# Abstract

In liquid pipelines drag reduction by polymer injection has increased the efficiency considerably. In this thesis drag reduction in gas pipelines has been studied experimentally.

In order to show if drag reduction has occurred, the friction factor for single phase gas flow and gas-solid flow was calculated and compared. When calculating the experimental friction factor, the uncertainty of the pipe diameter had to be investigated.

Experiments were performed with the injection of glass beads, polyamide and polyethylene in gas flow using a pipe of plexiglass. Practical problems related to the injection system arised when fiber was used as an additive. Most experiments failed due to packing of the injection pipe. A needle valve, that controlled particle or fiber injection, was replaced with a globe valve and a T-bend was replaced with a jet mixer to improve the injection system.

The gas-solid flow resulted in electrostatic build up in the pipe. To eliminate the electrostatics, introduced by particles and fibers, the pipes were grounded and a copper wire was placed inside the pipe.

A scanning electron microscope was used to investigate how the particles and fibers were affected in gas-solid flow.

## Acknowledgments

This master thesis has been carried out at Statoil Research Center in Trondheim in the period 15.01.2004 – 07.06.2004.

I would like to thank my supervisors, professor Sigurd Skogestad at department of Chemical Engineering (NTNU) and Odd Tore Isaksen at Statoil K-lab, for pointing out the directions in which to proceed, and for their support along the way. I would also like to thank Dr.Ing Andre Strupstad and professor Tor Ytrehus for fruitful discussions. They have been acting as extra supervisors to me in this thesis. Thanks!

Thanks to Tony Boasson at Statoil Research Center for teaching me how to use the scanning electron microscope.

Thanks to Tore Arnesen and all the workers in the electro- and mechanical workshop at Statoil Research Center in Trondheim.

Thanks to Gassco and Ida V. Andersen for support, motivation, visiting trip and literature.

Thanks to hot chocolate machines at Statoil Research Center in Trondheim for giving me energy when I needed it the most.

Thanks to my significant other, Kristin, for being supporting and patient with me after many hours in the lab.

Finally, I would like to thank my parents for everything they have done for me!

Trondheim 07.06.2004

------------------------------
Ingvald Bårdsen

# Contents

# List of Figures

# List of Tables

# Chapter 1

# Introduction

## 1.1 Motivation

Use of drag reducing agents in liquid pipelines can offer large economic advantages and a larger effectiveness of the liquid transportation. Drag reducing agents were first documented in the middle the $19^{th}$ century. In liquid pipe flow drag reducing agents are typically long chain or high molecular weight polymers that are suspended in a solvent. When injected into the pipeline these long chain polymers act as buffers along the pipe wall to decrease the amount of energy lost in turbulence formation. The reduction in the turbulent energy results in a reduction in the frictional pressure loss for a given flow rate. Experimentally it has been found that very small concentrations, on the order of a few ppm by weight, of dissolved high-polymer substance can reduce the frictional resistance in turbulent flow to as low as one-fourth that of pure solvent [1].

Statoil, Hydro and Gassco have an ongoing research where the primary objective is to increase the transport capacity in rich-gas pipelines by at least 5%. It is believed that especially fibers can be feasible flow improvers in gas pipe flow. In general little work has considered flow improvement in gas by addition of particles or fibers, however, the results in [1] are promising. This article presents experimental data with up to 30% drag reduction in horizontal gas pipe flow.

## 1.2 Thesis Overview

The master thesis is composed of five chapters and a CD. In the end of the thesis there is a concluding chapter, and in addition there are 5 appendices A, B, C, D and E.

Chapter 1 motivates the research on drag reduction, and gives an overview of the thesis.

Chapter 2 presents the basic theory of gas transport, turbulence and drag reduction.

Chapter 3 presents the experimental equipment used and gives important details of the lab and the lab instructions.

Chapter 4 presents the results and the discussion.

Chapter 5 sums up the discussion, and gives a conclusion. Directions for further work is also included.

The included CD is written using Macromedia Flash MX. It is a interactive summary of the thesis along with animations and sound. For instructions how to play the CD the reader should open readme.txt. The CD is *not* meant to replace the written thesis, but only as a supplement.

# Chapter 2

# General Theory

## 2.1 Norwegian Pipeline System

A general insight in the gas pipeline structure and how the transport system functions is useful when working with technology that can improve the transport capacity.

Fig. 2.1.1 gives an overview of the norwegian pipeline system. The Langeled project is not included in the figure.

The pipeline system can be divided into different areas (Fig. 2.1.2).

- A: Statpipe rich gas
- B: Åsgard Transport rich gas
- C: Kårstø processing complex
- D: Dry gas

This information is from [2].

- *Gassco* is responsible as operator for transporting Norwegian gas to continental Europe and the UK through a 6600 kilometer network of pipelines. Gasscos architect role gives it responsibility for assessing needs and coordinating further development of the gas transport system. The aim is to ensure that Norway has an integrated and well-run network which ensures optimum utilisation of its offshore resources. In its role as capacity allocator, Gassco is required to provide access to the gas transport system on objective and transparent terms. These must serve all gas shippers and contribute to the most efficient possible utilisation of Norwegian offshore resources.

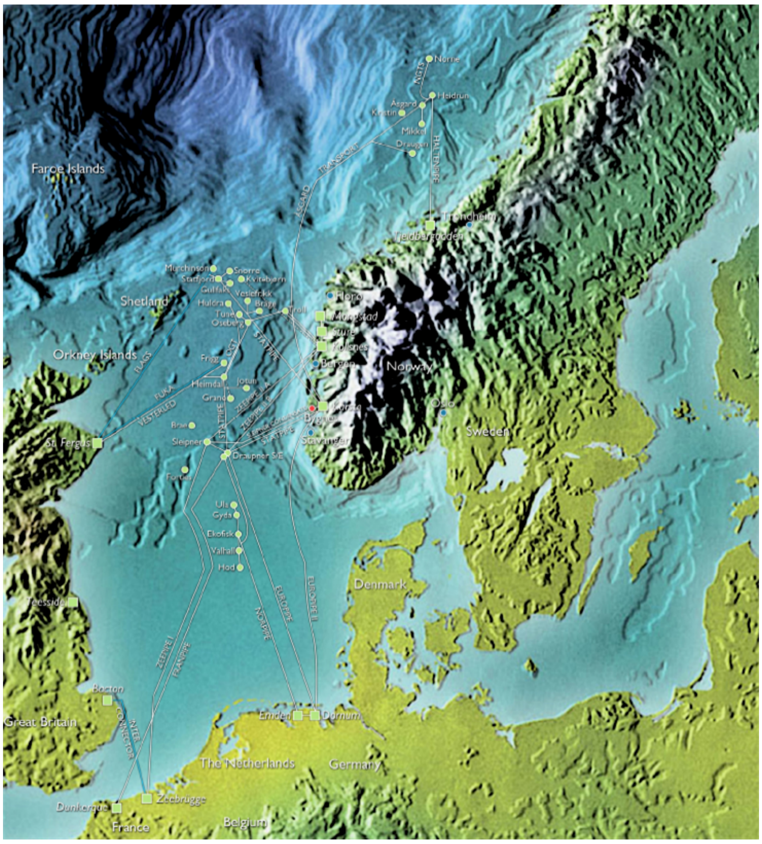


Figure 2.1.1: Norwegian pipeline system.

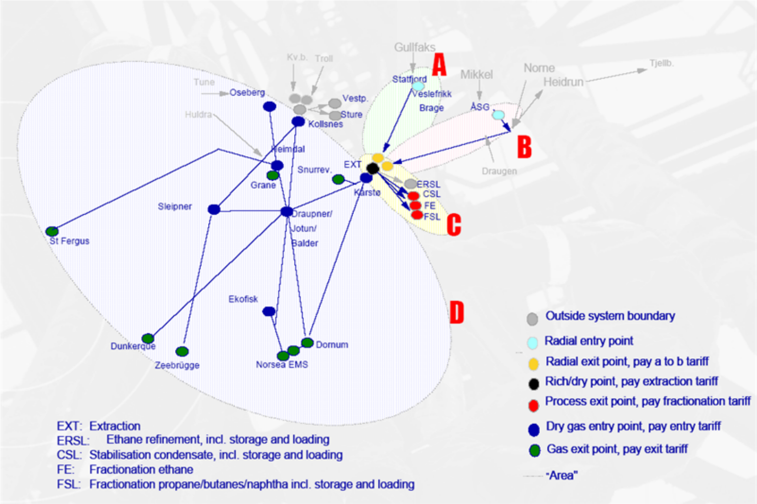


Figure 2.1.2: Gassled areas.

- *Gassled* is a joint venture between oil and gas companies on the Norwegian continental shelf. Established on 1 January 2003, it has no employees and is organised through various committees with specific assignments. This partnership serves as the formal owner of the Norwegian gas transport infrastructure.

Table 2.1.1: Gassled owners

| | |
|---|---|
| Petoro | 38.293 |
| Statoil | 20.379 |
| Hydro | 11.134 |
| Total | 9.038 |
| Esso | 5.179 |
| Shell | 4.681 |
| Mobil | 4.576 |
| Norsea Gas | 3.018 |
| ConocoPhillips | 2.033 |
| Eni | 1,669 |

**Practial terms to know are:**

- *Dry gas/sales gas*: Consists mainly of methane, ethane and some LPG. The gas will not condense at normal conditions.

- *Rich gas/wet gas*: Consists mainly of methane, ethane, LPG, buthane, some naphtha and condensate. The gas will condense at normal conditions.

- *Hydraulic Capacity* (Hyd): The maximum volume of natural gas physically possible to transport through the pipeline under given conditions.

- *Available Technical Capacity* (ATC): The capacity may be limited by a system boundary condition, e.g. lack of export compression to fill the pipeline. The ATC is the actual capacity available for a given period.

- *Committable Capacity* (Com) The committable capacity takes into account both the fuel consumption and an operational flexibility factor.

- *Bookable capacity* : This capacity defines the maximum allowed booking level.

## 2.2 Gas Transport and Basic Equations

### 2.2.1 Density, velocity and volumetric flow rate for experimental data

Eq. 2.2.1 presents the ideal gas law.

$$PV = nRT. \tag{2.2.1}$$

Using the ideal gas law modified with the compressibility factor $z$, mole $n = \frac{m}{M}$ and with mass $m = \rho V$, the equation of state used is

$$\rho = \frac{PM}{zRT}. \tag{2.2.2}$$

The volumetric flow rate can be calculated by

$$Q = \frac{\dot{m}}{\rho}, \tag{2.2.3}$$

and the gas velocity by

$$v = \frac{\dot{m}}{\rho A}. \tag{2.2.4}$$

### 2.2.2 Friction factor for experimental data

> It is very important in working from suspension pressure drop data that the carrying gas properties (especially not the mixture density), be used in calculating friction factors. Use of the mixture density can lead to an apparent drag reduction but not one consistent with the preceding definition [1].

The definition of drag reduction in [1] is given in Eq. 2.5.1.
From Fig. 2.2.1 the equation of motion is given by

$$\begin{aligned} PA - \left(PA + \frac{\partial PA}{\partial x}\Delta x\right) - \tau_w \pi D \Delta x - \rho A \Delta x g \sin\alpha \\ + \left(P + \frac{\partial P}{\partial x}\frac{\Delta x}{2}\right)\frac{\partial A}{\partial x}\Delta x = \rho A \Delta x \frac{dv}{dt}, \end{aligned} \tag{2.2.5}$$

where

$$\frac{dv}{dt} = \frac{\partial v}{\partial t} + \frac{\partial v}{\partial x}\frac{dx}{dt}. \tag{2.2.6}$$

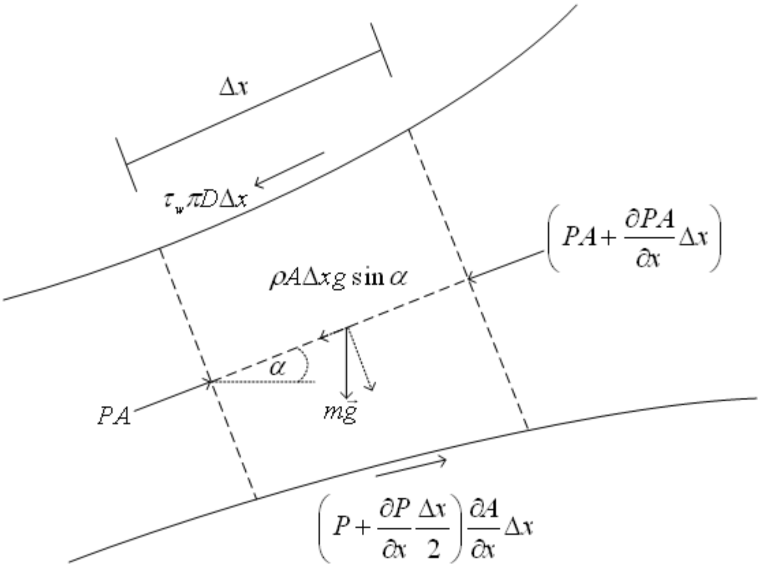


Figure 2.2.1: General equation of motion for gas pipe flow.

For a pipe with constant crossection and negligible elevations Eq. 2.2.5 is reduced to

$$-A\frac{dP}{dx} - \tau_w \pi D = A\rho v\frac{dv}{dx}. \tag{2.2.7}$$

The Moody friction factor, $f_m$, is defined as

$$f_m = \frac{8\tau_w}{\rho v^2}. \tag{2.2.8}$$

The equation of state as

$$\rho = \frac{PM}{zRT}. \tag{2.2.9}$$

Combining Eq. 2.2.7, Eq. 2.2.8 and Eq. 2.2.9 gives (deduction in Sec. A.1 on p. 62)

$$f_m = \frac{\pi^2 D^5 M}{16\dot{m}^2 zRTL}(P_1^2 - P_2^2) + 2\frac{D}{L}\ln\frac{P_2}{P_1}. \tag{2.2.10}$$

Eq. 2.2.10 is used when analysing the experimental data.

### 2.2.3 Friction factors from literature

For smooth pipe the dependence of f on $L/D$ arises from the development of the time-average velocity distribution from its flat entry shape toward

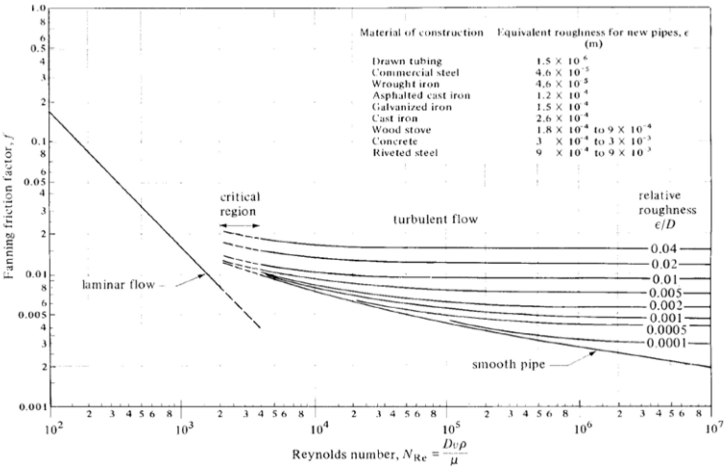


Figure 2.2.2: Fanning friction factor.

more rounded profiles at downstream length values. For turbulent flow this development occurs within an entrance region of length $L_e \approx 60D$, beyond which the shape of the velocity distribution is fully developed [3].

For smooth pipe and turbulent flow *Prandtl* friction formula is given by [3]

$$\frac{1}{\sqrt{f}_m} = 2.0\log(Re\sqrt{f}_m) - 0.8. \tag{2.2.11}$$

The most recent and most accurate experiments have been those carried out at Princeton in the super pipe experiment by Zagarola with Reynolds numbers in the range $3.2\cdot 10^4 \leq Re \leq 3.5\cdot 10^7$. The *Zagarola* friction formula for smooth pipe is [4]

$$\frac{1}{\sqrt{f}_m} = 1.889\log(Re\sqrt{f}_m) - 0.3577. \tag{2.2.12}$$

Fig. 2.2.2 gives the Fanning friction factor versus Reynoldsnumber. It should be noted that $f_d = f_f$ and that $4f_f = f_m$. This diagram also include the transition zone between laminar and turbulent flow normally expressed with the Colebrook-White equation [5]

$$f_m = \frac{1}{\sqrt{f}} + 2\log\left(\frac{e/d}{3.7} + \frac{2.51}{Re\sqrt{f}}\right). \tag{2.2.13}$$

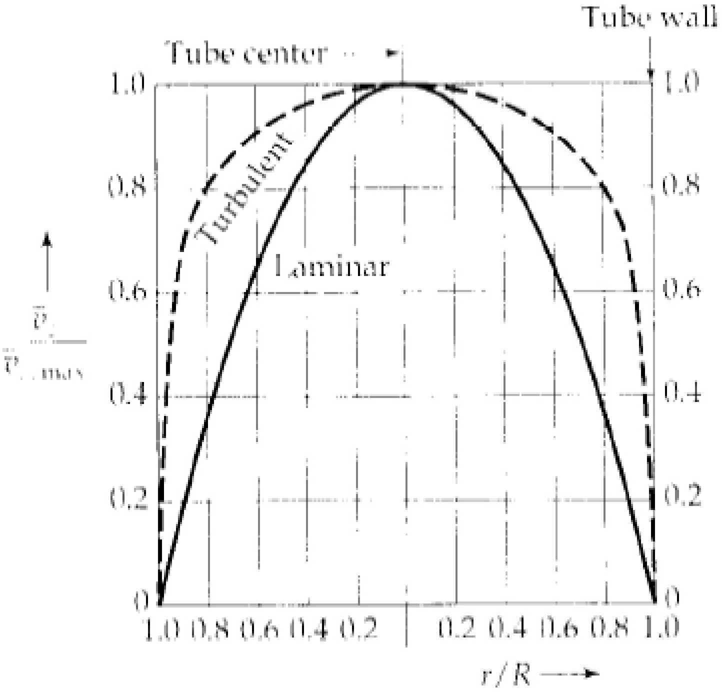


Figure 2.3.1: Qualitative comparison of laminar and turbulent velocity profiles.

## 2.3 Turbulence

> Laminar flow is strictly limited to a finite value of the critical parameter Reynolds number. Beyond that, laminar flow is unstable and will evolve-if the critical parameter is high enough- to a new flow regime. That new regime is a fluctuation, disorderly motion called *turbulence* [6].

Fig. 2.3.1 gives a qualitative comparison of laminar and turbulent velocity profiles[1]. For a more detailed description of the turbulent velocity distribution near the wall, see Fig. 2.3.2 and Fig. 2.3.4. Eq. 2.3.1, 2.3.2 and 2.3.3 gives the dimensionless velocity distribution as visualized in Fig. 2.3.2, for the viscous sublayer, the buffer zone and the main turbulent stream respectively.

---

[1] The reader can play a video, in the CD attached, showing the laminar and the turbulent velocity profiles.

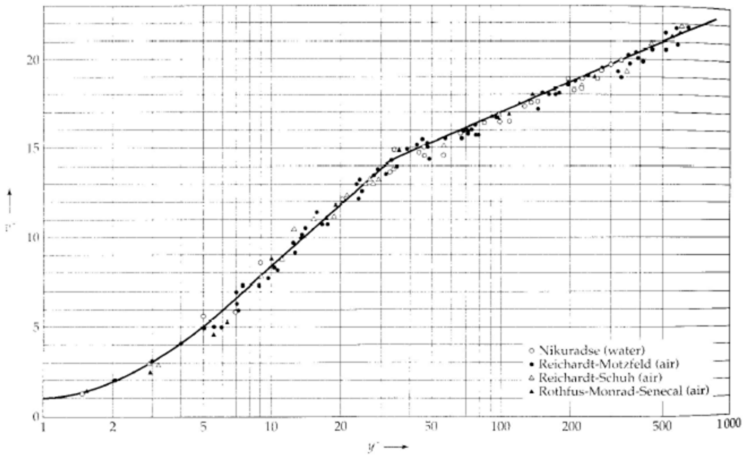


Figure 2.3.2: Dimensionless velocity distribution for turbulent flow in circular pipes [3].

$$0 < y^+ < 5: \qquad v^+ = y^+[1 - \frac{1}{4}(y^+/14.5)^3] \tag{2.3.1}$$

$$5 < y^+ < 30: \qquad v^+ = 5\ln(y^+ + 0.205) - 3.27 \tag{2.3.2}$$

$$30 > y^+: \qquad v^+ = 2.5\ln y^+ + 5.5 \tag{2.3.3}$$

$$\tag{2.3.4}$$

Turbulence can be described by

- *Fluctuations* in pressure and velocity (and also temperature when there is heat transfer). Velocity fluctuates in all three directions. Fluctuations are superimposed upon a mean value of each property.

- *Eddies* or fluid packets of many sizes, which intermingle and fill the shear layer.

- *Random* variations in fluid properties which have a particular form (not white noise).

- *Self-sustaining* motion. Once triggered, turbulent flow can maintain itself by producing new eddies to replace those lost by viscous dissipation.

- *Mixing* which is much stronger than that due to laminar (molecular) action. Turbulent eddies actively move about in three dimensions and cause rapid diffusion of mass, momentum and energy. Ambient fluid

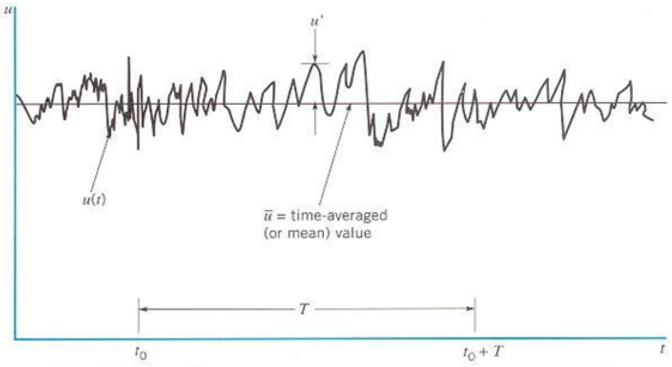


Figure 2.3.3: Velocity fluctuation in turbulent flow.

from non turbulent zones will be strongly entrained into a turbulent flow. Heat transfer and friction are greatly enhanced compared to laminar flow. Turbulent mixing is associated with a gradient in the time-mean flow.

Apart from a rather qualitative insight into the dynamics a complete theory of turbulence is still lacking because we are not able to analyse in detail the non-linear equations that govern the turbulent flow. It is, however, convenient to distinguish four regions of turbulent flow near a wall [3]:

1. the *viscous sublayer* very near the wall, where turbulence is damped out and the boundary layer is dominated by viscous shear.

2. the *buffer layer* in which the transition occurs between the viscous and inertial sub layers.

3. the *inertial sublayer* at the beginning of the main turbulent stream, in which viscosity plays at most a minor role.

4. the *main turbulent stream*, in which the time-smoothed velocity distribution is nearly flat and viscosity is unimportant. It must be emphasized that this classification into regions is somewhat arbitrary.

For laminar flow the pressure drop in a pipe is proportional with the Reynolds number. The transition from laminar to turbulent flow gives rise to an extra pressure drop, i.e. the pressure drop more than doubles with a doubling of the Reynolds number. This increase in pressure drop is due to the chaotic turbulent motions, which give rise to turbulent stresses in the flow. The pressure drop as a function of Reynolds numbers can easily be found from e.g. the well known Moody chart for pipe flow , Fig. 2.2.2. The

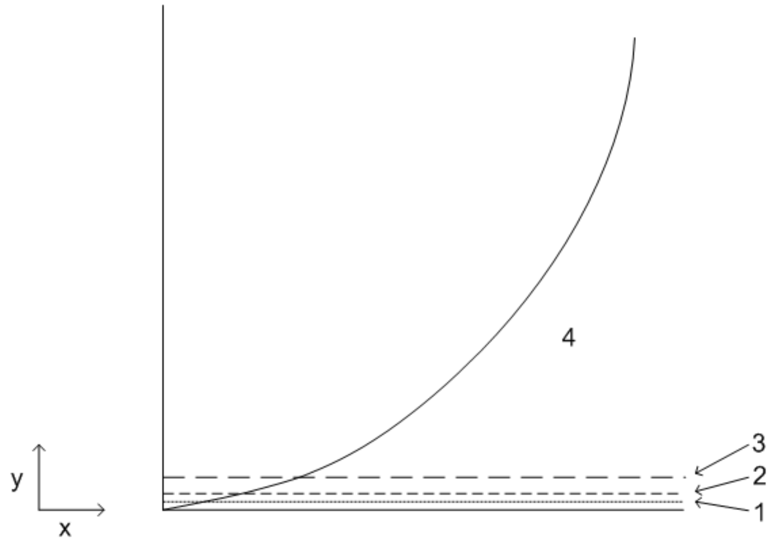


Figure 2.3.4: Flow regions for describing turbulent flow near a wall:1-viscous sublayer, 2-buffer layer,3-inertial sublayer and 4-main turbulent stream

important lesson to learn from such charts is that the pressure drop in a pipe is dependent (but not only) on the Reynolds number. Wall roughness is also important and plays a major role for the pressure drop. When the wall roughness interacts with the turbulence it creates even higher pressure drop. This illustrates that the pressure drop can be changed by manipulating the turbulence, especially in the near-wall region [7].

## 2.4 The Reynolds Number

Reynolds number is essentially a mean of comparing one flow with another, and provided that corresponding lengths and corresponding velocities are compared in the two flows where the particular choices of length and velocity, do not matter. For turbulent flow, the velocity considered is inevitably an average velocity. In such a flow the instaneous velocity at one point is in continual fluctuation, but if the flow is "steady", an average of the velocity at one particular point, taken over a sufficient time interval, is constant in magnitude and direction. These average velocities are characteristic of the given pattern of the flow and they are readily measurable [8].

The Reynolds number is

$$Re = \frac{\rho \bar{v} D}{\mu}, \tag{2.4.1}$$

where $\rho$ is the density, $\bar{v}$ is the average velocity, $D$ is the inner diameter of the pipe and $\mu$ is the dynamic viscosity. By using that $\dot{m} = \rho \bar{v} A$

$$Re = \frac{4\dot{m}}{\pi \mu D}. \tag{2.4.2}$$

The size of the Reynolds number determines if the flow is laminar of turbulent. For pipe flow with Reynolds number less than approximately 2100 the flow is laminar, and for Reynolds number greater than approximately 4000 the flow is turbulent. For Reynolds numbers between these two limits, the flow may switch between laminar and/or turbulent condition in an apparently random fashion (transitional flow) [8].

## 2.5 Drag Reduction by Particle Addition

Experimental data have revealed that under certain operation conditions the pressure drop of the gas-solid mixture is less than that of particle-free flow [9], [10]. The improvement can be either defined as a reduction in pressure drop at a constant flow rate, or as a flow rate increase at a constant pressure drop [11]. The phenomenon is termed *drag reduction* and is illustrated in Fig. 2.5.1 for the acceleration region and in Fig. 2.5.2 for the fully developed region. Drag reduction reflects that it is possible to consume less energy to transport a two-phase flow than to transport a single-phase flow. Theoretical explanations for drag reduction in gas-solid flow vary although it appears to be generally accepted that the presence of solids affects some aspect of the turbulent structure of the flow that existed before solid addition. However, serious gaps in knowledge about the modified structure of the turbulence (macro scale and micro scale) after solids have been added to the flow greatly limit current ability to confirm theory. The most serious limitations are those associated with complete and reliable measurements of boundary-layer velocity profiles, turbulence intensities throughout, velocities and trajectories of the solids, solid distributions and spin near the wall, and other items affecting solid behavior, such as deposition rates, agglomeration, and electrostatics [1]. Theoretical explanations have likewise been limited for the most part by the difficulty in characterizing non uniformities in the particle size, shape, density distribution and flow field.

[1] gives a practical definition of drag reduction, a ratio of pressure drop, corrected as appropriate for any static head or acceleration terms, or as a ratio of friction factors before and after particle addition

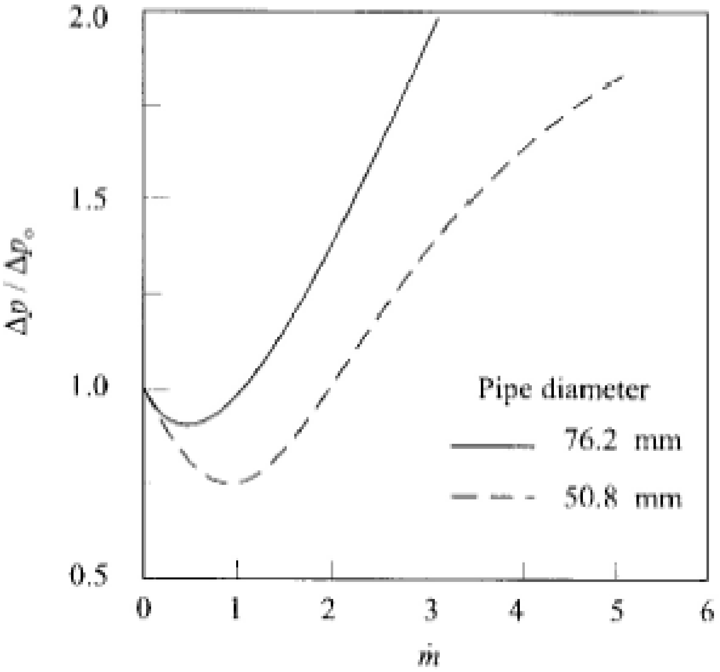


Figure 2.5.1: Pressure drop ratio as a function of mass flux ratio for $10\mu$ zinc particles in the acceleration region of $Re = 53000$ [12]

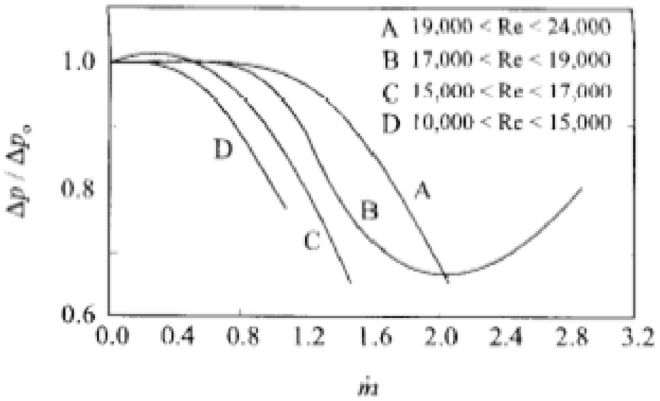


Figure 2.5.2: Pressure drop ratio as a function of mass flux ratio for 36 $\mu m$ glass beads in a fully developed region [12].

$$DR\ [\%] = 100\% \left(1 - \frac{dP_{corrected}}{dP_{0,corrected}}\right), \qquad or\ DR\ [\%] = 100\% \left(1 - \frac{f}{f_0}\right). \tag{2.5.1}$$

The pressure drop across the test section containing a gas-solid suspension is given by [1]

$$\underset{(1)}{dP = dP_{ag}} + \underset{(2)}{dP_{ap}} + \underset{(3)}{dP_{hg}} + \underset{(4)}{dP_{hp}} + \underset{(5)}{dP_{gp}} + \underset{(6)}{dP_{wp}} + \underset{(7)}{dP_{dp}} \tag{2.5.2}$$

1. Represents acceleration of the gas for sections in which flow is not fully developed or there are changes in geometry, gas density, or flow direction.

2. Represents acceleration of the dispersed solids through the test section for any of the reasons given above, or if the relaxation time of the particle is so large that the velocity profile of the particles has not become fully developed, even if the fluid velocity profile has reached its fully developed condition.

3. Represents the hydrostatic pressure change component associated with the gas.

4. Represents the increase in hydrostatic pressure within the gas caused by the presence of particles. The gas is, in effect, supporting the weight of particles in a vertical flow situation.

5. Represents the pressure differential required to overcome the friction between the gas and the wall in the presence of solid particles, the term of immediate significance for drag reduction.

6. Represents the pressure differential required to move particles from the wall after contact, in effect, a combination of particle wall friction and acceleration of particles that have contacted a wall.

7. Represents pressure differential required to drag the particles along the flow direction, the accumulation of local friction between individual particles and the surrounding gas.

## 2.6 Particles and Fibers

In the literature of drag reduction by *particle* addition typical diameter of the particles vary between $10-200\mu m$. In comparison with drag reducing agents in liquid pipe flow a high aspect ratio of length to diameter gives the best results. This suggests that *fibers* can be feasible flow improvers in gas pipe flow. Since there are many unknown terms in the fiber industry, some of the most important ones will be given. Fibers can be classified as in Fig. 2.6.1. This table includes some examples of different fiber types.

Table 2.6.1: General fiber classification

| Natural fiber | Man-made fiber |
|---|---|
| Plant | Based on natural polymers |
| -cotton | -cellulose acetate |
| -hemp | -viscose rayon |
| | |
| Animal | Based on synthetic polymers |
| -wool | -polypropylene |
| -hair | -polyethylene |
| -silk | -nylon 6,nylon 66 |

The thickness of fibers and filaments ranges from 10 to 50 $\mu$ [13]. Measuring thickness by means of conventional instruments is very difficult. To make a statistically valid statement about the fineness of a fiber (fiber density), length and mass are computed instead of thickness. The units *tex* and *denier* are used to express the fiber fineness:

- 1 tex=1 g per 1000m
- 1 denier=1 g per 9000m

# Chapter 3

# Experimental setup

## 3.1 Lab Description

The lab at Statoil Research Center in Trondheim was built by Phd. student Andre Strupstad. A process diagram of the lab is given in Fig. 3.1.1[1], and a picture of the injection system used is given in Fig 3.1.2[2].

The compressed air is cleaned using three filters before the mass flow rate is measured. Main part of the air flow goes directly into the pipeline (plexiglass), but some air goes through the particle tank. The particle injection system is based on a pressure gradient. A higher pressure in the particle tank than PT01 is controlled by the valve NVT. Particles and air flow are mixed at the start section of the pipe, which have two differential pressure sensors. The differential pressure transmitters are limited to 62 mbar. The end section of the pipe includes a microphone used to measure the particle flow rate, and a cyclone separator showed in Fig. 3.1.4 and Fig. 3.1.5.

The particle counter gives an output voltage signal dependent on the gas- and particle flow rate. This means that it needs to be calibrated for every gas flow rate in a $\Delta P$ experiment. The voltage signal will be mentioned as Part.raw [V] in this report and is visualized in Fig. 3.1.3. Phd.student Andre Strupstad has written a Matlab function that analyse Part.raw [V] and gives as output the particle flow rate.

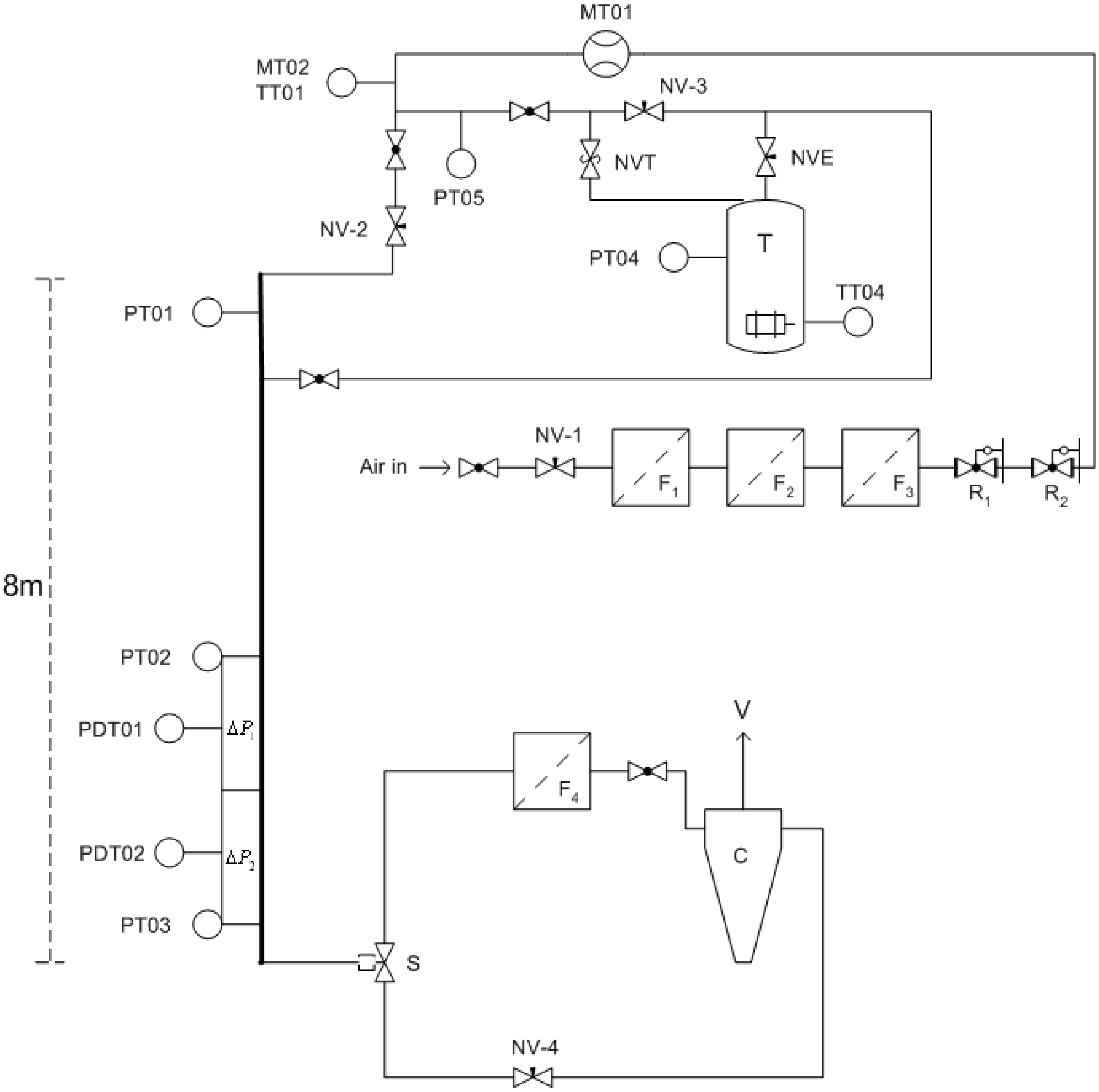
## 3.2 Lab Instructions

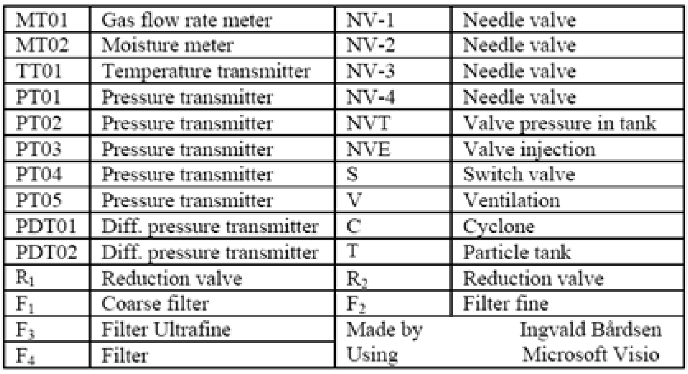
1. Preparations

---

[1] The reader should explore the attached CD. Experimental Setup- Process flowsheet.

[2] The reader should explore the attached CD. Experimental Setup- Injection system.





| MT01 | Gas flow rate meter | NV-1 | Needle valve |
|---|---|---|---|
| MT02 | Moisture meter | NV-2 | Needle valve |
| TT01 | Temperature transmitter | NV-3 | Needle valve |
| PT01 | Pressure transmitter | NV-4 | Needle valve |
| PT02 | Pressure transmitter | NVT | Valve pressure in tank |
| PT03 | Pressure transmitter | NVE | Valve injection |
| PT04 | Pressure transmitter | S | Switch valve |
| PT05 | Pressure transmitter | V | Ventilation |
| PDT01 | Diff. pressure transmitter | C | Cyclone |
| PDT02 | Diff. pressure transmitter | T | Particle tank |
| $R_1$ | Reduction valve | $R_2$ | Reduction valve |
| $F_1$ | Coarse filter | $F_2$ | Filter fine |
| $F_3$ | Filter Ultrafine | Made by | Ingvald Bårdsen |
| $F_4$ | Filter | Using | Microsoft Visio |

Figure 3.1.1: The original lab setup.

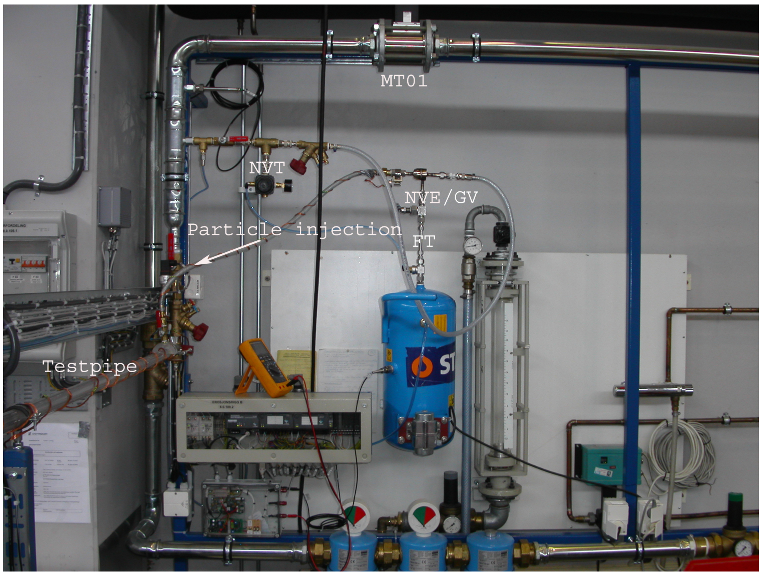


Figure 3.1.2: The injection system.

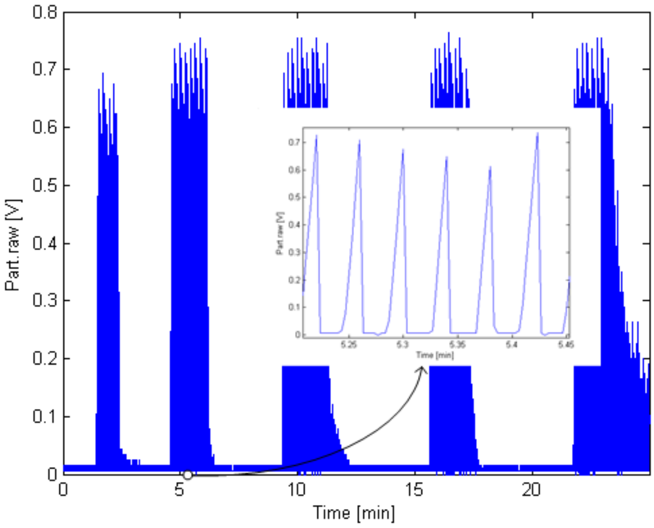


Figure 3.1.3: Particle counter signal.

Figure 3.1.4: Cyclone used in the lab

Figure 3.1.5: Cyclone used in the lab

  - Let the mass flow rate meter stabilize in 1/2 hour.
  - Fill in particles. Remember to close NVE.
  - Clean the filters, and measure the weight.
  - Adjust the air flow rate to be used in a $\Delta P$ (Pressure drop) test. The flow should also go through the particle injection system.
  - Adjust the cutoff value on the particle counter (Fig 3.2.2).
  - Update the log for all changes made.
  - At the choicen flow rate use NV4 to keep PT03 constant when changing the switch valve from position 0 to position 1.
  - Start the micro vibrator on the particle tank.

2. Calibration of particle counter
   - When switch position is 1 the particles are collected in the filters. Particle raw signal should be stable during the calibration. Measure the weight of particles in the filters and update the log files.
   - Remember to close the globe valve when the filter is changed.
   - Adjust NV4 to get the same pressure drop over the switch valve with the new filter as with the old one.
   - Do at least 5 calibrations for the same air flow rate.

3. Friction vs. Reynolds-number. Re-f test.
   - Start on maximum flow rate ( PDT01 and PDT02 has a maximum range of 62 mbar). Wait until the flow rate is stable and start data logging.
   - Reduce the flow rate with approximately 10kg/h. Update the events in the log file.

4. $\Delta P$ test
   - Open NVE.
   - Adjust NVT until desired particle flow rate is achieved.
   - Close NVT.
   - Repeat this operation with different NVE openings until there are no more particles left in the tank.

5. Ending a test

   - Close the air globe valve. Let the system stabilize around atmospheric pressures and zero flow rate. Define this as the last event in the log files.
   - Empty/ clean the cyclone and the tank.
   - If another particle or fiber type is used new pipes should be installed. In this case the cyclone and the particle tank should be thoroughly cleaned.

Fig. 3.2.1 gives a graphic illustration of the procedure in the lab. It should be noted that the calibration of the particle counter is time consuming. Estimated effective time in the lab for a specific particle type is 2 weeks *with* calibration, and 1 week *without* calibration. Due to long delivery time on fibers ordered, experimental work was performed without calibrating the particle counter. This means that the flow rate of particles is unknown. However, in this project, the goal is to find an effect when particles and fibers are added in gas flow. When finding particles or fibers with drag reduction the experimental work can be repeated using the particle counter.

## 3.3 Modified Setup

Due to problems with the injection of fibers the needle valve and the t-bend in Fig. 3.3.1 and Fig. 3.3.2 were replaced with a globe valve and a jet mixer showed in Fig. 3.3.3.

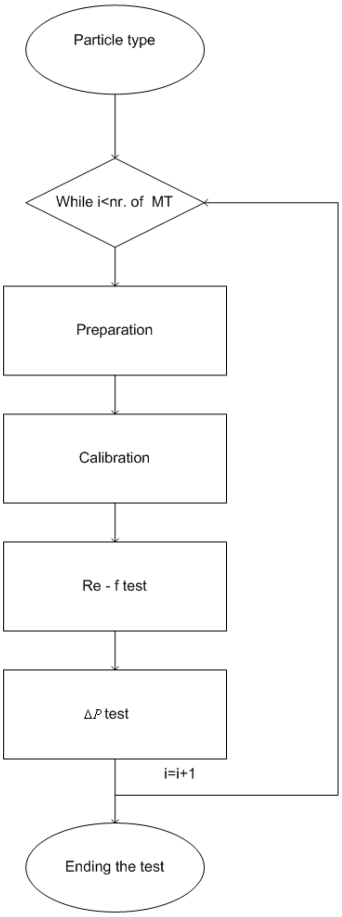


Figure 3.2.1: Lab procedure where the nr. of MT is the total nr. of different air flow rates used for a particle type.

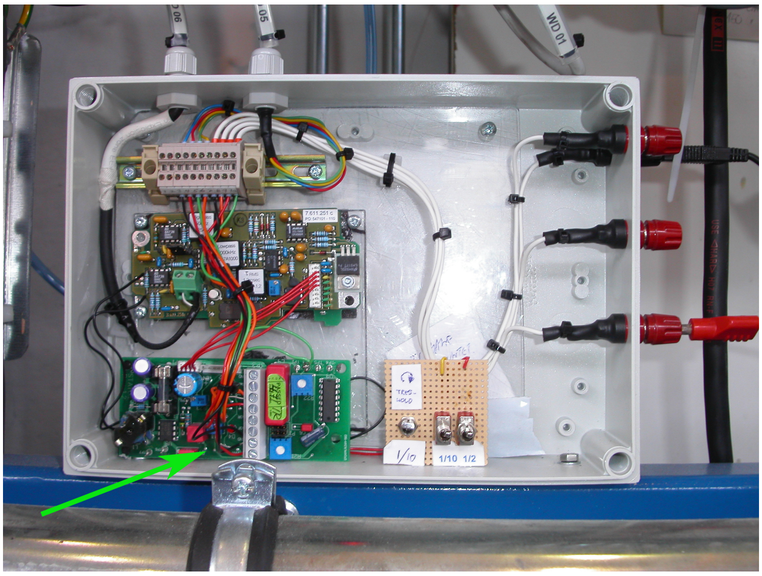


Figure 3.2.2: Adjusting cutoff value for particle counter.

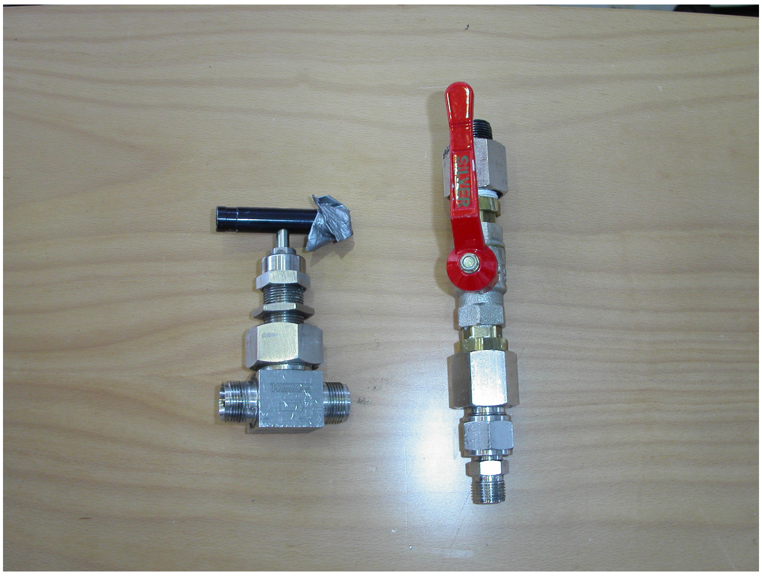


Figure 3.3.1: Needle valve (NVE) and global valve (GV) in injection system.

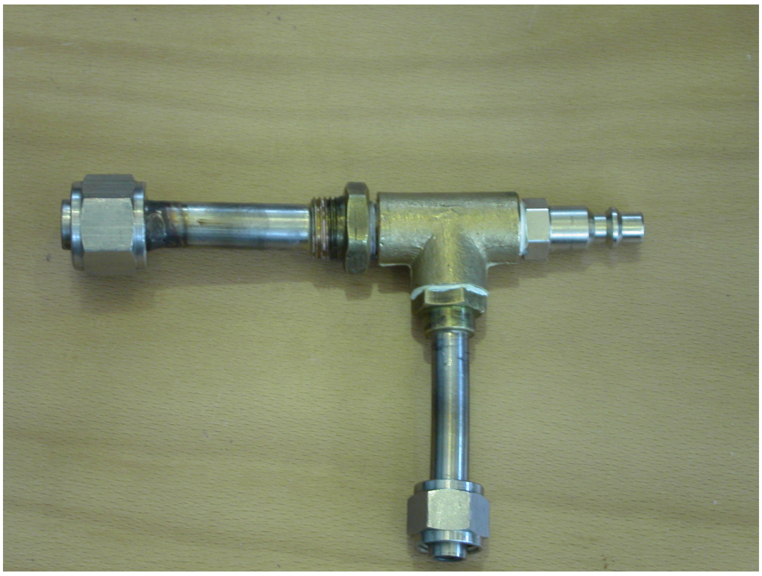


Figure 3.3.2: T-bend in injection system.

Figure 3.3.3: Jet mixer in injection system.

# Chapter 4

# Results and Discussion

For all results presented the following is standard notation:

- The horizontal yellow lines at the top and bottom of the figures represent the region where NVE/GV is open (needle valve or global valve used to control particle or fiber injection).

- MT is the air flow rate, Part.raw [V] is the voltage signal from the particle counter and Event is the actions described in Appendix C.

- *Test section* is the section where the differential pressure transmitters are located. Test section 1 (and index 1) is then the section for PDT01, and test section 2 (index 2) is the section where PDT02 is installed.

- Density, velocity and the volumetric flow rate of the gas is calculated as the average density, the average velocity and the average volumetric flow rate of air in the pipe from Eq. 2.2.2, 2.2.4 and Eq. 2.2.3 respectively, and are given in Appendix B.

- Prandtl, Zagarola and Colebrook in the legends of the friction versus Reynolds number plots are based on the friction coefficient calculated from Eq. 2.2.11, Eq. 2.2.12 and Eq. 2.2.13 respectively.

- When graphing the friction factor versus Reynolds numbers for particle or fiber flow it is important to have a reference friction factor. This reference friction is taken to be the friction factor for single phase gas flow, with the same lab setting as experiments with injection of particles or fiber.

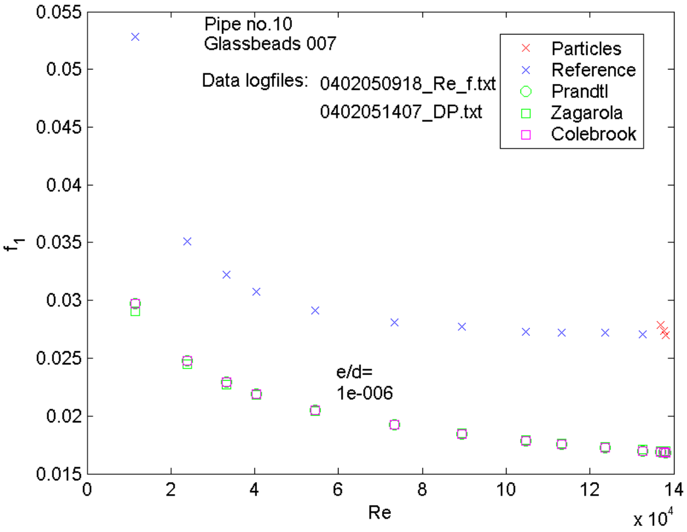


Figure 4.1.1: Friction coefficient for test section 1

## 4.1 Difference between Experimental Friction and Correlations

Fig. 4.1.1 and Fig. 4.1.2 are examples of typical friction versus Reynolds number plots in this thesis. The blue crosses represent the experimental reference friction for single phase gas flow, while the red crosses represent the experimental friction for gas-particle flow. In Fig. 4.1.1 and Fig. 4.1.2 the experimental calculated reference friction factor versus the Prandtl, Zagarola and the Colebrook-White friction factor differ considerably. This difference is repeated in plots of friction versus the Reynolds number for all experiments performed. In these figures the Colebrook-White friction factor is adjusted for a smooth pipe with $e/d = 10^{-6}$. The pipe is made of plexiglass, considered to be smooth, according to roughness tests performed by Phd. student Andre Strupstad. The Phd. thesis by Strupstad is in progress, and is therefore not given in the reference list. If the roughness factor in the Colebrook-White equation is increased, as in Fig. 4.1.3 and Fig. 4.1.4, the experimental results agrees better with the Colebrook-White correlation, but still there exists a difference between the correlation and the experimental work.

To investigate the spread of data for the experimental calculated friction more Reynolds number versus friction tests were performed. Fig 4.1.5 and Fig. 4.1.6 gives the result. In these graphs results from 4 different Re-f experiments are gathered with a low spread of data.

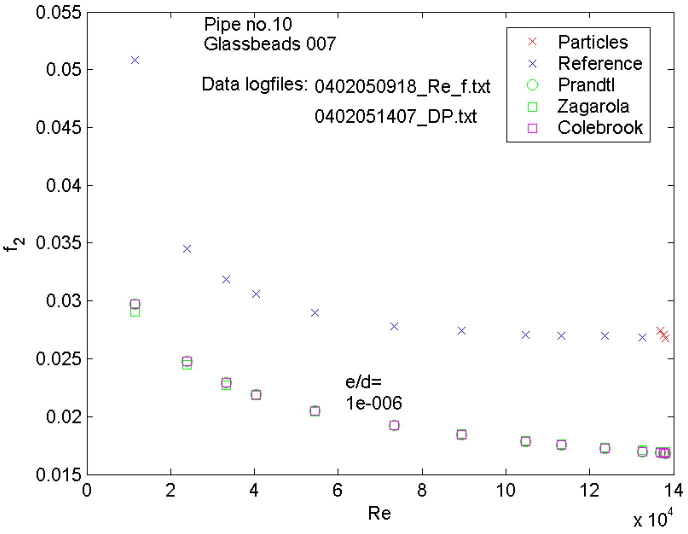


Figure 4.1.2: Friction coefficient for test section 2

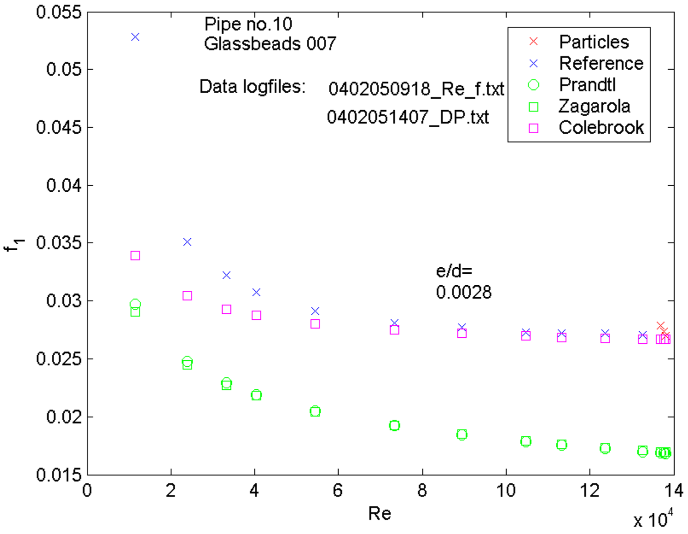


Figure 4.1.3: Friction coefficient for test section 1 using Colebrook-White with adjusted roughness parameter.

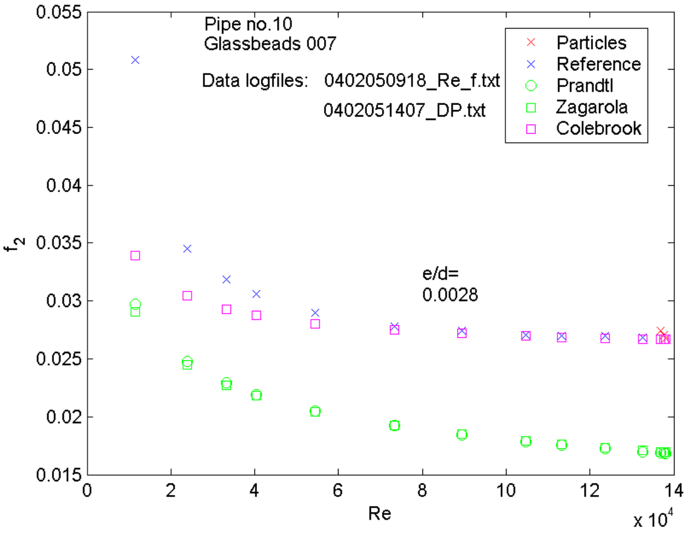


Figure 4.1.4: Friction coefficient for test section 2 using Colebrook-White with adjusted roughness parameter.

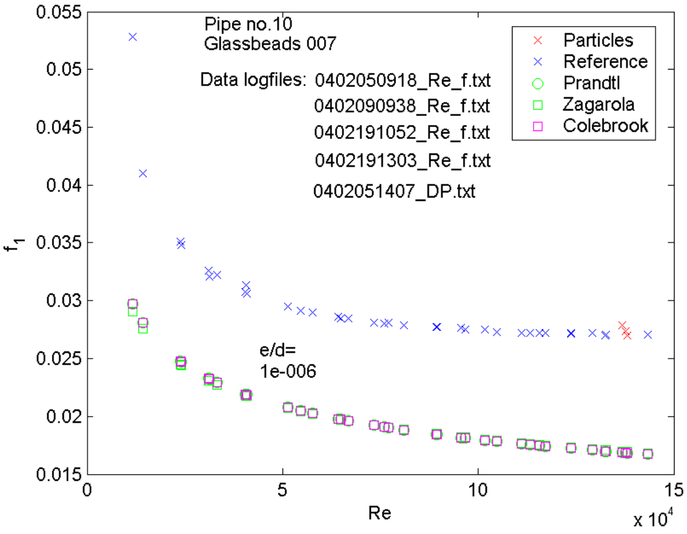


Figure 4.1.5: Friction coefficient for test section 1- spread of data

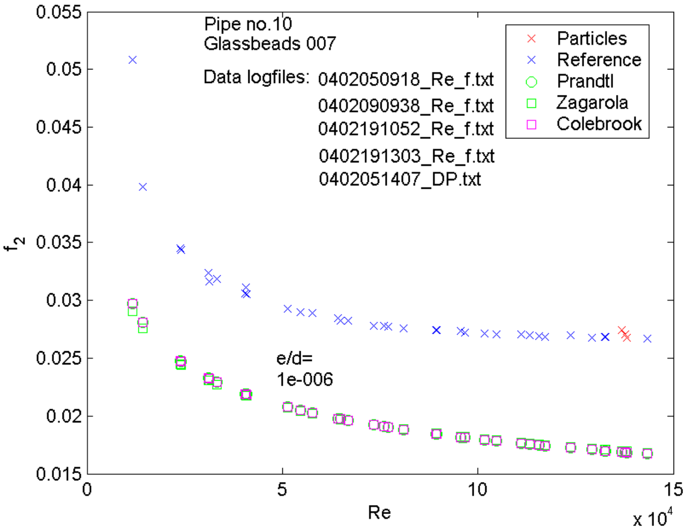


Figure 4.1.6: Friction coefficient for test section 2- spread of data

The large difference between the friction correlations from literature and the experimental friction factor can not be explained without considering the uncertainty in the variables in the experimental friction equation . Increasing the roughness, using the Colebrook-White correlation, gives less difference between the experimental friction factor and the correlation, but this is not consistent with the roughness information from the tests performed by Phd. student Andre Strupstad. In Eq. 2.2.10 the friction factor depends on the diameter raised to the 5th power. Uncertainty in the diameter will therefore have considerably impact on the experimental friction factor. Fig. 4.1.7 and Fig. 4.1.8 illustrates the effect of changing the diameter of the pipe. The diameter of the pipes was found by students working on the summer project at Statoil Research Center. The pipes were filled with water to find the volume. The diameter was then calculated from Eq. A.3.1. The students did not introduce any uncertainty discussion on their data and the uncertainty on the measuring instruments used are not known. As a consequence a uncertainty calculation was performed in Appendix A.3 on p. 63 with guessed values on the uncertainty of the measuring instruments . The result is visualised in Fig. 4.1.9. $S_d$, $S_h$ and $S_v$ are the uncertainties of the diameter, measured height and measured volume respectively.

In Fig. 4.1.7 and Fig. 4.1.8 the best fit with the experimental friction to the correlations is for a diameter approximately 2 mm below the original data value. Fig. 4.1.9 illustrates that if there is a volume measurement uncertainty of 250 ml and a height measurement uncertainty of 10 cm there will be an

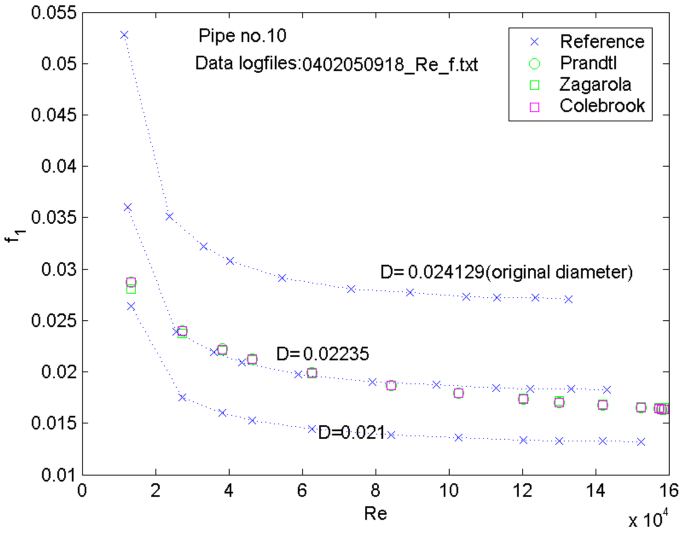


Figure 4.1.7: Friction coefficient when manipulating the diameter of the pipe.

uncertainty in the pipe diameter of ±2.0 mm. In order to have a uncertainty of the pipe diameter about 2 mm the measurement uncertainty of the volume and height must be so large that it is doubtingly the real case. One should also keep in mind that for *all* plots of friction versus Reynolds number, using given diameter data, the experimental friction is considerably larger than the correlations. The experimental work performed by the summer students should then be repeated in order to get data which can be fully trusted. A systematic error might have been introduced in their experimental work, which can explain the difference between the experimental friction factor and the correlations.

Uncertainty in the pipe diameter will not be discussed any further in this thesis. The experimental reference friction factor versus Reynolds number will be adjusted to best fit with the correlations. For pipe nr. 10 the resulting diameter is 0.0224m .The adjustment will involve changing the diameter data that were given for the respective pipes. After conversations with Phd. student Andre Strupstad the uncertainties in the pressure transmitters and the mass flow rate meter are insignificant for a mass flow rate of gas above 20 kg/h. All experiments performed in this thesis uses a gas flow rate between 40 − 175 kg/h. Uncertainty in the experimental friction factor, as a result of any uncertainties in the pressure transmitters (also the differential pressure transmitter), or mass flow rate meter will then be negligible. The Phd. thesis of Andre Strupstad is in progress. A more detailed discussion about the uncertainties in the data acquisition will be covered in the Phd.

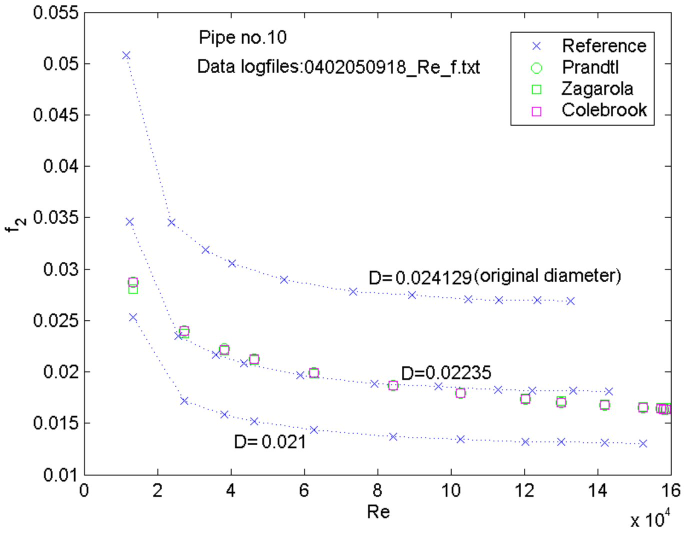


Figure 4.1.8: Friction coefficient when manipulating the diameter of the pipe.

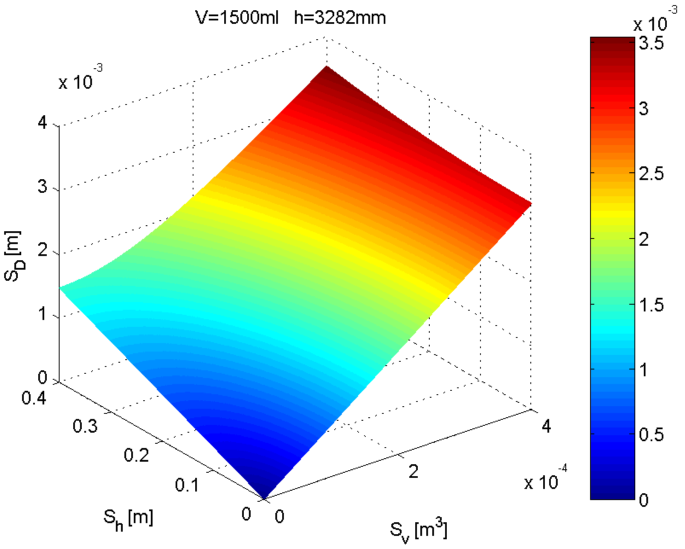


Figure 4.1.9: Uncertainty of the pipe diameter

thesis by Strupstad.

## 4.2 Particles

Phd. student Andre Strupstad has performed several experiments with particles. Further experiments with particles will therefore have lower priority than experiments with use of fibers. However, during the first weeks, particles were used as a part of the operator training.

Glass beads were injected in the gas flow. With the valve positions given in Fig. C.1.2 the starting gas flow rate used for the $\Delta P$ experiment was 171±1 (close to the maximum gas flow rate limited by the differential pressure transmitters). As visualized in Fig. 3.2.1 the $\Delta P$ experiment for a particle type should be repeated for several gas flow rates, and a Reynolds number vs. friction experiment should be performed before every $\Delta P$ experiment.

Fig. 4.2.1 (raw data), 4.2.2 (raw data), B.1.1, B.1.2, B.1.3, 4.2.3 and 4.2.4 presents the results for the experiment with glass beads injected in the gas flow. Fig. 4.2.1 indicates a relative large pressure drop reduction when particles are added. This result is promising, but it is also important to consider the other variables in the system. The pressure in the pipe increases, and the mass flow rate and the volumetric flow rate decreases when glass beads are injected. These changes in the system , which is highly dependent on type of injection system used, means that a pressure drop reduction test alone is *not* enough to draw conclusions on the effect of adding glass beads in gas flow. This will be further discussed when fibers are injected. The friction coefficient given in Eq. 2.2.10 is useful when there is changes in pressure and mass flow rate. This equation are therefore used to investigate the effect of injecting particles or fibers in gas flow.

Despite the pressure drop reduction the calculated friction coefficient in gas-particle flow from Eq. 2.2.10, given in Fig. 4.2.3 and Fig. 4.2.4, is slightly larger than the friction coefficient for particle free flow (red and blue crosses respectively). This can be explained with Fig. 4.2.1 and Fig. 4.2.2 where the mass flow rate decreases and the pressure in the pipe (PT01, PT02 and PT03) increases when particles are added. Further $\Delta P$ experiments should be performed in order to complete Fig. 4.2.3 and Fig. 4.2.4. The two friction plots are only based on one $\Delta P$ experiment. Experiments with other gas flow rates should also have been performed, but as already mentioned injection with fibers are preferred. Problems with the injection of fibers are expected to be time-consuming, and needs to be focused.

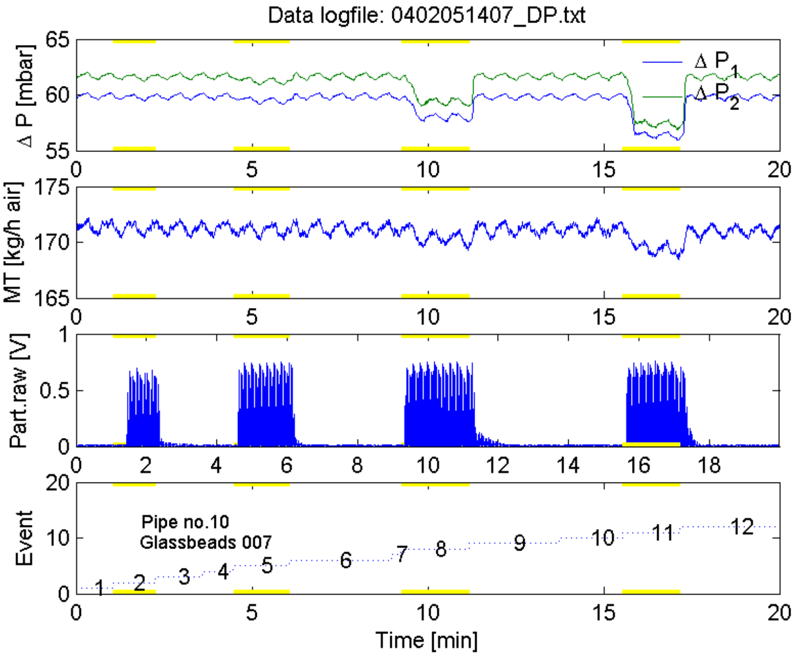


Figure 4.2.1: Pressure drop experiment. LOG: 0402051407.

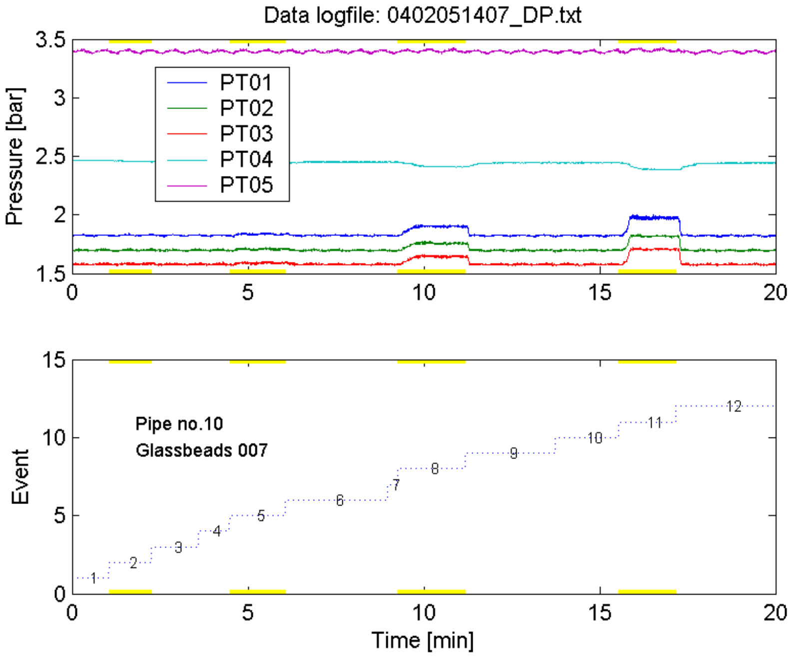


Figure 4.2.2: Pressure in particle tank and pipe. LOG: 0402051407.

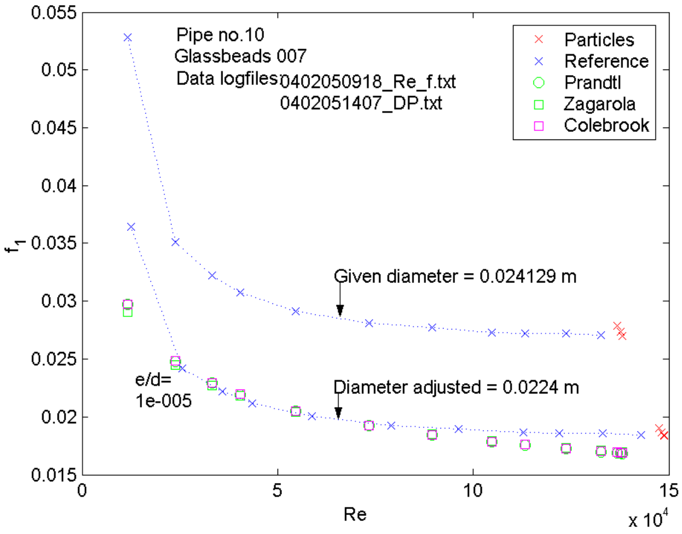


Figure 4.2.3: Friction coefficient for test section 1. LOG: 0402051407.

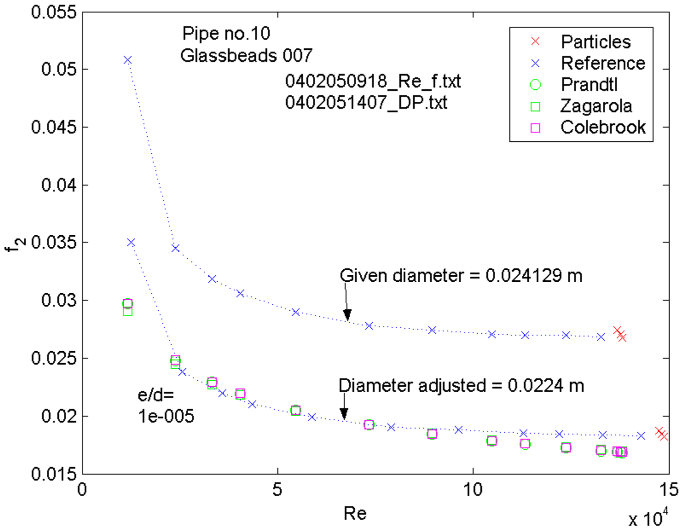


Figure 4.2.4: Friction coefficient for test section 2. LOG: 0402051407.

## 4.3 Fibers

### 4.3.1 Fiber producers

A great deal of work has gone into searching for fiber producers of short cut fibers. Between 50-100 different companies has been contacted by email. In general few were able to deliver fibers with a length$<$ 0.5mm which was believed to be crucial for the injection system. Appendix D gives information about the suppliers and the orders that were made. During the experimental work it was realized that the fibers could have been of greater length, which would made the search for short cut fiber suppliers a lot easier. Considering the suppliers delivery time and the time needed for experimental work, it was not possible to order new fiber types and perform new experiments.

### 4.3.2 Injection of polyamide $0.3$ mm $3.3$ dtex

Fig. 4.3.1, Fig. 4.3.2 and Fig. 4.3.3 presents the raw data from a test with injection of polyamide. More results are given in Fig. B.2.1, Fig. B.2.2 and Fig. B.2.3. The details of the experiment is given in Appendix C, Fig. C.2.1. Opposed to the injection of glass beads in Fig. 4.2.1 injection of fibers gives an increase in mass flow rate and also in the $\Delta P$. This repeats itself through all experiments with fibers. The reason for this is that when following the original lab procedure, given on p. 21, the fibers tends to pack together and then stop the flow in the pipe from the particle tank. This is due to, in general, the mechanical structure of the fibers. They tend to stick together, which makes injection in gas flow hard with the injection system used in Fig. 3.1.2. Instead of keeping the injection valve ,NVE on Fig. 3.1.1, closed to build up a higher pressure in the tank and then open the injection valve, as for glass beads, NVE was kept open when starting up the system [1]. The result is that the fibers in the tank gets mixed with air as the pressure in the tank increases. When the pressure in the tank is large enough fibers *and* air, as opposed to only particles for glass beads, will flow through FT (see Fig. 3.1.2) and into the main pipe. This is the reason why the mass flow rate increases when the injection valve is opened. It is also clear from Fig. 4.3.3 that air flows with fibers out from the particle tank when the NVE is opened. PT04 increases when NVE is closed and decreases when NVE is opened.

Due to the different behavior of the system with injection of fibers, compared to the injection of glass beads, a new type of friction versus Reynolds numbers experiment was performed. The new procedure is given

---

[1] This is better explained in the attached CD. Animation in Experimental Setup- Injection system.

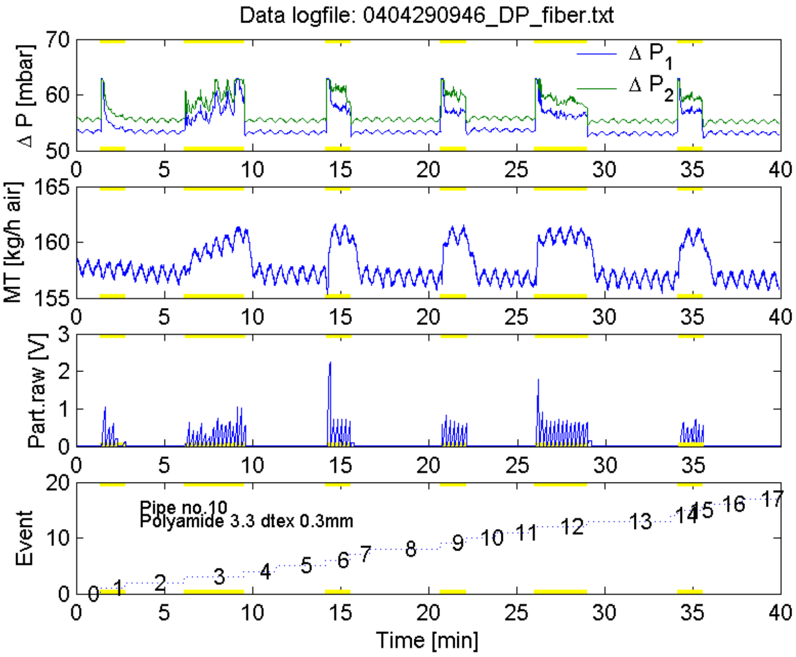


Figure 4.3.1: Injection of polyamide. LOG: 0404290946.

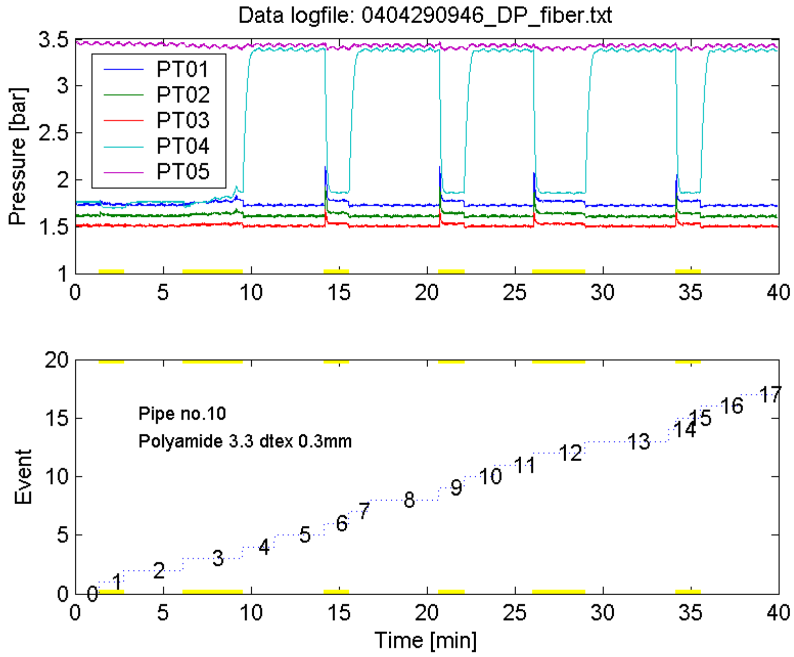


Figure 4.3.2: Pressure in the pipe. LOG: 0404290946.

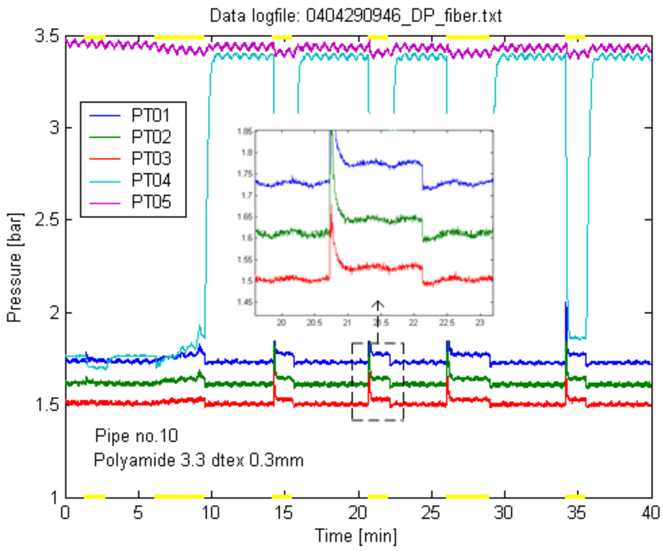


Figure 4.3.3: Pressure in the pipe. LOG: 0404290946.

in Fig. C.2.2 and is exactly the same as for an experiment with injection of fibers. Fig. B.2.4 and Fig. B.2.5 gives the raw data for a friction versus Reynolds number experiment for single phase gas flow. More results are given in Fig B.2.6, B.2.7 and Fig B.2.39.

The reason why the procedure was changed is obvious from Fig. 4.3.4 and Fig. 4.3.5. In these two plots there are only single phase gas flow, but still the friction coefficient when NVE is opened or closed differ. This is, as already mentioned, due to the increased mass flow of air and pressure when opening NVE, which can been seen from Fig. B.2.4 and Fig. B.2.5. When plotting the friction factor versus the Reynolds number for fiber injection in gas flow, it is important to use the experimental friction for single phase gas flow for *open* NVE, as a reference friction factor. This is done automatically in the written matlab code that analyzes the different log files.

The Part.raw signal in Fig. 4.3.1 indicates a fluctuating flow rate of fibers in the experiment. This agrees with the observations for the experiment. When injecting polyamide a peak in the Part.raw signal could be observed. This is due to the increased mass flow rate of gas when NVE is opened, and also a large injection rate the first seconds after NVE is opened[2].

Several experiments with injection of polyamide were performed. Raw data plots and plots of density, velocity and the volumetric flow rate are

---

[2] The reader should take a tour in the attached CD, which includes videos of typical injections with polyamide.

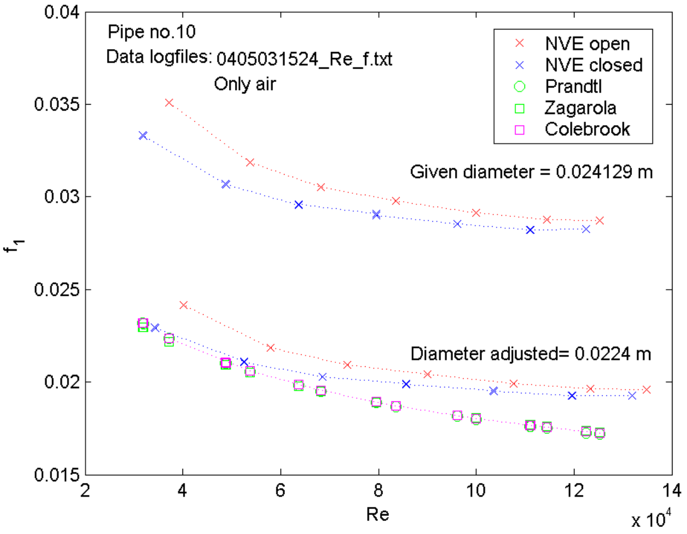


Figure 4.3.4: Friction coefficient for test section 1

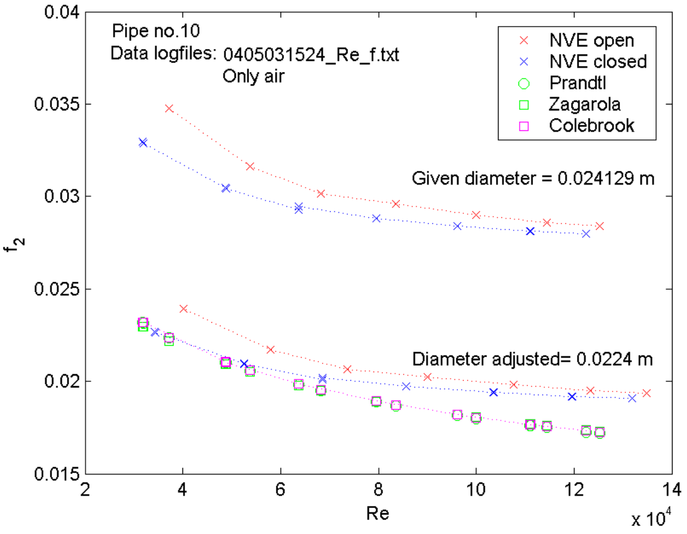


Figure 4.3.5: Friction coefficient for test section 2

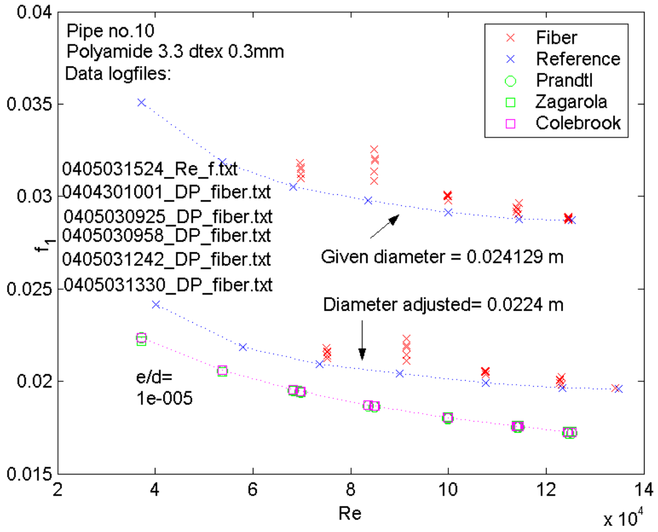


Figure 4.3.6: Friction coefficient for test section 1

given in Appendix B.

Fig. 4.3.6 and Fig. 4.3.7 gives the friction factors versus the Reynolds number for different log files. The friction, when injecting polyamide, is larger than the reference friction for single phase gas flow. The diameter that was given when starting the experiments is compared with the adjusted diameter discussed on p.31. A larger friction factor when polyamide is injected means a larger $\Delta P$ loss. The experiment performed was therefore not successful in showing a positive effect of polyamide as an additive in gas flow. One can not, however, exclude polyamide as an additive based on the experiment performed. There *could* be a drag reduction effect for polyamide with a different length, and with a different injection rate than what was used. When looking for drag reduction effect it is very important to have the ability to control the size of additives used [14]. A good experiment should therefore test a large number of different sizes. In the experiments at Statoil Research Center there were only a few different fibers types available.

Another interesting observation when injecting polyamide is the electrostatic build up in the pipe. Sparks were observed from metal pieces in contact with the plexipipe, even though the pipe was grounded with copper wire, as in Fig. 4.3.8. To reduce the electrostatic build up a copper wire was placed inside the pipe. The electrostatics were then reduced, but still not eliminated[3]. A picture of the flow is given in Fig. 4.3.9. What happened was

---

[3] The reader should play the videos in the attached CD.

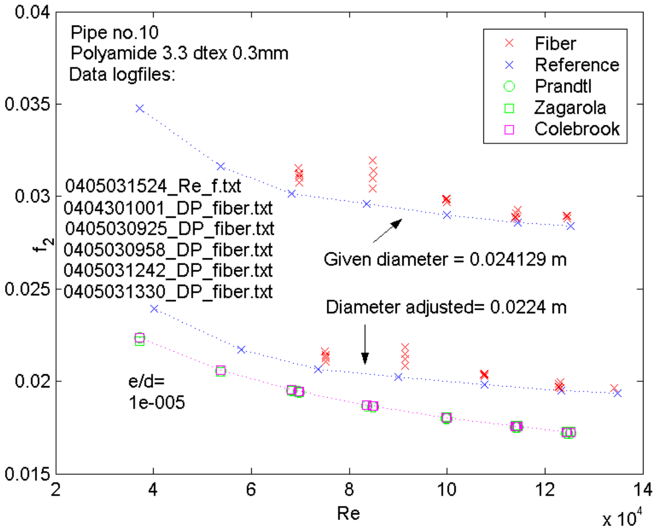


Figure 4.3.7: Friction coefficient for test section 2

that polyamide was creeping along the wall due to the electrostatics that were created. The electrostatics will therefore contribute to a larger friction factor when polyamide is injected in gas flow compared to single phase gas flow. This can explain why the experimental friction factor is larger than the reference in Fig. 4.3.6 and Fig. 4.3.7. If the electrostatic forces can be eliminated, and a greater range of fiber lengths are available, the experiments can be repeated to either eliminate or recommend the use of polyamide as an additive in gas flow. In steel pipes the electrostatic build up will probably not be a problem. Steel pipes were ordered, but delivery and installation time were too long for experiments to be performed with these.

A second group of experiments were performed with injection of polyamide. Fig. 4.3.6 and Fig. 4.3.7 uses pipe nr. 10, while new data were obtained using a new plexipipe, pipe nr. 42. A picture of the two pipes is given in Fig. 4.3.10. The old pipe has been used with glass beads, which have scratched the inner surface of the pipe and made it less transparent. Using SEM pictures of glass beads were taken, which shows that many of the glass beads were not even spherical and had sharp edges. These pictures ca be seen in Fig. 4.5.1, 4.5.2, 4.5.3, 4.5.4, 4.5.5 and Fig. 4.5.6. A very interesting observation made when injecting new polyamide fibers in the new pipe, was that the fibers were not creeping along the inner wall of the pipe. It seemed like the electrostatic build up were less than for the experiments performed in Fig. 4.3.6 and Fig. 4.3.7. An explanation might have something to do with the roughness of the two pipes. In the old one, the roughness was increased due to the

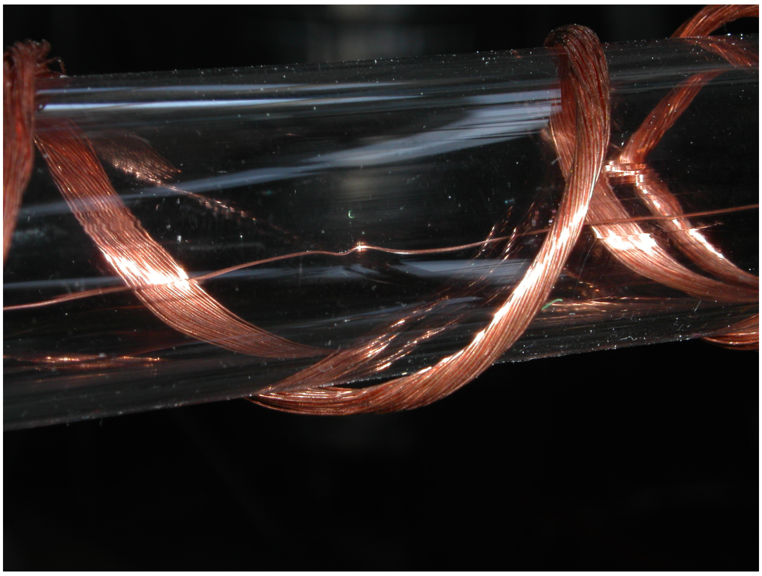


Figure 4.3.8: Grounded pipe

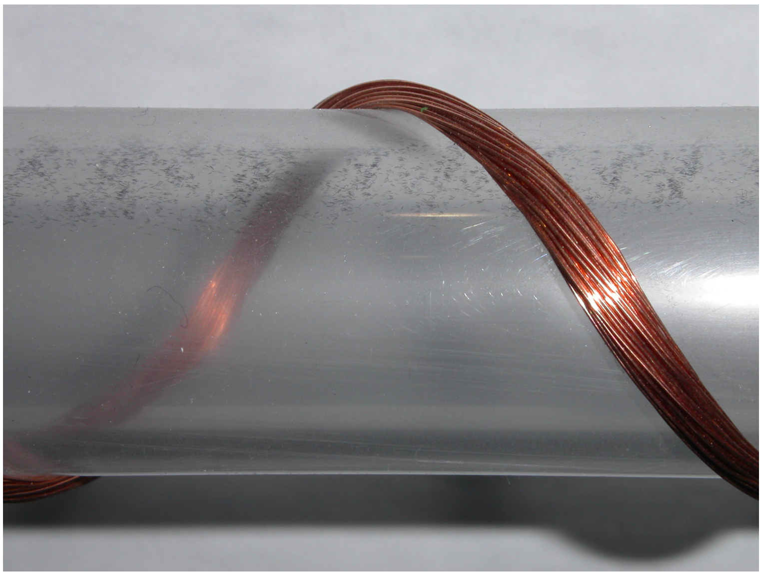


Figure 4.3.9: Air flow in pipe with polyamide 0.3 mm 3.3 dtex

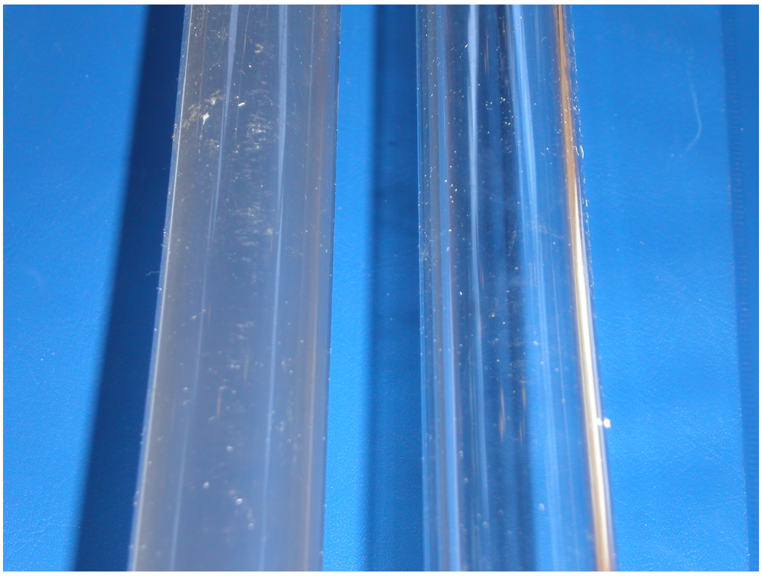


Figure 4.3.10: Old and new plexipipe

injection of glass beads, which can have an effect on the electrostatic build up in the pipe. The results of the new experiments with polyamide in the new pipe are given in Fig. 4.3.11 and Fig. 4.3.12. Compared to experiments with pipe nr.10 the friction factor is lower when using new polyamide fiber and a new pipe. The reason is probably the electrostatics introduced in pipe nr.10, while in pipe nr.42 the electrostatics could not be seen. In Fig. 4.3.11 and Fig. 4.3.12 the friction, when injecting polyamide, is about the same and many data points are even less than for single phase gas flow. This result is promising, and indicates a small drag reduction effect. When electrostatic forces clearly can be seen in the pipe the friction increases, while it decreases when the electrostatic forces are reduced or eliminated. The reproducibility of this result is unknown. Further results with polyamide in steel pipe should be performed in order to draw any conclusions on the effect of polyamide as an additive in gas flow.

### 4.3.3 Injection of polyethylene

Several experiments with injection of polyethylene were performed. Raw data and calculated velocity, density and volumetric flow rate of gas are given in Appendix B.

When starting experiments with polyethylene new pipes were installed. Fig. 4.3.13 and Fig. 4.3.14 gives the result when adjusting the diameter for the new pipe. The reason why adjusting the diameter is discussed in Sec.

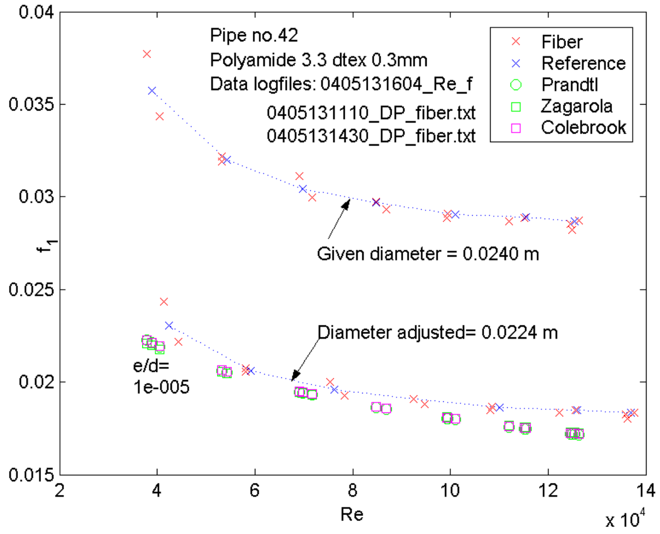


Figure 4.3.11: Friction coefficient for test section 1

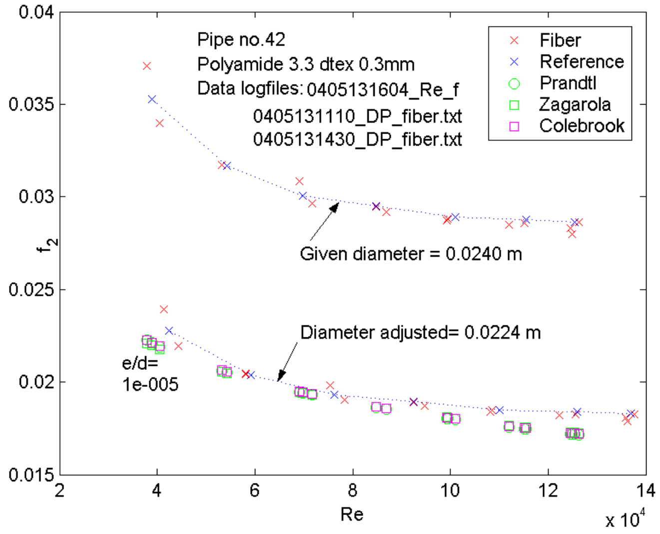


Figure 4.3.12: Friction coefficient for test section 2

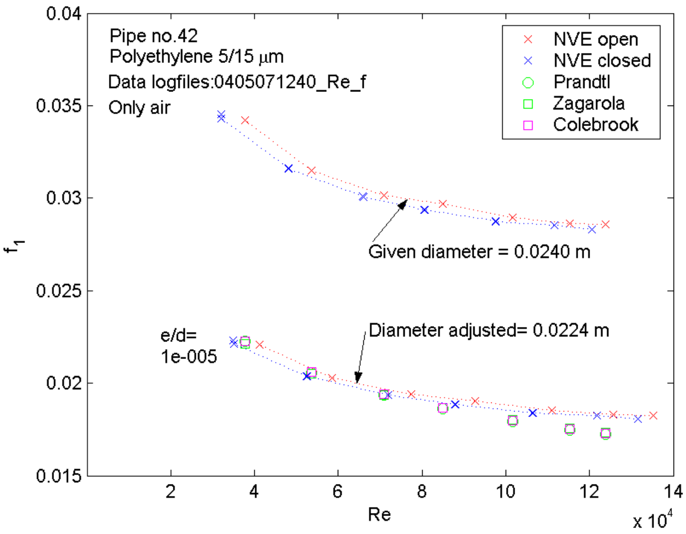


Figure 4.3.13: Friction coefficient for only air in test section 1

4.1. The friction factor when NVE is open will be used as a reference friction when injecting polyethylene.

The first group of results that were achieved, with polyethylene as an additive in gas flow, are given in Fig. 4.3.15 and in in Fig. 4.3.16. These figures are based on one experiment, used as a reference friction, and four $\Delta P$ experiments for high gas flow rates. Experimental details are given in Appendix B and in Appendix C. Injection of polyethylene was difficult to control. It was observed slug flow of fibers[4]. The friction factor for gas flow with polyethylene is about the same, or larger, than the experimental reference friction factor. No drag reduction effect has been observed.

The second group of experiments, with polyethylene as an additive, are given in Fig. 4.3.17 and in in Fig. 4.3.18. These figures are based on two Re-f experiments, used as references, and two $\Delta P$ experiments for high gas flow rates. Experimental details are given in Appendix B and in Appendix C. Injection of polyethylene was again difficult to control. It was observed slug flow of fibers, and the injection rate was generally very low. From Fig. 4.3.17 and in Fig. 4.3.18 the friction for gas flow with polyethylene is about the same, or larger, than the experimental reference friction factor. No drag reduction effect has been observed.

When starting the experiments with polyethylene the particle counter did not detect any flow of fiber despite a large injection rate, and a high gas

---

[4] The reader should play the videos in the attached CD where the slug flow is visualized.

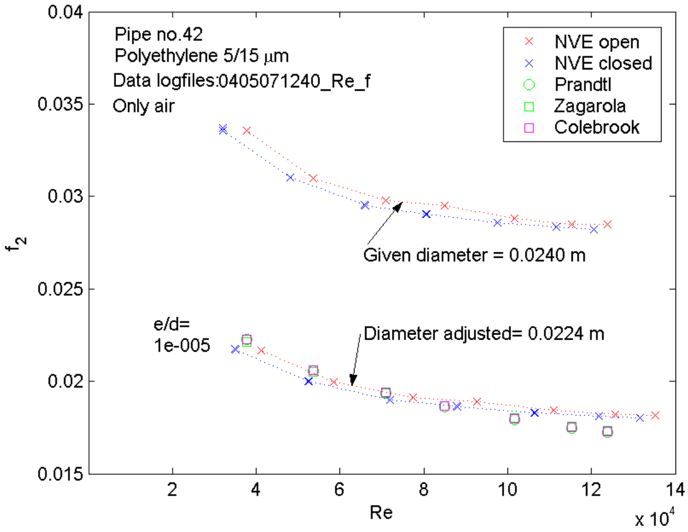


Figure 4.3.14: Friction coefficient for only air in test section 2

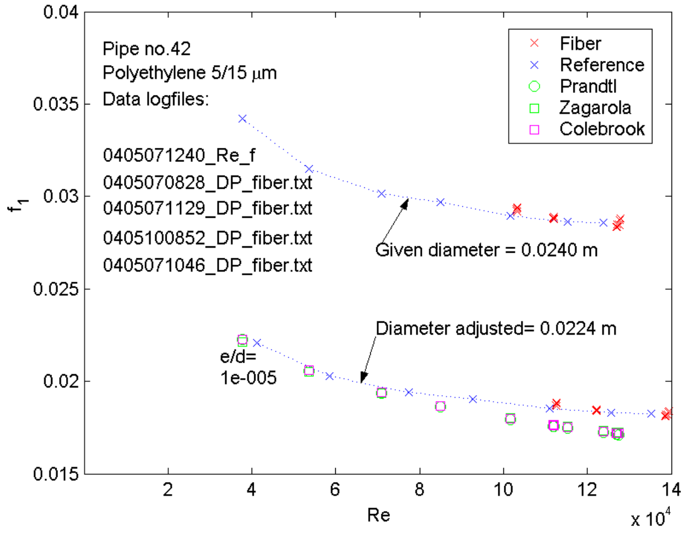


Figure 4.3.15: Friction coefficient for test section 1

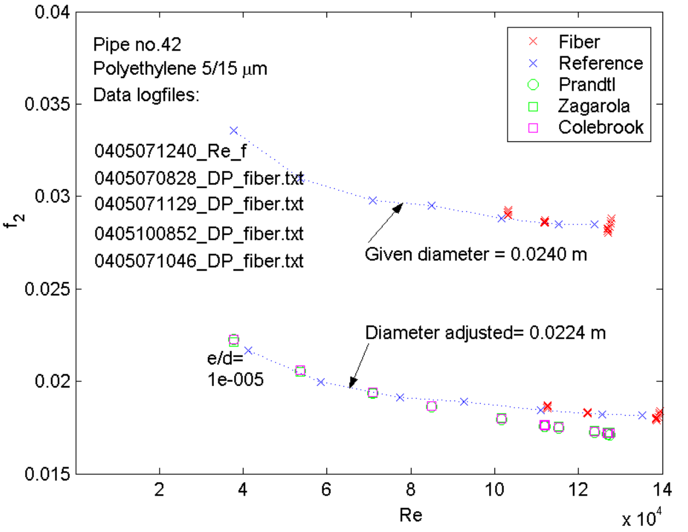


Figure 4.3.16: Friction coefficient for test section 2

flow rate. This can be seen in Fig. B.3.1, where the Part.raw signal is zero. The particle counter needs to be repaired. This means that the experiments performed after 07.05.2004, will be without information about the mass flow rate of fiber. It was tried to measure the weight of fibers placed in the particle tank and the weight of fibers in the cyclone after injection. With the time used for open NVE/GV an estimate of the mass flow rate of fibers could be obtained, but difficulties with the injection of the fibers resulted in too many uncertainties. Fibers got easily stuck in FT (Fig. 3.1.2), with the result that most experiments needed to be shut down and restarted. It was also difficult to get polyethylene inside the particle tank, resulting in some mass of fibers that were spilled. Polyethylene will most likely also go through the ventilation suction. These factors together means that information about the mass of polyethylene in particle tank before injection, and mass of polyethylene in the cyclone after injection is useless.

The experimental work carried out at Statoil gives a higher friction for polyethylene in gas flow than for single phase gas flow, but further experiments should be performed in order to recommend or exclude the fiber as an additive in gas flow. Possible experiments performed in the future should test different sizes of the fiber, and be able to control the injection rate.

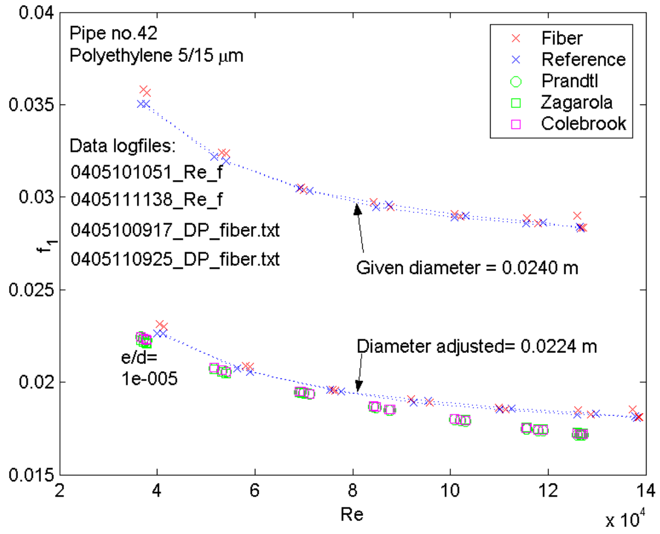


Figure 4.3.17: Friction coefficient for test section 1

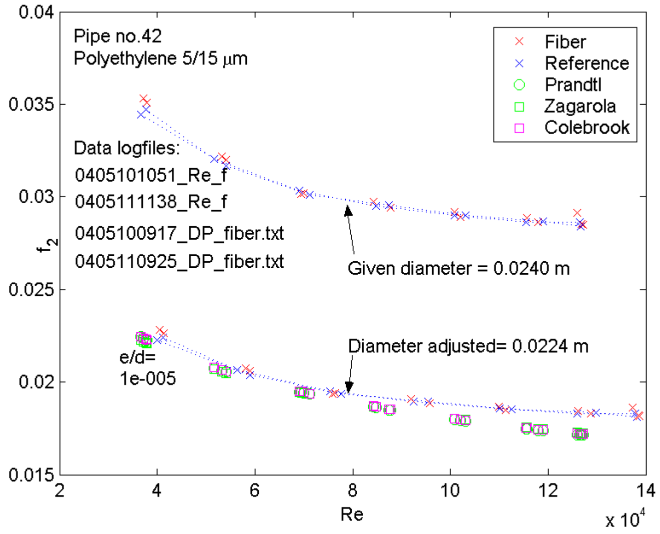


Figure 4.3.18: Friction coefficient for test section 2

Figure 4.4.1: Particle/ fiber tank with polyamide.

## 4.4 Practical problems in the lab

When using fibers as additives the injection system is very unreliable. In the experiments with polyamide and polyethylene only few were successful regarding the injection. The injection rate of fibers was, in general, unstable and it was not possible to vary the rate. Most experiments failed due to packing of the injection pipe (FT in Fig. 3.1.2), and needed to be restarted. This is very time consuming since it means that the cyclone needs to be emptied, and the particle tank refilled. A picture of the refilling of polyamide is given in Fig. 4.4.1. Polyamide was easier to place in the tank than polyethylene. Estimated time for refilling of polyamide versus polyethylene is 1/2 an hour versus 1 hour. After the injection of polyethylene the cyclone needed to be opened (at the top) to remove the fibers. In general the fibers are not vey floatable. In order to drain the particle tank and the cyclone they both must be shaked heavily. Comressed air was used when cleaning the particle tank.

Experiments with glass fiber were unsuccessful. The fibers were difficult to place in the tank, no injection in the gas flow was observed and the fibers were also hard to remove from the particle tank. The length of the glass fibers were too large ($L \approx 5$mm).

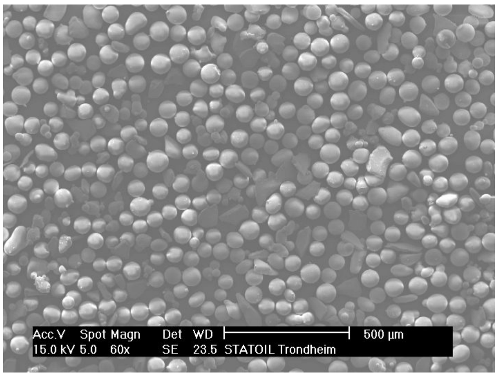


Figure 4.5.1: SEM- Glass beads before injection. Magn: 60x

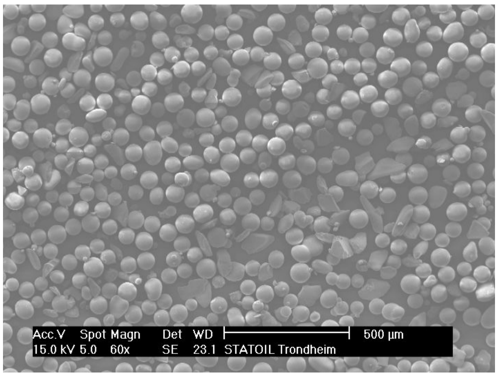


Figure 4.5.2: SEM- Glass beads after injection. Magn: 60x

## 4.5 Scanning electron microscope

Using *SEM* particles and fibers were analysed before and after injection.

### 4.5.1 Glass beads

Fig. 4.5.1, 4.5.2, 4.5.3, 4.5.4, 4.5.5 and Fig. 4.5.6 gives pictures taken of glass beads before and after injection with different zoom settings. The glass beads were supposed to be of uniform size and to be spherical, but the pictures taken are clearly abhorrent to the suppliers promises. All the glass beads are not even spherical before injection, and have sharp edges. This is probably the reason why the pipes roughness increased after the injection of glass beads. No measurement of the pipe roughness has been measured, but the pipes transparency is given in Fig. 4.3.10 and serves as an observable measurement of the pipes roughness. The glass beads used is not recommendable when looking for a drag reduction effect, due to the increased friction caused by the sharp edges in the particle distribution.

### 4.5.2 Polyamide

Fig. 4.5.7, 4.5.8, 4.5.9, 4.5.10, 4.5.11 and Fig. 4.5.12 gives pictures taken of polyamide before and after injection with different zoom settings. There is no observable damage on polyamide after the pipe injection. Some remainders of glass beads can be observed in Fig. 4.5.12. When testing wear and tear on fibers injected in gas pipe flow a closed loop lab will be preferred. The experiment can then run for hours without continuous operator monitoring.

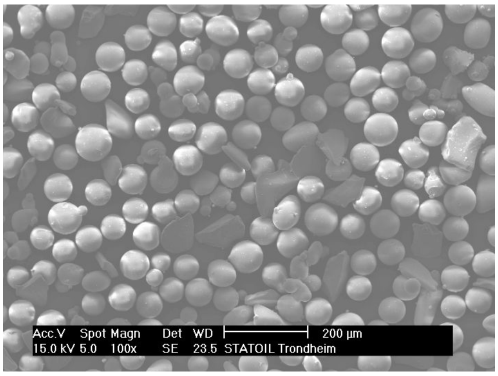


Figure 4.5.3: SEM- Glass beads before injection. Magn: 100x

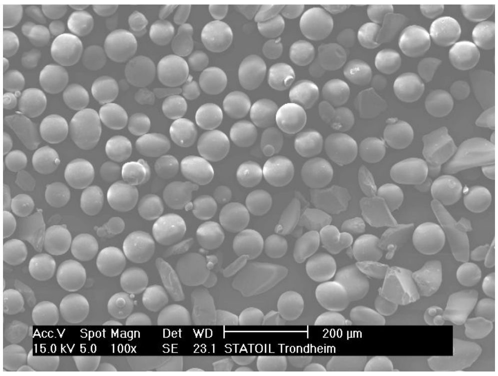


Figure 4.5.4: SEM- Glass beads after injection. Magn: 100x

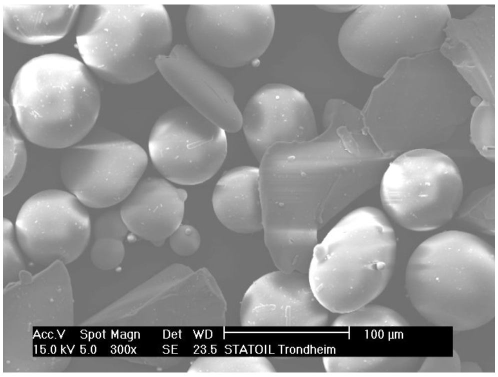


Figure 4.5.5: SEM- Glass beads before injection. Magn: 300x

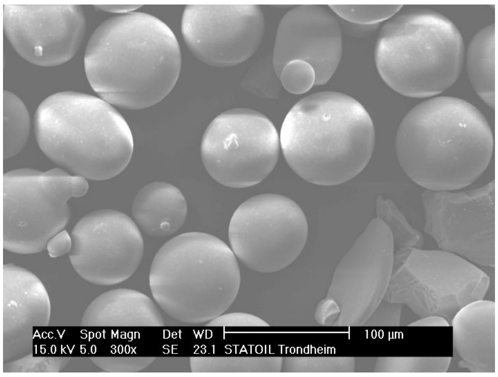


Figure 4.5.6: SEM- Glass beads after injection. Magn: 300x

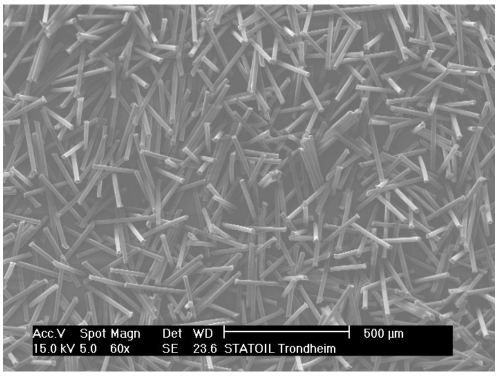


Figure 4.5.7: SEM- Polyamide before injection. Magn: 60x

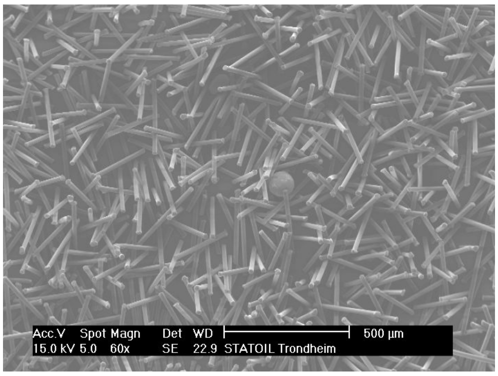


Figure 4.5.8: SEM- Polyamide after injection. Magn: 60x

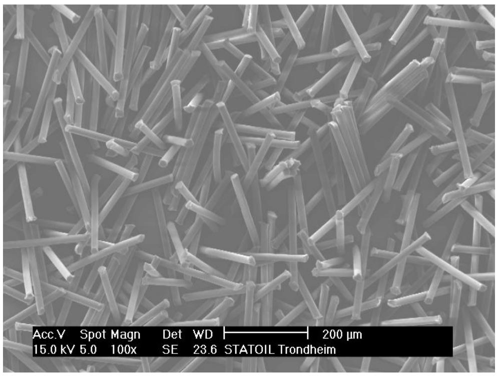


Figure 4.5.9: SEM- Polyamide before injection. Magn: 100x

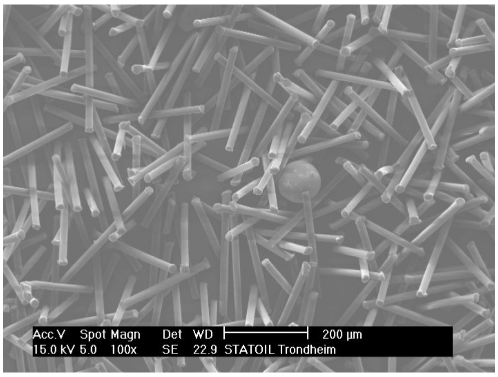


Figure 4.5.10: SEM- Polyamide after injection. Magn: 100x

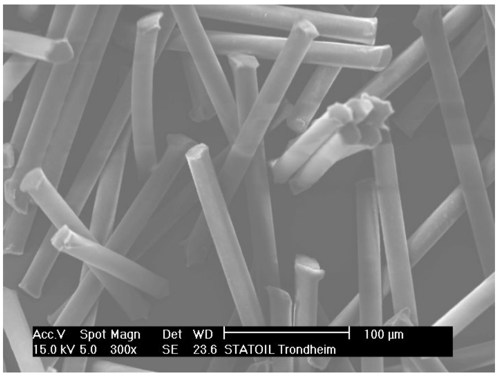


Figure 4.5.11: SEM- Polyamide before injection. Magn: 300x

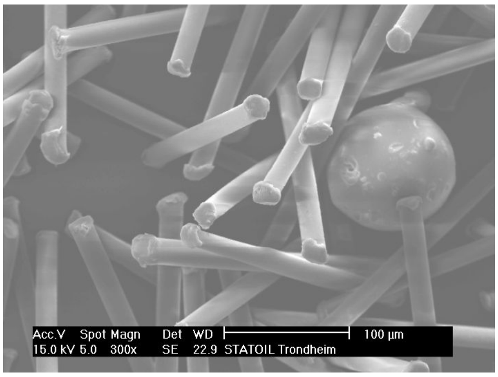


Figure 4.5.12: SEM- Polyamide after injection. Magn: 300x

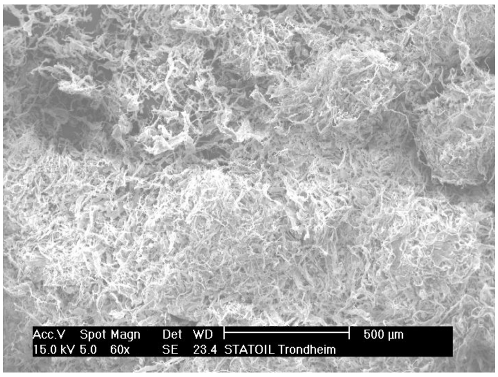


Figure 4.5.13: SEM- Polyethylene before injection. Magn: 60x

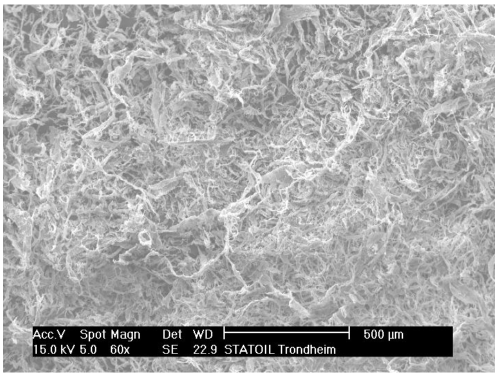


Figure 4.5.14: SEM- Polyethylene after injection. Magn: 60x

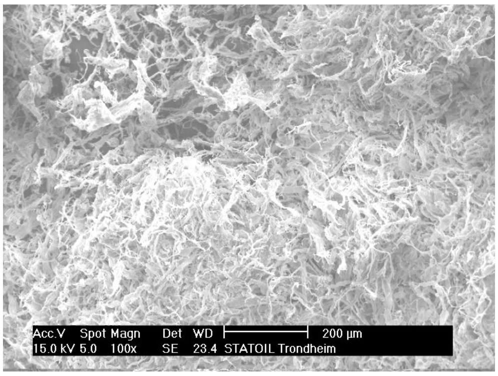


Figure 4.5.15: SEM- Polyethylene before injection. Magn: 100x

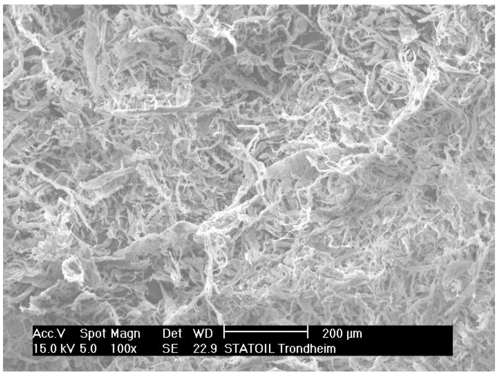


Figure 4.5.16: SEM- Polyethylene after injection. Magn: 100x

### 4.5.3 Polyethylene

Fig. 4.5.13, 4.5.14, 4.5.15, 4.5.16, 4.5.17 and Fig. 4.5.18 gives pictures taken of polyethylene before and after injection with different zoom settings. There is no observable damage on polyethylene after the pipe injection.

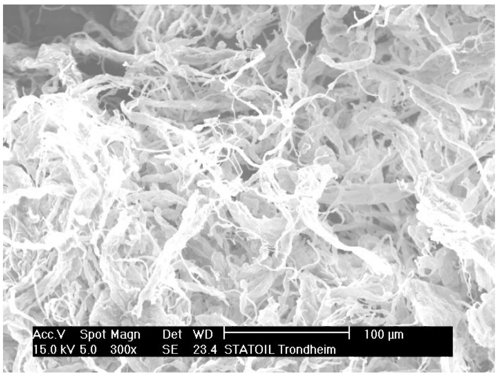


Figure 4.5.17: SEM- Polyethylene before injection. Magn: 300x

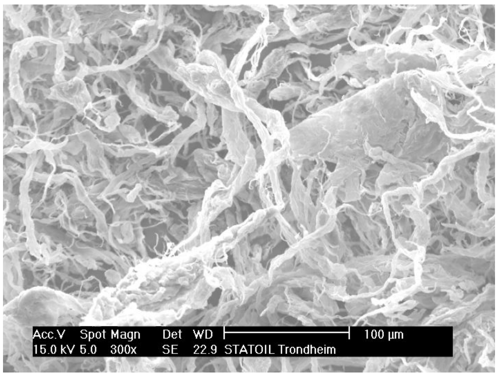


Figure 4.5.18: SEM- Polyethylene after injection. Magn: 300x

# Chapter 5

# Conclusions and Future Work

## 5.1 Conclusion

The difference in the experimental friction versus the correlations for smooth pipe flow, is most likely a result of questionable diameter data. The experiments performed by the summer project students should be repeated, and the diameter of the pipe should be reported *with* a uncertainty.

Injection of glass beads in gas flow indicates a relative large pressure drop reduction when particles are added. Despite the pressure drop reduction the calculated friction coefficient in gas-particle flow is slightly larger than the friction coefficient for particle free flow. No drag reduction effect of adding glass beads in air flow has been found in the experiment performed.

The experimental friction factor when injecting polyamide was sensitive to electrostatic forces in the pipe. When pipe nr. 9 was used, the electrostatic forces were evident, and the calculated friction was larger for gas flow with polyamide than for single phase gas flow. When pipe nr. 42 was used, the electrostatic forces were not observable, and some experimental friction data points for high flow rates of gas, with polyamide injected, were lower than the reference friction for single phase gas flow. This result indicates a drag reduction effect, however, only one experiment with injection of polyamide in pipe nr.42 was performed. The reproducibility of the positive result is therefore unknown.

Injection of polyethylene in gas flow gives a experimental friction factor about the same, or larger, than the experimental reference friction factor for single phase gas flow. No drag reduction effect with polyethylene has been observed.

There is no observable damage on glass beads, polyamide or polyethylene after the pipe injection.

## 5.2 Future Work

Based on the experiments performed glass beads, polyamide and polyethylene can not be excluded or recommended as additives in gas flow. When testing a solid for drag reduction effect a wide variety of particle or fiber sizes should be available. The next step in this research should be to search for a set of fibers with many different sizes. The drag reduction effect *can* be very dependent on the size of the solid injected, and a conservative approach to the experimental work is important.

The lab at Statoil Research Center in Trondheim is very time consuming. Some keywords are: manual filling and cleaning of particle tank, emptying and cleaning the cyclone, calibrating the particle counter and cleaning the filters. Important improvements will therefore be to make the lab more efficient, as regards to time used in the lab. The particle tank should be replaced with a larger tank, at least double size, which has a transparent top that can be opened. With a larger tank the operator can get more results before the tank is empty, and needs to be refilled.

The particle counter needs to be calibrated for every experiment with a new gas flow rate, which makes it to be the bottleneck for an efficiency improvement of the lab. One idea is to place a sensitive weight underneath the tank in order to gain some information about the mass flow rate of particles or fibers. A more interesting idea, presented by one of the researches at Statoil, is to build a new lab. The new lab can be a loop, shaped as the eight number. The advantages with this approach is that the particle counter, the bottleneck, can be eliminated and then also the problem of knowing the mass flow rate of particles or fibers.

The injection system is both insufficient and inefficient when it comes to injecting fibers. If the fibers do get injected in the gas flow, the injection rate can be very unstable. It is important to be able to control the injection rate. This was not possible when the experimental work with fibers in this thesis was performed. It is believed that a large aspect ratio in length/diameter will be favourable when looking for a drag reduction effect. The injection system will have problems using fibers larger than $1 - 2$ mm since the injection pipe (FT) easily get packed. The injection system is therefore the second bottleneck of the labs efficiency and reliability. The best solution to this problem will be to build a new lab that can be a closed loop system, with a known mass of fibers placed in the pipe. The loop mentioned will then also solve the problem with a unstable injection rate.

It is important to eliminate any electrostatic build up in the pipe. Using a steel pipe the electrostatics will probably not be a problem. Steel pipes have been ordered, and must be installed when they arrive to continue the research. It is recommended to have a section about 1/2 m of a transparent pipe in the middle to be able to see the flow pattern.

When testing wear and tear, on fibers injected in gas pipe flow, a closed loop lab will be preferred. The experiment can then be run for hours without continuous operator monitoring.

# Nomenclature

| | | |
|---|---|---|
| $\Delta P$ | Pressuredrop over testlength | $[Pa]$ |
| $\dot{m}$ | Mass flow rate of gas | $[kg/s]$ |
| $\mu$ | Viscosity of gas | $[Ns/m^2]$ |
| $\rho_g$ | Density of gas | $[kg/m^3]$ |
| $\tau_w$ | Wall shear stress | $[N/m^2]$ |
| $A$ | Pipe crossover area | $[m^2]$ |
| $dP$ | Pressure drop | $[Pa]$ |
| $dP_{ag}$ | Pressure drop due to acceleration of the gas | $[Pa]$ |
| $dP_{ap}$ | Pressure drop due to particle acceleration | $[Pa]$ |
| $dP_{gp}$ | Pressure drop due to friction between the gas and the wall in the presence of particles | $[Pa]$ |
| $dP_{hg}$ | Pressure drop due to hydrostatic pressure change component for the gas | $[Pa]$ |
| $dP_{hp}$ | Pressure drop due to the increase in hydrostatic pressure within the gas caused by the presence of particles | $[Pa]$ |
| $dP_{wp}$ | Pressure drop due to collisions of particles with the wall | $[Pa]$ |
| $e/d$ | Roughness of the pipe | $[-]$ |
| $f_d$ | Darcy friction factor | $[-]$ |
| $f_f$ | Fanning friction factor | $[-]$ |
| $f_m$ | Moody friction factor | $[-]$ |

| | | |
|---|---|---|
| $h$ | Height/Length of pipe | $[m]$ |
| $L$ | Length of pipe | $[m]$ |
| $M$ | Molar weight of gas | $[kg/mole]$ |
| $n$ | Mole of gas | $[mole]$ |
| $P$ | Pressure of gas | $[Pa]$ |
| $Q$ | Volumetric flowrate of gas | $[m^3/s]$ |
| $R$ | Universial gas constant | $[J/K \cdot mole]$ |
| $Re$ | Reynolds number | $[-]$ |
| $S_D$ | Uncertainty in the pipe diameter | $[m]$ |
| $S_h$ | Uncertainty in the measured pipe length | $[m]$ |
| $S_v$ | Uncertainty in the the measured volume | $[m^3]$ |
| $T$ | Gas temperature | $[K]$ |
| $V$ | Volume of gas | $[m^3]$ |
| $v$ | Superficial gas velocity | $[m/s]$ |
| $z$ | Compressibility factor | $[-]$ |

# Bibliography

[1] Ronald S. Kane. Drag reduction by particle addition. *American Institute of Aeronautics and Astronautics*, 123:433–456, 1989.

[2] http://gcweb04.gassco.no/.

[3] R. Byron Bird, Warren E. Stewart, and Edwin N. Lightfoot. *Transport-phenomena.* John Wiley & sons, second edition, 2002.

[4] http://www.psig.org/papers/2001/0202.pdf.

[5] Dr. John Piggott, Norman Revell, and Dr. Thomas Kurschat. Taking the rough with the smooth. *PSIG*, 23, Oct 2002.

[6] Frank M. White. *Viscous Fluid Flow.* McGraw-Hill Inc., second edition, 1991.

[7] S. Solbakken, P.H. Mortensen, and H.I. Andersson. An introduction to turbulent wall bounded flows. *Internal report Gassco*, 2004.

[8] B.R. Munson, D.F. Young, and T.H. Okiishi. *Fundamentals of Fluid Mechanics.* John Wiley & sons, 1990.

[9] D.G. Thomas. Transport characteristics of suspensions. *AICHE*, 8:373, 1962.

[10] R.S Kane and R.Pfeffer. Characteristics of dilute gas-solids suspensions in drag reduction flow. *NASA*, CR-2267, 1973.

[11] Y.H. Li, G.R. Chesnut, R.D. Richmond, and G.L. Beer. Laboratory tests and field implementation of gas drag reduction chemicals. In *SPE, Texas*, February 1997.

[12] Liang Shih Fan and Chao Zhu. *Principles of Gas-Solid Flows.* Cambridge University Press, 1998.

[13] Karl Heinz Herlinger and Fritz Scultze Gebhardt. *Fibers.* Wiley-VCH Verlag, 2002.

[14] Professor Tor Ytrehus. *NTNU.*

[15] F. E. Jones. Techniques and topics in flow measurement. *CRC Press, Boca Raton, Florida*, 1995.

# Appendix A

# Calculations

## A.1 Friction

The one dimensional continuity equation for a pipe with constant cross section area

$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho v}{\partial x} = 0 \tag{A.1.1}$$

For steady state flow $\frac{\partial \rho}{\partial t} = \frac{\partial \rho v}{\partial x} = 0$.

$$\frac{\partial \rho v^2}{\partial x} = \underbrace{\frac{\partial \rho v}{\partial x}}_{0} v + \frac{\partial v}{\partial x}\rho v = \rho v \frac{dv}{dx} \tag{A.1.2}$$

$$\frac{\partial \rho v^2}{\partial x} = \frac{d\left(\frac{\dot{m}}{A}\right)^2 \frac{1}{\rho}}{dx} = \frac{d\left(\frac{\dot{m}}{A}\right)^2 \frac{zRT}{PM}}{dx} = -\frac{\dot{m}^2 zRT}{A^2 M}\frac{1}{P^2}\frac{dP}{dx} \tag{A.1.3}$$

The force balance for a gas pipe with constant crossection area and negligible elevations are

$$-A\frac{dP}{dx} - \tau_w \pi D = A\rho v \frac{dv}{dx} \qquad , \quad \tau_w = \frac{f_m \rho v^2}{8} \tag{A.1.4}$$

Substituting for the shear stress and Eq. A.1.3 into Eq. A.1.4 gives

$$A\frac{dP}{dx} + \left(\frac{\dot{m}}{A}\right)^2 \frac{zRT}{PM}\frac{\pi D}{8} f_m = \frac{\dot{m}^2}{A}\frac{zRT}{M}\frac{1}{P^2}\frac{dP}{dx} \tag{A.1.5}$$

Rearrange

$$f_m dx = \frac{8A}{\pi D}\frac{dP}{P} - \frac{8A^3 M}{\dot{m}^2 zRT\pi D} P dP$$

$$\int_{x=0}^{x=L} f_m dx = 2D\int_{P_1}^{P_2}\frac{dP}{P} - \frac{\pi^2 D^5 M}{8\dot{m}^2 zRT}\int_{P_1}^{P_2} P dP \tag{A.1.6}$$

Assuming that the compressibility factor $z$ and the temperature $T$ are constants when integrating

$$f_m = \frac{\pi^2 D^5 M}{16\dot{m}^2 zRTL}(P_1^2 - P_2^2) + 2\frac{D}{L}\ln\frac{P_2}{P_1} \tag{A.1.7}$$

## A.2 Viscosity

[15] give the viscosity for air as a function of pressure and temperature

$$\mu_{air} = A_0 + A_1 T - A_2 T^2 + A_3 P + A_4 P^2 \tag{A.2.1}$$

where the units are: $P$ [psi], $T$ [C] and $\mu$ [cp]

Table A.2.1: Viscosity coefficients

| Constant | Value |
|---|---|
| $A_0$ | 0.0170257 |
| $A_1$ | $6.05434 \cdot 10^{-5}$ |
| $A_2$ | $1.33200 \cdot 10^{-7}$ |
| $A_3$ | $8.08321 \cdot 10^{-7}$ |
| $A_4$ | $5.97259 \cdot 10^{-10}$ |

Fig. A.2.1 shows the viscosity of air for temperature and pressure between $10 - 200$°C and $1 - 100$bar, respectively.

## A.3 Uncertainty Discussion

The diameter of the pipes was found by students working on the summer project at Statoil Research Center. The pipes was filled with water to find the volume. The diameter was then calculated from Eq. A.3.1. The students did not introduce any uncertainty values on their data.

$$V = Ah = \frac{\pi D^2}{4}h.$$

$$D = \sqrt{\frac{4V}{\pi h}} \tag{A.3.1}$$

Using the error propagation formula given in Eq. A.3.2 and Eq. A.3.3 the expression for the diameter uncertainty is derived in Eq. A.3.4.

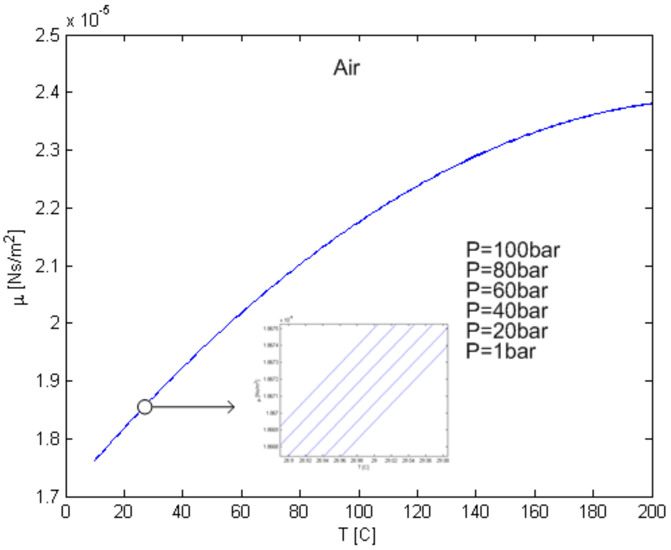


Figure A.2.1: Viscosity of air

$$S_y = \sqrt{\left(\frac{\partial Y}{\partial x_1} \cdot S_{x1}\right)^2 + \left(\frac{\partial Y}{\partial x_2} \cdot S_{x2}\right)^2 + .... + \left(\frac{\partial Y}{\partial x_n} \cdot S_{xn}\right)^2} \tag{A.3.2}$$

$$S_D = \sqrt{\left(\frac{\partial D}{\partial V} \cdot S_v\right)^2 + \left(\frac{\partial D}{\partial h} \cdot S_h\right)^2} \tag{A.3.3}$$

$$S_D = \sqrt{\frac{1}{\pi h V} {S_v}^2 + \frac{V}{\pi h^3} {S_h}^2} \tag{A.3.4}$$

$$[S_D] = \sqrt{\frac{1}{m^3 \cdot m} \cdot m^6 + \frac{m^3}{m^3} \cdot m^2} = [m]$$

# Appendix B

# Experimental data

## B.1 Glass beads

The original given diameter of the pipe is used when calculating the velocity of air.

## B.2 Polyamide 3.3 dtex 0.3 mm

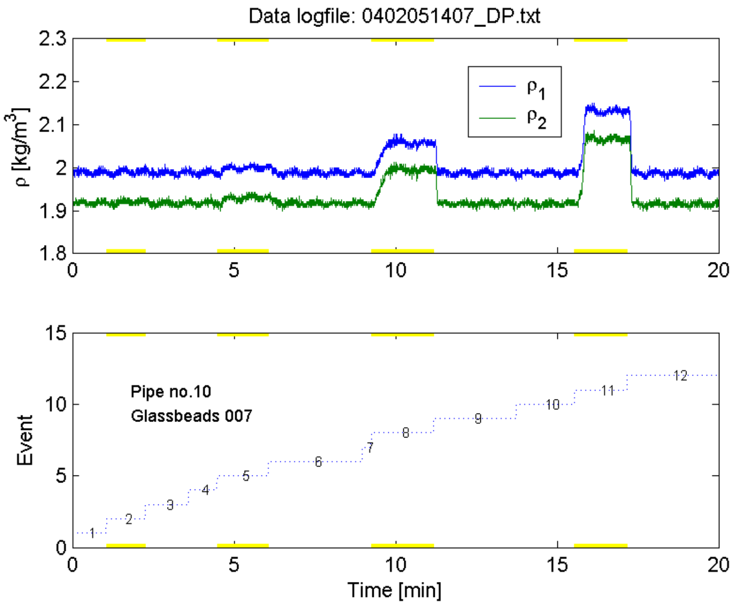


Figure B.1.1: Average density of air in the pipe at test section.

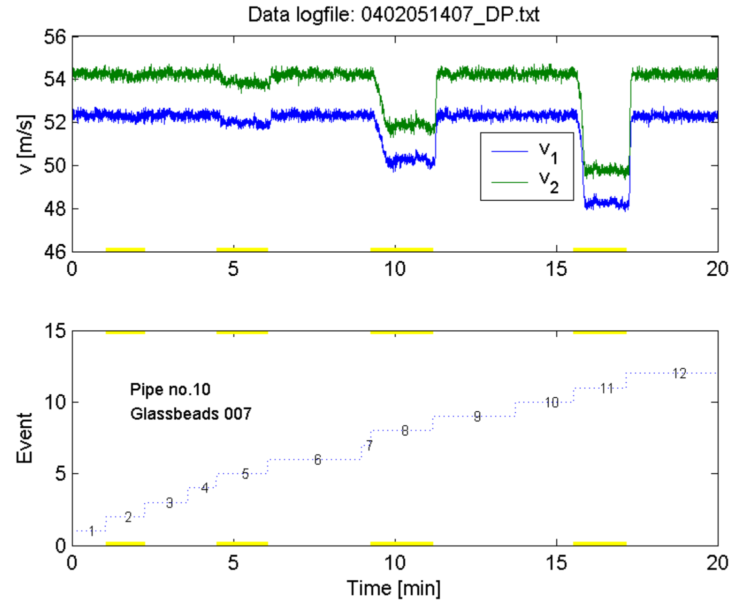


Figure B.1.2: Average air velocity at test section.

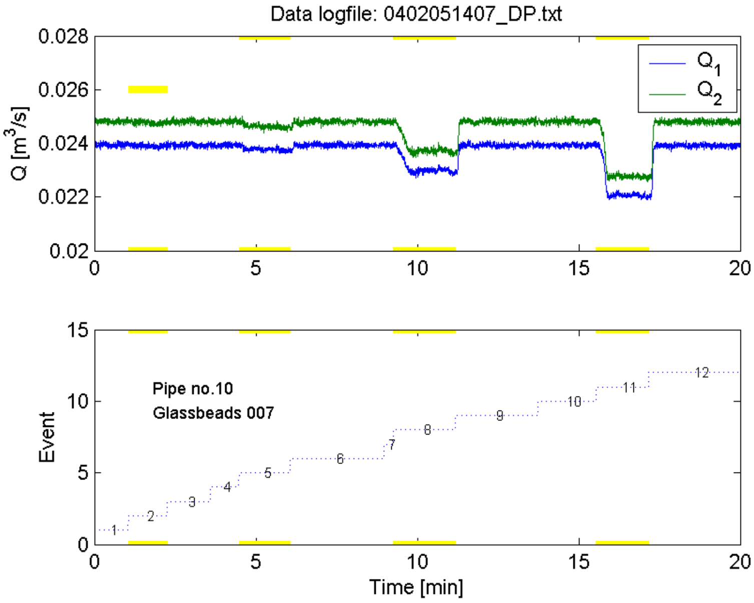


Figure B.1.3: Average volumetric flow rate at test section.

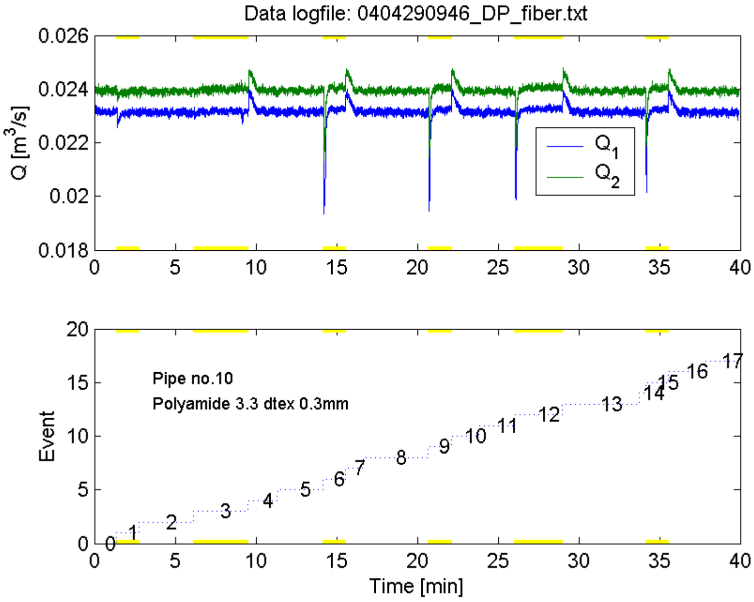


Figure B.2.1: Average volumetric flow rate at test section.

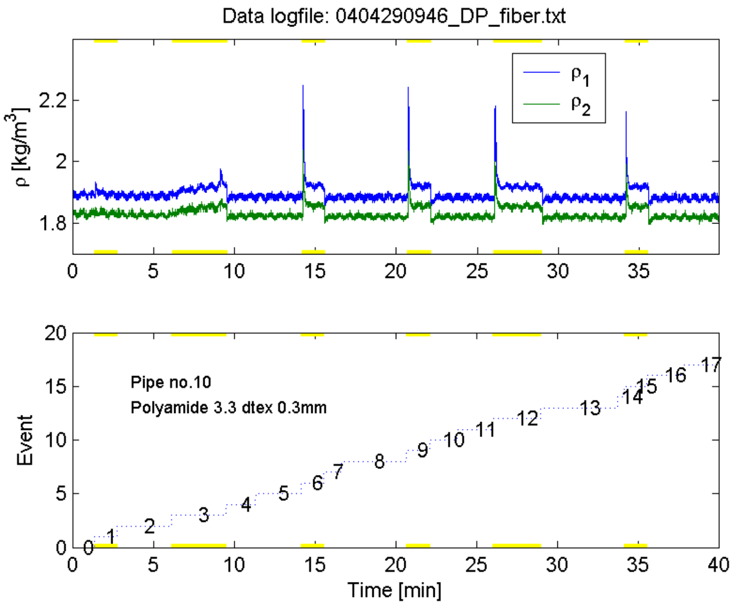


Figure B.2.2: Average density of air in the pipe at test section.

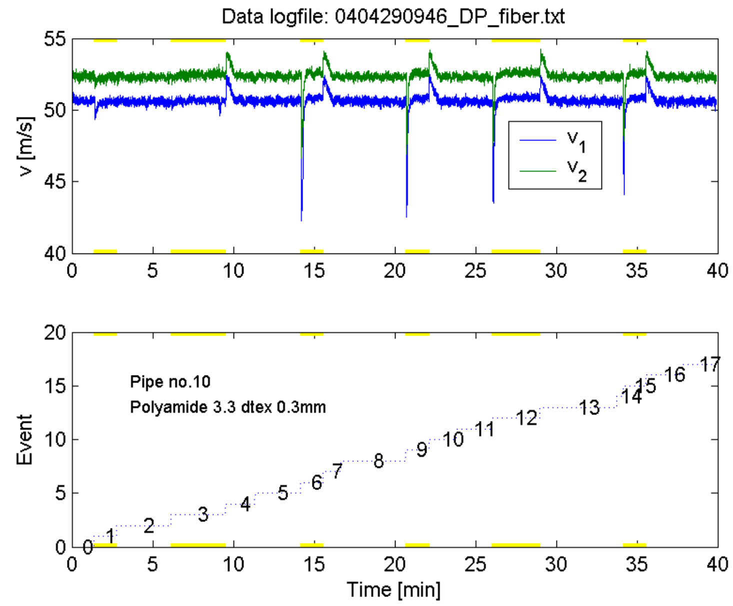


Figure B.2.3: Average air velocity at test section.

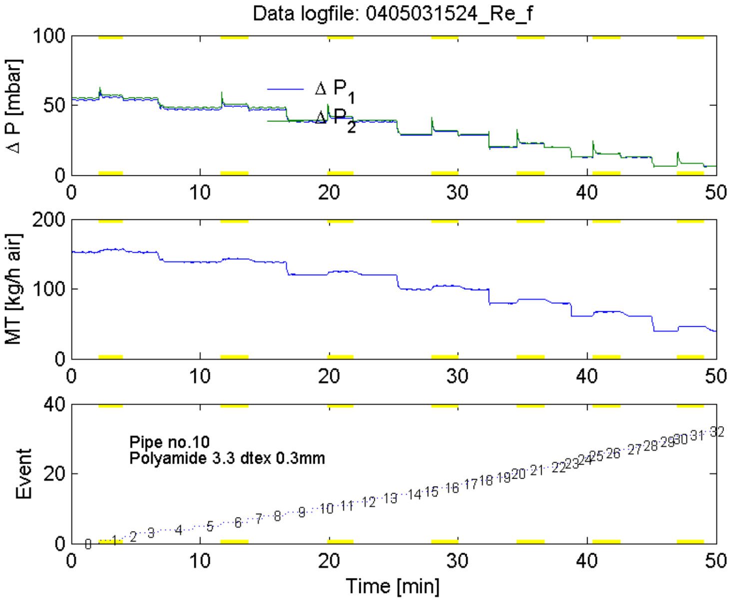


Figure B.2.4: Re-f test. No fiber flow. Used as a reference.

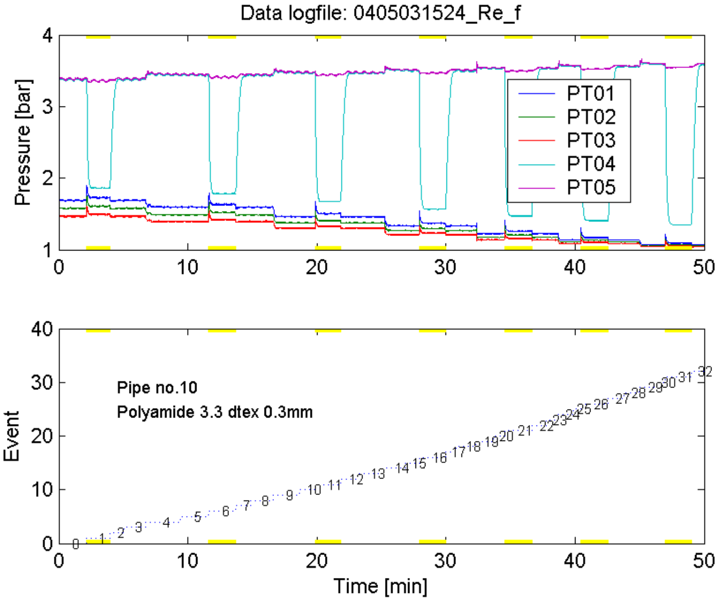


Figure B.2.5: Pressure in the pipe. LOG: 0405031524.

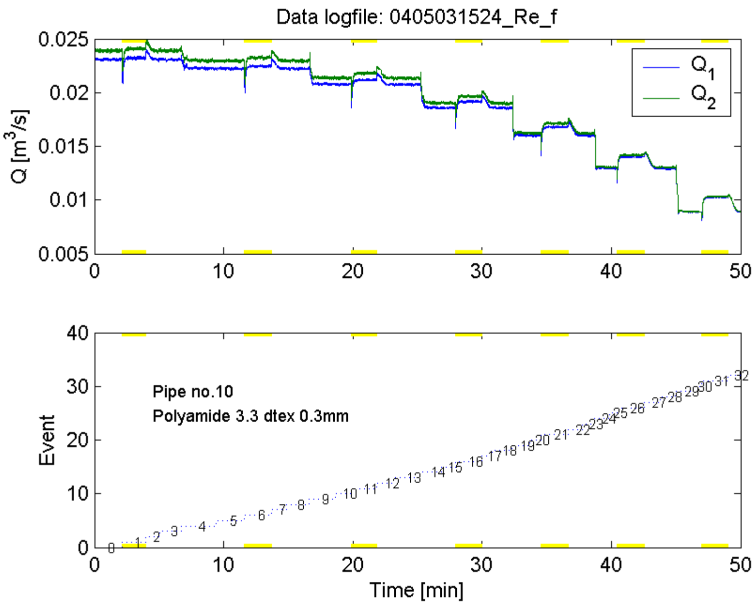


Figure B.2.6: Average volumetric flow rate at test section.

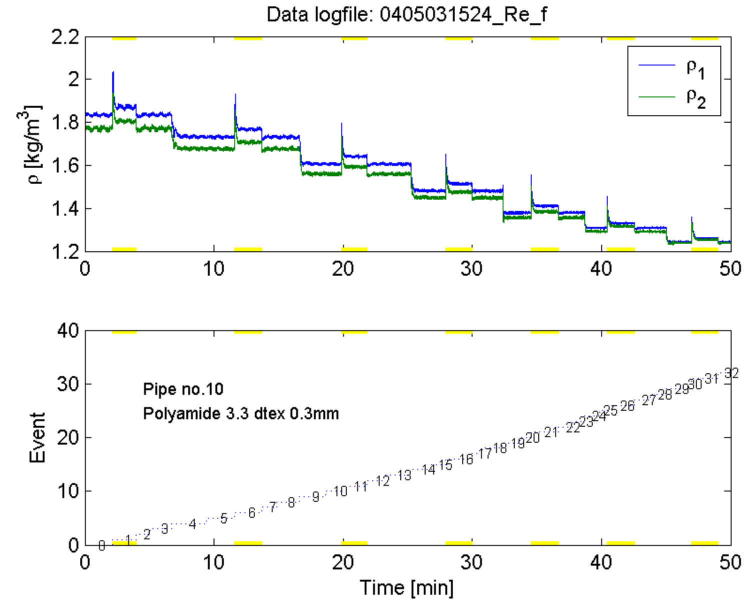


Figure B.2.7: Average density of air in the pipe at test section.

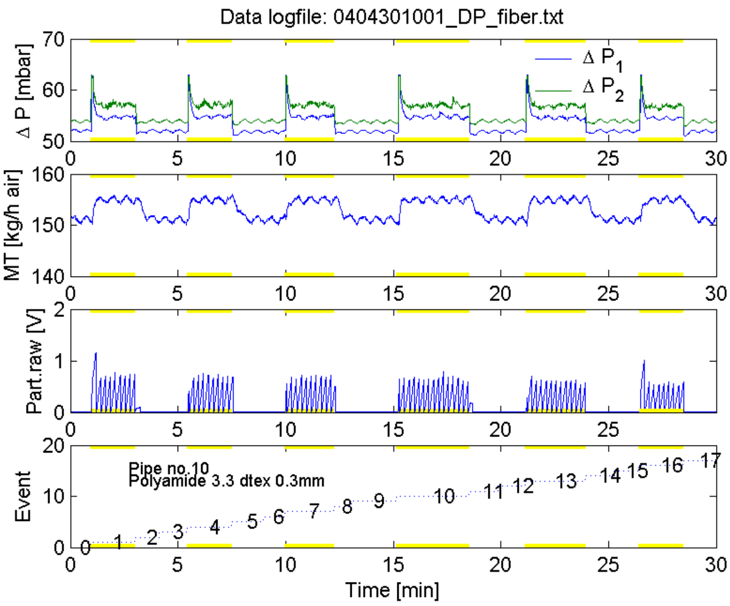


Figure B.2.8: Injection of polyamide 0.3 mm 3.3 dtex. LOG: 0404301001.

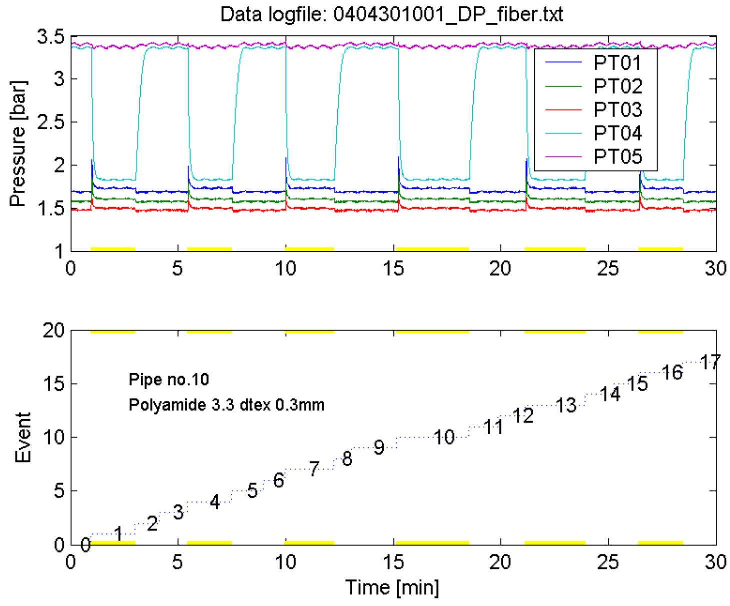


Figure B.2.9: Pressure in the pipe. LOG: 0404301001.

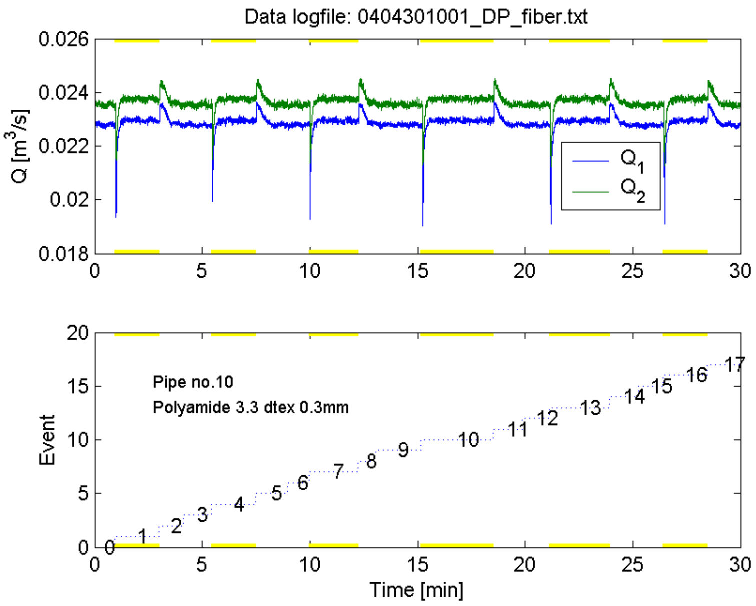


Figure B.2.10: Average volumetric flow rate at test section.

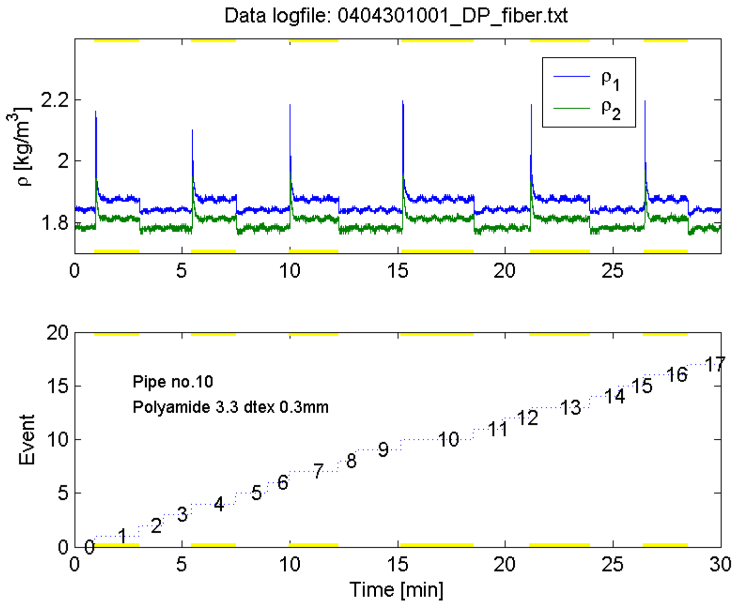


Figure B.2.11: Average density of air in the pipe at test section.

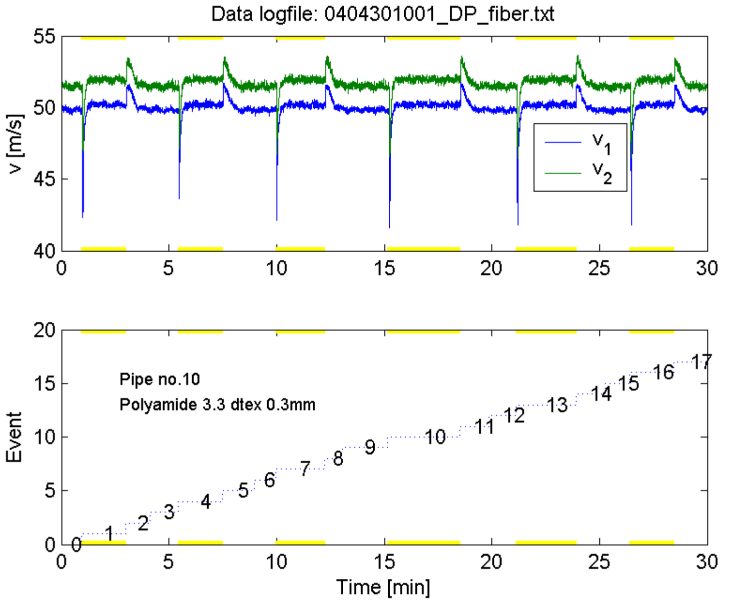


Figure B.2.12: Average air velocity at test section.

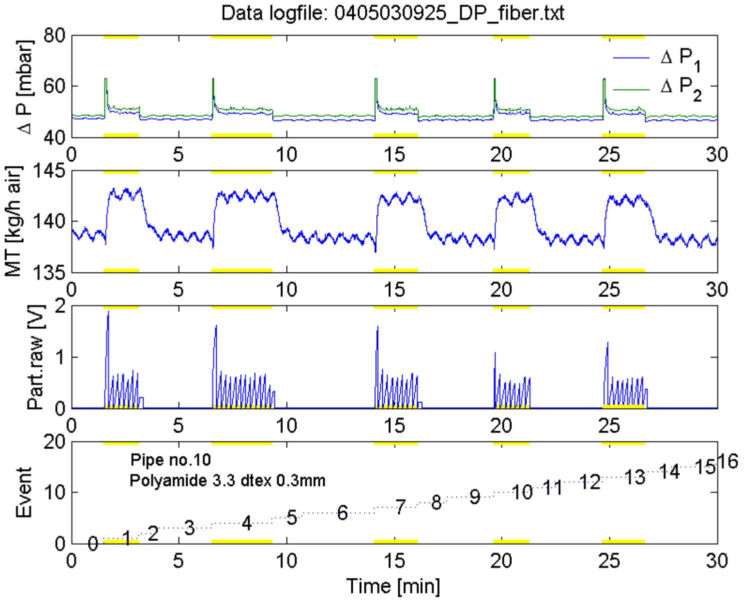


Figure B.2.13: Injection of polyamide 0.3 mm 3.3 dtex. LOG: 0405030925.

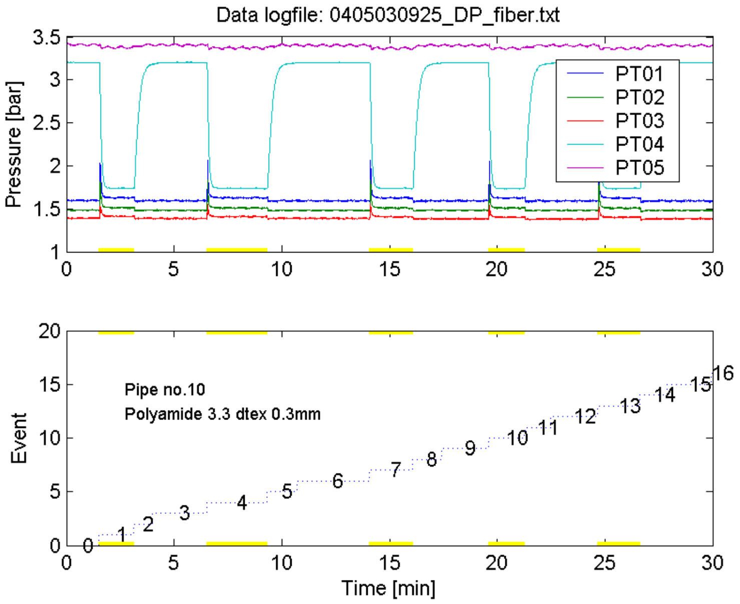


Figure B.2.14: Pressure in the pipe. LOG: 0405030925.

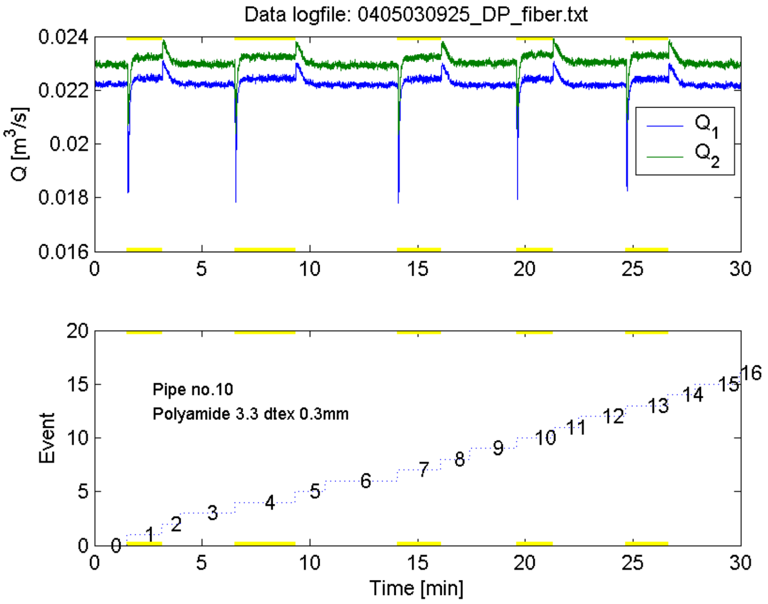


Figure B.2.15: Average volumetric flow rate at test section.

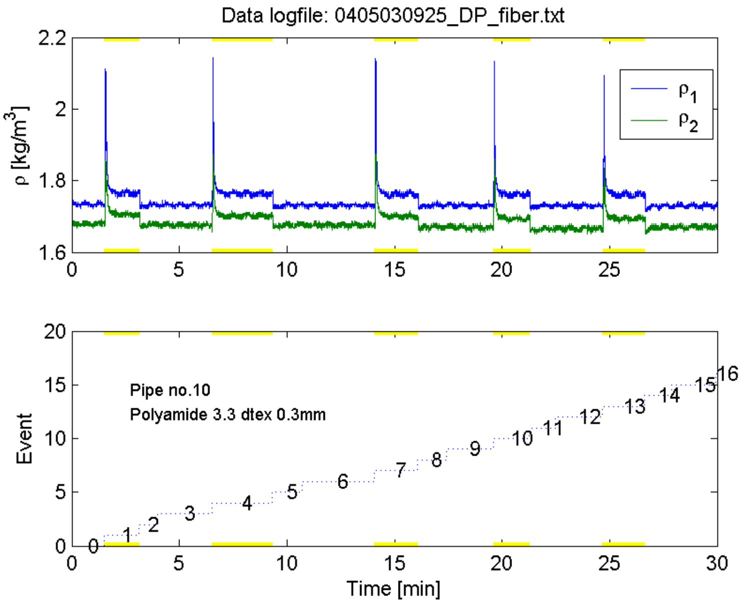


Figure B.2.16: Average density of air in the pipe at test section.

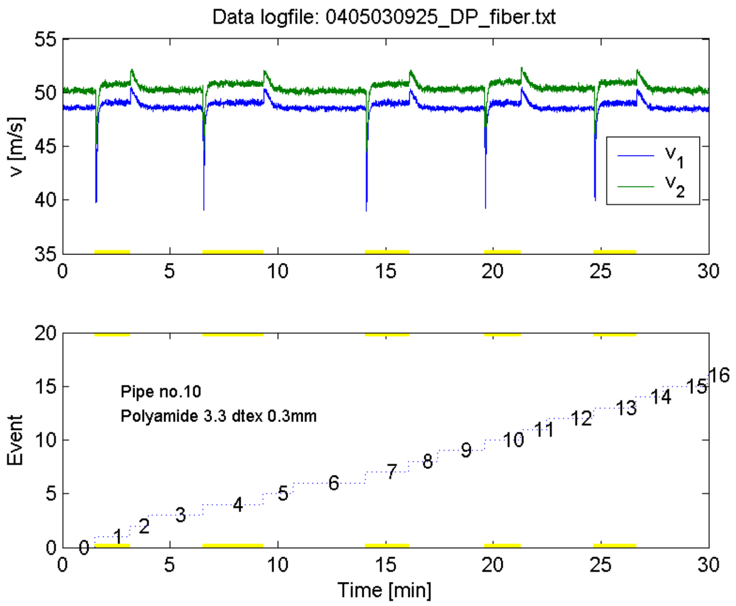


Figure B.2.17: Average air velocity at test section.

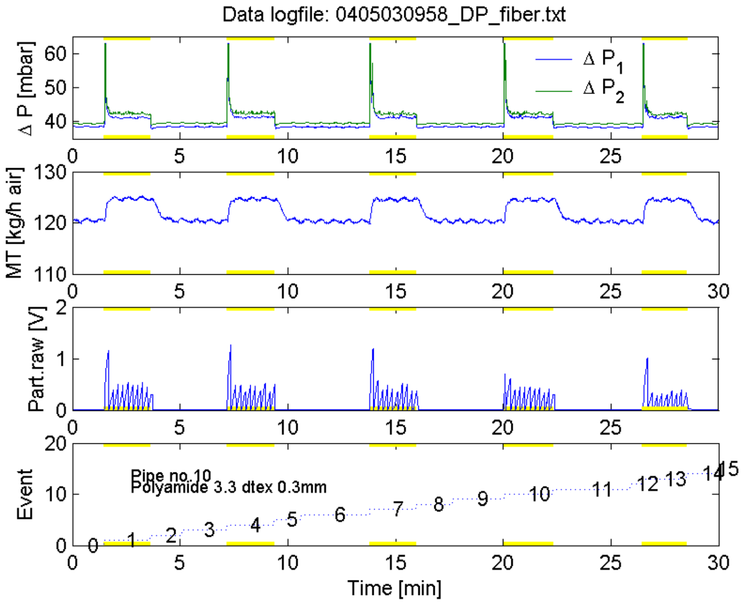


Figure B.2.18: Injection of polyamide 0.3 mm 3.3 dtex. LOG: 0405030958.

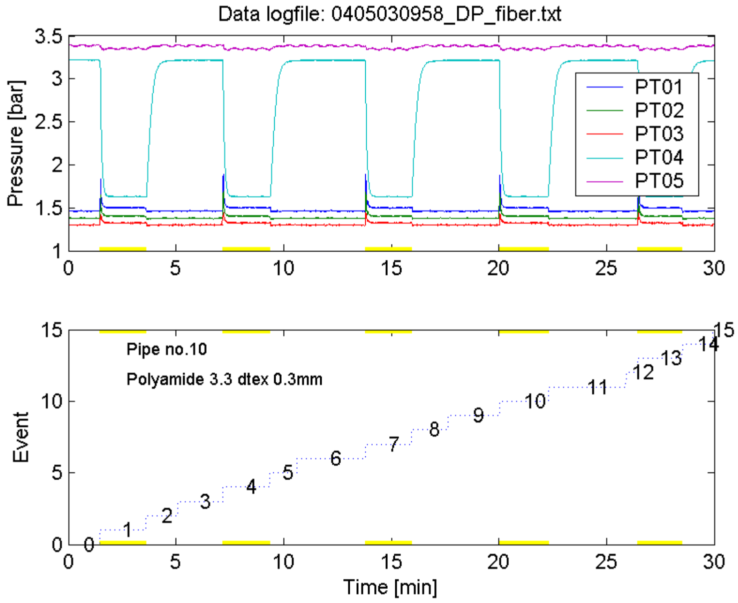


Figure B.2.19: Pressure in the pipe. LOG: 0405030958.

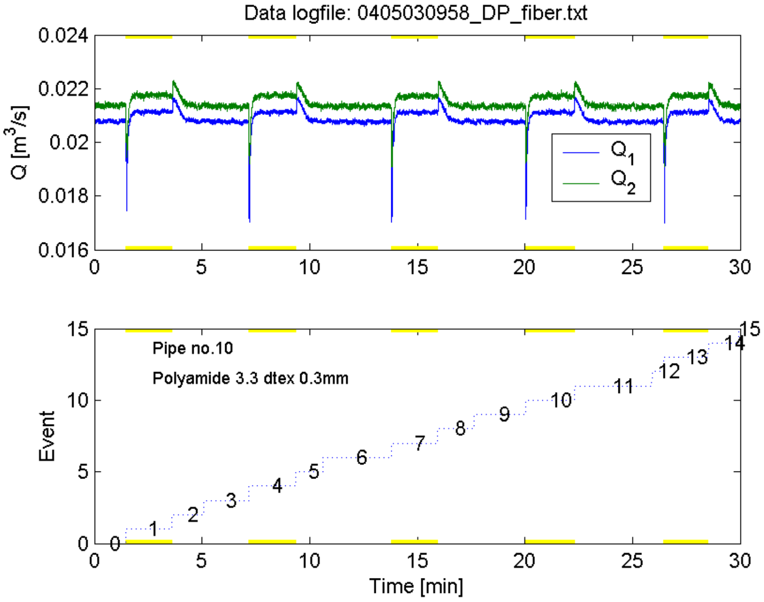


Figure B.2.20: Average volumetric flow rate at test section.

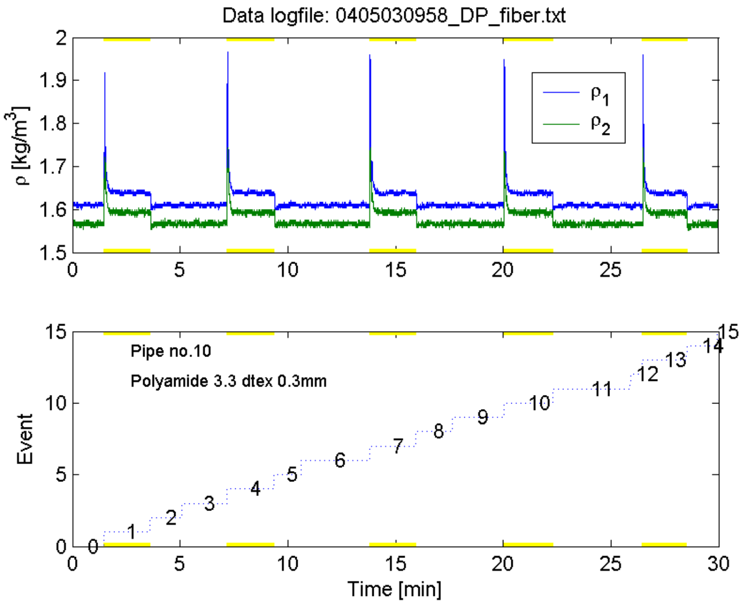


Figure B.2.21: Average density of air in the pipe at test section.

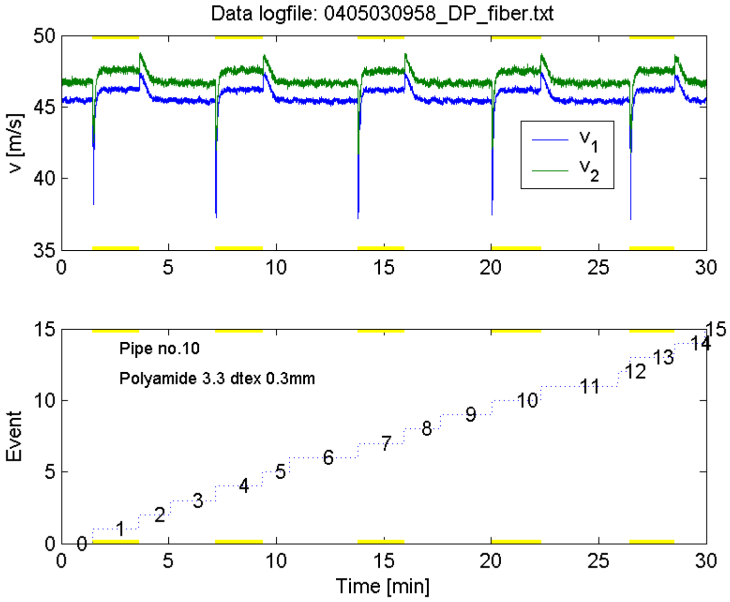


Figure B.2.22: Average air velocity at test section.

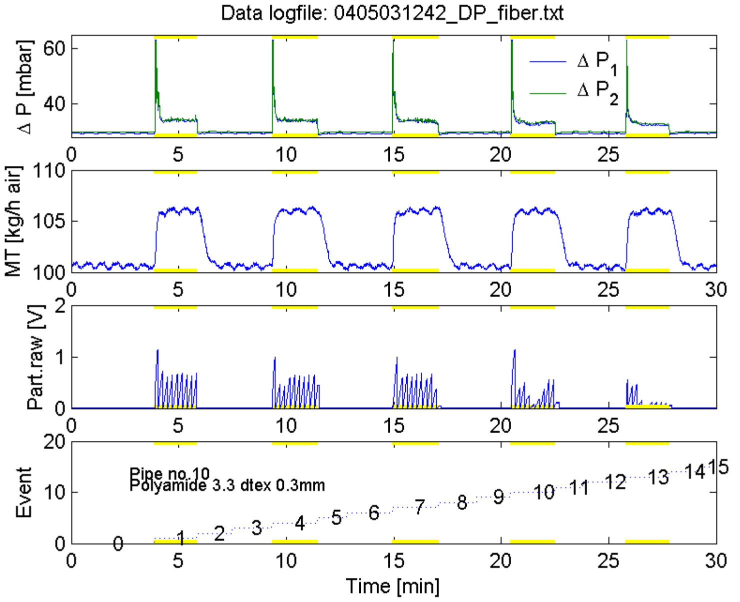


Figure B.2.23: Injection of polyamide 0.3 mm 3.3 dtex. LOG: 0405031242.

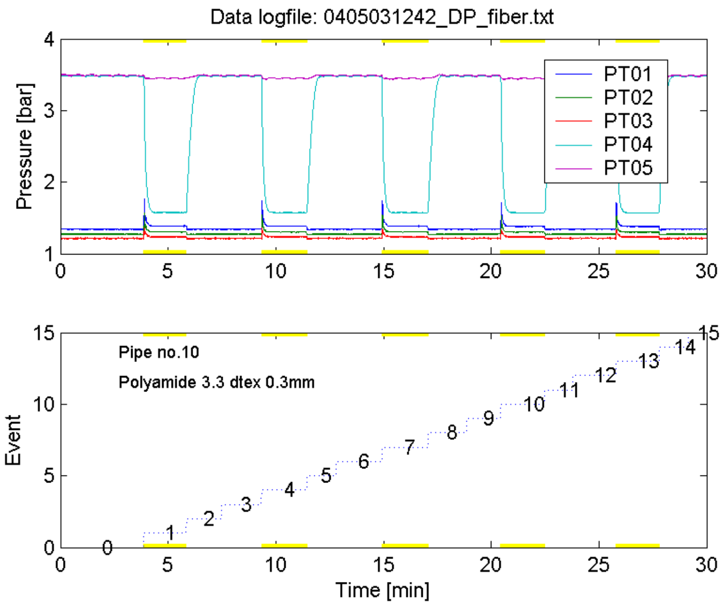


Figure B.2.24: Pressure in the pipe. LOG: 0405031242.

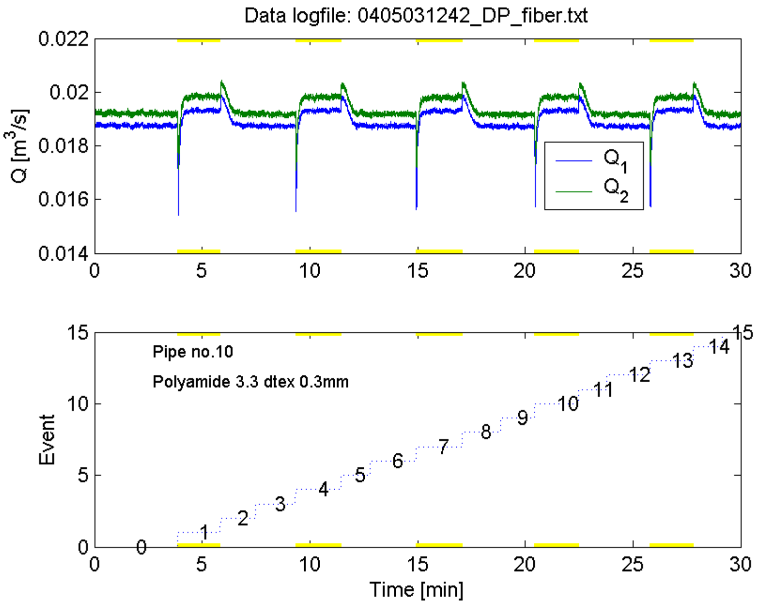


Figure B.2.25: Average volumetric flow rate at test section.

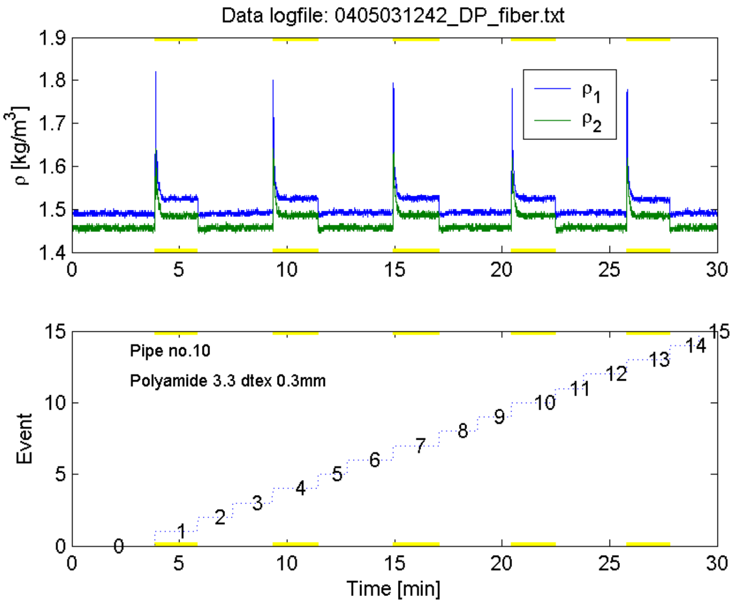


Figure B.2.26: Average density of air in the pipe at test section.

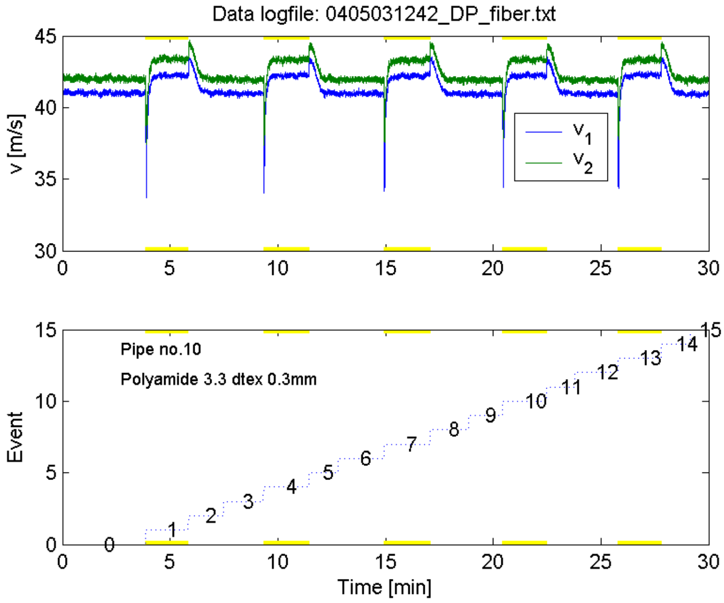


Figure B.2.27: Average air velocity at test section.

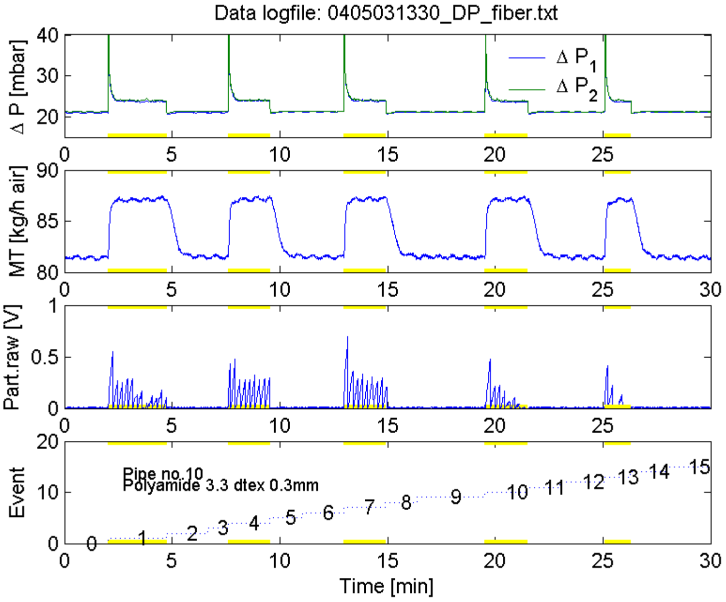


Figure B.2.28: Injection of polyamide 0.3 mm 3.3 dtex. LOG: 0405031330.

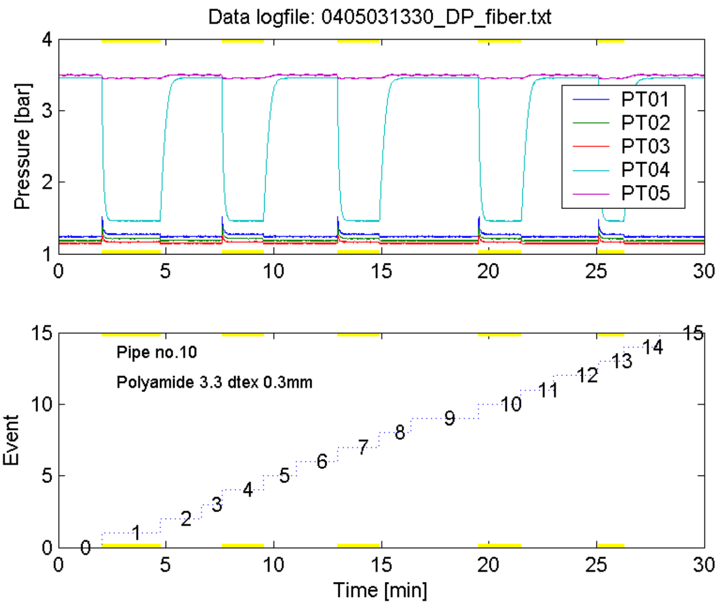


Figure B.2.29: Pressure in the pipe. LOG: 0405031330.

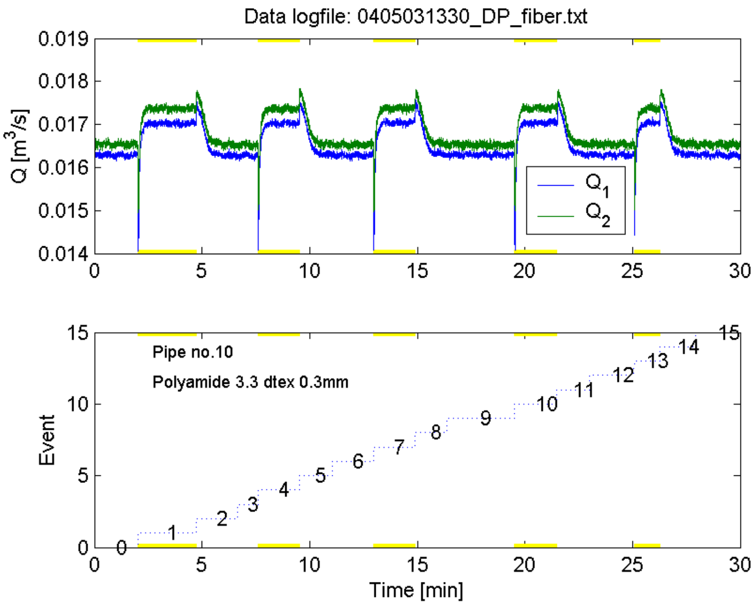


Figure B.2.30: Average volumetric flow rate at test section.

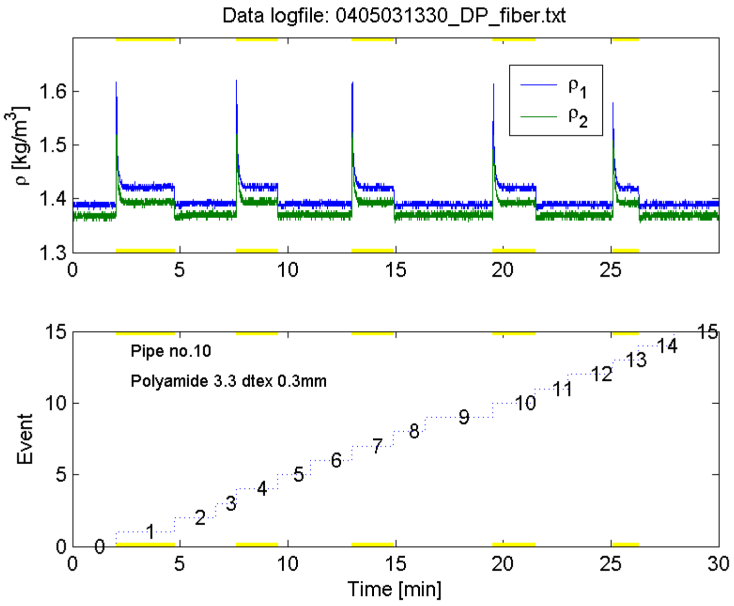


Figure B.2.31: Average density of air in the pipe at test section.

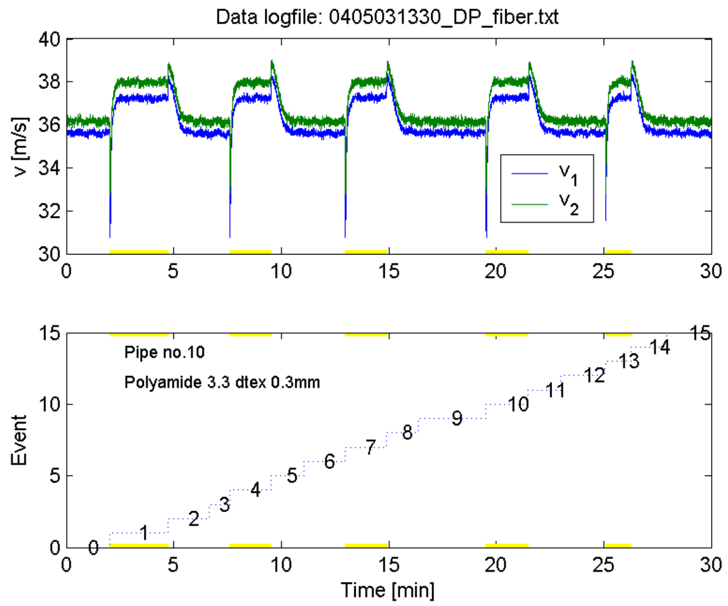


Figure B.2.32: Average air velocity at test section.

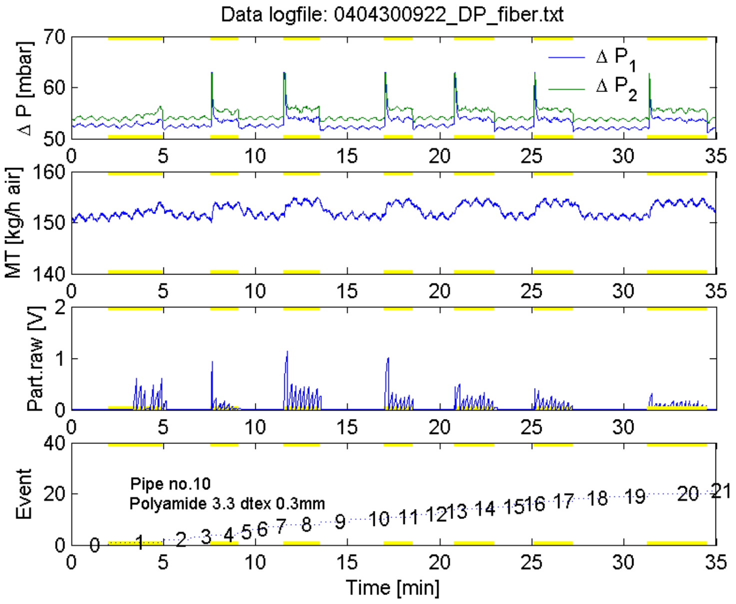


Figure B.2.33: Injection of polyamide 0.3 mm 3.3 dtex. LOG: 0404300922.

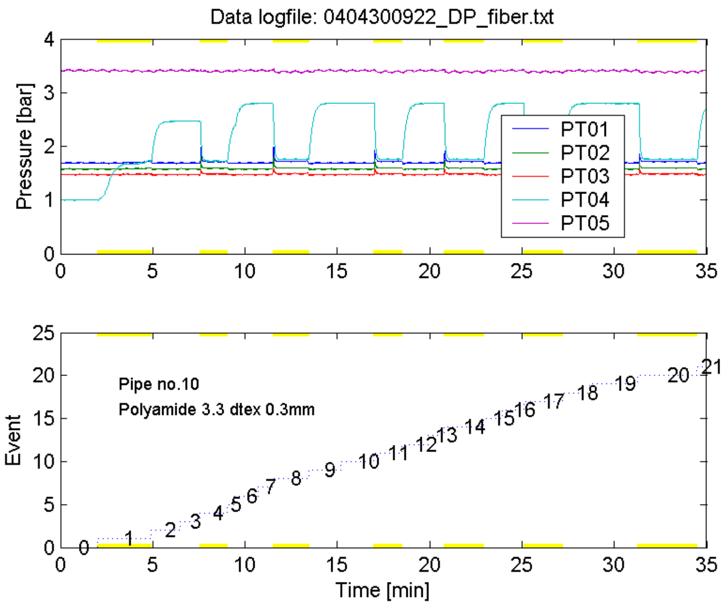


Figure B.2.34: Pressure in the pipe. LOG: 0404300922.

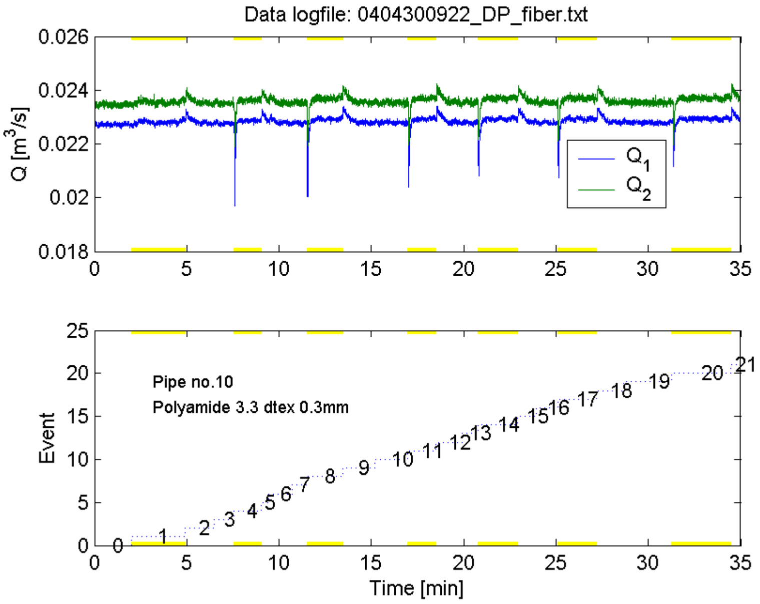


Figure B.2.35: Average volumetric flow rate at test section.

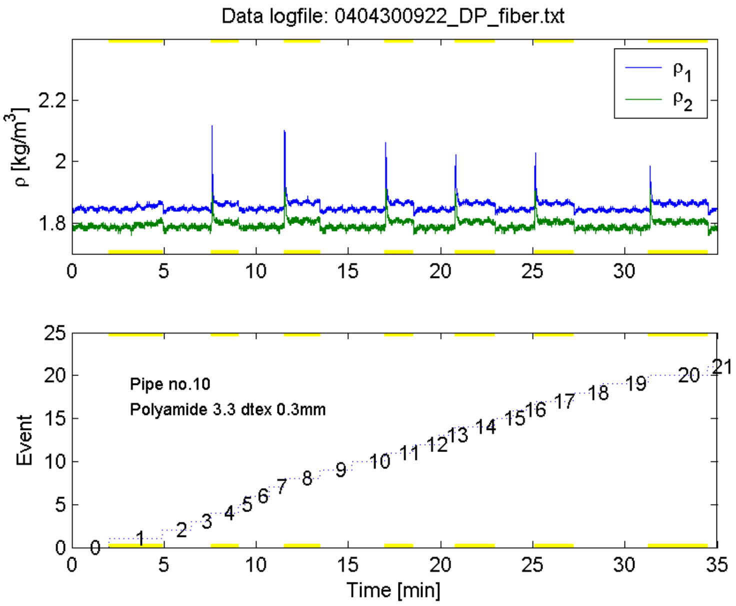


Figure B.2.36: Average density of air in the pipe at test section.

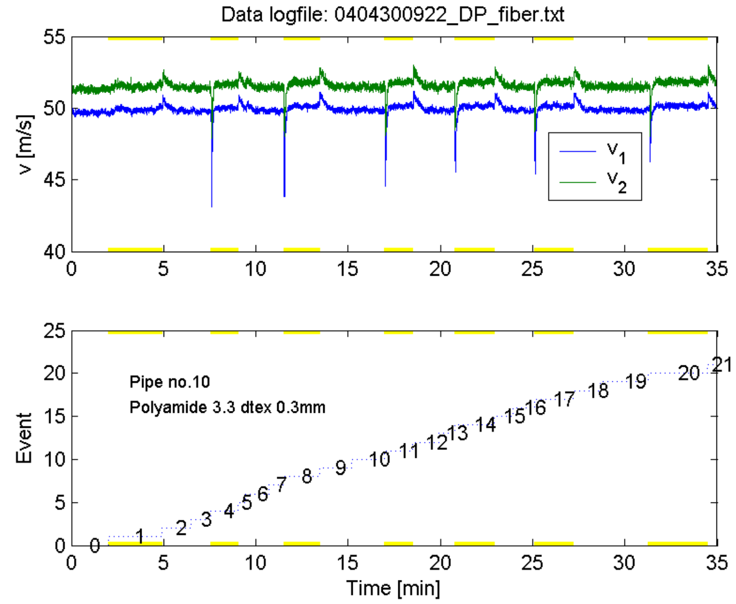


Figure B.2.37: Average air velocity at test section.

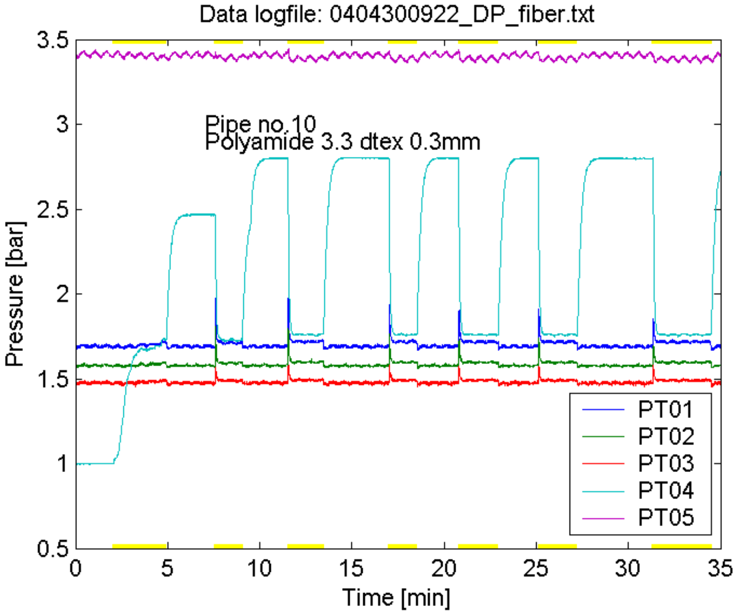


Figure B.2.38: Pressure in the pipe at test section.

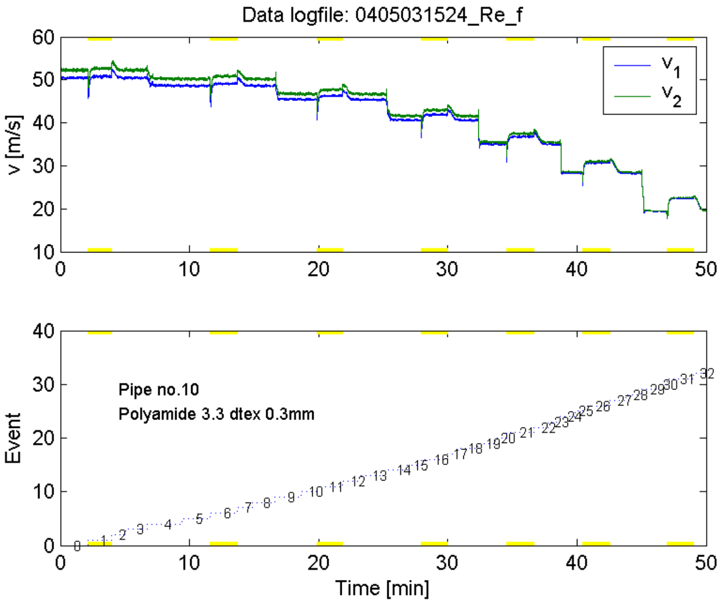


Figure B.2.39: Average air velocity at test section.

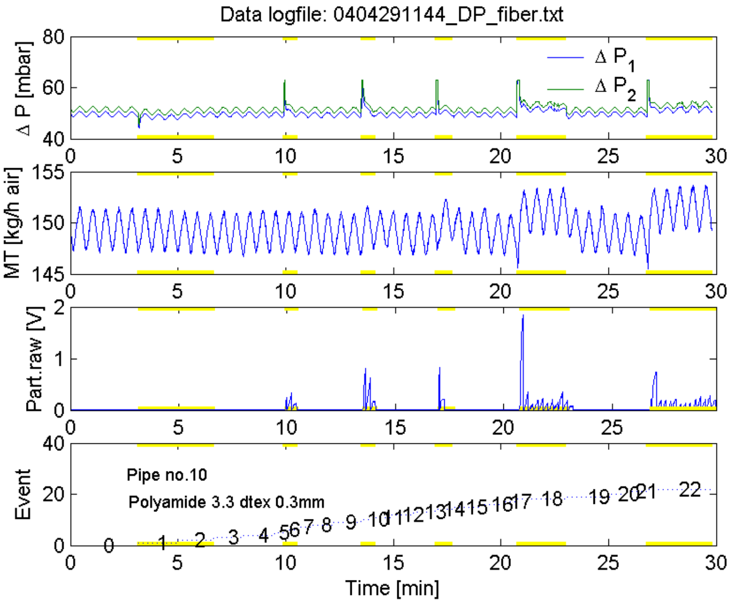


Figure B.2.40: Injection of polyamide 0.3 mm 3.3 dtex.

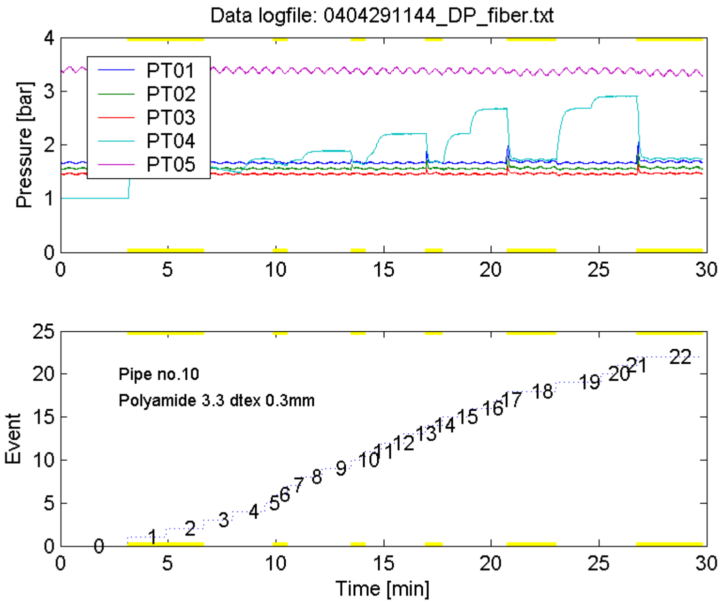


Figure B.2.41: Pressure in the pipe at test section.

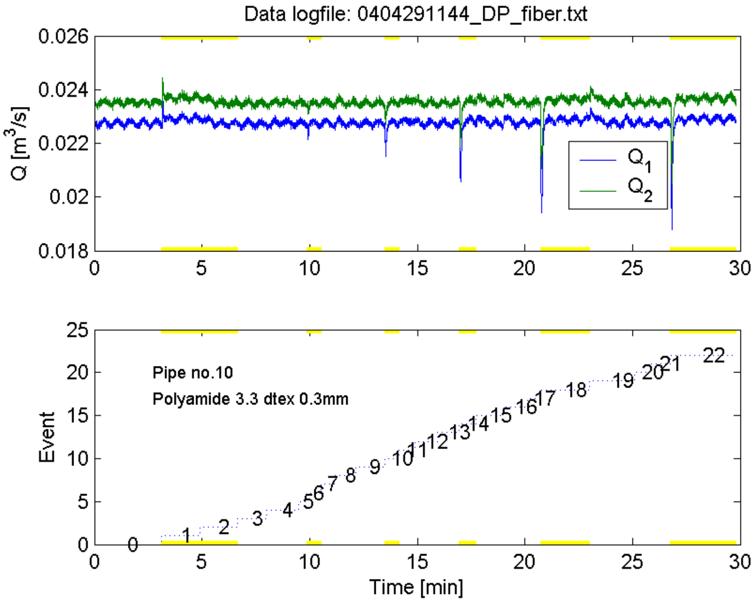


Figure B.2.42: Average volumetric flow rate at test section.

## B.3 Polyethylene 5/15 $\mu m$

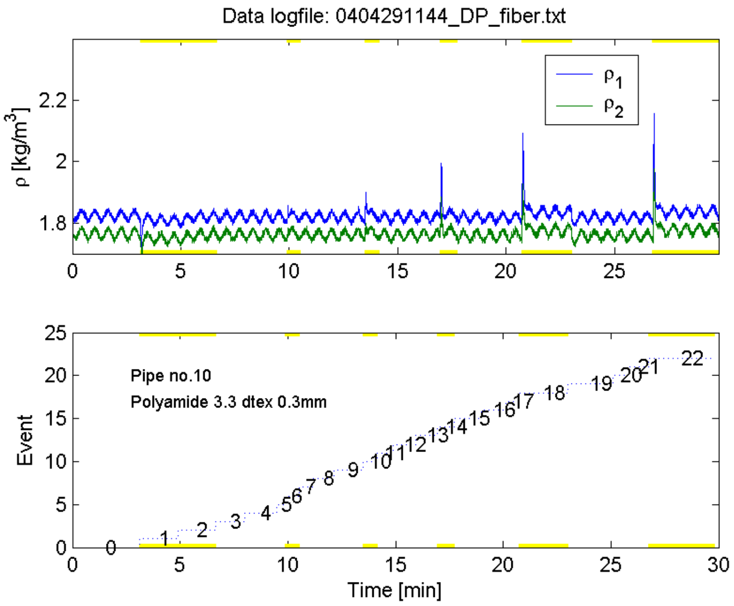


Figure B.2.43: Average density of air in the pipe at test section.

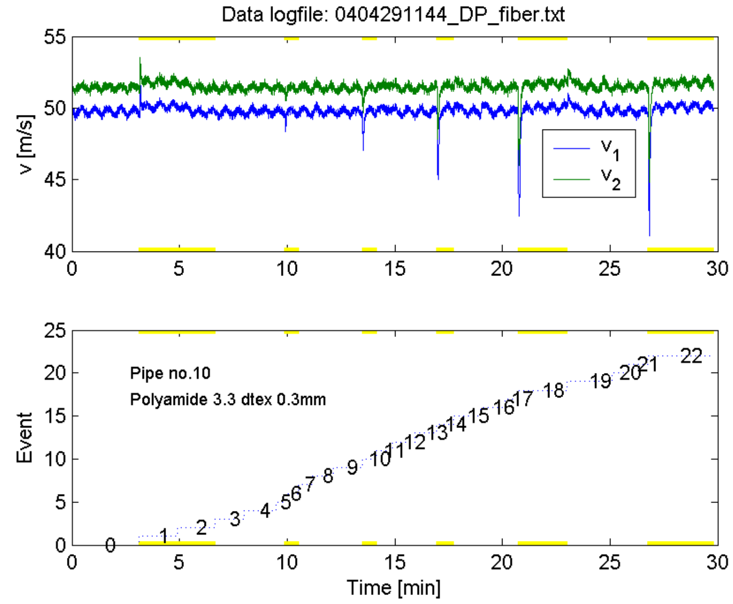


Figure B.2.44: Average air velocity at test section.

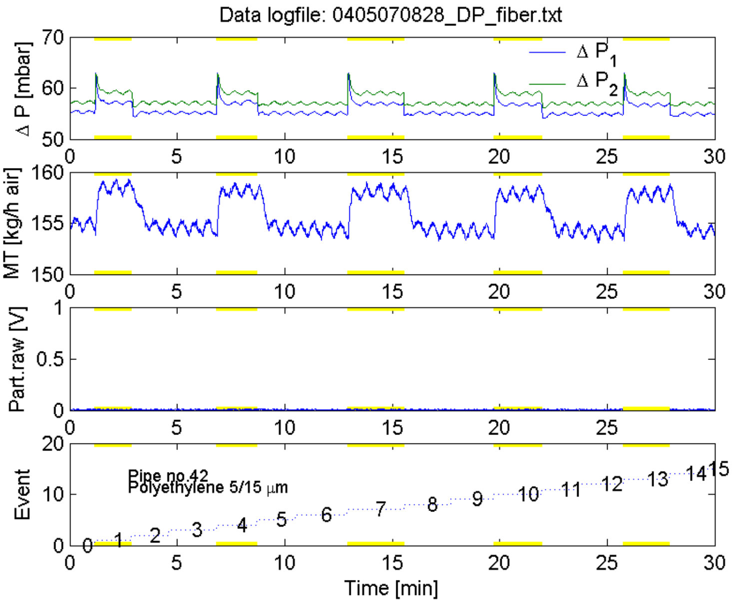


Figure B.3.1: Injection of polyethylene: LOG: 0405070828.

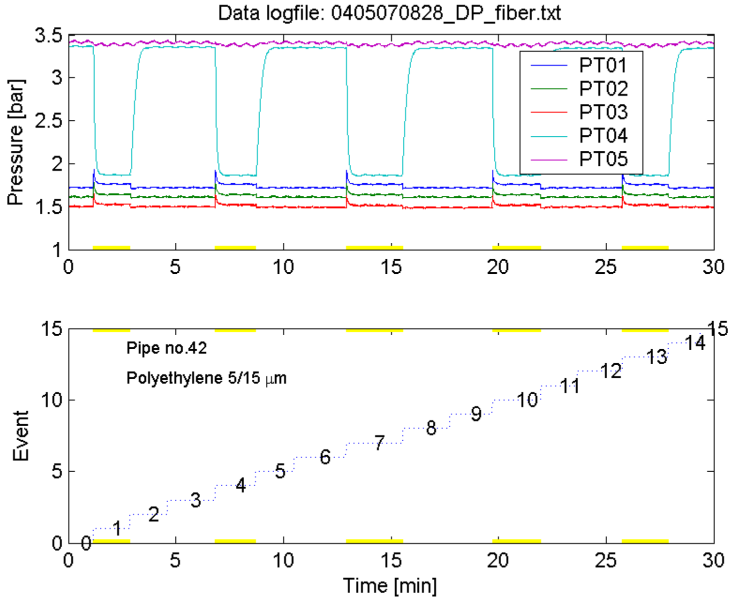


Figure B.3.2: Pressure in pipe- LOG: 0405070828.

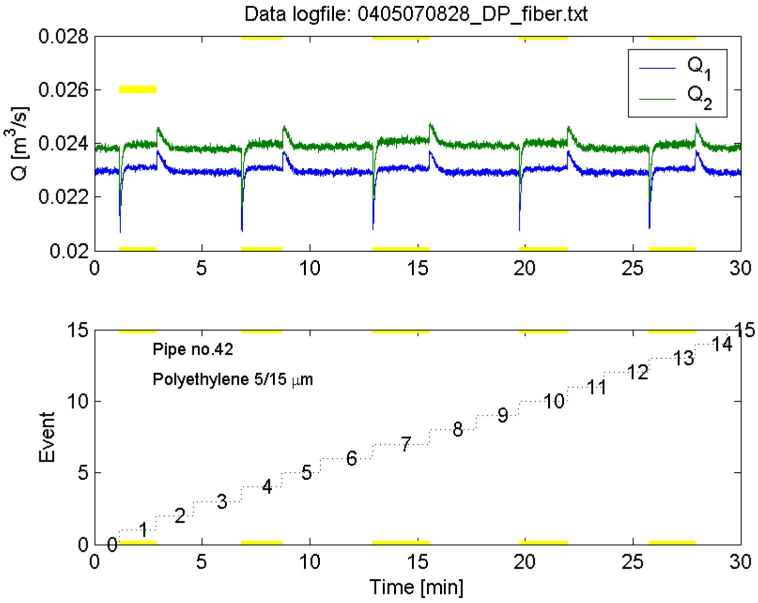


Figure B.3.3: Average volumetric flow rate at test section.

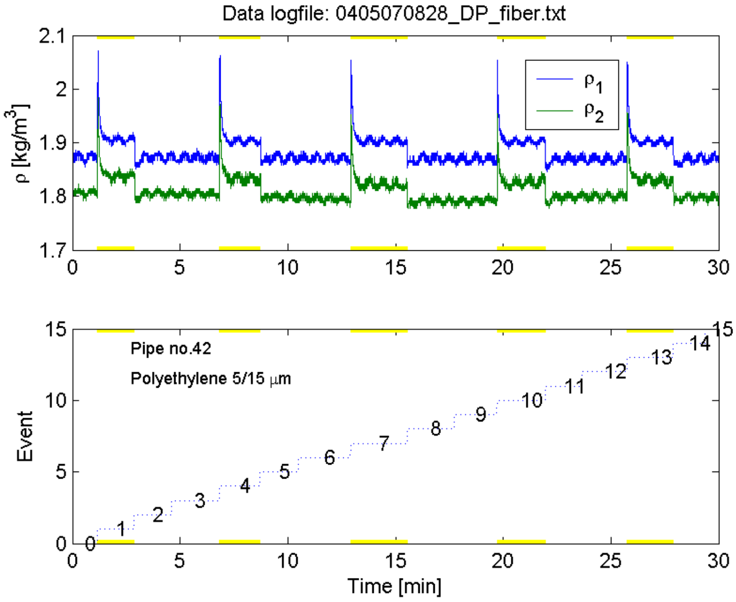


Figure B.3.4: Average density of air in the pipe at test section.

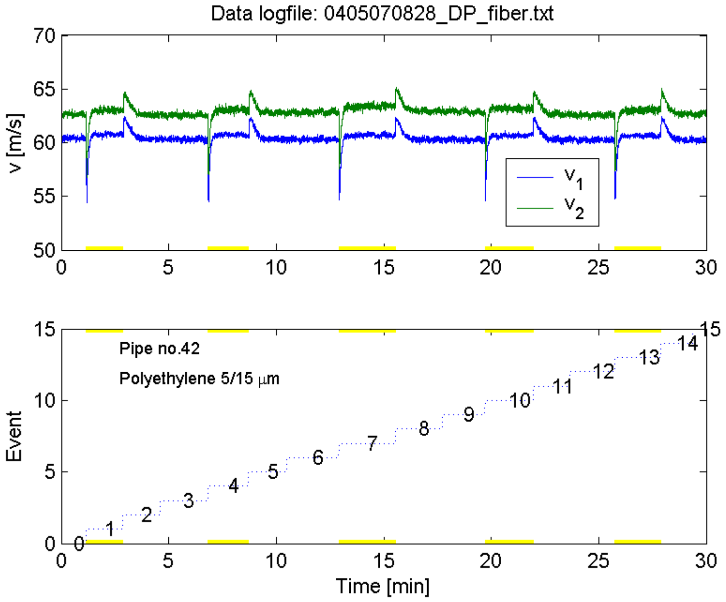


Figure B.3.5: Average air velocity at test section.

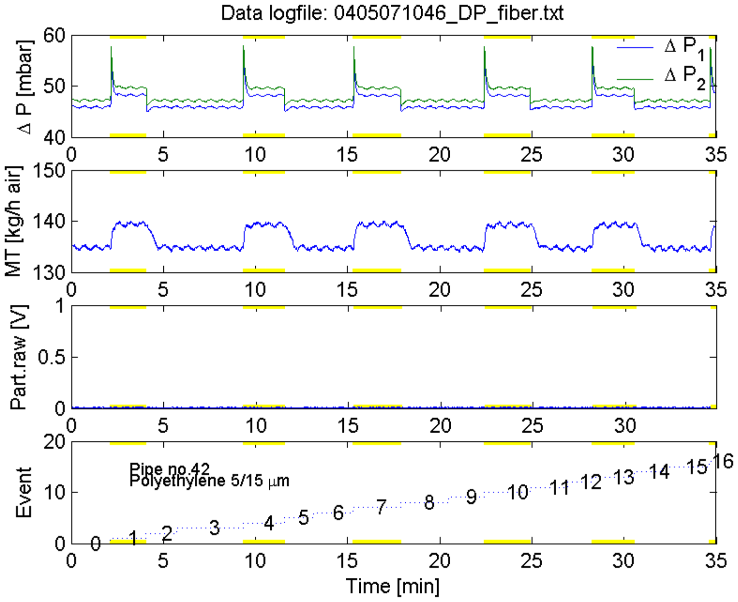


Figure B.3.6: Injection of polyethylene: LOG: 0405071046.

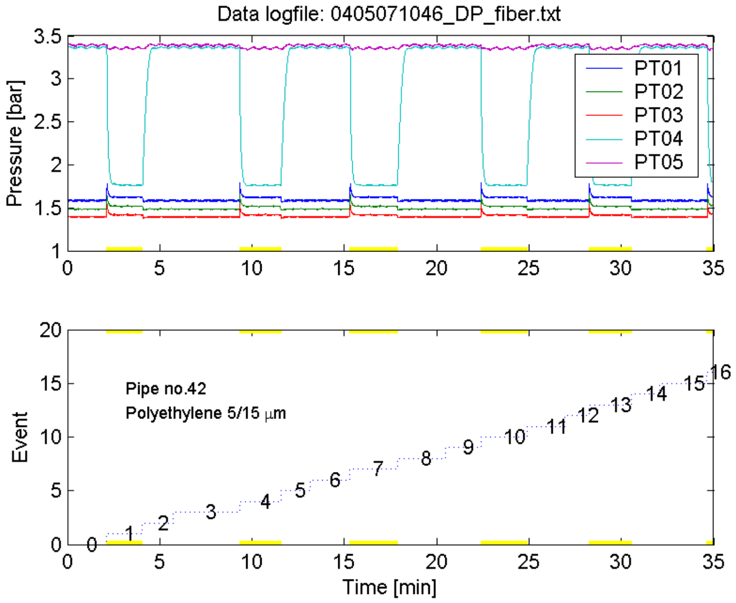


Figure B.3.7: Pressure in pipe- LOG: 0405071046.

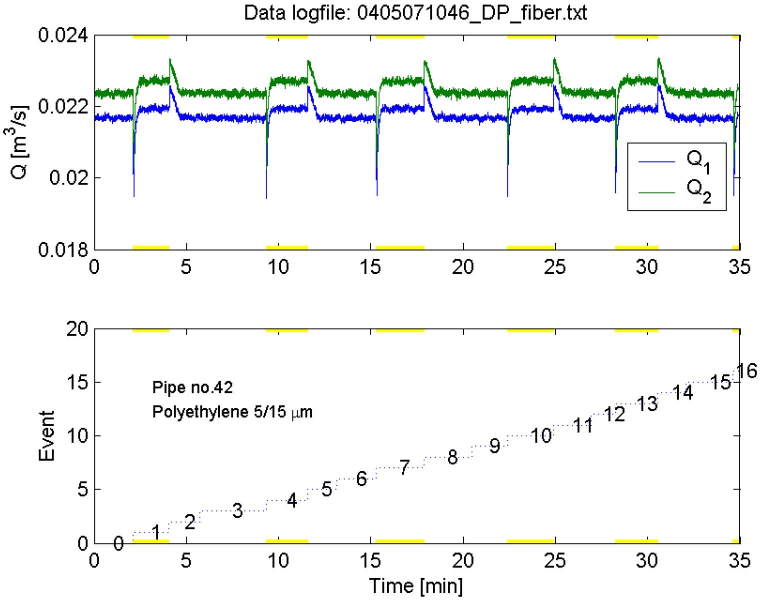


Figure B.3.8: Average volumetric flow rate at test section.

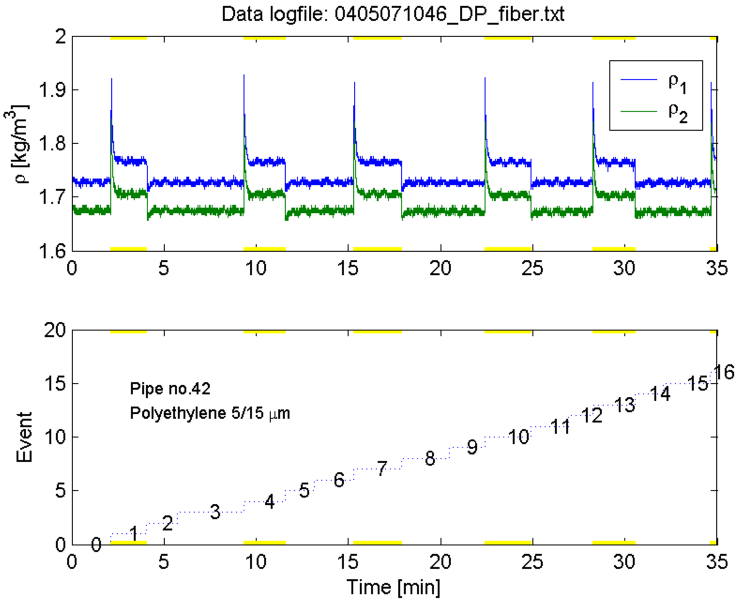


Figure B.3.9: Average density of air in the pipe at test section.

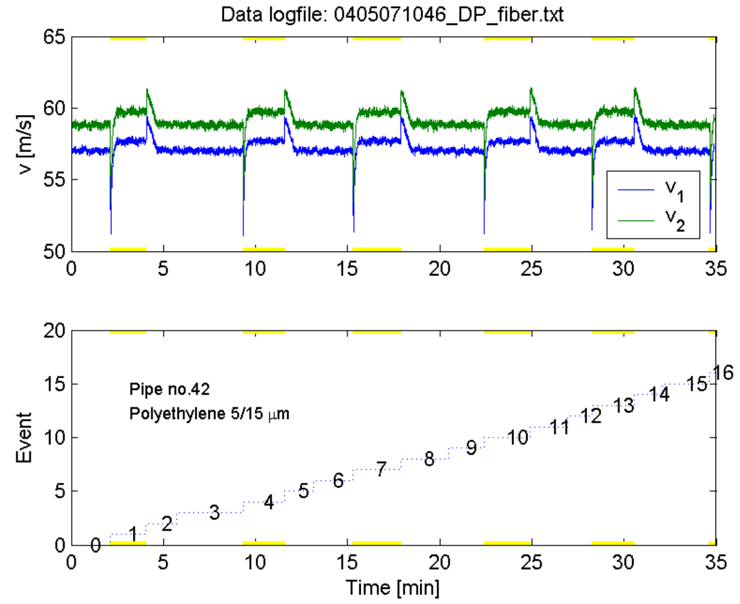


Figure B.3.10: Average air velocity at test section.

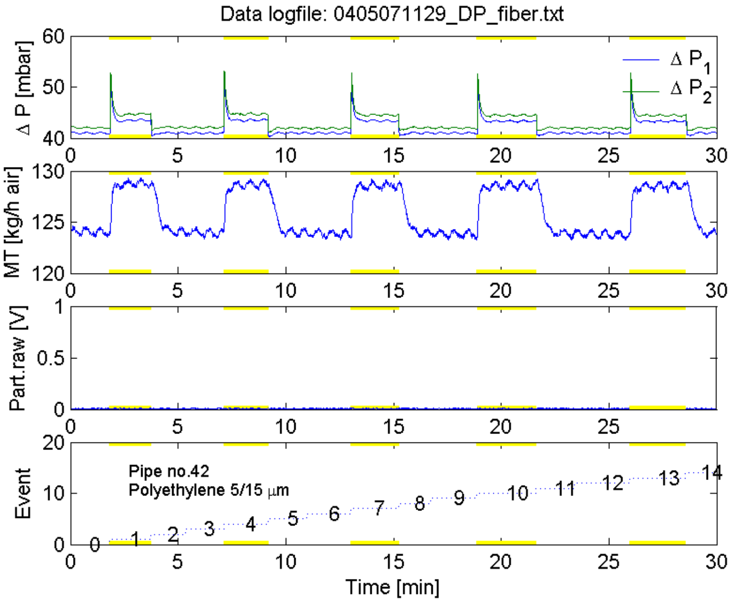


Figure B.3.11: Injection of polyethylene: LOG: 0405071129.

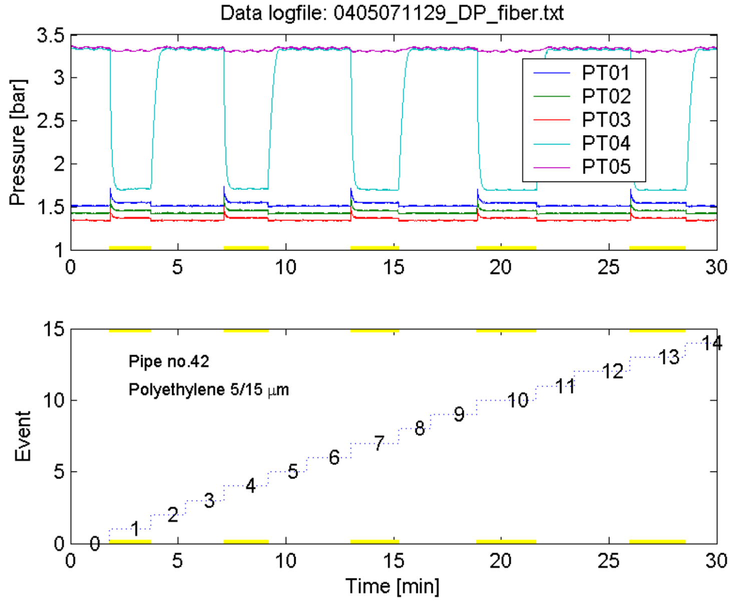


Figure B.3.12: Pressure in pipe- LOG: 0405071129.

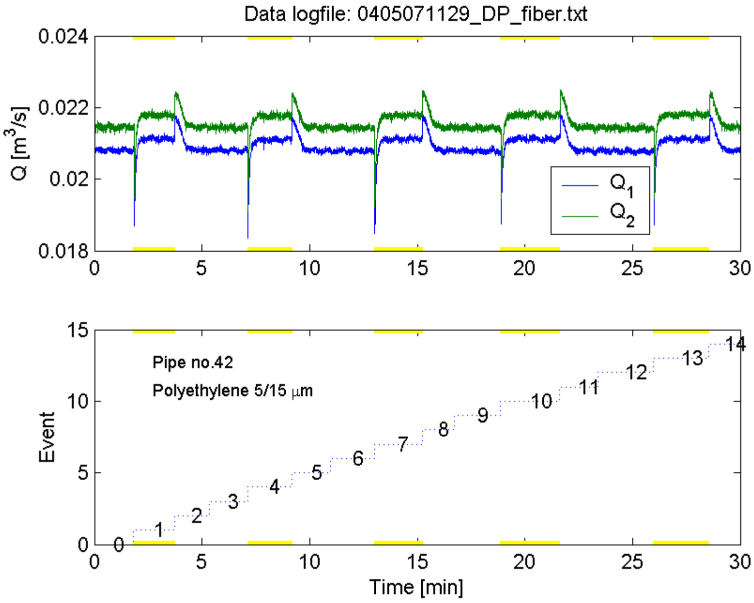


Figure B.3.13: Average volumetric flow rate at test section.

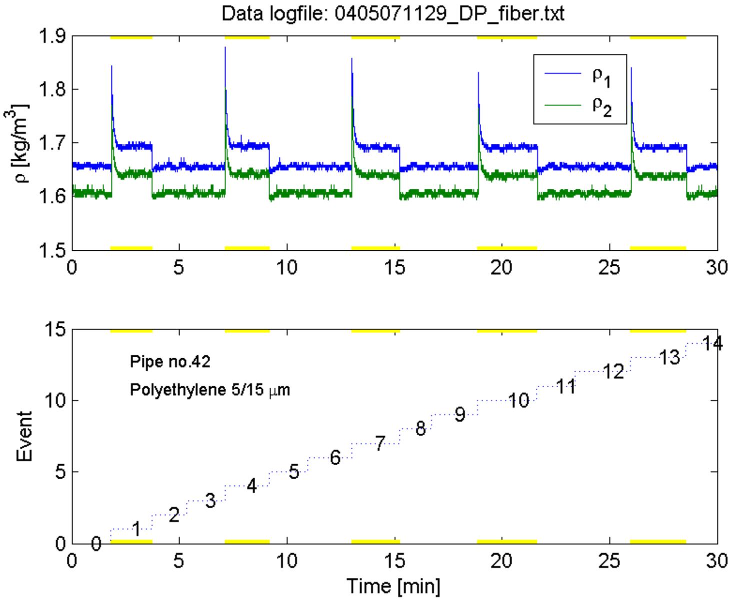


Figure B.3.14: Average density of air in the pipe at test section.

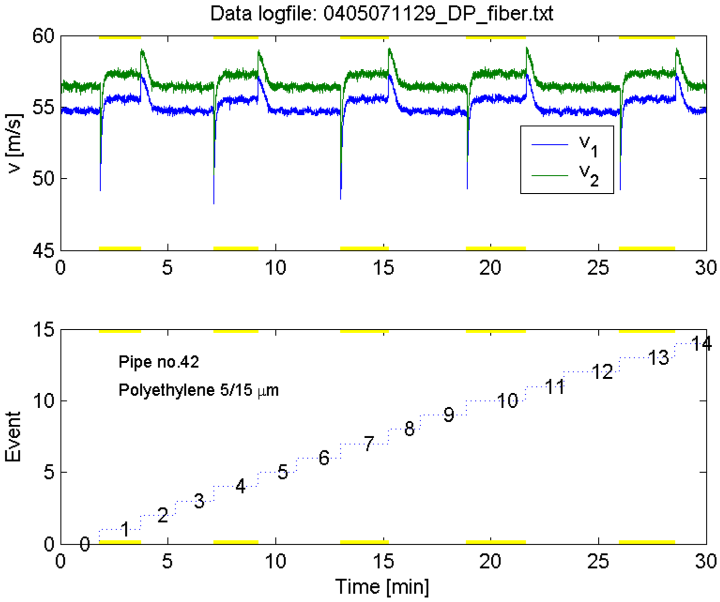


Figure B.3.15: Average air velocity at test section.

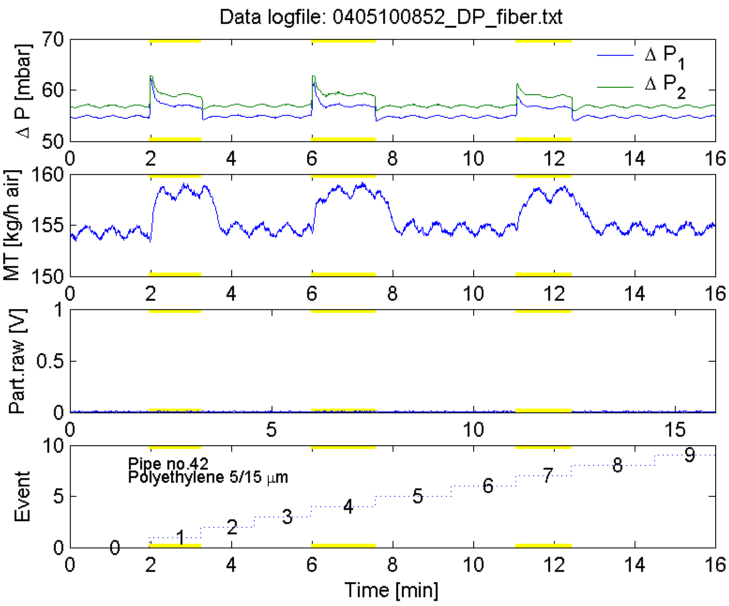


Figure B.3.16: Injection of polyethylene: LOG: 0405100852.

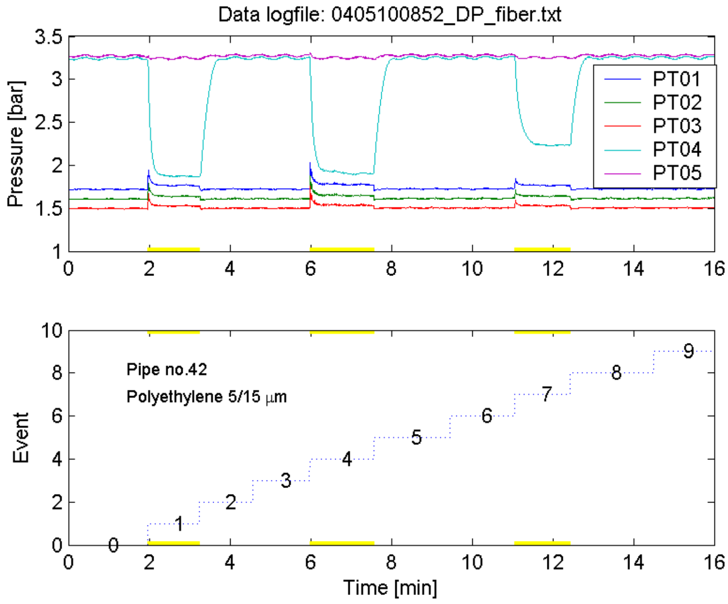


Figure B.3.17: Pressure in pipe- LOG: 0405100852.

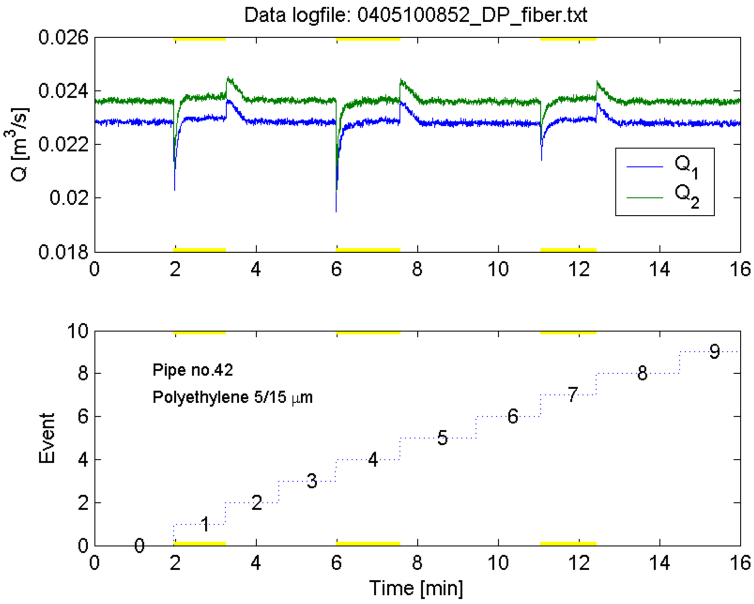


Figure B.3.18: Average volumetric flow rate at test section.

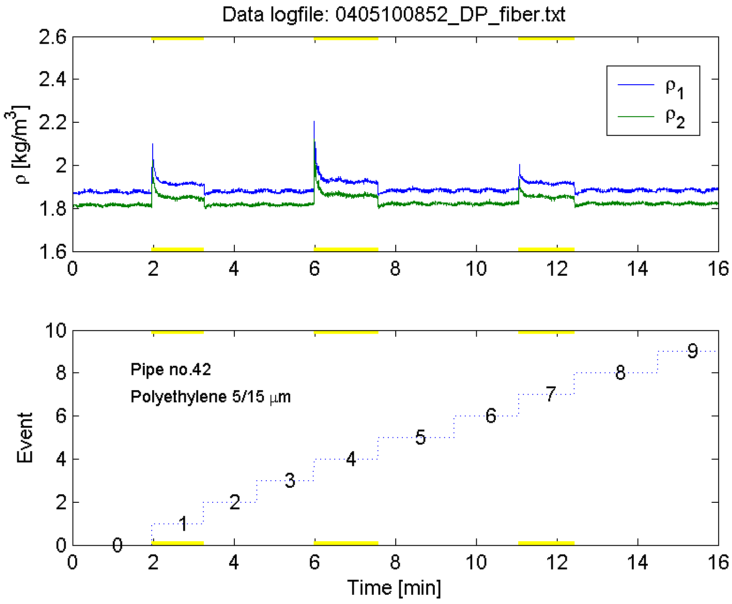


Figure B.3.19: Average density of air in the pipe at test section.

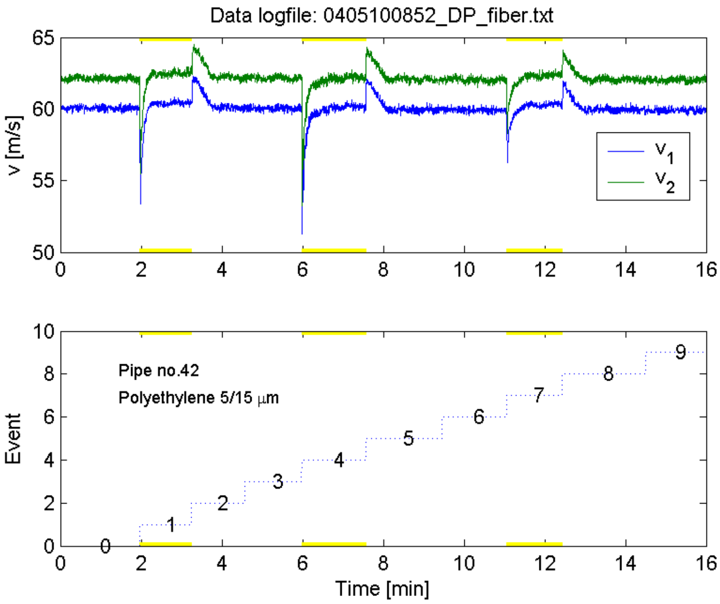


Figure B.3.20: Average air velocity at test section.

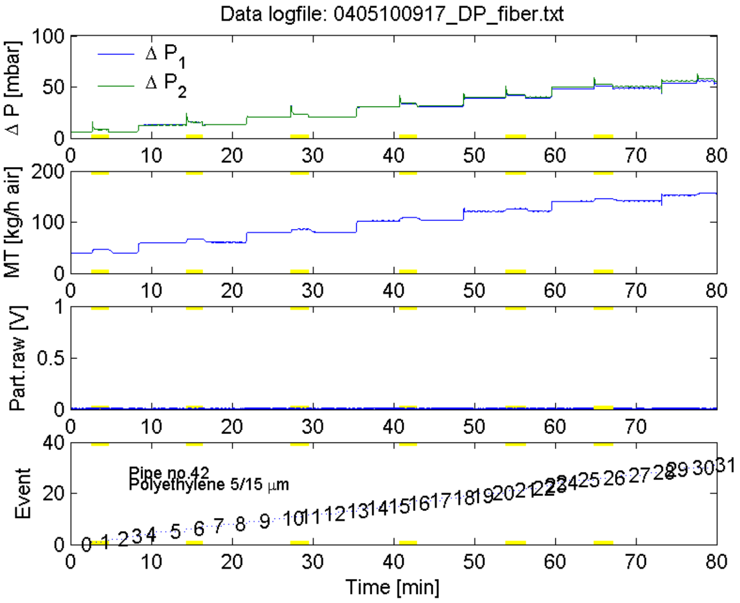


Figure B.3.21: Injection of polyethylene: LOG: 0405100917.

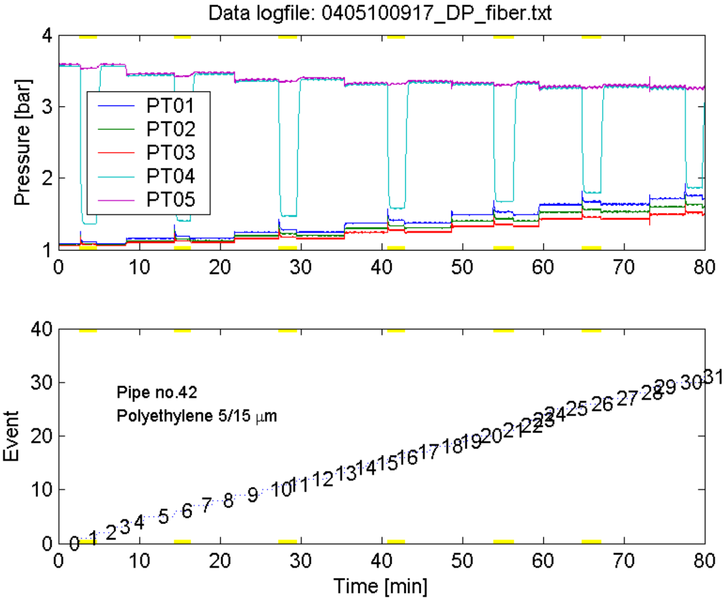


Figure B.3.22: Pressure in pipe- LOG: 0405100917.

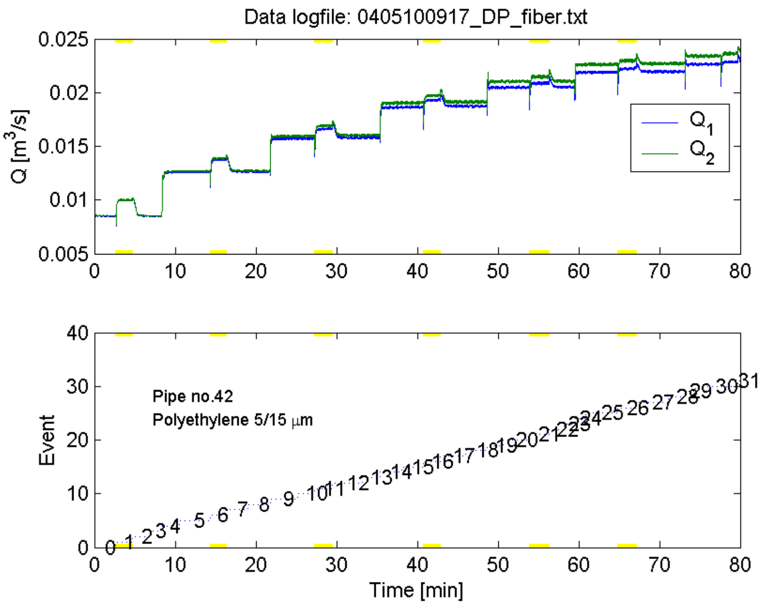


Figure B.3.23: Average volumetric flow rate at test section.

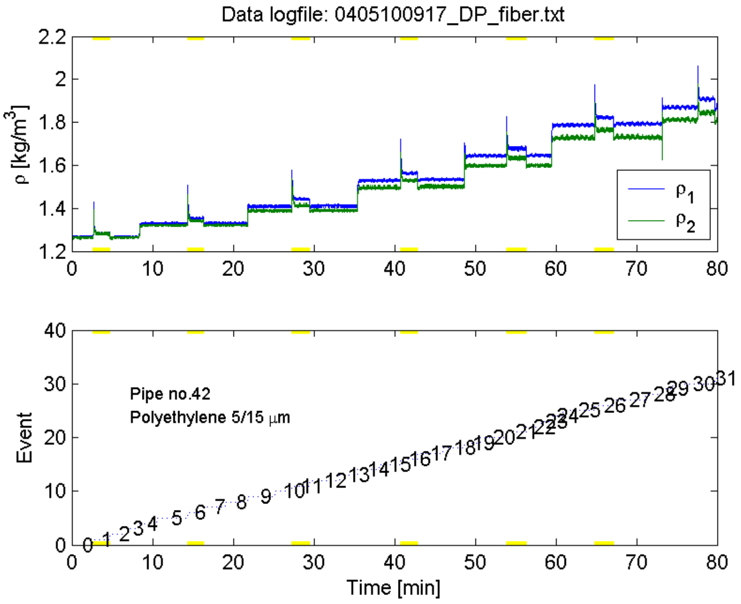


Figure B.3.24: Average density of air in the pipe at test section.

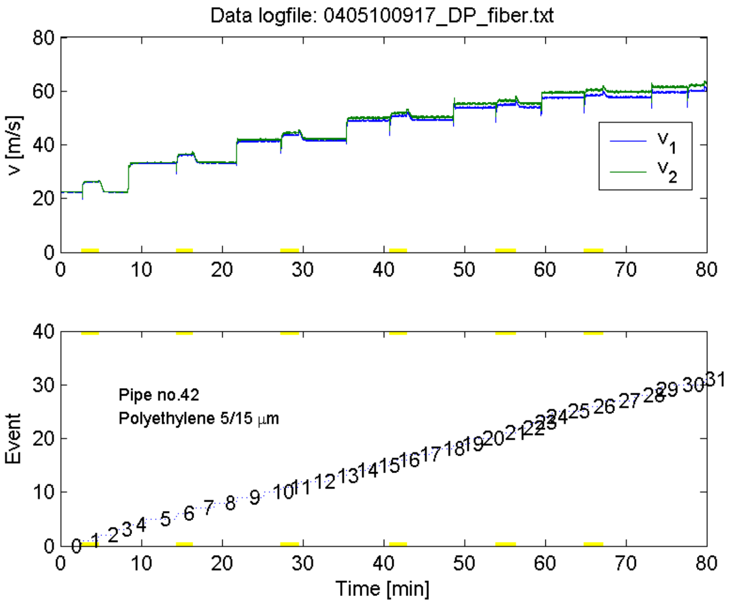


Figure B.3.25: Average air velocity at test section.

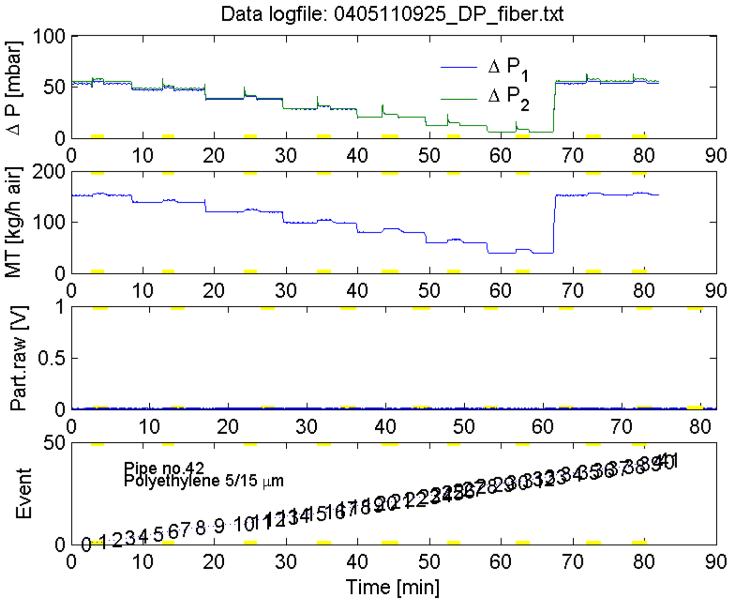


Figure B.3.26: Injection of polyethylene: LOG: 0405110925.

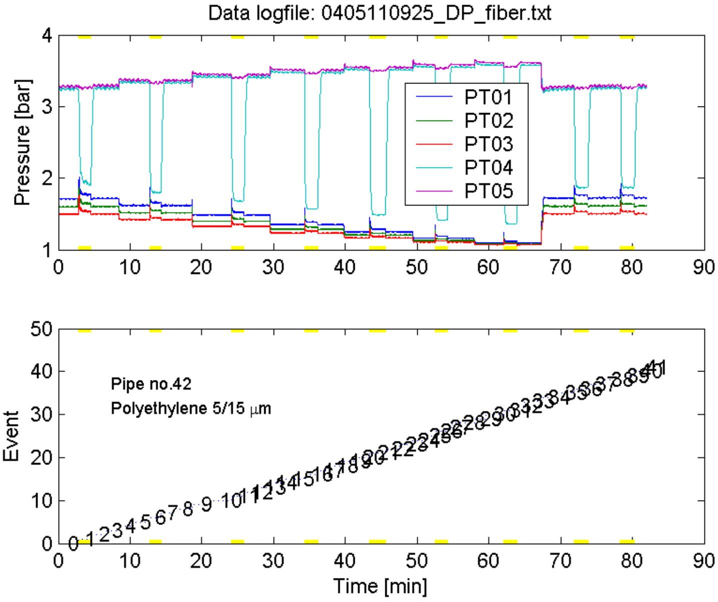


Figure B.3.27: Pressure in pipe- LOG: 0405110925.

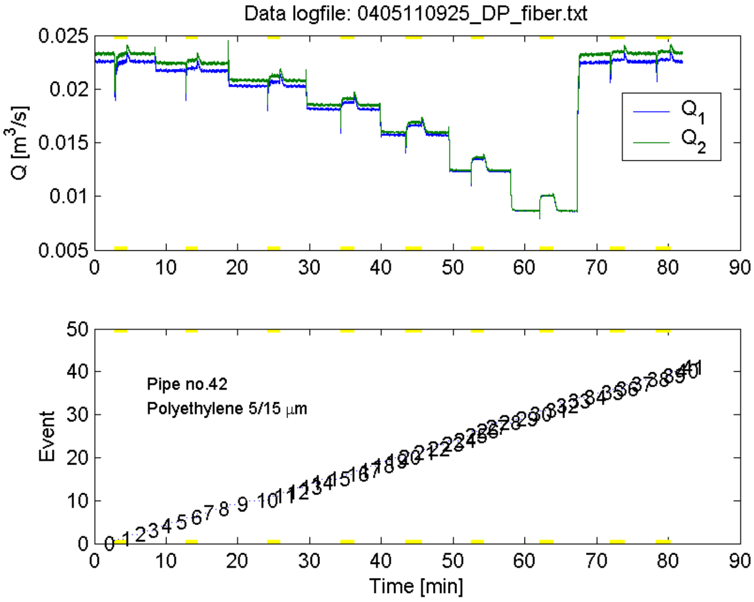


Figure B.3.28: Average volumetric flow rate at test section.

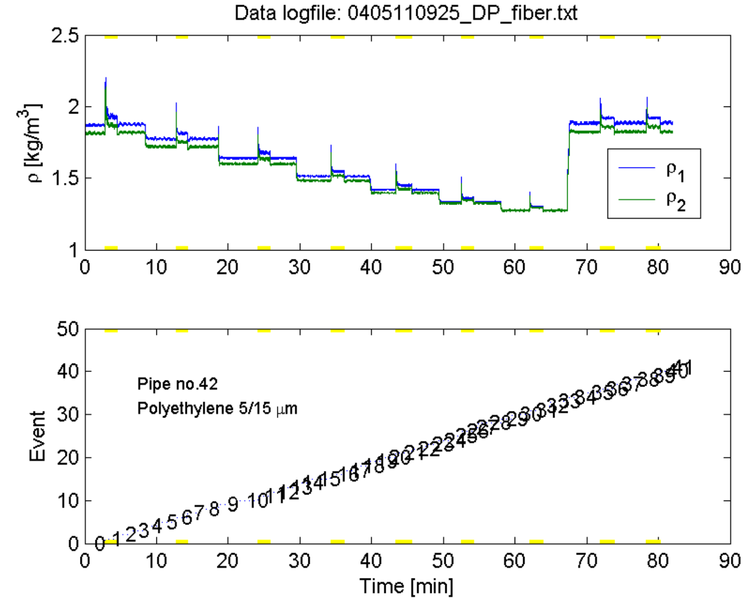


Figure B.3.29: Average density of air in the pipe at test section.

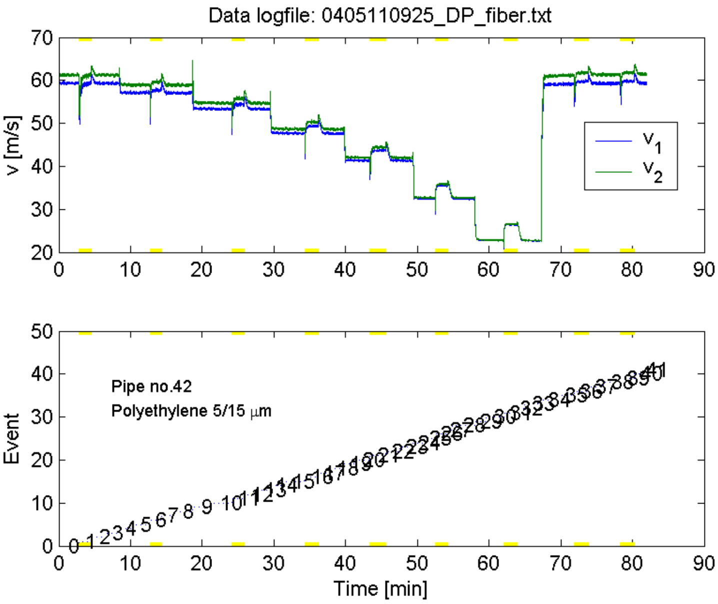


Figure B.3.30: Average air velocity at test section.

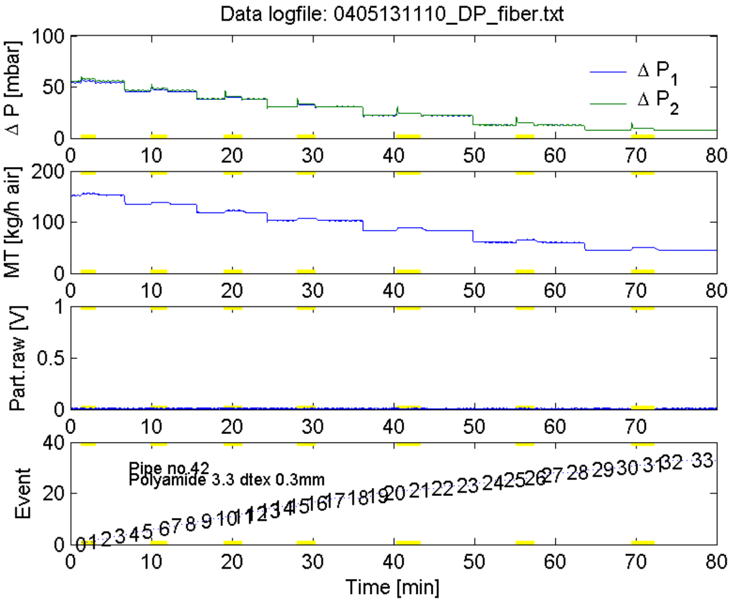


Figure B.3.31: Injection of polyamide: LOG: 0405131110.

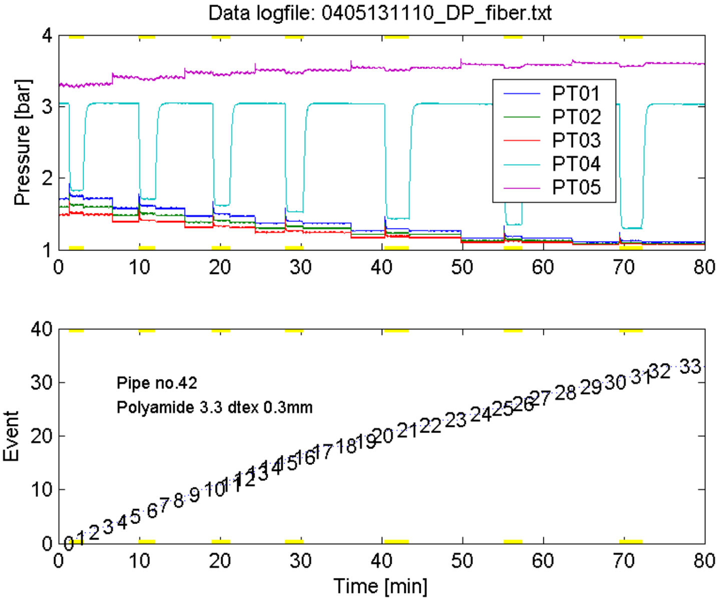


Figure B.3.32: Pressure in pipe- LOG: 0405131110.

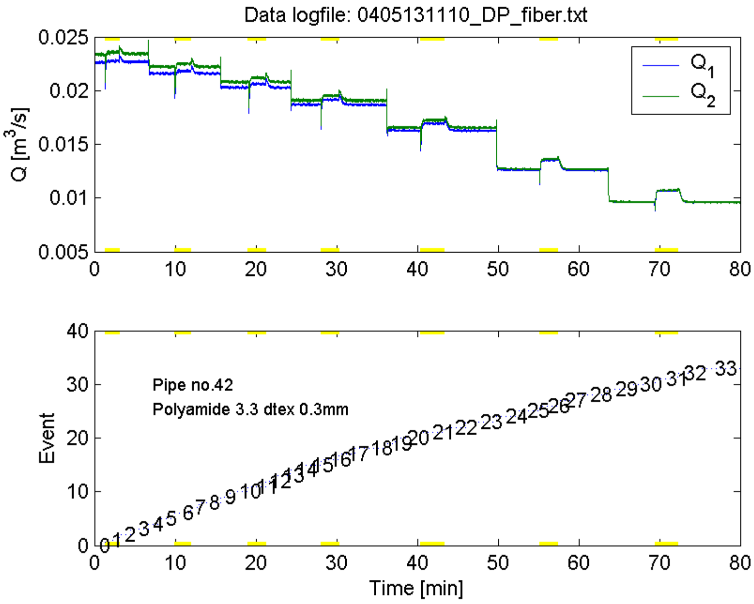


Figure B.3.33: Average volumetric flow rate at test section.

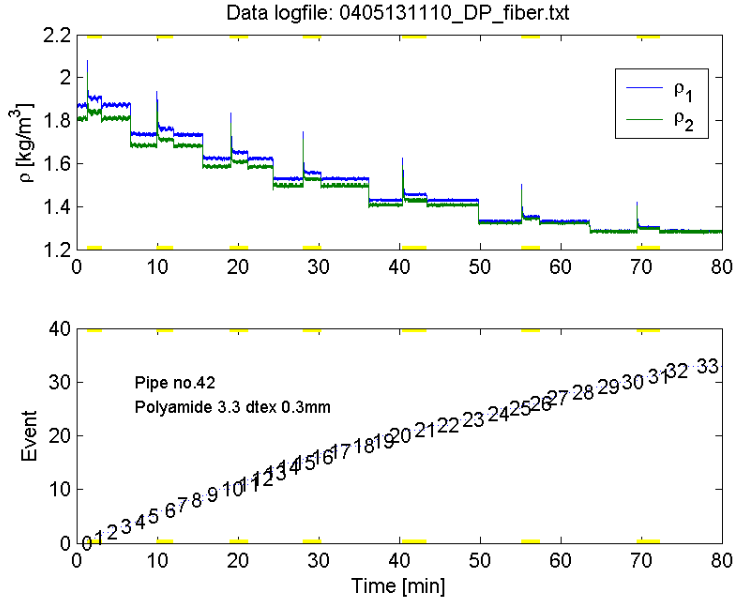


Figure B.3.34: Average density of air in the pipe at test section.

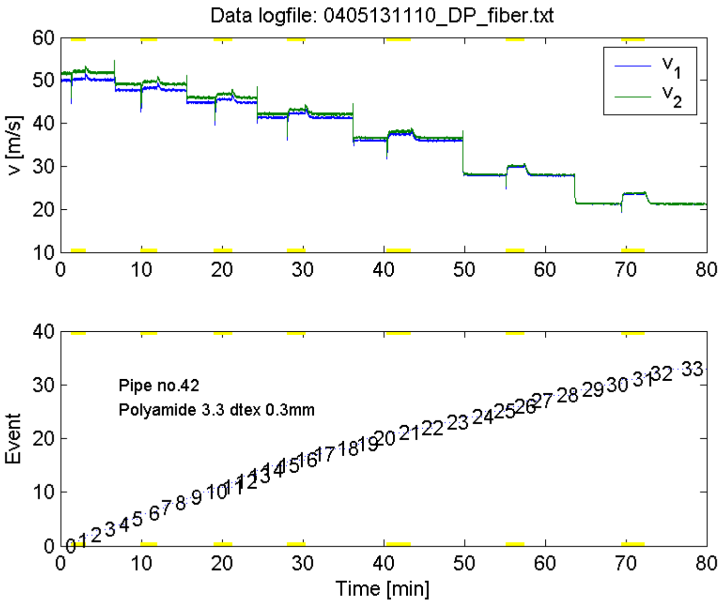


Figure B.3.35: Average air velocity at test section.

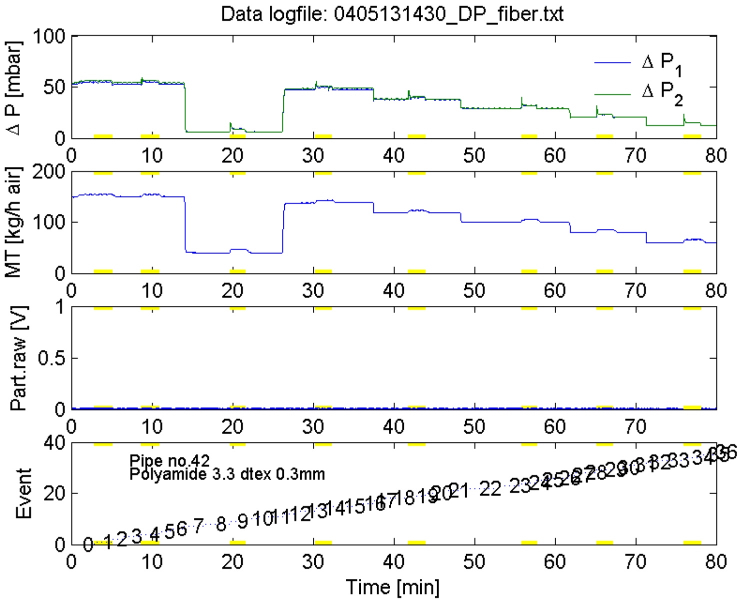


Figure B.3.36: Injection of polyamide: LOG: 0405131430.

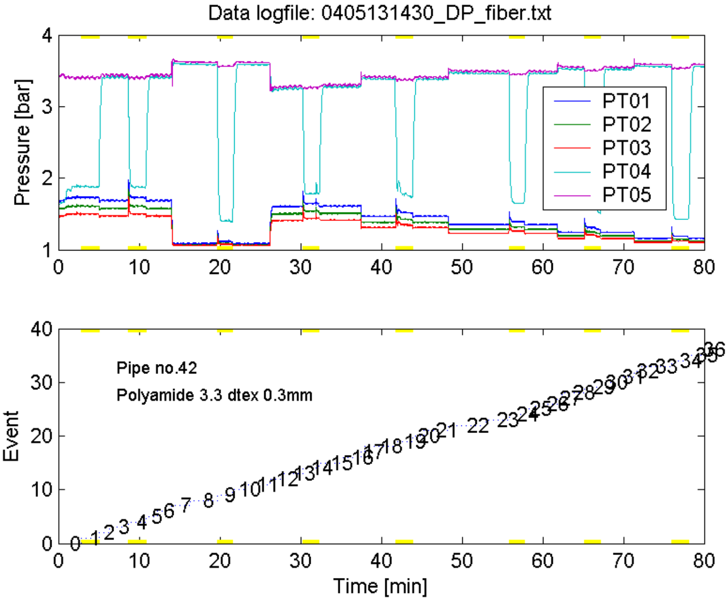


Figure B.3.37: Pressure in pipe- LOG: 0405131430.

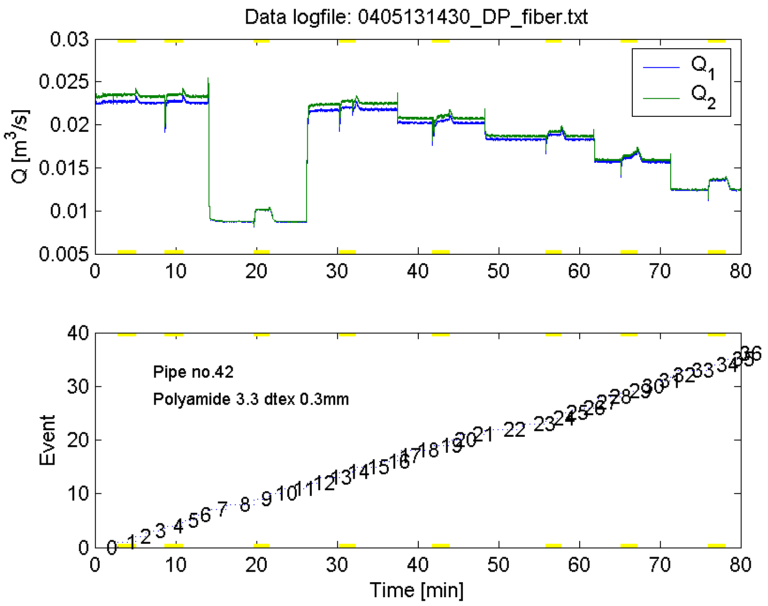


Figure B.3.38: Average volumetric flow rate at test section.

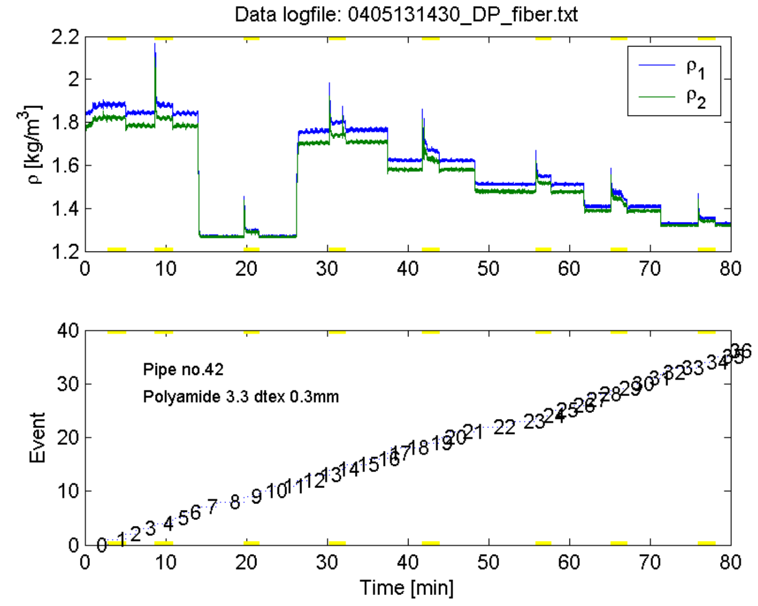


Figure B.3.39: Average density of air in the pipe at test section.

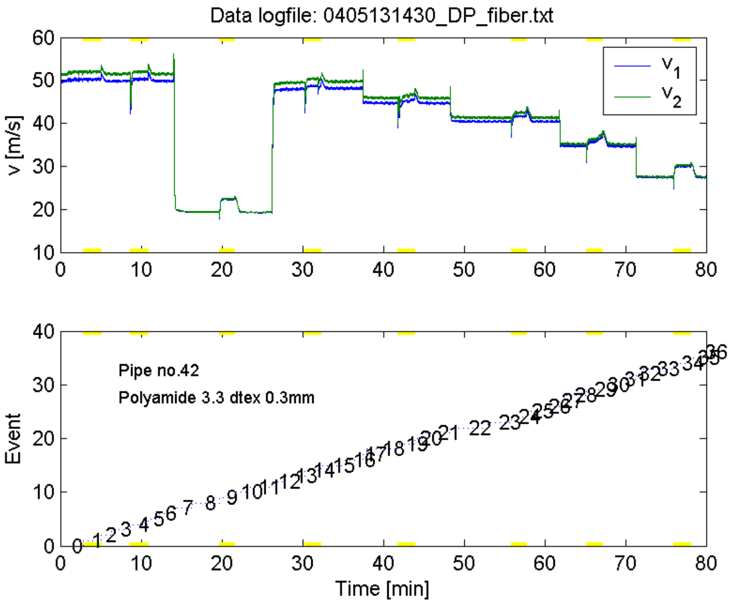


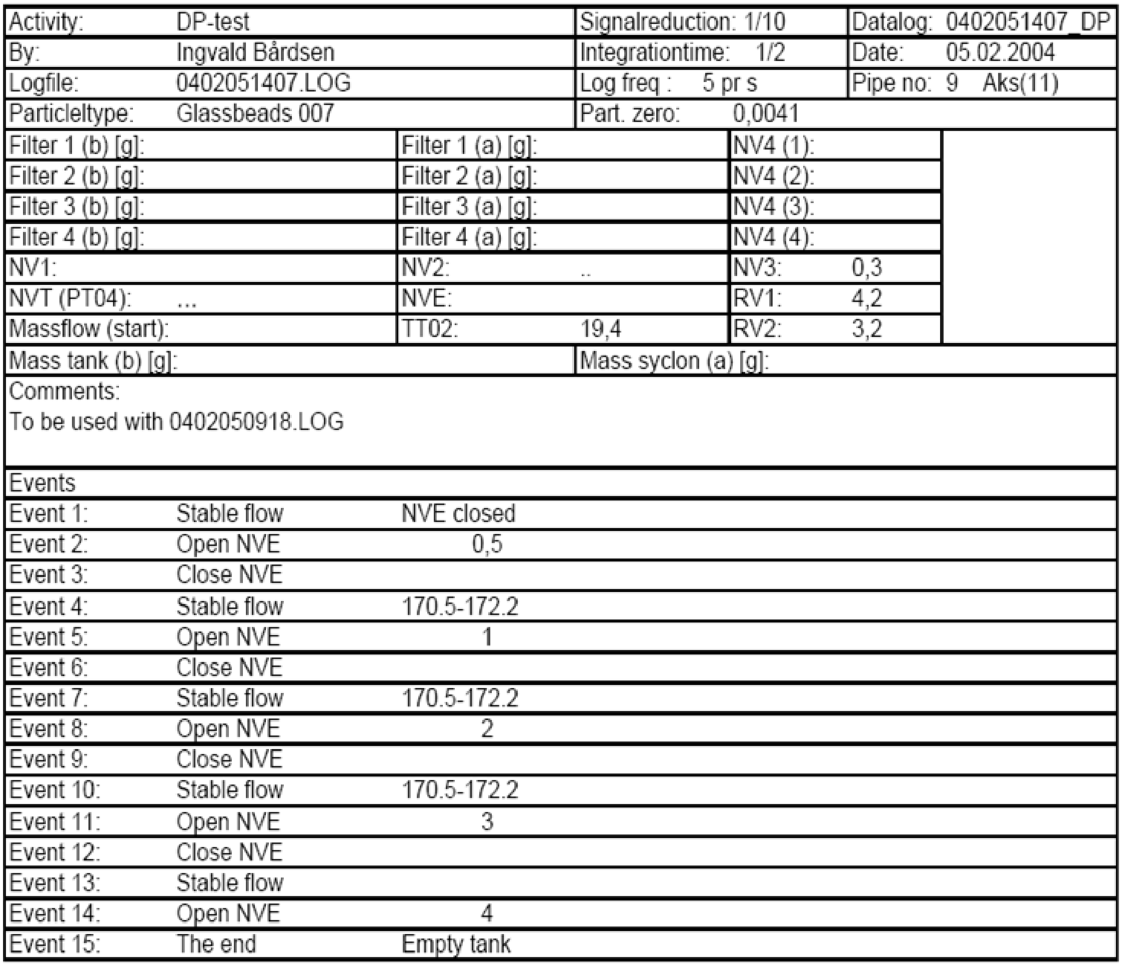
Figure B.3.40: Average air velocity at test section.

# Appendix C

# Lab diary

## C.1 Glass beads

## C.2 Experimental data for polyamide



| | | | |
|---|---|---|---|
| Activity: | DP-test | Signalreduction: 1/10 | Datalog: 0402051407_DP |
| By: | Ingvald Bårdsen | Integrationtime: 1/2 | Date: 05.02.2004 |
| Logfile: | 0402051407.LOG | Log freq : 5 pr s | Pipe no: 9 Aks(11) |
| Particleltype: | Glassbeads 007 | Part. zero: 0,0041 | |

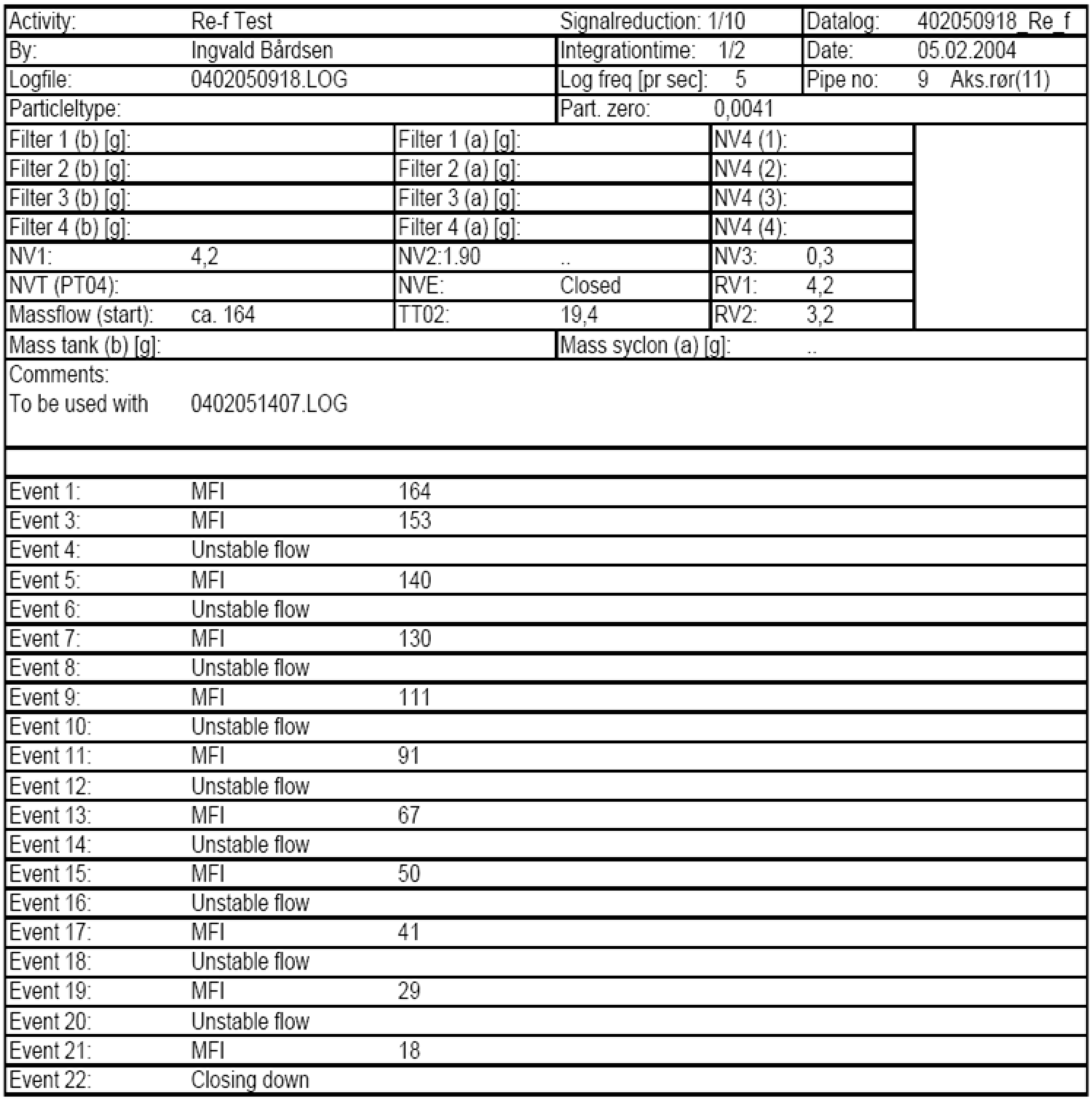
| | | |
|---|---|---|
| Filter 1 (b) [g]: | Filter 1 (a) [g]: | NV4 (1): |
| Filter 2 (b) [g]: | Filter 2 (a) [g]: | NV4 (2): |
| Filter 3 (b) [g]: | Filter 3 (a) [g]: | NV4 (3): |
| Filter 4 (b) [g]: | Filter 4 (a) [g]: | NV4 (4): |
| NV1: | NV2: .. | NV3: 0,3 |
| NVT (PT04): ... | NVE: | RV1: 4,2 |
| Massflow (start): | TT02: 19,4 | RV2: 3,2 |

| | |
|---|---|
| Mass tank (b) [g]: | Mass syclon (a) [g]: |

Comments:
To be used with 0402050918.LOG

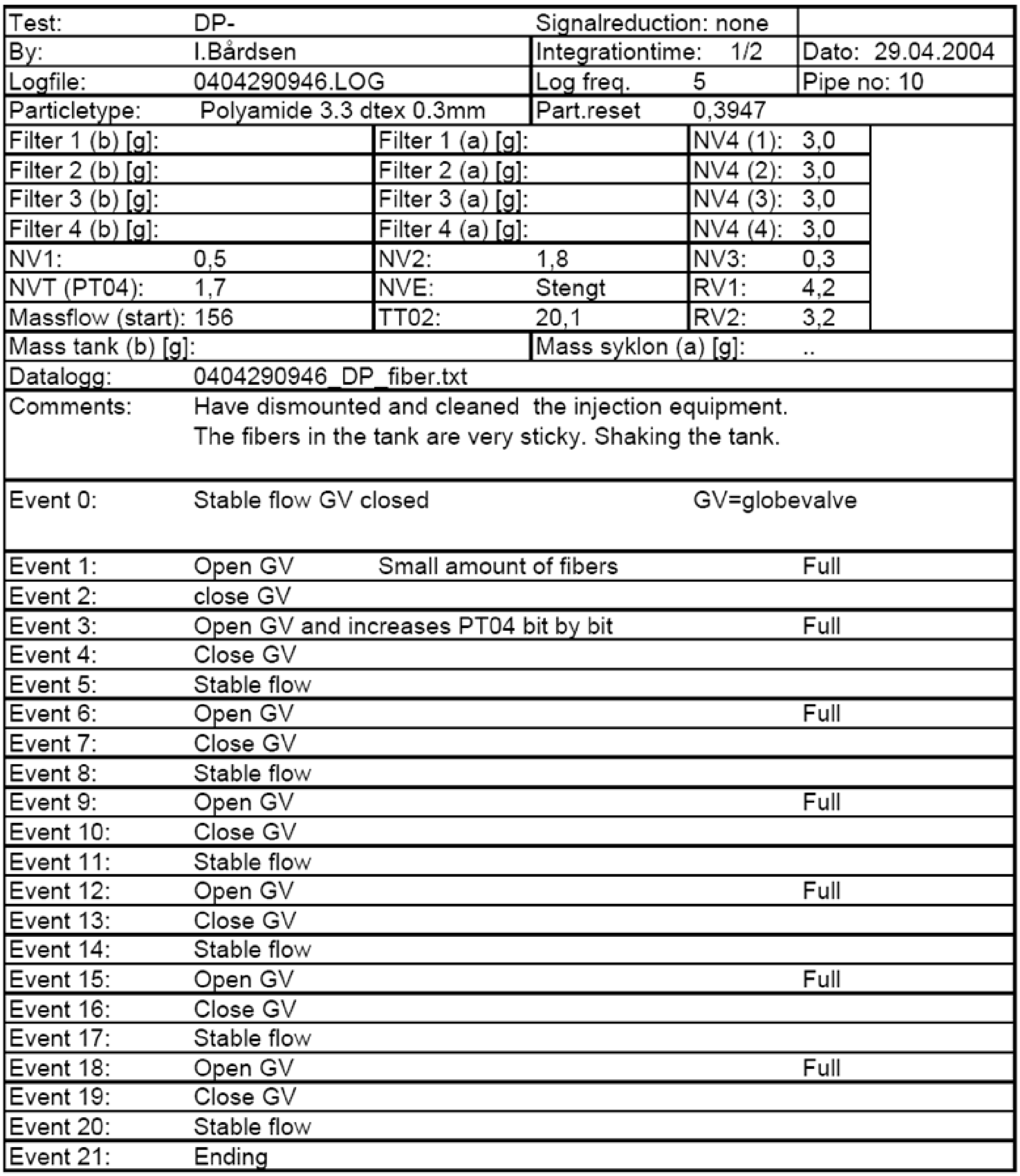
| Events | | |
|---|---|---|
| Event 1: | Stable flow | NVE closed |
| Event 2: | Open NVE | 0,5 |
| Event 3: | Close NVE | |
| Event 4: | Stable flow | 170.5-172.2 |
| Event 5: | Open NVE | 1 |
| Event 6: | Close NVE | |
| Event 7: | Stable flow | 170.5-172.2 |
| Event 8: | Open NVE | 2 |
| Event 9: | Close NVE | |
| Event 10: | Stable flow | 170.5-172.2 |
| Event 11: | Open NVE | 3 |
| Event 12: | Close NVE | |
| Event 13: | Stable flow | |
| Event 14: | Open NVE | 4 |
| Event 15: | The end | Empty tank |

Figure C.1.1: Lab diary $\Delta P$ experiment. Glassbeads 007.



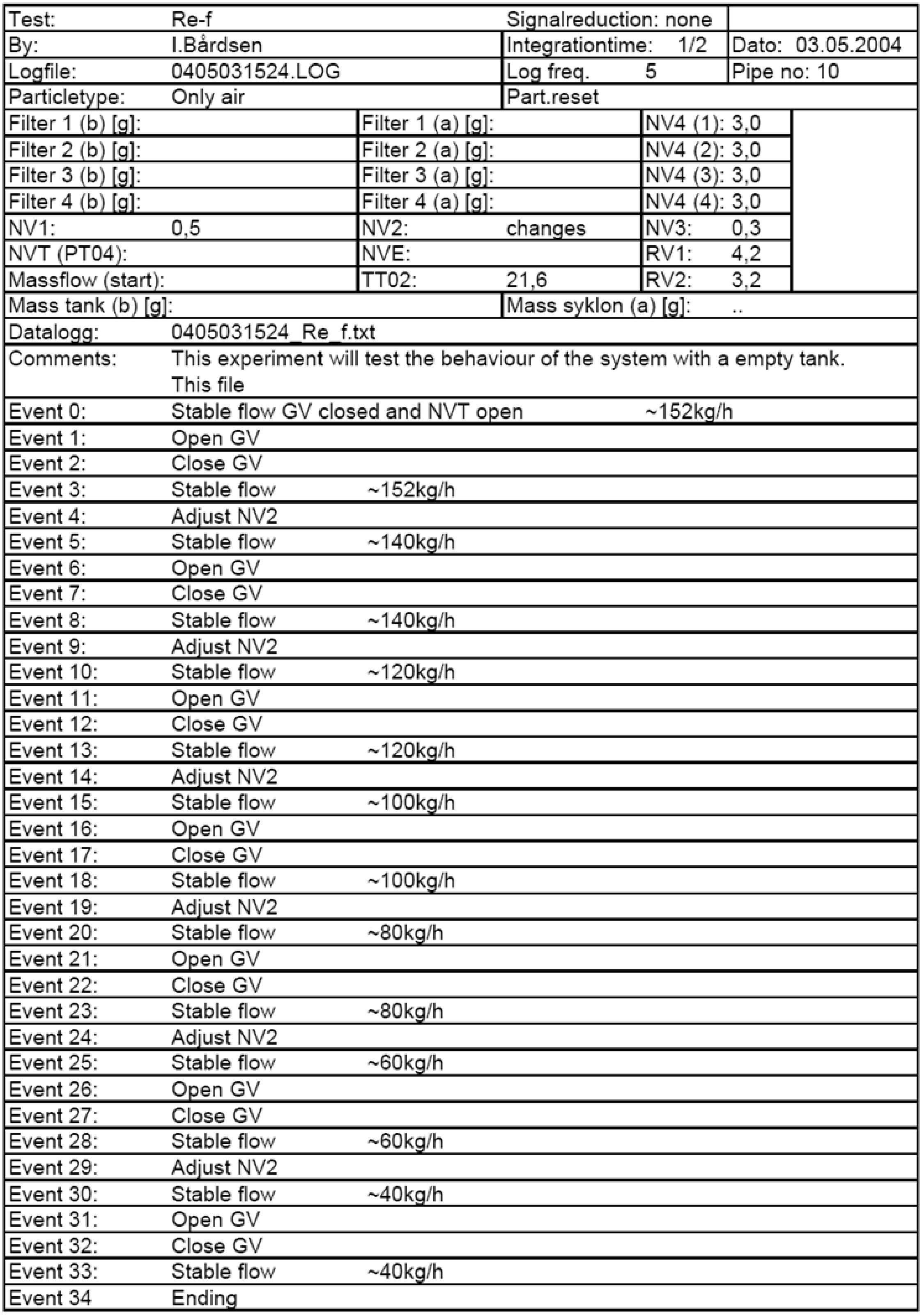
| | | | | | |
|---|---|---|---|---|---|
| Activity: | Re-f Test | Signalreduction: | 1/10 | Datalog: | 402050918_Re_f |
| By: | Ingvald Bårdsen | Integrationtime: | 1/2 | Date: | 05.02.2004 |
| Logfile: | 0402050918.LOG | Log freq [pr sec]: | 5 | Pipe no: | 9 Aks.rør(11) |
| Particleltype: | | Part. zero: | 0,0041 | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | |
| NV1: | 4,2 | NV2:1.90 | .. | NV3: | 0,3 |
| NVT (PT04): | | NVE: | Closed | RV1: | 4,2 |
| Massflow (start): | ca. 164 | TT02: | 19,4 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syclon (a) [g]: | .. | | |
| Comments: | | | | | |
| To be used with | 0402051407.LOG | | | | |
| | | | | | |
| Event 1: | MFI | 164 | | | |
| Event 3: | MFI | 153 | | | |
| Event 4: | Unstable flow | | | | |
| Event 5: | MFI | 140 | | | |
| Event 6: | Unstable flow | | | | |
| Event 7: | MFI | 130 | | | |
| Event 8: | Unstable flow | | | | |
| Event 9: | MFI | 111 | | | |
| Event 10: | Unstable flow | | | | |
| Event 11: | MFI | 91 | | | |
| Event 12: | Unstable flow | | | | |
| Event 13: | MFI | 67 | | | |
| Event 14: | Unstable flow | | | | |
| Event 15: | MFI | 50 | | | |
| Event 16: | Unstable flow | | | | |
| Event 17: | MFI | 41 | | | |
| Event 18: | Unstable flow | | | | |
| Event 19: | MFI | 29 | | | |
| Event 20: | Unstable flow | | | | |
| Event 21: | MFI | 18 | | | |
| Event 22: | Closing down | | | | |

Figure C.1.2: Lab diary Re-f experiment.



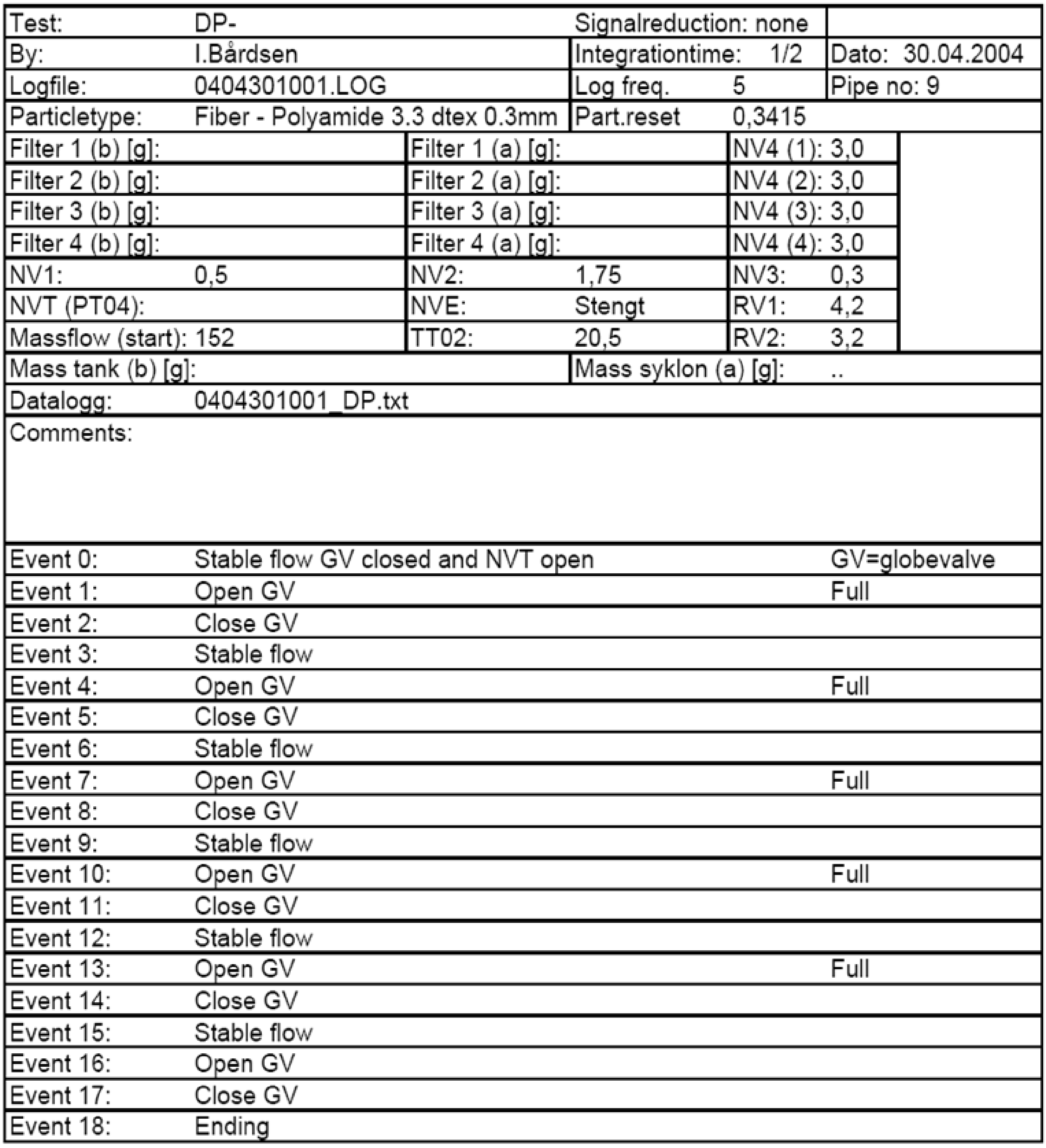
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- | Signalreduction: none | | | |
| By: | I.Bårdsen | Integrationtime: | 1/2 | Dato: 29.04.2004 | |
| Logfile: | 0404290946.LOG | Log freq. | 5 | Pipe no: 10 | |
| Particletype: | Polyamide 3.3 dtex 0.3mm | Part.reset | 0,3947 | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,8 | NV3: | 0,3 |
| NVT (PT04): | 1,7 | NVE: | Stengt | RV1: | 4,2 |
| Massflow (start): | 156 | TT02: | 20,1 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | 0404290946_DP_fiber.txt | | | | |
| Comments: | Have dismounted and cleaned the injection equipment.<br>The fibers in the tank are very sticky. Shaking the tank. | | | | |
| Event 0: | Stable flow GV closed | | | GV=globevalve | |
| Event 1: | Open GV | Small amount of fibers | | | Full |
| Event 2: | close GV | | | | |
| Event 3: | Open GV and increases PT04 bit by bit | | | | Full |
| Event 4: | Close GV | | | | |
| Event 5: | Stable flow | | | | |
| Event 6: | Open GV | | | | Full |
| Event 7: | Close GV | | | | |
| Event 8: | Stable flow | | | | |
| Event 9: | Open GV | | | | Full |
| Event 10: | Close GV | | | | |
| Event 11: | Stable flow | | | | |
| Event 12: | Open GV | | | | Full |
| Event 13: | Close GV | | | | |
| Event 14: | Stable flow | | | | |
| Event 15: | Open GV | | | | Full |
| Event 16: | Close GV | | | | |
| Event 17: | Stable flow | | | | |
| Event 18: | Open GV | | | | Full |
| Event 19: | Close GV | | | | |
| Event 20: | Stable flow | | | | |
| Event 21: | Ending | | | | |

Figure C.2.1: Lab diary $\Delta P$ experiment. Polyamide 0.3mm.



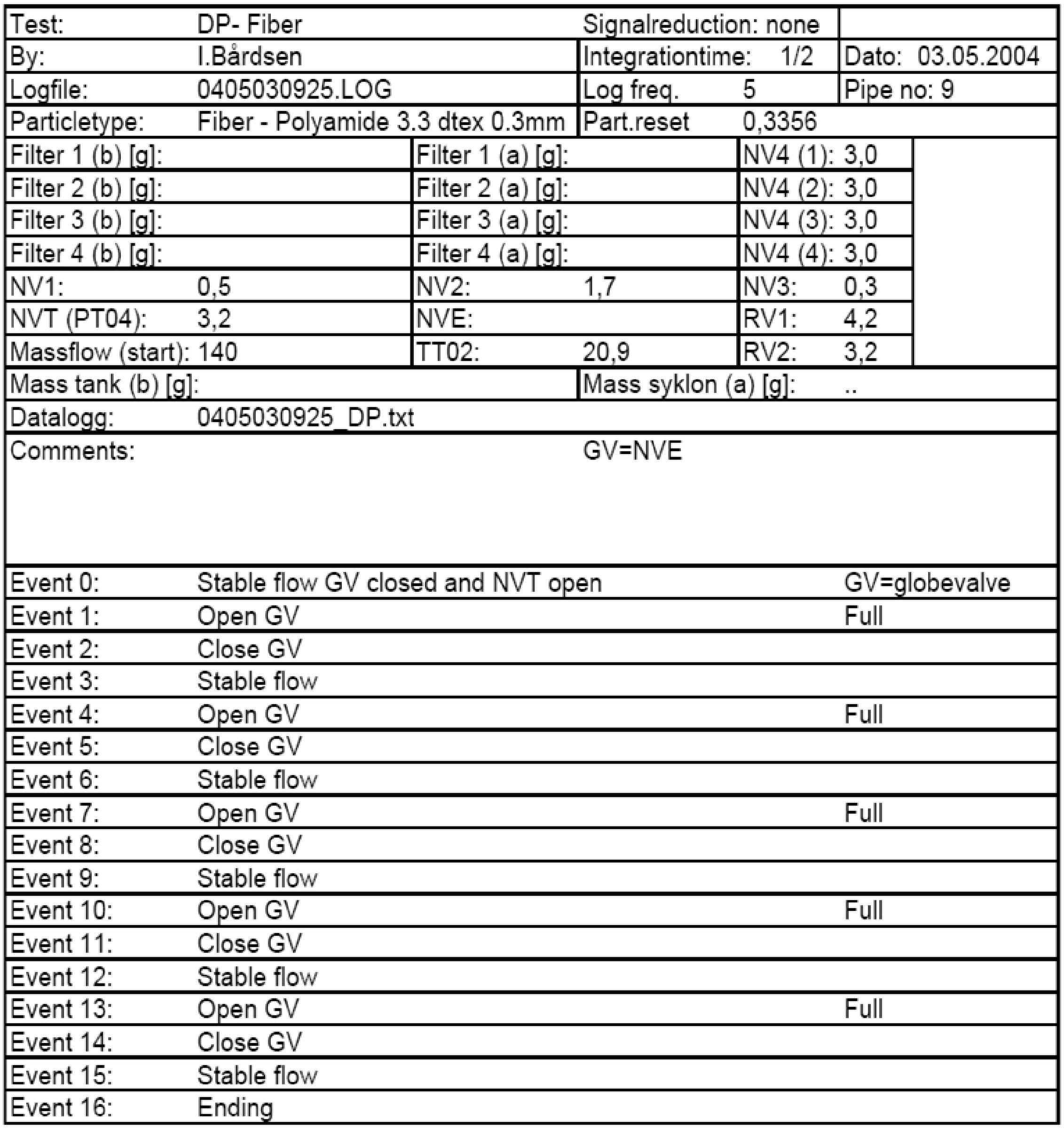
| | | | | | |
|---|---|---|---|---|---|
| Test: | Re-f | Signalreduction: none | | | |
| By: | I.Bårdsen | Integrationtime: | 1/2 | Dato: 03.05.2004 | |
| Logfile: | 0405031524.LOG | Log freq. | 5 | Pipe no: 10 | |
| Particletype: | Only air | Part.reset | | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | changes | NV3: | 0,3 |
| NVT (PT04): | | NVE: | | RV1: | 4,2 |
| Massflow (start): | | TT02: | 21,6 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | 0405031524_Re_f.txt | | | | |
| Comments: | This experiment will test the behaviour of the system with a empty tank.<br>This file | | | | |
| Event 0: | Stable flow GV closed and NVT open | | | ~152kg/h | |
| Event 1: | Open GV | | | | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | ~152kg/h | | | |
| Event 4: | Adjust NV2 | | | | |
| Event 5: | Stable flow | ~140kg/h | | | |
| Event 6: | Open GV | | | | |
| Event 7: | Close GV | | | | |
| Event 8: | Stable flow | ~140kg/h | | | |
| Event 9: | Adjust NV2 | | | | |
| Event 10: | Stable flow | ~120kg/h | | | |
| Event 11: | Open GV | | | | |
| Event 12: | Close GV | | | | |
| Event 13: | Stable flow | ~120kg/h | | | |
| Event 14: | Adjust NV2 | | | | |
| Event 15: | Stable flow | ~100kg/h | | | |
| Event 16: | Open GV | | | | |
| Event 17: | Close GV | | | | |
| Event 18: | Stable flow | ~100kg/h | | | |
| Event 19: | Adjust NV2 | | | | |
| Event 20: | Stable flow | ~80kg/h | | | |
| Event 21: | Open GV | | | | |
| Event 22: | Close GV | | | | |
| Event 23: | Stable flow | ~80kg/h | | | |
| Event 24: | Adjust NV2 | | | | |
| Event 25: | Stable flow | ~60kg/h | | | |
| Event 26: | Open GV | | | | |
| Event 27: | Close GV | | | | |
| Event 28: | Stable flow | ~60kg/h | | | |
| Event 29: | Adjust NV2 | | | | |
| Event 30: | Stable flow | ~40kg/h | | | |
| Event 31: | Open GV | | | | |
| Event 32: | Close GV | | | | |
| Event 33: | Stable flow | ~40kg/h | | | |
| Event 34 | Ending | | | | |

Figure C.2.2: Lab diary Re-f experiment.



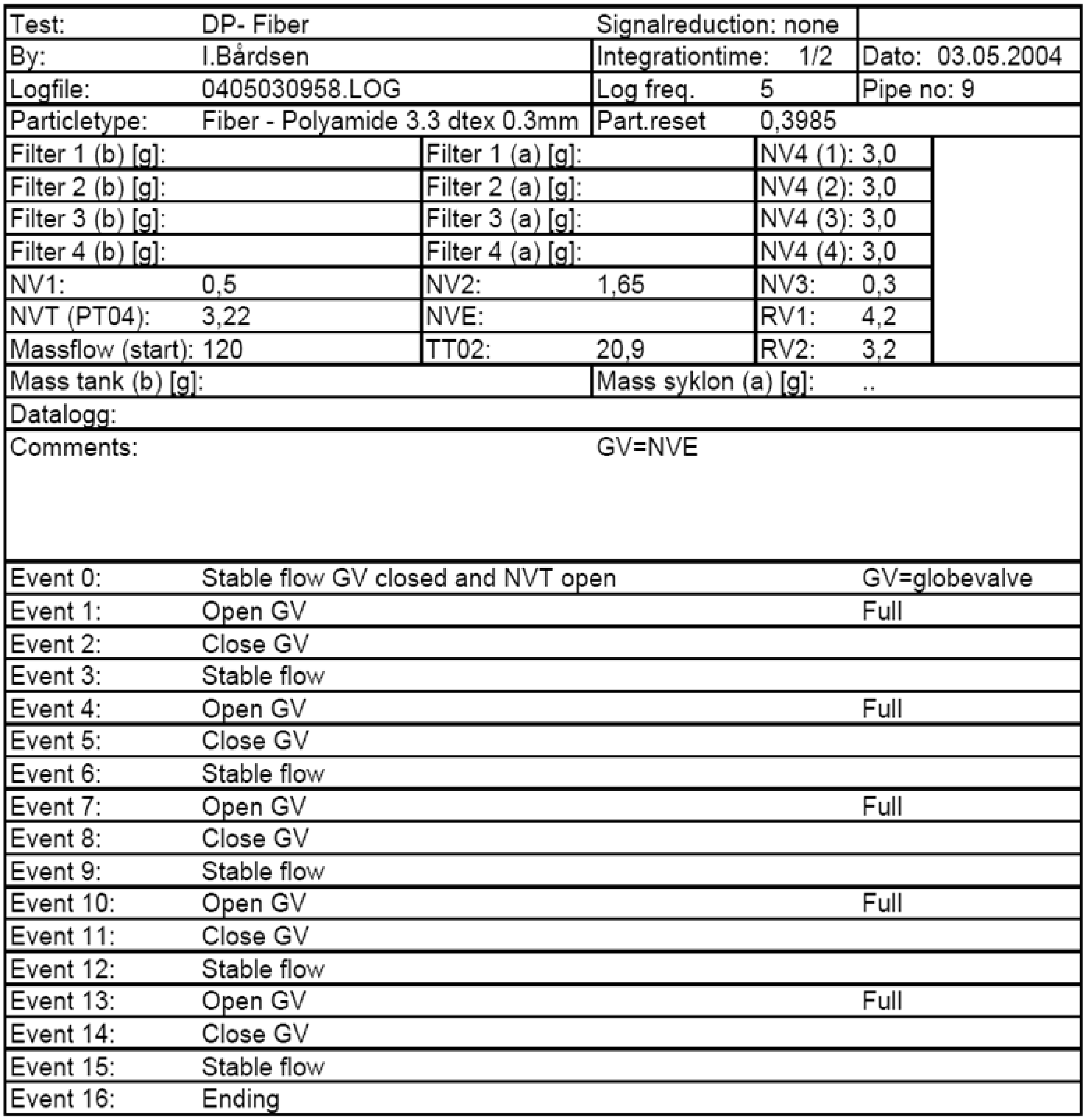
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- | Signalreduction: none | | | |
| By: | I.Bårdsen | Integrationtime: | 1/2 | Dato: | 30.04.2004 |
| Logfile: | 0404301001.LOG | Log freq. | 5 | Pipe no: | 9 |
| Particletype: | Fiber - Polyamide 3.3 dtex 0.3mm | Part.reset | 0,3415 | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,75 | NV3: | 0,3 |
| NVT (PT04): | | NVE: | Stengt | RV1: | 4,2 |
| Massflow (start): | 152 | TT02: | 20,5 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | 0404301001_DP.txt | | | | |
| Comments: | | | | | |
| Event 0: | Stable flow GV closed and NVT open | | | GV=globevalve | |
| Event 1: | Open GV | | | Full | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | | | |
| Event 4: | Open GV | | | Full | |
| Event 5: | Close GV | | | | |
| Event 6: | Stable flow | | | | |
| Event 7: | Open GV | | | Full | |
| Event 8: | Close GV | | | | |
| Event 9: | Stable flow | | | | |
| Event 10: | Open GV | | | Full | |
| Event 11: | Close GV | | | | |
| Event 12: | Stable flow | | | | |
| Event 13: | Open GV | | | Full | |
| Event 14: | Close GV | | | | |
| Event 15: | Stable flow | | | | |
| Event 16: | Open GV | | | | |
| Event 17: | Close GV | | | | |
| Event 18: | Ending | | | | |

Figure C.2.3: Lab diary $\Delta P$ experiment. Polyamide 0.3mm.



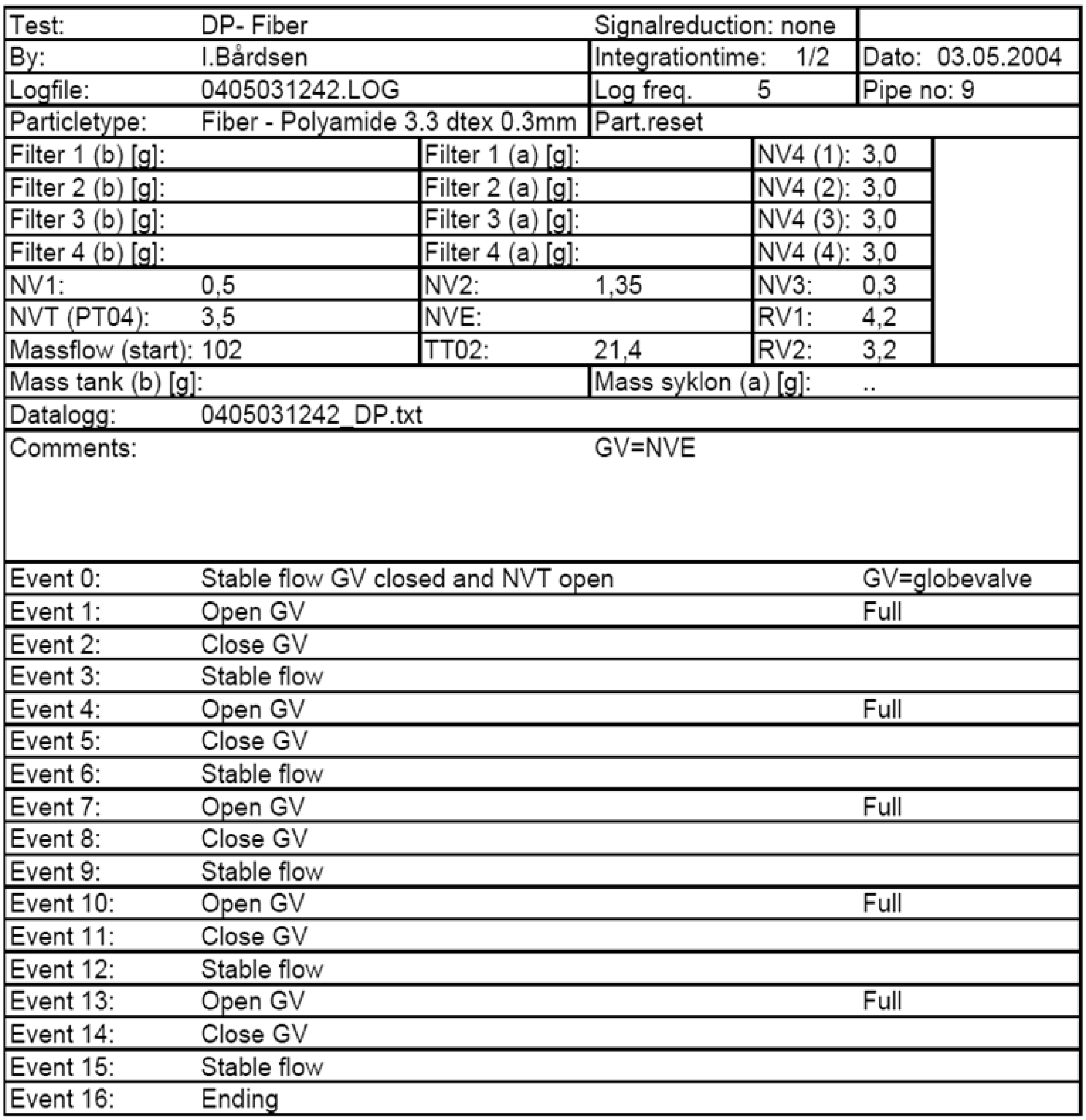
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- Fiber | Signalreduction: none | | | |
| By: | I.Bårdsen | Integrationtime: | 1/2 | Dato: | 03.05.2004 |
| Logfile: | 0405030925.LOG | Log freq. | 5 | Pipe no: | 9 |
| Particletype: | Fiber - Polyamide 3.3 dtex 0.3mm | Part.reset | 0,3356 | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,7 | NV3: | 0,3 |
| NVT (PT04): | 3,2 | NVE: | | RV1: | 4,2 |
| Massflow (start): | 140 | TT02: | 20,9 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | 0405030925_DP.txt | | | | |
| Comments: | | GV=NVE | | | |
| Event 0: | Stable flow GV closed and NVT open | | | GV=globevalve | |
| Event 1: | Open GV | | | Full | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | | | |
| Event 4: | Open GV | | | Full | |
| Event 5: | Close GV | | | | |
| Event 6: | Stable flow | | | | |
| Event 7: | Open GV | | | Full | |
| Event 8: | Close GV | | | | |
| Event 9: | Stable flow | | | | |
| Event 10: | Open GV | | | Full | |
| Event 11: | Close GV | | | | |
| Event 12: | Stable flow | | | | |
| Event 13: | Open GV | | | Full | |
| Event 14: | Close GV | | | | |
| Event 15: | Stable flow | | | | |
| Event 16: | Ending | | | | |

Figure C.2.4: Lab diary $\Delta P$ experiment. Polyamide 0.3mm.



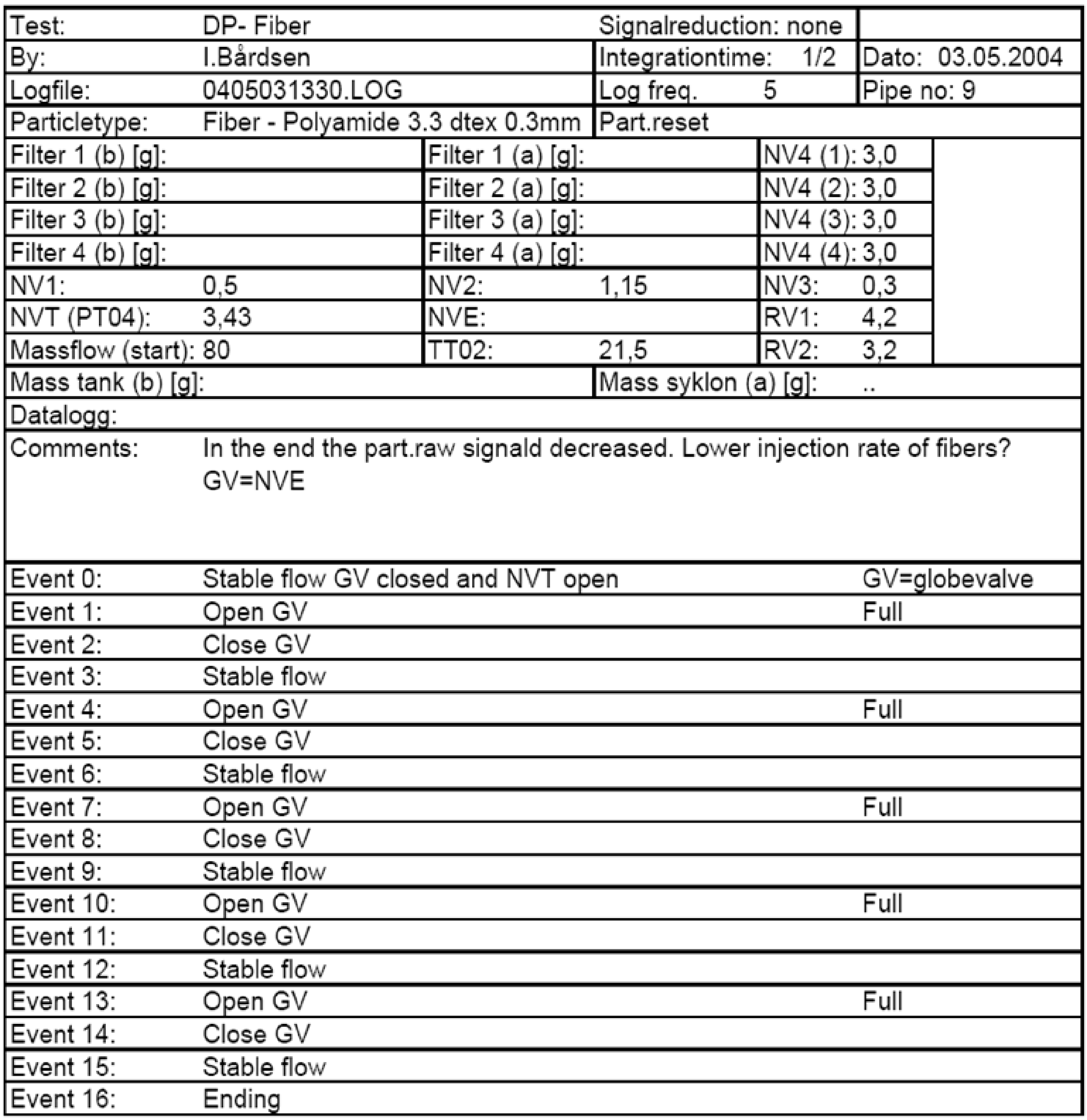
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- Fiber | Signalreduction: none | | | |
| By: | I.Bårdsen | Integrationtime: | 1/2 | Dato: 03.05.2004 | |
| Logfile: | 0405030958.LOG | Log freq. | 5 | Pipe no: 9 | |
| Particletype: | Fiber - Polyamide 3.3 dtex 0.3mm | Part.reset | 0,3985 | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,65 | NV3: | 0,3 |
| NVT (PT04): | 3,22 | NVE: | | RV1: | 4,2 |
| Massflow (start): | 120 | TT02: | 20,9 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | | | | | |
| Comments: | | GV=NVE | | | |
| Event 0: | Stable flow GV closed and NVT open | | | GV=globevalve | |
| Event 1: | Open GV | | | Full | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | | | |
| Event 4: | Open GV | | | Full | |
| Event 5: | Close GV | | | | |
| Event 6: | Stable flow | | | | |
| Event 7: | Open GV | | | Full | |
| Event 8: | Close GV | | | | |
| Event 9: | Stable flow | | | | |
| Event 10: | Open GV | | | Full | |
| Event 11: | Close GV | | | | |
| Event 12: | Stable flow | | | | |
| Event 13: | Open GV | | | Full | |
| Event 14: | Close GV | | | | |
| Event 15: | Stable flow | | | | |
| Event 16: | Ending | | | | |

Figure C.2.5: Lab diary $\Delta P$ experiment. Polyamide 0.3mm.



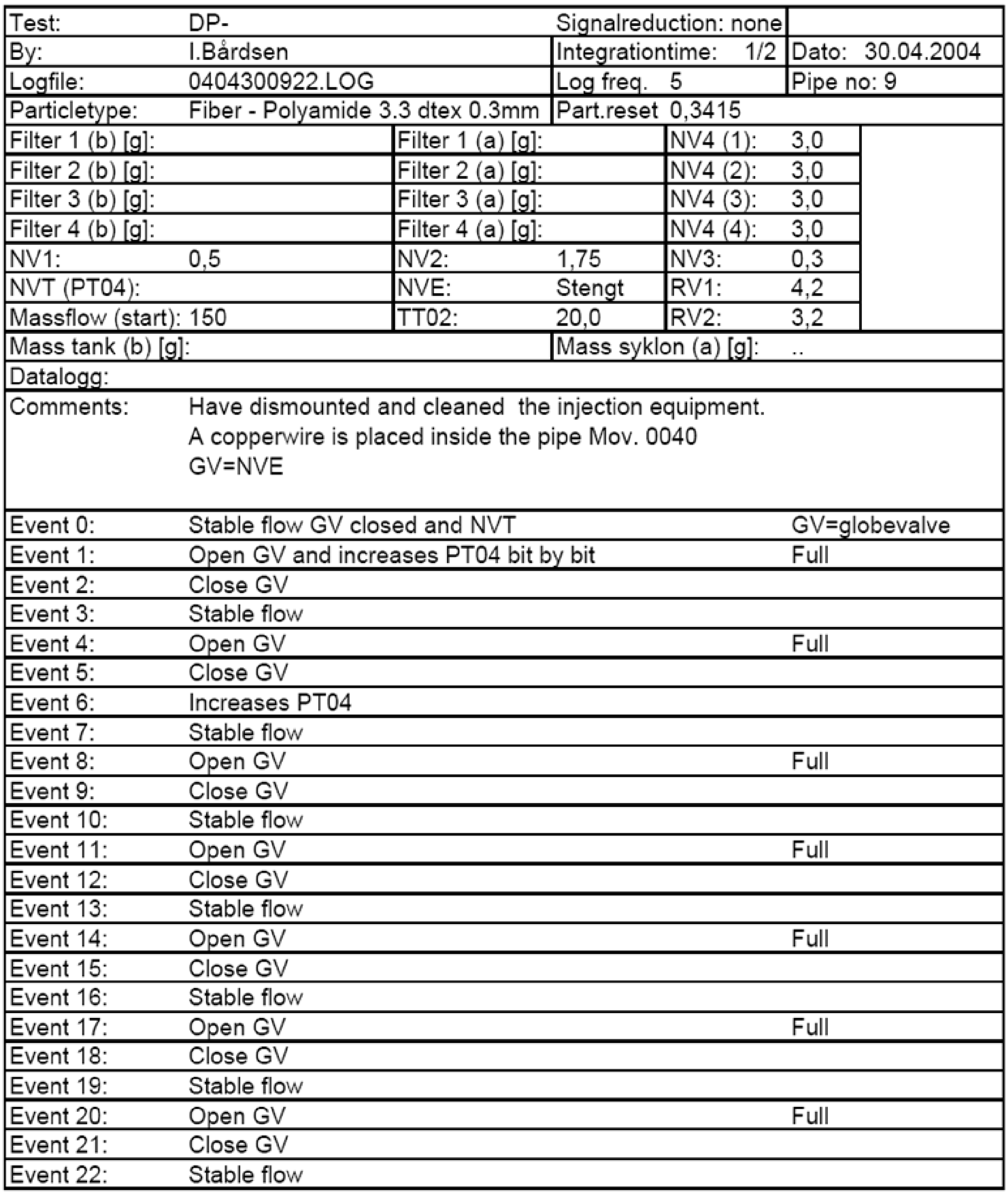
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- Fiber | Signalreduction: | none | | |
| By: | I.Bårdsen | Integrationtime: | 1/2 | Dato: | 03.05.2004 |
| Logfile: | 0405031242.LOG | Log freq. | 5 | Pipe no: | 9 |
| Particletype: | Fiber - Polyamide 3.3 dtex 0.3mm | Part.reset | | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,35 | NV3: | 0,3 |
| NVT (PT04): | 3,5 | NVE: | | RV1: | 4,2 |
| Massflow (start): | 102 | TT02: | 21,4 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | 0405031242_DP.txt | | | | |
| Comments: | | GV=NVE | | | |
| Event 0: | Stable flow GV closed and NVT open | | | GV=globevalve | |
| Event 1: | Open GV | | | Full | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | | | |
| Event 4: | Open GV | | | Full | |
| Event 5: | Close GV | | | | |
| Event 6: | Stable flow | | | | |
| Event 7: | Open GV | | | Full | |
| Event 8: | Close GV | | | | |
| Event 9: | Stable flow | | | | |
| Event 10: | Open GV | | | Full | |
| Event 11: | Close GV | | | | |
| Event 12: | Stable flow | | | | |
| Event 13: | Open GV | | | Full | |
| Event 14: | Close GV | | | | |
| Event 15: | Stable flow | | | | |
| Event 16: | Ending | | | | |

Figure C.2.6: Lab diary $\Delta P$ experiment. Polyamide 0.3mm.



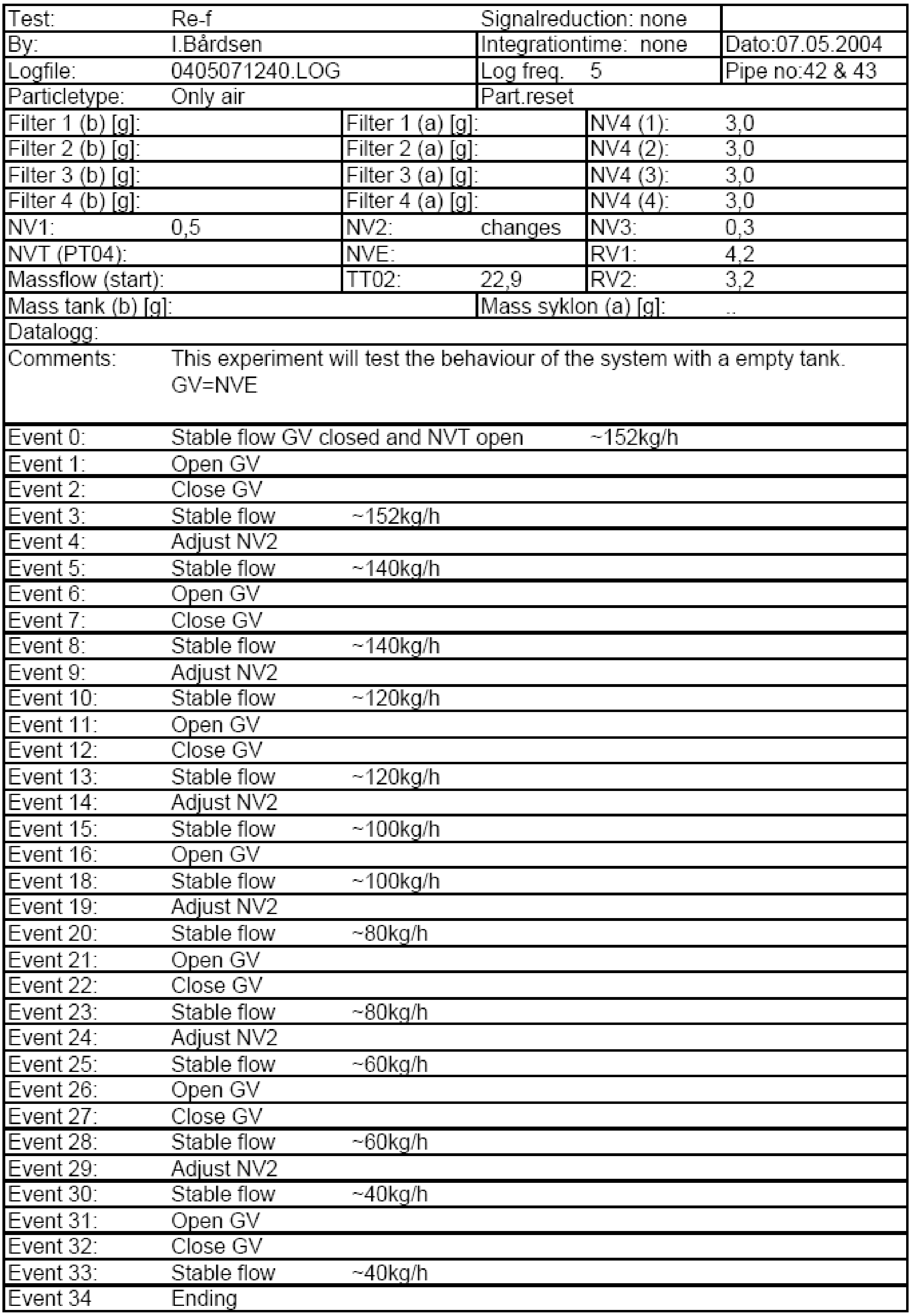
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- Fiber | | Signalreduction: none | | |
| By: | I.Bårdsen | | Integrationtime: 1/2 | Dato: 03.05.2004 | |
| Logfile: | 0405031330.LOG | | Log freq. 5 | Pipe no: 9 | |
| Particletype: | Fiber - Polyamide 3.3 dtex 0.3mm | | Part.reset | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,15 | NV3: | 0,3 |
| NVT (PT04): | 3,43 | NVE: | | RV1: | 4,2 |
| Massflow (start): | 80 | TT02: | 21,5 | RV2: | 3,2 |
| Mass tank (b) [g]: | | | Mass syklon (a) [g]: | .. | |
| Datalogg: | | | | | |
| Comments: | In the end the part.raw signald decreased. Lower injection rate of fibers?<br>GV=NVE | | | | |
| Event 0: | Stable flow GV closed and NVT open | | | GV=globevalve | |
| Event 1: | Open GV | | | Full | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | | | |
| Event 4: | Open GV | | | Full | |
| Event 5: | Close GV | | | | |
| Event 6: | Stable flow | | | | |
| Event 7: | Open GV | | | Full | |
| Event 8: | Close GV | | | | |
| Event 9: | Stable flow | | | | |
| Event 10: | Open GV | | | Full | |
| Event 11: | Close GV | | | | |
| Event 12: | Stable flow | | | | |
| Event 13: | Open GV | | | Full | |
| Event 14: | Close GV | | | | |
| Event 15: | Stable flow | | | | |
| Event 16: | Ending | | | | |

Figure C.2.7: Lab diary $\Delta P$ experiment. Polyamide 0.3mm.



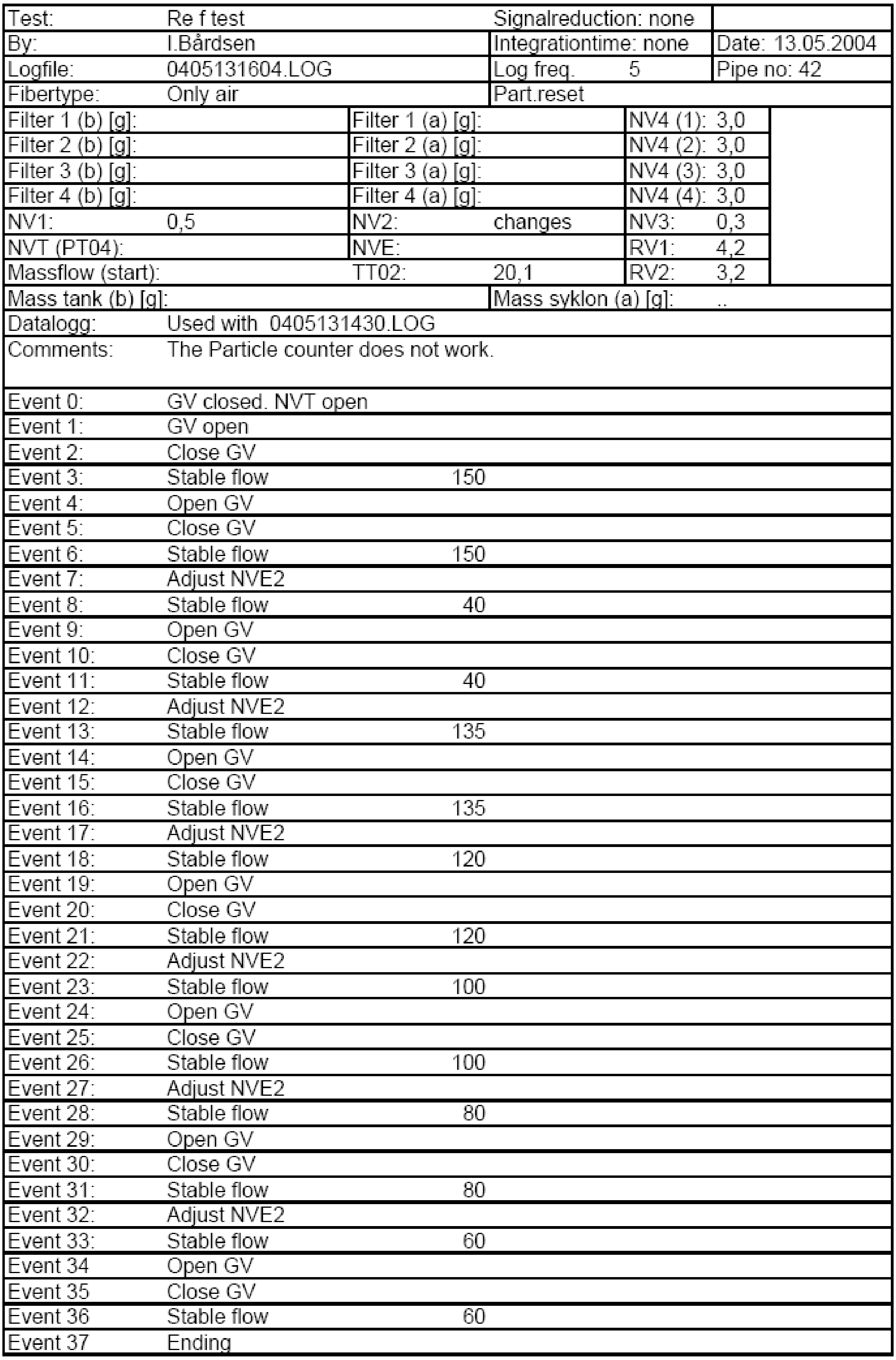
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- | | | Signalreduction: none | |
| By: | I.Bårdsen | Integrationtime: | 1/2 | Dato: | 30.04.2004 |
| Logfile: | 0404300922.LOG | Log freq. | 5 | Pipe no: | 9 |
| Particletype: | Fiber - Polyamide 3.3 dtex 0.3mm | Part.reset | 0,3415 | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,75 | NV3: | 0,3 |
| NVT (PT04): | | NVE: | Stengt | RV1: | 4,2 |
| Massflow (start): | 150 | TT02: | 20,0 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | | | | | |
| Comments: | Have dismounted and cleaned the injection equipment.<br>A copperwire is placed inside the pipe Mov. 0040<br>GV=NVE | | | | |
| Event 0: | Stable flow GV closed and NVT | | | GV=globevalve | |
| Event 1: | Open GV and increases PT04 bit by bit | | | Full | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | | | |
| Event 4: | Open GV | | | Full | |
| Event 5: | Close GV | | | | |
| Event 6: | Increases PT04 | | | | |
| Event 7: | Stable flow | | | | |
| Event 8: | Open GV | | | Full | |
| Event 9: | Close GV | | | | |
| Event 10: | Stable flow | | | | |
| Event 11: | Open GV | | | Full | |
| Event 12: | Close GV | | | | |
| Event 13: | Stable flow | | | | |
| Event 14: | Open GV | | | Full | |
| Event 15: | Close GV | | | | |
| Event 16: | Stable flow | | | | |
| Event 17: | Open GV | | | Full | |
| Event 18: | Close GV | | | | |
| Event 19: | Stable flow | | | | |
| Event 20: | Open GV | | | Full | |
| Event 21: | Close GV | | | | |
| Event 22: | Stable flow | | | | |

Figure C.2.8: Lab diary $\Delta P$ experiment. Polyamide 0.3mm.



| | | | | | |
|---|---|---|---|---|---|
| Test: | Re-f | Signalreduction: none | | | |
| By: | I.Bårdsen | Integrationtime: none | | Dato:07.05.2004 | |
| Logfile: | 0405071240.LOG | Log freq. | 5 | Pipe no:42 & 43 | |
| Particletype: | Only air | Part.reset | | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | changes | NV3: | 0,3 |
| NVT (PT04): | | NVE: | | RV1: | 4,2 |
| Massflow (start): | | TT02: | 22,9 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | | | | | |
| Comments: | This experiment will test the behaviour of the system with a empty tank.<br>GV=NVE | | | | |
| Event 0: | Stable flow GV closed and NVT open | ~152kg/h | | | |
| Event 1: | Open GV | | | | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | ~152kg/h | | | |
| Event 4: | Adjust NV2 | | | | |
| Event 5: | Stable flow | ~140kg/h | | | |
| Event 6: | Open GV | | | | |
| Event 7: | Close GV | | | | |
| Event 8: | Stable flow | ~140kg/h | | | |
| Event 9: | Adjust NV2 | | | | |
| Event 10: | Stable flow | ~120kg/h | | | |
| Event 11: | Open GV | | | | |
| Event 12: | Close GV | | | | |
| Event 13: | Stable flow | ~120kg/h | | | |
| Event 14: | Adjust NV2 | | | | |
| Event 15: | Stable flow | ~100kg/h | | | |
| Event 16: | Open GV | | | | |
| Event 18: | Stable flow | ~100kg/h | | | |
| Event 19: | Adjust NV2 | | | | |
| Event 20: | Stable flow | ~80kg/h | | | |
| Event 21: | Open GV | | | | |
| Event 22: | Close GV | | | | |
| Event 23: | Stable flow | ~80kg/h | | | |
| Event 24: | Adjust NV2 | | | | |
| Event 25: | Stable flow | ~60kg/h | | | |
| Event 26: | Open GV | | | | |
| Event 27: | Close GV | | | | |
| Event 28: | Stable flow | ~60kg/h | | | |
| Event 29: | Adjust NV2 | | | | |
| Event 30: | Stable flow | ~40kg/h | | | |
| Event 31: | Open GV | | | | |
| Event 32: | Close GV | | | | |
| Event 33: | Stable flow | ~40kg/h | | | |
| Event 34 | Ending | | | | |

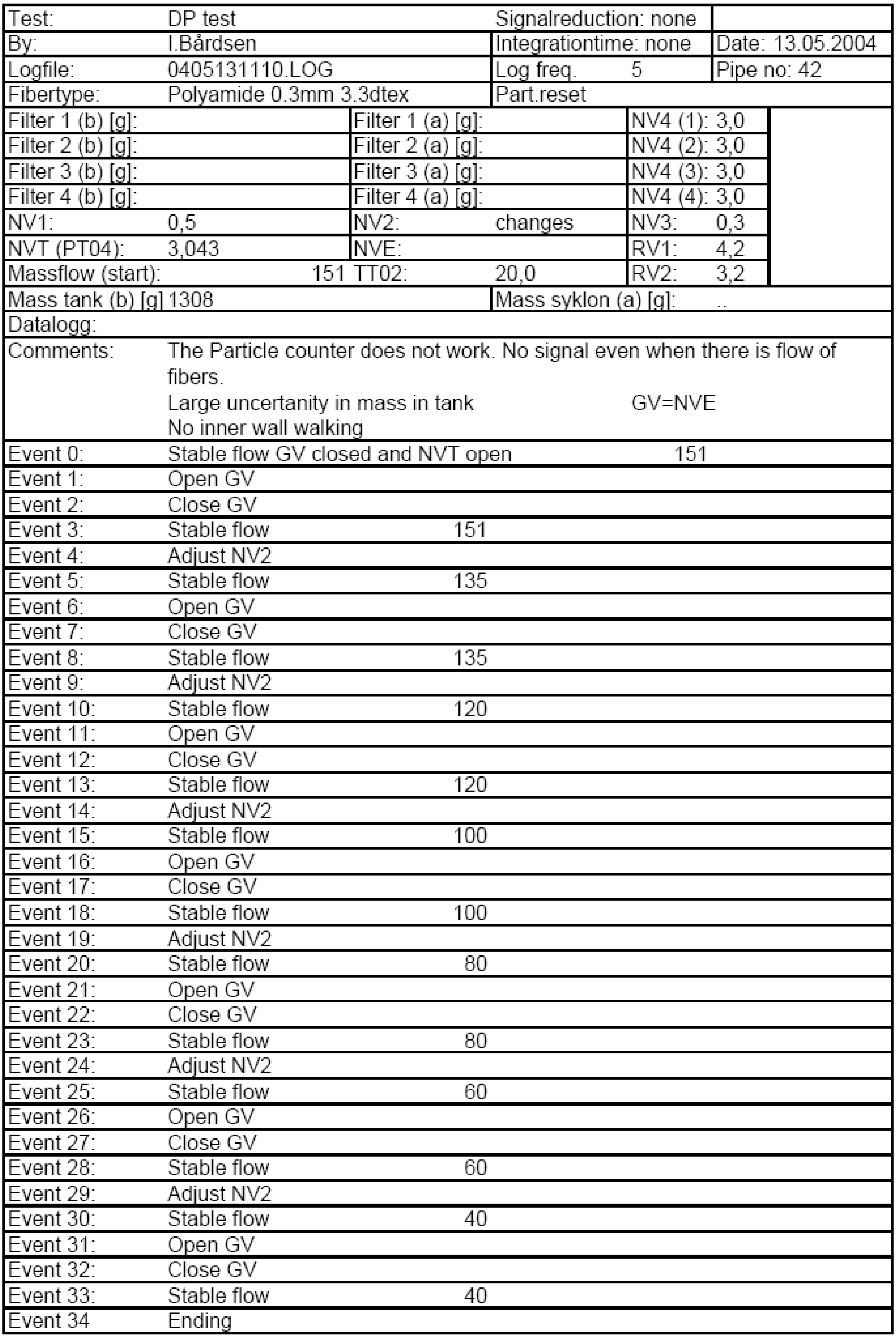
Figure C.2.9: Lab diary Re-f experiment.



| | | | | | |
|---|---|---|---|---|---|
| Test: | Re f test | | Signalreduction: none | | |
| By: | I.Bårdsen | | Integrationtime: none | | Date: 13.05.2004 |
| Logfile: | 0405131604.LOG | | Log freq. | 5 | Pipe no: 42 |
| Fibertype: | Only air | | Part.reset | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | changes | NV3: | 0,3 |
| NVT (PT04): | | NVE: | | RV1: | 4,2 |
| Massflow (start): | | TT02: | 20,1 | RV2: | 3,2 |
| Mass tank (b) [g]: | | | Mass syklon (a) [g]: | .. | |
| Datalogg: | Used with 0405131430.LOG | | | | |
| Comments: | The Particle counter does not work. | | | | |
| Event 0: | GV closed. NVT open | | | | |
| Event 1: | GV open | | | | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | 150 | | | |
| Event 4: | Open GV | | | | |
| Event 5: | Close GV | | | | |
| Event 6: | Stable flow | 150 | | | |
| Event 7: | Adjust NVE2 | | | | |
| Event 8: | Stable flow | 40 | | | |
| Event 9: | Open GV | | | | |
| Event 10: | Close GV | | | | |
| Event 11: | Stable flow | 40 | | | |
| Event 12: | Adjust NVE2 | | | | |
| Event 13: | Stable flow | 135 | | | |
| Event 14: | Open GV | | | | |
| Event 15: | Close GV | | | | |
| Event 16: | Stable flow | 135 | | | |
| Event 17: | Adjust NVE2 | | | | |
| Event 18: | Stable flow | 120 | | | |
| Event 19: | Open GV | | | | |
| Event 20: | Close GV | | | | |
| Event 21: | Stable flow | 120 | | | |
| Event 22: | Adjust NVE2 | | | | |
| Event 23: | Stable flow | 100 | | | |
| Event 24: | Open GV | | | | |
| Event 25: | Close GV | | | | |
| Event 26: | Stable flow | 100 | | | |
| Event 27: | Adjust NVE2 | | | | |
| Event 28: | Stable flow | 80 | | | |
| Event 29: | Open GV | | | | |
| Event 30: | Close GV | | | | |
| Event 31: | Stable flow | 80 | | | |
| Event 32: | Adjust NVE2 | | | | |
| Event 33: | Stable flow | 60 | | | |
| Event 34 | Open GV | | | | |
| Event 35 | Close GV | | | | |
| Event 36 | Stable flow | 60 | | | |
| Event 37 | Ending | | | | |

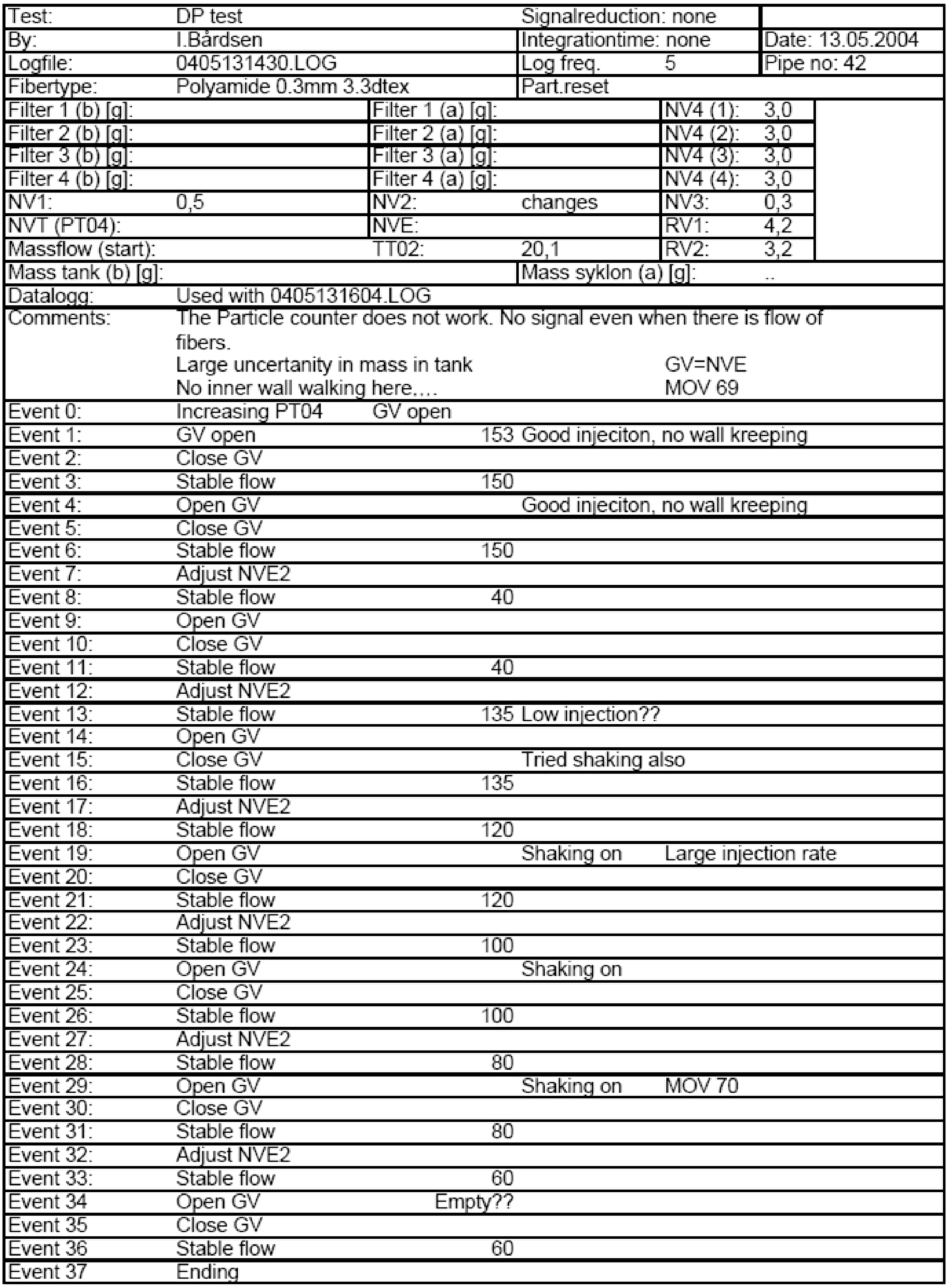
Figure C.2.10: Lab diary Re-f experiment. Polyamide.

## C.3 Experimental data for polyethylene



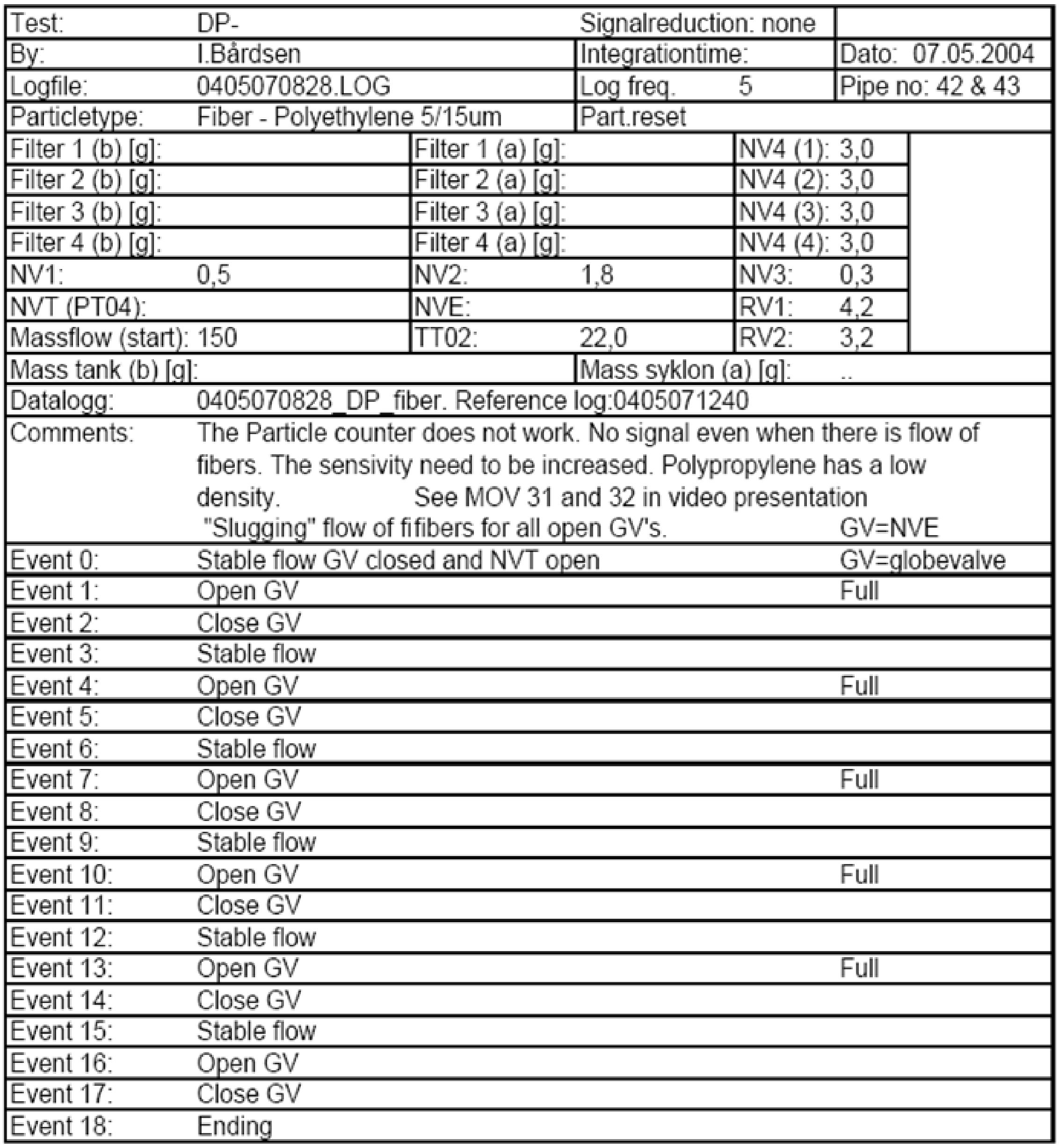
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP test | | Signalreduction: none | | |
| By: | I.Bårdsen | | Integrationtime: none | | Date: 13.05.2004 |
| Logfile: | 0405131110.LOG | | Log freq. 5 | | Pipe no: 42 |
| Fibertype: | Polyamide 0.3mm 3.3dtex | | Part.reset | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): 3,0 | |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): 3,0 | |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): 3,0 | |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): 3,0 | |
| NV1: | 0,5 | NV2: | changes | NV3: 0,3 | |
| NVT (PT04): | 3,043 | NVE: | | RV1: 4,2 | |
| Massflow (start): | 151 | TT02: | 20,0 | RV2: 3,2 | |
| Mass tank (b) [g] | 1308 | | Mass syklon (a) [g]: .. | | |
| Datalogg: | | | | | |
| Comments: | The Particle counter does not work. No signal even when there is flow of fibers.<br>Large uncertanity in mass in tank<br>No inner wall walking | | | GV=NVE | |
| Event 0: | Stable flow GV closed and NVT open | | | 151 | |
| Event 1: | Open GV | | | | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | 151 | | |
| Event 4: | Adjust NV2 | | | | |
| Event 5: | Stable flow | | 135 | | |
| Event 6: | Open GV | | | | |
| Event 7: | Close GV | | | | |
| Event 8: | Stable flow | | 135 | | |
| Event 9: | Adjust NV2 | | | | |
| Event 10: | Stable flow | | 120 | | |
| Event 11: | Open GV | | | | |
| Event 12: | Close GV | | | | |
| Event 13: | Stable flow | | 120 | | |
| Event 14: | Adjust NV2 | | | | |
| Event 15: | Stable flow | | 100 | | |
| Event 16: | Open GV | | | | |
| Event 17: | Close GV | | | | |
| Event 18: | Stable flow | | 100 | | |
| Event 19: | Adjust NV2 | | | | |
| Event 20: | Stable flow | | 80 | | |
| Event 21: | Open GV | | | | |
| Event 22: | Close GV | | | | |
| Event 23: | Stable flow | | 80 | | |
| Event 24: | Adjust NV2 | | | | |
| Event 25: | Stable flow | | 60 | | |
| Event 26: | Open GV | | | | |
| Event 27: | Close GV | | | | |
| Event 28: | Stable flow | | 60 | | |
| Event 29: | Adjust NV2 | | | | |
| Event 30: | Stable flow | | 40 | | |
| Event 31: | Open GV | | | | |
| Event 32: | Close GV | | | | |
| Event 33: | Stable flow | | 40 | | |
| Event 34 | Ending | | | | |

Figure C.2.11: Lab diary $\Delta P$ experiment. Polyamide.



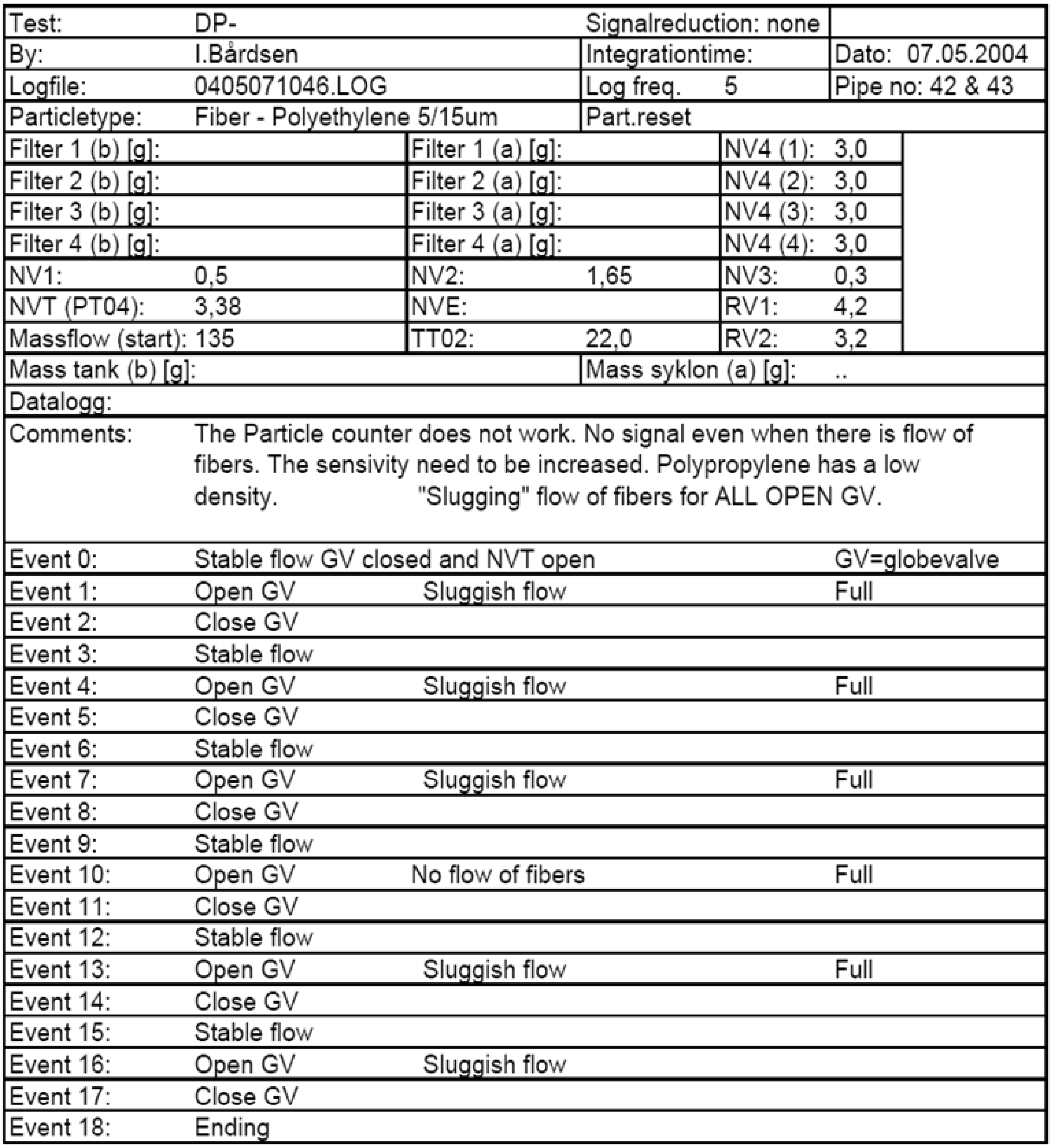
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP test | | Signalreduction: none | | |
| By: | I.Bårdsen | | Integrationtime: none | | Date: 13.05.2004 |
| Logfile: | 0405131430.LOG | | Log freq. | 5 | Pipe no: 42 |
| Fibertype: | Polyamide 0.3mm 3.3dtex | | Part.reset | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | changes | NV3: | 0,3 |
| NVT (PT04): | | NVE: | | RV1: | 4,2 |
| Massflow (start): | | TT02: | 20,1 | RV2: | 3,2 |
| Mass tank (b) [g]: | | | Mass syklon (a) [g]: | .. | |
| Datalogg: | Used with 0405131604.LOG | | | | |
| Comments: | The Particle counter does not work. No signal even when there is flow of fibers.<br>Large uncertanity in mass in tank<br>No inner wall walking here.... | | | GV=NVE<br>MOV 69 | |
| Event 0: | Increasing PT04 | GV open | | | |
| Event 1: | GV open | 153 | Good injeciton, no wall kreeping | | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | 150 | | | |
| Event 4: | Open GV | | Good injeciton, no wall kreeping | | |
| Event 5: | Close GV | | | | |
| Event 6: | Stable flow | 150 | | | |
| Event 7: | Adjust NVE2 | | | | |
| Event 8: | Stable flow | 40 | | | |
| Event 9: | Open GV | | | | |
| Event 10: | Close GV | | | | |
| Event 11: | Stable flow | 40 | | | |
| Event 12: | Adjust NVE2 | | | | |
| Event 13: | Stable flow | 135 | Low injection?? | | |
| Event 14: | Open GV | | | | |
| Event 15: | Close GV | | Tried shaking also | | |
| Event 16: | Stable flow | 135 | | | |
| Event 17: | Adjust NVE2 | | | | |
| Event 18: | Stable flow | 120 | | | |
| Event 19: | Open GV | | Shaking on | Large injection rate | |
| Event 20: | Close GV | | | | |
| Event 21: | Stable flow | 120 | | | |
| Event 22: | Adjust NVE2 | | | | |
| Event 23: | Stable flow | 100 | | | |
| Event 24: | Open GV | | Shaking on | | |
| Event 25: | Close GV | | | | |
| Event 26: | Stable flow | 100 | | | |
| Event 27: | Adjust NVE2 | | | | |
| Event 28: | Stable flow | 80 | | | |
| Event 29: | Open GV | | Shaking on | MOV 70 | |
| Event 30: | Close GV | | | | |
| Event 31: | Stable flow | 80 | | | |
| Event 32: | Adjust NVE2 | | | | |
| Event 33: | Stable flow | 60 | | | |
| Event 34 | Open GV | Empty?? | | | |
| Event 35 | Close GV | | | | |
| Event 36 | Stable flow | 60 | | | |
| Event 37 | Ending | | | | |

Figure C.2.12: Lab diary $\Delta P$ experiment. Polyamide.



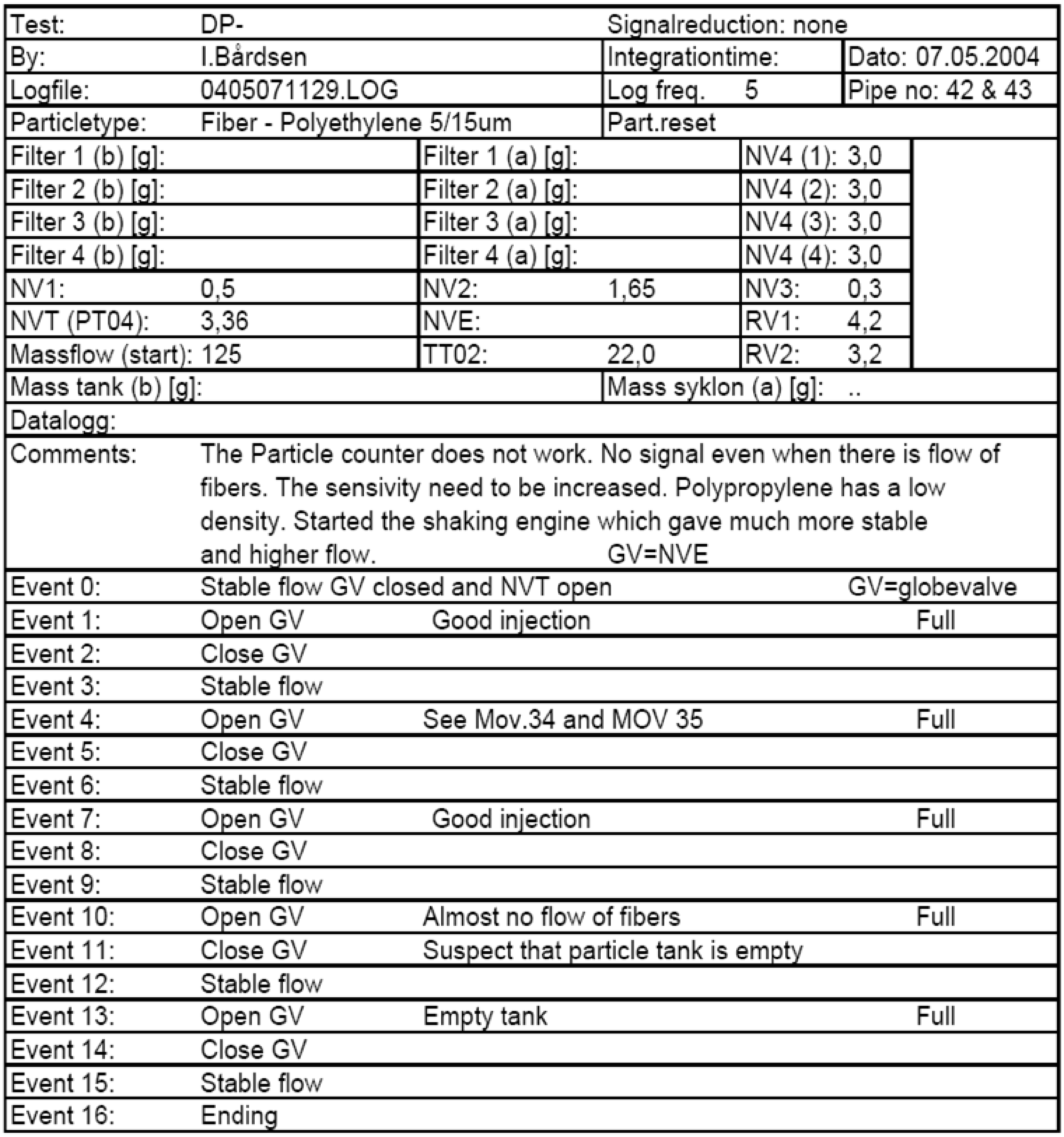
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- | Signalreduction: none | | | |
| By: | I.Bårdsen | Integrationtime: | | Dato: 07.05.2004 | |
| Logfile: | 0405070828.LOG | Log freq. | 5 | Pipe no: 42 & 43 | |
| Particletype: | Fiber - Polyethylene 5/15um | Part.reset | | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,8 | NV3: | 0,3 |
| NVT (PT04): | | NVE: | | RV1: | 4,2 |
| Massflow (start): | 150 | TT02: | 22,0 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | 0405070828_DP_fiber. Reference log:0405071240 | | | | |
| Comments: | The Particle counter does not work. No signal even when there is flow of fibers. The sensivity need to be increased. Polypropylene has a low density. See MOV 31 and 32 in video presentation<br>"Slugging" flow of fifibers for all open GV's. | | | | GV=NVE |
| Event 0: | Stable flow GV closed and NVT open | | | | GV=globevalve |
| Event 1: | Open GV | | | | Full |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | | | |
| Event 4: | Open GV | | | | Full |
| Event 5: | Close GV | | | | |
| Event 6: | Stable flow | | | | |
| Event 7: | Open GV | | | | Full |
| Event 8: | Close GV | | | | |
| Event 9: | Stable flow | | | | |
| Event 10: | Open GV | | | | Full |
| Event 11: | Close GV | | | | |
| Event 12: | Stable flow | | | | |
| Event 13: | Open GV | | | | Full |
| Event 14: | Close GV | | | | |
| Event 15: | Stable flow | | | | |
| Event 16: | Open GV | | | | |
| Event 17: | Close GV | | | | |
| Event 18: | Ending | | | | |

Figure C.3.1: Lab diary $\Delta P$ experiment. Polyethylene.



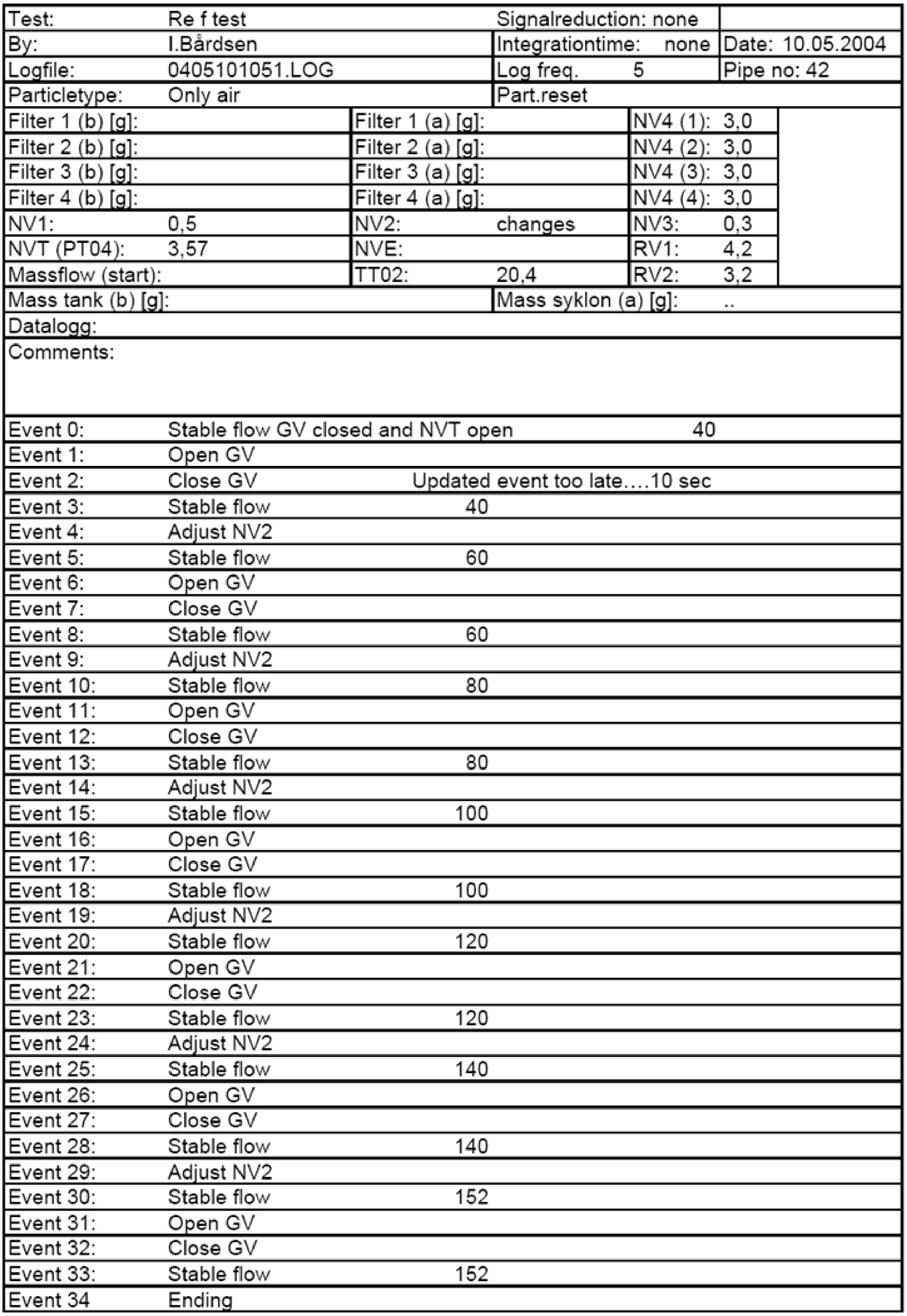
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- | | | Signalreduction: none | |
| By: | I.Bårdsen | Integrationtime: | | Dato: 07.05.2004 | |
| Logfile: | 0405071046.LOG | Log freq. | 5 | Pipe no: 42 & 43 | |
| Particletype: | Fiber - Polyethylene 5/15um | Part.reset | | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,65 | NV3: | 0,3 |
| NVT (PT04): | 3,38 | NVE: | | RV1: | 4,2 |
| Massflow (start): | 135 | TT02: | 22,0 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | | | | | |
| Comments: | The Particle counter does not work. No signal even when there is flow of fibers. The sensivity need to be increased. Polypropylene has a low density. "Slugging" flow of fibers for ALL OPEN GV. | | | | |
| Event 0: | Stable flow GV closed and NVT open | | | GV=globevalve | |
| Event 1: | Open GV | Sluggish flow | | Full | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | | | |
| Event 4: | Open GV | Sluggish flow | | Full | |
| Event 5: | Close GV | | | | |
| Event 6: | Stable flow | | | | |
| Event 7: | Open GV | Sluggish flow | | Full | |
| Event 8: | Close GV | | | | |
| Event 9: | Stable flow | | | | |
| Event 10: | Open GV | No flow of fibers | | Full | |
| Event 11: | Close GV | | | | |
| Event 12: | Stable flow | | | | |
| Event 13: | Open GV | Sluggish flow | | Full | |
| Event 14: | Close GV | | | | |
| Event 15: | Stable flow | | | | |
| Event 16: | Open GV | Sluggish flow | | | |
| Event 17: | Close GV | | | | |
| Event 18: | Ending | | | | |

Figure C.3.2: Lab diary $\Delta P$ experiment. Polyethylene.



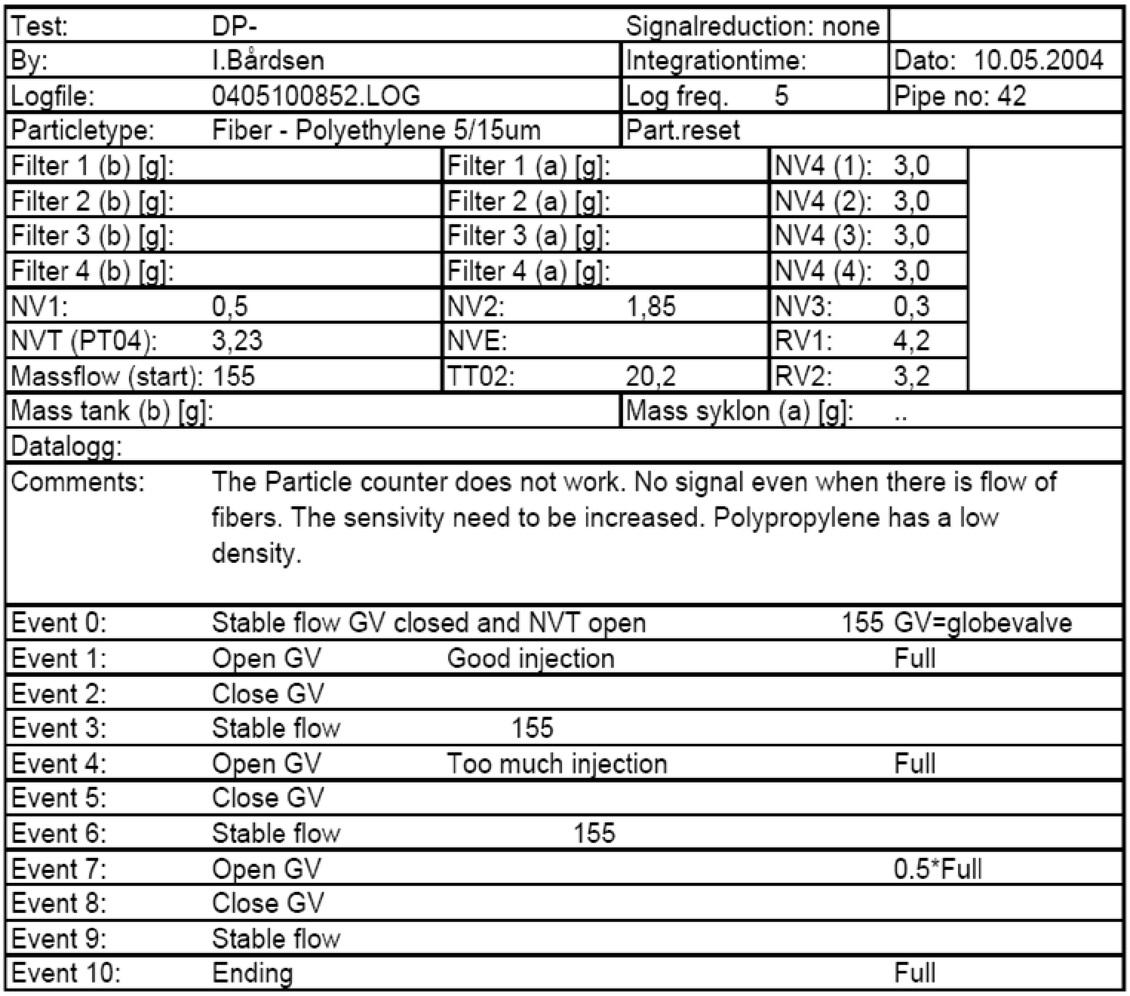
| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- | Signalreduction: none | | | |
| By: | I.Bårdsen | Integrationtime: | | Dato: 07.05.2004 | |
| Logfile: | 0405071129.LOG | Log freq. | 5 | Pipe no: 42 & 43 | |
| Particletype: | Fiber - Polyethylene 5/15um | Part.reset | | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,65 | NV3: | 0,3 |
| NVT (PT04): | 3,36 | NVE: | | RV1: | 4,2 |
| Massflow (start): | 125 | TT02: | 22,0 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | | | | | |
| Comments: | The Particle counter does not work. No signal even when there is flow of fibers. The sensivity need to be increased. Polypropylene has a low density. Started the shaking engine which gave much more stable and higher flow. GV=NVE | | | | |
| Event 0: | Stable flow GV closed and NVT open | | | GV=globevalve | |
| Event 1: | Open GV | Good injection | | | Full |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | | | |
| Event 4: | Open GV | See Mov.34 and MOV 35 | | | Full |
| Event 5: | Close GV | | | | |
| Event 6: | Stable flow | | | | |
| Event 7: | Open GV | Good injection | | | Full |
| Event 8: | Close GV | | | | |
| Event 9: | Stable flow | | | | |
| Event 10: | Open GV | Almost no flow of fibers | | | Full |
| Event 11: | Close GV | Suspect that particle tank is empty | | | |
| Event 12: | Stable flow | | | | |
| Event 13: | Open GV | Empty tank | | | Full |
| Event 14: | Close GV | | | | |
| Event 15: | Stable flow | | | | |
| Event 16: | Ending | | | | |

Figure C.3.3: Lab diary $\Delta P$ experiment. Polyethylene.



| | | | | | |
|---|---|---|---|---|---|
| Test: | Re f test | | Signalreduction: none | | |
| By: | I.Bårdsen | | Integrationtime: none | | Date: 10.05.2004 |
| Logfile: | 0405101051.LOG | | Log freq. 5 | | Pipe no: 42 |
| Particletype: | Only air | | Part.reset | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | changes | NV3: | 0,3 |
| NVT (PT04): | 3,57 | NVE: | | RV1: | 4,2 |
| Massflow (start): | | TT02: | 20,4 | RV2: | 3,2 |
| Mass tank (b) [g]: | | | Mass syklon (a) [g]: | .. | |
| Datalogg: | | | | | |
| Comments: | | | | | |
| Event 0: | Stable flow GV closed and NVT open | | | 40 | |
| Event 1: | Open GV | | | | |
| Event 2: | Close GV | | Updated event too late….10 sec | | |
| Event 3: | Stable flow | | 40 | | |
| Event 4: | Adjust NV2 | | | | |
| Event 5: | Stable flow | | 60 | | |
| Event 6: | Open GV | | | | |
| Event 7: | Close GV | | | | |
| Event 8: | Stable flow | | 60 | | |
| Event 9: | Adjust NV2 | | | | |
| Event 10: | Stable flow | | 80 | | |
| Event 11: | Open GV | | | | |
| Event 12: | Close GV | | | | |
| Event 13: | Stable flow | | 80 | | |
| Event 14: | Adjust NV2 | | | | |
| Event 15: | Stable flow | | 100 | | |
| Event 16: | Open GV | | | | |
| Event 17: | Close GV | | | | |
| Event 18: | Stable flow | | 100 | | |
| Event 19: | Adjust NV2 | | | | |
| Event 20: | Stable flow | | 120 | | |
| Event 21: | Open GV | | | | |
| Event 22: | Close GV | | | | |
| Event 23: | Stable flow | | 120 | | |
| Event 24: | Adjust NV2 | | | | |
| Event 25: | Stable flow | | 140 | | |
| Event 26: | Open GV | | | | |
| Event 27: | Close GV | | | | |
| Event 28: | Stable flow | | 140 | | |
| Event 29: | Adjust NV2 | | | | |
| Event 30: | Stable flow | | 152 | | |
| Event 31: | Open GV | | | | |
| Event 32: | Close GV | | | | |
| Event 33: | Stable flow | | 152 | | |
| Event 34 | Ending | | | | |

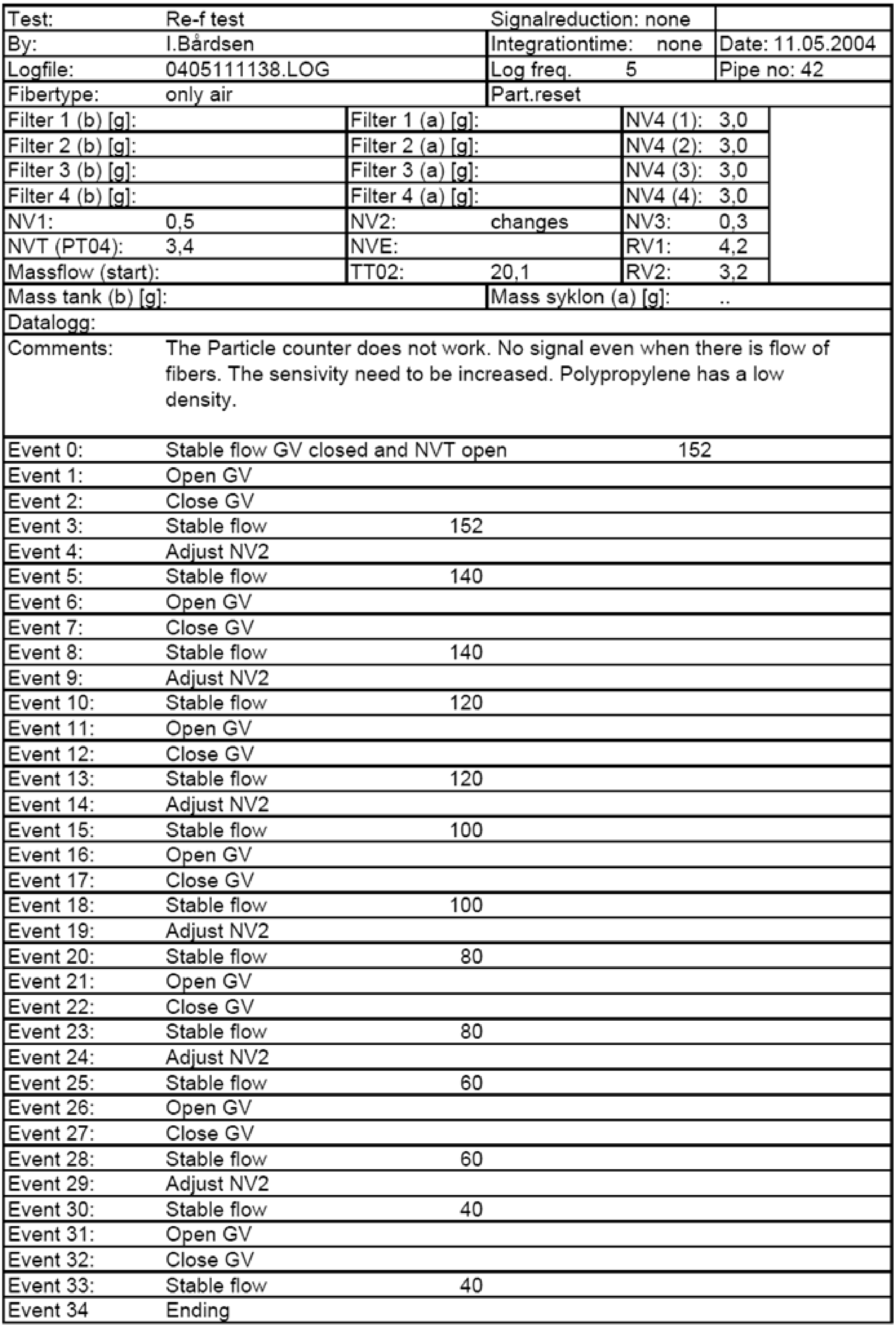
Figure C.3.4: Lab diary Re-f experiment. Polyethylene.



| | | | | | |
|---|---|---|---|---|---|
| Test: | DP- | | | Signalreduction: none | |
| By: | I.Bårdsen | | Integrationtime: | | Dato: 10.05.2004 |
| Logfile: | 0405100852.LOG | | Log freq. | 5 | Pipe no: 42 |
| Particletype: | Fiber - Polyethylene 5/15um | | Part.reset | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | 1,85 | NV3: | 0,3 |
| NVT (PT04): | 3,23 | NVE: | | RV1: | 4,2 |
| Massflow (start): | 155 | TT02: | 20,2 | RV2: | 3,2 |
| Mass tank (b) [g]: | | | Mass syklon (a) [g]: | .. | |
| Datalogg: | | | | | |
| Comments: | The Particle counter does not work. No signal even when there is flow of fibers. The sensivity need to be increased. Polypropylene has a low density. | | | | |

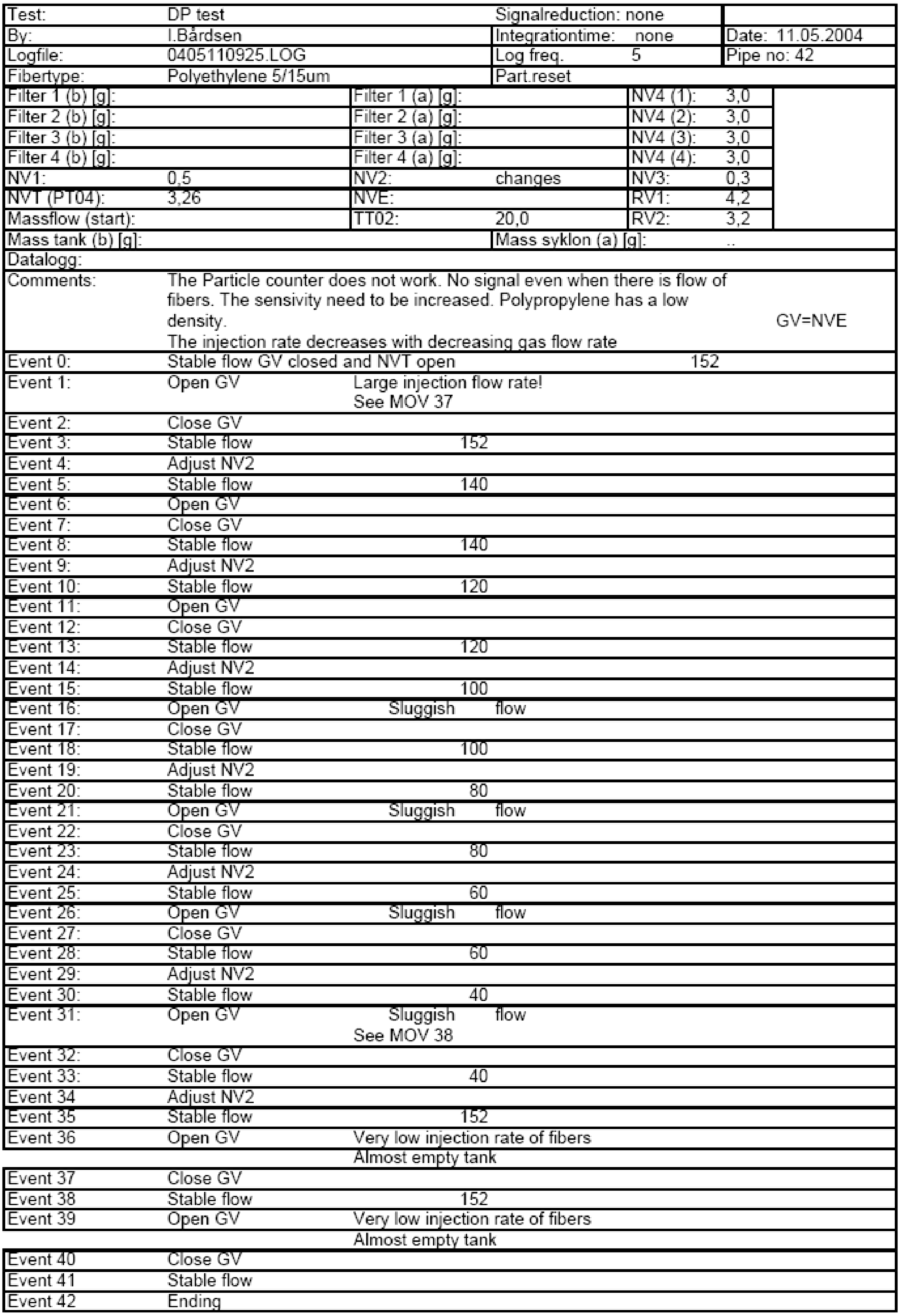
| | | | |
|---|---|---|---|
| Event 0: | Stable flow GV closed and NVT open | | 155 GV=globevalve |
| Event 1: | Open GV | Good injection | Full |
| Event 2: | Close GV | | |
| Event 3: | Stable flow | 155 | |
| Event 4: | Open GV | Too much injection | Full |
| Event 5: | Close GV | | |
| Event 6: | Stable flow | 155 | |
| Event 7: | Open GV | | 0.5*Full |
| Event 8: | Close GV | | |
| Event 9: | Stable flow | | |
| Event 10: | Ending | | Full |

Figure C.3.5: Lab diary $\Delta P$ experiment. Polyethylene.



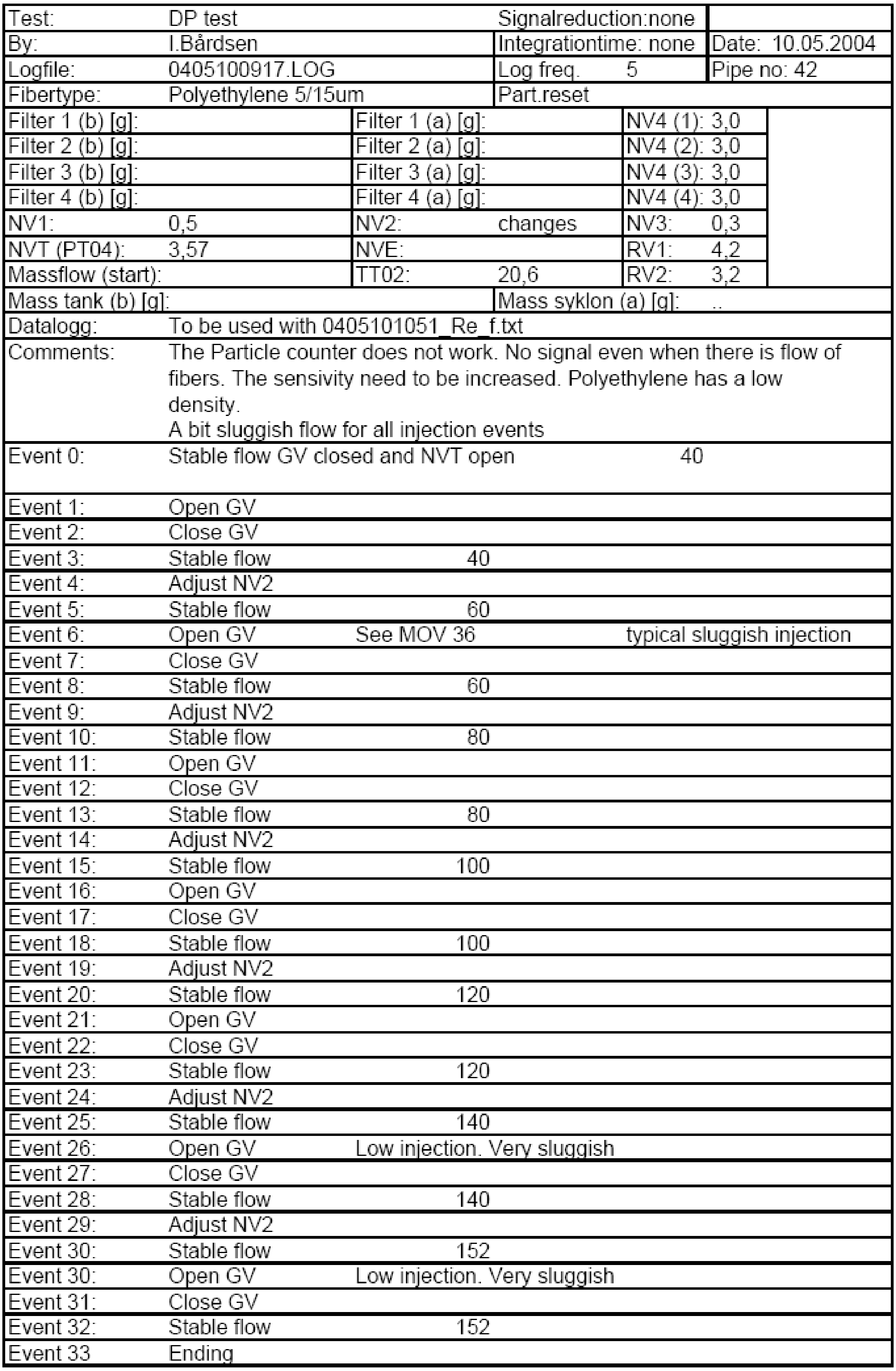
| | | | | | |
|---|---|---|---|---|---|
| Test: | Re-f test | Signalreduction: none | | | |
| By: | I.Bårdsen | Integrationtime: | none | Date: 11.05.2004 | |
| Logfile: | 0405111138.LOG | Log freq. | 5 | Pipe no: 42 | |
| Fibertype: | only air | Part.reset | | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | changes | NV3: | 0,3 |
| NVT (PT04): | 3,4 | NVE: | | RV1: | 4,2 |
| Massflow (start): | | TT02: | 20,1 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | | | | | |
| Comments: | The Particle counter does not work. No signal even when there is flow of fibers. The sensivity need to be increased. Polypropylene has a low density. | | | | |
| Event 0: | Stable flow GV closed and NVT open | | | 152 | |
| Event 1: | Open GV | | | | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | 152 | | | |
| Event 4: | Adjust NV2 | | | | |
| Event 5: | Stable flow | 140 | | | |
| Event 6: | Open GV | | | | |
| Event 7: | Close GV | | | | |
| Event 8: | Stable flow | 140 | | | |
| Event 9: | Adjust NV2 | | | | |
| Event 10: | Stable flow | 120 | | | |
| Event 11: | Open GV | | | | |
| Event 12: | Close GV | | | | |
| Event 13: | Stable flow | 120 | | | |
| Event 14: | Adjust NV2 | | | | |
| Event 15: | Stable flow | 100 | | | |
| Event 16: | Open GV | | | | |
| Event 17: | Close GV | | | | |
| Event 18: | Stable flow | 100 | | | |
| Event 19: | Adjust NV2 | | | | |
| Event 20: | Stable flow | 80 | | | |
| Event 21: | Open GV | | | | |
| Event 22: | Close GV | | | | |
| Event 23: | Stable flow | 80 | | | |
| Event 24: | Adjust NV2 | | | | |
| Event 25: | Stable flow | 60 | | | |
| Event 26: | Open GV | | | | |
| Event 27: | Close GV | | | | |
| Event 28: | Stable flow | 60 | | | |
| Event 29: | Adjust NV2 | | | | |
| Event 30: | Stable flow | 40 | | | |
| Event 31: | Open GV | | | | |
| Event 32: | Close GV | | | | |
| Event 33: | Stable flow | 40 | | | |
| Event 34 | Ending | | | | |

Figure C.3.6: Lab diary Re-f experiment.



| | | | | | |
|---|---|---|---|---|---|
| Test: | DP test | Signalreduction: none | | | |
| By: | I.Bårdsen | Integrationtime: none | | Date: 11.05.2004 | |
| Logfile: | 0405110925.LOG | Log freq. 5 | | Pipe no: 42 | |
| Fibertype: | Polyethylene 5/15um | Part.reset | | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | changes | NV3: | 0,3 |
| NVT (PT04): | 3,26 | NVE: | | RV1: | 4,2 |
| Massflow (start): | | TT02: | 20,0 | RV2: | 3,2 |
| Mass tank (b) [g]: | | Mass syklon (a) [g]: | .. | | |
| Datalogg: | | | | | |
| Comments: | The Particle counter does not work. No signal even when there is flow of fibers. The sensivity need to be increased. Polypropylene has a low density.<br>The injection rate decreases with decreasing gas flow rate | | | GV=NVE | |
| Event 0: | Stable flow GV closed and NVT open | | 152 | | |
| Event 1: | Open GV | Large injection flow rate!<br>See MOV 37 | | | |
| Event 2: | Close GV | | | | |
| Event 3: | Stable flow | | 152 | | |
| Event 4: | Adjust NV2 | | | | |
| Event 5: | Stable flow | | 140 | | |
| Event 6: | Open GV | | | | |
| Event 7: | Close GV | | | | |
| Event 8: | Stable flow | | 140 | | |
| Event 9: | Adjust NV2 | | | | |
| Event 10: | Stable flow | | 120 | | |
| Event 11: | Open GV | | | | |
| Event 12: | Close GV | | | | |
| Event 13: | Stable flow | | 120 | | |
| Event 14: | Adjust NV2 | | | | |
| Event 15: | Stable flow | | 100 | | |
| Event 16: | Open GV | Sluggish flow | | | |
| Event 17: | Close GV | | | | |
| Event 18: | Stable flow | | 100 | | |
| Event 19: | Adjust NV2 | | | | |
| Event 20: | Stable flow | | 80 | | |
| Event 21: | Open GV | Sluggish flow | | | |
| Event 22: | Close GV | | | | |
| Event 23: | Stable flow | | 80 | | |
| Event 24: | Adjust NV2 | | | | |
| Event 25: | Stable flow | | 60 | | |
| Event 26: | Open GV | Sluggish flow | | | |
| Event 27: | Close GV | | | | |
| Event 28: | Stable flow | | 60 | | |
| Event 29: | Adjust NV2 | | | | |
| Event 30: | Stable flow | | 40 | | |
| Event 31: | Open GV | Sluggish flow<br>See MOV 38 | | | |
| Event 32: | Close GV | | | | |
| Event 33: | Stable flow | | 40 | | |
| Event 34 | Adjust NV2 | | | | |
| Event 35 | Stable flow | | 152 | | |
| Event 36 | Open GV | Very low injection rate of fibers<br>Almost empty tank | | | |
| Event 37 | Close GV | | | | |
| Event 38 | Stable flow | | 152 | | |
| Event 39 | Open GV | Very low injection rate of fibers<br>Almost empty tank | | | |
| Event 40 | Close GV | | | | |
| Event 41 | Stable flow | | | | |
| Event 42 | Ending | | | | |

Figure C.3.7: Lab diary $\Delta P$ experiment. Polyethylene.



| | | | | | |
|---|---|---|---|---|---|
| Test: | DP test | | Signalreduction:none | | |
| By: | I.Bårdsen | | Integrationtime: none | | Date: 10.05.2004 |
| Logfile: | 0405100917.LOG | | Log freq. 5 | | Pipe no: 42 |
| Fibertype: | Polyethylene 5/15um | | Part.reset | | |
| Filter 1 (b) [g]: | | Filter 1 (a) [g]: | | NV4 (1): | 3,0 |
| Filter 2 (b) [g]: | | Filter 2 (a) [g]: | | NV4 (2): | 3,0 |
| Filter 3 (b) [g]: | | Filter 3 (a) [g]: | | NV4 (3): | 3,0 |
| Filter 4 (b) [g]: | | Filter 4 (a) [g]: | | NV4 (4): | 3,0 |
| NV1: | 0,5 | NV2: | changes | NV3: | 0,3 |
| NVT (PT04): | 3,57 | NVE: | | RV1: | 4,2 |
| Massflow (start): | | TT02: | 20,6 | RV2: | 3,2 |
| Mass tank (b) [g]: | | | Mass syklon (a) [g]: | .. | |
| Datalogg: | To be used with 0405101051_Re_f.txt | | | | |
| Comments: | The Particle counter does not work. No signal even when there is flow of fibers. The sensivity need to be increased. Polyethylene has a low density.<br>A bit sluggish flow for all injection events | | | | |

| | | | | |
|---|---|---|---|---|
| Event 0: | Stable flow GV closed and NVT open | | | 40 |
| Event 1: | Open GV | | | |
| Event 2: | Close GV | | | |
| Event 3: | Stable flow | | 40 | |
| Event 4: | Adjust NV2 | | | |
| Event 5: | Stable flow | | 60 | |
| Event 6: | Open GV | See MOV 36 | | typical sluggish injection |
| Event 7: | Close GV | | | |
| Event 8: | Stable flow | | 60 | |
| Event 9: | Adjust NV2 | | | |
| Event 10: | Stable flow | | 80 | |
| Event 11: | Open GV | | | |
| Event 12: | Close GV | | | |
| Event 13: | Stable flow | | 80 | |
| Event 14: | Adjust NV2 | | | |
| Event 15: | Stable flow | | 100 | |
| Event 16: | Open GV | | | |
| Event 17: | Close GV | | | |
| Event 18: | Stable flow | | 100 | |
| Event 19: | Adjust NV2 | | | |
| Event 20: | Stable flow | | 120 | |
| Event 21: | Open GV | | | |
| Event 22: | Close GV | | | |
| Event 23: | Stable flow | | 120 | |
| Event 24: | Adjust NV2 | | | |
| Event 25: | Stable flow | | 140 | |
| Event 26: | Open GV | Low injection. Very sluggish | | |
| Event 27: | Close GV | | | |
| Event 28: | Stable flow | | 140 | |
| Event 29: | Adjust NV2 | | | |
| Event 30: | Stable flow | | 152 | |
| Event 30: | Open GV | Low injection. Very sluggish | | |
| Event 31: | Close GV | | | |
| Event 32: | Stable flow | | 152 | |
| Event 33 | Ending | | | |

Figure C.3.8: Lab diary $\Delta P$ experiment. Polyethylene.

# Appendix D

# Fiber data

## D.1 Polyamide

## D.2 Polyethylene

Table D.1.1: Swissflock company information

| Company | Products/ Orders/ Samples |
|---|---|
| SWISSFLOCK<br>Zweigniederlassung Deutschland<br>Schulze-Delitzsch-Str. 15<br>70 565 Stuttgart<br>Web www.swissflock.com | Polyamide 3.3dtex<br>10kg Length 0.3mm Black<br>10kg Length 0.5mm Black<br>10kg Length 1.0mm White |
| Andreas Fröhler<br>Head of Sales<br>Phone +49-(0)711-66646-31<br>Fax +49-(0)711-66646-44<br>Mobil +49-(0)160-7926418<br>Andreas.Froehler@SwissFlock.de | Order:17.03.2004<br>Delivery:05.04.2004<br>Comments:<br>Excellent. Quick response on questions by email.<br>Free samples. Very good service. |
| Company Name: Swissflock<br>Street: Schulze Delitzsch Str. 15<br>City: Stuttgart<br>PO BOX: 70565<br>City PO BOX: Stuttgart<br>Country: Germany/Deutschland<br>Telephone: 0049-711-66646-0<br>Telefax: 0049-711-66646-44<br>Vat reg.no: DE 813 515 947<br>Bank country: Deutschland<br>Bank city: Commerzbank Stuttgart<br>Bank key/ABA nr:60040071<br>Bank account: 5 333 034<br>Bank swift: COBADEFF600 | |

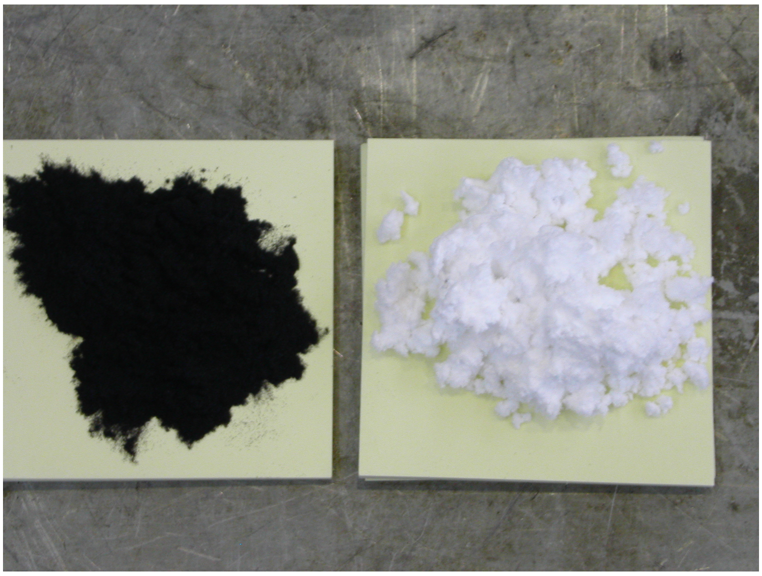


Figure D.1.1: Polyamide and Polyethylene

Table D.2.1: Minifibers company information

| Company | Products/ Orders/ Samples |
|---|---|
| MINIFIBERS INC. | 20lb. Polyethylene fiber |
| 2923 Boones Creek Road | Short stuff Synthetic Pulp. |
| Johnson City, Tennessee 37615 USA | Fluff dried. Type ESS5F. |
| Web: www.minifibers.com | 0.1mm length |
|  | 5microns diameter |
| Andy Taylor |  |
| Phone: (001) 423-282-4242 | 10lb. Polyethylene fiber |
| Fax: (001) 423-282-1450 | Short stuff Synthetic Pulp. |
| ataylor@minifibers.com | Fluff dried |
|  | 0.1mm length |
| Company : MiniFIBERS, Inc. | 15microns diameter |
| Street: 2923 Boones Creek Road |  |
| City: Johnson City | Order:19.03.2004 |
| PO BOX: none | Delivery: 12.05.2004 |
| City PO BOX: none |  |
| Country: USA |  |
| Telephone: 423-282-4242 | Comments: |
| Telefax: 423-282-1450 | Need to pay in advance. Slow response on emails. |
| Vat reg.no: Not applicable |  |
| Bank country: USA |  |
| Bank city: Johnson City |  |
| Bank key/ABA: 084000026 |  |
| Bank account: 171022769 |  |
| Bank swift: FTBMUS44 |  |

# Appendix E

# Matlab Code

## E.1 The main programs

### E.1.1 Input data program

```
function [OPEN_NVE_REFERENCE,ax,akse,f_faktor,Add1,draught_factor,n,...
        Chart,e_d,plot_Re_f_basis,partikkel_basis,stabil_basis,...
        reference_file,saveat,particlelines,cutoff,solid,filnavn_plott,...
        Re_f_filnavn_plott,DP_test_nr,Partikkeltype,...
        tot_ant_DP_tester,frictionfactor,L1,L2,d,pipeno,p1,...
        Re_f_filnavn,filnavn,PartHend,StabilHend,...
        PartKalifilnavn,PartKalifilnavn_ID,Kalikurvefil]...
    = InputData(ant_filer,nr_DP,nr_Re_f)
%*********************************************************************
% Comment : In this function the user defines his input data for the experiment
% performed. This function has to been used with TOTAL.m and databehandling_DP
%
%
% Written by Ingvald Bårdsen
% Date: 01.02.2004-20.05.2004
% Student at NTNU,Trondheim
% Dept.of Chemical Engineering
% email: ingvald@stud.ntnu.no
%**********************************************************************

%Pipe data
%**********************************************************************
pipeno =10;                             %pipe nr.
[L1,L2,d] = RorData(pipeno);
%**********************************************************************
```

```
%Kalibreringskonstant
%***************************************************************************
p1=7.5488;
%***************************************************************************


%***************************************************************************
%Rxperimental friction factor
%frictionfactor='Enkel';
%frictionfactor='corrected';
frictionfactor='more';

%For use with the new transmission friction factor
draught_factor=1;
n=3;

%Adjust the Prandtl/Zagarola/Colebrook/Smooth friction formula
%with a factor
f_faktor=1;

%For use with Coolebrook correlation
%e_d=2.8E-3;%Fit for high Reynoldsnumbers for pipe 9  (0402050918)
%e_d=5E-3;%Fit for low Re numbers for pipe 9
%e_d=3.25E-3;%Fit for high Reynoldsnumbers for pipe 42 (0405031043)
%e_d=5E-3;%Fit for low Re numbers for pipe 42
e_d=1E-5;
%***************************************************************************



%Re f basis
%***************************************************************************
ant_Re_f_filer=1;
logfiles_Re_f=cell(1,ant_Re_f_filer);
 logfiles_Re_f{1,1}='0402050918'
 %logfiles_Re_f{1,2}='0402090938'
 %logfiles_Re_f{1,3}='0402191052'
 %logfiles_Re_f{1,4}='0402191303'
% logfiles_Re_f{1,1}='0403100757'
 %logfiles_Re_f{1,1}='0405031043'
%logfiles_Re_f{1,1}='0405031524'
```

```
 %logfiles_Re_f{1,1}='0405071240'
%logfiles_Re_f{1,1}='0405101051'
%logfiles_Re_f{1,1}='0405111138'
 %logfiles_Re_f{1,1}='0405131604'

%Want to use OPEN NVE as a reference for particle/fiber flow?
%1=Yes
%0=No
OPEN_NVE_REFERENCE=1;


%DP experiment
%**************************************************************************
% pa=experiment with one gas flow rate using polyamide
% pet=experiment with one gas flow rate using polyethylene
% (pa)=experiment with several gas flow rates using polyamide
% (pet)=experiment with several gas flow rates using polyethylene

ant_DP_filer=1;
logfiles_DP=cell(1,ant_DP_filer);
logfiles_DP{1,1}='nr 1';     % nr1   0402051407  %G007
% logfiles_DP{1,1}='nr 2';     % nr2   0403151200  %G005
%logfiles_DP{1,1}='nr 3';     % nr3   0404290946  %pa
% logfiles_DP{1,1}='nr 4';     % nr4   0404291144  %pa
% logfiles_DP{1,1}='nr 5';     % nr5   0404300922  %pa
% logfiles_DP{1,1}='nr 6';     % nr6   0404301001  %pa
%logfiles_DP{1,2}='nr 7';     % nr7   0405030925  %pa
% logfiles_DP{1,3}='nr 8';     % nr8   0405030958  %pa
% logfiles_DP{1,4}='nr 9';     % nr9   0405031242  %pa
% logfiles_DP{1,5}='nr10';    % nr10   0405031330  %pa
%logfiles_DP{1,1}='nr11';    % nr11   0405070828  %pet
%logfiles_DP{1,1}='nr12';    % nr12  0405071046  %pet low injection rates
%logfiles_DP{1,1}='nr13';    % nr13  0405071129  %pet
%logfiles_DP{1,1}='nr14';    % nr14  0405100852  %pet
 %logfiles_DP{1,1}='nr15';    % nr15  0405100917  %(pet)
%logfiles_DP{1,1}='nr16';    % nr16  0405110925  %(pet)   ************
 %logfiles_DP{1,1}='nr17';    % nr17  0405121626  %(pa)    ? Mangler
%logfiles_DP{1,1}='nr18';    % nr18  0405121650  %(pa)     ? Mangler
% logfiles_DP{1,1}='nr19';    % nr19  0405131036  %(pa)  FEIL
%logfiles_DP{1,1}='nr20';    % nr20  0405131110  %(pa)
%logfiles_DP{1,1}='nr21';    % nr21  0405131430  %(pa)
%logfiles_DP{1,1}='nr22';    % nr21  0405031524  %Re f
```

```
[partikkel_basis,stabil_basis,Re_f_filnavn,Re_f_filnavn_plott,...
        solid,Partikkeltype,filnavn,filnavn_plott,PartHend,StabilHend]...
    = Lab_Diary(OPEN_NVE_REFERENCE,logfiles_DP,logfiles_Re_f,nr_DP,nr_Re_f);

%NOT USED
tot_ant_DP_tester=1; %Antall DP tester som foretas.
% f.eks. 4 DP tester for en partikkeltype ved flowrate gass 160,120,80,40
DP_test_nr=1; %Dette er DP testen nr. x for denne partikkeltypen
%*************************************************************************


%Partikkel kalibrering (THis part needs to use a calibration function
%written by Andre Strupstad) I do not use this function since I did not
%use the particle counter
%*************************************************************************
ikkemedTot=0;
VektfilterEtterAllefiler=[2234.7;2237.3;1993;2092.9;2089.4;1874.8;2039.2];
VektfilterForAllefiler=[1685.6;1686.8;1884.2;1687.7;1688.6;1689;1689.2];
%Navnet angir partikkeltype og gasshastighet som kalibreres
PartKalifilnavn=strcat('CM100 100-125 160.kal');
%Navnet angir partikkeltype og gasshastighet som kalibreres
PartKalifilnavn_ID = strcat('CM100 100-125 160');
Kalikurvefil='Kalibreringskurver_CM100 100-125 160.kal';
%*************************************************************************



%Plotting
%*************************************************************************
saveat='C:\Documents and Settings\Ingvald\My Documents\Fag\Hovedoppgave'
'Vår 2004\LateX\Hovedoppgave\Figurer\Resultater\Polyamide\Group2';

%Choose plotting properties for the friction base lines...
plot_Re_f_basis{1,1}='bx';
plot_Re_f_basis{1,2}='cx';
plot_Re_f_basis{1,3}='mx';


%Choose your Chart types:
%Chart=1;    %Basis Zagarola and Prandtl.Only air
%Chart=2;  %Basis Zagarola,Prandtl & Colebrook.Only air
%Chart=3;  %Basis, particles and Colebrook
%Chart=4;  %Basis,particles,Zagarola and Prandtl
```

```
Chart=5;   %Basis,particles,Zagarola,Prandtl and Colebrook

%Choose axes values for chart f vs. Re
%ax=1;%Choose Yes,
ax=0;
akse=[1.99 14E4 0.015 0.04];
%akse=[2 14E4 0.015 0.025];

%Add1=1;%Also plots events for stable flow
Add1=0;

%***********************************************************************
%reference_file=1;
reference_file=0;

cutoff=79.99;   %after Time axis after x minutes Only used for
%cutoff=0; %dont cut off axis                 databehandling_DP

particlelines=1;% Plots yellow horizontal lines when NVE is open
%when particlelines=1 . Without lines: Use 0
%***********************************************************************
```

### E.1.2 Main program - graphing friction factors

```
%**************************************************************************
% Comment:
% This is the main program that calculates and graphs the friction
% versus Reynoldsnumber for specified logfiles

%INPUTDATA
clear all,close all,clc
ant_DP_filer=1;
ant_Re_f_filer=1;
nr_Re_f=1;%initialize
nr_DP=1;%initialize

% Written by Ingvald Bårdsen
% Date: 01.02.2004-20.05.2004
% Student at NTNU,Trondheim
% Dept.of Chemical Engineering
% email: ingvald@stud.ntnu.no
%**************************************************************************
%**************************************************************************
%THIS PART IS GENERAL AND SHOULD NOT BE CHANGED
for nr_DP=1:ant_DP_filer
    [OPEN_NVE_REFERENCE,ax,akse,f_faktor,Add1,draught_factor,n,Chart,e_d,...
            plot_Re_f_basis,partikkel_basis,stabil_basis,...
            reference_file,saveat,particlelines,cutoff,solid,filnavn_plott,...
            Re_f_filnavn_plott,DP_test_nr,Partikkeltype,...
            tot_ant_DP_tester,frictionfactor,L1,L2,d,pipeno,p1,...
            Re_f_filnavn,filnavn,PartHend,StabilHend,...
            PartKalifilnavn,PartKalifilnavn_ID,Kalikurvefil]...
        = InputData(ant_DP_filer,nr_DP,nr_Re_f);

    data=load(filnavn);
    M = 28.96235284;      %[g/mol]
    R=8.31431;                  %[g*m*m/K*mol*s*s]
    D=d;
    variables%Get variables from datafile
    %Comment out with a %-sign to check for cutoff time
    if cutoff==0
        ind_time=length(TIME)
    else
        ind_time=find(abs(TIME-cutoff)==min(abs(TIME-cutoff)));
    end
    %Find where we wanna cuf off the axes
```

```
TIME=TIME(1:ind_time);
%Need to adjust the other vectors too...
PT04=PT04(1:ind_time);
PDT01=PDT01(1:ind_time);
PDT02=PDT02(1:ind_time);
PT01=PT01(1:ind_time);
PT02=PT02(1:ind_time);
PT03=PT03(1:ind_time);
PT05=PT05(1:ind_time);
Event=Event(1:ind_time);
TT02=TT02(1:ind_time);
Part_V=PART_V(1:ind_time);
Part_raw=PART_RAW(1:ind_time);
MT=MT(1:ind_time);
Hend=Event;
FT01=MT;
%**********************************************************************
%   Stable flow events
for i=1:length(StabilHend)
    Ind=find(Hend==StabilHend(i));%finds  indexes for stable flow
    pdt01_stab(i)=(mean(PDT01(Ind(1):Ind(end))));
    pdt02_stab(i)=(mean(PDT02(Ind(1):Ind(end))));%the average [mbar]
    pt01_stab(i)=mean(PT01(Ind(1):Ind(end)));
    pt02_stab(i)=mean(PT02(Ind(1):Ind(end)));
    pt03_stab(i)=mean(PT03(Ind(1):Ind(end)));
    tt02_stab(i)=mean(TT02(Ind(1):Ind(end)));    %C
    ft01_stab(i)=mean(FT01(Ind(1):Ind(end)))/3600;%kg/s

    pmid1 = pt02_stab(i)-pdt01_stab(i)/(2*1000);%[bar]
    pmid2=pt03_stab(i)+pdt02_stab(i)/(2*1000);

    my_stab1(i)=viscosity(pmid1,tt02_stab(i));
    my_stab2(i)=viscosity(pmid2,tt02_stab(i));

    Re_stab1(i,1)=4*ft01_stab(i)/(pi*my_stab1(i)*d);
    Re_stab2(i,1)=4*ft01_stab(i)/(pi*my_stab2(i)*d);

    z1_stab(i)=compressibility_factor(pmid1*1E5,'Air');
    z2_stab(i)=compressibility_factor(pmid2*1E5,'Air');

    rho1_stab(i)=pmid1*M*100/(z1_stab(i)*R*(tt02_stab(i)+273.15));
    rho2_stab(i)=pmid2*M*100/(z2_stab(i)*R*(tt02_stab(i)+273.15));
```

```
        v1_stab(i)=4*ft01_stab(i)/(rho1_stab(i)*pi*D^2);
        v2_stab(i)=4*ft01_stab(i)/(rho2_stab(i)*pi*D^2);

        DP1_stab(i)=pdt01_stab(i); %mbar
        DP2_stab(i)=pdt02_stab(i);

        P1_f1_stab(i)=pt02_stab(i)*1E5;  %bar til Pa
        P2_f1_stab(i)=(pt02_stab(i)-pdt01_stab(i)/1000)*1E5;
        P1_f2_stab(i)=(pt03_stab(i)+pdt02_stab(i)/1000)*1E5;
        P2_f2_stab(i)=pt03_stab(i)*1E5;
    end%for i=1:length(StabilHend)

    switch frictionfactor
        case 'Enkel'
            f1_stab = frictionFactorEnkel(pdt01_stab./1000,v1_stab,L1,d,rho1_stab);
            f2_stab = frictionFactorEnkel(pdt02_stab./1000,v2_stab,L2,d,rho2_stab);
            %     case 'corrected'
            % f1_stab=frictionFactor(D,M,rho1_stab,z1_stab,R,tt02_stab,L1,...
            %v1_stab,DP1_stab./1000);
            % f2_stab=frictionFactor(D,M,rho2_stab,z2_stab,R,tt02_stab,L2,...
            %v2_stab,DP2_stab./1000);
        case 'more'
            f1_stab=frictionFactorMore(D,M,ft01_stab,z1_stab,R,tt02_stab,L1,...
                P1_f1_stab,P2_f1_stab);
            f2_stab=frictionFactorMore(D,M,ft01_stab,z2_stab,R,tt02_stab,L2,...
                P1_f2_stab,P2_f2_stab);
    end
    % %*******************************************************************
    %Events for particle or fiber flow
    for i=1:length(PartHend)
        Ind=find(Hend==PartHend(i));%finner indekser for stabil flow
        pdt01_part(i)=(mean(PDT01(Ind(1):Ind(end))));
        pdt02_part(i)=(mean(PDT02(Ind(1):Ind(end))));
        pt01_part(i)=mean(PT01(Ind(1):Ind(end)));
        pt02_part(i)=mean(PT02(Ind(1):Ind(end)));
        pt03_part(i)=mean(PT03(Ind(1):Ind(end)));
        tt02_part(i)=mean(TT02(Ind(1):Ind(end)));    %C
        ft01_part(i)=mean(FT01(Ind(1):Ind(end)))/3600;%kg/s

        pmid1 = pt02_part(i)-pdt01_part(i)/(2*1000);
        pmid2=pt03_part(i)+pdt02_part(i)/(2*1000);

        my_part1(i)=viscosity(pmid1,tt02_part(i));
```

```
    my_part2(i)=viscosity(pmid2,tt02_part(i));

    Re_part1(i,1)=4*ft01_part(i)/(pi*my_part1(i)*d);
    Re_part2(i,1)=4*ft01_part(i)/(pi*my_part2(i)*d);

    z1_part(i)=compressibility_factor(pmid1*1E5,'Air');
    z2_part(i)=compressibility_factor(pmid2*1E5,'Air');
    rho1_part(i)=pmid1*M*100/(z1_part(i)*R*(tt02_part(i)+273.15));
    rho2_part(i)=pmid2*M*100/(z2_part(i)*R*(tt02_part(i)+273.15));
    v1_part(i)=4*ft01_part(i)/(rho1_part(i)*pi*D^2);
    v2_part(i)=4*ft01_part(i)/(rho2_part(i)*pi*D^2);
    DP1_part(i)=pdt01_part(i);
    DP2_part(i)=pdt02_part(i);

    P1_f1_part(i)=pt02_part(i)*1E5;  %bar til Pa
    P2_f1_part(i)=(pt02_part(i)-pdt01_part(i)/1000)*1E5;
    P1_f2_part(i)=(pt03_part(i)+pdt02_part(i)/1000)*1E5;
    P2_f2_part(i)=pt03_part(i)*1E5;
end%for i=1:length(PartHend)

switch frictionfactor
    case 'Enkel'
        f1_part = frictionFactorEnkel(pdt01_part./1000,v1_part,L1,d,rho1_part)
        f2_part = frictionFactorEnkel(pdt02_part./1000,v2_part,L2,d,rho2_part)
        %     case 'corrected'
        % f1_part=frictionFactor(D,M,rho1_part,z1_part,R,tt02_part,L1,...
        %v1_part,DP1_part./1000);
        % f2_part=frictionFactor(D,M,rho2_part,z2_part,R,tt02_part,L2,...
        %v2_part,DP2_part./1000);
    case 'more'
        f1_part=frictionFactorMore(D,M,ft01_part,z1_part,R,tt02_part,L1,...
            P1_f1_part,P2_f1_part);
        f2_part=frictionFactorMore(D,M,ft01_part,z2_part,R,tt02_part,L2,...
            P1_f2_part,P2_f2_part);
end
%**********************************************************************
DP_Cellarray{1,nr_DP}=f1_part;
DP_Cellarray{2,nr_DP}=f2_part;
DP_Cellarray{3,nr_DP}=Re_part1;
DP_Cellarray{4,nr_DP}=Re_part2;
DP_Cellarray{5,nr_DP}=Re_stab1;
DP_Cellarray{6,nr_DP}=f1_stab;
DP_Cellarray{7,nr_DP}=f2_stab;
```

```
    loggefilnavn_DP{1,nr_DP}=filnavn_plott;
end%for j=1:ant_DP_filer

[row_DP,col_DP]=size(DP_Cellarray);
for i=1:col_DP
    f1_part=DP_Cellarray{1,i};
    f2_part=DP_Cellarray{2,i};
    Re_part1=DP_Cellarray{3,i};
    Re_part2=DP_Cellarray{4,i};
    Re_stab1=DP_Cellarray{5,i};
    f1_stab=DP_Cellarray{6,i};
    f2_stab=DP_Cellarray{7,i};

    f_Prandtl_part = frictionFactor_Prandtl(Re_part1);
    f_Zagarola_part = frictionFactor_Zagarola(Re_part1);
    f_Colebrook_part=friction2(Re_part1,e_d,'colebrook');
    f_New_transission_friction_part=friction2(Re_part1,e_d,'new_transission',...
        draught_factor,n);
    f_Smooth_part=Smooth(Re_part1);

    f_Prandtl_stab = frictionFactor_Prandtl(Re_stab1);
    f_Zagarola_stab = frictionFactor_Zagarola(Re_stab1);
    f_Colebrook_stab=friction2(Re_stab1,e_d,'colebrook');
    f_New_transission_friction_stab=friction2(Re_stab1,e_d,'new_transission',...
        draught_factor,n);
    f_Smooth_stab=Smooth(Re_stab1);

    for nr_Re_f=1:ant_Re_f_filer
        [OPEN_NVE_REFERENCE,ax,akse,f_faktor,Add1,draught_factor,n,Chart,...
                e_d,plot_Re_f_basis,partikkel_basis,stabil_basis,...
                reference_file,saveat,particlelines,cutoff,solid,filnavn_plott,...
                Re_f_filnavn_plott,DP_test_nr,Partikkeltype,...
                tot_ant_DP_tester,frictionfactor,L1,L2,d,pipeno,p1,...
                Re_f_filnavn,filnavn,PartHend,StabilHend,...
                PartKalifilnavn,PartKalifilnavn_ID,Kalikurvefil]...
            = InputData(ant_DP_filer,nr_DP,nr_Re_f);

        [Re_basis,f1_basis,f2_basis,rho1_basis,rho2_basis,v1_basis,v2_basis]...
            =Re_f_Basedata(Re_f_filnavn,L1,L2,D,stabil_basis,frictionfactor,M,R)

        [A,index]=sort(Re_basis);
        fa=f1_basis(index);
        fb=f2_basis(index);
```

```
Re_basis=flipud(A);
f1_basis=flipud(fa);
f2_basis=flipud(fb);
f_Prandtl_basis = frictionFactor_Prandtl(Re_basis);
f_Zagarola_basis = frictionFactor_Zagarola(Re_basis);
f_Colebrook_basis=friction2(Re_basis,e_d,'colebrook');

%Adjust frictionfactors
f_Prandtl_part=f_Prandtl_part.*f_faktor;
f_Zagarola_part=f_Zagarola_part.*f_faktor;
f_Colebrook_part=f_Colebrook_part.*f_faktor;
f_Prandtl_stab=f_Prandtl_stab.*f_faktor;
f_Zagarola_stab=f_Zagarola_stab.*f_faktor;
f_Colebrook_stab=f_Colebrook_stab.*f_faktor;
f_Prandtl_basis=f_Prandtl_basis.*f_faktor;
f_Zagarola_basis=f_Zagarola_basis.*f_faktor;
f_Colebrook_basis=f_Colebrook_basis.*f_faktor;

[A,index]=sort(Re_part1);
fa=f1_part(index);
fb=f2_part(index);
f_Prandtl_part=flipud(f_Prandtl_part(index));
f_Zagarola_part=flipud(f_Zagarola_part(index));
f_Colebrook_part=flipud(f_Colebrook_part(index));
Re_part1=flipud(A);
f1_part=flipud(fa);
f2_part=flipud(fb);

[A,index]=sort(Re_stab1);
f1_stab=flipud(f1_stab(index));
f2_stab=flipud(f2_stab(index));
f_Prandtl_stab=f_Prandtl_stab(index);
f_Zagarola_stab=flipud(f_Zagarola_stab(index));
f_Colebrook_stab=flipud(f_Colebrook_stab(index));

if Chart==1
    figure(100)
    plot(Re_basis,f1_basis,'bx'),hold on
    plot(Re_basis,f_Prandtl_basis,'go',Re_basis,f_Zagarola_basis,'gs')
    hold on

    figure(200)
    plot(Re_basis,f2_basis,'bx'),hold on
```

```
        plot(Re_basis,f_Prandtl_basis,'go',Re_basis,f_Zagarola_basis,'gs')
        hold on
        if Add1==1
            figure(100)
            plot(Re_stab1,f1_stab,'b+'),hold on
            plot(Re_stab1,f_Prandtl_stab,'go',Re_stab1,f_Zagarola_stab,'gs')
            figure(200)
            plot(Re_stab1,f2_stab,'b+'),hold on
            plot(Re_stab1,f_Prandtl_stab,'go',Re_stab1,f_Zagarola_stab,'gs')
            figure(33)
            plot(1,2,'bx',1,5,'b+',1,3,'go',1,4,'gs')
            legend('Reference','Stable flow','Prandtl','Zagarola')
        else
            figure(33)
            plot(1,2,'bx',1,3,'go',1,4,'gs')
            legend('Reference','Prandtl','Zagarola')
        end%Add==1
    elseif Chart==2
        figure(100)
        plot(Re_basis,f1_basis,'bx'),hold on
        plot(Re_basis,f_Prandtl_basis,'go',Re_basis,f_Zagarola_basis,'gs',...
            Re_basis,f_Colebrook_basis,'ms'),hold on
        figure(200)
        plot(Re_basis,f2_basis,'bx'),hold on
        plot(Re_basis,f_Prandtl_basis,'go',Re_basis,f_Zagarola_basis,'gs',...
            Re_basis,f_Colebrook_basis,'ms'),hold on
        if Add1==1
            figure(100)
            plot(Re_stab1,f1_stab,'b+'),hold on
            plot(Re_stab1,f_Prandtl_stab,'go',Re_stab1,f_Zagarola_stab,'gs',...
                Re_stab1,f_Colebrook_stab,'ms')
            figure(200)
            plot(Re_stab1,f2_stab,'b+'),hold on
            plot(Re_stab1,f_Prandtl_stab,'go',Re_stab1,f_Zagarola_stab,'gs',...
                Re_stab1,f_Colebrook_stab,'ms')
            figure(33)
            plot(1,2,'bx',1,5,'b+',1,3,'go',1,4,'gs',1,6,'ms')
            legend('Reference','Stable flow','Prandtl','Zagarola','Colebrook')
        else
            figure(33)
            plot(1,2,'bx',1,3,'go',1,4,'gs',1,6,'ms')
            legend('Reference','Prandtl','Zagarola','Colebrook')
        end%Add==1
```

```
elseif Chart==3
    figure(100)
    plot(Re_part1,f1_part,'rx'),hold on
    plot(Re_part1,f_Colebrook_part,'ms'),hold on
    plot(Re_basis,f1_basis,'bx'),hold on
    plot(Re_basis,f_Colebrook_basis,'ms'),hold on

    figure(200)
    plot(Re_part1,f2_part,'rx'),hold on
    plot(Re_part1,f_Colebrook_part,'ms'),hold on
    plot(Re_basis,f2_basis,'bx'),hold on
    plot(Re_basis,f_Colebrook_basis,'ms'),hold on
    if Add1==1
        figure(100)
        plot(Re_stab1,f1_stab,'b+'),hold on
        plot(Re_stab1,f_Colebrook_stab,'ms')
        figure(200)
        plot(Re_stab1,f2_stab,'b+'),hold on
        plot(Re_stab1,f_Colebrook_stab,'ms')
        figure(33)
        plot(1,1,'rx',1,5,'b+',1,2,'bx',1,6,'ms')
        legend(solid,'Stable flow','Reference','Colebrook')

    else
        figure(33)
        plot(1,1,'rx',1,2,'bx',1,6,'ms')
        legend(solid,'Reference','Colebrook')
    end%Add==1

elseif Chart==4
    figure(100)
    plot(Re_part1,f1_part,'rx'),hold on
    plot(Re_part1,f_Prandtl_part,'go',Re_part1,f_Zagarola_part,'gs')
    hold on
    plot(Re_basis,f1_basis,'bx'),hold on
    plot(Re_basis,f_Prandtl_basis,'go',Re_basis,f_Zagarola_basis,'gs')
    hold on

    figure(200)
    plot(Re_part1,f2_part,'rx'),hold on
    plot(Re_part1,f_Prandtl_part,'go',Re_part1,f_Zagarola_part,'gs')
    hold on
    plot(Re_basis,f2_basis,'bx'),hold on
```

```
        plot(Re_basis,f_Prandtl_basis,'go',Re_basis,f_Zagarola_basis,'gs')
        hold on
        if Add1==1
            figure(100)
            plot(Re_stab1,f1_stab,'b+'),hold on
            plot(Re_stab1,f_Prandtl_stab,'go',Re_stab1,f_Zagarola_stab,'gs')
            figure(200)
            plot(Re_stab1,f2_stab,'b+'),hold on
            plot(Re_stab1,f_Prandtl_stab,'go',Re_stab1,f_Zagarola_stab,'gs')
            figure(33)
            plot(1,1,'rx',1,5,'b+',1,2,'bx',1,3,'go',1,4,'gs')
            legend(solid,'Stable flow','Reference','Prandtl','Zagarola')
        else
            figure(33)
            plot(1,1,'rx',1,2,'bx',1,3,'go',1,4,'gs')
            legend(solid,'Reference','Prandtl','Zagarola')
        end%Add==1

    elseif Chart==5
        figure(100)
        plot(Re_part1,f1_part,'rx'),hold on
        plot(Re_part1,f_Prandtl_part,'go',Re_part1,f_Zagarola_part,'gs',...
            Re_part1,f_Colebrook_part,'ms'),hold on
        plot(Re_basis,f1_basis,'bx'),hold on
        plot(Re_basis,f_Prandtl_basis,'go',Re_basis,f_Zagarola_basis,'gs',...
            Re_basis,f_Colebrook_basis,'ms'),hold on
        figure(200)
        plot(Re_part1,f2_part,'rx'),hold on
        plot(Re_part1,f_Prandtl_part,'go',Re_part1,f_Zagarola_part,'gs',...
            Re_part1,f_Colebrook_part,'ms'),hold on
        plot(Re_basis,f2_basis,'bx'),hold on
        plot(Re_basis,f_Prandtl_basis,'go',Re_basis,f_Zagarola_basis,'gs',...
            Re_basis,f_Colebrook_basis,'ms'),hold on
        if Add1==1
            figure(100)
            plot(Re_stab1,f1_stab,'b+'),hold on
            plot(Re_stab1,f_Prandtl_stab,'go',Re_stab1,f_Zagarola_stab,'gs',...
                Re_stab1,f_Colebrook_stab,'ms')
            figure(200)
            plot(Re_stab1,f2_stab,'b+'),hold on
            plot(Re_stab1,f_Prandtl_stab,'go',Re_stab1,f_Zagarola_stab,'gs',...
                Re_stab1,f_Colebrook_stab,'ms')
```

```
                figure(33)
                plot(1,1,’rx’,1,5,’b+’,1,2,’bx’,1,4,’go’,1,5,’gs’,1,6,’ms’)
                legend(solid,’Stable flow’,’Reference’,’Prandtl’,’Zagarola’...
                ,’Colebrook’)
            else
                figure(33)
                plot(1,1,’rx’,1,2,’bx’,1,4,’go’,1,5,’gs’,1,6,’ms’)
                legend(solid,’Reference’,’Prandtl’,’Zagarola’,’Colebrook’)
            end%Add==1

        else
        end%if
        figure(100)
        h=gca;a=axis(h);y=a(3:4)’;x=a(1:2)’;
        text(x(2)/5,y(2)*0.9,Re_f_filnavn_plott,’FontSize’,10)
        figure(200)
        h=gca;a=axis(h);y=a(3:4)’;x=a(1:2)’;
        text(x(2)/5,y(2)*0.9,Re_f_filnavn_plott,’FontSize’,10)

    end%nr_Re_f=1:ant_Re_f_filer

end%for i=1:col_DP

if ax==1
    figure(100)
    axis(akse)
    figure(200)
    axis(akse)
else
end

for i=1:length(loggefilnavn_DP)
    figure(100)
    h=gca;a=axis(h);y=a(3:4)’;x=a(1:2)’;
    text(x(2)/5,y(2)*0.9,loggefilnavn_DP{1,i},’FontSize’,10)
    figure(200)
    h=gca;a=axis(h);y=a(3:4)’;x=a(1:2)’;
    text(x(2)/5,y(2)*0.9,loggefilnavn_DP{1,i},’FontSize’,10)
end
```

```
%Plotting
%***********************************************************************
%***********************************************************************
%***********************************************************************
figure(100)
FigTekst=[sprintf('Pipe no.%2.0f',pipeno)];
h=gca;a=axis(h);y=a(3:4)';x=a(1:2)';
text(x(2)/5,y(2)*0.98,FigTekst,'FontSize',10)
text(x(2)/5,y(2)*0.95,Partikkeltype,'FontSize',10)
ylabel('f_1');
xlabel('Re');
text(x(2)/1.3,y(2)*0.97,'Data logfiles: ','FontSize',10)
%  gtext({'e/d=',num2str(e_d)})
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\Ref1.eps'],opts)
% print Ref1 -dpng

figure(200)
FigTekst=[sprintf('Pipe no.%2.0f',pipeno)];
h=gca;a=axis(h);y=a(3:4)';x=a(1:2)';
text(x(2)/5,y(2)*0.98,FigTekst,'FontSize',10)
text(x(2)/5,y(2)*0.95,Partikkeltype,'FontSize',10)
ylabel('f_2');
xlabel('Re');
text(x(2)/1.3,y(2)*0.97,'Data logfiles: ','FontSize',10)
% gtext({'e/d=',num2str(e_d)})
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\Ref2.eps'],opts)
% print Ref2 -dpng
%

%***********************************************************************
%***********************************************************************
%***********************************************************************
% gtext('Given diameter = 0.024129 m')
% gtext('Diameter adjusted= 0.0224 m')
```

### E.1.3 Main program - Plotting pressure, mass flow rate, density, velocity and volumetric flow rate.

```
%**********************************************************************
% DP test with particles.
% This script calculates and graphs the raw data for DP experiments,
% and the velocity, density and the volumetric flowrate

% Written by Ingvald Bårdsen
% Started writing 07.02.2004
% Finished 17.05.2004
%**********************************************************************
%Input your choices:
clear all,close all,clc
ant_filer=1;
nr_DP=1;
nr_Re_f=1;
%**********************************************************************
%This part is completely general
[OPEN_NVE_REFERENCE,ax,akse,f_faktor,Add1,draught_factor,n,Chart,e_d,...
        plot_Re_f_basis,partikkel_basis,stabil_basis,...
        reference_file,saveat,particlelines,cutoff,solid,filnavn_plott,...
        Re_f_filnavn_plott,DP_test_nr,Partikkeltype,...
        tot_ant_DP_tester,frictionfactor,L1,L2,d,pipeno,p1,...
        Re_f_filnavn,filnavn,PartHend,StabilHend,...
        PartKalifilnavn,PartKalifilnavn_ID,Kalikurvefil]...
    = InputData(ant_filer,nr_DP,nr_Re_f)

j=nr_DP;
data=load(filnavn);
M = 28.96235284;      %[g/mol]
R=8.31431;                 %[g*m*m/K*mol*s*s]
variables%Get variables from datafile
%Comment out with a %-sign to check for cutoff time
if cutoff==0
    ind_time=length(TIME)
else
    ind_time=find(abs(TIME-cutoff)==min(abs(TIME-cutoff)));
end
%Find where we wanna cuf off the axes
TIME=TIME(1:ind_time);
%Need to adjust the other vectors too...
PT04=PT04(1:ind_time);
```

```
PDT01=PDT01(1:ind_time);
PDT02=PDT02(1:ind_time);
PT01=PT01(1:ind_time);
PT02=PT02(1:ind_time);
PT03=PT03(1:ind_time);
PT05=PT05(1:ind_time);
Event=Event(1:ind_time);
TT02=TT02(1:ind_time);
Part_V=PART_V(1:ind_time);
Part_raw=PART_RAW(1:ind_time);
MT=MT(1:ind_time);

%***********************************************************************
%%Calculations
D=d;
A=pi*D^2/4;
pmid1 = PT02-(PDT01/1000)/2;
pmid2=PT03+(PDT02/1000)/2;
my1=viscosity(pmid1,TT02);
my2=viscosity(pmid2,TT02);
P1_f1=PT02*1E5;  %bar til Pa
P2_f1=(PT02-PDT01/1000)*1E5;
P1_f2=(PT03+PDT02/1000)*1E5;
P2_f2=PT03*1E5;
z1=compressibility_factor(pmid1*1E5,'Air');
z2=compressibility_factor(pmid2*1E5,'Air');
rho1=pmid1.*M*100./(z1.*R.*(TT02+273.15));
rho2=pmid2.*M*100./(z2.*R.*(TT02+273.15));
Re1=4.*(MT./3600)./(pi.*my1.*D);
Re2=4.*(MT./3600)./(pi.*my2.*D);
v1=4.*(MT./3600)./(rho1.*pi*D^2);
v2=4.*(MT./3600)./(rho2.*pi*D^2);
DP1=PDT01;
DP2=PDT02;
Q1=(MT./3600)./rho1;%m3/s
Q2=(MT./3600)./rho2;%m3/s
switch frictionfactor
    case 'Enkel'
        f1 = frictionFactorEnkel(PDT01./1000,v1,L1,D,rho1);
        f2 = frictionFactorEnkel(PDT02./1000,v2,L2,D,rho2);
        %     case 'corrected'
        %     f1=frictionFactor(D,M,rho1,z1,R,TT02,L1,v1,DP1);
        %     f2=frictionFactor(D,M,rho2,z2,R,TT02,L2,v2,DP2);
```

```
    case 'more'
        f1=frictionFactorMore(D,M,(MT./3600),z1,R,TT02,L1,P1_f1,P2_f1);
        f2=frictionFactorMore(D,M,(MT./3600),z2,R,TT02,L2,P1_f2,P2_f2);
end
%***************************************************************************
if reference_file==0
    %Plotting
    j=1;
    for i=1:length(PartHend)
        Ind=find(Event==PartHend(i));
        time_start_part=TIME(Ind(1));
        time_end_part=TIME(Ind(end));
        x_start=[time_start_part;time_start_part];
        x_end=[time_end_part;time_end_part];

        FigTekst=[sprintf('Pipe no.%2.0f',pipeno)];
        figure(1)
        subplot(4,1,1)
        plot(TIME,PDT01,TIME,PDT02)
        %axis([TIME(1) TIME(end) 15 40])
        title(['Data logfile: ',filnavn_plott]);
        ylabel('\Delta P [mbar]')
        legend('\Delta P_1','\Delta P_2',0)
        legend('boxoff')
        if particlelines==1
            hold on
            h=gca;a=axis(h);y=a(3:4)';
            plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
            plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
        else
        end
        subplot(4,1,2)
        plot(TIME,MT)
        ylabel('MT [kg/h air]')
        if particlelines==1
            hold on
            h=gca;a=axis(h);y=a(3:4)';
            plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
            plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
        else
        end
        subplot(4,1,3)
        plot(TIME,Part_raw)
```

```
ylabel('Part.raw [V]')
xlabel('Time [min]')
axis([TIME(1) TIME(end) 0 ceil(max(Part_raw))])
%axis([TIME(1) TIME(end) 0 1.3])

if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)';
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
subplot(4,1,4)
plot(TIME,Event,':')
ylabel('Event')
xlabel('Time [min]')
text(TIME(end)/11,Event(end)/1.1,FigTekst,'FontSize',8)
text(TIME(end)/11,Event(end)/1.3,Partikkeltype,'FontSize',8)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)';
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
for i=Event(1):Event(end)
    Ind_event=find(Event==i);
    x=TIME(Ind_event);
    x=(x(end)+x(1))/2;
    hold on
    text(x,i,num2str(i));
end
%pause
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\subplot1.eps'],opts)
% print -dpng subplot1
figure(2)
subplot(2,1,1)
plot(TIME,PT01,TIME,PT02,TIME,PT03,TIME,PT04,TIME,PT05)
title(['Data logfile: ',filnavn_plott]);
%text(TIME(end)/5,3,FigTekst,'FontSize',10)
```

```
%text(TIME(end)/5,2.9,Partikkeltype,'FontSize',10)
ylabel('Pressure [bar]')
legend('PT01','PT02','PT03','PT04','PT05',0)
h=gca;a=axis(h);y=a(3:4)';
if particlelines==1
    hold on
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
subplot(2,1,2)
plot(TIME,Event,':')
ylabel('Event')
xlabel('Time [min]')
text(TIME(end)/11,Event(end)/1.1,FigTekst,'FontSize',8)
text(TIME(end)/11,Event(end)/1.3,Partikkeltype,'FontSize',8)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)';
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
for i=Event(1):Event(end)
    Ind_event=find(Event==i);
    x=TIME(Ind_event);
    x=(x(end)+x(1))/2;
    hold on
    text(x,i,num2str(i));
end
%pause
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\subplotPT.eps'],opts)
% print -dpng subplotPT
figure(3)
subplot(2,1,1)
plot(TIME,rho1,TIME,rho2)
title(['Data logfile: ',filnavn_plott]);
%text(TIME(end)/5,max(rho1),FigTekst,'FontSize',10)
%text(TIME(end)/5,0.99*max(rho1),Partikkeltype,'FontSize',10)
legend('\rho_1','\rho_2')
```

```
ylabel('\rho [kg/m^3]')
%xlabel('Time [min]')
%axis([TIME(1) TIME(end) 1.3 1.7])
h=gca;a=axis(h);y=a(3:4)';
if particlelines==1
    hold on
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
subplot(2,1,2)
plot(TIME,Event,':')
ylabel('Event')
xlabel('Time [min]')
text(TIME(end)/11,Event(end)/1.1,FigTekst,'FontSize',8)
text(TIME(end)/11,Event(end)/1.3,Partikkeltype,'FontSize',8)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)';
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
for i=Event(1):Event(end)
    Ind_event=find(Event==i);
    x=TIME(Ind_event);
    x=(x(end)+x(1))/2;
    hold on
    text(x,i,num2str(i));
end
%pause
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\subplotrho.eps'],opts)
% print -dpng subplotrho
figure(4)
subplot(2,1,1)
plot(TIME,v1,TIME,v2)
title(['Data logfile: ',filnavn_plott]);
%text(TIME(end)/5,1.01*min(v2),FigTekst,'FontSize',10)
%text(TIME(end)/5,min(v2),Partikkeltype,'FontSize',10)
legend('v_1','v_2')
```

```
ylabel('v [m/s]')
if particlelines==1
    h=gca;a=axis(h);y=a(3:4)';
    hold on
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
subplot(2,1,2)
plot(TIME,Event,':')
ylabel('Event')
xlabel('Time [min]')
text(TIME(end)/11,Event(end)/1.1,FigTekst,'FontSize',8)
text(TIME(end)/11,Event(end)/1.3,Partikkeltype,'FontSize',8)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)';
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
for i=Event(1):Event(end)
    Ind_event=find(Event==i);
    x=TIME(Ind_event);
    x=(x(end)+x(1))/2;
    hold on
    text(x,i,num2str(i));
end
%pause
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\subplotv.eps'],opts)
% print -dpng subplotv
figure(5)
subplot(2,1,1)
plot(TIME,Q1,TIME,Q2)
title(['Data logfile: ',filnavn_plott]);
%text(TIME(end)/9,min(Q1)*1.07,FigTekst,'FontSize',10)
%text(TIME(end)/9,min(Q1)*1.06,Partikkeltype,'FontSize',10)
ylabel('Q [m^3/s]')
%xlabel('Time [min]')
legend('Q_1','Q_2')
```

```
%axis([TIME(1) TIME(end) 0.02 0.026])
if particlelines==1
    h=gca;a=axis(h);y=a(3:4)';
    hold on
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
subplot(2,1,2)
plot(TIME,Event,':')
ylabel('Event')
xlabel('Time [min]')
text(TIME(end)/11,Event(end)/1.1,FigTekst,'FontSize',8)
text(TIME(end)/11,Event(end)/1.3,Partikkeltype,'FontSize',8)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)';
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
for i=Event(1):Event(end)
    Ind_event=find(Event==i);
    x=TIME(Ind_event);
    x=(x(end)+x(1))/2;
    hold on
    text(x,i,num2str(i));
end
%pause
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\subplotQ.eps'],opts)
% print -dpng subplotQ
figure(6)
plot(TIME,PT01,TIME,PT02,TIME,PT03,TIME,PT04,TIME,PT05)
title(['Data logfile: ',filnavn_plott]);
text(TIME(end)/5,3,FigTekst,'FontSize',10)
text(TIME(end)/5,2.9,Partikkeltype,'FontSize',10)
ylabel('Pressure [bar]')
xlabel('Time [min]')
legend('PT01','PT02','PT03','PT04','PT05',0)
h=gca;a=axis(h);y=a(3:4)';
```

```
        if particlelines==1
            hold on
            plot([x_start(1);x_end(1)],[y(1);y(1)],’y’,’LineWidth’,4),hold on
            plot([x_start(1);x_end(1)],[y(2);y(2)],’y’,’LineWidth’,4)
        else
        end
        %pause
        % g=gcf;
        % set(g,’PaperUnits’,’centimeters’,’PaperType’,’A4’)
        % opts = struct(’FontMode’,’fixed’,’FontSize’,9,’Width’,13,’Color’,’rgb’);
        % exportfig(g,[saveat ’\PT.eps’],opts)
        % print -dpng PT
        j=j+1;
    end%for
    %**************************************************************************
    %**************************************************************************
    %**************************************************************************
    %**************************************************************************
    %**************************************************************************
    %**************************************************************************
else
    %Plotting
    j=1;
    for i=1:length(PartHend)
        Ind=find(Event==PartHend(i));
        time_start_part=TIME(Ind(1));
        time_end_part=TIME(Ind(end));
        x_start=[time_start_part;time_start_part];
        x_end=[time_end_part;time_end_part];
        FigTekst=[sprintf(’Pipe no.%2.0f’,pipeno)];
        figure(1)
        subplot(3,1,1)
        plot(TIME,PDT01,TIME,PDT02)
        %axis([TIME(1) TIME(end) 15 40])
        title([’Data logfile: ’,filnavn_plott]);
        ylabel(’\Delta P [mbar]’)
        legend(’\Delta P_1’,’\Delta P_2’,0)
        legend(’boxoff’)
        if particlelines==1
            hold on
            h=gca;a=axis(h);y=a(3:4)’;
            plot([x_start(1);x_end(1)],[y(1);y(1)],’y’,’LineWidth’,4),hold on
            plot([x_start(1);x_end(1)],[y(2);y(2)],’y’,’LineWidth’,4)
```

```
else
end
subplot(3,1,2)
plot(TIME,MT)
ylabel(’MT [kg/h air]’)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)’;
    plot([x_start(1);x_end(1)],[y(1);y(1)],’y’,’LineWidth’,4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],’y’,’LineWidth’,4)
else
end
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)’;
    plot([x_start(1);x_end(1)],[y(1);y(1)],’y’,’LineWidth’,4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],’y’,’LineWidth’,4)
else
end
subplot(3,1,3)
plot(TIME,Event,’:’)
ylabel(’Event’)
xlabel(’Time [min]’)
text(TIME(end)/11,Event(end)/0.9,FigTekst,’FontSize’,8)
text(TIME(end)/11,Event(end)/2.5,Partikkeltype,’FontSize’,8)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)’;
    plot([x_start(1);x_end(1)],[y(1);y(1)],’y’,’LineWidth’,4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],’y’,’LineWidth’,4)
else
end
for i=Event(1):Event(end)
    Ind_event=find(Event==i);
    x=TIME(Ind_event);
    x=(x(end)+x(1))/2;
    hold on
    text(x,i,num2str(i),’FontSize’,7);
end
%pause
% g=gcf;
% set(g,’PaperUnits’,’centimeters’,’PaperType’,’A4’)
% opts = struct(’FontMode’,’fixed’,’FontSize’,9,’Width’,15,’Color’,’rgb’);
```

```
% exportfig(g,[saveat '\subplot1.eps'],opts)
% print -dpng subplot1
figure(2)
subplot(2,1,1)
plot(TIME,PT01,TIME,PT02,TIME,PT03,TIME,PT04,TIME,PT05)
title(['Data logfile: ',filnavn_plott]);
%text(TIME(end)/5,3,FigTekst,'FontSize',10)
%text(TIME(end)/5,2.9,Partikkeltype,'FontSize',10)
ylabel('Pressure [bar]')
legend('PT01','PT02','PT03','PT04','PT05',0)
h=gca;a=axis(h);y=a(3:4)';
if particlelines==1
    hold on
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
subplot(2,1,2)
plot(TIME,Event,':')
ylabel('Event')
xlabel('Time [min]')
text(TIME(end)/11,Event(end)/1.1,FigTekst,'FontSize',8)
text(TIME(end)/11,Event(end)/1.3,Partikkeltype,'FontSize',8)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)';
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
for i=Event(1):Event(end)
    Ind_event=find(Event==i);
    x=TIME(Ind_event);
    x=(x(end)+x(1))/2;
    hold on
    text(x,i,num2str(i),'FontSize',7);
end
%pause
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\subplotPT.eps'],opts)
% print -dpng subplotPT
```

```
figure(3)
subplot(2,1,1)
plot(TIME,rho1,TIME,rho2)
title(['Data logfile: ',filnavn_plott]);
%text(TIME(end)/5,max(rho1),FigTekst,'FontSize',10)
%text(TIME(end)/5,0.99*max(rho1),Partikkeltype,'FontSize',10)
legend('\rho_1','\rho_2')
ylabel('\rho [kg/m^3]')
%xlabel('Time [min]')
%axis([TIME(1) TIME(end) 1.3 1.7])
h=gca;a=axis(h);y=a(3:4)';
if particlelines==1
    hold on
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
subplot(2,1,2)
plot(TIME,Event,':')
ylabel('Event')
xlabel('Time [min]')
text(TIME(end)/11,Event(end)/1.1,FigTekst,'FontSize',8)
text(TIME(end)/11,Event(end)/1.3,Partikkeltype,'FontSize',8)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)';
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
for i=Event(1):Event(end)
    Ind_event=find(Event==i);
    x=TIME(Ind_event);
    x=(x(end)+x(1))/2;
    hold on
    text(x,i,num2str(i),'FontSize',7);
end
%pause
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\subplotrho.eps'],opts)
% print -dpng subplotrho
```

```
figure(4)
subplot(2,1,1)
plot(TIME,v1,TIME,v2)
title(['Data logfile: ',filnavn_plott]);
%text(TIME(end)/5,1.01*min(v2),FigTekst,'FontSize',10)
%text(TIME(end)/5,min(v2),Partikkeltype,'FontSize',10)
legend('v_1','v_2')
ylabel('v [m/s]')
if particlelines==1
    h=gca;a=axis(h);y=a(3:4)';
    hold on
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
subplot(2,1,2)
plot(TIME,Event,':')
ylabel('Event')
xlabel('Time [min]')
text(TIME(end)/11,Event(end)/1.1,FigTekst,'FontSize',8)
text(TIME(end)/11,Event(end)/1.3,Partikkeltype,'FontSize',8)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)';
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
for i=Event(1):Event(end)
    Ind_event=find(Event==i);
    x=TIME(Ind_event);
    x=(x(end)+x(1))/2;
    hold on
    text(x,i,num2str(i),'FontSize',7);
end
%pause
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\subplotv.eps'],opts)
% print -dpng subplotv
figure(5)
subplot(2,1,1)
```

```
plot(TIME,Q1,TIME,Q2)
title(['Data logfile: ',filnavn_plott]);
%text(TIME(end)/9,min(Q1)*1.07,FigTekst,'FontSize',10)
%text(TIME(end)/9,min(Q1)*1.06,Partikkeltype,'FontSize',10)
ylabel('Q [m^3/s]')
%xlabel('Time [min]')
legend('Q_1','Q_2')
h=gca;a=axis(h);y=a(3:4)';
if particlelines==1
    hold on
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
subplot(2,1,2)
plot(TIME,Event,':')
ylabel('Event')
xlabel('Time [min]')
text(TIME(end)/11,Event(end)/1.1,FigTekst,'FontSize',8)
text(TIME(end)/11,Event(end)/1.3,Partikkeltype,'FontSize',8)
if particlelines==1
    hold on
    h=gca;a=axis(h);y=a(3:4)';
    plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
    plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
else
end
for i=Event(1):Event(end)
    Ind_event=find(Event==i);
    x=TIME(Ind_event);
    x=(x(end)+x(1))/2;
    hold on
    text(x,i,num2str(i),'FontSize',7);
end
%pause
% g=gcf;
% set(g,'PaperUnits','centimeters','PaperType','A4')
% opts = struct('FontMode','fixed','FontSize',9,'Width',15,'Color','rgb');
% exportfig(g,[saveat '\subplotQ.eps'],opts)
% print -dpng subplotQ
figure(6)
plot(TIME,PT01,TIME,PT02,TIME,PT03,TIME,PT04,TIME,PT05)
title(['Data logfile: ',filnavn_plott]);
```

```
        text(TIME(end)/5,3,FigTekst,'FontSize',10)
        text(TIME(end)/5,2.9,Partikkeltype,'FontSize',10)
        ylabel('Pressure [bar]')
        xlabel('Time [min]')
        legend('PT01','PT02','PT03','PT04','PT05',0)
        h=gca;a=axis(h);y=a(3:4)';
        if particlelines==1
            hold on
            plot([x_start(1);x_end(1)],[y(1);y(1)],'y','LineWidth',4),hold on
            plot([x_start(1);x_end(1)],[y(2);y(2)],'y','LineWidth',4)
        else
        end
        %pause
        % g=gcf;
        % set(g,'PaperUnits','centimeters','PaperType','A4')
        % opts = struct('FontMode','fixed','FontSize',9,'Width',13,'Color','rgb');
        % exportfig(g,[saveat '\PT.eps'],opts)
        % print -dpng PT
        j=j+1;
    end%for
end %if
```

## E.2 Help functions written

### E.2.1 The compressibility factor

```
function Z=compressibility_factor(P,gas)
% ------------------------------------------------------------------------
%     Comment : For 20C
%     Input arguments: P: Pressure [Pa], gas: 'Air' or 'N2'
%
%     Output arguments: Z , compressibility factor
%
%     Call command: Z=compressibility_factor(P,'Air')
%
%     Reference:    http://www.divetekadventures.com/Technical_zfactor
%                                                  _gascompress.htm
% Written by Ingvald Bårdsen
% Date: 10.02.2003
% Student at NTNU,Trondheim
% Dept.of Chemical Engineering
% email: ingvald@stud.ntnu.no
% ------------------------------------------------------------------------
P=P/6894.75728;%Converting from Pa to psia
x=P;
switch gas
    case 'Air'
        % Coefficients:
        p1 = -5.7593e-024;
        p2 = 1.3842e-019;
        p3 = -1.1513e-015;
        p4 = 3.3681e-012;
        p5 = 8.4151e-009;
        p6 = -2.3417e-005;
        p7 = 0.99922;
    case 'N2'
        p1 = -1.0139e-023;
        p2 = 1.3997e-019;
        p3 = -8.0604e-016;
        p4 = 1.2483e-012;
        p5 = 1.324e-008;
        p6 = -1.9966e-005;
        p7 = 0.99998;
end
Z=p1.*x.^6+p2.*x.^5+p3.*x.^4+p4.*x.^3+p5.*x.^2+p6.*x.^1+p7;
```

### E.2.2 Testing empty cell array

```
function [output,pos]=empty_cell(cellarray)
% -------------------------------------------------------------------------
%
%     Comment:To test if a cell array have some empty entries
%
%     Input arguments: cellarray that are tested
%
%
%     Output arguments:
%     -output is 1 if the cell array is full, and 0 for "open positions"
%     -pos vector with the position ([i;j]) for empty entrys
%
%     Call command: [output,pos]=empty_cell(cellarray)
%
% Written by Ingvald Bårdsen
% Date: 05.03.2004
% Student at NTNU,Trondheim
% Dept.of Chemical Engineering
% email: ingvald@stud.ntnu.no
% -------------------------------------------------------------------------
[rad,kol]=size(cellarray);
pos=[];
for i=1:rad
    for j=1:kol
        test=isempty(cellarray{i,j});
        a=find(test==1);
        if length(a)==length(test)
            b=[i;j];
            pos=[pos b];
        else
        end%if
    end%for
end%for
if isempty(pos)
    output=1;%The cell array is full
else
    output=0;%The cell array have "vacant" entrys
end%if
```

### E.2.3 Different friction equations

```
function friction=friction2(Re,e_d,method,varargin)
% ---------------------------------------------------------------------------
% This function calculates the moody friction based on
% the following equations:
%
%     Colebrook equation in transition area
%                  1           /  e/d       2.51 \
%            f = ------ + 2 log|------- + ----------|
%                 (1/2)        |  3.7          (1/2)|
%                f             \            Re f  /
%
%     Laminar flow
%                  64
%            f  = ----
%                  Re
%
%     Zagarola                     (1/2)
%               f = 1.889 log (Re f    ) - 0.3577
%
%     Prandtl                     (1/2)
%               f = 2.0 log (Re f    ) - 0.8
%
%     Input arguments
%     -Re : Reynoldsnumber
%     -e_d is the roughness of the pipe
%     -method: Either 'colebrook','laminar','zagarola' or 'prandtl'
%     -varargin: Only used for the 'new transmission friction',
%               or the smooth 'test friction'
%     Output arguments
%     -f: moody friction
%
%     Call command (example with use of colebrook)
%     friction=friction2(Re,e_d,'colebrook')
%
% Written by Ingvald Bårdsen
% Date: 26.03.04-20.05.04
% Student at NTNU,Trondheim
% Dept.of Chemical Engineering
% email: ingvald@stud.ntnu.no
% ---------------------------------------------------------------------------
[row,col]=size(Re)
X0=0.03*ones(row,col) %Initial guess
```

```
options=optimset('Display','off');   % Option to display output
switch method
    case 'colebrook'
        f_method=fsolve(@Colebrook,X0,options,e_d,Re);
    case 'laminar'
        f_method=64./Re;
    case 'zagarola'
        f_method =fsolve(@Zagarola,X0,options);
    case 'prandtl'
        f_method =fsolve(@Prandtl,X0,options);
        % case 'new_transission'
        %     draught_factor = varargin{1,1}; % Cell array indexing
        %     n = varargin{1,2};
        %     f_method=fsolve(@New_transission_friction,X0,...
        %options,e_d,Re,draught_factor,n);
        %
        % case 'test_friction'
        %     f_method=Smooth(Re);
end%switch
friction=f_method;
```

### E.2.4 Prandtl friction equation

```
function f = frictionFactor_Prandtl(Re);
% Written by Andre Strupstad 2003
numRows = length(Re);
j=1;
while j <= numRows
    F = 0.03;
    i = 1;
    while i < 1000
        fy = F - (1 / (2 * log10(Re(j) * (F ^ 0.5)) - 0.8)) ^ 2;
        if abs(fy) < 0.000001
            i=2000;
        else
            dfdy = 1 + (2 / (F * (2 * log(Re(j) * (F ^ 0.5)) - 0.8) ^ 3));
            F = F - fy / dfdy;
            i = i + 1;
        end
    end
    fric(j,1) = F;
    j=j+1;
```

```
end
 f=fric;
```

### E.2.5 Zagarola friction

```
function f = frictionFactor_Zagarola(Re);
% Written by Andre Strupstad 2003
numRows = length(Re);
j=1;
while j <= numRows
    F = 0.03;
    i = 1;
    while i < 1000
        fy = F - (1 / (1.889 * log10(Re(j) * (F ^ 0.5)) - 0.3577)) ^ 2;
        if abs(fy) < 0.000001
            i=2000;
        else
            dfdy =1+(1.889/(F*(1.889*log10(Re(j)*(F^0.5))-0.3577)^3));
            F = F - fy / dfdy;
            i = i + 1;
        end
    end
    fric(j,1) = F;
    j=j+1;
end
 f=fric;
```

### E.2.6 Simplified friction equation

```
function f = frictionFactorEnkel(dp,Vg,L,d,ro_g);
% Written by Andre Strupstad 2003
%   dp - differensialtrykk [bar]
%   Vg - gassgastighet [m/s]
%   L  - length of pipe [m]
%   d  - diameter of pipe [m]
%   ro_g - gasstetthet [kg/s]

%   Qg  - injection rate [m3/s]
%   Molmasse  - molecular weight [g/mol]
%   Tcelsius  - temperature [C]
%   T - temperatur [K]
%   l  - length [m]
%   d  - diameter [m]
```

```
%   gasstetthet - gasstetthet [kg/s]l
%   w - mass flow rate [kg/s]
%   wg - mass flow rate [g/s]
%   Output: Friksjonsfaktor
     idp = dp.*100000;        %[Pa]
     %R = 8.3143;               %R i forhold til trykk[Pa], volum [m3],
     %temperatur [K], Molmasse [g/mol]
     numRows = length(Vg);
     %w = gasstetthet.*Qg;      %Beregner mass flow rate [kg/s]
     %fra injection rate [m^3/s]
     %wg = w.*1000;             %[g/s]
     %fric = w;                 %Gir variabel fric samme dimensjon som w.
     i=1;
     while i <= numRows
         if Vg(i) == 0;
             fric(i,1)=0;
         else
             fric(i,1)=2*idp(i)*d/(L*ro_g(i)*Vg(i)*Vg(i));  %Moody == Darcy
             %fric(i,1)=idp(i)*d/(2*L*ro_g(i)*Vg(i)*Vg(i));  %Fanning
             %fric(i,1)=2*idp(i)*d/(L*ro_g(i)*Vg(i));
             if fric(i) < 0;
                 fric(i,1) = 0;
             end
         end
         i=i+1;
     end
     f = fric;
```

### E.2.7 Experimental friction equation

```
function f=frictionFactormore(D,M,m_dot,z,R,T,L,P1,P2)
% ---------------------------------------------------------------------------
%     Comment: Calculated the experimental friction coefficient given by
%
%                                                 /P2\
%                    2  5   /  2     2\   2 D ln|----|
%                  pi   D  M \P1  - P2 /          \P1/
%              f = -------------------- + ----------
%                    16 m_dot z R T L         L
%
%     Input arguments
%     -D:diameter pipe [m]
%     -M:molar weight [kg/kmole]
```

```
%     -m_dot: flow rate [kg/s]
%     -z:compressibility factor
%     -R:Gas constant 8.314 [J/Kmole]
%     -T:Temperature [K]
%     -P:Pressure [Pa]
%
%     Output arguments
%     -f: Moody friction factor
%
% Written by Ingvald Bårdsen
% Date:26.03.2004
% Student at NTNU,Trondheim
% Dept.of Chemical Engineering
% email: ingvald@stud.ntnu.no
% ----------------------------------------------------------------------------
M=M/1000;
     n = length(P1);
     i=1;
     for i=1:n
         if m_dot(i) == 0;
             f(i,1)=0;
         else
             f(i,1)=((pi^2*D^5*M)/(16*m_dot(i)^2*z(i)*R*(T(i)+273.15)*L))...
                 *(P1(i)^2-P2(i)^2)+(2*D/L)*log(P2(i)/P1(i));  %Moody
              if f(i) < 0;
                 f(i,1) = 0;
             end
         end
         i=i+1;
     end
```

### E.2.8 Lab Diary

```
function [partikkel_basis,stabil_basis,Re_f_filnavn,Re_f_filnavn_plott,...
        solid,Partikkeltype,filnavn,filnavn_plott,PartHend,StabilHend]...
    = Lab_Diary(OPEN_NVE_REFERENCE,logfiles_DP,logfiles_Re_f,nr_DP,nr_Re_f)
% ---------------------------------------------------------------------------------
% Comment: Information about the experiments performed should be implemented
% in this function.

% nr1:0402051407   This is the codes for the DP experiments.
% nr2:0404281254
% nr3:0404290946
```

```
% nr4:0404291144
% nr5:0404300922
% nr6:0404301001
% nr7:0405030925
% nr8:0405030958
% nr9:0405031242
% nr10:0405031330
% nr11:0405070828
% nr12:0405071046
% nr13:0405071129
% nr14:0405100852
% nr15:0405100917
%nr16='0405110925';
%nr17='0405131036';
%nr18='0405131110';
%nr19='0405131430';

% Written by Ingvald Bårdsen
% Date: 01.02.2004-16.05.2004
% Student at NTNU,Trondheim
% Dept.of Chemical Engineering
% email: ingvald@stud.ntnu.no
% ----------------------------------------------------------------------------

logfile_DP=logfiles_DP{1,nr_DP};
logfile_Re_f=logfiles_Re_f{1,nr_Re_f};
%*************************************************************************
%Re f test log files
%*************************************************************************
if logfile_Re_f=='0402050918'
    solid='Air';
    Re_f_filnavn=('0402050918_Re_f.txt');
    Re_f_filnavn_plott =('0402050918\_Re\_f.txt');
    partikkel_basis=[1 3 5 7 9 11 13 15 17 19 21];%Dont use
    stabil_basis=[1 3 5 7 9 11 13 15 17 19 21];

elseif logfile_Re_f=='0402090938'
    solid='Air';
    Re_f_filnavn=('0402090938_Re_f.txt');
    Re_f_filnavn_plott =('0402090938\_Re\_f.txt');
    partikkel_basis=[1 3 5 7 9 11 13 15 17];%Dont use
    stabil_basis=[1 3 5 7 9 11 13 15 17];
```

```
elseif logfile_Re_f=='0402191052'
    solid='Air';
    Re_f_filnavn=('0402191052_Re_f.txt');
    Re_f_filnavn_plott =('0402191052\_Re\_f.txt');
    partikkel_basis=[1 3 5 7 9 11 13 15];%Dont use
    stabil_basis=[1 3 5 7 9 11 13 15];

elseif logfile_Re_f=='0402191303'
    solid='Air';
    Re_f_filnavn=('0402191303_Re_f.txt');
    Re_f_filnavn_plott =('0402191303\_Re\_f.txt');
    partikkel_basis=[1 3 5 7 9 11 13 15 17];%Dont use
    stabil_basis=[1 3 5 7 9 11 13 15];% 17];

elseif logfile_Re_f=='0403100757'
    solid='Air';
    Re_f_filnavn=('0403100757_Re_f.txt');
    Re_f_filnavn_plott =('0403100757\_Re\_f.txt');
    partikkel_basis=[1 3 5 7 9 11 13 15 17 19];%Dont use
    stabil_basis=[1 3 5 7 9 11 13 15 17 19];

elseif logfile_Re_f=='0405031043'
    solid='Air';
    Re_f_filnavn=('0405031043_Re_f.txt');
    Re_f_filnavn_plott =('0405031043\_Re\_f.txt');
    partikkel_basis=[1 3 5 7 9 11 13 15 17];%Do not plot particles
    stabil_basis=[1 3 5 7 9 11 13 15 17];

elseif logfile_Re_f=='0405031524'
    solid='Air-NVE open';
    Re_f_filnavn=('0405031524_Re_f.txt');
    Re_f_filnavn_plott =('0405031524\_Re\_f.txt');
    partikkel_basis=[1 6 11 16 21 26 31];
    if OPEN_NVE_REFERENCE==1
        stabil_basis=partikkel_basis;
    else
        stabil_basis=[3 5 8 10 13 15 18 20 23 25 28 30 33];
    end

elseif logfile_Re_f=='0405071240'
    Re_f_filnavn =('0405071240_Re_f.txt');
    Re_f_filnavn_plott =('0405071240\_Re\_f');
    partikkel_basis=[1 6 11 16 21 26 31];
```

```
    if OPEN_NVE_REFERENCE==1
        stabil_basis=partikkel_basis;
    else
        stabil_basis=[3 5 8 10 13 15 18 20 23 25 28 30 33];
    end
    solid='Air-NVE open';

elseif logfile_Re_f=='0405101051'
    Re_f_filnavn =('0405101051_Re_f.txt');
    Re_f_filnavn_plott =('0405101051\_Re\_f');
    partikkel_basis=[1 6 11 16 21 26 31];
    if OPEN_NVE_REFERENCE==1
        stabil_basis=partikkel_basis;
    else
        stabil_basis=[0 3 5 8 10 13 15 18 20 23 25 28 30 33];
    end
    solid='Air-NVE open';

elseif logfile_Re_f=='0405111138'
    Re_f_filnavn =('0405111138_Re_f.txt');
    Re_f_filnavn_plott =('0405111138\_Re\_f');
    partikkel_basis=[1 6 11 16 21 26 31];
    if OPEN_NVE_REFERENCE==1
        stabil_basis=partikkel_basis;
    else
        stabil_basis=[0 3 5 8 10 13 15 18 20 23 25 28 30 33];
    end
    solid='Air-NVE open';

elseif logfile_Re_f=='0405131604'
    Re_f_filnavn =('0405131604_Re_f.txt');
    Re_f_filnavn_plott =('0405131604\_Re\_f');
    partikkel_basis=[4 9 14 19 24 29 34];
    if OPEN_NVE_REFERENCE==1
        stabil_basis=partikkel_basis;
    else
        stabil_basis=[3 6 8 11 13 16 18 21 23 26 28 31 36];
    end
    solid='Air-NVE open';

end
%***********************************************************************
%DP logfiles
```

```
%***************************************************************************
if logfile_DP=='nr 1'
    filnavn =('0402051407_DP.txt');
    filnavn_plott =('0402051407\_DP.txt');
    PartHend =[2 5 8 11];% 14];
    StabilHend = [4 7 10];% 13];
    Partikkeltype=strcat('Glassbeads 007');
    solid='Particles';

elseif logfile_DP=='nr 2'
    filnavn =('0403151200_DP.txt');
    filnavn_plott =('0403151200\_DP.txt');
    PartHend =[2 5 8 11 14];
    StabilHend = [1 4 7 10 13 16]; %Not really stable
    Partikkeltype=strcat('Glassbeads 005');
    solid='Particles';

elseif logfile_DP=='nr 3'
    filnavn =('0404290946_DP_fiber.txt');
    filnavn_plott =('0404290946\_DP\_fiber.txt');
    PartHend=[3 6 9 12 15 18];  %
    StabilHend=[5 8 11 14 17 20];%
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr 4'
    filnavn =('0404291144_DP_fiber.txt');
    filnavn_plott =('0404291144\_DP\_fiber.txt');
    PartHend=[1 2 6 10 14 18 22];  %
    StabilHend=[5 9 13 17 21 24];%
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr 5'
    filnavn =('0404300922_DP_fiber.txt');
    filnavn_plott =('0404300922\_DP\_fiber.txt');
    PartHend=[4 8 11 14 17 20];
    StabilHend=[3 7 10 13 16 19 22];
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr 6'
    filnavn =('0404301001_DP_fiber.txt');
```

```
    filnavn_plott =('0404301001\_DP\_fiber.txt');
    PartHend=[1 4 7 10 13 16];
    StabilHend=[0 3 6 9 12 15];
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr 7'
    filnavn =('0405030925_DP_fiber.txt');
    filnavn_plott =('0405030925\_DP\_fiber.txt');
    PartHend=[1 4 7 10 13];
    StabilHend=[0 3 6 9 12 15];
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr 8'
    filnavn =('0405030958_DP_fiber.txt');
    filnavn_plott =('0405030958\_DP\_fiber.txt');
    PartHend=[1 4 7 10 13];
    StabilHend=[0 3 6 9 12 15];
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr 9'
    filnavn =('0405031242_DP_fiber.txt');
    filnavn_plott =('0405031242\_DP\_fiber.txt');
    PartHend=[1 4 7 10 13];
    StabilHend=[0 3 6 9 12 15];
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr10'
    filnavn =('0405031330_DP_fiber.txt');
    filnavn_plott =('0405031330\_DP\_fiber.txt');
    PartHend=[1 4 7 10 13];
    StabilHend=[0 3 6 9 12 15];
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr11'
    filnavn =('0405070828_DP_fiber.txt');
    filnavn_plott =('0405070828\_DP\_fiber.txt');
    PartHend=[1 4 7 10 13 16];
    StabilHend=[0 3 6 9 12 15];
```

```
    Partikkeltype=strcat('Polyethylene 5/15 \mum');
    solid='Fiber';

elseif logfile_DP=='nr12'
    filnavn =('0405071046_DP_fiber.txt');
    filnavn_plott =('0405071046\_DP\_fiber.txt');
    PartHend=[1 4 7 10 13 16];
    StabilHend=[0 3 6 9 12 15];
    Partikkeltype=strcat('Polyethylene 5/15 \mum');
    solid='Fiber';

elseif logfile_DP=='nr13'
    filnavn =('0405071129_DP_fiber.txt');
    filnavn_plott =('0405071129\_DP\_fiber.txt');
    PartHend=[1 4 7 10 13 16];
    StabilHend=[0 3 6 9 12 15];
    Partikkeltype=strcat('Polyethylene 5/15 \mum');
    solid='Fiber';

elseif logfile_DP=='nr14'
    filnavn =('0405100852_DP_fiber.txt');
    filnavn_plott =('0405100852\_DP\_fiber.txt');
    PartHend=[1 4 7];
    StabilHend=[0 3 6 9];
    Partikkeltype=strcat('Polyethylene 5/15 \mum');
    solid='Fiber';

elseif logfile_DP=='nr15'
    filnavn =('0405100917_DP_fiber.txt');
    filnavn_plott =('0405100917\_DP\_fiber.txt');
    PartHend=[1 6 11 16 21 26];
    StabilHend=[0 3 5 8 10 13 15 18 20 23 25 28];
    Partikkeltype=strcat('Polyethylene 5/15 \mum');
    solid='Fiber';

elseif logfile_DP=='nr16'
    filnavn =('0405110925_DP_fiber.txt');
    filnavn_plott =('0405110925\_DP\_fiber.txt');
    PartHend=[1 6 11 16 21 26 31 36 39];%36 39low injection
    StabilHend=[0 3 5 8 10 13 15 18 20 23 25 28];
    Partikkeltype=strcat('Polyethylene 5/15 \mum');
    solid='Fiber';
```

```
elseif logfile_DP=='nr17'
    filnavn =('0405121626_DP_fiber.txt');
    filnavn_plott =('0405121626\_DP\_fiber.txt');
    PartHend=[6 11 16 21 26 31];
    StabilHend=[0 3 5 8 10 13 15 18 20 23 25 28 33];%No stable Events for ref.
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr18'
    filnavn =('0405121650_DP_fiber.txt');
    filnavn_plott =('0405121650\_DP\_fiber.txt');
    PartHend=[6 11 16 21 26 31 36];%36?
    StabilHend=[0 3 5 8 10 13 15 18 20 23 25 28 33 35 38 41];No stable...
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr19'
    filnavn =('0405131036_DP_fiber.txt');
    filnavn_plott =('0405131036\_DP\_fiber.txt');
    PartHend=[1 3 5 7 9 11 13];
    StabilHend=[1 3 5 7 9 11 13]; %No stable Events for reference
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr20'
    filnavn =('0405131110_DP_fiber.txt');
    filnavn_plott =('0405131110\_DP\_fiber.txt');
    PartHend=[1 6 11 16 21 26 31];
    StabilHend=[0 3 5 8 10 13 15 18 20 23 25 28 30 33];
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr21'
    filnavn =('0405131430_DP_fiber.txt');
    filnavn_plott =('0405131430\_DP\_fiber.txt');
    PartHend=[1 4 9 14 19 24 29 34];%Empty 34?
    StabilHend=[3 5 8 11 13 16 18 21 23 26 28 31 33 36];
    Partikkeltype=strcat('Polyamide 3.3 dtex 0.3mm');
    solid='Fiber';

elseif logfile_DP=='nr22'
    solid='Air-NVE open';
    filnavn=('0405031524_Re_f.txt');
```

```
    filnavn_plott =('0405031524\_Re\_f.txt');
    PartHend=[1 6 11 16 21 26 31];
    StabilHend=[3 5 8 10 13 15 18 20 23 25 28 30 33];
    Partikkeltype=strcat('Only air')
else
end %if
```

### E.2.9 Reference friction function

```
function [Re,f1,f2,rho1,rho2,v1,v2]=Re_f_Basedata(Re_f_filnavn,L1,L2,...
    D,stabil_basis,frictionfactor,M,R)
% ------------------------------------------------------------------------------
%    Comment:
%    This function calculates the Reynoldsnumber and the friction factors from
%    experimental data using either frictionFactor_Enkel or frictionFactor
%
%    Input arguments:
%    Re_f_filnavn:the filename for txt. file with data
%    L1,L2:length over testsection [m]
%    D:Pipe diameter [m]
%    stabil_basis: array with event nr. for stable flow
%    frictionfactor: choice of friction equation 'Enkel'=frictionFactorEnkel,...
%                   'corrected'=frictionFactor
%    M: Molar weight g/mol
%    R:Gas constant J/Kmol
%
%    Call command:
%    [Re,f1,f2,rho1,rho2,v1,v2]=Re_f_Basedata(Re_f_filnavn,L1,L2,D,...
%                          stabil_Hend_friksjon_basis,'corrected',M,R)
%
% Written by Ingvald Bårdsen
% Date: 03.03.2004
% Student at NTNU,Trondheim
% Dept.of Chemical Engineering
% email: ingvald@stud.ntnu.no
% -----------------------------------------------------------------------------
loggedata=load(Re_f_filnavn);
tid(:,1) = loggedata(:,4);    % Tid
PDT01(:,1) = loggedata(:,7); %Differensial trykk mbar
PDT02(:,1) = loggedata(:,8); %Differensial trykk mbar
PT01(:,1) = loggedata(:,9);%Absolutt Trykk i bar (I partikkeltank)
PT02(:,1) = loggedata(:,10);%Absolutt Trykk i bar (Ved begynnelsen av dp måling)
PT03(:,1) = loggedata(:,11);%Absolutt Trykk i bar (Ved slutten av dp måling)%
```

```
FT01(:,1) = loggedata(:,21); %Masserate [kg/h]
TT01(:,1) = loggedata(:,20); %Temperatur fuktighetsmåler, før avtak [C]
TT02(:,1) = loggedata(:,13); %Temperatur ved bend [C]
TT03(:,1) = loggedata(:,14); %Temperatur ved etter dp målinger [C]
MT01(:,1) = loggedata(:,19); %Fuktighetsmåling
Part(:,1) = loggedata(:,12); %Partikkel måling
Hend(:,1) = loggedata(:,22);%Hendelser
PartRow(:,1) = loggedata(:,5);
%PartKont = loggedata(:,26)  Fikses fra PartRow ovenfor
Ventil(:,1) = loggedata(:,25);

for i=1:length(stabil_basis)
    Ind=find(Hend==stabil_basis(i));%finds indexes for stable flow
    pdt01(i)=(mean(PDT01(Ind(1):Ind(end)))/1000);%stable flow
    pdt02(i)=(mean(PDT02(Ind(1):Ind(end)))/1000);%
    pt01(i)=mean(PT01(Ind(1):Ind(end)));
    pt02(i)=mean(PT02(Ind(1):Ind(end)));
    pt03(i)=mean(PT03(Ind(1):Ind(end)));
    tt02(i)=mean(TT02(Ind(1):Ind(end)));    %C
    ft01(i)=mean(FT01(Ind(1):Ind(end)))/3600;%kg/s

    pmid1(i) = pt02(i)-pdt01(i)/2;
    pmid2(i)=pt03(i)+pdt02(i)/2;
    my(i)=viscosity(pmid2(i),tt02(i));
    z(i)=compressibility_factor(pmid2(i)*1E5,'Air');
    rho(i)=pmid2(i)*M*100/(z(i)*R*(tt02(i)+273.15));

    P1_f1(i)=pt02(i)*1E5;  %bar til Pa
    P2_f1(i)=(pt02(i)-pdt01(i))*1E5;
    P1_f2(i)=(pt03(i)+pdt02(i))*1E5;
    P2_f2(i)=pt03(i)*1E5;
    z1(i)=compressibility_factor(pmid1(i)*1E5,'Air');
    z2(i)=compressibility_factor(pmid2(i)*1E5,'Air');
    rho1(i)=pmid1(i)*M*100/(z1(i)*R*(tt02(i)+273.15));
    rho2(i)=pmid2(i)*M*100/(z2(i)*R*(tt02(i)+273.15));

    Re(i,1)=4*ft01(i)/(pi*my(i)*D);
    v(i)=4*ft01(i)/(rho(i)*pi*D^2);
    v1(i)=4*ft01(i)/(rho1(i)*pi*D^2);
    v2(i)=4*ft01(i)/(rho2(i)*pi*D^2);
    DP1(i)=pdt01(i);
    DP2(i)=pdt02(i);
end
```

```
switch frictionfactor
    case 'Enkel'
        f1 = frictionFactorEnkel(pdt01,v,L1,D,rho);
        f2 = frictionFactorEnkel(pdt02,v,L2,D,rho);
    case 'corrected'
        f1=frictionFactor(D,M,rho1,z1,R,tt02,L1,v1,DP1);
        f2=frictionFactor(D,M,rho2,z2,R,tt02,L2,v2,DP2);
    case 'more'
        f1=frictionFactorMore(D,M,ft01,z1,R,tt02,L1,P1_f1,P2_f1);
        f2=frictionFactorMore(D,M,ft01,z2,R,tt02,L2,P1_f2,P2_f2);
end
```

### E.2.10 Reynoldsnumber and friction- Cellarray

```
filename=['Re_f_data_',Partikkeltype];
eksisterer=exist([filename '.mat']);
if eksisterer==2
    load([filename '.mat'])
    [output,pos]=empty_cell(Re_f_cellarray_DP_tester);
    if output==1 %full cellarray
        color_code='bgrcmyk';%Color code
        plotting_code='o.x+*sdv^<>ph-:';
        tell=1;
        [rad,kol]=size(Re_f_cellarray_DP_tester);
        for i=2:rad
            Navn_DP_fil=Re_f_cellarray_DP_tester{i,1};
            Navn_Re_fil=Re_f_cellarray_DP_tester{i,2};
            f1_basis=Re_f_cellarray_DP_tester{i,3};
            f2_basis=Re_f_cellarray_DP_tester{i,4};
            Re_basis=Re_f_cellarray_DP_tester{i,5};
            f1_part=Re_f_cellarray_DP_tester{i,6};
            f2_part=Re_f_cellarray_DP_tester{i,7};
            Re_part=Re_f_cellarray_DP_tester{i,8};

            if rad>length(color_code)
                x=['b' plotting_code(tell)];
            else
                x=[color_code(tell) 'o'];
            end%if

            plot(Re_basis,f1_basis,x)
            tell=tell+1;
```

```
            hold on
        end%for

    else disp('Remember to update DP_test_nr...')
        Re_f_cellarray_DP_tester{DP_test_nr+1,1}=filnavn;
        Re_f_cellarray_DP_tester{DP_test_nr+1,2}=Re_f_filnavn;
        Re_f_cellarray_DP_tester{DP_test_nr+1,3}=f1_basis;
        Re_f_cellarray_DP_tester{DP_test_nr+1,4}=f2_basis;
        Re_f_cellarray_DP_tester{DP_test_nr+1,5}=Re_basis;
        Re_f_cellarray_DP_tester{DP_test_nr+1,6}=f1_part_mean;
        Re_f_cellarray_DP_tester{DP_test_nr+1,7}=f2_part_mean;
        Re_f_cellarray_DP_tester{DP_test_nr+1,8}=Re_part_mean;
        save(filename,'Re_f_cellarray_DP_tester')
    end%if

else
    Re_f_cellarray_DP_tester=cell(tot_ant_DP_tester+1,8);
    Re_f_cellarray_DP_tester{1,1}='Name DP file';
    Re_f_cellarray_DP_tester{1,2}='Name Re-f file';
    Re_f_cellarray_DP_tester{1,3}='f1 basis';
    Re_f_cellarray_DP_tester{1,4}='f2 basis';
    Re_f_cellarray_DP_tester{1,5}='Re basis';
    Re_f_cellarray_DP_tester{1,6}='f1 part';
    Re_f_cellarray_DP_tester{1,7}='f2 part';
    Re_f_cellarray_DP_tester{1,8}='Re part';

    Re_f_cellarray_DP_tester{DP_test_nr+1,1}=filnavn;
    Re_f_cellarray_DP_tester{DP_test_nr+1,2}=Re_f_filnavn;
    Re_f_cellarray_DP_tester{DP_test_nr+1,3}=f1_basis;
    Re_f_cellarray_DP_tester{DP_test_nr+1,4}=f2_basis;
    Re_f_cellarray_DP_tester{DP_test_nr+1,5}=Re_basis;
    Re_f_cellarray_DP_tester{DP_test_nr+1,6}=f1_part_mean;
    Re_f_cellarray_DP_tester{DP_test_nr+1,7}=f2_part_mean;
    Re_f_cellarray_DP_tester{DP_test_nr+1,8}=Re_part_mean;
    save(filename,'Re_f_cellarray_DP_tester')
end%if
```

### E.2.11 Split array

```
function split_array=reduce_array(array)
% --------------------------------------------------------------------------------
%     Comment: This function takes an array and splits it up according to:
%     ex. array=[1 2 3 4 30 31 32 383 384 385]
```

```
%     to [1 2 3 4] and [30 31 32] and [383 384 385] in a cell array
%
%     Input arguments:- array that are going to be divided
%
%     Output arguments: split_array, cell array
%
%     Call command: split_array=reduce_array(array)
%
%
% Written by Ingvald Bårdsen
% Date: 19.02.2004
% Student at NTNU,Trondheim
% Dept.of Chemical Engineering
% email: ingvald@stud.ntnu.no
% ---------------------------------------------------------------------------
p=1;
j=1;
X=array(1);
for i=2:length(array)
    if (array(i)-array(i-1))==1
        X(j+1)=array(i);
        j=j+1;
    else
    Y{1,p}=X;
    clear X
    p=p+1;
    j=1;
  X=array(i);
    end
end
Y{p}=X;
j=1;
for i=2:length(Y)
    if (Y{i}(1)-Y{i-1}(1)<10 | Y{i}(1)-Y{i-1}(end)<10)
    Y{i}=[Y{i-1} Y{i}];
    Y{i-1}=[];
    else
    end
end
for i=1:length(Y)

    a=isempty(Y{i});
    if a==1
```

```
    dt_ind_start(i)=0;
    dt_ind_end(i)=0;
    else
    dt_ind_start(i)=Y{i}(1);
    dt_ind_end(i)=Y{i}(end);
    end
end
j=1;a=[];
for i=1:length(dt_ind_start)
    if dt_ind_start(i)~=0
    a(j)=dt_ind_start(i);
    b(j)=dt_ind_end(i);
    split_array{1,j}=[a(j):b(j)];
    j=j+1;
    else
    end
end
```

### E.2.12 Pipe data

```
function [L1,L2,d] = RorData(pipeno)
%Inneholder dp1(L1) og dp2(L2) lengder og diameteren av de ulike rørene.
%
%
% Skrevet av Andre Strupstad 2003 - 2004
%L1=Lengde av rett rørstrekning [m] der dp1 cellen måler over rør
%L2=Lengde av rett rørstrekning [m] der dp2 cellen måler over rør
%d=%Rørdiameter på testseksjon rør

if pipeno == 14
    %Rørkonstanter for rør 14
    L1 = 1.958;
    L2 = 1.851;
    d = 0.02415;
end

if pipeno == 5
    %Rørkonstanter for rør 5
    L1 = 1.90;
    L2 = 1.90;
    d = 0.02414;
end
```

```
if pipeno == 10
    %Rørkonstanter for rør 10
    L1 = 1.904;
    L2 = 1.904;
   % d = 0.024129;
%d=0.0241;
   d=0.0224;
%    d=0.02205;
end

if pipeno == 9
    %Rørkonstanter for rør 9
    L1 = 1.904;
    L2 = 1.904;
    d = 0.024;
end

if pipeno == 140

    L1 = 1.958;
    L2 = 1.851;
     d = 0.02415;
end

if pipeno == 100
    %Rørkonstanter for rør 10
    L1 = 1.904;
    L2 = 1.904;
    d = 0.0225;
end

if pipeno == 101
    %Rørkonstanter for rør 10
    L1 = 1.904;
    L2 = 1.904;
    d = 0.024;

end

    if pipeno == 42
    L1 = 1.904;
    L2 = 1.904;
    d = 0.024;
```

```
    %d=0.0220
    end
```

### E.2.13 Viscosity

```
function my=viscosity(P,T)
% -------------------------------------------------------------------------
%     Viscosity calculator for dry air
%
%     Input arguments: -P [bar]
%                      -T [C]
%
%     Output arguments:- mu (viscosity ) Ns/m^2
%
%     Call command:    - mu=viscosity(P,T)
%
%     Reference :Jones, F. E., "Techniques and Topics in Flow Measurement,"
%     CRC Press, Boca Raton, Florida, 1995.
%
% Written by Ingvald Bårdsen
% Date: 06.02.2004
% Student at NTNU,Trondheim
% Dept.of Chemical Engineering
% email: ingvald@stud.ntnu.no
% -------------------------------------------------------------------------
P=P.*(1/14.5037738); %Conversion from BAR to PSI
my=0.0170257 + (6.05434*1E-5).*T - (1.33200*1E-7).*T.^2 + ...
    (8.08321*1E-7).*P + (5.97259*1E-10).*P.^2;
my=my.*0.001; %Converting from cp to Ns/m^2
```