PAPER 18

DEVELOPMENT OF A DYNAMIC PRESSURE ANEMOMETER FOR MEASURING THE AXIAL VELOCITY COMPONENT

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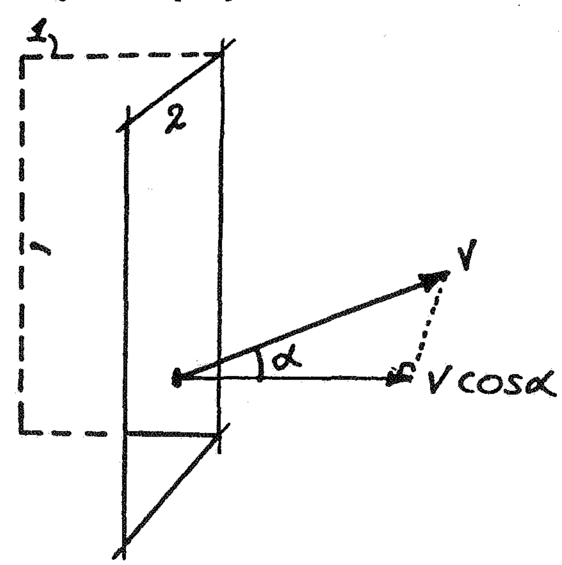
DEVELOPMENT OF A DYNAMIC PRESSURE ANEMOMETER FOR MEASURING THE AXIAL VELOCITY COMPONENT

SUMMARY

The dynamic pressure anemometer described here belongs to the group of so-called pressure-tube anemometers (pitot-static tube) and is intended for measurement of one velocity component in a threedimensional flow field at air velocities of 0,1 up to 10 m/s. The usable flow direction area is unlimited (0 ... 360^o) in three dimensions. The maximum error in the indication of the velocity component is less than 5% (if the actual velocity is put at 100%).
At low air velocities (<< 1 m/s) the zero drift of the differential pressure transducer used is the determining factor for the error in the reading which may be considerable.

INTRODUCTION

During a study of the air velocities in and volume flows through an opened window there was a need for simultaneous measurement of the air velocity and the flow direction.
In Figure 1, the situation is given where air with a velocity , v, flows through an open window. In this case it is important to know if the air movement is directed inward or outward. To be able to make an estimate of the volume flow through the window plane it is necessary that the velocity component perpendicular to the window plane be determined.



1. window
2. window pane-frame

Figure 1 : Air velocity in an opened window.

Determination of the flow direction by means of smoke, as was done sometimes in the past, must be rejected here because this method does not work for fluctuating flows and is not directly suitable for automatic processing of the data.

A configuration like a pitot tube was built to which air would flow from both sides.
After some experimenting with the results of wind pressure measurements around rectangular buildings it seemed not impossible to find a form where the pressure signal might be convertible to the velocity component from one certain direction, as given in formula (1):

$$v\cos\alpha = C \cdot \mathrm{sign}(\Delta p)\sqrt{|\Delta p|} \qquad (1)$$

In figure 2, the velocity vector v, and vcosα are sketched in a system of coordinates.

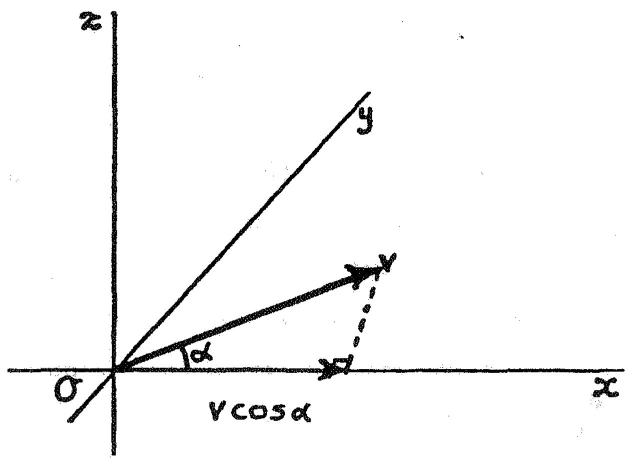


Figure 2 : v and vcosα given for an angle of incidence, α. The anemometer is situated in O for measuring the x component of v.

INVESTIGATION

After measurements on some prototypes, an investigation into the disc forms with the desired direction characteristic was started. This direction characteristic is

$$\Delta p = K.\ \tfrac{1}{2}\ \rho(v.\cos\alpha\ )^2 \quad ----- \qquad (2)$$

Formula (2) has been derived from formula (1) by defining Δp explicitly. The factor K is the dimensionless proportion between the pressure difference measured and the dynamic pressure.
In this investigation the following parameters were varied:

- form (section) of the disc
- diameter of the disc
- form of the pressure measuring openings in the disc
- diameter of the pressure measuring openings.

Measurements were also made on discs of porous material. The direction characteristics were taken in two wind tunnels:

at 2 - 12 m/s with a degree of turbulence of about 3%;

at 0,1 - 2 m/s with a degree of turbulence of about 30%.

RESULTS

It appeared that the form of the disc had much influence on the form of the direction characteristics. With a beveled disc form (Figure 3) the best results were obtained (Figure 5).

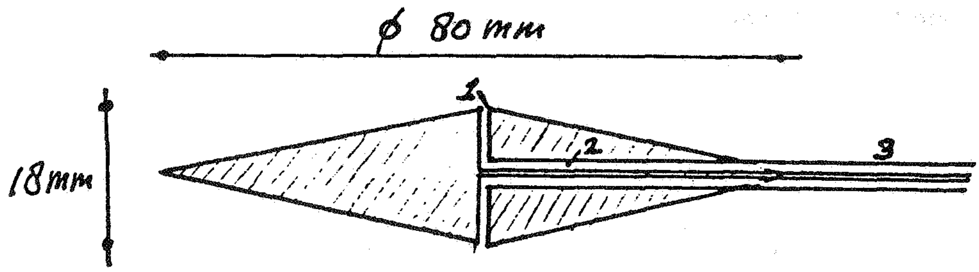


Figure 3 : Section of the velocity pressure disc.
1. Pressure measuring opening (ø 1 mm).
2. Bore to connection pipe.
3. Connection pipe.

The diameter of this disc is 80 mm, but can be made smaller (e.g. 20 mm) without affecting the properties. For comparison, in Figures 4 and 5, direction charactaristics of a disc with rectangular section and the disc of Figure 3 are given.

The direction characteristics appeared practically independent of the velocity. Possibly, the degree of turbulence of the air has some influence on this characteristic.

So, it appeared that the direction characteristics better agreed with formula (1) at a higher degree of turbulence (30%) than one of 3%.

Vertical : proportion between the pressure measured and the velocity pressure of the flow (K):

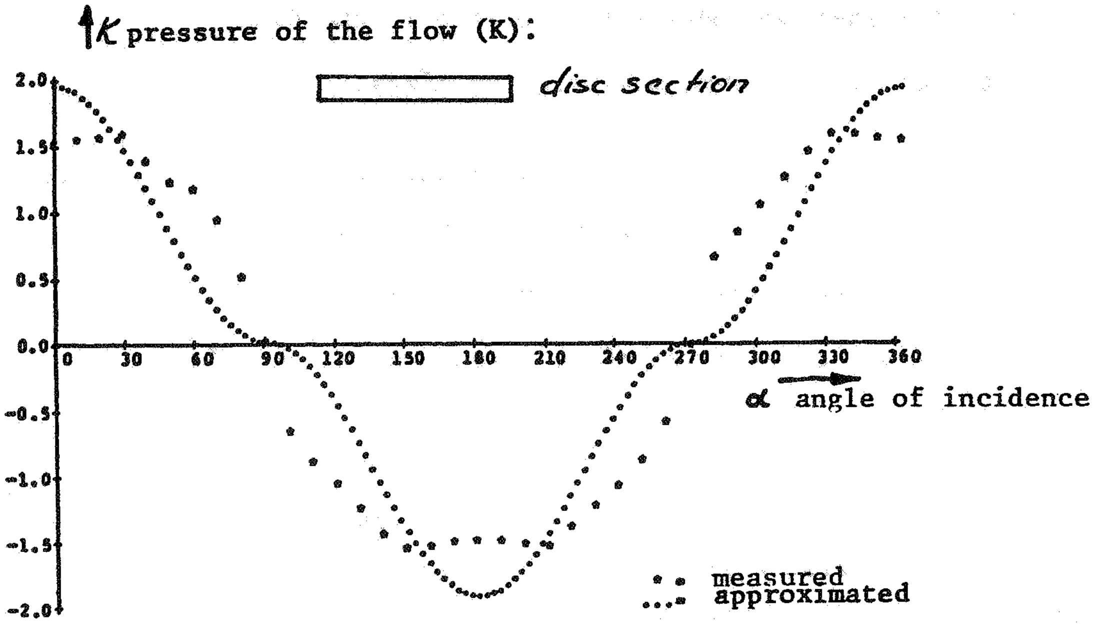


Figure 4 : Direction characteristic of a rectangular disc as a function of the angle of incidence (α); degree of turbulence = about 3%.

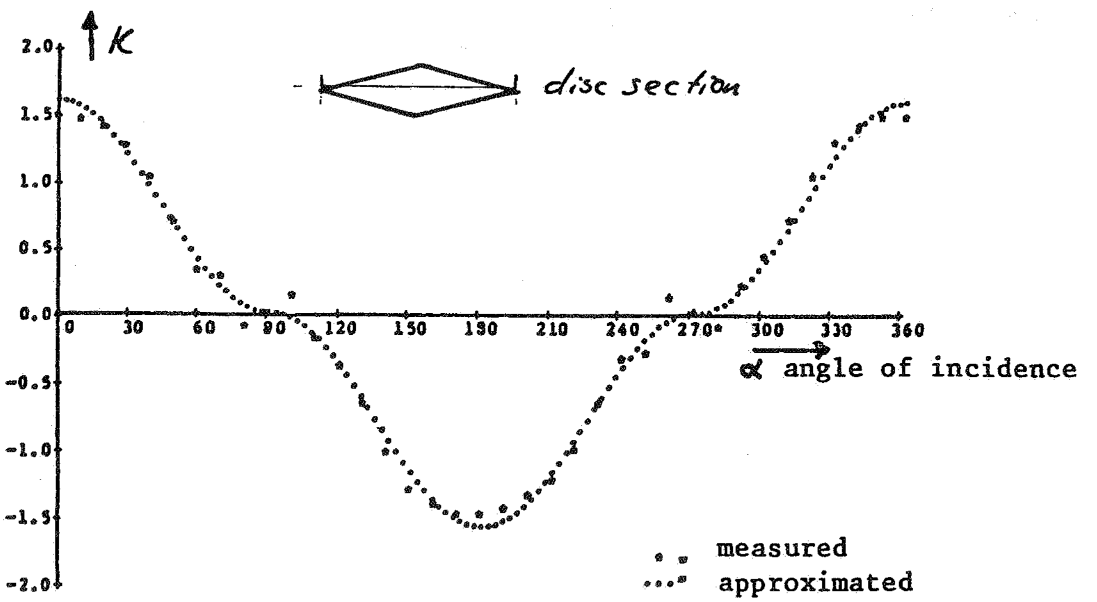


Figure 5 : Direction characteristic of the beveled disc (Figure 3) as a function of the angle of incidence (α); degree of turbulence = about 3%.

In the direction area around 90^{o} and 270^{o} the direction characteristic oscillates through zero. Consequently, the sign of the velocity component which according to formula (1) is calculated from the measuring signal does not agree with the actual velocity component; in other words, while the air enters through a window (nearly parallel to the window plane) the anemometer here indicates that air is flowing outside. It is supposed that this undesirable phenomenon can be prevented by flattening the disc somewhat more near the pressure measuring openings.

With three of these anemometers placed perpendicularly on each other it must be possible to determine the three velocity components and, consequently, the flow velocity in force and in direction.

A condition for this is that the anemometers do not influence each other which will be attained by mounting them at some distance from each other. The flow in this area around the three anemometers must be homogeneous and the dimensions of the eddies must be considerably larger than the distance between the anemometers.

The response time for the discs examined is about 0.1s, so that fluctuations in the air velocity to about 10 Hz can be measured.

APPLICATION

In the above-mentionded investigation into air flows in an open window it was measured with a measuring arrangement as sketched in Figure 6.

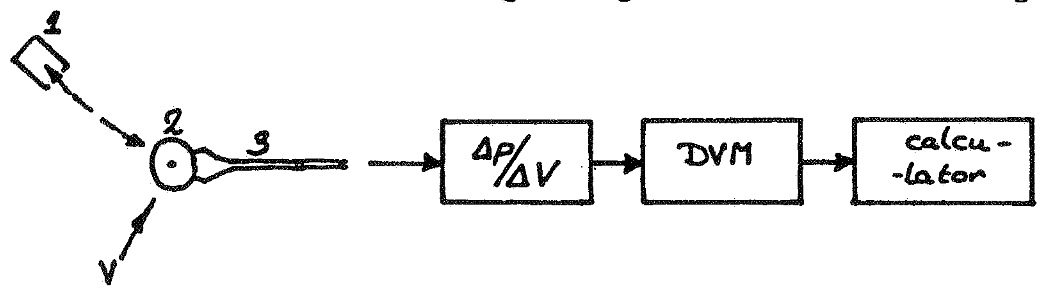


Figure 6: Measuring arrangement.

1. Cap for screening the velocity pressure, measuring disc during determination of the offset voltage.
2. dynamic pressure measuring disc.
3. connecting tubes.

The influence of temperature differences between the connecting tubes of the disc to the differential pressure transducer is minimized by placing these connections horizontally. The offset of the pressure transducer is determined by pushing regularly (every 5 minutes) a cap over the disc, owing to which the air velocity around the disc becomes zero temporarily. The offset voltage determined in this way is subtracted from the measuring values with the calculator before the air velocity component is calculated with it.
For perpendicular flow, the following pressures may be expected, see Table 1.

Table 1 : Relationship between air velocity v, and pressure signal, Δp, for $\alpha = 0^o$.

v (m/s)	Δ_p (Pa)
0,01	0,0001
0,05	0,0025
0,10	0,01
0,5	0,25
1,0	1,0
10	100,0

In view of the small pressure differences at low velocities it is important to minimize the zero drift of the arrangement and also to determine regularly the offset voltage. For the differential pressure transducer, the zero drift can be about 0.0002 Pa/s. The error in the indication of the air velocity is determined then by the time passed between the measurement and the determination of the offset voltage. In Figure 7, the error in indication is plotted in m/s for some values of the zero error as a function of the velocity. In form of a formula this relationship is:

$$\delta = \text{sign.}(v^2.C - \Delta) . \sqrt{|v^2.C - \Delta|} - v, \quad \text{for } \alpha = 0^o \tag{3}$$

where δ = error in indication ;

Δ = zero error of the differential pressure transducer

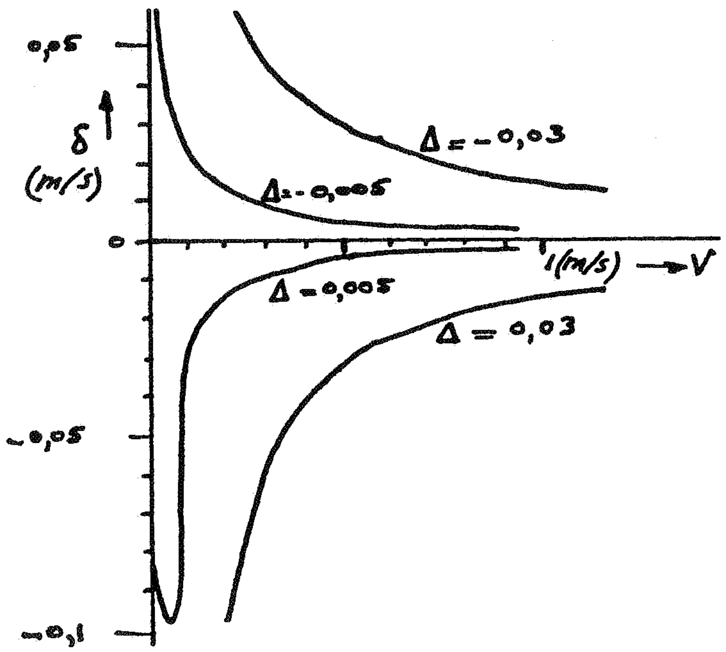


Figure 7 : Reading error of a dynamic pressure anemometer due to a zero error in the differential pressure transducer of ± 0.005 Pa and ± 0.030 Pa.

CONCLUSION

With the dynamic pressure discs described here it is possible to measure air velocity components at air velocities of about 0,1 m/s and more at frequencies lower than 10 Hz.
Information about the flow direction is obtained from the polarity of the pressure signal.
If the offset voltage is determined regularly the measuring errors, e.g. for 0,1 m/s and more can remain within ± 0,02 m/s.
A disadvantage of this measuring method, and of all dynamic pressure anemometers in general is that high demands are made upon the differential pressure transducer because of the quadratic relationship between the pressure signal and the air velocity.

LIST OF SYMBOLS

C =	a constant (dependent on temperature) $C \approx 1$ at 20 °C. $C = \sqrt{\frac{2}{K.\rho}}$	[$kg^{-\frac{1}{2}}.\ m^{1\frac{1}{2}}$]
K =	pressure factor	[-]
p =	air pressure difference	[Pa]
v =	air velocity	[m/s]
V =	electric tension	[V]
α =	angle of incidence	[°]
δ =	error in indication	[m/s]
Δ =	zero error	[Pa]
ρ =	specific mass of air	[$kg.m^{-3}$]

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