FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MECHATRONICS ENGINEERING

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Fluid Mechanics Lab ENME312

Exp (9): pressure losses in Ductwork

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ABSTRACT

This experiment aims to analyze pressure losses in ductwork, with a focus on understanding how air flow dynamics and duct characteristics contribute to overall system efficiency in HVAC applications. The objective is to quantify the pressure drop across different types of duct sections, such as straight runs, bends, and fittings, and to identify key factors that influence these losses.

The principles underlying this experiment are based on fluid dynamics, particularly the concepts of frictional resistance and turbulence. Pressure losses in ductwork occur as air encounters resistance from the duct walls and any changes in direction or velocity. By measuring these pressure drops, we can calculate frictional losses and assess how duct geometry and flow rates affect air movement. To conduct the experiment, various sections of ductwork are connected, and differential pressure gauges are used to record pressure losses across each segment. Controlled air flow is introduced, and measurements are taken at different points to evaluate how duct shape, length, and bends impact pressure.

The results from the experiment are summation of the pressure difference in pa which equals 3776.8 from the device and 4095.6 pa and the L equivalent value is 15 m.

For part 2 the relation between the Hydraulic Gradient Vs average velocity is linear relation and experimental and theoretical friction factor values are very near to each other.

OBJECTIVES & MEASUREMENT METHOD'S

The aim of this experiment is to assess and examine pressure losses in duct systems to comprehend the main elements influencing air flow efficiency in HVAC systems. This specifically entails measuring pressure drops in different sections, such as straight runs, bends, and fittings, to see how each affects total energy losses. Moreover, the study seeks to assess how frictional resistance on duct surfaces affects flow, considering factors like material and surface roughness. This study will emphasize the impact of bends, expansions, and contractions on pressure loss by analyzing variations in duct geometry, such as diameter, length, and fittings. The study also examines how different flow rates impact pressure losses, intending to offer insights that can inform effective duct design and minimize energy consumption in HVAC systems.

<u>SAMPLE CALCULATIONS</u>

NOTE: all calculations are done for run1

For part a:

- ΔP loss= $f\,\frac{Leq}{D}(0.5\ \rho v^2)$ =$K(0.5\ \rho v^2)$

  K=f* L eq/ D

Where:

ΔP loss: static pressure loss (Pa)

D: diameter of the pipe which equals 0.0984 (m)

Leq: the equivalent length 7.42 (m)

ρ: air density which equals 1.2 kg/m^3

V: air velocity (m/s)

f: friction coefficient (0.025)

k: pressure loss factor

- Q= A*V

Where:

Q: air flow rate (m^3/s)

V: air velocity (m/s)

A: cross sectional area in which the air flows (m^2)

- Q venturi = 163.3 $\sqrt{hv}$

Qv= 163.3*12.8^0.5=584.2 m^3/s

Where:

hv: air head for venturi (mbar)

- Q orifice = 123.7 $\sqrt{ho}$

Qo=123.7*21.7^0.5=576.2 m^3/s

Where:

ho: air head for the orifice (mbar)

- Q avg= (Qv+Qo)/2
- V avg = Q avg/2
- A= 3.14*D^2/4= 0.0076 m^2
- Vv= Qv/A*3600= 584.2/0.0076*3600=21.3 m/s
- Vo=Qo/A*3600=576.2/0.0076*3600=21.06 m/s
- V main= $\frac{Vv+Vo}{2}$

Where:

Vv: air velocity measured by the venturi meter (m/s)

Vo: air velocity measured by the orifice meter (m/s)

- K= 2*Δp/(1.2*Vmain^2)= 2*1716.75/1.2*21.2=2.81
- Leq= D*K/f= 0.0984*2.81/0.025=11.08 m
- Leq= D*Ktotal/f= 0.0894*6.3/0.025=1643.3 m

For part b:

- A= 3.14*D^2/4= 0.00000707 m^2

Where:

D: the internal nominal diameter of the pipe (0.003 m)

- U= Q/A=2.2/0.000007=3.21 m/s

Where:

Q: volume flow rate in m^3/s

A: internal area of the pipe in m^2

- Re = $\frac{\rho u D}{\mu}$= u*D/v

Where:

Re: Reynolds number

- Hagen Poiseuille's equation for laminar flow hf= $\frac{32\mu u}{\rho g D^2}$ = i

Where:

μ: viscosity of water (0.00089 pa.s)

ρ: water density (1000 kg/m^3)

g: gravity acceleration (9.8 m/s^2)

hf: friction head loss

i: hydraulic gradient

- Darcy Welsbach formula for turbulent flow hf= $\frac{4fu^2}{2gD}$= i

Where:

f: the friction factor

D: diameter 0.003 (m)

L: length which equals 0.524 (m)

- Friction factor f= i*2*g*D/4*u^2
- f theoretical= 0.0756 Re^-0.25

PRESENTATION & RESULTS

Table 1: data and calculations for ductwork. (orifice and venturi head (m), orifice and venturi flow rates (m^3/s), venturi, orifice and main velocities (m/s), sections, pressure loss (mm), pressure (pa), pressure loss factor and the equivalent length (m)).

		fast fan			
h0 (mbar)=	21.7	Qv (m^3/hr)=	584.2398412	Vv (m/s)=	21.35379536
hv (mbar)=	12.8	Q0 (m^3/hr)=	576.2349113	Vo (m/s)=	21.06121752
		v main (m/s)=	21.20750644		
section		Δp loss (mm H2O)	P (Pa)	K	L eq (cm)
1_2	screen	50	490.5	1.815503131	7.145820323
2_3	straight duct	0	0	0	0
3_5	orifice meter	22	215.82	0.798821378	3.144160942
5_6	round elbow	2	19.62	0.072620125	0.285832813
6_7	straight duct	0.5	4.905	0.018155031	0.071458203
7_10	venturi meter	4	39.24	0.14524025	0.571665626
10_11	round elbow	2	19.62	0.072620125	0.285832813
11_12	heat bank	4.5	44.145	0.163395282	0.643123829
12_13	straight duct	1.5	14.715	0.054465094	0.21437461
13_14	round elbow	2.5	24.525	0.090775157	0.357291016
14_15	straight duct	0.5	4.905	0.018155031	0.071458203
15_16	right angle duct	10	98.1	0.363100626	1.429164065
16_18	straight duct	12	117.72	0.435720751	1.714996878
1_18	total Δp loss	145	1422.45	5.26495908	
sum		111.5	1093.815	4.048571982	
			Leq (m)	438.864	15.93517932

Table 2: data and calculations for the pipe. (run, volume flow rate (m^3/s), time (s), velocity (m/s), head difference (m), gradient, temperature (c), viscosity (pa.s), Reynolds number, friction factor and theoretical friction factor).

run	Qty (ml)	Time (s)	Q (m^3/s)	u (m/s)	Δh (mm)	Δh (m)	I laminar	Tempreture (c)	viscosity (pa.s)	Re	friction factor	theoritical friction
1	500	22	2.27273E-05	3.214607175	2	0.002	1.041607	21.2	0.000894	10787.2724	0.001483229	0.007418121
2	500	24	2.08333E-05	2.946723244	1.8	0.0018	0.954806417	21.2	0.000894	9888.333033	0.437207311	0.007581254
3	500	27	1.85185E-05	2.61930955	1.6	0.0016	0.848716815	21.2	0.000894	8789.629362	0.437207311	0.007807809
4	500	28	1.78571E-05	2.52576278	1.4	0.0014	0.8184055	21.2	0.000894	8475.714028	0.437207311	0.00787912
5	500	31	1.6129E-05	2.281334124	1.2	0.0012	0.739204968	21.2	0.000894	7655.483638	0.437207311	0.008082182
6	500	33	1.51515E-05	2.14307145	1	0.001	0.694404667	21.2	0.000894	7191.514933	0.437207311	0.0082095
7	500	38	1.31579E-05	1.861088364	0.8	0.0008	0.603035632	21.2	0.000894	6245.262968	0.437207311	0.008504213
8	500	43	1.16279E-05	1.644682741	0.6	0.0006	0.532915209	21.2	0.000894	5519.0696	0.437207311	0.008771126
9	500	53	9.43396E-06	1.334365242	0.4	0.0004	0.43236517	21.2	0.000894	4477.735713	0.437207311	0.009241813

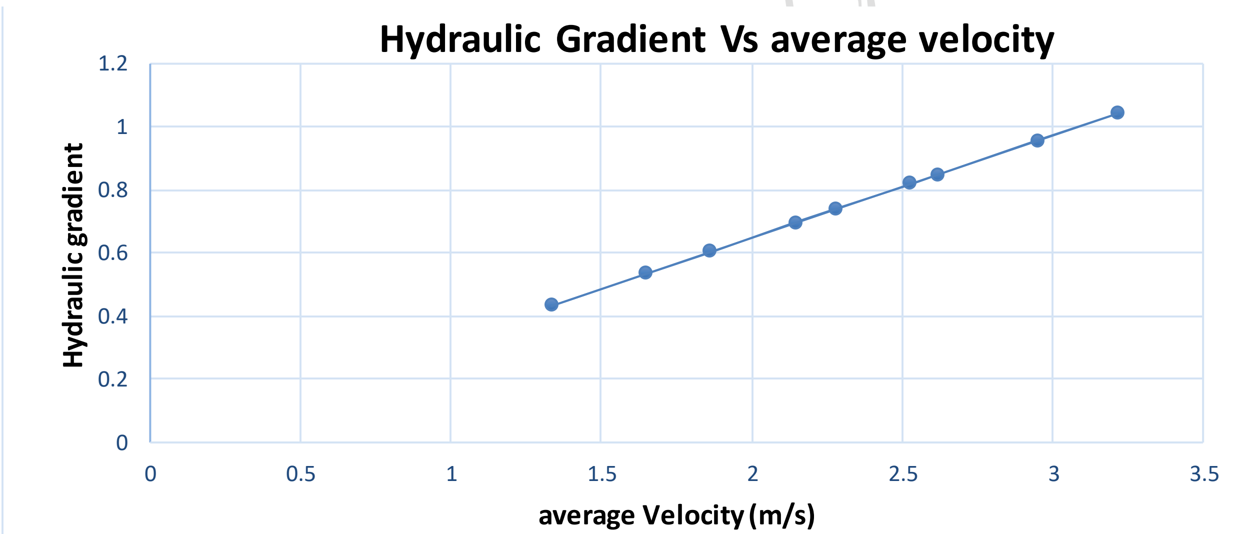


Figure 1: Hydraulic Gradient Vs average velocity

DISCUSSION OF RESULTS

There is an obvious relation between the measurements and the results because if any value in the measurements is changed all results will change for example there is direct relation between the pressure losses with the loss factor and the equivalent length, also the friction factor will increase if the velocity decrease and so the hydraulic gradient will decrease, it is also obvious that when the velocity decrease Reynolds number will decrease (direct relationship).

From graph 1 which shows the relation between hydraulic gradient Vs average velocity we have a linear relationship so when the velocity increase the hydraulic gradient will increase.

The final results agree with the theoretical ones for example the experimental and theoretical friction factors are near to each other with little differences due to some sources of error and uncertainty like Mistakes in Instrument Calibration, the pressure or flow rate may not be read correctly since the pressure gauges, flowmeters, and other measuring devices may not have been calibrated correctly. Even minor calibration errors can produce large measurement discrepancies for pressure loss. Imprecise Flow Rate Calculations: When flow rates are derived from indirect methods (such as velocity readings), mistakes in these computations may carry over into the pressure loss information. Underestimating the velocity profile or airflow pattern results in inaccurate predictions of pressure loss, temperature variations, measurement instruments errors and duct geometry inaccuracies.

To enhance the experiments results we need to be more accurate while record the readings, calibrate instruments and using the phone timer instead of the stop watch because it is more accurate.

The L equivalent we got which equals 15 is not near to 7 due to errors above.

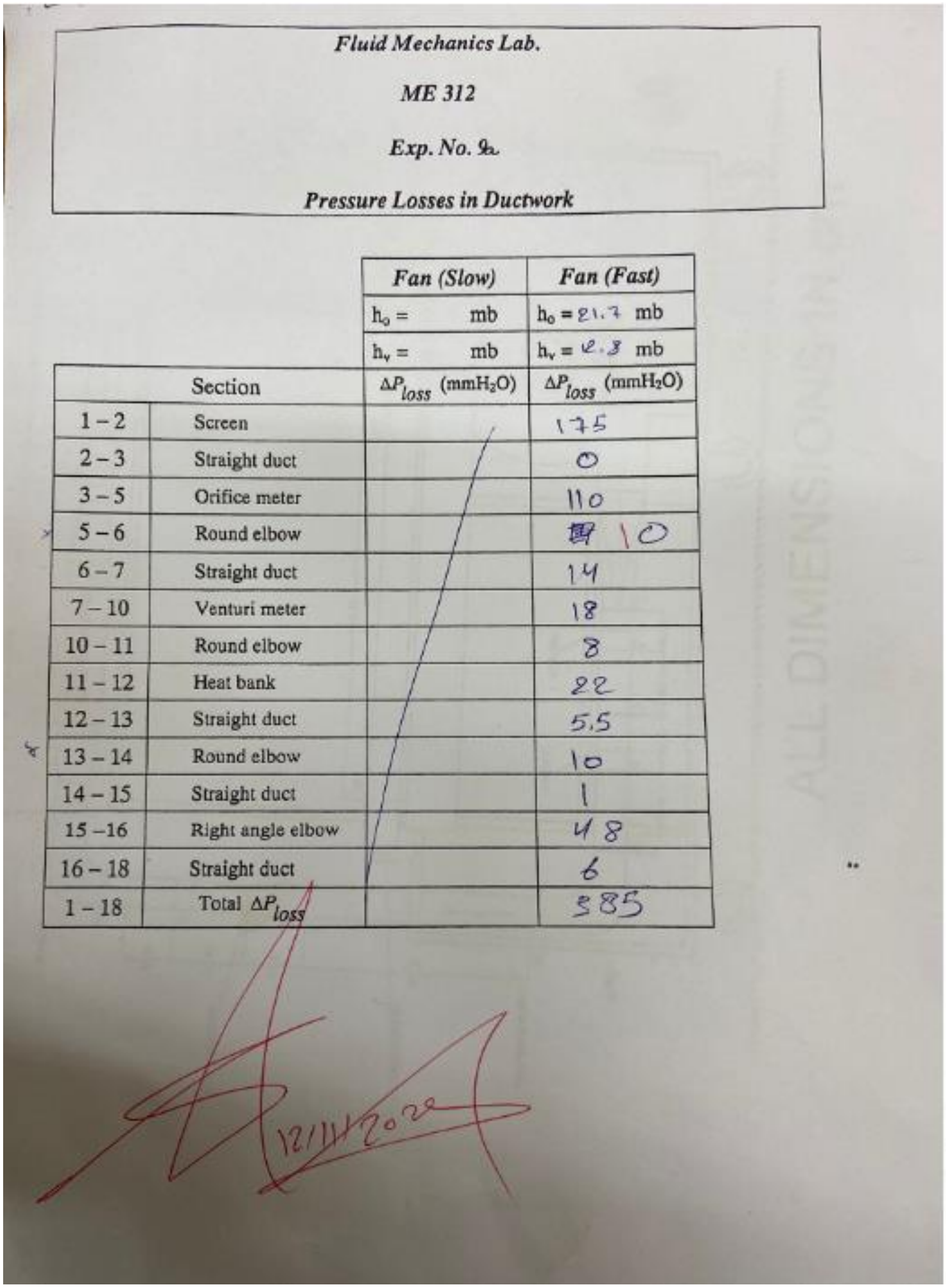
The maximum pressure is due to screen, orifice and right angle while the minimum values are from the straight duct and round elbow.

CONCLUSIONS

The study on pressure drops in duct systems revealed the considerable influence of duct features and flow parameters on overall system performance. Results show that pressure losses rise with variables like extended duct lengths, reduced diameters, and the existence of bends or fittings, mainly attributed to increased frictional resistance and turbulence. Abrupt angles and quick alterations in duct shape were demonstrated to cause increased pressure drops, highlighting the necessity of seamless transitions in design to ensure optimal airflow. Moreover, heightened flow rates led to larger pressure losses, emphasizing the necessity to align air velocity with duct configuration for optimal energy efficiency. These findings highlight the importance of meticulous duct design to decrease avoidable pressure losses, lower energy usage, and enhance the functionality of HVAC systems. This research offers valuable guidance for choosing duct materials, refining duct designs, and applying strategies that enhance sustainability and cost-efficiency in HVAC systems

APPENDICES

Original Data Sheets



Fluid Mechanics Lab.

ME 312

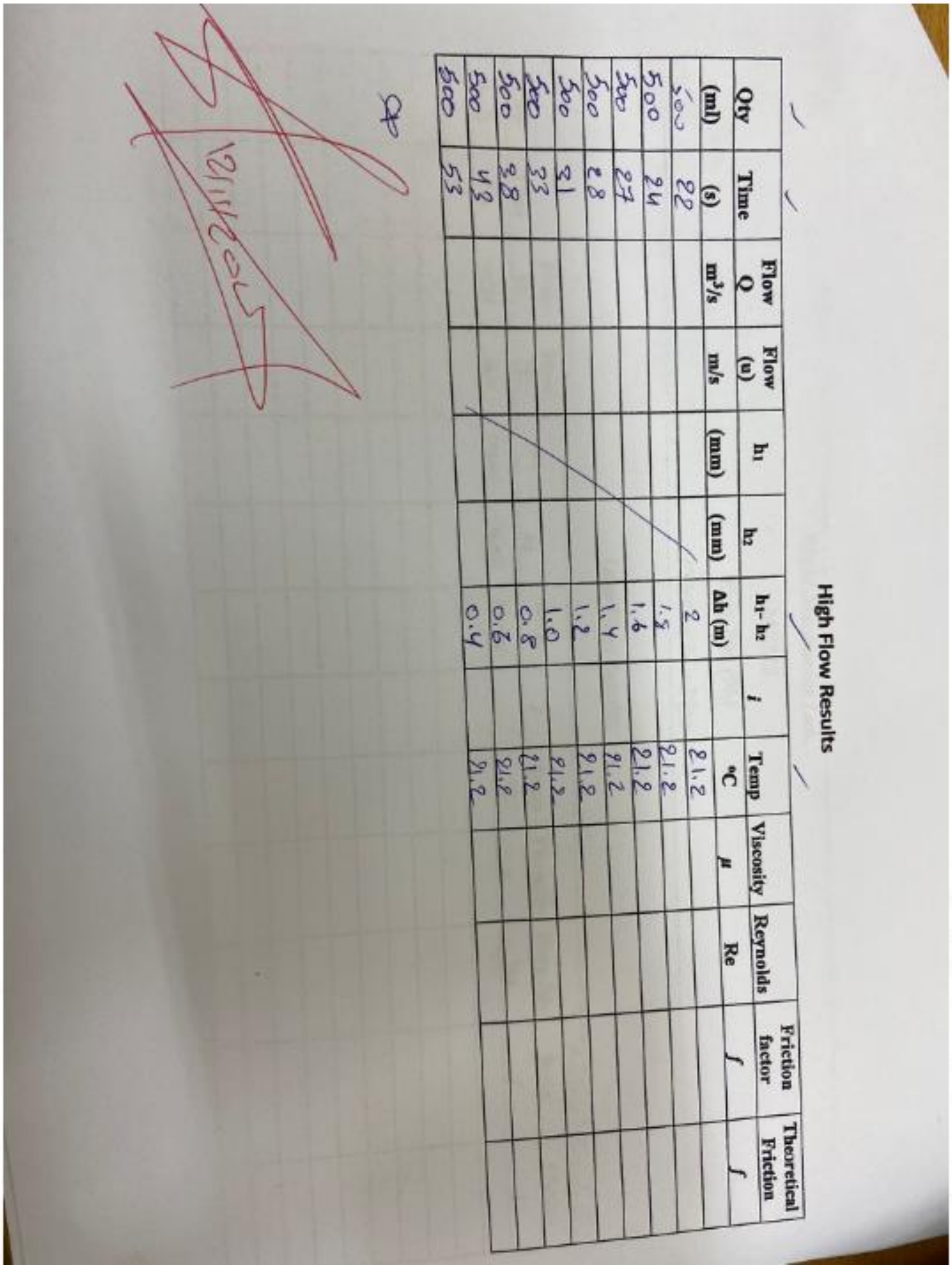
Exp. No. 9a

Pressure Losses in Ductwork

Section		Fan (Slow)	Fan (Fast)
		h_o = mb	h_o = 21.7 mb
		h_v = mb	h_v = 2.3 mb
Section		ΔP_{loss} (mmH_2O)	ΔP_{loss} (mmH_2O)
1 – 2	Screen		175
2 – 3	Straight duct		0
3 – 5	Orifice meter		110
5 – 6	Round elbow		10
6 – 7	Straight duct		14
7 – 10	Venturi meter		18
10 – 11	Round elbow		8
11 – 12	Heat bank		22
12 – 13	Straight duct		5.5
13 – 14	Round elbow		10
14 – 15	Straight duct		1
15 – 16	Right angle elbow		48
16 – 18	Straight duct		6
1 – 18	Total ΔP_{loss}		385

12/11/202

Figure 2: data sheet 1



High Flow Results

Qty (ml)	Time (s)	Flow Q m^3/s	Flow (u) m/s	h_1 (mm)	h_2 (mm)	$h_1 - h_2$ Δh (m)	*i*	Temp °C	Viscosity μ	Reynolds Re	Friction factor *f*	Theoretical Friction *f*
500	22					2		21.2				
500	24					1.5		21.2				
500	27					1.6		21.2				
500	28					1.4		21.2				
500	31					1.2		21.2				
500	33					1.0		21.2				
500	38					0.8		21.2				
500	43					0.6		21.2				
500	53					0.4		21.2				

Figure 2: data sheet 2