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Swiss Federal Office of Metrology

EUROMET Project No. 388

Final Report

Intercomparison of Anemometers

Part 1: Results

by

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Abstract

Three windmill-type anemometer of different size were calibrated by 10 European and 2 overseas laboratories. The instrumentation used for the calibration was very different. Wind tunnels of different sizes and carriages moving in still air were used. In conjunction with the wind tunnels Laser Doppler Anemometers, Pitot/Prandtl tubes, and gas volume metering devices (meters and diaphragms) served as standards. The movement of the carriages was measured with interferometers or by measuring length and time. The results are shown grouped from several points of view. No systematic dependence was found. More investigation, mainly concerning the blocking effect (influence of the anemometer to the surrounding air) is necessary.

1 Introduction

The purpose of international intercomparisons is generally to test the realisation of the respective unit and to verify that the national standards are equivalent for the practical application. They also help to gain confidence in the calibrations and increase the experience.

Switzerland proposed an intercomparison of measurement of airflow with 3 windmill-type anemometers of different size. 12 Laboratories in 10 European and 2 overseas countries took part, several of them using more than one test installation.

2 Organisation

2.1 Participating Laboratories

Country	*Code*	*Laboratory/Institute*
Belgium	BE	Jean-Marie Seynhaeve Unité TERM - Université. Catholique du Louvain Bâtiment Simon STEVIN 2, Place du Levant B - 1348 Louvain-la-Neuve Belgium e-mail: jms@term.ucl.ac.be
Denmark	DK	John Frederiksen Dansk Technologisk Institut Teknologiparken DK - 8000 Aarhus C Denmark e-mail: john.frederiksen@dti.dk

Country	*Code*	*Laboratory/Institute*
Finland	FI	Mr. Keijo Kovanen VTT Building Technology Indoor Climate P.O. Box 1804 FIN-02044 VTT Finland e-mail: keijo.kovanen@vtt.fi
France	FR	Madame Isabelle Caré Centre Technique des Industries Aérauliques et Thermiques, CETIAT 27-29, Boulevard du 11 Novembre 1918 BP 2042 F - 69603 Villeurbanne CEDEX France e-mail: isabelle.care@cetiat.fr
Germany	DE	Dr. Rainer Kramer Physikalisch-Technische Bundesanstalt Labor für Gasmessgeräte (1.33) Postfach 3345 D - 38023 Braunschweig Deutschland e-mail: rainer.kramer@ptb.de
Italy	IT	Dr. Ing Pier Giorgio Piantà Centro di Studio per la Dinamica dei Fluidi del C.N.R, CSDF-CNR c/o Politecnico di Torino Corso Duca degli Abruzzi, 24 I - 10129 Torino Italia e-mail: pianta@polito.it
Japan	JP	Dr Yoshiya Terao Head of Flow Measurement Lab. National Research Lab. of Metrology 1-1-4 Umezono, Tsukuba Ibaraki 305-8563, JAPAN e-mail:terao@nrlm.go.jp

The Netherlands	NL	Ing. M.P. van der Beek NMi Van Swinden Laboratory Department Flow PO Box 394 NL - 3300 AJ Dordrecht The Netherlands e-mail: mvanderbeek@nmi.nl

Country	*Code*	*Laboratory/Institute*
Poland	PL	Dr Waclaw Dziurzynski Strata Mechanics Research Institute ul. Reymonta 27 PL - 30-059 Krakow Poland e-mail: dziurzyn@aga.img-pan.krakow.pl
Switzerland	CH	Heinrich Lerch Eidgenössisches Amt für Messwesen Lindenweg 50 CH -3003 Bern - Wabern Schweiz e-mail: heinrich.lerch@eam.admin.ch
United Kingdom	GB	Dr. W.C. Pursley National Engineering Laboratory East Kilbride Glasgow G75 0QU United Kingdom e-mail: wpursley@nel.uk
United States of America	US	Vern Bean National Institute of Standards and Technology Gaithersburg, MD 20899 United States of America e-mail: vern.bean@nist.gov

2.2 Short Description of Installation Used by the Participating Laboratories

Lab	*Apparatus*	*Standard*	
BE	Wind tunnel 420 mm X 560 mm	LDA	
DK	Wind tunnel 500 mm x 500 mm	< 2 m/s: Vane Anemometer based upon length and time measurement > 2 m/s: 8 mm Pitot tube	
FI	Wind tunnel Ø 250 mm	0.1 to 5.5 m/s: 3 to 22 m/s:	orifice (ISO5167) + LDA 4 mm Pitot (Prandtl)
FR	Wind tunnel 250 mm x 250 mm	LDA	
DE	Wind tunnel Ø 152 mm	LDA	
	Pipe Ø 200 mm	LDA	

Lab	*Apparatus*	*Standard*	
IT	Wind tunnel Ø 3 m	3 to 50 m/s:	dynamic pressure 0 to 200 Pa and 0 to 2000 Pa (Pitot)
	Wind tunnel Ø 0.5 m	1 to 23 m/s:	dynamic pressure 0 to 200 Pa and 0 to 2000 Pa (Pitot)
	Whirling arm radius 3.5 m	0.2 to 3 m/s:	Measurement of circular speed
	Carriage in tank 2.2 m x 1 m x 30 m net length 20 m	0.003 m/s to 3 m/s:	calibrated wheel on carriage with encoder
JP	Wind tunnel (closed) 400 mm x 400 mm	3 to 20 m/s:	Ultrasonic anemometer calibrated by a LDA
	Towed carriage Room: 2.9 m x 2.9 m Rail: 45 m calibration between 5 m and 28 m	0.2 to 1 m/s:	Laser displacement meter and timer (<= 1 m/s)
NL	Wind tunnel Ø 300/400/600 mm	Measurement of air flow (32 to 12000 m^3/h)	
PL	Wind tunnel 630 mm x 815 mm	0.05 to 2 m/s: 2 to 40 m/s:	(multi-) orifice Pitot/Prandtl
CH	Carriage in tunnel 2.4 m x 2.4 m x 52 m net length 30 m	Measurement of length and time	
GB	Wind tunnel Ø 450 mm	Pitot tube	
US	Low speed wind tunnel 0.9m high 0.9 m wide 6.1 m long	LDA	
	High speed wind tunnel 2.1 m high 1.5 m wide 12.2 m long	Pitot tube	

LDA: Laser Doppler Anemometer

2.3 Time Table

Lab	Institute	Time
CH1	Swiss Federal Office of Metrology, Bern-Wabern	Aug 1996/Jan 1997
Dk	Dansk Technologisk Institut, Aarhus	April/ 1997
FI	Technical Research Center of Finland	June 1997
NL	NMi Van Swinden Laboratory, Dordrecht	July 1997
PL	Strata Mechanics Research Institute, Krakow	August 1997
BE	Université Catholique de Louvain, Louvain-la-Neuve	September 1997
FR	CETIAT, Villeurbanne (France)	Oktober 1997
IT	Politecnico di Torino	December 1997
DE	PTB, Braunschweig	Jan1998
GB	National Engineering Laboratory, East Kilbride	April 1998
CH2	Swiss Federal Office of Metrology, Bern-Wabern	May 1998
JP	National Research Lab. of Metrology, Tsukuba	August 1998
US	NIST, Gaithersburg, MD	January 1999

3 Transfer Standards

3.1 Instruments

We used 3 windmill-type anemometers manufactured by Schiltknecht Messtechnik AG, CH-8625 Gossau/Switzerland. The type designation is MiniAir60 Macro, MiniAir60 Mini, and MiniAir60 Micro. The maximum air velocity is 20 m/s (for all). The minimum air velocity is 0.15 m/s (Macro), 0.3 m/s (Mini), and 0.5 m/s (Micro). All generate 1 electrical pulse per vane and turn on a TTL-level. In order to simplify pulse counting, we have built 2 power supplies with a pulse amplifier, one is battery-powered and one is mains driven (230 V, 50 Hz).

For testing purposes (checking), a spare anemometer head was added to the 3 instruments.

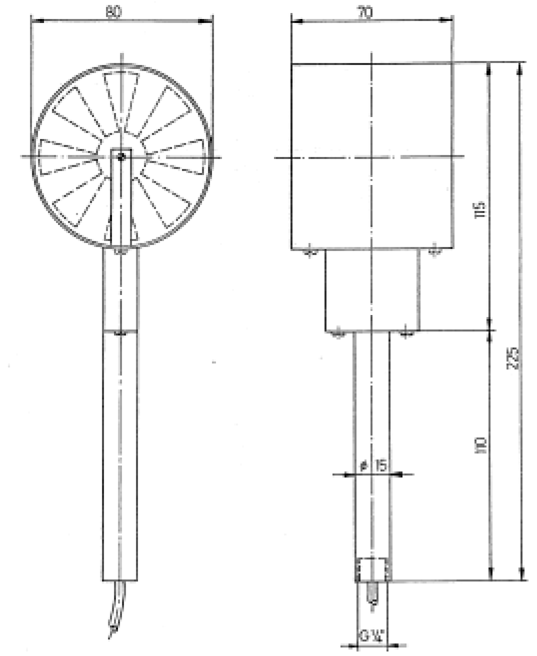

Figure 1: Anemometer Macro

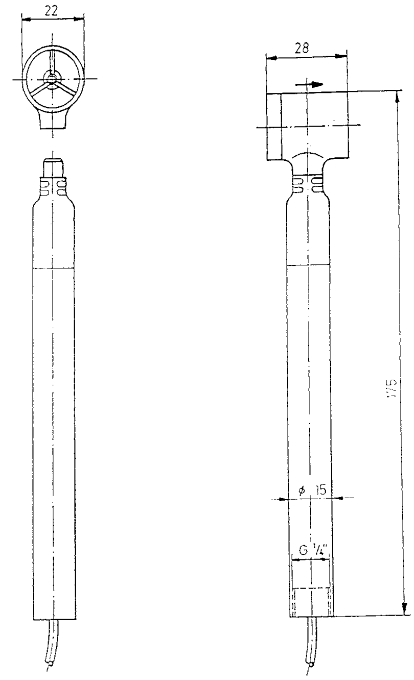

Figure 2: Anemometer Mini

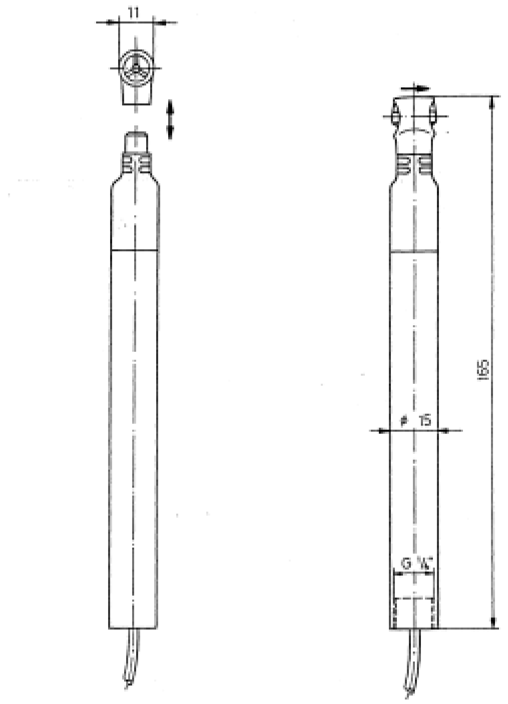

Figure 3: Anemometer Micro

3.2 Transportation

The instruments were located in small plastic box filled with foam. A rugged plastic box also filled with foam contained the small plastic box with the anemometers, the pulse amplifiers and the papers necessary for the measurements.

Every laboratory sent the whole package to the next laboratory. For customs purposes, a Carnet ATA was used.

4 Measurement Task

Each laboratory should calibrate the 3 anemometers as usual. The planned air velocities were the following (not mandatory):

0.2	m/s	only Macro
0.3	m/s	only Macro and Mini
0.5	m/s	
0.75	m/s	
1.0	m/s	
1.5	m/s	
2.0	m/s	
3.0	m/s	
5.0	m/s	
7.5	m/s	
10	m/s	
13	m/s	
15	m/s	
20	m/s	

We asked the laboratories to report the following values for every measured point:

air velocity in m/s
frequency in Hz
anemometer constant in pulses per meter (chapters 5.1 and 6.1).

We also asked to indicate the uncertainty value(s) (U_{95}).

Furthermore, we invited the laboratories to give us all the calculations (mean values, standard deviations, least squares fit, etc) and informations of which they think they could be useful for the project.

5 Results

5.1 Measurements from the Participating Laboratories

The laboratories sent us their results as EXCEL tables. This simplified our task very much. The detailed reports are noted in part 3.

In order to have readable diagrams (only one value per air velocity), we calculated the mean values for those laboratories which sent more than one value per air velocity. For some graphs, we calculated the standard deviations of the anemometer constant (if necessary).

5.2 Intercomparisons

We generally use the anemometer constant for the intercomparison. This anemometer constant is the number of pulses of the anemometer per unit of length of the air column passing through the anemometer. For more explanations see chapter 6.1.

Some laboratories have used more than one test installation. Therefore, the results are shown for each test installation if the air velocity ranges were overlapping.

For the Macro, NL has corrected for blocking effects. Both values are shown.

Abbreviations:

CH1	CH:	measurement before journey through Europe
CH2	CH:	measurement after journey through Europe
DE	DE:	measurement made in wind tunnel
DE Pipe	DE:	measurement made in pipe (only Mini)
IT Lar	IT:	measurement made in large wind tunnel
IT Sma	IT:	measurement made in small wind tunnel
IT Arm	IT:	measurement made on rotating arm
IT Tank	IT:	measurement made on carriage in tank
JP WT	JP:	measurement made in wind tunnel
JP Car	JP:	measurement made on towed carriage
NL Raw	NL:	not corrected for blocking effects
NL Cor	NL:	corrected for blocking effects
US Low	US:	measurement made in low speed wind tunnel
US High	US:	measurement made in high speed wind tunnel
US S Low	US:	measurement of spare anemometer made in low speed wind tunnel (only micro)
US S High	US:	measurement of spare anemometer made in high speed wind tunnel (only micro).

5.2.1 Over All Information

The following figures show the mean values of the anemometer constant as a function of the air velocity. The results from all laboratories are shown on the same diagram.

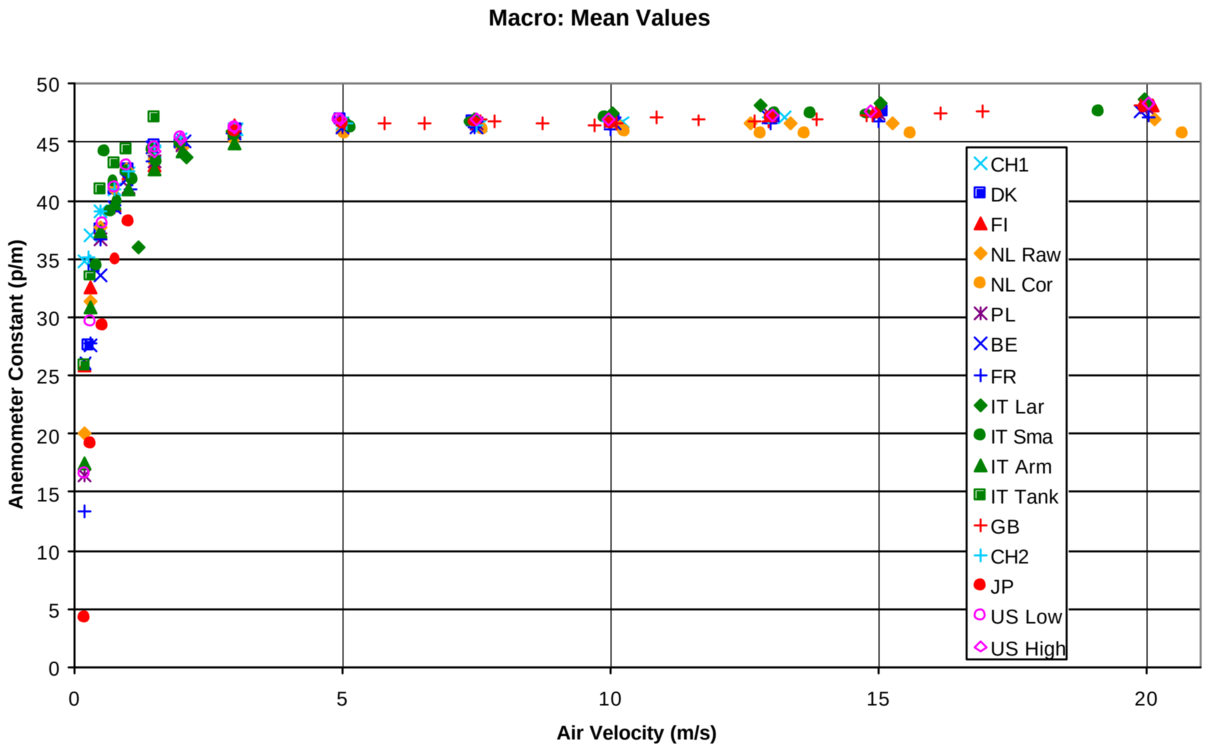

Figure 4: Macro, overview

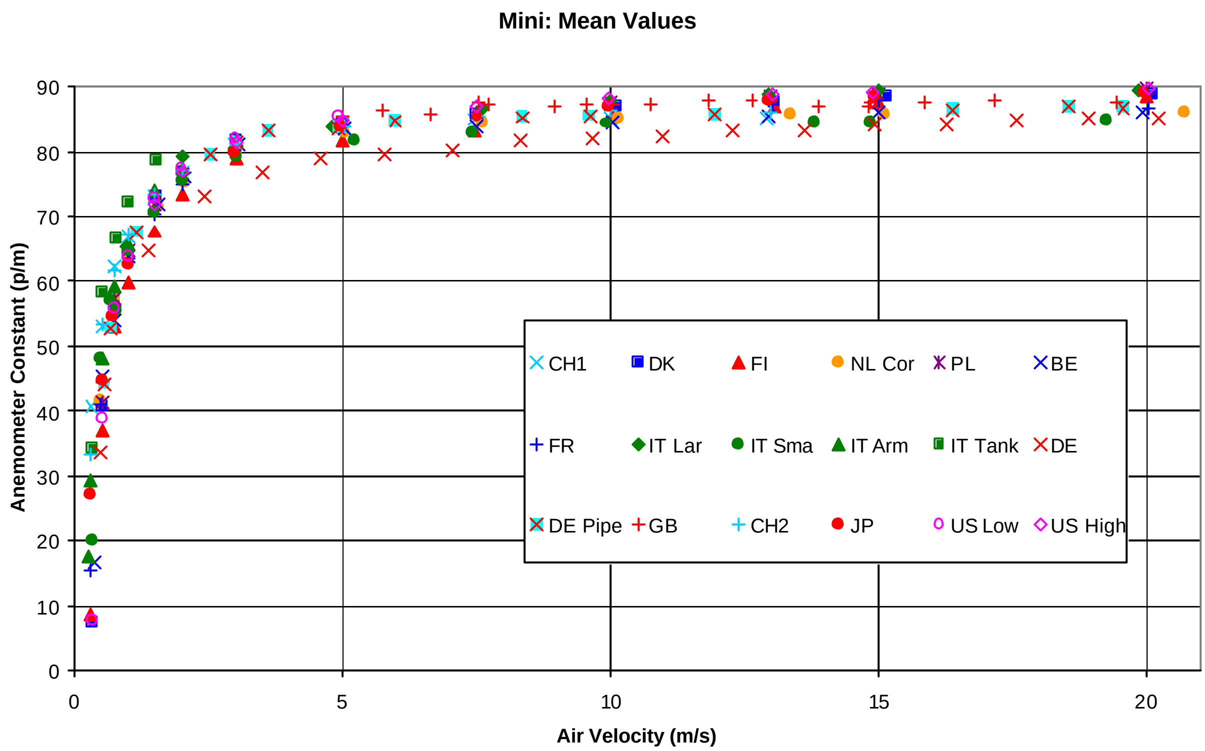

Figure 5: Mini, overview

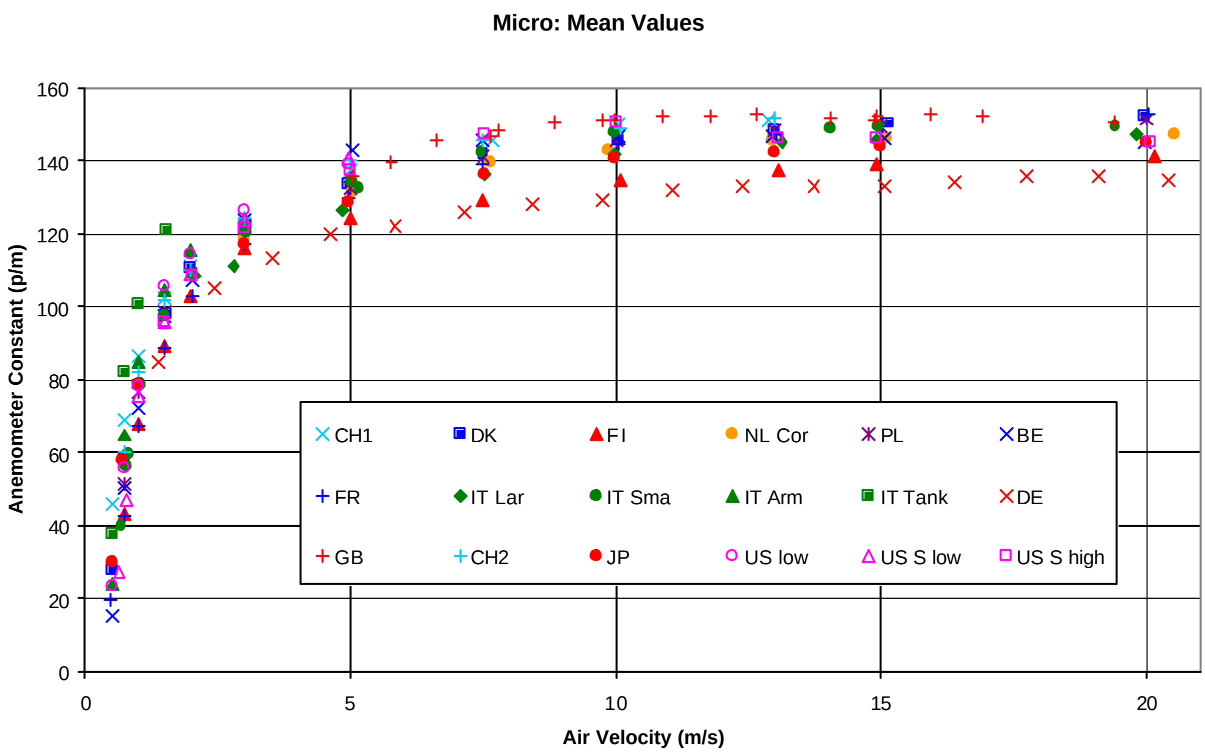

Figure 6: Micro, overview

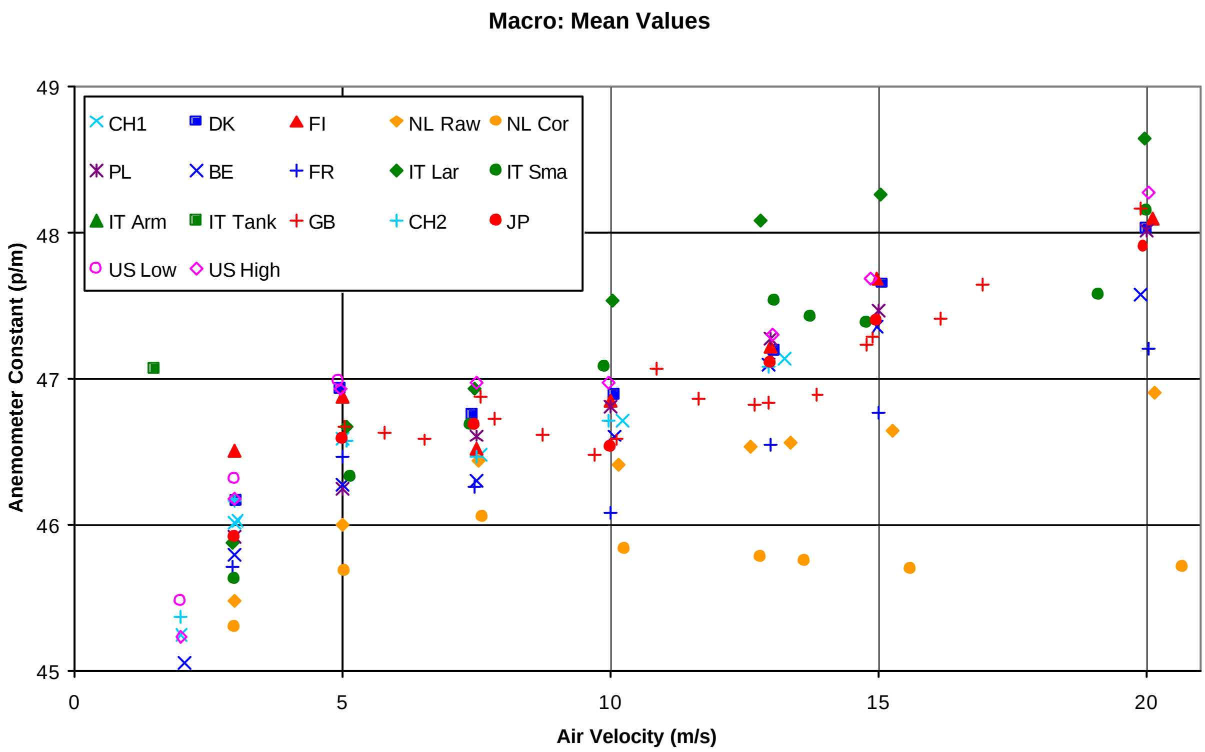

Figure 7: Macro, mean values, overview over upper velocity range

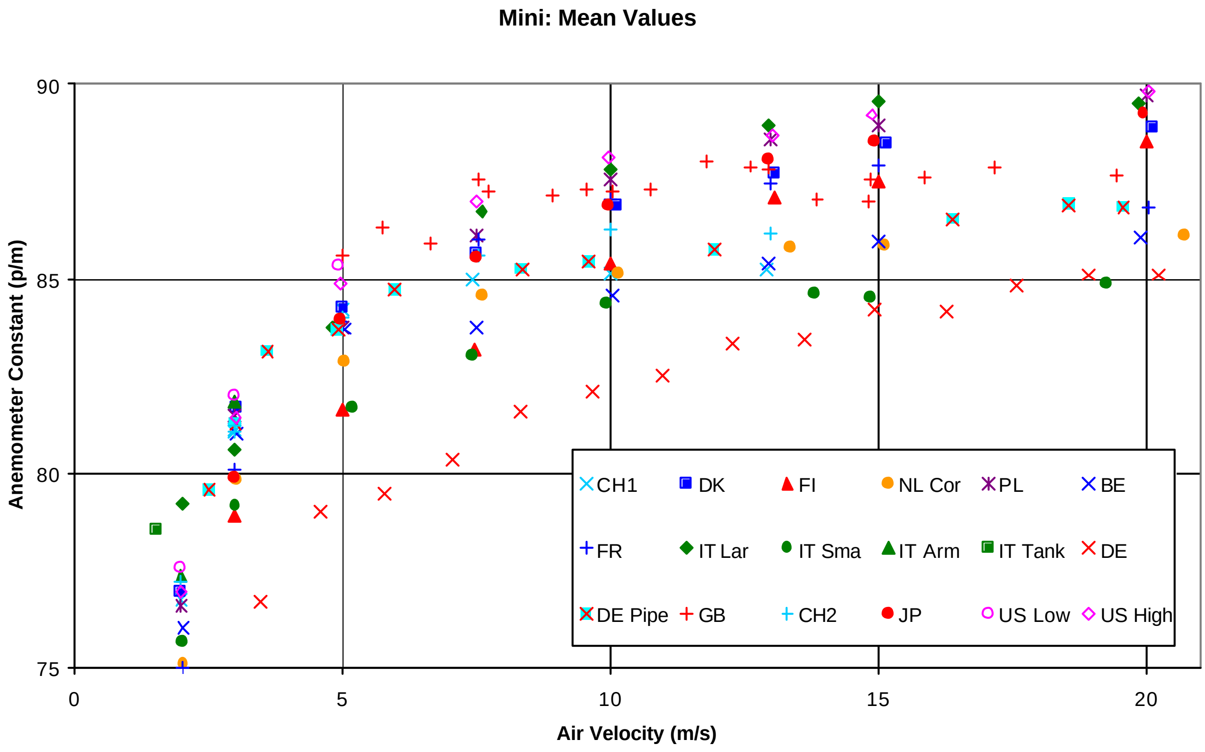

Figure 8: Mini, mean values, overview over upper velocity range

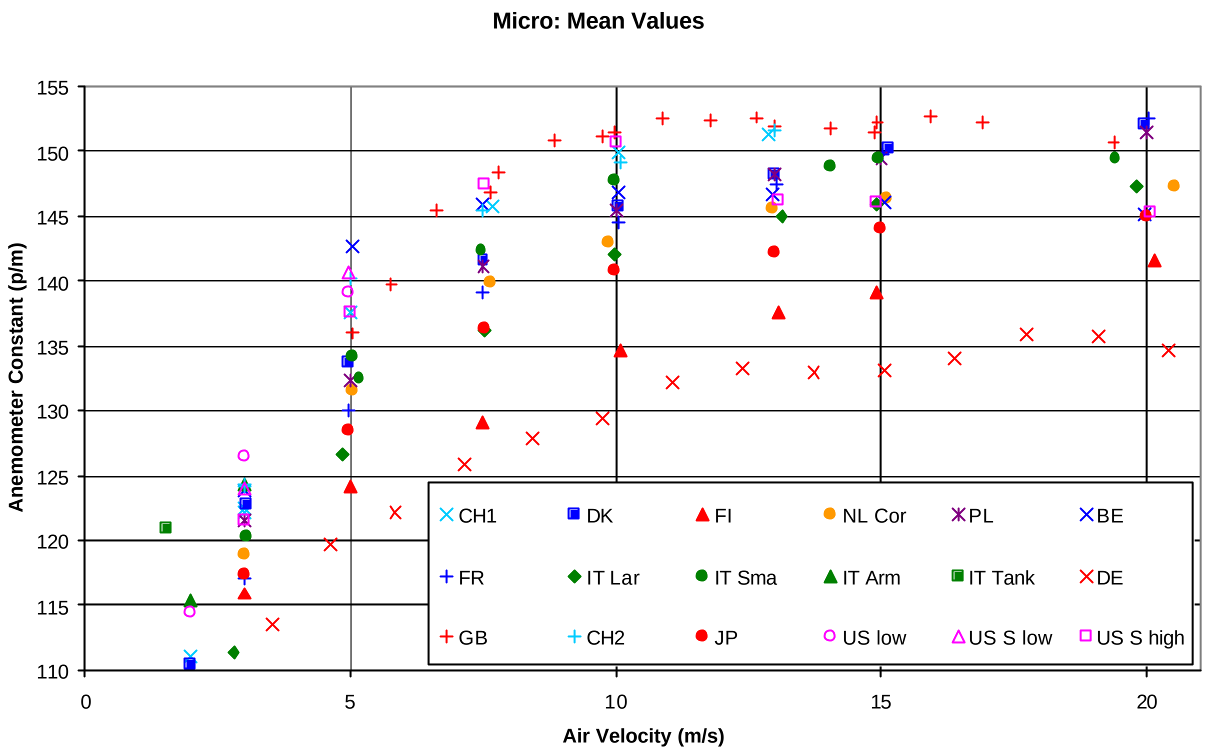

Figure 9: Micro, mean values, overview over upper velocity range

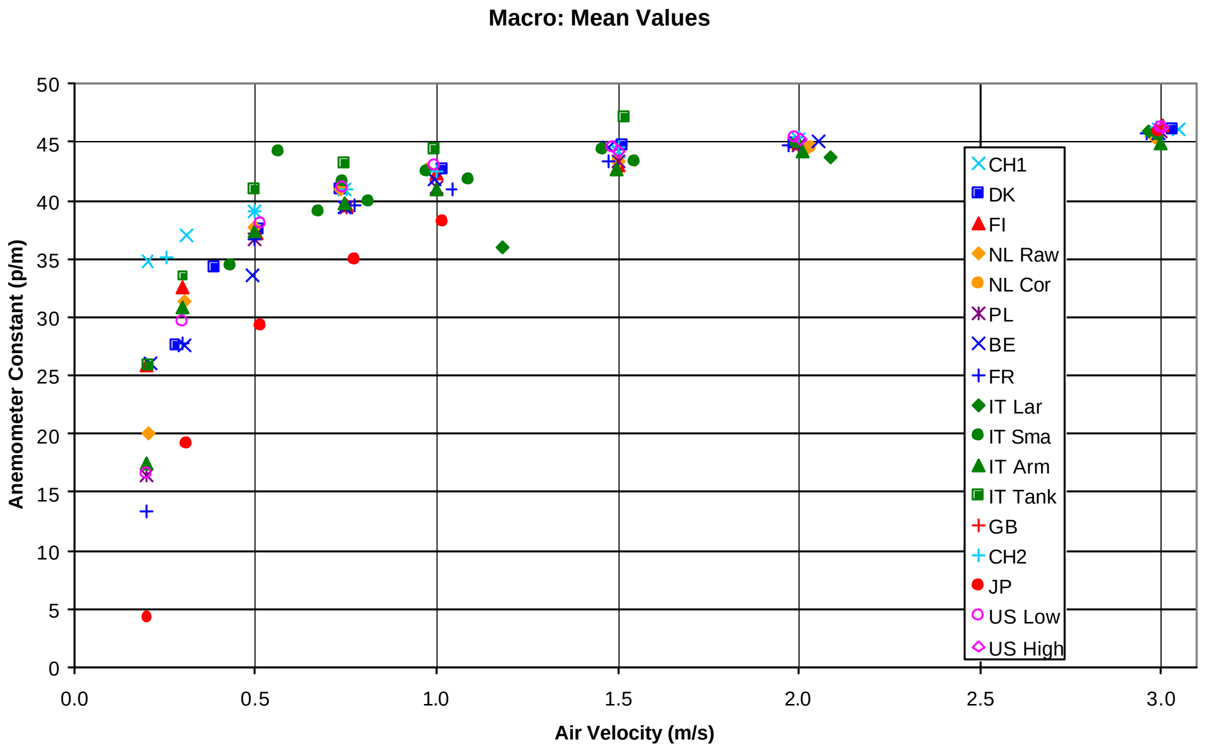

Figure 10: Macro, mean values, overview over lower velocity range

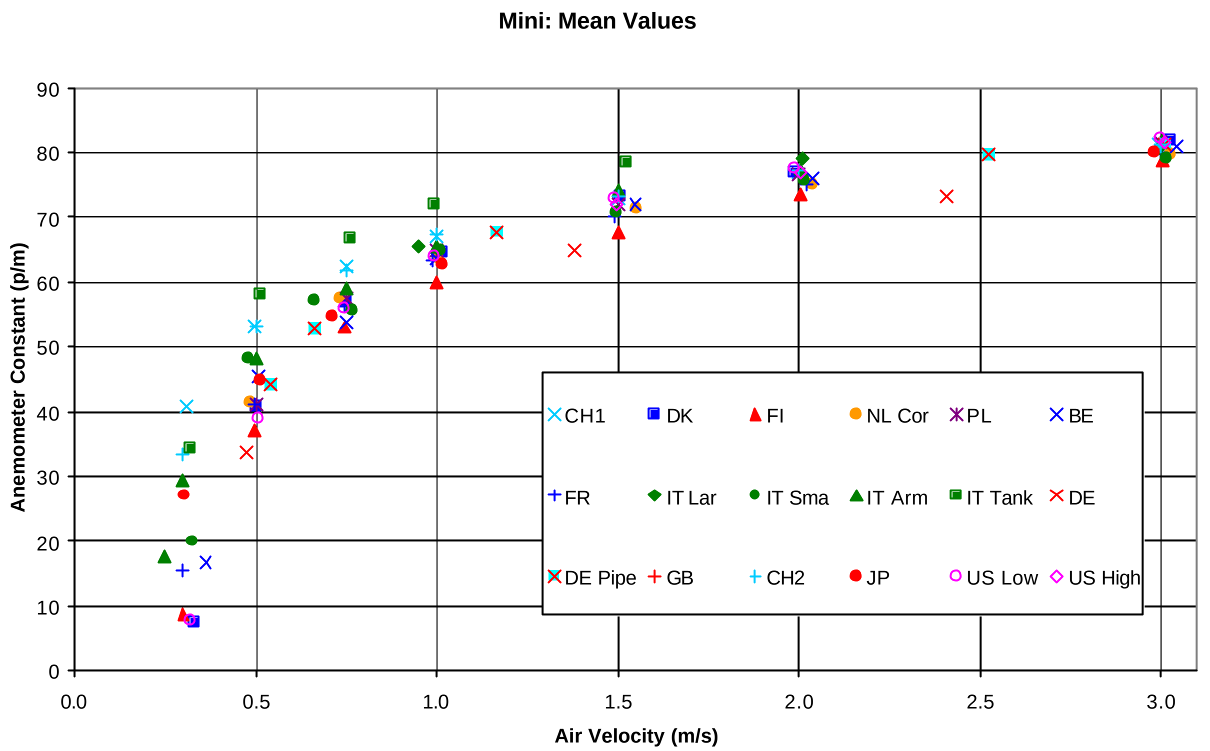

Figure 11: Mini, mean values, overview over lower velocity range

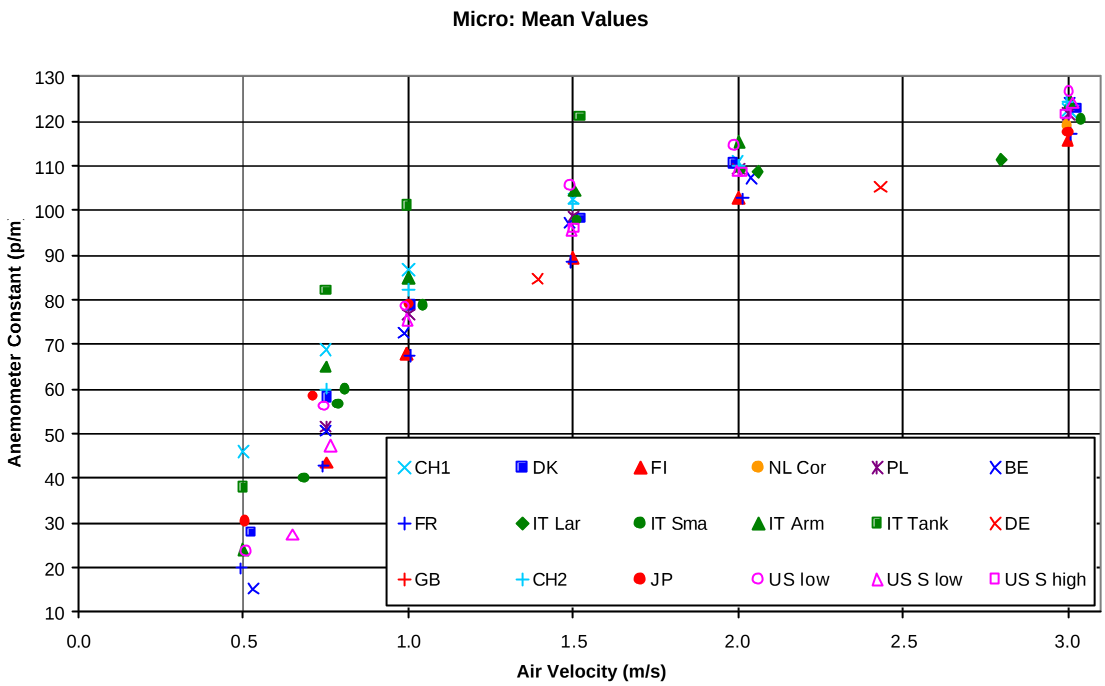

Figure 12: Micro, mean values, overview over lower velocity range

5.2.2 Wind tunnel Measurements

The measurements made in wind tunnels are shown. Again, first all mean values are shown then the mean values for the upper and lower air velocity range.

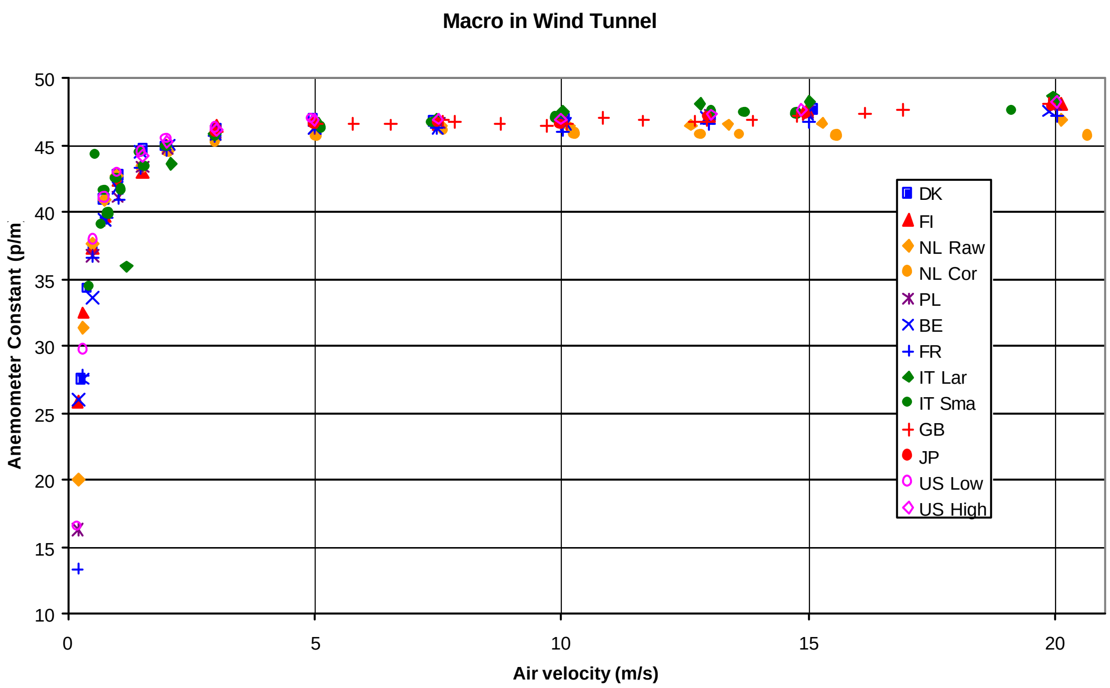

Figure 13: Macro in wind tunnel, all mean values

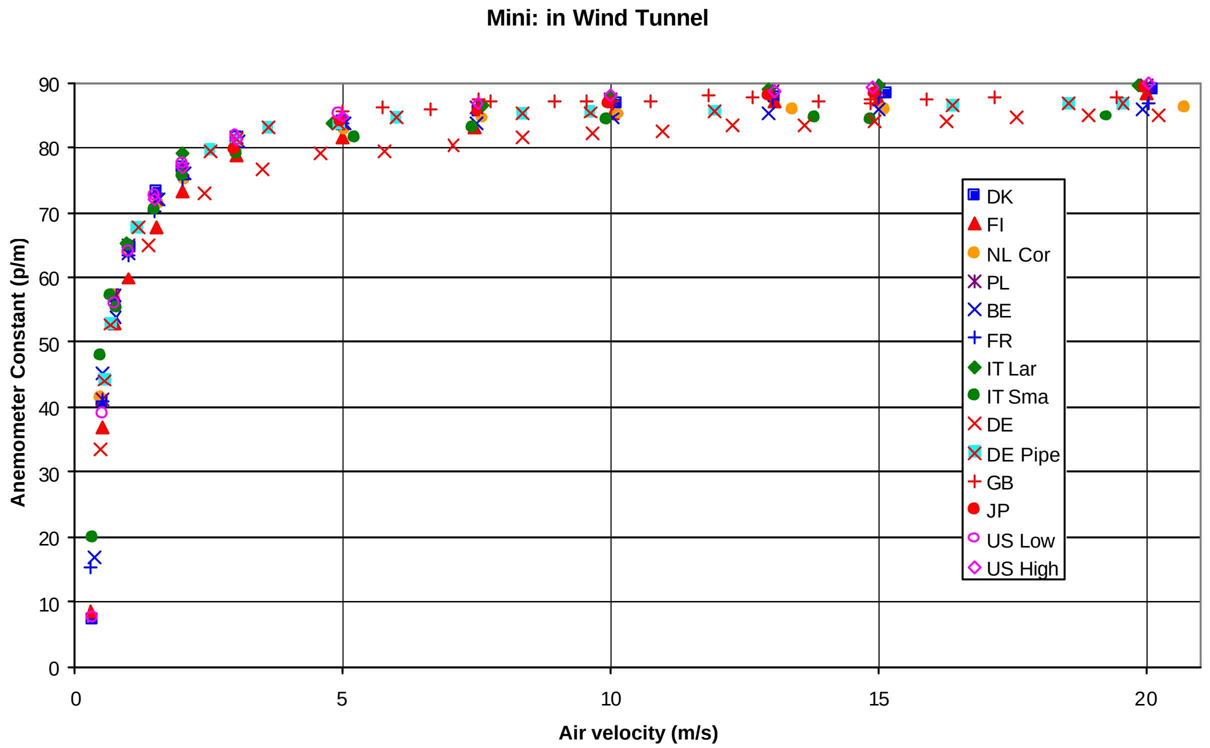

Figure 14: Mini in wind tunnel, all mean values

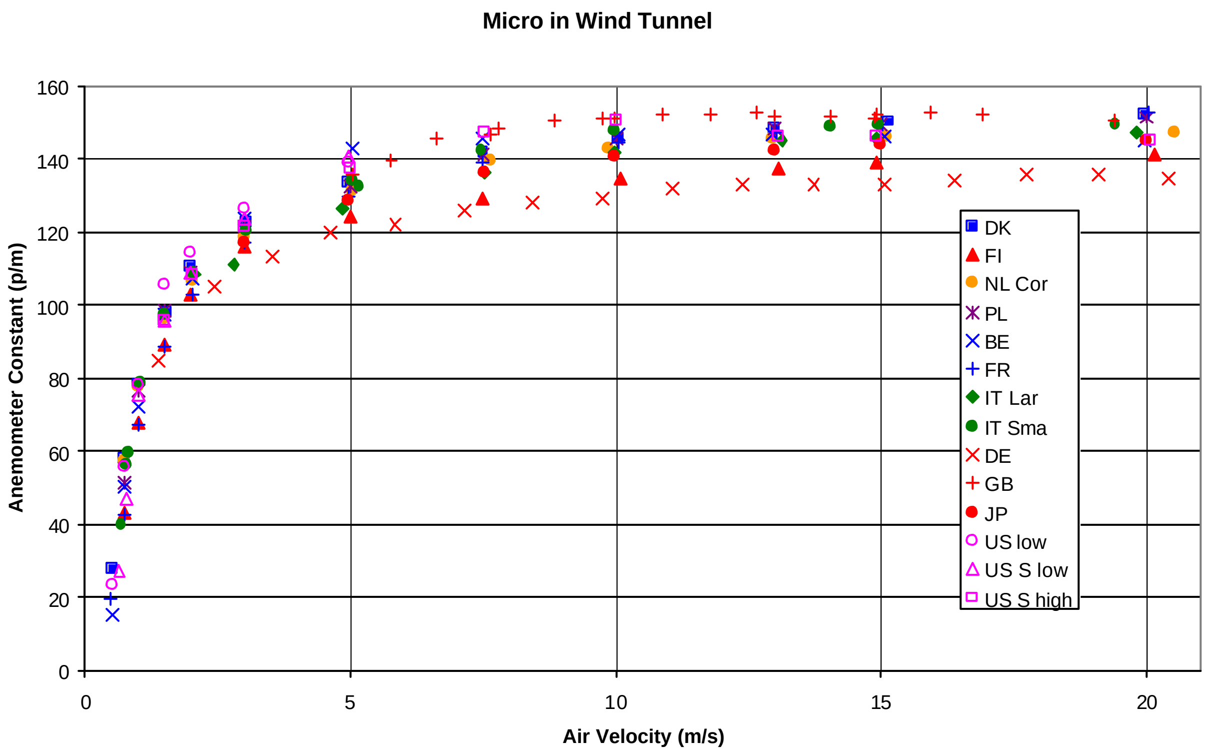

Figure 15: Micro in wind tunnel, all mean values

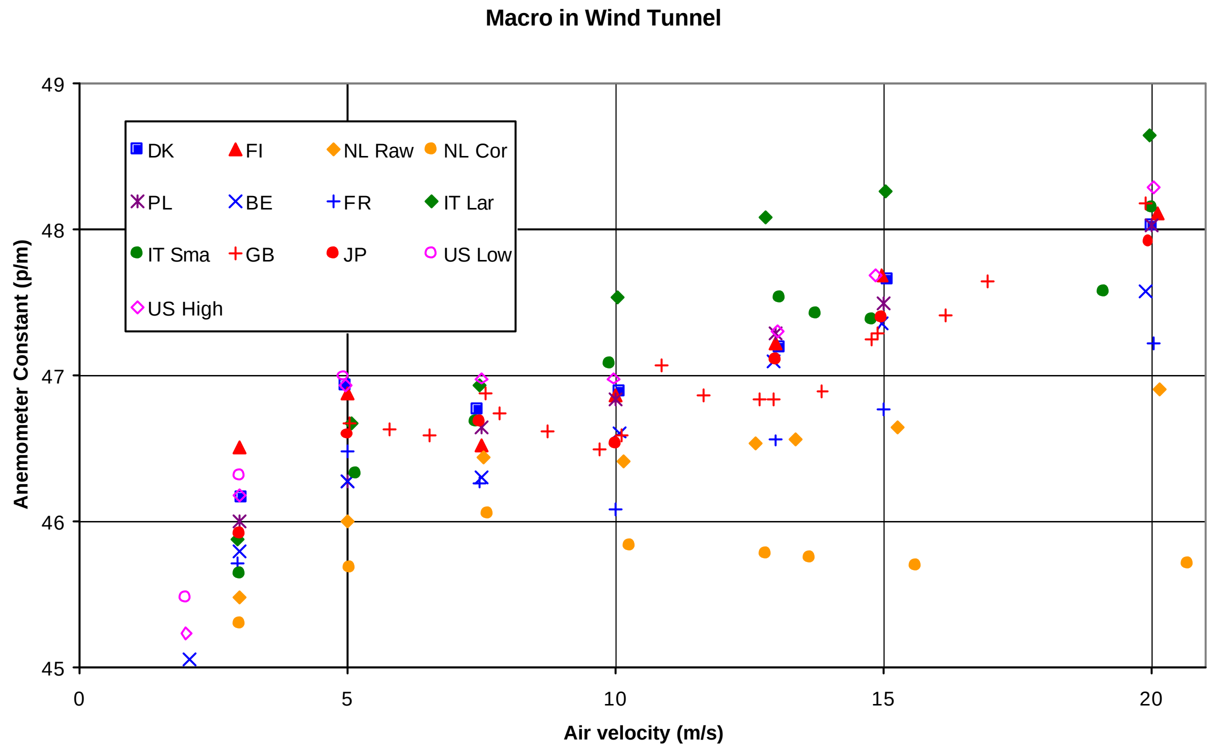

Figure 16: Macro in wind tunnel, mean values for upper velocity range

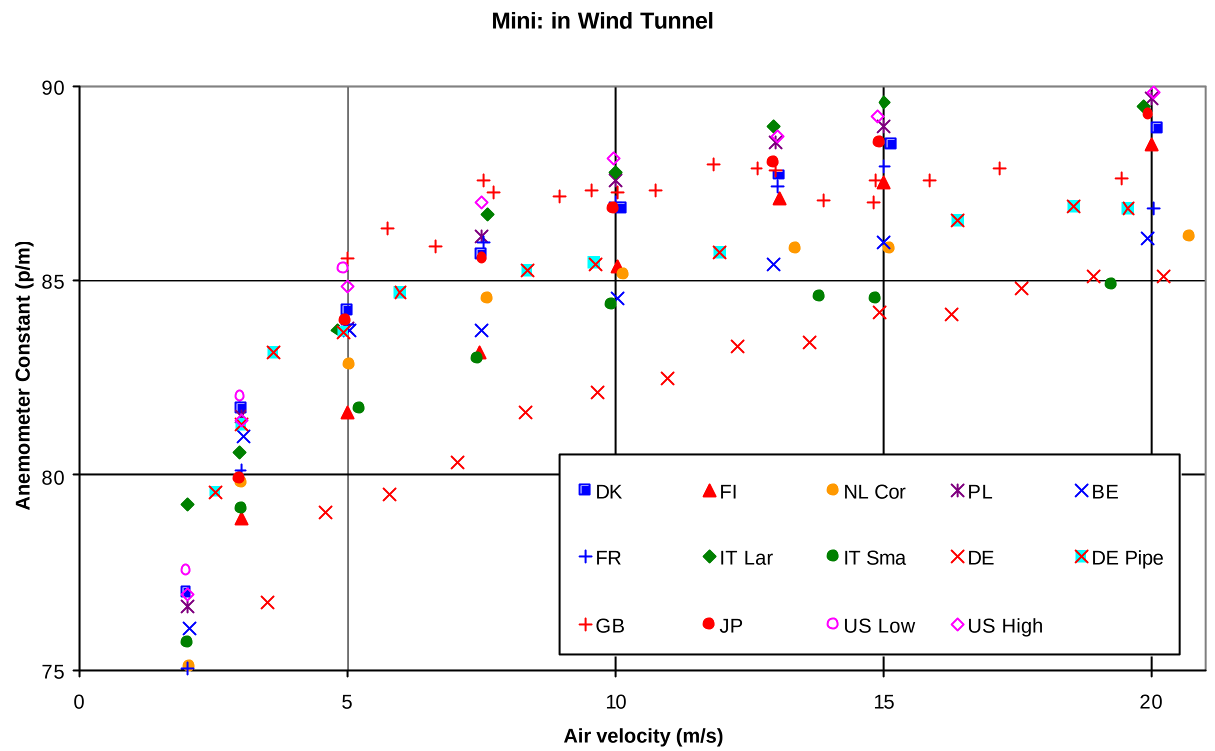

Figure 17: Mini in wind tunnel, mean values for upper velocity range

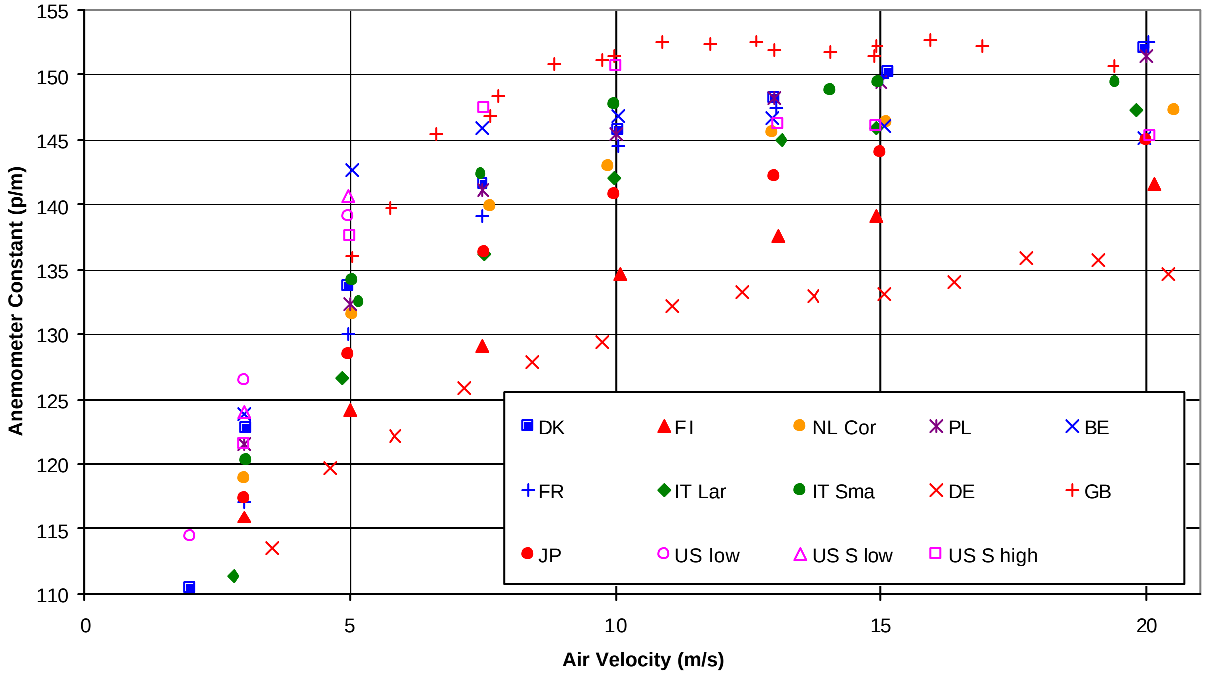

Figure 18: Micro in wind tunnel, mean values for upper velocity range

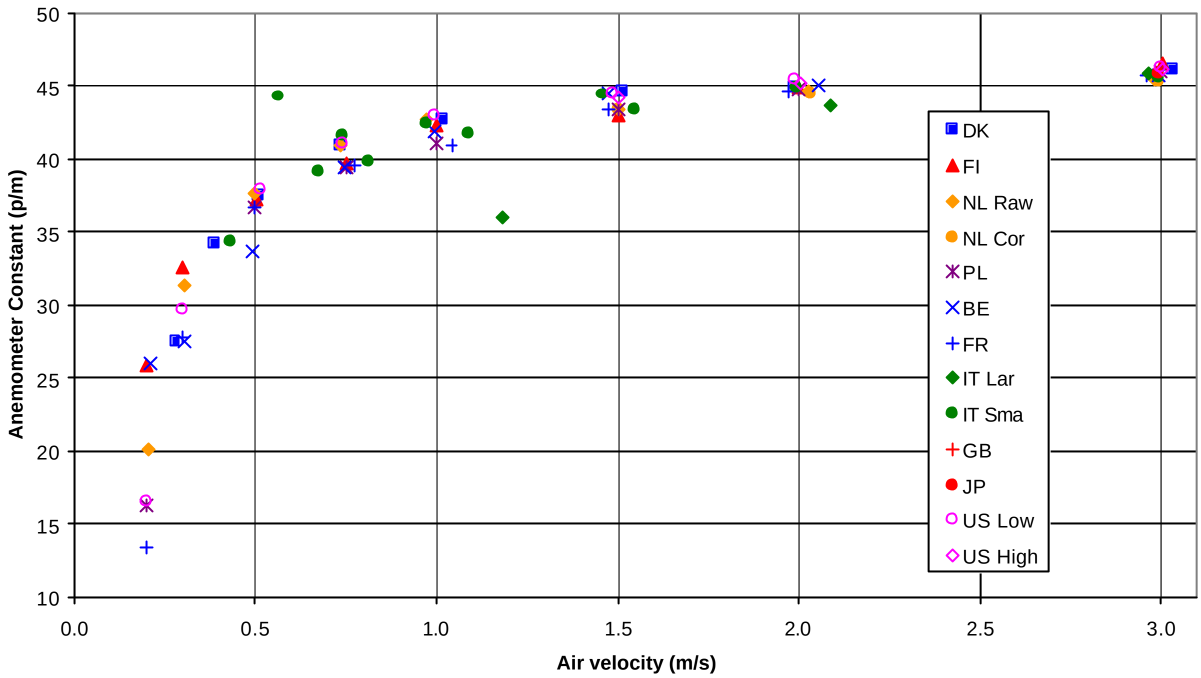

Figure 19: Macro in wind tunnel, mean values for lower velocity range

Mini: in Wind Tunnel

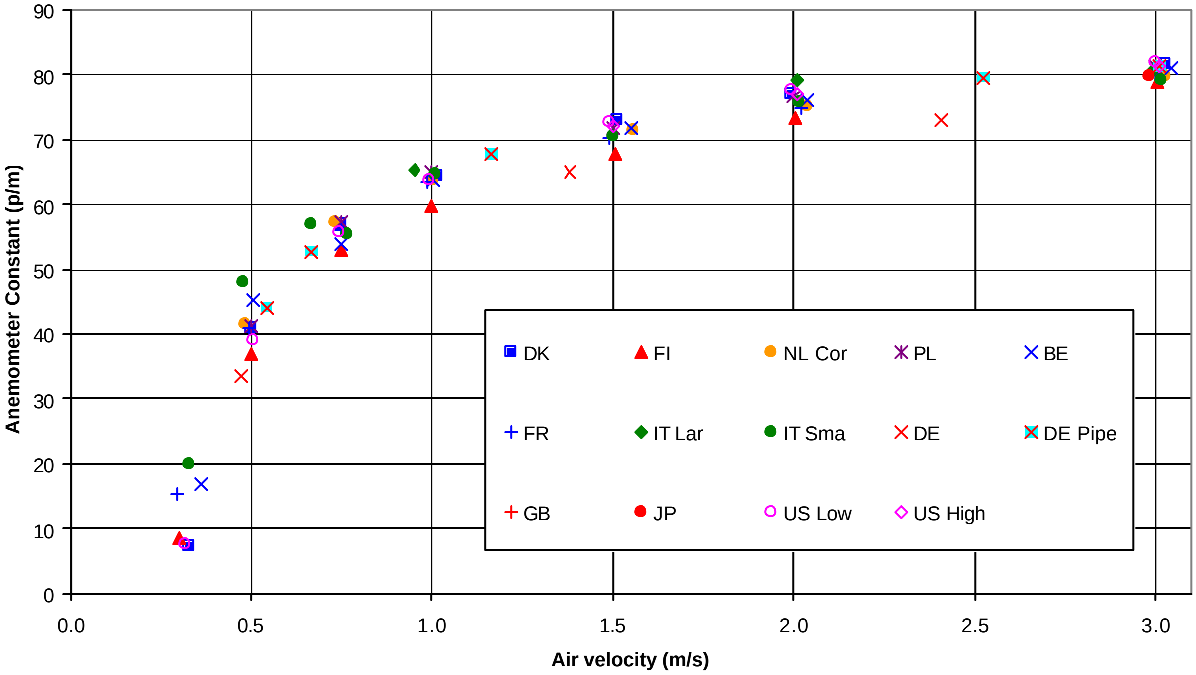

Figure 20: Mini in wind tunnel, mean values for lower velocity range

Micro in Wind Tunnel

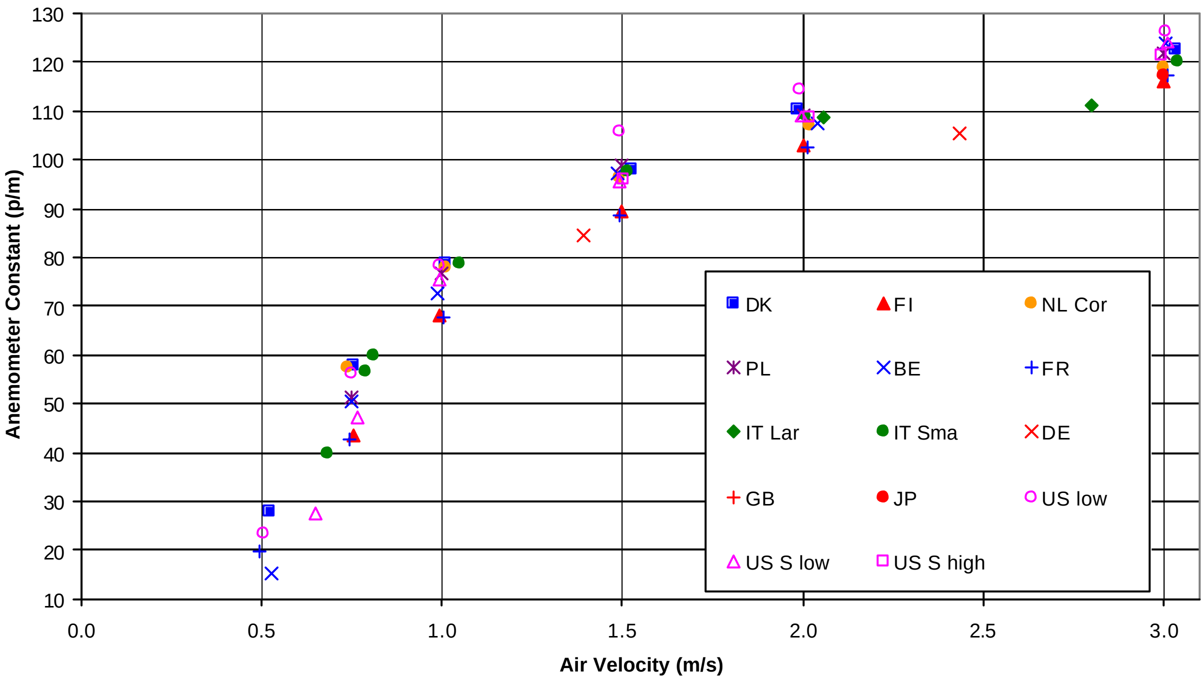

Figure 21: Micro in wind tunnel, mean values for lower velocity range

5.2.3 Measurements in Still Air

The anemometers were moved either on a carriage or on a turning arm in a room where the air stood still. The mean results are shown. Because of the small number of points, only the overviews are shown.

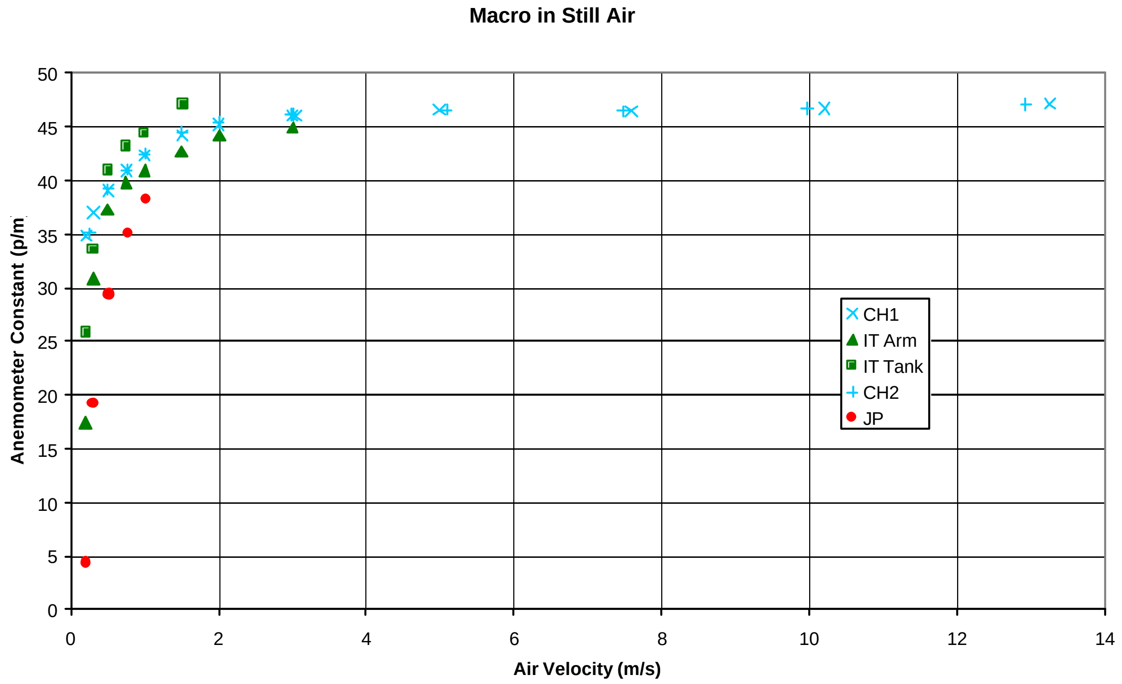

Figure 22: Macro in movement in a room where the air stood still

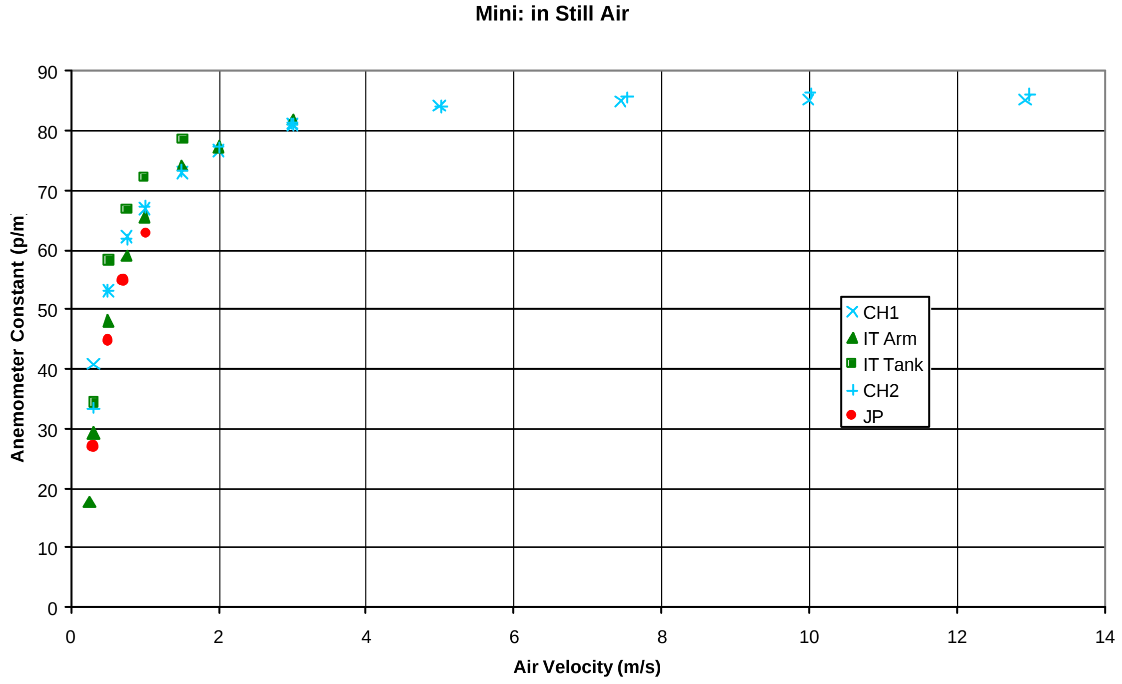

Figure 23: Mini in movement in a room where the air stood still

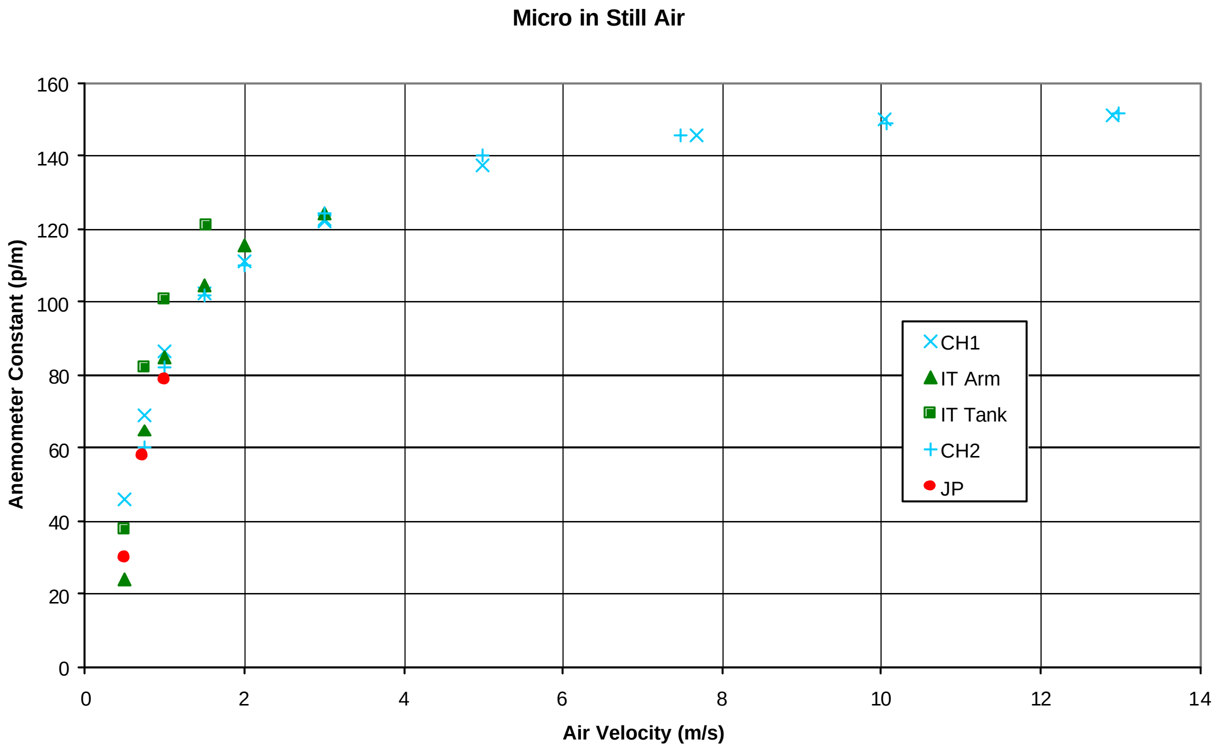

Figure 24: Micro in movement in a room where the air stood still

5.2.4 Dependence from Area of Wind Tunnel or Room

In order to see an eventual dependence from the dimension of the wind tunnel or room in which the anemometer is calibrated, the anemometer constant is shown in function of this dimension.

For wind tunnels, the value on the abscissa is the cross section area of its outlet.

For the apparatus using a carriage, we took the cross section area of the room in which the carriage moves.

For the turning arm (IT Arm) we fixed this area somewhat arbitrarily to 3 m^2.

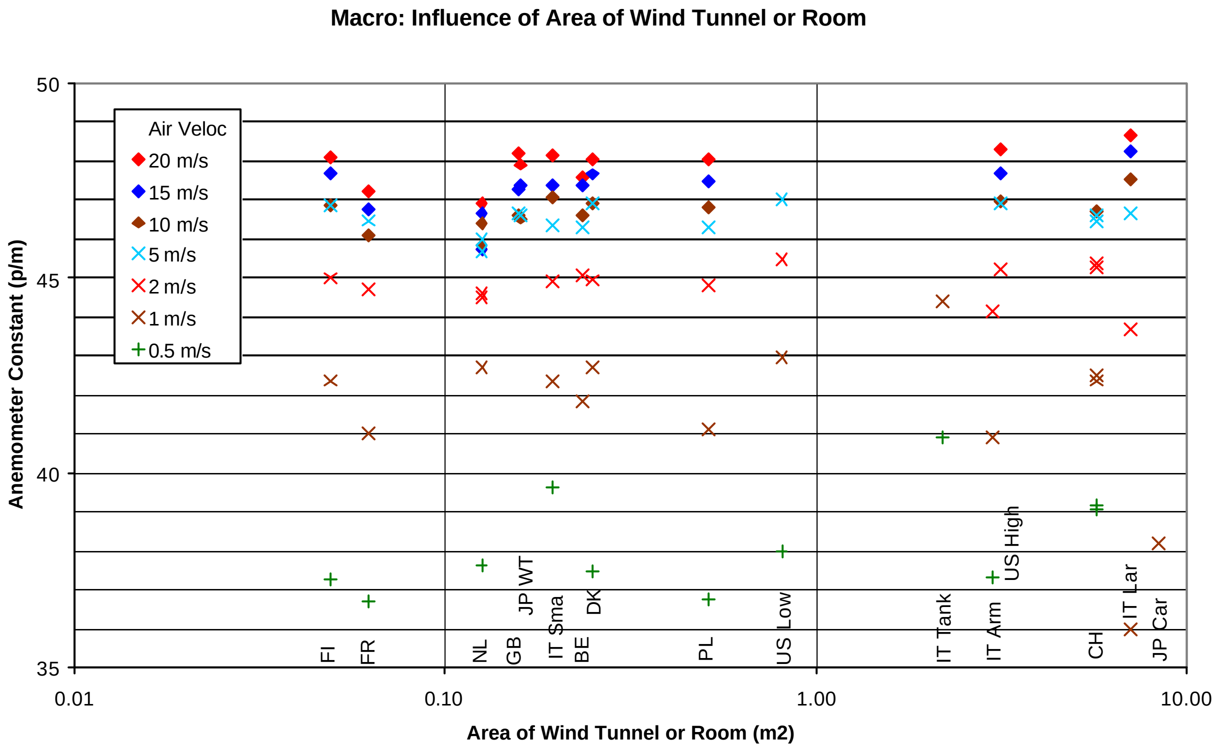

Figure 25: Macro, dependence from area of wind tunnel or room

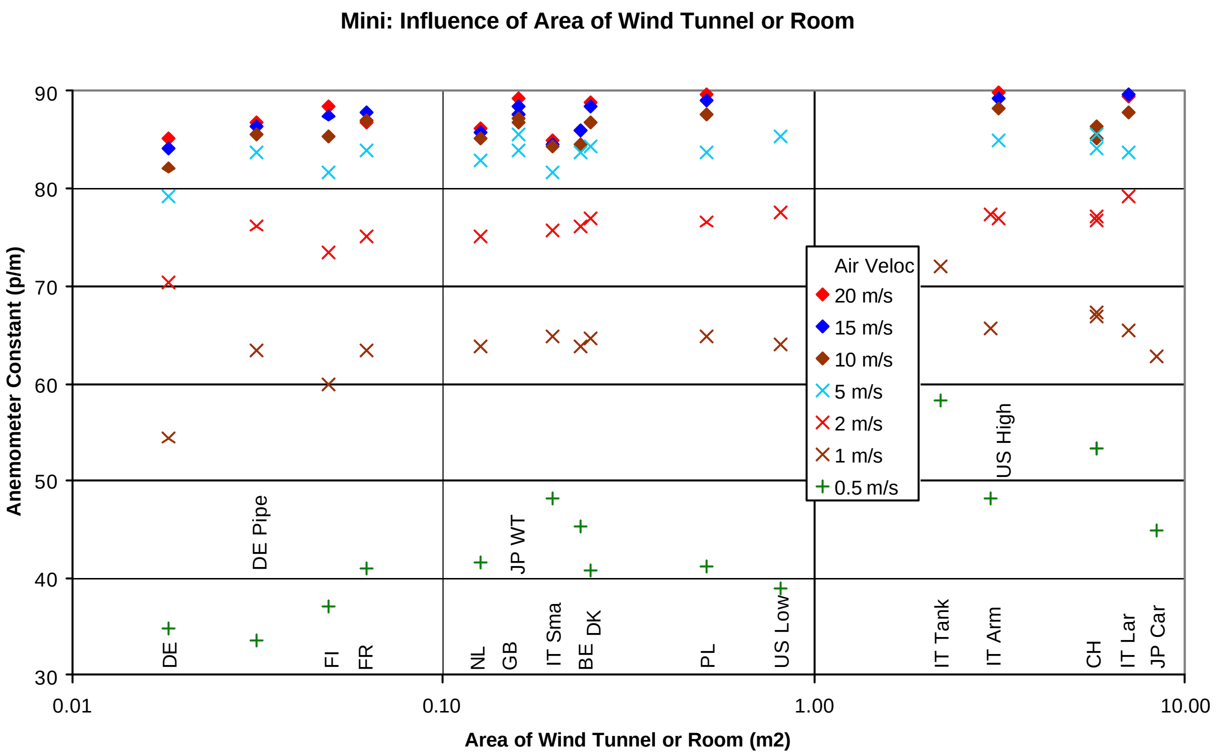

Figure 26: Mini, dependence from area of wind tunnel or room

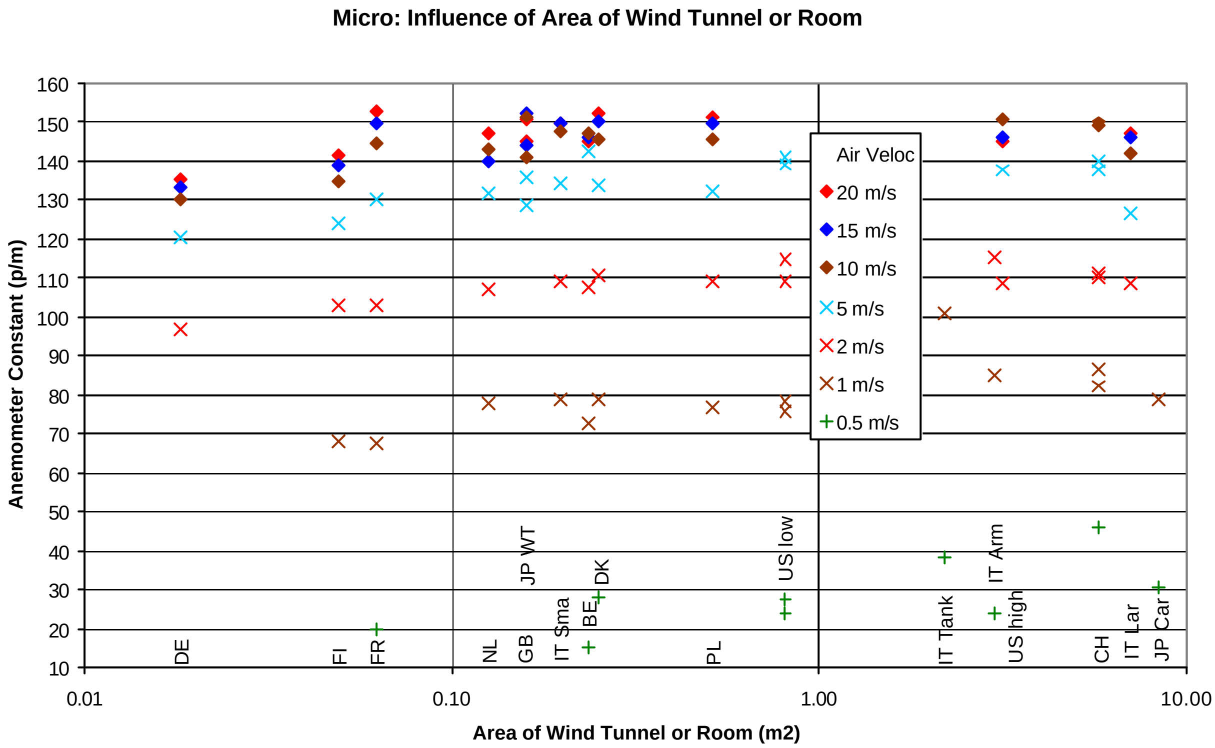

Figure 27: Micro, dependence from area of wind tunnel or room

5.2.5 Mean Results Classified Depending on Standard Used for Calibration

In order to discover an eventual dependence we putted the mean results basing upon the same standards together. For every of these groups, we calculated a fifth order polynome as the best-fit curve.

The first group consists of the measurements based on a Laser Doppler Anemometer (LDA) standard.

The second group shows the measurements based on a standard using differential pressure methods like a Pitot or Prandl tube.

The third group consists of the measurements made in a room where the air stands still. The anemometer is either moved on a carriage or on a rotating arm. The movement of the anemometer is measured by registering the length of its path and the time needed to run this path.

The fourth group shows the measurements based on measurements of the airflow in the wind tunnel: The amount of air passing through the outlet per unit time is measured and the flow profile is known.

Finally, all the polynomes are shown together. The corresponding mean deviations of the values from the polynome (mean residua) are also shown. The mean residuum is the mean deviation of a point from the polynome. For the calculation of the polynome, we used the points shown in the diagrams: only 1 (mean) value per air velocity per laboratory. The polynomes are functions of the natural logarithm of the air velocity:

$$AC = a_0 + a_1 \cdot \ln(v) + a_2 \cdot (\ln(v))^2 + a_3 \cdot (\ln(v))^3 + a_4 \cdot (\ln(v))^4 + a_5 \cdot (\ln(v))^5$$

AC Anemometer Constant
v Air Velocity
a_i Polynome - Coefficients

The use of a fifth order polynome and of the natural logarithm is purely mathematical and has no physical background. The only aim was to find the curve that fitted best with a reasonable amount of work.

For the calculation of the values of the upper part of the velocity range, we reduced the order of the polynome appropriately in order to get an approximation making sense.

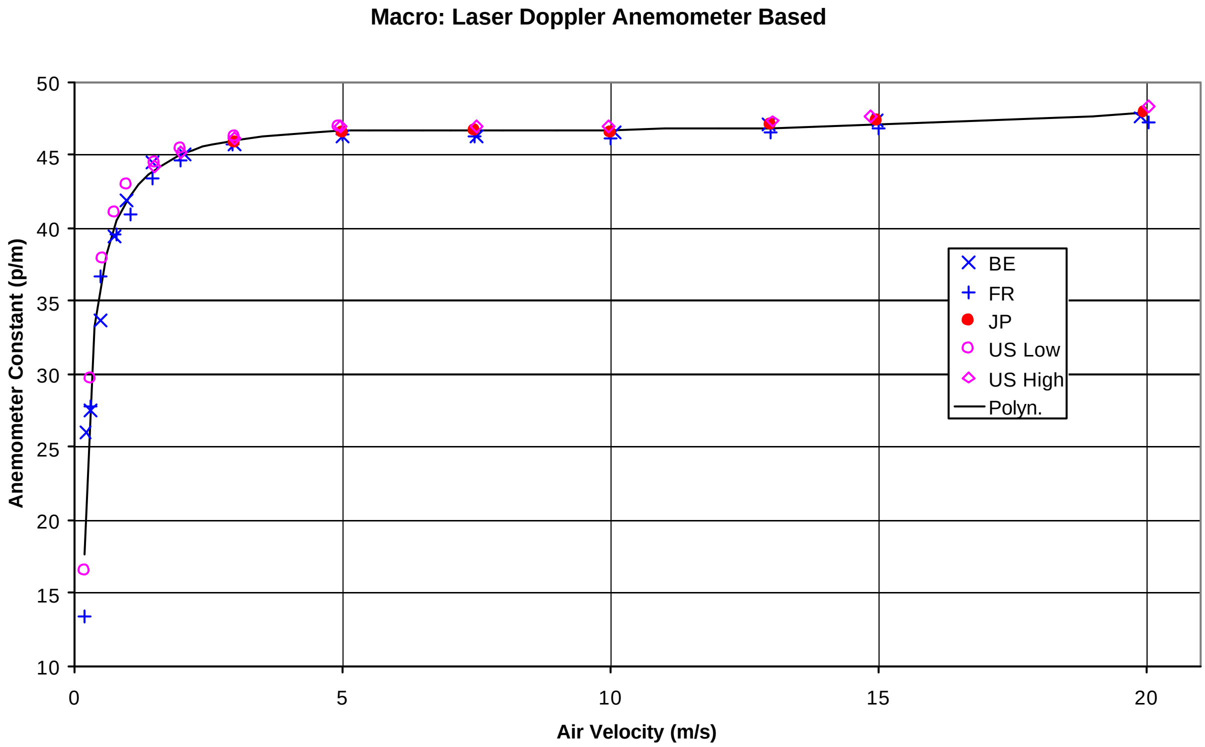

Figure 28: Macro, Laser Doppler Anemometer based calibrations

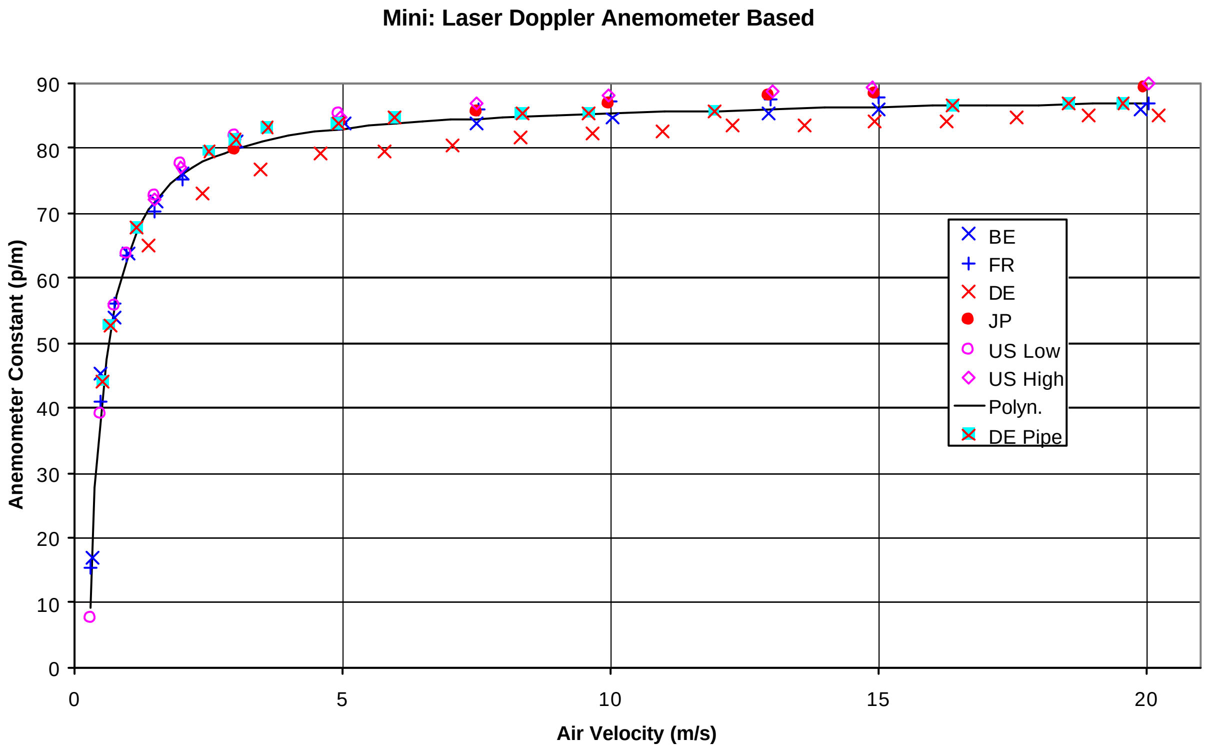

Figure 29: Mini, Laser Doppler Anemometer based calibrations

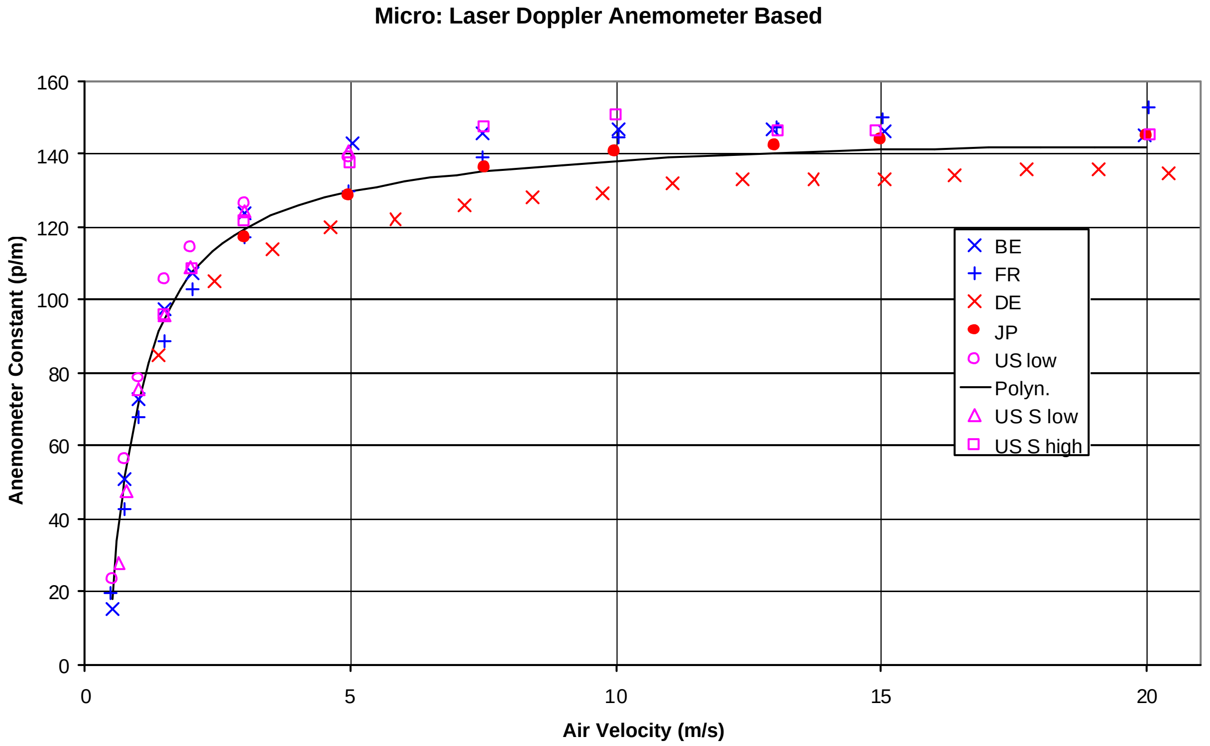

Figure 30: Micro, Laser Doppler Anemometer based calibrations

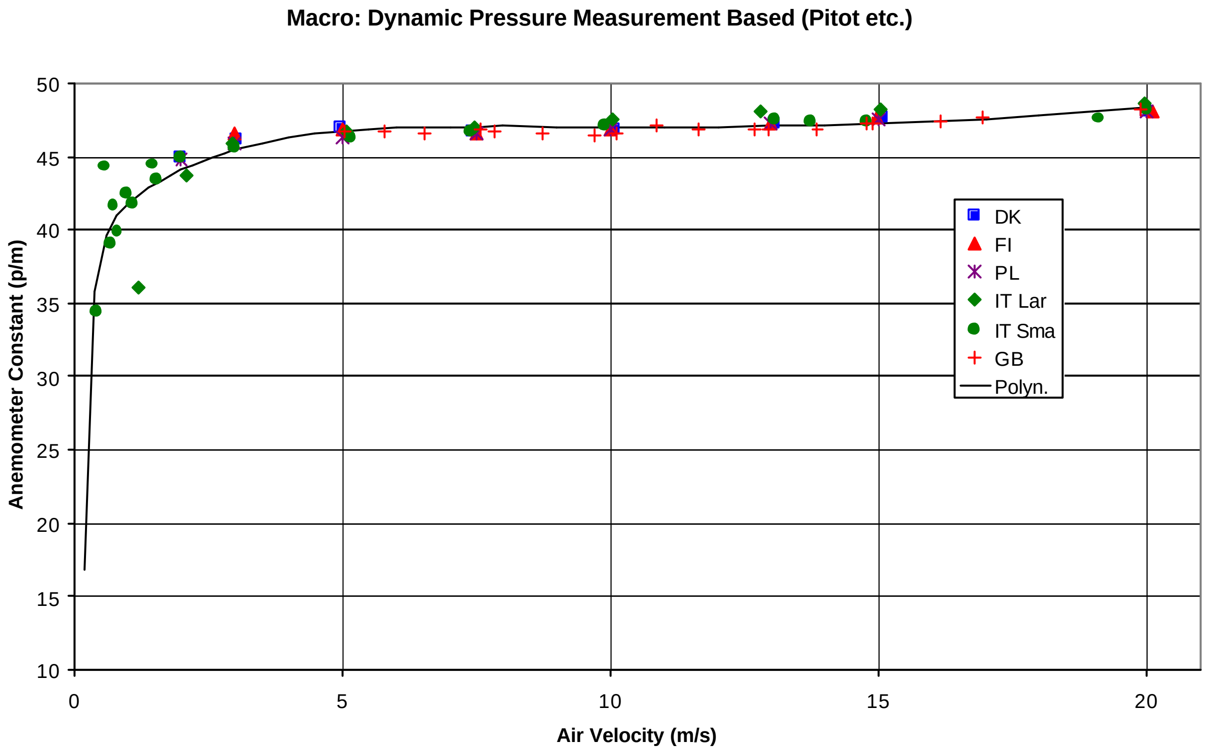

Figure 31: Macro, dynamic pressure measurement (Pitot etc.) based calibrations

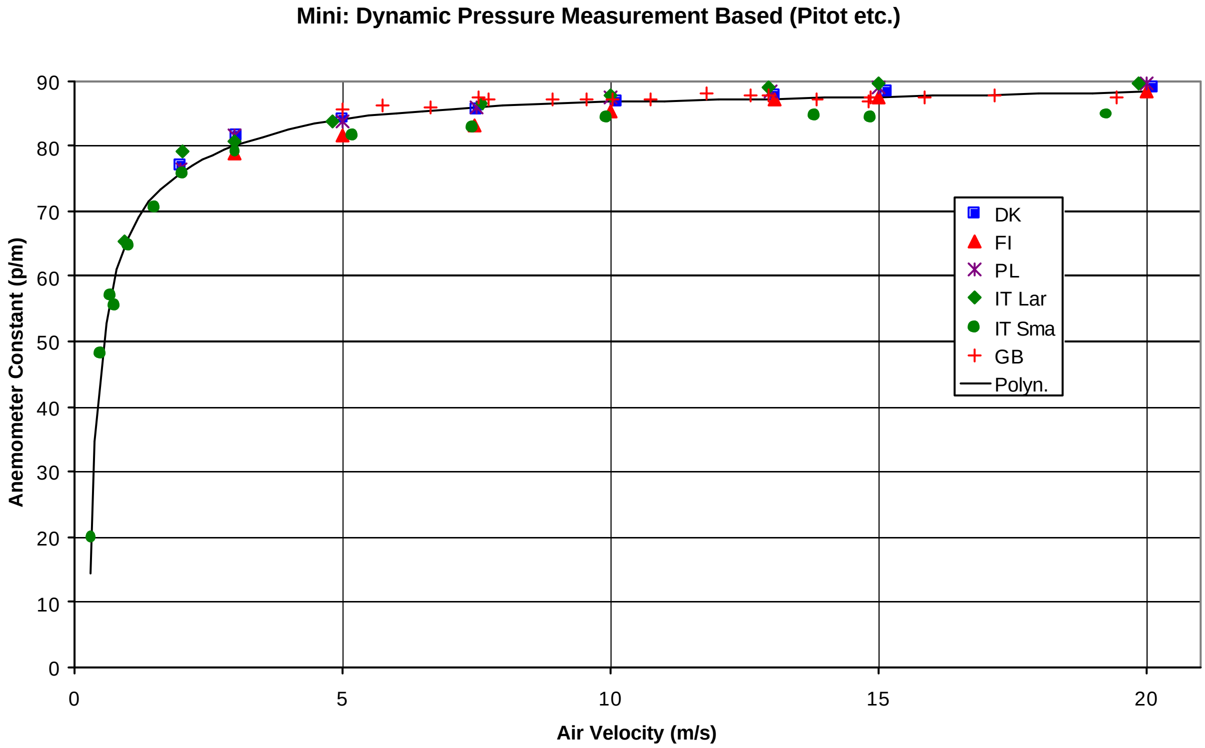

Figure 32: Mini, dynamic pressure measurement (Pitot etc.) based calibrations

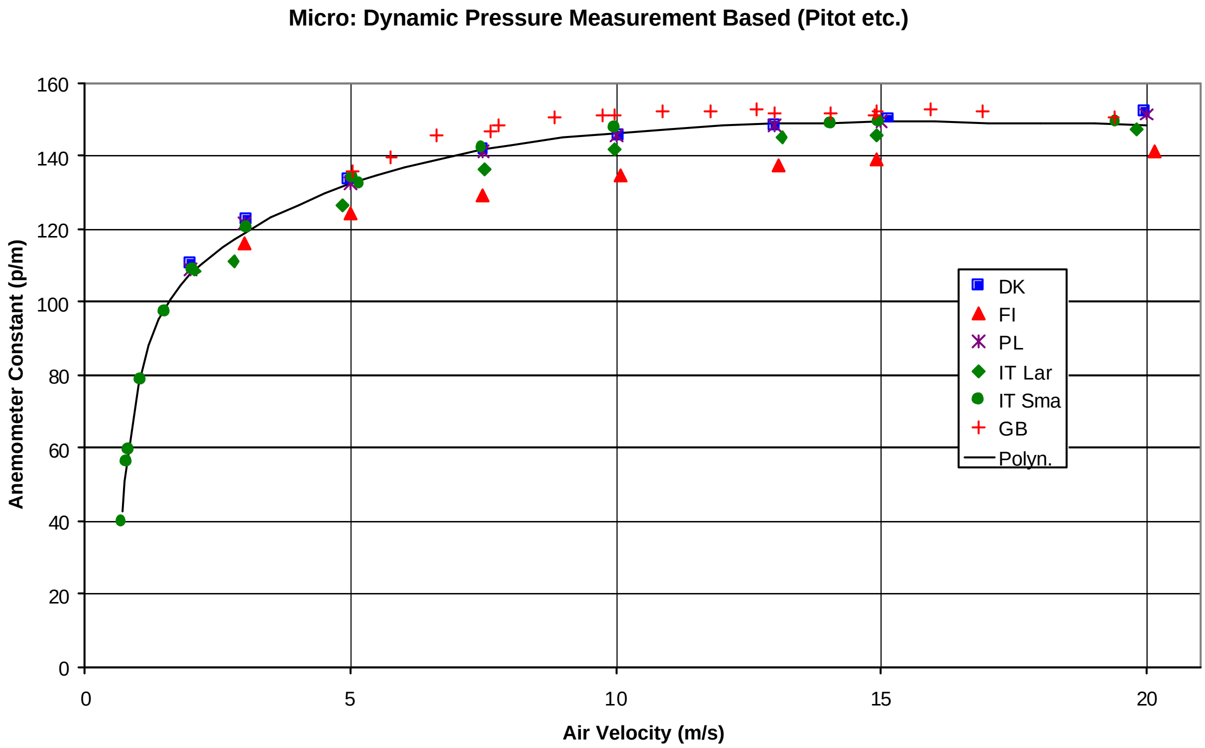

Figure 33: Micro, dynamic pressure measurement (Pitot etc.) based calibrations

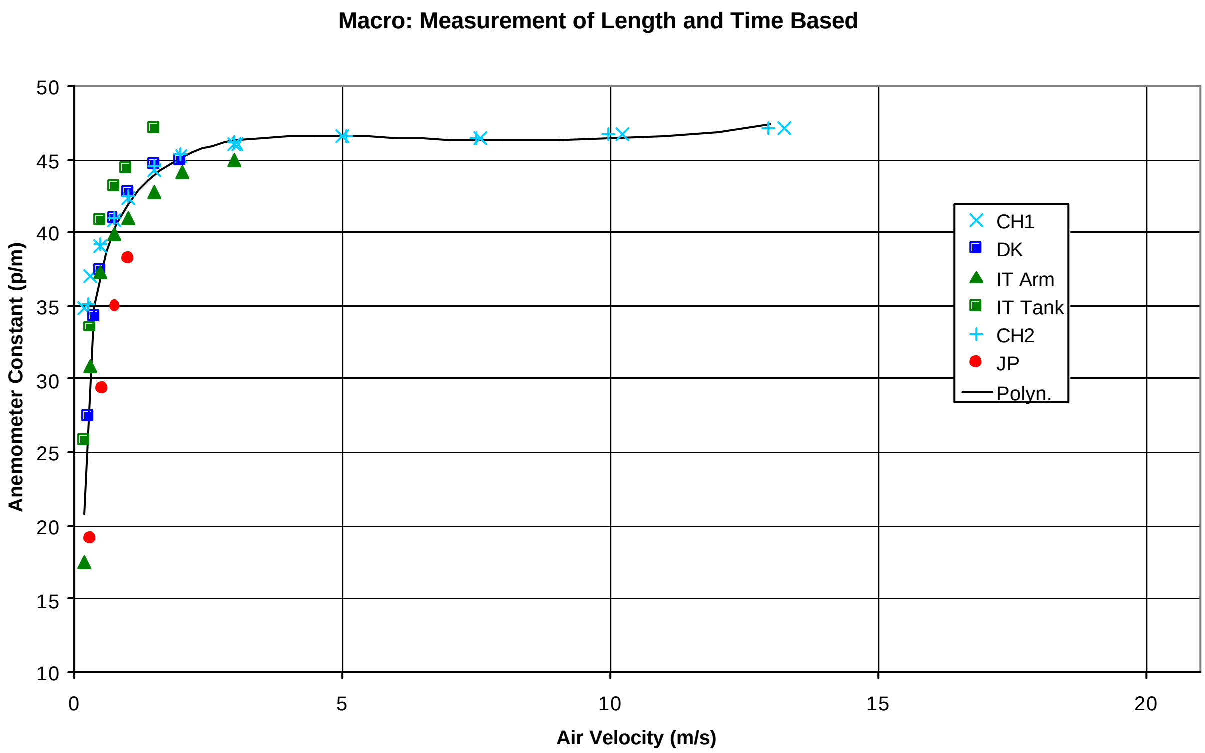

Figure 34: Macro, measurement of length and time based calibrations

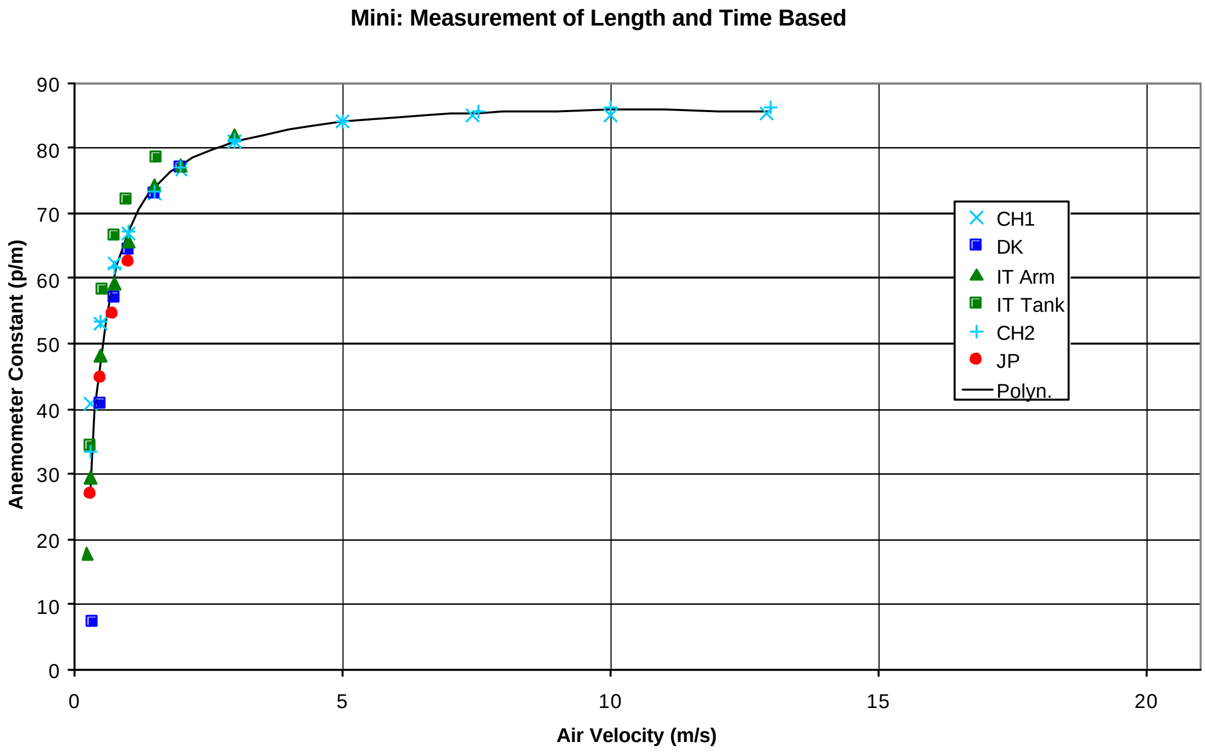

Figure 35: Mini, measurement of length and time based calibrations

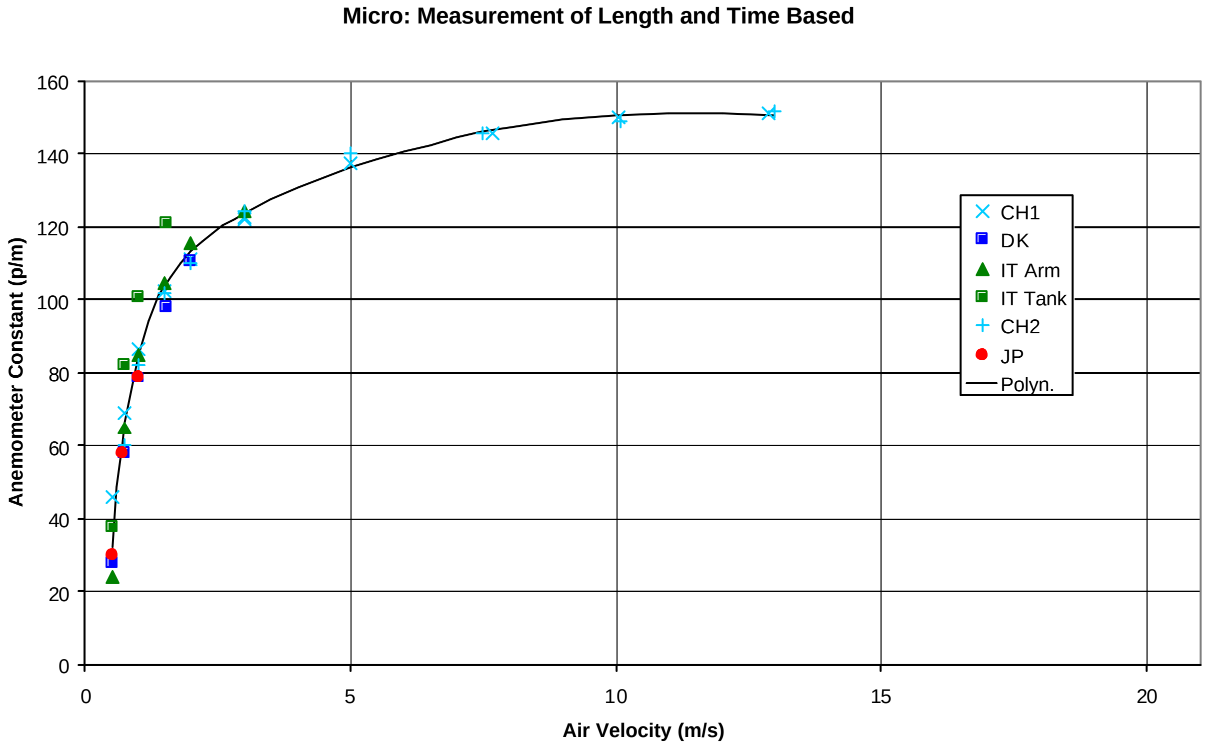

Figure 36: Micro, measurement of length and time based calibrations

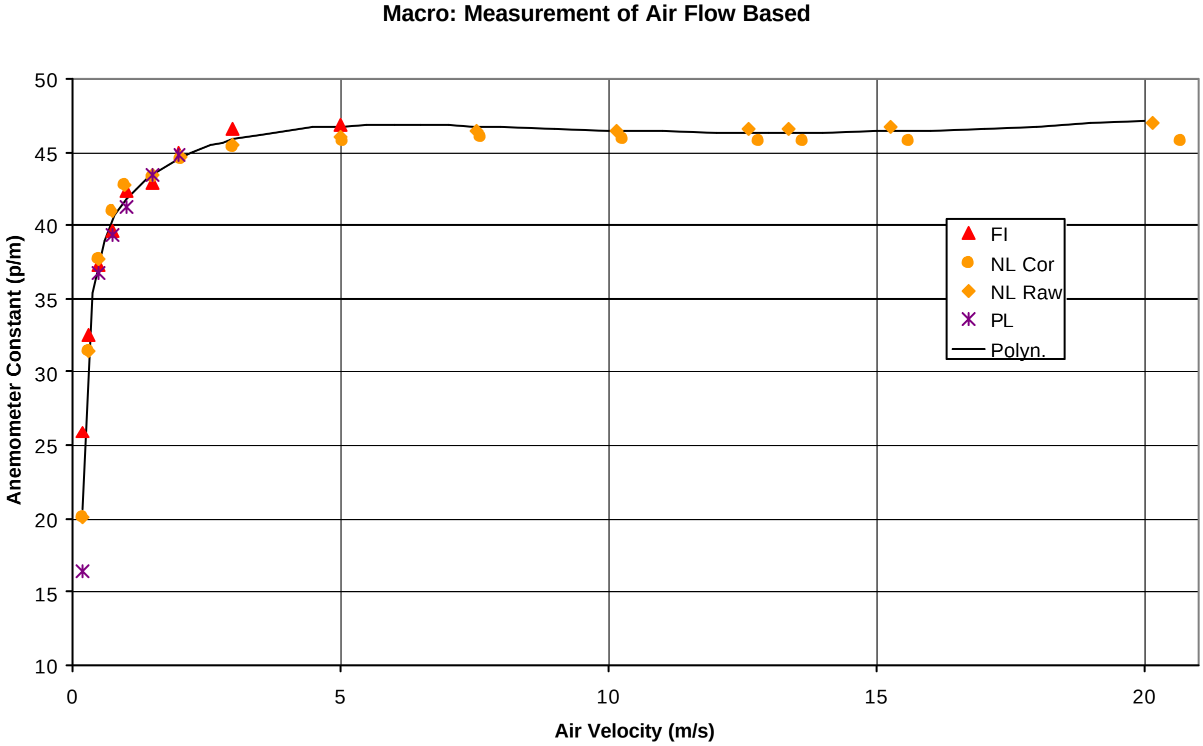

Figure 37: Macro, measurement of airflow based calibrations

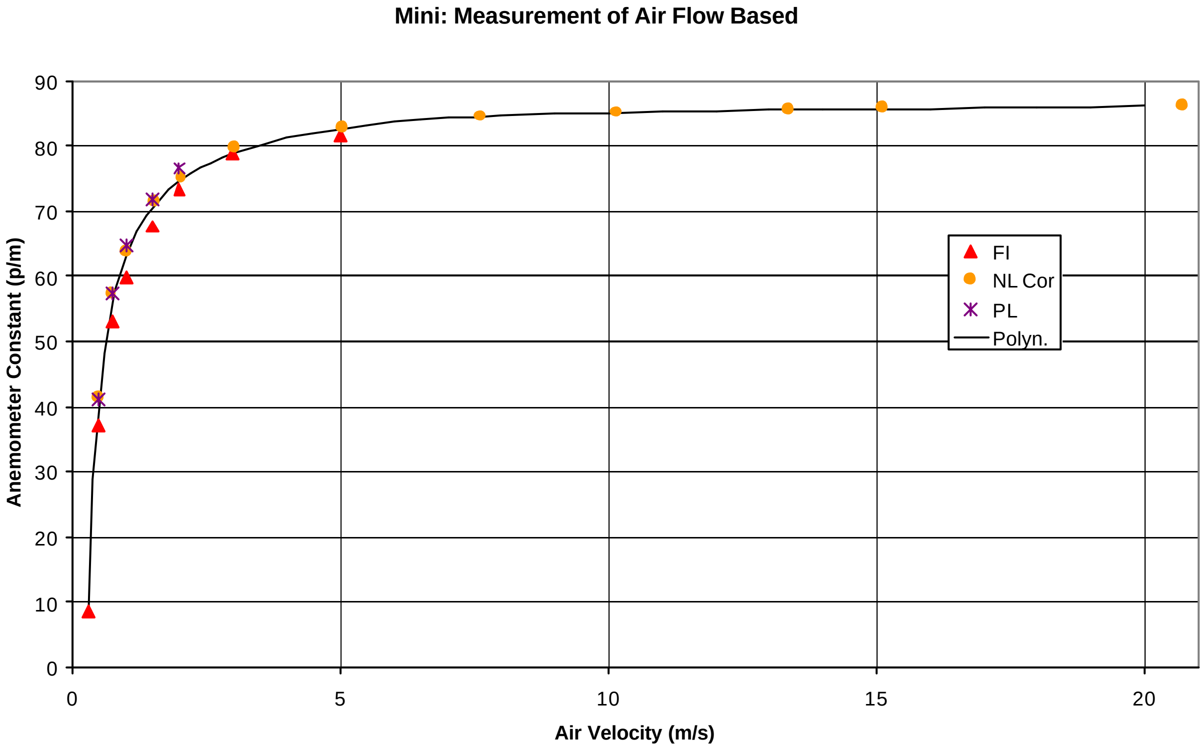

Figure 38: Mini, measurement of airflow based calibrations

Micro: Measurement of Air Flow Based

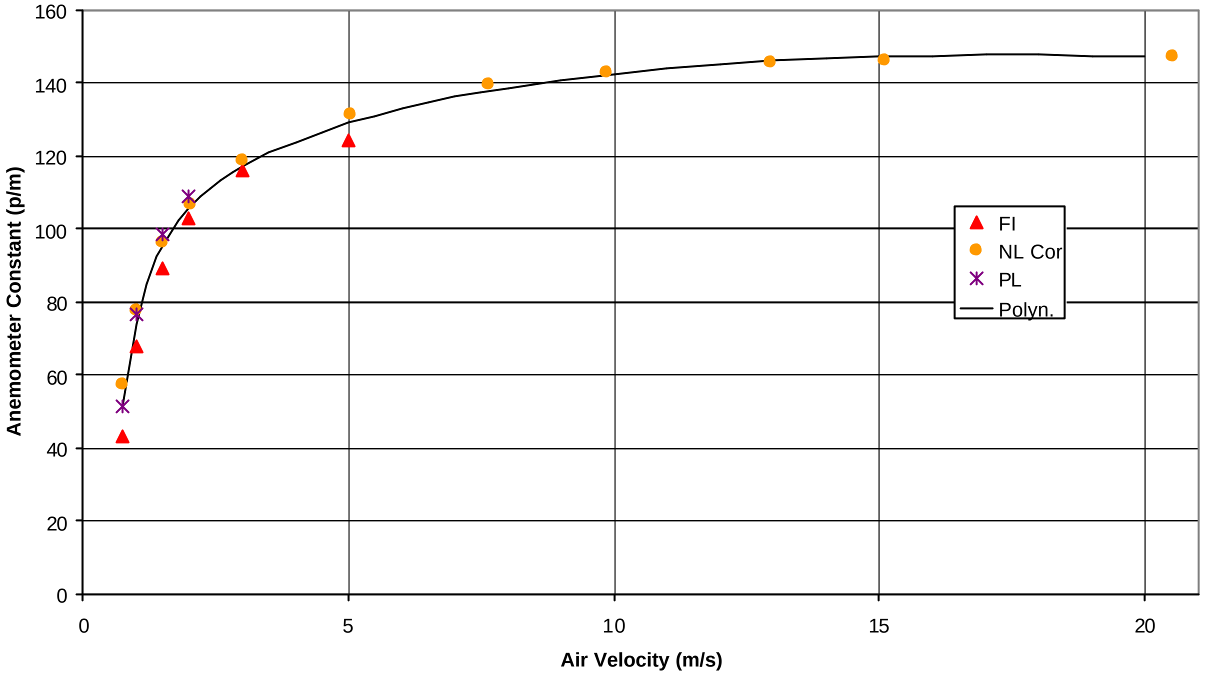

Figure 39: Micro, measurement of airflow based calibrations

Anemometer Constant Depending from Standard: Polynome Approximation Lines

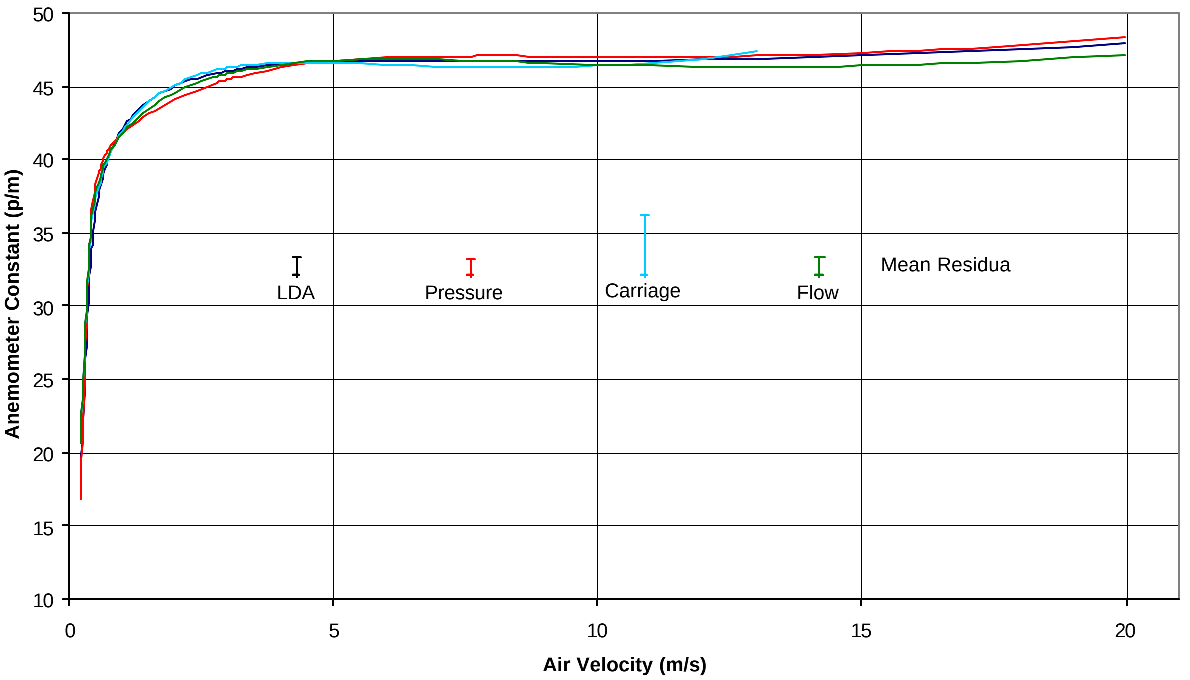

Figure 40: Macro, synopsis of the results depending on the standards used

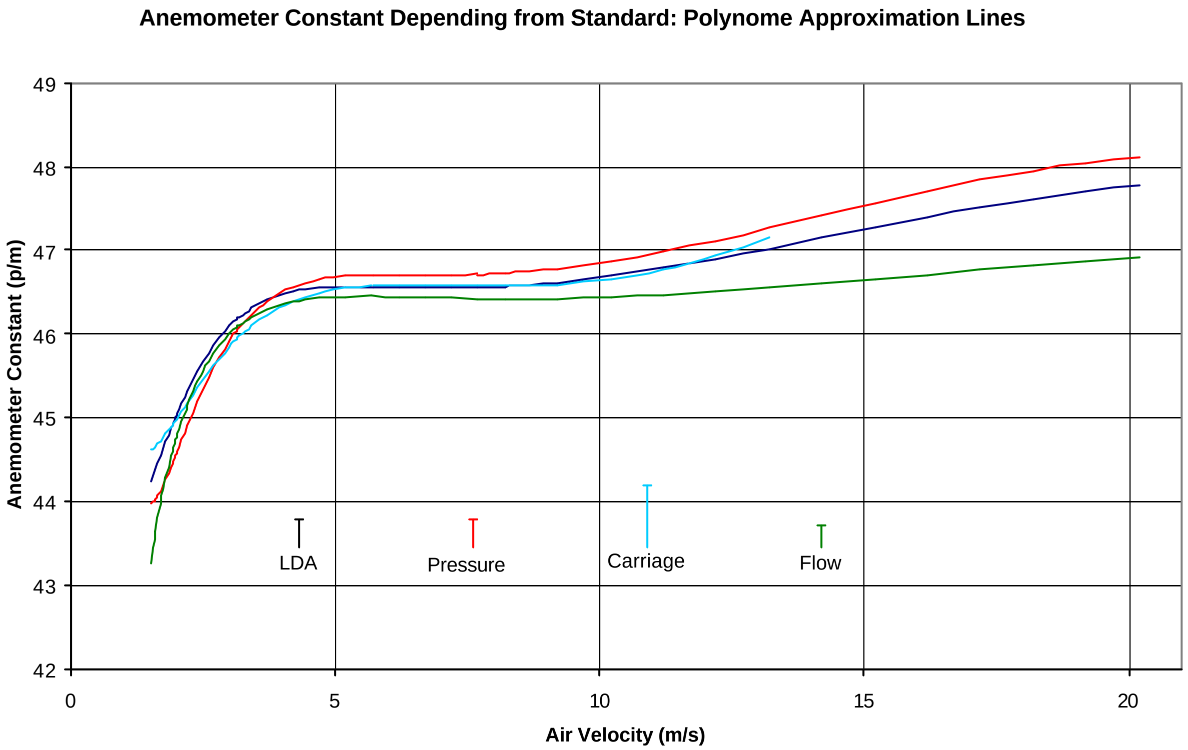

Figure 41: Macro, synopsis for upper velocity range

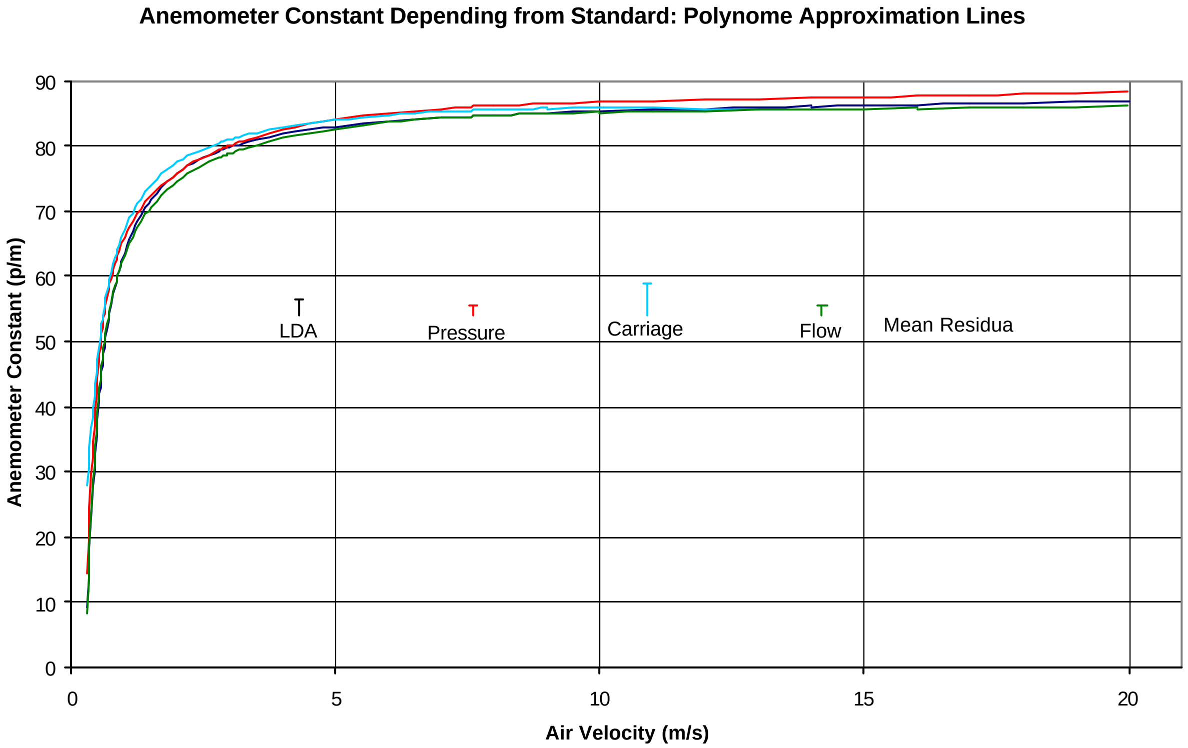

Figure 42: Mini, synopsis of the results depending on the standards used

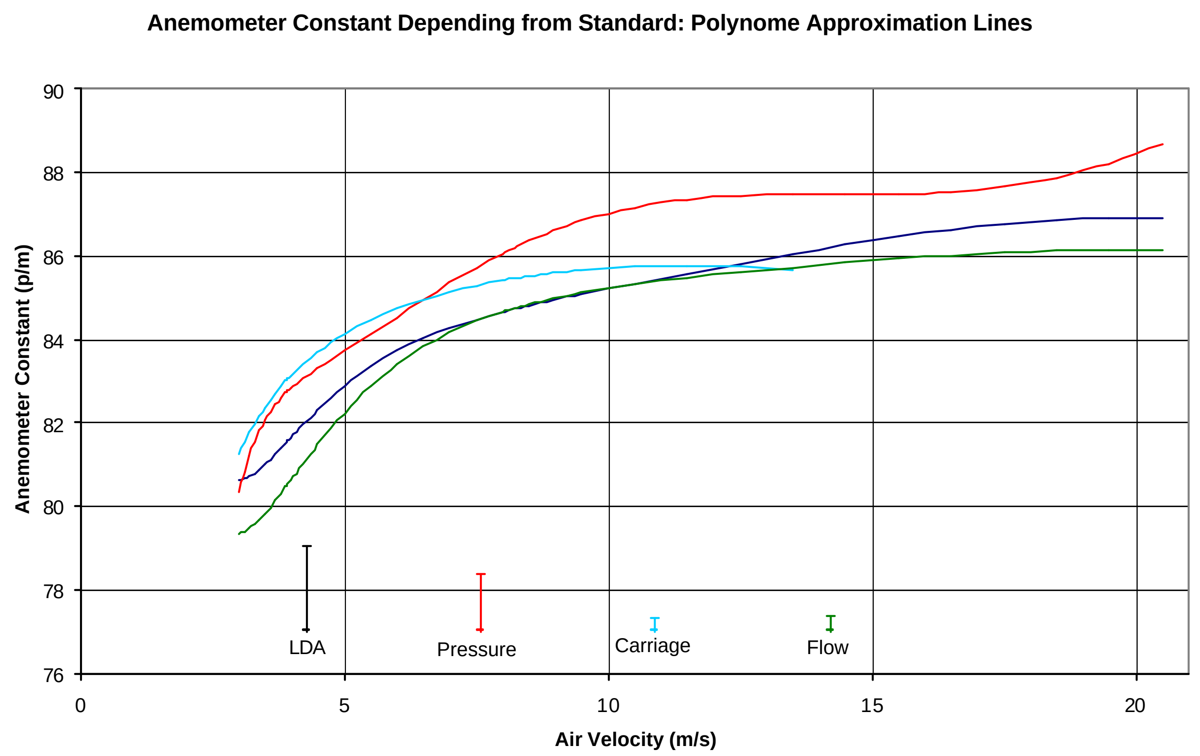

Figure 43: Mini, synopsis for upper velocity range

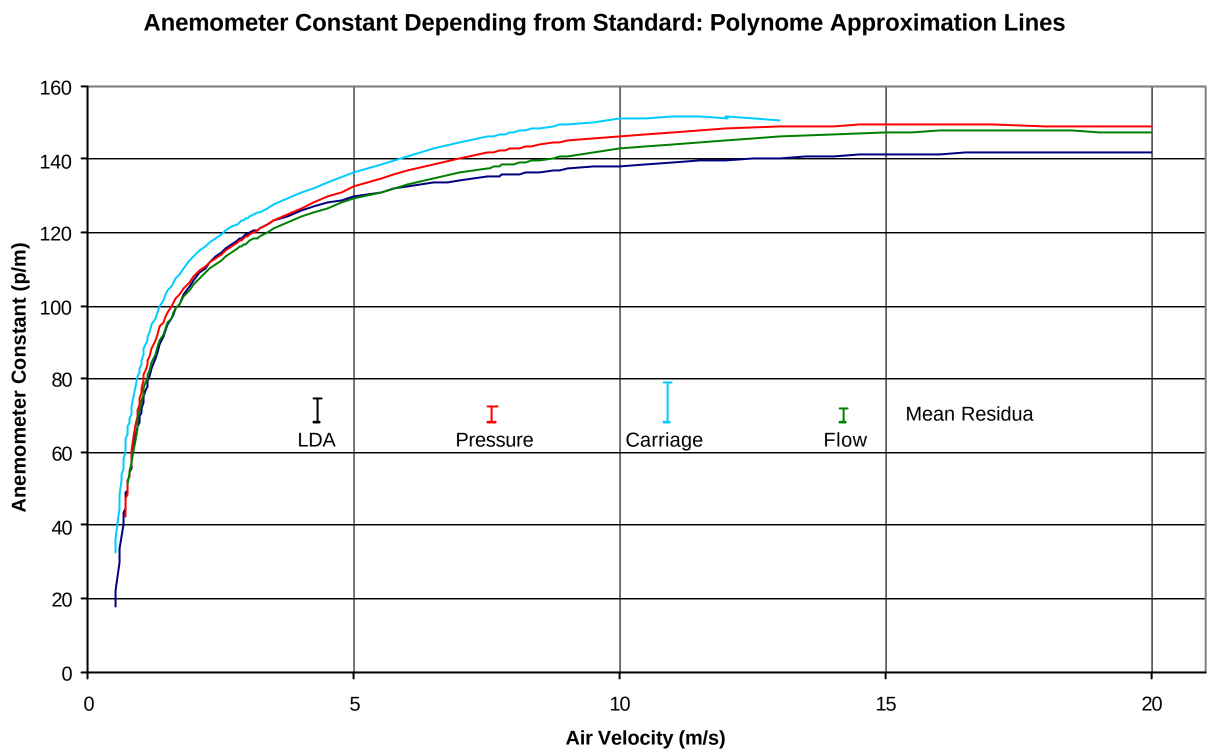

Figure 44: Micro, synopsis of the results depending on the standards used

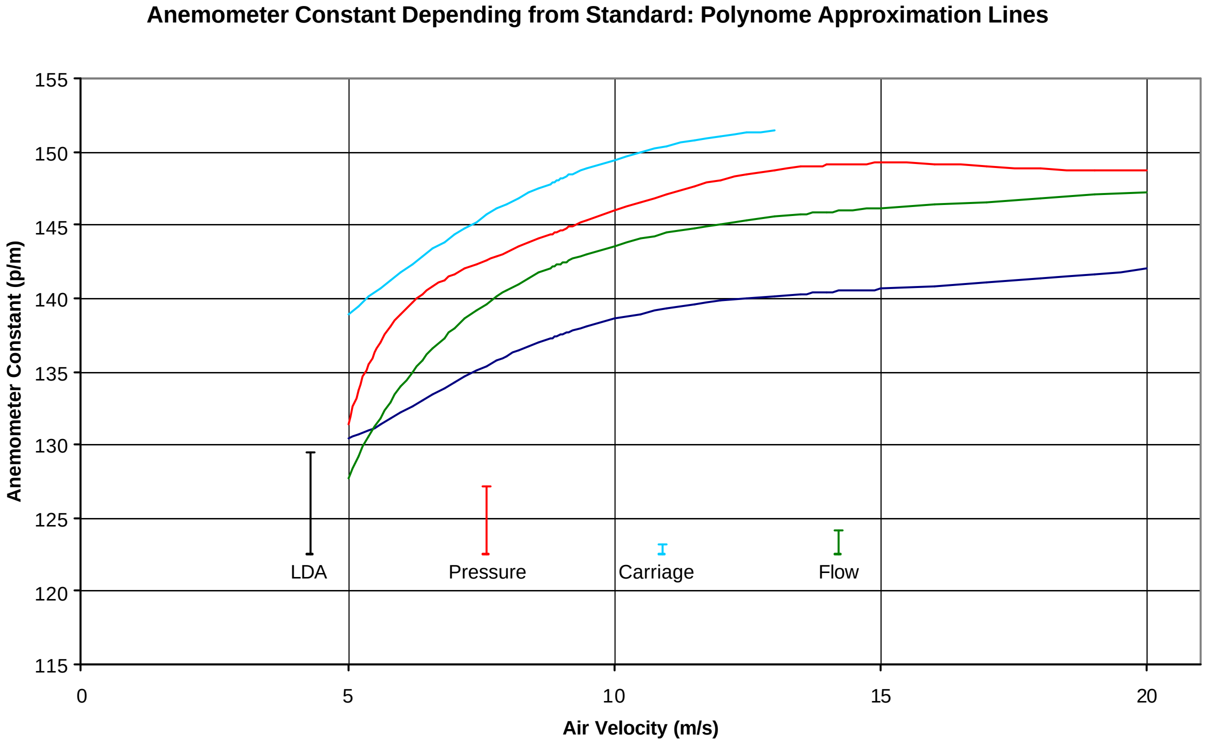

Figure 45: Micro, synopsis for upper velocity range

5.2.6 Youden Plots

For a distinct air velocity, we draw the anemometer constants of two anemometers on the same graph. For this air velocitiy, along the x-axis is the mean anemometer constant of one anemometer and along the y-axis is the mean anemometer constant of the other anemometer. In addition to the anemometer constant, we draw (if given) the corresponding standard deviation (1·s). If the anemometers were not measured at the air velocity of the plot, we calculated the anemometer constant by linear interpolation between the nearest two air velocities.

The indicated values are the deviations in percent from the mean value. This mean value, indicated along the axis, is the mean values of all measurements at the corresponding velocity. In order to have the same weight for all laboratories, we took the mean value of every laboratory to calculate the mean indicated in the plot.

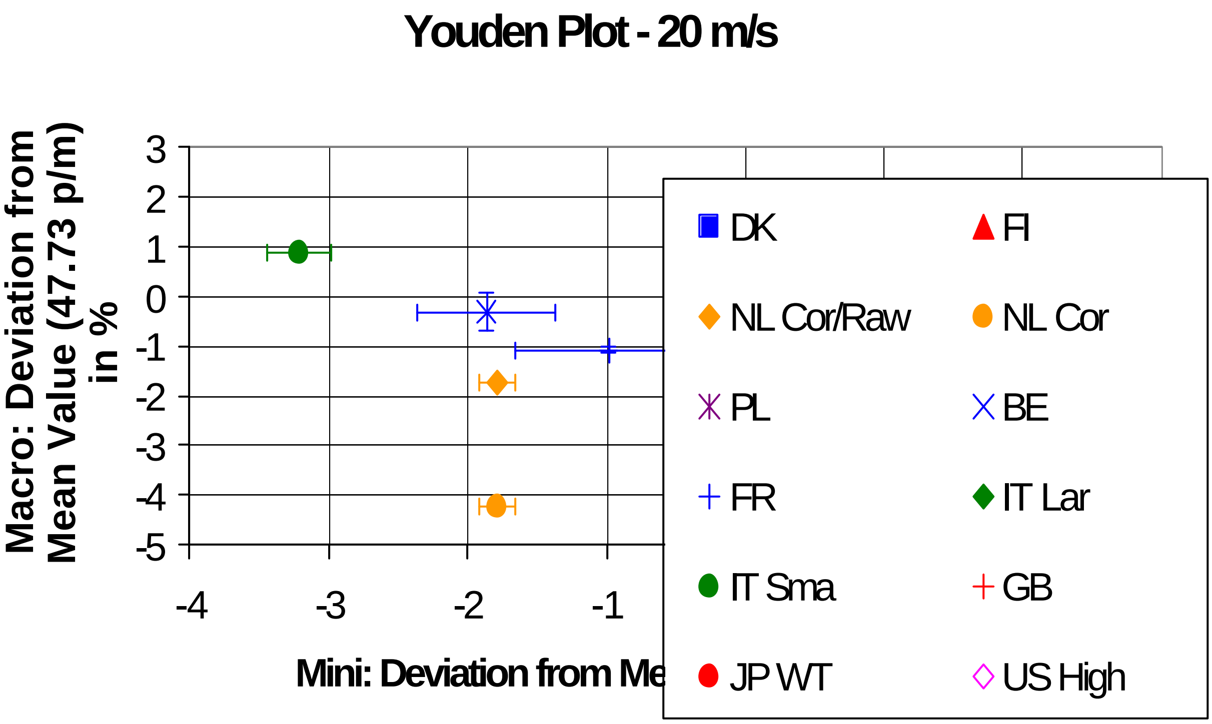

Figure 46: Macro vs Mini at 20 m/s

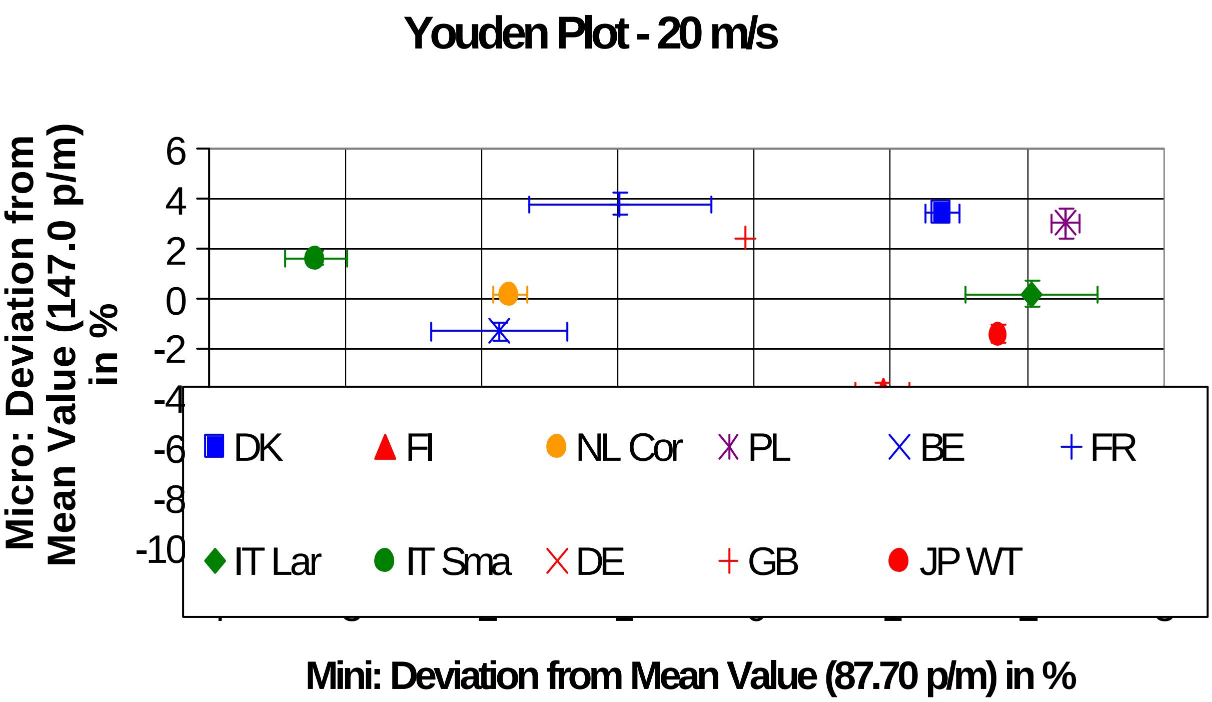

Figure 47: Micro vs Mini at 20 m/s

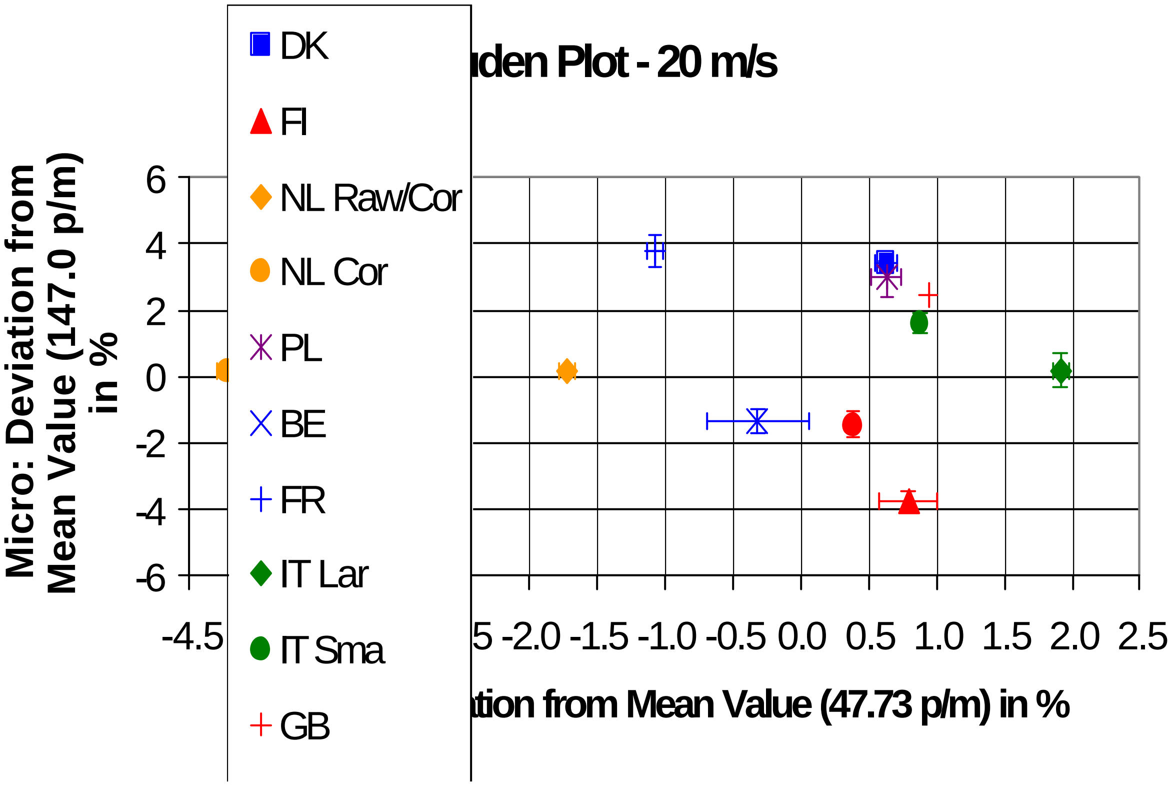

Figure 48: Micro vs Macro at 20 m/s

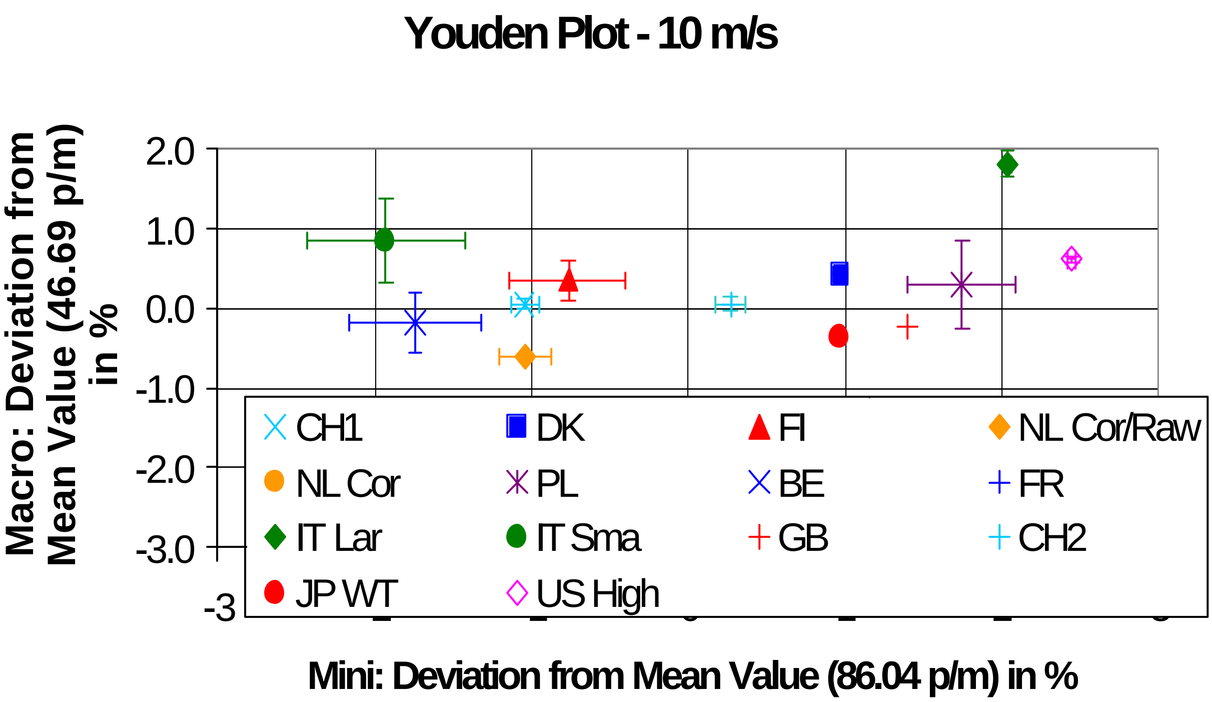

Figure 49: Macro vs Mini at 10 m/s

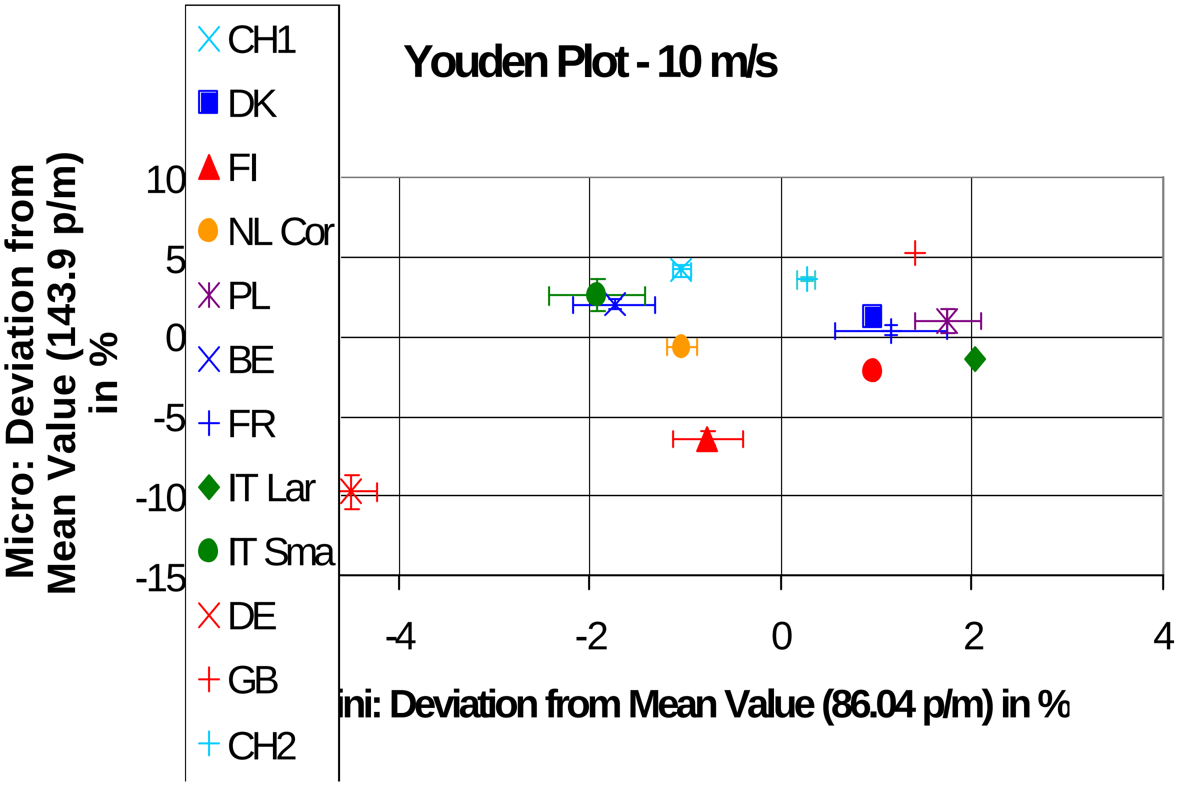

Figure 50: Micro vs Mini at 10 m/s

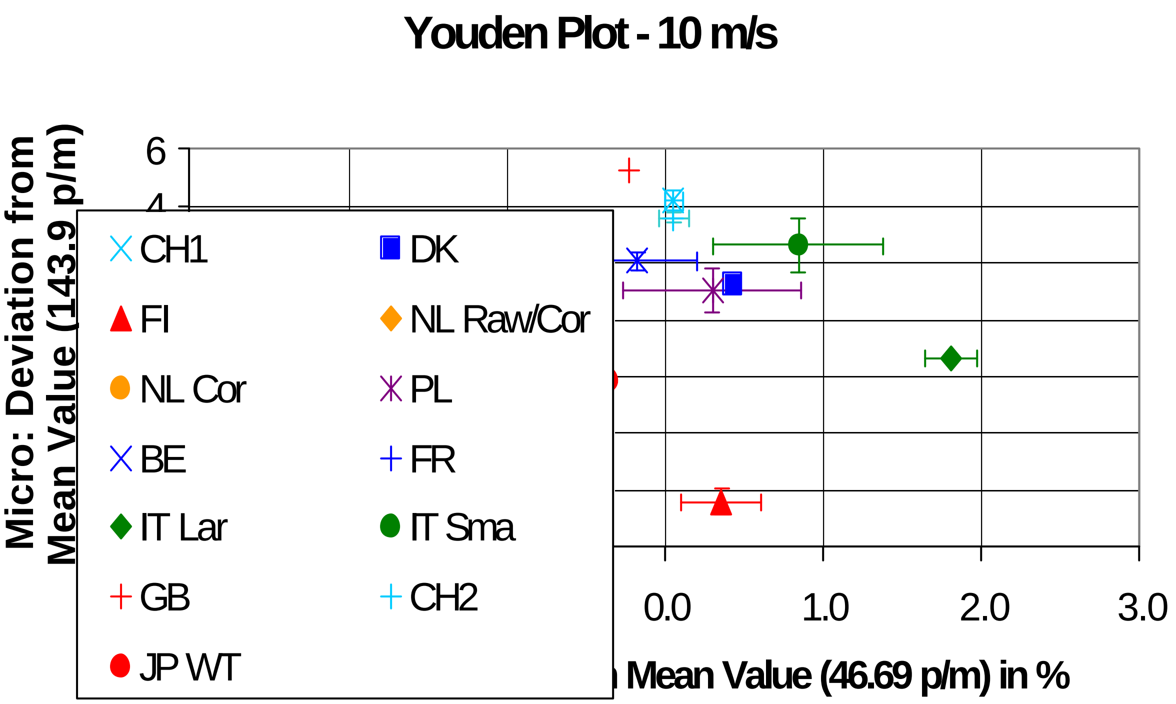

Figure 51: Micro vs Macro at 10 m/s

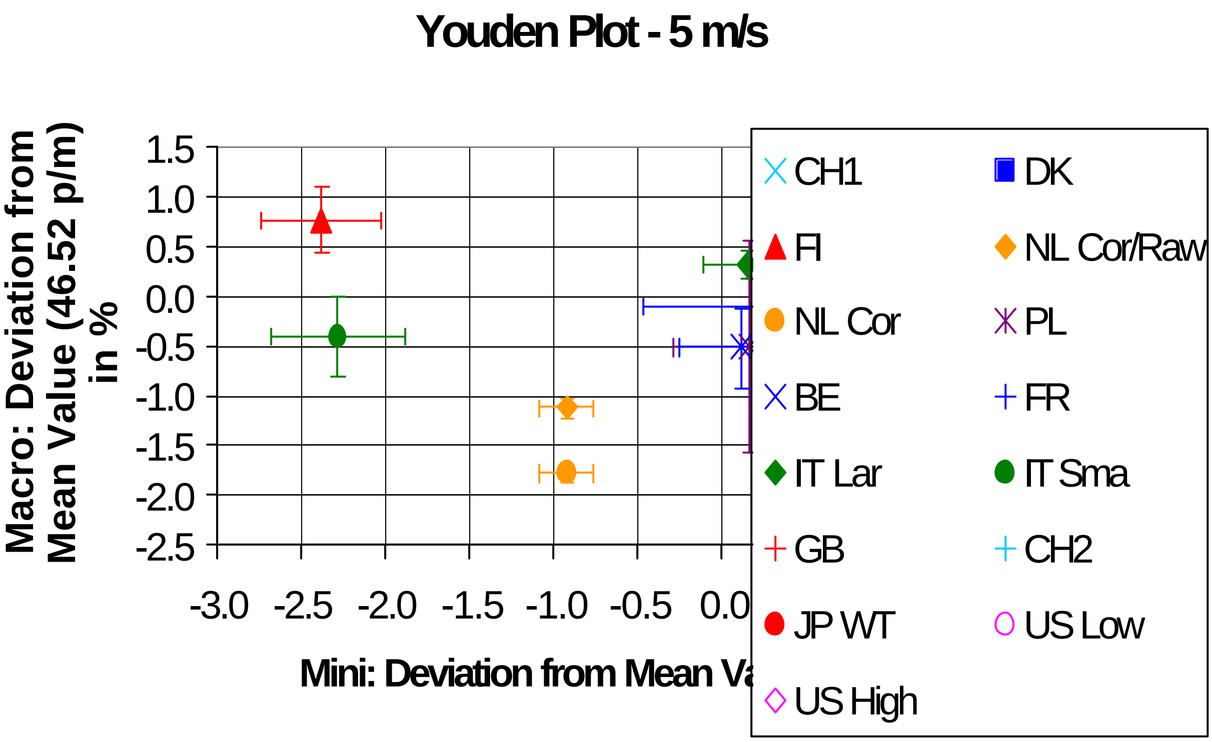

Figure 52: Macro vs Mini at 5 m/s

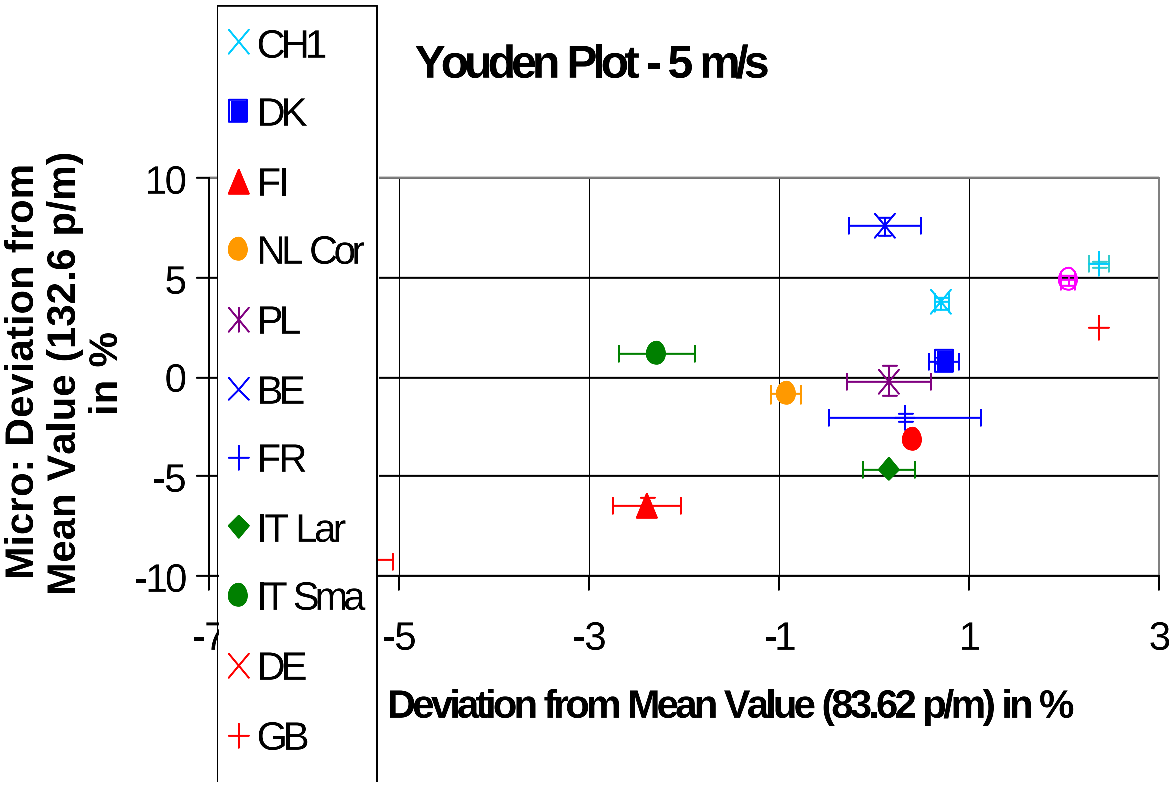

Figure 53: Micro vs Mini at 5 m/s

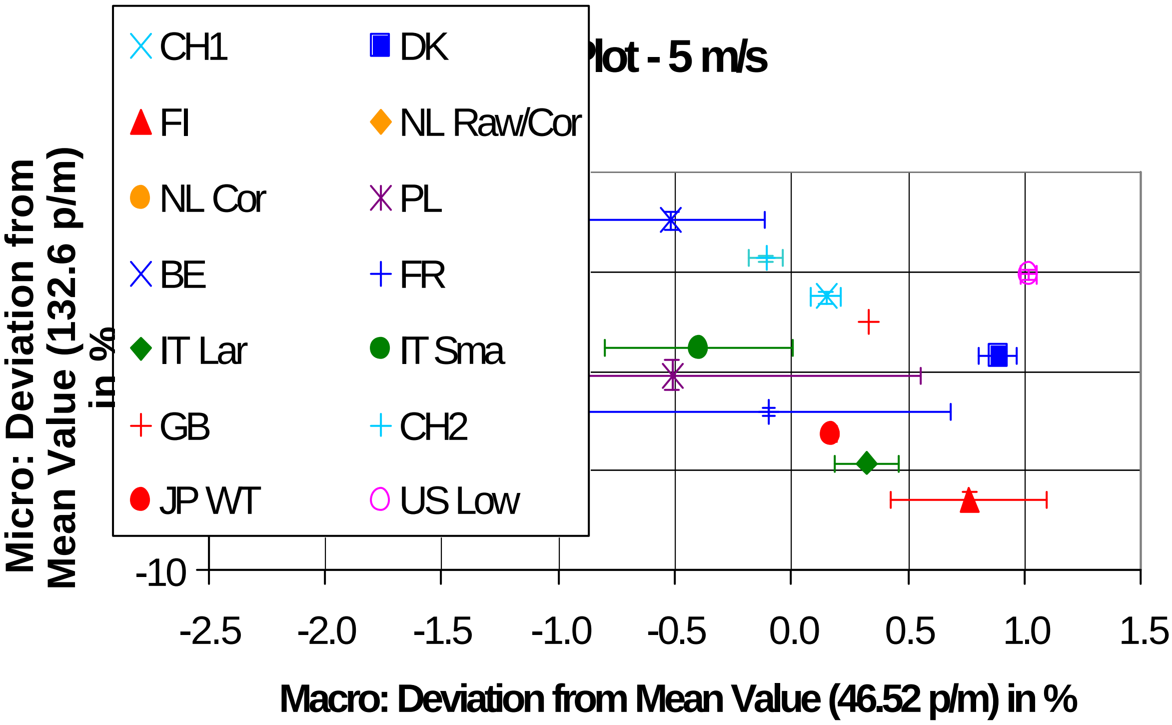

Figure 54: Micro vs Macro at 5 m/s

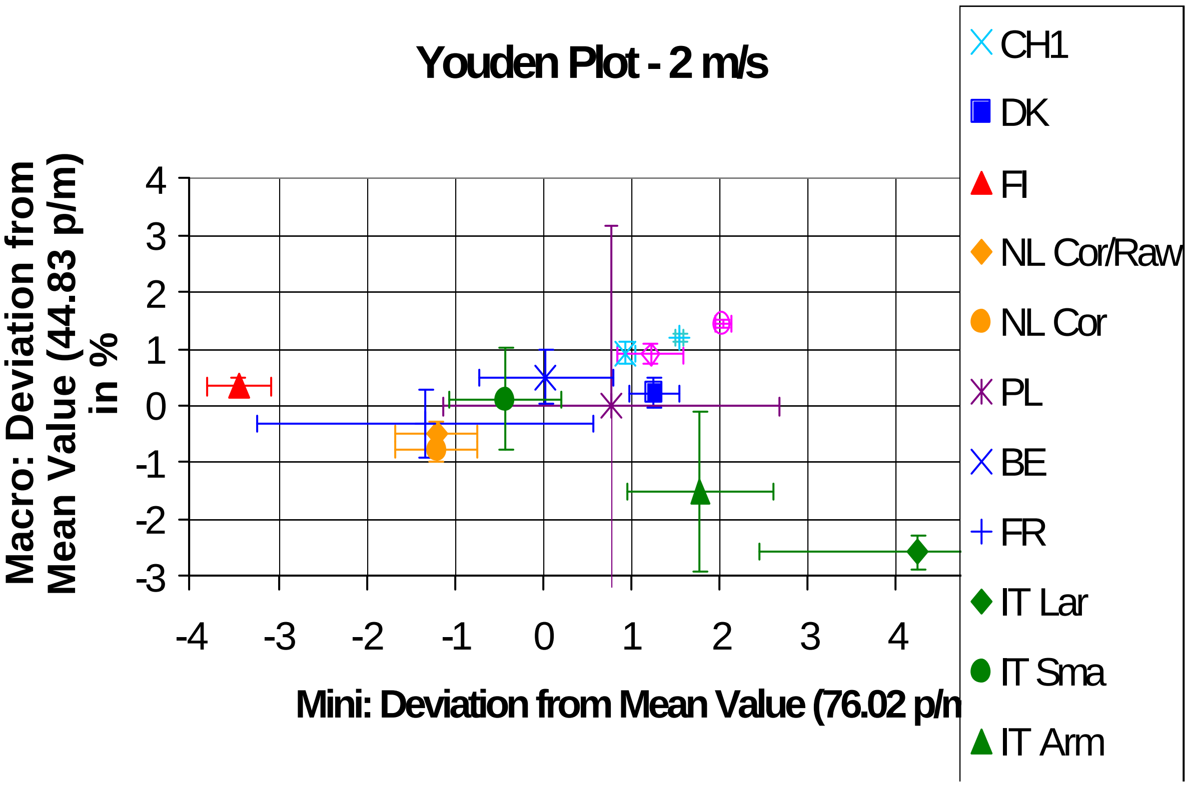

Figure 55: Macro vs Mini at 2 m/s

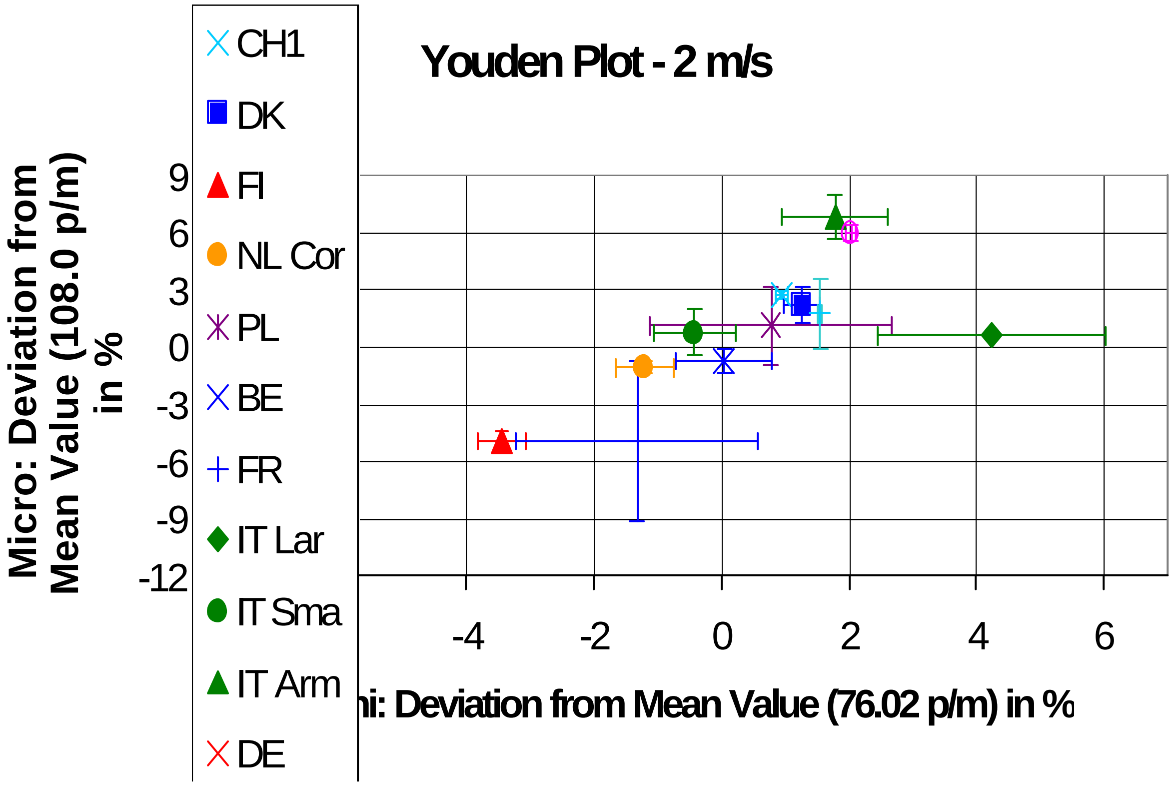

Figure 56: Micro vs Mini at 2 m/s

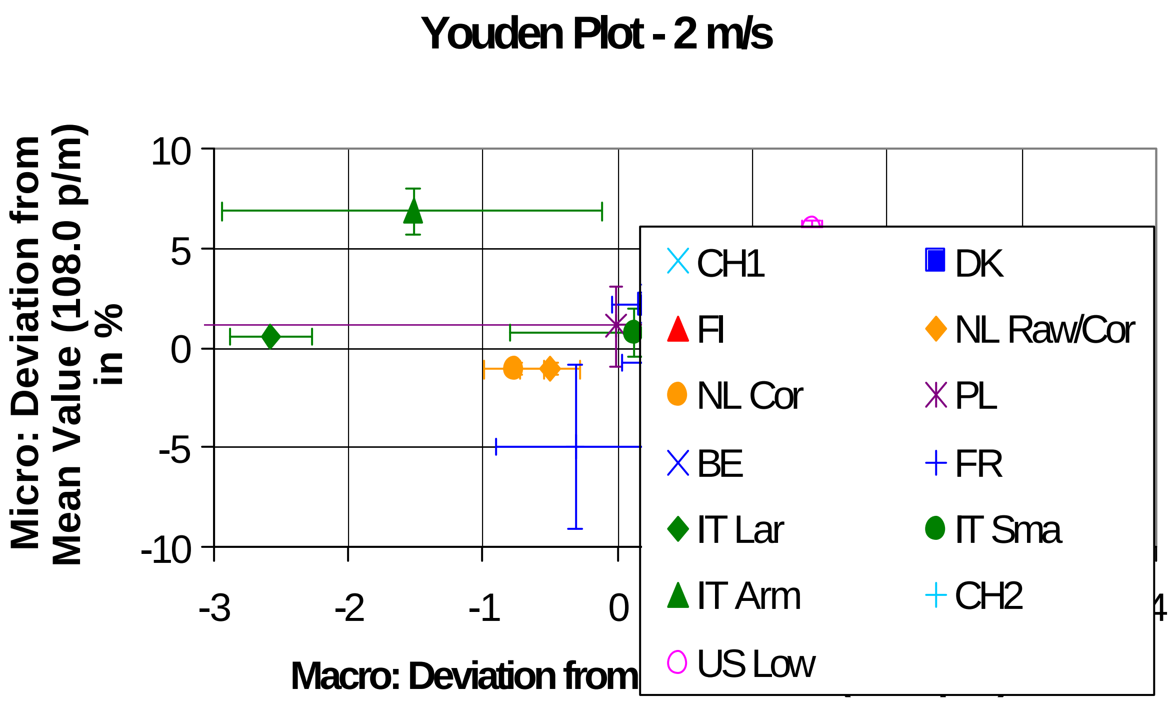

Figure 57: Micro vs Macro at 2 m/s

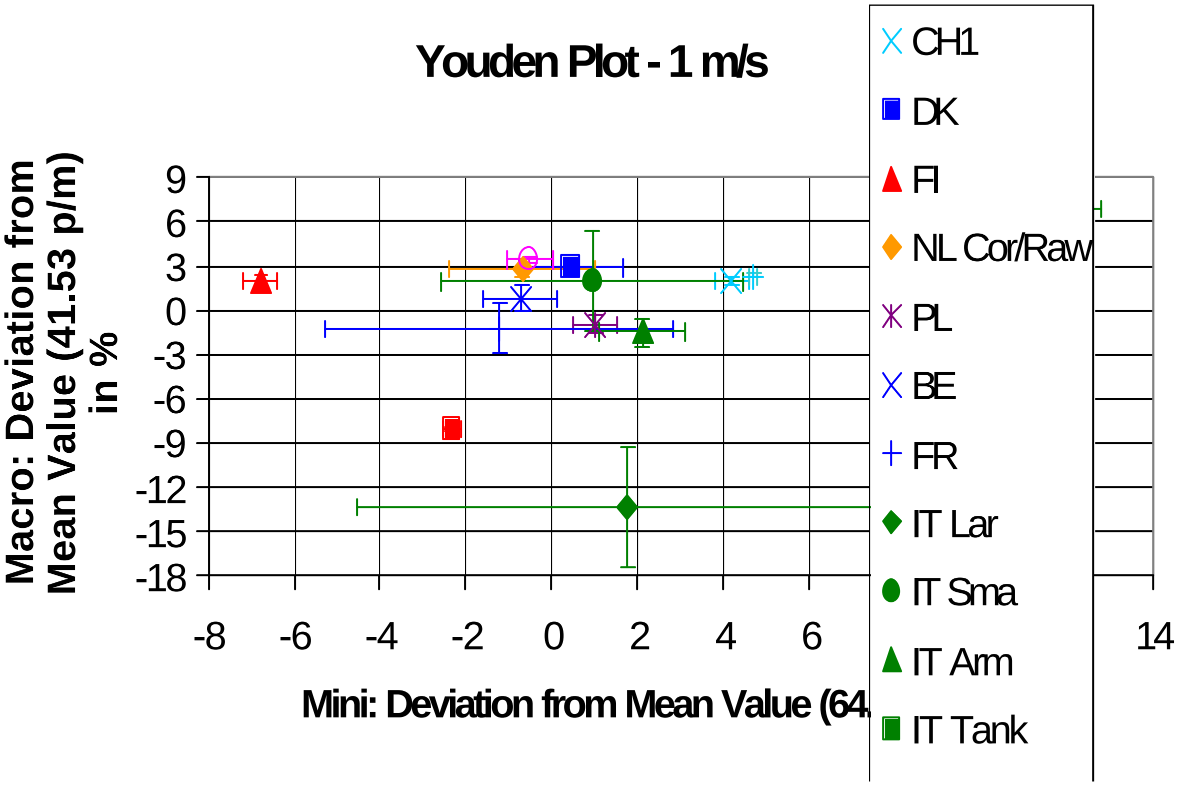

Figure 58: Macro vs Mini at 1 m/s

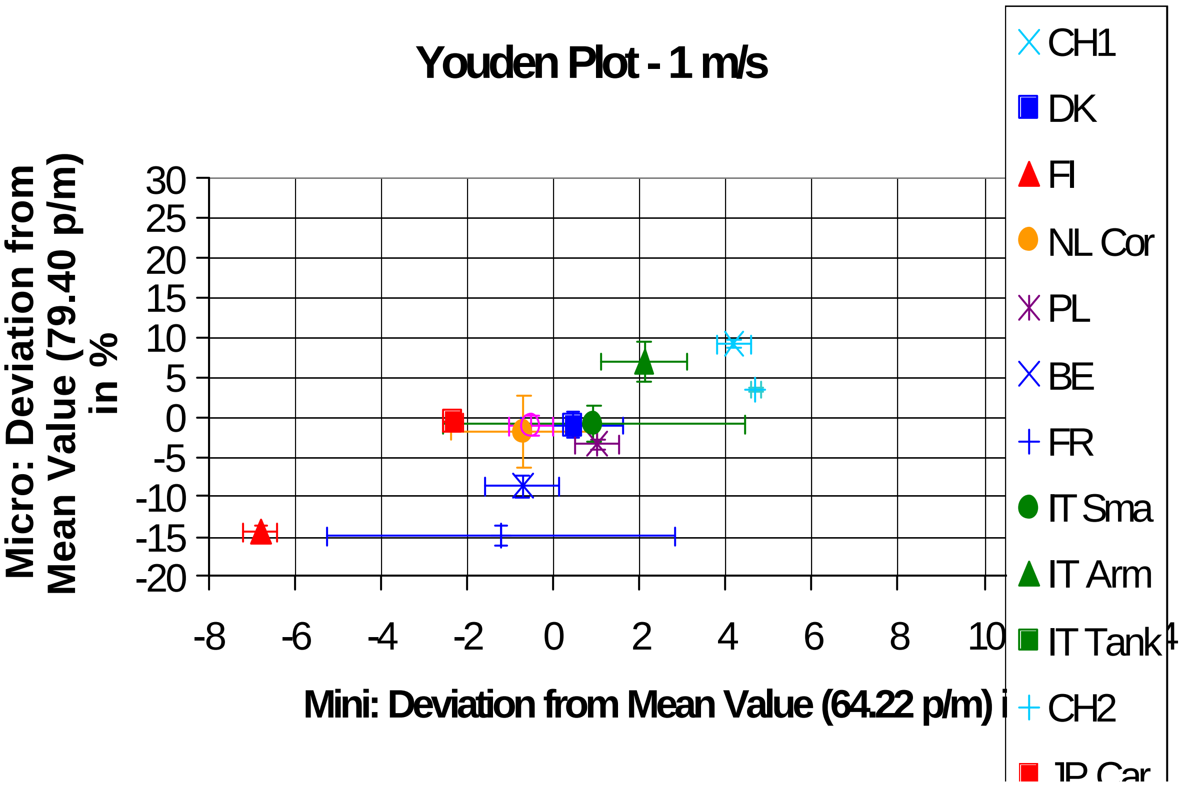

Figure 59: Micro vs Mini at 1 m/s

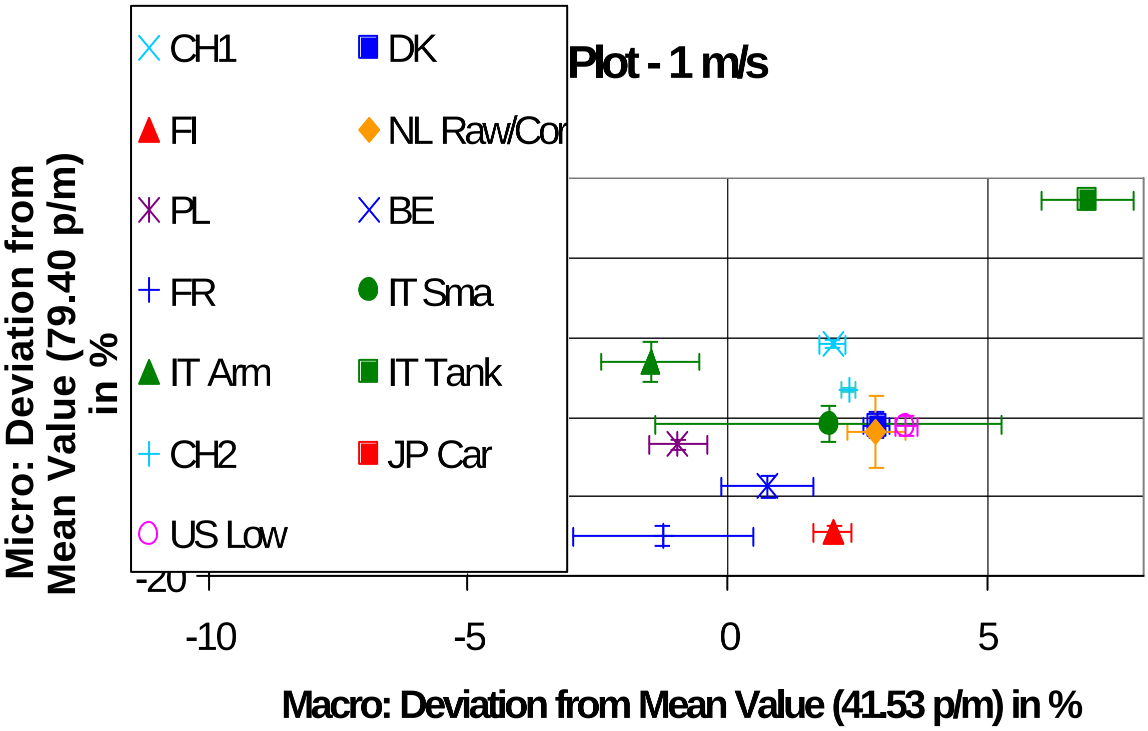

Figure 60: Micro vs Macro at 1 m/s

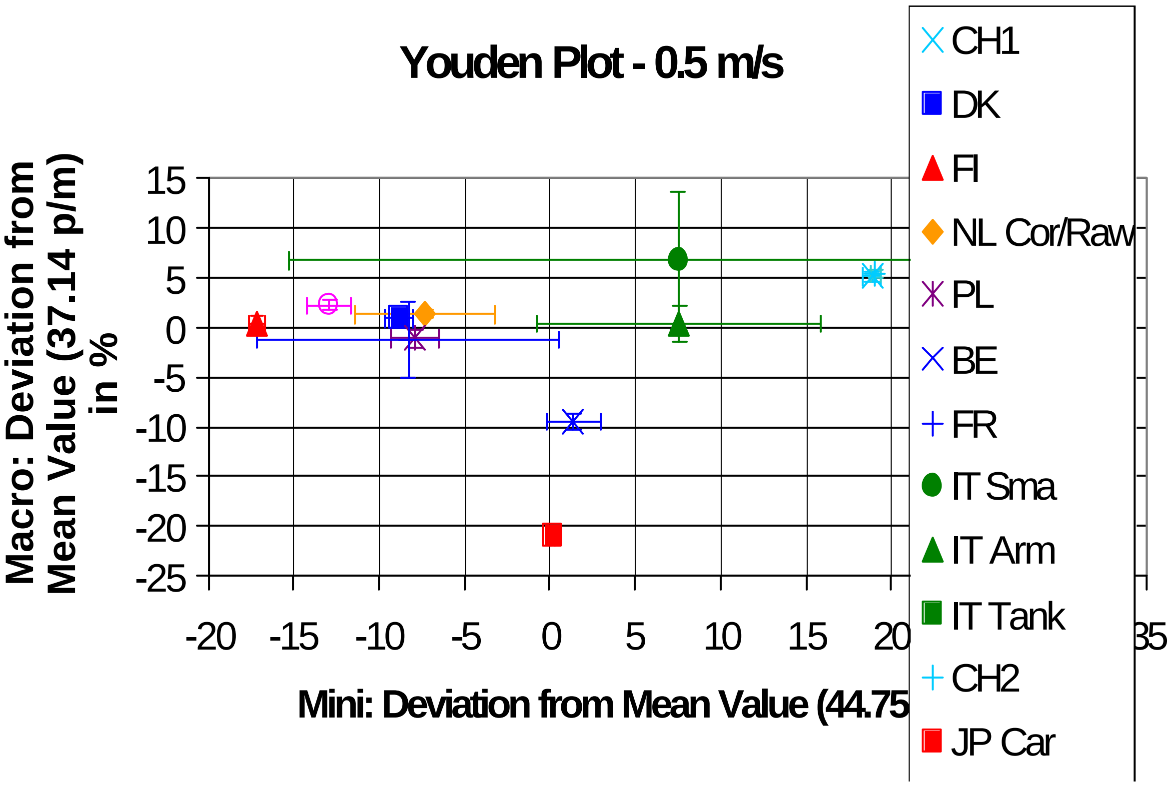

Figure 61: Macro vs Mini at 0.5 m/s

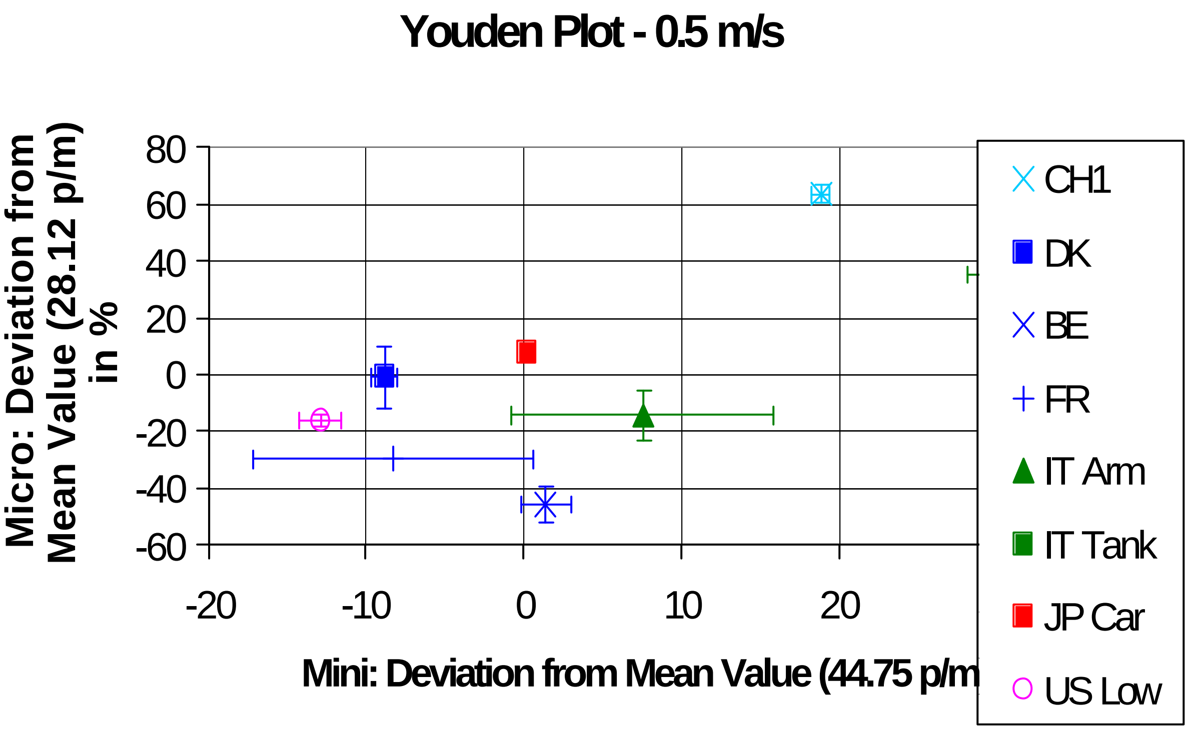

Figure 62: Micro vs Mini at 0.5 m/s

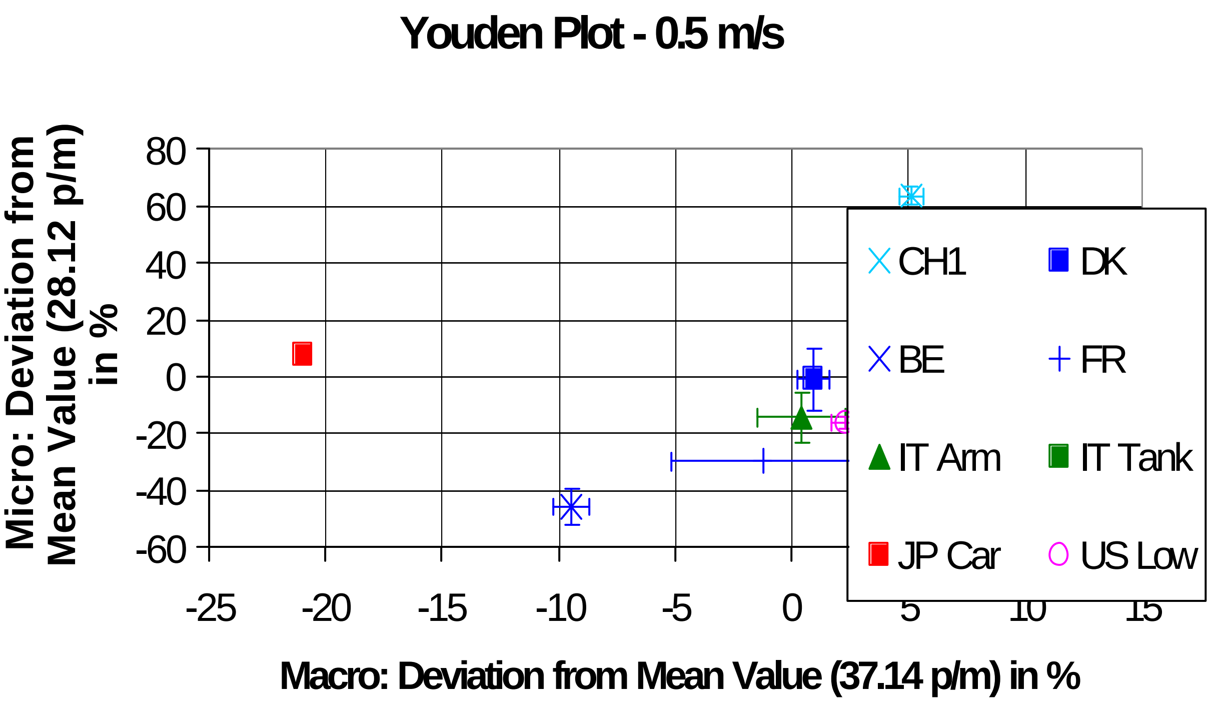

Figure 63: Micro vs Macro at 0.5 m/s

5.2.7 Stability

In order to find out an eventual degradation with time (wear), the anemometer constant versus the date of measurement is drawn.

Macro: Influence of Date of Measurement

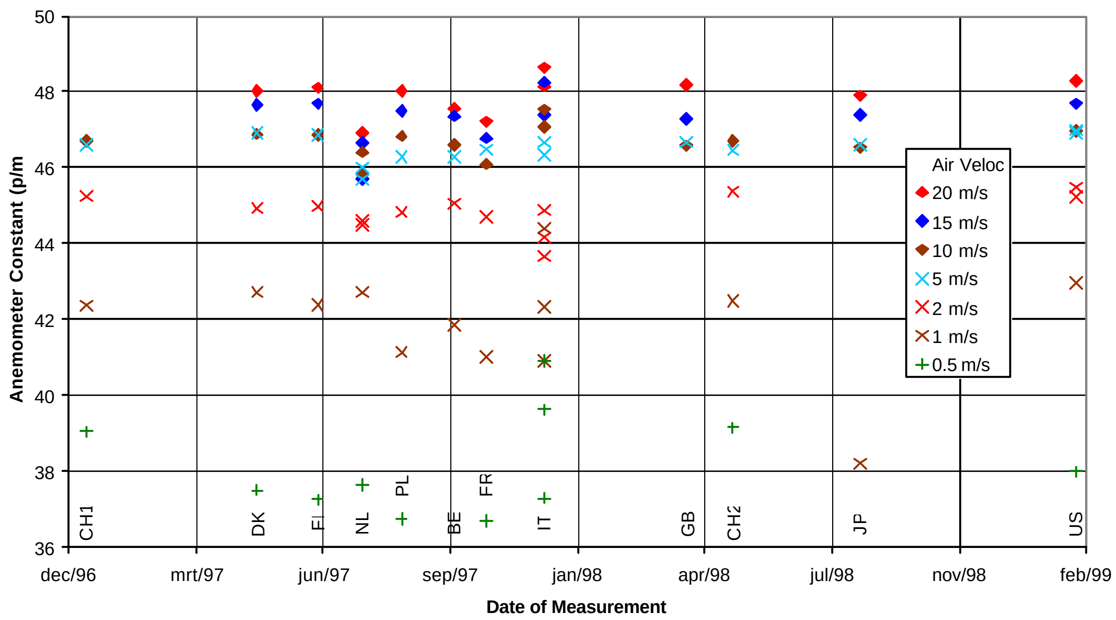

Figure 64: Macro: Stability

Mini: Influence of Date of Measurement

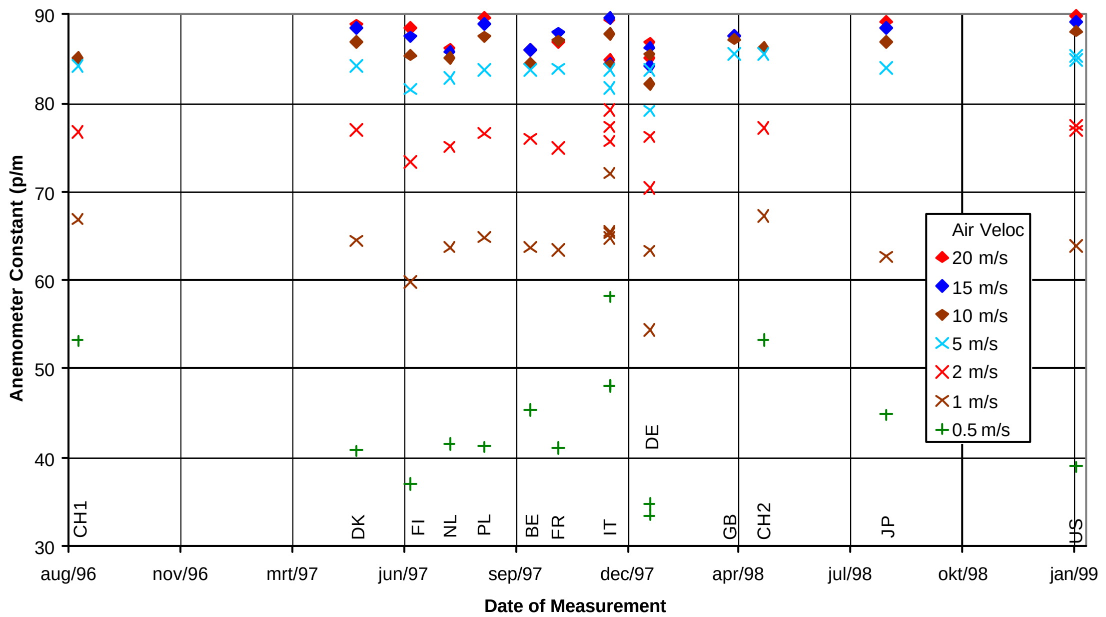

Figure 65: Mini: Stability

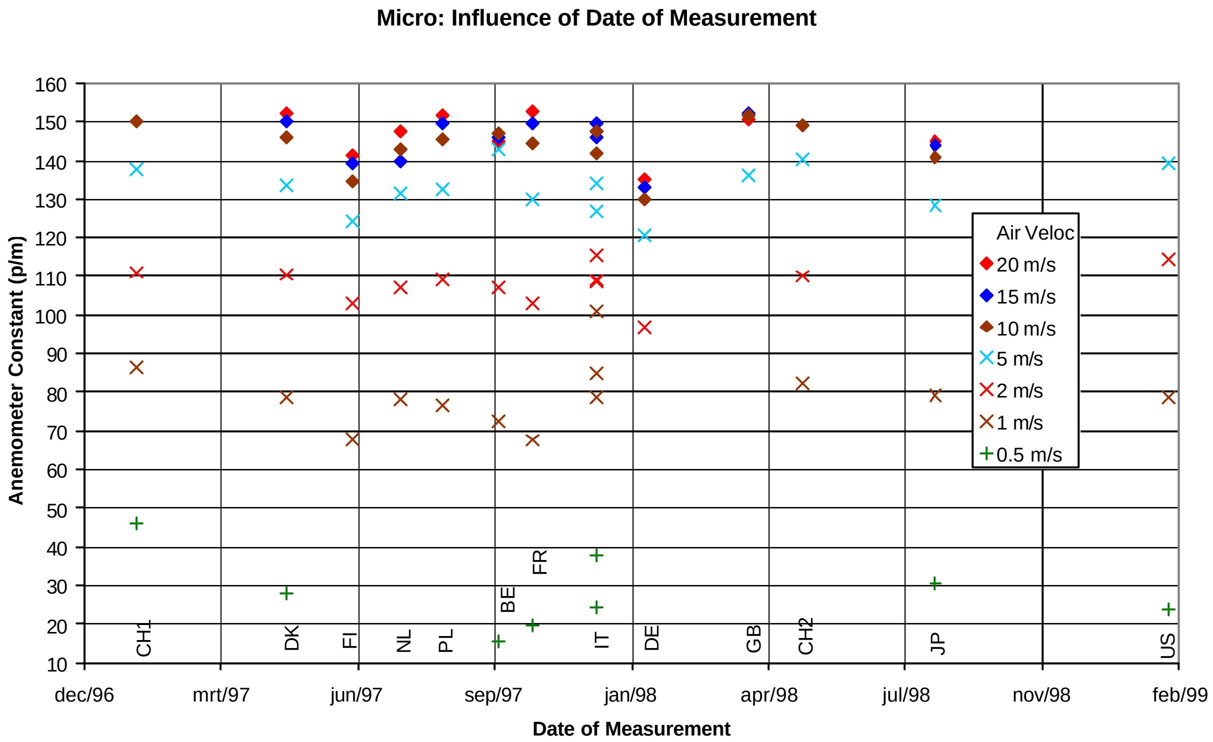

Figure 66: Micro, Stability

6 Discussion

6.1 Meaning of a Calibration

The first thing to discuss is what does the calibration mean or what was intended by the calibration. We think, the intention of a calibration is the dependence of the indication from the air velocity.

The air velocity is the velocity of the field of air passing through the anemometer. This field has infinitive dimensions: the diameter of this field is much bigger than the diameter of the anemometer. All vectors of the air velocity throughout the field are parallel and have the same absolute value. The field is completely free of swirls. These conditions are valid before the anemometer is entered into the field. The vectors of the air velocity of the undisturbed field are parallel to the axis of the rotating vanes of the anemometer. The absolute value of these vectors is the value of the applied air velocity.

The indication of the anemometer may be either the pulse frequency or what we call the anemometer constant. The anemometer constant is the number of pulses per length unit of the air column passing through the anemometer (under ideal circumstances, see last paragraph). Mathematically, it is the pulse frequency divided by the air velocity. Very roughly, it is the reciprocal of the distance between the rotor blades in the axis direction.

We prefer the indication of the anemometer constant, because it eases the intercomparison. If there were no friction or aerodynamical effects, the anemometer constant would be a constant value over the whole air velocity range. At lower air velocities, the friction becomes bigger compared with the driving forces and therefore, the anemometer constant decreases.

The disturbance caused by introducing an anemometer into the airflow is called blocking effect.

6.2 General

The anemometer constant was measured over a relatively big range. Especially at low air velocities, the anemometer constant decreases considerably and the scatter between the laboratories increases.

To our understanding, especially at lower air velocities where the anemometer constant decreases considerably, the scatter is an indication to the sensitivity of the anemometer to small influences of the environmental conditions and to the kind of facility used.

6.3 Overview

From Figure 4 to Figure 12 the mean values from all laboratories are shown.

For the Macro, the anemometer constant decreases below ca. 2 m/s, whereas for the smaller instruments, this limit is considerably higher: ca. at 4 m/s for the Mini and ca. 8 m/s for the Micro. The scatter over the whole range (differences between the laboratories) is also bigger for the smaller anemometers.

6.4 Measurement in Wind Tunnels vs Measurements in Still Air

Having so many results, we made two groups for clearer viewing. From Figure 13 to Figure 21, the measurements in wind tunnels are shown, and from Figure 22 to Figure 24 the measurements in still air are shown.

We see similar pictures as discussed in chapter 6.3.

6.5 Area of Wind Tunnel or Room

In order to find out an eventual dependence of the area of wind tunnel or room, in Figure 25 to Figure 27 we drew the mean results of every laboratory in function of the area of the wind tunnel or the room in which the anemometer was moved (chapter 5.2.4). The air velocity is here the additional parameter. The measurements made in still air are towards the right side of the diagram: IT Tank, IT Arm, CH, and JP Car, but not IT Lar and US High.

There is no obvious dependence from the area. At the lowest air velocities, one might guess a very small increase of the anemometer constant with increasing area.

6.6 Dependence on Standard Used

From Figure 28 to Figure 39 the mean results are grouped depending on the standard used for calibration. The six following figures (Figure 40 to Figure 45) show the synopsis of all polynomes (chapter 5.2.5).

As the polynomes differ less than the mean residua, we conclude that there is no significant difference caused by the type of standard used. If we look only at the upper part of the velocity range where the anemometer constant varies less, we make the same conclusion because the differences between the laboratories are not smaller in this range. Also, the number of results becomes very small, in some cases, only one laboratory contributes to the polynome approximation.

6.7 Youden Plots

The anemometer constant of two anemometers corresponding to the same air velocity is shown from Figure 46 to Figure 63.

If a point is situated on the upper right part or the lower left part of the diagram, then both anemometer constants are on the same side of the mean value: either both are higher (upper right) or lower (lower left). This indicates a similar reaction of both anemometers to the measurement conditions or might be a hint for a systematic influence. As the points are dispersed over the plots, we can deduce nothing clearly.

6.8 Stability

The anemometer constant versus date of measurement is shown from Figure 64 to Figure 66.

No trend can be seen. The two measurements made in our laboratory (CH1 and CH2) were intended as first and last measurement. As Japan and the United States joined the project later, the stability was good (CH1 and CH2) and time became short, we didn't repeat the complete measurements. 6 and 7 April 1999, we checked the anemometer constant for a few air velocities. These measurements confirmed well the former measurements of our laboratory (results not shown in this report). We deduce that the stability over the whole intercomparison was good.

7 Conclusions

The differences between the laboratories are relatively big. We could not find the reasons for these differences. This leads us to the one and only conclusion that the topic needs more investigations.

8 Comments

Here are the comments received of the laboratories after reading the draft of this report.

8.1 The Netherlands

The impact of the blockage area will be different on the reading of the anemometer due to the ventilator control system of the wind tunnel. A) if the ventilator has a feedback system (i.e.: the nominal velocity is kept constant) then probably the real velocity at the edge of the windmill type anemometer will increase, thus giving overreading of the anemometer (pulse factor is increasing) B) if the ventilator is passive, then the flowrate of the wind tunnel is decreasing to a certain extend, when the reference velocity is not corrected for this decrease then the normal overreading effect will be compensated partly or totally. Dependent on flow characteristics of the flow generating system, sometimes the blockage overreading effect will be totally absorbed due to the decrease of real flow and thus the anemometer will give an underreading effect.
- In my opinion it would be interesting to discriminate the several wind tunnels based on the way of controlling the flowrate, i.e. passive or active.

It should be considered to correct for the blockage factors of all three anemometers after the blockage factors have been determined on the same (set of) wind tunnels. We expect that the results will show a better overall performance. The expected blockage areas of the three anemometers that were used are: Macro: 39 cm^2; Mini : 26 cm^2; Micro: 24 cm^2. The areas are determined on the bases of the geometry of the anemometers inclusive the handles. The uncertainty level of the estimation is 10% (2s).

The total area of the carriage of relevant tests should be taken into account in total with the blockage area of the meter under test.

9 Acknowledgement

We thank all participating laboratories and the EUROMET authorities for their kind and helpful co-operation.