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# Non-Newtonian loss coefficients for Saunders diaphragm valves

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# NON-NEWTONIAN LOSS COEFFICIENTS FOR SAUNDERS DIAPHRAGM VALVES

**by**

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## ABSTRACT

The prediction of the energy losses when designing pipeline and pumping systems requires accurate loss coefficient data. But the loss coefficient data found in the open literature was not adequate for predicting the loss coefficient for Saunders straight-through diaphragm valves.

As more accurate loss coefficient data to enable more efficient pipeline designs are scarce in the open literature, it is problematic to predict the head loss due to the pipeline fittings, and particularly for diaphragm valves. Most of the data given in the literature are for turbulent flow based on water. Due to water shortages mining operations are forced to increase their solids concentrations and to operate in laminar flow (Slatter, 2002). Consequently there is a need to determine loss coefficient data in laminar flow for valves used in these industries to ensure energy efficient designs (Pienaar et al., 2001; 2004) or if needed, to derive a new correlation to predict losses through Saunders diaphragm valves.

However, a systematic study of various sizes of diaphragm valves of different manufacturers to ascertain, if the same loss coefficient can be applied, has never been done. Therefore a comparison will be made between the data produced in this work and the existing correlations.

The objective of this research was to determine loss coefficient data in laminar, transitional and turbulent flow for the Saunders type straight-through diaphragm valves ranging from 40 mm to 100 mm in the fully open, 75 %, 50 % and 25 % open positions, using a range of Newtonian and non-Newtonian fluids. The test work was conducted on the valve test rig in the Flow Process Research Centre at the Cape Peninsula University of Technology.

This work investigated only Newtonian and time independent homogeneous non-Newtonian fluids or slurries flowing through Saunders straight-through diaphragm valves in the turbulent, transitional and laminar regimes.

Weir-type Saunders valves and time-dependent fluid behaviour were not investigated in this study.

The results for each test are presented in the form of valve loss coefficient ($k_{valve}$) against Reynolds number (Re).

This thesis adds new loss coefficient data to the open literature, and a new correlation, which will be useful for designing pipelines in industries, as well as contributing to the academic debate in this discipline.

## DECLARATION

I, Aimé Mume Kabwe, hereby declare that the content of this dissertation represents my own unaided work, and that the dissertation has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

……………………… 03 / 03 / 2009

Aimé Mume Kabwe

## DEDICATION

This dissertation is dedicated to:

My father, Mr. Kabwe-Ka-Mahango Louis Rufin – for being a pillar of strength through my entire life, and for his impartation of wisdom and encouragement through the many trials that I have faced

My mother, Ms. Jacqueline Fatuma wa Kaite – for the breath and nurturing you instilled in me

My nephews and nieces – this might inspire you for your further studies

My future wife – for your incessant future kindness and love

My friends, colleagues and family – thank you for your continuous support

The Almighty God – for the victory that he gives me through the Lord Jesus Christ (1 Corinthians 15:57)

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## NOMENCLATURE

| SYMBOL | DESCRIPTION | UNITS |
|---|---|---|
| $\dot{\gamma}$ | Shear rate | $s^{-1}$ |
| $\alpha$ | Effect of partial opening and change in Reynolds number | |
| $\lambda_{\Omega}$ | Nominal turbulent loss coefficient | |
| $\theta$ | Valve opening position | |
| $\sigma$ | Standard deviation | |
| $\overline{X}$ | Population mean or average | |
| $\%C_v$ | Volumetric percentage of the slurry | |
| $\nu$ | Kinematic viscosity | $m^2/s$ |
| $\rho$ | Density of the fluid | $kg/m^3$ |
| $\mu$ | Dynamic viscosity of the fluid | Pa.s |
| $\tau$ | Shear stress | Pa |
| $\tau_y$ | Yield stress | Pa |
| P | Static pressure | Pa |
| $\Delta P$ | Total pressure loss | Pa |
| A | Cross section area of the pipe | $m^2$ |
| $C_v$ | Laminar flow valve loss coefficient constant | |
| D | Pipe diameter | m |
| E | Total energy per unit mass | J/kg |
| F | Friction loss coefficient | |
| g | Gravitational acceleration | $m/s^2$ |
| G | Elasticity modulus | |
| H | Total head of the system | m |
| k | Pipe roughness | |
| $k_v$ | Loss coefficient of the valve | |
| K | Fluid consistency index | $Pa.s^n$ |
| K' | Apparent fluid consistency index | $Pa.s^n$ |
| L | The length of the pipe | m |
| Le | Equivalent length | m |
| m | Mass of a substance | kg |

| | | |
|---|---|---|
| $m_1$ | Slope | |
| N | Size of population | |
| n | Flow behaviour index | |
| n' | Apparent flow behaviour index | |
| p | Pressure (static) | Pa |
| Q | Volumetric flow rate | $m^3/s$ |
| r | Plug radius | m |
| R | Pipe radius | m |
| RD | Relative density | |
| Re | Reynolds number | |
| $Re_{MR}$ | Metzner-Reed Reynolds number for pseudo plastic fluids | |
| $Re_S$ | Slatter's Reynolds number for yield pseudo plastic and Bingham plastic fluids | |
| T | Time | s |
| U | Point velocity | m/s |
| V | Mean velocity | m/s |
| X | Data point in a population | |
| Z | Height of the pie centre-line above datum | m |
| Є | Pipe wall roughness | m |

| SUBSCRIPT | DEFINITION |
|---|---|
| 1 | First point of measurement |
| 2 | Second point of measurement |
| 3 | Third point of measurement |
| Ann | Annulus |
| B | Bingham |
| HB | Herschel-Buckley |
| Liq | Liquid |
| O | Pipe wall |
| W | Water |
| ∞ | Infinite |

# CHAPTER 1 INTRODUCTION

## 1.1 INTRODUCTION

Accurate loss coefficient data to enable more efficient pipeline designs for non-Newtonian fluids are scarce in the open literature, making it difficult to predict the head loss due to the pipeline fittings, and particularly for diaphragm valves. Most of the data given in the literature are for turbulent flow based on water. Due to water shortages, mining operations are forced to increase their solids concentrations, so that they are now forced to operate in laminar flow (Slatter, 2002). As a consequence there is a need to determine loss coefficient data in laminar flow for valves used in these industries to ensure energy efficient designs (Pienaar et al., 2001; 2006).

However, a systematic study of various sizes of diaphragm valves of different manufacturers to ascertain if the same loss coefficient can be applied has not yet been done.

The objective of this project is to produce a data base of loss coefficient data for Saunders valves for various diameters and openings. A comparison of the results with those obtained previously for Natco diaphragm valves will be conducted to evaluate the effect of valves produced by different manufacturers. This will provide input data to enable more efficient pipeline plant designs.

## 1.2 STATEMENT OF RESEARCH PROBLEM

The prediction of the energy losses when designing pipeline and pumping systems requires accurate loss coefficient data. However, there is a lack of sufficient laminar loss coefficient data of non-Newtonian fluids through straight-through diaphragm valves, as well as a need for a complete comparison of loss coefficient data between valves from two different manufacturers.

## 1.3 AIM AND OBJECTIVES

The objective of this work was:

- To experimentally determine the loss coefficient of Saunders diaphragm valves at different opening positions, for a range of Newtonian and non-Newtonian materials.

- To compare the loss coefficient data for fully, 75 %, 50 %, and 25 % open valve position between Natco and Saunders diaphragm valves.

- To evaluate existing correlations for predicting losses through straight-through diaphragm valves and, if needed, to derive a correlation for predicting losses in Saunders valves.

## 1.4 METHODOLOGY

In order to achieve the objectives, the following was done:

A literature review of related topics on flows of both Newtonian and non-Newtonian fluids through pipe fittings was conducted.

The losses through Saunders diaphragm valves of 40 mm, 50 mm, 65 mm, 80 mm and 100 mm bore diameter at fully, 75 %, 50 % and 25 % open was measured using the valve test rig in the slurry lab at the Cape Peninsula University of Technology. The five straight pipes could also be used for the determination of the rheology. The valve test rig has been commissioned and the data obtained proved to be reliable (Kazadi, 2005).

Water, a Newtonian fluid, was used for the calibration of the valve test rig and non-Newtonian fluids (carboxymethylcellulose and kaolin at three different concentrations) were used.

The results for each test are presented in the form of valve loss coefficient ($k_{valve}$) against Reynolds number (Re).

Correlations were evaluated and, a new correlation was derived to predict losses through Saunders diaphragm valves.

## 1.5 SCOPE

This work investigates only Newtonian and time-independent homogeneous non-Newtonian fluids or slurries flowing through Saunders straight-through diaphragm valves in the turbulent, transitional and laminar regimes.
Weir-type Saunders valves and time-dependent fluid behaviour were not investigated in this thesis.

## 1.6 IMPORTANCE AND BENEFITS

This thesis adds loss coefficient data to the open literature, which will be useful for designing pipelines in industries, as well as contributing to the academic debate in this discipline.

# CHAPTER 2 LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter reviews the theory and literature relevant to Newtonian and non-Newtonian fitting losses. The definition, description, purposes of the fittings and its impact on pipeline design is described. An overview of the methodology used to measure the additional losses in the fittings is also given.

Some rheological models used by many researchers are outlined. The behaviour of Newtonian fluids through valves is reviewed and the current methods to predict non-Newtonian laminar flow through valves are discussed.

## 2.2 PURPOSE OF FITTINGS

Fittings in piping and tubing systems have five main functions (Franck et al., 2001):

- Changing the direction of the flow
- Providing branch connections
- Changing the sizes of lines
- Closing lines
- Connecting lines

## 2.3 DEFINITION AND CLASSIFICATION OF PIPE FITTINGS

Crane (1999) classified fittings in different types such as deflecting, branching, reducing and expanding.

Deflecting fittings are part of those which change the direction of the flow, such as bends, elbows, etc., while tees, crosses and side outlet elbows may be called branching fittings. Reducing or expanding fittings are those which change the area of the fluid passageway (Crane, 1999).

Franck et al. (2001) defined a valve as any device by which the flow may be started, stopped, or regulated by a movable part that opens or obstructs passage.

Those that exhibit a straight-through flow would fall in the low resistance class. On the other hand, those that cause a change in flow path direction would fall in the high resistance class (Crane, 1999).

In general, valves are differentiated according to their design features such as sliders, cocks and flaps. However, in practice, they are often distinguished according to their function, type and function, or combined construction type-function and material (Myles, 2000).

## 2.4 TYPES OF VALVES

There are many kind of valves, but in the context of this investigation the straight-through diaphragm type will be studied. However, other types of valves that can be encountered will be described briefly in the section below.

Gate valves, closed or opened. They can be used for long periods on a variety of water, gas and chemical duties with a sure satisfactory operation when needed. Erosion can arise from attempting fine control or throttling. High lift valves are needed for installation and maintenance, for high stem and service with heavy solids in suspension could be troublesome, possibly creating seat wear and shut-off problems (Myles, 2000).

Globe valves are not suitable for handling virulent sluggish and as ideal steam valves. They are used with other modifications as both stop and control valves. They can be found in both globe type body or angled versions in a range of materials (Myles, 2000).

Ball valves are suitable for wide choice of materials and size range, and for high pressure and high temperature in isolation, or combined with other valves. Where other valves, they are useful for abrasive duties, sterility, coagulating fluids and throttling applications (Myles, 2000).

The $90^{o}$ to $270^{o}$ plug valves are available with either taper or parallel plugs. They offer a very full capacity and streamlined flow in the open position. For effective operation, lubricant under pressure is injected between the plug face and body seat. Pressure loss is minimal and high pressure easily handled with both liquids and gases (Myles, 2000).

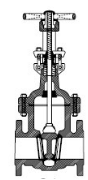
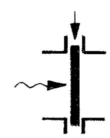
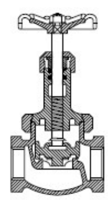
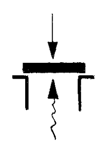
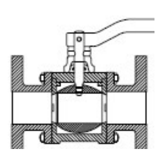
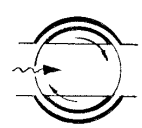
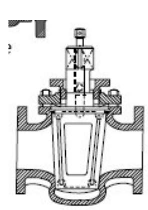
Butterfly valves are excellent for systems requiring a lightweight compact unit which is good for on-off and regulation work. Large and heavy solids services should be avoided, as should too rapid disc operation, seeing that there is a possibility of induced pressure surge and water hammer (Myles, 2000).

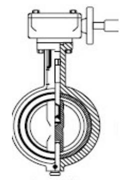
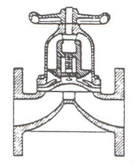
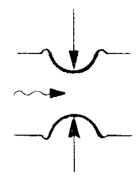
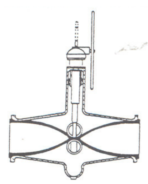
Pinch valves are probably the simplest and most cost efficient valves available. Basically they comprise of a rubber hose or sleeve which is clamped in a pipeline and pinched or squeezed to stop or control the flow. In the fully open position the valve is similar to a straight-through rubber-lined pipe. They are used mainly where abrasion, sewerage, solids handling and/or corrosion is a factor (Myles, 2000).

Diaphragm valves are equally suited to on-off plus throttling, pressure and high vacuum, air or hazardous chemicals. The maintenance is practically nil. It has set flow characteristics, but the expansive coverage provided is such that almost every industry has absorbed it somewhere into the process (Myles, 2000).

Table 2.1 shows common types of valves, a sectional view and their mode of closure (Myles, 2000).

**Table 2.1: Type of valves (Myles, 2000).**

| NAME | SECTIONAL VIEW | TYPE OF CLOSURE |
|---|---|---|
| Gate valve |  |  |
| Globe valve |  |  |
| Ball valve |  |  |
| Plug valve |  | |

| NAME | SECTIONAL VIEW | TYPE OF CLOSURE |
|---|---|---|
| Butterfly valve |  |  |
| Diaphragm valve |  |  |
| Pinch Valve |  | |

## 2.5 DIAPHRAGM VALVES

### 2.5.1 Advantages of diaphragm valves

Diaphragm valves offer distinct advantages in applications where absolute 100 % sealing is required, and where the line fluid cannot be contaminated by the ingress of the atmosphere. Even when slurries are being handled, or solids are present in the liquids, leak-tightness is assured, due to the ability of the diaphragm to engulf particles on closure, and release them downstream when the valve is again opened.

Diaphragm valves provide an equally effective shut-off with gases under pressure, or vacuum. There is no need for any gland-packing devices for the stem, as the diaphragm provides total sealing between the medium and atmosphere.

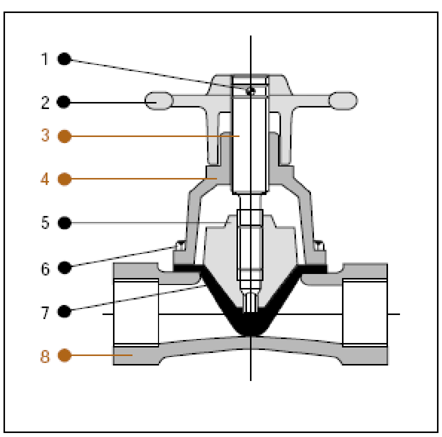
### 2.5.2 Features of diaphragm valves

There are three basic components in a diaphragm valve, namely, the body, the bonnet, and the diaphragm. Additional features can be summarised as follows:

- The diaphragm, which is the only component which needs to be replaced, can be replaced without the need to dismantle the body from the pipeline.
- Contamination-free performance and smooth flow characteristics are ensured through the pocket-less design.
- Appropriate selection of diaphragm materials permits handling of a wide range of media.
- The valve can be mounted in any position and can be supplied with offset flange drilling to suit.
- Operation can be by handwheel or linear actuator.
- Opened, closed, or intermediate positions are indicated.
- Mechanical locking arrangements are available.
- The valve may, in certain applications, be used for throttling.

Types of diaphragm valves

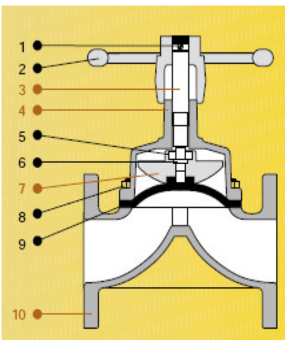
Two types of diaphragm valves are available, namely: the straight-through type diaphragm valve and the weir or dam-type diaphragm valve shown respectively in details in Figures 2.1 and 2.2.




| Material Specification | | |
|---|---|---|
| Part No | Component | Material |
| 1 | Hand wheel pin | Spring steel |
| 2 | Hand wheel | Cast iron |
| 3 | Stem | Stainless steel |
| 4 | Bonnet | Cast iron |
| 5 | Compressor | Cast iron |
| 6 | Studs/bolts & nuts | Carbon steel |
| 7 | Diaphragm | Rubber |
| 8 | Body | Cast iron |

**Figure 2.1: The straight-through type diaphragm valve (Saunders valves, 2007).**

The straight-through type diaphragm valves are suitable for slurries or suspensions and fluids which coagulate and powders where pigging or rodding is needed. They are available with flanged or screwed bodies (Myles, 2000).




| Material Specification | | |
|---|---|---|
| Part No | Component | Material |
| 1 | Hand wheel pin | Spring steel |
| 2 | Hand wheel | Cast iron |
| 3 | Stem | Stainless steel |
| 4 | Bonnet | Cast iron |
| 5 | Compressor pin | Cast iron |
| 6 | Thrust disc | Spring steel |
| 7 | Compressor | Polyacetal |
| 8 | Studs/bolts & nuts | Carbon steel |
| 9 | Diaphragm | Rubber |
| 10 | Body | Cast iron |

**Figure 2.2: The weir- or dam-type diaphragm valve (Saunders valves, 2007).**

The body incorporates an internal weir which reduces diaphragm travel and allows for precise throttling control. They are available with either flanges or with screwed socket (Myles, 2000). The weir-type diaphragm valves are suitable for less viscous fluids.

## 2.6 IMPACT OF FITTINGS

The so-called minor losses outweigh the ordinary friction loss in short pipes (Massey, 1990). The losses invariably arise from sudden changes of velocity (either in magnitude or direction). These changes generate large-scale turbulence in which energy is dissipated as heat (Massey, 1990).

## 2.7 FLOWS IN STRAIGHT PIPES

### 2.7.1 Shear stress distribution in a straight pipe

With regard to the flow of an incompressible fluid in a closed conduit, such a pipe is subject to inertia forces and viscous forces (Massey, 1990). Due to these forces, one is able to distinguish two different types of flow, namely the laminar and the turbulent flow. Laminar flow may occur in many situations. It occurs at velocities low enough for forces due to viscosity to predominate over inertia forces. Turbulent flow is subject to random fluctuating components that are superimposed on the main flow, and these hap-hazard movements are unpredictable (Massey, 1990).

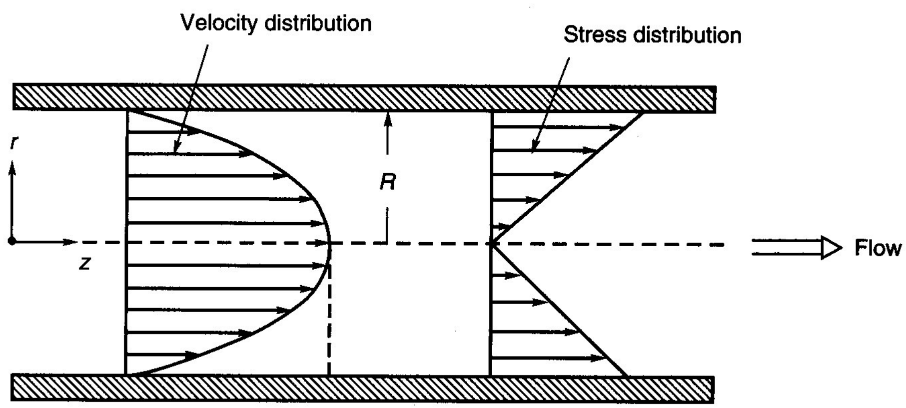



**Figure 2.3: Velocity and shear stress distribution (Slatter, 1994)**

The shear stress distribution, illustrated in Figure 2.3, in a pipe is given by the relationship:

$$\tau = \frac{\Delta pr}{2L}$$ **Equation 2.1**

where Δp is the pressure gradient in the portion of a straight pipe of length L and the radial distance r (Chhabra & Richardson, 1999)

At the pipe wall Equation 2.1 becomes:

$$\tau_o = \frac{\Delta p D}{4L}$$ **Equation 2.2**

### 2.7.2 Energy loss in straight pipe

When a fluid flows in a straight pipe the dissipation of energy manifests itself as head loss and can be calculated using the Darcy-Weisbach formula (Massey, 1990):

$$\Delta H = \frac{4fL}{D}\left(\frac{V^2}{2g}\right)$$ **Equation 2.3**

Where f is the fanning friction factor defined as (Massey, 1990):

$$f = \frac{2\tau_o}{\rho V^2}$$ **Equation 2.4**

The velocity V is obtained from Equation 2.5 and is given by:

$$V = \frac{Q}{A}$$ **Equation 2.5**

Equations 2.1 – 2.5 do not depend on the nature of the fluid (Newtonian or non-Newtonian), or on the nature of the flow (laminar or turbulent). They depend on the homogeneity of the fluid and on the development of the flow (Massey, 1990).

### 2.7.3 Newtonian laminar flow in straight pipes

#### 2.7.3.1 Velocity distribution

The velocity distribution in a pipe in laminar flow (if there is no slip or hold-up effect at the pipe wall) is (Massey, 1990):

$$u = \frac{\tau_o}{2R\mu}\left(R^2 - r^2\right),$$ **Equation 2.6**

where u is maximum for $r = 0$ and is:

$$u_{max} = \frac{\tau_o R}{2\mu},$$ **Equation 2.7**

and the mean velocity is: $$V = \frac{u_{max}}{2}$$ **Equation 2.8**

$$V = \frac{\tau_o R}{4\mu}$$ **Equation 2.9**

#### 2.7.3.2 Friction factor

In general the friction factor is determined using equation 2.4. The friction factor is generally a function of both the Reynolds number and the pipe wall roughness. In Newtonian laminar flow, the pipe wall roughness has no effect on the friction factor and the friction factor is given by (Massey, 1970):

$$f = \frac{16}{Re}$$ **Equation 2.10**

### 2.7.4 Newtonian turbulent flow in straight pipes

Turbulent flow is a flow characterised by large, random, swirling or eddy motions. Particle path cross and velocity (both direction and magnitude), and pressure fluctuate on a continuous and random basis. Turbulent flow is very complex and a consistent mathematical analysis has not yet been done. Predictions are obtained empirically from experiments (Massey, 1990).

The friction factor in turbulent flow is a function of the Reynolds number and the pipe wall roughness k. It can be obtained using the Colebrook & White equation (Massey, 1990):

$$\frac{1}{\sqrt{f}} = -4\log\left[\frac{k}{3,7D} + \frac{1,26}{Re\sqrt{f}}\right]$$ **Equation 2.11**

It must be noted that the Moody diagram presents the friction factor f versus Re and is a useful tool when it comes to the friction factor determination. Figure 2.4 gives the Moody diagram. In case of a smooth pipe and for Reynolds numbers between 3000 and 100000, the Blasius equation is used to determine the friction factor (Massey, 1990).

$$f = \frac{0.079}{(Re)^{0.25}}$$ **Equation 2.12**

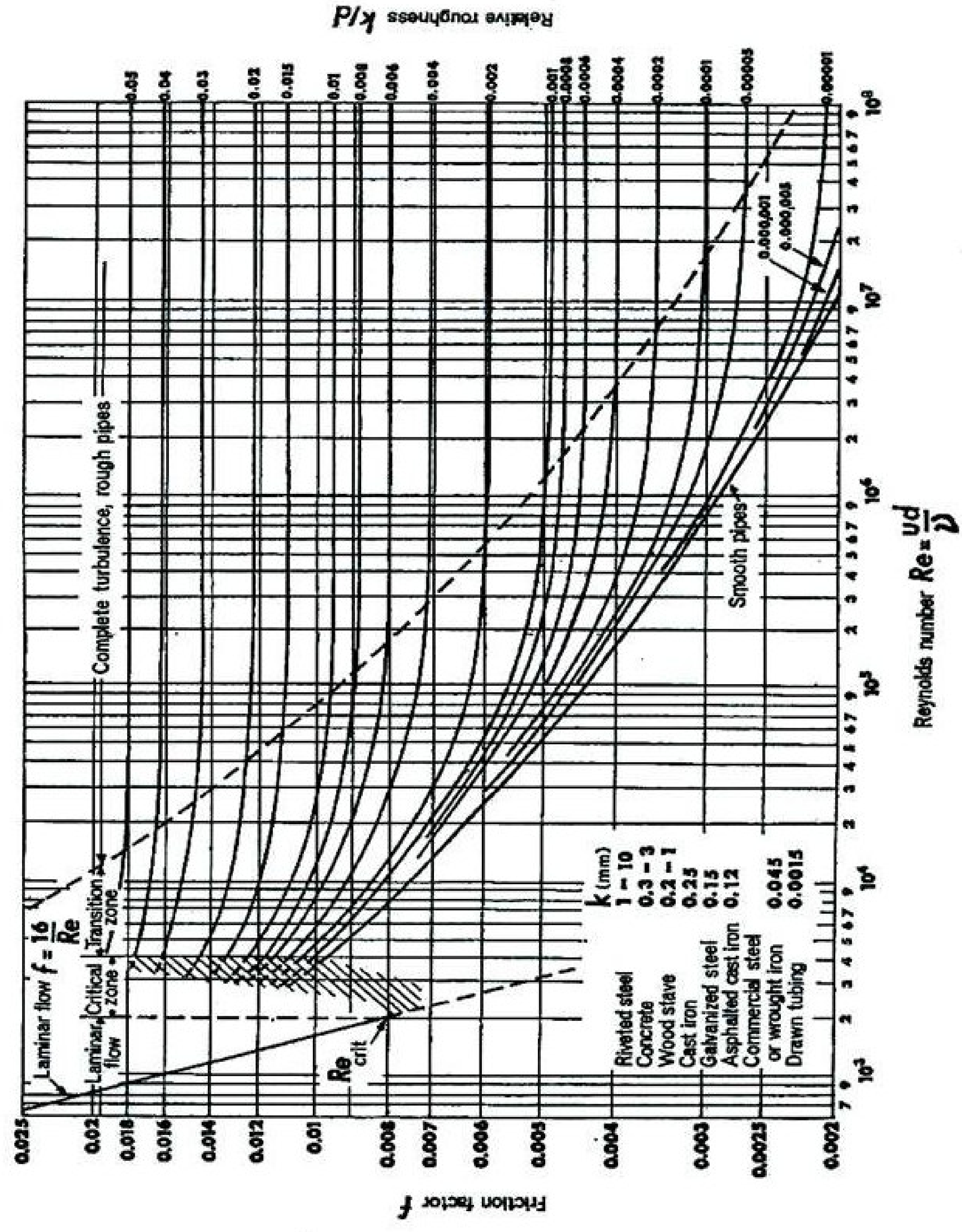



**Figure 2.4: Moody diagram (Massey, 1990)**

The fundamental relationships given in Equations 2.1 - 2.5 on the shear rate, energy loss in pipes and velocity are also valid for non-Newtonian fluids, as stated earlier in sections 1 & 2.

**2.7.5 Non-Newtonian laminar flow in straight pipes**

The following rheological relationship can be accommodated in the yield pseudoplastic model Equation 2.59 (Chhabra & Richardson, 1999).

- Yield dilatant ( $\tau_y > 0$ and $n > 1$ )
- Bingham plastic ( $\tau_y > 0$ and $n = 1$ )
- Dilatant ( $\tau_y = 0$ and $n > 1$ )
- Newtonian ( $\tau_y = 0$ and $n = 1$ )
- Pseudoplastic ( $\tau_y = 0$ and $n < 1$ )

In laminar flow, the velocity distribution of a yield pseudoplastic fluid is for $R > r > r_{plug}$ ;

$$u = \frac{R}{K^{\frac{1}{n}}\tau_o}\frac{n}{n+1}\left[\left(\tau_o - \tau_y\right)^{\frac{n+1}{n}} - \left(\tau - \tau_y\right)^{\frac{n+1}{n}}\right]$$ **Equation 2.13**

when $0 < r < r_{plug}$ the fluid moves as a plug at a uniform plug velocity $u_{plug}$

The volumetric discharge Q and the average velocity are obtained from the relation (Slatter, 1994):

$$\frac{32Q}{\pi D^3} = \frac{8V}{D} = \frac{4n}{K^{\frac{1}{n}}\tau_o^3}\left(\tau_o - \tau_y\right)^{\frac{1+n}{n}}\left[\frac{\left(\tau_o - \tau_y\right)^2}{1+3n} + \frac{2\tau_y\left(\tau_o - \tau_y\right)}{1+2n} + \frac{\tau_y^2}{1+n}\right]$$ **Equation 2.14**

With $\tau_o$ as defined by Equation 2.2 and V = Q/A (Equation 2.5)

For a Newtonian fluid $\tau_y = 0$, K= μ and n = 1, Equation 2.14 becomes:

$$\tau_o = \mu\frac{8V}{D}$$ **Equation 2.15**

Equation 2.15 shows that wall shear rate at pipe wall for a Newtonian fluid is $\frac{8V}{D}$. It is of great importance in non-Newtonian fluid flow in general, and in this investigation in particular.

**2.7.5.1 The Rabinowitsch-Mooney relation**

The true shear rate can be obtained from the pseudo shear rate of a non-Newtonian fluid, by multiplying the pseudo shear rate by the Rabinowitsch-Mooney relation (Rabinowitsch, 1929):

$$\left[-\frac{du}{dr}\right]_o = \frac{8v}{D}\left[\frac{3n'+1}{4n'}\right]$$ **Equation 2.16**

$$n' = \frac{d\left(\text{Log}\,\tau_0\right)}{d\left(\text{Log}\,\frac{8V}{D}\right)}$$ **Equation 2.17**

In case the rheological parameters of the fluid are known ($\tau_y$, K and n), K' and n' can be obtained directly using relations (2.18) and (2.19) for pseudoplastic fluids, and (2.20) and (2.21) for yield pseudoplastic fluids (Kazadi, 2005).

$$K' = K\left(\frac{3n+1}{4n}\right)^n$$ **Equation 2.18**

$$n = n'$$ **Equation 2.19**

$$n' = \frac{1}{-3 + \frac{(1+n)}{n}\frac{\tau_o}{(\tau_o - \tau_y)} + \frac{2\tau_o(1+n)(\tau_o + 2n\tau_o + n\tau_y)}{(1+n)(1+2n)(\tau_o - \tau_y)^2 + 2\tau_y(\tau_o - \tau_y)(1+n)(1+3n) + \tau_y^2(1+2n)(1+3n)}}$$
**Equation 2.20**

$$K' = \frac{\tau_o}{\left\{\left[\frac{4n}{K^{\frac{1}{n}}\tau_o^3}(\tau_o - \tau_y)^{\frac{1+n}{n}}\left[\frac{(\tau_o - \tau_y)^2}{1+3n} + \frac{2\tau_y(\tau_o - \tau_y)}{1+2n} + \frac{\tau_y^2}{1+n}\right]\right]^{n'}\right\}}$$ **Equation 2.21**

### 2.7.5.2 Metzner & Reed generalised Reynolds number

It has been demonstrated that for laminar pipe flow of any given time independent fluid that 8V/D is some unique function of $\tau_0$ only. According to Metzner & Reed (1955), this may be expressed as:

$$\tau_o = \frac{D\Delta p}{4L} = K'\left(\frac{8V}{D}\right)^{n'} \quad \textbf{Equation 2.22}$$

In most cases K' and n' are not constants, but vary with 8V/D. Thus on logarithmic plot of $\tau_o$ versus 8V/D, Equation 2.22 is simply the equation of the tangent to the curve at a given value of 8V/D, n' being the slope of this tangent and K' its intercept on the ordinate at 8V/D equal to unity (Skelland, 1967).

Metzner & Reed (1955) developed a generalised Reynolds number from the considerations above as:

$$Re_{MR} = \frac{8V^2\rho}{K'\left(\frac{8V}{D}\right)^{n'}} \quad \textbf{Equation 2.23}$$

This relation may be rewritten after transformation as:

$$Re_{MR} = \frac{\rho V^{2-n'} D^{n'}}{8^{n'-1} K'} \quad \textbf{Equation 2.24}$$

In practice, n' is the tangent of the double logarithmic plot of $\tau_o$ versus (8V/D) at any particular value of $\tau_o$ or 8V/D. Log K' is the intercept on the y-axis.

It has been found experimentally that for many fluids K' (Equation 2.18) and n' (Equation 2.19) are constant over any range of $\tau_o$ or 8V/D for which the power law is valid. This is not the case in general (the log-log plot is not always a straight line) and care must be taken to ensure that the range of application is narrow. The quantity n' characterizes the degree of non-Newtonian behaviour for a given fluid. The greater the departure of n' from unity, the more non-Newtonian is the fluid. The quantity K' is a measure of the consistency of the fluid; the larger the value of K' the thicker or less mobile is the fluid (Metzner & Reed, 1955).

Thus (2.23) becomes:

$$Re_{MR} = \frac{\rho V^{2-n} D^{n}}{8^{n-1} K \left(\frac{3n+1}{4n}\right)^{n}}$$ **Equation 2.25**

For a Bingham plastic fluid (Skelland, 1967):

$$n' = 1 - \frac{4\tau_y}{3\tau_o}$$ **Equation 2.26**

### 2.7.5.3 Slatter Reynolds number

The Slatter Reynolds number takes directly into account the yield stress of non-Newtonian fluids. Slatter has proposed a Reynolds number which seeks to express the ratio of inertial forces to viscous shear forces in the sheared portion of the flow (Chhabra and Richardson, 1999).

The Slatter Reynolds number is given by:

$$Re_s = \frac{8V_{ann}^{2}\rho}{\tau_y + K\left(\frac{8V_{ann}}{D_{shear}}\right)^{n}}$$ **Equation 2.27**

For a fluid with a yield stress there is a plug flow at the centre of the pipe in laminar flow, and the radius of the plug is:

$$r_{plug} = \frac{\tau_y}{\tau_o} R$$ **Equation 2.28**

The shear diameter is:

$$D_{shear} = D - D_{plug}$$ **Equation 2.29**

$$D_{plug} = 2r_{plug}$$ **Equation 2.30**

The mean velocity of the annulus is:

$$V_{ann} = \frac{Q_{ann}}{A_{ann}}$$ **Equation 2.31**

$$Q_{ann} = Q - Q_{plug}$$ **Equation 2.32**

$$Q_{plug} = u_{plug} . A_{plug}$$ **Equation 2.33**

$$u_{plug} = \frac{R}{K^{\frac{1}{n}} \tau_o} \frac{n}{n+1} \left(\tau_o - \tau_y\right)^{\frac{n+1}{n}}$$ **Equation 2.34**

The transitional value of the Slatter Reynolds number from laminar to turbulent flow in straight pipes is $Re_s = 2100$ ( Lazarus & Slatter, 1988).

### 2.7.5.4 Friction factor for non-Newtonian fluids

In the case of inelastic non-Newtonian fluids, the Fanning friction factor in laminar flow is given by (Chhabra & Richardson, 1999):

$$f = \frac{16}{Re_{MR}}$$ **Equation 2.35**

Slatter (1999) also developed a friction factor for non-Newtonian fluids with a yield stress:

$$f_{ann} = \frac{2\tau_o}{\rho V_{ann}^2}$$ **Equation 2.36**

In this case the transition is considered to occur when $f_{ann}$ equals 0.008.

## 2.8 FLOW IN PIPE FITTINGS

The Bernoulli formula gives the macroscopic mechanical energy balance for a pipe system, as well as the total head loss in the system, and is used in the determination of different losses in the system (Massey, 1990).

The Bernoulli formula for a system of two pipes in series connected by a fitting can be written as follows:

$$z_1 + \frac{\alpha_1 V_1^2}{2g} + \frac{P_1}{\rho g} = z_2 + \frac{\alpha_2 V_2^2}{2g} + \frac{P_2}{\rho g} + H_1 + H_{fitt} + H_2$$ **Equation 2.37**

Where z is the elevation of the datum, α is the kinetic energy correction factor, P is the static pressure, and H the head loss.

Subscripts 1 and 2 refer to the upstream and downstream pipes respectively.

$H_{fitt}$ is the fitting head loss in metres and is predicted using the formula (Massey, 1990):

$$H_{fitt} = k_{fitt} \frac{V^2}{2g}$$ **Equation 2.38**

For a valve it is written

$$H_v = k_v \frac{V^2}{2g},$$ **Equation 2.39**

where $k_{fitt}$ and $k_v$ is the fitting or valve head loss coefficient, and is defined as the non-dimensionalised difference in overall pressure between the ends of two long, straight pipes when there is no fitting, and when the real fitting is installed (Miller, 1990). This is shown graphically on Figure 2.5 for a valve.

$$k_{fitt} = H_{fitt} \frac{2g}{V^2}$$ **Equation 2.40**

$$k_{fitt} = \frac{\Delta p_{fitt}}{\frac{1}{2}\rho V^2}$$ **Equation 2.41**

The loss coefficient can be calculated in two ways, by including or excluding the length of the fitting.

If the length of the fitting is excluded, $k_{fitt}$ is called $k_{gross}$ and is obtained by the equation (Turian et al., 1997):

$$k_{gross} = \frac{1}{\frac{\rho V^2}{2}}\left[-\Delta p - \frac{\rho V^2}{2}\frac{4f}{D}\left(L_u + L_d\right)\right]$$ **Equation 2.42**

If the length of the fitting is included, $k_{fitt}$ is called $k_{net}$ and is obtained by the equation (Turian et al., 1997):

$$k_{net} = \frac{1}{\frac{\rho V^2}{2}}\left[-\Delta p - \frac{\rho V^2}{2}\frac{4f}{D}\left(L_u + L_{fitt} + L_d\right)\right]$$ **Equation 2.43**

With the exception of abrupt contractions and expansions, all other fittings have a physical length.

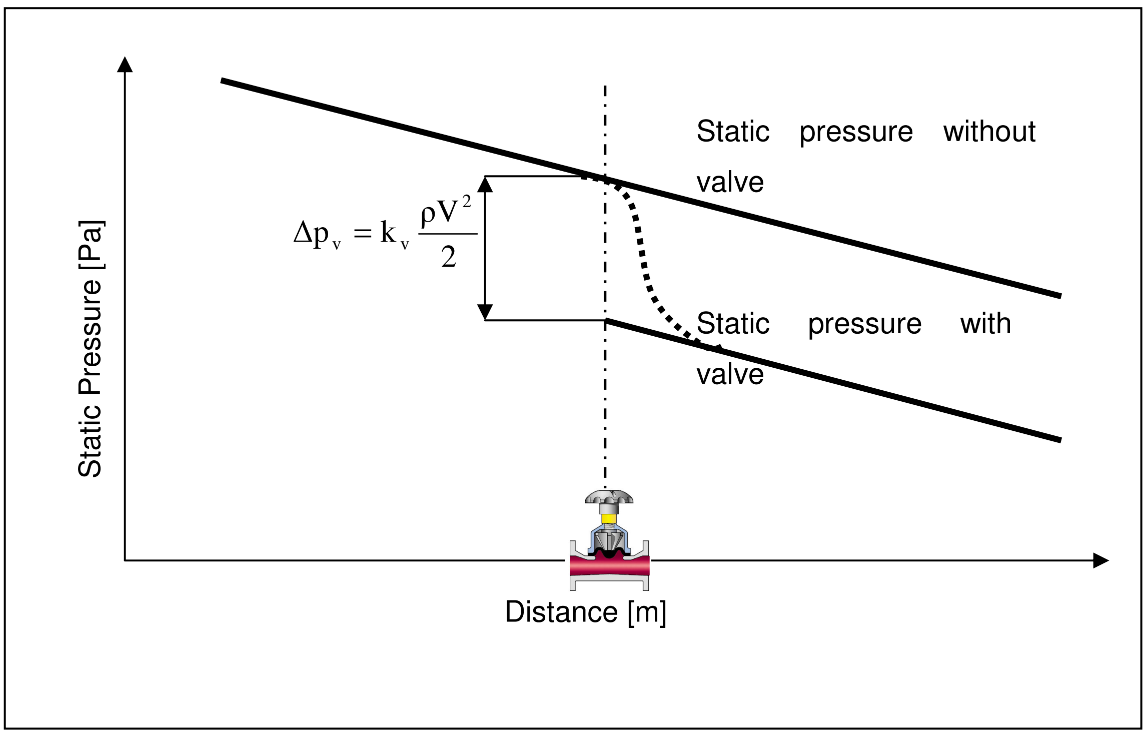



**Figure 2.5: Definition of the loss coefficient (Miller, 1990)**

## 2.9 NEWTONIAN AND NON-NEWTONIAN FLOW IN VALVES

### 2.9.1 Pressure drop in valves

The loss of pressure due to a valve consists of three parts (Turian et al., 1997):
The pressure drop within the valve itself is due to the viscous stresses that cause internal friction and separate flows.
The pressure drop in the upstream pipe is in excess of that which would normally occur if there were no valve in the line. This effect is small.
The pressure drop in the downstream pipe is in excess of that which would normally occur if there were no valve in the line. This effect may be comparatively large.

### 2.9.2 Valve loss coefficient

Friction losses for valves are obtained using Equation 2.39 where $k_v$ is the valve loss coefficient and is defined as the number of velocity heads lost due to a valve.
The head loss is independent of the Reynolds number. In laminar flow the valve loss coefficient is Reynolds number dependent and in laminar flow is defined as $C_v$, the laminar flow valve loss coefficient constant (Pienaar et al., 2004):

$$C_v = k_v.\mathrm{Re}$$ **Equation 2.44**

The loss coefficient is usually presented as a function of the Reynolds number. Figure 2.6 gives a typical presentation of $k_v$ versus Re.

The laminar flow valve loss coefficient in Equation 2.44 is determined from experimental data in the laminar flow region by the least square method.
It is obtained by minimizing the logarithmic least square error:

$$\mathrm{Minimum}\sum\left(\mathrm{Log}\frac{C_v}{\mathrm{Re}} - \mathrm{Log}k_{v/obs}\right)^2$$ **Equation 2.45**

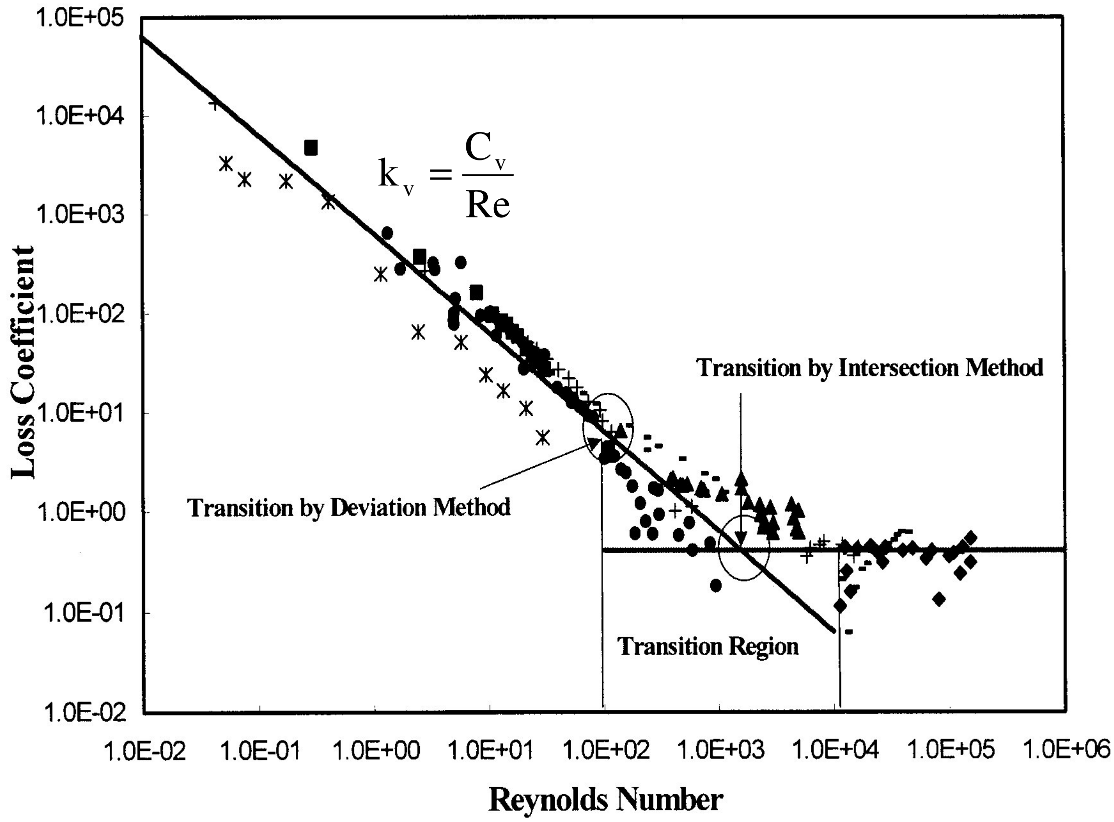



**Figure 2.6: Typical representation of $k_v$ vs. Re for a fitting (Pienaar et al., 2001)**

Figure 2.6 shows also the transition from laminar to turbulent flow for a range of Newtonian and non-Newtonian fluids. Some authors define it as the intersection of the laminar loss coefficient and turbulent loss coefficient loci, while others refer to it as a point where the experimental data start to deviate from the laminar flow line (Pienaar et al., 2001).

### 2.9.3 Methodology to determine loss coefficient

Generally, there are two methods used in the determination of valves or fittings loss coefficient: the hydraulic grade line (HGL) approach and the total pressure method. Banerjee et al., (1994), Kazadi (2005) and Baudouin (2003) adopted the hydraulic grade line approach for the determination of loss coefficients. The first two authors used it to determine loss coefficients in valves and the latter for loss coefficients in sudden contractions. It consists of measuring and plotting the static pressure gradients upstream and downstream of the valve in the region of fully developed flow, far from the valve plan, to avoid disturbance of the flow due to the presence of the valve.

The valve pressure loss is obtained as an extrapolation of the pressure gradients measured in the fully developed flow regions, upstream and downstream of the valve.

To measure static pressure at different points upstream and downstream of the valve, Banerjee et al., (1994) used U-tube manometers containing mercury, beneath water, connected to pressure tappings. Baudouin (2003) and Kazadi (2005) used point pressure transducers and differential pressure cells connected to pressure tappings.

Turian et al., (1997) and Pienaar (1998) used the total pressure method to determine the loss coefficient through fittings and valves. Two pipes in series were joined by a fitting or valve. The method consists of measuring the pressure gradient between two points in the region of fully developed flow in straight pipes around the fitting and valve. Thus knowing the losses in the straight pipe portions one can deduct the fitting or valve loss.

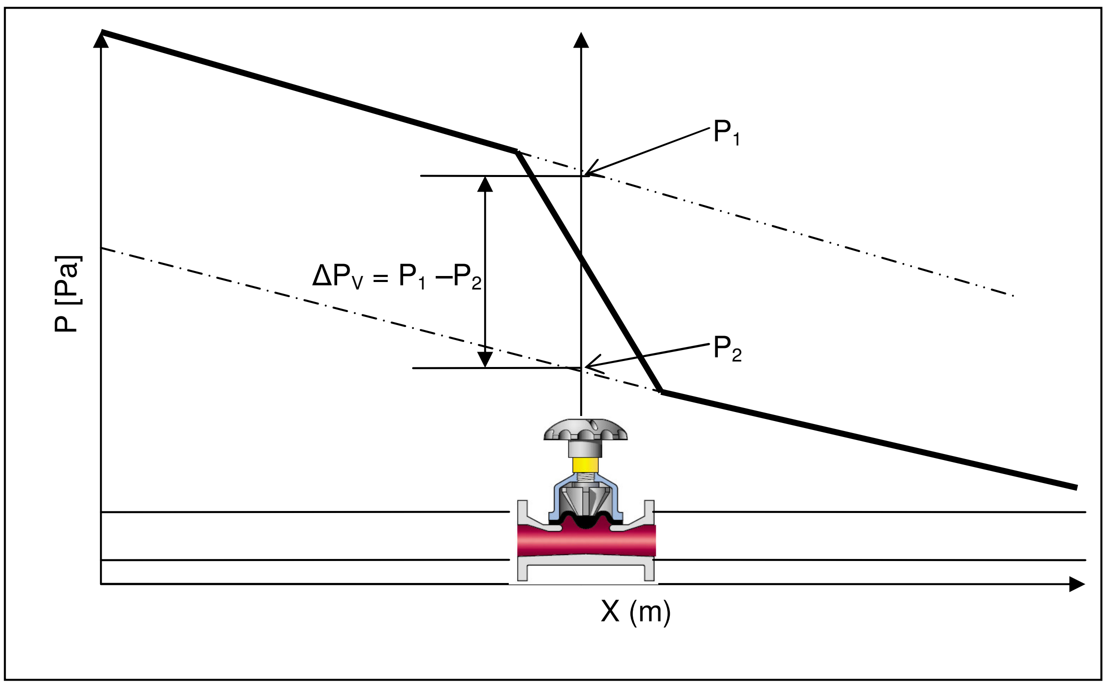



**Figure 2.7: Diagram illustrating the calculation of valve loss coefficient**

On a graph, static pressure (P) vs. axial distance (X) points of coordinates ($P_i$, $X_i$) are plotted from the experimental data. For the two pipes upstream and downstream of the test valve, the curves of static pressure drops follow a linear law and are straight lines as shown on Figure 2.7.

The coordinates of the points upstream of the test valve plane, which is the y-axis in this case, are used to calculate by linear regression the slope $m_1$ and intercept $P_1$ of the line upstream. The coordinates of the points downstream of the valve are used to calculate, also by linear regression, the slope $m_2$ and intercept $P_2$ of the line downstream of the valve.

In the case of valves, the pipes upstream and downstream of the test valve have the same diameters, the two hydraulic grade lines upstream and downstream of the test valve have the same slopes, $m_1$ and $m_2$ are equal and the pressure drop due to the test valve is given by:

$$\Delta p_v = P_1 - P_2$$ **Equation 2.46**

And using Equation 2.41:

$$k_v = \frac{\Delta p_v}{\frac{1}{2}\rho V^2}$$ **Equation 2.47**

$$k_v = \frac{(P_1 - P_2)}{\frac{1}{2}\rho V^2}$$ **Equation 2.48**

### 2.9.4 Equivalent length

Alternatively, the valve loss coefficient can be expressed in terms of the equivalent length of straight pipe of the same diameter and having the same loss as the valve. The equivalent length is expressed in numbers of pipe diameters, (Le/D) and is obtained by equating the Darcy-Weisbach formula, Equations 2.3 and 2.39 (Hooper, 1981):

$$\left(\frac{Le}{D}\right) = \frac{k_v}{4f}$$ **Equation 2.49**

The drawback of this method is the fact that the equivalent length for a given fitting is not constant, but depends on Reynolds number and roughness, as well as size and geometry. Therefore, the use of equivalent length methods requires consideration of all these factors (Hooper, 1981).

It has been shown using dimensional analysis that $k_v$ for incompressible Newtonian fluids is a dimensionless function of Re and of dimensionless geometric ratios characteristic of the valve (Turian et al., 1997):

$$k_v = \text{fn}(\text{Re}, \text{geometric ratios})$$ **Equation 2.50**

This relation suggests that the resistance coefficient is the same for all sizes of a given type of valve provided dynamic similarity is enforced for instance equality of Reynolds number and geometric similarity are maintained (Turian et al., 1997).

### 2.9.5 Flow coefficient

In some branches of the valve industry, particularly for control valves, the capacity of the valve is expressed in terms of a flow coefficient.

However, there is no agreement on the definition of a flow coefficient in terms of SI units. In the USA and UK the flow coefficient in use is designated by $C_{valve}$ and in other European countries by $K_{valve}$ and are defined as:

$C_{valve}$ is the rate of flow of water, in either US or UK gallons per minute, at 60°F, at a pressure drop of one pound per square inch across the valve.

$K_{valve}$ is the rate of flow of water in cubic metres per hour at a pressure drop of one kilogram force per square centimeter across the valve (Crane Co, 1999)

$$C_{valve} = 0.0694Q\sqrt{\frac{\rho}{\Delta p(999)}}$$ **Equation 2.51**

where:

Q is the flow rate in litres per min

$\rho$ is the density of the fluid in kg/m$^3$

$\Delta p$ is pressure gradient in bar

## 2.10 CLASSIFICATION OF FLUIDS

Either external applied pressure or effects produced under the action of a shear stress may play a major role in the classification of fluids (Chhabra & Richardson, 1999). We can encounter 'compressible' and 'incompressible' fluids, but in this thesis all the fluids tested are assumed to be incompressible. The flow characteristics of single phase liquids, solutions and pseudo-homogeneous mixtures (such as slurries, emulsions, gas-liquid dispersions) which may be treated as a continuum if they are stable in the absence of turbulent eddies are considered, depending on their response to externally imposed shearing action.

In general fluids belong to one of the two main categories, namely Newtonian fluids or non-Newtonian fluids.

### 2.10.1 Newtonian fluids

One of the fundamental concepts in rheology is an idea of a Newtonian (or Newton-Stokes) liquid. This is the simplest linear liquid where the linear relationships between components of stress and rate of deformation tensors exist (Malkin, 1994). The coefficient for this linear relationship is viscosity (or Newtonian viscosity), and according to the definition, viscosity of Newtonian liquids is a material characteristic of a liquid which does not depend on conditions of flow, namely the stresses or rates of deformation.

Thus, the complete definition of a Newtonian fluid is that it not only possesses a constant viscosity, but also when the shear stress is plotted against the shear rate, the result for a Newtonian fluid is shown in Figure 2.8 and is a straight line going through the origin of the coordinates. Note that graphs plotting shear stress versus shear rate are called rheograms. Physically, the shear rate is the velocity gradient or the rate of angular deformation of the fluid (Liu, 2003).

Mathematically, a Newtonian fluid can be represented as follows:

$$\tau = \mu_n \dot{\gamma}$$ **Equation 2.52**

where $\tau$ the shear stress, $\mu_n$ is the viscosity and $\dot{\gamma}$ the shear rate.

Figure 2.8 illustrates the general flow curve of a Newtonian fluid.

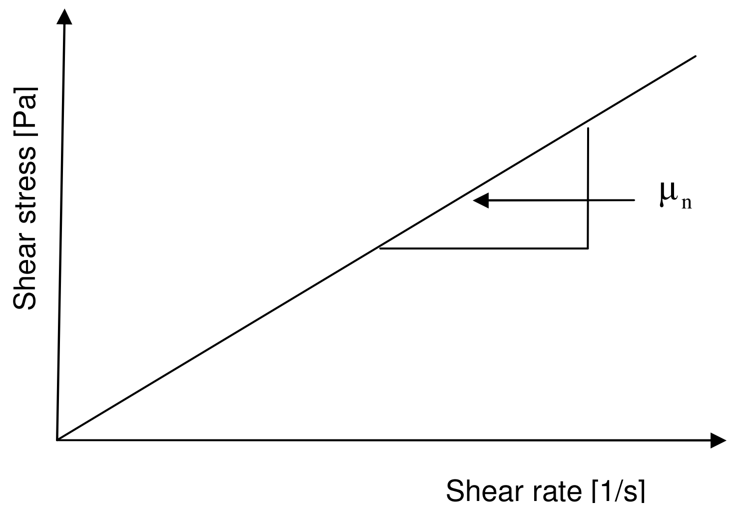



**Figure 2.8: Rheogram of a Newtonian fluid**

The slope of the straight line in any rheogram of a Newtonian fluid represents the viscosity (or more specifically, the dynamic viscosity) of the fluid. The higher the viscosity of a fluid, the steeper the slope in the rheogram becomes (Liu, 2003), as given in Figure 2.9.

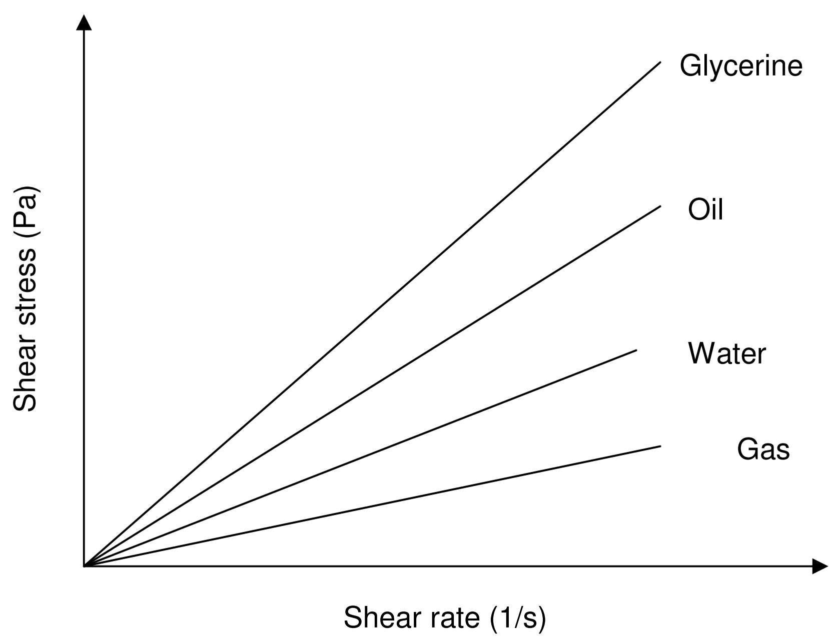



**Figure 2.9: Rheogram of various Newtonian fluids**

### 2.10.2 Non-Newtonian fluids

Many real liquids are non-Newtonian. It means that their apparent coefficient of viscosity, determined as a ratio of shear stress to shear rate of deformations, depends on conditions of flow (Malkin, 1994). A non-Newtonian fluid is one of which the flow curve (shear stress versus shear rate) is non-linear or does not pass through the origin. It means that the apparent viscosity is not a constant at given temperature and pressure, but is dependent on flow conditions such as flow geometry, shear rate, etc., and sometimes even on the kinematic history of the fluid element under consideration.

### 2.10.3 Classification of non-Newtonian fluids

Non-Newtonian fluids may be conveniently grouped into three general classes. Even though in those most real materials, they often exhibit a combination of two or even all the three types of non-Newtonian features. Generally, it is, however, possible to identify the dominant non-Newtonian characteristic and to take this as the basis for the subsequent process calculation (Chhabra & Richardson, 1999). In this work, only the time-independent non-Newtonian fluids will be considered, but few explanations will be given for the time-dependent fluids and the visco-elastic fluids.

### 2.10.4 Time-independent non-Newtonian fluids

Time-independent non-Newtonian fluids are fluids of which the rate of shear at any point is determined only by the value of the shear stress at that point at that instant.

The constitutive relation of the time independent non-Newtonian fluid can be described as follows (Chhabra & Richardson, 1999):

$$\dot{\gamma}_{yx} = f(\tau_{yx})$$ **Equation 2.53**

Or its inverse form,

$$\tau_{yx} = f_1(\dot{\gamma}_{yx})$$ **Equation 2.54**

These fluids may be further subdivided into three types:

#### 2.10.4.1 Pseudoplastic or shear thinning fluids

This type of time-independent non-Newtonian fluid is characterised by a shear rate which increases with decreasing of the apparent viscosity. This common type of fluid behaviour observed is pseudoplasticity or shear-thinning (Chhabra & Richardson, 1999).

#### 2.10.4.2 Dilatant or shear thickening fluids

Dilatant fluids are similar to pseudoplastic fluids in that they exhibit no yield stress, but their shear rate increases with increasing apparent viscosity; thus these fluids are also called shear-thickening (Chhabra & Richardson, 1999). This phenomenon is due to the fact that at high shear rates, the material expands or dilates slightly so that there is no longer sufficient liquid to fill the increased void space and facilitate direct solid-solid contacts which result in increased friction and higher shear stress. This mechanism causes the apparent viscosity to rise rapidly with increasing shear rate.

#### 2.10.4.3 Viscoplastic fluids

This type of fluid behaviour is characterised by the existence of a yield stress which must be exceeded before the fluid will flow or deform, but strictly speaking, it is virtually impossible to ascertain whether any real material has a true yield stress or not (Chhabra & Richardson, 1999). Nevertheless, the concept of yield stress has proved to be convenient in practice. Conversely, such a material will deform elastically (or flow en masse like a rigid body) when the externally applied stress is smaller than the yield stress (Chhabra & Richardson, 1999). It is very important to note that a viscoplastic material also displays an apparent viscosity, which decreases with increasing shear rate for yield pseudoplastic fluids only, and is constant for Bingham plastic fluids. The flow curve may be linear or not, but will not pass through the origin.

a) Bingham plastic fluids (BP)

This is a fluid with a linear flow curve with a yield stress (Chhabra & Richardson, 1999). It is also characterised by a constant plastic viscosity (the slope of the shear stress versus the shear rate curve) and a yield stress.

b) Yield pseudoplastic fluids (YPP)

A yield pseudoplastic fluid possesses a yield stress as well as a non-linear flow curve on linear coordinates (Chhabra & Richardson, 1999).

### 2.10.5 Time dependent non-Newtonian fluids

Practically speaking, apparent viscosity may depend not only on the shear rate, but also on the time for which the fluid has been subjected to shearing (Chhabra & Richardson, 1999). When certain materials are sheared at a constant rate following a long period of rest, their apparent viscosities gradually become less as the internal structure of the material is progressively broken down. This can be divided further in two different groups.

#### 2.10.5.1 Thixothropic fluids

When a material is sheared at a constant rate and its apparent viscosity decreases with the time of shearing, this fluid s called thixothropic fluid (Chhabra & Richardson, 1999).

#### 2.10.5.2 Rheopectic fluids

Also referred to as the negative thixotropy, the rheopectic fluids are related to fluids for which the apparent viscosity increases with time of shearing (Chhabra & Richardson, 1999).

#### 2.10.5.3 Visco-elastic fluids

In the Newtonian fluid the shearing stress is proportional to the rate of shear. Many substances show both elastic and viscous effects under appropriate circumstances. The substance is said to be visco-elastic.

At the other extreme, when a perfect solid is deformed elastically, it regains its original form on removal of the stress. In the classical theory of elasticity, the stress in a sheared body is directly proportional to the strain. For tension, Hooke's law applies and the coefficient of proportionality is known as Young's modulus, G:

$$\tau_{yx} = -G\frac{dx}{dy} = G(\dot{\gamma}_{yx})$$ **Equation 2.55**

Where dx is the shear displacement of two elements separated by a distance dy.

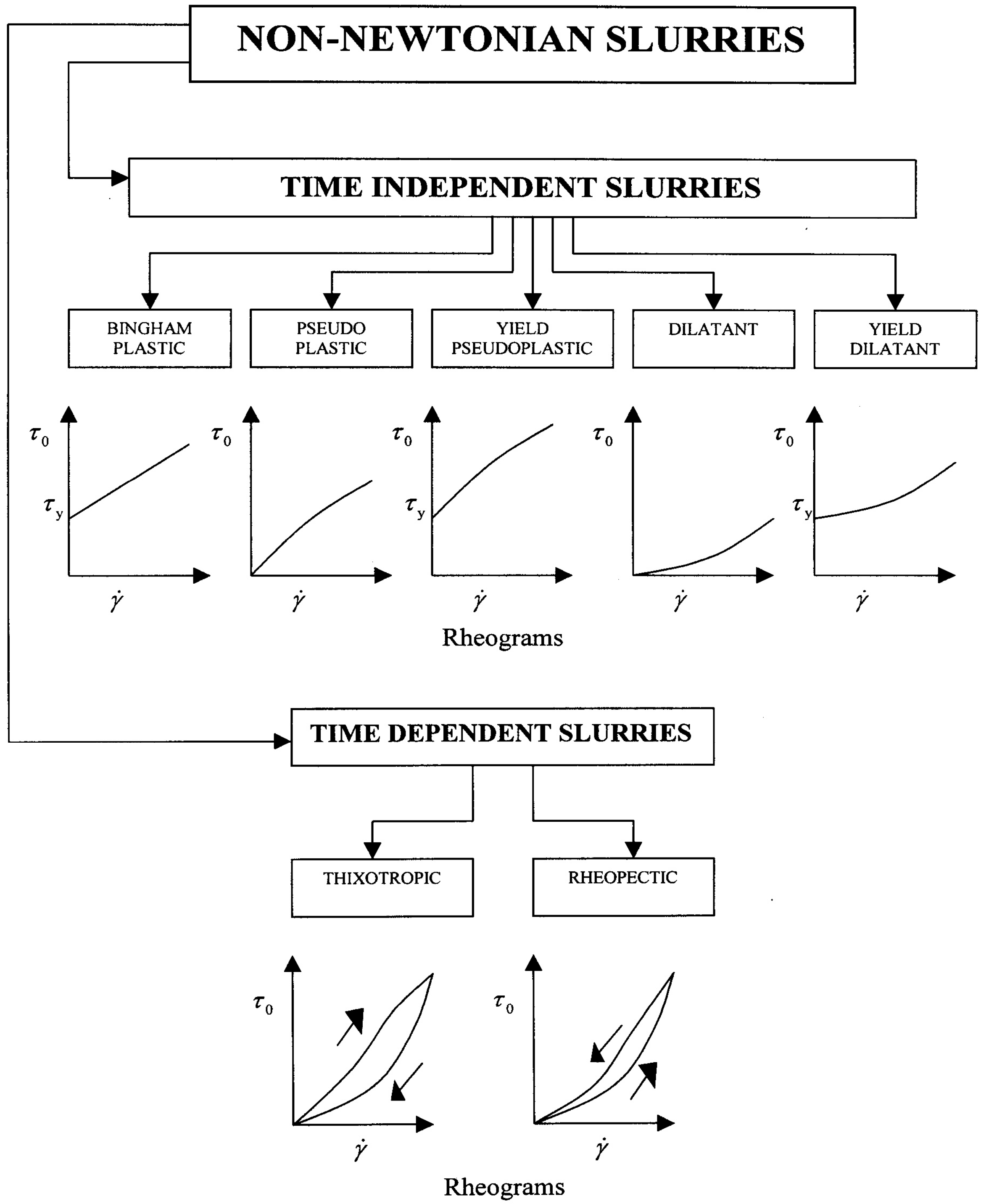



Figure 2.10: Non-Newtonian fluids flow curves (Paterson & Cooke, 1999)

### 2.10.6 Settling slurries

They are solutions or pseudo-homogeneous mixtures where particles in suspension settle very quickly, relative to their residence time in the pipeline (Heywood & Brown, 1991) or a mixture in which solid and liquid phases are separated and the liquid properties are generally considered to be unaltered by the presence of solids. Particles are supported by turbulent mixing and antiparticle collisions (Paterson & Cooke, 1999).

## 2.11 RHEOLOGY

Rheology (from the Greek “rheos”: flow and “logos”: knowledge) is the science of flow phenomena. Malkin (1994) defined rheology as a science dealing with materials having properties not described by models of Newton-Stokes and Hooke. It is a negative statement. The positive statement says that rheology studies materials having properties described by any relationship between force and deformation (Malkin, 1994). In this sense, the Newton-Stokes and Hooke laws limit cases formally lying on the border of rheology. Within the context of this work, rheology is defined as the viscous characteristic of a fluid or homogeneous solid-liquid mixture (Chhabra & Richardson, 1999).

The science of rheology as it is known today, owes its origin to Sir Isaac Newton who postulated the relationship between the shear stress and shear rate in a fluid as follows (Barr, 1931):-

“The resistance which arises from the lack of slipperiness originating in a fluid – other things being equal – is proportional to the velocity by which the parts of the fluid are being separated from each other.”

### 2.11.1 Rheological properties and laws of non-Newtonian fluids

The viscosity defined by Newton’s law of viscosity is the only one rheological parameter for Newtonian fluids. However, non-Newtonian fluids have two or three rheological parameters, defined by the following laws.

#### 2.11.1.1 Power-law fluids

The relationship between shear stress and the velocity gradient, for certain non-Newtonian fluids can be expressed satisfactorily with the following power laws:

$$\tau = K\left(\frac{du}{dy}\right)^{n} \qquad \textbf{Equation 2.56}$$

From which

$$\mu = K\left(\frac{du}{dy}\right)^{n-1} \qquad \textbf{Equation 2.57}$$

Equation 2.56 is applicable to pseudoplastic fluids when n < 1, dilatant fluids when n > 1, and Newtonian fluids when n = 1. From Equation 2.56, the two rheological properties of pseudoplastic and dilatant fluids that can be represented by the equation are the coefficient K and the power n. The constant K is usually referred to as the consistency index or power-law coefficient, whereas the constant n is referred to as the flow-behaviour index, or power-law exponent. The constant μ in Equation 2.57 is the apparent viscosity, which reduces to the dynamic viscosity when the fluid is Newtonian ($n = 1$) (Liu, 2003).

#### 2.11.1.2 Bingham fluids

For any Bingham plastic fluid (or Bingham fluids, for short), the following law holds:

$$\tau = \tau_y + \mu\frac{du}{dy} \qquad \textbf{Equation 2.58}$$

Where $\tau_y$ is the yield stress; and μ is the coefficient of rigidity, or simply the rigidity of the fluid.

#### 2.11.1.3 Yield fluids

For yield pseudoplastic fluids and yield dilatant fluids, the following law can be used:

$$\tau = \tau_y + K\left(\frac{du}{dy}\right)^n$$ **Equation 2.59**

This is the combination of Equation 2.56 and 2.58. The exponent n in Equation (2.57) is bigger than one for yield dilatant fluids, and less than one for yield pseudoplastic fluids. When $n = 1$, Equation (2.59) reduces to Equation (2.58), which is for Bingham fluids.

### 2.11.1.4 Other non-Newtonian fluids

There are many other laws proposed in the literature for various types of non-Newtonian fluids. They will not be discussed here, but they are represented in the Table 2.2 below:

**Table 2.2: Rheological models (Chhabra & Richardson, 1985)**

| Fluid Model | Constitutive equation | Number of Parameter | Parameters |
|---|---|---|---|
| Carreau | $\frac{\mu - \mu_o}{\mu_o \mu_\infty} = \left[1 + \left(\lambda\left(-\frac{du}{dy}\right)\right)^2\right]^{\frac{n-1}{2}}$ | 4 | $\mu_\infty$, $\mu_o$, $\lambda$ and n |
| Casson | $\sqrt{\tau} = \sqrt{\tau_y} + \sqrt{\mu_c\left(-\frac{du}{dy}\right)}$ | 2 | $\tau_y$ and $\mu_c$ |
| Cross | $\frac{\mu - \mu_o}{\mu_o \mu_\infty} = \left[1 + \left(\lambda\left(-\frac{du}{dy}\right)\right)\right]^{\frac{n-1}{2}}$ | 4 | $\mu_\infty$, $\mu_o$, $\lambda$ and n |
| e-function | $\mu = \mu_o \exp\left[m\left(-\frac{du}{dy}\right)\right]$ | 2 | $\mu_o$ and m |
| Ellis | $\mu = \frac{\mu_o}{1 + \left(\frac{\tau}{\tau_{\frac{1}{2}}}\right)^{\alpha - 1}}$ | 3 | $\mu_o$, $\alpha$ and $\tau_{1/2}$ |

### 2.11.2 Choice of rheological model

Many rheological models have been presented and can be used.
The rheological characterisation of non-Newtonian fluids is not easy (Chhabra & Richardson, 1999), and can be done using a rheometer or a tube viscometer. In the context of this investigation, tube viscometer was used because the experimental test loop could also be used as an in-line tube viscometer having a range of five different pipe diameters.

#### 2.11.2.1 Rotational viscometry

The instrument used to measure viscous properties of non-Newtonian fluids in this case is known as a rheometer. The rheometer usually consists of a concentric bob and cup, one of which is rotated to produce shear in the test fluid located in the gap between the bob and the cup. The shear stress is determined by measuring the applied torque on one of the elements.
The rheometer is a very sophisticated instrument and capable of measuring the full range of rheological phenomena. The rheometers can be found using one of the many geometries, among others: concentric cylinders, cone and plate, parallel disks. And the main measurements are angular velocity and applied torque. The software connected to these instruments converts these signals into shear rate and shear stress (Chhabra & Richardson, 1999).

#### 2.11.2.2 Tube viscometer

In a tube viscometer the test fluid flows at a controlled, measured rate through a tube of known diameter and the pressure drop over a known length of the tube is measured.
Data from tube viscometer yields a series of coordinates of pseudo shear rate and wall shear stresses (8V/D, $\tau_0$). These data must be processed in order to give the required rheology.
Assuming a yield pseudoplastic rheology

$$\frac{32Q}{\pi D^3} = \frac{8V}{D} = \frac{4n}{K^{\frac{1}{n}}\tau_o^3}\left(\tau_o - \tau_y\right)^{\frac{1+n}{n}}\left[\frac{\left(\tau_o - \tau_y\right)^2}{1+3n} + \frac{2\tau_y\left(\tau_o - \tau_y\right)}{1+2n} + \frac{\tau_y^2}{1+n}\right]$$ Equation 2.14

The following technique was used (Slatter, 1994):

A pseudo shear diagram was plotted using the pseudo shear rate (8V/D) as abscissa and shear stress (DΔp/4L) as ordinate. Data points in laminar flow only from all tubes are used. The best curve is fitted to the data. A realistic value of $\tau_y$ is then adjusted until the error function is minimised. The error function E is the root square difference between observed data and calculated as:

$$E = \sqrt{\frac{\sum_{i=1}^{N}\left[\left(\frac{8V}{D}\right)_{i_{obs}} - \left(\frac{8V}{D}\right)_{i_{calc}}\right]^2}{N-1}}$$ **Equation 2.60**

And K value for minimum error $K_{min}$ is given by:

$$K_{min} = \frac{1}{\left[\frac{2\sum_{1}^{N}\left(\frac{8V}{D}\right)_i /8}{n\sum_{i=1}^{N}\left(\tau_o - \tau_y\right)^{\frac{1+n}{n}}\left[\frac{\left(\tau_o-\tau_y\right)^2}{1+3n} + \frac{2\tau_y\left(\tau_o-\tau_y\right)}{1+2n} + \frac{\tau_y^2}{1+n}\right]}\right]}$$ **Equation 2.61**

- The wall slip effect occurs when the layers of particles near the wall are more diluted than the bulk flow (Heywood & Brown, 1991). As a result, the viscosity near the wall will be reduced and apparent slip will occur. Chhabra & Richardson (1999) warn that serious errors could occur when the wall slip is not accounted for. To account for the wall slip, more than one diameter tube should be tested. The laminar flow data should coincide for all pipe diameters if there is no wall slip. If they do not coincide, the slip velocity must be calculated for each tube and deducted from the measured mean velocity (Heywood & Brown, 1991).
- Entrance and exit losses: it is important that the entrance and exit losses in tubes that are used are minimised. This is possible by making sure that the flow is fully developed before differential pressure readings are taken, usually at least 50 pipe diameter is allowed.

## 2.12 PREVIOUS WORK ON LOSSES IN FITTINGS

Substantial work has been done on the prediction of minor losses in pipe systems. In this section a brief review of work relevant to this investigation is presented.

The work of Edwards et al., (1985), Banerjee et al., (1994) and Turian et al., (1978) are all based on gate and globe valves, not on diaphragm valves. They are relevant to this work because of the methodology and presentation of results.

Kittredge and Rowley (1957) had quite correctly noted the existence of a critical Reynolds number below 1000 for valves and fittings. For valves, fittings, and bends in turbulent flow, the friction coefficient's relative independence of Reynolds number is expected and attributable to the turbulence normal to the pipe flow. They concluded that the increasing friction coefficient with decreasing Reynolds number in laminar flow is characterised by the disappearance of induced turbulence and reported the losses for bends at low Reynolds number which are less than those caused by an equal length of straight pipe.

Miller (1990) classified the valve loss coefficients in three classes:

Class 1 or definitive loss coefficients: Loss coefficients in this class are based on experimental data usually from two or more sources or from research programmes, which have been crosschecked against other work. The loss coefficients are considered definitive.
In practice, the loss coefficients in class 1 are usually not directly applicable, because of the severe restraints imposed on inlet and outlet conditions and geometrical accuracy.

Class 2 or adequate loss coefficient for design purposes: Experimentally derived loss coefficients from isolated research programmes where no detailed crosschecking is possible against other sources.
Estimated loss coefficients from two or more research programmes of which the results do not agree with what could be expected to be the experimental accuracy.
Loss coefficients from Class 1 converted to apply outside the strict limitations imposed in class 1 coefficients and for which experimental information is available to predict the effects of departing from class 1 conditions.

Class 3 or suggested loss coefficient: Experimentally derived values from less reliable sources. Loss coefficients from class 1 and 2 converted to apply outside their range of application and about which there is little or no information to predict the effects of departing from the conditions under which they were derived.

Loss coefficients in diaphragm valves are classified as class 3 and are given in turbulent flow. These loss coefficients can be obtained from the Figure 2.11 for both weir and straight-through diaphragm valves.

In the fully open position in turbulent flow, the loss coefficient is approximately 0.8 for the straight-through diaphragm valve.

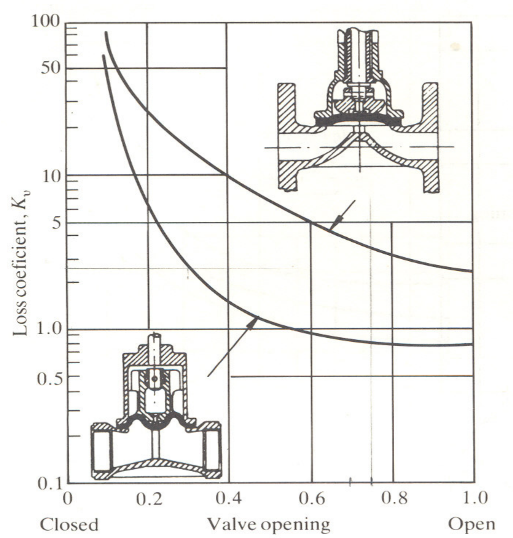



**Figure 2.11: Loss coefficient vs. valve opening (Miller, 1990)**

Miller (1990) represented the general shape of loss coefficient Reynolds number curves in the laminar to turbulent transition region as shown in Figure 2.12. It is evident that the laminar to turbulent transition region is the most complex flow region of internal flow.

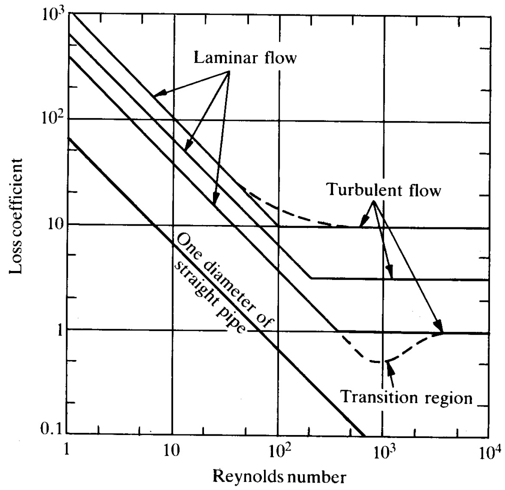



**Figure 2.12: Trends in loss coefficients in the laminar to turbulent transition region**

The Technical Paper published by Crane Co (1981) since 1957, reflected the latest design information available for valves and fittings, especially for gate, globe, angle, angle lift check and stop check valves and those data were obtained by experimental investigation.

Hooper (1981), using the two-K method, defined a dimensionless factor K as the excess head loss in a pipe fitting, expressed in velocity heads. K does not depend on the roughness of the fitting (or attached pipe) or the size of the system, but is a function of the Reynolds number and the exact geometry of the fitting and is given by:

$$K = \frac{K_1}{Re_{MR}} + K_\infty\left(1 + \frac{1}{D}\right)$$ **Equation 2.62**

where: $K_1$ is K for the fitting at $Re_{MR} = 1$, $K_\infty$ is K for a large fitting at $Re_{MR} = \infty$ and D the pipe internal diameter in inches. He found $K_1 = 1000$ and $K_\infty = 2$ for a dam or weir type diaphragm valve. Doing the analogy with the definition in this study, it can be said that $C_v = 1000$ and $k_v = 2$.

**Table 2.3: Loss coefficients of different types of valves, published by Hooper (1981)**

| Valve type | Loss coefficient constant, $C_v$ | Loss coefficient, $k_v$ |
|---|---|---|
| Globe, standard | 1500 | 4 |
| Globe, angle or Y-type | 1000 | 2 |
| Diaphragm, dam type | 1000 | 2 |
| Butterfly | 800 | 0.25 |

Steffe et al., (1984) determined the friction loss coefficient for apple sauce flowing under laminar condition through a tee, a plug valve and an elbow. The experimental investigation indicated that friction loss coefficients increase significantly for a decreasing value of generalised Reynolds number in laminar flow regime. The recommendations for estimating the pressure loss which are found in the laminar flow of pseudoplastics through valves and fittings were given.

Edwards et al., (1985) presented head loss charts for a range of Newtonian and non-Newtonian fluids for gate and globe valves of 25 and 50 mm useful for design purposes. They have tested a range of Newtonian and non-Newtonian fluids flowing through gate and globe valves of 25 and 50 mm, fully opened. The data were presented as a relationship between the loss coefficient and a generalised Reynolds number. It has been observed that in the laminar flow region, the loss coefficient in inversely proportional to the Reynolds number and can be obtained as given in Equation 2.39:

At higher Reynolds numbers a rapid transition is observed to a region in which the loss coefficient becomes constant, at about Re = 300. In the case of gate valves, for various test fluids and for the two sizes used, the data fall together, and the analysis of experimental data gave the correlation:

$$k_v = \frac{273}{Re}$$ **Equation 2.63**

For globe valves the data for the two dimensions do not fall together. The transition from laminar flow is very rapid and occurs at low Reynolds number of about 10. For the particular design of globe valves tested, in the fully open transition, the following correlations were obtained:

For 25 mm valve:

Re < 12 $$k_v = \frac{1460}{Re}$$ **Equation 2.64**

Re > 12 $k_v = 122$ **Equation 2.65**

For a 50 mm valve:

Re < 15 $$k_v = \frac{384}{Re}$$ **Equation 2.66**

Re > 15 $k_v = 25.4$ **Equation 2.67**

Banerjee et al., (1994) presented experimental data on the pressure drop across 12.5 mm globe and gate valves in the horizontal plane for pseudoplastic fluids in laminar flow. They used generalised correlations in terms of various physical and dynamic variables for the prediction of the frictional pressure drop for each valve.

The effect of pressure drop across the valve can be obtained by plotting static pressure against length for a designated fluid

The effect of the valve opening on pressure drop across the valve can be obtained by plotting pressure drop against volumetric flow rate at different opening position: The pressure drop increases with an increase in volumetric flow rate for a constant opening. As the opening became smaller, the curve became steeper.

The effect of the non-Newtonian characteristic on pressure drop across the valve was obtained by plotting pressure drop against the volumetric flow rate for different concentration of slurries. At a particular opening of the valve, the pressure drop decreases as the flow behaviour index increases.

The dimensional analysis of the experimental data, suggested the following relationship:

$$\frac{\Delta p}{\rho V^2} = f(Re, \alpha)$$ **Equation 2.68**

α is the valve opening coefficient

The functional relationships developed by using the above equation through multivariable linear regression analysis, were as follows:

Correlation for globe valve:

$$\frac{\Delta p}{\rho V^2} = 8.266 Re^{-0.061 \pm 0.013} \alpha^{-0.797 \pm 0.030}$$ **Equation 2.69**

After plotting this, the values of $\frac{\Delta p}{\rho V^2}$ predicted using the equation above and the experimental values, the correlation coefficient and variance of estimate are 0.9496 and 1.326x10$^{-2}$.

Correlation for gate valve:

$$\frac{\Delta p}{\rho V^2} = 1.905 \mathrm{Re}^{-0.197 \pm 0.046} \alpha^{-1.987 \pm 0.091}$$ **Equation 2.70**

After plotting this, the values of $\frac{\Delta p}{\rho V^2}$ predicted using the equation above and the experimental values, the correlation coefficient and variance of estimate are 0.9344 and 1.106 x 10$^{-2}$.

Mc Neil & Morris (1995) generated the energy loss coefficient under laminar conditions for both Newtonian and non-Newtonian fluids through nozzles and derived an approximation for flow in laminar, transition and turbulent flow in a range of fittings.

Turian et al., (1997) determined losses for the flow of concentrated slurries of laterite and gypsum solutions through 25 and 50 mm globe and gate valves. The loss coefficients were found to be inversely proportional to the generalised Reynolds number for laminar flow and to approach constant asymptotic values for turbulent flow, through gate and globe valves.

The following correlations were obtained:

For the 25 mm gate valve the transition from laminar to turbulent flow was observed between Re = 100 and Re = 1000 and $k_v = \frac{320}{\mathrm{Re}}$ for the laminar region and after the transition, in turbulent flow, $k_v$ = 0.797.

For the 50 mm gate valve the transition from laminar to turbulent flow was observed between Re = 1000 and Re = 10000 and $k_v = \frac{320}{\mathrm{Re}}$ for the laminar region and after the transition, in turbulent flow, $k_v$ = 0.168.

For the 25 mm globe valve, the transition from laminar to turbulent flow was observed earlier for Re < 100 and the correlation obtained was $k_v$ = 10.039 for turbulent flow.

For the 50 mm globe valve also the transition was observed earlier for Re < 100 and the correlation obtained was $k_v$ = 6.719.

Pienaar et al., (2004) reported the discrepancies found in the literature and provided additional loss coefficient data for three different sizes of globe valve and a rubber-lined diaphragm valve.

Kazadi (2005) presented loss coefficient data for Natco diaphragm valves at fully open position and without any comparison with different manufacturers. He also confirmed the theory that in fittings in general, and valves in particular, the transition from laminar to turbulent occurs earlier than in straight pipes, and showed that the Slatter Reynolds number is a useful tool that can also be used for design purposes.

Fester et al., (2007) tested a 40 mm nominal bore diameter diaphragm valve over a Reynolds number range from 1 to 50000 using various Newtonian and non-Newtonian fluids and obtained $C_v$ = 1000 and $k_v$ = 2.

Table 2.4 shows the review of frictional pressure losses for flow of non-Newtonian fluids through

**Table 2.4: Available valve loss coefficient data in the open literature (Pienaar et al., 2004)**

| Type | Size [mm] | Reference | $C_v$ |
|---|---|---|---|
| Gate | 25 | Turian et al., 1998 | |
| | 50 | Turian et al., 1998 | 320 |
| | 25 | Edwards et al., 1985 | 273 |
| | 50 | Edwards et al., 1985 | 273 |
| Globe | 25 | Turian et al., 1998 | |
| | 50 | Turian et al., 1998 | |
| | 25 | Edwards et al., 1985 | 1460 |
| | 50 | Edwards et al., 1985 | 384 |
| 3-way plug | - | Steffe et al., 1984 | |
| Check valves | 12.5 | Kittredge & Rowley, 1957 | |
| Ball | | | |
| Horizontal lift | | | |
| Bronze disc swing | | | |
| Composition disc swing | | | |
| Diaphragm | - | Hooper, 1981 | 1000 |

various valve sizes. Edwards et al., (1985) found the same laminar loss coefficient for various valve sizes and almost similar to that found by Turian et al., (1998) for the 50 mm gate valve. For globe valves, however, Edwards et al., (1985) found different laminar loss coefficient for various valve sizes. And finally, Hooper (1981) found a laminar loss coefficient through diaphragm valves of 1000 for unknown pipe sizes.

**Table 2.5: Loss coefficients for turbulent flow through diaphragm valves (Perry & Chilton, 1997)**

| Operating mode | Loss coefficient, $k_v$ |
|---|---|
| Open | 2.3 |
| ¾ Open | 2.6 |
| ½ Open | 4.3 |
| ¼ Open | 21 |

The Engineering Science Data Unit (ESDU) estimates the loss coefficient of various types of diaphragm valves, at fully open position, using the Figure 2.13

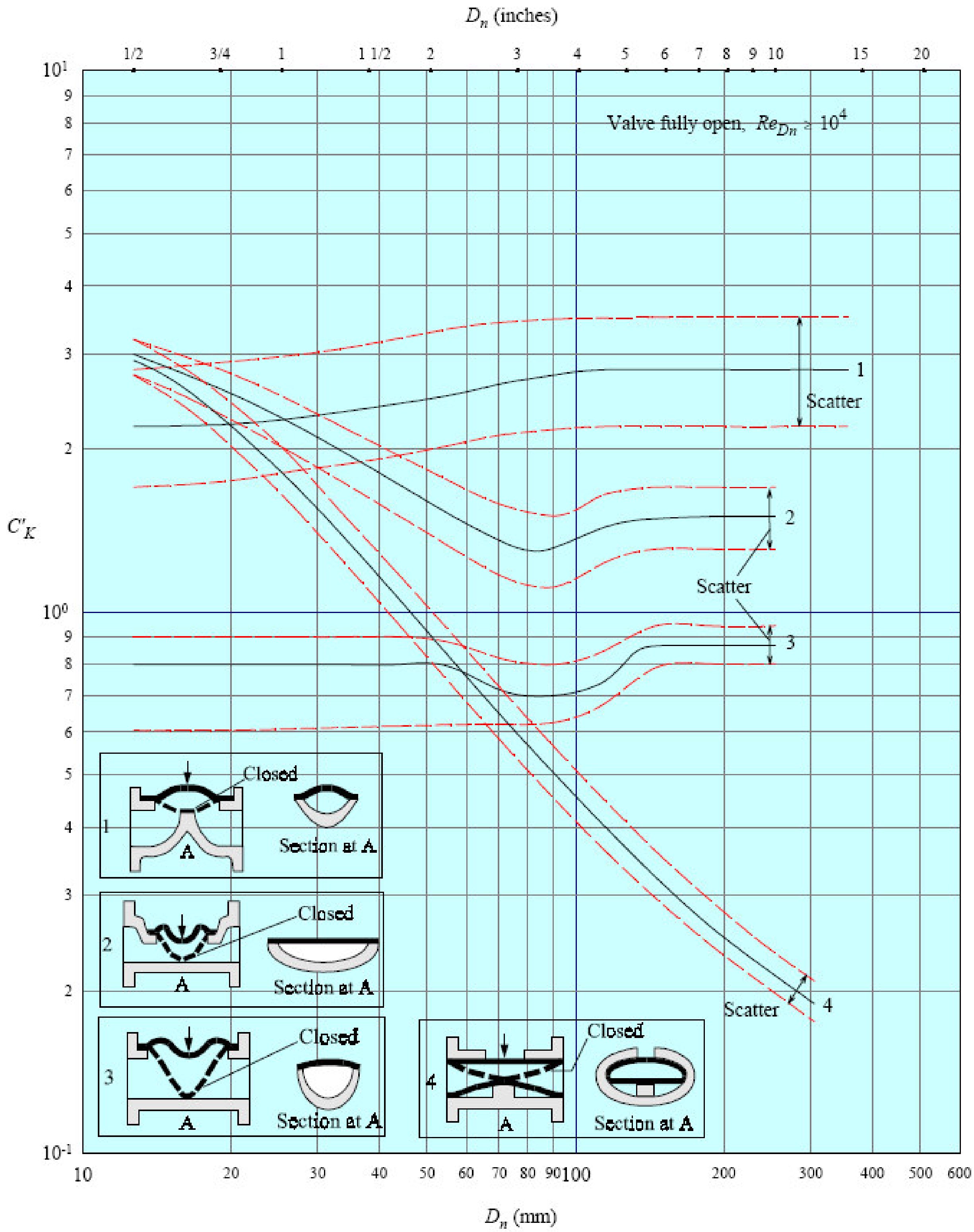



**Figure 2.13: $C'_k$ for diaphragm valves (ESDU, 2004)**

For a partially open valve, which is at ¾, ½ and ¼ open position, the loss coefficient of the diaphragm valve, as estimated by the ESDU, is determined by the following equation:

$$C_k = C'_k \times \alpha_1 \times \alpha_2$$ **Equation 2.71**

where $\alpha_1$ and $\alpha_2$ are given by the graphs in Figure 2.14 and Figure 2.15, which incorporates the effect of partial opening and change in Reynolds number (ESDU, 2004).

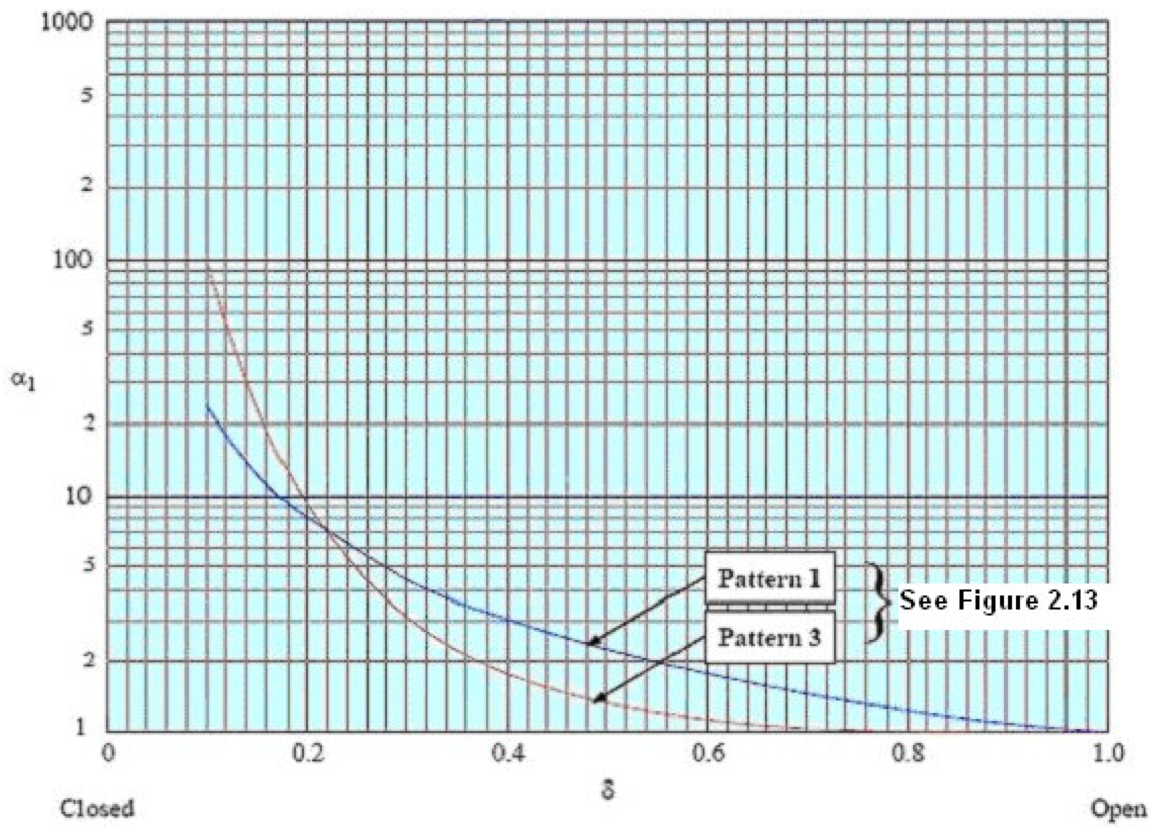



**Figure 2.14: Approximate effect of partial opening, diaphragm valves (ESDU, 2004)**

Figure 2.14 illustrates the approximate effect of partial opening for weir-type and straight-through diaphragm valves, where pattern 1 is related to the weir-type diaphragm valves and pattern 3 is related to the straight-through diaphragm valves.

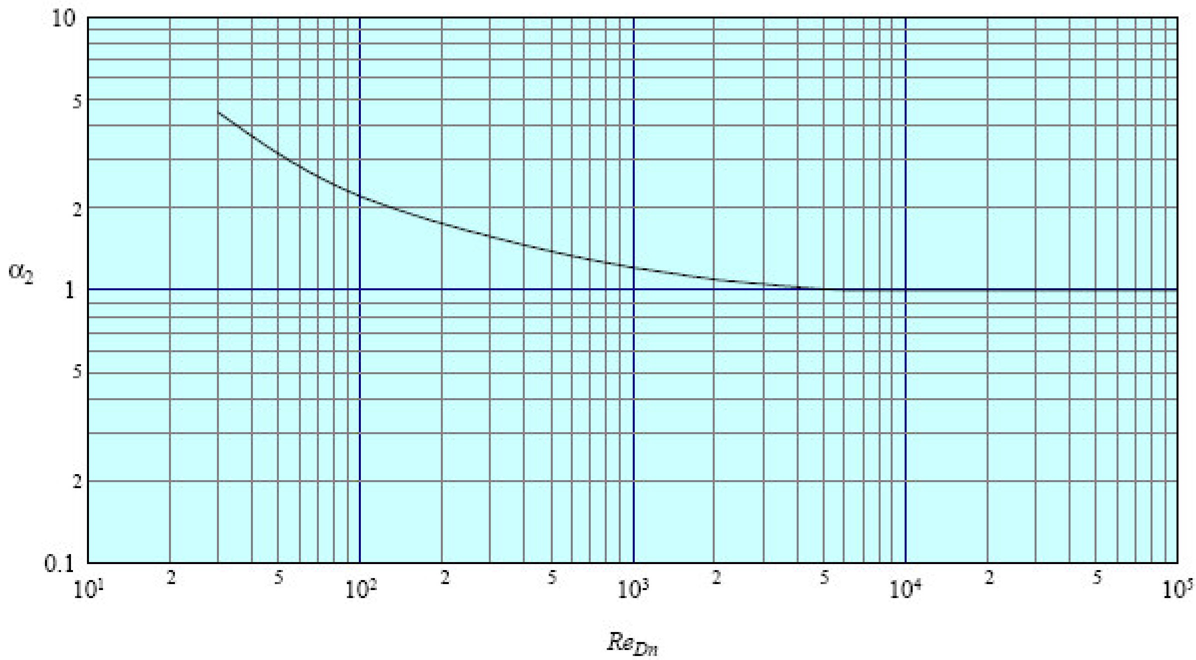



**Figure 2.15: Approximate effect of Reynolds number, diaphragm valve (ESDU, 2004)**

Kazadi (2005) found the loss coefficient of Natco diaphragm valves in the fully open position to have the following loss coefficients (Table 2.6):

**Table 2.6: Loss coefficients of different sizes of Natco diaphragm valves (Kazadi, 2005)**

| Valve bore size (mm) | Loss coefficient constant, $C_v$ | Loss coefficient, $k_v$ |
|---|---|---|
| 40 | 1200 | 7.96 |
| 50 | 946 | 2.53 |
| 65 | 555 | 1.21 |
| 80 | 515 | 2.54 |
| 100 | 69 | 1.30 |

In 2007, Fester et al., have also derived an equation (Equation 5.2) that can predict the loss coefficient for both laminar and turbulent flow only for the fully opening position for straight-through diaphragm valves.

$$k_v = \frac{C_v}{Re_s} + \lambda_\Omega \qquad \textbf{Equation 2.72}$$

**Table 2.7: Comparison of loss coefficient data for Natco and Saunders valves (Fester et al., 2007)**

| Valve Position Opening (%) | Saunders valve (65 mm bore diameter) | | Natco valve (65 mm bore diameter) | | % Difference | |
|---|---|---|---|---|---|---|
| | $C_{valve}$ | $k_v$ | $C_{valve}$ | $k_v$ | $C_{valve}$ | $k_v$ |
| 25 | 3887 | 32.1 | 3511 | 62.9 | 11 | 49 |
| 50 | 1086 | 5.9 | 2133 | 15.5 | 49 | 62 |
| 75 | 587 | 2.2 | 522 | 2.8 | 12 | 24 |
| 100 | 205 | 0.6 | 766 | 1.3 | 73 | 52 |

Finally in 2008 Mbiya developed a two-constant model to predict the pressure loss through the straight-through diaphragm valves from Natco valves which can be summarised by the following equations:

$$k_v = \frac{1006}{Re_s} \qquad \textbf{Equation 2.73}$$

$$k_v = \frac{38.6}{D^{1.24}\sqrt{Re_s}\,\theta^2} + \frac{\lambda_\Omega}{\theta^2} \qquad \textbf{Equation 2.74}$$

While testing the Natco diaphragm valves, Mbiya (2008) compared his results to the ESDU model and concluded that the ESDU model worked well with the 40 mm valve in the fully opened position, and in the closure position with other valve sizes. This is why Equation 2.74 was derived by Mbiya (2008).

## 2.13 CONCLUSION

Perry et al. (1997) and Miller (1990) provide loss coefficients for diaphragm valves at various openings, but discrepancies exist between the two sets. There is a need to determine loss coefficient data for non-Newtonian fluids in diaphragm valves to ensure energy efficient designs (Pienaar et al., 2001; 2006). In 2004 ESDU published graphs to predict the loss coefficient in straight-through and weir diaphragm valves. Mbiya (2008), while testing the Natco diaphragm valves, compared his results to the ESDU model and concluded that the ESDU model worked well with the 40 mm valve in the fully opened position, and in the closure position with other valve sizes. In 2008 Mbiya established the two-constant model to predict losses in diaphragm valves from one manufacturer. No study has been done to ascertain if the same loss coefficient can be applied for diaphragm valves produced by different manufacturers.

## 2.14 RESEARCH TOPICS IDENTIFIED

The research topics identified from the literature is the determination of loss coefficient data through diaphragm valves from a different manufacturer, to establish if existing correlations can be used to estimate the loss coefficient value.

This work will be based on Newtonian and non-Newtonian fluids or slurries flowing through Saunders diaphragm valves in the turbulent, transitional and laminar regimes. Newtonian fluids will be used to calibrate the valve test rig. Only time-independent fluid behaviour will be investigated throughout this thesis. It also important to define experimental procedures in the determination of loss coefficients in valves, because the value of the loss coefficient depends on the experimental procedure used and definitions (Chhabra & Slatter, 2001).

# CHAPTER 3 EXPERIMENTAL WORK

## 3.1 INTRODUCTION

The details of the valve test rig and how it was used to gather loss coefficient data are described in this chapter. The test rig was already built and commissioned by Kazadi (2005); only the previous set of fittings were removed and replaced in order to provide another set of loss coefficient data in both turbulent and laminar flow for Saunders diaphragm valves.

Non-Newtonian slurries were tested in pipes of outside diameter (OD) ranging from 50 mm to 110 mm. An important aspect of the experiments is that the same slurry was used for each test set. A test set is a set of tests using different pipe diameters, but the same slurry.

## 3.2 DESCRIPTION OF VALVE TEST RIG

The experimental rig consists of six lines of PVC pipes with diameters ranging from 50 mm to 110 mm OD. Each line is 25 m long and contains a test diaphragm valve. This length was chosen to allow a fully developed flow before and after each test valve.

Test fluids were mixed in a 1.7 $m^3$ mixing tank. The tank was rubber-lined to avoid chemical reactions of fluid with metal. The fluids were circulated in a continuous loop, as follows: From the storage tank, fluids were pumped out with a positive displacement pump before passing through a heat exchanger. The heat exchanger was followed by two valves coupled in parallel that directed the flow either to the high part of the rig (which contained smaller pipe 42 mm and 50 mm ID) or the lower part (which contained bigger pipes, 2 x 63 mm, 80 mm and 100 mm ID). Each of the two routes was fitted with a flow meter. After the flow meters the fluids could enter any of the 6 test sections. An on/off valve was situated at the beginning of each line for isolation, so that only one line was tested at a time. After a fluid had passed a test section it was collected via a common pipe and directed to the mixing tank. At the outlet it was possible to send the fluid through a weigh tank used for calibration purposes.

A schematic representation of the valve test rig is illustrated in Figure 3.1

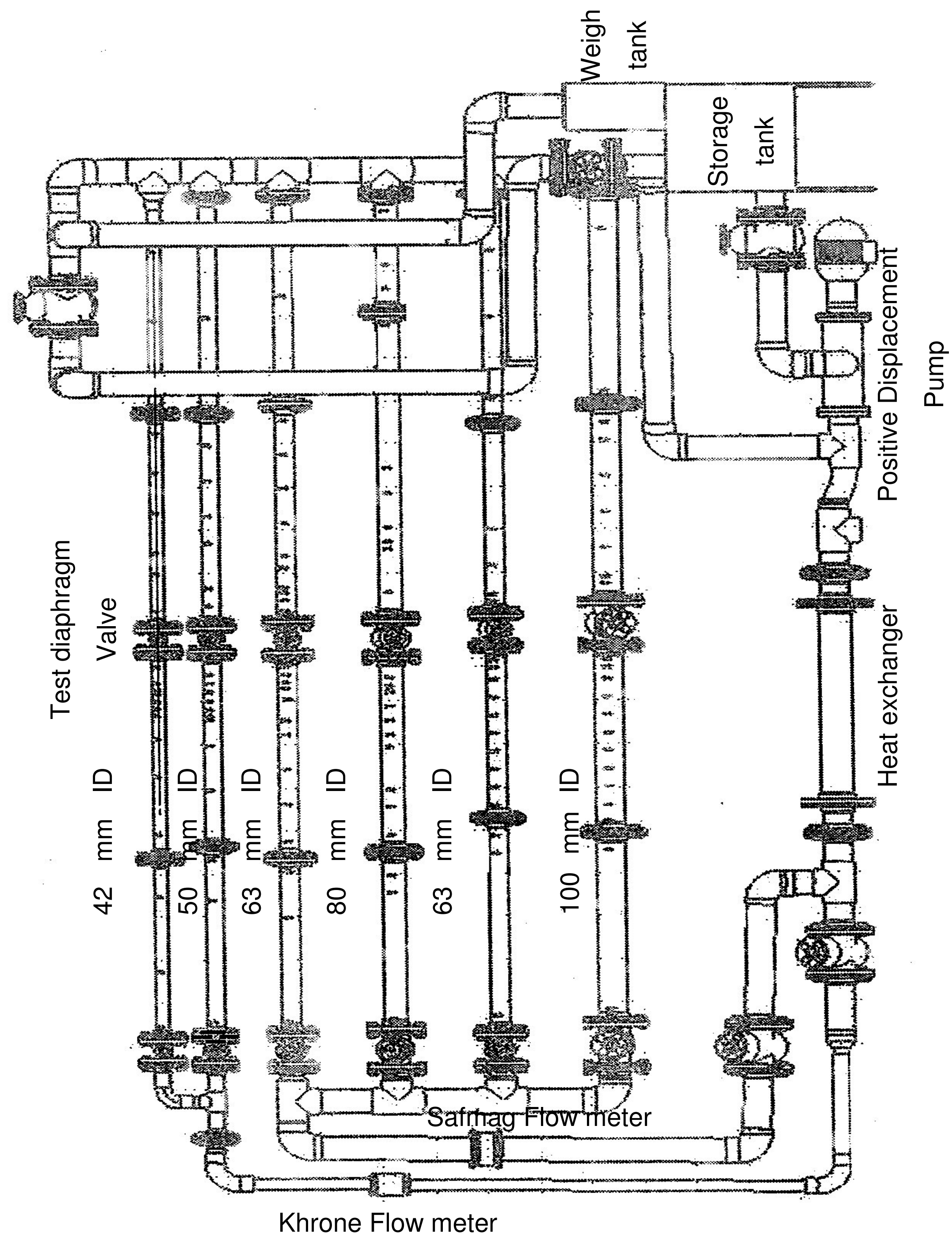



**Figure 3.1: Schematic representation of the valve test rig**

## 3.3 INSTRUMENTATION

This section presents all the instruments connected to the rig or used in order to collect experimental data.

### 3.3.1 Pressure transducers

Point pressure transducers and differential pressure transducers were used.
The Point Pressure Transducer (PPT) was used to measure the static pressure at a given point in the line test.
The pressure gradients were measured with a set of point pressure transducers selected from 14 point pressure transducers of the type PHPWO1V1-AKAYY-OY [GP] version 25.0 Fuji Electric. Nine of these instruments had a maximum range of 130 kPa with a precision of 0.25 %, while five others had a maximum range of 500 kPa. The output of these instruments was a DC current ranging from 4 to 20 mA, proportional to the pressure applied. The range and span of these instruments were adjusted by a handheld communicator (HHC).

The Differential Pressure Transducer (DP Cell) was used to measure the difference of static pressure between two points.
Two DP cells of the type IKKW35VI-AKCYYAA [DP], version 25.0 Fuji Electric, were used to measure differential pressures. The maximum ranges were 6 kPa and 130 kPa respectively. They had the same characteristics as the PTT, i.e. a precision of 0.25 %, and could be adjusted with a handheld communicator.

### 3.3.2 The handheld communicator (HHC)

A Fuji electric handheld communicator, type FXY 10AY A3, was used. This portable instrument was connected to the PPT or DP cell to change parameters such as: data display, range, span, time constant, units, calibration, etc. It was mainly used to change the ranges and to calibrate the transducers.

### 3.3.3 Data acquisition unit

A Hewlett Packard (HP) data acquisition unit (DAU) of the type HP 34970A was connected to a computer. This instrument received, through various channels, analogue signals from different parts of the rig (DP cell, PTT, temperature probes, load cell) and converted them to digital signals compatible with a PC.

### 3.3.4 Computer

All processes were controlled by a central PC, a Celeron 300. This was coupled with the DAU as an interface and was used to capture and process the experimental data automatically. Test programs were written in Visual Basic 6. The computation of the data was made using pre-programmed Microsoft Excel spreadsheets.

### 3.3.5 Flow meters

Two magnetic flow meters were used during test work and were mounted vertically

- A Krohne IFC 010D of 50 mm internal diameter
- A Safmag 100A2NESSR0032 of 110 mm internal diameter

### 3.3.6 Pumps

A progressive cavity positive displacement pump, driven by a 5.5 kW electric motor, was used to circulate the fluid in the test loop. It had a maximum capacity of 11 l/s (39.6 $m^3$/h). A connection to another rig was made in order to have a higher flow rate, so that sufficient pressure drop could be obtained in bigger pipes when pumping water. This rig had two centrifugal pumps, of 80 l/s and 140 l/s (288 $m^3$/h and 504 $m^3$/h) maximum flow rate, and they were driven by a 45 kW and a 90 kW electric motor respectively.

### 3.3.7 Weigh tank and load cell

The weigh tank, similar to the bucket and stopwatch method, was used to determine the mass slurry distribution between the two vessels. The operation of the weigh tank is quite simple. The output voltage of the load cell varies linearly with the applied force, and is proportional to the input voltage. The resistors are connected to a power supply which is connected to the DAU. The input voltage divided by the output voltage gives a non-dimensional load cell reading which is independent of the input voltage. An accurate calibration of the load cell is essential and the procedure is given in section 3.4.1.1

### 3.3.8 Heat exchanger

A double pipe heat exchanger was installed at the inlet of the rig to keep the test fluids at a constant temperature.

### 3.3.9 Temperature probes

Two temperature probes were installed to measure the temperature before and after a fluid had entered a test section. It is located at the exit point of the heat exchanger and before the diversion point between the weigh tank and the mixing tank. This information was used to regulate the temperature of the test fluid, using the heat exchanger, and by either reducing or increasing the flow rate of water.

### 3.3.10 Mixer

A mixer, driven by a 3 kW electrical motor, was fitted to the storage tank to mix the test fluids at the preparation stage. At times, the mixer was run during a test to keep the fluid particles suspended.

### 3.3.11 Valves board

A switchboard made of small ball valves, as shown in Figure 3.2, was used to select a particular test section and direct their pressure readings to specific pressure transducers, so that different test modes could be possible.

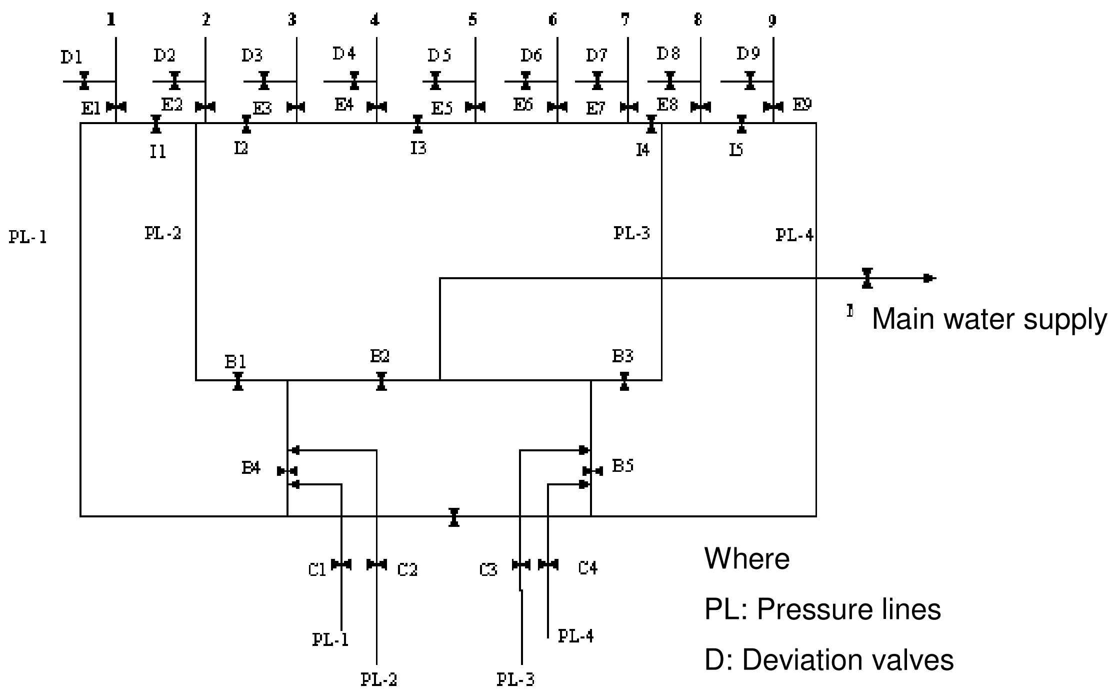



**Figure 3.2: Pressure lines board of the valve test rig**

Figure 3.2 gives a schematic presentation the connection of pressure lines on the valves board. These pressure lines were made of nylon tubes of 3 mm internal diameter and filled with water. Deviation valves (D1, D2, …, D9) were on-off valves giving access to pressure transducers. Pressures lines [(PL1, …, PL4) and (1,2, …,9)] were connected to the test sections' pressure tappings via pods filled with water. The purpose of the pods was to collect any solid particles that might come from the test fluid, preventing it from entering the pressure lines. Each pod had a valve on top and at the bottom. The top valve was for flushing away any air bubbles and the bottom valve was used for flushing away any solids particles.

## 3.4 EXPERIMENTAL PROCEDURES

This section describes the procedure used to collect the experimental data. It consists of the calibration of transducers, load cell and flow meters, measuring the pipe internal diameter, setting the valve positions, measuring the density, running tests to measure the viscous properties of fluids and running tests to measure valve loss coefficients.

### 3.4.1 Calibration procedures

The aim of the calibration was twofold: firstly, to ensure that the measuring instrument readings were valid (normally this is done by double checking the measurement with other devices), and secondly, to ensure that the readings appearing on the PC via the DAU were as close as possible to actual readings.

#### 3.4.1.1 Load cell

To calibrate the weigh tank, it should be empty. It must be ensured that nothing disturbs the tank. The calibration procedure was as follows:

- Switch on the computer and load the calibration program.
- Select channel 118 on the DAU, assigned to capture the voltage induced on the load cell.
- Divert the water flow into the weigh tank and fill it to a certain level.
- Re-direct the water to the mixing tank.
- Record the voltage indicated on the DAU and use the bucket to collect all water from the weigh tank, and weigh it on the portable scale.
- Repeat the exercise for 4 to 5 different water levels and record both the voltage and the weight.
- Plot the weight versus the voltage and determine the slope and the intercept of the linear relationship.

The linear relationship of the weight versus the voltage for load cell calibration is given in Figure 3.3

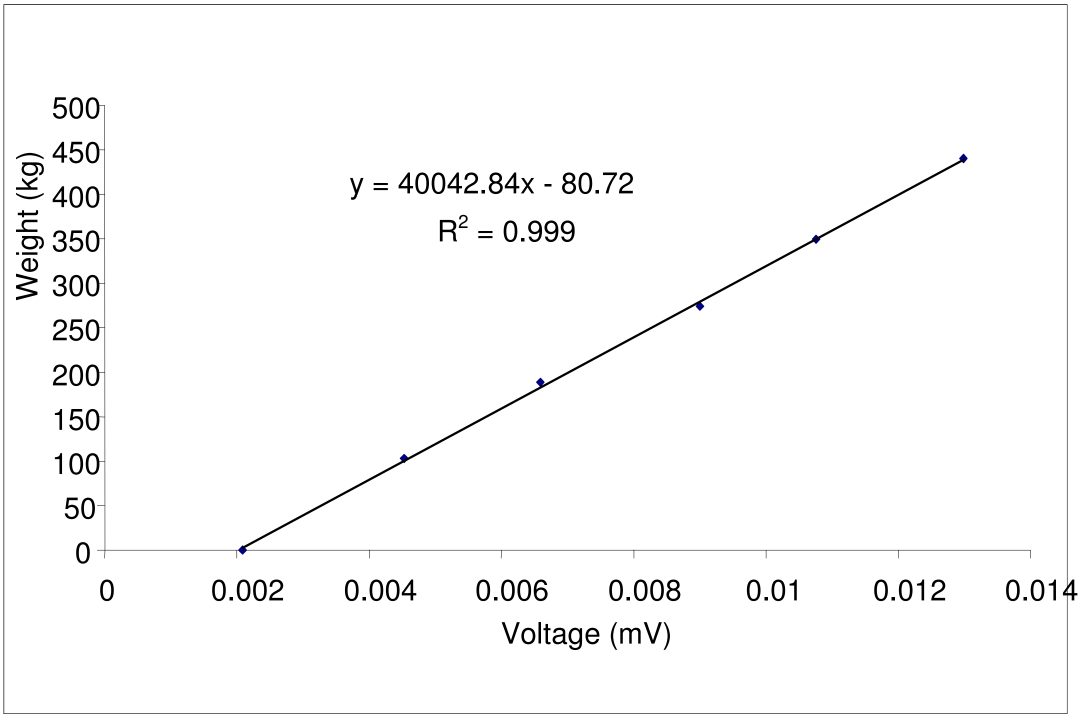



**Figure 3.3: Load cell calibration line**

### 3.4.1.2 Flow meter

The calibration procedure was a follows:

- Open the computer programme and select channel 113 on the DAU for the Khrone flow meter.
- Choose the time interval at which the weight of the tank should be recorded by the computer programme.
- Pump the water through the rig and close valve VR07 and the VR16 to divert the flow through the Khrone flow meter and the weigh tank.
- Close the valve at the bottom of the weigh tank to accumulate water in the tank.
- Start the computer programme. Stop it when the tank is almost full.
- Record the voltage reading on the DAU.
- Empty the weigh tank by opening the valve at the bottom of the tank.
- Vary the speed of the pump to change the flow rate of water though the rig.

- Repeat step 4 to 7 to record another set of data.
- Repeat the procedure to acquire at least 5 sets of data at differing flow rates.
- Follow the same procedure to calibrate the Safmag flow meter. Water flow was diverted through the Safmag flow meter by first opening valve VR07 and closing valve VR06.

The mass flow rate through the flow meter was determined as the ratio of the recorded mass of the weigh tank to the time it took to fill it. It was converted to the volumetric flow rate by dividing the ratio with the density of water at its recorded temperature. .

The linear relationship of the flow rate versus the voltage for Khrone flow meter calibration is given in Figure 3.4.

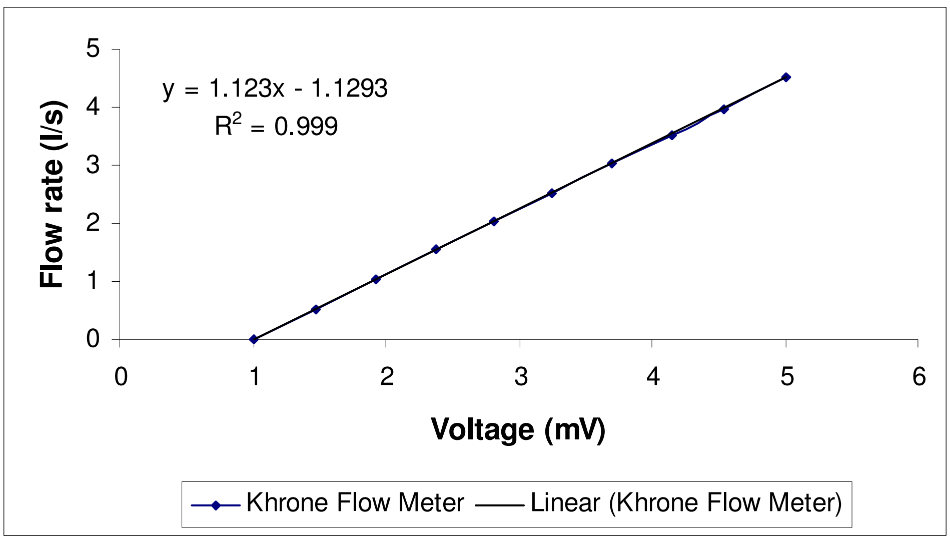



**Figure 3.4: Khrone flow meter calibration constants**

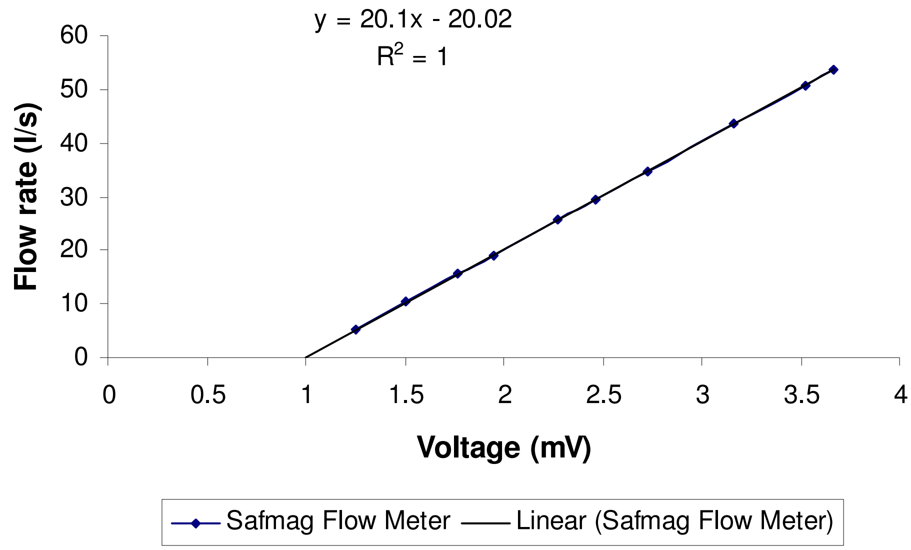



**Figure 3.5: Safmag flow meter calibration constants**

### 3.4.1.3 Transducer

The point pressure and differential pressure transducers were calibrated using equipment called the Handheld Communicator. Using water, a known pressure was applied directly to the transducers.

The calibration procedure was as follows:

- Open the calibration computer program and switch on the DAU to channel 101.
- Open the transducer's cap and set it to zero.
- Open the pipe valves leading to the transducers and expose them to the atmosphere, to release any pressure induced by the system.
- Connect the Handheld Communicator to the transducers and switch it on.
- Set the Handheld Communicator to the desired pressure range, either 0-40 kPa or 0-130 kPa, and set it on data recording mode.
- Read the pressure recorded by the Handheld Communicator and the voltage recorded by the DAU. This was considered as the zero mark.
- Apply pressure on the transducers and record both the pressure and the voltage reading on the Handheld Communicator and the DAU, respectively.

- Continue to increase the pressure on the transducers, recording the pressure and voltage readings to acquire at least 6 different readings.
- Plot the pressure readings against the voltage reading to determine the linear relationship between them. The slope and the intercept of this linear relationship were used to relate the pressure applied by the test fluid in the rig to the voltage recorded by the DAU.

The linear relationship of the pressure versus the voltage for point pressure transducers calibration is given in Figure 3.6:

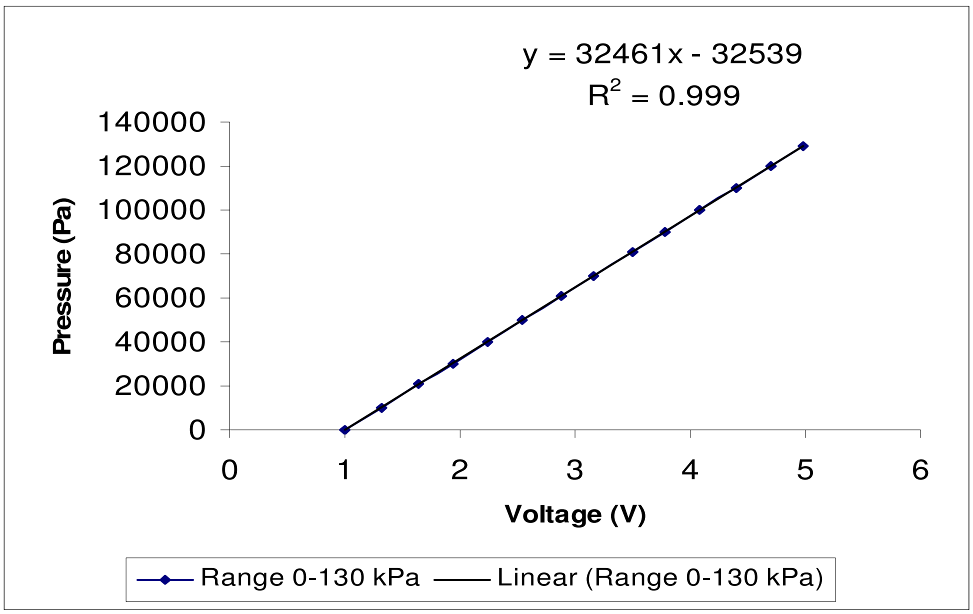



**Figure 3.6: Calibration curve of the Point Pressure Transducer**

The calibration of the DP cell was conducted in a similar manner to the procedure used to calibrate the point pressure transducers. The only difference was the channel used on the DAU to record the voltage produced by the pressure in the system. Channel 115 and 116 of the DAU were used to calibrate the DC cells for a pressure drop range of 6 kPa and 130 kPa respectively. The linear relationship of the pressure versus the voltage for the 130 kPa differential pressure transducers calibration is given in Figure 3.8

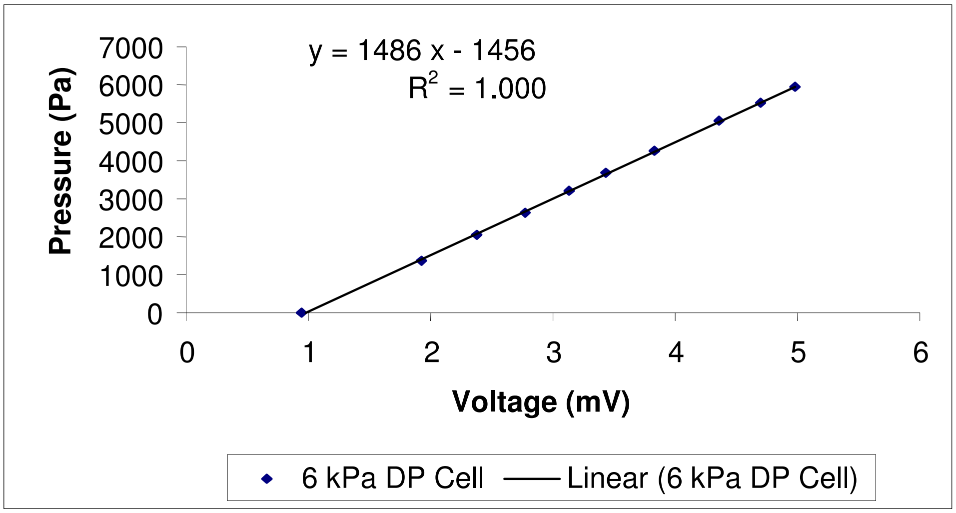



**Figure 3.7: The calibration curve of the 6 kPa DP cell**

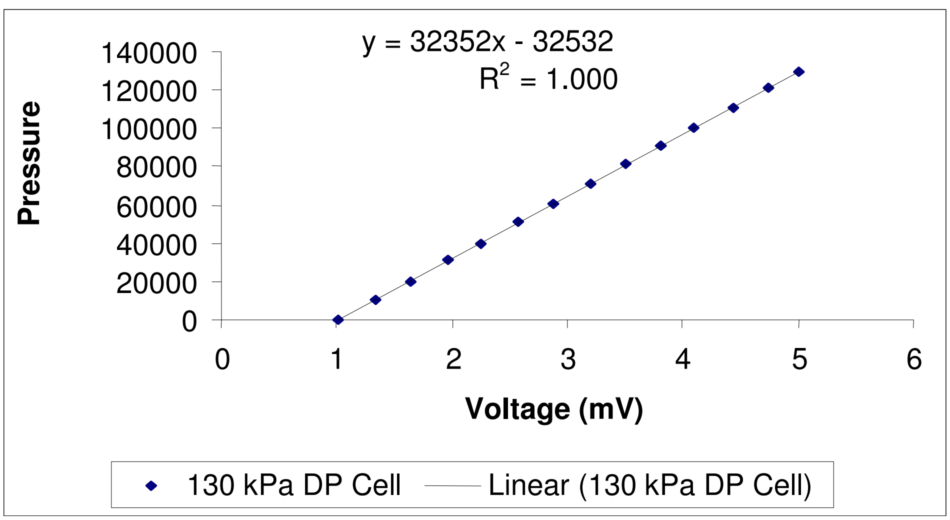



**Figure 3.8: Calibration curve of the 130 kPa DP cell**

### 3.4.2 Fluid relative density

The slurry density (ρ) and the relative density were determined carefully for each fluid tested, by performing the followings steps:

- Three clean, dry 250 ml volumetric flasks were weighed ($M_1$).
- A slurry sample was taken from a tapping in the pipe wall of any of the 5 pipes and was weighed ($M_2$).
- The volumetric flasks were filled to the 250 ml level with clear water and weighed again ($M_3$).
- The volumetric flasks were emptied, filled with clear water and weighed again ($M_4$).
- The relative density $S_m$ defined as $S_m = \rho / \rho_w$

$$RD = \frac{\text{Mass of fluid}}{\text{Mass of equal volume of water}} = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$ **Equation 3.1**

### 3.4.3 Valve test procedures

In general, the operation of the valve test rig was as follows:

Switch on the computer and open the desired programme of test operation, i.e. the HGL manual mode, automatic mode, DP cell mode or the straight pipe test.
In case of testing a particular slurry, switch on the mixer to mix the slurry evenly.

- Open fully the by-pass valve positioned immediately after the pump, to ensure that there is no build-up of pressure in the rig if the wrong valves or no valves are open.
- Switch on the pump and set it at the desired speed to achieve a certain flow rate.
- Open all the diaphragm valves in the system to circulate the test fluid left in the rig.
- Close the bypass valve and let the rig run for an hour to thoroughly mix the test fluid.
- To conduct a test on the 42 mm and 50 mm ID pipes, ensure that valve VR08 is open and close valve VR07. Then choose either the 42 mm ID pipe or the 50 mm ID pipe by closing either VR01 or VR02.
- To conduct a test on the 63 mm ID, 80 mm ID or the 100 mm ID pipes, open valve VR07 and close VR08.

- Select the desired pipe among the four pipes fed through VR07 by opening or closing the appropriate valves among VR03, VR04, VR05 and VR06.
- Choose the desired pressure tappings on the test pipes and record their distances from the valve in the appropriate columns on the computer programme.
- Flush the pressure pods and the pressure line board and fill them with tap water, ensuring that there are no bubbles in the tubes.
- Open the valves of the tappings leading to the pressure pods.
- Use the Handheld Communicator to determine the pressure range to be used during the test.
- Set the computer programme to the determined pressure range and the chosen pipe diameter, and indicate the type of fluid to be tested.
- Open the appropriate valves on the pressure lines board and start the test.
- Take a sample of the fluid and conduct rheology and RD tests, and record the information on the computer programme.
- Increase the flow rate of the fluid by increasing or decreasing the pump speed.

The test liquid was circulated from the tank by means of a positive displacement pump to the test section. The flow rate was controlled by a by-pass valve and measured with two different flow meters. The liquid discharge from the test section was returned to the liquid storage tank. The test section is 25 m long and comprised a horizontal upstream straight pipe, a diaphragm valve and a downstream straight pipe. The test section was provided with pressure taps at various points of the upstream and downstream sections of the pipe. The static pressure at different points was measured by means of point pressure transducers or differential pressure transducers mode. Different pipe diameters ranging from 40 mm to 100 mm bore diameter of Saunders diaphragm valves were used in this experimental investigation. All the valves were positioned horizontally. Under steady state conditions the liquid flow rates were recorded at various flow rates. The percentage openings of the valves used in the experiment were full, 75%, 50% and 25% open. The fluids were maintained at a temperature between 25$^{o}$C and 30$^{o}$C while using the positive displacement pump.

The following steps were used to compute the loss coefficient as illustrated on Figure 2.7.

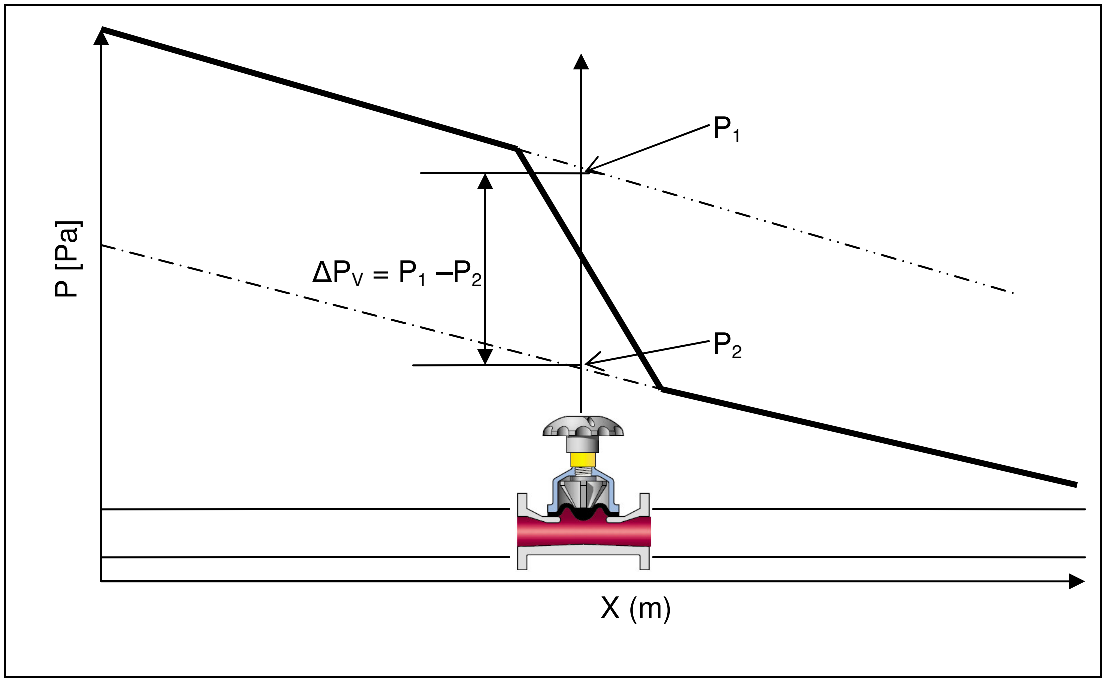



Figure 2.7: Diagram illustrating the calculation of valve loss coefficient

The measurement of static pressure at different points upstream and downstream of the test valve were taken. (In total nine points were used, four upstream and five downstream of the test valve.)

The calculation of the shear stress in the two pipes upstream and downstream of the test valve was done in the regions of fully developed flow. Six points are used to calculate the shear stress (three points upstream and three points downstream respectively) of the test valve, all in regions of fully developed flow as defined above. The three points close to the test valve, one point upstream and two points downstream, are discarded because they are in the region of influence of the valve. The shear stress in the two pipes upstream and downstream is calculated using the Equation 2.2.

### 3.4.4 Pressure tapping

The setting of the pressure pods and the pressure transducers of the Valve Test Rig are as shown in Figure 3.9.

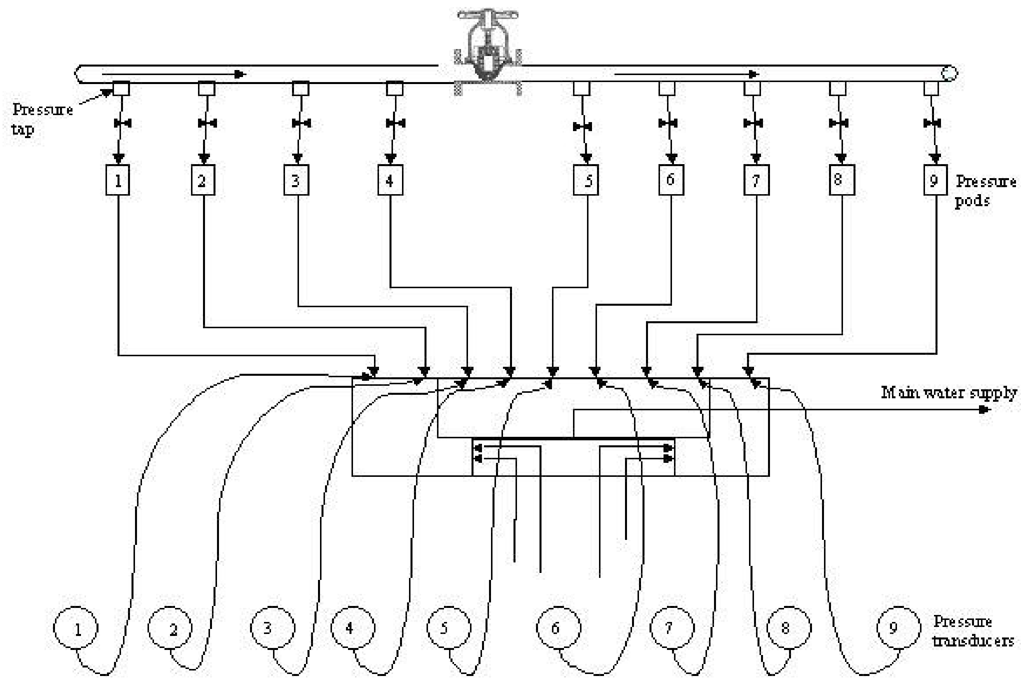



**Figure 3.9: Valve test rig pressure lines**

Pressure is transferred from the fluid within the test pipe to the pressure transducers through the water-filled pods. The pressure is converted into a voltage signal, detected and captured by the DAU.

### 3.4.5 Single point pressure transducers mode (manual mode)

The manual mode of the Valve Test Rig was conducted in two ways, namely, by reading the static pressure at one tapping point using all the nine point pressure transducers, or by using only one point pressure transducer. Using all nine transducers, the setting of the ball valves on the Pressure Lines Board (Figure 3.2) was as follows, referring to Figure 3.9.

- The exit valves: E1 was opened to read the pressure on tapping 1.
- E2 to E9 were closed.
- Deviation valves (D1 to D9) were opened. The isolation valves (I1, I2 and I3) were closed.
- The bypass ball valves (B1 to B5) and the connecting valves (C1 to C4) were closed.
- Take the reading (all the transducers should read the same pressure).
- Close valve E1 and open E2.
- Read the pressure, close E2 and open E3.
- Continue this procedure until valve E9 is open.

At the completion of the process all nine point pressure transducers will record each one Pressure Grade line separately. The procedure of conducting the test, using only a one-point pressure transducer, was as follows:

- The exit valve E1 is open to read the pressure on tapping 1.
- E2 to E9 are closed.
- The deviation valves (D1 to D9) are closed. The isolation valves are open.
- The bypass valves (B1 to B6) are closed, also closed are the connecting ball valves except C1.
- C1 is connected to the point pressure transducer 1.
- Record the pressure reading.
- Close valve E1 and open E2.
- Read the pressure, close E2 and open E3.
- Continue the procedure until E9 is open.

### 3.4.6 Straight pipe test

The straight pipe test can be conducted simultaneously on the downstream and upstream legs of the Valve Test Rig. The procedure is as follows referring to Figures 3.2 and 3.9:

- Choose the straight pipe section on which the pressure drop will be measured and record the tapping distance.
- On the Pressure Lines Board close the isolating valve 11, I3 and I4.

- Open the valves E according to the test sections chosen. All deviation valves and the other E valves must be closed.
- Close the bypass valve B2, B4, B5, and B6.
- Use the pressure line PL-1 and PL-2 to measure the pressure drop upstream of the test valve by opening the connecting valves C1 and C2.
- Ensure that the pressure line PL-1 is connected to the High side of the DP cell and PL-2 to the Low side of the DP cell.
- Use the pressure line PL-3 and PL-4 to measure the pressure drop downstream of the test valve by opening the connecting valves C3 and C4.

### 3.4.7 Differential pressure transducers mode

The pressure grade line was determined using the DP cell for reading high pressures. This was achieved by isolating the first pod from the others and opening the pressure taps, from the second pod to the ninth pod, one after another and reading the pressure gradient. The procedure is the same as the straight pipe test described above, up to the $6^{th}$ step. It continues as follows:

- Open the isolating valve I3.
- Open the respective E2, and take the reading.
- Close E2 and open E3, and continue until E9 is open.
- Change the flow rate and repeat step 2 and 3

## 3.5 VALVES TESTED

The valves tested in this study were the straight-through type, i.e. without a weir. These valves are suitable for slurry applications. A schematic diagram and a photograph of one these valves are shown in Figure 3.10 and Figure 3.11, respectively. They consist of two principal parts, the bonnet and the base, which are separated by a paraboloidal-shaped flexible rubber band (the diaphragm). The bonnet consists of a hand-wheel and the spindle, which together drive the diaphragm down across the flow area to obstruct the flow.

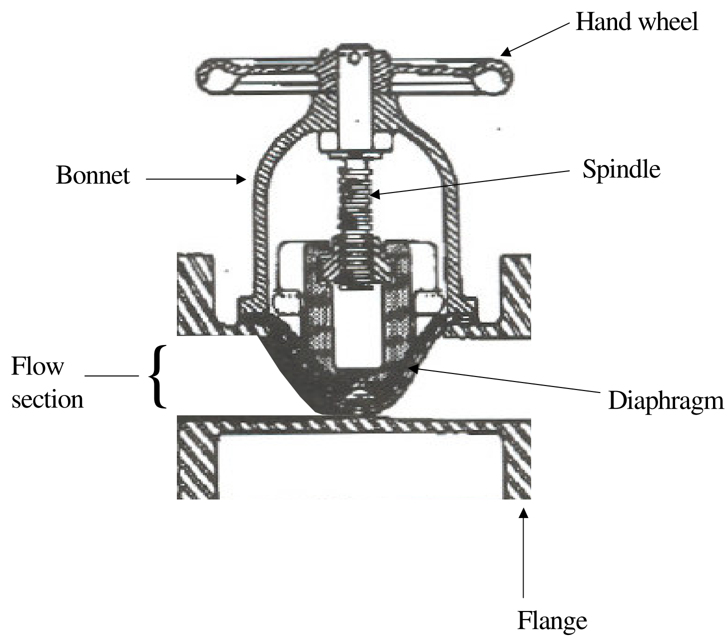


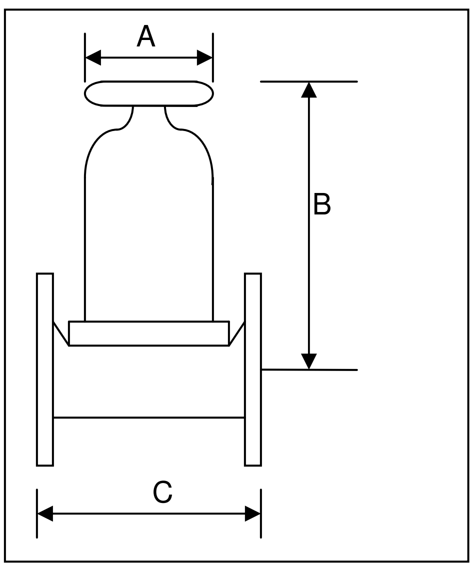

**Figure 3.10**: Schematic diagram of a Saunders diaphragm valve

**Figure 3.11: Photograph of a Saunders diaphragm valve**

Five diaphragm valves (from Saunders Valves supplied by DFC, South Africa) have been tested for the purpose of this thesis. Other valves from a different manufacturer (from Natco Valves) have already been tested (Mbiya 2008). The external dimensions of the Saunders valves are shown in Table 3.1

**Table 3.1: External dimensions of Saunders valves**

| Nominal bore | A | B | C | Safe working Pressure |
|---|---|---|---|---|
| mm | mm | mm | mm | kPa |
| 40 | 83 | 121 | 159 | 700 |
| 50 | 140 | 181 | 191 | 700 |
| 65 | 165 | 200 | 216 | 700 |
| 80 | 197 | 245 | 254 | 700 |
| 100 | 254 | 267 | 305 | 700 |




### 3.5.1 Internal Dimension of Valves

The valves' internal dimensions were measured after they had been unscrewed. A schematic diagram of the inside dimensions of the valves is shown in Figure 3.12.

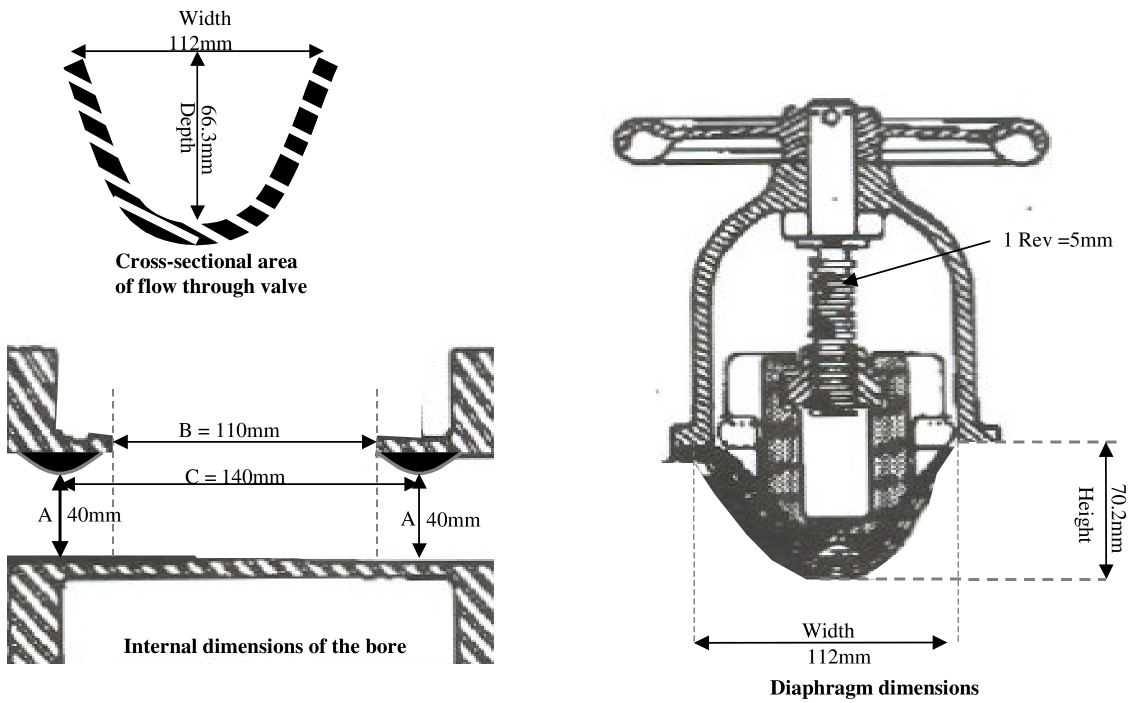



**Figure 3.12: Internal dimension of the 80 mm bore diaphragm Natco valve (Pienaar et al., 2006)**

The internal measured dimensions for all the Saunders valves tested are shown in Table 3.2.

**Table 3.2: Internal dimensions of the diaphragm valves**

| Bore size | Cross section area (mm) | | Diaphragm dimensions (mm) | | | Bore dimensions (mm) | | |
|---|---|---|---|---|---|---|---|---|
| | Depth | Width | Height | Width | Per Rev | A | B | C |
| 40 | 35.26 | 42.78 | 36.00 | 47.38 | 3.44 | 28.20 | 54.06 | 90.04 |
| 50 | 46.65 | 64.26 | 47.00 | 66.34 | 3.88 | 35.26 | 67.15 | 133.4 |
| 65 | 62.42 | 90.82 | 63.00 | 92.14 | 3.64 | 51.98 | 82.36 | 152.5 |
| 80 | 68.92 | 112.00 | 69.00 | 114.20 | 2.98 | 58.64 | 118.5 | 171.4 |
| 100 | 74.72 | 124.46 | 75.00 | 129.92 | 2.78 | 59.56 | 126.7 | 262.6 |

A close look at the values given in Table 3.2 showed that the measured values also did not portray a systematic geometrical similarity. However, some dimensions such as the depth of the cross sectional area and the height of the diaphragm proved a close correlation with the bore dimensions.

### 3.5.2 The gravity test

In this test, about 3 $m^3$ of water was stored in a tank (from another rig) as shown in Figure 3.13. The test valve was connected at the end of the exit pipe so that water flowed freely by gravity when the valve was opened. The test valve was causing the major obstruction to the flow of water; therefore the flow depended on the discharge coefficient of the valve and the level of water in the storage tank.

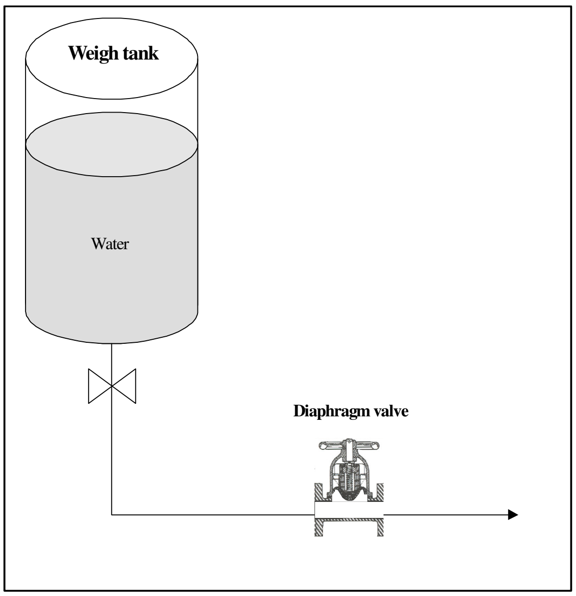



**Figure 3.13: Gravity flow system used to determine the valve positions**

The procedure was as follows:

- Open the computer program that records the mass of water within the weigh tank.
- Fill the weigh tank with water.
- Set the valve at fully opened position.
- Select the time interval, for which the mass of water was to be recorded, ideally at 1-sec. intervals.
- Start the program to record the mass of water in the tank every second.
- Open the valve at the bottom of the weigh tank to allow water to run through the valve, recording the change in mass simultaneously.
- Stop the computer programme once the tank is emptied.

- Close the valve, at the bottom of the tank, and refill it.
- Set the valve position by revolving the hand-wheel once (first revolution), towards the closing position.
- Repeat steps 4 to 8.
- Set the valve position by revolving the hand-wheel once more. This was a second revolution, towards the closing position.
- Repeat steps 4 to 8.
- Conduct the experiment until the valve is fully closed.

### 3.5.3 Valves opening setting

To determine the valve position, i.e. the ¼, ½, and ¾ open positions, a gravity flow system was implemented. By running water through the valve at different settings, the desired valve positions could be identified. To determine the ½ open mark, for instance, the mark was determined by counting the number of revolutions of the hand-wheel at which the ratio of water flow rate at that mark, and the flow rate when the valve is fully open, was fifty per cent (50%). The procedure was as follows:

- Open the computer programme that records the mass of water within the weigh tank.
- Fill the weigh tank with water.
- Set the valve at fully open mode.
- Select the time interval at which the mass of water is to be recorded; ideally at 1-second intervals.
- Start the programme to record the mass of water in the tank every second.
- Open the valve at the bottom of the weigh tank to allow water to run through the valve, recording the change in mass simultaneously.
- Stop the computer programme once the tank is empty.
- Close the valve, at the bottom of the tank, and refill it with water.
- Set the valve position by revolving the hand-wheel once, first revolution, en route for the closing position.
- Repeat step 4 to 8.
- Set the valve position by revolving the hand-wheel once, second revolution, en route for the closing position.

- Repeat step 4 to 8.
- Conduct the experiment until the valve is fully closed.

Figure 3.14 gives the percentage delivery of the 40 mm to 100 mm bore size range after each revolution, from a fully open to fully closed position. The graph was used to determine the 75%, 50% and 25% delivery positions, which were regarded as the ¼, ½ and ¾ open positions. Note that the graph curves are not all smooth, and that the valve setting was changed from fully open to fully closed positions. The number of revolutions to obtain the desired valve opening are given in Table 3.3.

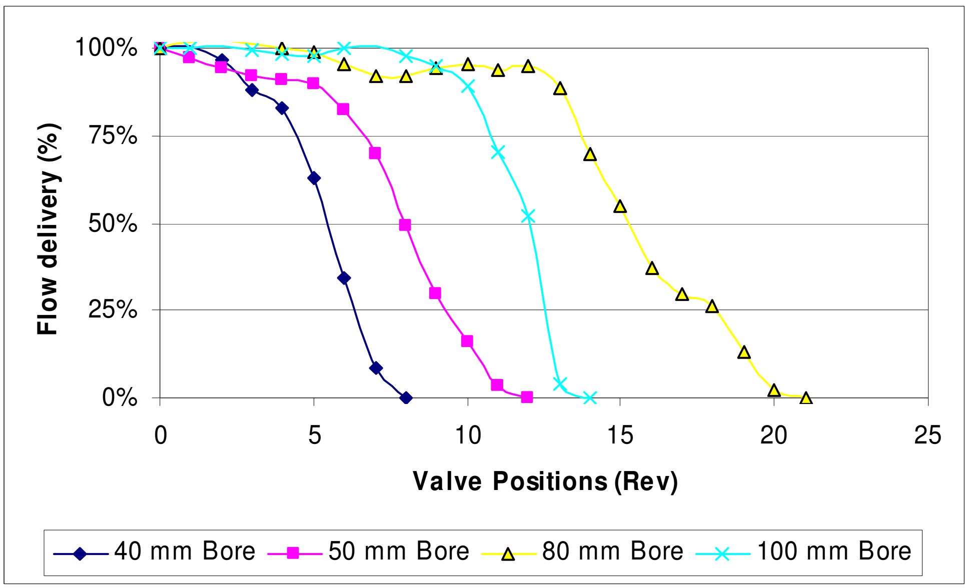



**Figure 3.14: Percentage flow delivery at different valve positions**

**Table 3.3: Valve position**

| | | Number of revolutions to obtain the desired valve opening | | |
|---|---|---|---|---|
| Valve bore size | Pipe outer diameter | 75% Open | 50% Open | 25% Open |
| 40 mm | 50 mm | 4.5 | 5.5 | 7.8 |
| 50 mm | 63 mm | 6.5 | 8 | 9.25 |
| 80 mm | 90 mm | 13.75 | 15.25 | 18 |
| 100 mm | 110 mm | 8.75 | 10 | 11.75 |

## 3.6 MATERIAL/FLUID TESTED

In order to perform the tests, the Newtonian fluid (water) was used for the calibration of the valve test rig and non-Newtonian fluids (carboxymethylcellulose and kaolin at three different concentrations) will be tested to derive and to provide loss coefficient data to the open literature, which will be useful for designing pipelines in industries, as well as contributing to the academic discourse and debate in this discipline.

### 3.6.1 Water

Water was tested in straight pipes to establish credibility, accuracy and precision of the valve test rig. The typical properties of water are as follows: A pH of 9 with a total alkalinity of 35 mg/l as $CaCO_3$ and an ionic strength of less than 0.01 molar scale (Haldenwang, 2003).

### 3.6.2 Carboxyl methyl cellulose (CMC)

The CMC was obtained in granular form, which easily dissolves in water at a low concentration. Municipal tap water was used for this research work. Solutions of CMC are stable between pH of 2 and 10. Below pH 2, precipitation of the solids occurs, and above pH 10 the 'viscosity' decreases rapidly. The pH of the solutions tested for this study was pH 9.0 at 20 $^0$C.

CMC is used in drilling mud, in detergents as a soil-suspending agent, in resin emulsion paints, adhesives, printing inks, as protective colloid in general and as a stabilizer in foods. The flow properties of the CMC solutions proved to be constant throughout the test work. The concentrations tested were 5% by mass. At a high concentration, dissolution of the CMC in water deteriorated and required long periods of mixing time to achieve homogeneous solutions.

### 3.6.3 Kaolin

The kaolin used in the preparation of kaolin suspensions is supplied by Serina Kaolin (Pty) Ltd, and was mined in the Fish Hoek area near Cape Town. Pellets of kaolin clay were mixed with tap water in preparation of the slurry to be tested. A mixer, in the mixing tank was used to mix the solution thoroughly. The kaolin slurry was mixed in volumetric concentration of 10% and 13%.

## 3.7 EXPERIMENTAL ERRORS

Absolute accuracy in measuring is not always achieved, unless the data are discrete numbers. It is important to be able to determine the margins of error which may be found in a set of data, and to know how they are affected by various arithmetic processes such as addition, multiplication, root extraction, etc., (Benzinger & Aksay, 1999).

There are three types of error: Gross errors, systematic errors and random errors (Benzinger & Aksay, 1999).

### 3.7.1 Gross errors

Gross errors are due to blunders, equipment failure and power failure. A gross error is immediate cause for rejection of a measurement (Benzinger & Aksay, 1999).

### 3.7.2 Systematic or cumulative errors

Systematic errors result in a constant bias in an experimental measurement. Systematic errors are those that are due to known conditions. These conditions might be:

- Natural (temperature, pressure, humidity, etc.)
- Instrumental (calibration, graduation, range, etc.)
- Personal (poor sight of the experimenter, inability of the experimenter to take correct reading, etc.) size (Barry, 1991).

In this work precautions were taken to prevent those errors occurring: e.g. checking the calibration of instruments by another instrument not related to the instrument, or independent calibration, and also by checking the reproducibility of the results.

### 3.7.3 Random errors

Random errors are those that are due to chance variation. Most experiments proceed with minor variations that change from event to event and follow no systematic trend. The same quantity may be measured many times, giving close but not identical results. The fluctuations in the measurement are assumed to be random and lead to a distribution of values (Barry, 1991).

### 3.7.4 Evaluation of errors

The absolute error is the difference between the true value of any number or quantity and the value obtained or used for that the number or quantity in a given circumstance. If the true value of a number or quantity is X, the value obtained or used for that number or quantity is A, and the absolute error is ΔA than:

$$X = A \pm \Delta A \qquad \textbf{Equation 3.2}$$

This means that X is comprised between A – ΔA and A + ΔA. ΔA is called the maximum error or absolute error. If X is a quantity, ΔA is expressed in the same unit. ΔA is here the smallest division of the instrument, and the smallest value detected by the instrument (Barry, 1991). ΔA is calculated from the standard deviation of a set repeated measurement as well. The absolute error for A at 99,9% confidence interval is given by the equation:

$$\Delta A = 3.29\sigma$$ **Equation 3.3**

where σ is the standard deviation

If at 95% confidence level is considered, then the absolute error may be approximated by:

$$\Delta A = 2\sigma$$ **Equation 3.4**

The relative or percentage error of a number or quantity is calculated by:

$$\delta A = \frac{\Delta A}{A}$$ **Equation 3.5**

### 3.7.5 Combined errors

When a variable is a result of a computation of other variables with their subsequent errors, the resulting error is the combination of the independent variables errors (mean quadratic value of the independent errors). If a variable X is a function of n other variables, i.e., X = F (A, B, C… N), the expected highest error (Brinckworth, 1968) can be calculated from:

$$\left(\frac{\Delta X}{X}\right)^2 = \sum\left(\frac{\partial X}{\partial N}\right)^2\left(\frac{N}{X}\right)^2\left(\frac{\Delta N}{N}\right)^2$$ **Equation 3.6**

## 3.8 ERROR OF MEASURABLE VARIABLES

### 3.8.1 Axial distance

The axial distances were measured using a measuring tape divided up in mm. The absolute error on measurements was 0.001 m.

### 3.8.2 Weight

The mass of all samples was measured using the weigh scale graduated in grams. The absolute error on measurements was 0.001 kg.

### 3.8.3 Flow rate

The flow meters used are accurate to 0.001 l/s, which can be assumed as the absolute error.

### 3.8.4 Pressure

The pressure transducers used are accurate at 0.25%. Care should be taken in calibration to obtain a correlation coefficient of 0.999. Such calibration can rise to an average of 0.35% (Baudouin, 2003).

### 3.8.5 Error of derived variables

#### 3.8.5.1 Pipe diameter

The combined error of the diameter of the Valve Test Rig pipes was determined using the following equation:

$$D = \sqrt{\frac{4M_{H_2O}}{\pi \rho_{H_2O} L}}$$ **Equation 3.7**

The highest expected error in calculating the pipe diameter is obtained by applying the Equations 3.6 and 3.7, and that yields:

$$\frac{\Delta D}{D} = \pm \frac{1}{2}\sqrt{\left(\frac{\Delta M_{H_2O}}{M_{H_2O}}\right)^2 + \left(\frac{\Delta L}{L}\right)^2}$$ **Equation 3.8**

The highest expected error and experimental errors on the measurements of the five diameters of the Valve Test Rig are given in Table 3.4.

**Table 3.4: Expected highest error and experimental errors in the measurements of the valve test rig pipe diameters**

| Pipe position | Nominal outer diameter (mm) | Average internal diameter (mm) | Length (mm) | Experimental error (%) | Highest expected error (%) |
|---|---|---|---|---|---|
| Top | 50 | 42.1 | 5000 | 0.63 | 2.38 |
| 2nd Top | 63 | 52.8 | 5000 | 0.32 | 1.90 |
| 3rd Top | 75 | 63.1 | 5000 | 0.45 | 1.59 |
| 4th Top | 90 | 80.4 | 5000 | 0.22 | 1.25 |
| 2nd bottom | 75 | 63.1 | 5000 | 0.36 | 1.01 |
| Bottom | 110 | 97.2 | 5000 | 0.37 | 1.03 |

### 3.8.5.2 Velocity

The velocity in a pipe is determined Equation 2.5. Q and A respectively, the flow rate and the cross section area of the pipe. The application of the Equation 3.6 to the Equation 2.5 yields the highest expected error on the velocity given by:

$$\frac{\Delta V}{V} = \pm\sqrt{\left(\frac{\Delta Q}{Q}\right)^2 + 4\left(\frac{\Delta D}{D}\right)^2}$$ **Equation 3.9**

The pseudo shear rate is determined using the Equation 2.14

$$\dot{\gamma}_o = \frac{8V}{D}$$ **Equation 3.10**

The application of the Equation 3.6 to 2.14 gives the expected higher error on the pseudo shear rate and it yields:

$$\frac{\Delta\dot{\gamma}_o}{\dot{\gamma}_o} = \pm\sqrt{\left(\frac{\Delta Q}{Q}\right)^2 + 5\left(\frac{\Delta D}{D}\right)^2}$$ **Equation 3.11**

**3.8.5.3 Wall shear stress errors**

The combined error of the wall shear stress of the slurries tested in the Valve Test Rig pipes was determined using the following equation:

$$\tau_o = \frac{\Delta PD}{4L}$$

The application of the Equation 3.6 to 2.2 gives the expected highest error on the shear stress and that yields:

$$\frac{\Delta\tau_o}{\tau_o} = \pm\sqrt{\left(\frac{\Delta(\Delta P)}{\Delta P}\right)^2 + \left(\frac{\Delta D}{D}\right)^2 + \left(\frac{\Delta L}{L}\right)^2}$$ **Equation 3.12**

**3.8.5.4 Reynolds number**

The Reynolds number errors in this work are evaluated for the Slatter Reynolds number $Re_s$ (Equation 2.27)

$$Re_S = \frac{8V_{ann}^2\rho}{\tau_y + K\left(\frac{8V_{ann}}{D_{shear}}\right)^n}$$

Application of Equation 3.6 to 2.27 yields

$$\frac{\Delta Re_s}{Re_s} = \sqrt{\left(\frac{\Delta\rho}{\rho}\right)^2 + 4\left(\frac{\Delta Q}{Q}\right)^2 + \left(\frac{\Delta L}{L}\right)^2 + 25\left(\frac{\Delta D}{D}\right)^2 + \left(\frac{\Delta\Delta P}{P}\right)^2}$$ **Equation 3.13**

**3.8.5.5 The valve loss coefficient**

The valve loss coefficient is obtained from the Equation 2.38

$$H_v = k_v \frac{V^2}{2g}$$

Or the pressure loss due to the valve is related to the head loss by:

$$\Delta P_v = \rho g H_v$$

Then:

$$k_v = \frac{\Delta P}{\frac{1}{2}\rho V^2}$$

$$\left(\frac{\Delta k_v}{k_v}\right)^2 = \left(\frac{\Delta(\Delta P_v)}{\Delta P_v}\right)^2 + \left(\frac{\Delta\rho}{\rho}\right)^2 + 4\left(\frac{\Delta Q}{Q}\right)^2 + 16\left(\frac{\Delta D}{D}\right)^2$$ **Equation 3.14**

A sample of 25 readings at constant flow rate were collected to evaluate the accuracy and precision of the rig in capturing data relevant to loss coefficient determination. The shear stress was determined from the pressure gradient. The average mean and standard deviation were determined. The error incurred in calculating the wall shear stress was determined as the ratio of the standard deviation and the average mean.

Table 3.5 to Table 3.9 show the statistical analysis for the absolute errors for different pipes. It can be seen that the loss coefficient absolute error for the 25 % opening position is higher than for the other opening positions.

**Table 3.5: Absolute error for 40 mm bore diameter**

| Opening position | Fluid | ΔQ | Δρ | $\Delta(\Delta P_v)$ | ΔD | $\Delta k_v$ | ΔRe |
|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 0.080 | 3.750 | 4126 | 0.265 | 15.26 | 42.92 |
| 50 % Open | Kaolin 10% | 0.022 | 3.750 | 1527 | 0.265 | 1.622 | 18.33 |
| 75 % Open | Kaolin 10% | 0.062 | 3.750 | 2343 | 0.265 | 1.539 | 76.63 |
| 100 % Open | Kaolin 10% | 0.026 | 3.750 | 1186 | 0.265 | 0.696 | 64.89 |

**Table 3.6: Absolute error for 50 mm bore diameter**

| Opening position | Fluid | ΔQ | Δρ | $\Delta(\Delta P_v)$ | ΔD | $\Delta k_v$ | ΔRe |
|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 0.022 | 3.75 | 1812 | 0.169 | 1.480 | 27.86 |
| 50 % Open | Kaolin 10% | 0.060 | 3.75 | 1274 | 0.169 | 0.647 | 42.47 |
| 75 % Open | Kaolin 10% | 0.036 | 3.75 | 1064 | 0.169 | 0.817 | 28.21 |
| 100 % Open | Kaolin 10% | 0.011 | 3.75 | 575.8 | 0.169 | 0.578 | 13.95 |

**Table 3.7: Absolute error for 65 mm bore diameter**

| Opening position | Fluid | ΔQ | Δρ | $\Delta(\Delta P_v)$ | ΔD | $\Delta k_v$ | ΔRe |
|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 0.026 | 3.75 | 1793 | 0.284 | 1.170 | 47.81 |
| 50 % Open | Kaolin 10% | 0.026 | 3.75 | 1255 | 0.284 | 1.173 | 41.54 |
| 75 % Open | Kaolin 10% | 0.026 | 3.75 | 816.3 | 0.284 | 0.391 | 32.32 |
| 100 % Open | Kaolin 10% | 0.033 | 3.75 | 498.0 | 0.284 | 0.230 | 41.04 |

**Table 3.8: Absolute error for 80 mm bore diameter**

| Opening position | Fluid | ΔQ | Δρ | $\Delta(\Delta P_v)$ | ΔD | $\Delta k_v$ | ΔRe |
|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 0.040 | 3.75 | 626 | 0.177 | 1.529 | 19.72 |
| 50 % Open | Kaolin 10% | 0.032 | 3.75 | 863 | 0.177 | 2.218 | 11.61 |
| 75 % Open | Kaolin 10% | 0.046 | 3.75 | 285 | 0.177 | 0.773 | 9.256 |
| 100 % Open | Kaolin 10% | 0.073 | 3.75 | 559 | 0.177 | 0.578 | 27.97 |

**Table 3.9: Absolute error for 100 mm bore diameter**

| Opening position | Fluid | ΔQ | Δρ | $\Delta(\Delta P_v)$ | ΔD | $\Delta k_v$ | ΔRe |
|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 0.058 | 3.75 | 473.1 | 0.360 | 2.365 | 21.16 |
| 50 % Open | Kaolin 10% | 0.134 | 3.75 | 1296 | 0.360 | 3.538 | 78.02 |
| 75 % Open | Kaolin 10% | 0.061 | 3.75 | 819.9 | 0.360 | 1.960 | 46.00 |
| 100 % Open | Kaolin 10% | 0.128 | 3.75 | 215.8 | 0.360 | 0.537 | 22.49 |

**Table 3.10: Mean value for 40 mm bore diameter**

| Opening position | Fluid | Flow Rate | ρ | $\Delta P_v$ | D | $k_v$ | Re |
|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 1.311 | 1169 | 36972 | 42.10 | 71.65 | 336.5 |
| 50 % Open | Kaolin 10% | 1.859 | 1169 | 40039 | 42.10 | 38.50 | 627.3 |
| 75 % Open | Kaolin 10% | 2.147 | 1169 | 12698 | 42.10 | 9.144 | 805.0 |
| 100 % Open | Kaolin 10% | 2.399 | 1169 | 4283 | 42.10 | 2.470 | 963.1 |

The mean value for the loss coefficient has been presented in Table 3.10 to Table 3.14. This proved the qualitative trend that as the opening position decreases, the loss coefficient increases as well.

**Table 3.11: Mean value for 50 mm bore diameter**

| Opening position | Fluid | Flow Rate | ρ | $\Delta P_v$ | D | $k_v$ | Re |
|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 3.262 | 1169 | 30520 | 52.8 | 23.53 | 933.6 |
| 50 % Open | Kaolin 10% | 3.408 | 1169 | 13132 | 52.8 | 9.266 | 1003 |
| 75 % Open | Kaolin 10% | 3.352 | 1169 | 4790 | 52.8 | 3.496 | 972.6 |
| 100 % Open | Kaolin 10% | 2.845 | 1169 | 1188 | 52.8 | 1.203 | 718.2 |

**Table 3.12: Mean value for 65 mm bore diameter**

| Opening position | Fluid | Flow Rate | ρ | $\Delta P_v$ | D | $k_v$ | Re |
|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 5.245 | 1169 | 31856 | 63.1 | 19.34 | 1199 |
| 50 % Open | Kaolin 10% | 4.127 | 1169 | 4505 | 63.1 | 4.417 | 764.7 |
| 75 % Open | Kaolin 10% | 6.090 | 1169 | 4304 | 63.1 | 1.939 | 1544 |
| 100 % Open | Kaolin 10% | 6.069 | 1169 | 471.8 | 63.1 | 0.214 | 1541 |

**Table 3.13: Mean value for 80 mm bore diameter**

| Opening position | Fluid | Flow Rate | ρ | $\Delta P_v$ | D | $k_v$ | Re |
|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 4.858 | 1169 | 46111 | 80.4 | 86.26 | 482.9 |
| 50 % Open | Kaolin 10% | 4.228 | 1169 | 13341 | 80.4 | 32.95 | 376.2 |
| 75 % Open | Kaolin 10% | 4.379 | 1169 | 2376 | 80.4 | 5.471 | 404.8 |
| 100 % Open | Kaolin 10% | 6.461 | 1169 | 414.1 | 80.4 | 0.451 | 701.4 |

**Table 3.14: Mean value for 100 mm bore diameter**

| Opening position | Fluid | Flow Rate | ρ | $\Delta P_v$ | D | $k_v$ | Re |
|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 5.475 | 1169 | 27769 | 97.2 | 87.13 | 302.9 |
| 50 % Open | Kaolin 10% | 6.284 | 1169 | 10905 | 97.2 | 25.99 | 402.6 |
| 75 % Open | Kaolin 10% | 6.267 | 1169 | 3193 | 97.2 | 7.645 | 403.9 |
| 100 % Open | Kaolin 10% | 5.267 | 1169 | 80.94 | 97.2 | 0.431 | 235.2 |

Mbiya (2003) has derived the relative or percentage error for the loss coefficient and it can be seen that the experimental loss coefficients relative errors are almost the same with the calculated ones using the Equation 3.13. The relative error increases as the opening position increases as well.

Table 3.15 to 3.19 show the experimental relative error compared to the relative error using Equation 3.13.

**Table 3.15: Relative or percentage error for 40 mm bore diameter**

| Opening position | Fluid | $\Delta Q/Q$ | $\Delta\rho/\rho$ | $\Delta(\Delta P_v)/\Delta P_v$ | $\Delta D/D$ | $(\Delta k_v/k_v)$Exp | $\Delta Re/Re$ | $(\Delta k_v/k_v)$Calc |
|---|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 6.102 | 0.003 | 11.16 | 0.629 | 21.29 | 12.76 | 16.73 |
| 50 % Open | Kaolin 10% | 1.183 | 0.003 | 3.814 | 0.629 | 4.214 | 2.921 | 5.147 |
| 75 % Open | Kaolin 10% | 2.888 | 0.003 | 18.45 | 0.629 | 16.83 | 9.519 | 19.50 |
| 100 % Open | Kaolin 10% | 1.084 | 0.003 | 27.68 | 0.629 | 28.18 | 6.738 | 27.88 |

**Table 3.16: Relative or percentage error for 50 mm bore diameter**

| Opening position | Fluid | $\Delta Q/Q$ | $\Delta\rho/\rho$ | $\Delta(\Delta P_v)/\Delta P_v$ | $\Delta D/D$ | $(\Delta k_v/k_v)$Exp | $\Delta Re/Re$ | $(\Delta k_v/k_v)$Calc |
|---|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 0.674 | 0.003 | 5.937 | 0.32 | 6.291 | 2.984 | 6.221 |
| 50 % Open | Kaolin 10% | 1.761 | 0.003 | 9.701 | 0.32 | 6.983 | 4.236 | 10.40 |
| 75 % Open | Kaolin 10% | 1.074 | 0.003 | 22.22 | 0.32 | 23.37 | 2.901 | 22.36 |
| 100 % Open | Kaolin 10% | 0.387 | 0.003 | 48.48 | 0.32 | 48.05 | 1.942 | 48.51 |

**Table 3.17: Relative or percentage error for 65 mm bore diameter**

| Opening position | Fluid | $\Delta Q/Q$ | $\Delta\rho/\rho$ | $\Delta(\Delta P_v)/\Delta P_v$ | $\Delta D/D$ | $(\Delta k_v/k_v)$Exp | $\Delta Re/Re$ | $(\Delta k_v/k_v)$Calc |
|---|---|---|---|---|---|---|---|---|
| 25 % Open | kaolin 10% | 0.496 | 0.003 | 5.628 | 0.45 | 6.049 | 3.988 | 5.992 |
| 50 % Open | kaolin 10% | 0.630 | 0.003 | 27.86 | 0.45 | 26.56 | 5.432 | 27.94 |
| 75 % Open | kaolin 10% | 0.427 | 0.003 | 18.97 | 0.45 | 20.17 | 2.093 | 19.07 |
| 100 % Open | kaolin 10% | 0.544 | 0.003 | 105.5 | 0.45 | 107.5 | 2.664 | 105.6 |

**Table 3.18: Relative or percentage error for 80 mm bore diameter**

| Opening position | Fluid | $\Delta Q/Q$ | $\Delta\rho/\rho$ | $\Delta(\Delta P_v)/\Delta P_v$ | $\Delta D/D$ | $(\Delta k_v/k_v)$Exp | $\Delta Re/Re$ | $(\Delta k_v/k_v)$Calc |
|---|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 0.823 | 0.003 | 1.357 | 0.22 | 1.773 | 4.084 | 2.308 |
| 50 % Open | Kaolin 10% | 0.757 | 0.003 | 6.468 | 0.22 | 6.732 | 3.086 | 6.700 |
| 75 % Open | Kaolin 10% | 1.050 | 0.003 | 12.00 | 0.22 | 14.13 | 2.286 | 12.21 |
| 100 % Open | Kaolin 10% | 1.130 | 0.003 | 135.1 | 0.22 | 128.2 | 3.988 | 135.1 |

**Table 3.19: Relative or percentage error for 100 mm bore diameter**

| Opening position | Fluid | $\Delta Q/Q$ | $\Delta\rho/\rho$ | $\Delta(\Delta P_v)/\Delta P_v$ | $\Delta D/D$ | $(\Delta k_v/k_v)$Exp | $\Delta Re/Re$ | $(\Delta k_v/k_v)$Calc |
|---|---|---|---|---|---|---|---|---|
| 25 % Open | Kaolin 10% | 1.059 | 0.003 | 1.704 | 0.37 | 2.714 | 6.986 | 3.096 |
| 50 % Open | Kaolin 10% | 2.132 | 0.003 | 11.89 | 0.37 | 13.62 | 19.38 | 12.72 |
| 75 % Open | Kaolin 10% | 0.973 | 0.003 | 25.67 | 0.37 | 25.64 | 11.39 | 25.79 |
| 100 % Open | Kaolin 10% | 2.430 | 0.003 | 266.6 | 0.37 | 124.6 | 9.565 | 266.6 |

## 3.9 CONCLUSION

The experimental equipment has been described. It is reliable and can be used to measure the loss coefficient through different fittings, in this case in particular, through Saunders diaphragm valves.

The diaphragm valve has also been described and the detailed external and internal dimensions have been provided.

The basic operation used to provide useful data of loss coefficient for different purposes has been outlined. The results will be presented in the next chapter where the loss coefficient will be plotted against the Slatter Reynolds number.

The materials tested, as well as their particular purposes, have been described. The water test results will be correlated to the Colebrook & White equation and the Rheological characterisation of the non-Newtonian fluids will also be presented in Chapter 4.

The relative error Equation 3.14 derived by Mbiya (2003) has been evaluated and it was shown to be successful, because it can be used to predict the percentage error for the loss coefficient. The difference in percentage between the experimental loss coefficient relative error and the calculated ones is very small.

# CHAPTER 4 ANALYSIS OF RESULTS

## 4.1 INTRODUCTION

The purpose of this work was to measure pressure losses in Saunders straight-through diaphragm valves.

Firstly, Newtonian fluid (water) was tested through five pipes of different size and the plot of the velocity against the wall shear stress was correlated to the Colebrook & White equation to ascertain the accuracy and the credibility of the equipment.

Secondly, the rheological characterisation was done for each non-Newtonian fluid used, applying the rheology test. It consists of using the data points in laminar flow from the test data of ($\tau_0$, 8V/D) to obtain the rheological constants $\tau_y$, K and n (Slatter, 1994).

Finally, the laminar and turbulent loss coefficients were calculated, based on the pressure drop through the diaphragm valves, and they were then correlated to the Reynolds number.

Thus, the objective of this chapter is

- to present the water test results;
- to present the rheological constants obtained for the fluids under evaluation;
- to present the correlation of loss coefficient with Reynolds number.

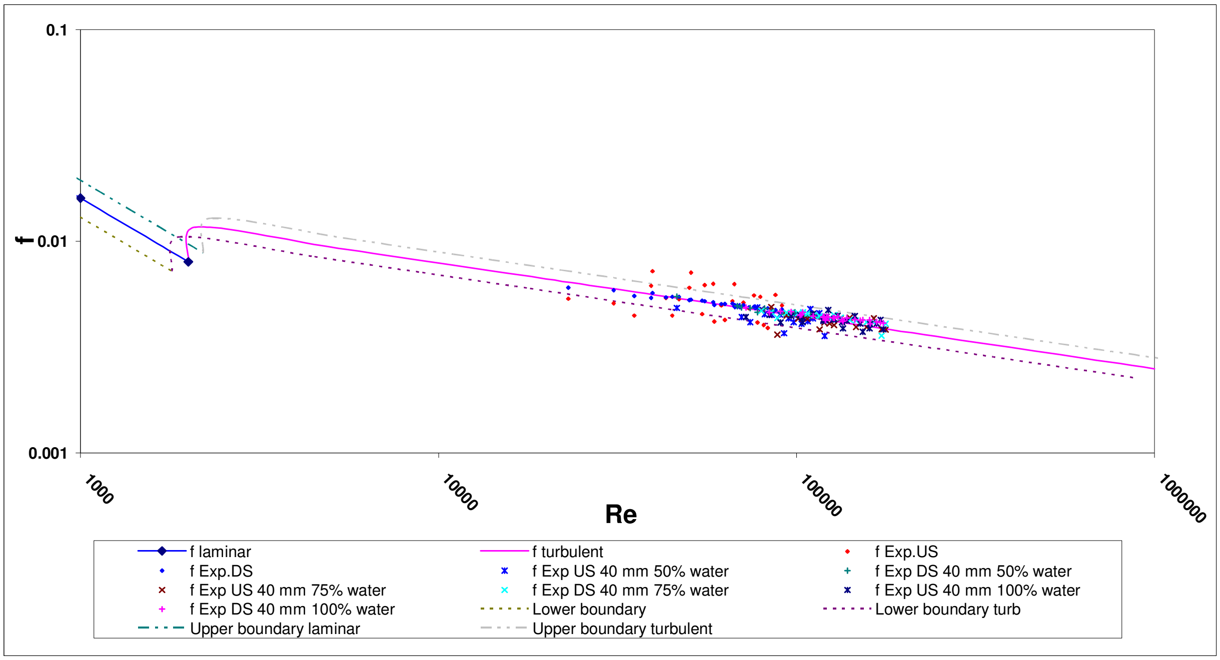
## 4.2 STRAIGHT PIPE RESULTS

The results obtained in the straight pipe section will be presented here for both water and non-Newtonian fluids. The straight pipe results are important for establishing credibility of the test rig, as well as for the rheological characterisation of non-Newtonian fluids.

### 4.2.1 Water

The water test was conducted in the straight pipes to establish the credibility and accuracy of the test equipment.

A plot of the Fanning friction factor (f) against the Reynolds number (Re) for water for the 50 mm OD pipe is shown in Figure 4.1.




*50 mm OD*

**Figure 4.1: Friction factor for 50 mm OD for different opening positions**

We can see that 80 % of the data fall within +/- 10 % of the calculated line for the small pipes in Figure 4.1. Such an agreement indicates the validity and degree of accuracy of the experimental technique and equipment used in this experimental investigation.

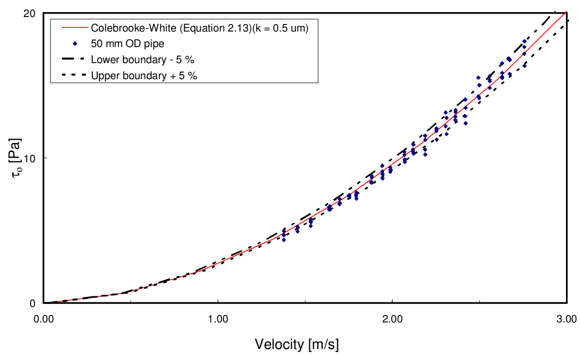
From Equation 2.5, we have calculated the velocity that was plotted against the shear stresses. Figure 4.2 shows a comparison of experimental results with the Colebrook & White equation (Equation 2.11) for all the pipes tested. The surface roughness (k) of all the pipes was less than 20 µm, as specified for smooth pipes. The results obtained from different pipes revealed an experimental error of 5 % in the 50 mm, 63 mm and 90 mm outside diameter (OD); 10 % in the 75 mm and 15 % in the 110 mm outside diameter (OD) pipes. The friction was determined using Colebrook & White equation (Equation 2.11) and the shear stress ($\tau_o$) was subsequently determined using Equation 2.4

A summary of the results are given in Table 4.1.

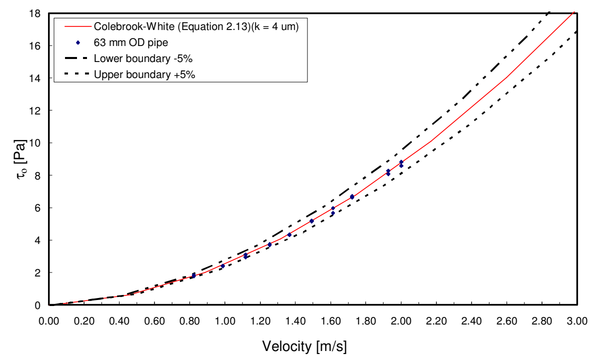
**Table 4.1: Surface roughness for various pipe sizes**

| Nominal Diameter (mm) | Internal diameter (mm) | Surface roughness (μm) | *Percentage error (%)* |
|---|---|---|---|
| 40 | 42.12 | 0.5 | *4* |
| 50 | 50 | 4 | *1* |
| 65 | 63 | 20 | *4* |
| 80 | 80 | 20 | *4* |
| *100* | *100* | *0.5* | *9* |

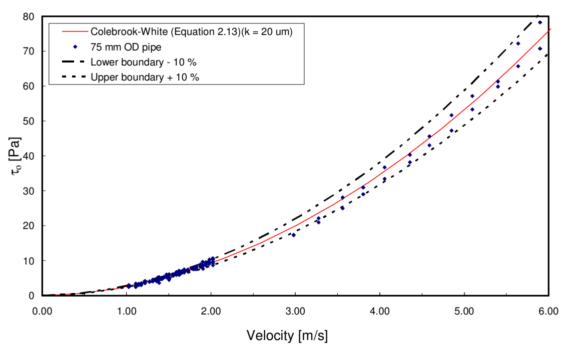
The pipe roughness was determined by measuring the pressure drop across a known length of pipe and by comparing it with the Colebrook & White equation (Equation 2.11) (King, 2002)



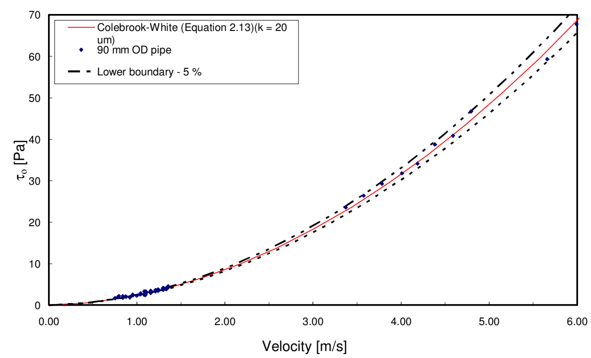

40 mm bore diameter



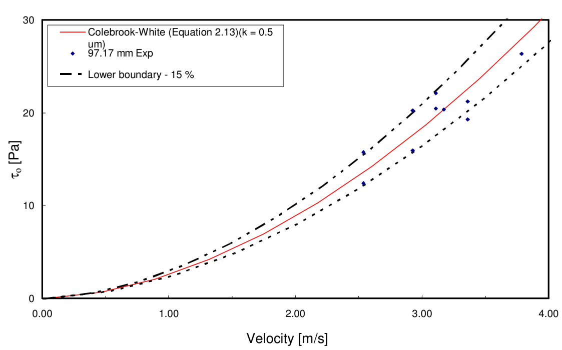

50 mm bore diameter




65 mm bore diameter




80 mm bore diameter




100 mm bore diameter

**Figure 4.2: Comparison of water tests with Colebrook & White equation for all pipe sizes.**

### 4.2.2 Non-Newtonian fluids

The non-Newtonian fluids selected were kaolin suspensions and CMC solutions that typically display yield pseudoplastic and pseudoplastic behaviour (Fester et al., 2007). Rheological constants obtained for non-Newtonian fluids will be presented in this work namely 6%, 10% and 13% volume concentration of kaolin, as well as 5% mass concentration of CMC.
The objective of this section is to explain how the fluids under evaluation were characterised and how the different models were fitted to determine the rheological constants $\tau_y$ , K and n for yield pseudoplastic or K and n for pseudoplastic where $\tau_y$ equals zero.

#### 4.2.2.1 Fitting the pseudoplastic model

The pseudoplastic model or power law was used to model the flow behaviour of CMC and was fitted to the laminar shear stress and shear rate data from all straight pipes to determine K and n.
A power law trend curve was fitted to the wall shear stress ($\tau_0$) and pseudo shear rate (8V/D) data to obtain the constant n' (apparent flow behaviour index) and K' (apparent fluid consistency index).

An example of the pseudoplastic model fit is given in Figure 4.3 for a 5 % CMC solution.
Table 4.2 gives the rheological constants used in this work for CMC 5 %.

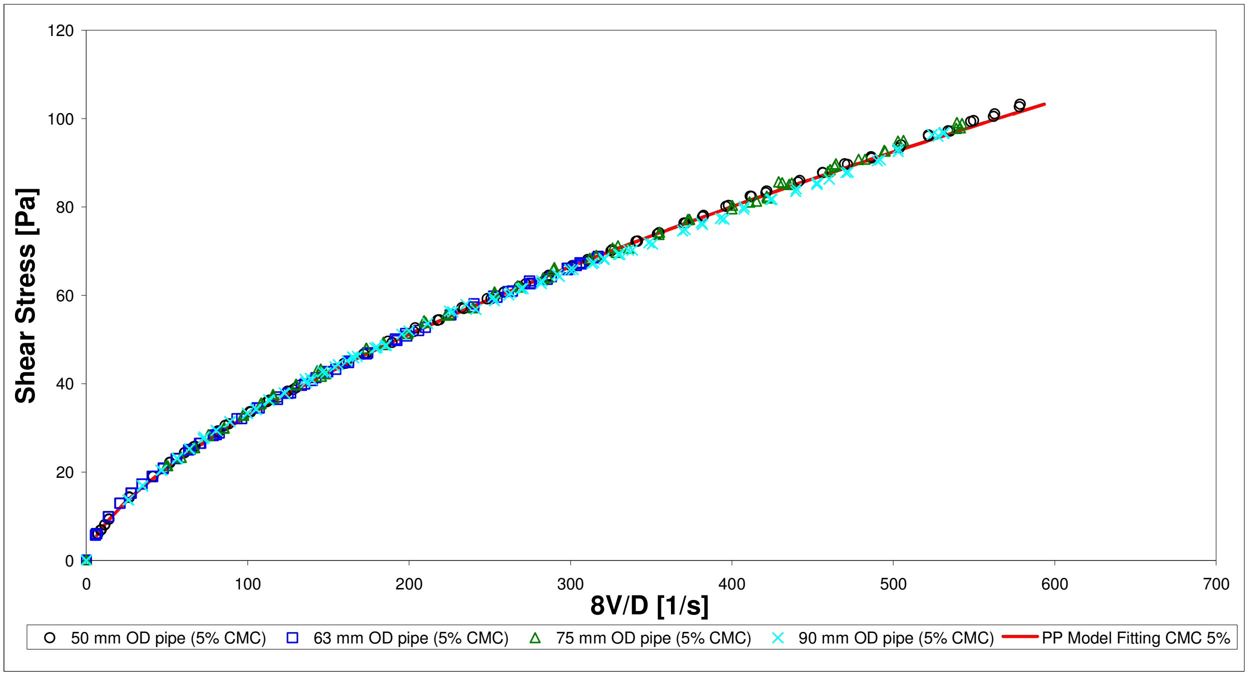



**Figure 4.3: Pseudo-shear diagram for straight pipe test of CMC 5 %**

**Table 4.2: Rheological characteristic of CMC 5 %**

| Density (kg/m$^3$) | Concentration (%) | K' (Pa/s$^n$) | n' |
|---|---|---|---|
| 1026.8 | 5% | 1.542 | 0.645 |

### 4.2.2.2 Fitting the yield pseudoplastic model

The yield pseudoplastic model was used to determine the flow behaviour of kaolin, and fitted to the laminar shear stress and shear rate data from all straight pipes to determine $\tau_y$ , K and n.

An example of the yield pseudoplastic model fit is given in Figure 4.4 for kaolin in suspension at three different concentrations. Table 4.3 gives the different rheological constants used in this work for kaolin 6 %, 10 % and 13 %. The yield stress ( $\tau_y$ ) was increasing with increasing slurry concentration. K and n were obtained using Equations 2.60 and 2.61.

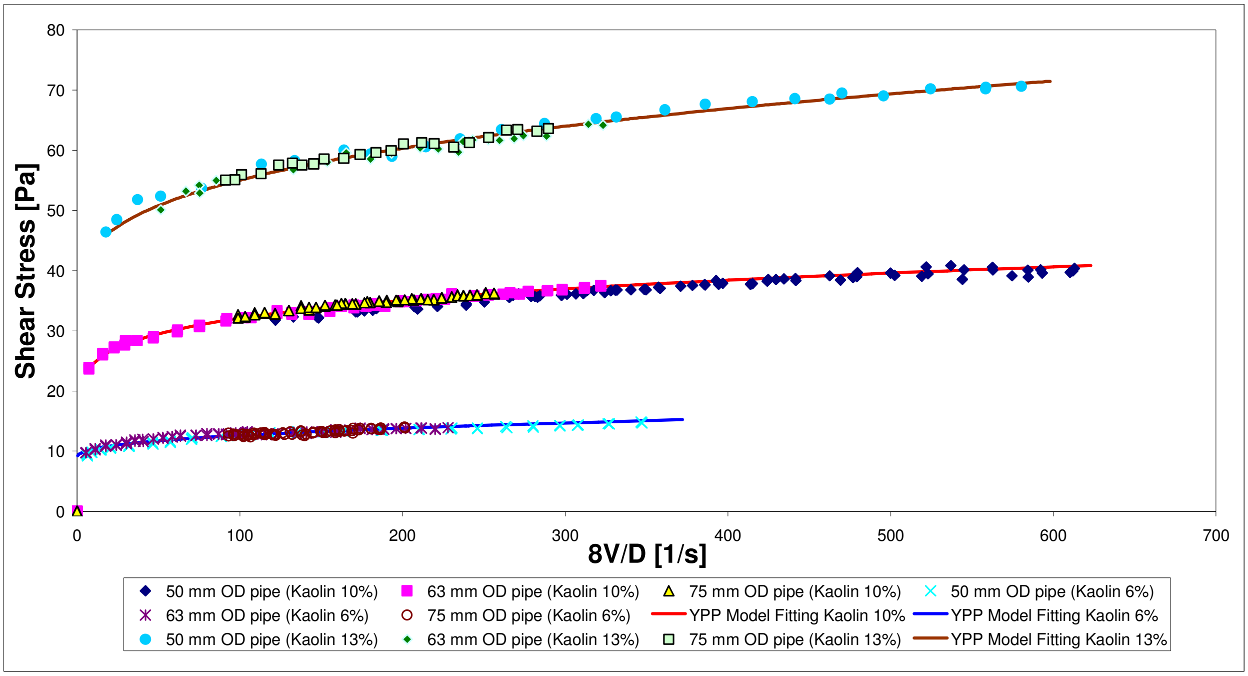



**Figure 4.4: Straight pipe test of 6 %, 10 % and 13 % Kaolin slurry**

**Table 4.3: Rheological characteristics of Kaolin 6 %, 10 % and 13 % slurry**

| Density ($kg/m^3$) | Concentration (%) | $\tau_y$ (Pa) | K' ($Pa\ s^n$) | n' |
|---|---|---|---|---|
| 1103.6 | 6% | 3.071 | 2.038 | 0.264 |
| 1169.4 | 10% | 8.965 | 7.098 | 0.175 |
| 1215.5 | 13% | 18.97 | 16.14 | 0.242 |

## 4.3 DIAPHRAGM VALVE LOSS COEFFICIENT

The objective of this work was to measure the diaphragm valve loss coefficient that should be correlated to the Reynolds number for further analysis.

### 4.3.1 Graphical presentation of $k_v$ versus Reynolds number

In order to analyse the experimental loss coefficient data, they will be plotted on a graph versus Reynolds number, as it is customary in the field of fluid mechanics (Edwards et al., 1985; Turian et al., 1997; Pienaar, 1998; Kazadi, 2005; Mbiya, 2008).
In this work, the Slatter Reynolds ($Re_3$) was used to make such representation.

#### 4.3.1.1 Loss coefficients for 40 mm bore valve

Figures 4.5 to 4.9 show the correlation between the loss coefficient using Equation 2.52 and the Reynolds number ranging from 1 to 100000 for the 40 mm to 100 mm bore diameter.
The turbulent flow occurs earlier at Reynolds around 1000 in pipe fittings, as can be seen in Figures 4.5 to 4.9, and the loss coefficients are given below for different opening positions. However, not all the fluids tested could reach the turbulent flow for different opening positions due to safety conditions under which we could operate the rig.

- Fully open ($k_v$ = 2.68)
- 75 % open ($k_v$ = 8.15)
- 50 % open ($k_v$ = 32.82)
- 25 % open ($k_v$ = 68.79)

The unpredictable transition region from Reynolds number 10 up to 1000 depended on the type of fluids tested and the opening position, as can been seen in Figure 4.5. The transition is not smooth for the fully open position. This could be because of the interaction between the secondary flow and the core region that tends to delay the onset of turbulence to well above Reynolds number at which straight pipe flow could become turbulent.
In laminar flow for Reynolds number less than 10, although this is not the case for all the opening positions, there is a similar trend for different fluids tested and at different opening positions. In this region, the viscous forces overcome the inertia forces and the plot of the loss coefficients and ratio of forces coincide and the loss coefficient is typical to a hyperbolic relationship.

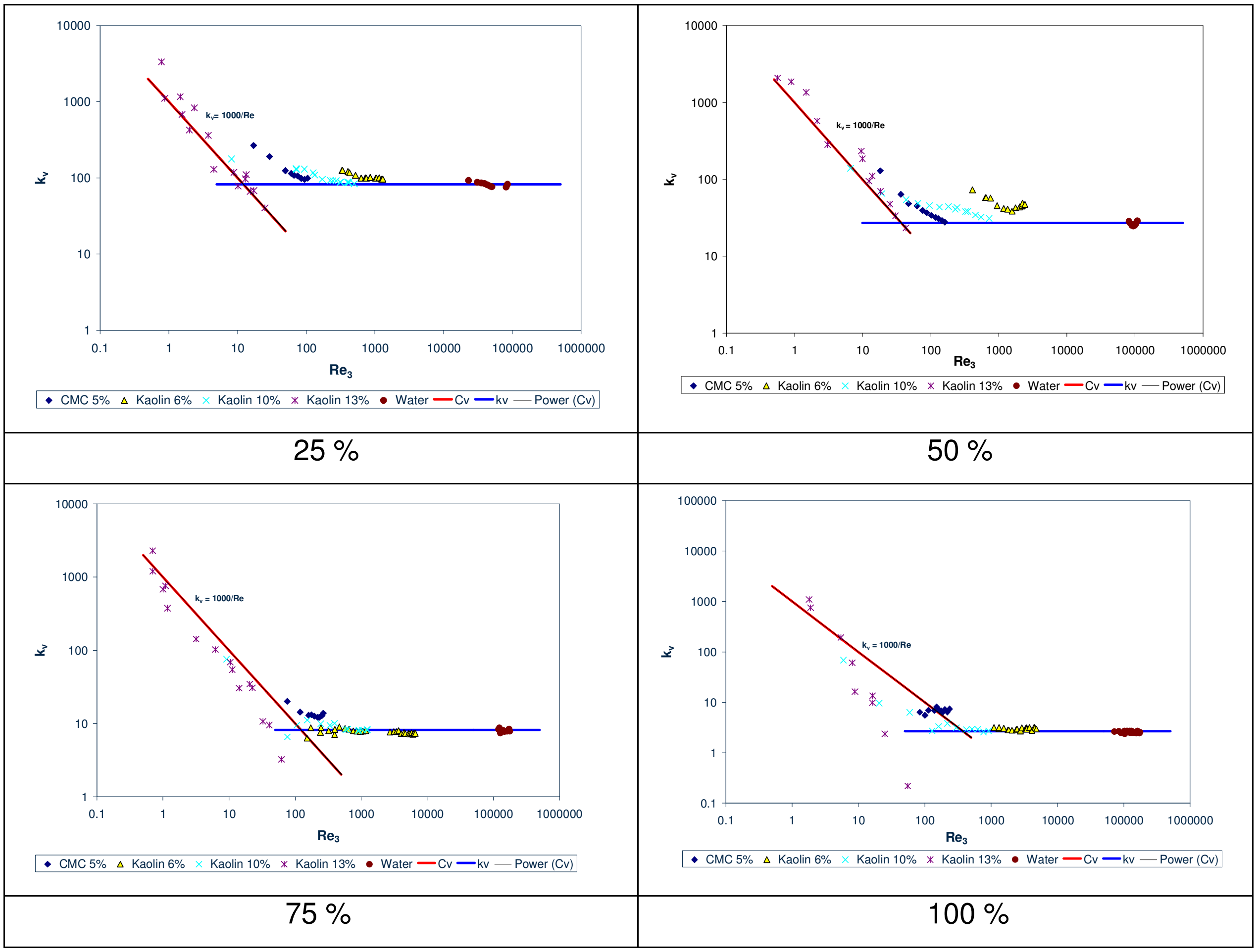



**Figure 4.5: Loss coefficient data of the 40 mm bore Saunders diaphragm valve at all opening positions.**

### 4.3.1.2 Loss coefficients for 50 mm bore valve

- Fully open ($k_v$ = 1.60)
- 75 % open ($k_v$ = 3.88)
- 50 % open ($k_v$ = 10.25)
- 25 % open ($k_v$ = 28.46)

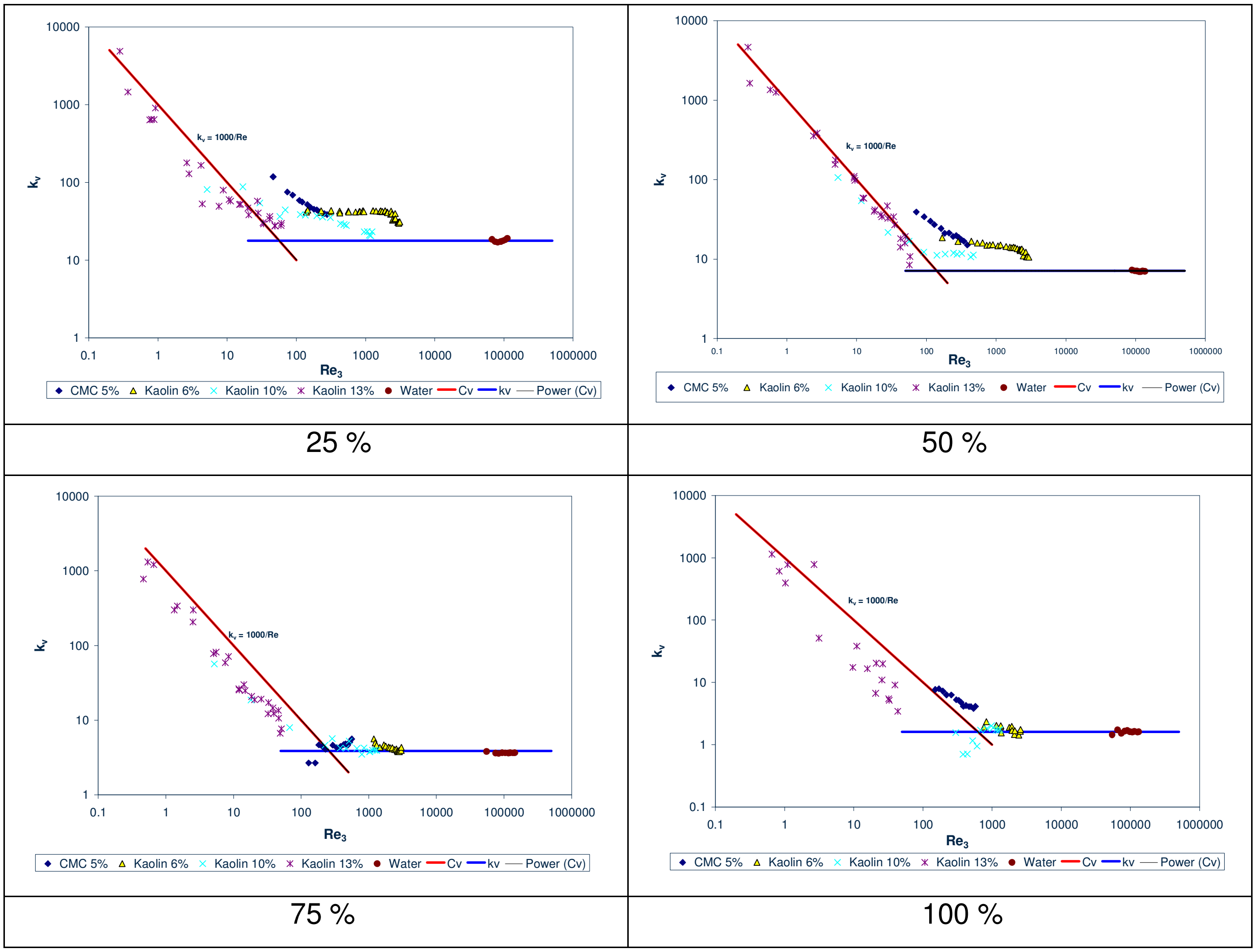



**Figure 4.6: Loss coefficient data of the 50 mm bore Saunders diaphragm valve at all opening positions.**

### 4.3.1.3 Loss coefficients for 65 mm bore valve

- Fully open ($k_v$ = 0.57)
- 75 % open ($k_v$ = 1.77)
- 50 % open ($k_v$ = 3.63)
- 25 % open ($k_v$ = 22.43)

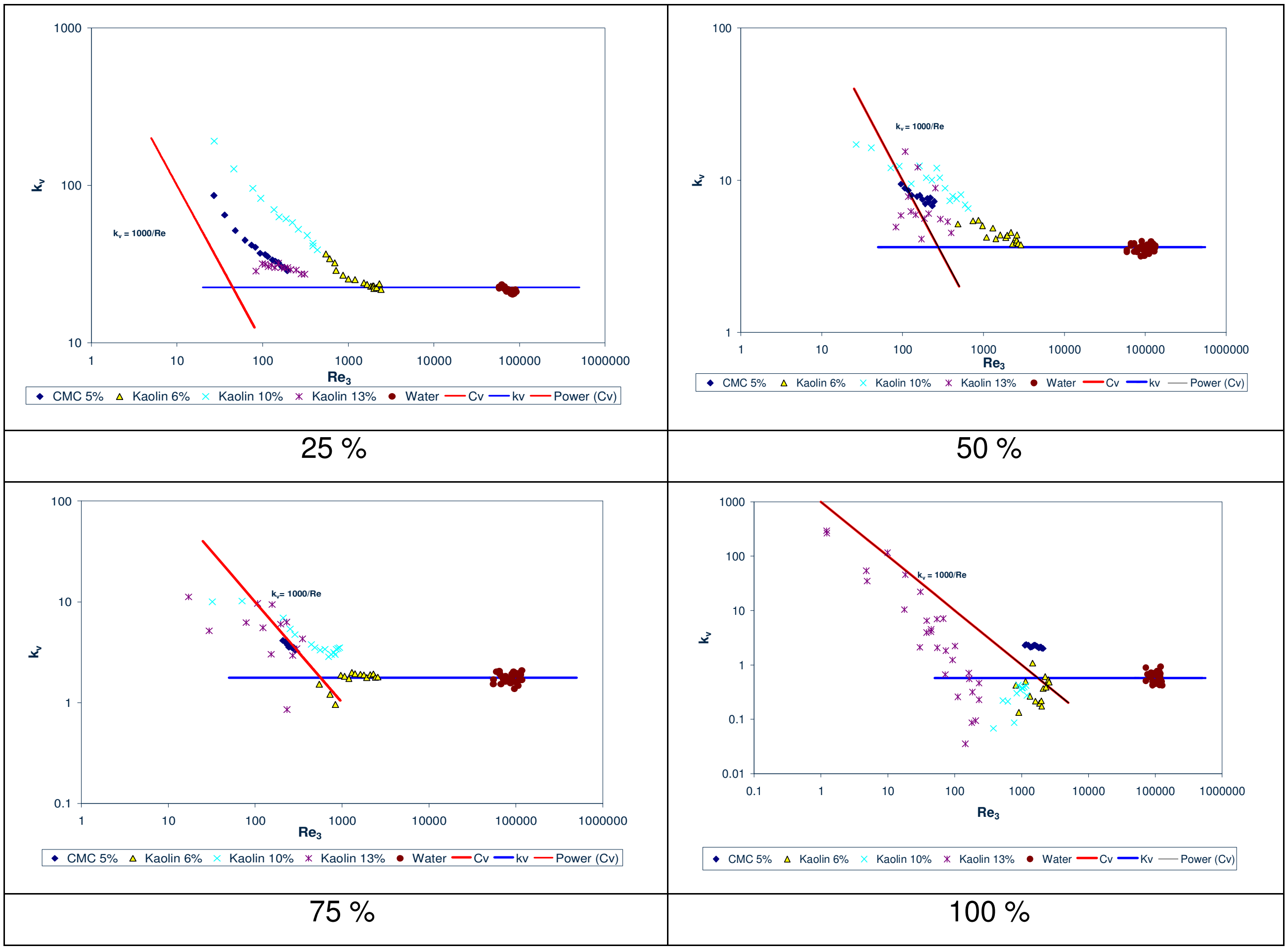



**Figure 4.7: Loss coefficient data of the 65 mm bore Saunders diaphragm valve at all opening positions.**

#### 4.3.1.4 Loss coefficients for 80 mm bore valve

- Fully open ($k_v$ = 0.46)
- 75 % open ($k_v$ = 4.27)
- 50 % open ($k_v$ = 18.86)
- 25 % open ($k_v$ = 88.79)

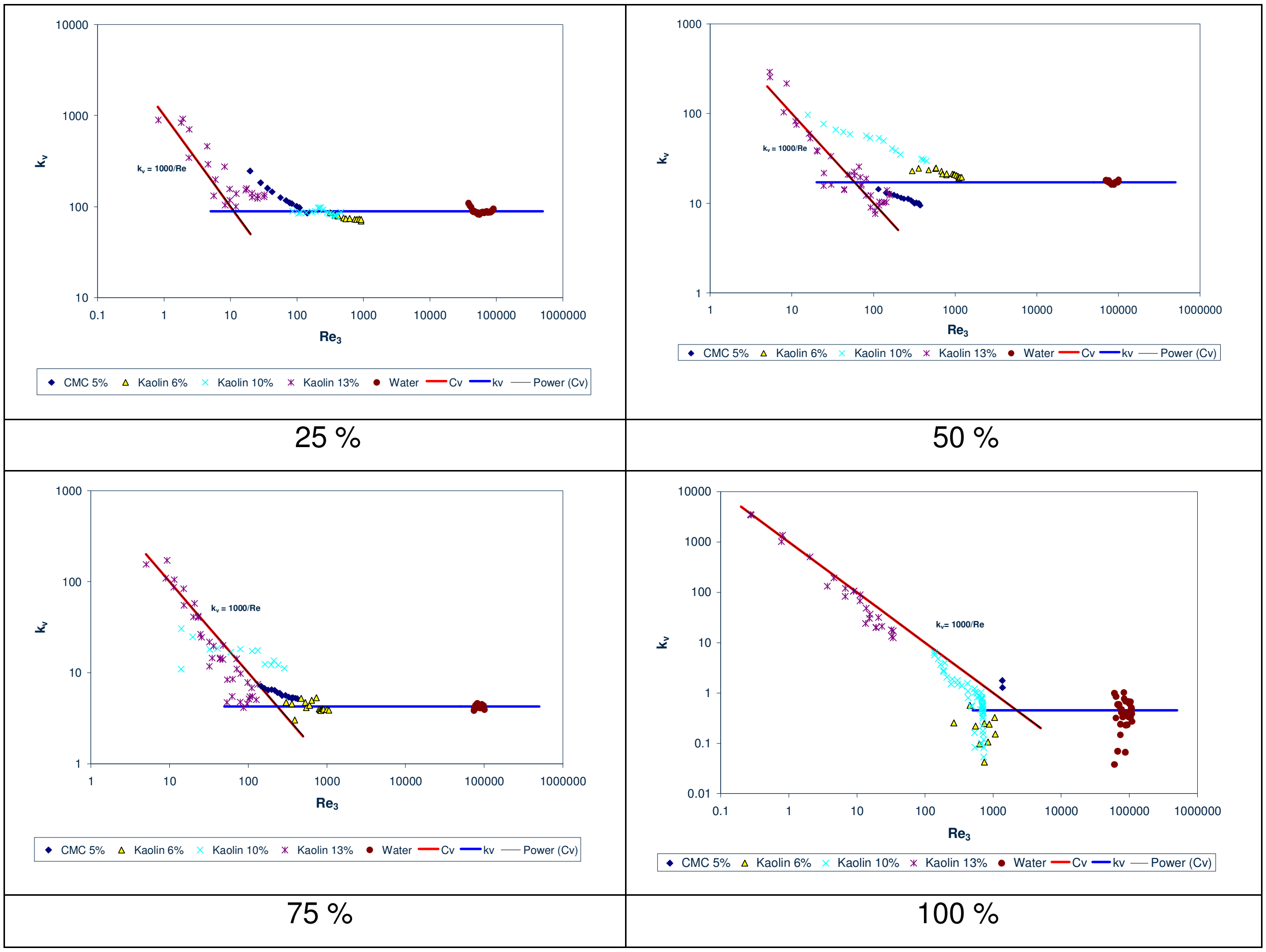
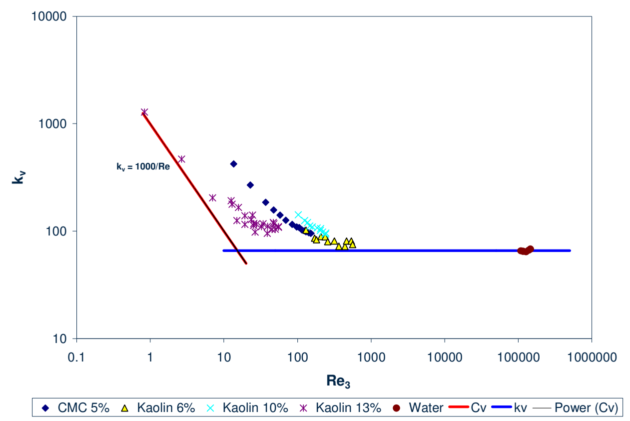


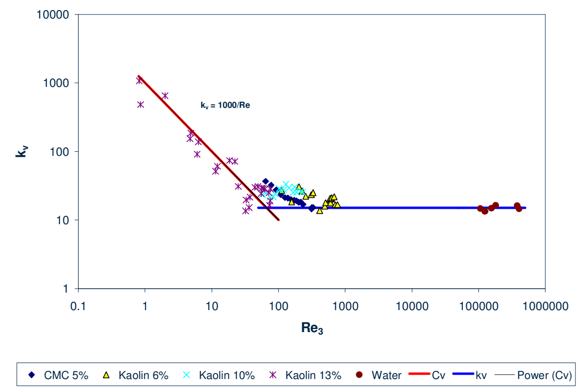

**Figure 4.8: Loss coefficient data of the 80 mm bore Saunders diaphragm valve at all opening positions.**

### 4.3.1.5 Loss coefficients for 100 mm bore valve

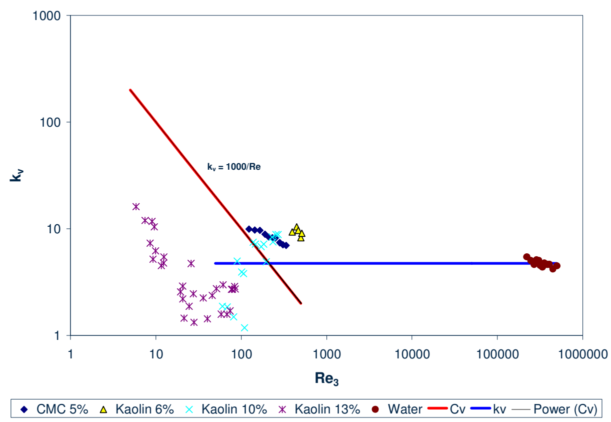
- Fully open ($k_v$ = 1.04)
- 75 % open ($k_v$ = 4.75)
- 50 % open ($k_v$ = 17.84)
- 25 % open ($k_v$ = 72.26)



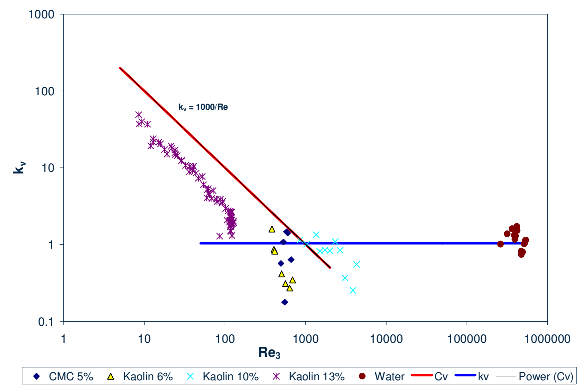

25 %




50 %




75 %




100 %

**Figure 4.9: Loss coefficient data of the 100 mm bore Saunders diaphragm valve at all opening positions.**

The procedure followed to calculate the loss coefficient and loss coefficient constant data have been highlighted in chapter 2. The results obtained from the straight pipe test to ascertain the reliability of the equipment have also been presented in this chapter.

Figure 4.10 represents different graphs for different pipe sizes at various opening positions.

There was good agreement between the results found for different slurries and with the turbulent loss coefficient for small pipe size (40 mm and 50 mm bore diameter). As the bore diameter increases, there is a lot of scatter in the results, especially in the transition zone for the 65 mm, 80 mm and 100 mm bore diameter.

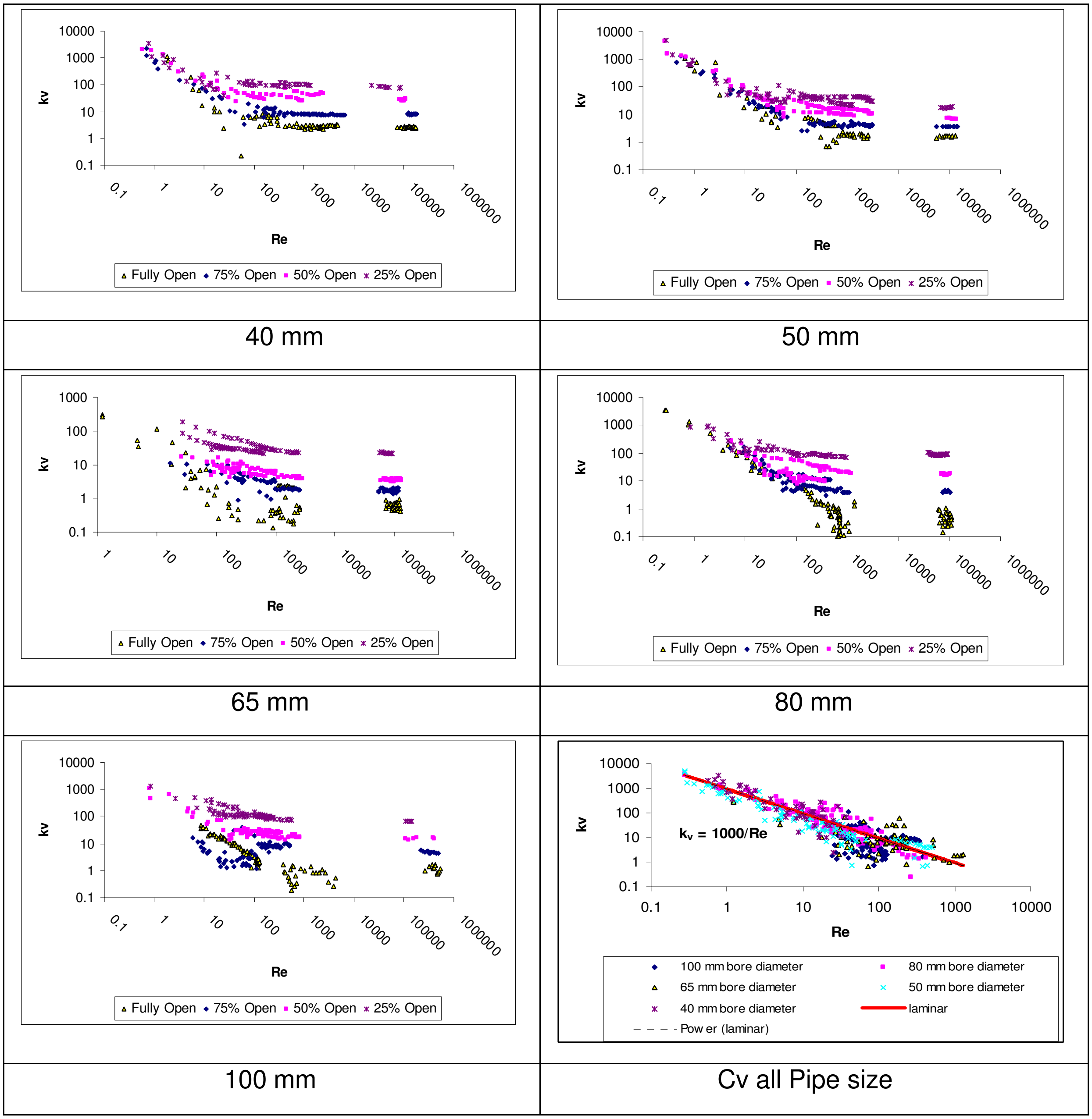



**Figure 4.10: Typical loss coefficient versus Reynolds number plot obtained for all pipe sizes**

Table 4.4 shows the loss coefficient data for different straight-through diaphragm valves ranging from 40 mm bore diameter to 100 mm bore diameter at different opening positions, from 100 % open to 25 % open.

**Table 4.4: Loss coefficients of the 40, 50, 65, 80 and 100 mm bore valve**

| Valve position (%) | 25 | | 50 | | 75 | | 100 | |
|---|---|---|---|---|---|---|---|---|
| Bore diameter (mm) | $k_v$ | Stdev | $k_v$ | Stdev | $k_v$ | Stdev | $k_v$ | Stdev |
| 40 | 68.79 | ±11.20 | 32.82 | ±7.88 | 8.15 | ±0.98 | 2.68 | ±0.24 |
| 50 | 28.46 | ±8.70 | 10.25 | ± 2.50 | 3.88 | ± 0.24 | 1.60 | ± 0.10 |
| 65 | 22.43 | ±1.85 | 3.63 | ±0.30 | 1.77 | ±0.18 | 0.57 | ± 0.36 |
| 80 | 88.79 | ±5.41 | 18.86 | ± 3.53 | 4.27 | ±0.20 | 0.46 | ± 0.26 |
| 100 | 72.26 | ±8.92 | 17.84 | ±2.83 | 4.75 | ±0.35 | 1.04 | ±0.40 |

The scatter of results are prominent in the larger valves (65, 80 and 100 mm) in the fully open positions where the pressure drop was similar to the pressure drop encountered within the pipes.

## 4.4 CONCLUSION

In conclusion, this chapter outlined the results obtained from the valve test rig. Water tests in straight pipes have been done to ascertain the credibility of the equipment. Thus the plot of the shear stresses versus the velocities has been correlated to the Colebrook & White equation, as shown in Figure 4.2. This illustrated the efficiency of the system.

Rheological characteristics of the different materials tested have been measured using tube viscometer. In this work the pseudoplastic and the yield pseudoplastic model have been used for CMC and kaolin respectively.

Finally, the loss coefficient through Saunders diaphragm valves ranging from 40 to 100 mm nominal bore diameters at various opening positions have been calculated in laminar and turbulent flow. Figure 4.10 shows that in turbulent flow, the loss coefficient depends on the size of the valve; meanwhile, in laminar flow the laminar loss coefficients converge together for different pipe sizes and are equal to 1000, which is well explained in Chapter 5.

# CHAPTER 5 DISCUSSION AND EVALUATION OF RESULTS

## 5.1 INTRODUCTION

In this chapter the comparison between the Saunders diaphragm valve loss coefficients obtained in this work and those found in the literature are presented. Due to the discrepancies found, a new correlation was developed and is presented here. This new correlation offers advantages over those in the literature for smaller diameter valves. As the objective of this work is to provide the laminar and turbulent loss coefficients, this section will essentially focus on the

- Comparison of the experimental data with the open literature
- New correlation for determining the loss coefficient for Saunders diaphragm valves.

The experimental work is compared to results from Miller (1990) and Perry & Chilton (1997), as well as correlations developed by Hooper (1981), ESDU (2004) and Mbiya (2008).

## 5.2 COMPARISON WITH LITERATURE

One of the important objectives of this work is to compare the results obtained from this experimental investigation to the data found in the open literature in general., The nominal bore diameter of the Saunders diaphragm valves is identical to the Natco valves used by Mbiya (2008), ranging from 40 mm to 100 mm. The sizes for which loss coefficients are valid were not given by Miller (1990), Hooper (1981) and Perry & Chilton (1997).

The relative errors were calculated for $Re < 10$ and $Re > 10000$. The following details from the literature review were used for comparison, namely:

- Miller (1990) using Figure 2.11
- Hooper (1981) using Equation 2.62
- Perry & Chilton (1997) using Table 2.5
- ESDU (2004) using Equation 2.71
- Mbiya (2008) using Equation 2.74

### 5.2.1 Laminar (viscous) flow (Re < 10)

Figures 5.1 to 5.5 show that $C_v$ is equal to 1000 in laminar flow, the loss coefficient predicted by Hooper (1981) is in good agreement with the results obtained from this work, within +/- 60 % experimental error. The laminar loss coefficient was valid for all different diameters used in this experimental investigation ranging from 40 mm to 100 mm, as well as at different opening positions. The same was found by Mbiya (2008) for laminar flow in Natco diaphragm valves.

### 5.2.2 Turbulent flow Re >10000

#### 5.2.2.1 Comparison between literature and new data for 40 mm bore diameter valve

For Re > 10000, Figure 5.1 shows the following with regard to the 40 mm bore diameter at various openings:

a) Fully open (100 %)

The loss coefficients for straight-through Saunders diaphragm valves are within 25 % and 14 % error respectively to those predicted by Hooper (1981) and Perry & Chilton (1997). The loss coefficients predicted by ESDU (2004) and those found in the work published by Mbiya (2008) are higher than those found in this experimental investigation of about 199 % and 202 % error respectively. The loss coefficients obtained by Miller (1990) are 70 % less than those found in this work.
For 10 < Re < 1000, the loss coefficients of Saunders diaphragm valves are lower than those predicted by Mbiya (2008) in all the opening position, except for the 50 % where they are identical.

b) 75 % open

Mbiya (2008) found higher loss coefficients of 121 % error than those seen in the Saunders diaphragm valves.

Miller (1990), Hooper (1981) and Perry & Chilton (1997) obtained lower loss coefficients than those found in this work, of about 90 %, 75 % and 68 % error respectively. The loss coefficients predicted by the ESDU (2004) are within -2 % error to those found in this work.

c) 50 % open

The loss coefficients found by Mbiya (2008) and in this work are within 7 % error while Miller (1990), Hooper (1981) and Perry & Chilton (1997) and the ESDU (2004) found lower loss coefficients than those obtained in this experimental investigation of -96 %, -94 %, -87 % and -66 % error respectively.

d) 25 % open

The loss coefficients obtained from this work are lower than those found by Mbiya (2008) and higher than those obtained by Miller (1990), Hooper (1981) and Perry & Chilton (1997) and the ESDU (2004).

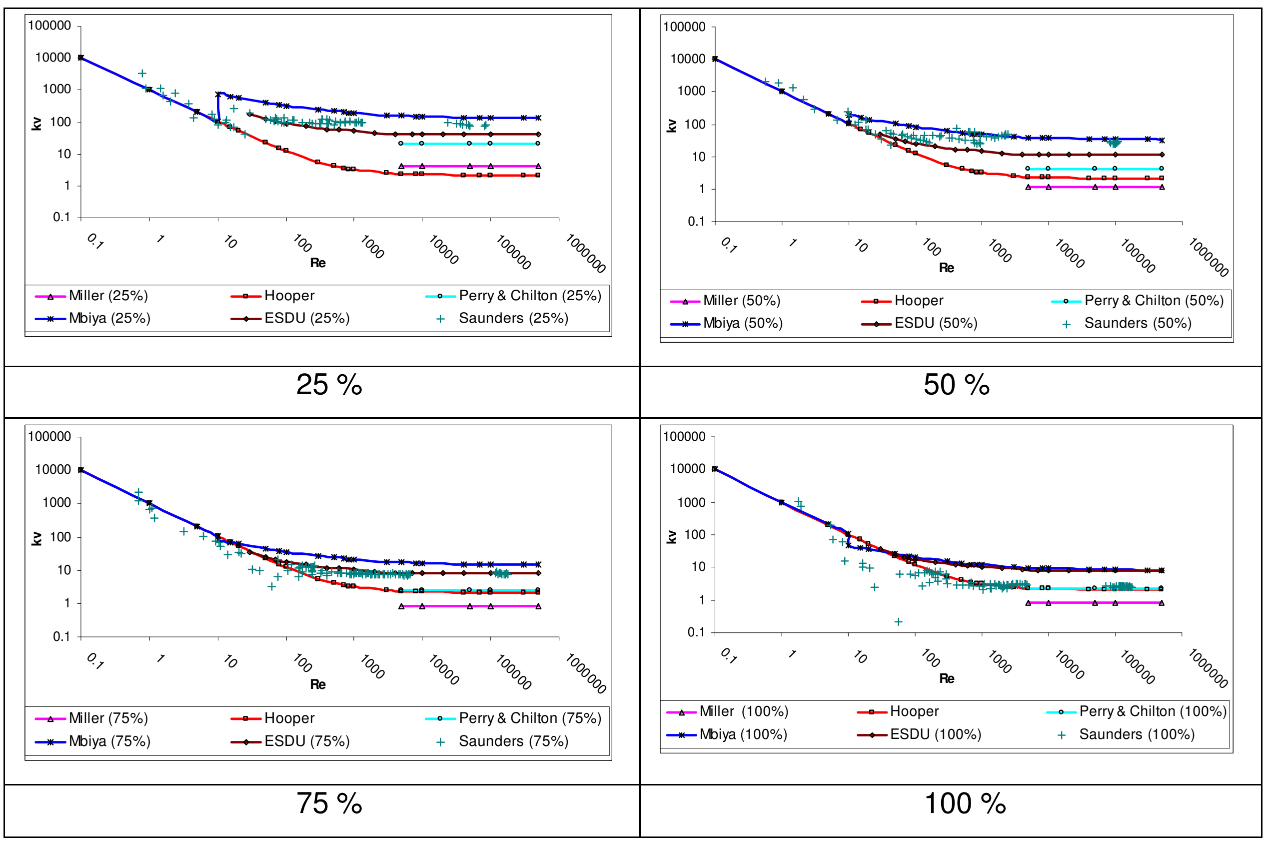



**Figure 5.1: Comparison between Saunders diaphragm valves and literature for 40 mm bore diameter**

#### 5.2.2.2 Comparison between literature and new data for 50 mm bore diameter valve

For Re > 10, Figure 5.2 shows for the 50 mm bore diameter at various openings that:

a) Fully open (100 %)

The loss coefficients for straight-through Saunders diaphragm valves are within 25 %, 44 % and 56 % error to those predicted respectively by Hooper (1981), Perry & Chilton (1997) and Mbiya (2008).
The loss coefficients predicted by ESDU (2004) are higher than those found in this experimental investigation of 400 % error.
The loss coefficients obtained by Miller (1990) are lower than found in this work of -50 % error.
For 10 < Re < 1000, the loss coefficients of Saunders diaphragm valves are lower than those predicted by Mbiya (2008) in all the opening position, except for the 50 % where they are identical.,

b) 75 % open

Mbiya (2008) found loss coefficients of 109 % error compared to those seen in the Saunders diaphragm valves, while Hooper (1981) obtained loss coefficients of -48 % error compared to those found in this work.
Perry & Chilton (1997) obtained loss coefficients within -33 % error compared to those found in this work. The ESDU (2004) found loss coefficients of about 106 % error than those provided by this work.

c) 50 % open

The loss coefficients found by Mbiya (2008) and ESDU (2004) are within 144 % and 9 % error to those found in this work, and those found by Perry & Chilton (1997) are within -58 % error to those obtained in this experimental investigation. The loss coefficients in the Saunders diaphragm valves are higher than those predicted by Hooper (1981) and Miller (1990), with an error of -80 % and -88 % respectively.

d) 25 % open

The loss coefficients obtained from this work are lower than those found by Mbiya (2008) and ESDU (2004), and higher than those obtained by Miller (1990) and Hooper (1981), while they are within -26 % error to those found by Perry & Chilton (1997).

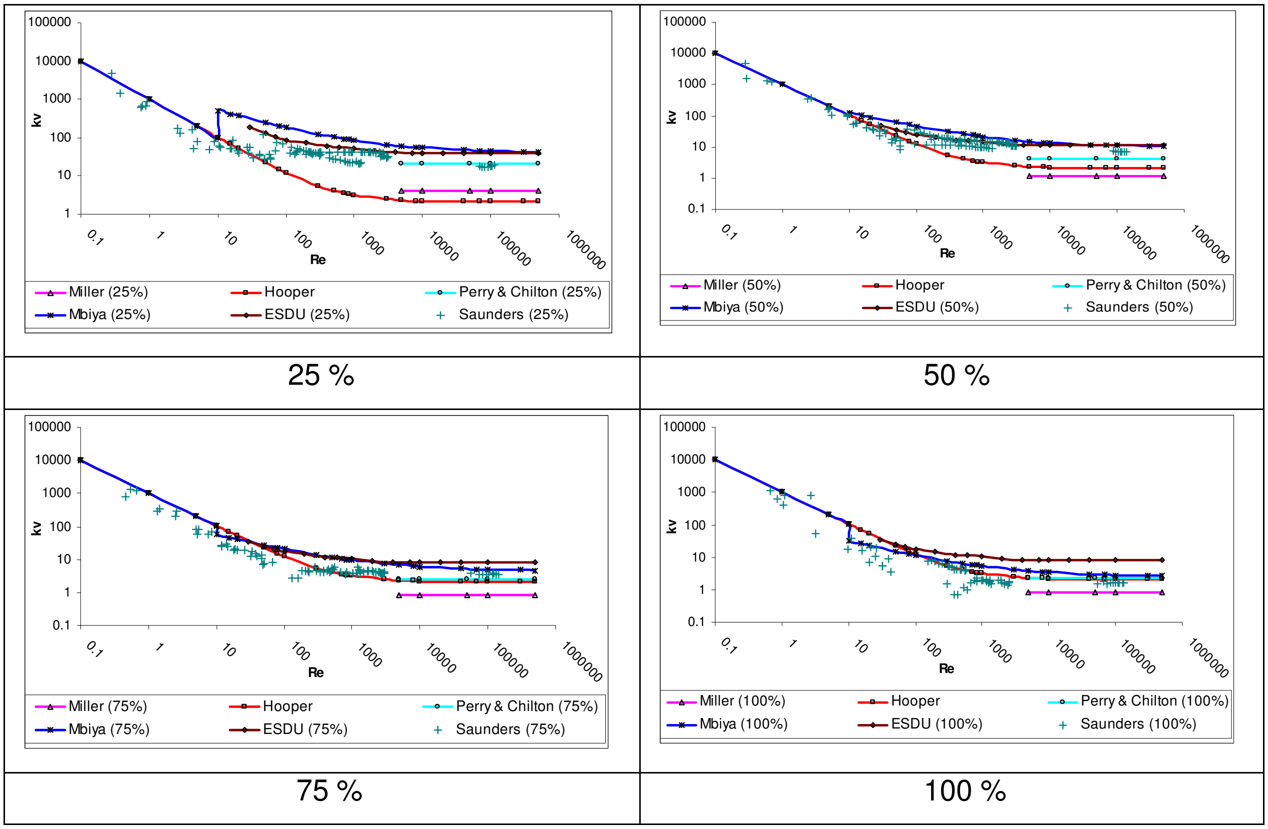



**Figure 5.2: Comparison between Saunders diaphragm valves and literature for 50 mm bore diameter**

### 5.2.2.3 Comparison between literature and new data for 65 mm bore diameter valve

For Re > 10, Figure 5.3 shows for the 65 mm bore diameter at various openings that:

a) Fully open (100 %)

The loss coefficients for straight-through Saunders diaphragm valves are within 40 % and 111 % to those predicted respectively by Miller (1990) and Mbiya (2008).

The loss coefficients obtained by Hooper (1981), Perry & Chilton (1997) and the ESDU (2004) are within 251 %, 304 % and 1286 % error to those found in this work.
For 10 < Re < 1000, the loss coefficients of Saunders diaphragm valves are lower than those predicted by Mbiya (2008) in all the opening positions.

b) 75 % open

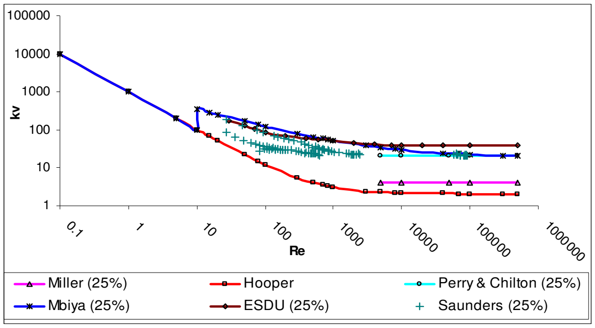
Mbiya (2008), Hooper (1981) and Perry & Chilton (1997) found loss coefficients of 58 %, 13 % and 47 % error respectively to those seen in the Saunders diaphragm valves.
Miller (1990) obtained loss coefficients of -55 % error to those found in this work and the ESDU (2004) found loss coefficients of 346 % error to those found in the Saunders diaphragm valves.

c) 50 % open

The loss coefficients found by Perry & Chilton (1997) and in this work are within 18 % error while for those found by Miller (1990) and Hooper (1981) are within -67 % and -45 % error to those respectively obtained in this experimental investigation.
The loss coefficients found from this work are within 341 % and 205 % to those found by Mbiya (2008) and the ESDU (2004) respectively.

d) 25 % open

The loss coefficients obtained from this work are within 181 % and 76 % error respectively to those found by Mbiya (2008), and the ESDU (2004). Perry & Chilton, Miller (1990) and Hooper (1981) predicted loss coefficients within -6 %, -82 % and -91 % respectively to those obtained in this work.

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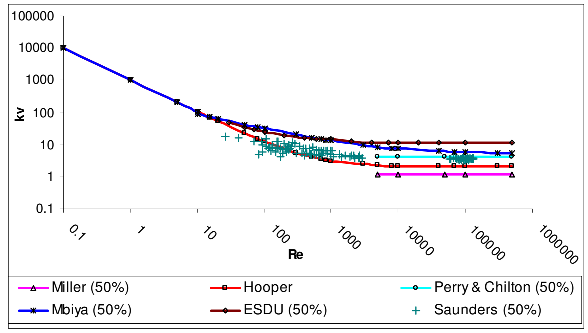
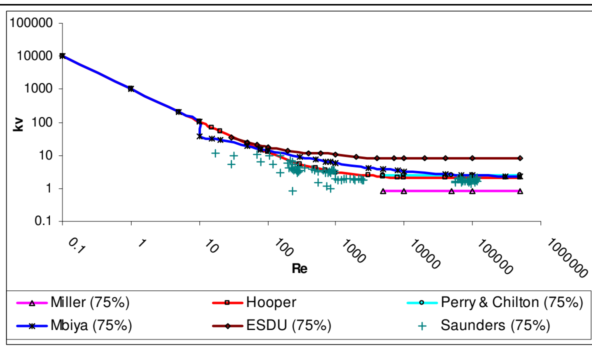
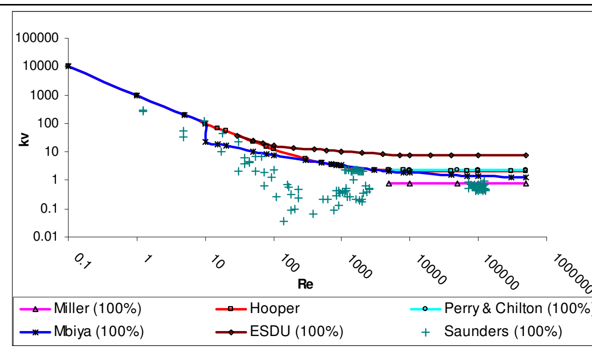



50 %




75 %




100 %

**Figure 5.3: Comparison between Saunders diaphragm valves and literature for 65 mm bore diameter**

### 5.2.2.4 Comparison between literature and new data for 80 mm bore diameter valve

For Re > 10, Figure 5.4 shows for the 80 mm bore diameter at various openings that:

a) Fully open (100 %)

The loss coefficients for straight-through Saunders diaphragm valves are within 74 % error to those predicted by Miller (1990).

The loss coefficients obtained by Hooper (1981), Perry & Chilton (1997), the ESDU (2004) and Mbiya (2008) are within 335 %, 400 %, 1422 % and 443 % error respectively to those found in this work.

For 10 < Re < 1000, the loss coefficients of Saunders diaphragm valves are identical to those predicted by Mbiya (2008) for all the opening positions.

b) 75 % open

Mbiya (2008) found loss coefficients of 59 % error to those obtained in the Saunders diaphragm valves.
Miller (1990) obtained loss coefficients of -81 % error to those found in this work.
The loss coefficients predicted by the ESDU (2004) are within 72 % to those found in the Saunders diaphragm valves, while those obtained by Hooper (1981) and Perry & Chilton (1997) are within -53 % and -39 % error to those found in this work.

c) 50 % open

The loss coefficients found by Mbiya (2008) and the ESDU (2004) are within -5 % and -48 % error to those obtained in this work, while for Perry & Chilton (1997), Hooper (1981) and Miller (1990); the loss coefficients are within -77 %, -89 % and -94 % error to those found in this experimental investigation respectively.

d) 25 % open

The loss coefficients obtained from this work are respectively within -25 %, -95 %, -98 %, -76 % and -61 % error to those found by Mbiya (2008), Miller (1990), Hooper (1981), the ESDU (2004) and Perry & Chilton (1997).

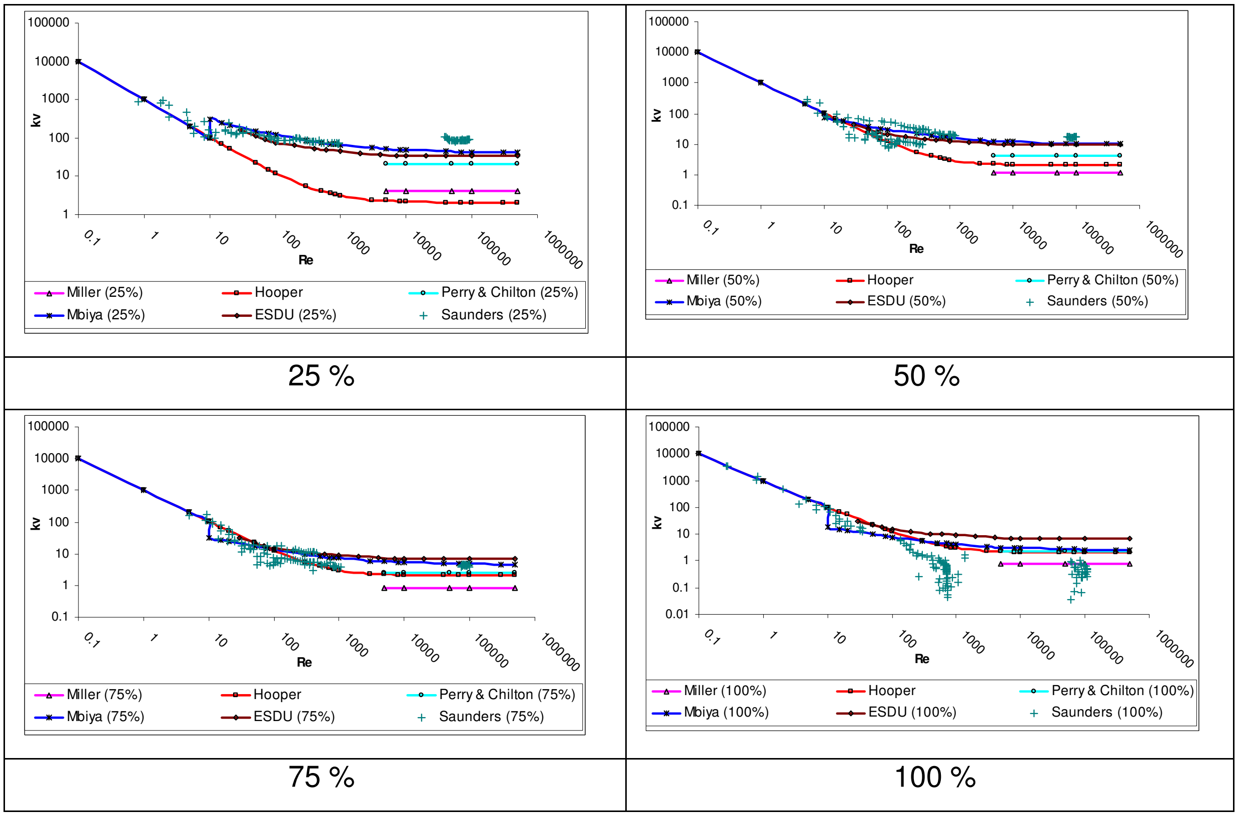



**Figure 5.4: Comparison between Saunders diaphragm valves and literature for 80 mm bore diameter**

### 5.2.2.5 Comparison between literature and new data for 100 mm bore diameter valve

For Re > 10, Figure 5.5 and Table 5.1 show for the 100 mm bore diameter at various openings that:

a) Fully open 100 %

The loss coefficients for straight-through Saunders diaphragm valves are respectively within 92 %, 121 % and 35 % error to those predicted by Hooper (1981), Perry & Chilton (1997) and Mbiya (2008).

The loss coefficients predicted by ESDU (2004) are within 592 % error to those found in this experimental investigation.

The loss coefficients obtained by Miller (1990) are within -23 % error to those found in this work.

For $10 < Re < 1000$, the loss coefficients of Saunders diaphragm valves are identical to those predicted by Mbiya (2008) in all the opening position.

b) 75 %

Mbiya (2008), Hooper (1981) and Perry & Chilton (1997) found loss coefficients of 111 %, -58 % and -45 % error respectively to those obtained in the Saunders diaphragm valves, while the ESDU (2004) obtained loss coefficients of 52 % error to those found in this experimental investigation. Miller (1990) obtained loss coefficients of -83 % error to those found in this work.

c) 50 %

The loss coefficients found by Hooper (1981), Miller (1990), Perry & Chilton (1997) and Mbiya (2008) are within -89 %, -93 %, -76 % and 63 % to those obtained in this work respectively, while those found by the ESDU (2004) are within -43 % to those obtained in this experimental investigation.

d) 25 %

The loss coefficients obtained from this work are respectively within 38 %, -94 %, -97 %, -50 % and -71 % to those found by Mbiya (2008), Miller (1990), Hooper (1981), the ESDU (2004) and Perry & Chilton (1997).

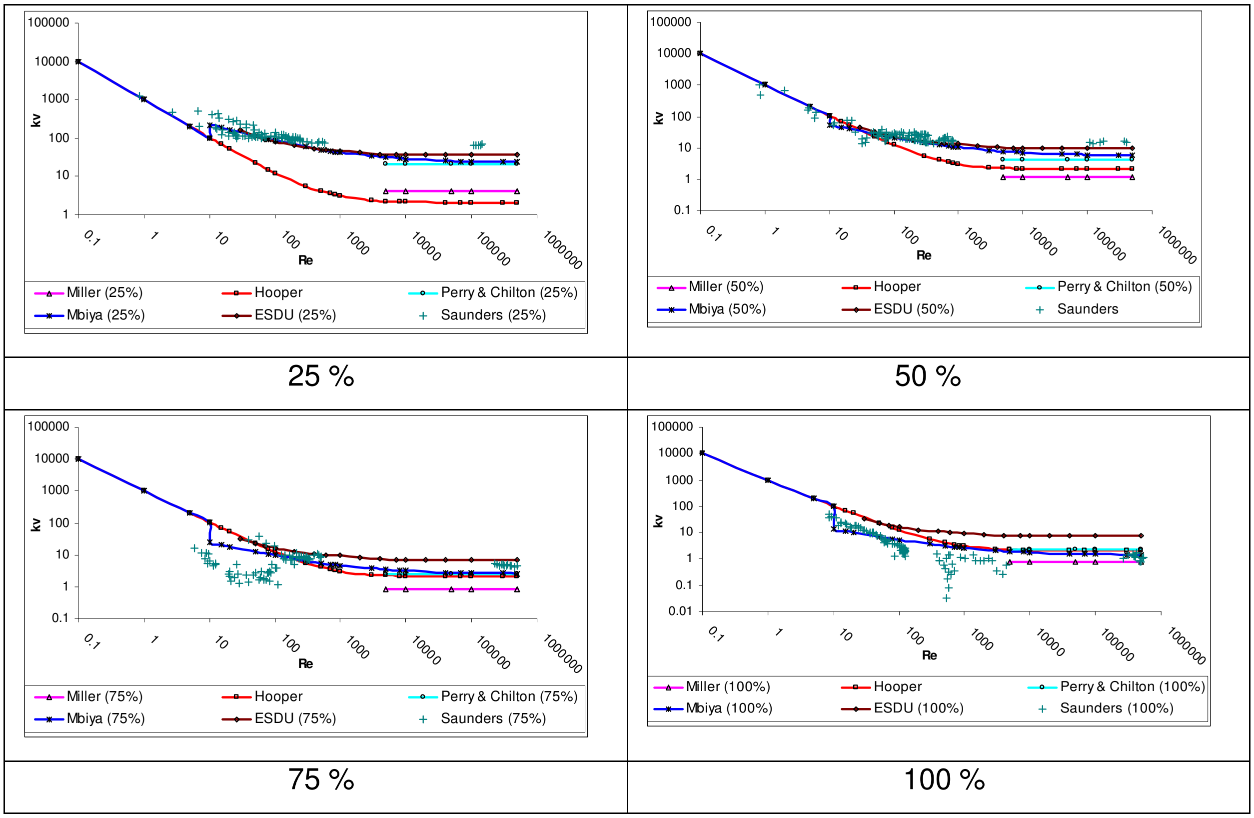



**Figure 5.5: Comparison between Saunders diaphragm valves and literature for 100 mm bore diameter**

Table 5.1 illustrates numerical discrepancies between the data found in the open literature and the data obtained from this work. The relative error was calculated using Equation 3.5 between the loss coefficients found in this work and those found in the literature in the turbulent regime. The positive error means that the results in literature were higher than those obtained for this work, and the negative error means that it was lower.

**Table 5.1: Percentage error: Comparison of literature and this work**

| Bore diameter (mm) | Opening position (%) | Miller | Hooper | Perry & Chilton | ESDU | Mbiya |
|---|---|---|---|---|---|---|
| 40 | 25 | -94% | -97% | -69% | -42% | 207% |
| | 50 | -96% | -94% | -87% | -66% | 7% |
| | 75 | -90% | -75% | -68% | -2% | 121% |
| | 100 | -70% | -25% | -14% | 199% | 202% |
| 50 | 25 | -86% | -93% | -26% | 41% | 199% |
| | 50 | -88% | -80% | -58% | 9% | 144% |
| | 75 | -79% | -48% | -33% | 106% | 109% |
| | 100 | -50% | 25% | 44% | 400% | 56% |
| 65 | 25 | -82% | -91% | -6% | 76% | 181% |
| | 50 | -67% | -45% | 18% | 205% | 341% |
| | 75 | -55% | 13% | 47% | 346% | 58% |
| | 100 | 40% | 251% | 304% | 1286% | 111% |
| 80 | 25 | -95% | -98% | -76% | -61% | -25% |
| | 50 | -94% | -89% | -77% | -48% | -5% |
| | 75 | -81% | -53% | -39% | 72% | 59% |
| | 100 | 74% | 335% | 400% | 1422% | 443% |
| 100 | 25 | -94% | -97% | -71% | -50% | 38% |
| | 50 | -93% | -89% | -76% | -43% | 63% |
| | 75 | -83% | -58% | -45% | 52% | 111% |
| | 100 | -23% | 92% | 121% | 592% | 35% |

In conclusion we can say that:

None of the data found in the open literature or the commercially available model from ESDU (2004) performed well over the wide range of conditions tested in this work, i.e. Reynolds number, valve opening position and valve size.

Mbiya (2008) derived a two-constant model to predict the loss coefficients for diaphragm valves using Natco diaphragm valves. The model has been extended to this work as recommended by Mbiya (2008) to predict the loss coefficient for Saunders diaphragm valves. It was found that the two-constant model (Mbiya, 2008) performed well for 100 % open valves, but failed to predict well over the range of different valve opening positions for different valve sizes, as can be seen in Figures 5.6 to 5.8. It consistently overpredicted the loss coefficient in the fully turbulent regime, indicating that Natco valves gave higher resistance than Saunders valves.

The ESDU (2004) model, because of its poor prediction over the wide range of size diameter and openings position, will not be discussed in the next section.

However, Mbiya's model will be closely compared again to the results found from this work by using the $\lambda_\Omega$ values obtained for Saunders valves in this work.

## 5.3 APPLICATION OF TWO-CONSTANT MODEL (MBIYA, 2008) TO SAUNDERS VALVES

The two-constant model requires the $\lambda_\Omega$ for fully open or 25 % open, and these were provided for use with this model. The $\lambda_\Omega$ provided was for Natco valves tested.

As shown in the previous section large errors were obtained compared with Saunders results, clearly indicating that Natco valves show higher resistance than Saunders valves.

To evaluate the wider applicability of this model, the $\lambda_\Omega$ values for Saunders valves are then substituted and the model is evaluated again against the experimental results obtained in this work.

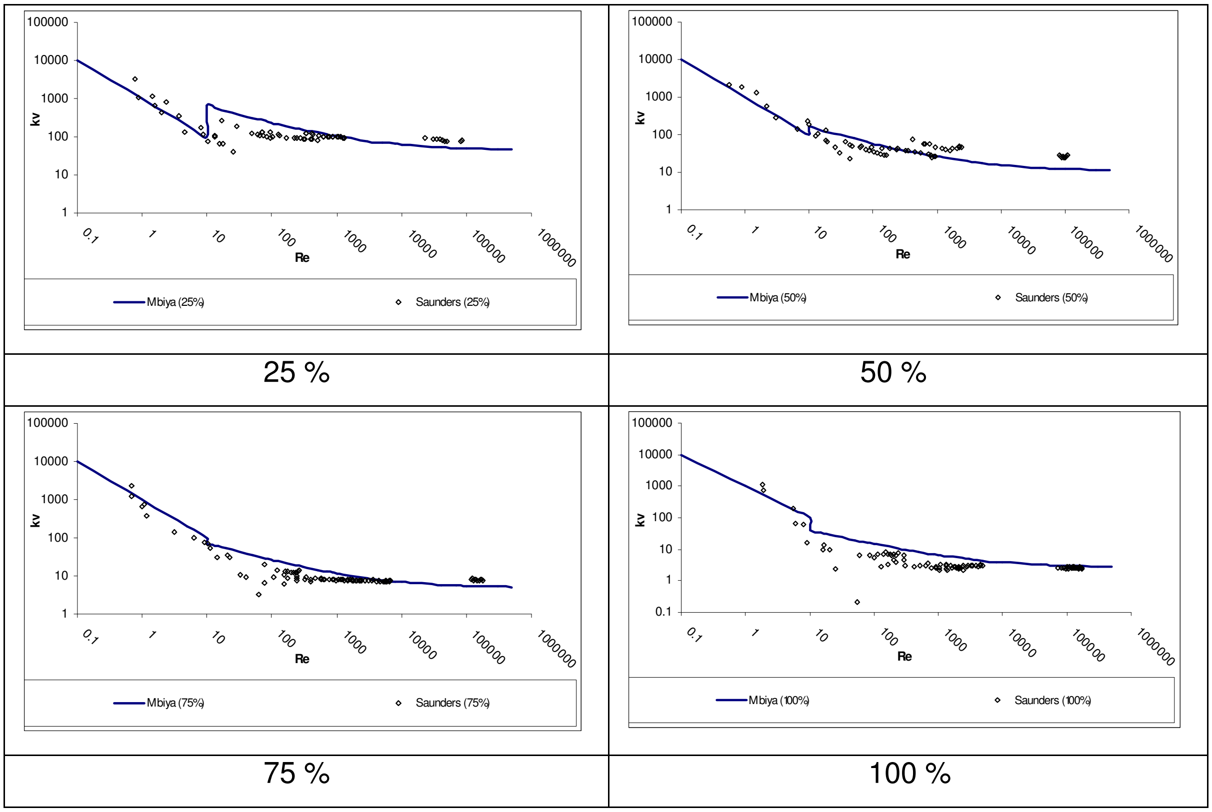



**Figure 5.6: Comparison between the Saunders diaphragm valves for the 40 mm bore diameter at different opening positions and two-constant model (Mbiya, 2008) using $\lambda_{\Omega Saunders}$.**

In turbulent flow, Figure 5.6 shows reasonable agreement between the data obtained in the experimental investigation and Mbiya's Model for the 40 mm bore diameter at different opening positions, except for the 100 % open. However, Figures 5.7 and 5.8 show how the model performance deteriorates with increasing valve diameter and valve opening.

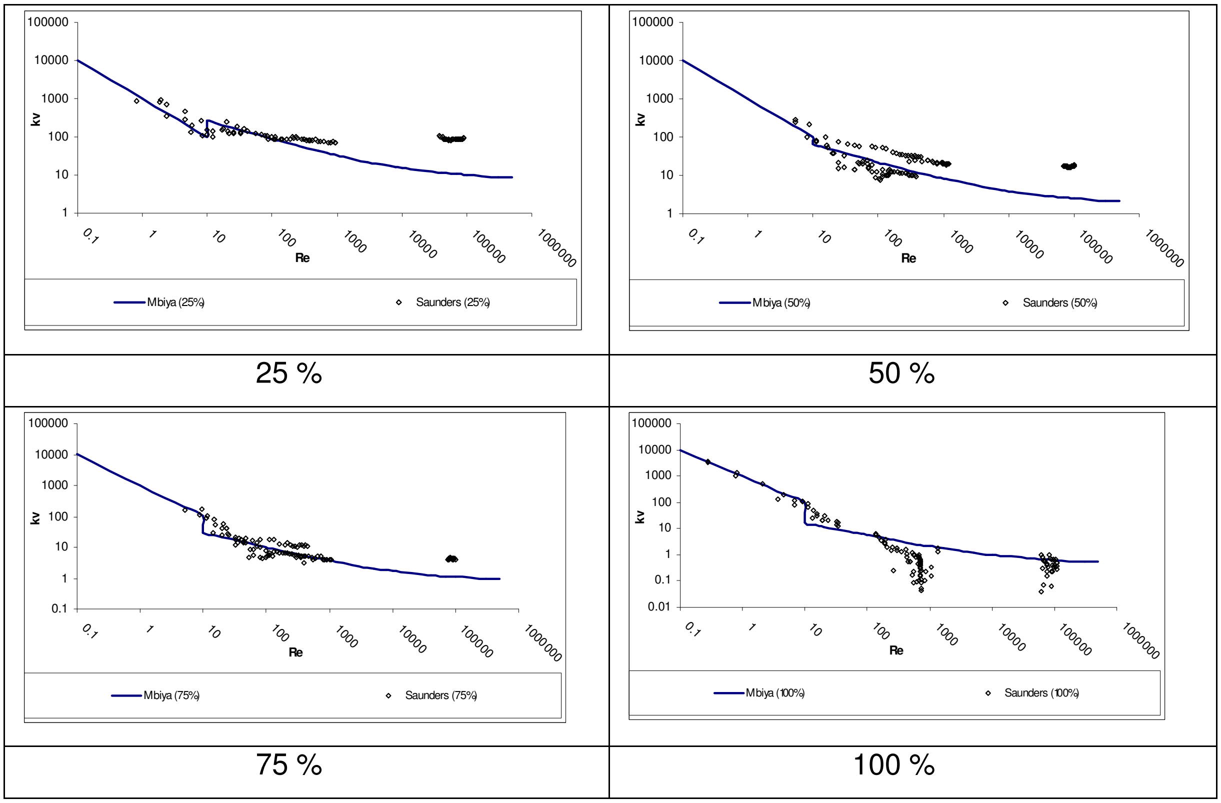



**Figure 5.7: Comparison between the Saunders diaphragm valves for the 80 mm bore diameter at different opening positions and two-constant model (Mbiya, 2008) using $\lambda_{\Omega Saunders}$.**

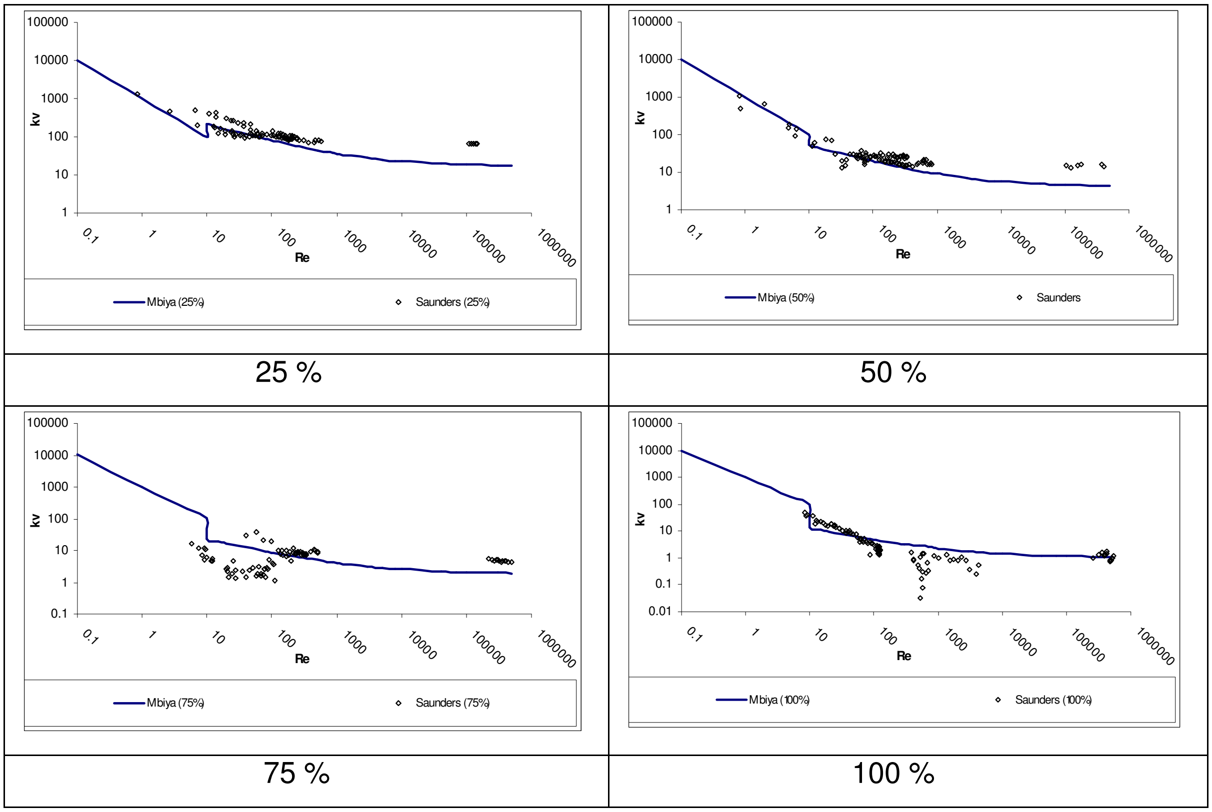



**Figure 5.8: Comparison between the Saunders diaphragm valves for the 100 mm bore diameter at different opening positions and two-constant model (Mbiya, 2008) using $\lambda_{\Omega Saunders}$.**

Mbiya's (2008) correlation failed to predict well and did not clearly specify for which pipe size the $\lambda_{\Omega}$ of the fully open should be used or not. This is why a simpler correlation based on the experimental work conducted in this experimental investigation is proposed, which will be described in the next section. Table 5.2 shows the deviation between Mbiya's correlation and the data found in this work. This proved that Mbiya's model does not provide a good prediction of the pressure losses through Saunders straight-through diaphragm valves.

**Table 5.2: Loss coefficient error for the two-constant model application**

| Bore diameter (mm) | Opening position (%) | Application of two-constant model with Saunders $\lambda_\Omega$ (Mbiya) |
|---|---|---|
| 40 | 25 | -29% |
| | 50 | -63% |
| | 75 | -33% |
| | 100 | 14% |
| 50 | 25 | 6% |
| | 50 | -26% |
| | 75 | -13% |
| | 100 | 18% |
| 65 | 25 | -44% |
| | 50 | -14% |
| | 75 | -22% |
| | 100 | 37% |
| 80 | 25 | -89% |
| | 50 | -87% |
| | 75 | -74% |
| | 100 | 35% |
| 100 | 25 | -74% |
| | 50 | -74% |
| | 75 | -59% |
| | 100 | 12% |

## 5.4 CORRELATION OF THE LOSS COEFFICIENT TO THE REYNOLDS NUMBER

The lack of adequate correlation to predict the losses through Saunders diaphragm valves necessitated the development of a new correlation for the prediction of the loss coefficients through Saunders valves, as shown in Figures 5.12 to 5.16.

The purpose of this section is to present the derivation of the new correlation and comparison with the experimental data. The correlation will be plotted against the Slatter Reynolds number for the analysis.

### 5.4.1 Laminar (viscous) flow Re < 10

The first term still holds as the laminar flow equation shown in Figure 5.9. For Re < 10, the loss coefficient $k_v$ is only a function of Re and can be predicted using $C_v$ = 1000 as given by Hooper (1981).

$$k_v = \frac{C_v}{Re}$$ **Equation 5.1**

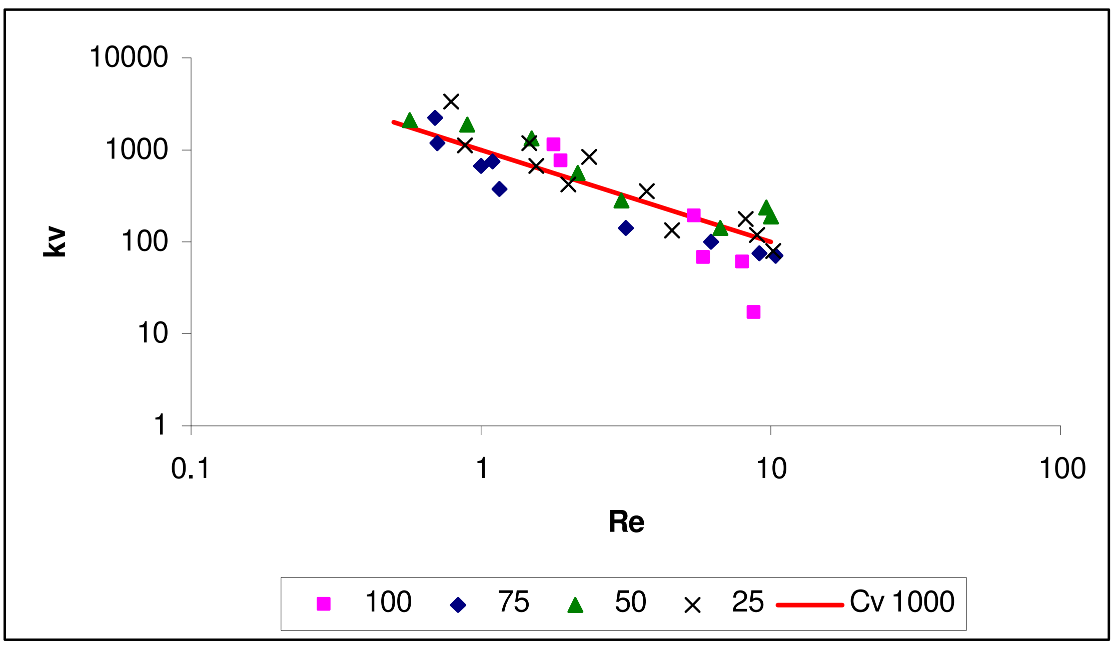



**Figure 5.9: 40 mm bore diameter at various opening positions**

It can be seen on Figure 5.9 that the laminar loss coefficient $C_v$ does not depend on the valve size or opening positions, but is dependent on the Reynolds number only.

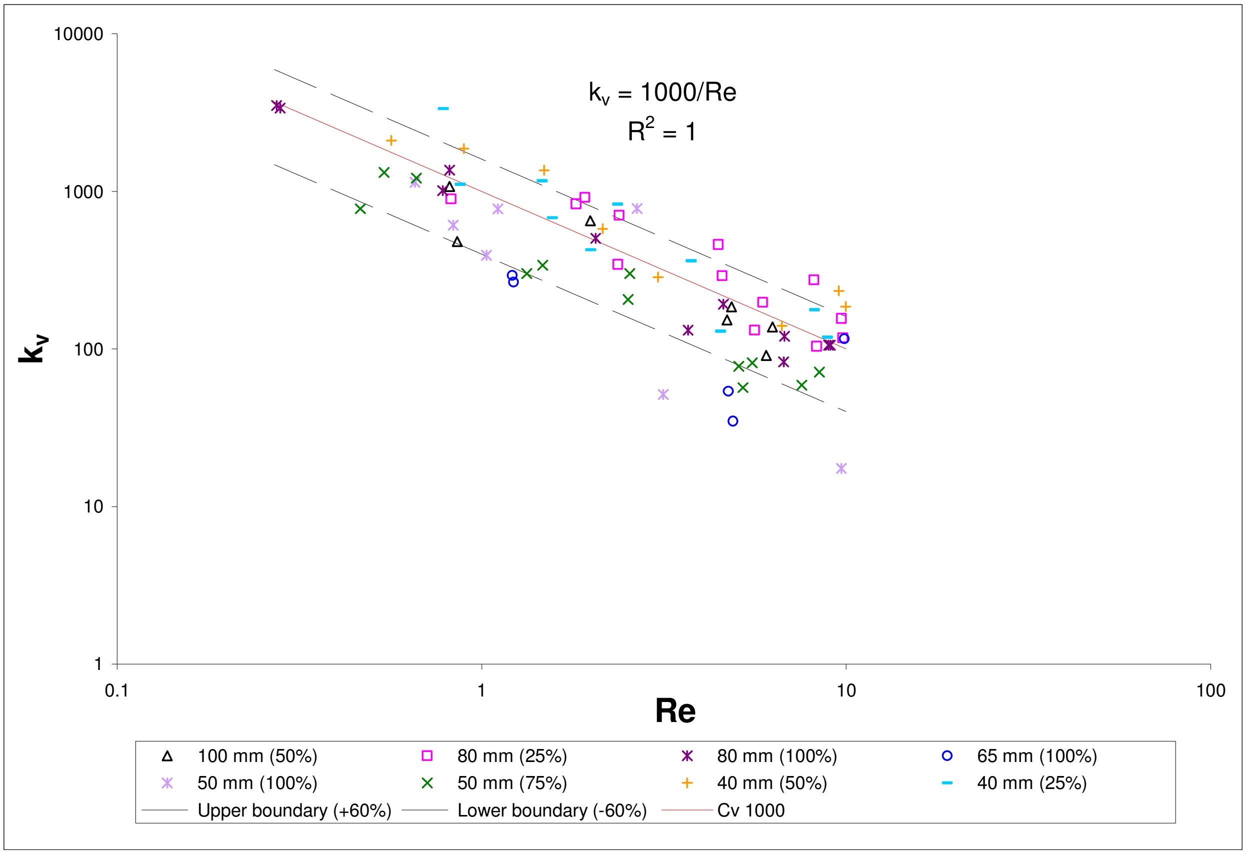



**Figure 5.10: $k_v$ versus Re less than 10 for different pipe sizes at different opening positions**

### 5.4.2 Turbulent flow

In the turbulent regime, the loss coefficient becomes a constant and does not depend on the Reynolds number (Turian et al., 1998). It does, however, depend on the opening position of the valve.

The analysis of loss coefficients in turbulent flow has proceeded from the following initial assumptions:

- The loss coefficient in turbulent flow is constant and depends on the opening position of the valve (θ).
- The loss coefficient depends on the bore diameter of the valve
- The length of the valve has been neglected.
- The valve friction has not been taken into account

Hooper (1981) derived a two-K method (Equation 2.62) to predict the loss coefficient through the dam diaphragm valve from laminar to turbulent for only the fully open position. A minimum value of 2 was found for the turbulent loss coefficient and 1000 for the laminar loss coefficient at Reynolds number equals to 1.

In 2007 Fester et al., derived an equation (Equation 2.72) that can predict the loss coefficient for both laminar and turbulent flow only for the fully opening position for straight-through diaphragm valves.

$$k_v = \frac{C_v}{Re_s} + \lambda_\Omega \qquad \text{Equation 2.72}$$

The new correlation builds and extends the latter model to include different opening positions. A relationship between the turbulent loss coefficient $\lambda_\Omega$ and the valve opening θ was derived.

Figure 5.11 shows that the plot of the opening position against the loss coefficient follows a power law trend for different bore diameter size. Due to the fact that the power law coefficient is more or less equal to the loss coefficient for the fully open position, an average power constant of 2.5 has been calculated and taken into consideration from different bore diameter size to predict the turbulent loss coefficient for different bore diameter size and the coefficient is similar to the loss coefficient at fully open position as seen in Table 5.3.

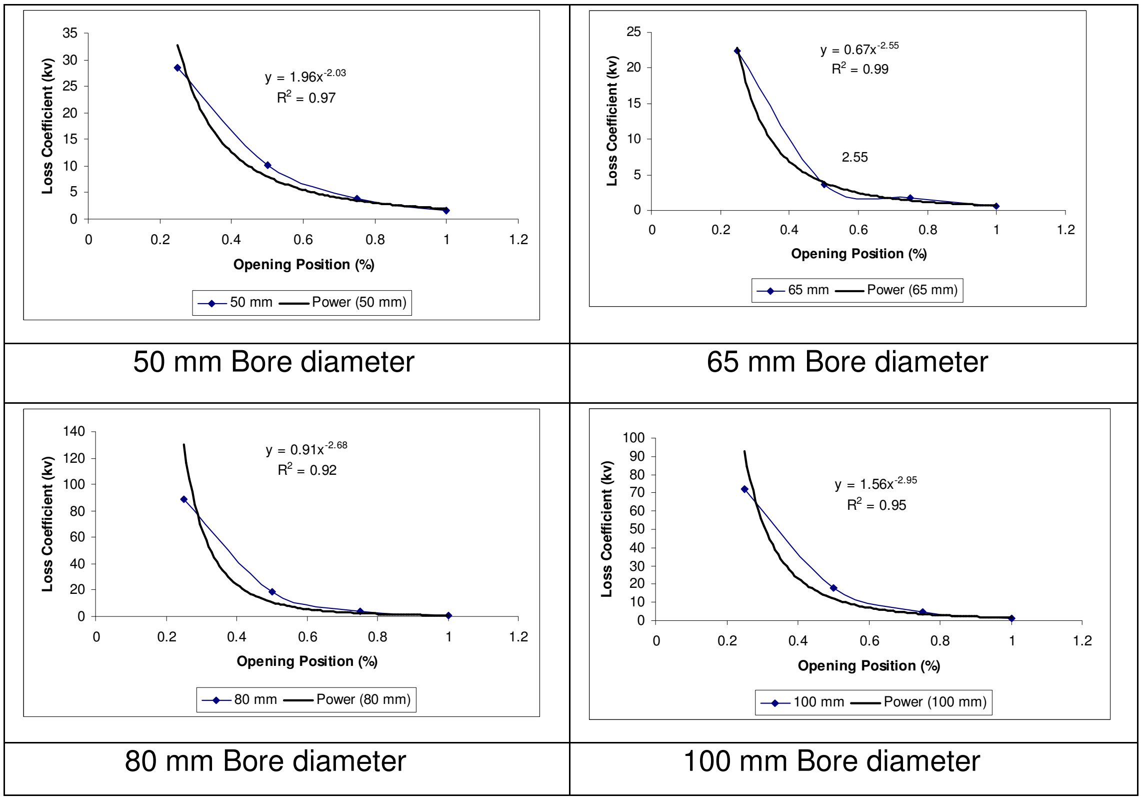



**Figure 5.11: Plot of opening position against the turbulent loss coefficient for various pipe sizes**

**Table 5.3: Power law fit for turbulent loss coefficient for various pipe sizes**

| Nominal bore diameter | Power law trend | Power law constant | $R^2$ |
|---|---|---|---|
| 40 | $k_v = \frac{3.82}{\theta^{2.30}}$ | 2.30 | 0.91 |
| 50 | $k_v = \frac{1.96}{\theta^{2.03}}$ | 2.03 | 0.97 |
| 65 | $k_v = \frac{0.67}{\theta^{2.55}}$ | 2.55 | 0.99 |
| 80 | $k_v = \frac{0.91}{\theta^{3.58}}$ | 3.58 | 0.92 |
| 100 | $k_v = \frac{1.56}{\theta^{2.95}}$ | 2.95 | 0.95 |
| Mean average | | 2.50 | |
| Standard deviation | | 0.35 | |

Benziger (1999) stated that all the $R^2$ above 0.90 represents good fits of experimental data. Table 5.4 gives us the power law trend for the prediction of the loss coefficient for different opening positions as well as the power law constant used in this work.

**Table 5.4: General power law fit for turbulent loss coefficient**

| Power law | Average | Standard deviation |
|---|---|---|
| $k_v = \frac{\lambda_\Omega}{\theta^{2.5}}$ | 2.5 | 0.35 |

It can be seen in Figure 5.11 that the coefficient is almost similar to the experimental loss coefficient at 100 % open position, and the latter is a function of the opening position.

$$k_v = \frac{1000}{Re_s} + \frac{\lambda_\Omega}{\theta^{2.5}}$$ **Equation 5.2**

Finally Equation 5.2 represents the relationship to predict the loss coefficients at different opening positions from laminar to turbulent flow.
The new correlation (Equation 5.2) will be applied for Saunders straight-through diaphragm valves ranging from 40 mm to 100 mm in the fully, 75 %, 50 % and 25 % open position.

## 5.5 COMPARISON BETWEEN THE EXISTING MODELS AND THE NEW CORRELATION

The new correlation (Equation 5.2) derived as part of this work has firstly been compared to the experimental data obtained from this thesis, and then to literature.
Figure 5.12 shows a good agreement between the data obtained in the experimental investigation and the new correlation derived from this work for the 40 mm bore diameter at different opening positions except for the 50 % open.

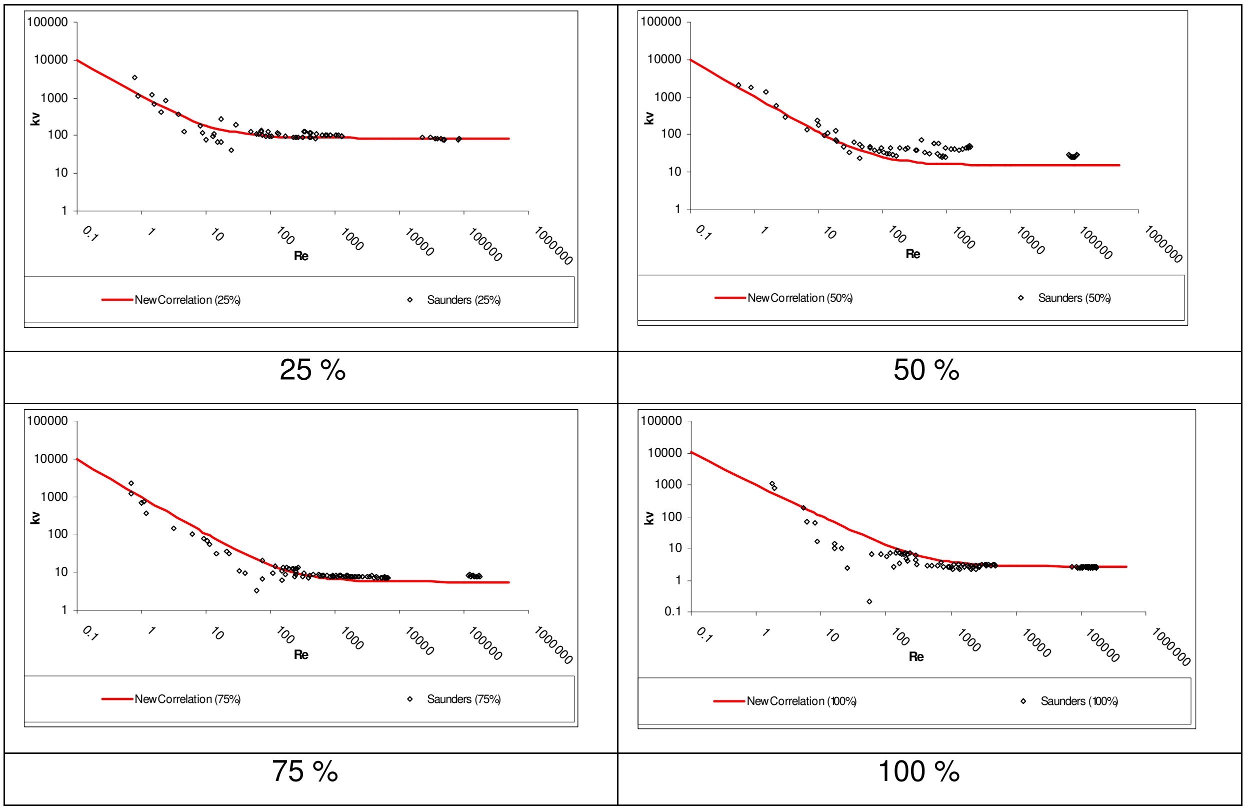
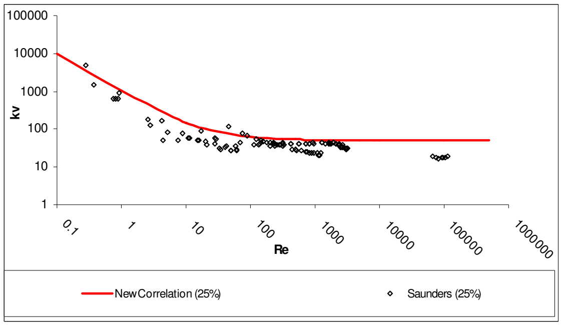
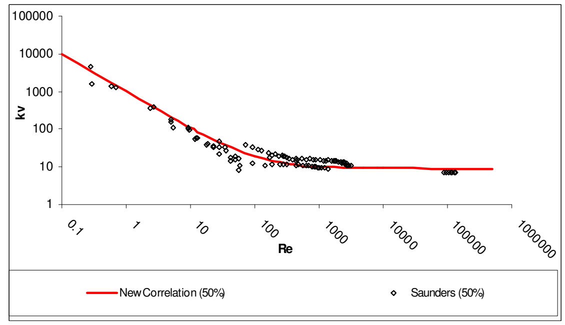



**Figure 5.12: Comparison between the Saunders diaphragm valves for the 40 mm at different opening positions and the new correlation**

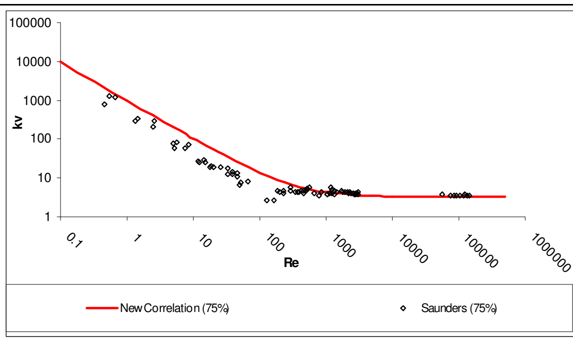
Figure 5.13 shows a good agreement between the data obtained in the experimental investigation and the new correlation derived from this work for the 50 mm bore diameter at different opening positions, except for the 25 % open.



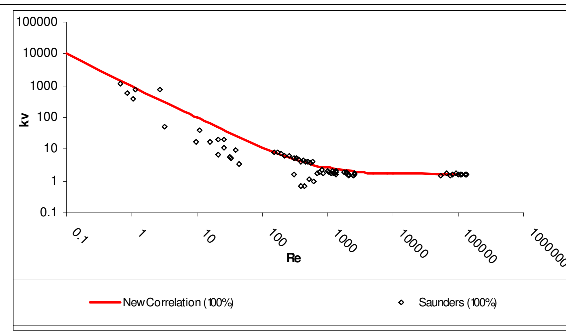

25 %




50 %




75 %




100 %

**Figure 5.13: Comparison between the Saunders diaphragm valves for the 50 mm bore diameter at different opening positions and the new correlation**

Figure 5.14 shows a good agreement between the data obtained in the experimental investigation and the new correlation derived from this work for the 65 mm bore diameter at different opening positions.

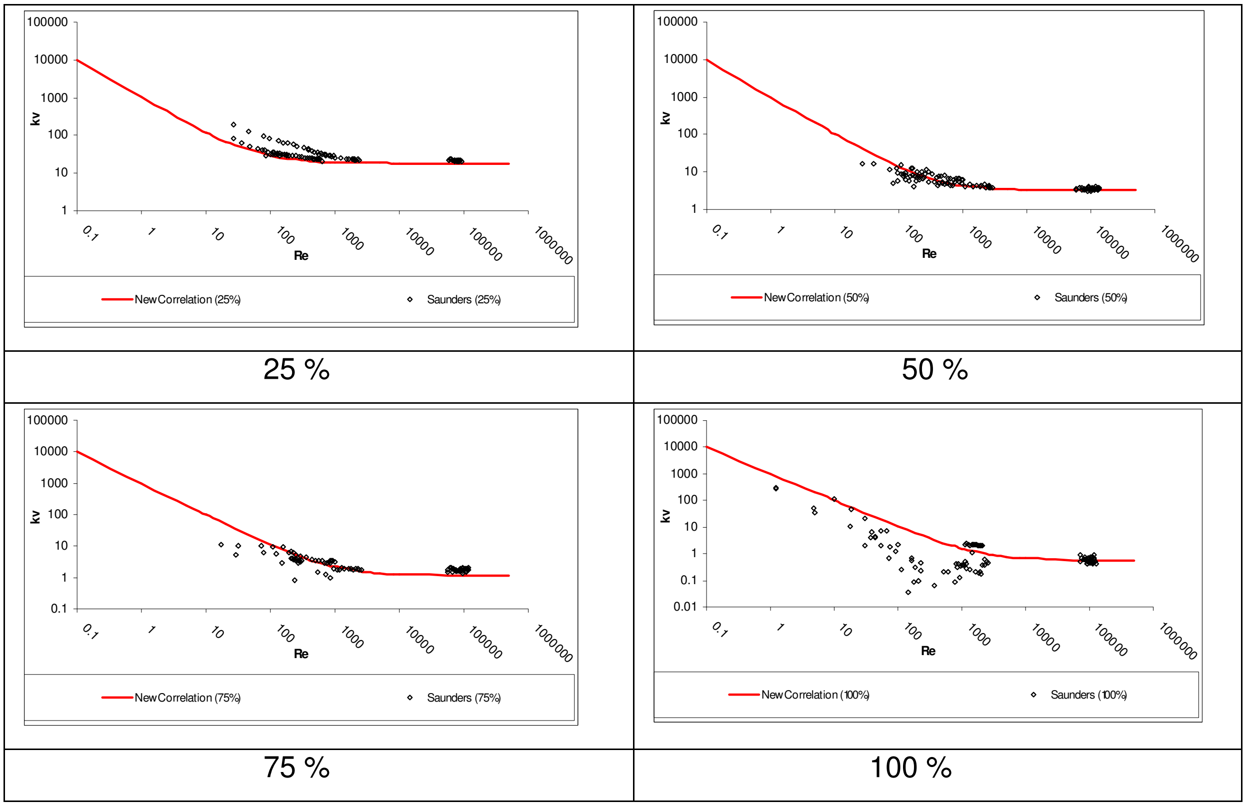



**Figure 5.14: Comparison between the Saunders diaphragm valves for the 65 mm bore diameter at different opening positions and the new correlation**

Figure 5.15 shows a poor agreement between the data obtained in the experimental investigation and the new correlation derived from this work for the 80 mm bore diameter at different opening positions except for the 100 % open. This poor prediction is due to the fact that the results have errors of above 40 %.

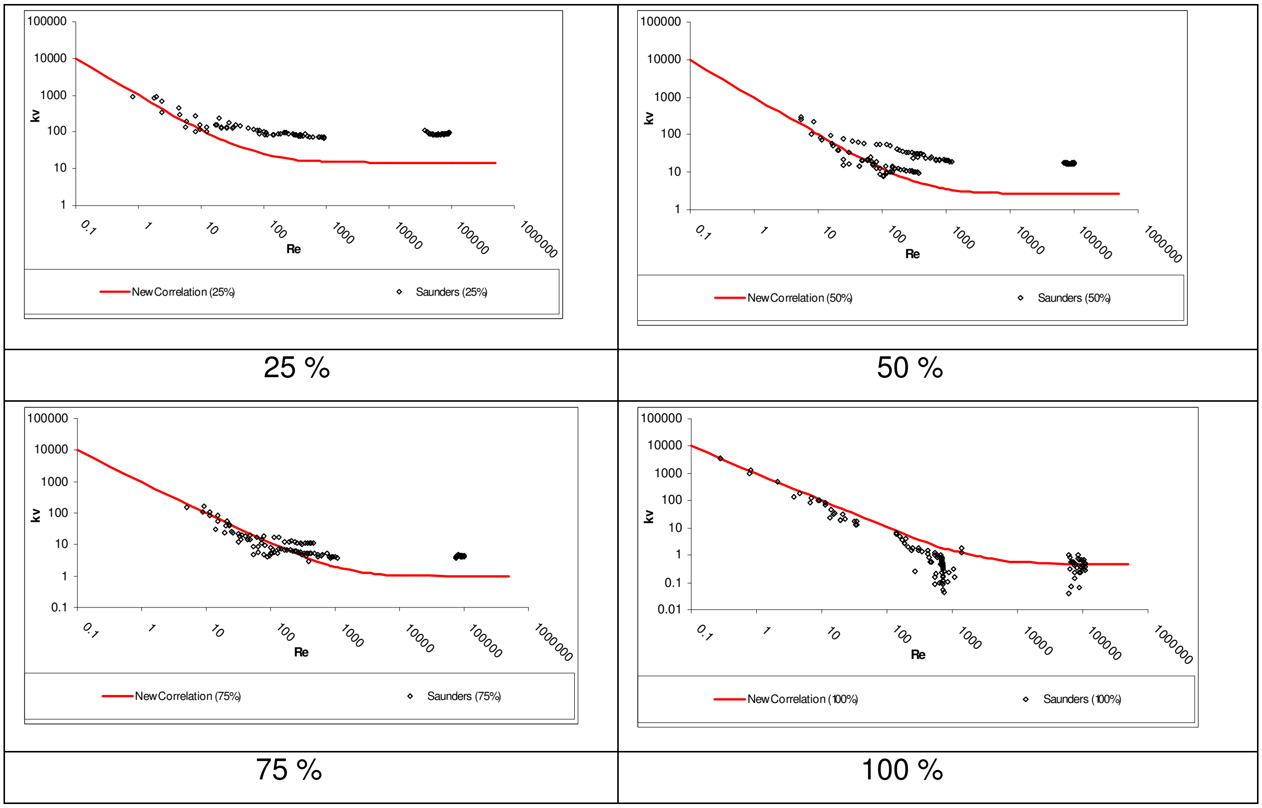



**Figure 5.15: Comparison between the Saunders diaphragm valves for the 80 mm bore diameter at different opening positions and the new correlation**

Figure 5.16 shows a poor agreement between the data obtained in the experimental investigation and the new correlation derived from this work for the 100 mm bore diameter at different opening positions except for the 100 % open.

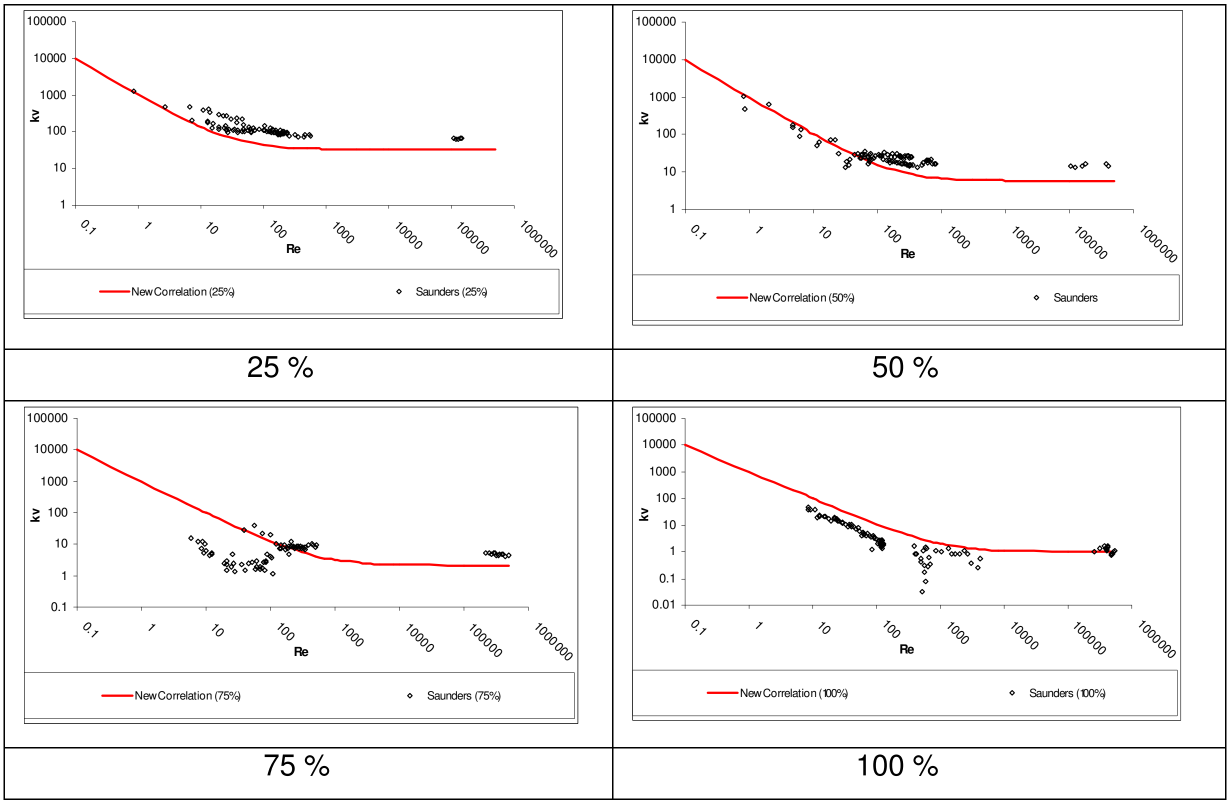



**Figure 5.16: Comparison between the Saunders diaphragm valves for the 100 mm bore diameter at different opening positions and the new correlation**

Table 5.5 illustrates the discrepancies between the new correlation compared to the experimental results in literature. It is noticeable that the error obtained for the new correlation is in most cases lower than those obtained using the existing correlations in literature.

**Table 5.5: Loss coefficient error for the new correlation**

| Bore diameter (mm) | Opening position (%) | Miller | Hooper | Perry & Chilton | ESDU | Mbiya | New correlation |
|---|---|---|---|---|---|---|---|
| 40 | 25 | -94% | -97% | -69% | -42% | 207% | -39% |
| | 50 | -96% | -94% | -87% | -66% | 7% | -68% |
| | 75 | -90% | -75% | -68% | -2% | 121% | -42% |
| | 100 | -70% | -25% | -14% | 199% | 202% | 0% |
| 50 | 25 | -86% | -93% | -26% | 41% | 199% | 46% |
| | 50 | -88% | -80% | -58% | 9% | 144% | -20% |
| | 75 | -79% | -48% | -33% | 106% | 109% | -5% |
| | 100 | -50% | 25% | 44% | 400% | 56% | 6% |
| 65 | 25 | -82% | -91% | -6% | 76% | 181% | 40% |
| | 50 | -67% | -45% | 18% | 205% | 341% | 17% |
| | 75 | -55% | 13% | 47% | 346% | 58% | -25% |
| | 100 | 40% | 251% | 304% | 1286% | 111% | 2% |
| 80 | 25 | -95% | -98% | -76% | -61% | -25% | -40% |
| | 50 | -94% | -89% | -77% | -48% | -5% | -74% |
| | 75 | -81% | -53% | -39% | 72% | 59% | -71% |
| | 100 | 74% | 335% | 400% | 1422% | 443% | 2% |
| 100 | 25 | -94% | -97% | -71% | -50% | 38% | 354% |
| | 50 | -93% | -89% | -76% | -43% | 63% | 4% |
| | 75 | -83% | -58% | -45% | 52% | 111% | -28% |
| | 100 | -23% | 92% | 121% | 592% | 35% | 1% |

## 5.6 CONCLUSION

The objective of this research was to determine the loss coefficient data in laminar, transitional and turbulent flow for the Saunders type straight-through diaphragm valves ranging from 40 mm to 100 mm in the fully, 75 %, 50 % and 25 % open positions, using a range of Newtonian and non-Newtonian fluids. After the comparison of the data obtained from this work was done with the existing models, it was seen that there was a lack of good prediction within the wide range of conditions i.e. valve opening position, valve size and Reynolds number. Due to the fact stated in the previous sentence, a new correlation has been derived to predict the loss coefficients for Saunders diaphragm valves. The correlation shows a good agreement with the experimental results and can be used to predict the loss coefficient in both turbulent and laminar flow. The test work has been conducted on the valve test rig in the Institute of Material and Science Technology at the Cape Peninsula University of Technology. The experimental results have been compared to the data found in the open literature. In laminar flow, the loss coefficients are similar, and Equation 5.2 can be used to predict the laminar and turbulent loss coefficients.

The main outcome of this project is the establishment of a new correlation of loss coefficient for Saunders valves for various diameters and openings. This will provide input data to enable more efficient pipeline plant designs.

# CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

## 6.1 INTRODUCTION

Due to water scarcity and the new water law, mining operations are obliged to increase their solids concentrations and are now faced with the reality of laminar flow operation (Slatter, 2002). Consequently there was a need to ascertain which loss coefficient data in laminar flow for the control valves (Diaphragm valves) can be used in industry, to ensure energy efficient designs (Pienaar et al., 2001; 2004).

The head losses in the valves can outweigh the head losses in straight pipes for short piping circuits (Massey, 1990). This diaphragm valve is used for pipe flow regulation in industry, but the data found in the open literature are for unknown valve sizes, except for the work produced by Fester et al., (2007) and Mbiya (2008). This section will give a summary of the work done, specifically for Saunders valves, the main contribution and recommendation for future research.

## 6.2 SUMMARY

A range of straight-through diaphragm valves (Saunders), from 40 mm bore diameter to 100 mm bore diameter, have been mounted horizontally and tested at different opening positions of fully, 75 %, 50 % and 25 % open positions in the Flow Process Research Centre at the Cape Peninsula University of Technology. Loss coefficient data were derived for laminar, transitional and turbulent flow in these valves.

The experimental data were compared with data and correlations in the literature, such as Perry & Chilton (1997), Miller (1990), Hooper (1981), the ESDU (2004) and Mbiya (2008). The work of Mbiya (2008) was found pertinent as it dealt with the same sizes of Natco valves. Evaluation of this work revealed three important points:

- In laminar flow, the laminar flow coefficient was the same
- For turbulent flow, Natco valves showed higher resistance to flow than Saunders valves and
- The same loss coefficients could not be used for to determine pressure losses for transitional and turbulent data for valves produced by different manufacturers.

This model could predict well for fully open position and failed to predict well for different opening positions.

Therefore a new correlation has been developed, based on the work done by Fester et al., in 2007 (Equation 2.72), which was for fully open position. And in this work, the relationship has been extended to account different opening positions.

The nominal turbulent coefficient ($\lambda_\Omega$) for fully open position is provided in Table 6.1 to be used with Equation 5.2

$$k_v = \frac{1000}{Re} + \frac{\lambda_\Omega}{\theta^{2.5}} \qquad \text{Equation 5.2}$$

**Table 6.1:Nominal turbulent coefficient ($\lambda_\Omega$) for fully open position for various pipe sizes**

| Bore diameter (mm) | Loss coefficient ($\lambda_\Omega$) |
|---|---|
| 40 | 2.68 |
| 50 | 1.60 |
| 65 | 0.57 |
| 80 | 0.46 |
| 100 | 1.04 |

## 6.3 CONTRIBUTIONS

This thesis added loss coefficient data to the open literature and a design correlation for straight-through diaphragm valves, which will be useful for designing pipelines in industries and design correlation for straight-through Saunders valves, as well as contributing to the academic discourse and debate in this discipline.

The loss coefficient data found in this work was orders of magnitude lower than those for the Natco valves. Therefore, it is clear that the same loss coefficients could not be used in the turbulent flow for two different manufacturers, but in laminar flow the laminar loss coefficient found by Hooper (1981) and in this work are also similar to the one found by Mbiya (2008).

## 6.4 CONCLUSION

A new correlation has been derived to predict the loss coefficients for straight-through Saunders diaphragm valves at various openings from laminar to turbulent regimes.

## 6.5 RECOMMENDATIONS

At the end of this experimental investigation, the following is recommended:

- Further tests should be done to verify whether the loss coefficient for other manufacturers will differ to the existing loss coefficient found for Saunders and Natco valves using the same approach.
- The horizontal position of the valves should be changed either in a vertical or inclined position to ascertain if the loss coefficient found in this work will remain the same.
- The reason for discrepancies between Sanders and Natco valves should be investigated based on a micro-scale investigation using CFD and UVP.

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## APPENDICES: HYDRAULIC GRADE LINE TEST RESULTS

### Table of content of appendices

## Appendix 1: CMC 5 % in 40 mm valve, 25 % open

### CMC 5 % in 40 mm valve, 25 % open

CMC 5% in 40 mm valve, 25 % open

| | | |
|---|---|---|
| **Date:** | 12/10/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | ¼ Open | Area[m2] |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| | |
|---|---|
| **Material Type:** | CMC 5% |
| **Density[kg/m3 ]:** | 1026.8 |
| **Concentration:** | 5% |
| **ty:** | 0.000 |
| **K:** | 2.177 |
| **n:** | 0.608 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | K1/n |
|---|---|---|---|
| 1.645 | 0.378 | 2.645 | 3.595 |

| | | | | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Axial distances** | -6.248 | -4.518 | -1.830 | -0.571 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 | |
| | | | **Valve plane** | | | | | | | | | | |
| | | | **Non-dimensionalised distances incl.[L/D]:** | -148.3 | -107.3 | -43.45 | -13.54 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 | |
| | | | **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.324 | 8.933 | 12.29 | 14.32 | 16.22 | |
| **Run #** | **Re3** | | **kv.** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| **Run 1** | 104 | | 98.91 | 124189 | 115682 | 103599 | 98006 | 64117 | 57076 | 42607 | 33825 | 25742 | 1.05 |
| **Run 2** | 95 | | 95.12 | 115596 | 108523 | 97741 | 93171 | 61912 | 55278 | 41621 | 33313 | 25632 | 0.98 |
| **Run 3** | 85 | | 97.90 | 109216 | 102630 | 92916 | 88149 | 59838 | 53599 | 40678 | 32816 | 25528 | 0.90 |
| **Run 4** | 75 | | 105.92 | 103355 | 97145 | 87392 | 83047 | 57796 | 51991 | 39699 | 32285 | 25429 | 0.82 |
| **Run 5** | 66 | | 108.05 | 97364 | 91835 | 82597 | 78341 | 55881 | 50368 | 38839 | 31804 | 25334 | 0.76 |
| **Run 6** | 61 | | 114.24 | 93603 | 87864 | 79342 | 75327 | 54345 | 49102 | 38124 | 31398 | 25262 | 0.71 |
| **Run 7** | 50 | | 124.43 | 84953 | 80953 | 72800 | 69624 | 51431 | 46656 | 36673 | 30672 | 25106 | 0.61 |
| **Run 9** | 29 | | 190.61 | 71262 | 66311 | 59909 | 57022 | 45251 | 41485 | 33823 | 29187 | 24764 | 0.42 |
| **Run 11** | 17 | | 266.83 | 60149 | 56360 | 51029 | 49346 | 40632 | 37801 | 31727 | 27968 | 24515 | 0.29 |

## Appendix 2: Kaolin 6 % in 40 mm valve, 25 % open

### Kaolin 6 % in 40 mm valve, 25 % open

Kaolin 6% in 40 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 7/13/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.04 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.04212 | 0.00139337 |

| | |
|---|---|
| Material Type: | Kaolin 6% |
| Density[kg/m³]: | 1103.9 |
| Concentration: | 6% |
| $t_y$: | 3.071 |
| K: | 2.038 |
| n: | 0.264 |
| PPT used: | 105 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -147.7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| Distances[m]: | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 2 | 337 | | 125.46 | 62313 | 60256 | 57545 | 56322 | 25852 | 23866 | 20142 | 17986 | 15953 | 0.90 |
| Run 3 | 331 | | 124.86 | 62245 | 60389 | 57372 | 56271 | 25582 | 23874 | 20260 | 17980 | 16039 | 0.90 |
| Run 4 | 405 | | 120.73 | 69466 | 67382 | 64386 | 62870 | 26159 | 24207 | 20491 | 18287 | 16200 | 1.02 |
| Run 12 | 428 | | 116.83 | 69300 | 67287 | 64424 | 62689 | 26195 | 24385 | 20630 | 18345 | 16268 | 1.03 |
| Run 13 | 520 | | 107.99 | 74963 | 72898 | 69933 | 68684 | 26165 | 24454 | 20660 | 18354 | 16243 | 1.15 |
| Run 14 | 633 | | 99.65 | 80523 | 78266 | 75516 | 73847 | 25968 | 24584 | 20782 | 18414 | 16264 | 1.27 |
| Run 15 | 630 | | 99.45 | 80034 | 77929 | 74988 | 73910 | 25484 | 24461 | 20636 | 18367 | 16221 | 1.27 |
| Run 16 | 733 | | 99.33 | 86903 | 84747 | 81971 | 80581 | 25881 | 24654 | 20754 | 18534 | 16392 | 1.36 |
| Run 17 | 726 | | 100.06 | 86992 | 85112 | 81984 | 80311 | 25475 | 24550 | 20656 | 18373 | 16317 | 1.36 |
| Run 18 | 852 | | 101.44 | 99653 | 97627 | 94472 | 92959 | 26564 | 24818 | 20641 | 18496 | 16268 | 1.50 |
| Run 19 | 856 | | 101.23 | 99653 | 97627 | 94472 | 92959 | 25998 | 24768 | 20860 | 18560 | 16378 | 1.50 |
| Run 27 | 1299 | | 95.97 | 132520 | 129435 | 127216 | 125012 | 27117 | 25058 | 20986 | 18417 | 16191 | 1.88 |
| Run 28 | 1284 | | 95.37 | 131504 | 129090 | 126081 | 125035 | 27025 | 24955 | 20899 | 18382 | 16135 | 1.88 |
| Run 29 | 1258 | | 96.10 | 131733 | 128976 | 126167 | 125272 | 26666 | 24761 | 20738 | 18212 | 15951 | 1.87 |
| Run 30 | 1152 | | 100.55 | 125239 | 122801 | 119848 | 118016 | 26718 | 24731 | 20764 | 18316 | 16109 | 1.77 |
| Run 32 | 1029 | | 99.36 | 112964 | 110809 | 107711 | 106536 | 26668 | 24645 | 20745 | 18273 | 16060 | 1.66 |
| Run 33 | 1052 | | 99.36 | 112875 | 110778 | 107827 | 106518 | 26577 | 24657 | 20707 | 18295 | 16076 | 1.66 |
| Run 35 | 750 | | 99.61 | 90528 | 88267 | 85358 | 84091 | 26425 | 24641 | 20791 | 18400 | 16264 | 1.40 |

## Appendix 3: Kaolin 10 % in 40 mm valve, 25 % open

### Kaolin 10 % in 40 mm valve, 25 % open

Kaolin 10 % in 40 mm valve, 25 % open

| | | | |
|---|---|---|---|
| Date: | 2007/08/13 | Test done by Mume & Sisonke | |
| Valve Type: | Diaphragm | | |
| Valve dimension[m]: | 0.04 | | |
| Valve position: | ¼ Open | Area[m²] | |
| Pipe Diameter [m]: | 0.04212 | 0.00139337 | |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | Kaolin 10% | | | | | | | | | | | | |
| Density[kg/m³]: | 1169.4 | | | | | | | | | | | | |
| Concentration: | 10% | | | | | | | | | | | | |
| $\tau_y$: | 8.965 | | | | | | | | | | | | |
| K: | 7.098 | | | | | | | | | | | | |
| n: | 0.175 | Axial distances | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 | | |
| PPT used: | 101 to 109 | Valve plane | | | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -147.7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 | | |
| | | Distances[m]: | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 | | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 2 | 498 | | 83.477 | 131841 | 127314 | 119301 | 115566 | 37498 | 32901 | 22168 | 15840 | 10179 | 1.70 |
| Run 3 | 399 | | 88.281 | 121131 | 116398 | 108580 | 104460 | 37285 | 32205 | 21970 | 15623 | 9883 | 1.52 |
| Run 4 | 406 | | 86.844 | 129099 | 123307 | 115666 | 111477 | 37333 | 32332 | 22124 | 15601 | 9859 | 1.62 |
| Run 5 | 420 | | 86.895 | 127047 | 121810 | 113993 | 109734 | 37377 | 32247 | 21955 | 15537 | 9899 | 1.61 |
| Run 7 | 317 | | 87.618 | 115181 | 109266 | 101691 | 98089 | 36988 | 31992 | 21863 | 15488 | 9967 | 1.46 |
| Run 8 | 310 | | 87.535 | 110484 | 105100 | 97360 | 93612 | 36539 | 31876 | 21676 | 15459 | 9792 | 1.40 |
| Run 9 | 329 | | 87.913 | 108704 | 103784 | 96271 | 92392 | 36287 | 31645 | 21599 | 15526 | 9779 | 1.38 |
| Run 10 | 272 | | 91.244 | 105152 | 100214 | 92115 | 88594 | 36595 | 31455 | 21587 | 15487 | 9897 | 1.31 |
| Run 31 | 244 | | 91.571 | 99826 | 94595 | 86911 | 83182 | 36244 | 31424 | 21436 | 15407 | 9818 | 1.24 |
| Run 32 | 224 | | 92.388 | 94223 | 89129 | 81668 | 78104 | 36051 | 31175 | 21300 | 15295 | 9796 | 1.15 |
| Run 33 | 171 | | 95.370 | 87474 | 81553 | 74677 | 71357 | 35309 | 30489 | 20780 | 14849 | 9476 | 1.04 |
| Run 34 | 133 | | 108.862 | 83254 | 78260 | 70519 | 67314 | 34494 | 30095 | 20532 | 14643 | 9437 | 0.93 |
| Run 35 | 126 | | 116.953 | 78272 | 73724 | 66683 | 63606 | 34347 | 29539 | 20209 | 14504 | 9212 | 0.82 |
| Run 36 | 94 | | 130.683 | 74881 | 70068 | 62759 | 59211 | 33713 | 29256 | 19811 | 14374 | 9234 | 0.75 |
| Run 37 | 72 | | 128.377 | 68754 | 63913 | 56992 | 53573 | 33232 | 28813 | 19791 | 14210 | 9185 | 0.64 |
| Run 41 | 8 | | 177.294 | 47636 | 43772 | 37550 | 34704 | 28959 | 25161 | 17240 | 12421 | 8145 | 0.20 |
| Run 42 | 71 | | 132.012 | 65905 | 61354 | 54693 | 51339 | 32169 | 28075 | 19220 | 13778 | 8962 | 0.61 |

## Appendix 4: Kaolin 13 % in 40 mm valve, 25 % open

### Kaolin 13 % in 40 mm valve, 25 % open

Kaolin 13 % in 40 mm valve, 25 % open

| | | | |
|---|---|---|---|
| Date: | 12/7/2007 | Test done by Mume & Rendani | |
| Valve Type: | Diaphragm | | |
| Valve dimension[m]: | 0.04 | | |
| Valve position: | ¼ Open | Area[m²] | |
| Pipe Diameter [m]: | 0.04212 | 0.00139337 | |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | Kaolin 13% | | | | | | | | | | |
| Density[kg/m³]: | 1215.5 | | | | | | | | | | |
| Concentration: | 13% | | | | | | | | | | |
| $t_y$: | 18.973 | | | | | | | | | | |
| K: | 16.141 | | | | | | | | | | |
| n: | 0.242 | Axial distances | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| PPT used: | 105 | Valve plane | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -147.7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| | | Distances[m]: | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 2 | 25.00 | | 40.19 | 115554 | 106832 | 93437 | 86831 | 70858 | 62685 | 44899 | 33733 | 23427 | 0.54 |
| Run 3 | 15.31 | | 66.36 | 112917 | 103465 | 89781 | 83890 | 69552 | 61248 | 43679 | 32738 | 22681 | 0.41 |
| Run 4 | 17.25 | | 67.86 | 110575 | 100911 | 87405 | 81627 | 67994 | 60300 | 43021 | 32346 | 22749 | 0.44 |
| Run 5 | 13.39 | | 110.10 | 106259 | 97667 | 85284 | 79261 | 65480 | 57779 | 41534 | 31261 | 22353 | 0.37 |
| Run 6 | 13.03 | | 96.86 | 106824 | 97991 | 84604 | 79050 | 65831 | 58367 | 41927 | 31211 | 22447 | 0.37 |
| Run 7 | 8.88 | | 118.58 | 103806 | 94351 | 82087 | 76727 | 63833 | 56583 | 41024 | 30955 | 22085 | 0.30 |
| Run 8 | 10.21 | | 78.03 | 100799 | 93014 | 79966 | 75159 | 63528 | 55873 | 40500 | 30916 | 21936 | 0.32 |
| Run 10 | 4.53 | | 129.6 | 99305 | 91076 | 78744 | 72780 | 62431 | 55466 | 40193 | 30422 | 21811 | 0.21 |
| Run 11 | 3.76 | | 362.5 | 91044 | 84476 | 74885 | 69417 | 59621 | 52488 | 37553 | 29289 | 21540 | 0.17 |
| Run 13 | 1.56 | | 680.2 | 87352 | 80566 | 71209 | 66295 | 57030 | 50333 | 36813 | 29151 | 21470 | 0.11 |
| Run 14 | 1.99 | | 425.3 | 86104 | 78522 | 68198 | 64062 | 57242 | 50581 | 36686 | 28413 | 21530 | 0.12 |
| Run 15 | 2.36 | | 828.6 | 77404 | 71065 | 62114 | 58111 | 50710 | 45282 | 33685 | 26981 | 20887 | 0.12 |
| Run 16 | 1.47 | | 1166.67 | 80985 | 75440 | 64757 | 59735 | 51429 | 46002 | 34471 | 27104 | 20568 | 0.10 |
| Run 17 | 0.78 | | 3343.4 | 79028 | 73505 | 63379 | 59051 | 52294 | 46487 | 33916 | 26880 | 20863 | 0.07 |
| Run 20 | 0.87 | | 1107.17 | 71768 | 66607 | 57272 | 54010 | 47554 | 42303 | 32541 | 25572 | 20345 | 0.07 |

**Appendix 5: Water in 40 mm valve, 25 % open**

## Water in 40 mm valve, 25 % open

**Water in 40 mm valve, 25 % open**

| | | |
|---|---|---|
| **Date:** | 11/17/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | ¼ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| | |
|---|---|
| **Material Type:** | **Water** |
| **Density[kg/m³]:** | **995.4** |
| **Concentration:** | **100%** |
| **$t_y$:** | **0** |
| **K:** | 0.000772 |
| **n:** | 1 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0007725 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.248 | -4.518 | -1.830 | -0.571 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -148.3 | -107.3 | -43.45 | -13.54 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| **Distances(m):** | 0 | 1.73 | 4.418 | 5.678 | 7.324 | 8.933 | 12.29 | 14.32 | 16.22 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 1 | 90996 | | 66.35 | 126104 | 125357 | 123181 | 122711 | 29081 | 27813 | 25670 | 24343 | 23183 | 2.34 |
| Run 2 | 87259 | | 61.12 | 111224 | 110026 | 108213 | 108134 | 28709 | 27488 | 25477 | 24293 | 23204 | 2.24 |
| Run 3 | 83036 | | 56.04 | 97090 | 96566 | 95184 | 94054 | 28096 | 27171 | 25333 | 24231 | 23236 | 2.13 |
| Run 4 | 79132 | | 52.80 | 86971 | 85961 | 84545 | 84102 | 27832 | 26889 | 25185 | 24175 | 23296 | 2.03 |
| Run 5 | 76014 | | 51.60 | 80976 | 80243 | 78701 | 78531 | 27425 | 26659 | 25074 | 24138 | 23286 | 1.95 |
| Run 6 | 70984 | | 54.04 | 75872 | 75161 | 74040 | 73840 | 27033 | 26281 | 24910 | 24093 | 23325 | 1.82 |
| Run 7 | 67042 | | 56.36 | 71860 | 71162 | 69861 | 69830 | 26402 | 26041 | 24733 | 24045 | 23341 | 1.72 |
| Run 8 | 63095 | | 57.83 | 67496 | 67111 | 66297 | 65858 | 26342 | 25754 | 24663 | 23973 | 23393 | 1.62 |
| Run 9 | 58894 | | 60.29 | 63259 | 62828 | 62232 | 61770 | 26128 | 25532 | 24488 | 23921 | 23393 | 1.51 |
| Run 10 | 55419 | | 62.20 | 59979 | 59114 | 58626 | 58379 | 25822 | 25253 | 24417 | 23882 | 23408 | 1.42 |
| Run 11 | 50707 | | 66.26 | 55864 | 55038 | 54568 | 54372 | 25533 | 25010 | 24263 | 23818 | 23404 | 1.30 |
| Run 12 | 44959 | | 68.11 | 49476 | 49431 | 48837 | 48667 | 25043 | 24727 | 24121 | 23751 | 23425 | 1.15 |
| Run 13 | 39576 | | 71.80 | 44818 | 44334 | 44017 | 43921 | 24765 | 24466 | 23989 | 23697 | 23426 | 1.02 |
| Run 14 | 84941 | | 82.31 | 132211 | 131233 | 129802 | 129321 | 28002 | 27178 | 25249 | 24144 | 23137 | 2.18 |
| Run 15 | 80954 | | 75.30 | 114720 | 114064 | 112853 | 112237 | 27789 | 26853 | 25146 | 24100 | 23157 | 2.08 |
| Run 16 | 77764 | | 70.53 | 102922 | 102092 | 101151 | 100550 | 27532 | 26660 | 25051 | 24050 | 23208 | 2.00 |
| Run 17 | 73573 | | 64.81 | 89390 | 88629 | 87540 | 87154 | 27132 | 26334 | 24900 | 24015 | 23237 | 1.89 |
| Run 18 | 69541 | | 61.24 | 79318 | 79002 | 77637 | 77242 | 26795 | 26078 | 24752 | 23946 | 23257 | 1.79 |
| Run 19 | 66208 | | 63.03 | 75645 | 75175 | 74027 | 73847 | 26460 | 25858 | 24637 | 23923 | 23234 | 1.70 |
| Run 20 | 61613 | | 66.81 | 71103 | 70622 | 69764 | 69059 | 26076 | 25545 | 24489 | 23862 | 23281 | 1.58 |
| Run 21 | 58471 | | 68.93 | 67824 | 66869 | 66296 | 65968 | 25880 | 25341 | 24388 | 23809 | 23278 | 1.50 |
| Run 22 | 54489 | | 72.21 | 63574 | 63159 | 62622 | 62229 | 25535 | 25108 | 24265 | 23752 | 23284 | 1.40 |
| Run 23 | 50201 | | 76.23 | 59344 | 58603 | 58267 | 58016 | 25282 | 24885 | 24136 | 23705 | 23298 | 1.29 |
| Run 24 | 46964 | | 78.06 | 55378 | 55426 | 54547 | 54417 | 25065 | 24708 | 24060 | 23658 | 23299 | 1.21 |
| Run 25 | 43168 | | 80.96 | 51344 | 51308 | 50631 | 50387 | 24839 | 24540 | 23954 | 23625 | 23317 | 1.11 |
| Run 26 | 39214 | | 84.31 | 47449 | 47033 | 46777 | 46617 | 24570 | 24358 | 23848 | 23574 | 23325 | 1.01 |

## Appendix 6: CMC 5 % in 40 mm valve, 50 % open

### CMC 5 % in 40 mm valve, 50 % open

CMC 5 % in 40 mm valve, 50 % open

| | | |
|---|---|---|
| **Date:** | 12/10/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.645 | 0.378 | 2.645 | 3.595 |

| | |
|---|---|
| **Material Type:** | CMC 5% |
| **Density[kg/m³]:** | 1026.8 |
| **Concentration:** | 5% |
| **$\tau_y$:** | 0.000 |
| **K:** | 2.177 |
| **n:** | 0.608 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.248 | -4.518 | -1.830 | -0.571 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 | |
| **Valve plane** | | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -148.3 | -107.3 | -43.45 | -13.54 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 | |
| **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.324 | 8.933 | 12.29 | 14.32 | 16.22 | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 161 | | 27.82 | 126049 | 117382 | 103338 | 96699 | 72704 | 64424 | 46757 | 36028 | 26191 | 1.43 |
| Run 2 | 146 | | 29.24 | 120990 | 111807 | 98870 | 92361 | 70670 | 62753 | 45671 | 35503 | 26055 | 1.33 |
| Run 3 | 130 | | 30.72 | 114883 | 106393 | 93807 | 88021 | 68298 | 60734 | 44496 | 34874 | 25936 | 1.23 |
| Run 4 | 118 | | 32.09 | 109977 | 101928 | 90023 | 84359 | 66058 | 58759 | 43523 | 34364 | 25842 | 1.14 |
| Run 5 | 102 | | 34.03 | 103490 | 96492 | 85435 | 80196 | 63413 | 56500 | 42229 | 33718 | 25709 | 1.03 |
| Run 6 | 87 | | 36.71 | 96849 | 90592 | 80143 | 75421 | 60306 | 53925 | 40860 | 32915 | 25554 | 0.92 |
| Run 7 | 76 | | 39.56 | 91375 | 85334 | 75865 | 71435 | 57546 | 51810 | 39653 | 32250 | 25435 | 0.83 |
| Run 8 | 63 | | 45.22 | 85297 | 79559 | 70628 | 66574 | 54752 | 49291 | 38289 | 31569 | 25286 | 0.73 |
| Run 9 | 47 | | 48.38 | 77274 | 71355 | 63276 | 60163 | 50648 | 46299 | 36617 | 30596 | 25106 | 0.59 |
| Run 10 | 37 | | 64.11 | 71099 | 65699 | 59274 | 55894 | 47766 | 43800 | 35045 | 29815 | 24933 | 0.49 |
| Run 12 | 18 | | 129.51 | 58075 | 54902 | 49484 | 47398 | 41345 | 38454 | 31958 | 28141 | 24563 | 0.30 |

## Appendix 7: Kaolin 6 % in 40 mm valve, 50 % open

### Kaolin 6 % in 40 mm valve, 50 % open

Kaolin 6 % in 40 mm valve, 50 % open

| | | |
|---|---|---|
| **Date:** | 7/12/2007 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| | |
|---|---|
| **Material Type:** | Kaolin 6% |
| **Density[kg/m³]:** | 1103.9 |
| **Concentration:** | 6% |
| **$t_y$:** | 3.071 |
| **K:** | 2.038 |
| **n:** | 0.264 |
| **PPT used:** | 105 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -147.7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 19 | 411 | | 73.18 | 53627 | 51602 | 48780 | 47497 | 24437 | 22697 | 19028 | 16719 | 14668 | 1.00 |
| Run 23 | 633 | | 57.99 | 61352 | 59210 | 56196 | 55066 | 26318 | 24262 | 20365 | 18027 | 15935 | 1.28 |
| Run 24 | 649 | | 57.98 | 61297 | 59437 | 56326 | 55170 | 26281 | 24285 | 20372 | 18108 | 15937 | 1.28 |
| Run 25 | 755 | | 57.10 | 67098 | 64909 | 62000 | 60622 | 26446 | 24710 | 20826 | 18398 | 16170 | 1.40 |
| Run 27 | 945 | | 45.57 | 68047 | 65764 | 62795 | 61216 | 27048 | 25224 | 21061 | 18720 | 16480 | 1.59 |
| Run 28 | 1179 | | 41.92 | 74963 | 72688 | 69573 | 67485 | 27821 | 25476 | 21386 | 18800 | 16480 | 1.79 |
| Run 29 | 1348 | | 40.84 | 77877 | 75694 | 72567 | 70873 | 25839 | 24669 | 20501 | 18144 | 15790 | 1.92 |
| Run 30 | 1569 | | 38.55 | 82557 | 80404 | 77593 | 75514 | 26824 | 25356 | 21187 | 18640 | 16267 | 2.05 |
| Run 31 | 1762 | | 42.75 | 93544 | 91356 | 88585 | 87174 | 26828 | 25221 | 20934 | 18416 | 16161 | 2.18 |
| Run 32 | 2015 | | 43.68 | 107091 | 105053 | 101652 | 99766 | 27969 | 25414 | 20865 | 18252 | 15806 | 2.38 |
| Run 33 | 2180 | | 45.07 | 119566 | 116683 | 113585 | 111880 | 26265 | 24647 | 20380 | 17641 | 15240 | 2.54 |
| Run 34 | 2230 | | 49.23 | 131989 | 128980 | 125410 | 124069 | 22377 | 20665 | 16004 | 13373 | 10941 | 2.67 |
| Run 35 | 2414 | | 47.29 | 123984 | 121134 | 118742 | 116736 | 22758 | 20499 | 16150 | 13363 | 10986 | 2.61 |
| Run 36 | 2214 | | 46.07 | 114395 | 112638 | 108681 | 106920 | 21264 | 18981 | 14554 | 11850 | 9415 | 2.53 |

## Appendix 8: Kaolin 10 % in 40 mm valve, 50 % open

### Kaolin 10 % in 40 mm valve, 50 % open

Kaolin 10 % in 40 mm valve, 50 % open

| | | |
|---|---|---|
| **Date:** | 8/12/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | **Kaolin 10%** | | | | | | | | | | |
| **Density[kg/m³]:** | **1169.4** | | | | | | | | | | |
| **Concentration:** | **10%** | | | | | | | | | | |
| **$t_y$:** | **8.965** | | | | | | | | | | |
| **K:** | **7.098** | | | | | | | | | | |
| **n:** | **0.175** | **Axial distances** | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | |
| **Range selected:** | 0 130 | **Non-dimensionalised distances incl.[L/D]:** | -147.7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| | | **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 |

| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 833.9 | | 25.49 | 121653 | 114759 | 105922 | 101200 | 40672 | 35384 | 23963 | 17167 | 10756 | 2.70 |
| **Run 2** | 942.8 | | 25.73 | 117048 | 111174 | 102377 | 97845 | 40440 | 35166 | 23833 | 17052 | 10755 | 2.60 |
| **Run 3** | 887.1 | | 26.50 | 113278 | 107686 | 98914 | 94504 | 40122 | 34880 | 23700 | 16919 | 10632 | 2.47 |
| **Run 4** | 781.8 | | 27.98 | 109913 | 104311 | 95539 | 91627 | 39939 | 34785 | 23501 | 16701 | 10537 | 2.34 |
| **Run 5** | 721.6 | | 31.05 | 109514 | 103880 | 95313 | 91343 | 39605 | 34325 | 23255 | 16563 | 10485 | 2.23 |
| **Run 6** | 547.8 | | 32.26 | 99751 | 94220 | 85498 | 81823 | 38684 | 33597 | 22814 | 16339 | 10359 | 1.98 |
| **Run 7** | 454.5 | | 34.44 | 93435 | 88005 | 79535 | 75879 | 38202 | 33172 | 22551 | 16096 | 10226 | 1.77 |
| **Run 8** | 421.8 | | 37.06 | 90636 | 85593 | 77241 | 73356 | 37869 | 32950 | 22394 | 15925 | 10157 | 1.64 |
| **Run 9** | 349.8 | | 38.42 | 85668 | 80489 | 72351 | 68502 | 37529 | 32573 | 22178 | 15860 | 10175 | 1.50 |
| **Run 10** | 325.6 | | 38.21 | 82808 | 77823 | 69686 | 65689 | 37270 | 32364 | 22039 | 15780 | 10086 | 1.43 |
| **Run 11** | 244.6 | | 43.02 | 79636 | 73936 | 66353 | 62244 | 36398 | 31674 | 21610 | 15321 | 9795 | 1.27 |
| **Run 12** | 229.4 | | 40.85 | 76493 | 71241 | 63333 | 59574 | 36281 | 31386 | 21358 | 15157 | 9594 | 1.22 |
| **Run 13** | 182.6 | | 44.25 | 71878 | 66896 | 59021 | 55357 | 35858 | 30899 | 20838 | 15031 | 9438 | 1.08 |
| **Run 14** | 134.5 | | 43.63 | 67480 | 62309 | 54725 | 51022 | 35046 | 30563 | 20865 | 14937 | 9593 | 0.93 |
| **Run 15** | 95.64 | | 45.79 | 63527 | 58376 | 50960 | 47402 | 34495 | 29959 | 20420 | 14607 | 9364 | 0.79 |
| **Run 16** | 64.92 | | 48.75 | 59519 | 54631 | 47382 | 44071 | 33551 | 29308 | 19981 | 14366 | 9215 | 0.63 |
| **Run 17** | 43.66 | | 54.48 | 56635 | 51703 | 44814 | 41315 | 32898 | 28650 | 19532 | 14023 | 9065 | 0.51 |
| **Run 18** | 19.18 | | 65.53 | 52357 | 47717 | 40936 | 37800 | 31507 | 27419 | 18706 | 13428 | 8686 | 0.34 |
| **Run 19** | 6.67 | | 139.92 | 43830 | 39760 | 33908 | 31055 | 26538 | 23302 | 16172 | 11711 | 7744 | 0.18 |

## Appendix 9: Kaolin 13 % in 40 mm valve, 50 % open

Kaolin 13 % in 40 mm valve, 50 % open

Kaolin 13 % in 40 mm valve, 50 % open

| | | |
|---|---|---|
| Date: | 12/7/2007 | Test done by Mume & Rendani |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.04 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | |
|---|---|
| Material Type: | Kaolin 13% |
| Density[kg/m³]: | 1215.5 |
| Concentration: | 13% |
| $t_y$: | 18.973 |
| K: | 16.141 |
| n: | 0.242 |
| PPT used: | 105 |
| Range selected: | 0-130 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -147.7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| Distances[m]: | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 2 | 43.34 | | 23.45 | 121181 | 111468 | 96415 | 89444 | 75268 | 66667 | 47441 | 35629 | 25076 | 0.74 |
| Run 3 | 30.31 | | 33.49 | 120287 | 109829 | 95057 | 88012 | 74652 | 65561 | 46194 | 35329 | 23839 | 0.61 |
| Run 4 | 31.93 | | 15.68 | 118561 | 108857 | 93620 | 86395 | 72896 | 64354 | 45908 | 34612 | 23276 | 0.63 |
| Run 6 | 25.18 | | 47.83 | 113517 | 103143 | 89460 | 83405 | 70139 | 61957 | 44058 | 33704 | 23367 | 0.54 |
| Run 7 | 23.88 | | 15.18 | 114249 | 104483 | 89937 | 82487 | 71535 | 63094 | 45354 | 34078 | 23736 | 0.53 |
| Run 8 | 16.03 | | 36.54 | 112497 | 102670 | 89157 | 82758 | 70627 | 62485 | 44173 | 33291 | 23039 | 0.43 |
| Run 9 | 17.59 | | 13.81 | 110143 | 100147 | 86620 | 81339 | 68870 | 60629 | 43394 | 32875 | 22414 | 0.45 |
| Run 10 | 18.32 | | 70.01 | 109187 | 99449 | 85461 | 80075 | 67763 | 59930 | 42269 | 31964 | 22337 | 0.45 |
| Run 11 | 12.44 | | 94.85 | 109968 | 100102 | 86795 | 78757 | 67662 | 59611 | 42909 | 32497 | 22816 | 0.37 |
| Run 12 | 13.80 | | 111.0 | 106383 | 96711 | 83944 | 77472 | 66149 | 58676 | 41514 | 31745 | 22483 | 0.38 |
| Run 13 | 9.56 | | 233.7 | 102690 | 94135 | 81222 | 75350 | 65027 | 57126 | 40297 | 30742 | 22515 | 0.31 |
| Run 14 | 9.97 | | 185.8 | 100196 | 92608 | 79960 | 74094 | 63928 | 56162 | 39911 | 30537 | 22324 | 0.31 |
| Run 15 | 4.56 | | 99.5 | 100623 | 91935 | 80000 | 74179 | 64377 | 56716 | 40853 | 30777 | 22181 | 0.21 |
| Run 17 | 3.05 | | 285.3 | 94244 | 85897 | 74391 | 69179 | 59899 | 52825 | 39045 | 31103 | 22253 | 0.16 |
| Run 18 | 1.48 | | 1360 | 91009 | 83514 | 72123 | 66781 | 57989 | 51091 | 37446 | 28860 | 21835 | 0.11 |
| Run 19 | 2.15 | | 578.0 | 88454 | 81686 | 72348 | 67583 | 58120 | 51033 | 37166 | 29389 | 21734 | 0.13 |
| Run 20 | 0.89 | | 1868 | 76814 | 71699 | 61532 | 57447 | 51411 | 45961 | 33097 | 25639 | 19899 | 0.07 |
| Run 21 | 0.57 | | 2101 | 74620 | 70031 | 60613 | 56201 | 49819 | 44798 | 33575 | 27106 | 20931 | 0.05 |
| Run 22 | 0.62 | | 731.4 | 75107 | 69379 | 62207 | 58405 | 50338 | 44749 | 33708 | 26601 | 20743 | 0.06 |

## Appendix 10: Water in 40 mm valve, 50 % open

# Water in 40 mm valve, 50 % open

**Water in 40 mm valve, 50 % open**

| | | |
|---|---|---|
| **Date:** | 11/22/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0008145 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Material Type:** | **Water** | | | | | | | | | | | |
| | **Density[kg/m³]:** | **995.864** | | | | | | | | | | | |
| | **Concentration:** | **100%** | | | | | | | | | | | |
| | **$t_y$:** | **0** | | | | | | | | | | | |
| | **K:** | **0.00081** | | | | | | | | | | | |
| | **n:** | **1** | **Axial distances** | -6.248 | -4.518 | -1.830 | -0.571 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 | |
| | **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| | **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -148.3 | -107.3 | -43.45 | -13.54 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 | |
| | | | **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.324 | 8.933 | 12.29 | 14.32 | 16.22 | |
| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 119818 | | 34.81 | 134487 | 132870 | 130446 | 129100 | 32493 | 30763 | 26863 | 24733 | 22471 | 3.24 |
| **Run 2** | 115666 | | 32.98 | 122451 | 120616 | 117634 | 116327 | 32352 | 30365 | 26786 | 24577 | 22674 | 3.13 |
| **Run 3** | 111073 | | 30.47 | 109429 | 107528 | 105234 | 103960 | 31559 | 29876 | 26626 | 24573 | 22749 | 3.01 |
| **Run 4** | 107412 | | 29.04 | 100441 | 98928 | 96636 | 95623 | 31126 | 29511 | 26381 | 24482 | 22818 | 2.91 |
| **Run 5** | 103255 | | 27.04 | 90852 | 89393 | 87432 | 86283 | 30730 | 29078 | 26219 | 24502 | 22876 | 2.79 |
| **Run 6** | 98889 | | 25.07 | 81909 | 80843 | 78433 | 77558 | 30052 | 28695 | 26069 | 24432 | 22897 | 2.68 |
| **Run 7** | 94911 | | 24.67 | 76529 | 75428 | 73466 | 72516 | 29599 | 28378 | 25853 | 24384 | 22981 | 2.57 |
| **Run 8** | 89947 | | 25.07 | 71999 | 70839 | 69123 | 68234 | 29154 | 27969 | 25669 | 24287 | 23035 | 2.43 |
| **Run 9** | 85278 | | 26.90 | 69541 | 68747 | 66971 | 66294 | 28672 | 27439 | 25460 | 24211 | 23084 | 2.31 |
| **Run 10** | 77719 | | 30.04 | 65248 | 64462 | 62930 | 62094 | 27404 | 26866 | 25123 | 24119 | 23171 | 2.10 |
| **Run 11** | 70195 | | 31.68 | 59300 | 59047 | 57599 | 57541 | 26885 | 26396 | 24901 | 24018 | 23222 | 1.90 |
| **Run 18** | 109268 | | 28.88 | 103170 | 101200 | 98669 | 97232 | 31811 | 29928 | 26642 | 24678 | 22902 | 2.96 |
| **Run 19** | 103498 | | 26.32 | 89899 | 88606 | 86128 | 85712 | 30613 | 29370 | 26338 | 24624 | 22925 | 2.80 |
| **Run 20** | 98148 | | 25.22 | 81559 | 79977 | 78413 | 77224 | 30138 | 28837 | 26116 | 24545 | 23023 | 2.66 |
| **Run 21** | 92248 | | 25.70 | 75528 | 73972 | 73063 | 71234 | 29707 | 28231 | 25769 | 24427 | 23070 | 2.50 |
| **Run 23** | 81457 | | 28.48 | 67928 | 67029 | 65565 | 64558 | 28325 | 27304 | 25456 | 24280 | 23218 | 2.20 |
| **Run 24** | 74199 | | 31.81 | 63884 | 63134 | 62086 | 61294 | 27539 | 26824 | 25144 | 24210 | 23281 | 2.01 |
| **Run 25** | 68369 | | 33.57 | 59466 | 58812 | 57650 | 57549 | 27071 | 26415 | 24960 | 24109 | 23341 | 1.85 |
| **Run 29** | 46291 | | 38.50 | 42410 | 41845 | 41593 | 41038 | 25405 | 24944 | 24251 | 23809 | 23427 | 1.25 |

## Appendix 11: CMC 5 % in 40 mm valve, 75 % open

### CMC 5 % in 40 mm valve, 75 % open

CMC 5 % in 40 mm valve, 75 % open

| | | | |
|---|---|---|---|
| **Date:** | 12/9/2006 | Test done by Mume | |
| **Valve Type:** | Diaphragm | | |
| **Valve dimension[m]:** | 0.04 | | |
| **Valve position:** | ¾ Open | **Area[m$^2$]** | |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 | |

| 1/n | n/(n+1) | (n+1)/n | K$^{1/n}$ |
|---|---|---|---|
| 1.550 | 0.392 | 2.550 | 1.957 |

| | |
|---|---|
| **Material Type:** | CMC 5% |
| **Density[kg/m$^3$]:** | 1026.8 |
| **Concentration:** | 5% |
| $t_y$: | 0.000 |
| **K:** | 1.542 |
| **n:** | 0.645 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.248 | -4.518 | -1.830 | -0.571 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -148.3 | -107.3 | -43.45 | -13.54 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.324 | 8.933 | 12.29 | 14.32 | 16.22 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 267.25 | | 13.89 | 125638 | 115315 | 100825 | 94211 | 73832 | 65039 | 47097 | 36222 | 26098 | 1.86 |
| Run 2 | 254.42 | | 12.81 | 121423 | 112245 | 98226 | 91729 | 72448 | 64061 | 46477 | 35832 | 26023 | 1.80 |
| Run 3 | 243.71 | | 12.52 | 118366 | 109769 | 96345 | 89666 | 71123 | 63039 | 45901 | 35556 | 25940 | 1.74 |
| Run 4 | 231.13 | | 12.09 | 114999 | 106652 | 93817 | 87636 | 69780 | 61834 | 45275 | 35181 | 25855 | 1.67 |
| Run 5 | 216.97 | | 12.17 | 111612 | 103895 | 90486 | 84703 | 68674 | 60669 | 44622 | 34795 | 25759 | 1.60 |
| Run 6 | 193.82 | | 12.63 | 105919 | 98404 | 86738 | 80792 | 66107 | 58623 | 43319 | 34183 | 25618 | 1.47 |
| Run 7 | 176.47 | | 13.19 | 101948 | 94865 | 83372 | 77867 | 64195 | 57141 | 42459 | 33732 | 25520 | 1.37 |
| Run 8 | 159.74 | | 12.99 | 97705 | 91038 | 80062 | 74970 | 62129 | 55574 | 41610 | 33221 | 25430 | 1.27 |
| Run 10 | 119.29 | | 14.34 | 86924 | 80833 | 71684 | 67254 | 56753 | 51063 | 39179 | 31904 | 25210 | 1.03 |
| Run 12 | 75.96 | | 20.08 | 73881 | 68607 | 61320 | 57361 | 50108 | 45594 | 36042 | 30285 | 24912 | 0.74 |

## Appendix 12: Kaolin 6 % in 40 mm valve, 75 % open

### Kaolin 6 % in 40 mm valve, 75 % open

Kaolin 6 % in 40 mm valve, 75 % open

| | | |
|---|---|---|
| Date: | 7/11/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.04 | |
| Valve position: | ¾ Open | Area[m²] |
| Pipe Diameter [m]: | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | Kaolin 6% | | | | | | | | | | |
| Density[kg/m³]: | 1103.9 | | | | | | | | | | |
| Concentration: | 6% | | | | | | | | | | |
| $t_y$: | 3.071 | | | | | | | | | | |
| K: | 2.038 | | | | | | | | | | |
| n: | 0.264 | Axial distances | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| PPT used: | 105 | Valve plane | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -147.7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| | | Distances[m]: | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 152.2 | | 6.30 | 32098 | 30160 | 27448 | 26064 | 23362 | 21784 | 18336 | 16070 | 14139 | 0.60 |
| Run 2 | 245.9 | | 8.77 | 33458 | 31549 | 28718 | 27324 | 23839 | 22163 | 18505 | 16190 | 14183 | 0.77 |
| Run 3 | 241.4 | | 7.56 | 33396 | 31506 | 28648 | 27300 | 23839 | 22056 | 18492 | 16196 | 14114 | 0.76 |
| Run 4 | 172.9 | | 8.74 | 32499 | 30595 | 27831 | 26503 | 23541 | 21887 | 18284 | 16078 | 14061 | 0.64 |
| Run 5 | 322.3 | | 7.92 | 34426 | 32406 | 29547 | 28075 | 24090 | 22334 | 18598 | 16253 | 14107 | 0.89 |
| Run 6 | 398.7 | | 8.29 | 35323 | 33269 | 30314 | 28965 | 24244 | 22427 | 18657 | 16235 | 14078 | 1.00 |
| Run 7 | 395.8 | | 7.06 | 35209 | 33158 | 30208 | 28772 | 24186 | 22337 | 18702 | 16214 | 14054 | 0.99 |
| Run 8 | 467.2 | | 8.98 | 35848 | 34005 | 30908 | 29422 | 24215 | 22481 | 18671 | 16282 | 14104 | 1.08 |
| Run 9 | 566.9 | | 8.60 | 36891 | 34858 | 31836 | 30230 | 24537 | 22672 | 18759 | 16295 | 14080 | 1.20 |
| Run 10 | 649.9 | | 8.38 | 37598 | 35382 | 32528 | 30960 | 24660 | 22775 | 18851 | 16362 | 14138 | 1.29 |
| Run 11 | 757.2 | | 7.95 | 38420 | 36356 | 33281 | 31791 | 24710 | 22828 | 18922 | 16390 | 14100 | 1.40 |
| Run 12 | 857.0 | | 7.83 | 39248 | 37088 | 34018 | 32505 | 24899 | 23003 | 18939 | 16407 | 14056 | 1.50 |
| Run 13 | 971.3 | | 7.81 | 40340 | 38183 | 35072 | 33403 | 25087 | 23133 | 19022 | 16426 | 14038 | 1.61 |
| Run 14 | 1068 | | 7.87 | 40929 | 38740 | 35613 | 34129 | 25147 | 23172 | 19047 | 16454 | 14103 | 1.69 |
| Run 15 | 1172 | | 7.97 | 41839 | 39696 | 36493 | 34966 | 25291 | 23251 | 19057 | 16477 | 14067 | 1.78 |
| Run 16 | 1326 | | 7.67 | 42898 | 40864 | 37526 | 36037 | 25375 | 23391 | 19163 | 16480 | 14073 | 1.90 |
| Run 17 | 1467 | | 7.79 | 44202 | 41947 | 38778 | 37135 | 25492 | 23483 | 19180 | 16542 | 14049 | 2.01 |
| Run 18 | 1599 | | 8.21 | 44998 | 42866 | 39631 | 37975 | 25526 | 23409 | 18963 | 16541 | 13939 | 2.10 |
| Run 19 | 1733 | | 7.84 | 45991 | 43925 | 40498 | 38832 | 25606 | 23470 | 19149 | 16414 | 14000 | 2.20 |
| Run 20 | 1844 | | 7.75 | 46900 | 44839 | 41348 | 39504 | 25492 | 23307 | 19115 | 16395 | 13872 | 2.28 |
| Run 21 | 2071 | | 7.74 | 48290 | 46141 | 42790 | 41030 | 25568 | 23283 | 19077 | 16189 | 13838 | 2.42 |
| Run 22 | 2345 | | 7.81 | 49923 | 47492 | 43885 | 42356 | 25527 | 23501 | 18887 | 15999 | 13559 | 2.55 |
| Run 23 | 2724 | | 7.67 | 48341 | 46156 | 42604 | 40866 | 21735 | 19421 | 14709 | 11936 | 9283 | 2.77 |
| Run 24 | 3121 | | 7.73 | 52794 | 50167 | 46438 | 44638 | 22132 | 19742 | 15064 | 12043 | 9269 | 2.99 |
| Run 25 | 3432 | | 7.77 | 56748 | 53993 | 49585 | 47834 | 22897 | 20627 | 15573 | 12336 | 9390 | 3.15 |
| Run 26 | 3675 | | 7.96 | 59951 | 57201 | 52772 | 50533 | 24205 | 21641 | 15959 | 12660 | 9612 | 3.27 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Run 27** | 4030 | | 7.23 | 62913 | 59773 | 55025 | 53187 | 24423 | 22028 | 16095 | 12438 | 8915 | 3.44 |
| **Run 28** | 4463 | | 7.51 | 68289 | 64591 | 59639 | 57124 | 25885 | 22921 | 16463 | 12735 | 8990 | 3.64 |
| **Run 29** | 4656 | | 7.27 | 69828 | 66542 | 61371 | 58872 | 26975 | 23869 | 16730 | 12711 | 8929 | 3.73 |
| **Run 30** | 6338 | | 7.27 | 89525 | 85599 | 78393 | 75045 | 30335 | 25894 | 17293 | 11924 | 7092 | 4.43 |
| **Run 31** | 6349 | | 7.39 | 89663 | 85688 | 78519 | 75214 | 30289 | 26015 | 17155 | 11908 | 7104 | 4.43 |
| **Run 32** | 6616 | | 7.36 | 93521 | 88845 | 81588 | 78689 | 31132 | 26581 | 17112 | 11700 | 6441 | 4.54 |
| **Run 33** | 5749 | | 7.26 | 81482 | 76615 | 70205 | 67874 | 27928 | 23931 | 15910 | 11053 | 6599 | 4.20 |
| **Run 34** | 5766 | | 7.46 | 81555 | 77040 | 70702 | 68037 | 27606 | 23939 | 15463 | 10964 | 6338 | 4.20 |
| **Run 35** | 6055 | | 7.15 | 85094 | 80285 | 73799 | 70752 | 28690 | 24825 | 16414 | 11323 | 6613 | 4.32 |
| **Run 36** | 5435 | | 7.20 | 77904 | 73576 | 67419 | 64651 | 27689 | 23770 | 16175 | 11293 | 7254 | 4.07 |
| **Run 37** | 5170 | | 7.28 | 74324 | 70498 | 64142 | 61847 | 26530 | 23091 | 15803 | 11295 | 7396 | 3.95 |

## Appendix 13: Kaolin 10 % in 40 mm valve, 75 % open

### Kaolin 10 % in 40 mm valve, 75 % open

**Kaolin 10 % in 40 mm valve, 75 % open**

| | | | |
|---|---|---|---|
| **Date:** | 8/12/2007 | Test done by Mume | |
| **Valve Type:** | Diaphragm | | |
| **Valve dimension[m]:** | 0.04 | | |
| **Valve position:** | ¾ Open | **Area[m²]** | |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 | |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | |
|---|---|
| **Material Type:** | Kaolin 10% |
| **Density[kg/m³]:** | 1169.4 |
| **Concentration:** | 10% |
| **$t_y$:** | 8.965 |
| **K:** | 7.098 |
| **n:** | 0.175 |
| **PPT used:** | 101 to 109 |
| **Ra~ge selected:** | 0-130 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -147.7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 9.15 | | 75.65 | 50901 | 46299 | 39421 | 36436 | 31351 | 27312 | 18627 | 13386 | 8786 | 0.26 |
| Run 2 | 76.26 | | 6.55 | 54689 | 50180 | 43117 | 39689 | 34055 | 29624 | 20108 | 14446 | 9284 | 0.64 |
| Run 3 | 106.4 | | 9.45 | 58865 | 53734 | 46011 | 42470 | 35766 | 31000 | 21139 | 15103 | 9709 | 0.85 |
| Run 4 | 152.6 | | 11.09 | 61630 | 56384 | 48399 | 44593 | 36520 | 31761 | 21548 | 15567 | 9855 | 1.03 |
| Run 5 | 244.1 | | 9.91 | 64776 | 59277 | 51163 | 47353 | 37510 | 32578 | 22108 | 15749 | 10088 | 1.31 |
| Run 6 | 335.5 | | 9.43 | 67873 | 62405 | 53949 | 50073 | 38380 | 33333 | 22560 | 16087 | 10213 | 1.55 |
| Run 7 | 393.2 | | 10.05 | 70681 | 64951 | 56508 | 52448 | 38883 | 33902 | 22842 | 16305 | 10313 | 1.69 |
| Run 8 | 583.9 | | 8.22 | 73479 | 67919 | 59381 | 55308 | 39679 | 34362 | 23380 | 16617 | 10504 | 2.00 |
| Run 9 | 627.0 | | 8.38 | 76610 | 70427 | 61710 | 57813 | 40022 | 34715 | 23592 | 16808 | 10591 | 2.21 |
| Run 10 | 906.2 | | 7.85 | 80140 | 74551 | 65669 | 61656 | 40577 | 35297 | 23953 | 17062 | 10714 | 2.51 |
| Run 11 | 913.1 | | 8.14 | 84077 | 78014 | 68704 | 64413 | 41080 | 35784 | 24269 | 17210 | 10819 | 2.70 |
| Run 12 | 1223 | | 8.23 | 87592 | 81893 | 72925 | 68122 | 41506 | 36108 | 24488 | 17483 | 11041 | 2.92 |
| Run 13 | 1041 | | 8.17 | 87256 | 81413 | 71699 | 67661 | 41520 | 36063 | 24491 | 17430 | 10982 | 2.90 |
| Run 14 | 1245 | | 8.20 | 90143 | 84929 | 74824 | 70651 | 41880 | 36473 | 24797 | 17606 | 11240 | 3.08 |
| Run 15 | 1495 | | 7.93 | 94507 | 89198 | 79201 | 74767 | 42533 | 36937 | 25114 | 17801 | 11276 | 3.33 |
| Run 16 | 1567 | | 7.87 | 97817 | 91503 | 82079 | 78054 | 42885 | 37067 | 25119 | 17918 | 11172 | 3.50 |
| Run 17 | 1768 | | 7.82 | 103904 | 97550 | 87698 | 83183 | 43282 | 37554 | 25353 | 17976 | 11231 | 3.83 |
| Run 18 | 1999 | | 7.83 | 108591 | 101760 | 92377 | 87621 | 43921 | 37981 | 25611 | 18220 | 11406 | 4.04 |
| Run 19 | 2233 | | 7.74 | 111644 | 104674 | 95574 | 91099 | 44381 | 38307 | 25776 | 18362 | 11511 | 4.20 |
| Run 20 | 2381 | | 7.61 | 116263 | 109552 | 99730 | 95252 | 44461 | 38076 | 25626 | 18075 | 11196 | 4.46 |
| Run 21 | 2675 | | 7.50 | 119419 | 112431 | 103073 | 97952 | 44598 | 38135 | 25414 | 17792 | 10836 | 4.62 |

## Appendix 14: Kaolin 13 % in 40 mm valve, 75 % open

### Kaolin 13 % in 40 mm valve, 75 % open

Kaolin 13 % in 40 mm valve, 75 % open

| | | |
|---|---|---|
| **Date:** | 12/7/2007 | Test done by Mume & rendani |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | ¾ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Material Type:** | Kaolin 13% | | | | | | | | | | | | |
| | **Density[kg/m³]:** | 1215.5 | | | | | | | | | | | | |
| | **Concentration:** | 13% | | | | | | | | | | | | |
| | **$t_y$:** | 18.973 | | | | | | | | | | | | |
| | **K:** | 16.141 | | | | | | | | | | | | |
| | **n:** | 0.242 | **Axial distances** | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 | | |
| | **PPT used:** | 105 | **Valve plane** | | | | | | | | | | | |
| | **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -147.7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 | | |
| | | | **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 | | |
| **Run #** | **$Re_3$** | | **$k_{v,incl}$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** | |
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** | |
| **Run 2** | 62.02 | | 3.229 | 128868 | 117753 | 101825 | 93720 | 80390 | 70586 | 50050 | 37291 | 25147 | 0.92 | |
| **Run 3** | 40.60 | | 9.535 | 124449 | 113769 | 98255 | 90753 | 78371 | 68784 | 48430 | 36358 | 24648 | 0.72 | |
| **Run 5** | 32.57 | | 10.70 | 119220 | 109751 | 94183 | 87317 | 75911 | 66497 | 47105 | 35268 | 24384 | 0.63 | |
| **Run 6** | 20.64 | | 34.65 | 118134 | 108273 | 92588 | 85943 | 74756 | 65354 | 46379 | 34983 | 24242 | 0.50 | |
| **Run 7** | 22.53 | | 30.77 | 115587 | 105548 | 90503 | 83764 | 72953 | 64173 | 45642 | 34629 | 24103 | 0.52 | |
| **Run 8** | 14.20 | | 30.43 | 114536 | 104756 | 90492 | 83370 | 72463 | 63647 | 45143 | 34149 | 23470 | 0.40 | |
| **Run 10** | 10.40 | | 68.86 | 109350 | 100374 | 86103 | 79815 | 69504 | 60936 | 43559 | 32762 | 23224 | 0.34 | |
| **Run 11** | 11.15 | | 54.48 | 107634 | 98371 | 84685 | 78001 | 67554 | 59652 | 43022 | 32934 | 23035 | 0.35 | |
| **Run 12** | 6.20 | | 102.9 | 105706 | 96808 | 83115 | 77386 | 67220 | 59271 | 42166 | 32135 | 22489 | 0.25 | |
| **Run 18** | 3.17 | | 142.2 | 94797 | 86768 | 75952 | 70942 | 62414 | 54700 | 39172 | 30127 | 21820 | 0.17 | |
| **Run 19** | 1.00 | | 681.1 | 89332 | 82009 | 70500 | 65468 | 58202 | 52523 | 37897 | 29437 | 21929 | 0.09 | |
| **Run 20** | 1.17 | | 376.4 | 88982 | 81884 | 72428 | 66957 | 58422 | 51250 | 37624 | 28860 | 21539 | 0.09 | |
| **Run 25** | 1.09 | | 757.3 | 83717 | 78277 | 68025 | 62490 | 54355 | 48089 | 36071 | 28171 | 21257 | 0.09 | |
| **Run 26** | 0.70 | | 1199 | 80226 | 74590 | 64927 | 60308 | 52390 | 46259 | 35163 | 28171 | 21213 | 0.07 | |
| **Run 27** | 0.70 | | 2299 | 79360 | 73877 | 63510 | 59105 | 53018 | 47497 | 34573 | 27515 | 21083 | 0.06 | |

## Appendix 15: Water in 40 mm valve, 75 % open

### Water in 40 mm valve, 75 % open

**Water in 40 mm valve, 75 % open**

| | | |
|---|---|---|
| **Date:** | 11/22/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | ¾ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.00078658 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | Water | | | | | | | | | | |
| **Density[kg/m³]:** | 995.356 | | | | | | | | | | |
| **Concentration:** | 100% | | | | | | | | | | |
| **$t_y$:** | 0 | | | | | | | | | | |
| **K:** | 0.00078658 | | | | | | | | | | |
| **n:** | 1 | **Axial distances** | -6.248 | -4.518 | -1.830 | -0.571 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -148.3 | -107.3 | -43.45 | -13.54 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| | | **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.324 | 8.933 | 12.29 | 14.32 | 16.22 |

| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 177356 | | 7.82 | 94085 | 90573 | 85247 | 82748 | 35550 | 31953 | 24782 | 20378 | 16406 | 4.64 |
| **Run 2** | 172682 | | 8.39 | 90063 | 86681 | 81643 | 78986 | 34443 | 31148 | 24489 | 20324 | 17511 | 4.51 |
| **Run 3** | 164298 | | 7.84 | 84959 | 81726 | 76384 | 74508 | 34373 | 31365 | 25105 | 21346 | 17813 | 4.30 |
| **Run 4** | 156722 | | 7.81 | 79044 | 76231 | 71956 | 69427 | 33089 | 30437 | 24608 | 21159 | 17951 | 4.10 |
| **Run 5** | 146466 | | 7.73 | 71538 | 69225 | 65330 | 63553 | 31559 | 29115 | 23983 | 20921 | 18055 | 3.83 |
| **Run 6** | 140690 | | 8.09 | 68912 | 66414 | 62579 | 60733 | 30606 | 28373 | 23624 | 20805 | 18125 | 3.68 |
| **Run 7** | 132938 | | 7.95 | 63577 | 61453 | 57957 | 56043 | 29511 | 27552 | 23226 | 20598 | 18183 | 3.48 |
| **Run 8** | 123635 | | 8.71 | 59499 | 57845 | 54906 | 53405 | 28257 | 26497 | 22666 | 20411 | 18327 | 3.23 |
| **Run 9** | 115985 | | 8.93 | 55406 | 54211 | 51618 | 50262 | 27075 | 25558 | 22298 | 20251 | 18406 | 3.03 |
| **Run 10** | 107224 | | 9.13 | 51011 | 49608 | 47376 | 46078 | 26081 | 24712 | 21910 | 20133 | 18483 | 2.80 |
| **Run 11** | 101012 | | 9.19 | 47648 | 46228 | 44414 | 43725 | 25441 | 24066 | 21628 | 19992 | 18579 | 2.64 |
| **Run 12** | 93736 | | 9.98 | 44902 | 43679 | 42019 | 41357 | 24641 | 23618 | 21251 | 19860 | 18611 | 2.45 |
| **Run 13** | 84913 | | 11.01 | 41561 | 40602 | 38968 | 38396 | 23747 | 22866 | 20861 | 19746 | 18683 | 2.22 |
| **Run 20** | 127196 | | 7.40 | 51639 | 49715 | 46869 | 45558 | 21525 | 19844 | 15815 | 13424 | 11080 | 3.33 |
| **Run 21** | 119413 | | 8.32 | 48938 | 47014 | 44611 | 43008 | 20539 | 18898 | 15362 | 13259 | 11299 | 3.12 |
| **Run 22** | 111949 | | 8.71 | 45586 | 44030 | 41497 | 40310 | 19860 | 18267 | 14996 | 13165 | 11329 | 2.93 |
| **Run 23** | 104302 | | 9.00 | 41873 | 40736 | 38377 | 37134 | 18686 | 17317 | 14573 | 12789 | 11291 | 2.73 |
| **Run 24** | 96234 | | 9.53 | 38164 | 36997 | 35076 | 34106 | 17566 | 16531 | 14034 | 12564 | 11255 | 2.52 |
| **Run 25** | 88352 | | 9.65 | 41266 | 40532 | 39188 | 38431 | 24243 | 23358 | 21199 | 19980 | 18986 | 2.31 |
| **Run 26** | 79780 | | 10.71 | 42576 | 41691 | 40361 | 39791 | 26983 | 26341 | 24503 | 23495 | 22547 | 2.09 |

## Appendix 16: CMC 5 % in 40 mm valve, 100 % open

### CMC 5 % in 40 mm valve, 100 % open

**CMC 5 % in 40 mm valve, 100 % open**

| | | |
|---|---|---|
| **Date:** | 12/9/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.550 | 0.392 | 2.550 | 1.957 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | CMC 5% | | | | | | | | | | |
| **Density[kg/m³]:** | 1026.8 | | | | | | | | | | |
| **Concentration:** | 5% | | | | | | | | | | |
| $t_y$**:** | 0.000 | | | | | | | | | | |
| **K:** | 1.542 | | | | | | | | | | |
| **n:** | 0.645 | **Axial distances** | -6.248 | -4.518 | -1.830 | -0.571 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -148.3 | -107.3 | -43.45 | -13.54 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 |
| | | **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.324 | 8.933 | 12.29 | 14.32 | 16.22 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 261.6 | | 8.06 | 120887 | 110910 | 96088 | 89106 | 74324 | 65459 | 47315 | 36350 | 26125 | 1.83 |
| Run 2 | 235.3 | | 7.41 | 114039 | 105458 | 90771 | 85062 | 71392 | 63176 | 45972 | 35545 | 25943 | 1.70 |
| Run 3 | 218.4 | | 6.43 | 109454 | 101143 | 88347 | 82211 | 69165 | 61438 | 45032 | 35114 | 25848 | 1.61 |
| Run 4 | 200.6 | | 7.20 | 105962 | 97802 | 85601 | 79497 | 67700 | 59952 | 44102 | 34608 | 25738 | 1.51 |
| Run 5 | 187.6 | | 6.44 | 102367 | 95308 | 83003 | 77142 | 65924 | 58729 | 43434 | 34261 | 25653 | 1.43 |
| Run 6 | 174.8 | | 6.79 | 99952 | 93045 | 81068 | 75406 | 64402 | 57686 | 42840 | 33879 | 25585 | 1.36 |
| Run 7 | 162.0 | | 7.19 | 97393 | 90014 | 78444 | 73498 | 63120 | 56356 | 42177 | 33497 | 25525 | 1.29 |
| Run 8 | 150.2 | | 8.12 | 94244 | 87561 | 76265 | 71299 | 61711 | 55203 | 41386 | 33147 | 25462 | 1.22 |
| Run 9 | 139.5 | | 6.91 | 91373 | 85048 | 74378 | 69429 | 60366 | 53922 | 40822 | 32822 | 25397 | 1.15 |
| Run 10 | 113.4 | | 6.96 | 84909 | 78560 | 69331 | 64745 | 56835 | 51124 | 39212 | 31972 | 25215 | 0.99 |
| Run 11 | 100.6 | | 5.56 | 80766 | 75038 | 66273 | 62231 | 54848 | 49396 | 38309 | 31483 | 25130 | 0.91 |
| Run 12 | 83.9 | | 6.41 | 75518 | 70383 | 62435 | 58700 | 52172 | 47255 | 36984 | 30799 | 25011 | 0.79 |

## Appendix 17: Kaolin 6 % in 40 mm valve, 100 % open

### Kaolin 6 % in 40 mm valve, 100 % open

Kaolin 6 % in 40 mm valve, 100 % open

| | | |
|---|---|---|
| Date: | 7/7/2007 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.04 | |
| Valve position: | Open | Area[m²] |
| Pipe Diameter [m]: | 0.04212 | 0.00139337 |

| | |
|---|---|
| Material Type: | Kaolin 6% |
| Density[kg/m³]: | 1103.9 |
| Concentration: | 6% |
| $t_y$: | 3.071 |
| K: | 2.038 |
| n: | 0.264 |
| PPT used: | 105 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -6.248 | -4.518 | -1.830 | -0.571 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -148.3 | -107.3 | -43.45 | -13.54 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 | |
| | | | Distances[m]: | 0 | 1.73 | 4.418 | 5.678 | 7.324 | 8.933 | 12.29 | 14.32 | 16.22 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 204.2 | | 4.63 | 35379 | 33376 | 30354 | 28829 | 26589 | 24739 | 20924 | 18682 | 16529 | 0.72 |
| Run 3 | 288.9 | | 4.47 | 36129 | 34083 | 31174 | 29617 | 26921 | 25110 | 21178 | 18849 | 16702 | 0.85 |
| Run 4 | 290.5 | | 6.26 | 35945 | 33971 | 30868 | 29464 | 26842 | 24922 | 20889 | 18649 | 16498 | 0.86 |
| Run 9 | 694.6 | | 3.58 | 37940 | 35874 | 32734 | 31167 | 27602 | 25523 | 21267 | 18834 | 16532 | 1.35 |
| Run 11 | 916.9 | | 3.61 | 38229 | 37213 | 33651 | 32097 | 27834 | 25843 | 21427 | 18967 | 16550 | 1.59 |
| Run 13 | 1100 | | 3.16 | 39783 | 37577 | 34103 | 32533 | 27785 | 25767 | 21408 | 18887 | 16424 | 1.76 |
| Run 15 | 1309 | | 3.16 | 40709 | 38556 | 35037 | 33430 | 28121 | 26022 | 21475 | 18925 | 16383 | 1.92 |
| Run 16 | 1307 | | 3.03 | 40695 | 38411 | 34937 | 33303 | 27995 | 25992 | 21503 | 18860 | 16394 | 1.93 |
| Run 18 | 1546 | | 3.08 | 41312 | 39150 | 35703 | 34031 | 28228 | 26071 | 21523 | 18905 | 16413 | 2.09 |
| Run 19 | 1788 | | 2.84 | 42471 | 40106 | 36483 | 34768 | 28169 | 26006 | 21492 | 18560 | 16127 | 2.29 |
| Run 20 | 1835 | | 2.84 | 41943 | 39820 | 36218 | 34502 | 28093 | 25949 | 21349 | 18604 | 16106 | 2.29 |
| Run 22 | 2072 | | 2.80 | 42453 | 40446 | 36578 | 35070 | 27939 | 25613 | 20976 | 18321 | 15624 | 2.46 |
| Run 23 | 2450 | | 2.97 | 39368 | 37821 | 33927 | 32314 | 24221 | 22119 | 17093 | 14351 | 11784 | 2.65 |
| Run 24 | 2370 | | 2.86 | 39756 | 37588 | 33862 | 32443 | 24348 | 22097 | 17129 | 14345 | 11695 | 2.64 |
| Run 25 | 2775 | | 2.82 | 41510 | 39402 | 35399 | 33305 | 24651 | 22427 | 17186 | 14394 | 11532 | 2.89 |
| Run 26 | 2747 | | 2.70 | 41633 | 39101 | 35419 | 33680 | 24351 | 22229 | 17207 | 14382 | 11472 | 2.89 |
| Run 28 | 2910 | | 3.13 | 43051 | 40330 | 36128 | 34195 | 24282 | 21588 | 16444 | 13333 | 10622 | 3.08 |
| Run 29 | 3437 | | 2.95 | 46061 | 43019 | 38259 | 35567 | 23181 | 20617 | 14770 | 11384 | 7964 | 3.45 |
| Run 30 | 3298 | | 3.05 | 47446 | 44523 | 39249 | 37014 | 23740 | 21090 | 15327 | 11689 | 8305 | 3.44 |
| Run 32 | 3436 | | 3.13 | 50080 | 46649 | 41149 | 39092 | 24890 | 21778 | 15255 | 11319 | 7901 | 3.65 |
| Run 33 | 4124 | | 2.79 | 55397 | 51817 | 46174 | 43785 | 26414 | 23067 | 16070 | 11570 | 7372 | 3.91 |
| Run 34 | 3780 | | 3.15 | 55382 | 51513 | 45775 | 42720 | 26388 | 23194 | 16067 | 11898 | 7864 | 3.89 |
| Run 35 | 4454 | | 3.22 | 60346 | 56715 | 50553 | 47197 | 28118 | 24474 | 16228 | 11533 | 7156 | 4.16 |
| Run 38 | 4809 | | 2.96 | 67870 | 63210 | 56643 | 53464 | 30366 | 26367 | 17519 | 11710 | 6879 | 4.50 |
| Run 40 | 4555 | | 3.11 | 64102 | 60334 | 53485 | 49974 | 30172 | 25866 | 17161 | 12315 | 7429 | 4.33 |

## Appendix 18: Kaolin 10 % in 40 mm valve, 100 % open

### Kaolin 10 % in 40 mm valve, 100 % open

Kaolin 10 % in 40 mm valve, 100 % open

| | | |
|---|---|---|
| **Date:** | 8/9/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Material Type:** | **Kaolin 10%** | | | | | | | | | | | |
| | **Density[kg/m³]:** | **1169.4** | | | | | | | | | | | |
| | **Concentration:** | **10%** | | | | | | | | | | | |
| | **$t_y$:** | **8.965** | | | | | | | | | | | |
| | **K:** | **7.098** | | | | | | | | | | | |
| | **n:** | **0.175** | **Axial distances** | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 | |
| | **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| | **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -147.7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 | |
| | | | **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 | |
| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 2190 | | 2.57 | 90220 | 83068 | 72785 | 68381 | 46570 | 39861 | 26826 | 18981 | 11751 | 4.58 |
| **Run 2** | 2117 | | 2.47 | 88393 | 81538 | 71211 | 66500 | 46044 | 39638 | 26781 | 18842 | 11693 | 4.41 |
| **Run 3** | 2414 | | 2.21 | 86091 | 79625 | 70136 | 65147 | 45601 | 39259 | 26625 | 18663 | 11488 | 4.27 |
| **Run 4** | 1895 | | 2.66 | 84929 | 78359 | 68238 | 63351 | 44550 | 38535 | 26043 | 18398 | 11424 | 4.07 |
| **Run 5** | 2042 | | 2.30 | 82276 | 76221 | 66816 | 61781 | 44689 | 38292 | 26042 | 18420 | 11326 | 3.86 |
| **Run 6** | 1611 | | 2.62 | 81305 | 75514 | 64983 | 60098 | 43840 | 37864 | 25797 | 18258 | 11371 | 3.69 |
| **Run 7** | 1024 | | 2.58 | 79306 | 72901 | 61839 | 58305 | 42979 | 37384 | 25183 | 17622 | 10826 | 3.50 |
| **Run 8** | 1369 | | 2.21 | 76202 | 70824 | 60788 | 56667 | 43099 | 37614 | 25344 | 17982 | 11162 | 3.21 |
| **Run 9** | 1326 | | 2.34 | 76088 | 70393 | 60921 | 56066 | 42866 | 37403 | 25269 | 18023 | 11145 | 3.11 |
| **Run 10** | 1049 | | 2.14 | 74210 | 67887 | 58547 | 54039 | 42329 | 36659 | 24937 | 17739 | 10931 | 2.91 |
| **Run 11** | 927.5 | | 2.64 | 73261 | 67349 | 57693 | 53564 | 41926 | 36427 | 24603 | 17486 | 10915 | 2.75 |
| **Run 12** | 914.3 | | 2.72 | 72044 | 65834 | 57094 | 52305 | 41649 | 36009 | 24366 | 17361 | 10913 | 2.60 |
| **Run 13** | 764.9 | | 2.58 | 70017 | 64014 | 55222 | 50850 | 40803 | 35320 | 23962 | 16914 | 10630 | 2.38 |
| **Run 14** | 628.6 | | 2.91 | 68854 | 62815 | 54054 | 49901 | 40388 | 35021 | 23751 | 16930 | 10673 | 2.19 |
| **Run 15** | 514.2 | | 2.96 | 67245 | 61146 | 52662 | 48612 | 39744 | 34639 | 23494 | 16744 | 10628 | 1.97 |
| **Run 16** | 423.6 | | 2.89 | 65973 | 60283 | 51591 | 47630 | 39356 | 34206 | 23295 | 16592 | 10502 | 1.78 |
| **Run 17** | 299.0 | | 3.15 | 63637 | 58020 | 49703 | 45673 | 38460 | 33366 | 22764 | 16347 | 10345 | 1.47 |
| **Run 18** | 218.4 | | 3.82 | 61728 | 56173 | 48191 | 44225 | 37512 | 32565 | 22176 | 15885 | 10097 | 1.24 |
| **Run 19** | 129.1 | | 2.71 | 58264 | 53266 | 45658 | 41918 | 36127 | 31358 | 21367 | 15295 | 9758 | 0.90 |
| **Run 20** | 59.01 | | 6.32 | 55736 | 50869 | 43307 | 39944 | 34606 | 30077 | 20474 | 14677 | 9411 | 0.63 |
| **Run 21** | 5.94 | | 68.51 | 47609 | 43736 | 37031 | 34242 | 29799 | 25946 | 17599 | 12792 | 8181 | 0.18 |
| **Run 22** | 20.54 | | 9.63 | 52279 | 47645 | 40729 | 37521 | 32423 | 28306 | 19388 | 13961 | 8980 | 0.36 |
| **Run 23** | 161.1 | | 3.32 | 59604 | 54507 | 46340 | 42721 | 36696 | 31799 | 21685 | 15522 | 9876 | 1.06 |

## Appendix 19: Kaolin 13 % in 40 mm valve, 100 % open

### Kaolin 13 % in 40 mm valve, 100 % open

Kaolin 13 % in 40 mm valve, 100 % open

| | | |
|---|---|---|
| **Date:** | 12/7/2007 | Test done by Mume & Rendani |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | Open | **Area[m$^2$]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | Kaolin 13% | | | | | | | | | | | |
| **Density[kg/m$^3$]:** | 1215.5 | | | | | | | | | | | |
| **Concentration:** | 13% | | | | | | | | | | | |
| **$t_y$:** | 18.973 | | | | | | | | | | | |
| **K:** | 16.141 | | | | | | | | | | | |
| **n:** | 0.242 | **Axial distances** | -6.219 | -4.489 | -1.801 | -0.542 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 | |
| **PPT used:** | 105 | **Valve plane** | | | | | | | | | | |
| **Range selected·** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -147 7 | -106.6 | -42.76 | -12.86 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 | |
| | | **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.295 | 8.904 | 12.26 | 14.29 | 16.19 | |

| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 5** | 55.50 | | 0.22 | 125520 | 113860 | 98080 | 90659 | 78970 | 69301 | 48768 | 35925 | 24298 | 0.86 |
| **Run 9** | 24.94 | | 2.37 | 118134 | 107552 | 93103 | 85657 | 74823 | 65845 | 46659 | 34898 | 23932 | 0.55 |
| **Run 12** | 16.31 | | 13.53 | 113442 | 103947 | 89142 | 82273 | 72045 | 63394 | 45094 | 34028 | 23461 | 0.43 |
| **Run 13** | 16.22 | | 9.87 | 113494 | 103685 | 89014 | 82249 | 72044 | 63265 | 45014 | 33929 | 23302 | 0.43 |
| **Run 14** | 8.02 | | 61.01 | 110048 | 100999 | 86873 | 80009 | 70135 | 61748 | 44032 | 33279 | 23401 | 0.29 |
| **Run 16** | 8.85 | | 16.33 | 108254 | 99237 | 85200 | 78261 | 68754 | 60639 | 43844 | 33125 | 23354 | 0.31 |
| **Run 17** | 5.44 | | 193.1 | 103195 | 94830 | 81324 | 75109 | 65745 | 58030 | 41811 | 32112 | 23160 | 0.23 |
| **Run 22** | 1.90 | | 753.3 | 94609 | 88485 | 76097 | 70277 | 61911 | 54546 | 39011 | 30501 | 22239 | 0.12 |
| **Run 27** | 1.80 | | 1096 | 79116 | 71915 | 62914 | 58161 | 50922 | 45087 | 34385 | 28225 | 21405 | 0.10 |
| **Run 28** | 1.34 | | 3079 | 81948 | 76033 | 65022 | 60073 | 52482 | 46577 | 34006 | 27195 | 21048 | 0.09 |

## Appendix 20: Water in 40 mm valve, 100 % open

### Water in 40 mm valve, 100 % open

**Water in 40 mm valve, 100 % open**

| | | |
|---|---|---|
| **Date:** | 11/22/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.04 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.04212 | 0.00139337 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0007991 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Material Type:** | Water | | | | | | | | | | | |
| | **Density[kg/m³]:** | 995.356 | | | | | | | | | | | |
| | **Concentration:** | 100% | | | | | | | | | | | |
| | **$t_y$:** | 0 | | | | | | | | | | | |
| | **K:** | 0.0007991 | | | | | | | | | | | |
| | **n:** | 1 | **Axial distances** | -6.248 | -4.518 | -1.830 | -0.571 | 1.076 | 2.685 | 6.046 | 8.075 | 9.975 | |
| | **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| | **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -148.3 | -107.3 | -43.45 | -13.54 | 25.53 | 63.73 | 143.5 | 191.7 | 236.8 | |
| | | | **Distances[m]:** | 0 | 1.73 | 4.418 | 5.678 | 7.324 | 8.933 | 12.29 | 14.32 | 16.22 | |
| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 174710 | | 2.54 | 66370 | 62885 | 57485 | 54939 | 36653 | 33094 | 25869 | 21487 | 17406 | 4.64 |
| **Run 2** | 167476 | | 2.54 | 62951 | 59672 | 54247 | 52398 | 35443 | 32087 | 25486 | 21340 | 17611 | 4.45 |
| **Run 3** | 160586 | | 2.71 | 59768 | 56607 | 51814 | 48927 | 34324 | 31220 | 24904 | 21217 | 17809 | 4.27 |
| **Run 4** | 153072 | | 2.45 | 55897 | 53401 | 49247 | 47050 | 33044 | 30298 | 24566 | 21132 | 17854 | 4.07 |
| **Run 5** | 145412 | | 2.57 | 52891 | 50235 | 45783 | 44266 | 31861 | 29172 | 24068 | 20951 | 17981 | 3.86 |
| **Run 6** | 138084 | | 2.48 | 49503 | 47490 | 43410 | 41800 | 30749 | 28488 | 23661 | 20808 | 18087 | 3.67 |
| **Run 7** | 134686 | | 2.62 | 47845 | 45988 | 42511 | 40536 | 29993 | 27877 | 23261 | 20693 | 18131 | 3.58 |
| **Run 8** | 127348 | | 2.55 | 45293 | 43283 | 40011 | 38902 | 28995 | 27039 | 23008 | 20521 | 18262 | 3.38 |
| **Run 9** | 116778 | | 2.55 | 42059 | 40531 | 37562 | 36367 | 28027 | 26142 | 22575 | 20356 | 18392 | 3.15 |
| **Run 11** | 104005 | | 2.39 | 37014 | 35956 | 33609 | 32312 | 26020 | 24683 | 21874 | 20182 | 18501 | 2.76 |
| **Run 13** | 90300 | | 2.48 | 32899 | 31908 | 30342 | 29552 | 24361 | 23386 | 21204 | 19848 | 18633 | 2.40 |
| **Run 14** | 84053 | | 2.67 | 31289 | 30105 | 28887 | 28304 | 23808 | 22859 | 20904 | 19796 | 18710 | 2.23 |
| **Run 15** | 72170 | | 2.63 | 32772 | 32215 | 31041 | 30536 | 27137 | 26424 | 25001 | 24089 | 23291 | 1.92 |
| **Run 16** | 130225 | | 2.71 | 51483 | 49221 | 45748 | 44389 | 33775 | 31790 | 27418 | 24803 | 22381 | 3.46 |
| **Run 17** | 171540 | | 2.46 | 64509 | 61153 | 55025 | 52792 | 36368 | 33071 | 25916 | 21707 | 17719 | 4.56 |
| **Run 18** | 159890 | | 2.52 | 59866 | 56665 | 52355 | 49639 | 34188 | 31418 | 25167 | 21414 | 17835 | 4.25 |
| **Run 19** | 150715 | | 2.57 | 55671 | 52053 | 48639 | 46340 | 32824 | 30152 | 24494 | 21235 | 18014 | 4.00 |
| **Run 20** | 120362 | | 2.55 | 51775 | 49273 | 45277 | 43784 | 31225 | 29021 | 23912 | 20960 | 18131 | 3.78 |
| **Run 21** | 122648 | | 2.72 | 44231 | 42062 | 38826 | 37641 | 28521 | 26780 | 22927 | 20591 | 18484 | 3.26 |
| **Run 22** | 121304 | | 2.64 | 43744 | 41321 | 38830 | 37169 | 28330 | 26694 | 22870 | 20594 | 18505 | 3.22 |
| **Run 23** | 111251 | | 2.70 | 39815 | 38419 | 35542 | 34626 | 27130 | 25590 | 22289 | 20408 | 18584 | 2.95 |
| **Run 24** | 102253 | | 2.71 | 36797 | 35335 | 33250 | 32285 | 26023 | 24614 | 21789 | 20145 | 18637 | 2.72 |
| **Run 27** | 133903 | | 2.57 | 40385 | 38194 | 34742 | 33075 | 22419 | 20434 | 15944 | 13191 | 10782 | 3.56 |
| **Run 28** | 126518 | | 2.50 | 37471 | 35373 | 32302 | 30779 | 21373 | 19520 | 15518 | 13106 | 10829 | 3.36 |

## Appendix 21: CMC 5 % in 50 mm valve, 25% open

### CMC 5 % in 50 mm valve, 25 % open

CMC 5 % in 50 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 12/9/2006 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.550 | 0.392 | 2.550 | 1.957 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | CMC 5% | | | | | | | | | | | |
| Density[kg/m³]: | 1026.8 | | | | | | | | | | | |
| Concentration: | 5% | | | | | | | | | | | |
| $t_y$: | 0.000 | | | | | | | | | | | |
| K: | 1.542 | | | | | | | | | | | |
| n: | 0.645 | Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 6.566 | 8.566 | 10.57 | |
| PPT used: | 101 to 109 | Valve plane | | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 124.3 | 162.2 | 200.2 | |
| | | Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 13.14 | 15.14 | 17.14 | |

| Run # | $Re_3$ | $k_{v\ excl.}$ | $k_{v\ incl.}$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 1 | 323.2 | | 37.59 | 122867 | 110497 | 106104 | 99992 | 59170 | 52642 | 41606 | 34145 | 26698 | 3.02 |
| Run 2 | 293.3 | | 38.13 | 115509 | 104704 | 100454 | 95356 | 57239 | 51308 | 40810 | 33647 | 26537 | 2.82 |
| Run 3 | 276.9 | | 38.46 | 111631 | 100734 | 97264 | 91900 | 56202 | 50539 | 40293 | 33348 | 26413 | 2.70 |
| Run 4 | 253.2 | | 39.54 | 105686 | 96323 | 91803 | 87262 | 55060 | 49232 | 39568 | 32873 | 26271 | 2.53 |
| Run 5 | 234.4 | | 39.90 | 100699 | 91697 | 87623 | 83077 | 53642 | 48135 | 38893 | 32499 | 26132 | 2.39 |
| Run 6 | 215.9 | | 41.58 | 97130 | 88053 | 84330 | 80105 | 52462 | 47305 | 38365 | 32180 | 26016 | 2.25 |
| Run 7 | 197.8 | | 44.31 | 93436 | 84464 | 81097 | 76501 | 51339 | 46244 | 37687 | 31809 | 25918 | 2.11 |
| Run 8 | 179.8 | | 44.82 | 88869 | 80342 | 77408 | 72939 | 50080 | 45281 | 37055 | 31429 | 25790 | 1.96 |
| Run 9 | 159.3 | | 47.72 | 83957 | 76547 | 72921 | 68979 | 48753 | 43991 | 36303 | 30918 | 25665 | 1.79 |
| Run 10 | 144.6 | | 51.72 | 80818 | 73266 | 70253 | 66422 | 47507 | 42992 | 35646 | 30628 | 25583 | 1.67 |
| Run 11 | 121.7 | | 55.58 | 75133 | 68309 | 65465 | 61862 | 45480 | 41539 | 34741 | 30085 | 25412 | 1.47 |
| Run 12 | 111.0 | | 58.60 | 72582 | 66016 | 63458 | 60079 | 44730 | 40816 | 34285 | 29788 | 25336 | 1.37 |
| Run 13 | 88.47 | | 68.41 | 66736 | 60800 | 58493 | 55522 | 42572 | 39001 | 33234 | 29180 | 25155 | 1.16 |
| Run 14 | 74.28 | | 75.04 | 62924 | 57097 | 55052 | 52512 | 41011 | 37926 | 32463 | 28748 | 25025 | 1.02 |
| Run 15 | 46.21 | | 117.9 | 54494 | 49140 | 46678 | 44949 | 37207 | 34930 | 30611 | 27713 | 24751 | 0.72 |

**Appendix 22: Kaolin 6 % in 50 mm valve, 25 % open**

## Kaolin 6 % in 50 mm valve, 25 % open

Kaolin 6 % in 50 mm valve, 25 % open

| | | |
|---|---|---|
| **Date:** | 7/24/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.05 | |
| **Valve position:** | ¼ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.0528 | 0.002189564 |

| | |
|---|---|
| **Material Type:** | Kaolin 6% |
| **Density[kg/m³]:** | 1103.9 |
| **Concentration:** | 0.06 |
| **$t_y$:** | 3.071 |
| **K:** | 2.038 |
| **n:** | 0.264 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Axial distances** | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 | |
| | | | **Valve plane** | | | | | | | | | | |
| | | | **Non-dimensionalised distances incl.[L/D]:** | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 | |
| | | | **Distances[m]:** | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 | |
| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 3118 | | 29.92 | 99967 | 97235 | 96191 | 94788 | 20355 | 18185 | 15391 | 13361 | 11335 | 4.57 |
| **Run 2** | 2857 | | 31.92 | 98761 | 95648 | 94771 | 93179 | 20728 | 18714 | 15581 | 13676 | 11679 | 4.39 |
| **Run 3** | 2691 | | 28.93 | 87992 | 84912 | 83996 | 82128 | 20211 | 18243 | 15466 | 13577 | 11576 | 4.25 |
| **Run 4** | 2548 | | 28.80 | 82505 | 80080 | 78713 | 77532 | 20516 | 18591 | 15631 | 13926 | 11954 | 4.09 |
| **Run 5** | 1932 | | 30.99 | 71169 | 68588 | 67548 | 66313 | 21645 | 19876 | 17338 | 15518 | 13940 | 3.48 |
| **Run 6** | 1728 | | 30.85 | 66393 | 63898 | 62764 | 61435 | 21718 | 19897 | 17434 | 15690 | 14011 | 3.28 |
| **Run 7** | 1618 | | 30.36 | 62846 | 60103 | 59207 | 57982 | 21611 | 19791 | 17378 | 15728 | 14060 | 3.17 |
| **Run 8** | 1516 | | 30.77 | 59312 | 56909 | 56025 | 54667 | 21531 | 19837 | 17398 | 15671 | 14158 | 3.00 |
| **Run 9** | 1364 | | 30.17 | 55425 | 52741 | 52136 | 50851 | 21394 | 19767 | 17392 | 15693 | 14144 | 2.83 |
| **Run 10** | 1197 | | 30.56 | 52167 | 49815 | 48851 | 47577 | 21755 | 20269 | 17939 | 16345 | 14800 | 2.63 |
| **Run 11** | 1067 | | 30.50 | 49192 | 46745 | 45939 | 44676 | 21705 | 20277 | 18018 | 16376 | 14891 | 2.47 |
| **Run 12** | 895.9 | | 30.19 | 48929 | 46508 | 45730 | 44633 | 25471 | 24115 | 21925 | 20235 | 18847 | 2.24 |
| **Run 13** | 736.3 | | 32.18 | 47137 | 44586 | 43736 | 42422 | 25455 | 24160 | 21981 | 20371 | 18897 | 2.05 |
| **Run 14** | 648.5 | | 31.91 | 44250 | 42032 | 41156 | 39997 | 25365 | 24073 | 21906 | 20285 | 18854 | 1.87 |
| **Run 15** | 503.5 | | 31.92 | 41241 | 39024 | 38315 | 37297 | 25599 | 24338 | 22190 | 20501 | 19151 | 1.61 |
| **Run 16** | 407.1 | | 33.00 | 38902 | 36619 | 35972 | 34810 | 24936 | 23819 | 21746 | 20061 | 18763 | 1.44 |
| **Run 17** | 307.4 | | 33.52 | 38003 | 35901 | 35127 | 34020 | 25914 | 24726 | 22582 | 20914 | 19526 | 1.24 |
| **Run 18** | 229.2 | | 36.52 | 36220 | 33967 | 33301 | 32092 | 25429 | 24264 | 22207 | 20493 | 19222 | 1.06 |
| **Run 19** | 147.6 | | 38.10 | 33364 | 31076 | 30462 | 29372 | 24696 | 23530 | 21555 | 19908 | 18747 | 0.84 |
| **Run 20** | 2351 | | 30.08 | 77577 | 75340 | 74030 | 72963 | 20025 | 18103 | 15255 | 13491 | 11802 | 3.86 |
| **Run 21** | 2111 | | 31.34 | 73658 | 71386 | 70186 | 69032 | 20012 | 18165 | 15603 | 13887 | 12197 | 3.63 |

## Appendix 23: Kaolin 10 % in 50 mm valve, 25 % open

### Kaolin 10 % in 50 mm valve, 25 % open

Kaolin 10 % in 50 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 8/14/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| | |
|---|---|
| Material Type: | Kaolin 10% |
| Density[kg/m³]: | 1169.4 |
| Concentration: | 10% |
| $t_y$: | 8.965 |
| K: | 7.098 |
| n: | 0.175 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.574 | -3.526 | -2.281 | -0.760 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 |
| Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 1141 | | 20.84 | 108543 | 99929 | 97144 | 93277 | 34654 | 30265 | 22842 | 17772 | 12760 | 4.61 |
| Run 2 | 1189 | | 20.56 | 102662 | 94892 | 91870 | 88348 | 34312 | 29937 | 22547 | 17523 | 12639 | 4.43 |
| Run 3 | 1246 | | 23.17 | 104430 | 97128 | 94593 | 90886 | 34063 | 29615 | 22331 | 17318 | 12377 | 4.24 |
| Run 4 | 1064 | | 23.29 | 99719 | 92203 | 89336 | 85812 | 33613 | 29329 | 22078 | 17079 | 12244 | 4.06 |
| Run 5 | 956 | | 23.05 | 96130 | 88379 | 85549 | 81899 | 33665 | 29235 | 21985 | 16975 | 12115 | 3.92 |
| Run 6 | 878 | | 23.03 | 92384 | 84706 | 81822 | 78108 | 32884 | 28930 | 21807 | 16781 | 11948 | 3.76 |
| Run 7 | 815 | | 23.14 | 88935 | 81040 | 78403 | 74586 | 32972 | 28464 | 21397 | 16458 | 11713 | 3.63 |
| Run 8 | 736 | | 24.75 | 86981 | 79381 | 76550 | 73053 | 31746 | 28117 | 21231 | 16079 | 11531 | 3.43 |
| Run 9 | 722 | | 24.56 | 82048 | 74941 | 72329 | 68478 | 31862 | 27740 | 20899 | 15869 | 11228 | 3.21 |
| Run 10 | 615 | | 26.43 | 79412 | 72423 | 69568 | 65976 | 31744 | 27406 | 20587 | 15687 | 11022 | 3.00 |
| Run 11 | 528 | | 27.94 | 76473 | 69287 | 66491 | 62990 | 31235 | 27170 | 20244 | 15303 | 10910 | 2.82 |
| Run 12 | 490 | | 28.62 | 74098 | 67001 | 64365 | 60838 | 31107 | 27040 | 20217 | 15268 | 10885 | 2.66 |
| Run 13 | 437 | | 29.53 | 71309 | 64257 | 61653 | 58254 | 30850 | 26730 | 20051 | 15120 | 10865 | 2.50 |
| Run 14 | 311 | | 35.27 | 67315 | 60129 | 57547 | 54220 | 30115 | 26131 | 19455 | 14625 | 10559 | 2.16 |
| Run 15 | 240 | | 35.68 | 61627 | 54767 | 52151 | 48991 | 29504 | 25600 | 19058 | 14430 | 10227 | 1.86 |
| Run 16 | 198 | | 37.08 | 59208 | 52433 | 49740 | 46584 | 28127 | 25327 | 18913 | 14184 | 10177 | 1.70 |
| Run 17 | 135 | | 37.97 | 53568 | 47056 | 44429 | 41314 | 28418 | 24784 | 18535 | 13806 | 10072 | 1.37 |
| Run 18 | 114.7 | | 38.69 | 51382 | 44729 | 42397 | 39211 | 27946 | 24328 | 18203 | 13563 | 9916 | 1.25 |
| Run 19 | 69.3 | | 44.20 | 48242 | 41889 | 39373 | 36412 | 27376 | 23873 | 17801 | 13293 | 9678 | 0.98 |
| Run 20 | 57.7 | | 36.35 | 45968 | 39742 | 37380 | 34457 | 26800 | 23389 | 17453 | 13308 | 9397 | 0.86 |
| Run 21 | 29.7 | | 54.11 | 42292 | 36483 | 34343 | 31425 | 25623 | 22399 | 16561 | 12682 | 9054 | 0.58 |
| Run 22 | 16.83 | | 87.53 | 40103 | 34398 | 32291 | 29510 | 24292 | 21254 | 15824 | 12192 | 8723 | 0.44 |
| Run 23 | 5.12 | | 80.93 | 36904 | 31500 | 29438 | 26946 | 22708 | 19790 | 15094 | 11555 | 8300 | 0.24 |

## Appendix 24: Kaolin 13 % in 50 mm valve, 25 % open

### Kaolin 13 % in 50 mm valve, 25 % open

Kaolin 13 % in 50 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 12/8/2007 | Test done by Mume & Rendani |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| | |
|---|---|
| Material Type: | Kaolin 13% |
| Density[kg/m³]: | 1215.5 |
| Concentration: | 13% |
| $t_y$: | 18.973 |
| K: | 16.141 |
| n: | 0.242 |
| PPT used: | 105 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 | |
| | | | Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 60.33 | | 27.75 | 100020 | 86331 | 82292 | 75851 | 59778 | 53306 | 40910 | 31916 | 24022 | 1.33 |
| Run 2 | 60.65 | | 29.57 | 100060 | 86697 | 81970 | 75860 | 59702 | 53083 | 40807 | 31861 | 23991 | 1.34 |
| Run 3 | 48.80 | | 27.65 | 97360 | 84788 | 79946 | 73492 | 59366 | 52527 | 40740 | 32269 | 24201 | 1.18 |
| Run 4 | 49.17 | | 27.45 | 96893 | 83678 | 79174 | 72948 | 58919 | 52152 | 40400 | 31715 | 23908 | 1.19 |
| Run 5 | 41.22 | | 33.48 | 94553 | 81946 | 77442 | 71229 | 58074 | 51577 | 39780 | 31320 | 23804 | 1.07 |
| Run 6 | 41.31 | | 36.33 | 94584 | 82143 | 77460 | 71342 | 58067 | 51772 | 39683 | 31111 | 23774 | 1.07 |
| Run 7 | 33.05 | | 30.32 | 92629 | 79847 | 75576 | 69407 | 56955 | 51006 | 39308 | 30698 | 23348 | 0.95 |
| Run 8 | 33.66 | | 29.26 | 91939 | 78890 | 74990 | 68815 | 56518 | 50447 | 39640 | 30782 | 23958 | 0.95 |
| Run 9 | 28.06 | | 40.41 | 88703 | 77138 | 72732 | 66755 | 55419 | 49429 | 38199 | 30593 | 23240 | 0.85 |
| Run 10 | 27.42 | | 57.46 | 89878 | 77814 | 72929 | 67153 | 55859 | 49492 | 38239 | 30459 | 23363 | 0.84 |
| Run 11 | 19.91 | | 46.56 | 88421 | 75949 | 72259 | 66307 | 55384 | 49301 | 38318 | 30415 | 23272 | 0.71 |
| Run 12 | 20.56 | | 38.02 | 87432 | 75374 | 70678 | 65442 | 54493 | 48653 | 37972 | 30024 | 22941 | 0.72 |
| Run 13 | 15.04 | | 51.63 | 86207 | 73991 | 70457 | 64885 | 54089 | 48373 | 37595 | 29413 | 22804 | 0.60 |
| Run 14 | 15.61 | | 52.31 | 85484 | 74104 | 69760 | 64361 | 54132 | 48407 | 37447 | 29931 | 22885 | 0.61 |
| Run 15 | 11.18 | | 57.23 | 79109 | 70128 | 66330 | 61463 | 51389 | 46240 | 35658 | 29329 | 22358 | 0.49 |
| Run 16 | 10.67 | | 59.82 | 81773 | 71722 | 67634 | 61992 | 52696 | 46949 | 36367 | 29089 | 22405 | 0.49 |
| Run 17 | 8.795 | | 79.54 | 76302 | 66496 | 62582 | 58237 | 49896 | 44306 | 34657 | 28346 | 21939 | 0.42 |
| Run 18 | 7.633 | | 49.25 | 78477 | 69315 | 65298 | 60017 | 50999 | 45490 | 35479 | 28734 | 22046 | 0.40 |
| Run 19 | 4.195 | | 166.04 | 77308 | 66666 | 63002 | 58106 | 49667 | 44286 | 34969 | 27819 | 21964 | 0.29 |
| Run 20 | 4.361 | | 52.59 | 77361 | 67463 | 64093 | 59194 | 50378 | 44879 | 36250 | 28211 | 21967 | 0.29 |
| Run 21 | 2.613 | | 178.2 | 72476 | 63819 | 60349 | 56657 | 48835 | 43039 | 34050 | 28047 | 22096 | 0.21 |
| Run 22 | 2.803 | | 129.1 | 72501 | 63376 | 60166 | 55498 | 47589 | 42929 | 34123 | 27639 | 22088 | 0.22 |
| Run 23 | 0.799 | | 646.9 | 67751 | 58336 | 55710 | 52671 | 45349 | 40608 | 32503 | 26822 | 21568 | 0.11 |
| Run 24 | 0.880 | | 643.7 | 67142 | 58806 | 55659 | 51561 | 44602 | 40752 | 32224 | 26782 | 21396 | 0.11 |
| Run 25 | 0.922 | | 903.6 | 63025 | 55773 | 52165 | 48149 | 42968 | 38368 | 31158 | 26220 | 21347 | 0.10 |

## Appendix 25: Water in 40 mm valve, 50 % open

### Water in 50 mm valve, 25 % open

Water in 50 mm valve, 25 % open

| | | |
|---|---|---|
| **Date:** | 11/30/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.05 | |
| **Valve position:** | ¼ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.0528 | 0.002189564 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.000802 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | Water | | | | | | | | | | | |
| **Density[kg/m³]:** | 995.660427 | | | | | | | | | | | |
| **Concentration:** | 100% | | | | | | | | | | | |
| $t_y$: | 0 | | | | | | | | | | | |
| **K:** | 0.000802 | | | | | | | | | | | |
| **n:** | 1 | **Axial distances** | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 6.566 | 8.566 | 10.57 | |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 124.3 | 162.2 | 200.2 | |
| | | **Distances[m]:** | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 13.14 | 15.14 | 17.14 | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 1 | 138159 | | 23.79 | 82810 | 80579 | 79593 | 78807 | 24386 | 22853 | 20572 | 19055 | 17632 | 4.61 |
| Run 2 | 131833 | | 22.24 | 75313 | 73286 | 72574 | 71569 | 25118 | 23725 | 21594 | 20244 | 18879 | 4.40 |
| Run 3 | 125584 | | 20.99 | 67958 | 66236 | 65441 | 64557 | 24490 | 23260 | 21398 | 20176 | 18899 | 4.19 |
| Run 4 | 119261 | | 20.10 | 61674 | 60135 | 59336 | 58593 | 24023 | 22894 | 21173 | 20050 | 18918 | 3.98 |
| Run 5 | 112366 | | 19.05 | 55395 | 54008 | 53317 | 52556 | 23401 | 22455 | 20912 | 19926 | 18895 | 3.75 |
| Run 6 | 104971 | | 18.18 | 49786 | 48471 | 47830 | 47249 | 22873 | 22054 | 20703 | 19814 | 18910 | 3.51 |
| Run 7 | 97503 | | 17.67 | 45154 | 44031 | 43541 | 42940 | 22375 | 21635 | 20490 | 19709 | 18905 | 3.26 |
| Run 8 | 90255 | | 17.28 | 41098 | 40178 | 39687 | 39221 | 21962 | 21306 | 20299 | 19618 | 18928 | 3.01 |
| Run 9 | 81455 | | 16.88 | 36877 | 36080 | 35647 | 35296 | 21450 | 20913 | 20081 | 19510 | 18916 | 2.72 |
| Run 10 | 74981 | | 17.21 | 34402 | 33692 | 33379 | 33051 | 21085 | 20625 | 19928 | 19408 | 18930 | 2.50 |
| Run 11 | 67519 | | 18.43 | 32165 | 31562 | 31320 | 31012 | 20700 | 20353 | 19754 | 19339 | 18939 | 2.26 |
| Run 12 | 49545 | | 22.12 | 31740 | 31396 | 31241 | 31073 | 24447 | 24246 | 23900 | 23670 | 23428 | 1.65 |

## Appendix 26: CMC 5 % in 50 mm valve, 50 % open

CMC 5 % in 50 mm valve, 50 % open

CMC 5 % in 50 mm valve, 50 % open

| | | |
|---|---|---|
| Date: | 12/9/2006 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.550 | 0.392 | 2.550 | 1.957 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | CMC 5% | | | | | | | | | | |
| Density[kg/m³]: | 1026.8 | | | | | | | | | | |
| Concentration: | 5% | | | | | | | | | | |
| $t_y$: | 0.000 | | | | | | | | | | |
| K: | 1.542 | | | | | | | | | | |
| n: | 0.645 | Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 6.566 | 8.566 | 10.57 |
| PPT used: | 101 to 109 | Valve plane | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 124.3 | 162.2 | 200.2 |
| | | Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 13.14 | 15.14 | 17.14 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 465.9 | | 15.18 | 123709 | 109764 | 104076 | 97468 | 66121 | 58339 | 45251 | 36259 | 27335 | 3.96 |
| Run 2 | 431.2 | | 14.72 | 117364 | 104292 | 99213 | 92460 | 64437 | 56982 | 44321 | 35732 | 27174 | 3.74 |
| Run 3 | 385.4 | | 15.07 | 110353 | 98744 | 93401 | 87917 | 62124 | 55158 | 43118 | 35109 | 26983 | 3.44 |
| Run 4 | 344.0 | | 16.89 | 105638 | 93852 | 89085 | 83358 | 60101 | 53365 | 42093 | 34479 | 26779 | 3.17 |
| Run 5 | 316.8 | | 17.67 | 101692 | 90088 | 85867 | 80386 | 58743 | 52096 | 41391 | 34050 | 26631 | 2.98 |
| Run 6 | 291.7 | | 18.73 | 98170 | 87568 | 83233 | 77582 | 57213 | 50979 | 40626 | 33584 | 26512 | 2.80 |
| Run 7 | 268.0 | | 19.79 | 94822 | 84492 | 80380 | 75363 | 55901 | 49890 | 39967 | 33121 | 26392 | 2.63 |
| Run 8 | 241.7 | | 19.23 | 90081 | 80572 | 76530 | 72028 | 54271 | 48796 | 39268 | 32687 | 26213 | 2.44 |
| Run 9 | 211.1 | | 21.37 | 85086 | 76134 | 72311 | 67897 | 52354 | 46957 | 38178 | 32047 | 25985 | 2.21 |
| Run 10 | 183.2 | | 21.14 | 79953 | 71932 | 68409 | 64297 | 50521 | 45602 | 37188 | 31462 | 25808 | 1.99 |
| Run 11 | 162.3 | | 24.32 | 76726 | 68881 | 65496 | 61434 | 48873 | 44271 | 36443 | 31063 | 25707 | 1.82 |
| Run 12 | 130.3 | | 27.19 | 70527 | 63474 | 60476 | 56936 | 46307 | 42156 | 35086 | 30293 | 25477 | 1.55 |
| Run 13 | 114.3 | | 30.07 | 67447 | 60688 | 58005 | 54697 | 44887 | 40976 | 34436 | 29844 | 25351 | 1.40 |
| Run 14 | 92.73 | | 34.17 | 62829 | 56963 | 54532 | 51423 | 42761 | 39344 | 33378 | 29253 | 25197 | 1.20 |
| Run 15 | 71.89 | | 39.23 | 58055 | 52605 | 50377 | 47996 | 40688 | 37657 | 32205 | 28606 | 25003 | 1.00 |

**Appendix 27: Kaolin 6 % in 50 mm valve, 50 % open**

## Kaolin 6 % in 50 mm valve, 50 % open

Kaolin 6 % in 50 mm valve, 50 % open

| | | | |
|---|---|---|---|
| Date: | 7/20/2007 | Test done by Mume & Sisonke | |
| Valve Type: | Diaphragm | | |
| Valve dimension[m]: | 0.05 | | |
| Valve position: | ½ Open | Area[m²] | |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 | |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| Material Type: | Kaolin 6% | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Density[kg/m³]: | 1103.9 | | | | | | | | | | | | |
| Concentration: | 6% | | | | | | | | | | | | |
| $t_y$: | 3.071 | | | | | | | | | | | | |
| K: | 2.038 | | | | | | | | | | | | |
| n: | 0.264 | Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 | | |
| PPT used: | 105 | Valve plane | | | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 | | |
| | | Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 | | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 2956 | | 9.04 | 46203 | 43408 | 42083 | 40642 | 17235 | 15292 | 12105 | 9962 | 7939 | 4.50 |
| Run 2 | 2837 | | 9.40 | 46775 | 44053 | 42943 | 41797 | 18256 | 16357 | 13297 | 11313 | 9160 | 4.35 |
| Run 3 | 2556 | | 9.10 | 44575 | 41608 | 40482 | 38649 | 18304 | 16406 | 13630 | 11654 | 9546 | 4.16 |
| Run 4 | 2367 | | 9.75 | 42845 | 40019 | 38769 | 37202 | 17737 | 15975 | 13040 | 11333 | 9249 | 3.99 |
| Run 5 | 1995 | | 9.82 | 42060 | 39201 | 37863 | 36692 | 19046 | 17316 | 14602 | 12703 | 10705 | 3.68 |
| Run 6 | 2169 | | 9.99 | 42038 | 39240 | 37966 | 36648 | 17823 | 15804 | 13258 | 11260 | 9385 | 3.81 |
| Run 7 | 1916 | | 9.48 | 40722 | 38020 | 36996 | 35674 | 19126 | 17489 | 14740 | 12811 | 10726 | 3.50 |
| Run 8 | 1761 | | 10.07 | 39366 | 36812 | 35682 | 34338 | 19132 | 17475 | 14881 | 12996 | 11167 | 3.33 |
| Run 10 | 1580 | | 10.67 | 38287 | 35549 | 34567 | 33354 | 19068 | 17453 | 14898 | 12999 | 11317 | 3.15 |
| Run 11 | 1401 | | 11.26 | 36917 | 34306 | 33064 | 31726 | 18589 | 17233 | 14676 | 12848 | 11236 | 2.98 |
| Run 12 | 1429 | | 11.21 | 37020 | 34282 | 33287 | 32065 | 18933 | 17342 | 14840 | 12957 | 11418 | 2.99 |
| Run 13 | 797.3 | | 16.13 | 37584 | 35078 | 34043 | 33054 | 23067 | 21780 | 19463 | 17728 | 16416 | 2.16 |
| Run 14 | 697.4 | | 15.92 | 36535 | 33973 | 33068 | 31947 | 23169 | 21769 | 19415 | 17570 | 16268 | 2.00 |
| Run 15 | 608.8 | | 15.84 | 35039 | 32570 | 31801 | 30642 | 22736 | 21598 | 19254 | 17583 | 16152 | 1.83 |
| Run 16 | 549.1 | | 16.50 | 34249 | 31936 | 31167 | 29891 | 22965 | 21643 | 19400 | 17611 | 16398 | 1.71 |
| Run 17 | 416.3 | | 16.67 | 32570 | 30080 | 29421 | 28298 | 22670 | 21353 | 19165 | 17727 | 16239 | 1.48 |
| Run 18 | 316.0 | | 16.44 | 31233 | 28885 | 28155 | 27063 | 22397 | 21090 | 18943 | 17400 | 15995 | 1.27 |
| Run 19 | 233.1 | | 29.38 | 29737 | 27493 | 26735 | 25709 | 21963 | 20740 | 18602 | 17083 | 16220 | 1.06 |
| Run 20 | 165.6 | | 26.27 | 28210 | 26055 | 25335 | 24376 | 21360 | 20191 | 18189 | 16498 | 15685 | 0.87 |
| Run 21 | 98.97 | | 29.54 | 26712 | 24557 | 23859 | 22954 | 20629 | 19499 | 17625 | 16084 | 15181 | 0.67 |
| Run 22 | 63.42 | | 19.61 | 25716 | 23619 | 22905 | 22020 | 19983 | 18975 | 17131 | 15546 | 14567 | 0.53 |

## Appendix 28: Kaolin 10 % in 50 mm valve, 50 % open

# Kaolin 10 % in 50 mm valve, 50 % open

**Kaolin 10 % in 50 mm valve, 50 % open**

| | | |
|---|---|---|
| Date: | 8/14/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| | |
|---|---|
| Material Type: | Kaolin 10% |
| Density[kg/m³]: | 1169.4 |
| Concentration: | 10% |
| $t_y$: | 8.965 |
| K: | 7.098 |
| n: | 0.175 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 |
| Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 1365 | | 8.70 | 78672 | 70299 | 67977 | 63987 | 34768 | 30444 | 23003 | 17558 | 12630 | 4.67 |
| Run 2 | 1213 | | 9.28 | 76547 | 68719 | 65850 | 62024 | 34653 | 30142 | 22689 | 17597 | 12569 | 4.42 |
| Run 3 | 1101 | | 9.46 | 74220 | 66457 | 63588 | 59829 | 34020 | 29658 | 22301 | 17123 | 12221 | 4.20 |
| Run 4 | 1017 | | 9.53 | 72939 | 64955 | 62213 | 58586 | 33772 | 29496 | 22156 | 17046 | 12128 | 4.08 |
| Run 5 | 960.8 | | 9.56 | 71153 | 63101 | 60625 | 57026 | 33528 | 29294 | 22060 | 16815 | 12073 | 3.91 |
| Run 6 | 890.6 | | 10.08 | 69488 | 62070 | 59120 | 55483 | 33159 | 28974 | 21825 | 16755 | 12033 | 3.73 |
| Run 7 | 837.1 | | 10.10 | 67758 | 60186 | 57515 | 53777 | 32754 | 28524 | 21469 | 16416 | 11726 | 3.58 |
| Run 8 | 768.7 | | 9.92 | 65912 | 58576 | 55821 | 52150 | 32445 | 28415 | 21362 | 16392 | 11592 | 3.40 |
| Run 9 | 679.8 | | 10.81 | 64294 | 56787 | 54072 | 50422 | 32161 | 27953 | 20873 | 15989 | 11436 | 3.25 |
| Run 10 | 626.9 | | 10.57 | 62290 | 55114 | 52335 | 48779 | 31746 | 27635 | 20649 | 15805 | 11174 | 3.05 |
| Run 11 | 552.7 | | 10.84 | 61114 | 53650 | 51005 | 47430 | 31440 | 27418 | 20480 | 15548 | 11078 | 2.91 |
| Run 12 | 472.6 | | 11.33 | 59039 | 51687 | 49064 | 45506 | 31181 | 27181 | 20294 | 15479 | 11074 | 2.68 |
| Run 13 | 432.7 | | 10.67 | 56806 | 49498 | 47062 | 43604 | 30789 | 26763 | 20007 | 15219 | 10876 | 2.51 |
| Run 14 | 321.7 | | 11.78 | 54516 | 47355 | 45035 | 41631 | 30325 | 26440 | 19764 | 14927 | 10737 | 2.13 |
| Run 15 | 275.2 | | 11.53 | 52808 | 46001 | 43548 | 40106 | 29872 | 26150 | 19561 | 14752 | 10608 | 1.94 |
| Run 16 | 245.3 | | 11.94 | 51489 | 44767 | 42222 | 38819 | 29490 | 25702 | 19220 | 14467 | 10452 | 1.84 |
| Run 17 | 186.2 | | 11.58 | 49194 | 42619 | 40159 | 36927 | 28923 | 25232 | 18856 | 14185 | 10255 | 1.58 |
| Run 18 | 141.8 | | 11.21 | 47379 | 41030 | 38583 | 35357 | 28398 | 24760 | 18481 | 13807 | 10018 | 1.35 |
| Run 19 | 91.84 | | 12.27 | 45027 | 38938 | 36554 | 33447 | 27463 | 24007 | 17880 | 13470 | 9717 | 1.06 |
| Run 20 | 56.51 | | 16.81 | 42943 | 37075 | 34818 | 31912 | 26415 | 23213 | 17284 | 12963 | 9478 | 0.81 |
| Run 21 | 28.18 | | 21.76 | 40816 | 35123 | 32961 | 30274 | 25526 | 22213 | 16587 | 12512 | 9087 | 0.56 |
| Run 22 | 11.68 | | 54.11 | 39435 | 33734 | 31680 | 28994 | 24549 | 21465 | 16009 | 12038 | 8784 | 0.37 |
| Run 23 | 5.415 | | 106.6 | 36478 | 31041 | 29148 | 26469 | 22631 | 19829 | 15005 | 11371 | 8364 | 0.24 |

## Appendix 29: Kaolin 13 % in 50 mm valve, 50 % open

### Kaolin 13 % in 50 mm valve, 50 % open

Kaolin 13 % in 50 mm valve, 50 % open

| | | |
|---|---|---|
| Date: | 12/8/2007 | Test done by Mume & Rendani |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| | |
|---|---|
| Material Type: | Kaolin 13% |
| Density[kg/m³]: | 1215.5 |
| Concentration: | 13% |
| $t_y$: | 18.973 |
| K: | 16.141 |
| n: | 0.242 |
| PPT used: | 105 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 | |
| | | | Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.58C | 12.53 | 14.53 | 16.53 | |
| | | | | | | | | | | | | | [l/s] |
| Run 1 | 57.19 | | 8.45 | 96888 | 83099 | 78492 | 72066 | 61062 | 53811 | 41441 | 32581 | 24319 | 1.30 |
| Run 2 | 58.21 | | 10.78 | 96544 | 83100 | 78122 | 71724 | 60678 | 53572 | 41315 | 32491 | 24405 | 1.31 |
| Run 3 | 49.09 | | 15.94 | 95374 | 81241 | 76419 | 70309 | 59749 | 52774 | 40628 | 32054 | 24076 | 1.20 |
| Run 4 | 50.02 | | 19.23 | 95370 | 81661 | 76667 | 70464 | 59484 | 52802 | 40565 | 31998 | 24176 | 1.21 |
| Run 5 | 42.25 | | 14.22 | 94262 | 81244 | 76516 | 70359 | 59524 | 52793 | 40720 | 32045 | 24280 | 1.09 |
| Run 6 | 42.75 | | 18.13 | 93940 | 80656 | 75546 | 69917 | 59015 | 52320 | 40316 | 31828 | 24056 | 1.10 |
| Run 7 | 33.81 | | 34.10 | 92565 | 79133 | 74085 | 68680 | 58382 | 52087 | 39827 | 31604 | 24248 | 0.97 |
| Run 8 | 35.05 | | 26.91 | 91716 | 78323 | 73840 | 67669 | 57463 | 51123 | 39505 | 31380 | 23883 | 0.98 |
| Run 9 | 27.48 | | 46.72 | 90717 | 78865 | 73884 | 67533 | 57763 | 51131 | 39015 | 31330 | 23841 | 0.85 |
| Run 10 | 27.95 | | 32.60 | 89850 | 77487 | 72382 | 66483 | 56574 | 50246 | 38922 | 30972 | 23602 | 0.86 |
| Run 11 | 22.35 | | 36.38 | 89126 | 76152 | 72257 | 65950 | 56327 | 50114 | 38584 | 30668 | 23317 | 0.76 |
| Run 12 | 23.03 | | 34.15 | 88546 | 76000 | 71282 | 65773 | 55813 | 49666 | 38536 | 30536 | 23362 | 0.77 |
| Run 13 | 17.85 | | 39.85 | 85649 | 73602 | 69561 | 63678 | 54212 | 48246 | 37454 | 29653 | 22755 | 0.66 |
| Run 14 | 18.24 | | 41.56 | 85635 | 74220 | 69889 | 63925 | 54460 | 48327 | 37411 | 29951 | 22756 | 0.67 |
| Run 15 | 12.37 | | 58.90 | 83937 | 72321 | 68360 | 62805 | 54039 | 47700 | 36964 | 29612 | 22660 | 0.54 |
| Run 16 | 12.70 | | 58.21 | 83895 | 72940 | 68285 | 62632 | 54348 | 48443 | 36865 | 29665 | 22533 | 0.55 |
| Run 17 | 9.196 | | 104.3 | 81294 | 70077 | 65987 | 60864 | 52128 | 46267 | 36137 | 29328 | 22586 | 0.45 |
| Run 18 | 9.169 | | 109.6 | 82557 | 71548 | 67360 | 61764 | 53251 | 47217 | 36526 | 29574 | 22734 | 0.45 |
| Run 19 | 9.470 | | 97.5 | 82292 | 70768 | 67022 | 61253 | 52780 | 46947 | 36264 | 29193 | 22422 | 0.46 |
| Run 20 | 4.962 | | 176.1 | 75369 | 66848 | 63022 | 57981 | 49983 | 44065 | 34410 | 27203 | 21877 | 0.31 |
| Run 21 | 4.918 | | 155.4 | 77409 | 68524 | 64357 | 59309 | 51241 | 45355 | 34933 | 29866 | 22087 | 0.31 |
| Run 22 | 2.408 | | 355.7 | 74261 | 64324 | 60476 | 55826 | 48373 | 43272 | 34088 | 28218 | 21912 | 0.21 |
| Run 23 | 2.730 | | 386.0 | 73842 | 64147 | 60378 | 56574 | 49005 | 43203 | 33513 | 27951 | 21448 | 0.22 |
| Run 26 | 0.577 | | 1351 | 65193 | 57401 | 54725 | 51264 | 44610 | 39702 | 31410 | 26211 | 21031 | 0.08 |
| Run 27 | 0.697 | | 1252 | 65363 | 57671 | 54822 | 50137 | 44278 | 39983 | 31348 | 26713 | 20996 | 0.09 |
| Run 30 | 0.277 | | 4638 | 59500 | 51586 | 49376 | 45819 | 40185 | 36705 | 30185 | 25713 | 21307 | 0.05 |
| Run 31 | 0.295 | | 1634 | 59367 | 51806 | 48746 | 45794 | 39966 | 36354 | 30132 | 25242 | 20947 | 0.05 |

**Appendix 30: Water in 50 mm valve, 50 % open**

## Water in 50 mm valve, 50 % open

**Water in 50 mm valve, 50 % open**

| | | |
|---|---|---|
| **Date:** | 11/30/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.05 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.0528 | 0.002189564 |

| | |
|---|---|
| **Material Type:** | Water |
| **Density[kg/m³]:** | 995.73191 |
| **Concentration:** | 100% |
| $t_y$: | 0 |
| **K:** | 0.0008061 |
| **n:** | 1 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0008061 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 6.566 | 8.566 | 10.57 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 124.3 | 162.2 | 200.2 |
| **Distances[m]:** | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 13.14 | 15.14 | 17.14 |

| Run # | $Re_3$ | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 1 | 135670 | 7.03 | 46342 | 44339 | 43513 | 42571 | 25198 | 23825 | 21675 | 20321 | 18781 | 4.55 |
| Run 2 | 126393 | 7.10 | 42924 | 41134 | 40289 | 39401 | 24469 | 23293 | 21394 | 20195 | 18878 | 4.24 |
| Run 3 | 118604 | 6.97 | 40080 | 38557 | 37801 | 37031 | 23852 | 22826 | 21163 | 20025 | 18891 | 3.98 |
| Run 4 | 112226 | 6.95 | 37980 | 36516 | 35814 | 35179 | 23466 | 22480 | 20960 | 19937 | 18892 | 3.77 |
| Run 5 | 104307 | 7.11 | 35508 | 34216 | 33653 | 33072 | 22824 | 22024 | 20704 | 19810 | 18948 | 3.50 |
| Run 6 | 97200 | 7.12 | 33561 | 32404 | 31906 | 31348 | 22377 | 21689 | 20497 | 19722 | 18916 | 3.26 |
| Run 7 | 88731 | 7.30 | 31475 | 30544 | 30108 | 29635 | 21861 | 21248 | 20281 | 19614 | 18919 | 2.98 |
| Run 8 | 81925 | 7.88 | 30100 | 29270 | 28864 | 28517 | 21511 | 20958 | 20098 | 19515 | 18934 | 2.75 |
| Run 9 | 75092 | 8.35 | 28714 | 27985 | 27643 | 27324 | 21161 | 20664 | 19940 | 19445 | 18943 | 2.52 |
| Run 10 | 67708 | 8.61 | 27175 | 26584 | 26289 | 26008 | 20794 | 20378 | 19784 | 19357 | 18936 | 2.27 |
| Run 11 | 60404 | 9.86 | 30464 | 29964 | 29753 | 29527 | 24945 | 24618 | 24105 | 23785 | 23445 | 2.03 |
| Run 12 | 48078 | 11.12 | 28363 | 28057 | 27922 | 27747 | 24424 | 24245 | 23911 | 23663 | 23468 | 1.61 |
| Run 13 | 40335 | 11.38 | 27065 | 26825 | 26725 | 26596 | 24172 | 24026 | 23787 | 23610 | 23447 | 1.35 |
| Run 14 | 26941 | 11.94 | 25151 | 25041 | 24989 | 24927 | 23763 | 23699 | 23580 | 23496 | 23411 | 0.90 |

## Appendix 31: CMC 5 % in 50 mm valve, 75 % open

### CMC 5 % in 50 mm valve, 75 % open

**CMC 5 % in 50 mm valve, 75 % open**

| | | |
|---|---|---|
| **Date:** | 12/9/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.05 | |
| **Valve position:** | ¾ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.0528 | 0.002189564 |

| | |
|---|---|
| **Material Type:** | CMC 5% |
| **Density[kg/m³]:** | 1026.8 |
| **Concentration:** | 5% |
| $t_y$: | 0.000 |
| **K:** | 1.542 |
| **n:** | 0.645 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.550 | 0.392 | 2.550 | 1.957 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 6.566 | 8.566 | 10.57 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 124.3 | 162.2 | 200.2 |
| **Distances[m]:** | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 13.14 | 15.14 | 17.14 |

| **Run #** | $Re_3$ | | $k_v$ | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 560.1 | | 5.62 | 123779 | 108272 | 102036 | 94504 | 70463 | 61791 | 47225 | 37442 | 27679 | 4.54 |
| **Run 2** | 524.1 | | 5.08 | 119078 | 104802 | 98889 | 91690 | 69157 | 60611 | 46642 | 37212 | 27670 | 4.32 |
| **Run 3** | 487.0 | | 4.62 | 114262 | 100896 | 95237 | 88270 | 67210 | 59154 | 45761 | 36556 | 27407 | 4.09 |
| **Run 4** | 454.3 | | 4.81 | 110696 | 97380 | 91705 | 85443 | 65704 | 57900 | 44942 | 36168 | 27282 | 3.89 |
| **Run 5** | 423.6 | | 4.71 | 106904 | 94383 | 88735 | 82490 | 64166 | 56800 | 44175 | 35656 | 27137 | 3.69 |
| **Run 6** | 382.0 | | 4.43 | 102215 | 89818 | 84984 | 78917 | 62085 | 55069 | 43224 | 35094 | 26952 | 3.42 |
| **Run 7** | 337.6 | | 4.30 | 96996 | 85251 | 80560 | 74778 | 59788 | 53276 | 42105 | 34373 | 26749 | 3.12 |
| **Run 8** | 293.1 | | 4.63 | 91254 | 80864 | 76470 | 70948 | 57487 | 51329 | 40731 | 33698 | 26535 | 2.81 |
| **Run 9** | 256.3 | | 4.24 | 86769 | 76554 | 72365 | 67476 | 55467 | 49561 | 39752 | 33049 | 26326 | 2.55 |
| **Run 10** | 229.1 | | 4.07 | 82779 | 73442 | 69380 | 64741 | 53573 | 48163 | 38813 | 32476 | 26139 | 2.35 |
| **Run 11** | 205.3 | | 4.45 | 79869 | 70681 | 66974 | 62476 | 52050 | 46933 | 38052 | 32028 | 25993 | 2.16 |
| **Run 12** | 182.9 | | 4.66 | 76619 | 67963 | 64473 | 60043 | 50483 | 45603 | 37254 | 31552 | 25863 | 1.99 |
| **Run 13** | 161.6 | | 2.67 | 72777 | 65070 | 61794 | 57740 | 48953 | 44346 | 36503 | 31087 | 25731 | 1.81 |
| **Run 14** | 129.4 | | 2.67 | 67479 | 60383 | 57542 | 53755 | 46348 | 42151 | 35144 | 30341 | 25503 | 1.54 |
| **Run 15** | 104.7 | | 0.08 | 62867 | 56464 | 53965 | 50901 | 43993 | 40382 | 34080 | 29685 | 25317 | 1.32 |

## Appendix 32: Kaolin 6 % in 50 mm valve, 75 % open

### Kaolin 6 % in 50 mm valve, 75 % open

Kaolin 6 % in 50 mm valve, 75 % open

| | | |
|---|---|---|
| Date: | 7/19/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | ¾ Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| | |
|---|---|
| Material Type: | Kaolin 6% |
| Density[kg/m³]: | 1103.9 |
| Concentration: | 6% |
| $\tau_y$: | 3.071 |
| K: | 2.038 |
| n: | 0.264 |
| PPT used: | 105 |
| Range selected: | 0-40 |

| 1/n | n/(n+1) | (n+1)/n | K''' |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 |
| Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 |

| Run # | $Re_3$ | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 1 | 3032 | 4.33 | 36940 | 33714 | 32472 | 31016 | 18774 | 16529 | 13317 | 11269 | 9220 | 4.65 |
| Run 2 | 3019 | 3.92 | 36889 | 33757 | 32304 | 30949 | 18701 | 16622 | 13244 | 11005 | 8812 | 4.66 |
| Run 3 | 2902 | 3.96 | 36303 | 33210 | 32024 | 30288 | 19056 | 16805 | 13886 | 11802 | 9674 | 4.49 |
| Run 4 | 2847 | 3.79 | 36440 | 32940 | 31867 | 30428 | 18939 | 17032 | 13977 | 11743 | 9656 | 4.52 |
| Run 5 | 2693 | 3.79 | 35558 | 32483 | 31171 | 29848 | 18746 | 16891 | 13965 | 11723 | 9682 | 4.34 |
| Run 6 | 2780 | 3.94 | 35388 | 32463 | 31309 | 29730 | 18833 | 16883 | 13872 | 11732 | 9734 | 4.35 |
| Run 7 | 2637 | 3.88 | 34713 | 31855 | 30748 | 29525 | 18716 | 16877 | 13868 | 11818 | 9739 | 4.20 |
| Run 8 | 2551 | 4.13 | 35189 | 32061 | 30888 | 29377 | 18705 | 16892 | 13921 | 11751 | 9803 | 4.20 |
| Run 9 | 2408 | 4.04 | 33901 | 30770 | 29656 | 28422 | 18298 | 16404 | 13574 | 11795 | 9569 | 4.07 |
| Run 10 | 2230 | 4.29 | 33162 | 30298 | 29109 | 27748 | 18142 | 16376 | 13494 | 11532 | 9561 | 3.86 |
| Run 11 | 2228 | 4.10 | 32801 | 29925 | 28752 | 27606 | 17888 | 16143 | 13458 | 11474 | 9525 | 3.86 |
| Run 12 | 2060 | 4.30 | 32235 | 29474 | 28197 | 27223 | 18044 | 16303 | 13439 | 11372 | 9577 | 3.70 |
| Run 13 | 1967 | 4.35 | 31859 | 28910 | 27821 | 26743 | 17915 | 16164 | 13391 | 11455 | 9578 | 3.61 |
| Run 14 | 1778 | 4.49 | 31295 | 28297 | 27245 | 26071 | 17809 | 16183 | 13424 | 11445 | 9651 | 3.43 |
| Run 15 | 1677 | 4.67 | 30994 | 28098 | 26973 | 25814 | 17751 | 16135 | 13455 | 11527 | 9737 | 3.32 |
| Run 16 | 1456 | 4.33 | 31569 | 28782 | 27559 | 26579 | 19307 | 17801 | 15114 | 13153 | 11353 | 3.08 |
| Run 17 | 1308 | 4.61 | 30865 | 27987 | 26906 | 25872 | 19141 | 17700 | 14988 | 13041 | 11331 | 2.90 |
| Run 18 | 1243 | 4.94 | 30713 | 28026 | 27091 | 25882 | 19788 | 18117 | 15425 | 13605 | 11919 | 2.75 |

## Appendix 33: Kaolin 10 % in 50 mm valve, 75 % open

Kaolin 10 % in 50 mm valve, 75 % open

Kaolin 10 % in 50 mm valve, 75 % open

| | | |
|---|---|---|
| Date: | 8/14/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | ¾ Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | |
|---|---|
| Material Type: | Kaolin 10% |
| Density[kg/m³]: | 1169.4 |
| Concentration: | 10% |
| $t_y$: | 8.965 |
| K: | 7.098 |
| n: | 0.175 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 186.6 | |
| | | | Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 | |
| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 1311 | | 3.93 | 65468 | 57595 | 54761 | 50869 | 34800 | 30358 | 22895 | 17527 | 12506 | 4.58 |
| Run 2 | 1229 | | 3.98 | 65180 | 57233 | 54196 | 50530 | 34515 | 30227 | 22836 | 17405 | 12493 | 4.55 |
| Run 3 | 1139 | | 3.98 | 63395 | 55469 | 52675 | 48935 | 34129 | 29802 | 22308 | 17101 | 12055 | 4.30 |
| Run 4 | 1042 | | 3.78 | 62000 | 53973 | 51295 | 47607 | 33620 | 29405 | 22169 | 16749 | 11927 | 4.11 |
| Run 5 | 1027 | | 3.78 | 60629 | 53464 | 50386 | 46720 | 33537 | 29276 | 22084 | 16950 | 12046 | 3.95 |
| Run 6 | 849.9 | | 4.25 | 59872 | 52242 | 49360 | 45716 | 33140 | 28881 | 21673 | 16476 | 11705 | 3.68 |
| Run 7 | 787.0 | | 3.49 | 58086 | 50503 | 47814 | 44118 | 32625 | 28451 | 21452 | 16223 | 11391 | 3.48 |
| Run 8 | 667.7 | | 4.19 | 56725 | 48992 | 46563 | 43010 | 32034 | 27933 | 20849 | 15774 | 11061 | 3.19 |
| Run 9 | 512.1 | | 5.23 | 54671 | 47067 | 44718 | 41088 | 31511 | 27511 | 20473 | 15433 | 11106 | 2.77 |
| Run 10 | 462.9 | | 4.20 | 53687 | 46393 | 43733 | 40095 | 31184 | 27251 | 20342 | 15290 | 10811 | 2.64 |
| Run 11 | 376.9 | | 4.24 | 51854 | 44605 | 42000 | 38675 | 30733 | 26812 | 20088 | 14993 | 10838 | 2.38 |
| Run 12 | 286.9 | | 5.65 | 50209 | 43111 | 40608 | 37282 | 30071 | 26127 | 19382 | 14692 | 10447 | 2.04 |
| Run 13 | 225.2 | | 4.62 | 48735 | 41637 | 39342 | 35946 | 29518 | 25738 | 19195 | 14351 | 10314 | 1.79 |
| Run 16 | 67.55 | | 7.97 | 44121 | 37765 | 35287 | 32248 | 27400 | 23794 | 17809 | 13341 | 9654 | 0.96 |
| Run 18 | 18.11 | | 18.64 | 40492 | 34547 | 32436 | 29609 | 25222 | 22062 | 16420 | 12425 | 8881 | 0.47 |
| Run 19 | 5.209 | | 56.78 | 38030 | 32409 | 30378 | 27739 | 23694 | 20672 | 15539 | 11806 | 8484 | 0.25 |

## Appendix 34: Kaolin 13 % in 50 mm valve, 75 % open

### Kaolin 13 % in 50 mm valve, 75 % open

Kaolin 13 % in 50 mm valve, 75 % open

| | | |
|---|---|---|
| Date: | 12/6/2007 | Test done by Mume & Rendani |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | ¾ Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| | |
|---|---|
| Material Type: | Kaolin 13% |
| Density[kg/m³]: | 1215.5 |
| Concentration: | 13% |
| $t_y$: | 18.973 |
| K: | 16.141 |
| n: | 0.242 |
| PPT used: | 105 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 | |
| | | | Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 49.04 | | 6.66 | 96071 | 82829 | 77445 | 71175 | 61330 | 54310 | 41652 | 32985 | 24640 | 1.20 |
| Run 2 | 51.20 | | 7.68 | 95555 | 82203 | 77333 | 71082 | 61283 | 54037 | 41355 | 32745 | 24510 | 1.22 |
| Run 3 | 45.93 | | 13.49 | 95842 | 82804 | 77689 | 71241 | 61234 | 54097 | 41707 | 33014 | 25102 | 1.15 |
| Run 4 | 46.60 | | 10.64 | 94777 | 81701 | 76511 | 70762 | 60744 | 53550 | 41077 | 32776 | 24506 | 1.16 |
| Run 5 | 38.15 | | 14.56 | 94214 | 81257 | 76321 | 70938 | 60460 | 53315 | 40844 | 32443 | 24422 | 1.04 |
| Run 6 | 39.21 | | 12.30 | 93190 | 79788 | 75251 | 68736 | 59305 | 52659 | 40468 | 32052 | 24185 | 1.05 |
| Run 7 | 32.54 | | 12.22 | 92550 | 79937 | 75078 | 68636 | 59065 | 52459 | 40475 | 31723 | 24228 | 0.95 |
| Run 8 | 33.03 | | 17.19 | 92153 | 78929 | 74119 | 67922 | 58361 | 51898 | 40041 | 31668 | 24017 | 0.96 |
| Run 9 | 25.66 | | 19.23 | 91681 | 77875 | 73757 | 67663 | 58240 | 51736 | 40239 | 31231 | 24300 | 0.83 |
| Run 10 | 18.55 | | 20.79 | 90684 | 76696 | 72698 | 67383 | 57245 | 51151 | 39559 | 30745 | 23625 | 0.70 |
| Run 11 | 20.46 | | 18.76 | 87667 | 74410 | 70858 | 64918 | 55787 | 49838 | 38744 | 30251 | 23498 | 0.72 |
| Run 12 | 14.90 | | 24.89 | 87354 | 73573 | 70052 | 64032 | 55381 | 49138 | 38467 | 29959 | 23225 | 0.62 |
| Run 13 | 14.22 | | 29.93 | 79716 | 69525 | 65591 | 60410 | 51916 | 46431 | 36053 | 29390 | 22510 | 0.56 |
| Run 14 | 12.17 | | 25.42 | 83888 | 73212 | 68821 | 62749 | 54685 | 48488 | 37779 | 29805 | 23264 | 0.53 |
| Run 15 | 12.03 | | 26.27 | 83705 | 73178 | 68580 | 63254 | 54933 | 48623 | 37520 | 29725 | 22995 | 0.53 |
| Run 16 | 7.550 | | 58.91 | 83623 | 71853 | 68033 | 62850 | 54252 | 48054 | 37297 | 29623 | 22898 | 0.41 |
| Run 17 | 8.437 | | 71.15 | 83112 | 71977 | 67796 | 62340 | 53993 | 47768 | 37144 | 29732 | 22987 | 0.44 |
| Run 18 | 5.072 | | 77.69 | 80953 | 69489 | 65961 | 60825 | 52712 | 46820 | 36403 | 29105 | 22523 | 0.33 |
| Run 19 | 5.532 | | 81.51 | 80949 | 69775 | 65985 | 60985 | 52904 | 46773 | 36011 | 29106 | 22088 | 0.35 |
| Run 20 | 2.548 | | 300.4 | 76034 | 66148 | 62173 | 57315 | 49942 | 44222 | 34546 | 28088 | 21863 | 0.22 |
| Run 21 | 2.522 | | 205.8 | 76881 | 66606 | 62109 | 57977 | 50507 | 44719 | 34901 | 28374 | 21891 | 0.22 |
| Run 22 | 1.330 | | 300.2 | 73584 | 62863 | 59090 | 55283 | 48453 | 43271 | 34244 | 28152 | 22002 | 0.16 |
| Run 23 | 1.469 | | 339.8 | 73933 | 63219 | 59633 | 54946 | 47776 | 42629 | 34140 | 27876 | 21819 | 0.16 |
| Run 24 | 0.662 | | 1215 | 68807 | 59560 | 56334 | 52040 | 46287 | 41266 | 32809 | 27399 | 21813 | 0.10 |
| Run 25 | 0.751 | | 1748 | 68590 | 59817 | 56643 | 52606 | 45518 | 40512 | 32471 | 27160 | 21695 | 0.10 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 26 | 0.712 | | 2256 | 65222 | 56341 | 53024 | 49855 | 43646 | 39430 | 31406 | 26429 | 21432 | 0.09 |
| Run 27 | 0.745 | | 2009 | 64916 | 57014 | 53595 | 49381 | 43042 | 39174 | 31312 | 26483 | 21324 | 0.10 |
| Run 28 | 0.465 | | 777 | 62524 | 55297 | 52703 | 48968 | 43387 | 38676 | 31155 | 25890 | 21277 | 0.07 |
| Run 29 | 0.540 | | 1317 | 62205 | 55146 | 52875 | 48938 | 43176 | 39234 | 31035 | 25824 | 21374 | 0.08 |
| Run 30 | 0.527 | | 2411 | 62843 | 54274 | 52400 | 48126 | 42404 | 38406 | 30944 | 26121 | 21371 | 0.08 |
| Run 31 | 0.238 | | 5936 | 59509 | 51973 | 49114 | 46406 | 40722 | 36912 | 30070 | 25433 | 21153 | 0.05 |
| Run 32 | 0.235 | | 7116 | 59805 | 52318 | 49160 | 45757 | 40600 | 36857 | 30039 | 25471 | 21111 | 0.05 |

**Appendix 35: Water in 50 mm valve, 75 % open**

## Water in 50 mm valve, 75 % open

Water in 50 mm valve, 75 % open

| | | |
|---|---|---|
| Date: | 11/29/2006 | Test done by Elelwani |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | ¾ Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0007723 |

| | | | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | Water | | | | | | | | | | |
| Density[kg/m³]: | 995.0746 | | | | | | | | | | |
| Concentration: | 100% | | | | | | | | | | |
| $t_y$: | 0 | | | | | | | | | | |
| K: | 0.0007723 | | | | | | | | | | |
| n: | 1 | Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 6.566 | 8.566 | 10.57 |
| PPT used: | 101 to 109 | Valve plane | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 124.3 | 162.2 | 200.2 |
| | | Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 13.14 | 15.14 | 17.14 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 143671 | | 3.66 | 39400 | 37280 | 36314 | 35398 | 25099 | 23838 | 21689 | 20239 | 18764 | 4.62 |
| Run 2 | 134816 | | 3.65 | 37195 | 35328 | 34469 | 33580 | 24445 | 23299 | 21412 | 20139 | 18779 | 4.34 |
| Run 3 | 123301 | | 3.68 | 34398 | 32816 | 32074 | 31391 | 23649 | 22692 | 21064 | 19966 | 18830 | 3.97 |
| Run 4 | 116457 | | 3.63 | 32747 | 31321 | 30663 | 30023 | 23166 | 22289 | 20851 | 19858 | 18838 | 3.75 |
| Run 5 | 103846 | | 3.65 | 30077 | 28926 | 28328 | 27836 | 22397 | 21676 | 20489 | 19702 | 18855 | 3.34 |
| Run 6 | 93925 | | 3.66 | 28175 | 27162 | 26724 | 26253 | 21803 | 21221 | 20226 | 19566 | 18864 | 3.02 |
| Run 7 | 83291 | | 3.58 | 26250 | 25457 | 25063 | 24706 | 21232 | 20772 | 19975 | 19419 | 18874 | 2.68 |
| Run 8 | 74914 | | 3.62 | 24948 | 24311 | 24002 | 23687 | 20840 | 20437 | 19787 | 19337 | 18880 | 2.41 |
| Run 9 | 55233 | | 3.81 | 26983 | 26597 | 26461 | 26273 | 24537 | 24315 | 23927 | 23633 | 23375 | 1.78 |

## Appendix 36: CMC 5 % in 50 mm valve, 100 % open

### CMC 5 % in 50 mm valve, 100 % open

**CMC 5 % in 50 mm valve, 100 % open**

| | | |
|---|---|---|
| **Date:** | 12/9/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.05 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.0528 | 0.002189564 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.550 | 0.392 | 2.550 | 1.957 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | CMC 5% | | | | | | | | | | |
| **Density[kg/m³]:** | 1026.8 | | | | | | | | | | |
| **Concentration:** | 5% | | | | | | | | | | |
| **$t_y$:** | 0.000 | | | | | | | | | | |
| **K:** | 1.542 | | | | | | | | | | |
| **n:** | 0.645 | **Axial distances** | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 6.566 | 8.566 | 10.57 |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 124.3 | 162.2 | 200.2 |
| | | **Distances[m]:** | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 13.14 | 15.14 | 17.14 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 575.2 | | 4.13 | 119051 | 103175 | 96674 | 89128 | 72786 | 63681 | 48574 | 38248 | 27953 | 4.63 |
| Run 2 | 541.4 | | 3.84 | 115012 | 100449 | 94119 | 86590 | 71200 | 62466 | 47759 | 37737 | 27801 | 4.43 |
| Run 3 | 494.3 | | 4.07 | 110595 | 96657 | 90019 | 83420 | 68899 | 60730 | 46571 | 37089 | 27594 | 4.14 |
| Run 4 | 463.1 | | 4.08 | 106994 | 93382 | 87690 | 80867 | 67373 | 59271 | 45866 | 36588 | 27430 | 3.94 |
| Run 5 | 421.0 | | 4.26 | 102805 | 89619 | 83983 | 77507 | 65265 | 57646 | 44811 | 36073 | 27256 | 3.68 |
| Run 6 | 386.4 | | 4.13 | 98696 | 86896 | 81284 | 75138 | 63299 | 56190 | 43836 | 35490 | 27101 | 3.45 |
| Run 7 | 356.2 | | 4.78 | 96052 | 83789 | 79121 | 72815 | 61919 | 54775 | 43192 | 35025 | 26948 | 3.25 |
| Run 8 | 329.3 | | 5.15 | 93126 | 81847 | 76429 | 70948 | 60492 | 53622 | 42283 | 34580 | 26820 | 3.07 |
| Run 9 | 303.6 | | 5.26 | 90349 | 79033 | 74414 | 69056 | 58887 | 52513 | 41486 | 34154 | 26670 | 2.89 |
| Run 11 | 257.1 | | 6.29 | 84744 | 74516 | 70428 | 65433 | 56046 | 50002 | 40052 | 33202 | 26400 | 2.55 |
| Run 12 | 219.8 | | 6.32 | 80194 | 70632 | 66716 | 62066 | 53534 | 48270 | 38872 | 32491 | 26140 | 2.28 |
| Run 13 | 194.2 | | 7.26 | 76786 | 67758 | 64015 | 59538 | 51864 | 46762 | 37960 | 31963 | 25991 | 2.08 |
| Run 14 | 170.7 | | 7.88 | 73473 | 65091 | 61413 | 57483 | 50213 | 45380 | 37123 | 31455 | 25838 | 1.89 |
| Run 15 | 151.1 | | 7.69 | 70270 | 62436 | 59154 | 55414 | 48620 | 44145 | 36296 | 30979 | 25700 | 1.73 |

## Appendix 37: Kaolin 6 % in 50 mm valve, 100 % open

### Kaolin 6 % in 50 mm valve, 100 % open

Kaolin 6 % in 50 mm valve, 100 % open

| | | |
|---|---|---|
| Date: | 7/18/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | Open | Area[m$^2$] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| | |
|---|---|
| Material Type: | Kaolin 6% |
| Density[kg/m$^3$]: | 1103.9 |
| Concentration: | 6% |
| $t_y$: | 3.071 |
| K: | 2.038 |
| n: | 0.264 |
| PPT used: | 105 |
| Range selected: | 0-40 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 |
| Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 4 | 2563 | | 1.64 | 30740 | 27521 | 26365 | 25002 | 19053 | 17381 | 14325 | 12061 | 10147 | 4.23 |
| Run 5 | 2580 | | 1.76 | 30841 | 27744 | 26528 | 24976 | 19224 | 17263 | 14343 | 12241 | 10231 | 4.23 |
| Run 6 | 2438 | | 1.43 | 30499 | 27455 | 26143 | 24635 | 19006 | 17315 | 14382 | 12196 | 10112 | 4.11 |
| Run 9 | 2139 | | 1.68 | 29099 | 26325 | 25051 | 23683 | 18639 | 16713 | 13886 | 11899 | 9902 | 3.78 |
| Run 10 | 2106 | | 1.46 | 29177 | 26247 | 25009 | 23690 | 18707 | 16933 | 13993 | 11939 | 9903 | 3.77 |
| Run 11 | 1947 | | 1.69 | 29005 | 26049 | 24921 | 23647 | 19903 | 18235 | 15021 | 13199 | 11367 | 3.60 |
| Run 12 | 1937 | | 1.96 | 30085 | 27253 | 25982 | 24736 | 19864 | 18303 | 15315 | 13392 | 11523 | 3.60 |
| Run 13 | 1776 | | 1.90 | 30182 | 27168 | 26110 | 24599 | 20041 | 18351 | 15639 | 13711 | 11821 | 3.43 |
| Run 14 | 1334 | | 2.01 | 28730 | 25830 | 24729 | 23410 | 19772 | 18089 | 15563 | 13644 | 11985 | 2.94 |
| Run 15 | 1357 | | 1.55 | 28787 | 26182 | 25214 | 23801 | 19933 | 18445 | 15852 | 13817 | 12176 | 2.88 |
| Run 16 | 1332 | | 1.93 | 28681 | 26200 | 24975 | 23782 | 19984 | 18358 | 15696 | 13910 | 12125 | 2.87 |
| Run 17 | 1156 | | 2.04 | 28704 | 25748 | 24704 | 23449 | 19888 | 18305 | 15750 | 13808 | 12164 | 2.73 |
| Run 20 | 829.0 | | 2.35 | 23161 | 20497 | 19394 | 18154 | 15153 | 13695 | 11157 | 9420 | 7756 | 2.25 |
| Run 23 | 761.6 | | 1.92 | 22921 | 20199 | 19226 | 17942 | 15108 | 13696 | 11188 | 9395 | 7761 | 2.14 |
| Run 24 | 590.9 | | 1.83 | 24357 | 21605 | 20651 | 19338 | 17069 | 15572 | 13131 | 11319 | 9775 | 1.88 |

## Appendix 38: Kaolin 10 % in 50 mm valve, 100 % open

### Kaolin 10 % in 50 mm valve, 100 % open

Kaolin 10 % in 50 mm valve, 100 % open

| | | |
|---|---|---|
| Date: | 8/14/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | Open | Area[m²] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | |
|---|---|
| Material Type: | Kaolin 10% |
| Density[kg/m³]: | 1169.4 |
| Concentration: | 10% |
| $t_y$: | 8.965 |
| K: | 7.098 |
| n: | 0.175 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 5.958 | 7.958 | 9.961 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 |
| Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 1 | 1299 | | 1.75 | 59993 | 52336 | 49167 | 45389 | 34987 | 30752 | 23295 | 18017 | 13007 | 4.61 |
| Run 2 | 1241 | | 1.70 | 59228 | 51418 | 48533 | 44552 | 34668 | 30420 | 23021 | 17690 | 12769 | 4.46 |
| Run 3 | 1146 | | 1.72 | 58430 | 50695 | 47811 | 43906 | 34313 | 30037 | 22660 | 17379 | 12451 | 4.27 |
| Run 4 | 1040 | | 1.87 | 57759 | 49931 | 47118 | 43242 | 34035 | 29895 | 22507 | 17278 | 12458 | 4.09 |
| Run 5 | 982.8 | | 2.00 | 57098 | 49333 | 46488 | 42598 | 33651 | 29529 | 22196 | 16997 | 12272 | 3.98 |
| Run 6 | 842.8 | | 1.83 | 55872 | 47812 | 45358 | 41398 | 33333 | 29275 | 22025 | 16827 | 12179 | 3.67 |
| Run 7 | 685.5 | | 1.70 | 53849 | 46315 | 43464 | 39944 | 32334 | 28200 | 21148 | 16112 | 11415 | 3.30 |
| Run 8 | 606.9 | | 0.95 | 52648 | 45356 | 42484 | 38821 | 31838 | 27799 | 20826 | 15779 | 10995 | 3.05 |
| Run 9 | 523.4 | | 1.16 | 51562 | 44272 | 41474 | 37937 | 31412 | 27439 | 20513 | 15565 | 10946 | 2.83 |
| Run 10 | 439.2 | | 0.71 | 50693 | 43424 | 40543 | 37237 | 31057 | 27136 | 20346 | 15289 | 10815 | 2.62 |
| Run 11 | 381.4 | | 0.70 | 49995 | 42625 | 40012 | 36565 | 30768 | 26840 | 20011 | 15072 | 10585 | 2.42 |
| Run 12 | 297.8 | | 1.56 | 48915 | 41723 | 38969 | 35670 | 30196 | 26401 | 19769 | 14847 | 10708 | 2.16 |

## Appendix 39: Kaolin 13 % in 50 mm valve, 100 % open

### Kaolin 13 % in 50 mm valve, 100 % open

| | | |
|---|---|---|
| **Date:** | 12/8/2007 | Test done by Mume & Rendani |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.05 | |
| **Valve position:** | Open | **Area[m$^2$]** |
| **Pipe Diameter [m]:** | 0.0528 | 0.002189564 |

**Kaolin 13 % in 50 mm valve, 100 % open**

| 1/n | n/(n+1) | (n+1)/n | K$^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | |
|---|---|
| **Material Type:** | Kaolin 13% |
| **Density[kg/m$^3$]:** | 1215.5 |
| **Concentration:** | 13% |
| **$t_y$:** | 18.973 |
| **K:** | 16.141 |
| **n:** | 0.242 |
| **PPT used:** | 105 |
| **Range selected:** | 0-130 |

| Run # | Re$_3$ | | k$_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Axial distances** | -6.574 | -3.526 | -2.281 | -0.780 | 1.297 | 3.012 | 5.958 | 7.958 | 9.961 | |
| | | | **Valve plane** | | | | | | | | | | |
| | | | **Non-dimensionalised distances incl.[L/D]:** | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 112.8 | 150.7 | 188.6 | |
| | | | **Distances[m]:** | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 12.53 | 14.53 | 16.53 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 44.40 | | 0.75 | 97805 | 84475 | 79269 | 72484 | 63298 | 55794 | 42980 | 34248 | 25516 | 1.14 |
| Run 2 | 43.40 | | 3.45 | 97268 | 83578 | 78714 | 71771 | 62636 | 55161 | 42281 | 33954 | 24958 | 1.13 |
| Run 4 | 39.46 | | 9.12 | 94082 | 80681 | 76082 | 69672 | 60850 | 53684 | 41279 | 32992 | 24851 | 1.06 |
| Run 5 | 32.12 | | 5.49 | 94527 | 81218 | 76621 | 69933 | 60928 | 53696 | 41329 | 32833 | 24558 | 0.95 |
| Run 6 | 32.68 | | 5.15 | 93535 | 80557 | 75635 | 69380 | 60383 | 53377 | 41114 | 32569 | 24546 | 0.96 |
| Run 7 | 25.54 | | 10.92 | 93138 | 79927 | 75420 | 68739 | 59796 | 52858 | 40648 | 32428 | 24224 | 0.83 |
| Run 8 | 26.27 | | 19.83 | 92055 | 78603 | 74168 | 68047 | 59008 | 52127 | 40266 | 32378 | 24347 | 0.84 |
| Run 9 | 20.72 | | 6.70 | 90417 | 77499 | 72804 | 66996 | 58292 | 51493 | 39750 | 31669 | 23731 | 0.74 |
| Run 10 | 21.13 | | 20.35 | 89888 | 76828 | 72302 | 66418 | 57977 | 51103 | 39678 | 31523 | 24093 | 0.75 |
| Run 11 | 15.75 | | 16.57 | 87449 | 74941 | 70764 | 64813 | 56652 | 50166 | 38954 | 31217 | 23751 | 0.63 |
| Run 12 | 11.08 | | 38.11 | 87265 | 75086 | 70870 | 65024 | 56566 | 50184 | 38637 | 30762 | 23516 | 0.52 |
| Run 14 | 9.693 | | 17.45 | 79882 | 68961 | 64755 | 59871 | 52113 | 46401 | 36659 | 29845 | 23014 | 0.46 |
| Run 15 | 6.040 | | 215.6 | 75829 | 65026 | 60979 | 55780 | 48791 | 43618 | 34284 | 27871 | 22039 | 0.35 |
| Run 16 | 2.915 | | 51.1 | 77049 | 66759 | 62762 | 57656 | 50291 | 44650 | 35876 | 28986 | 22812 | 0.24 |
| Run 17 | 3.150 | | 51.4 | 76676 | 67259 | 63334 | 58506 | 51215 | 45335 | 35467 | 28900 | 22420 | 0.25 |
| Run 18 | 1.109 | | 774.9 | 73275 | 63276 | 59398 | 54898 | 49137 | 43565 | 34341 | 28361 | 22501 | 0.14 |
| Run 19 | 2.669 | | 778.5 | 67200 | 58247 | 54784 | 50550 | 44047 | 39336 | 31810 | 27152 | 21723 | 0.19 |
| Run 20 | 0.836 | | 610.6 | 69090 | 60814 | 57245 | 52621 | 46199 | 41670 | 32972 | 27029 | 21698 | 0.11 |
| Run 21 | 1.031 | | 393.4 | 69954 | 59742 | 56816 | 52037 | 46556 | 41421 | 33421 | 27605 | 22047 | 0.13 |
| Run 22 | 0.656 | | 1144 | 63156 | 55578 | 52169 | 48730 | 43082 | 38842 | 31214 | 26458 | 21369 | 0.09 |
| Run 23 | 0.660 | | 2189 | 63243 | 55400 | 52282 | 48679 | 43152 | 38802 | 30902 | 25828 | 21211 | 0.09 |
| Run 24 | 0.275 | | 14800 | 62756 | 54072 | 50962 | 47301 | 42136 | 38096 | 30345 | 25682 | 21523 | 0.05 |
| Run 25 | 0.255 | | 5334 | 62399 | 54403 | 51395 | 47502 | 41810 | 37783 | 30527 | 25571 | 20918 | 0.05 |

## Appendix 40: Water in 50 mm valve, 100 % open

### Water in 50 mm valve, 100 % open

Water in 50 mm valve, 100 % open

| | | |
|---|---|---|
| Date: | 11/29/2006 | Test done by Elelwani |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.05 | |
| Valve position: | Open | Area[m$^2$] |
| Pipe Diameter [m]: | 0.0528 | 0.002189564 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0007954 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | Water | | | | | | | | | | |
| Density[kg/m$^3$]: | 995.53056 | | | | | | | | | | |
| Concentration: | 100% | | | | | | | | | | |
| $t_y$: | 0 | | | | | | | | | | |
| K: | 0.0007954 | | | | | | | | | | |
| n: | 1 | Axial distances | -6.574 | -3.526 | -2.281 | -0.780 | 1.257 | 3.012 | 6.566 | 8.566 | 10.57 |
| PPT used: | 101 to 109 | Valve plane | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -124.5 | -66.78 | -43.20 | -14.77 | 23.80 | 57.04 | 124.3 | 162.2 | 200.2 |
| | | Distances[m]: | 0 | 3.048 | 4.293 | 5.794 | 7.831 | 9.586 | 13.14 | 15.14 | 17.14 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 132261 | | 1.61 | 33466 | 31531 | 30674 | 29786 | 24587 | 23413 | 21479 | 20165 | 18804 | 4.38 |
| Run 2 | 127377 | | 1.60 | 32499 | 30738 | 29872 | 29101 | 24197 | 23132 | 21332 | 20093 | 18825 | 4.22 |
| Run 3 | 113829 | | 1.63 | 29986 | 28547 | 27829 | 27192 | 23222 | 22371 | 20910 | 19909 | 18876 | 3.77 |
| Run 4 | 106638 | | 1.59 | 28682 | 27440 | 26840 | 26205 | 22751 | 21988 | 20689 | 19778 | 18876 | 3.53 |
| Run 5 | 98638 | | 1.61 | 27415 | 26265 | 25738 | 25235 | 22258 | 21595 | 20470 | 19673 | 18897 | 3.27 |
| Run 6 | 90283 | | 1.68 | 26100 | 25153 | 24698 | 24256 | 21771 | 21193 | 20224 | 19568 | 18907 | 2.99 |
| Run 7 | 82862 | | 1.66 | 25057 | 24233 | 23854 | 23476 | 21350 | 20877 | 20045 | 19464 | 18910 | 2.75 |
| Run 8 | 73841 | | 1.52 | 23886 | 23229 | 22929 | 22610 | 20920 | 20512 | 19850 | 19380 | 18907 | 2.45 |
| Run 9 | 65248 | | 1.73 | 22895 | 22377 | 22109 | 21864 | 20531 | 20232 | 19679 | 19308 | 18952 | 2.16 |
| Run 10 | 54445 | | 1.44 | 26280 | 25890 | 25707 | 25514 | 24586 | 24354 | 23973 | 23682 | 23416 | 1.80 |

## Appendix 41: CMC 5 % in 65 mm valve, 25% open

### CMC 5 % in 65 mm valve, 25 % open

**CMC 5 % in 65 mm valve, 25 % open**

| | | | |
|---|---|---|---|
| **Date:** | 12/13/2006 | Test done by Mume | |
| **Valve Type:** | Diaphragm | | |
| **Valve dimension[m]:** | 0.065 | | |
| **Valve position:** | ¼ Open | **Area[m²]** | |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 | |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.724 | 0.367 | 2.724 | 10.04 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | CMC 5% | | | | | | | | | | | | |
| **Density[kg/m³]:** | 1026.7 | | | | | | | | | | | | |
| **Concentration:** | 5% | | | | | | | | | | | | |
| **$t_y$:** | 0 | | | | | | | | | | | | |
| **K:** | 3.81 | | | | | | | | | | | | |
| **n:** | 0.58 | **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 | | |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 | | |
| | | **Distances[m]:** | 0 | 2.068 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 | | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 194.9 | | 28.69 | 135555 | 126578 | 116611 | 107061 | 70817 | 65879 | 61091 | 56205 | 51729 | 4.16 |
| Run 2 | 178.1 | | 30.18 | 130835 | 120995 | 111793 | 102621 | 68967 | 64218 | 59601 | 54932 | 50515 | 3.90 |
| Run 3 | 166.1 | | 30.51 | 126337 | 116937 | 107652 | 98868 | 67353 | 62844 | 58312 | 53768 | 49458 | 3.72 |
| Run 4 | 153.9 | | 32.28 | 123352 | 114251 | 105143 | 96484 | 66681 | 62259 | 57861 | 53435 | 49290 | 3.52 |
| Run 5 | 140.3 | | 32.95 | 117545 | 108605 | 99933 | 91650 | 64500 | 60284 | 56083 | 51844 | 47869 | 3.30 |
| Run 6 | 130.4 | | 33.62 | 113321 | 104405 | 96309 | 88229 | 62926 | 58812 | 54769 | 50688 | 46828 | 3.13 |
| Run 7 | 114.3 | | 35.31 | 107078 | 99031 | 91279 | 83534 | 60631 | 56798 | 52985 | 49101 | 45448 | 2.86 |
| Run 8 | 107.2 | | 36.37 | 104383 | 96446 | 88783 | 81334 | 59652 | 55858 | 52135 | 48347 | 44781 | 2.73 |
| Run 9 | 93.41 | | 37.07 | 98403 | 90986 | 83802 | 76794 | 57442 | 53841 | 50278 | 46682 | 43301 | 2.48 |
| Run 10 | 82.13 | | 40.44 | 94251 | 87110 | 80248 | 73677 | 55726 | 52276 | 48852 | 45438 | 42220 | 2.26 |
| Run 11 | 74.04 | | 41.67 | 90679 | 84025 | 77532 | 71090 | 54452 | 51165 | 47900 | 44583 | 41528 | 2.10 |
| Run 12 | 62.36 | | 44.84 | 84558 | 78158 | 72194 | 66281 | 51726 | 48738 | 45719 | 42680 | 39817 | 1.86 |
| Run 13 | 47.84 | | 51.69 | 80575 | 74807 | 69410 | 64132 | 52054 | 49345 | 46625 | 43883 | 41363 | 1.55 |
| Run 14 | 36.20 | | 64.81 | 73750 | 68556 | 63847 | 59053 | 48840 | 46413 | 44059 | 41630 | 39384 | 1.27 |
| Run 15 | 26.98 | | 86.19 | 68189 | 63583 | 59174 | 54893 | 46049 | 43918 | 41796 | 39654 | 37639 | 1.03 |

## Appendix 42: Kaolin 6 % in 65 mm valve, 25 % open

### Kaolin 6 % in 65 mm valve, 25 % open

Kaolin 6 % in 65 mm valve, 25 % open

| | | |
|---|---|---|
| **Date:** | 8/1/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.065 | |
| **Valve position:** | ¼ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 |

| | |
|---|---|
| **Material Type:** | Kaolin 6% |
| **Density[kg/m³]:** | 1103.9 |
| **Concentration:** | 6% |
| **$t_y$:** | 3.071 |
| **K:** | 2.038 |
| **n:** | 0.264 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 2 | 2416 | | 21.83 | 66343 | 64678 | 63337 | 62106 | 20413 | 19245 | 18304 | 17243 | 16503 | 5.60 |
| Run 3 | 2298 | | 23.71 | 64961 | 63187 | 62048 | 60755 | 20665 | 19081 | 18040 | 17170 | 16557 | 5.41 |
| Run 4 | 2139 | | 22.40 | 60936 | 59421 | 58227 | 56965 | 20284 | 19005 | 18096 | 17236 | 16375 | 5.18 |
| Run 5 | 1999 | | 22.10 | 58462 | 56972 | 55424 | 54151 | 20436 | 19016 | 18075 | 17169 | 16463 | 5.07 |
| Run 6 | 1935 | | 22.95 | 56901 | 55285 | 53995 | 52696 | 20169 | 18710 | 17865 | 17045 | 16414 | 4.93 |
| Run 7 | 1833 | | 22.85 | 53123 | 51868 | 50458 | 49229 | 19600 | 18518 | 17768 | 16969 | 16421 | 4.70 |
| Run 8 | 1660 | | 23.54 | 51034 | 49559 | 48335 | 47081 | 19847 | 18638 | 17790 | 17078 | 16472 | 4.46 |
| Run 9 | 1520 | | 24.09 | 48903 | 47540 | 46423 | 45280 | 19701 | 18689 | 17779 | 16983 | 16411 | 4.20 |
| Run 10 | 1975 | | 22.93 | 45948 | 44745 | 43579 | 42157 | 19074 | 18016 | 17186 | 16410 | 15911 | 3.94 |
| Run 11 | 1205 | | 25.19 | 42986 | 41578 | 40622 | 39272 | 18744 | 17687 | 17034 | 16276 | 15728 | 3.67 |
| Run 12 | 1004 | | 25.43 | 41613 | 40267 | 39044 | 37927 | 19901 | 19185 | 18490 | 17768 | 17175 | 3.37 |
| Run 13 | 870.7 | | 26.88 | 38591 | 37295 | 36235 | 35042 | 19794 | 18965 | 18266 | 17634 | 17070 | 3.05 |
| Run 14 | 721.6 | | 28.82 | 37038 | 35715 | 34621 | 33517 | 19814 | 19089 | 18575 | 17895 | 17410 | 2.76 |
| Run 15 | 548.5 | | 36.66 | 35430 | 34269 | 33177 | 32061 | 20090 | 19401 | 18822 | 18303 | 17768 | 2.32 |
| Run 16 | 698.5 | | 32.20 | 35880 | 34649 | 33643 | 32491 | 19800 | 19076 | 18489 | 17920 | 17510 | 2.60 |
| Run 17 | 606.8 | | 34.13 | 36055 | 34895 | 33748 | 32509 | 20152 | 19372 | 18823 | 18152 | 17754 | 2.47 |

## Appendix 43: Kaolin 10 % in 65 mm valve, 25 % open

### Kaolin 10 % in 65 mm valve, 25 % open

Kaolin 10 % in 65 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 8/14/2007 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension(m): | 0.065 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.06308 | 0.003125167 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | |
|---|---|
| Material Type: | Kaolin 10% |
| Density[kg/m³]: | 1169.4 |
| Concentration: | 10% |
| $t_y$: | 8.965 |
| K: | 7.098 |
| n: | 0.175 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| Distances[m]: | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 1 | 941.6 | | 28.21 | 94358 | 89996 | 86687 | 82793 | 33893 | 31290 | 29123 | 27054 | 25375 | 5.21 |
| Run 2 | 845.9 | | 28.47 | 91404 | 87346 | 83505 | 79761 | 33513 | 30924 | 28898 | 26898 | 25213 | 5.05 |
| Run 3 | 825.7 | | 29.33 | 88717 | 84771 | 81149 | 77434 | 33115 | 30699 | 28713 | 26678 | 25048 | 4.84 |
| Run 4 | 726.8 | | 30.14 | 86438 | 82171 | 78634 | 74904 | 32840 | 30345 | 28386 | 26350 | 24708 | 4.65 |
| Run 5 | 682.2 | | 30.65 | 84090 | 79936 | 76354 | 72637 | 32615 | 30061 | 28281 | 26226 | 24603 | 4.48 |
| Run 6 | 631.0 | | 31.99 | 81506 | 77456 | 73834 | 70112 | 32205 | 29858 | 27914 | 26001 | 24362 | 4.29 |
| Run 7 | 556.6 | | 31.63 | 78852 | 74684 | 71049 | 67194 | 32002 | 29686 | 27826 | 25807 | 24084 | 4.09 |
| Run 8 | 482.3 | | 35.05 | 77619 | 73430 | 69744 | 66284 | 31652 | 29550 | 27605 | 25654 | 24040 | 3.88 |
| Run 9 | 434.4 | | 38.92 | 75529 | 71339 | 67885 | 64540 | 31261 | 29230 | 27326 | 25379 | 23794 | 3.58 |
| Run 10 | 385.2 | | 41.26 | 74059 | 70185 | 66363 | 62994 | 31206 | 29123 | 27225 | 25301 | 23719 | 3.41 |
| Run 11 | 387.3 | | 43.00 | 72794 | 68990 | 65670 | 61815 | 31019 | 28946 | 27194 | 25081 | 23492 | 3.21 |
| Run 12 | 331.3 | | 48.12 | 72521 | 68765 | 65092 | 61454 | 30867 | 28837 | 27097 | 25071 | 23528 | 3.07 |
| Run 13 | 262.1 | | 52.62 | 70970 | 66688 | 63279 | 59919 | 30713 | 28602 | 26886 | 24951 | 23353 | 2.86 |
| Run 14 | 264.2 | | 52.83 | 68301 | 64267 | 61031 | 57314 | 30206 | 28387 | 26613 | 24449 | 23002 | 2.70 |
| Run 15 | 223.0 | | 58.04 | 66094 | 62002 | 58806 | 55252 | 29783 | 27859 | 26102 | 24143 | 22567 | 2.50 |
| Run 16 | 187.5 | | 61.29 | 61764 | 58151 | 54618 | 51098 | 29044 | 27175 | 25488 | 23525 | 22079 | 2.26 |
| Run 17 | 155.7 | | 62.96 | 59450 | 55704 | 52246 | 48861 | 28489 | 26743 | 25026 | 23076 | 21530 | 2.09 |
| Run 18 | 135.4 | | 70.08 | 56887 | 53189 | 49991 | 46582 | 27978 | 26311 | 24585 | 22648 | 21182 | 1.87 |
| Run 19 | 95.46 | | 82.73 | 55248 | 51411 | 48150 | 44627 | 27566 | 25920 | 24254 | 22279 | 20832 | 1.64 |
| Run 20 | 77.08 | | 95.90 | 53012 | 49337 | 46182 | 42663 | 27273 | 25596 | 23950 | 22043 | 20572 | 1.42 |
| Run 21 | 46.21 | | 127.3 | 51349 | 47706 | 44356 | 40898 | 26858 | 25290 | 23656 | 21657 | 20285 | 1.16 |
| Run 22 | 27.24 | | 191.1 | 49027 | 45432 | 42208 | 38894 | 26638 | 24990 | 23295 | 21489 | 20102 | 0.90 |

## Appendix 44: Kaolin 13 % in 65 mm valve, 25 % open

# Kaolin 13 % in 65 mm valve, 25 % open

Kaolin 13 % in 65 mm valve, 25 % open

| | | | |
|---|---|---|---|
| Date: | 8/30/2007 | Test done by Mume & Sisonke | |
| Valve Type: | Diaphragm | | |
| Valve dimension[m]: | 0.065 | | |
| Valve position: | ¼ Open | Area[m²] | |
| Pipe Diameter [m]: | 0.06308 | 0.003125167 | |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.637 | 0.177 | 5.637 | 75890 |

| | |
|---|---|
| Material Type: | Kaolin 13% |
| Density[kg/m³]: | 1214.8 |
| Concentration: | 13% |
| $t_y$: | 17.442 |
| K: | 11.285 |
| n: | 0.216 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| Distances[m]: | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 634.4 | | 20.50 | 124153 | 116887 | 111231 | 104926 | 56416 | 53066 | 49848 | 46128 | 43215 | 5.60 |
| Run 2 | 590.7 | | 22.79 | 123167 | 115717 | 109886 | 103529 | 56061 | 52731 | 49500 | 45977 | 43228 | 5.39 |
| Run 3 | 559.9 | | 23.21 | 121714 | 114577 | 108567 | 101988 | 56010 | 52699 | 49346 | 45894 | 43003 | 5.23 |
| Run 4 | 530.9 | | 23.44 | 120445 | 113014 | 107138 | 100632 | 55722 | 52596 | 49297 | 45500 | 42912 | 5.11 |
| Run 5 | 513.7 | | 23.59 | 118717 | 111326 | 105525 | 98954 | 55375 | 52165 | 48922 | 45349 | 42564 | 5.01 |
| Run 6 | 485.5 | | 23.84 | 117599 | 109920 | 104305 | 97733 | 55503 | 52298 | 48856 | 45525 | 42440 | 4.88 |
| Run 7 | 470.3 | | 23.79 | 115482 | 108553 | 102223 | 95772 | 54734 | 51572 | 48344 | 44931 | 41940 | 4.80 |
| Run 8 | 463.4 | | 23.50 | 113113 | 106066 | 100308 | 93647 | 54157 | 51054 | 47698 | 43989 | 41321 | 4.71 |
| Run 9 | 433.6 | | 24.54 | 110927 | 104020 | 97944 | 91578 | 53507 | 50372 | 47295 | 43958 | 41102 | 4.55 |
| Run 10 | 403.0 | | 25.14 | 108595 | 101933 | 95789 | 89493 | 53409 | 50308 | 47226 | 43919 | 41090 | 4.36 |
| Run 11 | 376.4 | | 24.51 | 105000 | 98281 | 92208 | 85733 | 52445 | 49442 | 46505 | 43215 | 40392 | 4.20 |
| Run 12 | 340.6 | | 26.01 | 103882 | 97171 | 91107 | 84690 | 53012 | 49978 | 46996 | 43650 | 40947 | 3.98 |
| Run 13 | 309.7 | | 27.30 | 100343 | 93918 | 87903 | 81592 | 51539 | 48585 | 45631 | 42401 | 39660 | 3.75 |
| Run 14 | 283.7 | | 27.39 | 97422 | 91157 | 85299 | 78879 | 51118 | 48172 | 45239 | 42049 | 39300 | 3.56 |
| Run 15 | 245.9 | | 28.98 | 95219 | 88606 | 82753 | 76308 | 50860 | 47921 | 44973 | 41789 | 39103 | 3.32 |
| Run 16 | 214.2 | | 29.15 | 91896 | 85556 | 79597 | 72852 | 50337 | 47470 | 44499 | 41351 | 38645 | 3.08 |
| Run 17 | 196.6 | | 30.07 | 89988 | 83848 | 77835 | 71727 | 50057 | 47176 | 44182 | 41113 | 38404 | 2.93 |
| Run 18 | 180.1 | | 29.82 | 88069 | 81892 | 76020 | 70072 | 49809 | 46915 | 43982 | 40907 | 38230 | 2.79 |
| Run 19 | 167.1 | | 30.15 | 86368 | 80433 | 74485 | 68484 | 49487 | 46680 | 43682 | 40749 | 37983 | 2.67 |
| Run 20 | 152.9 | | 31.96 | 85230 | 79187 | 73405 | 67645 | 49424 | 46560 | 43593 | 40598 | 37992 | 2.53 |
| Run 21 | 139.5 | | 30.01 | 82929 | 76802 | 71153 | 65432 | 48907 | 46070 | 43110 | 40131 | 37503 | 2.41 |
| Run 22 | 126.8 | | 31.05 | 81657 | 75646 | 69932 | 64259 | 48649 | 45862 | 42872 | 39995 | 37320 | 2.29 |
| Run 23 | 116.6 | | 30.56 | 79994 | 74055 | 68723 | 62945 | 48324 | 45491 | 42605 | 39745 | 37091 | 2.16 |
| Run 24 | 106.8 | | 31.53 | 79880 | 73610 | 68016 | 62319 | 48085 | 45303 | 42461 | 39622 | 36912 | 2.11 |
| Run 25 | 99.20 | | 31.78 | 78500 | 72713 | 66985 | 61430 | 47893 | 45236 | 42328 | 39542 | 36847 | 2.00 |
| Run 26 | 83.65 | | 28.54 | 76877 | 71014 | 65646 | 60062 | 47443 | 44659 | 41953 | 39079 | 36339 | 1.82 |

**Appendix 45: Water in 65 mm valve, 50 % open**

Water in 65 mm valve, 25 % open

**Water in 65 mm valve, 25 % open**

| | | |
|---|---|---|
| **Date:** | 11/24/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.065 | |
| **Valve position:** | ¼ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.00079018 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | Water | | | | | | | | | | | | |
| **Density[kg/m³]:** | 995.427097 | | | | | | | | | | | | |
| **Concentration:** | 100% | | | | | | | | | | | | |
| **$t_y$:** | 0 | | | | | | | | | | | | |
| **K:** | 0.00079018 | | | | | | | | | | | | |
| **n:** | 1 | | **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 | |
| **PPT used:** | 101 to 109 | | **Valve plane** | | | | | | | | | | |
| **Range selected:** | 0-130 | | **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 | |
| | | | **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 | |
| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 86803 | | 27.71 | 40380 | 39979 | 39309 | 39040 | 22010 | 21534 | 21145 | 20795 | 20594 | 3.41 |
| **Run 2** | 97852 | | 25.24 | 44179 | 43528 | 42896 | 42612 | 22400 | 22007 | 21538 | 21082 | 20838 | 3.85 |
| **Run 3** | 105762 | | 24.37 | 47165 | 47039 | 46475 | 45819 | 22793 | 22310 | 21818 | 21415 | 21056 | 4.16 |
| **Run 4** | 113350 | | 24.58 | 51278 | 49954 | 49390 | 48855 | 23207 | 22708 | 22107 | 21625 | 21297 | 4.46 |
| **Run 5** | 119248 | | 24.93 | 55035 | 54005 | 53612 | 53271 | 23776 | 23054 | 22414 | 21884 | 21524 | 4.69 |
| **Run 6** | 127954 | | 24.72 | 59962 | 59483 | 58643 | 58012 | 23978 | 23393 | 22744 | 22069 | 21695 | 5.03 |
| **Run 7** | 134845 | | 25.83 | 64743 | 63840 | 62959 | 62455 | 23530 | 22819 | 21980 | 21310 | 20862 | 5.30 |
| **Run 8** | 142191 | | 26.81 | 71512 | 70606 | 69701 | 68828 | 23873 | 23103 | 22353 | 21599 | 21100 | 5.59 |
| **Run 9** | 148862 | | 28.30 | 79366 | 78412 | 77567 | 76372 | 24468 | 23596 | 22765 | 21948 | 21374 | 5.85 |
| **Run 10** | 156038 | | 30.40 | 89434 | 88222 | 86780 | 85913 | 25094 | 24081 | 23274 | 22250 | 21740 | 6.14 |
| **Run 11** | 164557 | | 31.68 | 98881 | 97818 | 96681 | 95156 | 25269 | 24393 | 23507 | 22640 | 21995 | 6.47 |
| **Run 12** | 170548 | | 33.01 | 108193 | 106555 | 105601 | 104486 | 25903 | 24743 | 23867 | 22823 | 22203 | 6.71 |
| **Run 13** | 176082 | | 35.69 | 119556 | 117755 | 116523 | 115260 | 26480 | 25271 | 24185 | 23215 | 22613 | 6.92 |
| **Run 14** | 179565 | | 36.02 | 124244 | 122768 | 121344 | 119911 | 26519 | 25338 | 24292 | 23270 | 22655 | 7.06 |

## Appendix 46: CMC 5 % in 65 mm valve, 50 % open

CMC 5 % in 65 mm valve, 50 % open

CMC 5 % in 65 mm valve, 50 % open

| | | | |
|---|---|---|---|
| Date: | 12/13/2006 | Test done by Mume | |
| Valve Type: | Diaphragm | | |
| Valve dimension[m]: | 0.065 | | |
| Valve position: | ½ Open | Area[m²] | |
| Pipe Diameter [m]: | 0.06308 | 0.003125167 | |

| | |
|---|---|
| Material Type: | CMC 5% |
| Density[kg/m³]: | 1026.7 |
| Concentration: | 5% |
| $t_y$: | 0 |
| K: | 3.88 |
| n: | 0.58 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.724 | 0.367 | 2.724 | 10.36 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| Distances[m]: | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.69 | 11.83 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 246.5 | | 7.24 | 129736 | 118152 | 107153 | 96459 | 77066 | 71519 | 66280 | 60870 | 55776 | 4.97 |
| Run 2 | 232.6 | | 6.78 | 125933 | 115009 | 104480 | 93860 | 75382 | 70160 | 64907 | 59723 | 54731 | 4.77 |
| Run 3 | 221.0 | | 7.66 | 123876 | 112746 | 102412 | 92204 | 74207 | 69024 | 63968 | 58856 | 54077 | 4.60 |
| Run 4 | 209.8 | | 7.14 | 120880 | 110335 | 100099 | 90134 | 72829 | 67907 | 62838 | 57877 | 53137 | 4.44 |
| Run 5 | 202.0 | | 7.58 | 119023 | 108612 | 98610 | 88765 | 71958 | 66966 | 62157 | 57240 | 52557 | 4.32 |
| Run 6 | 190.8 | | 6.98 | 116135 | 106112 | 96347 | 86898 | 70652 | 65940 | 61093 | 56284 | 51738 | 4.15 |
| Run 7 | 175.3 | | 7.46 | 112476 | 102755 | 93477 | 84121 | 68836 | 64145 | 59486 | 54885 | 50443 | 3.91 |
| Run 8 | 163.3 | | 7.95 | 110371 | 100869 | 91741 | 82824 | 68062 | 63510 | 59015 | 54501 | 50229 | 3.72 |
| Run 9 | 151.1 | | 7.80 | 107194 | 97832 | 89034 | 80398 | 66541 | 62139 | 57752 | 53374 | 49222 | 3.52 |
| Run 11 | 128.7 | | 7.97 | 100844 | 91901 | 83872 | 75834 | 63343 | 59229 | 55151 | 51005 | 47160 | 3.14 |
| Run 12 | 117.9 | | 8.55 | 97870 | 89441 | 81529 | 73710 | 61903 | 57887 | 53977 | 49982 | 46258 | 2.96 |
| Run 13 | 106.5 | | 8.86 | 94325 | 86385 | 78724 | 71291 | 60028 | 56282 | 52426 | 48674 | 45098 | 2.75 |
| Run 14 | 95.34 | | 9.41 | 90974 | 83156 | 75988 | 68815 | 58187 | 54636 | 51034 | 47367 | 43957 | 2.55 |

## Appendix 47: Kaolin 6 % in 65 mm valve, 50 % open

Kaolin 6 % in 65 mm valve, 50 % open

Kaolin 6 % in 65 mm valve, 50 % open

| | | |
|---|---|---|
| Date: | 8/1/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.065 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.06308 | 0.003125167 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | |
|---|---|
| Material Type: | Kaolin 6% |
| Density[kg/m³]: | 1103.9 |
| Concentration: | 6% |
| $t_y$: | 3.071 |
| K: | 2.038 |
| n: | 0.264 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 | |
| | | | Distances[m]: | 0 | 2.088 | 4.069 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 2902 | | 3.76 | 33978 | 32471 | 31034 | 29473 | 19763 | 18903 | 17989 | 17191 | 16448 | 6.15 |
| Run 2 | 2686 | | 3.84 | 33411 | 31847 | 30337 | 28896 | 19770 | 18982 | 18027 | 17283 | 16533 | 5.95 |
| Run 3 | 2571 | | 4.03 | 33122 | 31497 | 29983 | 28636 | 19845 | 18962 | 18116 | 17263 | 16708 | 5.84 |
| Run 4 | 2595 | | 4.36 | 33001 | 31428 | 29878 | 28803 | 19897 | 18850 | 18047 | 17396 | 16786 | 5.86 |
| Run 5 | 2523 | | 3.89 | 32715 | 31054 | 29807 | 28379 | 19776 | 18997 | 18141 | 17433 | 16706 | 5.68 |
| Run 6 | 2492 | | 4.17 | 32174 | 30660 | 29380 | 27950 | 19573 | 18680 | 18012 | 17238 | 16688 | 5.58 |
| Run 7 | 2280 | | 3.80 | 31391 | 29892 | 28673 | 27362 | 19489 | 18704 | 18025 | 17146 | 16611 | 5.31 |
| Run 8 | 2180 | | 4.54 | 30996 | 29478 | 28262 | 26974 | 19384 | 18579 | 17744 | 16998 | 16497 | 5.15 |
| Run 9 | 1969 | | 4.35 | 30295 | 28689 | 27637 | 26364 | 19299 | 18478 | 17729 | 16795 | 16424 | 4.87 |
| Run 10 | 1882 | | 4.19 | 29858 | 28498 | 27273 | 25962 | 19045 | 18395 | 17788 | 16996 | 16474 | 4.73 |
| Run 11 | 1609 | | 4.36 | 29288 | 27900 | 26549 | 25329 | 19107 | 18410 | 17734 | 16977 | 16413 | 4.40 |
| Run 12 | 1422 | | 4.12 | 28180 | 26754 | 25563 | 24123 | 18570 | 17934 | 17388 | 16700 | 16053 | 4.08 |
| Run 13 | 1302 | | 4.84 | 27309 | 25967 | 24826 | 23586 | 18406 | 17718 | 17073 | 16351 | 15865 | 3.83 |
| Run 14 | 1089 | | 4.21 | 28087 | 26749 | 25591 | 24378 | 19795 | 19132 | 18564 | 17776 | 17280 | 3.50 |
| Run 15 | 974 | | 5.02 | 27643 | 26355 | 25155 | 23896 | 19629 | 19042 | 18471 | 17699 | 17274 | 3.27 |
| Run 16 | 867 | | 5.45 | 27000 | 25798 | 24566 | 23450 | 19536 | 18957 | 18349 | 17588 | 17214 | 3.04 |
| Run 17 | 742 | | 5.40 | 26816 | 25582 | 24519 | 23338 | 19940 | 19416 | 18828 | 18194 | 17730 | 2.76 |
| Run 18 | 483 | | 5.14 | 26356 | 25158 | 24108 | 22961 | 20088 | 19524 | 19022 | 18294 | 17868 | 2.19 |

## Appendix 48: Kaolin 10 % in 65 mm valve, 50 % open

### Kaolin 10 % in 65 mm valve, 50 % open

Kaolin 10 % in 65 mm valve, 50 % open

| | | |
|---|---|---|
| Date: | 8/14/2007 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.065 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.06308 | 0.003125167 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | Kaolin 10% | | | | | | | | | | | |
| Density[kg/m³]: | 1169.4 | | | | | | | | | | | |
| Concentration: | 10% | | | | | | | | | | | |
| $t_y$: | 8.965 | | | | | | | | | | | |
| K: | 7.098 | | | | | | | | | | | |
| n: | 0.175 | Axial distances | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 | |
| PPT used: | 101 to 109 | Valve plane | | | | | | | | | | |
| Range selected: | 0 130 | Non-dimensionalised distances incl.[L/D]: | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 | |
| | | Distances[m]: | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 1016 | | 6.18 | 60590 | 56450 | 52545 | 48664 | 33449 | 31402 | 29439 | 27395 | 25641 | 5.59 |
| Run 2 | 977.6 | | 6.36 | 59756 | 55652 | 51860 | 48091 | 33272 | 31216 | 29261 | 27292 | 25537 | 5.41 |
| Run 3 | 870.5 | | 6.51 | 58585 | 54500 | 50689 | 46933 | 32952 | 30971 | 29113 | 27059 | 25377 | 5.12 |
| Run 4 | 836.7 | | 6.54 | 57748 | 53640 | 49942 | 46186 | 32665 | 30715 | 28791 | 26700 | 25057 | 4.97 |
| Run 5 | 778.0 | | 6.53 | 56735 | 52560 | 48935 | 44985 | 32318 | 30474 | 28508 | 26422 | 24789 | 4.80 |
| Run 6 | 719.6 | | 6.36 | 55659 | 51772 | 47980 | 44109 | 32075 | 30187 | 28294 | 26294 | 24524 | 4.57 |
| Run 7 | 646.2 | | 6.51 | 54731 | 50715 | 47009 | 43293 | 31723 | 29840 | 28077 | 25855 | 24332 | 4.35 |
| Run 8 | 592.8 | | 6.89 | 53812 | 49919 | 46198 | 42425 | 31402 | 29558 | 27735 | 25691 | 24039 | 4.13 |
| Run 9 | 525.4 | | 8.03 | 53566 | 49455 | 45739 | 42160 | 31383 | 29562 | 27533 | 25625 | 23989 | 4.01 |
| Run 10 | 465.0 | | 7.54 | 52765 | 48746 | 45038 | 41449 | 31188 | 29330 | 27492 | 25278 | 23798 | 3.73 |
| Run 11 | 415.5 | | 7.85 | 52213 | 48250 | 44487 | 40949 | 30843 | 29102 | 27300 | 25242 | 23603 | 3.53 |
| Run 12 | 384.0 | | 7.30 | 51613 | 47705 | 44122 | 40369 | 30751 | 28942 | 27171 | 24995 | 23354 | 3.30 |
| Run 13 | 334.4 | | 8.85 | 50999 | 47154 | 43490 | 39882 | 30513 | 28771 | 26906 | 24723 | 23212 | 3.10 |
| Run 14 | 287.8 | | 10.36 | 50180 | 46305 | 42714 | 38998 | 30244 | 28416 | 26632 | 24361 | 23048 | 2.88 |
| Run 15 | 264.1 | | 12.00 | 49831 | 45937 | 42372 | 38683 | 29986 | 28258 | 26419 | 24173 | 22934 | 2.77 |
| Run 16 | 230.2 | | 10.02 | 48136 | 44361 | 40905 | 37433 | 29404 | 27713 | 25929 | 23845 | 22354 | 2.52 |
| Run 17 | 196.0 | | 10.37 | 46477 | 42788 | 39212 | 35834 | 28738 | 26915 | 25120 | 23085 | 21630 | 2.34 |
| Run 18 | 161.9 | | 12.40 | 45596 | 41934 | 38345 | 34954 | 28230 | 26639 | 24771 | 22841 | 21386 | 2.15 |
| Run 19 | 127.7 | | 9.46 | 44594 | 40848 | 37411 | 33978 | 27754 | 26096 | 24418 | 22438 | 20899 | 1.90 |
| Run 20 | 90.73 | | 12.34 | 43593 | 39912 | 36446 | 33101 | 27356 | 25783 | 24030 | 22042 | 20604 | 1.62 |
| Run 21 | 71.37 | | 12.04 | 42882 | 39249 | 35877 | 32564 | 27077 | 25512 | 23810 | 21803 | 20384 | 1.41 |
| Run 22 | 40.95 | | 16.31 | 42043 | 38404 | 35072 | 31695 | 26818 | 25149 | 23494 | 21434 | 20117 | 1.10 |
| Run 23 | 26.62 | | 17.16 | 41368 | 37709 | 34526 | 31192 | 26495 | 24684 | 23215 | 21079 | 19844 | 0.89 |

**Appendix 49: Kaolin 13 % in 65 mm valve, 50 % open**

Kaolin 13 % in 65 mm valve, 50 % open

Kaolin 13 % in 65 mm valve, 50 % open

| | | |
|---|---|---|
| **Date:** | 8/30/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.065 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.637 | 0.177 | 5.637 | 75890 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | Kaolin 13% | | | | | | | | | | |
| **Density[kg/m³]:** | 1214.8 | | | | | | | | | | |
| **Concentration:** | 13% | | | | | | | | | | |
| $t_y$: | 17.44226 | | | | | | | | | | |
| K: | 11.28519 | | | | | | | | | | |
| n: | 0.21567 | **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| | | **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 694.5 | | 4.41 | 92500 | 85241 | 79024 | 72369 | 55346 | 52622 | 49327 | 45649 | 42828 | 5.91 |
| **Run 2** | 646.6 | | 4.51 | 92363 | 85050 | 78713 | 72114 | 55795 | 52845 | 49644 | 45678 | 43136 | 5.72 |
| **Run 3** | 592.3 | | 4.88 | 91589 | 83482 | 78000 | 71327 | 55647 | 52624 | 49487 | 46220 | 43145 | 5.44 |
| **Run 4** | 560.2 | | 4.89 | 89419 | 82550 | 76372 | 69937 | 55139 | 51987 | 48825 | 45378 | 42564 | 5.22 |
| **Run 5** | 514.8 | | 4.78 | 89397 | 82145 | 75945 | 69482 | 55179 | 52064 | 48886 | 45447 | 42521 | 5.05 |
| **Run 6** | 469.6 | | 5.30 | 87985 | 80784 | 74597 | 68261 | 54606 | 51450 | 48310 | 44846 | 42099 | 4.79 |
| **Run 7** | 429.8 | | 5.16 | 86582 | 79490 | 73210 | 66882 | 54323 | 51117 | 48039 | 44581 | 41874 | 4.57 |
| **Run 8** | 397.8 | | 4.50 | 84328 | 78015 | 71180 | 65509 | 53675 | 50573 | 47549 | 43776 | 41401 | 4.37 |
| **Run 9** | 361.2 | | 5.33 | 83776 | 76928 | 70725 | 64470 | 53049 | 50034 | 47043 | 43955 | 41035 | 4.13 |
| **Run 10** | 336.8 | | 4.76 | 81084 | 74891 | 68812 | 62691 | 51728 | 48681 | 45686 | 42450 | 39690 | 3.91 |
| **Run 11** | 292.0 | | 5.54 | 80609 | 74026 | 67954 | 61932 | 51259 | 48289 | 45349 | 42035 | 39404 | 3.66 |
| **Run 12** | 253.6 | | 8.87 | 79521 | 72829 | 66923 | 60732 | 50807 | 47791 | 44916 | 42214 | 39434 | 3.35 |
| **Run 13** | 210.0 | | 6.04 | 78806 | 72142 | 66268 | 60101 | 50930 | 47964 | 45008 | 41800 | 39152 | 3.07 |
| **Run 14** | 186.0 | | 5.59 | 77150 | 70596 | 64778 | 58601 | 49873 | 46910 | 44118 | 40887 | 38275 | 2.87 |
| **Run 15** | 171.0 | | 4.10 | 76588 | 70692 | 64711 | 58365 | 50188 | 47271 | 44437 | 40699 | 38525 | 2.72 |
| **Run 16** | 154.2 | | 12.14 | 75830 | 69452 | 63645 | 57156 | 49249 | 46484 | 43649 | 41255 | 38387 | 2.55 |
| **Run 17** | 145.3 | | 5.92 | 75308 | 68918 | 63332 | 57345 | 49210 | 46355 | 43508 | 40437 | 37799 | 2.49 |
| **Run 18** | 126.6 | | 6.22 | 75429 | 69128 | 63283 | 57325 | 49427 | 46639 | 43788 | 40573 | 38058 | 2.33 |
| **Run 19** | 117.6 | | 7.79 | 74566 | 67978 | 62397 | 56473 | 48735 | 45908 | 43064 | 39841 | 37440 | 2.24 |
| **Run 20** | 107.8 | | 15.42 | 73617 | 67146 | 61606 | 55587 | 48212 | 45454 | 42704 | 40309 | 37567 | 2.10 |
| **Run 21** | 95.45 | | 5.86 | 72845 | 66444 | 61092 | 55068 | 47881 | 45149 | 42434 | 39349 | 36834 | 1.98 |
| **Run 22** | 82.51 | | 4.91 | 73092 | 66811 | 61094 | 54904 | 48033 | 45367 | 42639 | 39220 | 36929 | 1.87 |

## Appendix 50: Water in 65 mm valve, 50 % open

### Water in 65 mm valve, 50 % open

**Water in 65 mm valve, 50 % open**

| | | |
|---|---|---|
| **Date:** | 11/24/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.065 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 |

| | |
|---|---|
| **Material Type:** | Water |
| **Density[kg/m³]:** | 999.87 |
| **Concentration:** | 100% |
| **$t_y$:** | 0 |
| **K:** | 0.001 |
| **n:** | 1 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.001 |

| Run # | $Re_3$ | $k_{v\ excl.}$ | $k_{v\ incl.}$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 | |
| | | | **Valve plane** | | | | | | | | | | |
| | | | **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 | |
| | | | **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 | |
| | | | | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [l/s] |
| Run 1 | 308602 | | 3.55 | 121922 | 115964 | 110083 | 103845 | 52120 | 49415 | 45895 | 42051 | 39360 | 15.29 |
| Run 2 | 303494 | | 3.69 | 119032 | 113130 | 107174 | 101439 | 51393 | 48346 | 45056 | 41249 | 38949 | 15.04 |
| Run 3 | 296314 | | 3.59 | 113515 | 107683 | 102212 | 96394 | 49875 | 46847 | 43618 | 40184 | 37743 | 14.68 |
| Run 4 | 287660 | | 3.43 | 106304 | 101412 | 95815 | 90821 | 47266 | 44993 | 42165 | 38554 | 36576 | 14.25 |
| Run 5 | 280043 | | 3.49 | 101851 | 97106 | 92052 | 86972 | 46463 | 43835 | 40764 | 37717 | 35560 | 13.88 |
| Run 6 | 270263 | | 3.70 | 95004 | 90326 | 85792 | 81097 | 43775 | 41778 | 38847 | 36319 | 34523 | 13.39 |
| Run 7 | 260826 | | 3.35 | 88888 | 84720 | 80223 | 75809 | 42011 | 40121 | 37729 | 35064 | 33332 | 12.92 |
| Run 8 | 253069 | | 3.27 | 83697 | 79520 | 75643 | 71327 | 40514 | 38431 | 36288 | 33824 | 32193 | 12.54 |
| Run 9 | 244809 | | 3.25 | 78880 | 75150 | 71302 | 67518 | 39167 | 37422 | 35046 | 32853 | 31271 | 12.13 |
| Run 10 | 233241 | | 3.06 | 72620 | 69198 | 65862 | 62287 | 36839 | 35210 | 33382 | 31248 | 29815 | 11.56 |
| Run 11 | 226578 | | 3.08 | 69551 | 66501 | 63337 | 59976 | 35681 | 34318 | 32463 | 30462 | 29101 | 11.23 |
| Run 12 | 218686 | | 3.05 | 65608 | 62500 | 59603 | 56575 | 34372 | 33005 | 31399 | 29490 | 28304 | 10.84 |
| Run 13 | 204816 | | 3.02 | 58627 | 55881 | 53326 | 50699 | 32018 | 30969 | 29548 | 27880 | 26982 | 10.15 |
| Run 14 | 193036 | | 2.75 | 53244 | 50828 | 48629 | 46190 | 30383 | 29423 | 28135 | 26738 | 25758 | 9.56 |
| Run 15 | 181005 | | 2.67 | 48132 | 46112 | 44185 | 42083 | 28713 | 27939 | 26818 | 25574 | 24804 | 8.97 |
| Run 16 | 172731 | | 2.54 | 45173 | 43279 | 41435 | 39566 | 28028 | 26899 | 25905 | 24766 | 24004 | 8.56 |
| Run 17 | 159041 | | 2.62 | 40677 | 38956 | 37420 | 35906 | 26113 | 25436 | 24505 | 23801 | 22992 | 7.88 |

**Appendix 51: CMC 5 % in 65 mm valve, 75 % open**

## CMC 5 % in 65 mm valve, 75 % open

CMC 5 % in 65 mm valve, 75 % open

| | | | |
|---|---|---|---|
| **Date:** | 12/13/2006 | Test done by Mume | |
| **Valve Type:** | Diaphragm | | |
| **Valve dimension[m]:** | 0.065 | | |
| **Valve position:** | ¾ Open | **Area[m²]** | |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 | |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.493 | 0.401 | 2.493 | 3.740 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | CMC 5% | | | | | | | | | | | |
| **Density[kg/m³]:** | 1026.7 | | | | | | | | | | | |
| **Concentration:** | 5% | | | | | | | | | | | |
| **$t_y$:** | 0 | | | | | | | | | | | |
| **K:** | 2.42 | | | | | | | | | | | |
| **n:** | 0.67 | **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 | |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 | |
| | | **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 | |

| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 289.4 | | 3.29 | 135214 | 123289 | 111451 | 99883 | 82549 | 76632 | 70809 | 64967 | 59445 | 5.63 |
| **Run 2** | 279.4 | | 3.50 | 133383 | 121523 | 109746 | 98290 | 81337 | 75557 | 69846 | 64094 | 58637 | 5.48 |
| **Run 3** | 272.3 | | 3.58 | 132224 | 120337 | 108814 | 97273 | 80701 | 74939 | 69277 | 63573 | 58177 | 5.38 |
| **Run 4** | 263.6 | | 3.51 | 130303 | 118769 | 106940 | 95919 | 79781 | 74154 | 68434 | 62838 | 57579 | 5.25 |
| **Run 5** | 254.8 | | 3.68 | 128804 | 116795 | 105754 | 94663 | 78815 | 73214 | 67732 | 62221 | 56905 | 5.12 |
| **Run 6** | 243.8 | | 3.55 | 125954 | 114547 | 103535 | 92732 | 77376 | 72044 | 66530 | 61081 | 56081 | 4.95 |
| **Run 7** | 235.9 | | 3.73 | 123862 | 112493 | 101771 | 91259 | 76159 | 71018 | 65566 | 60410 | 55356 | 4.83 |
| **Run 8** | 231.7 | | 3.84 | 122612 | 111457 | 100918 | 90413 | 75546 | 70418 | 65108 | 59937 | 55005 | 4.76 |
| **Run 9** | 221.6 | | 4.01 | 120659 | 109562 | 99157 | 88937 | 74600 | 69398 | 64204 | 59134 | 54254 | 4.61 |
| **Run 10** | 208.8 | | 4.13 | 118002 | 107190 | 97068 | 87073 | 73182 | 68171 | 63166 | 58181 | 53429 | 4.40 |

## Appendix 52: Kaolin 6 % in 65 mm valve, 75 % open

### Kaolin 6 % in 65 mm valve, 75 % open

Kaolin 6 % in 65 mm valve, 75 % open

| | | |
|---|---|---|
| Date: | 7/31/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.065 | |
| Valve position: | ¾ Open | Area[m²] |
| Pipe Diameter [m]: | 0.06308 | 0.003125167 |

| | |
|---|---|
| Material Type: | Kaolin 6% |
| Density[kg/m³]: | 1103.9 |
| Concentration: | 0.06 |
| $t_y$: | 3.071 |
| K: | 2.038 |
| n: | 0.264 |
| PPT used: | 101 to 109 |
| Range selected: | 0-40 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances / Valve plane | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| Non-dimensionalised distances incl.[L/D]: | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| Distances[m]: | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 4 | 2576 | | 1.79 | 36185 | 34690 | 33376 | 31845 | 26538 | 25711 | 25026 | 24125 | 23505 | 5.72 |
| Run 5 | 2420 | | 1.78 | 35537 | 34152 | 32764 | 31302 | 26485 | 25632 | 24875 | 24005 | 23397 | 5.52 |
| Run 6 | 2293 | | 1.93 | 35092 | 33604 | 32373 | 31000 | 26295 | 25526 | 24761 | 23919 | 23360 | 5.33 |
| Run 8 | 2110 | | 1.90 | 36443 | 34848 | 33674 | 32316 | 27940 | 27144 | 26424 | 25511 | 25027 | 5.11 |
| Run 10 | 1926 | | 1.78 | 35941 | 34354 | 33180 | 31858 | 27724 | 27014 | 26308 | 25396 | 24903 | 4.86 |
| Run 11 | 1788 | | 1.89 | 35354 | 33968 | 32717 | 31497 | 27639 | 26862 | 26201 | 25460 | 24870 | 4.62 |
| Run 12 | 1628 | | 1.92 | 35692 | 34317 | 33094 | 31824 | 28169 | 27463 | 26793 | 26057 | 25472 | 4.38 |
| Run 14 | 1412 | | 1.93 | 35193 | 33803 | 32541 | 31320 | 27988 | 27312 | 26664 | 25906 | 25360 | 4.07 |
| Run 15 | 1299 | | 2.00 | 34818 | 33465 | 32275 | 30951 | 27824 | 27181 | 26533 | 25781 | 25251 | 3.86 |
| Run 16 | 1198 | | 1.74 | 34444 | 33158 | 31928 | 30736 | 27771 | 27126 | 26482 | 25729 | 25193 | 3.69 |
| Run 18 | 1071 | | 1.83 | 34133 | 32849 | 31641 | 30403 | 27650 | 26990 | 26366 | 25648 | 25098 | 3.46 |
| Run 20 | 970.2 | | 1.88 | 33888 | 32506 | 31410 | 30126 | 27543 | 26886 | 26257 | 25501 | 25001 | 3.28 |
| Run 21 | 836.7 | | 0.96 | 33331 | 32081 | 30850 | 29736 | 27338 | 26670 | 26115 | 25409 | 24811 | 3.04 |
| Run 22 | 725.8 | | 1.21 | 33132 | 31775 | 30664 | 29498 | 27269 | 26681 | 26095 | 25366 | 24838 | 2.80 |
| Run 24 | 546.8 | | 1.52 | 32838 | 31478 | 30403 | 29162 | 27174 | 26580 | 26013 | 25156 | 24783 | 2.40 |

## Appendix 53: Kaolin 10 % in 65 mm valve, 75 % open

### Kaolin 10 % in 65 mm valve, 75 % open

**Kaolin 10 % in 65 mm valve, 75 % open**

| | | |
|---|---|---|
| **Date:** | 8/14/2007 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.065 | |
| **Valve position:** | ¾ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 |

| | |
|---|---|
| **Material Type:** | Kaolin 10% |
| **Density[kg/m³]:** | 1169.4 |
| **Concentration:** | 10% |
| **$t_y$:** | 8.965 |
| **K:** | 7.098 |
| **n:** | 0.175 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 1 | 980.5 | | 3.08 | 54527 | 50298 | 46481 | 42495 | 33195 | 31270 | 29328 | 27246 | 25527 | 5.50 |
| Run 2 | 934.6 | | 3.52 | 54019 | 49944 | 46056 | 42115 | 32989 | 31041 | 29124 | 27120 | 25457 | 5.34 |
| Run 3 | 894.5 | | 3.46 | 53634 | 49512 | 45660 | 41713 | 32828 | 30909 | 28970 | 26955 | 25286 | 5.23 |
| Run 4 | 858.3 | | 3.39 | 53162 | 49044 | 45259 | 41336 | 32581 | 30660 | 28765 | 26630 | 25050 | 5.09 |
| Run 5 | 832.0 | | 3.00 | 52613 | 48513 | 44760 | 40799 | 32387 | 30440 | 28604 | 26469 | 24813 | 4.98 |
| Run 6 | 807.2 | | 3.16 | 52016 | 48004 | 44236 | 40393 | 32153 | 30281 | 28356 | 26265 | 24636 | 4.88 |
| Run 7 | 754.9 | | 3.01 | 51378 | 47292 | 43595 | 39769 | 31834 | 29950 | 28118 | 26001 | 24387 | 4.72 |
| Run 8 | 699.7 | | 2.85 | 50491 | 46457 | 42765 | 38868 | 31325 | 29554 | 27741 | 25576 | 24005 | 4.53 |
| Run 9 | 637.9 | | 3.39 | 50077 | 46136 | 42349 | 38546 | 31137 | 29424 | 27516 | 25305 | 23866 | 4.33 |
| Run 10 | 558.4 | | 3.32 | 49412 | 45452 | 41732 | 38013 | 30833 | 29098 | 27252 | 24902 | 23567 | 4.04 |
| Run 11 | 488.3 | | 3.51 | 48866 | 44907 | 41307 | 37466 | 30654 | 28872 | 27056 | 24767 | 23386 | 3.74 |
| Run 12 | 443.1 | | 3.78 | 48308 | 44443 | 40789 | 37179 | 30443 | 28735 | 26880 | 24480 | 23257 | 3.56 |
| Run 14 | 286.3 | | 4.73 | 47059 | 43172 | 39569 | 35856 | 29816 | 27998 | 26240 | 24337 | 22662 | 2.88 |
| Run 15 | 252.1 | | 5.39 | 46527 | 42767 | 39109 | 35453 | 29327 | 27760 | 25885 | 23973 | 22331 | 2.69 |
| Run 16 | 210.4 | | 6.91 | 45262 | 41423 | 37877 | 34277 | 28622 | 26985 | 25139 | 23301 | 21729 | 2.47 |
| Run 20 | 70.53 | | 10.19 | 41251 | 37770 | 34446 | 31039 | 26733 | 25100 | 23370 | 21711 | 20126 | 1.36 |
| Run 21 | 32.03 | | 10.02 | 40512 | 36924 | 33603 | 30280 | 26251 | 24637 | 23005 | 21250 | 19725 | 0.98 |

## Appendix 54: Kaolin 13 % in 65 mm valve, 75 % open

### Kaolin 13 % in 65 mm valve, 75 % open

Kaolin 13 % in 65 mm valve, 75 % open

| | | |
|---|---|---|
| **Date:** | 12/12/2007 | Test done by Mume & Rendani |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.065 | |
| **Valve position:** | ¾ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 |

| | |
|---|---|
| **Material Type:** | Kaolin 13% |
| **Density[kg/m³]:** | 1215.5 |
| **Concentration:** | 13% |
| **$t_y$:** | 18.973 |
| **K:** | 16.141 |
| **n:** | 0.242 |
| **PPT used:** | 105 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 351.2 | | 4.30 | 86771 | 80486 | 74166 | 65976 | 56764 | 53187 | 49545 | 45982 | 43463 | 4.73 |
| **Run 2** | 301.8 | | 3.43 | 85544 | 79155 | 72995 | 64958 | 55499 | 51695 | 48278 | 44608 | 41843 | 4.41 |
| **Run 3** | 270.5 | | 2.94 | 84988 | 77781 | 71600 | 64560 | 54873 | 51503 | 48082 | 44678 | 41570 | 4.18 |
| **Run 4** | 232.5 | | 0.86 | 84405 | 77280 | 70520 | 63026 | 54219 | 50608 | 47776 | 43788 | 40817 | 3.91 |
| **Run 5** | 230.2 | | 6.29 | 82904 | 77044 | 70141 | 62131 | 54514 | 50098 | 47003 | 43399 | 41036 | 3.74 |
| **Run 6** | 197.0 | | 6.01 | 82389 | 76482 | 69567 | 61863 | 53691 | 49894 | 46967 | 43173 | 40891 | 3.45 |
| **Run 7** | 153.1 | | 3.01 | 80721 | 75431 | 68773 | 60918 | 53544 | 49768 | 46351 | 43869 | 40012 | 3.03 |
| **Run 8** | 156.3 | | 9.41 | 80334 | 75206 | 68437 | 60674 | 53382 | 49752 | 46296 | 43643 | 40650 | 2.96 |
| **Run 9** | 122.4 | | 5.54 | 80321 | 74431 | 67925 | 60842 | 53298 | 49614 | 46381 | 43476 | 40261 | 2.66 |
| **Run 10** | 106.6 | | 9.65 | 80283 | 73430 | 67047 | 60303 | 52759 | 49461 | 46140 | 43453 | 40246 | 2.45 |
| **Run 11** | 78.47 | | 6.23 | 79023 | 72419 | 65904 | 59663 | 52364 | 49369 | 46104 | 42983 | 40027 | 2.02 |
| **Run 12** | 29.42 | | 5.17 | 76117 | 70189 | 63921 | 58292 | 51270 | 48421 | 45408 | 42057 | 39519 | 1.25 |
| **Run 13** | 17.11 | | 11.19 | 75210 | 69810 | 63878 | 57540 | 50343 | 48117 | 45024 | 41864 | 39248 | 0.89 |

## Appendix 55: Water in 65 mm valve, 75 % open

### Water in 65 mm valve, 75 % open

Water in 65 mm valve, 75 % open

| | | |
|---|---|---|
| Date: | 11/24/2006 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.065 | |
| Valve position: | ¾ Open | Area[m²] |
| Pipe Diameter [m]: | 0.06308 | 0.003125167 |

| | |
|---|---|
| Material Type: | Water |
| Density[kg/m³]: | 999.87 |
| Concentration: | 100% |
| $t_y$: | 0 |
| K: | 0.001 |
| n: | 1 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.001 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 | |
| | | | Distances[m]: | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 | |
| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 320731 | | 2.35 | 121296 | 114119 | 106360 | 98694 | 61291 | 57575 | 53186 | 48522 | 45809 | 15.89 |
| Run 2 | 307874 | | 1.91 | 111461 | 105005 | 98219 | 90877 | 57686 | 54132 | 50226 | 46068 | 42732 | 15.25 |
| Run 3 | 297769 | | 2.04 | 105107 | 98726 | 92355 | 85541 | 54588 | 51625 | 48073 | 43852 | 41379 | 14.75 |
| Run 4 | 287621 | | 2.01 | 98507 | 92684 | 86603 | 80472 | 52109 | 49307 | 45844 | 41898 | 39632 | 14.25 |
| Run 5 | 277381 | | 1.91 | 91907 | 86417 | 80869 | 75110 | 49279 | 46527 | 43580 | 39949 | 37744 | 13.74 |
| Run 6 | 267518 | | 1.88 | 85818 | 80518 | 75763 | 70429 | 46938 | 44387 | 41406 | 38211 | 36073 | 13.26 |
| Run 7 | 256829 | | 2.10 | 79790 | 75005 | 70366 | 65713 | 44263 | 41908 | 39283 | 36671 | 34796 | 12.73 |
| Run 8 | 246337 | | 1.97 | 73846 | 69461 | 65277 | 61036 | 41385 | 39641 | 37197 | 34538 | 32989 | 12.21 |
| Run 9 | 236750 | | 2.04 | 68672 | 64908 | 61052 | 57217 | 39932 | 37692 | 35406 | 33246 | 31725 | 11.73 |
| Run 10 | 225981 | | 1.45 | 63380 | 60093 | 56708 | 52952 | 37309 | 35687 | 33930 | 31600 | 30003 | 11.20 |
| Run 11 | 216007 | | 1.77 | 58794 | 55667 | 52434 | 49315 | 35541 | 33886 | 32088 | 30359 | 28907 | 10.70 |
| Run 12 | 204873 | | 1.49 | 53701 | 51074 | 48268 | 45318 | 33237 | 31860 | 30479 | 28841 | 27486 | 10.15 |
| Run 13 | 195949 | | 1.48 | 50060 | 47589 | 45050 | 42474 | 31674 | 30565 | 29109 | 27505 | 26414 | 9.71 |
| Run 14 | 185781 | | 1.40 | 46111 | 43826 | 41596 | 39432 | 30036 | 28937 | 27813 | 26312 | 25427 | 9.21 |
| Run 15 | 175772 | | 1.40 | 42194 | 40257 | 38350 | 36365 | 28311 | 27447 | 26386 | 25258 | 24373 | 8.71 |
| Run 16 | 164719 | | 1.45 | 38515 | 36924 | 35217 | 33519 | 26932 | 25980 | 24990 | 24143 | 23320 | 8.16 |

**Appendix 56: CMC 5 % in 65 mm valve, 100 % open**

## CMC 5 % in 65 mm valve, 100 % open

**CMC 5 % in 65 mm valve, 100 % open**

| | | |
|---|---|---|
| **Date:** | 4/13/2007 | Test done by Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.065 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 |

| | |
|---|---|
| **Material Type:** | **cmc 5%** |
| **Density[kg/m³]:** | **1033.2** |
| **Concentration:** | **5%** |
| $t_y$: | 0.000 |
| **K:** | 1.542 |
| **n:** | 0.645 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.550 | 0.392 | 2.550 | 1.957 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| **Run #** | $Re_3$ | | $k_v$ | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 2037 | | 0.855 | 110803 | 101942 | 93762 | 85382 | 66003 | 61975 | 57702 | 53424 | 49490 | 15.37 |
| **Run 2** | 1989 | | 0.874 | 108307 | 99835 | 91663 | 83565 | 64495 | 60660 | 56554 | 52196 | 48554 | 15.10 |
| **Run 3** | 1929 | | 0.860 | 104502 | 96260 | 88641 | 80731 | 62779 | 58694 | 54907 | 50861 | 47224 | 14.76 |
| **Run 4** | 1873 | | 0.809 | 101615 | 93729 | 86185 | 78546 | 61164 | 57504 | 53712 | 49673 | 46152 | 14.44 |
| **Run 5** | 1808 | | 0.752 | 97910 | 90413 | 83190 | 75918 | 59318 | 55651 | 52213 | 48193 | 44871 | 14.07 |
| **Run 6** | 1747 | | 0.947 | 94215 | 87077 | 80045 | 73181 | 57238 | 53911 | 50316 | 46775 | 43626 | 13.72 |
| **Run 7** | 1681 | | 0.916 | 90979 | 83976 | 77387 | 70704 | 55623 | 52237 | 48857 | 45403 | 42363 | 13.33 |
| **Run 8** | 1600 | | 0.891 | 86596 | 80137 | 73858 | 67570 | 53241 | 50134 | 47050 | 43783 | 40889 | 12.86 |
| **Run 9** | 1538 | | 0.990 | 83204 | 76935 | 70969 | 65014 | 51503 | 48471 | 45543 | 42255 | 39811 | 12.49 |
| **Run 10** | 1800 | | 0.868 | 80377 | 74306 | 68694 | 62920 | 50008 | 47116 | 44298 | 41281 | 38626 | 12.17 |
| **Run 11** | 1436 | | 0.968 | 77753 | 72033 | 66613 | 61097 | 48626 | 45909 | 43088 | 40239 | 37766 | 11.87 |
| **Run 12** | 1366 | | 0.893 | 74122 | 68616 | 63601 | 58344 | 46646 | 44049 | 41527 | 38826 | 36414 | 11.44 |
| **Run 13** | 1287 | | 0.928 | 70154 | 65061 | 60325 | 55422 | 44672 | 42262 | 39811 | 37277 | 35072 | 10.95 |
| **Run 14** | 1222 | | 0.840 | 66773 | 62004 | 57493 | 52997 | 42780 | 40508 | 38372 | 35986 | 33824 | 10.54 |
| **Run 15** | 1174 | | 0.959 | 64213 | 59674 | 55399 | 51077 | 41546 | 39313 | 37199 | 34975 | 32993 | 10.23 |

## Appendix 57: Kaolin 6 % in 65 mm valve, 100 % open

### Kaolin 6 % in 65 mm valve, 100 % open

Kaolin 6 % in 65 mm valve, 100 % open

| | | |
|---|---|---|
| Date: | 7/31/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.065 | |
| Valve position: | Open | Area[m²] |
| Pipe Diameter [m]: | 0.06308 | 0.003125167 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | Kaolin 6% | | | | | | | | | | |
| Density[kg/m³]: | 1103.9 | | | | | | | | | | |
| Concentration: | 6% | | | | | | | | | | |
| $t_y$: | 3.071 | | | | | | | | | | |
| K: | 2.038 | | | | | | | | | | |
| n: | 0.264 | Axial distances | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| PPT used: | 101 to 109 | Valve plane | | | | | | | | | |
| Range selected: | 0-40 | Non-dimensionalised distances incl.[L/D]: | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| | | Distances[m]: | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 2574 | | 0.483 | 25484 | 23948 | 22511 | 21413 | 19022 | 18171 | 17430 | 16561 | 16038 | 5.76 |
| Run 2 | 2512 | | 0.532 | 24630 | 23332 | 22205 | 20901 | 18788 | 17921 | 17223 | 16523 | 15964 | 5.47 |
| Run 3 | 2313 | | 0.389 | 24742 | 23254 | 22042 | 20890 | 18894 | 18053 | 17330 | 16597 | 16019 | 5.32 |
| Run 4 | 2256 | | 0.608 | 24334 | 23055 | 21851 | 20631 | 18674 | 17932 | 17257 | 16547 | 16058 | 5.14 |
| Run 5 | 2103 | | 0.369 | 24221 | 22886 | 21627 | 20474 | 18425 | 17791 | 17192 | 16452 | 15928 | 5.01 |
| Run 6 | 2000 | | 0.173 | 24057 | 22772 | 21647 | 20279 | 18496 | 17734 | 17135 | 16355 | 15836 | 4.84 |
| Run 7 | 1968 | | 0.217 | 24258 | 22987 | 21747 | 20480 | 18720 | 18038 | 17419 | 16697 | 16145 | 4.81 |
| Run 8 | 1848 | | 0.197 | 23150 | 21890 | 20531 | 19253 | 17549 | 16915 | 16403 | 15685 | 15134 | 4.68 |
| Run 9 | 1617 | | 0.215 | 22497 | 21322 | 20238 | 19101 | 17433 | 16881 | 16294 | 15624 | 15131 | 4.23 |
| Run 10 | 1463 | | 1.079 | 22434 | 21234 | 20012 | 18888 | 17457 | 16922 | 16236 | 15583 | 15212 | 3.96 |
| Run 11 | 1333 | | 0.265 | 23564 | 22381 | 21476 | 20330 | 18880 | 18305 | 17920 | 17293 | 16869 | 3.71 |
| Run 12 | 1146 | | 0.498 | 23479 | 22233 | 21224 | 20020 | 18795 | 18232 | 17669 | 16942 | 16606 | 3.46 |
| Run 13 | 906.3 | | 0.134 | 27893 | 26674 | 25618 | 24632 | 23299 | 22786 | 22248 | 21399 | 21157 | 3.06 |
| Run 14 | 824.6 | | 0.423 | 22949 | 21767 | 20795 | 19673 | 18455 | 17974 | 17459 | 16822 | 16432 | 2.85 |

**Appendix 58: Kaolin 10 % in 65 mm valve, 100 % open**

## Kaolin 10 % in 65 mm valve, 100 % open

Kaolin 10 % in 65 mm valve, 100 % open

| | | |
|---|---|---|
| **Date:** | 8/14/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.065 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | Kaolin 10% | | | | | | | | | | |
| **Density[kg/m³]:** | 1169.4 | | | | | | | | | | |
| **Concentration:** | 10% | | | | | | | | | | |
| **$t_y$:** | 8.965 | | | | | | | | | | |
| **K:** | 7.098 | | | | | | | | | | |
| **n:** | 0.175 | **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | |
| **R~nge selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31 20 | 46.58 | 62.08 | 77.01 |
| | | **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 1199 | | 0.274 | 50215 | 46130 | 42100 | 38049 | 33401 | 31514 | 29569 | 27521 | 25680 | 6.09 |
| Run 2 | 1173 | | 0.416 | 50370 | 46173 | 42154 | 38137 | 33504 | 31480 | 29582 | 27486 | 25727 | 6.09 |
| Run 3 | 1091 | | 0.391 | 49896 | 45739 | 41684 | 37705 | 33098 | 31152 | 29240 | 27204 | 25390 | 5.88 |
| Run 4 | 1034 | | 0.377 | 49335 | 45193 | 41150 | 37187 | 32756 | 30793 | 28905 | 26885 | 25084 | 5.72 |
| Run 5 | 1012 | | 0.373 | 48956 | 44847 | 40837 | 36920 | 32454 | 30574 | 28656 | 26633 | 24854 | 5.63 |
| Run 6 | 961.5 | | 0.345 | 48381 | 44330 | 40332 | 36399 | 32035 | 30200 | 28260 | 26259 | 24474 | 5.45 |
| Run 7 | 898.5 | | 0.264 | 47984 | 43863 | 39932 | 36054 | 31790 | 29936 | 28006 | 26035 | 24220 | 5.28 |
| Run 8 | 892.0 | | 0.423 | 47951 | 43827 | 39890 | 36128 | 31753 | 29838 | 27972 | 26090 | 24239 | 5.27 |
| Run 9 | 847.4 | | 0.301 | 47551 | 43551 | 39604 | 35745 | 31522 | 29691 | 27813 | 25680 | 24064 | 5.08 |
| Run 10 | 772.6 | | 0.086 | 47118 | 43134 | 39234 | 35443 | 31289 | 29464 | 27556 | 25606 | 23786 | 4.82 |
| Run 11 | 622.8 | | 0.212 | 46377 | 42434 | 38702 | 34891 | 30871 | 29083 | 27189 | 25183 | 23512 | 4.26 |
| Run 12 | 524.0 | | 0.220 | 46002 | 42012 | 38183 | 34422 | 30519 | 28635 | 26795 | 24818 | 23110 | 3.99 |
| Run 16 | 379.4 | | 0.068 | 43457 | 39607 | 35922 | 32292 | 28628 | 26738 | 24965 | 23149 | 21392 | 3.31 |

## Appendix 59: Kaolin 13 % in 65 mm valve, 100 % open

### Kaolin 13 % in 65 mm valve, 100 % open

Kaolin 13 % in 65 mm valve, 100 % open

| | | |
|---|---|---|
| **Date:** | 12/12/2007 | Test done by Mume & Rendani |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.065 | |
| **Valve position:** | Open | **Area[m$^2$]** |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 |

| | |
|---|---|
| **Material Type:** | Kaolin 13% |
| **Density[kg/m$^3$]:** | 1215.5 |
| **Concentration:** | 13% |
| **$t_y$:** | 18.973 |
| **K:** | 16.141 |
| **n:** | 0.242 |
| **PPT used:** | 105 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised di~tances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 231.2 | | 0.461 | 83490 | 76138 | 69501 | 62620 | 55463 | 52158 | 48526 | 45062 | 41846 | 3.87 |
| Run 2 | 231.3 | | 0.229 | 83048 | 76006 | 69256 | 62359 | 55395 | 51876 | 48515 | 44904 | 41856 | 3.86 |
| Run 4 | 205.8 | | 0.094 | 82565 | 75729 | 68718 | 62044 | 54955 | 51867 | 48242 | 44858 | 41594 | 3.62 |
| Run 5 | 184.0 | | 0.316 | 82257 | 75561 | 68675 | 61922 | 54746 | 51599 | 48083 | 44581 | 41485 | 3.40 |
| Run 6 | 179.7 | | 0.086 | 81788 | 75031 | 68137 | 61602 | 54645 | 51405 | 47881 | 44334 | 41301 | 3.35 |
| Run 7 | 162.3 | | 0.705 | 81747 | 75017 | 68193 | 61446 | 54606 | 51386 | 47914 | 44596 | 41432 | 3.16 |
| Run 8 | 165.0 | | 0.555 | 81415 | 74718 | 67906 | 61382 | 54282 | 51222 | 47775 | 44377 | 41308 | 3.19 |
| Run 10 | 143.9 | | 0.035 | 81058 | 74122 | 67556 | 61070 | 53988 | 50824 | 47570 | 44075 | 41079 | 2.96 |
| Run 14 | 111.4 | | 0.258 | 79709 | 73125 | 66673 | 60433 | 53177 | 50187 | 47159 | 43931 | 40868 | 2.55 |
| Run 15 | 101.0 | | 2.218 | 80082 | 72784 | 66469 | 59764 | 53343 | 50237 | 47119 | 43814 | 40905 | 2.42 |
| Run 17 | 92.74 | | 1.230 | 78495 | 72030 | 65702 | 59177 | 52720 | 49778 | 46703 | 43430 | 40609 | 2.29 |
| Run 19 | 72.15 | | 0.663 | 78442 | 71588 | 65262 | 58960 | 52202 | 49256 | 46500 | 43236 | 40346 | 2.01 |
| Run 20 | 73.63 | | 1.820 | 78079 | 71101 | 64920 | 58266 | 52397 | 49331 | 46129 | 43060 | 40048 | 2.02 |
| Run 21 | 67.64 | | 7.110 | 77163 | 70360 | 64067 | 57681 | 51507 | 48876 | 45747 | 42542 | 39967 | 1.91 |
| Run 23 | 54.77 | | 2.061 | 76999 | 70135 | 64254 | 58117 | 51989 | 48877 | 45821 | 42676 | 39870 | 1.71 |
| Run 24 | 54.42 | | 6.953 | 76860 | 70441 | 63936 | 57591 | 51536 | 48624 | 45627 | 42515 | 39799 | 1.70 |
| Run 25 | 44.49 | | 4.495 | 75972 | 69824 | 63546 | 57627 | 51374 | 48496 | 45503 | 42388 | 39704 | 1.51 |
| Run 26 | 44.20 | | 4.081 | 75854 | 69592 | 63226 | 57034 | 50805 | 48085 | 45219 | 42162 | 39381 | 1.51 |
| Run 27 | 38.15 | | 6.481 | 74947 | 68915 | 62913 | 56697 | 50817 | 47899 | 44953 | 41788 | 39270 | 1.38 |
| Run 28 | 37.89 | | 3.937 | 74630 | 68681 | 62434 | 56414 | 50323 | 47584 | 44746 | 41571 | 39016 | 1.38 |
| Run 29 | 30.19 | | 2.106 | 73204 | 67518 | 61612 | 55970 | 49937 | 47066 | 44272 | 41285 | 38683 | 1.20 |
| Run 30 | 30.65 | | 21.95 | 73249 | 67367 | 61114 | 55333 | 49581 | 46648 | 43673 | 40791 | 38300 | 1.20 |
| Run 31 | 18.23 | | 45.40 | 69861 | 63970 | 58316 | 52758 | 47268 | 44703 | 42095 | 39439 | 37131 | 0.88 |
| Run 32 | 17.59 | | 10.35 | 70308 | 64576 | 59010 | 53714 | 48067 | 45414 | 42788 | 39929 | 37541 | 0.88 |
| Run 34 | 9.891 | | 116.05 | 68779 | 63556 | 57656 | 52323 | 47050 | 44514 | 41560 | 39388 | 36803 | 0.62 |

**Appendix 60: Water in 65 mm valve, 100 % open**

## Water in 65 mm valve, 100 % open

Water in 65 mm valve, 100 % open

| | | |
|---|---|---|
| **Date:** | 2006/11/24 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.065 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.06308 | 0.003125167 |

| | |
|---|---|
| **Material Type:** | Water |
| **Density[kg/m³]:** | 999.87 |
| **Concentration:** | 100% |
| $t_y$: | 0 |
| **K:** | 0.001 |
| **n:** | 1 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.001 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.974 | -4.886 | -2.885 | -0.937 | 0.987 | 1.968 | 2.938 | 3.916 | 4.858 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -110.6 | -77.45 | -45.74 | -14.85 | 15.65 | 31.20 | 46.58 | 62.08 | 77.01 |
| **Distances[m]:** | 0 | 2.088 | 4.089 | 6.037 | 7.961 | 8.942 | 9.912 | 10.89 | 11.83 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 387078 | | 0.434 | 126524 | 116199 | 106364 | 96108 | 75966 | 71719 | 65695 | 59946 | 55469 | 19.18 |
| Run 2 | 372029 | | 0.415 | 117976 | 108837 | 99638 | 89868 | 71562 | 67169 | 61803 | 56193 | 52268 | 18.43 |
| Run 3 | 355644 | | 0.374 | 109061 | 100492 | 92023 | 83555 | 66625 | 62510 | 57798 | 53238 | 49007 | 17.62 |
| Run 4 | 340432 | | 0.568 | 100765 | 92840 | 85245 | 77230 | 62099 | 58625 | 54128 | 49521 | 46655 | 16.87 |
| Run 5 | 321485 | | 0.437 | 91640 | 84758 | 77807 | 70803 | 57209 | 54026 | 50317 | 45885 | 43354 | 15.93 |
| Run 6 | 305957 | | 0.425 | 84186 | 78009 | 71915 | 65501 | 53171 | 50676 | 46844 | 43240 | 40552 | 15.16 |
| Run 7 | 289462 | | 0.462 | 77003 | 71347 | 65844 | 60327 | 49423 | 46793 | 43558 | 40406 | 38003 | 14.34 |
| Run 8 | 274624 | | 0.500 | 70645 | 65799 | 60739 | 55511 | 46035 | 43658 | 40695 | 37904 | 35782 | 13.61 |
| Run 9 | 255851 | | 0.333 | 63393 | 59033 | 54720 | 50207 | 41928 | 40258 | 37720 | 35008 | 33252 | 12.68 |
| Run 10 | 240004 | | 0.452 | 57620 | 54061 | 50095 | 46270 | 38901 | 37074 | 35089 | 32892 | 31326 | 11.89 |
| Run 11 | 224549 | | 0.289 | 52379 | 49061 | 45883 | 42503 | 36248 | 34650 | 32949 | 30995 | 29529 | 11.13 |
| Run 12 | 206578 | | 0.472 | 46578 | 43896 | 41150 | 38320 | 32989 | 31654 | 30208 | 28548 | 27507 | 10.24 |
| Run 13 | 187843 | | 0.574 | 41190 | 38926 | 36691 | 34403 | 30104 | 29212 | 27820 | 26540 | 25711 | 9.31 |

**Appendix 61: CMC 5 % in 80 mm valve, 25% open**

# CMC 5 % in 80 mm valve, 25 % open

CMC 5 % in 80 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 12/12/2006 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.695 | 0.371 | 2.695 | 8.562 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | CMC 5% | | | | | | | | | | |
| Density[kg/m³]: | 1026.7 | | | | | | | | | | |
| Concentration: | 5% | | | | | | | | | | |
| $t_y$: | 0 | | | | | | | | | | |
| K: | 3.55 | | | | | | | | | | |
| n: | 0.59 | Axial distances | -6.012 | -4.809 | -2.408 | -0.808 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| PPT used: | 101 to 109 | Valve plane | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| | | Distances[m]: | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.99 | 14.47 | 15.97 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 2 | 143.2 | | 84.69 | 110111 | 106867 | 101142 | 97698 | 49295 | 44129 | 38660 | 31952 | 28048 | 4.84 |
| Run 4 | 109.1 | | 97.46 | 95555 | 92586 | 87220 | 83352 | 45858 | 41170 | 36379 | 30444 | 26922 | 3.99 |
| Run 5 | 98.58 | | 101.2 | 90358 | 88076 | 82587 | 79056 | 44772 | 40237 | 35585 | 29911 | 26546 | 3.71 |
| Run 6 | 83.61 | | 108.0 | 83148 | 80795 | 75793 | 72358 | 42943 | 38706 | 34332 | 29057 | 25891 | 3.30 |
| Run 7 | 78.21 | | 109.9 | 80104 | 77899 | 72743 | 69637 | 42109 | 38057 | 33789 | 28641 | 25598 | 3.15 |
| Run 8 | 68.50 | | 117.0 | 75138 | 73251 | 68164 | 65070 | 40715 | 36865 | 32837 | 27981 | 25093 | 2.87 |
| Run 9 | 56.48 | | 125.8 | 68655 | 66921 | 62237 | 59508 | 38933 | 35422 | 31729 | 27261 | 24612 | 2.50 |
| Run 10 | 42.17 | | 145.2 | 61520 | 60226 | 55919 | 53446 | 37277 | 34189 | 30944 | 27007 | 24666 | 2.03 |
| Run 11 | 36.06 | | 159.5 | 58253 | 56860 | 53045 | 50578 | 36168 | 33218 | 30193 | 26469 | 24295 | 1.82 |
| Run 12 | 28.36 | | 183.0 | 57141 | 55861 | 52297 | 50118 | 38074 | 35411 | 32670 | 29291 | 27327 | 1.53 |
| Run 13 | 19.69 | | 246.0 | 51703 | 50713 | 47560 | 45706 | 35852 | 33628 | 31305 | 28412 | 26720 | 1.18 |

**Appendix 62: Kaolin 6 % in 80 mm valve, 25 % open**

## Kaolin 6 % in 80 mm valve, 25 % open

Kaolin 6 % in 80 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 7/26/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | |
|---|---|
| Material Type: | Kaolin 6% |
| Density[kg/m³]: | 1103.9 |
| Concentration: | 0.06 |
| $t_y$: | 3.071 |
| K: | 2.038 |
| n: | 0.264 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.415 | -4.009 | -2.408 | -1.209 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -79.76 | -49.84 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| Distances[m]: | 0 | 2.406 | 4.007 | 5.206 | 8.321 | 10.32 | 12.39 | 14.88 | 16.37 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 11 | 925.0 | | 72.35 | 62022 | 60933 | 59996 | 59491 | 16509 | 15431 | 14525 | 13361 | 12641 | 5.19 |
| Run 12 | 922.4 | | 69.38 | 55823 | 54634 | 54005 | 53425 | 16156 | 15032 | 14230 | 13112 | 12545 | 4.95 |
| Run 13 | 863.5 | | 73.09 | 53170 | 52007 | 51406 | 50814 | 15901 | 14885 | 13936 | 12856 | 12365 | 4.68 |
| Run 14 | 796.3 | | 72.63 | 49502 | 48504 | 48000 | 47440 | 15863 | 14759 | 13928 | 12785 | 12242 | 4.42 |
| Run 15 | 738.7 | | 72.74 | 46877 | 45804 | 45357 | 44886 | 15557 | 14625 | 13783 | 12680 | 12120 | 4.23 |
| Run 16 | 622.5 | | 74.17 | 43362 | 42259 | 41638 | 41073 | 15250 | 14289 | 13455 | 12267 | 11807 | 3.95 |
| Run 17 | 544.8 | | 73.71 | 40173 | 39104 | 38480 | 38022 | 15469 | 14512 | 13747 | 12536 | 12085 | 3.67 |
| Run 18 | 504.8 | | 75.36 | 38335 | 37266 | 36849 | 36292 | 15682 | 14776 | 13952 | 12773 | 12274 | 3.44 |
| Run 19 | 414.9 | | 79.31 | 36432 | 35277 | 34859 | 34302 | 17091 | 16253 | 15404 | 14227 | 13847 | 3.08 |
| Run 20 | 374.9 | | 80.62 | 33749 | 32560 | 32279 | 31838 | 16892 | 16180 | 15359 | 14281 | 13907 | 2.82 |
| Run 21 | 315.4 | | 85.67 | 32382 | 31448 | 30986 | 30650 | 17200 | 16385 | 15676 | 14535 | 14201 | 2.56 |

## Appendix 63: Kaolin 10 % in 80 mm valve, 25 % open

### Kaolin 10 % in 80 mm valve, 25 % open

Kaolin 10 % in 80 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 8/15/2007 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | |
|---|---|
| Material Type: | Kaolin 10% |
| Density[kg/m³]: | 1169.4 |
| Concentration: | 10% |
| $t_y$: | 8.965 |
| K: | 7.098 |
| n: | 0.175 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -6.012 | -4.809 | -2.408 | -0.808 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 | |
| | | | Distances[m]: | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.99 | 14.47 | 15.97 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 322.6 | | 86.90 | 104436 | 100360 | 98860 | 97060 | 26835 | 24033 | 21224 | 17646 | 15708 | 5.77 |
| Run 3 | 228.2 | | 80.58 | 91981 | 88594 | 86274 | 84599 | 26222 | 23533 | 20680 | 17126 | 15344 | 5.47 |
| Run 4 | 265.6 | | 78.64 | 86156 | 82793 | 80656 | 79092 | 25877 | 23177 | 20388 | 16846 | 15005 | 5.24 |
| Run 5 | 279.2 | | 78.46 | 83460 | 79735 | 78089 | 76108 | 25676 | 23033 | 20219 | 16613 | 14906 | 5.11 |
| Run 6 | 284.3 | | 79.91 | 80715 | 77320 | 75475 | 73712 | 25458 | 22865 | 20087 | 16396 | 14704 | 4.91 |
| Run 7 | 253.6 | | 82.10 | 78372 | 75013 | 73103 | 71329 | 25299 | 22701 | 19905 | 16173 | 14576 | 4.73 |
| Run 8 | 230.8 | | 83.98 | 75559 | 72298 | 70303 | 68457 | 25109 | 22477 | 19753 | 15962 | 14447 | 4.53 |
| Run 9 | 219.3 | | 86.43 | 73090 | 69555 | 67906 | 66106 | 24936 | 22347 | 19597 | 16050 | 14293 | 4.33 |
| Run 10 | 173.0 | | 92.08 | 70751 | 67209 | 65468 | 63834 | 24645 | 22111 | 19323 | 15891 | 14082 | 4.09 |
| Run 11 | 141.1 | | 96.27 | 69134 | 65882 | 63769 | 62395 | 24532 | 21972 | 19185 | 15715 | 13939 | 3.92 |
| Run 12 | 187.1 | | 97.65 | 66455 | 63277 | 61523 | 59763 | 24182 | 21620 | 18889 | 15363 | 13674 | 3.75 |
| Run 13 | 165.4 | | 96.73 | 63601 | 60389 | 58612 | 56975 | 23824 | 21219 | 18568 | 14994 | 13339 | 3.61 |
| Run 14 | 141.9 | | 88.77 | 57992 | 54844 | 52960 | 51252 | 23163 | 20767 | 18094 | 14644 | 13022 | 3.45 |
| Run 15 | 127.8 | | 87.74 | 54739 | 51511 | 49759 | 48214 | 22907 | 20520 | 17896 | 14477 | 12839 | 3.24 |
| Run 16 | 93.4 | | 85.58 | 50949 | 47667 | 45852 | 44467 | 22558 | 20083 | 17584 | 14199 | 12544 | 3.00 |
| Run 17 | 92.1 | | 85.74 | 48220 | 45234 | 43279 | 41824 | 22271 | 19910 | 17345 | 13827 | 12350 | 2.79 |
| Run 18 | 81.6 | | 85.35 | 45938 | 43005 | 41026 | 39456 | 21813 | 19462 | 16955 | 13647 | 11967 | 2.63 |
| Run 19 | 87.3 | | 84.24 | 43795 | 40899 | 39173 | 37631 | 21614 | 19274 | 16812 | 13367 | 11874 | 2.45 |
| Run 20 | 67.85 | | 88.55 | 41634 | 38821 | 36982 | 35516 | 21215 | 18988 | 16498 | 13125 | 11615 | 2.21 |

## Appendix 64: Kaolin 13 % in 80 mm valve, 25 % open

Kaolin 13 % in 80 mm valve, 25 % open

Kaolin 13 % in 80 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 12/11/2007 | Test done by Mume & Rndani |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| 1/n | n/(n+1) | (n+1)/n | K^(1/n) |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | Kaolin 13% | | | | | | | | | | |
| Density[kg/m³]: | 1215.5 | | | | | | | | | | |
| Concentration: | 13% | | | | | | | | | | |
| $t_y$: | 18.973 | | | | | | | | | | |
| K: | 16.141 | | | | | | | | | | |
| n: | 0.242 | Axial distances | -6.415 | -4.009 | -2.408 | -1.209 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| PPT used: | 105 | Valve plane | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -79.76 | -49.84 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| | | Distances[m]: | 0 | 2.406 | 4.007 | 5.206 | 8.321 | 10.32 | 12.39 | 14.88 | 16.37 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 32.02 | | 127.5 | 74228 | 68681 | 64796 | 61517 | 44213 | 39810 | 34701 | 28977 | 25806 | 1.98 |
| Run 2 | 32.30 | | 135.5 | 74234 | 68715 | 64630 | 61342 | 43949 | 39633 | 34632 | 28839 | 25957 | 1.98 |
| Run 3 | 25.82 | | 131.6 | 71811 | 66316 | 61926 | 58286 | 43179 | 39673 | 34513 | 28516 | 25698 | 1.78 |
| Run 4 | 25.48 | | 122.9 | 71950 | 65693 | 62073 | 58988 | 43150 | 39403 | 34385 | 28243 | 25341 | 1.78 |
| Run 5 | 21.07 | | 140.0 | 70402 | 65005 | 61018 | 57987 | 44214 | 39934 | 34978 | 28960 | 26259 | 1.58 |
| Run 6 | 21.20 | | 127.0 | 70279 | 65207 | 61208 | 58133 | 44583 | 40209 | 35288 | 28824 | 26484 | 1.58 |
| Run 7 | 17.44 | | 158.5 | 67861 | 63077 | 58640 | 55762 | 43446 | 39733 | 34679 | 28688 | 26366 | 1.40 |
| Run 8 | 17.11 | | 151.6 | 68176 | 63235 | 58943 | 55583 | 43208 | 39608 | 34587 | 28699 | 26031 | 1.40 |
| Run 9 | 12.05 | | 100.1 | 65121 | 60158 | 56775 | 53559 | 42512 | 38605 | 33915 | 27937 | 24936 | 1.16 |
| Run 10 | 12.22 | | 139.1 | 64970 | 59865 | 56278 | 53277 | 42271 | 38324 | 33622 | 27812 | 24992 | 1.16 |
| Run 11 | 9.795 | | 117.8 | 62792 | 58715 | 54993 | 51846 | 41700 | 37936 | 33300 | 27482 | 24729 | 1.01 |
| Run 12 | 9.718 | | 156.1 | 63103 | 58478 | 54601 | 51697 | 41655 | 37666 | 33120 | 27381 | 24700 | 1.01 |
| Run 13 | 8.305 | | 103.9 | 61243 | 57059 | 53569 | 50437 | 41136 | 37376 | 32839 | 27122 | 24384 | 0.92 |
| Run 14 | 8.167 | | 274.2 | 62669 | 57186 | 53405 | 50454 | 41179 | 37481 | 32722 | 27243 | 24901 | 0.92 |
| Run 15 | 5.904 | | 197.9 | 59183 | 55565 | 51900 | 48835 | 40238 | 36682 | 32381 | 26958 | 24565 | 0.74 |
| Run 16 | 5.611 | | 131.8 | 59447 | 55763 | 51535 | 48710 | 40486 | 36993 | 32664 | 27273 | 24539 | 0.74 |
| Run 17 | 4.572 | | 291.7 | 56886 | 52472 | 49109 | 46599 | 38758 | 35479 | 31392 | 26176 | 24095 | 0.62 |
| Run 18 | 4.458 | | 459.9 | 58054 | 53260 | 49638 | 46960 | 38932 | 35447 | 31333 | 26141 | 24139 | 0.62 |
| Run 19 | 2.366 | | 344.5 | 55437 | 51545 | 48480 | 46209 | 38462 | 35167 | 31164 | 26266 | 23857 | 0.43 |
| Run 21 | 2.385 | | 705.8 | 55268 | 51116 | 47479 | 45116 | 37449 | 34140 | 30356 | 25444 | 23351 | 0.43 |
| Run 22 | 1.920 | | 918.6 | 54138 | 50380 | 46989 | 44671 | 37391 | 34116 | 30173 | 25830 | 23387 | 0.37 |
| Run 23 | 1.815 | | 833.1 | 54961 | 50426 | 47348 | 44827 | 37577 | 34499 | 30527 | 25486 | 23595 | 0.37 |
| Run 25 | 0.825 | | 894.5 | 51839 | 47959 | 44624 | 42675 | 36094 | 33360 | 29929 | 25248 | 23268 | 0.23 |

## Appendix 65: Water in 80 mm valve, 25 % open

### Water in 80 mm valve, 25 % open

Water in 80 mm valve, 25 % open

| | | |
|---|---|---|
| **Date:** | 11/28/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.08 | |
| **Valve position:** | ¼ Open | **Area[m$^2$]** |
| **Pipe Diameter [m]:** | 0.08043 | 0.005080729 |

| | |
|---|---|
| **Material Type:** | Water |
| **Density[kg/m$^3$]:** | 993.6571 |
| **Concentration:** | 100% |
| **$t_y$:** | 0 |
| **K:** | 0.000707 |
| **n:** | 1 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0007074 |

| | | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | | -6.012 | -4.809 | -2.408 | -0.808 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| **Valve plane** | | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| **Distances[m]:** | | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.99 | 14.47 | 15.97 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 164237 | | 100.7 | 131221 | 130906 | 130640 | 129909 | 23331 | 22300 | 21715 | 20979 | 20462 | 7.39 |
| Run 2 | 158381 | | 97.41 | 119789 | 119470 | 118900 | 118458 | 23003 | 22051 | 21390 | 20779 | 20294 | 7.12 |
| Run 3 | 152472 | | 94.88 | 110431 | 110099 | 109841 | 109294 | 22595 | 21765 | 21160 | 20519 | 20040 | 6.86 |
| Run 4 | 147968 | | 92.63 | 103740 | 103589 | 103114 | 102653 | 22323 | 21622 | 21091 | 20336 | 19849 | 6.65 |
| Run 5 | 142037 | | 90.89 | 95317 | 95118 | 94638 | 94349 | 21940 | 21290 | 20731 | 20133 | 19655 | 6.39 |
| Run 6 | 139481 | | 89.75 | 91422 | 91136 | 90740 | 90523 | 21817 | 21079 | 20554 | 20026 | 19594 | 6.27 |
| Run 7 | 132712 | | 86.44 | 82012 | 81861 | 81457 | 81030 | 21528 | 20754 | 20266 | 19727 | 19438 | 5.97 |
| Run 8 | 127553 | | 84.26 | 75755 | 75629 | 75100 | 74877 | 20926 | 20498 | 20053 | 19664 | 19253 | 5.74 |
| Run 9 | 121955 | | 81.12 | 68874 | 68873 | 68422 | 68121 | 20705 | 20273 | 19831 | 19363 | 19121 | 5.48 |
| Run 10 | 117337 | | 78.05 | 63629 | 63484 | 63168 | 62869 | 20639 | 20051 | 19663 | 19271 | 18947 | 5.28 |
| Run 11 | 112189 | | 75.97 | 58559 | 58374 | 58110 | 57869 | 20276 | 19882 | 19594 | 19122 | 19029 | 5.05 |
| Run 12 | 107945 | | 75.04 | 55109 | 54971 | 54646 | 54558 | 20259 | 19698 | 19389 | 18975 | 18833 | 4.85 |
| Run 13 | 103527 | | 71.44 | 50600 | 50400 | 50145 | 49937 | 20084 | 19573 | 19162 | 18896 | 18621 | 4.66 |
| Run 14 | 97122 | | 67.15 | 46404 | 46185 | 46013 | 45703 | 19892 | 20148 | 20268 | 19992 | 19786 | 4.37 |
| Run 15 | 92606 | | 64.55 | 43255 | 43212 | 43033 | 42815 | 20790 | 20460 | 20241 | 19947 | 19749 | 4.16 |
| Run 16 | 88926 | | 62.52 | 40627 | 40514 | 40275 | 40240 | 20722 | 20317 | 20102 | 19832 | 19677 | 4.00 |
| Run 17 | 80887 | | 60.01 | 36229 | 36115 | 35915 | 35833 | 20539 | 20083 | 19889 | 19662 | 19541 | 3.64 |

**Appendix 66: CMC 5 % in 80 mm valve, 50 % open**

CMC 5 % in 80 mm valve, 50 % open

CMC 5 % in 80 mm valve, 50 % open

| | | |
|---|---|---|
| Date: | 12/13/2006 | Test done by MUME |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.639 | 0.379 | 2.639 | 7.221 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Material Type: | CMC 5% | | | | | | | | | | | | |
| | Density[kg/m³]: | 1026.7 | | | | | | | | | | | | |
| | Concentration: | 5% | | | | | | | | | | | | |
| | $t_y$: | 0 | | | | | | | | | | | | |
| | K: | 3.34 | | | | | | | | | | | | |
| | n: | 0.61 | Axial distances | -6.012 | -4.809 | -2.408 | -0.808 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 | | |
| | PPT used: | 101 to 109 | Valve plane | | | | | | | | | | | |
| | Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 | | |
| | | | Distances[m]: | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.99 | 14.47 | 15.97 | | |
| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] | |
| Run 1 | 372.8 | | 9.45 | 123777 | 119175 | 109911 | 103222 | 72469 | 64140 | 55564 | 45094 | 38927 | 9.84 | |
| Run 2 | 360.1 | | 10.00 | 121976 | 117086 | 107511 | 100813 | 71148 | 62915 | 54562 | 44286 | 38154 | 9.60 | |
| Run 3 | 335.6 | | 10.16 | 117401 | 112798 | 103339 | 97135 | 69062 | 61188 | 53009 | 43122 | 37161 | 9.13 | |
| Run 4 | 318.5 | | 9.96 | 114144 | 109526 | 100310 | 94039 | 67585 | 60203 | 52093 | 42415 | 36634 | 8.79 | |
| Run 5 | 303.0 | | 10.34 | 111222 | 106667 | 97847 | 91646 | 66347 | 58768 | 50917 | 41445 | 35841 | 8.48 | |
| Run 6 | 286.9 | | 10.77 | 108269 | 103907 | 94967 | 88986 | 64878 | 57431 | 49861 | 40590 | 35150 | 8.15 | |
| Run 7 | 265.1 | | 11.17 | 104031 | 99783 | 91121 | 85317 | 62813 | 55634 | 48310 | 39447 | 34165 | 7.70 | |
| Run 8 | 236.1 | | 11.20 | 98108 | 94443 | 86193 | 80627 | 60173 | 53462 | 46403 | 38022 | 32955 | 7.09 | |
| Run 9 | 217.9 | | 11.50 | 94559 | 90882 | 82995 | 77682 | 58600 | 51996 | 45290 | 37110 | 32273 | 6.69 | |
| Run 10 | 195.9 | | 11.98 | 90144 | 86744 | 79002 | 73954 | 56475 | 50223 | 43840 | 36017 | 31416 | 6.20 | |
| Run 11 | 178.0 | | 12.37 | 86660 | 83223 | 75824 | 71036 | 54707 | 48723 | 42489 | 35037 | 30552 | 5.78 | |
| Run 12 | 157.0 | | 12.75 | 82194 | 79092 | 71930 | 67402 | 52596 | 46927 | 41036 | 33931 | 29660 | 5.28 | |
| Run 13 | 143.0 | | 13.06 | 79284 | 75801 | 69510 | 65004 | 51184 | 45700 | 40013 | 33218 | 29137 | 4.94 | |
| Run 14 | 115.0 | | 14.31 | 72579 | 69882 | 63717 | 59754 | 47892 | 42924 | 37763 | 31571 | 27867 | 4.22 | |

## Appendix 67: Kaolin 6 % in 80 mm valve, 50 % open

### Kaolin 6 % in 80 mm valve, 50 % open

Kaolin 6 % in 80 mm valve, 50 % open

| | | |
|---|---|---|
| Date: | 7/26/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| 1/n | n/(n+1) | (n+1)/n | K''' |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | |
|---|---|
| Material Type: | Kaolin 6% |
| Density[kg/m³]: | 1103.9 |
| Concentration: | 0.06 |
| $\tau_y$: | 3.071 |
| K: | 2.038 |
| n: | 0.264 |
| PPT used: | 101 to 109 |
| Range selected: | 0-40 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.012 | -4.809 | -2.408 | -0.806 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| Distances[m]: | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.99 | 14.47 | 15.97 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 1171 | | 19.49 | 34025 | 32914 | 32429 | 31938 | 16914 | 16087 | 15111 | 13968 | 13310 | 5.64 |
| Run 2 | 1085 | | 19.48 | 33934 | 32793 | 32124 | 31562 | 17100 | 15991 | 15062 | 13938 | 13228 | 5.61 |
| Run 3 | 1072 | | 19.00 | 32940 | 31903 | 31266 | 30670 | 16826 | 15759 | 14966 | 13734 | 13091 | 5.46 |
| Run 4 | 1021 | | 19.97 | 32899 | 31877 | 31078 | 30584 | 16802 | 15729 | 14744 | 13596 | 12980 | 5.44 |
| Run 5 | 885 | | 20.67 | 32084 | 30821 | 30160 | 29695 | 16647 | 15616 | 14685 | 13585 | 12992 | 5.21 |
| Run 6 | 968 | | 20.45 | 31701 | 30604 | 29913 | 29503 | 16459 | 15450 | 14485 | 13413 | 12820 | 5.23 |
| Run 7 | 922.5 | | 20.97 | 30999 | 29965 | 29324 | 28784 | 16428 | 15382 | 14488 | 13312 | 12790 | 4.99 |
| Run 8 | 883.5 | | 21.19 | 30063 | 29019 | 28415 | 28020 | 16340 | 15304 | 14332 | 13246 | 12694 | 4.83 |
| Run 9 | 719.9 | | 20.50 | 28970 | 27734 | 27134 | 26643 | 15750 | 14992 | 14176 | 12979 | 12409 | 4.58 |
| Run 10 | 709.3 | | 21.23 | 28735 | 27555 | 26882 | 26385 | 15618 | 14741 | 13962 | 12677 | 12301 | 4.57 |
| Run 11 | 636.3 | | 20.97 | 28200 | 27021 | 26345 | 25845 | 15873 | 15069 | 14308 | 13132 | 12576 | 4.33 |
| Run 12 | 638.5 | | 22.55 | 26746 | 25603 | 25109 | 24612 | 15532 | 14703 | 13857 | 12705 | 12294 | 4.04 |
| Run 13 | 525.0 | | 24.07 | 25454 | 24286 | 23787 | 23304 | 15402 | 14573 | 13771 | 12574 | 12297 | 3.66 |
| Run 14 | 539.9 | | 24.51 | 25265 | 24189 | 23641 | 23171 | 15287 | 14419 | 13549 | 12427 | 12085 | 3.66 |
| Run 15 | 448.7 | | 23.30 | 24211 | 23241 | 22675 | 22246 | 15730 | 14821 | 14012 | 12834 | 12483 | 3.27 |
| Run 16 | 331.5 | | 24.31 | 24631 | 23587 | 23047 | 22596 | 17168 | 16406 | 15568 | 14380 | 14045 | 2.84 |
| Run 17 | 284.8 | | 22.50 | 23699 | 22633 | 22296 | 21882 | 17375 | 16634 | 15889 | 14689 | 14396 | 2.49 |

## Appendix 68: Kaolin 10 % in 80 mm valve, 50 % open

### Kaolin 10 % in 80 mm valve, 50 % open

Kaolin 10 % in 80 mm valve, 50 % open

| | | |
|---|---|---|
| **Date:** | 8/15/2007 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.08 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.08043 | 0.005080729 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Material Type:** | Kaolin 10% | | | | | | | | | | | |
| | **Density[kg/m³]:** | 1169.4 | | | | | | | | | | | |
| | **Concentration:** | 10% | | | | | | | | | | | |
| | **$t_y$:** | 8.965 | | | | | | | | | | | |
| | **K:** | 7.098 | | | | | | | | | | | |
| | **n:** | 0.175 | **Axial distances** | -6.415 | -4.009 | -2.408 | -1.209 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 | |
| | **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| | **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -79.76 | -49.84 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 | |
| | | | **Distances[m]:** | 0 | 2.406 | 4.007 | 5.206 | 8.321 | 10.32 | 12.39 | 14.88 | 16.37 | |
| **Run #** | **Re₃** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 447.3 | | 29.49 | 59564 | 56194 | 54170 | 52330 | 27116 | 24452 | 21616 | 17879 | 16077 | 5.55 |
| **Run 2** | 407.3 | | 30.52 | 58867 | 55431 | 53353 | 51605 | 26978 | 24276 | 21449 | 17780 | 15932 | 5.40 |
| **Run 3** | 386.2 | | 31.02 | 57766 | 54339 | 52328 | 50622 | 26765 | 24012 | 21283 | 17552 | 15707 | 5.20 |
| **Run 4** | 360.4 | | 31.83 | 55984 | 52578 | 50611 | 48937 | 26429 | 23790 | 21013 | 17289 | 15570 | 4.98 |
| **Run 5** | 340.2 | | 30.30 | 53733 | 50438 | 48426 | 46613 | 26151 | 23557 | 20801 | 17045 | 15339 | 4.80 |
| **Run 6** | 321.5 | | 31.66 | 52763 | 49485 | 47561 | 45781 | 25721 | 23280 | 20524 | 16805 | 15090 | 4.60 |
| **Run 7** | 290.8 | | 32.59 | 51344 | 48094 | 46090 | 44375 | 25518 | 22972 | 20155 | 16412 | 14791 | 4.41 |
| **Run 8** | 261.1 | | 33.41 | 49852 | 46480 | 44661 | 42905 | 25214 | 22683 | 19971 | 16246 | 14608 | 4.15 |
| **Run 9** | 233.2 | | 34.36 | 48866 | 45579 | 43639 | 41960 | 25020 | 22506 | 19849 | 16212 | 14460 | 3.95 |
| **Run 10** | 213.5 | | 35.01 | 48161 | 44980 | 42986 | 41317 | 24826 | 22336 | 19766 | 15970 | 14271 | 3.75 |
| **Run 11** | 187.7 | | 38.37 | 47319 | 43971 | 42176 | 40443 | 24777 | 22237 | 19639 | 15873 | 14239 | 3.51 |
| **Run 12** | 168.5 | | 40.76 | 46356 | 43061 | 41326 | 39696 | 24489 | 22164 | 19418 | 15610 | 14006 | 3.27 |
| **Run 13** | 133.2 | | 49.68 | 44734 | 41608 | 39732 | 38121 | 24017 | 21685 | 18964 | 15390 | 13770 | 2.90 |
| **Run 14** | 116.8 | | 53.40 | 43351 | 40218 | 38444 | 36828 | 23752 | 21232 | 18587 | 15192 | 13457 | 2.68 |
| **Run 15** | 90.75 | | 53.15 | 41319 | 38183 | 36332 | 34686 | 23015 | 20639 | 18079 | 14517 | 12896 | 2.41 |
| **Run 16** | 81.64 | | 56.53 | 39558 | 36605 | 34716 | 33184 | 22687 | 20342 | 17644 | 14237 | 12670 | 2.22 |
| **Run 17** | 51.80 | | 58.92 | 37071 | 33844 | 32183 | 30602 | 22064 | 19693 | 17175 | 13757 | 12243 | 1.81 |
| **Run 18** | 42.57 | | 62.41 | 36209 | 33235 | 31363 | 29879 | 21846 | 19498 | 16969 | 13547 | 12040 | 1.64 |
| **Run 19** | 34.46 | | 65.87 | 35559 | 32487 | 30712 | 29314 | 21671 | 19354 | 16872 | 13369 | 11981 | 1.49 |
| **Run 20** | 24.52 | | 76.30 | 34850 | 31872 | 30025 | 28648 | 21446 | 19181 | 16678 | 13318 | 11764 | 1.27 |
| **Run 21** | 15.69 | | 96.97 | 33845 | 30926 | 29106 | 27635 | 21057 | 18832 | 16364 | 13062 | 11500 | 1.01 |

## Appendix 69: Kaolin 13 % in 80 mm valve, 50 % open

### Kaolin 13 % in 80 mm valve, 50 % open

Kaolin 13 % in 80 mm valve, 50 % open

| | | |
|---|---|---|
| Date: | 12/10/2007 | Test done by Mume & Rendani |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | |
|---|---|
| Material Type: | Kaolin 13% |
| Density[kg/m³]: | 1215.5 |
| Concentration: | 13% |
| $t_y$: | 18.973 |
| K: | 16.141 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n: | 0.242 | Axial distances | -6.012 | -4.809 | -2.408 | -0.808 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 | |
| | PPT used: | 105 | Valve plane | | | | | | | | | | |
| | Range selected: | 0-130 | Non-dimensionalised distances incl.[L/D]: | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 | |
| | | | Distances[m]: | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.99 | 14.47 | 15.97 | |
| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 3 | 4.868 | | 264.8 | 58875 | 53128 | 50436 | 48076 | 40185 | 36724 | 31942 | 26477 | 24496 | 0.6987833 |
| Run 4 | 5.029 | | 235.3 | 58796 | 53515 | 50662 | 47648 | 40262 | 36576 | 32032 | 26258 | 24498 | 0.70 |
| Run 5 | 7.251 | | 92.3 | 61460 | 55769 | 52389 | 49459 | 41455 | 37750 | 33147 | 27491 | 24778 | 0.92 |
| Run 6 | 7.754 | | 203.9 | 61101 | 55782 | 52142 | 49543 | 41130 | 37622 | 32912 | 27423 | 25304 | 0.92 |
| Run 7 | 10.58 | | 68.09 | 61224 | 55712 | 52256 | 49460 | 41602 | 37581 | 33069 | 27323 | 24780 | 1.11 |
| Run 8 | 10.00 | | 73.08 | 62019 | 56137 | 52642 | 49693 | 41627 | 37851 | 33289 | 27383 | 24898 | 1.11 |
| Run 9 | 14.70 | | 53.13 | 64022 | 57818 | 54224 | 51150 | 42884 | 38915 | 34174 | 27981 | 25545 | 1.38 |
| Run 10 | 15.77 | | 48.47 | 63148 | 57481 | 53940 | 50836 | 42467 | 38529 | 33864 | 27751 | 25302 | 1.38 |
| Run 11 | 19.28 | | 33.35 | 64192 | 58048 | 54679 | 51669 | 43218 | 39033 | 34267 | 28305 | 25434 | 1.57 |
| Run 12 | 18.66 | | 34.92 | 65049 | 59030 | 55268 | 52299 | 43591 | 39486 | 34721 | 28629 | 25758 | 1.57 |
| Run 13 | 23.34 | | 13.97 | 65044 | 59454 | 55633 | 52449 | 43948 | 40097 | 35080 | 28750 | 25861 | 1.74 |
| Run 14 | 23.50 | | 20.16 | 65024 | 59569 | 55685 | 52514 | 44089 | 39950 | 34827 | 28749 | 25642 | 1.74 |
| Run 15 | 28.83 | | 15.08 | 66033 | 60611 | 56457 | 53661 | 44854 | 40328 | 35516 | 29201 | 26196 | 1.96 |
| Run 16 | 27.91 | | 30.82 | 66509 | 60383 | 56397 | 53433 | 44415 | 40194 | 35245 | 29155 | 26219 | 1.96 |
| Run 17 | 42.75 | | 13.91 | 66450 | 61462 | 57701 | 54548 | 45405 | 41166 | 35899 | 29230 | 26729 | 2.35 |
| Run 18 | 42.73 | | 14.41 | 65363 | 60520 | 56454 | 53143 | 43856 | 39756 | 34628 | 28230 | 25371 | 2.36 |
| Run 19 | 49.15 | | 20.10 | 66269 | 60863 | 57162 | 53825 | 43992 | 39847 | 34548 | 28038 | 25439 | 2.54 |
| Run 20 | 45.13 | | 19.06 | 67142 | 60676 | 56688 | 53606 | 44206 | 39940 | 34799 | 28511 | 25497 | 2.55 |
| Run 21 | 56.73 | | 22.13 | 66988 | 61869 | 58022 | 54556 | 44399 | 40196 | 34852 | 28570 | 25830 | 2.73 |
| Run 22 | 57.22 | | 20.47 | 66809 | 62175 | 57952 | 54568 | 44967 | 40119 | 34791 | 28473 | 25660 | 2.75 |
| Run 23 | 66.98 | | 19.22 | 67907 | 62699 | 58610 | 55414 | 44981 | 40458 | 35008 | 28983 | 25782 | 3.02 |
| Run 24 | 62.13 | | 23.78 | 69160 | 62200 | 58406 | 55124 | 44960 | 40404 | 34832 | 28382 | 25687 | 3.03 |
| Run 25 | 68.42 | | 15.42 | 69356 | 63118 | 59106 | 55794 | 45473 | 40498 | 35235 | 28543 | 25568 | 3.16 |
| Run 26 | 67.93 | | 15.02 | 68920 | 63024 | 58679 | 55478 | 44983 | 40447 | 35119 | 28298 | 25481 | 3.15 |
| Run 27 | 79.15 | | 12.06 | 68615 | 63361 | 59183 | 55926 | 45279 | 40969 | 35294 | 28611 | 25647 | 3.35 |
| Run 28 | 77.41 | | 18.25 | 69691 | 63880 | 59209 | 56003 | 44938 | 40513 | 35188 | 28742 | 25741 | 3.38 |
| Run 29 | 90.47 | | 9.23 | 69887 | 64954 | 60618 | 57024 | 45960 | 40802 | 35618 | 28817 | 25496 | 3.63 |

**Appendix 70: Water in 80 mm valve, 50 % open**

## Water in 80 mm valve, 50 % open

Water in 80 mm valve, 50 % open

| | | |
|---|---|---|
| Date: | 11/28/2006 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0006876 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | Water | | | | | | | | | | | | |
| Density[kg/m³]: | 993.0949 | | | | | | | | | | | | |
| Concentration: | 100% | | | | | | | | | | | | |
| $t_y$: | 0 | | | | | | | | | | | | |
| K: | 0.0006876 | | | | | | | | | | | | |
| n: | 1 | | Axial distances | -6.012 | -4.809 | -2.408 | -0.808 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 | |
| PPT used: | 101 to 109 | | Valve plane | | | | | | | | | | |
| Range selected: | 0-130 | | Non-dimensionalised distances incl.[L/D]: | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 | |
| | | | Distances[m]: | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.99 | 14.47 | 15.97 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 398301 | | 12.81 | 124654 | 123269 | 121285 | 118900 | 40833 | 38454 | 36297 | 33723 | 31804 | 17.42 |
| Run 2 | 379704 | | 12.82 | 116144 | 114799 | 112949 | 111120 | 38896 | 36680 | 34753 | 32328 | 30329 | 16.61 |
| Run 3 | 361827 | | 13.58 | 109231 | 108187 | 106176 | 104931 | 36779 | 34849 | 32882 | 30977 | 29228 | 15.82 |
| Run 4 | 343358 | | 13.63 | 101600 | 100726 | 98436 | 97182 | 35279 | 33166 | 31781 | 29647 | 28197 | 15.02 |
| Run 5 | 327975 | | 14.08 | 95601 | 95089 | 93363 | 92314 | 34001 | 32099 | 30563 | 28617 | 27433 | 14.34 |
| Run 6 | 310687 | | 14.49 | 90095 | 89131 | 87837 | 86627 | 32524 | 30588 | 29296 | 27456 | 26216 | 13.59 |
| Run 7 | 294677 | | 15.05 | 85023 | 84336 | 83216 | 82023 | 31325 | 29621 | 28265 | 26859 | 25368 | 12.89 |
| Run 8 | 276211 | | 15.93 | 78860 | 78303 | 77250 | 76392 | 30052 | 28467 | 27131 | 25744 | 24806 | 12.08 |
| Run 9 | 257849 | | 16.47 | 72482 | 72195 | 70850 | 69821 | 28413 | 26970 | 25823 | 24475 | 23672 | 11.28 |
| Run 10 | 241540 | | 16.18 | 65571 | 65072 | 64025 | 63329 | 27261 | 25943 | 24906 | 23804 | 22924 | 10.56 |
| Run 11 | 223908 | | 15.65 | 57932 | 57640 | 56686 | 56014 | 25916 | 24777 | 23946 | 22888 | 22231 | 9.79 |
| Run 12 | 209434 | | 15.34 | 51850 | 51480 | 50790 | 50305 | 24744 | 23633 | 22913 | 22141 | 21520 | 9.16 |
| Run 13 | 189328 | | 14.69 | 44967 | 44650 | 43796 | 43490 | 23334 | 22629 | 22007 | 21295 | 20803 | 8.28 |
| Run 14 | 174144 | | 14.08 | 40712 | 40506 | 39928 | 39496 | 22387 | 21903 | 21441 | 20702 | 20250 | 7.62 |
| Run 15 | 158539 | | 14.08 | 36449 | 36182 | 35626 | 35278 | 21762 | 21233 | 20736 | 20193 | 19841 | 6.93 |
| Run 16 | 139853 | | 13.51 | 32080 | 31827 | 31503 | 31172 | 20976 | 20473 | 20129 | 19601 | 19405 | 6.12 |
| Run 17 | 124278 | | 12.95 | 28788 | 28663 | 28294 | 28124 | 20256 | 19914 | 19615 | 19270 | 19004 | 5.44 |
| Run 18 | 110823 | | 13.21 | 26483 | 26404 | 26122 | 25965 | 19715 | 19414 | 19124 | 18853 | 18655 | 4.85 |

## Appendix 71: CMC 5 % in 80 mm valve, 75 % open

CMC 5 % in 80 mm valve, 75 % open

CMC 5 % in 80 mm valve, 75 % open

| | | |
|---|---|---|
| Date: | 12/13/2006 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ¾ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| | |
|---|---|
| Material Type: | CMC 5% |
| Density[kg/m³]: | 1026.7 |
| Concentration: | 5% |
| $t_y$: | 0 |
| K: | 3.5 |
| n: | 0.603 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.658 | 0.376 | 2.658 | 7.985 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -6.012 | -4.809 | -2.408 | -0.808 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 | |
| | | | Distances[m]: | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.99 | 14.47 | 15.97 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 420.9 | | 5.20 | 123363 | 118367 | 107798 | 100602 | 76591 | 67660 | 58464 | 47545 | 40983 | 10.81 |
| Run 2 | 400.1 | | 5.26 | 120351 | 114894 | 104579 | 97702 | 74694 | 66056 | 57156 | 46411 | 39955 | 10.43 |
| Run 3 | 370.9 | | 5.34 | 115945 | 110846 | 101085 | 94253 | 72431 | 64037 | 55450 | 44951 | 38788 | 9.88 |
| Run 4 | 354.6 | | 5.28 | 112897 | 108084 | 98494 | 91842 | 70922 | 62715 | 54249 | 44070 | 37982 | 9.57 |
| Run 5 | 326.7 | | 5.40 | 108358 | 103929 | 94623 | 88193 | 68465 | 60611 | 52415 | 42632 | 36769 | 9.02 |
| Run 6 | 297.2 | | 5.65 | 103785 | 99264 | 90169 | 84178 | 65944 | 58325 | 50614 | 41158 | 35516 | 8.43 |
| Run 7 | 270.6 | | 5.61 | 99308 | 95142 | 86475 | 80638 | 63596 | 56385 | 48821 | 39810 | 34392 | 7.88 |
| Run 8 | 251.5 | | 5.98 | 96299 | 92032 | 83751 | 78034 | 61797 | 54753 | 47550 | 38724 | 33549 | 7.48 |
| Run 9 | 236.7 | | 6.03 | 93549 | 89548 | 81453 | 75987 | 60400 | 53562 | 46520 | 38010 | 32933 | 7.16 |
| Run 10 | 217.1 | | 6.42 | 90432 | 86497 | 78674 | 73477 | 58606 | 51984 | 45225 | 36973 | 32113 | 6.73 |
| Run 11 | 198.9 | | 6.53 | 87209 | 83283 | 75898 | 70761 | 56826 | 50438 | 43938 | 35958 | 31272 | 6.32 |
| Run 12 | 178.9 | | 6.47 | 83452 | 79853 | 72752 | 67902 | 54943 | 48859 | 42586 | 35004 | 30483 | 5.86 |
| Run 13 | 161.7 | | 6.72 | 80255 | 76896 | 69941 | 65236 | 53178 | 47362 | 41296 | 34059 | 29692 | 5.45 |
| Run 14 | 146.0 | | 7.15 | 77322 | 74026 | 67420 | 62936 | 51537 | 45929 | 40174 | 33178 | 29036 | 5.07 |

## Appendix 72: Kaolin 6 % in 80 mm valve, 75 % open

### Kaolin 6 % in 80 mm valve, 75 % open

Kaolin 6 % in 80 mm valve, 75 % open

| | | |
|---|---|---|
| Date: | 7/26/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ¾ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | | |
|---|---|---|
| Material Type: | Kaolin 6% | |
| Density[kg/m³]: | 1103.9 | |
| Concentration: | 0.06 | |
| $\tau_y$: | 3.071 | |
| K: | 2.038 | |
| n: | 0.264 | |
| PPT used: | 101 to 109 | |
| Range selected: | 0-40 | |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.415 | -4.009 | -2.408 | -1.209 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -79.76 | -49.84 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| Distances[m]: | 0 | 2.406 | 4.007 | 5.206 | 8.321 | 10.32 | 12.39 | 14.88 | 16.37 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 1 | 1065 | | 3.89 | 23740 | 22680 | 21915 | 21290 | 17159 | 16317 | 15406 | 14186 | 13515 | 5.42 |
| Run 2 | 1001 | | 3.96 | 23250 | 22163 | 21477 | 20968 | 16976 | 16093 | 15213 | 14017 | 13371 | 5.20 |
| Run 3 | 905 | | 3.98 | 22909 | 21776 | 21087 | 20579 | 16910 | 15987 | 15080 | 13793 | 13251 | 4.95 |
| Run 4 | 886 | | 4.03 | 22639 | 21580 | 20905 | 20445 | 16833 | 15917 | 15016 | 13829 | 13219 | 4.83 |
| Run 5 | 823 | | 3.94 | 22244 | 21205 | 20583 | 20113 | 16704 | 15811 | 14989 | 13783 | 13242 | 4.59 |
| Run 6 | 836 | | 3.84 | 22316 | 21148 | 20727 | 20275 | 16830 | 15961 | 15075 | 13814 | 13338 | 4.59 |
| Run 7 | 802 | | 4.02 | 22523 | 21443 | 20757 | 20174 | 16805 | 15988 | 15143 | 13879 | 13369 | 4.59 |
| Run 8 | 735 | | 5.31 | 22261 | 21129 | 20490 | 19968 | 16863 | 15950 | 15022 | 13783 | 13407 | 4.33 |
| Run 9 | 641 | | 4.99 | 21242 | 20184 | 19477 | 18907 | 15988 | 15143 | 14224 | 13040 | 12544 | 4.05 |
| Run 10 | 602 | | 4.39 | 20700 | 19704 | 19058 | 18595 | 15910 | 15015 | 14073 | 12900 | 12402 | 3.84 |
| Run 11 | 534 | | 4.71 | 20647 | 19528 | 18906 | 18479 | 15963 | 15130 | 14245 | 13018 | 12642 | 3.64 |
| Run 12 | 548 | | 4.13 | 20588 | 19596 | 18999 | 18532 | 15999 | 15118 | 14266 | 13056 | 12625 | 3.62 |
| Run 14 | 470 | | 5.24 | 21913 | 20898 | 20306 | 19885 | 17557 | 16912 | 15909 | 14716 | 14395 | 3.28 |
| Run 15 | 389 | | 3.02 | 21944 | 20971 | 20409 | 19996 | 17977 | 17161 | 16371 | 15207 | 14783 | 2.97 |
| Run 16 | 302 | | 4.72 | 22178 | 21175 | 20544 | 20153 | 18196 | 17433 | 16618 | 15414 | 15079 | 2.63 |
| Run 17 | 358 | | 4.57 | 22222 | 21182 | 20667 | 20132 | 18112 | 17361 | 16447 | 15282 | 14870 | 2.84 |

## Appendix 73: Kaolin 10 % in 80 mm valve, 75 % open

### Kaolin 10 % in 80 mm valve, 75 % open

Kaolin 10 % in 80 mm valve, 75 % open

| | | |
|---|---|---|
| Date: | 8/15/2007 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | ¾ Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| | |
|---|---|
| Material Type: | Kaolin 10% |
| Density[kg/m³]: | 1169.4 |
| Concentration: | 10% |
| $t_y$: | 8.965 |
| K: | 7.098 |
| n: | 0.175 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.012 | -4.809 | -2.408 | -0.808 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| Distances[m]: | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.99 | 14.47 | 15.97 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 340.1 | | 10.67 | 46746 | 43334 | 41289 | 39589 | 26890 | 24337 | 21546 | 17791 | 15975 | 5.63 |
| Run 2 | 309.1 | | 11.19 | 45999 | 42495 | 40574 | 38873 | 26601 | 24066 | 21319 | 17607 | 15820 | 5.37 |
| Run 3 | 320.1 | | 11.08 | 45211 | 41831 | 39942 | 38201 | 26435 | 23890 | 21135 | 17350 | 15652 | 5.20 |
| Run 4 | 297.4 | | 11.47 | 44275 | 40933 | 39096 | 37379 | 26174 | 23706 | 20910 | 17258 | 15487 | 4.91 |
| Run 5 | 253.6 | | 11.32 | 43833 | 40443 | 38508 | 36614 | 25966 | 23483 | 20763 | 16869 | 15337 | 4.80 |
| Run 6 | 231.3 | | 10.28 | 42531 | 39204 | 37222 | 35300 | 25450 | 23023 | 20342 | 16515 | 14852 | 4.58 |
| Run 7 | 225.6 | | 10.79 | 41647 | 38329 | 36487 | 34704 | 25158 | 22706 | 20000 | 16350 | 14585 | 4.33 |
| Run 8 | 185.6 | | 11.05 | 41164 | 37883 | 35868 | 34228 | 24903 | 22506 | 19823 | 16010 | 14452 | 4.19 |
| Run 9 | 182.6 | | 11.97 | 40460 | 37202 | 35316 | 33806 | 24747 | 22301 | 19606 | 15884 | 14351 | 3.96 |
| Run 10 | 154.6 | | 13.31 | 40022 | 36791 | 34878 | 33157 | 24547 | 22277 | 19469 | 15720 | 14279 | 3.71 |
| Run 11 | 151.6 | | 12.04 | 39564 | 36391 | 34524 | 32858 | 24508 | 22071 | 19444 | 15689 | 14138 | 3.52 |
| Run 12 | 125.1 | | 12.32 | 38760 | 35722 | 33751 | 32135 | 24063 | 21862 | 19116 | 15433 | 13771 | 3.21 |
| Run 13 | 96.6 | | 17.14 | 38133 | 34934 | 33150 | 31453 | 23807 | 21342 | 18733 | 15091 | 13617 | 2.88 |
| Run 14 | 82.1 | | 16.89 | 37307 | 34163 | 32372 | 30828 | 23521 | 21126 | 18481 | 14996 | 13354 | 2.64 |
| Run 16 | 54.91 | | 17.76 | 35389 | 32428 | 30499 | 28976 | 22559 | 20261 | 17640 | 14097 | 12629 | 2.22 |
| Run 17 | 38.89 | | 16.03 | 34376 | 31262 | 29492 | 27990 | 22081 | 19694 | 17208 | 13731 | 12203 | 1.94 |
| Run 18 | 26.44 | | 17.48 | 33305 | 30334 | 28564 | 27040 | 21620 | 19336 | 16831 | 13337 | 11916 | 1.56 |
| Run 19 | 18.13 | | 16.74 | 32912 | 29929 | 28099 | 26584 | 21409 | 19156 | 16709 | 13190 | 11823 | 1.43 |
| Run 21 | 9.54 | | 22.21 | 32353 | 29340 | 27597 | 26164 | 21236 | 18869 | 16454 | 13067 | 11621 | 1.12 |
| Run 23 | 5.76 | | 27.70 | 31995 | 29088 | 27257 | 25863 | 20938 | 18782 | 16330 | 12882 | 11551 | 0.97 |

## Appendix 74: Kaolin 13 % in 80 mm valve, 75 % open

### Kaolin 13 % in 80 mm valve, 75 % open

Kaolin 13 % in 80 mm valve, 75 % open

| | | | |
|---|---|---|---|
| Date: | 12/10/2007 | Test done by Mume & Rendani | |
| Valve Type: | Diaphragm | | |
| Valve dimension[m]: | 0.08 | | |
| Valve position: | ¾ Open | Area[m²] | |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 | |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | |
|---|---|
| Material Type: | Kaolin 13% |
| Density[kg/m³]: | 1215.5 |
| Concentration: | 13% |
| $t_y$: | 18.973395 |
| K: | 16.141207 |
| n: | 0.2417628 |
| PPT used: | 105# |
| Range selected: | 0-130 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.415 | -4.009 | -2.408 | -1.209 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| Valve plane | # | | | | | | # | | |
| Non-dimensionalised distances incl.[L/D]: | -79.76 | -49.84 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| Distances[m]: | 0 | 2.406 | 4.007 | 5.206 | 8.321 | 10.32 | 12.39 | 14.88 | 16.37 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 131.8 | | 7.44 | 73879 | 67654 | 63709 | 59788 | 48541 | 43667 | 37445 | 30082 | 26953 | 4.48 |
| Run 2 | 127.0 | | 5.05 | 74586 | 67364 | 63636 | 59745 | 48316 | 43845 | 37840 | 30175 | 26927 | 4.46 |
| Run 3 | 110.6 | | 6.83 | 74352 | 66308 | 62866 | 58814 | 48086 | 43629 | 37608 | 30168 | 26861 | 4.16 |
| Run 4 | 113.3 | | 5.53 | 73874 | 66247 | 62915 | 59151 | 47798 | 43420 | 37464 | 29840 | 26668 | 4.19 |
| Run 5 | 102.0 | | 5.15 | 73291 | 65946 | 62274 | 58814 | 47638 | 43197 | 37391 | 30074 | 26584 | 3.96 |
| Run 6 | 105.0 | | 5.44 | 73129 | 66026 | 62325 | 58967 | 47991 | 43207 | 37424 | 30161 | 26719 | 4.00 |
| Run 7 | 97.28 | | 4.57 | 73001 | 65593 | 62153 | 58950 | 47821 | 43219 | 37306 | 29935 | 26485 | 3.85 |
| Run 8 | 98.10 | | 7.84 | 72911 | 65344 | 61983 | 58824 | 47658 | 43052 | 37009 | 29803 | 26500 | 3.85 |
| Run 9 | 87.93 | | 3.00 | 72125 | 64845 | 61477 | 58201 | 47128 | 42601 | 37004 | 29454 | 26168 | 3.64 |
| Run 10 | 86.94 | | 4.15 | 72255 | 64577 | 61320 | 58001 | 47195 | 42646 | 37038 | 29502 | 26307 | 3.63 |
| Run 11 | 80.17 | | 9.76 | 71322 | 64480 | 60607 | 57099 | 47064 | 42049 | 36435 | 29247 | 26203 | 3.43 |
| Run 12 | 79.21 | | 4.77 | 71109 | 63938 | 60584 | 57430 | 46727 | 42160 | 36499 | 29166 | 25942 | 3.42 |
| Run 13 | 71.49 | | 11.01 | 70824 | 63134 | 60195 | 56618 | 46377 | 42053 | 36307 | 28961 | 26283 | 3.21 |
| Run 14 | 71.31 | | 14.19 | 70532 | 63182 | 59836 | 56676 | 46234 | 41905 | 36085 | 29119 | 26266 | 3.19 |
| Run 15 | 63.17 | | 8.52 | 70164 | 63380 | 59536 | 56142 | 46448 | 41658 | 36147 | 29061 | 25901 | 3.02 |
| Run 16 | 62.51 | | 5.50 | 69742 | 62888 | 59184 | 55862 | 46237 | 41516 | 36022 | 28963 | 25663 | 3.00 |
| Run 17 | 54.31 | | 8.40 | 69524 | 62279 | 58893 | 55767 | 45888 | 41462 | 35918 | 28797 | 25755 | 2.78 |
| Run 18 | 53.75 | | 4.72 | 69173 | 62150 | 58815 | 55664 | 45739 | 41363 | 35934 | 28673 | 25671 | 2.76 |
| Run 19 | 47.84 | | 19.97 | 68787 | 62215 | 58286 | 55393 | 45800 | 40997 | 35542 | 28693 | 25951 | 2.56 |
| Run 20 | 47.61 | | 14.02 | 68643 | 61751 | 58342 | 55285 | 45435 | 40927 | 35478 | 28552 | 25648 | 2.56 |
| Run 21 | 44.14 | | 14.59 | 68120 | 61332 | 57810 | 54871 | 45360 | 40814 | 35360 | 28666 | 25605 | 2.45 |
| Run 22 | 43.58 | | 14.20 | 68392 | 61273 | 57979 | 55161 | 45194 | 40687 | 35378 | 28767 | 25531 | 2.45 |
| Run 23 | 36.11 | | 19.67 | 67719 | 60961 | 57545 | 54585 | 45170 | 40509 | 35251 | 28593 | 25648 | 2.19 |
| Run 24 | 34.75 | | 14.53 | 67858 | 60837 | 57342 | 54466 | 44822 | 40361 | 35290 | 28377 | 25477 | 2.17 |
| Run 25 | 32.05 | | 11.77 | 66836 | 60712 | 56583 | 54175 | 44847 | 40253 | 34990 | 28274 | 25192 | 2.07 |
| Run 26 | 32.21 | | 21.76 | 67362 | 60832 | 57042 | 54286 | 44544 | 40075 | 34962 | 28249 | 25350 | 2.07 |
| Run 27 | 24.76 | | 26.48 | 66633 | 59863 | 56154 | 53399 | 44457 | 39813 | 34779 | 28108 | 25307 | 1.80 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 28 | 25.50 | | 24.52 | 66515 | 59651 | 56542 | 53802 | 44485 | 40039 | 34936 | 28329 | 25535 | 1.80 |
| Run 29 | 23.18 | | 41.87 | 67460 | 60849 | 57837 | 54512 | 45530 | 41094 | 35962 | 29592 | 26878 | 1.69 |
| Run 30 | 23.07 | | 40.42 | 67102 | 60717 | 57291 | 53861 | 45201 | 40970 | 35887 | 29135 | 26868 | 1.69 |
| Run 31 | 20.71 | | 57.75 | 66537 | 59909 | 57033 | 53912 | 44737 | 40734 | 35675 | 29223 | 26997 | 1.56 |
| Run 32 | 20.19 | | 41.00 | 66322 | 59432 | 56778 | 53258 | 44572 | 40434 | 35216 | 28636 | 26161 | 1.56 |
| Run 33 | 15.26 | | 55.13 | 63538 | 58133 | 54481 | 51911 | 43427 | 39186 | 34329 | 28198 | 25728 | 1.31 |
| Run 34 | 15.11 | | 83.63 | 64430 | 58253 | 54989 | 51920 | 43626 | 39357 | 34320 | 28275 | 25846 | 1.31 |
| Run 35 | 11.47 | | 105.2 | 63963 | 57465 | 54715 | 51983 | 43425 | 39469 | 34451 | 28285 | 26135 | 1.12 |
| Run 36 | 11.29 | | 86.8 | 63691 | 57359 | 54402 | 51493 | 42864 | 39101 | 34254 | 28111 | 25761 | 1.12 |
| Run 37 | 9.311 | | 172.0 | 62385 | 56605 | 53529 | 51159 | 42143 | 38590 | 33709 | 27980 | 25837 | 0.97 |
| Run 38 | 8.911 | | 109.1 | 62202 | 56942 | 53270 | 50721 | 42091 | 38516 | 33732 | 27745 | 25427 | 0.97 |
| Run 39 | 5.039 | | 155.2 | 60024 | 54037 | 51343 | 48473 | 40522 | 37078 | 32521 | 26972 | 24384 | 0.71 |
| Run 41 | 4.483 | | 495.6 | 52380 | 48431 | 45433 | 43418 | 36457 | 33103 | 29451 | 24847 | 23216 | 0.54 |
| Run 43 | 2.961 | | 1824 | 47284 | 42944 | 40169 | 38233 | 31815 | 29343 | 26662 | 23431 | 21550 | 0.33 |
| Run 44 | 2.561 | | 1629 | 47881 | 44184 | 41355 | 39509 | 33292 | 30261 | 26953 | 23602 | 21553 | 0.33 |

## Appendix 75: Water in 80 mm valve, 75 % open

### Water in 80 mm valve, 75 % open

**Water in 80 mm valve, 75 % open**

| | | | |
|---|---|---|---|
| Date: | 11/30/2006 | Test done by Mume | |
| Valve Type: | Diaphragm | | |
| Valve dimension[m]: | 0.08 | | |
| Valve position: | Open | Area[m²] | |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 | |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.000693 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Type: | Water | | | | | | | | | | | | |
| Density[kg/m³]: | 993.24906 | | | | | | | | | | | | |
| Concentration: | 100% | | | | | | | | | | | | |
| $t_y$: | 0 | | | | | | | | | | | | |
| K: | 0.000693 | | | | | | | | | | | | |
| n: | 1 | Axial distances | -6.012 | -4.809 | -2.408 | -0.808 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 | | |
| PPT used: | 101 to 109 | Valve plane | | | | | | | | | | | |
| Range selected: | 0-130 | Non-dimensionalised distances Incl.[L/D]: | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 | | |
| | | Distances[m]: | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.9C | 14.47 | 15.97 | | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 558488 | | 3.02 | 124041 | 120884 | 116307 | 111670 | 71012 | 66391 | 61379 | 56167 | 52328 | 24.61 |
| Run 2 | 540275 | | 2.61 | 117002 | 114219 | 109835 | 105151 | 68170 | 63713 | 59364 | 53511 | 49742 | 23.81 |
| Run 3 | 519706 | | 2.83 | 109231 | 106947 | 102346 | 98750 | 63845 | 60135 | 55876 | 50802 | 47640 | 22.91 |
| Run 4 | 501999 | | 2.58 | 102277 | 100425 | 95812 | 92400 | 60900 | 56435 | 53262 | 48143 | 45005 | 22.12 |
| Run 5 | 481034 | | 2.40 | 94529 | 92190 | 88758 | 85347 | 56987 | 53041 | 50093 | 45244 | 42275 | 21.20 |
| Run 6 | 461466 | | 2.44 | 88358 | 86521 | 82382 | 79547 | 53844 | 50555 | 47328 | 43392 | 40083 | 20.34 |
| Run 7 | 443363 | | 2.45 | 82168 | 80441 | 77018 | 74230 | 50578 | 47756 | 44712 | 41164 | 38209 | 19.54 |
| Run 8 | 420298 | | 2.31 | 74657 | 73402 | 70568 | 68010 | 47090 | 44424 | 41849 | 38449 | 35992 | 18.52 |
| Run 9 | 400960 | | 2.40 | 70062 | 68126 | 65667 | 63597 | 44369 | 41917 | 39745 | 36599 | 34522 | 17.67 |
| Run 10 | 386400 | | 2.31 | 65765 | 64453 | 61944 | 59685 | 42664 | 40056 | 37915 | 35028 | 32934 | 17.03 |
| Run 11 | 361999 | | 2.21 | 59615 | 58316 | 56194 | 54399 | 39446 | 37176 | 35377 | 32846 | 30927 | 15.95 |
| Run 12 | 345275 | | 2.32 | 55251 | 54465 | 52242 | 50553 | 37290 | 35197 | 33397 | 31081 | 29530 | 15.22 |
| Run 13 | 323243 | | 2.17 | 50759 | 49783 | 48084 | 46589 | 34575 | 33061 | 31468 | 29451 | 27865 | 14.25 |
| Run 14 | 305793 | | 2.10 | 46812 | 46055 | 44445 | 43035 | 32768 | 31277 | 29912 | 27970 | 26730 | 13.48 |
| Run 15 | 283737 | | 2.18 | 42634 | 42059 | 40721 | 39464 | 30547 | 29228 | 28004 | 26430 | 25305 | 12.51 |
| Run 16 | 267391 | | 2.00 | 39673 | 39107 | 37698 | 36867 | 29059 | 27902 | 26841 | 25397 | 24331 | 11.78 |
| Run 17 | 249131 | | 2.17 | 36398 | 35848 | 34706 | 33713 | 27307 | 26278 | 25347 | 24233 | 23336 | 10.98 |

## Appendix 76: Kaolin 6 % in 80 mm valve, 100 % open

Kaolin 6 % in 80 mm valve, 100 % open

Kaolin 6 % in 80 mm valve, 100 % open

| | | |
|---|---|---|
| Date: | 7/25/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |

| | |
|---|---|
| Material Type: | Kaolin 6% |
| Density[kg/m³]: | 1103.9 |
| Concentration: | 6% |
| $t_y$: | 3.071 |
| K: | 2.038 |
| n: | 0.264 |
| PPT used: | 101 to 109 |
| Range selected: | 0-40 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.415 | -4.009 | -2.408 | -1.209 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -79.76 | -49.84 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| Distances[m]: | 0 | 2.406 | 4.007 | 5.206 | 8.321 | 10.32 | 12.39 | 14.88 | 16.37 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 1074 | | 0.152 | 22060 | 20992 | 20215 | 19696 | 17865 | 16983 | 16062 | 14770 | 14173 | 5.46 |
| Run 2 | 1056 | | 0.324 | 21827 | 20689 | 19970 | 19429 | 17614 | 16676 | 15718 | 14441 | 13831 | 5.42 |
| Run 4 | 880 | | 0.239 | 21358 | 20308 | 19590 | 19015 | 17406 | 16466 | 15527 | 14199 | 13708 | 4.84 |
| Run 5 | 844 | | 0.106 | 19109 | 18061 | 17439 | 16901 | 15318 | 14483 | 13512 | 12291 | 11745 | 4.66 |
| Run 6 | 744 | | 0.043 | 20885 | 19793 | 19158 | 18660 | 17130 | 16280 | 15387 | 14261 | 13635 | 4.38 |
| Run 7 | 742 | | 0.249 | 21034 | 19885 | 19306 | 18859 | 17321 | 16323 | 15414 | 14121 | 13669 | 4.37 |
| Run 8 | 633 | | 0.098 | 23585 | 22459 | 21795 | 21297 | 19898 | 18787 | 18089 | 16809 | 16356 | 4.05 |
| Run 9 | 553 | | 0.219 | 20962 | 20002 | 19226 | 18596 | 17112 | 16145 | 15415 | 14115 | 13666 | 3.75 |
| Run 10 | 456 | | 0.565 | 21763 | 20593 | 20023 | 19531 | 17995 | 17294 | 16405 | 15177 | 14755 | 3.37 |
| Run 11 | 266 | | 0.254 | 23106 | 21996 | 21457 | 20875 | 19508 | 18768 | 17891 | 16675 | 16254 | 2.49 |

## Appendix 77: Kaolin 10 % in 80 mm valve, 100 % open

Kaolin 10 % in 80 mm valve, 100 % open

**Kaolin 10 % in 80 mm valve, 100 % open**

| | | |
|---|---|---|
| Date: | 8/22/2007 | Test done by Mume & Sisonke |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.08 | |
| Valve position: | Open | Area[m²] |
| Pipe Diameter [m]: | 0.08043 | 0.005080729 |
| Material Type: | Kaolin 10% | |
| Concentration: | 10% | |
| Density[kg/m³]: | 1169.4 | |

| | |
|---|---|
| $\tau_y$: | 8.965 |
| K: | 7.098 |
| n: | 0.175 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -6.415 | -4.009 | -2.408 | -1.209 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.: | -79.76 | -49.84 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| Distances[m]: | 0 | 2.406 | 4.007 | 5.206 | 8.321 | 10.32 | 12.39 | 14.88 | 16.37 |

| Run # | $Re_3$ | | $k_v$ | $DP_1$ | $DP_2$ | $DP_3$ | $DP_4$ | $DP_5$ | $DP_6$ | $DP_7$ | $DP_8$ | $DP_9$ | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [l/s] |
| Run 1 | 716.2 | | 0.151 | 0 | 2912 | 4524 | 6009 | 9609 | 11847 | 14202 | 17174 | 18868 | 6.46 |
| Run 2 | 725.9 | | 0.054 | 0 | 2866 | 4491 | 5983 | 9682 | 11926 | 14212 | 17213 | 18868 | 6.50 |
| Run 3 | 705.5 | | 0.485 | 0 | 3066 | 4562 | 6096 | 9648 | 11911 | 14209 | 17248 | 19012 | 6.51 |
| Run 4 | 714.1 | | 0.314 | 0 | 3001 | 4586 | 6108 | 9677 | 11899 | 14245 | 17224 | 18962 | 6.49 |
| Run 5 | 700.2 | | 0.458 | 0 | 3041 | 4567 | 6130 | 9607 | 11857 | 14229 | 17212 | 19030 | 6.48 |
| Run 6 | 711.4 | | 0.393 | 0 | 2904 | 4619 | 6123 | 9556 | 11844 | 14215 | 17237 | 18964 | 6.50 |
| Run 7 | 706.5 | | 0.348 | 0 | 2901 | 4594 | 6238 | 9586 | 11655 | 14226 | 17305 | 18976 | 6.48 |
| Run 8 | 699.6 | | 0.527 | 0 | 2948 | 4609 | 6450 | 9665 | 11870 | 14205 | 17249 | 19027 | 6.50 |
| Run 9 | 729.3 | | 0.118 | 0 | 2825 | 4577 | 5905 | 9630 | 11904 | 14260 | 17148 | 18777 | 6.42 |
| Run 10 | 679.4 | | 0.100 | 0 | 2900 | 4577 | 6037 | 9693 | 11894 | 14259 | 17365 | 18886 | 6.26 |
| Run 11 | 709.1 | | 0.175 | 0 | 2932 | 4665 | 6014 | 9657 | 11895 | 14246 | 17195 | 18824 | 6.37 |
| Run 12 | 701.6 | | 0.407 | 0 | 3014 | 4650 | 6019 | 9623 | 11842 | 14192 | 17336 | 18866 | 6.40 |
| Run 13 | 726.1 | | 0.083 | 0 | 2805 | 4550 | 5905 | 9655 | 11905 | 14238 | 17176 | 18793 | 6.43 |
| Run 14 | 695.7 | | 0.223 | 0 | 2845 | 4641 | 5926 | 9651 | 11887 | 14269 | 17187 | 18940 | 6.37 |
| Run 15 | 696.1 | | 0.534 | 0 | 2892 | 4670 | 5963 | 9614 | 11827 | 14199 | 17151 | 18982 | 6.45 |
| Run 16 | 694.1 | | 0.553 | 0 | 2889 | 4702 | 6059 | 9615 | 11869 | 14208 | 17163 | 18980 | 6.43 |
| Run 17 | 716.0 | | 0.409 | 0 | 2892 | 4683 | 5991 | 9641 | 11879 | 14270 | 17297 | 19015 | 6.52 |
| Run 18 | 703.5 | | 0.608 | 0 | 2878 | 4713 | 6022 | 9679 | 11864 | 14220 | 17283 | 19037 | 6.51 |
| Run 19 | 695.4 | | 0.671 | 0 | 2861 | 4707 | 5970 | 9672 | 11887 | 14193 | 17190 | 19041 | 6.49 |
| Run 20 | 680.2 | | 0.804 | 0 | 2925 | 4739 | 6093 | 9739 | 11866 | 14199 | 17172 | 19080 | 6.44 |
| Run 21 | 703.4 | | 0.563 | 0 | 2865 | 4645 | 6109 | 9676 | 11856 | 14181 | 17155 | 19008 | 6.52 |
| Run 22 | 685.6 | | 0.732 | 0 | 2927 | 4669 | 6083 | 9711 | 11855 | 14197 | 17196 | 19096 | 6.48 |
| Run 23 | 683.1 | | 0.778 | 0 | 2999 | 4692 | 6060 | 9584 | 11853 | 14193 | 17227 | 19073 | 6.46 |
| Run 24 | 667.4 | | 1.029 | 0 | 3084 | 4706 | 6071 | 9608 | 11815 | 14187 | 17302 | 19182 | 6.46 |
| Run 25 | 680.6 | | 0.805 | 0 | 2786 | 4712 | 6100 | 9664 | 11896 | 14206 | 17304 | 19168 | 6.50 |
| Run 26 | 709.5 | | 0.417 | 0 | 2779 | 4589 | 6082 | 9621 | 11852 | 14182 | 17296 | 18994 | 6.53 |
| Run 27 | 656.1 | | 0.470 | 0 | 2850 | 4630 | 6083 | 9519 | 11714 | 14129 | 17360 | 18852 | 6.22 |
| Run 28 | 637.1 | | 0.860 | 0 | 2957 | 4684 | 6220 | 9557 | 11734 | 14122 | 17118 | 18987 | 6.22 |
| Run 29 | 585.6 | | 0.816 | 0 | 2751 | 4534 | 5892 | 9402 | 11679 | 14020 | 17079 | 18957 | 6.01 |
| Run 30 | 578.5 | | 0.988 | 0 | 2769 | 4578 | 5950 | 9460 | 11677 | 13958 | 16925 | 18896 | 5.97 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 31 | 533.6 | | 1.213 | 0 | 2773 | 4568 | 5840 | 9402 | 11591 | 13905 | 16865 | 18892 | 5.76 |
| Run 32 | 544.9 | | 1.026 | 0 | 2828 | 4559 | 5845 | 9384 | 11622 | 13911 | 16875 | 18797 | 5.76 |
| Run 33 | 540.5 | | 0.083 | 0 | 2706 | 4400 | 5701 | 9387 | 11437 | 13852 | 16616 | 18327 | 5.47 |
| Run 34 | 536.2 | | 0.162 | 0 | 2761 | 4405 | 5815 | 9358 | 11476 | 13805 | 16629 | 18338 | 5.48 |
| Run 35 | 484.5 | | 0.540 | 0 | 2760 | 4449 | 5771 | 9226 | 11431 | 13724 | 16615 | 18315 | 5.24 |
| Run 36 | 484.0 | | 0.558 | 0 | 2777 | 4416 | 5723 | 9231 | 11363 | 13692 | 16541 | 18293 | 5.24 |
| Run 37 | 426.6 | | 1.090 | 0 | 2878 | 4359 | 5763 | 9180 | 11272 | 13558 | 16516 | 18263 | 4.97 |
| Run 38 | 420.8 | | 1.551 | 0 | 2908 | 4415 | 5806 | 9183 | 11202 | 13472 | 16444 | 18232 | 4.97 |
| Run 39 | 431.0 | | 0.798 | 0 | 2620 | 4311 | 5473 | 9054 | 11175 | 13534 | 16113 | 17677 | 4.68 |
| Run 42 | 346.4 | | 1.381 | 0 | 2748 | 4291 | 5638 | 9013 | 11146 | 13314 | 16213 | 17961 | 4.44 |
| Run 43 | 300.7 | | 1.478 | 0 | 2753 | 4245 | 5534 | 9033 | 11132 | 13219 | 16223 | 17804 | 4.10 |
| Run 44 | 299.8 | | 1.779 | 0 | 2803 | 4360 | 5618 | 8960 | 11077 | 13273 | 16255 | 17852 | 4.09 |
| Run 45 | 251.1 | | 1.878 | 0 | 3065 | 4348 | 5541 | 8884 | 10928 | 13124 | 15847 | 17452 | 3.61 |
| Run 46 | 240.9 | | 1.514 | 0 | 2588 | 4260 | 5628 | 8839 | 11042 | 13088 | 15710 | 17546 | 3.60 |
| Run 47 | 209.5 | | 2.050 | 0 | 2702 | 4201 | 5535 | 8776 | 10947 | 12931 | 15891 | 17348 | 3.33 |
| Run 48 | 196.7 | | 3.972 | 0 | 2681 | 4309 | 5613 | 8695 | 10845 | 12888 | 15869 | 17505 | 3.32 |
| Run 49 | 186.5 | | 2.823 | 0 | 2654 | 4232 | 5505 | 8736 | 10932 | 12848 | 15636 | 17275 | 3.14 |
| Run 50 | 188.0 | | 2.648 | 0 | 2754 | 4168 | 5583 | 8742 | 10828 | 12877 | 15565 | 17328 | 3.17 |
| Run 51 | 169.7 | | 3.681 | 0 | 2486 | 4253 | 5460 | 8616 | 10643 | 12746 | 15564 | 17225 | 3.02 |
| Run 54 | 155.8 | | 4.779 | 0 | 2596 | 4201 | 5504 | 8611 | 10510 | 12643 | 15623 | 17168 | 2.91 |
| Run 55 | 138.2 | | 5.706 | 0 | 2559 | 4230 | 5573 | 8480 | 10613 | 12570 | 15602 | 17061 | 2.72 |
| Run 56 | 137.6 | | 6.375 | 0 | 2687 | 4222 | 5648 | 8481 | 10508 | 12579 | 15664 | 17128 | 2.74 |

## Appendix 78: Kaolin 13 % in 80 mm valve, 100 % open

### Kaolin 13 % in 80 mm valve, 100 % open

Kaolin 13 % in 80 mm valve, 100 % open

| | | |
|---|---|---|
| **Date:** | 12/10/2007 | Test done by Mume & Rendani |
| **Valve Type:** | Diaphragm. | |
| **Valve dimension[m]:** | 0.08 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.08043 | 0.005080729 |

| | |
|---|---|
| **Material Type:** | Kaolin 13% |
| **Density[kg/m³]:** | 1215.5 |
| **Concentration:** | 13% |
| **$t_y$:** | 18.973 |
| **K:** | 16.141 |
| **n:** | 0.242 |
| **PPT used:** | 105 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Axial distances** | -6.012 | -4.809 | -2.408 | -0.808 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 | |
| | | | **Valve plane** | | | | | | | | | | |
| | | | **Non-dimensionalised distances incl.[L/D]:** | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 | |
| | | | **Distances[m]:** | 0 | 1.203 | 3.604 | 5.204 | 7.918 | 9.919 | 11.99 | 14.47 | 15.97 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 32.08 | | 14.84 | 67640 | 61116 | 57499 | 54413 | 45790 | 40956 | 35602 | 28996 | 25988 | 2.13 |
| Run 2 | 32.24 | | 10.32 | 67432 | 60917 | 57383 | 54307 | 45441 | 40960 | 35658 | 29055 | 25971 | 2.13 |
| Run 4 | 30.18 | | 14.81 | 67625 | 60655 | 57621 | 53637 | 45092 | 41444 | 35540 | 28734 | 25959 | 2.05 |
| Run 5 | 31.11 | | 11.34 | 66617 | 60450 | 57167 | 54422 | 45416 | 40771 | 35536 | 29260 | 26045 | 2.04 |
| Run 10 | 21.26 | | 18.59 | 68033 | 61929 | 57714 | 54256 | 46066 | 41722 | 36524 | 29771 | 26947 | 1.74 |
| Run 11 | 19.32 | | 25.71 | 67671 | 60692 | 57926 | 55006 | 46392 | 41841 | 36540 | 29943 | 27321 | 1.60 |
| Run 13 | 17.74 | | 14.01 | 67014 | 60183 | 57295 | 53931 | 45834 | 41651 | 36436 | 29556 | 27141 | 1.53 |
| Run 14 | 17.85 | | 15.97 | 66711 | 60391 | 57059 | 54186 | 45575 | 41349 | 36245 | 29373 | 26955 | 1.53 |
| Run 15 | 14.08 | | 24.69 | 66279 | 59883 | 56572 | 53487 | 45155 | 41120 | 35981 | 29339 | 26806 | 1.36 |
| Run 16 | 14.32 | | 29.30 | 66173 | 59506 | 56555 | 53304 | 45028 | 41030 | 36014 | 29212 | 27015 | 1.36 |
| Run 17 | 12.41 | | 19.75 | 65112 | 59362 | 55606 | 52559 | 44639 | 40556 | 35564 | 28994 | 26440 | 1.26 |
| Run 18 | 12.67 | | 42.34 | 65158 | 59165 | 55718 | 53160 | 44448 | 40453 | 35500 | 28565 | 26704 | 1.26 |
| Run 19 | 10.41 | | 60.76 | 64463 | 58662 | 55479 | 52377 | 43618 | 39631 | 34878 | 28522 | 26118 | 1.11 |
| Run 20 | 10.15 | | 80.01 | 63917 | 57970 | 54568 | 51564 | 43605 | 39642 | 34727 | 28393 | 26302 | 1.11 |
| Run 21 | 8.38 | | 93.1 | 63570 | 57430 | 54675 | 51797 | 43467 | 39503 | 34635 | 28593 | 26249 | 0.98 |
| Run 22 | 8.14 | | 96.4 | 63242 | 57601 | 54095 | 51263 | 43164 | 39271 | 34577 | 28418 | 26234 | 0.98 |
| Run 23 | 6.15 | | 111.2 | 61645 | 56423 | 52706 | 49966 | 42529 | 38405 | 33819 | 27950 | 25573 | 0.84 |
| Run 24 | 6.15 | | 70.6 | 61626 | 56027 | 52727 | 50459 | 42674 | 38719 | 33997 | 27924 | 25660 | 0.84 |
| Run 26 | 4.15 | | 173.4 | 59723 | 54365 | 51097 | 48612 | 41018 | 37254 | 32716 | 27089 | 24767 | 0.67 |
| Run 28 | 3.41 | | 114.6 | 59231 | 54124 | 51032 | 48566 | 40995 | 37464 | 32866 | 27068 | 24827 | 0.59 |
| Run 29 | 1.92 | | 457.4 | 56418 | 51510 | 48986 | 46965 | 39490 | 35971 | 31547 | 26384 | 24269 | 0.40 |
| Run 31 | 0.66 | | 870 | 54545 | 49613 | 46761 | 44702 | 38120 | 34747 | 30671 | 25675 | 23531 | 0.24 |
| Run 32 | 0.71 | | 1203 | 54373 | 49315 | 46829 | 44781 | 37849 | 34415 | 30314 | 25709 | 23270 | 0.24 |
| Run 33 | 0.25 | | 3161 | 49968 | 46007 | 43688 | 41734 | 36038 | 32964 | 29435 | 24929 | 23281 | 0.12 |
| Run 34 | 0.27 | | 3189 | 49590 | 45937 | 43620 | 42010 | 36434 | 33269 | 29249 | 24924 | 23119 | 0.12 |

## Appendix 79: Water in 80 mm valve, 100 % open

### Water 80 mm valve, 100 % open

**Water in 80 mm valve, 100 % open**

| | | |
|---|---|---|
| **Date:** | 11/30/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.08 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.08043 | 0.005080729 |

| | |
|---|---|
| **Material Type:** | Water |
| **Density[kg/m³]:** | 994.27247 |
| **Concentration:** | 100% |
| **$t_y$:** | 0 |
| **K:** | 0.0007317 |
| **n:** | 1 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0007317 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -6.413 | -4.009 | -2.408 | -1.209 | 1.906 | 3.907 | 5.977 | 8.461 | 9.956 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -79.73 | -59.79 | -29.94 | -15.03 | 23.70 | 48.58 | 74.31 | 105.2 | 123.8 |
| **Distances[m]:** | 0 | 2.404 | 4.005 | 5.204 | 8.319 | 10.32 | 12.39 | 14.87 | 16.37 |

| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 654809 | | 0.231 | 127076 | 121205 | 117076 | 113102 | 94785 | 87722 | 81214 | 72691 | 67809 | 30.44 |
| **Run 2** | 618537 | | 0.153 | 118365 | 110217 | 106544 | 103234 | 85381 | 80082 | 75196 | 66274 | 62275 | 28.76 |
| **Run 3** | 591528 | | 0.059 | 109802 | 103008 | 100297 | 96299 | 81672 | 75652 | 70774 | 63337 | 58593 | 27.50 |
| **Run 5** | 524078 | | 0.301 | 91998 | 86649 | 83889 | 81010 | 68970 | 64110 | 59749 | 54319 | 50510 | 24.36 |
| **Run 6** | 501537 | | 0.027 | 87084 | 81334 | 78949 | 76340 | 65159 | 61004 | 56959 | 51580 | 47398 | 23.32 |
| **Run 7** | 479068 | | 0.105 | 81525 | 76430 | 73804 | 72181 | 61613 | 56840 | 53805 | 48730 | 45242 | 22.27 |
| **Run 8** | 457383 | | 0.149 | 76349 | 71711 | 69553 | 67442 | 57633 | 53976 | 50793 | 45806 | 43062 | 21.26 |
| **Run 9** | 438298 | | 0.297 | 72299 | 67992 | 65967 | 63864 | 54681 | 51209 | 48164 | 43955 | 41208 | 20.38 |
| **Run 10** | 413262 | | 0.208 | 67192 | 63198 | 61360 | 59591 | 51354 | 47968 | 45305 | 41641 | 38756 | 19.21 |
| **Run 11** | 390661 | | 0.270 | 62424 | 58888 | 57170 | 55516 | 47891 | 45425 | 42451 | 39058 | 36598 | 18.16 |
| **Run 12** | 368557 | | 0.402 | 58215 | 54988 | 53528 | 51957 | 45204 | 42789 | 40116 | 37174 | 35050 | 17.13 |
| **Run 13** | 345250 | | 0.268 | 53981 | 51280 | 49564 | 48284 | 42148 | 39883 | 37624 | 34772 | 32788 | 16.05 |
| **Run 14** | 325921 | | 0.219 | 50725 | 48222 | 46714 | 45557 | 40028 | 37904 | 35853 | 33063 | 31396 | 15.15 |
| **Run 15** | 300132 | | 0.523 | 46594 | 44414 | 43159 | 41947 | 37120 | 35176 | 33234 | 31081 | 29573 | 13.95 |

## Appendix 80: CMC 5 % in 100 mm valve, 25% open

CMC 5 % in 100 mm valve, 25 % open

CMC 5 % in 100 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 12/13/2006 | Test done by Mume |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.1 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.09717 | 0.007415736 |

| | |
|---|---|
| Material Type: | CMC 5% |
| Density[kg/m³]: | 1026.7 |
| Concentration: | 5% |
| $t_y$: | 0 |
| K: | 3.16 |
| n: | 0.618 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.618 | 0.382 | 2.618 | 6.435 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 |
| Distances[m]: | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 (Pa) | Pod 2 (Pa) | Pod 3 (Pa) | Pod 4 (Pa) | Pod 5 (Pa) | Pod 6 (Pa) | Pod 7 (Pa) | Pod 8 (Pa) | Pod 9 (Pa) | Average Q [l/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 1 | 200.2 | | 86.7 | 127127 | 125052 | 121177 | 117743 | 57584 | 55779 | 53767 | 51463 | 49463 | 8.34 |
| Run 2 | 192.0 | | 87.9 | 123290 | 121029 | 117050 | 114074 | 56518 | 54827 | 52810 | 50578 | 48636 | 8.09 |
| Run 3 | 181.6 | | 88.9 | 118330 | 116538 | 112528 | 109810 | 55398 | 53802 | 51811 | 49611 | 47714 | 7.77 |
| Run 4 | 170.0 | | 91.2 | 113212 | 111358 | 107437 | 104598 | 54054 | 52474 | 50507 | 48371 | 46554 | 7.41 |
| Run 5 | 161.0 | | 92.7 | 108990 | 107134 | 103326 | 100520 | 52980 | 51404 | 49514 | 47446 | 45621 | 7.12 |
| Run 6 | 152.1 | | 95.2 | 105189 | 103264 | 99568 | 96718 | 51909 | 50435 | 48581 | 46521 | 44882 | 6.83 |
| Run 7 | 142.1 | | 96.4 | 100169 | 98123 | 94824 | 92143 | 50478 | 49063 | 47316 | 45351 | 43645 | 6.51 |
| Run 8 | 130.9 | | 98.9 | 94830 | 93188 | 89579 | 87110 | 49040 | 47728 | 46010 | 44110 | 42490 | 6.13 |
| Run 9 | 123.7 | | 100.9 | 91768 | 89871 | 86774 | 84046 | 48201 | 46912 | 45251 | 43430 | 41795 | 5.88 |
| Run 10 | 115.2 | | 103.0 | 87788 | 86081 | 82753 | 80329 | 47076 | 45850 | 44188 | 42419 | 40830 | 5.59 |
| Run 11 | 106.1 | | 108.2 | 84193 | 82545 | 79425 | 76919 | 46011 | 44829 | 43223 | 41518 | 40050 | 5.27 |
| Run 12 | 98.2 | | 109.3 | 80050 | 78589 | 75554 | 73144 | 44872 | 43778 | 42270 | 40613 | 39147 | 4.98 |
| Run 13 | 84.8 | | 115.9 | 74137 | 72591 | 69773 | 67649 | 42910 | 42029 | 40576 | 38992 | 37665 | 4.48 |
| Run 14 | 69.4 | | 126.3 | 67258 | 65756 | 63216 | 61376 | 40863 | 39929 | 38638 | 37151 | 35918 | 3.88 |
| Run 15 | 58.1 | | 140.8 | 62716 | 61503 | 59094 | 57229 | 39635 | 38709 | 37498 | 36171 | 35022 | 3.41 |
| Run 16 | 47.6 | | 157.3 | 57482 | 56456 | 54234 | 52549 | 37707 | 36839 | 35740 | 34559 | 33502 | 2.95 |
| Run 17 | 37.1 | | 185.3 | 52484 | 51462 | 49497 | 48037 | 35614 | 34861 | 33888 | 32784 | 31861 | 2.46 |
| Run 18 | 23.0 | | 268.1 | 48831 | 47825 | 46251 | 45037 | 36048 | 35411 | 34629 | 33698 | 33004 | 1.74 |
| Run 19 | 13.6 | | 423.6 | 43178 | 42418 | 41233 | 40255 | 33427 | 32962 | 32305 | 31567 | 31040 | 1.19 |

**Appendix 81: Kaolin 6 % in 100 mm valve, 25 % open**

Kaolin 6 % in 100 mm valve, 25 % open

Kaolin 6 % in 100 mm valve, 25 % open

| | | |
|---|---|---|
| **Date:** | 8/5/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | ¼ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | Kaolin 6% | | | | | | | | | | | | |
| **Density[kg/m³]:** | 1103.9 | | | | | | | | | | | | |
| **Concentration:** | 6% | | | | | | | | | | | | |
| **$t_y$:** | 3.071 | | | | | | | | | | | | |
| **K:** | 2.038 | | | | | | | | | | | | |
| **n:** | 0.264 | | **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| **PPT used:** | 101 to 109 | | **Valve plane** | | | | | | | | | | |
| **Range selected:** | 0-40 | | **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | | **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 537.8 | | 80.52 | 36045 | 35502 | 35205 | 34577 | 14524 | 14351 | 13946 | 13529 | 13326 | 4.91 |
| Run 2 | 466.6 | | 80.88 | 35121 | 34525 | 34280 | 33509 | 15361 | 14984 | 14668 | 14349 | 13992 | 4.65 |
| Run 4 | 563.7 | | 74.62 | 34932 | 34247 | 33951 | 33375 | 16780 | 16441 | 16106 | 15766 | 15630 | 4.73 |
| Run 5 | 440.7 | | 71.98 | 33424 | 32906 | 32605 | 32031 | 17042 | 16813 | 16472 | 16107 | 15830 | 4.44 |
| Run 6 | 364.5 | | 71.78 | 32300 | 31737 | 31411 | 30764 | 16811 | 16347 | 16211 | 15571 | 15416 | 4.22 |
| Run 8 | 316.2 | | 80.39 | 30866 | 30335 | 29898 | 29285 | 16638 | 16400 | 16049 | 15678 | 15381 | 3.86 |
| Run 10 | 258.7 | | 79.45 | 29440 | 28870 | 28420 | 27863 | 16615 | 16339 | 16153 | 15751 | 15419 | 3.58 |
| Run 11 | 238.9 | | 87.41 | 29290 | 28738 | 28424 | 27879 | 17965 | 17654 | 17364 | 17017 | 16707 | 3.23 |
| Run 12 | 207.7 | | 88.35 | 28312 | 27775 | 27371 | 26800 | 17864 | 17727 | 17484 | 16946 | 16846 | 3.05 |
| Run 14 | 181.7 | | 82.13 | 27558 | 27053 | 26705 | 26164 | 18041 | 17786 | 17513 | 17014 | 16732 | 2.88 |
| Run 15 | 170.4 | | 85.22 | 26901 | 26382 | 26081 | 25488 | 17973 | 17834 | 17526 | 17026 | 16801 | 2.73 |
| Run 16 | 130.6 | | 100.8 | 26099 | 25612 | 25227 | 24768 | 18243 | 18062 | 17732 | 17254 | 17062 | 2.36 |

## Appendix 82: Kaolin 10 % in 100 mm valve, 25 % open

### Kaolin 10 % in 100 mm valve, 25 % open

**Kaolin 10 % in 100 mm valve, 25 % open**

| | | |
|---|---|---|
| **Date:** | 8/15/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | ¼ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |

| | |
|---|---|
| **Material Type:** | Kaolin 10% |
| **Density[kg/m³]:** | 1169.4 |
| **Concentration:** | 10% |
| $\tau_y$: | 8.965 |
| **K:** | 7.098 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **n:** | 0.175 | **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| | **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| | **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | | **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |
| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 238.9 | | 92.7 | 62646 | 61075 | 59701 | 57770 | 25829 | 25068 | 24087 | 23055 | 21929 | 5.48 |
| **Run 2** | 241.3 | | 95.4 | 62173 | 60662 | 59345 | 57442 | 26246 | 25349 | 24324 | 23151 | 22265 | 5.38 |
| **Run 3** | 219.4 | | 97.1 | 60217 | 58669 | 57335 | 55470 | 25554 | 24738 | 23770 | 22633 | 21662 | 5.18 |
| **Run 4** | 204.1 | | 100.8 | 58003 | 56508 | 55253 | 53446 | 25320 | 24342 | 23435 | 22165 | 21323 | 4.91 |
| **Run 5** | 206.8 | | 104.8 | 56526 | 55430 | 53978 | 52396 | 24854 | 24186 | 23215 | 22181 | 21275 | 4.77 |
| **Run 6** | 185.6 | | 106.3 | 55496 | 54021 | 52735 | 50999 | 25153 | 24330 | 23313 | 22264 | 21360 | 4.62 |
| **Run 7** | 159.5 | | 108.4 | 52614 | 51147 | 49746 | 48064 | 24309 | 23569 | 22630 | 21579 | 20665 | 4.35 |
| **Run 8** | 147.8 | | 110.3 | 51218 | 49663 | 48356 | 46624 | 24227 | 23419 | 22489 | 21381 | 20518 | 4.19 |
| **Run 9** | 137.4 | | 118.6 | 49925 | 48362 | 47149 | 45475 | 24311 | 23586 | 22615 | 21550 | 20743 | 3.93 |
| **Run 10** | 125.4 | | 124.4 | 49414 | 47955 | 46619 | 44743 | 24157 | 23517 | 22609 | 21579 | 20709 | 3.78 |
| **Run 11** | 102.5 | | 140.1 | 47165 | 45688 | 44372 | 42778 | 23860 | 23230 | 22263 | 21283 | 20415 | 3.40 |
| **Run 12** | 86.40 | | 150.3 | 45377 | 44076 | 42761 | 41034 | 23693 | 22886 | 21962 | 20937 | 19959 | 3.08 |
| **Run 13** | 69.74 | | 174.0 | 44357 | 42783 | 41538 | 39987 | 23565 | 22742 | 21716 | 20650 | 19850 | 2.84 |
| **Run 14** | 63.93 | | 203.5 | 44102 | 42496 | 41400 | 39644 | 23076 | 22316 | 21377 | 20376 | 19534 | 2.63 |
| **Run 15** | 56.13 | | 211.4 | 42030 | 40660 | 39359 | 37699 | 22270 | 21564 | 20645 | 19667 | 18769 | 2.46 |
| **Run 16** | 46.36 | | 216.0 | 40735 | 39266 | 38011 | 36270 | 22099 | 21666 | 20853 | 19756 | 18924 | 2.28 |
| **Run 17** | 36.64 | | 226.7 | 37838 | 36413 | 35035 | 33373 | 21582 | 20899 | 19982 | 19051 | 18160 | 2.07 |
| **Run 18** | 30.15 | | 221.3 | 36107 | 34596 | 33400 | 31646 | 21714 | 21016 | 20162 | 19167 | 18234 | 1.83 |
| **Run 19** | 25.66 | | 268.2 | 34156 | 32902 | 31485 | 29941 | 21029 | 20256 | 19315 | 18384 | 17590 | 1.65 |
| **Run 20** | 19.67 | | 291.0 | 33577 | 32266 | 30939 | 29325 | 21304 | 20589 | 19708 | 18798 | 17913 | 1.44 |
| **Run 21** | 13.83 | | 323.5 | 32475 | 31048 | 29804 | 28166 | 21122 | 20351 | 19488 | 18583 | 17639 | 1.24 |
| **Run 22** | 10.86 | | 380.8 | 31668 | 30276 | 29029 | 27381 | 20900 | 20213 | 19347 | 18386 | 17535 | 1.09 |
| **Run 23** | 6.605 | | 464.9 | 30592 | 29209 | 27967 | 26429 | 20633 | 20006 | 19176 | 18194 | 17305 | 0.86 |

## Appendix 83: Kaolin 13 % in 100 mm valve, 25 % open

### Kaolin 13 % in 100 mm valve, 25 % open

Kaolin 13 % in 100 mm valve, 25 % open

| | | |
|---|---|---|
| Date: | 12/11/2007 | Test done by Mume & Rendani |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.1 | |
| Valve position: | ¼ Open | Area[m²] |
| Pipe Diameter [m]: | 0.09717 | 0.007415736 |

| | |
|---|---|
| Material Type: | Kaolin 13% |
| Density[kg/m³]: | 1215.5 |
| Concentration: | 13% |
| $t_y$: | 18.973 |
| K: | 16.141 |
| n: | 0.242 |
| PPT used: | 105 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| Axial distances | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 |
| Valve plane | | | | | | | | | |
| Non-dimensionalised distances incl.[L/D]: | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 |
| Distances[m]: | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 71.68 | | 105.7 | 83520 | 81304 | 78164 | 74051 | 45642 | 44886 | 42836 | 39890 | 38650 | 4.52 |
| Run 2 | 72.14 | | 105.3 | 83008 | 80773 | 78051 | 73544 | 45431 | 44444 | 42810 | 39693 | 38684 | 4.51 |
| Run 3 | 64.32 | | 101.2 | 80234 | 77445 | 74791 | 70143 | 44685 | 44048 | 42136 | 38938 | 37830 | 4.30 |
| Run 4 | 62.45 | | 95.5 | 80225 | 77796 | 74744 | 69838 | 45241 | 44177 | 42403 | 39103 | 37818 | 4.29 |
| Run 5 | 60.82 | | 116.4 | 79600 | 76348 | 73243 | 69322 | 45111 | 44046 | 42075 | 39630 | 38269 | 4.12 |
| Run 6 | 60.97 | | 116.7 | 79791 | 76594 | 73448 | 69598 | 45424 | 44161 | 42193 | 39838 | 38391 | 4.13 |
| Run 7 | 55.13 | | 108.1 | 76936 | 74535 | 71159 | 67490 | 45241 | 44022 | 42024 | 39429 | 37935 | 3.92 |
| Run 8 | 55.37 | | 106.5 | 76991 | 74432 | 71230 | 67312 | 45748 | 43835 | 42246 | 39824 | 38171 | 3.93 |
| Run 9 | 49.98 | | 101.2 | 75076 | 71986 | 69196 | 65314 | 45128 | 43920 | 41982 | 39152 | 37757 | 3.76 |
| Run 10 | 48.12 | | 114.3 | 75071 | 71776 | 68391 | 64778 | 45344 | 43814 | 41779 | 38916 | 37887 | 3.72 |
| Run 11 | 45.29 | | 101.2 | 71327 | 69472 | 66491 | 62806 | 44346 | 43101 | 41347 | 38671 | 37258 | 3.49 |
| Run 12 | 47.06 | | 117.0 | 71828 | 68980 | 66216 | 62288 | 44529 | 42846 | 41067 | 38555 | 37382 | 3.48 |
| Run 13 | 38.86 | | 92.1 | 68613 | 65876 | 62873 | 58981 | 43874 | 42751 | 41084 | 38361 | 36964 | 3.25 |
| Run 14 | 39.41 | | 107.3 | 68834 | 66046 | 62622 | 58608 | 43641 | 42543 | 40812 | 38184 | 37006 | 3.26 |
| Run 15 | 34.19 | | 112.3 | 66896 | 63695 | 60639 | 56797 | 43475 | 42281 | 40491 | 37858 | 36786 | 3.01 |
| Run 16 | 32.56 | | 106.2 | 66717 | 64105 | 60375 | 56699 | 43280 | 42096 | 40486 | 37738 | 36565 | 2.99 |
| Run 17 | 27.57 | | 111.4 | 64744 | 61874 | 58618 | 54507 | 43081 | 41918 | 40238 | 37527 | 36404 | 2.70 |
| Run 18 | 26.53 | | 92.6 | 64611 | 61643 | 58708 | 54933 | 42935 | 42249 | 40308 | 37337 | 36129 | 2.67 |
| Run 19 | 25.37 | | 107.7 | 62770 | 60134 | 57186 | 53281 | 42691 | 41581 | 39904 | 37236 | 36126 | 2.52 |
| Run 20 | 25.47 | | 112.5 | 63256 | 60507 | 57774 | 53984 | 42679 | 41379 | 39778 | 37015 | 35954 | 2.53 |
| Run 21 | 23.53 | | 122.3 | 62614 | 60105 | 57163 | 53660 | 43134 | 41642 | 39882 | 37506 | 36195 | 2.39 |
| Run 22 | 24.49 | | 135.6 | 62149 | 59866 | 56804 | 53264 | 42663 | 41358 | 39566 | 37330 | 36094 | 2.39 |
| Run 23 | 19.39 | | 109.0 | 60596 | 58246 | 55270 | 51885 | 42487 | 41332 | 39692 | 37232 | 35922 | 2.17 |
| Run 24 | 19.31 | | 131.6 | 60742 | 58334 | 55052 | 51534 | 42141 | 41094 | 39442 | 37059 | 35841 | 2.15 |
| Run 25 | 15.04 | | 116.0 | 59322 | 56603 | 53747 | 50346 | 42279 | 40935 | 39442 | 37057 | 35709 | 1.90 |
| Run 26 | 15.85 | | 155.5 | 59145 | 56363 | 53512 | 50107 | 41964 | 40753 | 38986 | 36759 | 35580 | 1.90 |
| Run 27 | 12.57 | | 178.7 | 58560 | 55231 | 52268 | 48624 | 41715 | 40532 | 38578 | 36471 | 35236 | 1.76 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 28 | 12.98 | | 164.6 | 58276 | 55013 | 52219 | 49007 | 41220 | 40350 | 38527 | 36354 | 35121 | 1.76 |
| Run 29 | 5.98 | | 155.1 | 57891 | 53376 | 50443 | 47167 | 41124 | 39781 | 38332 | 36015 | 34652 | 1.53 |
| Run 30 | 7.06 | | 181.7 | 57671 | 53537 | 50568 | 47244 | 41065 | 39909 | 38203 | 35940 | 34686 | 1.53 |
| Run 31 | 4.30 | | 211.4 | 55821 | 51960 | 49004 | 46246 | 40759 | 39504 | 37681 | 35465 | 34102 | 1.16 |
| Run 32 | 4.25 | | 162.6 | 55622 | 51942 | 48761 | 45457 | 40027 | 38828 | 37710 | 35495 | 33992 | 1.16 |
| Run 33 | 3.07 | | 295.2 | 52880 | 49653 | 46832 | 43818 | 39389 | 38261 | 36683 | 34621 | 33366 | 0.86 |
| Run 34 | 2.66 | | 413.0 | 53401 | 50310 | 47028 | 43884 | 39249 | 38088 | 36588 | 34422 | 33321 | 0.86 |
| Run 35 | 2.74 | | 659.3 | 50377 | 47559 | 45208 | 42423 | 38319 | 37166 | 35488 | 33882 | 32712 | 0.67 |
| Run 36 | 2.71 | | 760.4 | 50527 | 48060 | 45309 | 42587 | 38179 | 37078 | 35328 | 33620 | 32554 | 0.67 |
| Run 37 | 0.84 | | 1053 | 48156 | 46024 | 43671 | 40801 | 36849 | 35986 | 34657 | 32763 | 31707 | 0.36 |
| Run 38 | 0.85 | | 1597 | 48120 | 46136 | 43429 | 40688 | 36784 | 35821 | 34439 | 32610 | 31610 | 0.36 |

## Appendix 84: Water in 100 mm valve, 50 % open

### Water in 100 mm valve, 25 % open

Water in 100 mm valve, 25 % open

| | | | |
|---|---|---|---|
| Date: | 11/27/2006 | Test done by Mume | |
| Valve Type: | Diaphragm | | |
| Valve dimension[m]: | 0.1 | | |
| Valve position: | ¼ Open | Area[m²] | |
| Pipe Diameter [m]: | 0.09717 | 0.007415736 | |

| | |
|---|---|
| Material Type: | Water |
| Density[kg/m³]: | 993.48062 |
| Concentration: | 100% |
| $t_y$: | 0 |
| K: | 0.0007016 |
| n: | 1 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0007016 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | | Distances[m]: | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 194266 | | 83.74 | 110179 | 109470 | 109410 | 109256 | 25876 | 25680 | 25431 | 25158 | 25018 | 10.47 |
| Run 2 | 183100 | | 83.11 | 99348 | 99201 | 99039 | 99162 | 24939 | 24857 | 24617 | 24322 | 24210 | 9.87 |
| Run 3 | 177637 | | 81.76 | 93289 | 93184 | 93030 | 92719 | 24640 | 24429 | 24274 | 24053 | 23941 | 9.57 |
| Run 6 | 145771 | | 68.07 | 61037 | 60850 | 60856 | 60583 | 22290 | 22238 | 22036 | 21917 | 21790 | 7.86 |
| Run 7 | 138710 | | 66.44 | 56124 | 55886 | 55835 | 55689 | 21926 | 21822 | 21640 | 21442 | 21413 | 7.48 |
| Run 8 | 127238 | | 64.08 | 49094 | 48899 | 48708 | 48710 | 21315 | 21131 | 21069 | 20893 | 20870 | 6.86 |
| Run 9 | 116165 | | 64.97 | 44092 | 44137 | 44075 | 43954 | 20734 | 20749 | 20539 | 20452 | 20395 | 6.26 |
| Run 10 | 108666 | | 65.55 | 41159 | 41079 | 41028 | 40947 | 20469 | 20374 | 20253 | 20121 | 20104 | 5.86 |

## Appendix 85: CMC 5 % in 100 mm valve, 50 % open

### CMC 5 % in 100 mm valve, 50 % open

**CMC 5 % in 100 mm valve, 50 % open**

| | | |
|---|---|---|
| **Date:** | 12/13/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.639 | 0.379 | 2.639 | 7.147 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | CMC 5% | | | | | | | | | | | |
| **Density[kg/m³]:** | 1026.7 | | | | | | | | | | | |
| **Concentration:** | 5% | | | | | | | | | | | |
| **$t_y$:** | 0 | | | | | | | | | | | |
| **K:** | 3.319 | | | | | | | | | | | |
| **n:** | 0.61 | **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 359.0 | | 15.85 | 117677 | 114646 | 108283 | 104070 | 75505 | 73020 | 70275 | 67194 | 64430 | 12.81 |
| Run 2 | 329.7 | | 15.21 | 110426 | 107707 | 102228 | 98069 | 72406 | 70177 | 67450 | 64449 | 61905 | 12.05 |
| Run 3 | 317.3 | | 15.26 | 107308 | 105076 | 100057 | 95787 | 71017 | 68981 | 66218 | 63369 | 61007 | 11.72 |
| Run 4 | 312.5 | | 14.53 | 106215 | 103699 | 98449 | 94730 | 70602 | 68701 | 65771 | 63028 | 60458 | 11.59 |
| Run 5 | 294.7 | | 15.55 | 102475 | 100415 | 95397 | 91663 | 68495 | 66351 | 63689 | 61088 | 58554 | 11.12 |
| Run 6 | 281.8 | | 16.14 | 100277 | 97896 | 92918 | 89234 | 67116 | 65073 | 62539 | 59918 | 57547 | 10.76 |
| Run 7 | 265.3 | | 16.21 | 96658 | 94508 | 89754 | 86235 | 65440 | 63476 | 61007 | 58469 | 56199 | 10.31 |
| Run 8 | 247.6 | | 16.86 | 93364 | 91200 | 86590 | 83107 | 63363 | 61567 | 59218 | 56700 | 54517 | 9.81 |
| Run 9 | 232.6 | | 16.93 | 90157 | 87976 | 83511 | 80210 | 61466 | 59857 | 57621 | 55205 | 52921 | 9.37 |
| Run 10 | 216.2 | | 18.20 | 86906 | 84674 | 80211 | 77108 | 59535 | 57946 | 55837 | 53476 | 51417 | 8.90 |
| Run 11 | 201.0 | | 18.17 | 83878 | 81627 | 77521 | 74316 | 57863 | 56381 | 54325 | 52017 | 49920 | 8.44 |
| Run 12 | 185.5 | | 19.09 | 80521 | 78482 | 74352 | 71294 | 56121 | 54620 | 52583 | 50396 | 48458 | 7.97 |
| Run 13 | 171.3 | | 19.37 | 77360 | 75423 | 71416 | 68558 | 54467 | 53018 | 51062 | 48941 | 47056 | 7.52 |
| Run 14 | 153.7 | | 19.95 | 73772 | 71825 | 67982 | 65221 | 52445 | 51023 | 49158 | 47086 | 45244 | 6.96 |
| Run 15 | 138.2 | | 20.92 | 70138 | 68405 | 64900 | 62057 | 50482 | 49117 | 47345 | 45368 | 43684 | 6.45 |
| Run 16 | 125.4 | | 21.30 | 67599 | 65810 | 62400 | 59817 | 48994 | 47713 | 45953 | 44051 | 42363 | 6.01 |
| Run 17 | 107.9 | | 23.54 | 63725 | 62091 | 58803 | 56427 | 46808 | 45564 | 43914 | 42114 | 40602 | 5.39 |
| Run 18 | 92.06 | | 27.40 | 60393 | 58847 | 55793 | 53556 | 44667 | 43478 | 41991 | 40304 | 38860 | 4.81 |
| Run 19 | 77.33 | | 32.14 | 57079 | 55602 | 52896 | 50844 | 42579 | 41495 | 40071 | 38562 | 37209 | 4.25 |
| Run 20 | 63.97 | | 36.75 | 54101 | 52998 | 50436 | 48592 | 41068 | 40104 | 38801 | 37398 | 36161 | 3.70 |

**Appendix 86: Kaolin 6 % in 100 mm valve, 50 % open**

## Kaolin 6 % in 100 mm valve, 50 % open

**Kaolin 6 % in 100 mm valve, 50 % open**

| | | |
|---|---|---|
| **Date:** | 8/3/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Material Type:** | Kaolin 6% | | | | | | | | | | | |
| | **Density[kg/m³]:** | 1103.9 | | | | | | | | | | | |
| | **Concentration:** | 6% | | | | | | | | | | | |
| | **$t_y$:** | 3.071 | | | | | | | | | | | |
| | **K:** | 2.038 | | | | | | | | | | | |
| | **n:** | 0.264 | **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| | **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| | **Range selected:** | 0-40 | **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | | **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |
| **Run #** | **$Re_3$** | | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 816.4 | | 16.65 | 26735 | 26366 | 25912 | 25300 | 17040 | 16812 | 16496 | 16046 | 15713 | 6.50 |
| **Run 2** | 811.2 | | 16.98 | 26797 | 26381 | 25947 | 25381 | 17133 | 16920 | 16548 | 16071 | 15779 | 6.47 |
| **Run 3** | 766.8 | | 16.61 | 26451 | 26022 | 25669 | 25046 | 17138 | 16908 | 16601 | 16106 | 15803 | 6.29 |
| **Run 4** | 707.2 | | 16.58 | 25594 | 25148 | 24742 | 24272 | 16994 | 16703 | 16458 | 16008 | 15690 | 6.00 |
| **Run 5** | 601.0 | | 17.53 | 24794 | 24375 | 23833 | 23279 | 16913 | 16719 | 16461 | 15961 | 15725 | 5.52 |
| **Run 6** | 494.8 | | 15.61 | 23703 | 23117 | 22725 | 22120 | 16559 | 16311 | 16043 | 15442 | 15167 | 5.10 |
| **Run 7** | 681.8 | | 21.62 | 27024 | 26506 | 26114 | 25555 | 17399 | 17086 | 16774 | 16321 | 16069 | 5.82 |
| **Run 8** | 624.5 | | 20.90 | 26793 | 26260 | 25789 | 25123 | 17562 | 17303 | 16958 | 16415 | 16211 | 5.69 |
| **Run 9** | 617.5 | | 20.08 | 26224 | 25643 | 25314 | 24691 | 17483 | 17216 | 16914 | 16322 | 16169 | 5.57 |
| **Run 10** | 594.0 | | 20.50 | 25527 | 25009 | 24608 | 24048 | 17359 | 17034 | 16775 | 16245 | 16088 | 5.38 |
| **Run 11** | 585.3 | | 19.70 | 24912 | 24430 | 23953 | 23361 | 17252 | 16889 | 16633 | 16140 | 15975 | 5.33 |
| **Run 12** | 510.0 | | 17.59 | 24221 | 23803 | 23415 | 22844 | 16912 | 16697 | 16348 | 15816 | 15524 | 5.06 |
| **Run 13** | 414.8 | | 13.36 | 23542 | 23009 | 22539 | 21963 | 16805 | 16641 | 16399 | 15760 | 15376 | 4.71 |
| **Run 14** | 330.4 | | 24.55 | 23008 | 22464 | 21971 | 21476 | 16675 | 16365 | 16212 | 15847 | 15545 | 4.05 |
| **Run 15** | 309.9 | | 22.91 | 22467 | 21987 | 21672 | 21180 | 16748 | 16514 | 16175 | 15777 | 15446 | 3.77 |
| **Run 16** | 256.0 | | 21.69 | 22019 | 21595 | 21145 | 20513 | 16555 | 16271 | 16140 | 15712 | 15348 | 3.48 |
| **Run 17** | 225.4 | | 25.92 | 23105 | 22677 | 22189 | 21623 | 18054 | 17884 | 17549 | 16984 | 16837 | 3.22 |
| **Run 18** | 202.0 | | 29.86 | 22703 | 22199 | 21801 | 21284 | 18007 | 17849 | 17528 | 17085 | 16902 | 2.95 |
| **Run 19** | 157.3 | | 17.36 | 21963 | 21430 | 21140 | 20522 | 17887 | 17794 | 17584 | 17053 | 16817 | 2.65 |
| **Run 20** | 111.7 | | 25.66 | 21438 | 20960 | 20665 | 20082 | 17908 | 17739 | 17528 | 17034 | 16857 | 2.13 |

## Appendix 87: Kaolin 10 % in 100 mm valve, 50 % open

Kaolin 10 % in100 mm valve, 50 % open

**Kaolin 10 % in 100 mm valve, 50 % open**

| | | |
|---|---|---|
| **Date:** | 8/15/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | ½ Open | **Area[m$^2$]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |

| 1/n | n/(n+1) | (n+1)/n | K$^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | Kaolin 10% | | | | | | | | | | | |
| **Density[kg/m$^3$]:** | 1169.4 | | | | | | | | | | | |
| **Concentration:** | 10% | | | | | | | | | | | |
| **$t_y$:** | 8.965 | | | | | | | | | | | |
| **K:** | 7.098 | | | | | | | | | | | |
| **n:** | 0.175 | **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 342.2 | | 25.22 | 44272 | 42888 | 41489 | 39623 | 26436 | 25633 | 24689 | 23619 | 22615 | 6.41 |
| Run 2 | 305.0 | | 25.90 | 43668 | 42097 | 40678 | 38898 | 26205 | 25397 | 24448 | 23293 | 22369 | 6.21 |
| Run 3 | 299.6 | | 27.00 | 43035 | 41605 | 40067 | 38352 | 26074 | 25281 | 24288 | 23112 | 22309 | 6.09 |
| Run 4 | 292.8 | | 26.47 | 41477 | 40041 | 38698 | 36875 | 25257 | 24507 | 23554 | 22590 | 21567 | 5.86 |
| Run 5 | 273.4 | | 25.85 | 40855 | 39346 | 38026 | 36314 | 25428 | 24691 | 23681 | 22639 | 21691 | 5.70 |
| Run 6 | 259.9 | | 25.38 | 40045 | 38528 | 37190 | 35552 | 25205 | 24437 | 23472 | 22149 | 21475 | 5.57 |
| Run 7 | 239.6 | | 24.84 | 38660 | 37265 | 35877 | 34173 | 24733 | 24007 | 23046 | 22021 | 21058 | 5.29 |
| Run 8 | 230.5 | | 24.78 | 37974 | 36577 | 35203 | 33526 | 24560 | 23841 | 22887 | 21887 | 20936 | 5.16 |
| Run 9 | 214.4 | | 25.66 | 36795 | 35378 | 34046 | 32299 | 23984 | 23261 | 22307 | 21310 | 20408 | 4.93 |
| Run 10 | 185.4 | | 24.48 | 36534 | 35091 | 33654 | 31970 | 24167 | 23446 | 22570 | 21453 | 20583 | 4.71 |
| Run 11 | 173.9 | | 29.20 | 35996 | 34471 | 33056 | 31453 | 24027 | 23234 | 22198 | 21364 | 20424 | 4.54 |
| Run 12 | 166.1 | | 24.26 | 35320 | 33890 | 32697 | 30792 | 23707 | 22967 | 22091 | 21126 | 20071 | 4.33 |
| Run 13 | 143.1 | | 28.22 | 34383 | 32989 | 31682 | 29953 | 23324 | 22670 | 21768 | 20729 | 19867 | 3.98 |
| Run 14 | 128.8 | | 31.71 | 34101 | 32568 | 31263 | 29471 | 23245 | 22505 | 21463 | 20592 | 19629 | 3.84 |
| Run 15 | 118.8 | | 26.02 | 33177 | 31758 | 30457 | 28660 | 22918 | 22205 | 21331 | 20372 | 19369 | 3.66 |
| Run 16 | 107.2 | | 25.65 | 32049 | 30572 | 29253 | 27598 | 22487 | 21710 | 20815 | 19690 | 18904 | 3.50 |
| Run 17 | 102.1 | | 26.99 | 31299 | 29849 | 28575 | 26859 | 22171 | 21469 | 20507 | 19553 | 18679 | 3.34 |
| Run 18 | 89.31 | | 22.06 | 30169 | 28818 | 27509 | 25845 | 21808 | 21076 | 20163 | 19203 | 18290 | 3.10 |
| Run 19 | 82.94 | | 19.86 | 29283 | 27968 | 26687 | 25062 | 21349 | 20636 | 19771 | 18809 | 17915 | 2.96 |
| Run 20 | 74.46 | | 19.29 | 28567 | 27352 | 26035 | 24478 | 21011 | 20375 | 19464 | 18534 | 17633 | 2.76 |
| Run 21 | 64.72 | | 22.04 | 28501 | 27194 | 25907 | 24295 | 21089 | 20402 | 19481 | 18627 | 17683 | 2.58 |
| Run 22 | 57.21 | | 20.51 | 27791 | 26531 | 25270 | 23681 | 20810 | 20086 | 19213 | 18360 | 17442 | 2.39 |

## Appendix 88: Kaolin 13 % in 100 mm valve, 50 % open

### Kaolin 13 % in 100 mm valve, 50 % open

| | | |
|---|---|---|
| Date: | 12/11/2007 | Test done by Mume & Rendani |
| Valve Type: | Diaphragm | |
| Valve dimension[m]: | 0.1 | |
| Valve position: | ½ Open | Area[m²] |
| Pipe Diameter [m]: | 0.09717 | 0.007415736 |

Kaolin 13 % in 100 mm valve, 50 % open

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 4.136 | 0.195 | 5.136 | 99167 |

| | |
|---|---|
| Material Type: | Kaolin 13% |
| Density[kg/m³]: | 1215.5 |
| Concentration: | 13% |
| $\tau_y$: | 18.973 |
| K: | 16.141 |
| n: | 0.242 |
| PPT used: | 105 |
| Range selected: | 0-130 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | | Distances[m]: | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 73.32 | | 14.76 | 62281 | 59797 | 56722 | 52145 | 45386 | 43917 | 42041 | 39942 | 37931 | 4.57 |
| Run 2 | 74.94 | | 17.57 | 61974 | 59967 | 56600 | 52129 | 45228 | 44243 | 42057 | 39743 | 38114 | 4.56 |
| Run 3 | 75.36 | | 26.62 | 61075 | 58667 | 55948 | 51090 | 44781 | 43184 | 41093 | 38555 | 37559 | 4.40 |
| Run 4 | 71.82 | | 23.04 | 61544 | 58423 | 55659 | 51566 | 44803 | 43897 | 41664 | 38558 | 37979 | 4.40 |
| Run 5 | 59.25 | | 26.52 | 60720 | 57786 | 54422 | 51304 | 44487 | 42826 | 40659 | 38517 | 36934 | 4.03 |
| Run 6 | 62.33 | | 26.17 | 60381 | 57803 | 54715 | 50844 | 44588 | 42962 | 40520 | 38579 | 36841 | 4.06 |
| Run 7 | 54.90 | | 21.94 | 59886 | 57279 | 54877 | 50807 | 44294 | 43635 | 40563 | 38434 | 36724 | 3.80 |
| Run 8 | 56.12 | | 26.78 | 59738 | 57163 | 54136 | 50909 | 44478 | 42910 | 40542 | 38576 | 36911 | 3.81 |
| Run 11 | 49.25 | | 28.63 | 57638 | 56189 | 52088 | 49350 | 43868 | 43293 | 40622 | 38348 | 37247 | 3.45 |
| Run 12 | 44.11 | | 26.88 | 58369 | 55864 | 52010 | 49192 | 44903 | 41313 | 40539 | 38257 | 36978 | 3.42 |
| Run 13 | 36.32 | | 10.88 | 58744 | 55351 | 52377 | 48934 | 44328 | 42387 | 40625 | 38253 | 36544 | 3.19 |
| Run 14 | 37.50 | | 17.54 | 58358 | 55210 | 52113 | 48608 | 43545 | 42283 | 40314 | 38021 | 36417 | 3.20 |
| Run 15 | 32.14 | | 8.71 | 57557 | 54265 | 51403 | 48323 | 43441 | 42071 | 40257 | 37900 | 36277 | 2.95 |
| Run 16 | 32.60 | | 15.09 | 57327 | 54400 | 51263 | 48668 | 42636 | 41616 | 39953 | 37561 | 36064 | 2.95 |
| Run 20 | 24.92 | | 25.55 | 55452 | 53112 | 50059 | 46804 | 42256 | 41027 | 39265 | 37013 | 35687 | 2.44 |
| Run 22 | 22.21 | | 63.32 | 55750 | 52561 | 50414 | 46381 | 42093 | 40844 | 38854 | 36775 | 35616 | 2.20 |
| Run 24 | 18.46 | | 65.93 | 53770 | 51650 | 48714 | 45444 | 41315 | 40375 | 38250 | 36343 | 35105 | 1.95 |
| Run 25 | 12.14 | | 48.83 | 53574 | 51234 | 48154 | 44937 | 40921 | 40105 | 38268 | 36027 | 34845 | 1.64 |
| Run 26 | 11.38 | | 39.19 | 53652 | 51326 | 47851 | 44544 | 40491 | 39712 | 38070 | 35902 | 34505 | 1.64 |
| Run 29 | 6.04 | | 62.41 | 51911 | 49143 | 46538 | 43524 | 39782 | 38811 | 37254 | 35027 | 33896 | 1.12 |
| Run 30 | 6.28 | | 109.2 | 51611 | 48797 | 46271 | 43050 | 39442 | 38322 | 36840 | 34794 | 33630 | 1.12 |
| Run 31 | 4.85 | | 145.6 | 50211 | 47384 | 44922 | 42108 | 38796 | 37740 | 36064 | 34152 | 33005 | 0.96 |
| Run 32 | 4.71 | | 115.6 | 50134 | 47500 | 44851 | 41896 | 38275 | 37444 | 35981 | 33968 | 32820 | 0.96 |
| Run 34 | 1.99 | | 549.1 | 48148 | 45675 | 43046 | 40140 | 36990 | 36093 | 34665 | 32901 | 31865 | 0.57 |
| Run 35 | 0.82 | | 803.6 | 46060 | 43708 | 41448 | 38769 | 35771 | 35016 | 33806 | 32001 | 31071 | 0.34 |
| Run 36 | 0.86 | | 251.0 | 45028 | 43072 | 40780 | 38209 | 35614 | 34738 | 33514 | 31676 | 30757 | 0.34 |

## Appendix 89: Water in 100 mm valve, 50 % open

### Water in 100 mm valve, 50 % open

**Water in 100 mm valve, 50 % open**

| | | |
|---|---|---|
| **Date:** | 11/30/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | ½ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0007152 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | Water | | | | | | | | | | | |
| **Density[kg/m³]:** | 993.87994 | | | | | | | | | | | |
| **Concentration:** | 100% | | | | | | | | | | | |
| $t_y$: | 0 | | | | | | | | | | | |
| **K:** | 0.0007152 | | | | | | | | | | | |
| **n:** | 1 | **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 404428 | | 14.59 | 129579 | 129203 | 128137 | 126452 | 59454 | 58748 | 58274 | 57256 | 56689 | 22.21 |
| Run 2 | 379411 | | 16.18 | 121979 | 121659 | 120688 | 119888 | 54256 | 53575 | 53074 | 52507 | 51725 | 20.84 |
| Run 3 | 359597 | | 18.01 | 118034 | 117188 | 116750 | 115646 | 50743 | 50369 | 49480 | 48609 | 48243 | 19.75 |
| Run 4 | 328448 | | 19.88 | 108092 | 107618 | 107426 | 106349 | 44952 | 44411 | 44225 | 43293 | 42885 | 18.04 |
| Run 5 | 312994 | | 21.70 | 102575 | 101950 | 101557 | 100607 | 42259 | 42128 | 41360 | 41068 | 40586 | 17.19 |
| Run 6 | 295022 | | 21.67 | 93571 | 92652 | 92702 | 91566 | 39398 | 39311 | 38721 | 38418 | 37943 | 16.20 |
| Run 7 | 276216 | | 20.85 | 82526 | 82036 | 81604 | 80905 | 36734 | 36240 | 35913 | 35558 | 35130 | 15.17 |
| Run 8 | 259364 | | 20.07 | 73665 | 73521 | 73050 | 72761 | 34395 | 34167 | 33901 | 33352 | 33143 | 14.24 |
| Run 9 | 235883 | | 19.11 | 62513 | 62167 | 61702 | 61267 | 31337 | 31160 | 30790 | 30495 | 30120 | 12.95 |
| Run 10 | 208781 | | 18.03 | 51237 | 51060 | 50955 | 50508 | 28319 | 28171 | 27881 | 27652 | 27412 | 11.47 |
| Run 12 | 179681 | | 16.41 | 41057 | 40956 | 40639 | 40358 | 25405 | 25217 | 25075 | 24887 | 24689 | 9.87 |
| Run 13 | 155128 | | 14.84 | 34052 | 33895 | 33756 | 33537 | 23228 | 23086 | 22963 | 22886 | 22640 | 8.52 |
| Run 15 | 124324 | | 13.33 | 27397 | 27342 | 27219 | 27067 | 21088 | 20956 | 20910 | 20836 | 20696 | 6.83 |
| Run 16 | 106259 | | 14.72 | 25122 | 25129 | 24999 | 24913 | 20131 | 20150 | 20023 | 19970 | 19878 | 5.84 |

**Appendix 90: CMC 5 % in 100 mm valve, 75 % open**

## CMC 5 % in 100 mm valve, 75 % open

CMC 5 % in 100 mm valve, 75 % open

| | | | |
|---|---|---|---|
| Date: | 12/14/2006 | Test done by Mume | |
| Valve Type: | Diaphragm | | |
| Valve dimension[m]: | 0.1 | | |
| Valve position: | ¾ Open | Area[m²] | |
| Pipe Diameter [m]: | 0.09717 | 0.007415736 | |

| | |
|---|---|
| Material Type: | CMC 5% |
| Density[kg/m³]: | 1026.7 |
| Concentration: | 5% |
| $t_y$: | 0 |
| K: | 2.826 |
| n: | 0.639 |
| PPT used: | 101 to 109 |
| Range selected: | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1.565 | 0.390 | 2.565 | 5.082 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Axial distances | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| | | | Valve plane | | | | | | | | | | |
| | | | Non-dimensionalised distances incl.[L/D]: | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | | Distances[m]: | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |
| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
| | | | | | | | | | | | | | [l/s] |
| Run 6 | 336.4 | | -2.67 | 98258 | 95915 | 90716 | 86870 | 72104 | 69872 | 67277 | 64470 | 56203 | 12.06 |
| Run 7 | 308.2 | | -3.18 | 93361 | 90910 | 86263 | 82545 | 68809 | 66883 | 64370 | 61658 | 54002 | 11.31 |
| Run 8 | 280.7 | | -3.49 | 88896 | 86678 | 82043 | 78433 | 65651 | 63893 | 61550 | 58954 | 51702 | 10.56 |
| Run 9 | 250.4 | | -3.91 | 84027 | 81845 | 77303 | 73819 | 62358 | 60587 | 58283 | 55902 | 49107 | 9.71 |
| Run 10 | 230.5 | | -4.47 | 80505 | 78548 | 74185 | 70914 | 60080 | 58460 | 56292 | 53916 | 47573 | 9.14 |
| Run 11 | 210.8 | | -5.02 | 77027 | 75033 | 70783 | 67705 | 57781 | 56239 | 54119 | 51858 | 45908 | 8.56 |
| Run 12 | 189.4 | | -5.48 | 73392 | 71509 | 67357 | 64379 | 55395 | 53869 | 51836 | 49748 | 44151 | 7.91 |
| Run 13 | 164.8 | | -6.51 | 68998 | 67126 | 63351 | 60537 | 52578 | 51040 | 49189 | 47144 | 42090 | 7.14 |
| Run 14 | 144.5 | | -7.35 | 65258 | 63563 | 59939 | 57384 | 50135 | 48748 | 46990 | 45137 | 40473 | 6.48 |
| Run 15 | 123.3 | | -9.59 | 61216 | 59628 | 56284 | 53898 | 47511 | 46190 | 44446 | 42678 | 38499 | 5.77 |

## Appendix 91: Kaolin 6 % in 100 mm valve, 75 % open

### Kaolin 6 % in 100 mm valve, 75 % open

Kaolin 6 % in 100 mm valve, 75 % open

| | | |
|---|---|---|
| **Date:** | 8/2/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | ¾ Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | Kaolin 6% | | | | | | | | | | |
| **Density[kg/m³]:** | 1103.9 | | | | | | | | | | |
| **Concentration:** | 6% | | | | | | | | | | |
| $t_y$**:** | 3.071 | | | | | | | | | | |
| **K:** | 2.038 | | | | | | | | | | |
| **n:** | 0.264 | **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | |
| **Range selected:** | 0-40 | **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 |
| | | **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 513.2 | | 8.86 | 22915 | 22447 | 21834 | 21324 | 17841 | 17503 | 17158 | 16744 | 16351 | 5.26 |
| Run 2 | 497.0 | | 7.99 | 22845 | 22311 | 21861 | 21237 | 17962 | 17670 | 17283 | 16892 | 16444 | 5.09 |
| Run 3 | 465.1 | | 9.40 | 22684 | 22211 | 21683 | 21095 | 17840 | 17567 | 17207 | 16763 | 16420 | 4.89 |
| Run 4 | 447.2 | | 10.13 | 22362 | 21800 | 21389 | 20800 | 17702 | 17442 | 17096 | 16585 | 16365 | 4.72 |
| Run 5 | 395.6 | | 9.00 | 22044 | 21614 | 21108 | 20552 | 17682 | 17473 | 17114 | 16623 | 16335 | 4.43 |
| Run 6 | 373.1 | | 12.85 | 21829 | 21227 | 20827 | 20240 | 17557 | 17207 | 16954 | 16526 | 16330 | 4.21 |
| Run 9 | 254.3 | | 12.07 | 20870 | 20441 | 19991 | 19382 | 17372 | 17169 | 16837 | 16417 | 16181 | 3.35 |
| Run 10 | 210.0 | | 11.21 | 20632 | 20223 | 19834 | 19115 | 17021 | 16829 | 16608 | 16132 | 15877 | 3.06 |
| Run 11 | 204.5 | | 16.49 | 20070 | 19708 | 19331 | 18717 | 16810 | 16547 | 16221 | 15865 | 15610 | 2.86 |
| Run 13 | 155.2 | | 15.80 | 20038 | 19430 | 19064 | 18382 | 16791 | 16553 | 16240 | 15868 | 15602 | 2.66 |
| Run 14 | 99.05 | | 17.73 | 21221 | 20700 | 20261 | 19670 | 18252 | 18046 | 17745 | 17382 | 17097 | 2.11 |
| Run 15 | 57.32 | | 35.83 | 20605 | 20133 | 19699 | 19271 | 18173 | 17922 | 17611 | 17113 | 17069 | 1.50 |
| Run 16 | 73.60 | | 19.79 | 21099 | 20575 | 20085 | 19563 | 18261 | 18026 | 17675 | 17275 | 17015 | 1.89 |
| Run 17 | 39.47 | | 25.35 | 20978 | 20487 | 19983 | 19473 | 18416 | 18277 | 17899 | 17456 | 17263 | 1.38 |

## Appendix 92: Kaolin 10 % in 100 mm valve, 75 % open

### Kaolin 10 % in 100 mm valve, 75 % open

Kaolin 10 % in 100 mm valve, 75 % open

| | | | |
|---|---|---|---|
| Date: | 8/15/2007 | Test done by Mume & Maanda | |
| Valve Type: | Diaphragm | | |
| Valve dimension[m]: | 0.1 | | |
| Valve position: | ¾ Open | Area[m²] | |
| Pipe Diameter [m]: | 0.09717 | 0.007415736 | |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 5.702 | 0.149 | 6.702 | 71319 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Material Type: | Kaolin 10% | | | | | | | | | | | | |
| | Density[kg/m³]: | 1169.4 | | | | | | | | | | | | |
| | Concentration: | 10% | | | | | | | | | | | | |
| | $t_y$: | 8.965 | | | | | | | | | | | | |
| | K: | 7.098 | | | | | | | | | | | | |
| | n: | 0.175 | | Axial distances | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| | PPT used: | 101 to 109 | | Valve plane | | | | | | | | | | |
| | Range selected: | 0-130 | | Non-dimensionalised distances incl.[L/D]: | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | | | Distances[m]: | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |
| Run # | $Re_3$ | | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
| | | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 343.2 | | | 7.20 | 37099 | 35663 | 34285 | 32377 | 26602 | 25833 | 24861 | 23809 | 22685 | 6.50 |
| Run 2 | 327.3 | | | 7.03 | 36899 | 35361 | 34019 | 32107 | 26432 | 25751 | 24787 | 23735 | 22605 | 6.39 |
| Run 3 | 312.5 | | | 7.41 | 36357 | 34915 | 33532 | 31591 | 26184 | 25523 | 24515 | 23368 | 22373 | 6.18 |
| Run 4 | 294.8 | | | 8.09 | 35774 | 34262 | 32883 | 31117 | 25909 | 25131 | 24171 | 23182 | 22123 | 6.00 |
| Run 5 | 269.2 | | | 8.26 | 35209 | 33743 | 32299 | 30569 | 25719 | 24912 | 23931 | 22861 | 21900 | 5.74 |
| Run 6 | 255.5 | | | 8.18 | 34620 | 33119 | 31727 | 29996 | 25290 | 24582 | 23588 | 22465 | 21570 | 5.57 |
| Run 7 | 234.7 | | | 6.83 | 33857 | 32344 | 30962 | 29261 | 24906 | 24183 | 23203 | 21979 | 21123 | 5.36 |
| Run 8 | 229.0 | | | 7.64 | 33121 | 31692 | 30374 | 28608 | 24489 | 23788 | 22874 | 21763 | 20909 | 5.14 |
| Run 9 | 195.6 | | | 4.03 | 32609 | 31050 | 29813 | 28075 | 24278 | 23531 | 22604 | 21367 | 20429 | 4.86 |
| Run 10 | 183.4 | | | 6.23 | 31919 | 30400 | 29202 | 27305 | 23804 | 23176 | 22168 | 20991 | 20148 | 4.59 |
| Run 11 | 170.8 | | | 5.80 | 31645 | 30098 | 28934 | 27160 | 23562 | 22999 | 22050 | 20751 | 20017 | 4.43 |
| Run 12 | 146.4 | | | 6.08 | 31124 | 29666 | 28306 | 26589 | 23324 | 22592 | 21661 | 20460 | 19631 | 4.16 |
| Run 13 | 138.0 | | | 6.23 | 30525 | 29080 | 27860 | 26138 | 22984 | 22299 | 21362 | 20093 | 19380 | 3.93 |
| Run 14 | 109.4 | | | -0.36 | 29765 | 28263 | 26975 | 25264 | 22471 | 21789 | 20928 | 19596 | 18765 | 3.61 |
| Run 15 | 106.0 | | | 2.14 | 29456 | 27908 | 26734 | 25051 | 22242 | 21644 | 20698 | 19392 | 18641 | 3.49 |
| Run 16 | 101.0 | | | 2.10 | 28999 | 27399 | 26337 | 24525 | 22064 | 21383 | 20494 | 19419 | 18516 | 3.35 |
| Run 17 | 89.27 | | | 3.22 | 28719 | 27351 | 25855 | 24288 | 21859 | 21210 | 20275 | 19226 | 18310 | 3.26 |
| Run 18 | 86.73 | | | -1.13 | 28165 | 26857 | 25507 | 23828 | 21557 | 20931 | 20006 | 18928 | 17993 | 3.11 |
| Run 19 | 81.18 | | | -0.53 | 27734 | 26424 | 25079 | 23428 | 21371 | 20677 | 19777 | 18810 | 17837 | 2.98 |
| Run 20 | 68.77 | | | -0.63 | 27159 | 25828 | 24560 | 22908 | 21054 | 20345 | 19456 | 18488 | 17581 | 2.69 |
| Run 21 | 60.11 | | | -0.99 | 26749 | 25408 | 24118 | 22601 | 20742 | 20129 | 19242 | 18334 | 17414 | 2.51 |

## Appendix 93: Kaolin 13 % in 100 mm valve, 75 % open

### Kaolin 13 % in 100 mm valve, 75 % open

**Kaolin 13 % in 100 mm valve, 75 % open**

| | | |
|---|---|---|
| **Date:** | 9/30/2007 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | ¾ Open | **Area[m$^2$]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |
| **Material Type:** | Kaolin 13% | |
| **Concentration:** | 13% | |
| **Density[kg/m$^3$]:** | 1204.1 | |

| | |
|---|---|
| $t_y$: | 17.442 |
| K: | 11.285 |
| n: | 0.216 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Pod Number:** | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
| **Axial distances** | -5.551 | -4.043 | -2.542 | -0.699 | 0.700 | 1.502 | 2.502 | 4.499 | 9.511 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.:** | -57.12 | -41.60 | -26.16 | -7.19 | 7.20 | 15.45 | 25.75 | 46.30 | 97.88 |
| **Distances[m]:** | 0 | 1.508 | 3.009 | 4.852 | 6.251 | 7.053 | 8.053 | 10.05 | 15.06 |

| Run # | $Re_3$ | | $k_v$ | $DP_1$ | $DP_2$ | $DP_3$ | $DP_4$ | $DP_5$ | $DP_6$ | $DP_7$ | $DP_8$ | $DP_9$ | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [l/s] |
| Run 1 | 78.41 | | 2.71 | 0 | 4215 | 7499 | 11735 | 17257 | 18919 | 20956 | 25427 | 37529 | 5.56 |
| Run 2 | 76.85 | | 2.71 | 0 | 4159 | 7633 | 11969 | 17433 | 18995 | 21043 | 25820 | 37707 | 5.56 |
| Run 3 | 83.24 | | 2.88 | 0 | 4152 | 7566 | 12146 | 17755 | 19212 | 21373 | 25788 | 38220 | 5.83 |
| Run 4 | 85.27 | | 2.72 | 0 | 4167 | 7692 | 12455 | 17964 | 19525 | 21539 | 25827 | 38266 | 5.83 |
| Run 6 | 68.15 | | 1.58 | 0 | 4154 | 7750 | 11882 | 17835 | 19231 | 21086 | 25506 | 37892 | 5.38 |
| Run 7 | 73.89 | | 1.70 | 0 | 4167 | 7786 | 11483 | 17697 | 19030 | 20945 | 24960 | 36927 | 5.16 |
| Run 10 | 61.42 | | 3.00 | 0 | 4157 | 7295 | 11629 | 16833 | 18349 | 20287 | 24884 | 36619 | 4.94 |
| Run 12 | 58.34 | | 1.59 | 0 | 4141 | 7496 | 11941 | 16898 | 18172 | 20158 | 24592 | 36223 | 4.73 |
| Run 13 | 51.25 | | 2.75 | 0 | 4066 | 7057 | 11393 | 16151 | 17741 | 19682 | 24132 | 35867 | 4.55 |
| Run 16 | 45.73 | | 2.37 | 0 | 4061 | 6933 | 11277 | 15755 | 17279 | 19216 | 23772 | 35290 | 4.30 |
| Run 18 | 40.09 | | 1.43 | 0 | 4399 | 6840 | 11186 | 15552 | 16900 | 18875 | 23526 | 34898 | 4.07 |
| Run 20 | 35.96 | | 2.25 | 0 | 3939 | 6770 | 11033 | 15313 | 16760 | 18700 | 23216 | 34564 | 3.84 |
| Run 24 | 27.34 | | 2.46 | 0 | 3860 | 6677 | 10864 | 15000 | 16405 | 18319 | 22854 | 33928 | 3.38 |
| Run 25 | 27.99 | | 1.32 | 0 | 3876 | 7037 | 11108 | 15074 | 16440 | 18430 | 22951 | 33972 | 3.38 |
| Run 27 | 24.46 | | 1.88 | 0 | 3898 | 6952 | 11048 | 14872 | 16257 | 18232 | 22715 | 33696 | 3.19 |
| Run 28 | 20.55 | | 2.91 | 0 | 3804 | 6503 | 10670 | 14651 | 15977 | 17911 | 22336 | 33267 | 2.95 |
| Run 29 | 21.28 | | 1.45 | 0 | 3831 | 6906 | 11010 | 14803 | 16135 | 18104 | 22569 | 33355 | 2.95 |
| Run 30 | 19.47 | | 2.56 | 0 | 3426 | 5945 | 10309 | 13141 | 14510 | 16428 | 20630 | 31721 | 2.87 |
| Run 31 | 20.66 | | 2.20 | 0 | 3352 | 5997 | 10024 | 13119 | 14610 | 16392 | 20700 | 31545 | 2.89 |
| Run 32 | 25.80 | | 4.74 | 0 | 3014 | 6254 | 9940 | 13645 | 15218 | 17032 | 21543 | 31737 | 2.98 |
| Run 36 | 11.54 | | 4.54 | 0 | 2984 | 5798 | 9593 | 12765 | 14316 | 16031 | 19824 | 30933 | 2.27 |
| Run 37 | 12.38 | | 5.43 | 0 | 3182 | 5740 | 9426 | 12923 | 14072 | 15890 | 19618 | 30604 | 2.27 |
| Run 39 | 8.55 | | 7.32 | 0 | 2915 | 5784 | 9223 | 12879 | 14344 | 16126 | 19690 | 31278 | 2.14 |
| Run 41 | 9.92 | | 6.24 | 0 | 3056 | 5880 | 9150 | 12956 | 14141 | 15921 | 20067 | 30780 | 2.15 |
| Run 42 | 12.23 | | 4.78 | 0 | 3030 | 5885 | 8961 | 12744 | 14399 | 16452 | 20172 | 30809 | 2.15 |
| Run 43 | 9.27 | | 5.18 | 0 | 3206 | 5814 | 9231 | 12789 | 14491 | 16060 | 19910 | 30859 | 2.08 |
| Run 44 | 7.49 | | 12.01 | 0 | 3473 | 5907 | 9475 | 12976 | 14007 | 16124 | 20103 | 31334 | 2.08 |
| Run 48 | 8.99 | | 11.78 | 0 | 2929 | 5625 | 8947 | 12770 | 13863 | 16121 | 19850 | 30336 | 1.89 |
| Run 49 | 9.59 | | 10.46 | 0 | 3075 | 5716 | 8959 | 12798 | 14084 | 16234 | 19872 | 30282 | 1.88 |

## Appendix 94: Water in 100 mm valve, 75 % open

### Water in 100 mm valve, 75 % open

**Water in 100 mm valve, 75 % open**

| | | | |
|---|---|---|---|
| **Date:** | 11/30/2006 | Test done by Mume | |
| **Valve Type:** | Diaphragm | | |
| **Valve dimension[m]:** | 0.1 | | |
| **Valve position:** | ¾ Open | **Area[m²]** | |
| **Pipe Diameter [m]:** | 0.09717 | | 0.007415736 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0007238 |

| | |
|---|---|
| **Material Type:** | **Water** |
| **Density[kg/m³]:** | **994.115** |
| **Concentration:** | **100%** |
| $t_y$**:** | **0** |
| **K:** | **0.00072** |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **n:** | 1 | **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 |
| | | **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 |

| **Run #** | $Re_3$ | | $k_v$ | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 498099 | | 4.48 | 120183 | 119086 | 118042 | 116445 | 81343 | 80971 | 80078 | 79600 | 77917 | 27.68 |
| **Run 2** | 448058 | | 4.19 | 101555 | 101068 | 100085 | 97804 | 69886 | 69653 | 69124 | 67773 | 66886 | 24.90 |
| **Run 3** | 406221 | | 4.64 | 87546 | 87108 | 86211 | 84313 | 61585 | 61139 | 60334 | 59530 | 58879 | 22.57 |
| **Run 4** | 383876 | | 4.62 | 80967 | 80615 | 79572 | 78115 | 57533 | 56862 | 56340 | 55635 | 54932 | 21.33 |
| **Run 5** | 355438 | | 4.75 | 72714 | 72143 | 71538 | 70590 | 52367 | 52015 | 51317 | 50575 | 50172 | 19.75 |
| **Run 6** | 337893 | | 4.36 | 67675 | 67195 | 66367 | 65393 | 49099 | 48781 | 48132 | 47658 | 46751 | 18.77 |
| **Run 7** | 319080 | | 4.51 | 62893 | 62244 | 61819 | 60915 | 46034 | 45735 | 45330 | 44798 | 44183 | 17.73 |
| **Run 8** | 304914 | | 5.04 | 59165 | 59044 | 58153 | 57270 | 44075 | 43762 | 42955 | 42564 | 42157 | 16.94 |
| **Run 9** | 287688 | | 5.07 | 55309 | 54602 | 54233 | 53489 | 41279 | 40911 | 40477 | 40119 | 39741 | 15.98 |
| **Run 10** | 269585 | | 4.63 | 51202 | 50985 | 50341 | 49684 | 38792 | 38644 | 38127 | 37657 | 37204 | 14.98 |
| **Run 11** | 246534 | | 5.02 | 46542 | 46235 | 45779 | 45321 | 35996 | 35694 | 35264 | 35069 | 34595 | 13.70 |
| **Run 12** | 222160 | | 5.43 | 41902 | 41728 | 41224 | 40868 | 32971 | 32731 | 32526 | 31967 | 32025 | 12.34 |

**Appendix 95: CMC 5 % in 100 mm valve, 100 % open**

## CMC 5 % in 100 mm valve, 100 % open

**CMC 5 % in 100 mm valve, 100 % open**

| | | |
|---|---|---|
| **Date:** | 12/14/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | Open | **Area[m$^2$]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |

| 1/n | n/(n+1) | (n+1)/n | K$^{1/n}$ |
|---|---|---|---|
| 1.591 | 0.386 | 2.591 | 5.198 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material Type:** | CMC 5% | | | | | | | | | | | |
| **Density[kg/m$^3$]:** | 1026.7 | | | | | | | | | | | |
| **Concentration:** | 5% | | | | | | | | | | | |
| **$t_y$:** | 0 | | | | | | | | | | | |
| **K:** | 2.818 | | | | | | | | | | | |
| **n:** | 0.629 | **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 | |
| **PPT used:** | 101 to 109 | **Valve plane** | | | | | | | | | | |
| **Range selected:** | 0-130 | **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 | |
| | | **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 | |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 662.1 | | 0.637 | 124885 | 122088 | 115406 | 110427 | 99036 | 96575 | 93003 | 89131 | 85465 | 19.00 |
| Run 2 | 600.7 | | 1.409 | 118278 | 115183 | 108258 | 103946 | 93348 | 90993 | 87849 | 84402 | 81160 | 17.69 |
| Run 3 | 551.4 | | 0.177 | 109785 | 106846 | 101433 | 96131 | 86957 | 85671 | 82534 | 79430 | 75630 | 16.62 |
| Run 4 | 582.3 | | 1.464 | 112789 | 110247 | 104646 | 99783 | 89732 | 87540 | 84927 | 81619 | 78684 | 17.30 |
| Run 5 | 530.7 | | 1.077 | 105275 | 103235 | 97117 | 92926 | 83524 | 82294 | 79211 | 76277 | 73492 | 16.17 |
| Run 6 | 495.6 | | 0.567 | 100703 | 97981 | 92858 | 88826 | 81034 | 79244 | 75228 | 72860 | 70301 | 15.38 |

## Appendix 96: Kaolin 6 % in 100 mm valve, 100 % open

### Kaolin 6 % in 100 mm valve, 100 % open

**Kaolin 6 % in 100 mm valve, 100 % open**

| | | |
|---|---|---|
| **Date:** | 8/2/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | Open | **Area[m$^2$]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 3.795 | 0.209 | 4.795 | 14.90 |

| | |
|---|---|
| **Material Type:** | Kaolin 6% |
| **Density[kg/m$^3$]:** | 1103.9 |
| **Concentration:** | 6% |
| **$t_y$:** | 3.071 |
| **K:** | 2.038 |
| **n:** | 0.264 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-40 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 |
| **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 |

| **Run #** | **$Re_3$** | **$k_v$** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **(Pa)** | **[l/s]** |
| **Run 1** | 692.1 | 0.139 | 20289 | 19764 | 19380 | 18820 | 17841 | 17614 | 17219 | 16876 | 16495 | 5.90 |
| **Run 2** | 636.2 | 0.037 | 20465 | 19913 | 19458 | 18867 | 17912 | 17721 | 17367 | 16998 | 16625 | 5.75 |
| **Run 3** | 581.4 | -0.183 | 20391 | 19826 | 19344 | 18788 | 17823 | 17633 | 17316 | 16931 | 16563 | 5.54 |
| **Run 4** | 564.0 | 0.027 | 20271 | 19674 | 19266 | 18642 | 17748 | 17536 | 17242 | 16768 | 16512 | 5.37 |
| **Run 5** | 528.5 | -0.232 | 20000 | 19510 | 19005 | 18538 | 17616 | 17463 | 17068 | 16697 | 16342 | 5.18 |
| **Run 6** | 505.7 | 0.107 | 19895 | 19347 | 19039 | 18354 | 17592 | 17389 | 17021 | 16616 | 16338 | 4.88 |
| **Run 7** | 406.9 | 0.422 | 19993 | 19283 | 18899 | 18400 | 17616 | 17407 | 17012 | 16568 | 16324 | 4.63 |
| **Run 8** | 413.6 | 0.449 | 19678 | 19183 | 18813 | 18171 | 17589 | 17352 | 16972 | 16600 | 16340 | 4.30 |
| **Run 9** | 383.1 | 1.209 | 19123 | 18695 | 18220 | 17639 | 16965 | 16837 | 16583 | 16215 | 16009 | 4.04 |

## Appendix 97: Kaolin 10 % in 100 mm valve, 100 % open

Kaolin 10 % in 100 mm valve, 100 % open

**Kaolin 10 % in 100 mm valve, 100 % open**

| | | |
|---|---|---|
| **Date:** | 8/22/2007 | Test done by Mume & Sisonke |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |
| **Material Type:** | kaolin 10% | |
| **Concentration:** | 10% | |
| **Density[kg/m³]:** | 1169.4 | |

| | |
|---|---|
| $t_y$: | **8.965** |
| K: | **7.098** |
| n: | **0.175** |

| **Pod Number:** | **Pod 1** | **Pod 2** | **Pod 3** | **Pod 4** | **Pod 5** | **Pod 6** | **Pod 7** | **Pod 8** | **Pod 9** |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -5.551 | -4.043 | -2.542 | -0.699 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.:** | -57.12 | -41.60 | -26.16 | -7.19 | 7.20 | 16.00 | 25.75 | 36.03 | 46.30 |
| **Distances[m]:** | 0 | 1.508 | 3.009 | 4.852 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 |

| **Run #** | **$Re_3$** | | **$k_v$** | **$DP_1$** | **$DP_2$** | **$DP_3$** | **$DP_4$** | **$DP_5$** | **$DP_6$** | **$DP_7$** | **$DP_8$** | **$DP_9$** | **Average Q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [l/s] |
| Run 1 | 245.4 | | 0.785 | 0 | 1268 | 2496 | 4180 | 5929 | 6339 | 7116 | 8261 | 8985 | 5.31 |
| Run 3 | 227.9 | | 0.397 | 0 | 1280 | 2521 | 4304 | 5988 | 6273 | 7210 | 8287 | 9179 | 5.31 |
| Run 4 | 233.6 | | 0.279 | 0 | 1342 | 2612 | 4316 | 6049 | 6403 | 7165 | 8281 | 9132 | 5.37 |
| Run 5 | 231.5 | | 0.328 | 0 | 1305 | 2504 | 4327 | 6020 | 6434 | 7149 | 8265 | 9111 | 5.33 |
| Run 6 | 251.3 | | 0.969 | 0 | 1241 | 2486 | 3964 | 5859 | 6261 | 7153 | 8050 | 8972 | 5.28 |
| Run 7 | 249.2 | | 0.720 | 0 | 1303 | 2463 | 4240 | 5827 | 6387 | 7128 | 8004 | 8985 | 5.33 |
| Run 8 | 257.7 | | 0.884 | 0 | 1273 | 2490 | 4282 | 5853 | 6355 | 7154 | 8167 | 8997 | 5.40 |
| Run 9 | 242.5 | | 0.245 | 0 | 1257 | 2594 | 4205 | 5995 | 6301 | 7198 | 8217 | 9095 | 5.33 |
| Run 10 | 240.8 | | 0.243 | 0 | 1282 | 2590 | 4271 | 6066 | 6367 | 7219 | 8264 | 9137 | 5.35 |
| Run 11 | 225.4 | | 0.192 | 0 | 1284 | 2564 | 4076 | 5904 | 6290 | 7182 | 8305 | 9134 | 5.24 |
| Run 12 | 235.7 | | 0.144 | 0 | 1362 | 2580 | 4145 | 5867 | 6425 | 7218 | 8287 | 9155 | 5.33 |
| Run 13 | 236.2 | | 0.665 | 0 | 1304 | 2448 | 4255 | 5844 | 6292 | 7186 | 8171 | 9139 | 5.37 |
| Run 14 | 214.2 | | 0.312 | 0 | 1284 | 2499 | 4339 | 5827 | 6320 | 7117 | 8296 | 9091 | 5.15 |
| Run 16 | 215.0 | | 0.406 | 0 | 1305 | 2606 | 4120 | 6023 | 6289 | 7108 | 8319 | 9095 | 5.19 |
| Run 17 | 249.0 | | 0.416 | 0 | 1363 | 2586 | 4352 | 5996 | 6348 | 7212 | 8064 | 9029 | 5.26 |
| Run 18 | 228.2 | | 0.322 | 0 | 1294 | 2582 | 4200 | 5936 | 6313 | 7207 | 8198 | 9098 | 5.16 |
| Run 19 | 211.1 | | 0.478 | 0 | 1326 | 2657 | 4216 | 5957 | 6436 | 7243 | 8227 | 9220 | 5.12 |
| Run 23 | 230.1 | | 0.471 | 0 | 1317 | 2671 | 4328 | 6043 | 6419 | 7141 | 8140 | 9036 | 5.19 |
| Run 24 | 247.7 | | 0.287 | 0 | 1393 | 2658 | 4313 | 6095 | 6337 | 7217 | 8153 | 8995 | 5.17 |
| Run 25 | 230.9 | | 0.081 | 0 | 1400 | 2606 | 4315 | 5919 | 6396 | 7186 | 8212 | 9064 | 5.16 |

## Appendix 98: Kaolin 13 % in 100 mm valve, 100 % open

Kaolin 13 % in 100 mm valve, 100 % open

**Kaolin 13 % in 100 mm valve, 100 % open**

| | | |
|---|---|---|
| **Date:** | 10/1/2007 | Test done by Sisonke & Maanda |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |
| **Material Type:** | Kaolin 13% | |
| **Concentration:** | 13% | |
| **Density(kg/m³):** | 1204.1 | |

| | |
|---|---|
| $t_y$: | 18.973 |
| K: | 16.141 |
| n: | 0.242 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Pod Number:** | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
| **Axial distances** | -5.551 | -4.043 | -2.542 | -0.699 | 0.700 | 1.502 | 2.502 | 4.499 | 9.511 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.:** | -57.12 | -41.60 | -26.16 | -7.19 | 7.20 | 15.45 | 25.75 | 46.30 | 97.88 |
| **Distances[m]:** | 0 | 1.508 | 3.009 | 4.852 | 6.251 | 7.053 | 8.053 | 10.05 | 15.06 |

| Run # | $Re_3$ | | $k_v$ | $DP_1$ | $DP_2$ | $DP_3$ | $DP_4$ | $DP_5$ | $DP_6$ | $DP_7$ | $DP_8$ | $DP_9$ | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [Pa] | [l/s] |
| Run 1 | 134.0 | | 2.22 | 0 | 3963 | 7653 | 12200 | 15465 | 17133 | 19309 | 23644 | 36143 | 6.76 |
| Run 2 | 136.1 | | 2.02 | 0 | 4185 | 7445 | 11606 | 15371 | 16944 | 18993 | 23325 | 35561 | 6.79 |
| Run 3 | 133.1 | | 2.09 | 0 | 4501 | 7373 | 11767 | 15315 | 16776 | 18997 | 23429 | 35739 | 6.73 |
| Run 4 | 132.2 | | 2.07 | 0 | 4159 | 7564 | 12180 | 15292 | 16903 | 19135 | 23885 | 36064 | 6.73 |
| Run 5 | 133.0 | | 2.08 | 0 | 4064 | 7555 | 12186 | 15478 | 17057 | 19156 | 23613 | 35920 | 6.73 |
| Run 6 | 131.4 | | 2.37 | 0 | 4163 | 7607 | 11993 | 15351 | 17001 | 19048 | 23789 | 35926 | 6.70 |
| Run 7 | 131.5 | | 2.24 | 0 | 4272 | 7541 | 11967 | 15275 | 16923 | 19077 | 23724 | 35933 | 6.70 |
| Run 8 | 131.3 | | 2.73 | 0 | 4322 | 7691 | 12021 | 15347 | 17064 | 19230 | 23648 | 36087 | 6.69 |
| Run 9 | 132.1 | | 1.50 | 0 | 3977 | 7290 | 11708 | 15179 | 16869 | 18881 | 23642 | 35796 | 6.72 |
| Run 10 | 131.3 | | 1.72 | 0 | 4014 | 7434 | 11812 | 15145 | 16818 | 18936 | 23763 | 35724 | 6.68 |
| Run 11 | 130.6 | | 1.82 | 0 | 3873 | 7525 | 11863 | 15211 | 16844 | 18988 | 23787 | 35722 | 6.66 |
| Run 12 | 134.4 | | 1.92 | 0 | 3961 | 7549 | 11999 | 15250 | 16923 | 19077 | 23471 | 35549 | 6.73 |
| Run 13 | 131.0 | | 2.35 | 0 | 4444 | 7563 | 12109 | 15204 | 16916 | 19104 | 23722 | 35890 | 6.68 |
| Run 14 | 130.7 | | 2.08 | 0 | 4344 | 7572 | 11846 | 15314 | 16965 | 19080 | 23956 | 35869 | 6.67 |
| Run 15 | 131.5 | | 2.65 | 0 | 3962 | 7695 | 12312 | 15447 | 17045 | 19211 | 23449 | 35978 | 6.69 |
| Run 16 | 132.0 | | 1.84 | 0 | 3948 | 7417 | 11572 | 15207 | 16874 | 18958 | 23455 | 35647 | 6.69 |
| Run 17 | 131.5 | | 2.24 | 0 | 4426 | 7533 | 11749 | 15235 | 16892 | 18994 | 23665 | 35620 | 6.67 |
| Run 18 | 132.3 | | 1.88 | 0 | 3993 | 7567 | 11868 | 15386 | 16975 | 19095 | 23612 | 35588 | 6.67 |
| Run 19 | 131.4 | | 2.66 | 0 | 4504 | 7592 | 11864 | 15466 | 16982 | 19122 | 23327 | 35649 | 6.65 |
| Run 20 | 130.7 | | 1.89 | 0 | 3965 | 7572 | 11812 | 15259 | 16967 | 19114 | 23752 | 35766 | 6.65 |
| Run 21 | 130.7 | | 2.07 | 0 | 4244 | 7616 | 12081 | 15301 | 17022 | 19154 | 23798 | 35733 | 6.64 |
| Run 22 | 132.4 | | 2.66 | 0 | 4484 | 7671 | 12343 | 15484 | 17145 | 19245 | 23600 | 35965 | 6.71 |
| Run 23 | 131.4 | | 1.71 | 0 | 4119 | 7268 | 11480 | 15180 | 16768 | 18806 | 23538 | 35716 | 6.70 |
| Run 24 | 133.1 | | 1.31 | 0 | 4314 | 7291 | 11634 | 15175 | 16763 | 18926 | 23739 | 35571 | 6.71 |
| Run 25 | 130.8 | | 1.49 | 0 | 4352 | 7403 | 11770 | 15140 | 16873 | 18980 | 23976 | 35678 | 6.66 |
| Run 26 | 125.0 | | 2.76 | 0 | 4183 | 7472 | 11370 | 14935 | 16626 | 18787 | 23383 | 35664 | 6.52 |
| Run 27 | 126.2 | | 1.96 | 0 | 4041 | 7482 | 11659 | 15026 | 16834 | 18940 | 23652 | 35579 | 6.53 |
| Run 28 | 117.1 | | 2.07 | 0 | 4151 | 7496 | 11699 | 15076 | 16732 | 18904 | 23716 | 35406 | 6.25 |
| Run 29 | 115.6 | | 2.95 | 0 | 4263 | 7520 | 11625 | 15162 | 16812 | 18955 | 23305 | 35632 | 6.23 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run 30 | 105.5 | | 3.44 | 0 | 4288 | 7606 | 11799 | 15135 | 16745 | 18852 | 23445 | 35426 | 5.93 |
| Run 31 | 105.5 | | 3.63 | 0 | 4389 | 7580 | 11779 | 15263 | 16842 | 18898 | 23168 | 35364 | 5.91 |
| Run 32 | 101.1 | | 3.87 | 0 | 4209 | 7564 | 12092 | 15219 | 16795 | 18722 | 23153 | 35241 | 5.79 |
| Run 33 | 99.87 | | 1.28 | 0 | 4120 | 6988 | 11439 | 15006 | 16441 | 18703 | 23082 | 35212 | 5.75 |
| Run 34 | 93.79 | | 3.90 | 0 | 4182 | 7387 | 11531 | 14908 | 16524 | 18529 | 22993 | 35122 | 5.57 |
| Run 35 | 93.66 | | 3.61 | 0 | 4213 | 7438 | 11669 | 15170 | 16742 | 18662 | 23133 | 35127 | 5.55 |
| Run 36 | 87.87 | | 5.37 | 0 | 4179 | 7473 | 11447 | 14707 | 16415 | 18310 | 22741 | 34898 | 5.38 |
| Run 37 | 88.61 | | 5.05 | 0 | 3905 | 7350 | 11636 | 14348 | 16442 | 18022 | 22669 | 34698 | 5.41 |
| Run 38 | 81.69 | | 4.67 | 0 | 4046 | 7299 | 11489 | 14895 | 16245 | 18044 | 23107 | 34815 | 5.20 |
| Run 39 | 82.59 | | 3.96 | 0 | 4099 | 7356 | 11644 | 14948 | 16557 | 18365 | 23059 | 34726 | 5.18 |
| Run 40 | 77.02 | | 4.43 | 0 | 4101 | 7177 | 11364 | 14522 | 16012 | 17956 | 22661 | 34189 | 4.98 |
| Run 41 | 76.70 | | 5.35 | 0 | 4099 | 7363 | 11562 | 14690 | 16137 | 18117 | 22755 | 34476 | 4.98 |
| Run 42 | 73.09 | | 4.04 | 0 | 4092 | 7132 | 11362 | 14668 | 16379 | 18034 | 22771 | 34285 | 4.85 |
| Run 43 | 73.35 | | 5.17 | 0 | 4393 | 7351 | 11599 | 14814 | 16462 | 18067 | 23019 | 34270 | 4.85 |
| Run 44 | 67.31 | | 6.01 | 0 | 3991 | 7167 | 10977 | 14278 | 15663 | 17647 | 22364 | 33794 | 4.63 |
| Run 45 | 66.28 | | 7.65 | 0 | 4335 | 7245 | 10886 | 14516 | 15731 | 17536 | 22327 | 33775 | 4.60 |
| Run 46 | 62.28 | | 8.49 | 0 | 4193 | 7115 | 10891 | 14345 | 15588 | 17357 | 22179 | 34005 | 4.49 |
| Run 47 | 63.08 | | 7.31 | 0 | 4037 | 7212 | 11358 | 14368 | 15829 | 17538 | 22492 | 33967 | 4.50 |
| Run 48 | 55.35 | | 9.18 | 0 | 4125 | 6973 | 10733 | 13842 | 15196 | 16967 | 21921 | 33286 | 4.19 |
| Run 49 | 55.44 | | 10.45 | 0 | 4277 | 7358 | 11268 | 14396 | 16050 | 17396 | 22314 | 33622 | 4.19 |
| Run 50 | 52.00 | | 10.41 | 0 | 4000 | 7124 | 10988 | 13997 | 15435 | 17010 | 22041 | 33292 | 4.05 |
| Run 51 | 52.20 | | 9.74 | 0 | 4094 | 7224 | 11171 | 14295 | 15652 | 17255 | 22204 | 33269 | 4.04 |
| Run 52 | 46.66 | | 10.73 | 0 | 3910 | 7029 | 11043 | 14009 | 15266 | 16960 | 21882 | 33081 | 3.81 |
| Run 53 | 47.61 | | 8.83 | 0 | 3876 | 7103 | 11102 | 14185 | 15444 | 17221 | 22120 | 33029 | 3.83 |
| Run 54 | 41.50 | | 12.22 | 0 | 3725 | 7054 | 11017 | 14093 | 15473 | 16873 | 21747 | 32804 | 3.57 |
| Run 55 | 41.20 | | 12.45 | 0 | 3824 | 7075 | 11020 | 14092 | 15450 | 16952 | 21724 | 32816 | 3.55 |
| Run 56 | 37.32 | | 14.35 | 0 | 3606 | 6948 | 10517 | 13601 | 14847 | 16559 | 21335 | 32338 | 3.36 |
| Run 57 | 36.47 | | 14.82 | 0 | 4133 | 6999 | 11012 | 14096 | 15240 | 16810 | 21623 | 32646 | 3.33 |
| Run 58 | 32.37 | | 19.10 | 0 | 4235 | 7133 | 10981 | 13894 | 15229 | 16830 | 21479 | 32466 | 3.11 |
| Run 59 | 32.86 | | 17.09 | 0 | 4151 | 7081 | 10899 | 13763 | 15214 | 16676 | 21477 | 31966 | 3.11 |
| Run 60 | 30.71 | | 15.56 | 0 | 3610 | 7126 | 10872 | 13993 | 15315 | 16854 | 21360 | 31789 | 2.97 |
| Run 61 | 30.14 | | 17.98 | 0 | 4061 | 7186 | 11103 | 13938 | 15377 | 16907 | 21589 | 32076 | 2.96 |
| Run 62 | 26.48 | | 17.20 | 0 | 3741 | 6954 | 10696 | 13592 | 14926 | 16567 | 21542 | 31814 | 2.77 |
| Run 63 | 26.92 | | 15.02 | 0 | 3728 | 6854 | 10720 | 13455 | 15032 | 16623 | 21340 | 31702 | 2.78 |
| Run 64 | 23.75 | | 21.59 | 0 | 3927 | 6746 | 10357 | 13343 | 14606 | 16299 | 20926 | 31553 | 2.62 |
| Run 65 | 23.53 | | 20.42 | 0 | 3767 | 6716 | 10486 | 13444 | 14598 | 16242 | 20808 | 31286 | 2.59 |
| Run 66 | 20.09 | | 23.80 | 0 | 3899 | 6894 | 10433 | 13022 | 14759 | 16333 | 21324 | 31288 | 2.38 |
| Run 67 | 20.01 | | 21.64 | 0 | 3642 | 6986 | 10560 | 13489 | 14782 | 16345 | 21671 | 31270 | 2.37 |
| Run 68 | 17.66 | | 19.22 | 0 | 3895 | 6942 | 10601 | 13410 | 14692 | 16592 | 21720 | 31149 | 2.19 |
| Run 69 | 17.34 | | 36.81 | 0 | 4020 | 7009 | 10632 | 13579 | 14749 | 16542 | 20556 | 31303 | 2.19 |
| Run 71 | 16.15 | | 39.77 | 0 | 4067 | 6952 | 10685 | 13420 | 14680 | 16586 | 20474 | 31515 | 2.12 |
| Run 72 | 14.65 | | 37.11 | 0 | 3466 | 6893 | 10726 | 13533 | 14547 | 16408 | 20474 | 31120 | 2.00 |
| Run 73 | 20.04 | | 35.20 | 0 | 3515 | 6968 | 10263 | 13012 | 14043 | 15948 | 20186 | 30658 | 2.36 |

## Appendix 99: Water in 100 mm valve, 100 % open

### Water in 100 mm valve, 100 % open

**Water in 100 mm valve, 100 % open**

| | | |
|---|---|---|
| **Date:** | 11/27/2006 | Test done by Mume |
| **Valve Type:** | Diaphragm | |
| **Valve dimension[m]:** | 0.1 | |
| **Valve position:** | Open | **Area[m²]** |
| **Pipe Diameter [m]:** | 0.09717 | 0.007415736 |

| | |
|---|---|
| **Material Type:** | Water |
| **Density[kg/m³]:** | 995.09431 |
| **Concentration:** | 100% |
| $t_y$: | 0 |
| **K:** | 0.0007733 |
| **n:** | 1 |
| **PPT used:** | 101 to 109 |
| **Range selected:** | 0-130 |

| 1/n | n/(n+1) | (n+1)/n | $K^{1/n}$ |
|---|---|---|---|
| 1 | 0.5 | 2 | 0.0007733 |

| | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Axial distances** | -5.551 | -4.552 | -2.542 | -1.040 | 0.700 | 1.502 | 2.502 | 3.501 | 4.499 |
| **Valve plane** | | | | | | | | | |
| **Non-dimensionalised distances incl.[L/D]:** | -57.12 | -46.84 | -26.16 | -10.70 | 7.20 | 15.45 | 25.75 | 36.03 | 46.30 |
| **Distances[m]:** | 0 | 0.999 | 3.009 | 4.511 | 6.251 | 7.053 | 8.053 | 9.052 | 10.05 |

| Run # | $Re_3$ | | $k_v$ | Pod 1 | Pod 2 | Pod 3 | Pod 4 | Pod 5 | Pod 6 | Pod 7 | Pod 8 | Pod 9 | Average Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | (Pa) | [l/s] |
| Run 1 | 537269 | | 1.127 | 118322 | 117400 | 115240 | 113665 | 101141 | 100294 | 98664 | 96956 | 96303 | 31.87 |
| Run 3 | 517511 | | 0.992 | 98681 | 96831 | 95709 | 93327 | 83969 | 82741 | 81759 | 80665 | 79743 | 30.69 |
| Run 5 | 492262 | | 0.775 | 81537 | 80336 | 79587 | 77824 | 69811 | 69360 | 68195 | 67590 | 66450 | 29.20 |
| Run 6 | 474515 | | 0.724 | 76734 | 75811 | 75197 | 73200 | 66126 | 65560 | 65025 | 64080 | 63440 | 28.14 |
| Run 7 | 473457 | | 0.803 | 72671 | 71997 | 70700 | 69808 | 62851 | 62297 | 61477 | 60644 | 60112 | 28.08 |
| Run 18 | 420158 | | 1.507 | 105876 | 105239 | 103370 | 100460 | 90258 | 89937 | 88524 | 88138 | 86358 | 24.92 |
| Run 19 | 417157 | | 1.701 | 98577 | 97714 | 95839 | 94463 | 84526 | 84087 | 82317 | 81828 | 80644 | 24.74 |
| Run 21 | 402887 | | 1.232 | 84150 | 81916 | 81616 | 80431 | 72430 | 71867 | 70555 | 70024 | 68933 | 23.90 |
| Run 22 | 396559 | | 1.277 | 76187 | 75249 | 74704 | 72997 | 65796 | 64957 | 64354 | 63196 | 63012 | 23.52 |
| Run 23 | 396559 | | 1.153 | 70082 | 69571 | 68717 | 67424 | 61230 | 60385 | 59859 | 59145 | 58748 | 23.52 |
| Run 25 | 388776 | | 1.308 | 59037 | 58573 | 57887 | 56777 | 51704 | 51360 | 50164 | 50107 | 49553 | 23.06 |
| Run 28 | 365840 | | 1.564 | 75761 | 74665 | 73238 | 72389 | 64993 | 64015 | 63337 | 63025 | 61967 | 21.70 |
| Run 33 | 317395 | | 1.357 | 63910 | 63578 | 62782 | 61250 | 55554 | 54839 | 54553 | 53890 | 53304 | 18.82 |
| Run 37 | 262544 | | 0.988 | 45384 | 45044 | 44561 | 43757 | 40163 | 39805 | 39531 | 39163 | 38631 | 15.57 |