		1	0			1
1		0.0526	0		-1.27901	-2.277609	-0.53
2		0.08805	0.30103		-1.05530	-2.051521	-2.08307
3		0.11635	0.477121		-0.93633	-1.925497	-2.050879
4		[illegible]	0.60206		[illegible]	[illegible]	1.95764
5		0.2104	0.69897		0.67695	-1.675949	1.03164
6		[illegible]	0.778151		0.3021	-1.624397	-1.751849
7		[illegible]	0.845098		0.55094	1.570059	-1.694005
8		0.2897	0.90309		-0.5[illegible]	1.537247	1.62601
9		0.32575	0.954243		-0.48715	-1.481728	-1.555757
10		0.35505	1		-0.44971	-1.449405	1.54
11		0.3945	1.041393		-0.40395	-1.402542	1.402507
12		0.4208	1.079181		-0.37602	-1.374510	-1.193015
13		0.46026	1.113943		-0.33701	-1.335691	-1.410057
14		0.49055	1.146128		-0.31287	-1.311467	-1.383572
15		0.598	1.176091		-0.27501	-1.272643	-1.355908
16		0.5523	1.20412		-0.25792	-1.25642	-1.32553
17		0.5705	1.230449		-0.23782	-1.236217	-1.296394
18		0.6049	1.255273		-0.21832	-1.216911	-1.274727
19		0.64435	1.278754		-0.19085	-1.189473	-1.251246
20		0.67085	1.30103		-0.1735	-1.172099	-1.22397
40		1.2301	1.60206		0.092054	-0.905541	-0.95794
60		1.74385	1.778151		0.2415777	-0.755676	-0.761849
120		3.03705	2.079181		[illegible]02639	-0.616097	-0.450819
180		4.0755	2.255273		0.610297	-0.392300	-0.274727
240		4.09358	2.380211		[illegible]	-0.50405	-0.149789
300		6.72825	2.477121		0.757415	-0.24118	-0.052879
360		6.37776	2.556303		0.904687	-0.193027	0.0263025
420		8.90375	2.623249		0.939085	-0.15451	0.0932495
480		7.35865	2.681241		0.866339	0.138957	0.1510412
540		7.21005	[illegible]		[illegible]	-0.111031	0.2022345
600		[illegible]	2.778151		0.914056	0.0941[illegible]	0.2481815
660		[illegible]	2.819544		0.816605	-0.08871	0.2895438
720		8.48175	2.857332		0.929405	0.070309	0.3273325
780		8.6527	2.892095		0.937152	-0.061443	0.3620940
840		8.8105	2.924279		0.945001	0.052534	0.3942792
900		8.92965	2.954243		0.950706	-0.047799	0.4242425
960		9.0209	2.982271		0.95525	0.043345	0.4522712
1020		9.1861	3.0086		0.960205	0.03831	0.4785002
1080		9.21815	3.033424		0.964644	-0.033991	0.5034238
1140		9.2351	3.056905		0.96773	-0.030365	0.5269910
1200		9.32335	3.079181		0.969572	-0.029023	0.5491812
1260		9.3620	3.100371		0.971405	-0.027160	0.5703705
1320		9.40225	3.120574		0.973232	-0.025503	0.5905739
1380		9.49455	3.139879		0.976543	-0.02294	0.6098791
1440		9.5200	3.158362		0.978504	0.01963	0.6283625
1500		9.5469	3.176091		0.979882	-0.016733	0.6460913
1560		9.63395	3.193125		0.98403	-0.014605	0.6631246
1620		9.7047	3.209515		0.986922	-0.011013	0.679515
1680		9.7573	3.225309		0.98933	-0.009205	0.6953093
1740		9.8099	3.240549		0.991669	-0.00695	0.7105494
1800		9.87565	3.255273		0.994568	-0.004129	0.7252725
1860		9.9151	3.269513		0.996297	-0.002[illegible]	0.7395126
1920		9.95455	3.283301		0.998022	-0.000573	0.7533017
1980		9.9672	3.296665		0.998595	0	0.7666662
2040		9.9672	3.30963		0.998595	0	0.7796312
2100		9.9677	3.322219		0.998595	0	0.7922193
2160		9.9677	3.334454		0.998595	0	0.8044542

SUPERIMOPSING OF OUTFLOW CURVES



63 CLAY TEST AT APPLIED AIR PRESSURE 63 kPa

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	1473	0	ERR	ERR	ERR
1	-1472	0.01315	0	-1.88107	-1.8831103
2	-1471	0.0263	0.30103	-1.58004	-1.5837772
3	-1470	0.03945	0.477121	-1.40395	-1.3958035
7	-1466	0.09205	0.845098	-1.03599	-1.036813
[illegible]	-1465	0.1052	0.90309	-0.97799	-0.9801119
9	-1464	0.11835	0.954243	-0.92685	-0.9290906
10	-1463	0.1315	1	-0.88107	-0.8853571
11	-1462	0.14465	1.041393	-0.83963	-0.844055
12	-1461	0.1578	1.079181	-0.80188	-0.8070324
13	-1460	0.17095	1.113943	-0.76712	-0.7729459
14	-1459	0.1841	1.146128	-0.73495	-0.7404799
16	-1457	0.2104	1.20412	-0.67695	-0.6852788
17	1456	0.22355	1.230449	-0.65063	-0.6590349
18	-1454	0.24985	1.255273	-0.60232	-0.6357626
20	-1453	0.263	1.30103	-0.58001	-0.5910217
40	-1435	0.4997	1.60206	-0.30129	-0.296091
60	-1423	0.6575	1.778151	-0.1821	-0.1245172
120	1389	1.1046	2.079181	0.043205	0.1609159
180	-1362	1.45995	2.255273	0.164240	0.34195909
240	1341	1.7358	2.380211	0.2395	0.45414204
300	-1323	1.9725	2.477121	0.295017	0.55598291
360	-1309	2.1566	2.556303	0.33377	0.63832293
420	-1297	2.3144	2.623249	0.364432	0.70175087
480	-1289	2.4196	2.681241	0.383744	0.75246108
540	-1284	2.48535	2.732394	0.395389	0.80249649
600	-1279	2.5511	2.778151	0.406727	0.85323595
660	-1275	2.6037	2.819544	0.415591	0.89370778
720	-1270	2.66945	2.857332	0.426420	0.93065587
780	-1267	2.7089	2.892095	0.432793	0.96464443
840	-1265	2.7352	2.924279	0.436939	0.9961131
900	-1263	2.7615	2.954243	0.441145	1.02540974
960	-1261	2.7878	2.982271	0.445262	1.05281491
1020	-1260	2.80095	3.0086	0.447305	[illegible]
1080	1260	2.8141	[illegible]	[illegible]	1.10292040
1140	1259	[illegible]	[illegible]	[illegible]	[illegible]
1200	1259	2.8141	[illegible]	0.44934	[illegible]
1260	1259	2.8141	3.100371	0.44934	1.16820089
1150	1259	2.8141	3.120574	0.44934	1.18804092
1380	-1259	2.8141	3.139879	0.44934	1.20691849
1440	-1259	2.8141	3.158362	0.44934	1.2249xxx
1500	-1260	2.85755	3.176091	0.455305	1.24232406
1560	-1255	2.8667	3.193125	0.457332	1.25697740
1620	-1252	2.90615	3.209515	0.463313	1.27500321
1680	-1250	2.93245	3.225309	0.467231	1.29044614
1740	-1248	2.95875	3.240549	0.471109	1.30534707
1800	-1248	2.95875	3.255273	0.471109	1.31974079
1850	-1248	2.95875	3.269513	0.471109	1.33366541
1920	1248	2.95875	3.283301	0.471109	1.34714795
1980	-1250	2.93245	3.296665	0.467231	1.36021461
2040	-1253	2.893	3.30963	0.461348	1.37289115
2100	-1255	2.8667	3.322219	0.457392	1.38520021
2160	-1258	2.82725	3.334454	0.451364	1.39716849
2220	-1260	2.80095	3.346353	0.447305	1.409797
2280	-1262	2.77465	3.357935	0.443200	1.42012121
2340	-1264	2.74835	3.369216	0.439078	1.43115136
2400	-1265	2.7352	3.380211	0.436939	[illegible]
2460	-1267	2.7089	3.390935	0.432793	1.45239742
2520	-1269	[illegible]	3.401401	[illegible]	[illegible]
2580	-1269	2.69575	3.41162	0.43069	1.47261175
2640	[illegible]	2.61515	3.421604	0.422129	1.48237295
2700	-1271	2.61685	3.431364	0.417729	1.49191657
2760	-1275	2.59055	3.440909	0.413392	[illegible]
2820	-1279	[illegible]	3.450249	[illegible]	[illegible]
2880	-1280	2.53795	3.459392	0.404483	1.51932174
2940	-1281	2.5248	3.468347	0.402227	1.52807737
3000	1281	2.5248	3.477121	0.402227	[illegible]
3060	-1279	2.5511	3.485721	0.406727	1.54506494
3120	-1276	[illegible]	3.494155	[illegible]	[illegible]
3180	-1275	2.60455	3.502427	[illegible]	1.56135999
3040	-1277	2.5774	3.510545	0.411182	1.56923020
3300	-1276	[illegible]	3.518514	[illegible]	1.57712705
3360	-1276	2.59055	3.526339	0.413392	[illegible]
3420	-1277	2.5774	3.534026	0.411182	1.592235
3480	-1278	2.56425	3.541579	[illegible]	[illegible]
3540	-1280	2.53795	3.549003	0.404483	1.60693290
3600	1281	2.5248	3.556303	0.402227	1.61407501
3660	-1282	2.51165	3.563481	0.399959	1.6210947
3720	-1284	2.48535	3.570543	0.395389	1.62799945
3780	1285	2.4722	3.577492	0.393087	1.63479372
3840	1286	2.45905	3.584331	0.390767	1.64147009
3900	-1288	[illegible]	3.591065	[illegible]	[illegible]
3960	-1293	2.42275	3.597695	[illegible]	1.65454764
4020	1290	[illegible]	3.604226	[illegible]	[illegible]
4080	1291	[illegible]	[illegible]	[illegible]	1.66725415
4140	1294	2.35395	3.617	0.371770	1.67342339
4200	1296	[illegible]	3.623249	0.369346	1.67953325
4260	-1297	2.3144	3.62941	0.364439	1.68556651
4320	1298	[illegible]	[illegible]	[illegible]	[illegible]

Regression Output

Constant	-1.88317
Std Err of Y Est	0.019057
R Squared	0.999133
No. of Observations	17
Degrees of Freedom	15
X Coefficient(s)	[illegible]
Std Err of Coef	[illegible]

OUTFLOW

INITIAL 1473

ENDED [illegible]

VOLUME CHANGE VOLTAGE

VOLUME INITIAL -565 V

VOLUME FINAL -565 V

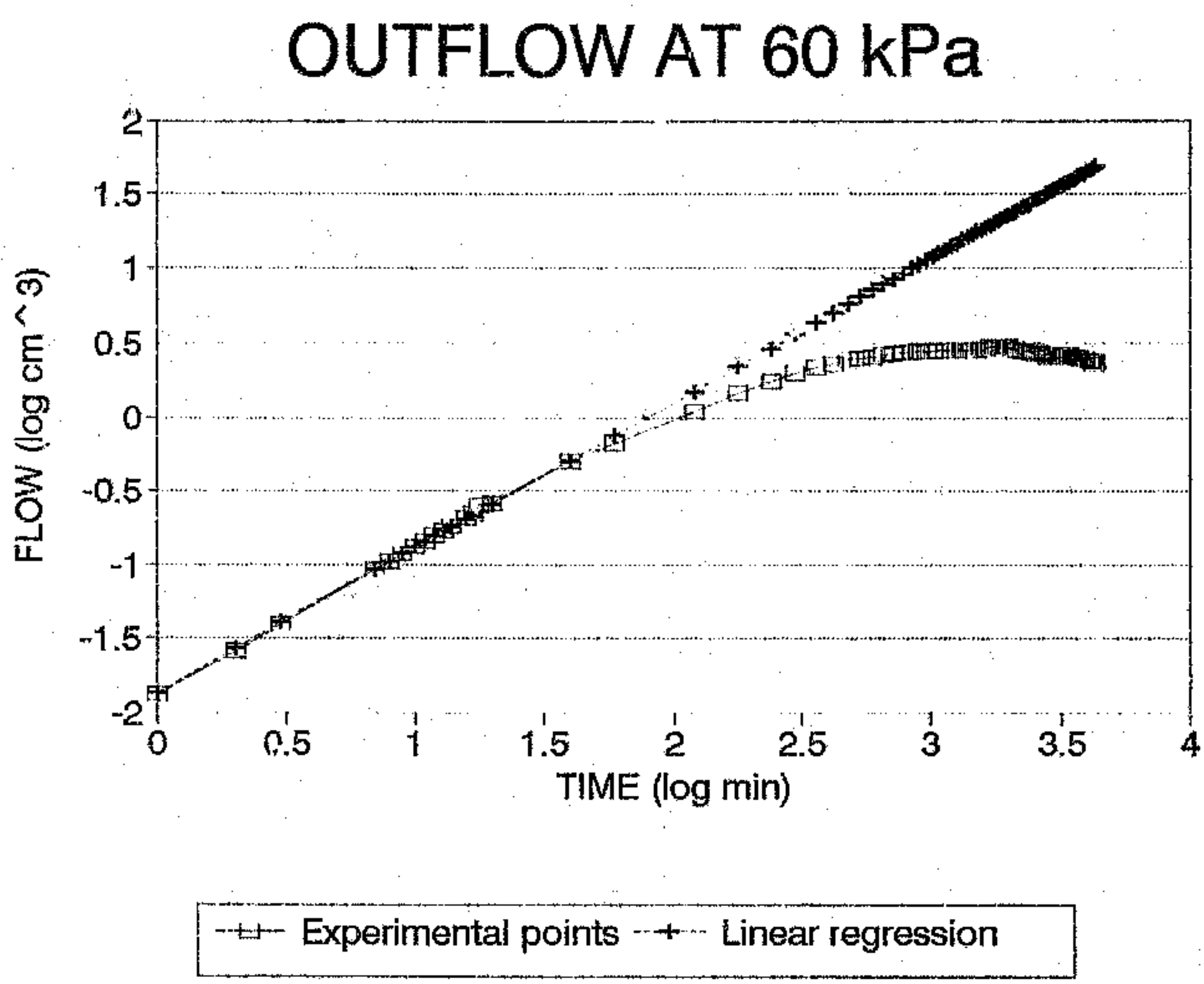
ALPHA

NOT AVAILABLE

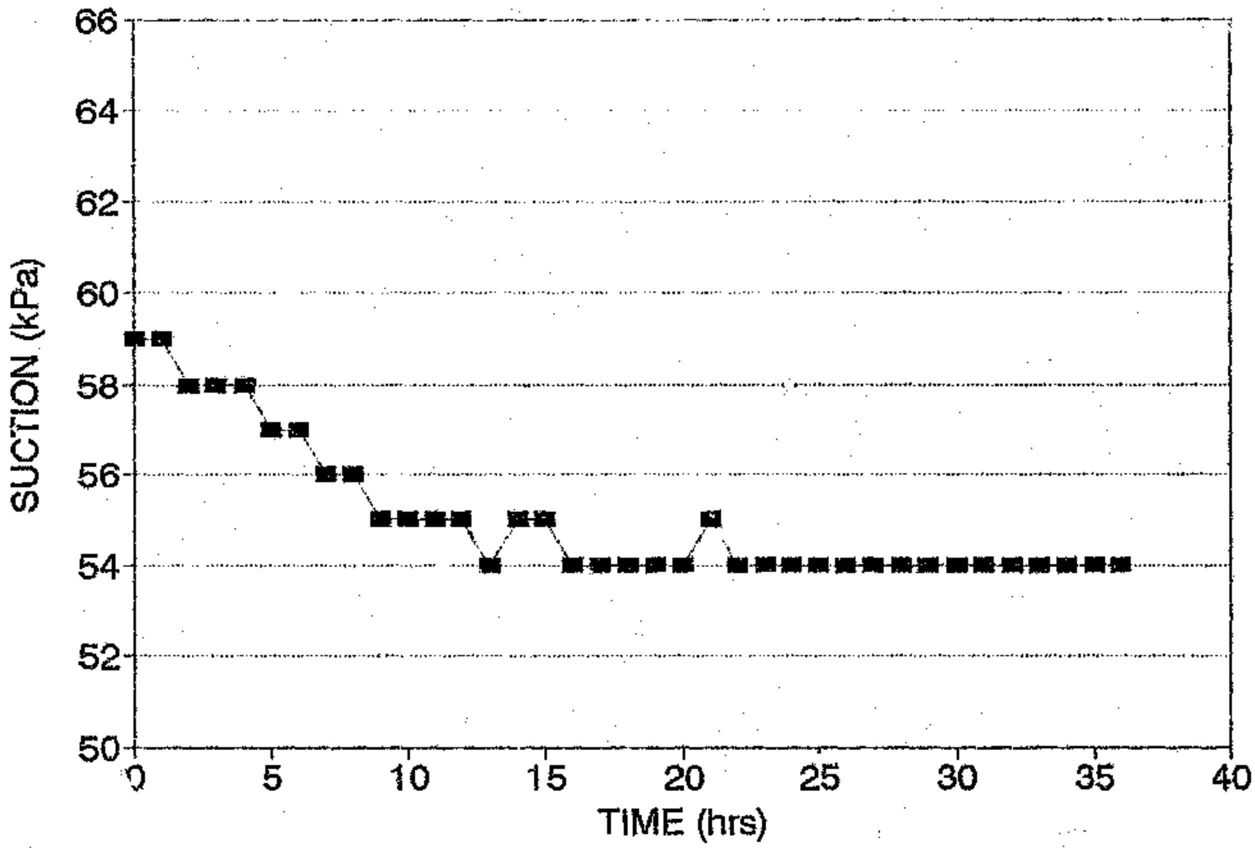
TIME TO

TIME

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	216	59.4294	59.0
1	215	59.10121	59.0
2	212	58.30362	58.0
3	210	57.88922	58.0
4	209	57.60602	58.0
5	[illegible]	[illegible]	57.0
6	207	57.08703	57.0
7	204	56.31084	56.0
8	201	55.31904	55.0
9	199	55.01405	55.0
10	197	54.75405	55.0
11	[illegible]	54.75405	55.0
12	[illegible]	54.75405	55.0
13	197	54.49560	54.0
14	193	54.75405	55.0
15	198	54.75165	55.0
16	195	53.97726	54.0
17	194	53.71600	54.0
18	195	53.97726	54.0
19	195	53.97726	54.0
20	196	54.23846	54.0
21	193	54.75405	55.0
22	194	53.71606	54.0
23	195	53.97726	54.0
24	195	53.97726	54.0
25	195	53.97726	54.0
26	195	53.97726	54.0
27	194	53.71606	54.0
28	191	53.71606	54.0
29	196	54.23846	54.0
30	194	53.71606	54.0
31	196	54.23846	54.0
32	195	53.97726	54.0
33	194	53.71606	54.0
34	194	53.71606	54.0
35	194	53.71606	54.0
36	195	53.97726	54.0


OUTFLOW AT 60 kPa
FLOW (log cm^3)
TIME (log min)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5
2
2.5
3
3.5
4
Experimental points
Linear regression

CAPILLARY PRESSURE AT 60 kPa



81 CLAY TEST AT APPLIED AIR PRESSURE 81 kPa

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-857	0	ERR	ERR	ERR
1	856	0.01316	0	-1.88107	1.79017415
3	-854	0.03946	0.477121	-1.40395	-1.4560007
5	[illegible]	0.0526	0.69897	-1.27901	-1.30061809
8	-852	0.06575	0.90309	-1.1821	-1.15765493
9	851	0.0789	0.954243	[illegible]	[illegible]
12	850	0.09205	1.079181	-1.03598	-1.03435076
14	-849	0.1052	1.146128	[illegible]	-0.98713164
16	848	0.1183	1.20412	[illegible]	[illegible]
17	847	0.1315	1.230449	[illegible]	[illegible]
40	840	0.22255	1.60206	-0.65263	0.66807897
60	835	0.2893	1.778151	-0.53865	-0.54476549
120	-824	0.43395	2.079181	-0.36256	-0.33352661
180	-815	0.5523	2.255273	-0.25782	-0.21059503
240	-808	0.64435	2.380211	-0.19088	-0.12308654
300	-803	0.7101	2.477121	-0.14868	-0.05521022
360	-798	0.77585	2.556303	-0.11022	0.00024/544
420	795	0.8153	2.623249	0.08863	0.047137106
480	-792	0.85476	2.681241	0.06816	0.08775444
540	-792	0.85476	2.732394	-0.06816	0.123581423
600	-791	0.8679	2.778151	-0.06153	0.155629751
660	790	0.88105	2.819544	0.055	0.184620981
720	-789	0.8942	2.857332	-0.04857	0.211087919
780	-786	0.93365	2.892095	-0.02982	0.235435133
840	-784	0.95995	2.924279	-0.01776	0.257977132
900	782	0.98625	2.954243	0.00601	0.2789[illegible]
960	780	1.01255	2.982271	0.005416	0.298[illegible]
1020	778	1.03885	3.0086	0.016653	0.3170[illegible]
1080	777	1.052	3.033424	0.022016	0.3314[illegible]
1140	-777	1.052	3.056905	0.022016	0.3508[illegible]
1200	-777	1.052	3.079181	0.022016	0.36[illegible]
1260	776	1.06515	3.100371	0.027411	0.381310611
1320	774	1.09145	3.120574	0.038004	0.3954[illegible]

Regression Output

Constant		-1.79017
Std Err of Y Est		0.041026
R Squared		0.992193
No. of Observations		13
Degrees of Freedom		11
X Coefficient(s)	0.70009	
Std Err of Coef	0.018805	

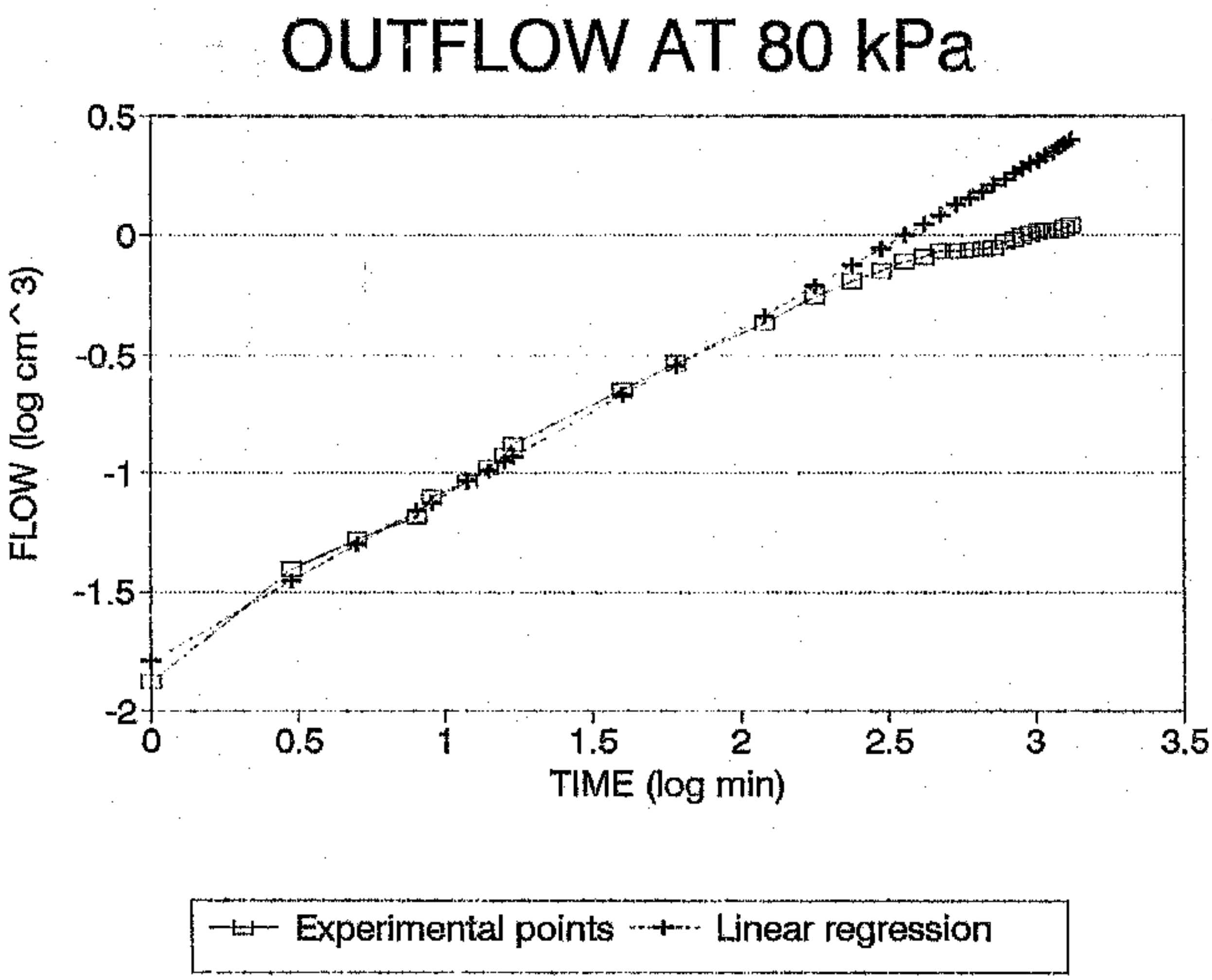
OUTFLOW
INITIAL 857
ENDED -774

VOLUME CHANGE VOLTAGE
VOLUME INITIAL -553 V
VOLUME FINAL -5[illegible] V

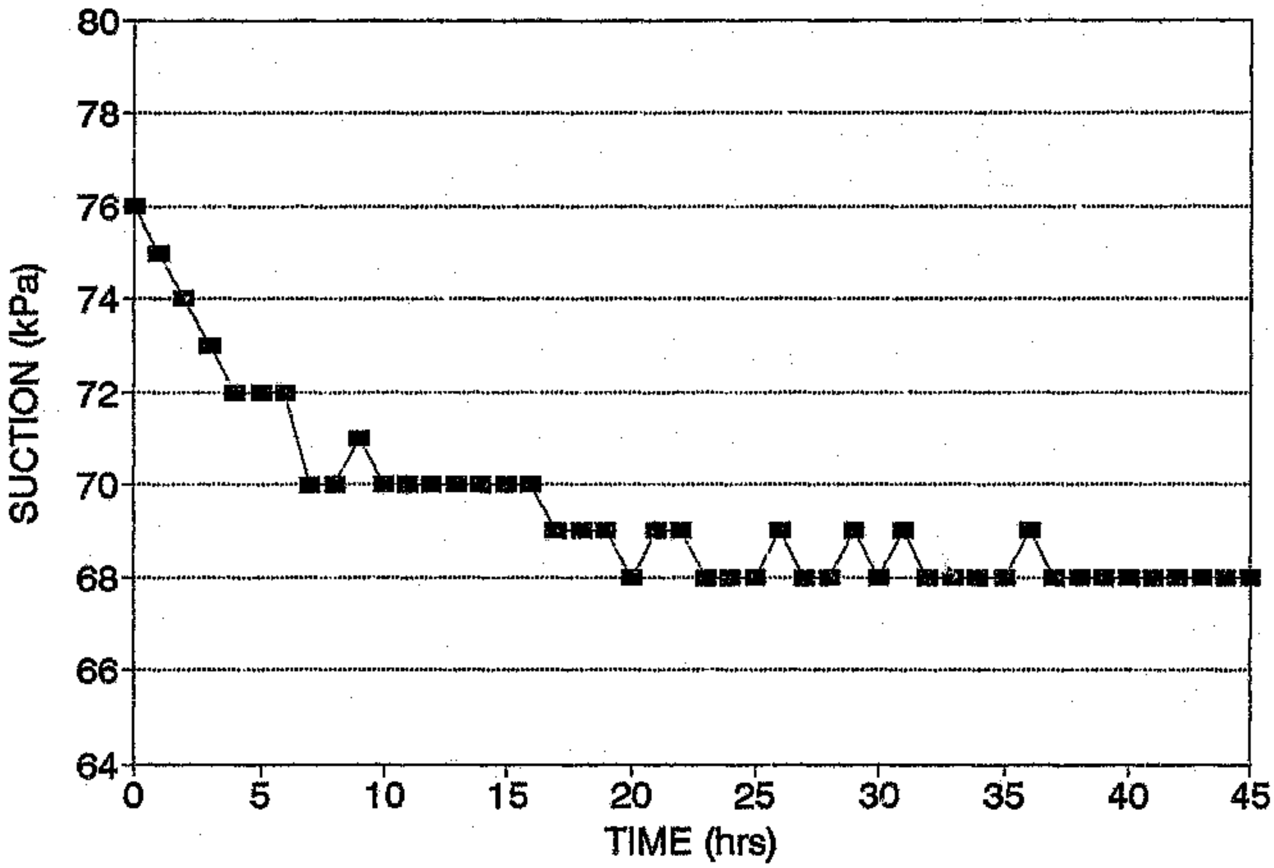
ALPHA
0.113146 (0.01-0.3)

TIME TRP
2.43
TIME minutes
269.1535

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	[illegible]8	76.8571	76.0
1	[illegible]6	74.87951	75.0
2	[illegible]3	74.35111	74.0
3	266	72.64673	73.0
4	265	72.28753	72.0
5	264	72.02834	72.0
6	264	72.02834	72.0
7	263	70.47315	70.0
8	258	70.47315	70.0
9	259	70.73235	71.0
10	255	69.69556	70.0
11	256	69.95476	70.0
12	256	69.95476	70.0
13	256	69.95476	70.0
14	255	69.69556	70.0
15	256	69.95476	70.0
16	256	69.95476	70.0
17	253	69.17717	69.0
18	253	69.17717	69.0
19	253	69.17717	69.0
20	249	68.14038	68.0
21	251	68.65877	69.0
22	251	68.65877	69.0
23	249	68.14038	68.0
24	249	68.14038	68.0
25	249	68.14038	68.0
26	251	68.65877	69.0
27	250	68.39958	68.0
28	249	68.14038	68.0
29	251	68.65877	69.0
30	250	68.39958	68.0
31	251	68.65877	69.0
32	250	68.39958	68.0
33	250	68.39958	68.0
34	250	68.39958	68.0
35	249	68.14038	68.0
36	251	68.65877	69.0
37	250	68.39958	68.0
38	250	68.39958	68.0
39	250	68.39958	68.0
40	249	68.14038	68.0
41	249	68.14038	68.0
42	250	68.39958	68.0
43	250	68.39958	68.0
44	249	68.14038	68.0
45	250	68.39958	68.0


OUTFLOW AT 80 kPa
0.5
0
-0.5
-1
-1.5
-2
FLOW (log cm^3)
0
0.5
1
1.5
2
2.5
3
3.5
TIME (log min)
Experimental points
Linear regression

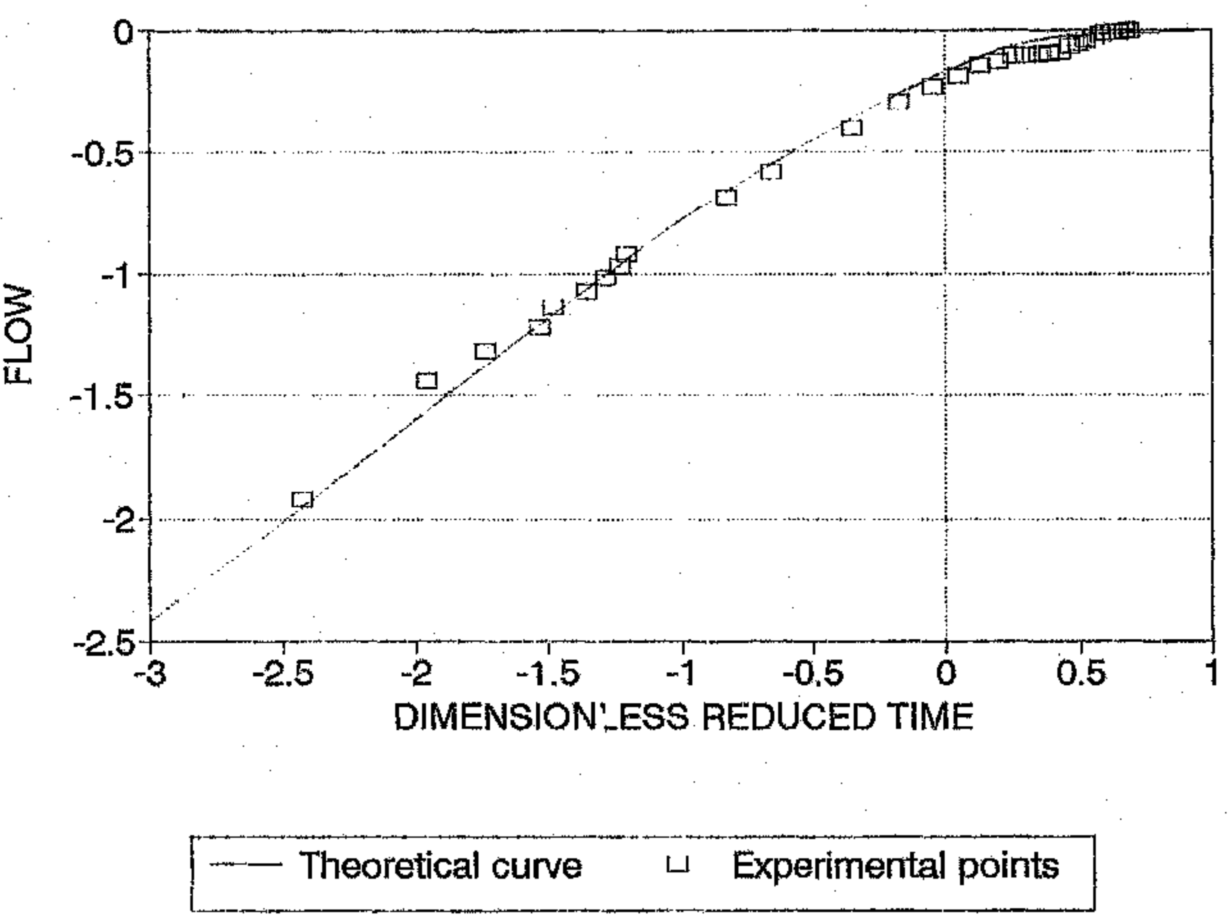
CAPILLARY PRESSURE AT 80 kPa



CLAY TEST AT APPLIED AIR PRESSURE 81 kPa

TIME	THEORETICAL Qo/Qt	EXPERIMENTAL Qt	LOG TIME	LOG Qo/Qt	LOG Qt	ADJUSTED Qt	ADJUSTED TIME
0.001	0.0038480924		-3	-2.41469			-3
0.1	0.1688588385		-1	-0.773			-1
0.2	[illegible]		-0.69897	0.57557			-0.69897
0.3	[illegible]		[illegible]	[illegible]			[illegible]
0.4	0.4076146911		-0.39794	[illegible]			0.39794
0.5	[illegible]		-0.30103	0.33249			0.30103
0.6	0.5164010848		-0.22185	-0.28701			-0.221849
0.7	[illegible]		-0.1549	-0.2498			-0.154902
0.8	0.6042803012		-0.09691	-0.21875			-0.09691
0.9	0.6419746993		-0.04576	-0.19248			-0.045757
1	0.6760566078		0	-0.17002			0
1.1	0.7058884396		0.041393	-0.15065			0.0413927
1.2	0.734783519		0.079181	-0.13384			0.0791812
1.3	0.7600579365		0.113943	-0.11917			0.1139434
1.4	0.7828400703		0.146128	-0.10632			0.146128
1.5	0.8035237853		0.176091	-0.095			0.1760913
1.6	0.8222210172		0.20412	-0.08501			0.20412
1.7	0.8391389434		0.230449	-0.07617			0.2304489
1.8	[illegible]		0.255273	-0.06831			0.2552725
1.9	0.8682801131		0.278754	-0.06133			0.2787536
2	0.8808312087		0.30103	-0.05511			0.30103
2.1	0.8921718191		0.322219	-0.04955			0.3222193
2.2	0.9024328464		0.342423	-0.04459			0.3424227
2.3	0.9117176087		0.361728	-0.04014			0.3617278
2.4	[illegible]		0.380211	-0.03616			0.3802112
2.5	0.927720475		0.39794	-0.03258			0.39794
2.6	0.9346987812		0.414973	-0.02937			0.4149733
2.7	0.9408225301		0.431364	-0.02649			0.4313638
2.8	0.9464540109		0.447158	-0.0239			0.447158
2.9	0.9516495955		0.462398	-0.02157			0.462398
3	[illegible]		0.477121	-0.01947			0.4771213
10	1		1	0			1
1		0.01315	0		-1.88107	-1.919078	-2.43
3		0.03945	0.477121		-1.40395	-1.441957	-1.952879
5		0.0526	0.69897		-1.27901	-1.317018	-1.73103
8		0.06575	0.90309		-1.1821	-1.220108	-1.62881
9		0.0789	0.954243		-1.10292	-1.140927	-1.475757
12		0.09205	1.079181		-1.03598	-1.07398	-1.350819
14		0.1052	1.146128		-0.97798	-1.015988	-1.283872
16		0.11835	1.20412		-0.92683	-0.964836	-1.22588
17		0.1315	1.230449		-0.88107	-0.919078	-1.199551
40		0.22355	1.60206		-0.65063	-0.688528	-0.82794
60		0.2893	1.778151		-0.53865	-0.576655	-0.651849
120		0.43395	2.079181		-0.36258	-0.400594	-0.350819
180		0.5523	2.255273		-0.25782	-0.295828	-0.174727
240		0.64435	2.380211		-0.19088	-0.228883	-0.049789
300		0.7101	2.477121		-0.14868	-0.186684	0.0471213
360		0.77686	2.556303		-0.11022	-0.148226	0.1203026
420		0.8153	2.623249		-0.08868	-0.126903	0.1903193
480		0.85476	2.681241		-0.06816	-0.106169	0.2612412
540		0.85476	2.732394		-0.06816	-0.106165	0.3023938
600		0.8379	2.778151		-0.08163	-0.089634	0.3481513
660		0.88103	2.819544		-0.055	-0.093003	0.3895438
720		0.8942	2.857332		-0.04857	-0.088589	0.4373330
780		0.93245	2.892095		-0.02982	-0.06787	0.4620946
840		0.96095	2.924279		-0.01775	-0.055755	0.4943793
900		0.98325	2.954243		-0.00601	-0.044017	0.5242425
960		1.01255	2.982271		0.005416	-0.032587	0.5522712
1020		1.03885	3.0086		0.016553	-0.021451	0.5786002
1080		1.052	3.033424		0.022016	-0.015988	0.6034238
1140		1.052	3.056905		0.022016	-0.015988	0.6269049
1200		1.052	3.079181		0.022016	-0.015988	0.6491812
1260		1.06515	3.100371		0.027411	-0.010593	0.6703705
1320		1.09146	3.120574		0.038004	0	0.6905739

SUPERIMPOSING OF OUTFLOW CURVES



125 CLAY TEST AT APPLIED AIR PRESSURE 125 kPa

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1283	0	ERR	ERR	ERR
1	-1280	0.02145	0	-1.40305	-1.38556784
2	-1278	0.03575	0.30103	-1.1821	-1.15478894
3	-1276	0.07205	0.477121	-1.00598	-1.0967903
4	-1274	0.11835	0.60206	-0.92683	-0.93801004
5	-1273	0.1315	0.69897	-0.88107	-0.8691086
6	-1271	0.1578	0.778151	-0.80183	-0.8129574
7	-1270	0.17095	0.845098	-0.76713	-0.76541456
8	-1269	0.1841	0.90309	-0.73495	-0.72423114
9	-1266	0.22355	0.954243	-0.65062	-0.68790476
10	-1265	0.2367	1	-0.6258	-0.6554097
11	-1264	0.24985	1.041393	-0.60232	-0.62601435
12	-1262	0.27615	1.079181	-0.55886	-0.5991785
14	-1261	0.2893	1.146128	-0.53865	-0.55163569
15	-1260	0.30245	1.176091	-0.51935	-0.53035706
16	-1259	0.3156	1.20412	-0.50085	-0.51046224
17	-1258	0.32875	1.230449	-0.48313	-0.49176463
19	-1257	0.3419	1.278754	[illegible]	-0.45745057
20	-1255	0.3682	1.30103	-0.43392	-0.4416308
40	-1240	0.56545	1.60206	-0.24761	-0.2278519
60	-1228	0.72325	1.778151	-0.14071	-0.10279926
80	-1216	[illegible]	1.90309	-0.04867	0.014073
140	-1188	1.24925	2.146128	0.096649	0.160522442
200	-1168	1.51225	2.30103	0.179624	0.26852739
260	-1152	1.72265	2.414973	0.236197	0.34945127
320	-1139	1.8936	2.50515	0.277288	0.413484705
380	-1127	2.0514	2.579784	0.31205	0.466488466
440	-1119	2.1566	2.643453	0.33377	0.511701581
500	-1113	2.2355	2.69897	0.349375	0.551127603
560	-1108	2.30125	2.748188	0.361964	0.586000942
620	-1102	2.38015	2.792392	0.376604	0.617471839
680	-1099	2.4196	2.832509	0.383744	0.645961404
740	-1094	2.48535	2.869232	0.395388	0.672040404
800	-1089	2.5511	2.90309	0.406727	0.696085128
860	-1083	2.63	2.934498	0.419956	0.718390105
920	-1081	2.6563	2.963788	0.424277	0.739190193
980	-1078	2.69575	2.991226	0.43068	0.758675689
1040	-1076	2.72205	3.017033	0.434896	0.777002927
1100	-1073	2.7615	3.041393	0.441145	0.794301914
1160	-1072	2.77465	3.064458	0.443208	0.810681928
1220	-1070	2.80095	3.08636	0.447305	0.826235698
1280	-1069	2.8141	3.10721	0.44934	0.841042594
1340	-1067	2.8404	3.127105	0.45338	0.855171069
1400	-1065	2.8667	3.146128	0.457382	0.868680576
1460	-1061	2.9193	3.164353	0.465279	0.88162308

Regression Output

Constant		-1.36557
Std Err of Y Est		0.024111
R Squared		0.99481
No. of Observations		21
Degrees of Freedom		19
X Coefficient(s)	0.710158	
Std Err of Coef	0.011767	

OUTFLOW

INITIAL -1283

ENDED -1061

VOLUME CHANGE VOLTAGE

VOLUME INITIAL -509 V

VOLUME FINAL -425 V

ALPHA

0.173239 (0.01 0.3)

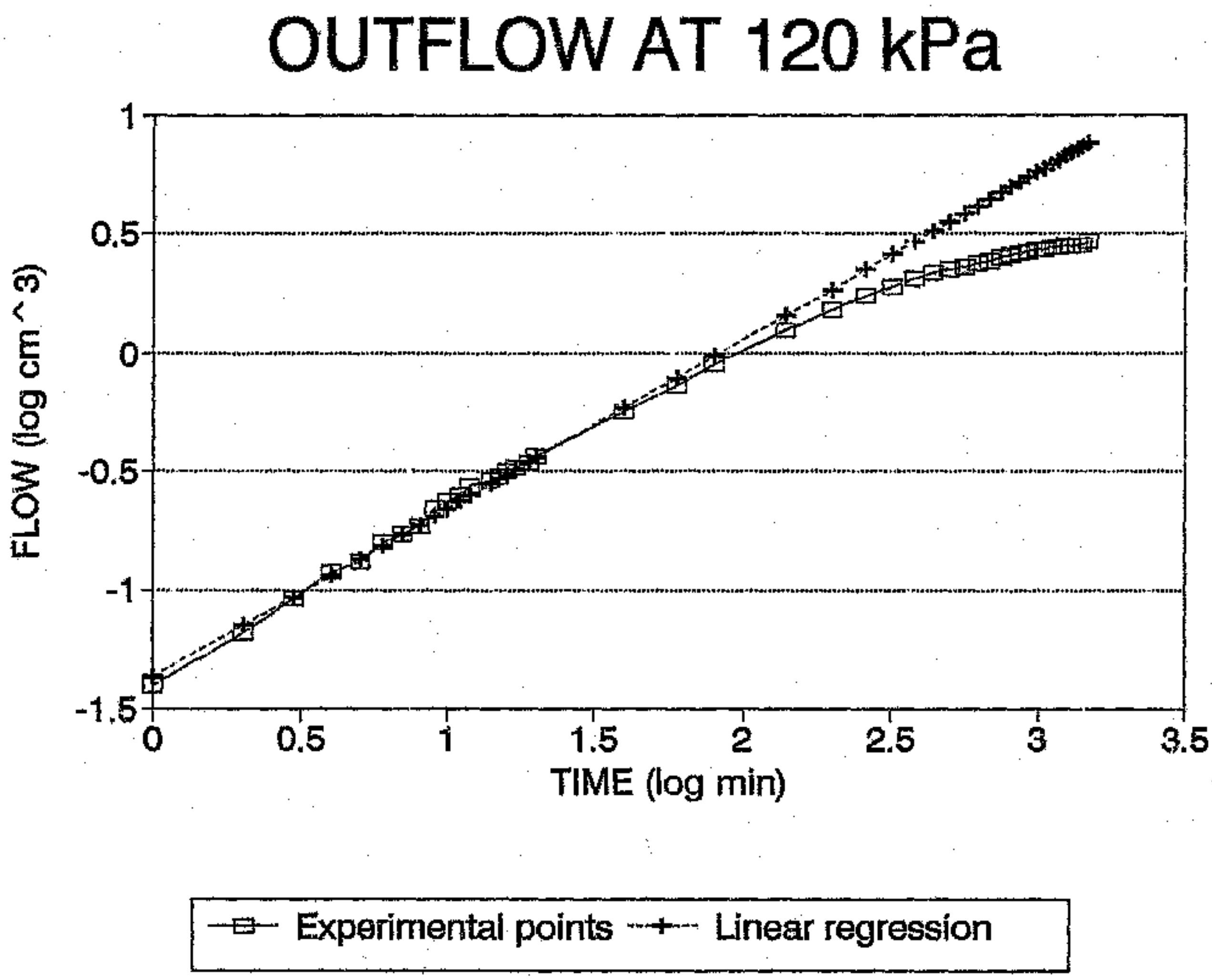
TIME TRF

239

TIME minutes

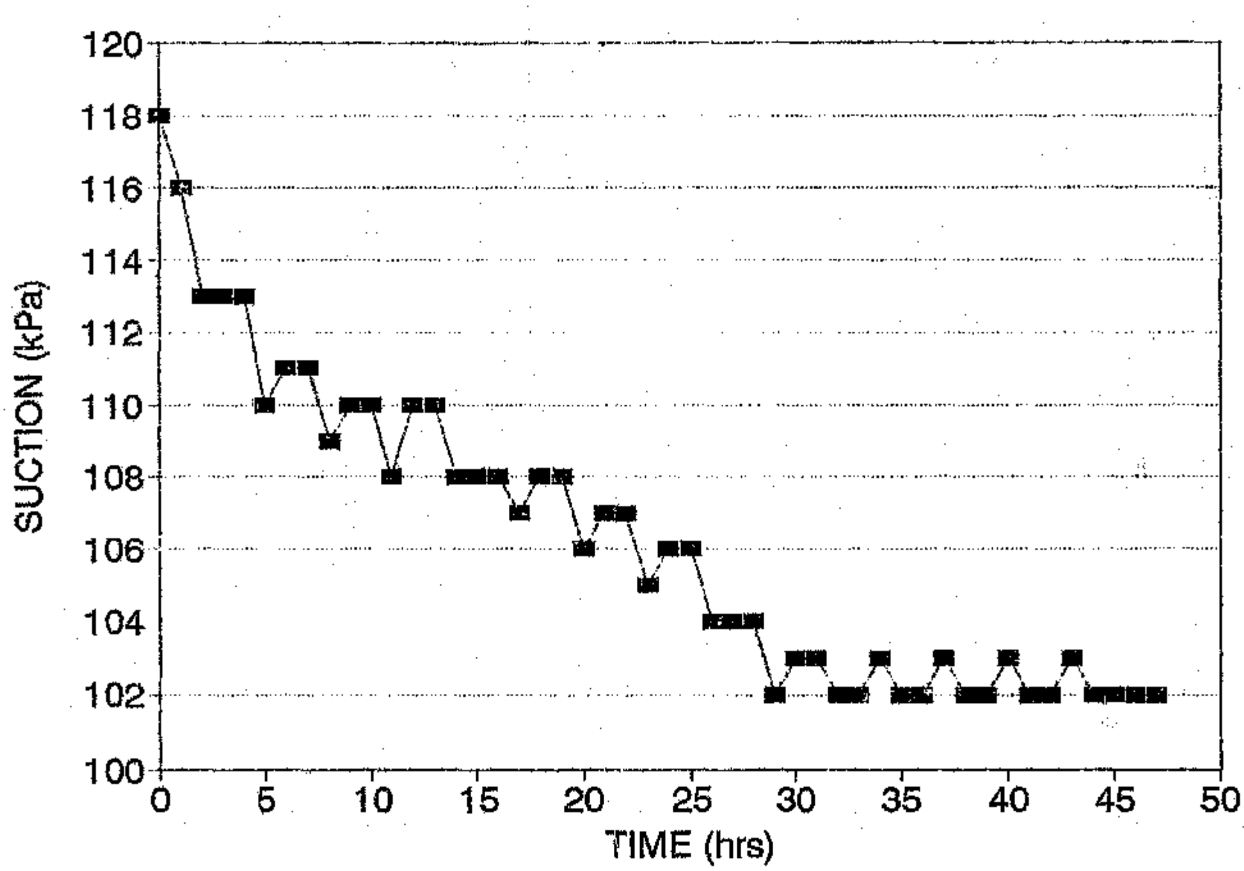
245.4709

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	440	118.054	118.0
1	434	116.4989	115.0
2	421	113.1292	113.0
3	422	113.3881	113.0
4	421	113.1292	113.0
5	410	110.2781	110.0
6	413	111.0556	111.0
7	412	110.7964	111.0
8	405	108.9821	109.0
9	409	110.0189	110.0
10	409	110.0189	110.0
11	403	108.4637	108.0
12	407	109.5005	110.0
13	407	109.5005	110.0
14	400	107.6861	108.0
15	402	108.2045	108.0
16	403	108.4637	108.0
17	397	106.9085	107.0
18	401	107.9453	108.0
19	401	107.9453	108.0
20	394	106.1309	106.0
21	399	107.4269	107.0
22	399	107.4269	107.0
23	390	105.0941	105.0
24	394	106.1309	106.0
25	393	105.8717	103.0
26	384	103.5389	104.0
27	387	104.3165	104.0
28	387	104.3165	104.0
29	378	101.9837	102.0
30	381	102.7613	103.0
31	382	103.0205	103.0
32	377	101.7245	102.0
33	379	102.2429	102.0
34	380	102.5021	103.0
35	377	101.7245	102.0
36	378	101.9837	102.0
37	380	102.6021	103.0
38	377	101.7245	102.0
39	378	101.9837	102.0
40	380	102.6021	103.0
41	377	101.7245	102.0
42	378	101.9837	102.0
43	380	102.6021	103.0
44	379	102.2429	102.0
45	378	101.9837	102.0
46	378	101.9837	102.0
47	378	101.9837	102.0



OUTFLOW AT 120 kPa
1
0.5
0
-0.5
-1
-1.5
FLOW (log cm ^ 3)
0
0.5
1
1.5
2
2.5
3
3.5
TIME (log min)
Experimental points
Linear regression

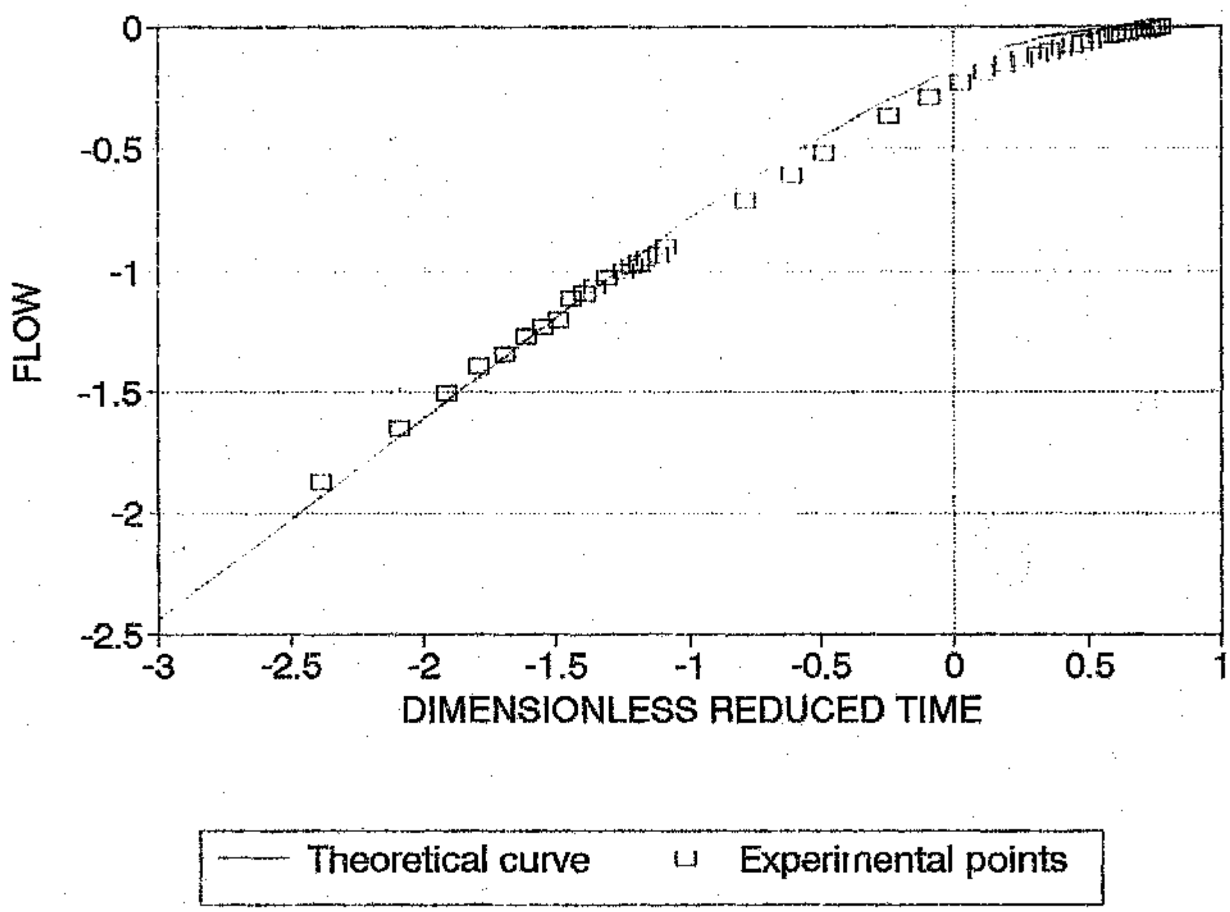
CAPILLARY PRESSURE AT 120 kPa



CLAY TEST AT APPLIED AIR PRESSURE 125 kPa

TIME	THEORETICAL Qa/Qt	EXPERIMENTAL Qt	LOG TIME	LOG Qa/Qt	LOG Qt	ADJUSTED Qt	ADJUSTED TIME
0.001	0.0036319791		-3	-2.43995			-3
0.1	0.1654722693		-1	-0.78127			-1
0.2	0.2623819913		-0.69897	-0.58107			-0.69897
0.3	0.3391578202		-0.52288	-0.4696			-0.522879
0.4	0.4046529592		-0.39794	-0.39292			-0.39794
0.5	0.4623520898		-0.30103	-0.33503			-0.30103
0.6	0.5139344589		-0.22185	-0.28909			-0.221849
0.7	0.5603571952		-0.1549	-0.25153			-0.154902
0.8	0.6022622933		-0.09691	-0.22021			-0.09691
0.9	0.6401390297		-0.04576	-0.19373			-0.045757
1	0.6743951507		0	-0.17109			0
1.1	0.7053848889		0.041393	-0.15157			0.0413927
1.2	0.7334229641		0.079181	-0.13466			0.0791812
1.3	0.7587918211		0.113943	-0.11988			0.1139434
1.4	0.7817460941		0.146128	-0.10693			0.146128
1.5	0.8025159119		0.176091	-0.09555			0.1760913
1.6	0.8213089619		0.20412	-0.08549			0.20412
1.7	0.8383136805		0.230449	-0.07659			0.2304489
1.8	0.8537001754		0.255273	-0.06869			0.2552725
1.9	0.8676224473		0.278754	-0.06167			0.2787536
2	0.8802158387		0.30103	-0.05541			0.30103
2.1	0.8916184581		0.322219	-0.04982			0.3222193
2.2	0.9019322985		0.342423	-0.04483			0.3424227
2.3	0.9112646743		0.361728	-0.04036			0.3617278
2.4	0.9197088957		0.380211	-0.03635			0.3802112
2.5	0.9273419		0.39794	-0.03275			0.39794
2.6	0.9342632639		0.414973	-0.02953			0.4149733
2.7	0.9405189324		0.431364	-0.02663			0.4313638
2.8	0.9461793044		0.447158	-0.02403			0.447158
2.9	0.9513010208		0.462398	-0.02168			0.462398
3	0.9559353414		0.477121	-0.01957			0.4771213
10	1		1	0			1
1		0.03046	0		-1.40390	-1.839232	-2.39
2		0.06575	0.30103		-1.1821	-1.647983	-2.08097
3		0.09205	0.477121		-1.03598	-1.501255	-1.912879
4		0.11835	0.60206		-0.92683	-1.39211	-1.78794
5		0.1316	0.69897		-0.88107	-1.346353	-1.69103
6		0.1578	0.778151		-0.80189	-1.26717	-1.611849
7		0.17095	0.84[illegible]		-0.76713	-1.23241	-1.544902
8		0.1841	0.90309		-0.73495	-1.200225	-1.48691
9		0.22366	0.954243		-0.65053	-1.115904	-1.435757
10		0.2367	1		-0.6258	-1.09108	-1.39
11		0.24985	1.041393		-0.60232	-1.067609	-1.348607
12		0.27615	1.079181		-0.55885	-1.024131	-1.310819
14		0.2993	1.146128		-0.52395	-1.00353	-1.243872
15		0.30246	1.176091		-0.51935	-0.984625	-1.213909
16		0.3156	1.20412		-0.50086	-0.966142	-1.18588
17		0.32875	1.230449		-0.48313	-0.948413	-1.159551
19		0.3419	1.278754		-0.4661	-0.93138	-1.111246
20		0.3682	1.30103		-0.43392	-0.899195	-1.08897
40		0.56545	1.60206		-0.24761	-0.712885	-0.78794
60		0.72295	1.778151		-0.14071	-0.60599	-0.611849
80		0.8942	1.90309		-0.04857	-0.513844	-0.48691
140		1.24925	2.146128		0.096649	-0.368629	-0.243872
200		1.51225	2.30103		0.179621	-0.285656	-0.08897
260		1.72265	2.414973		0.236197	-0.229082	0.0249733
320		1.8936	2.50515		0.277288	-0.18799	0.11515
560		2.0514	2.579784		0.31205	-0.153228	0.1897836
440		2.1566	2.643453		0.33377	-0.131509	0.2534527
500		2.2355	2.69897		0.349375	-0.115904	0.30897
560		2.30125	2.748188		0.361964	-0.103315	0.358188
620		2.38015	2.792392		0.376601	-0.088671	0.4023917
680		2.4196	2.832509		0.383744	-0.081535	0.4425089
740		2.48535	2.869232		0.395388	-0.069891	0.4792317
800		2.5511	2.90309		0.406727	-0.058551	0.51309
860		2.63	2.934498		0.419956	-0.045323	0.5444985
920		2.6563	2.963788		0.424277	-0.041002	0.5737878
980		2.69576	2.991226		0.43068	-0.034599	0.6012261
1040		2.72205	3.017033		0.434896	-0.030383	0.6270333
1100		2.7615	3.041393		0.441145	-0.024134	0.6513927
1160		2.77465	3.064458		0.443208	-0.02207	0.674458
1220		2.80095	3.08636		0.447306	-0.017973	0.6963598
1280		2.8141	3.10721		0.44934	-0.015939	0.71721
1340		2.8404	3.127105		0.45338	-0.011899	0.7371048
1400		2.8667	3.146128		0.457302	-0.007696	0.756128
1460		2.9193	3.164353		0.465279	0	0.7743529

SUPERIMPOSING OF OUTFLOW CURVES



160 CLAY TEST / T APPLIED AIR PRESSURE 160 kPa

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-125	0	ERR	ERR	ERR
1	124	0.01315	0	1.88107	1.52404542
2	-122	0.03945	0.30103	-1.40396	-1.34813578
3	-121	0.0526	0.477121	-1.27901	-1.24523692
4	-120	0.06575	0.60206	-1.1821	-1.7222813
5	-119	0.0789	0.69897	1.10292	1.11559919
6	-118	0.09205	0.778151	-1.03598	-1.05932817
8	-117	0.1052	0.90309	-0.97797	-0.99631948
10	-116	0.11835	1	-0.92683	-0.95968954
12	-115	0.1315	1.079181	-0.88107	-0.89341951
14	-114	0.14465	1.146128	-0.83968	-0.85429876
16	-113	0.1578	1.20412	-0.80189	-0.82041083
19	-112	0.17095	1.278754	-0.76713	-0.77679829
22	-111	0.1841	1.342423	-0.73495	-0.73959303
25	-110	0.19725	1.39794	-0.70498	-0.70716095
27	-109	0.2104	1.431364	-0.67695	-0.68761959
30	-108	0.22355	1.477121	-0.65063	-0.66088093
33	-107	0.2367	1.518514	-0.62578	-0.63669787
37	-106	0.24985	1.568202	-0.60232	-0.60765762
70	-99	0.3419	1.845098	-0.4661	-0.44585153
100	-93	0.4208	2	-0.37592	-0.35533465
120	-89	0.4734	2.113943	-0.32477	0.28875018
160	-86	0.51285	2.20412	-0.29001	-0.23605494
190	-84	0.53915	2.278754	-0.26829	-0.19244234
220	-83	0.5523	2.342423	-0.25782	-0.15523094
250	82	0.56545	2.39794	-0.24761	0.12270507
280	-82	0.56545	2.447158	-0.24761	-0.09403422
310	-82	0.56545	2.491362	-0.24761	-0.06820355
340	-82	0.56545	2.531479	-0.24761	-0.04476082
370	-81	0.5786	2.568202	-0.23762	-0.02330163
400	-81	0.5786	2.60206	-0.23762	-0.00351635
430	-80	0.59175	2.633468	-0.22786	0.01489737
460	-80	0.59175	2.662758	-0.22786	0.031952789
490	-80	0.59175	2.690196	-0.22786	0.047986491
520	-79	0.6049	2.716003	-0.21832	0.053067117
550	78	0.61805	2.740363	-0.20898	0.077301645
580	78	0.61805	2.763428	-0.20898	0.090779891
610	-77	0.6312	2.78533	-0.19983	0.103578401
640	-77	0.6312	2.80618	-0.19983	0.115762362
670	-77	0.6312	2.826075	0.19983	0.127388033
700	-76	0.64435	2.845098	-0.19088	0.138504363
730	-75	0.6575	2.863323	-0.1821	0.149154144
760	-75	0.6575	2.880814	-0.1821	0.159374957
790	-74	0.67065	2.897627	-0.1735	0.169200024
820	-73	0.6838	2.913814	-0.16507	0.178658865
850	-72	0.69695	2.929419	-0.1568	0.18777777
880	72	0.69695	2.944483	-0.1568	0.196580398
910	-71	0.7101	2.959041	-0.14868	0.20508787
940	-71	0.7101	2.973128	-0.14868	0.21331933
970	-70	0.72325	2.986772	-0.14071	0.221292221
1000	-70	0.72325	3	-0.14071	0.22902223
1030	-70	0.72325	3.012837	-0.14071	0.236523744
1060	-70	0.72325	3.025306	-0.14071	0.243809867
1090	-69	0.7364	3.037426	-0.13289	0.25089263
1120	69	0.7364	3.049218	0.13289	0.257783077
1150	-69	0.7364	3.060698	-0.13289	0.264491376
1180	-68	0.74955	3.071882	-0.1252	0.27102691
1210	-67	0.7627	3.08278	-0.11765	0.277398356
1240	66	0.77585	3.093422	0.11022	0.283613748
1270	-64	0.80215	3.103804	-0.09574	0.289680652
1300	-62	0.82845	3.113943	-0.08173	0.295605705
1330	-61	0.8416	3.123852	-0.07489	0.301395672
1360	-59	0.8679	3.133539	-0.06153	0.307056483
1390	-58	0.88105	3.143015	-0.055	0.312593777
1420	[illegible]	0.90735	3.152288	-0.04223	0.318012827
1450	-55	0.9205	3.161368	-0.03598	0.323318578

Regression Output:

Constant	-1.52405
Std Err of Y Est	0.022919
R Squared	0.993999
No. of Observations	20
Degrees of Freedom	18
X Coefficient(s)	0.584356
Std Err of Coef	0.010702

OUTFLOW
INITIAL -125
ENDED -55

VOLUME CHANGE
VOLUME INITIAL -425 V
VOLUME FINAL 394 V

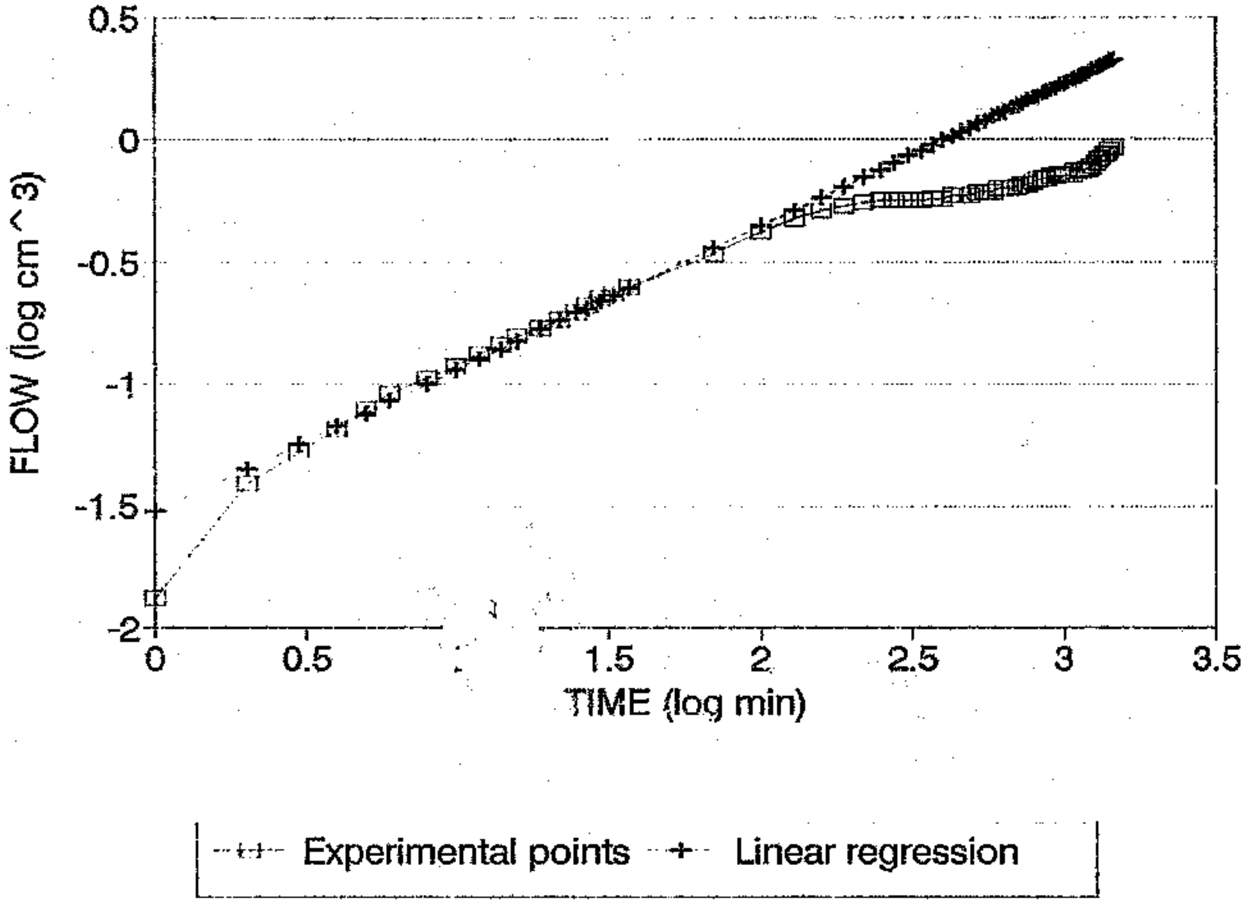
ALPHA
0.034015 (0.01-0.3)

TIME (SF
23

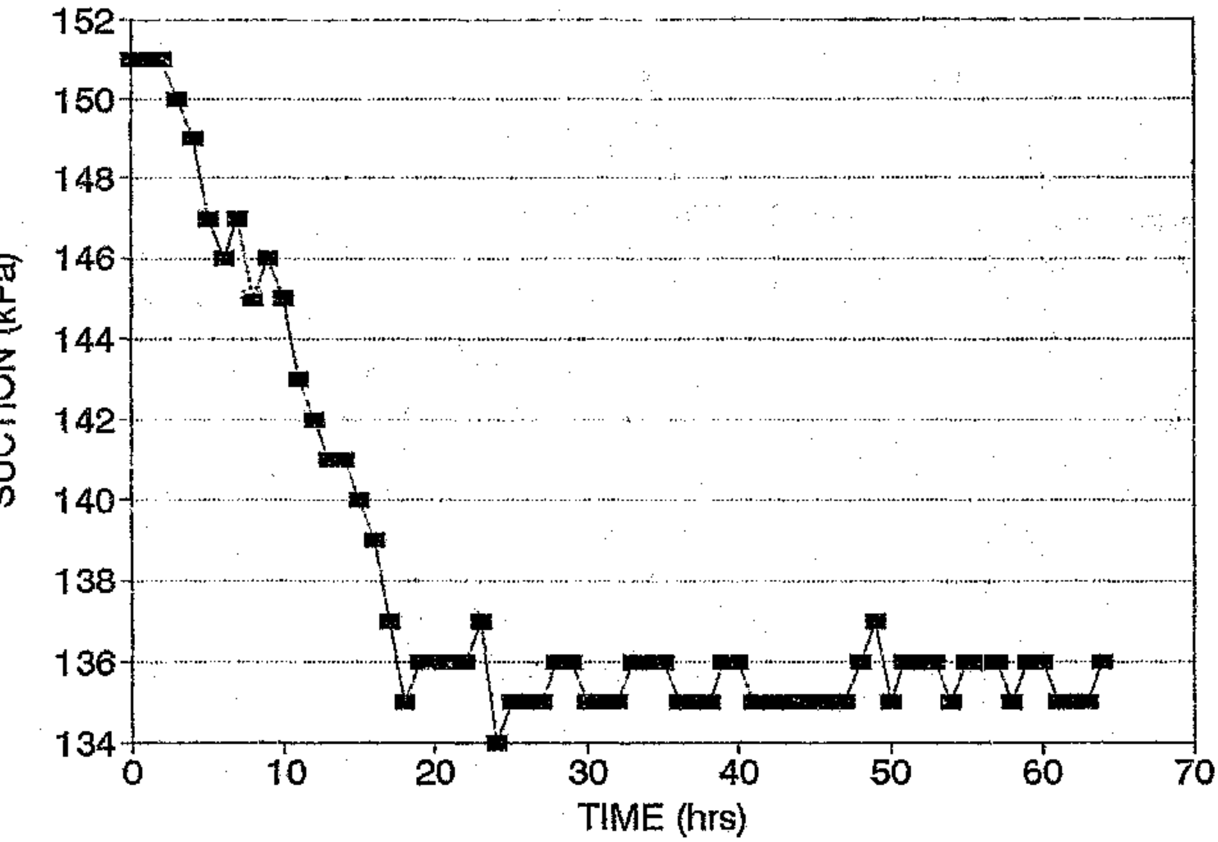
TIME minutes
199.5262

TIME hours	SUCTION volts	SUCTION kPa	SUCTION kPa
0	567	151.2957	151.0
1	565	150.7773	151.0
2	564	150.5181	151.0
3	561	149.7405	150.0
4	560	149.4813	149.0
5	550	146.8993	147.0
6	547	146.1118	146.0
7	549	146.6302	147.0
8	541	144.5566	145.0
9	545	145.9526	146.0
10	542	144.8158	145.0
11	535	143.0014	143.0
12	532	142.2238	142.0
13	529	141.4452	141.0
14	527	140.9278	141.0
15	525	140.4094	140.0
16	520	139.1134	139.0
17	512	137.0399	137.0
18	505	135.2265	135.0
19	507	135.7439	136.0
20	508	136.0031	136.0
21	508	126.0031	136.0
22	509	136.2623	136.0
23	511	136.7807	137.0
24	500	133.9295	134.0
25	504	134.9663	135.0
26	506	135.4847	135.0
27	506	135.4847	135.0
28	507	135.7439	136.0
29	507	135.7439	136.0
30	506	135.4847	135.0
31	504	134.9663	135.0
32	505	135.2255	135.0
33	507	135.7439	136.0
34	507	135.7439	136.0
35	509	136.2623	136.0
36	504	134.9663	135.0
37	506	135.4847	135.0
38	506	135.4847	135.0
39	508	136.0031	136.0
40	507	135.7439	136.0
41	503	134.7071	135.0
42	[illegible]	134.9663	135.0
43	505	135.2255	135.0
44	504	134.9663	135.0
45	504	134.9663	135.0
46	505	135.2255	135.0
47	503	134.7071	135.0
48	509	136.2623	136.0
49	511	136.7807	137.0
50	505	135.2255	135.0
51	508	136.0031	136.0
52	509	136.2623	136.0
53	507	135.7439	136.0
54	505	135.2255	135.0
55	509	136.2623	136.0
56	507	135.7439	136.0
57	508	136.0031	136.0
58	505	135.2255	135.0
59	507	135.7439	136.0
60	508	136.0031	136.0
61	505	135.2255	135.0
62	506	135.4847	135.0
63	506	135.4847	135.0
64	507	135.7439	136.0

OUTFLOW AT 160 kPa



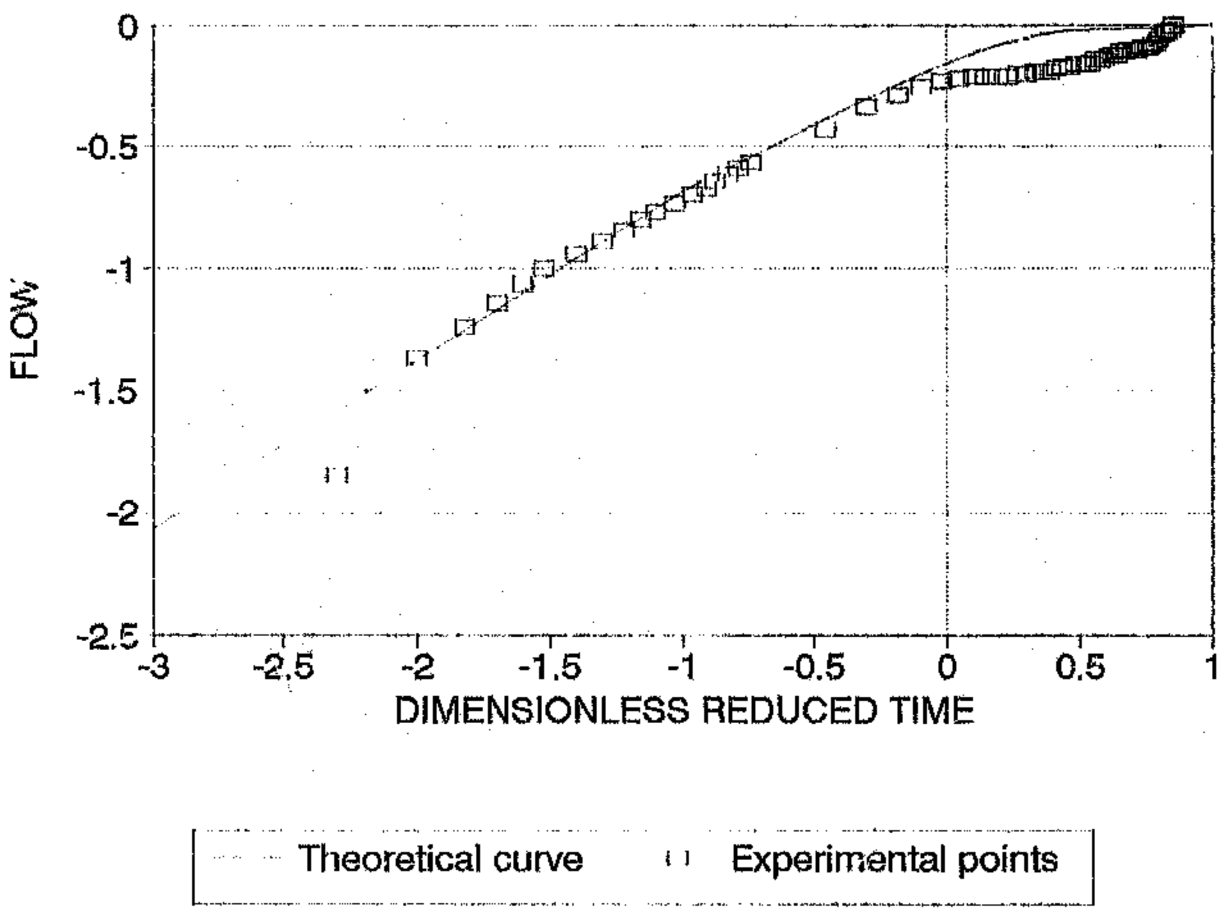
CAPILLARY PRESSURE AT 160 kPa



CLAY TEST AT APPLIED AIR PRESSURE 160 kPa

TIME	THEORETICAL GAGE	EXPERIMENTAL Gt	LOG TIME	LOG GAGE	LOG Gt	ADJUSTED Gt	ADJUSTED TIME
0.001	0.00556[illegible]		-3	-2.0352			-3
0.1	0.2039[illegible]		-1	-0.[illegible]			-1
0.2	0.305[illegible]		-0.699	-0.5274			-0.69897
0.3	0.374502415		-0.5229	-0.4264			-0.52288
0.4	0.4371[illegible]		-0.3979	-0.3592			-0.39794
0.5	0.491072[illegible]		-0.301	-0.3081			-0.30103
0.6	0.5[illegible]		-0.2218	-0.2660			-0.22185
0.7	0.5587[illegible]		-0.1549	-0.2931			-0.1549
0.8	0.624[illegible]		-0.0969	-0.2046			-0.09691
0.9	0.660107307		-0.0458	-0.1804			-0.04576
1	0.692465094		0	-0.1596			0
1.1	0.7[illegible]		0.04139	-0.1416			0.041393
1.2	0.740[illegible]		0.07918	-0.126			0.079181
1.3	0.772[illegible]		0.11394	-0.1125			0.113943
1.4	0.79[illegible]104		0.14613	-0.1003			0.146128
1.5	0.8[illegible]		0.17609	-0.0897			0.176091
1.6	0.8[illegible]		0.20412	-0.0803			0.20412
1.7	0.847[illegible]		0.23045	-0.072			0.230449
1.8	0.861821150		0.25527	-0.0646			0.255273
1.9	0.874[illegible]0502		0.27875	-0.058			0.278754
2	0.886[illegible]706		0.30103	-0.0521			0.30103
2.1	0.897[illegible]		0.32222	-0.0469			0.322219
2.2	[illegible]		[illegible]	[illegible]			[illegible]
2.3	0.916[illegible]		[illegible]	[illegible]			0.361728
2.4	0.924[illegible]		0.38021	-0.0341			0.380211
2.5	0.931[illegible]402		0.39794	-0.0309			0.39794
2.6	0.93791223		0.41497	-0.0279			0.414973
2.7	0.943[illegible]		0.4314	-0.0251			0.431364
2.8	0.949165[illegible]		0.44716	-0.0227			0.447158
2.9	0.954[illegible]249		0.4624	-0.0204			0.462398
3	0.959351[illegible]		0.47712	-0.0185			0.477121
10	1		1	0			1
1		0.01315	0		-1.8811	-1.6451	-2.3
2		0.03945	0.30103		-1.404	-1.30703	-1.90997
3		0.0526	0.47712		-1.279	-1.[illegible]	-1.[illegible]
4		0.06575	0.60206		-1.1821	-1.14013	-1.69794
5		0.0[illegible]	0.69897		-1.1049	-1.0[illegible]	-1.60103
6		0.09205	0.77815		-1.036	-1	-1.52185
8		0.1052	0.90309		-0.978	-0.96201	-1.39691
10		0.11835	1		-0.9268	-0.90858	-1.3
12		0.1315	1.07918		-0.8811	-0.8451	-1.22082
14		0.14465	1.14613		-0.8397	-0.79171	-1.15387
16		0.1578	1.20412		-0.8019	-0.76792	-1.09588
19		0.17095	1.27875		-0.7671	-0.72315	-1.02125
22		0.1841	1.34242		-0.7349	-0.69897	-0.95758
25		0.19725	1.39794		-0.705	-0.66901	-0.90206
27		0.2104	1.43136		-0.677	-0.64093	-0.86864
30		0.22355	1.47712		-0.6506	-0.61466	-0.82288
33		0.2367	1.51851		-0.6258	-0.58983	-0.78149
37		0.24985	1.5682		-0.6023	-0.56634	-0.7318
70		0.3419	1.8451		-0.4661	-0.45012	-0.4549
100		0.4340	2		-0.3759	-0.33905	-0.3
130		0.4734	2.11394		-0.3248	-0.[illegible]	-0.18606
160		0.51285	2.20412		-0.29	-0.26403	-0.09588
190		0.53915	2.27875		-0.2683	-0.24231	-0.02125
220		0.5522	2.34242		-0.2579	-0.22185	0.040422
250		0.56545	2.39794		-0.2476	-0.21165	0.09794
280		0.56545	2.44716		-0.2476	-0.21165	0.147159
310		0.56545	2.49136		-0.2476	-0.21165	0.191362
340		0.56545	2.53148		-0.2476	-0.21165	0.231479
370		0.5786	2.5682		-0.2376	-0.20165	0.268200
400		0.5786	2.60206		-0.2376	-0.20165	0.30206
430		0.59175	2.63347		-0.2279	-0.19189	0.333463
460		0.59175	2.66276		-0.2279	-0.19189	0.362758
490		0.59175	2.6902		-0.2279	-0.19189	0.390196
520		0.6049	2.716		-0.2183	-0.18231	0.416003
550		0.61805	2.74036		-0.209	-0.173	0.440363
580		0.61805	2.76343		-0.209	-0.173	0.463428
610		0.6312	2.78533		-0.1998	-0.16386	0.48533
640		0.6312	2.80618		-0.1998	-0.16386	0.50618
670		0.6312	2.82607		-0.1998	-0.16386	0.526075
700		0.64435	2.8451		-0.1909	-0.1549	0.545098
730		0.6575	2.86332		-0.1821	-0.14613	0.563321
760		0.6575	2.88081		-0.1821	-0.14613	0.580814
790		0.67065	2.89763		-0.1735	-0.13753	0.597627
820		0.6838	2.91381		-0.1651	-0.12909	0.613814
850		0.69695	2.92942		-0.1568	-0.12082	0.629410
880		0.69695	2.94448		-0.1568	-0.12082	0.644439
910		0.7101	2.95904		-0.1487	-0.1127	0.659041
940		0.7101	2.97313		-0.1487	-0.1127	0.673120
970		0.72325	2.98677		-0.1407	-0.10474	0.686770
1000		0.72325	3		-0.1407	-0.10474	0.7
1030		0.72325	3.01284		-0.1407	-0.10474	0.712837
1060		0.72325	3.02531		-0.1407	-0.10474	0.725300
1090		0.7364	3.03743		-0.1329	-0.09691	0.737426
1120		0.7364	3.04922		-0.1329	-0.09691	0.749219
1150		0.7364	3.0607		-0.1329	-0.09691	0.760703
1180		0.74955	3.07188		-0.1252	-0.08922	0.771882
1210		0.7627	3.08279		-0.1176	-0.08167	0.782787
1240		0.7759	3.09342		-0.1102	-0.07425	0.793420
1270		0.80215	3.1038		-0.0957	-0.05977	0.803804
1300		0.82845	3.11394		-0.0817	-0.04578	0.813943
1330		0.8416	3.12385		-0.0749	-0.03892	0.823865
1360		0.8679	3.13354		-0.0615	-0.02555	0.833539
1390		0.88105	3.14301		-0.055	-0.01902	0.843015
1420		0.90735	3.15229		-0.0422	-0.00625	0.852288
1450		0.9205	3.16137		-0.036	0	0.861368

SUPERIMPOSING OF OUTFLOW CURVES



25% CLAY TEST AT APPLIED AIR PRESSURE 20 kPa

TIME minutes	FLOW volts	FLOW cm^3	LOG TIME	LOG FLOW	PREDICTED FLOW
0	-1487	0	ERR	ERR	ERR
1	-1486	0 01316	0	-1 881074	-1 814 70388
2	1485	0 0263	0.30103	1.580044	1.57892095
4	1484	0 03945	0 60206	-1 403953	-1 34318604
5	-1483	0 0526	0 69897	-1.279014	-1 2672329
6	-1482	0 06575	0 7781513	-1.182104	-1 20521388
8	-1481	0 0789	0 90309	-1 102923	-1 10735513
9	-1480	0 09205	0 9542425	-1 035976	-1 06759072
11	1479	0 1052	1 0413927	-0 977984	-0 999029
12	-1478	0 11835	1 0791812	-0 926832	-0 96942097
14	-1477	0 1315	1.146128	-0 881074	-0 91699493
17	1476	0 14465	1.2304489	0 839682	0.85094997
19	-1476	0 1578	1 2787536	-0 801858	-0 81311514
21	-1474	0 17095	1 3222193	-0 767131	-0 77907047
23	-1473	0 1841	1 3617278	-0 734940	-0 74812925
25	-1472	0 19725	1.39794	-0 704983	-0 71976192
29	-1470	0 22355	1 462398	-0 650625	-0.66927495
60	-1459	0 3682	1 7781513	-0 433916	-0 42195999
90	1448	0 51285	1 9542425	-0 29001	-0 28403593
120	-1438	0 64435	2 0791812	-0.190878	-0.18617707
150	-1429	0 7627	2.1760913	-0.117643	-0 11037192
180	-1420	0.88105	2 2552725	-0 054999	-0.04825291
210	-1412	0 98635	2 3222193	-0 006013	0 004183424
240	-1404	1 09146	2 3802112	0 0380038	0 049605842
270	-1397	1 1635	2 4313638	0 0731683	0 089671254
300	-1391	1 2624	2 4771213	0 101197	0 125510987
330	-1385	1 3413	2 5185139	0.1275859	0 157981968
360	-1380	1 40705	2 5563025	0 1483095	0 187630006
390	-1377	1.4466	2.5910646	0.1603104	0 214767561
420	1372	1.61226	2 6232493	0 1796235	0 239966339
450	1369	1.5517	2 6532125	0 1908078	0 26343515
480	-1366	1 59115	2 6812412	0 2017111	0 285388757
510	-1363	1.6306	2 7075702	0 2123474	0 306011001
540	-1369	1 6832	2.7323938	0 2261357	0 32546417
570	-1358	1 69845	2 7558749	0 2295155	0 313845829
600	-1357	1 7095	2 7781513	0 2328691	0 361298902
630	-1354	1.74895	2 7993405	0 2427774	0 377890503
660	-1353	1 7621	2.8195439	0 2460306	0 393714884
690	1351	1.7884	2.8388491	0.2524647	0 403835722
720	-1349	1 8147	2 8573325	0 2588048	0 422312921
750	-1348	1.82785	2 8750613	0 2619106	0 437199047
780	-1346	1.85415	2 8920946	0 2681449	0 450540476
810	-1344	1.88045	2 908485	0 2742818	0 463378333
840	1342	1.90675	2 9242793	0 2802929	0 475740255
870	-1328	1 95935	2.9395193	0.292112	0 487686018
900	-1338	1 95935	2 9542425	0.292112	0 499218066
930	-1336	1 98565	2 9684829	0.2979027	0 510371946
960	-1335	1.9988	2 9822712	0 3007690	0 521171673
990	-1334	2.01195	2 9956352	0 3036172	0 531639048
1020	1332	2 03825	3 0086002	0 3092575	0 541793917
1050	-1330	2 06455	3 0211893	0 3148254	0 651654399
1080	-1330	2 06455	3 0334238	0 3148254	0 661237085
1110	-1328	2 09085	3 01533[illegible]	0 3203229	0 570557198
1140	-1329	2 0777	3.0569049	0 3175828	0 579638745
1170	-1329	2 0777	3 0681859	0 3175828	0 58846484
1200	-1328	2 09085	3.0791812	0 3203229	0 597076818
1230	-1328	2 09085	3 0899051	0 3203229	0 605476337
1260	-1327	2.104	3 1003705	0 3230457	0 613673419
1290	-1327	2.104	3.1105897	0 3230457	0 621677619
1320	-1327	2 104	3 1205739	0 3230457	0 629497799
1350	-1327	2.104	3 1303338	0 3230457	0.63714223
1380	-1326	2 11715	3 1398791	0 3257516	0 644610637
1410	-1325	2 1303	3.1492191	0 3284408	0 651934249
1440	-1324	2 14345	3 1583625	0 3311134	0 659095837
1470	-1321	2 1829	3 1673173	0 3390336	0 666109752
1500	-1318	2 22235	3 1760913	0 3468126	0 672981962
1530	-1316	2 24865	3 1846914	0 3519219	0 67971808
1560	-1313	2 2881	3 1931246	0 359475	0 686328392

Regression Output

Constant		-1.814704
Std Err of Y Est		0 0362627
R Squared		0.9578046
No. of Observations		25
Degrees of Freedom		23
X Coefficient(s)	0 7032320	
Std Err of Coef	0 0076607	

OUTFLOW

INTIAL -1489

ENDED -1313

VOLUME CHANGE VOLTAGE

VOLUME INITIAL -393 V

VOLUME INTERMEDIATE -333 V

VOLUME FINAL -323 V

ALPHA

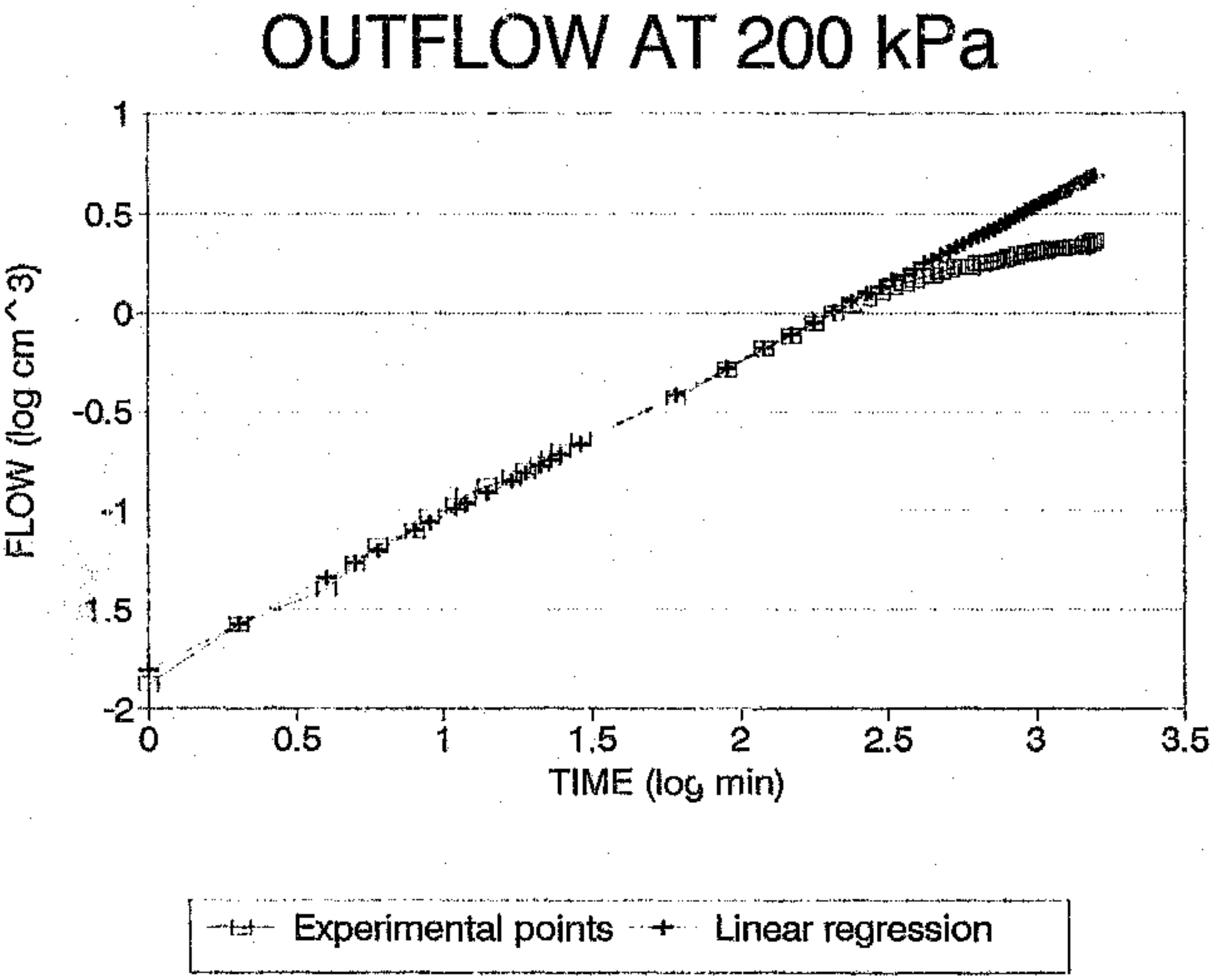
0.237051 (0.01-0.3)

TIME TRP

263

TIME minutes

426 07962

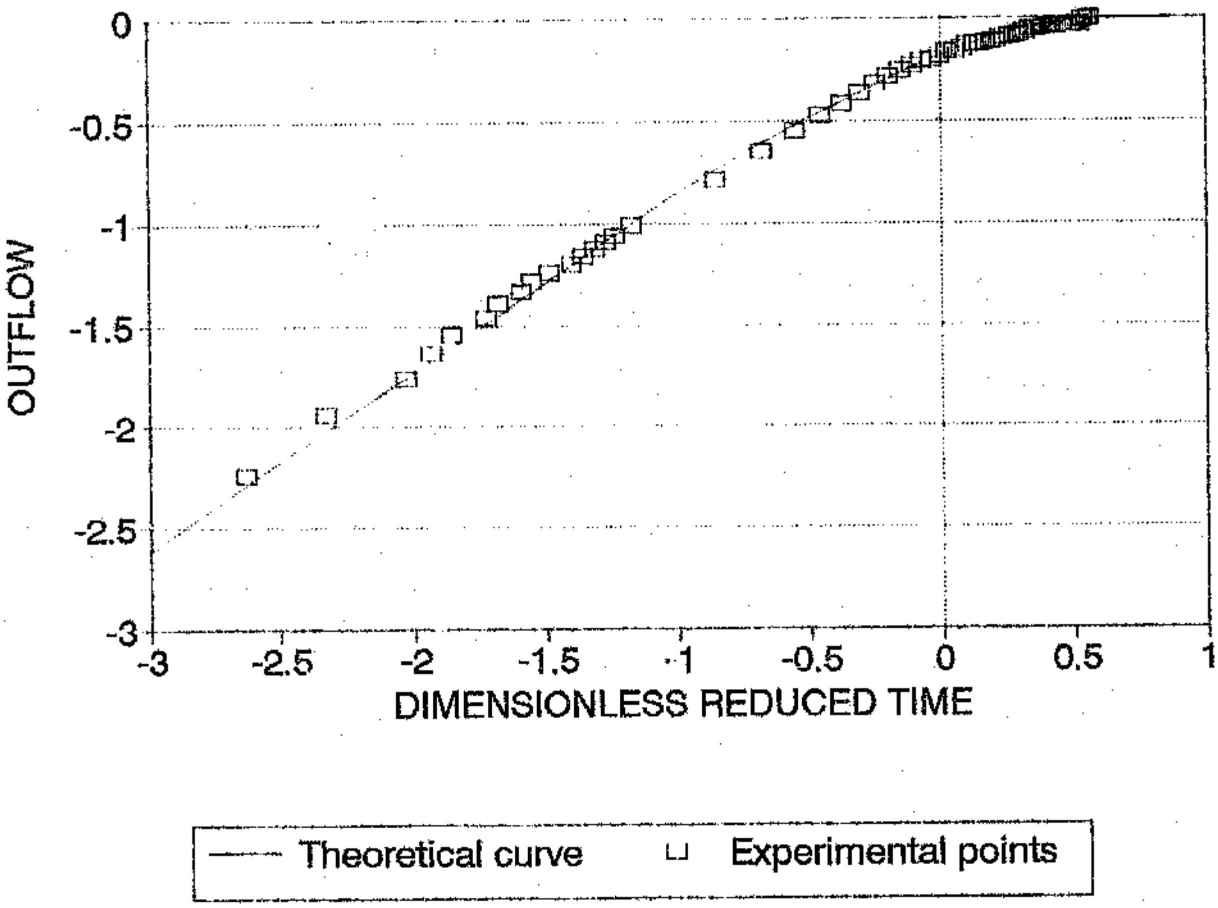


OUTFLOW AT 200 kPa
FLOW (log cm ^3)
TIME (log min)
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5
2
2.5
3
3.5
Experimental points
Linear regression

CLAY TEST: (T APPLIED AIR PRESSURE 204 kPa

TIME	THEORETICAL Qo/Qt	EXPERIMENTAL Qt	LOG TIME	LOG Qo/Qt	LOG Qt	ADJUSTED Qt	ADJUSTED TIME
0.001	0.00320731589		-3	-2.490376			-3
0.1	0.14090304531		-1	-0.850987			-1
0.2	0.20528524486		-0.69897	-0.628441			-0.69897
0.3	0.31287470528		-0.522879	-0.504607			-0.5228787
0.4	0.37054463004		-0.39794	-0.431284			-0.39794
0.5	0.43958326792		-0.30103	-0.357018			-0.30103
0.6	0.49312861137		-0.221849	-0.307041			-0.2218487
0.7	0.54146076859		-0.154902	-0.266423			-0.154902
0.8	0.58573418876		-0.09691	-0.232246			-0.09691
0.9	0.62462850075		-0.045757	-0.204376			-0.0457575
1	0.66006615217		0	-0.180222			0
1.1	0.69297782195		0.0413927	-0.159468			0.0413927
1.2	0.72164970266		0.0791812	-0.141505			0.0791812
1.3	0.74435187005		0.1139434	-0.128273			0.1139434
1.4	0.77233188856		0.146128	-0.112196			0.146128
1.5	0.79349073693		0.1760913	-0.100461			0.1760913
1.6	0.81580041652		0.20412	-0.088508			0.20412
1.7	0.83453936777		0.2304489	-0.080822			0.2304489
1.8	0.84733954246		0.2552725	-0.071917			0.2552725
1.9	0.86181234632		0.2787536	-0.064537			0.2787536
2	0.87509312642		0.30103	-0.057968			0.30103
2.1	0.88684739387		0.3222193	-0.052104			0.3222193
2.2	0.89770216323		0.3424227	-0.046863			0.3424227
2.3	0.90745307903		0.3617278	-0.042163			0.3617278
2.4	0.91634[illegible]		0.3802112	-0.037938			0.3802112
2.5	0.92421[illegible]		0.39794	-0.034227			0.39794
2.6	0.93142770[illegible]		0.4149733	-0.030861			0.4149733
2.7	0.93795321890		0.43136	-0.027816			0.4313638
2.8	0.94386776085		0.44716	-0.025093			0.4471580
2.9	0.94920039224		0.462398	-0.022612			0.462398
3	0.95403441407		0.4771213	-0.020436			0.4771213
10	1		1	0			1
1		0.04416	0		-1.381074	-1.2405482	-2.05
2		[illegible]	0.30103		-1.489044	-1.4306143	-2.32887
4		[illegible]	0.60206		-1.400965	-1.763485	-2.02794
5			0.69897		-1.276014	-1.6364623	-1.93103
6			0.778151		-1.183106	-1.6416762	-1.8516407
8			[illegible]		-1.102923	-1.482236	-1.72691
9					-1.025979	-1.3864612	-1.6724575
11					-0.977264	-1.3374662	-1.5880279
12					-0.920022	-1.3265087	-1.5506107
14					-0.861074	-1.2408452	-1.440673
17					-0.839852	-1.1491566	-1.3400911
19		0.[illegible]79	[illegible]		[illegible]801093	-1.160266	-1.3812404
21		[illegible]	[illegible]		[illegible]797131	-1.1589084	-1.3077607
23		0.3641	[illegible]		[illegible]	-1.0844212	-1.2480723
25		0.1[illegible]	1.39[illegible]		[illegible]	-1.062456	-1.22209
27		0.22355	[illegible]		[illegible]	-1.0491094	-1.1407603
60		0.3082	1.7781513		-0.432216	-0.7903012	-0.8516407
90		0.51525	1.9542425		[illegible]	-0.6470241	-0.6757575
120		0.84426	2.0791812		[illegible]	-0.5873613	-0.5306188
150		0.7627	2.1760913		-0.117646	-0.4775213	-0.4634087
180		0.88185	2.2552725		-0.054929	-0.4144544	-0.3747275
210		0.90125	2.3222193		-0.[illegible]	-0.465466	-0.3077607
240		1.09146	2.3802112		0.0380[illegible]	-0.3264718	-0.2497888
270		1.1835	2.4313638		0.0731863	-0.2663087	-0.1986162
300		1.2624	2.4771213		0.101107	-0.249276	-0.1528787
330		1.3413	2.5185139		0.1275259	-0.2319481	-0.1114861
360		1.40705	2.5563025		0.1483025	-0.2111656	-0.0736975
390		1.4495	2.5910646		0.1609184	-0.1861566	-0.0389054
420		1.51338	2.6232493		0.1794334	-0.1794614	-0.0067507
450		1.5517	2.6532125		0.1908078	-0.1909872	0.0232125
480		1.59115	2.6812412		0.2017111	-0.1677838	0.0512412
510		1.6300	2.7075702		0.2133474	-0.1471274	0.0775702
540		1.6632	2.7323938		0.2209357	-0.1533393	0.1023938
570		1.68658	2.7558749		0.2269960	-0.1296796	0.1258749
600		1.7095	2.7781513		0.2328681	-0.1266069	0.1481513
630		1.74075	2.7993405		0.2407731	-0.1168376	0.1693405
660		1.7621	2.8195439		0.2460106	-0.1104644	0.1895439
690		1.7564	2.8388491		0.2524647	-0.1070103	0.2088490
720		1.8047	2.8573325		0.2565049	-0.1006702	0.2273325
750		1.82765	2.8750613		0.2619408	-0.0978544	0.2450613
780		1.83415	2.8920946		0.2681449	-0.0810301	0.2620946
810		1.85045	2.908485		0.2742010	-0.0852025	0.2784850
840		1.90875	2.9242793		0.2808076	-0.0707012	0.2942793
870		1.95935	2.9395193		0.292112	-0.067363	0.3095193
900		1.97775	2.9542425		0.292112	-0.0577305	0.3242425
930		1.97505	2.9684829		0.2979037	-0.0615733	0.3384829
960		1.9886	2.9822712		0.3007603	-0.0567067	0.3522712
990		2.01195	2.9956352		0.3036272	-0.0538578	0.3656352
1020		2.03025	3.0086002		0.3063575	-0.0505870	0.3786002
1050		2.06465	3.0211893		0.3148254	-0.0446466	0.3911893
1080		2.06465	3.0334238		0.3148254	-0.0446486	0.4034238
1110		2.09085	3.0453230		0.3203229	-0.0391521	0.4153230
1140		2.0777	3.0569049		0.3175920	[illegible]	0.4269049
1170		2.0777	3.0681859		0.3175920	-0.0410922	0.4381859
1200		2.09085	3.0791812		0.3203229	-0.0391521	0.4491795
1230		2.09085	3.0899051		0.3203229	-0.0391521	0.4599051
1260		2.104	3.1003705		0.3230457	-0.0364293	0.4703705
1290		2.104	3.1105897		0.3230457	-0.0364293	0.4805897
1320		2.104	3.1205739		0.3230457	-0.0364293	0.4905739
1350		2.104	3.1303338		0.3230457	-0.0364293	0.5003338
1380		2.11715	3.1398791		0.3257518	-0.0337234	0.5098791
1410		2.1303	3.1492191		0.3284406	-0.0310343	0.5192191
1440		2.14545	3.1583625		0.3315174	-0.0282010	0.5283625
1470		2.1629	3.1673173		0.3350338	-0.0209412	0.5373173
1500		2.22236	3.1760913		0.3468126	-0.0126826	0.5460913
1620		2.24065	3.1846914		0.3503219	-0.0076331	0.5546914
1680		2.2601	3.1931246		0.355[illegible]	0	0.5631246

SUPERIMPOSING OF OUTFLOW CURVES



APPENDIX 6

COMPLETE RESULTS OF THE CURVE FITTING ANALYSIS DONE ON THE MOISTURE RETENTION CURVES OF ASH TEST 1,2 & 3

ASH TEST 1

ASH TEST 1 CURVE FITTING OF MOISTURE RETENTION CURVE
SUCTION VERSUS WATER CONTENT

VAN GENUCHTEN MODEL CONSTSNTS (m =1-1/n)			
b1	b2	b3	b4
0.346009	0.12737729	0.00226848	2.901576

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED W.C.
0	0.34600914	
50	0.34575049951584	
100	0.34409496284639	
150	0.33995129001571	0.339917
200	0.3326553219765	
250	0.32214506252616	
300	0.30897602949441	
350	0.29411837356797	
400	0.2786426763129	
420	0.27249209531467	0.272665
450	0.26345807454719	
500	0.24918982917029	
550	0.23618065714449	
600	0.22455529829241	
650	0.21429708262274	
670	0.21055684059704	0.210149
700	0.20531099402007	
750	0.19746699122998	
800	0.19062629663744	
850	0.18465566209193	
900	0.17943407250058	
950	0.17485507790515	
1000	0.17082679373426	
1090	0.164720929007	0.165441
1100	0.16412049159743	
1200	0.15882058106091	
1300	0.15457307126697	
1400	0.15112371565944	0.150664
1500	0.1482881270365	

ASH TEST 1 CURVE FITTING OF MOISTURE RETENTION CURVE
SUCTION VERSUS VOLUMETRIC WATER CONTENT

VAN GENUCHTEN MODEL CONSTANTS (m = 1-1/n)			
b1	b2	b3	b4
0.367039	0.15162434	0.00217461	3.083078

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED V.C.
0	0.36703933	
50	0.366883874536	
100	0.3657307166847	
150	0.3625553982073	0.362552
200	0.3565384648684	
250	0.3473127299441	
300	0.3351127710535	
350	0.3207125812692	
400	0.3051679315708	
420	0.298867074389	0.298887
450	0.2895097193706	
500	0.2745344392322	
550	0.2607376631514	
600	0.2483500329339	
650	0.2374139056527	
670	0.2334323933911	0.233407
700	0.2278584667412	
750	0.2195562950188	
800	0.2123598487392	
850	0.2061223209466	
900	0.2007081062791	
950	0.1959970361457	
1000	0.1918851823566	
1090	0.1857198447988	0.185784
1100	0.1851184106643	
1200	0.179852186281	
1300	0.1756930379305	
1400	0.1723618797101	0.172322
1500	0.1696589357222	

ASH TEST 1 CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(1-1/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations =1000
Number of data points = 5
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 4.00000000E-0001   b 2 = 1.00000000E-0001   b 3 = 1.00000000E-0002
b 4 = 2.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 34
Number of data points = 5
Sum of squares of errors = 9.272464976E-0007
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 9.629363933E-0004

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 2.4600914E-0001 (1.394E-0003) b 2 = 1.2737729E-0001 (3.308E-0003)
b 3 = 2.2684769E-0003 (2.811E-0005) b 4 = 2.9315763E+0000 (9.600E-0002)

x = CAPILLARY PRESSURE (cm)
y = WATER CONTENT (g/g)

	x	y obs	calc	obs - calc
1	1.5000000E+0002	3.3991700E-0001	3.3995129E-0001	-3.4291190E-0005
2	4.2000000E+0002	2.7266500E-0001	2.7249209E-0001	1.7290627E-0004
3	6.7000000E+0002	2.1014900E-0001	2.1055684E-0001	-4.0783846E-0004
4	1.0900000E+0003	1.6544100E-0001	1.6472093E-0001	7.2007177E-0004
5	1.4000000E+0003	1.5066400E-0001	1.5112372E-0001	-4.5971564E-0004

ASH TEST 1 CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS VOLUMETRIC WATER CONTENT

CURVE FITTING USING LEVENBERG MARQUARDT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(1-1/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations =1000
Number of data points = 5
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 4.50000000E-0001 b 2 = 1.00000000E-0001 b 3 = 1.00000000E-0002
b 4 = 2.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 36
Number of data points = 5
Sum of squares of errors = 6.759635128E-0009
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 8.221700024E-0005

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 3.6703933E-0001 (1.070E-0004) b 2 = 1.5162434E-0001 (2.412E-0004)
b 3 = 2.1746123E-0003 (1.957E-0006) b 4 = 3.0830777E+0000 (7.953E-0003)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC WATER CONTENT (cm^3/cm^3)

	x	y obs	calc	obs - calc
1	1.5000000E+0002	3.6255200E-0001	3.6255540E-0001	-3.3988852E-0006
2	4.2000000E+0002	2.9888700E-0001	2.9886708E-0001	1.9923337E-0005
3	6.7000000E+0002	2.3340700E-0001	2.3343239E-0001	-2.5394787E-0005
4	1.0900000E+0003	1.8578400E-0001	1.8571985E-0001	6.4154824E-0005
5	1.4000000E+0003	1.7232200E-0001	1.7236188E-0001	-3.9879903E-0005

ASH TEST 2

ASH TEST 2 CURVE FITTING OF MOISTURE RETENTION CURVE
SUCTION VERSUS WATER CONTENT

VAN GENUCHTEN MODEL CONSTANTS (m = 1-1/n)			
b1	b2	b3	b4
0.3390522	0.094378831	0.001501361	3.6596739

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED W.C.
0	0.33905221	
50	0.33903368892616	
100	0.33884376903063	
150	0.33813647821575	
200	0.33645027719043	
250	0.33325790003432	0.334263
300	0.32805428773844	
350	0.32048771198096	
400	0.31037077374241	
450	0.29794753410973	0.296216
500	0.28367980142709	
550	0.26824995345871	
600	0.25239088883046	
650	0.23879463070888	
700	0.22104070141227	
750	0.20819796619458	
800	0.19570898626734	
850	0.18453188873556	0.191217
900	0.17462567220408	
950	0.16590359346323	
980	0.16119291677782	0.15411
1000	0.15825371632836	
1100	0.14669851286609	
1200	0.13600406286320	
1250	0.13137925089396	0.131875
1300	0.12867919109476	
1400	0.12283292102216	
1500	0.11826510125087	
1600	0.11462494346605	
1700	0.11169225430634	
1800	0.10930468317685	
1850	0.10808277658118	0.108911
1900	0.1073 243576287	

VAN GENUCHTEN MODEL CONSTANTS (m & n)				
b1	b2	b3	b4	b5
0.3439259	0.10817013	0.00101774	2.8440524	2.1326513

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED W.C.
0	0.34392689	
50	0.34381961476635	
100	0.34318434321497	
150	0.34152641496816	
200	0.33853826607039	
250	0.33300708233282	0.334263
300	0.32745018078844	
350	0.31909111439286	
400	0.30888956406483	
450	0.29703383470254	0.298216
500	0.28382539116044	
550	0.26964878130146	
600	0.25489247928845	
650	0.24010732228222	
700	0.22650038711658	
750	0.21186170033661	
800	0.19880233130683	
850	0.18661412839543	0.191217
900	0.17576038086608	
950	0.16607609688163	
980	0.16081806160772	0.15411
1000	0.15753741882188	
1100	0.14382046777009	
1200	0.13332910005803	
1250	0.12854882647296	0.131975
1300	0.12584394831481	
1400	0.12046138539635	
1500	0.11860708980281	
1600	0.11384031520422	
1700	0.11186195350969	
1800	0.11042782047349	
1850	0.10978742724182	0.108911
1900	0.10838356091562	

ASH TEST 2 CURVE FITTING OF MOISTURE RETENTION CURVE
SUCTION VERSUS VOLUMETRIC WATER CONTENT

VAN GENUCHTEN MODEL CONSTANTS (m = 1-1/n)			
b1	b2	b3	b4
0.4339618	0.041896508	0.001853786	2.1827637

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED V.C.
0	0.43395178	
50	0.43277637888986	
100	0.42869011778578	
150	0.42163774169388	
200	0.41168161241448	
250	0.39924430697022	0.38889
300	0.38519184146403	
350	0.37002821281443	
400	0.36432353291266	
450	0.33864898739637	0.353236
500	0.32306402098772	
550	0.30812176890334	
600	0.29388459940365	
650	0.28044640903889	
700	0.2678421224016	
750	0.25607740559627	
800	0.24512908216209	
850	0.2349596436526	0.229665
900	0.2255231901927	
950	0.21676972585411	
980	0.21182429172539	0.185156
1000	0.2086483780381	
1100	0.19410604714389	
1200	0.18152540071265	
1250	0.1747858783487	0.158562
1300	0.17059173174226	
1400	0.16103734838762	
1500	0.15264198049638	
1600	0.14522456937219	
1700	0.13863846164281	
1800	0.13276637768438	
1850	0.12982334802944	0.130936
1900	0.12748037653888	

VAN GENUCHTEN MODEL CONSTANTS (m & n)				
b1	b2	b3	b4	b5
0.3949073	0.12719445	0.001161626	3.3149536	1.6359698

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED V.C.
0	0.39490733	
50	0.39487639444294	
100	0.39458979439004	
150	0.39368903947497	
200	0.39177476699147	
250	0.3884124423507	0.38885
300	0.38321589043446	
350	0.37587898055699	
400	0.36623046341904	
450	0.3542765200432	0.353236
500	0.3402194773258	
550	0.32444583037497	
600	0.30748249640788	
650	0.28992959267344	
700	0.2723881719067	
750	0.26539111682441	
800	0.2393626874532	
850	0.22459703956044	0.229665
900	0.21120146192541	
950	0.19541398371591	
980	0.19301161891187	0.185156
1000	0.18902853564673	
1100	0.1722738089953	
1200	0.16001626730074	
1250	0.15436882409735	0.158562
1300	0.15111840355508	
1400	0.14485763824095	
1500	0.14032099708027	
1600	0.13706105243742	
1700	0.13467568059922	
1800	0.13293412144738	
1850	0.13211522585894	0.130936
1900	0.13164444403191	

ASH TEST 2 CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

RESTRICTION m = 1-1/n

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(1-1/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations =1000
Number of data points = 6
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 3.50000000E-0001 b 2 = 1.00000000E-0001 b 3 = 1.00000000E-0003
b 4 = 2.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 4
Number of data points = 6
Sum of squares of errors = 9.988347741E-0005
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 7.066946915E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 3.3905221E-0001 (9.728E-0003) b 2 = 9.4378831E-0002 (1.229E-0002)
b 3 = 1.5813609E-0003 (1.053E-0004) b 4 = 3.6586739E+0000 (5.148E-0001)

x = CAPILLARY PRESSURE (cm)
y = WATER CONTENT (g/g)

	x	y obs	calc	obs - calc
1	2.5000000E+0002	3.3425300E-0001	3.3325791E-0001	9.9509222E-0004
2	4.5000000E+0002	2.9621600E-0001	2.9794754E-0001	-1.7315362E-0003
3	8.5000000E+0002	1.9121700E-0001	1.8453189E-0001	6.6851088E-0003
4	9.8000000E+0002	1.5411000E-0001	1.6119262E-0001	-7.0826199E-0003
5	1.2600000E+0003	1.3197500E-0001	1.3137925E-0001	5.9574728E-0004
6	1.8600000E+0003	1.0891100E-0001	1.0808278E-0001	8.2822267E-0004

ASH TEST 2 CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

RESTRICTION m & n INDEPENDANT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(b5)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E 0005
Maximum number of iterations = 1000
Number of data points = 6
Total number of parameters = 5
Number of parameters to be varied = 5

Initial estimates:
b 1 = 3.50000000E-0001 b 2 = 1.00000000E 0001 b 3 = 1.00000000E-0003
b 4 = 2.00000000E+0000 b 5 = 2.00000000F 1000

Step length = 1.000000000E-0
Number of iterations = 4
Number of data points = 6
Sum of squares of errors = 7.944527767E-0005
Total number of parameters = 5
Number of parameters varied = 5
Estimated standard deviation = 6.913208046E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 3.4392589E-0001 (1.920E-0002) b 2 = 1.0617013E-0001 (1.941E-0002)
b 3 = 1.0177397E-0003 (1.320E-0003) b 4 = 2.8440524E+0000 (1.510E+0000)
b 5 = 2.1326613E+0000 (6.084E+0000)

x = CAPILLARY PRESSURE (cm)
y = WATER CONTENT (g/g)

	x	y obs	calc	obs - calc
1	2.5000000E+0002	3.3425300E-0001	3.3390798E-0001	3.4501528E-0004
2	4.5000000E+0002	2.9621600E-0001	2.9703384E-0001	-8.1783875E-0004
3	8.5000000E+0002	1.9121700E-0001	1.8661413E-0001	4.6028655E-0003
4	9.8000000E+0002	1.5411000E-0001	1.6081866E-0001	-6.7086556E-0003
5	1.2600000E+0003	1.3197500E-0001	1.2854863E-0001	3.4263719E-0003
6	1.8600000E+0003	1.0891100E-0001	1.0976243E-0001	-8.5142653E-0004

ASH TEST 2 CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS VOLUMETRIC WATER CONTET

CURVE FITTING USING LEVENBERG MARQUARDT

RESTRICTION m = 1 1/n

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(1-1/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0006
Maximum number of iterations =1000
Number of data points = 6
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 4.00000000E-0001 b 2 = 1.00000000E-0001 b 3 = 1.00000000E-0002
b 4 = 2.00000000E+0000

Step length = 1.000000000E-0003
Number of iterations = 26
Number of data points = 6
Sum of squares of errors = 1.327359474E-0003
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 2.576198240E-0002

(Not converging further)

Final set of parameters (and estimated standard deviations):

b 1 = 4.3395176E-0001 (8.891E-0002) b 2 = 4.1996508E-0002 (2.027E-0001)
b 3 = 1.8537852E-0003 (1.012E-0003) b 4 = 2.1827537E+0000 (1.570E+0000)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC WATER CONTENT (cm^3/cm^3)

	x	y obs	calc	obs - calc
1	2.5000000E+0002	3.8889000E-0001	3.9924439E-0001	-1.0354393E-0002
2	4.5000000E+0002	3.5323600E-0001	3.3854898E-0001	1.4687017E-0002
3	8.5000000E+0002	2.2966500E-0001	2.3495964E-0001	-5.2946386E-0003
4	9.8000000E+0002	1.8515600E-0001	2.1182429E-0001	-2.6668287E-0002
5	1.2600000E+0003	1.5856200E-0001	1.7478587E-0001	-1.6223874E-0002
6	1.8600000E+0003	1.3093500E-0001	1.2952334E-0001	1.4116558E-0003

ASH TEST 2 CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS VOLUMETRC WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT
RESTRICTION m & n INDEPENDANT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(b5)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E 0005
Maximum number of iterations = 100
Number of data points = 6
Total number of parameters = 5
Number of parameters to be varied = 5

Initial estimates:
b 1 = 4.00000000E-0001 b 2 = 1.00000000E-0001 b 3 = 1.00000000E-0003
b 4 = 2.00000000E+0000 b 5 = 2.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 10
Number of data points = 6
Sum of squares of errors = 1.07681383 5E-0004
Total number of parameters = 5
Number of parameters varied = 5
Estimated standard deviation = 1.037696406E-0002

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 3.9490733E-0001 (1.738E-0002) b 2 = 1.2719445E-0001 (2.?75E-0002)
b 3 = 1.1515260E-0003 (9.852E-0004) b 4 = 3.3149536E+0000 (1.632E+0000)
b 5 = 1.5359696E+0000 (3.319E+0000)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC WATER CONTENT (cm^3)

	x	y obs	calc	obs - calc
1	2.5000000E+0002	3.8889000E-0001	3.8841244E-0001	4.7756101E-0004
2	4.5000000E+0002	3.5323600E-0001	3.5427652E-0001	-1.0405153E-0003
3	6.5000000E+0002	2.2966500E-0001	2.2459703E-0001	5.0679677E-0003
4	9.8000000E+0002	1.8515600E-0001	1.9301161E-0001	-7.8556135E-0003
5	1.2600000E+0003	1.5856200E-0001	1.5436882E-0001	4.1931803E-0003
6	1.8600000E+0003	1.3093500E-0001	1.3211522E-0001	-1.1802230E-0003

ASH TEST 3

ASH TEST 3 CURVE FIITING OF MOISTURE RETENTION CURVE
SUCTION VERSUS WATER CONTENT

VAN GENUCHTEN MODEL CONSTANTS (m = 1-1/n)			
b1	b2	b3	b4
0.30932	0.046740054	0.0039881	1.77392

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED W.C
0	0.30932437	
50	0.303023297651	
100	0.289618720998	
150	0.273336632059	
200	0.256707052414	
250	0.241023307618	
280	0.232300079607	0.231245
300	0.226796553708	
350	0.214126088464	
400	0.2029247128	
450	0.193036420682	
500	0.184291928664	
550	0.176532272709	
590	0.170938638267	0.168464
600	0.16961710827	
650	0.163426124087	
700	0.157857622696	
750	0.1528261467	
800	0.148259979693	
850	0.144098855516	
900	0.140291982624	
950	0.136796391343	
1000	0.133575572783	
1080	0.128917700086	0.124326
1100	0.12783805406	
1200	0.122879152909	
1300	0.118549093275	
1400	0.114733919059	
1500	0.111345534532	
1550	0.109789193783	0.111257
1600	0.108314834843	
1700	0.105586886741	
1800	0.103117490927	
1900	0.100870690799	0.096546

ASH TEST 3 CURVE FITTING OF MOISTURE RETENTION CURVE
SUCTION VERSUS VOLUMETRIC WATER CONTENT

VAN GENUCHTEN MODLE CONSTANTS (m = 1-1/n)			
b1	b2	b3	b4
0.31542	0.12555355	0.0024836	2.60584

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED V.C.
0	0.31542011	
50	0.314912059857	
100	0.312381518942	
150	0.307008748185	
200	0.298689313247	
250	0.287937157049	
280	0.280682207633	0.280324
300	0.275641862929	
350	0.262757479704	
400	0.250070877327	
450	0.238109827606	
500	0.227158451531	
550	0.217319817653	
590	0.210244853349	0.20937
600	0.208582534976	
650	0.200872837883	
700	0.194089266173	
750	0.188123309145	
800	0.1828704929	
850	0.178235582545	
900	0.174134422071	
950	0.170493988439	
1000	0.167251585263	
1080	0.162761070472	0.158985
1100	0.161754743364	
1200	0.157304347166	
1300	0.153654000499	
1400	0.150623588573	
1500	0.148079966479	
1550	0.146958523328	0.148447
1600	0.145923455485	
1700	0.144078457337	
1800	0.142486905751	
1900	0.141103658025	0.136999

ASH TEST 3 CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(1-1/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations = 100
Number of data points = 5
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 3.00000000E-0001 b 2 = 5.00000000E-0002 b 3 = 1.00000000E-0003
b 4 = 3.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 6
Number of data points = 5
Sum of squares of errors = 4.917820975E-0005
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 7.012717715E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 3.0932437E-0001 (2.233E-0001) b 2 = 4.6740054E-0002 (1.440E-0001)
b 3 = 3.9881255E-0003 (9.724E-0003) b 4 = 1.7739201E+0000 (1.496E+0000)

x = CAPILLARY PRESSURE (cm)
y = WATER CONTENT (g/g)

	x	y obs	calc	obs - calc
1	2.8000000E+0002	2.3124600E-0001	2.3230008E-0001	-1.0550830E-0003
2	5.9000000E+0002	1.6846400E-0001	1.7093864E-0001	-2.4746418E-0003
3	1.0800000E+0003	1.2432600E-0001	1.2891770E-0001	-4.5917032E-0003
4	1.5500000E+0003	1.1125700E-0001	1.0978920E-0001	1.4678035E-0003
5	1.9000000E+0003	9.6546000E-0002	1.0087069E-0001	-4.3246933E-0003

ASH TEST 3 CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS VOLUMETRIC WATER CONTENT

CURVE FITTING USING LEVENBERG MARQUARDT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(1-1/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E 0005
Maximum number of iterations = 1000
Number of data points = 5
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 3.00000000E-0001 b 2 = 1.00000000E-0001 b 3 = 1.00000000E-0003
b 4 = 3.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 6
Number of data points = 5
Sum of squares of errors = 3.442075243E-0005
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 5.8669820182E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 3.1542011E-0001 (4.914E-0002) b 2 = 1.2555355E-0001 (2.583E-0002)
b 3 = 2.4835660E-0003 (1.148E-0003) b 4 = 2.6058379E+0000 (1.129E+0000)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC CONTENT (cm^3/cm^3)

	x	y obs	calc	obs - calc
1	2.8000000E+0002	2.8032400E-0001	2.8068221E-0001	-3.5820850E-0004
2	5.9000000E+0002	2.0937000E-0001	2.1024485E-0001	-8.7485093E-0004
3	1.0800000E+0003	1.5895800E-0001	1.6276107E-0001	-3.8030666E-0003
4	1.5500000E+0003	1.4844700E-0001	1.4695852E-0001	1.4884807E-0003
5	1.9000000E+0003	1.3699900E-0001	1.4110365E-0001	-4.1046540E-0003

APPENDIX 7

COMPLETE RESULTS OF THE CURVE FITTING ANALYSIS DONE ON THE MOISTURE RETENTION CURVES OF THE GOLD TEST

GOLD TEST CURVE FITTING OF MOISTURE RETENTION CURVE
SUCTION VERSUS WATER CONTENT

VAN GENUCHTEN MODEL CONSTANTS (m= 1-1/n)			
b1	b2	b3	b4
0.2482693	0.027495651	0.002389239	1.9692034

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED W.C.
0	0.24826988	
50	0.24683288578284	
100	0.24306237076781	
160	0.23514907622458	
190	0.2284050054396	0.22806
200	0.22659770031217	
250	0.21700321913392	
300	0.20720933004279	
330	0.2012798383172	0.20199
350	0.19737101565393	
400	0.18786147604626	
450	0.17884909345365	
500	0.17041860042731	
550	0.16259860254821	
600	0.15538195609107	
650	0.14874158171446	
660	0.14747937541301	0.14585
700	0.1426392010118	
750	0.1370393831043	
800	0.13107763038730	
850	0.12719321250318	
900	0.12276021881688	
950	0.1187326549871	
960	0.11785246959791	0.11831
1000	0.11498795356259	
1100	0.10831291679081	
1200	0.10253573171998	
1200	0.090462556251910	0.09393
1300	0.097407583841325	
1400	0.093072210988569	
1500	0.089158811031247	
1510	0.0887923[illegible]396	0.08714
1600	0.0858[illegible]30014	

VAN GENUCHTEN MODEL CONSTANTS [illegible]				
b1	b2	b3	b4	b5
0.2293101	0.13479606	0.004062172	8.2720693	0.024227

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED W.C.
0	0.22931006	
50	0.22931003889442	
100	0.22930353750671	
160	0.22912491508321	
190	0.22806400357674	0.22806
200	0.22745868882795	
250	0.2208542301858	
300	0.20925809417104	
330	0.20193920338743	0.20199
350	0.19715282181169	
400	0.1861046882773	
450	0.17639830197705	
500	0.16784342770402	
550	0.16024048579551	
600	0.15341780368287	
650	0.14724301185027	
660	0.14607622407723	0.14585
700	0.14161233608438	
750	0.13644436260274	
800	0.13137402310012	
850	0.12724862515764	
900	0.12312526347907	
950	0.11926802263436	
960	0.11852579834124	0.11831
1000	0.11564708691585	
1100	0.10901688748296	
1200	0.10307366211761	
1200	0.090731705365028	0.09393
1300	0.0976[illegible]3265332	
1400	0.092795377516516	
1600	0.088297043950474	
1510	0.087867094798654	0.08714
1600	0.084145070120334	

GOLD TEST CURVE FITTING OF MOISTURE RETENTION CURVE
SUCTION VERSUS VOLUMETRIC WATER CONTENT

VAN GENUCHTEN MODEL CONSTANTS (m = 1 - 1/n)			
b1	b2	b3	b4
0.4011396	0.08525574	0.00221021	2.1080856

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED V.C.
0	0.4011396	
50	0.39945498355008	
100	0.3…04330837728	
150	0.38510246187804	
180	0.37586981457073	0.37513
200	0.3733107701[illegible]	
250	0.35850133027578	
300	0.34454005886748	
330	0.33532458260193	0.33693
350	0.32916513348225	
400	0.31383850012065	
450	0.29924942152452	
500	0.28553154234625	
550	0.27230804868341	
600	0.26030082020768	
650	0.24807414740694	
660	0.24695259818126	0.243989
700	0.23881603490796	
750	0.22939244877374	
800	0.22074260572943	
850	0.21279986072285	
900	0.20560018456449	
950	0.19878321858182	
980	0.19760470183835	0.19376
1000	0.19259313834345	
1100	0.18169484725814	
1200	0.17215580052739	
1280	0.16553576676765	0.16821
1300	0.16398419483562	
1400	0.15688823493039	
1500	0.15006294603691	
1510	0.15007194781139	0.14722
1600	0.14516118422038	

VAN GENUCHTEN MODEL CONSTANTS (m & n)				
b1	b2	b3	b4	b5
0.3758591	0.38648602	0.003916377	10.160719	0.0195948

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED V.C.
0	0.37585911	
50	0.37585910805642	
100	0.37585802644972	
150	0.37579234541267	
180	0.37613712887263	0.37513
200	0.374082672054	
250	0.34707410880188	
300	0.34920422040206	
330	0.33687348514084	0.33698
350	0.3268836611622	
400	0.31060530033497	
450	0.29443774320098	
500	0.28032144210233	
550	0.26778850028404	
600	0.25554812054112	
650	0.24627893881826	
660	0.24446612778116	0.243989
700	0.23710279430307	
750	0.22850074363897	
800	0.22073326517928	
850	0.21344390113006	
900	0.20666135483474	
950	0.20029694177824	
980	0.19907416167238	0.19376
1000	0.19433147683846	
1100	0.18340733602698	
1200	0.17361393580209	
1280	0.1684587731149	0.16821
1300	0.16476353858985	
1400	0.15687510219974	
1500	0.14928070778987	
1510	0.14855200983781	0.14722
1600	0.14241660036477	

GOLD TEST CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

RESTRICTION (m = 1-1/n)

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(1-1/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations =1000
Number of data points = 6
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 3.00000000E-0001 b 2 = 5.00000000E-0002 b 3 = 1.00000000E-0002
b 4 = 2.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 56
Number of data points = 6
Sum of squares of errors = 7.667640334E-0006
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 1.958014343E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 2.4826988E-0001 (8.023E-0003) b 2 = 2.7495691E-0002 (2.463E-0002)
b 3 = 2.3802387E-0003 (2.428E-0004) b 4 = 1.9692034E+0000 (2.497E-0001)

x = CAPILLARY PRESSURE (cm)
y = WATER CONTENT (g/g)

	x	y obs	calc	obs - calc
1	1.9000000E+0002	2.2806000E-0001	2.2840500E-0001	-3.4500172E-0004
2	3.3000000E+0002	2.0199000E-0001	2.0127984E-0001	7.1016429E-0004
3	6.6000000E+0002	1.4585000E-0001	1.4747938E-0001	-1.6293757E-0003
4	9.6000000E+0002	1.1831000E-0001	1.1795247E-0001	3.5752872E-0004
5	1.2800000E+0003	9.9690000E-0002	9.8452559E-0002	1.2374414E-0003
6	1.5100000E+0003	8.7140000E-0002	8.8792370E-0002	-1.6523702E-0003

GOLD TEST CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

RESTRICTION m & n INDEPENDANT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(b5)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations = 1000
Number of data points = 6
Total number of parameters = 5
Number of parameters to be varied = 5

Initial estimates:
b 1 = 6.00000000E-0001   b 2 = 1.00000000E-0001   b 3 = 1.00000000E-0002
b 4 = 2.00000000E+0000   b 5 = 5.00000000E-0002

Step length = 1.000000000E-0005
Number of iterations = 538
Number of data points = 6
Sum of squares of errors = 1.547340531E-0006
Total number of parameters = 5
Number of parameters varied = 5
Estimated standard deviation = 1.243921433E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 2.2931006E-0001 (1.378E-0002)   b 2 = -2.3479506E-0001 (4.387E-0001)
b 3 = 4.0621724E-0003 (3.022E-0004)   b 4 = 8.2720693E+0000 (3.053E+0001)
b 5 = 2.4226987E-0002 (1.189E-0001)

x = CAPILLARY PRESSURE (cm)
y = WATER CONTENT (g/g)

	x	y obs	y calc	obs - calc
1	1.9000000E+0002	2.2806000E-0001	2.2806410E-0001	-4.0976353E-0006
2	3.3000000E+0002	2.0199000E-0001	2.0193921E-0001	5.0792048E-0005
3	6.6000000E+0002	1.4585000E-0001	1.4607623E-0001	-2.2622833E-0004
4	9.6000000E+0002	1.1831000E-0001	1.1852580E-0001	-2.1590343E-0004
5	1.2600000E+0003	9.9690000E-0002	9.8731709E-0002	9.5829056E-0004
6	1.5100000E+0003	8.7140000E-0002	8.7867099E-0002	-7.2709872E-0004

GOLD TEST CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS VOLUMETRIC WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

RESTRICTION m = 1-1/n

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(1-1/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations =1000
Number of data points = 6
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 4.00000000E-0001   b 2 = 1.00000000E-0001   b 3 = 1.00000000E-0002
b 4 = 2.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 40
Number of data points = 6
Sum of squares of errors = 2.8916436617E-0005
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 3.802396361E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 4.0113960E-0001 (1.260E-0002)   b 2 = 6.5255740E-0002 (3.783E-0002)
b 3 = 2.2102104E-0003 (2.088E-0004)   b 4 = 2.1088856E+0000 (2.961E-0001)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC WATER CONTENT (cm^3/cm^3)

	x	y obs	calc	obs - calc
1	1.9000000E+0002	3.7513000E-0001	3.7585982E-0001	-7.2981790E-0004
2	3.3000000E+0002	3.3698000E-0001	3.3532459E-0001	1.6554126E-0003
3	6.6000000E+0002	2.4398900E-0001	2.4695254E-0001	-2.9635427E-0003
4	9.6000000E+0002	1.9876000E-0001	1.9750476E-0001	1.2552436E-0003
5	1.2800000E+0003	1.6821000E-0001	1.6553576E-0001	2.6742399E-0003
6	1.5100000E+0003	1.4722000E-0001	1.5007195E-0001	-2.8519521E-0003

GOLD TEST CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS VOLUMETRIC WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

RESTRICTION m & n INDEPENDANT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(b5)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations = 1000
Number of data points = 6
Total number of parameters = 5
Number of parameters to be varied = 5

Initial estimates:
b 1 = 4.00000000E-0001 b 2 = 1.00000000E-0001 b 3 = 1.00000000E-0002
b 4 = 2.00000000E+0000 b 5 = 1.00000000E-0001

Step length = 1.000000000E-0005
Number of iterations = 478
Number of data points = 6
Sum of squares of errors = 5.1684114 71E-0006
Total number of parameters = 5
Number of parameters varied = 5
Estimated standard deviation = 2.2734140 56E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 3.7585911E-0001 (1.508E-0002) b 2 = -3.8648802E-0001 (7.974E-0001)
b 3 = 3.9163774E-0003 (4.868E-0004) b 4 = 1.0166719E+0001 (5.541E+0001)
b 5 = 1.9594831E-0002 (1.323E-0001)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC WATER CONTENT (cm^3/cm^3)

	x	y obs	calc	obs - calc
1	1.9000000E+0002	3.7513000E-0001	3.7513712E-0001	-7.1246096E-0006
2	3.3000000E+0002	3.3698000E-0001	3.3687348E-0001	1.0651718E-0004
3	6.6000000E+0002	2.4398900E-0001	2.4445512E-0001	-4.6612288E-0004
4	9.6000000E+0002	1.9876000E-0001	1.9907416E-0001	-3.1415567E-0004
5	1.2800000E+0003	1.6821000E-0001	1.6645877E-0001	1.7512336E-0003
6	1.5100000E+0003	1.4722000E-0001	1.4855200E-0001	-1.3320028E-0003

APPENDIX 8

COMPLETE RESULTS OF THE CURVE FITTING ANALYSIS DONE ON THE MOISTURE RETENTION CURVES & COEFFICIENTS OF HYDRAULIC CONDUCTIVITY OF THE CLAY TEST

CLAY TEST CURVE FITTING OF MOISTURE RETENTION CURVE
SUCTION VERSUS WATER CONTENT

VAN GENUCHTEN MODEL CONSTSNTS (m= 1-1/n)			
b1	b2	b3	b4
0.8481747	0.21934058	0.12694284	1.4586368

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED W.C.
0	0.84817467	
50	0.48510382462011	
100	0.41658540778804	
130	0.39385268839062	0.394053
160	0.38297668187134	
200	0.36504238065766	
250	0.3492230749614	
300	0.3389047575456	
340	0.33229239458829	0.330367
350	0.33081317205803	
400	0.32424248829066	
450	0.31876571713463	
500	0.31410724382609	
540	0.31084194647023	0.311438
550	0.31008007126754	
600	0.3066522113158	
650	0.30342746661404	
680	0.30171636604722	0.304456
700	0.30063378426391	
750	0.2981160498325	
800	0.29583121082762	
850	0.29374610730561	
900	0.2918302318888	
950	0.29006414763434	
1000	0.28842834542576	
1020	0.28780695989375	0.285779
1100	0.28548833509805	
1200	0.28291344182731	
1300	0.28063319122668	
1350	0.2795865484983	0.27969
1400	0.27859485702084	
1500	0.2767580899339	

VAN GENUCHTEN MODEL CONSTSNTS (m & n)				
b1	b2	b3	b4	b5
0.8007639	0.21769154	0.11254819	2.9904254	0.1490336

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED W.C.
0	0.80078392	
50	0.48745078105292	
100	0.41590872196681	
130	0.39404362680583	0.394053
160	0.38316048914432	
200	0.36324202600884	
250	0.34946528897251	
300	0.33918172621576	
340	0.33259046162328	0.330367
350	0.33111665729164	
400	0.32456263896587	
450	0.3190974251102	
500	0.3144458847713	
540	0.31118362329784	0.311438
550	0.31042200217011	
600	0.30689498721573	
650	0.30376891768613	
680	0.30205627893708	0.304456
700	0.30097239830017	
750	0.29845063612279	
800	0.29616083459121	
850	0.29406907649133	
900	0.29214800830107	
950	0.29037532672856	
1000	0.28873281781196	
1020	0.28810840305711	0.285779
1100	0.28577818270464	
1200	0.28318841173294	
1300	0.28089313003708	
1350	0.27983897777285	0.27969
1400	0.2788398060666	
1500	0.27698821208422	

CLAY TEST CURVE FITTING OF MOISTURE RETENTION CURVE
SUCTION VERSUS VOLUMETRIC WATER CONTENT

VAN GENUCHTEN MODEL CONSTANTS (m= 1-1/n)			
b1	b2	b3	b4
1.7629932	0.41824627	0.066236507	2.4788916

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED V.C.
0	1.7629932	
50	0.63866200071278	
100	0.48927256238707	
130	0.47335729698538	0.473879
150	0.46288304782733	
200	0.44744432867919	
250	0.43924565677665	
300	0.43428565502178	
340	0.43157641182183	0.426382
350	0.43101723547659	
400	0.42872923803776	
450	0.42705370726805	
500	0.42576308401326	
540	0.42497234982764	0.42937
550	0.42476220301420	
600	0.42400183440895	
650	0.42336940972298	
680	0.42302035872902	0.429701
700	0.42282864527698	
750	0.42238415401764	
800	0.42200747025857	
850	0.42168492100585	
900	0.42140861878287	
950	0.42116335270081	
1000	0.42095024838867	
1020	0.42087220525871	0.419006
1100	0.42059474234465	
1200	0.42031116370487	
1300	0.42008033495489	
1350	0.41998105516761	0.416667
1400	0.41989020848447	
1500	0.41973073768403	

VAN GENUCHTEN MODEL CONSTANTS (m & n)				
b1	b2	b3	b4	b5
0.6381251	0.41819615	0.019682972	7.6501975	0.1922447

SUCTION cm	VAN GENUCHTEN MODEL	MEASURED V.C.
0	0.63812513	
50	0.61302904262464	
100	0.49046754396741	
130	0.47330187211908	0.473879
150	0.45300968849447	
200	0.4475500767614	
250	0.43923858116857	
300	0.43438587380565	
340	0.43164726557208	0.426382
350	0.43108566624388	
400	0.42878750636069	
450	0.42710298735849	
500	0.42582444580654	
540	0.42500809026089	0.42937
550	0.424828720406	
600	0.42403026354183	
650	0.42338235763187	
680	0.42304937604693	0.429701
700	0.42284682043085	
750	0.42239807553954	
800	0.42201758281097	
850	0.42169160724763	
900	0.4214097787341	
950	0.42116413580456	
1000	0.42094847492421	
1020	0.42088472244298	0.419006
1100	0.42058849091005	
1200	0.42030112553602	
1300	0.4200873680422	
1350	0.41998632831816	0.416667
1400	0.41987413370738	
1500	0.41971222444634	

CLAY TEST CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS
WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

RESTRICTION m = 1 - 1/n

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(1-1/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations = 1000
Number of data points = 6
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 8.00000000E-0001 b 2 = 2.00000000E-0001 b 3 = 1.00000000E-0001
b 4 = 2.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 86
Number of data points = 6
Sum of squares of errors = 1.573695590E-0005
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 2.805080738E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 8.4817467E-0001 (1.234E+0001) b 2 = 2.1934058E-0001 (8.829E-0002)
b 3 = 1.2594264E-0001 (5.823E+0000) b 4 = 1.4566368E+0000 (5.408E-0001)

x = CAPILLARY PRESSURE (cm)
y = WATER CONTENT (g/g)

	x	y obs	calc	obs - calc
1	1.3000000E+0002	3.9405300E-0001	3.9385270E-0001	2.0029655E-0004
2	3.4000000E+0002	3.3036700E-0001	3.3229241E-0001	-1.9254071E-0003
3	5.4000000E+0002	3.1143800E-0001	3.1084196E-0001	5.9604345E-0004
4	6.8000000E+0002	3.0445600E-0001	3.0171538E-0001	2.7406236E-0003
5	1.0200000E+0003	2.8577900E-0001	2.8780697E-0001	-2.0279692E-0003
6	1.3500000E+0003	2.7969000E-0001	2.7958656E-0001	1.0344313E-0004

CLAY TEST CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS WATER CONTENT

CURVE FITTING USING LEVENBERG MARQUARDT

RESTRICTION m & n INDEPENDANT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(b5)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations = 1000
Number of data points = 6
Total number of parameters = 5
Number of parameters to be varied = 5

Initial estimates:
b 1 = 8.00000000E-0001 b 2 = 2.00000000E-0001 b 3 = 1.00000000E-0001
b 4 = 2.00000000E+0000 b 5 = 1.00000000E-0001

Step length = 1.000000000E-0005
Number of iterations = 32
Number of data points = 6
Sum of squares of errors = 1.622040887E-0005
Total number of parameters = 5
Number of parameters varied = 5
Estimated standard deviation = 4.027456874E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 8.0078392E-0001 (3.001E+0004) b 2 = 2.1769154E-0001 (1.942E-0001)
b 3 = 1.1254819E-0001 (1.299E+0004) b 4 = 2.9904254E+0000 (1.210E+0005)
b 5 = 1.4903367E-0001 (6.030E+0003)

x = CAPILLARY PRESSURE (cm)
y = WATER CONTENT (g/g)

	x	y obs	calc	obs - calc
1	1.3000000E+0002	3.9405300E-0001	3.9404363E-0001	9.3702521E-0006
2	3.4000000E+0002	3.3036700E-0001	3.3259046E-0001	-2.2234647E-0003
3	5.4000000E+0002	3.1143800E-0001	3.1118353E-0001	2.5447399E-0004
4	6.8000000E+0002	3.0445600E-0001	3.0205528E-0001	2.4007175E-0003
5	1.0200000E+0003	2.8577900E-0001	2.8810841E-0001	-2.3294053E-0003
6	1.3500000E+0003	2.7969000E-0001	2.7983898E-0001	-1.4897987E-0004

CLAY TEST CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS VOLUMETRIC WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

RESTRICTION m = 1-1/n

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(1-1/b4)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations = 1000
Number of data points = 6
Total number of parameters = 4
Number of parameters to be varied = 4

Initial estimates:
b 1 = 1.00000000E+0000 b 2 = 3.00000000E-0001 b 3 = 2.00000000E-0002
b 4 = 2.00000000E+0000

Step length = 1.000000000E-0005
Number of iterations = 68
Number of data points = 6
Sum of squares of errors = 1.131980481E-0004
Total number of parameters = 4
Number of parameters varied = 4
Estimated standard deviation = 7.523232288E-0003

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 1.7529932E+0000 (1.368E+0003) b 2 = 4.1824627E-0001 (1.947E-0002)
b 3 = 6.6236507E-0002 (4.662E+0001) b 4 = 2.4789916E+0000 (5.474E+0000)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC WATER CONTNET (cm^3/cm^3)

	x	y obs	calc	obs - calc
1	1.3000000E+0002	4.7387900E-0001	4.7335729E-0001	5.2170866E-0004
2	3.4000000E+0002	4.2638200E-0001	4.3157642E-0001	-5.1944158E-0003
3	5.4000000E+0002	4.2937000E-0001	4.24972[illegible]5E-0001	4.3976528E-0003
4	6.8000000E+0002	4.2970100E-0001	4.2302936E-0001	6.6716439E-0003
5	1.0200000E+0003	4.1900600E-0001	4.2087220E-0001	-1.8662025E-0003
6	1.3500000E+0003	4.1566700E-0001	4.1998105E-0001	-4.3140489E-0003

CLAY TEST CURVE FITTING ANALYSIS RESULTS SUCTION VERSUS VOLUMETRIC WATER CONTENT

CURVE FITTING USING LEVENBERG-MARQUARDT

RESTRICTION m & n INDEPENDANT

FUNCTION:
(b1-b2)*((1+(b3*x)^b4)^(-(b5)))+b2

Factor for calculating derivatives = 1.000E-0009
Starting value for step length = 1.000E-0001
Smallest value for step length = 1.000E-0005
Maximum number of iterations = 1000
Number of data points = 6
Total number of parameters = 5
Number of parameters to be varied = 5

Initial estimates:
b 1 = 6.23415746E-0001 b 2 = 4.17849841E-0001 b 3 = 1.96230915E-0002
b 4 = 7.31365730E+0000 b 5 = 1.92648511E-0001

Step length = 1.000000000E-0005
Number of iterations = 4
Number of data points = 6
Sum of squares of errors = 1.130924857E-0004
Total number of parameters = 5
Number of parameters varied = 5
Estimated standard deviation = 1.063449508E-0002

Minimum obtained - normal termination

Final set of parameters (and estimated standard deviations):

b 1 = 6.3812513E-0001 (6.472E+0004) b 2 = 4.1819615E-0001 (2.576E-0002)
b 3 = 1.9662972E-0002 (3.934E+0003) b 4 = 7.6501975E+0000 (1.446E+0006)
b 5 = 1.9224471E-0001 (3.634E+0004)

x = CAPILLARY PRESSURE (cm)
y = VOLUMETRIC WATER CONTENT (cm^3/cm^3)

	x	y obs	calc	obs - calc
1	1.3000000E+0002	4.7387900E-0001	4.7350167E-0001	3.7733189E-0004
2	3.4000000E+0002	4.2638200E-0001	4.3164726E-0001	-5.2652626E-0003
3	5.4000000E+0002	4.2937000E-0001	4.2500809E-0001	4.3619117E-0003
4	6.8000000E+0002	4.2970100E-0001	4.2304937E-0001	6.6516265E-0003
5	1.0200000E+0003	4.1900600E-0001	4.2086947E-0001	-1.8634701E-0003
6	1.3500000E+0003	4.1566700E-0001	4.1996632E-0001	-4.2993241E-0003

CLAY TEST CURVE FITTING OF COEFFICIENT OF HYDRAULIC
CONDUCTIVITY CURVE VERSUS VOLUMETRIC WATER CONTENT

VAN GENUCHTEN MODEL (m = 1-1/n)				
b1	b2	b3	b4	b5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

V.C (cm^3/cm^3)	CALCULATED C.H.C. (cm/year)	MEASURED C.H.C. (cm/year)
0.3	1.0131056552152E-16	
0.305	2.1901449495151E-14	
0.31	3.0005180491727E-12	
0.315	1.4230134313761E-10	
0.32	2.3426302420434E-09	
0.325	2.0946896187544E-08	
0.33	1.3783896780388E-07	
0.335	6.9938342911926E-07	
0.34	2.9184604254295E-06	
0.345	1.04467553821E-05	
0.35	3.1037077338445E-05	
0.355	9.4333347247146E-05	
0.36	0.000247506246171	
0.365	0.000600371116003897	
0.37	0.00138933118190359	
0.375	0.00300170308569624	
0.38	0.00520998353650 6	
0.385	0.0123088169913424	
0.39	0.0234912286853344	
0.395	0.0433216856648526	
0.4	0.077441638468341	
0.404608	0.1289881141 8915	0.07820928
0.405	0.13454454373133	
0.41	0.22769232251603	
0.415	0.376044097 45873	
0.416667	0.40136817344627	0.06108632
0.419003	0.552889079534	0.3160216
0.42	0.60704911921082	
0.425	0.9591369651578	
0.428382	1.0844338590698	3.0999688
0.429701	1.4473034734176	0.1135298
0.43	1.4847979813987	
0.435	2.2541316808983	
0.44	3.3582402027802	
0.445	4.9123584057278	
0.45	7.0578141476826	
0.455	9.9819422711844	
0.46	13.914760739541	
0.465	19.821000255575	
0.47	26.186402901082	
0.473870	31.180000353305	31.22064
0.475	33.097018645143	
0.48	42.691768590935	
0.485	54.029396778943	
0.49	67.0531788776 43	
0.495	81.6560104577 87	
0.5	97.174091285792	
0.505	1 3.0594649301 3	
0.51	120.43212861128	
0.515	144.632290816	
0.52	158.21235658719	
0.525	159.6479891449	
0.53	178.24498337234	
0.535	184.21468397481	
0.54	187.09064609681	

REFERENCES

Bear, J. (1972) *Dynamics of fluids in porous media*, New York: American Elsevier Publishing Company.

Bumb, A.C., Murphy, C.L., Everett, L.G. (1992) A comparison of three functional forms for representing soil moisture characteristics, *Ground Water*, vol. 32, no. 2, pp. 177-185.

Cernica, J.N. (1982) *Geotechnical Engineering*. New York: College Publishing.

Corey, D., Coleman, J.D. (1961) Pore pressure and suction in soil, *Pore Pressure and Suction in Soils*, London, Butterworths, pp. 31-37.

El-Kadi, A.I. (1984) *Automatived estimation of the parameters of soil hydraulic properties*, USA: Indiana, International Ground Water Modeling Center.

Gardner, W.R. (1956) Calculation of capillary conductivity from pressure plate outflow data, *Proceedings of Soil Science Society of America*, vol. 20, pp. 317-320.

Kunze, R.J., Kirkham, D. (1962) Simplified accounting for membrane impedance in capillary conductivity determination, *Proceedings of Soil Science Society of America*, vol. 26, pp. 421-426.

Lorentz, S.A., Durnford, D.S., Corey, A.T. (1992) Liquid retention measurement on porous media using a controlled outflow cell, *Draft copy*.

Miller, E.E., Elrick, D.E. (1958) Dynamic determination of capillary conductivity extended for non-negligible membrane impedance, *Proceedings of Soil Science Society of America*, vol. 22, no. 6, pp. 483-486.

Richards, B.G. (1965) Determination of the unsaturated permeability and diffusivity functions from pressure plate outflow data with non-negligible membrane impedance, *Moisture equilibria and moisture changes in soil beneath covered areas, A symposium in print*, Aitchison, G.D. Editor, pp. 47-54.

Ritjema, P.E. (1959) Calculation of capillary conductivity from pressure plate outflow data with non-negligible membrane impedance, *Netherlands Agricultural Society Journal*, vol. 7, pp. 209-215.

van Genuchten, M.Th., Leij, F.J., Yates, S.R. (1992) *The RETC Code for quantifying the hydraulic function of unsaturated soils*, USA: Enviromental Protection Agency, Robert s. Kern Enviromental Research Laboratory.

BIBLIOGRAPHY

Ahuja, L.R. (1975) A one-step wetting procedure for determining both water characteristics and hydraulic conductivity of a soil core, *Proceedings, Soil Science Society of America*, vol. 39, pp. 418-423.

Ahuja, L.R. (1974) Unsaturated hydraulic conductivity from cumulative inflow data, *Proceedings, Soil Science Society of America*, vol. 38, no. 5, pp. 695-699.

Al-Khafaji, A.W., Andersland, O.B. (1992) *Geotechnical Engineering and Soil Testing*, USA : Saunders College Publishing.

Bear, J., Verrujh, A. (1987) *Modelling ground water flow and pollution*, Netherlands: D. Reidel Publishing Company.

Bishop, A.W., Henkel, D.J. (1972) *The measurement of soil properties in the triaxial test*, 2nd ed. Great Britain: Edward Arnold Publishers.

Bower, H. (1964) Unsaturated flow in ground-water hydraulics, *Hydraulics Division Proceedings of American Society of Civil Engineering Journal* , vol. 90, HY5, pp. 121-144.

Bowles, J.E. (1986) *Engineering properties of the soils and their measurement*, 3rd. ed. Singapore: McGraw-Hill Book Company.

Bresler, E., Russo, D., Miller, R.D. (1978) Rapid estimate of unsaturated hydraulic conductivity function, *Soil Science Society of America Journal*, vol. 42, pp. 170-172.

Clapp, R.B., Hornberger, G.M. (1978) Empirical equations for some soil hydraulic properties, *Water Resources Research*, vol. 14, no. 4, pp. 601-604.

Das, B.M. (1983) *Advanced soil mechanics*, USA: Hemisphere Publishing Incorporated.

Edit, T.B., Mortan, S.E. (1984) Laboratory evaluation of soil suction components, *Geotechnical Testing Journal*, vol. 7, no. 4, pp. 173-181.

Kaluarachchi, J.J., Parker, J.J. (1987) Effects of hysteresis with air entrapment on water flow in the unsaturated zone, *Water Resources Research*, vol. 23, no. 10, pp.1967-1976.

Kool, J.B., Parker, J.C. (1987) Development and evaluation of close-form expressions for hysteretic soil hydraulic properties, *Water Resources Research*, vol. 25, no. 1, pp. 105-114.

Lam, L., Fredlund, D.G., Barbour, S.L. (1987) Transient seepage model for saturated -unsaturated soil systems; a Geotechnical engineering approach, *Canadian Geotechnical Journal*, vol. 24, pp. 565-580.

Mualem, Y. (1976) A new model for predicting the hydraulic conductivity of unsaturated porous media, *Water Resources Research*, vol. 12, no. 3, pp. 513-522.

Schuh, W.M., Bauder, J.W., Gupta, S.C. (1984) Evaluation of simplified methods for determining unsaturated hydraulic conductivity of layered soils, *Soil Science Society of America Journal*, vol. 48, pp. 730-736.

Sills, G.C., Hoarse, S.D.L., Baker, N. (1986) An experimental assessment of the restricted flow consolidation test, *American Society for Testing and Materials*, pp. 203-216.

van Genuchten, M.Th. (1980) A closed-form equation for predicting the hydraulic conductivity of unsaturated soils, *Soil Science Society of America Journal*, vol. 44 pp. 892-898.

Wipplinger, O. (1990) Soil Moisture flow theory, *Die Siviele Ingenieur in Suid-Afrika*, March, pp. 91-101.

Wosten, J.H.M., van Genuchten, M.Th. (1988) Using texture and other soil properties to predict the unsaturated soil hydraulic function, *Soil Science Society of America Journal*, vol. 52, pp. 1762-1770.