Semester	2014 / 2015	**I.**
Subject	**Fluid Mechanics AG11**	
Measurement	A	
	B	**X**
	C	
	D	
Day and time	Tues 14-16	
Date of the measurement	**04. Nov. 2014.**	

LABORATORY MEASUREMENT REPORT

Measurement N^{r} **M10.**

PKNQCD-M10-63-4.89-20.8-51.15-25.55-56.66-60-451464f12b69a767cab1d7617472fb8f

EXPERIMENTAL INVENSTIGATION OF BORDA-CARNOT AND DIFFUSER GEOMETRY

Group: group **5-B**
(A) **ZACHARIOU Marios PKNQCD**
(B) **ASALI Mahmoud BU8HG2**

Measurement Leader submitting the report:
ZACHARIOU Marios

Instructor: **VARGA Árpád**
Lecturer: **Dr. Lohász Máté**

Measurement Location: BME / Dept. of Fluid Mechanics / LABORATORY
Date of **submission**:
Budapest, 16.11.2014

Table of Contents

Appendix

Aim and Objectives:

The aim of the measurement is to investigate the flow field in Borda-Carnot (right angle diffuser) and a diffuser (with a smaller angle) by two techniques:

1. Flow visualization
2. Taking the pressure distribution along the channel walls.

The objectives of the measurement are to determine the connection between the wall pressure distribution and the flow pattern and also to determine the efficiency of the both diffuser elements.

Measurement Task:

The assignments are as follows:

- Measuring the pressure distribution along the walls and determining the efficiency of both diffusers.
- Making sketches of the directions of the air flow in the channels based on flow visualization.
- Checking the inlet and outlet velocity profiles

General Data:

Before measurement:

$p_{room} = 99875\ [Pa]$

$T_{room} = 20.7\ [°C] = 293.85\ [K]$

After measurement:

$p_{room} = 99862\ [Pa]$

$T_{room} = 20.9\ [°C] = 294.05\ [K]$

Average:

$p_{room} = 99868.5\ [Pa]$

$T_{room} = 20.8\ [°C] = 293.95\ [K]$

Specific gas constant of the air: 287 [J/kgK]

Density of Air: $\rho_{air} = \frac{p_0}{R*T_0} = \frac{99868.5}{287*293.95}$ => $\rho_{air} = 1.184\ [\frac{kg}{m^3}]$

Geometry Dimensions of the Diffusers:

Orifice inlet plate diameter: 154 mm, cross-sectional area = 0.0186 m^2
Diffuser inlet cross-sectional area = Borda-Carnot inlet cross sectional area: 0.01 m^2
Diffuser outlet cross-sectional area = Borda-Carnot outlet cross sectional area: 0.016 m^2
Borda-Carnot bed length: 950 mm
Diffuser bed length: 942 m

Measurement Procedure:

The measurement began with recording the room's temperature and the ambient pressure. The inlet orifice diameter was measured, and the digital manometer was calibrated with the Betz manometer.
The first diffuser channel (Borda-Carnot) was set up. Borda-Carnot diffuser has a sudden cross section expansion (90 degrees angle) as shown in the figure 01. In this case the 200x50 mm cross-section is expanded to a 320x50 mm cross section. The walls of the channel were tried to be set as symmetrical as possible. Pins with threads attached to them were pinned to the bed of the channel. These threads are used to indicate the pattern of the air flow in the channel. There are 26 pressuring points (taps) on each wall side to be used for measuring the pressure at the walls of the channel.
After the set-up was ready the (miniature) wind tunnel was turned on. Firstly the inlet orifice's pressure was measured by a digital manometer. And by the use of a connecting tube, the pressures at the taps along both walls were measured one by one by the digital manometer.
Pictures were taken to record the shape and pattern of the threads in the channel. Finally by a Prantle-probe, the inlet dynamic pressure was measured at 11 point of the channels inlet cross-section. This was also done at the outlet of the channel at 10 points.

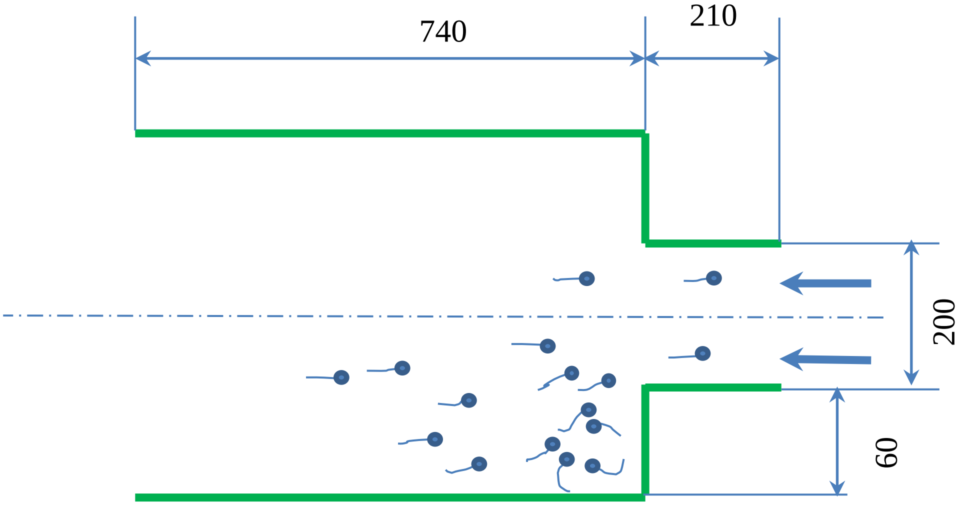


Figure 01

Then the channel was changed to a diffuser with a smaller angle of change and the same procedure was followed for the new set-up. This time there are 24 pointing measures on each diffuser wall sides, Figure 02. The Prantle-probe measurement was not repeated for the new setup's inlet cross-section since the inlet cross sectional area was the same. Though, it was done for the outlet of the diffuser at 10 points along the outlet cross-section.

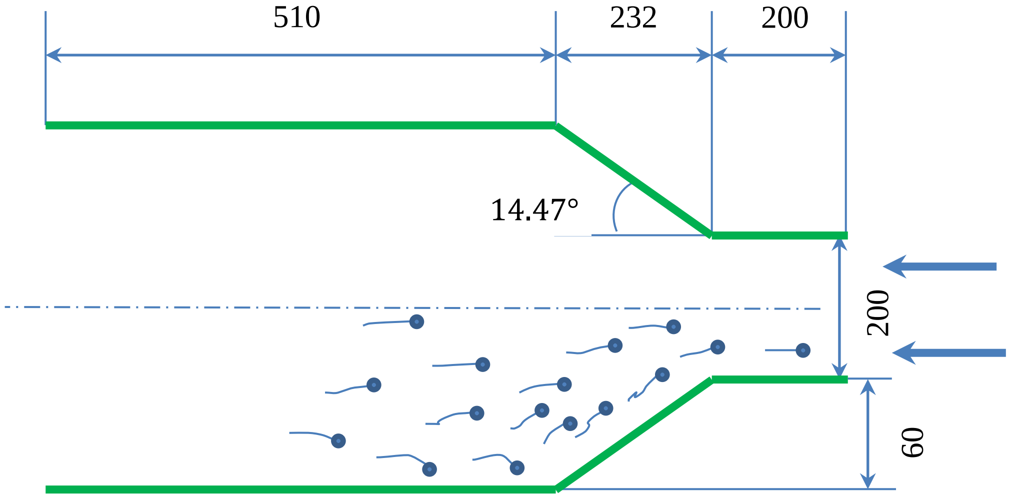


Figure 02

Calculations:

$$q_V = \alpha\epsilon \frac{d^2\pi}{4} \sqrt{\frac{2\Delta p_{or}}{\rho_{air}}} \quad => \quad (q_V)^2 = \alpha^2\epsilon^2 \frac{d^4\pi^2}{16} * \frac{2\Delta p_{or}}{\rho_{air}}$$

$$\Rightarrow \quad \frac{(q_V)^2}{A_{in}} = \frac{\alpha^2\epsilon^2\, d^4\pi^2\, 2\Delta p_{or}}{16\ \rho_{air}\ A_{in}^2} = \frac{\alpha^2\epsilon^2\, d^4\pi^2\, \Delta p_{or}}{8\ \rho_{air}\ A_{in}^2}$$

$$\eta = \frac{p_{in} - p_{out}}{\frac{\rho_{air}}{2}\left[\frac{\alpha^2\epsilon^2\, d^4\pi^2\, \Delta p_{or}}{8\ \rho_{air}\ A_{in}^2} - \frac{\alpha^2\epsilon^2\, d^4\pi^2\, \Delta p_{or}}{8\ \rho_{air}\ A_{out}^2}\right]}$$

$$\Rightarrow \quad \eta = \frac{p_{in} - p_{out}}{\frac{1}{16}\left[\alpha^2\epsilon^2 d^4\pi^2 \left(\frac{1}{A_{in}^2} - \frac{1}{A_{out}^2}\right)\Delta p_{or}\right]} = \frac{p_{in} - p_{out}}{0.7599 * \Delta p_{or}}$$

Error Calculation

Borda-Carnot

$$\frac{\partial \eta}{\partial \Delta p_{out-in}} = \frac{1}{0.7599*51.15} = 0.0257$$

$$\frac{\partial \eta}{\partial \Delta p_{or}} = \frac{-23.96}{0.7599*51.15^2} = -0.012$$

$$\delta\eta = \sqrt{(1.7 * 0.0257) + (1.7 * 0.012)^{\,2}} = 0.04812$$

$$\frac{\delta\eta}{\eta} = \frac{0.04812}{0.5666} = 0.0849 \;=>\; \frac{\delta\eta}{\eta} = 0.0849$$

Diffuser

$$\frac{\partial \eta}{\partial \Delta p_{out-in}} = \frac{1}{0.7599*52.42} = 0.0251$$

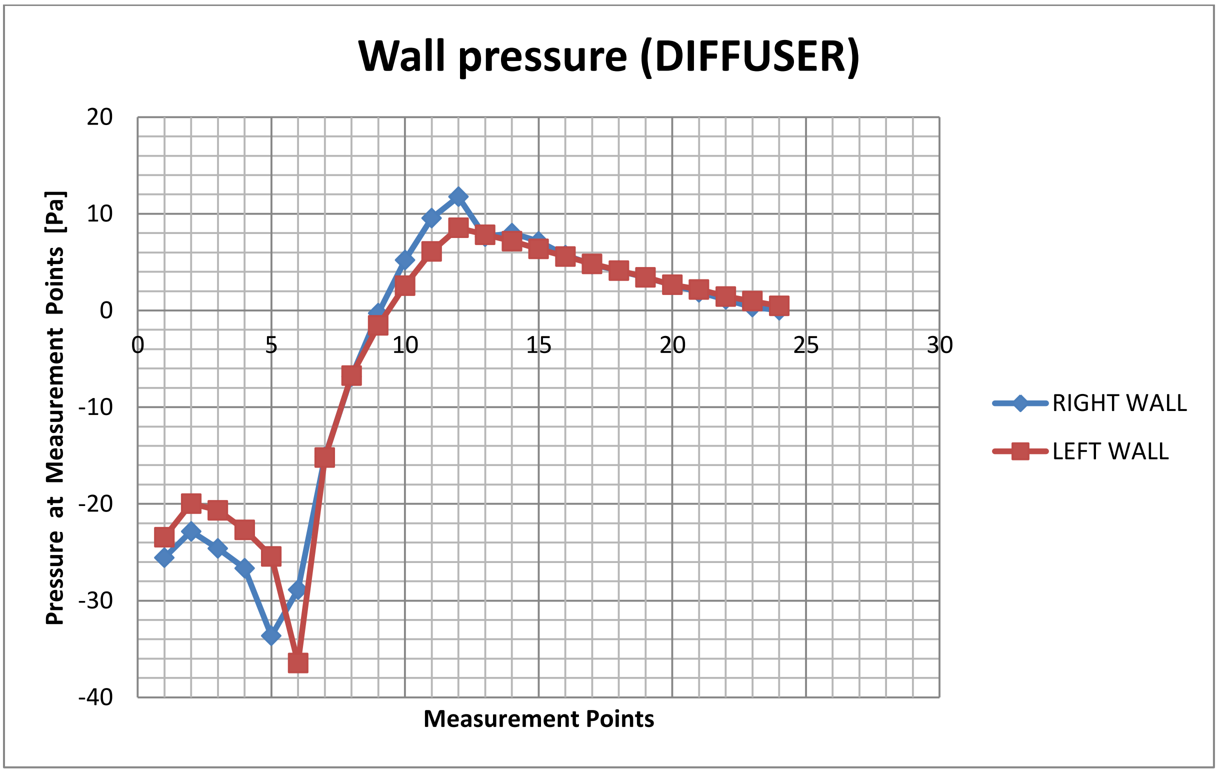
$$\frac{\partial \eta}{\partial \Delta p_{or}} = \frac{24.32}{0.7599*52.42^2} = 0.0116$$

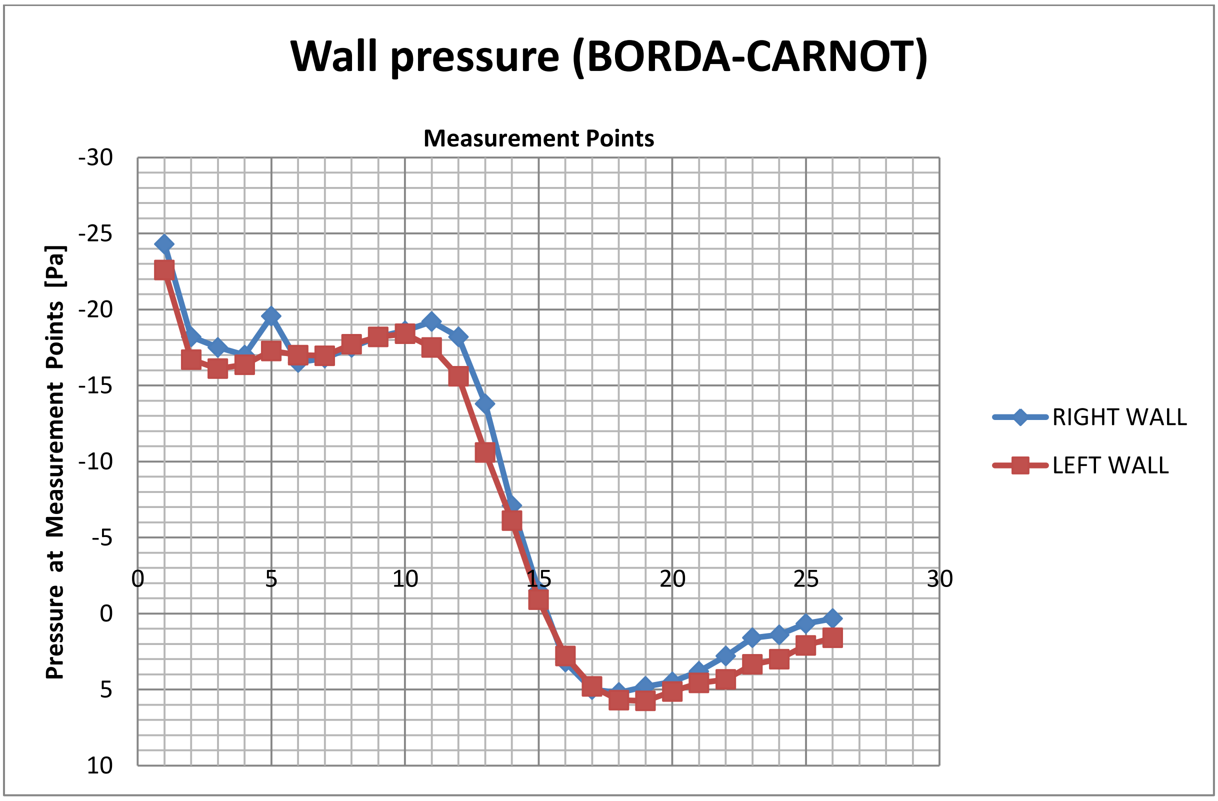
$$\delta\eta = \sqrt{0.0025 + 0.00054} = 0.0551$$

$$\frac{\delta\eta}{\eta} = 0.0918$$

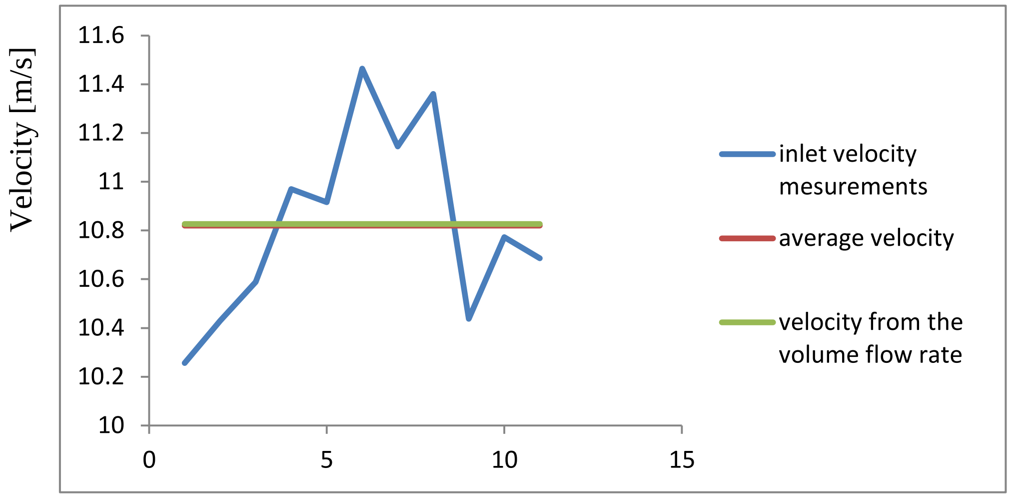
Conclusion:

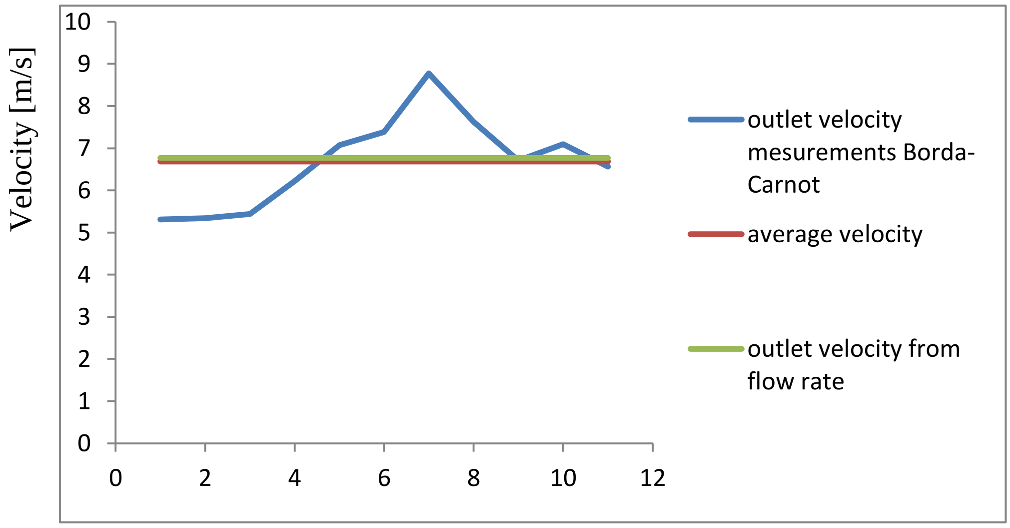
The calculations show that the efficiency of the diffuser channel is higher than the efficiency of the Borda-Carnot channel. By comparing the pictures of the flow visualization flags it is seen that in the Borda-Carnot setup, close to the right angle corner some of the flags are even pointing to the opposite direction of the initial flow. But on the diffuser setup this does not happen. The flags are tilted a bit at the cross-sectional area which the angle increases but none of them are turned to the opposite direction. This can support the calculations meaning that the boundary layer is thicker in the Borda-Carnot setup according to the pictures which results in the loss of energy and thus the decrease of efficiency of this Borda-Carnot setup compared to the diffuser setup in this very experiment.

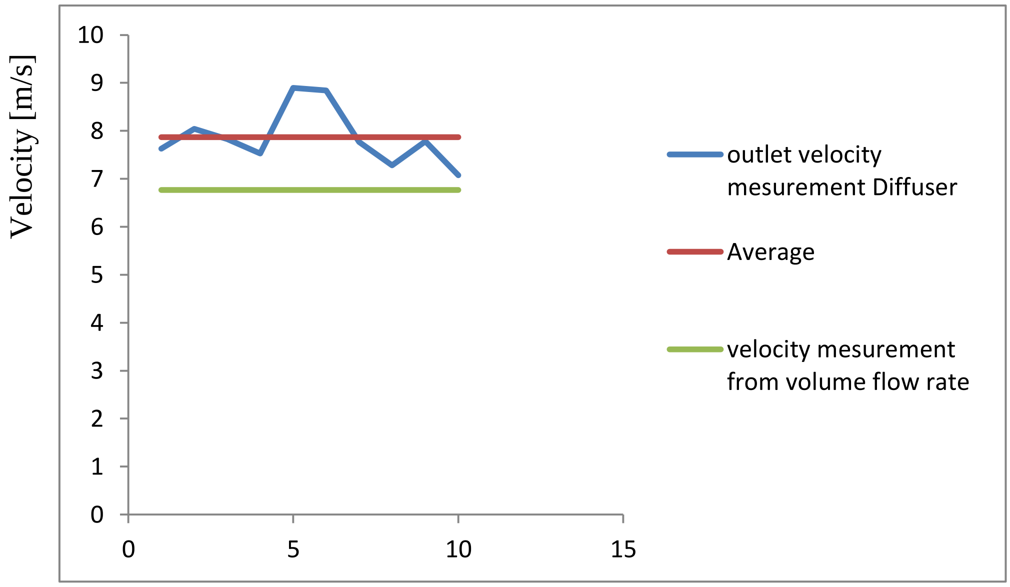

Wall pressure (DIFFUSER)
Pressure at Measurement Points [Pa]
20
10
0
-10
-20
-30
-40
0
5
10
15
20
25
30
Measurement Points
RIGHT WALL
LEFT WALL


Wall pressure (BORDA-CARNOT)
Measurement Points
Pressure at Measurement Points [Pa]
-30
-25
-20
-15
-10
-5
0
5
10
0
5
10
15
20
25
30
RIGHT WALL
LEFT WALL

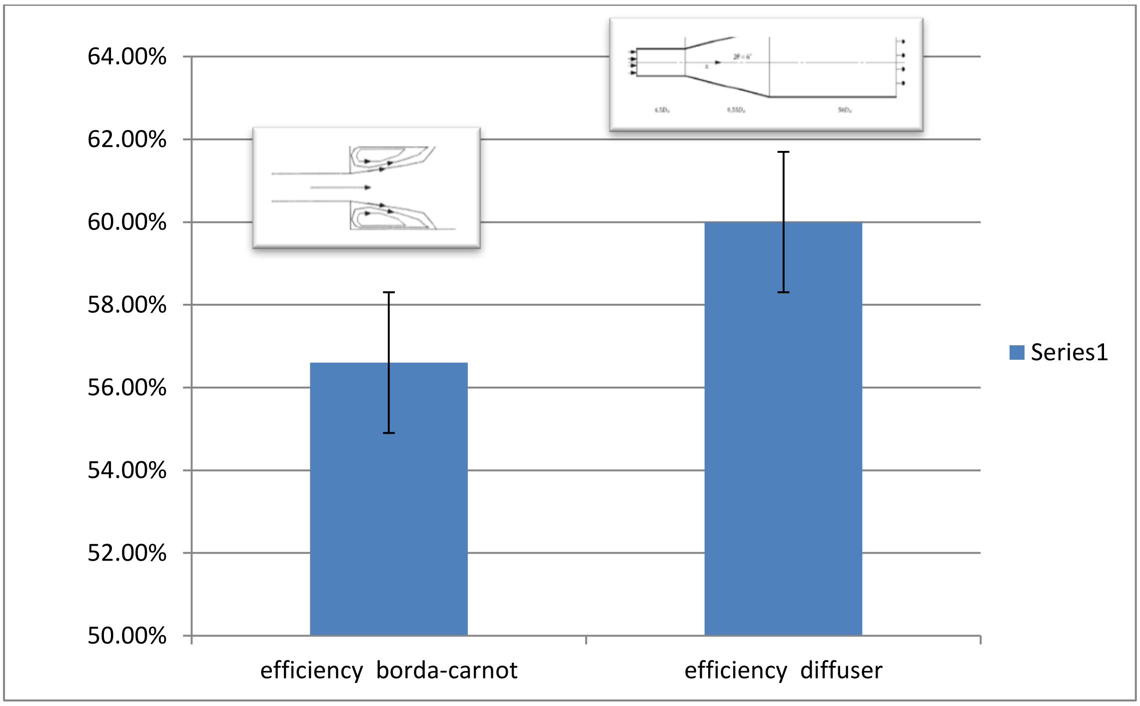
Comparing the Velocities in the Channel







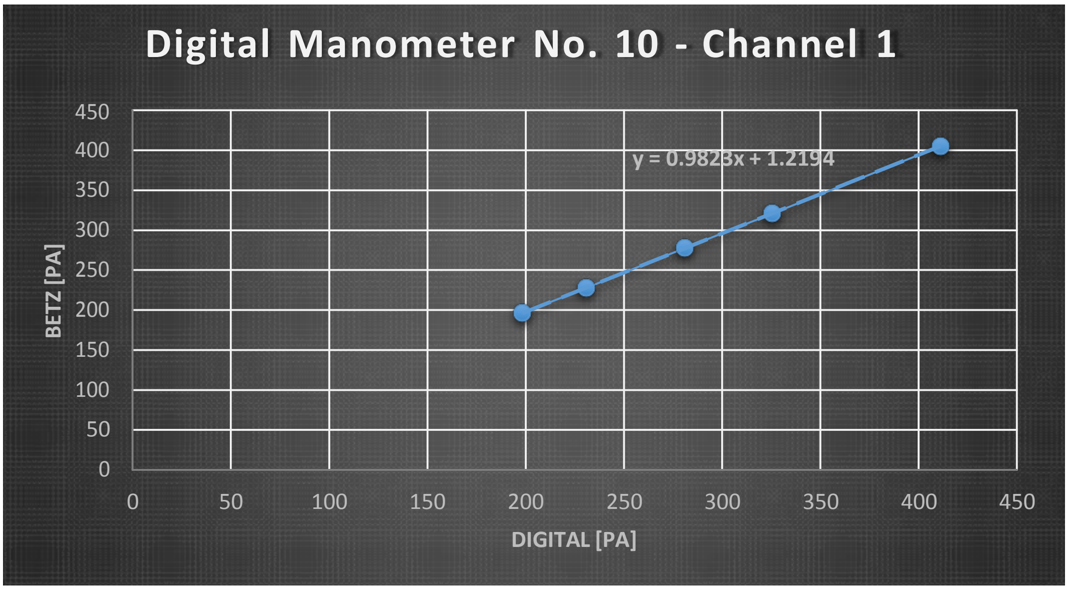
Comparing the Efficiency



digital manometer calibration with Betz manometer

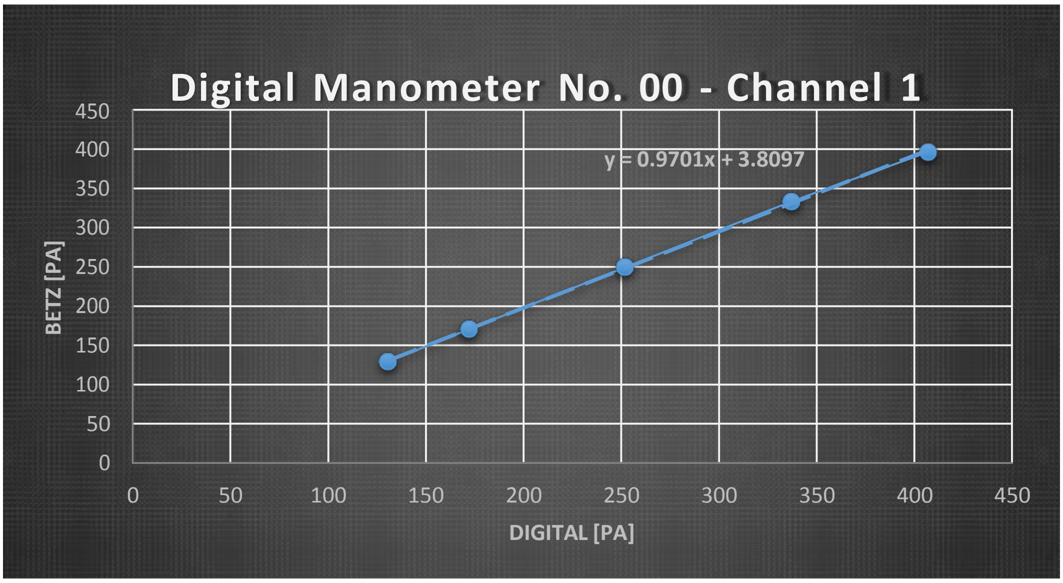
BetzΔh [mm]	Digital ΔP [Pa]
20	198.28
23.2	230.89
28.3	281.06
32.7	325.43
41.3	411.21

Betz ΔP [Pa]	Digital ΔP [Pa]
196.2	198.28
227.592	230.89
277.623	281.06
320.787	325.43
405.153	411.21



BetzΔh [mm]	Digital ΔP [Pa]
13.2	130.68
17.4	172.26
25.4	251.76
34	337.22
40.4	407.07

Betz ΔP [Pa]	Digital ΔP [Pa]
129.492	130.68
170.694	172.26
249.174	251.76
333.54	337.22
396.324	407.07



measured data of the diffuser (measurement of the sidewall pressure distribution)

Border-Carnot

Right

	[Pa]
ΔP_{op}	51,5
ΔP_1	24,3
ΔP_2	18,2
ΔP_3	17,5
ΔP_4	17
ΔP_5	19,55
ΔP_6	16,51
ΔP_7	16,8
ΔP_8	17,5
ΔP_9	18,2
ΔP_{10}	18,6
ΔP_{11}	19,2
ΔP_{12}	18,1
ΔP_{13}	13,8
ΔP_{14}	7,1
ΔP_{15}	1,5
ΔP_{16}	−3,2
ΔP_{17}	−5
ΔP_{18}	−5,2
ΔP_{19}	−4,8
ΔP_{20}	−4,5
ΔP_{21}	−3,8
ΔP_{22}	−2,8
ΔP_{23}	−1,6
ΔP_{24}	−1,4
ΔP_{25}	+0,67
ΔP_{26}	+0,34

ΔP_{left}	[Pa]
ΔP_1	22,6
ΔP_2	16,7
ΔP_3	16,1
ΔP_4	16,36
ΔP_5	17,27
ΔP_6	17
ΔP_7	16,95
ΔP_8	17,7
ΔP_9	18,2
ΔP_{10}	18,04
ΔP_{11}	17,5
ΔP_{12}	15,6
ΔP_{13}	10,6
ΔP_{14}	6,1
ΔP_{15}	0,9
ΔP_{16}	−2,78
ΔP_{17}	−4,8
ΔP_{18}	−5,7
ΔP_{19}	−5,75
ΔP_{20}	−5,13
ΔP_{21}	−4,57
ΔP_{22}	−4,34
ΔP_{23}	−3,35
ΔP_{24}	−3
ΔP_{25}	−2,21
ΔP_{26}	−1,62

$\Delta P_i = P_0 - P_{st_i}$

P_{st}: static pressure

ΔP_{op}: pressure loss on the orifice plate

(relative pressure as compared to the atmospheric pressure) measured at the tap following directly after the orifice plate at the beginning of the suction tube.

	[Pa]
ΔP_{op_1}	
ΔP_{op_2}	
ΔP_{op_3}	
ΔP_{op_4}	

manometer: 10

[illegible] 2014.11.04

manometer

Right wall

	[Pa]	0° ↓
ΔP_{op}	~~27,74~~	
ΔP_1	25,55	25,55
ΔP_2	24,42	22,85
ΔP_3	25,94	24,61
ΔP_4	27,48	26,64
ΔP_5	35,67	33,65
ΔP_6	29,26	28,87
ΔP_7	~~16,28~~	15,14
ΔP_8	6,85	
ΔP_9	0,27	60
ΔP_{10}	−5,02	
ΔP_{11}	−9,55	
ΔP_{12}	−11,76	
ΔP_{13}	−7,62	
ΔP_{14}	−8,20	
ΔP_{15}	−7,14	
ΔP_{16}	−5,72	
ΔP_{17}	−4,77	
ΔP_{18}	−4,11	
ΔP_{19}	−3,41	
ΔP_{20}	−2,64	
ΔP_{21}	−1,87	
ΔP_{22}	−1,14	
ΔP_{23}	−0,34	
ΔP_{24}	+0,03	
ΔP_{25}	X	

Left wall

	[Pa]
ΔP_1	23,41
2	19,97
3	20,66
4	22,57
5	25,42
6	38,41
7	15,21
8	6,22
9	1,54
10	−2,58
11	−6,12
12	−8,54
13	−7,83
14	−7,17
15	−6,37
16	−5,58
17	−4,83
18	−4,13
19	−3,44
20	−2,66
21	−2,17
22	−1,44
23	−0,96
24	−0,47
25	X

$\Delta P_{orifice} = 52,42$ [Pa] ✓✓

2014.11.04

Point to point Prandtl-probe measurement data

carnot

Inlet section ; spacing: [mm]

$P_{d_{in}}$ [Pa]

P_1	62,27
P_2	64,4
P_3	66,38
P_4	71,24
P_5	70,54
P_6	77,8
P_7	73,52
P_8	76,4
P_9	64,49
P_{10}	68,7
P_{11}	67,6
$\bar{P}_{in}$	

P_1	
P_2	

diffuse

Outlet section ; spacing: [mm]

$P_{d_{out}}$ [Pa]

P_1	16,7
P_2	16,9
P_3	17,5
P_4	22,9
P_5	29,59
P_6	32,28
P_7	45,55
P_8	34,42
P_9	26,65
P_{10}	29,8
P_{11}	25,48
$\bar{P}_{out}$	

[Pa]

P'_1	34,44
P'_2	38,27
P'_3	36,26
P'_4	33,52
P'_5	46,82
P'_6	46,27
P'_7	35,72
P'_8	31,41
P'_9	35,82
P'_{10}	29,52

diffuser

$A_{in} =$ m^2

$\bar{V}_{in} =$ $\frac{m}{s}$

$\left[\frac{m^3}{s}\right]$

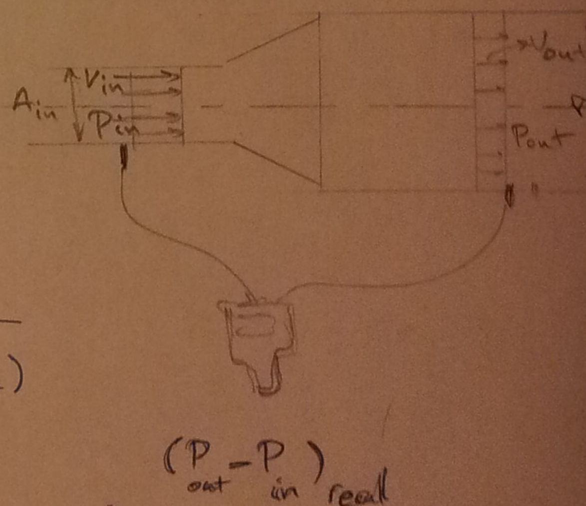
$A_{out} =$ m^2

$\bar{V}_{out} =$ m^2

determination of diffuser efficiency

real ΔP [Pa]

1		
2		
3		
⋮		
n		
	real ΔP	



$$\eta_d = \frac{(P_{in} - P_{out})_{real}}{\frac{\rho_{air}}{2}\left(V_{in}^2 - V_{out}^2\right)}$$

$(P_{out} - P_{in})_{real}$

$\rho_{air} = \frac{P_0}{R \cdot T_0}$ $\left[\frac{kg}{m^3}\right]$

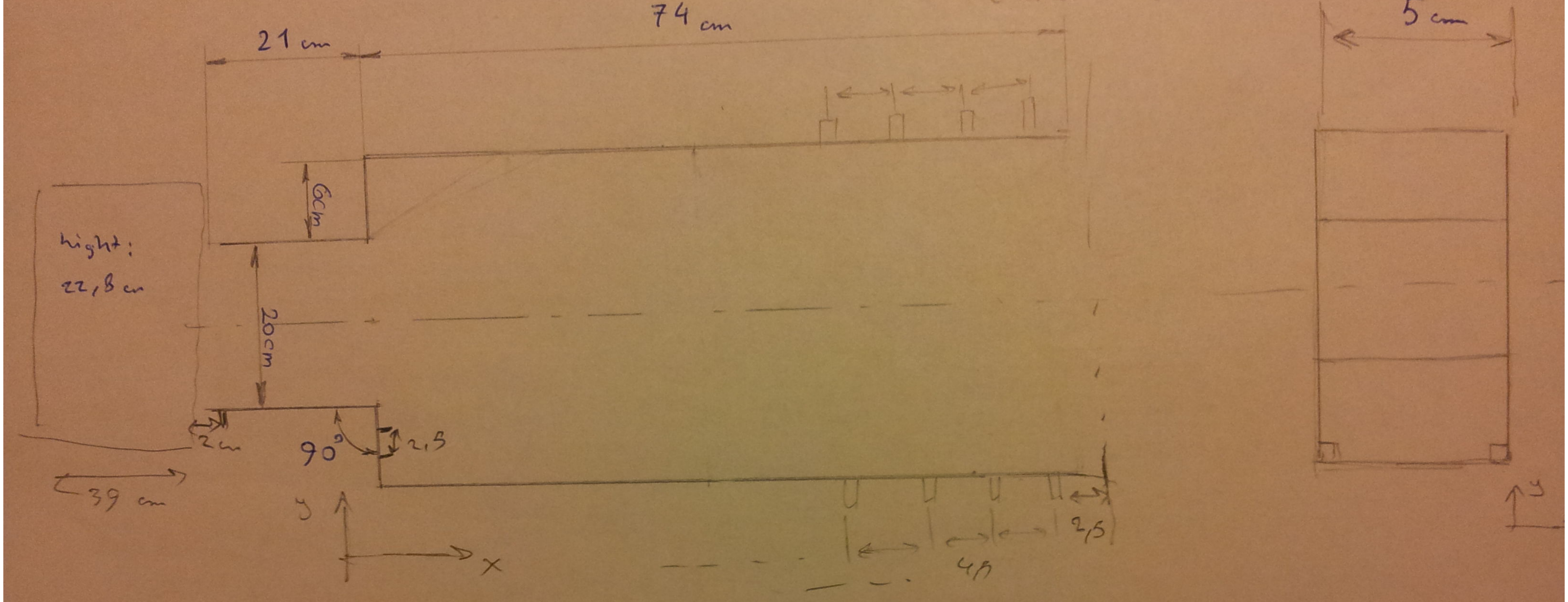
$R = 287$ $\left[\frac{J}{kg\,K}\right]$

$V_{out} = \frac{q_v}{A_{out}}$ $\left[\frac{m}{s}\right]$

$V_{in} = \frac{q}{A_{in}}$

2014.11.04

Carnot
we used manomete No. 10



A_{inlet} = [m^2]

A_{outlet} = [m^2]

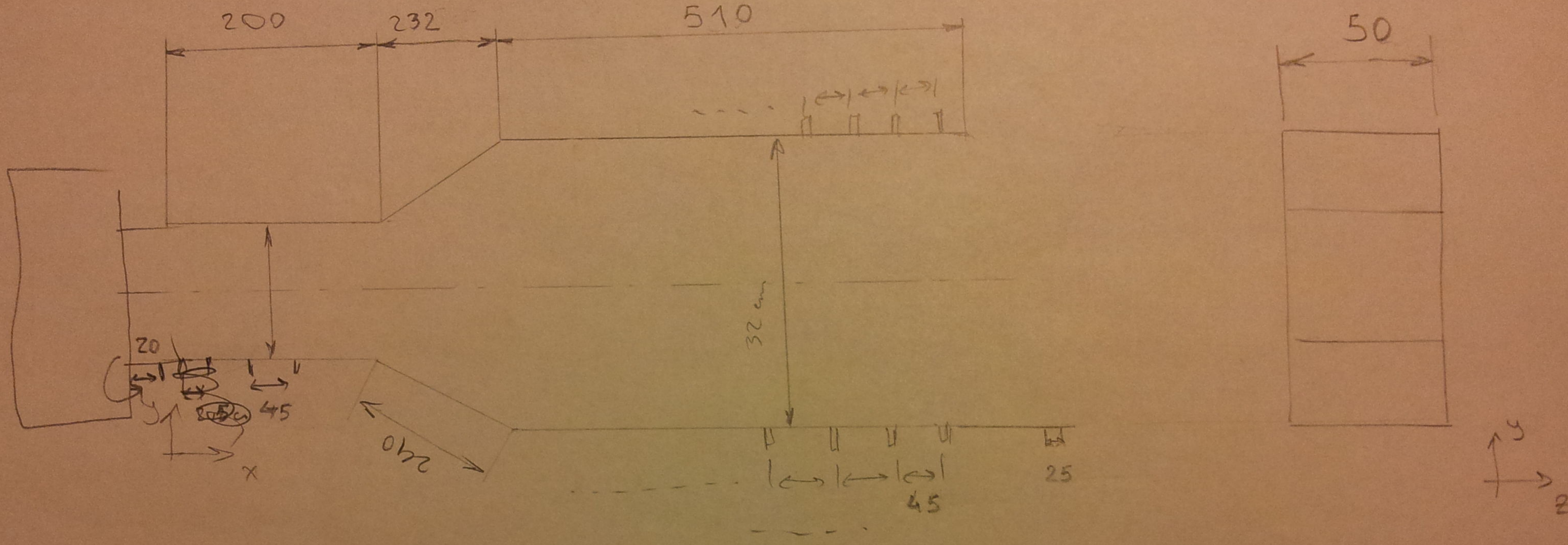
---

diameter of the inlet orifice : [m]

$\frac{20}{32} = 0,625$

∅ orifice inlet : 154 mm

length of the Wind ~~tunnel~~ tube 81,5 c we used manometer No. 09



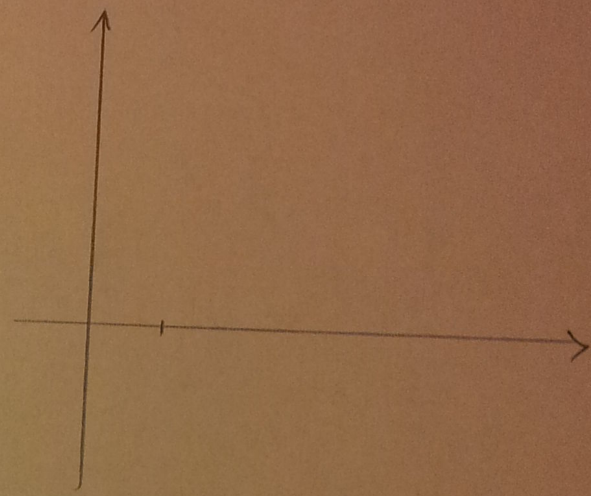
A_{inlet} : [m²]

A_{outlet} : [m²]

diameter of the inlet orifice plate : [m²] channel Nr. 1

Manometer Nr. 10

Betz Δh (mm)	Digital ΔP (Pa)
20	198,28
23,2	230,89
28,3	281,06
32,7	325,43
41,3	411,21



$P_e = \rho \cdot g \cdot h = 1000 \times 9{,}81 \times \Delta h$ (in m)

water ρ

$h \sim \Delta h$

00 chanél 1

Nr. 00

Betz Δh (mm)	Digital ΔP [Pa]
13,2	130,68
17,4	172,26
25,4	251,76
34	337,22
40,4	407,07
63,	629,05

2014.11