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HOLZKIRCHEN, DUITSLAND

Natural Ventilation of dwellings

Investigation of the relationship between the natural ventilation of a flat and the meteorological conditions.

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1. Introduction

Some years ago, people realized that energy from fossile fuel was getting more and more scarce. To save energy, possibilities were sought to limit the energy consumption for house heating. In extensive studies and analyses, investigators constantly hit upon the question how much ventilation contributes to the total energy consumption of the heating of a dwelling. This can only be estimated or calculated very roughly.
Very few measured values in dwellings are available. From literature, something is known about the range of ventilation rates, but the relationship between the meteorological parameters: wind velocity, wind direction, outdoortemperature and the natural ventilation in dwellings is not yet known. The meteorological wind velocity alone proved to be insufficient to predict the ventilation rate. The aim of this investigation is therefore to study the relation between the meteorological conditions and the resulting pressure differences on the building and fortuitous openings or specially provided apertures in that building, such as cracks, ventilation-windows or -grills, ventilation shafts and the resulting natural ventilation. Furthermore, we studied the possibility of developing a useful calculation model to predict the ventilation as a function of wind velocity, wind direction and stack effect.
This relationship is schematically represented in figure 1.

Because the occupant controls or influences ventilation by opening or closing windows and doors, it is necessary for a good understanding of the actual ventilationrate to become acquainted with the occupant's use of the ventilation provisions. One particular dwelling was chosen for the investigation because a lot was known already about energy consumption there.

2. Description of the object of investigation.

In Kijkduin (municipality of The Hague), there are blocks of flats on the first row of dunes seen from the North Sea. An occupant of one of them was interested in the energy problem and record the gas consumption weekly during a heating season and even daily during another heating season.

This flat has become an object for a detailed study of the energy consumption connected with the heating of houses. In all studies, special attention is called to the question whether it would be possible to make an explicable energy balance of a house. It was obvious that the flat mentioned above would be chosen as a study object for these ventilation measurements.

Data of the flat:

floor area:about 100 m^2
volume (gross):about 260 m^3
situation:near the coast (about 250 m distance)
one wall facing SE (living-room)
one wall facing SW (living-room and bedroom)
one wall facing NW (bathroom and kitchen)
3rd and highest storey
heating: hot water central heating with natural gas
boiler capacity 17,4 kW
ventilation:ventilation windows and ventilation shafts "shunt system"
in bathroom, kitchen and W.C.
ventilation grill between bathroom and corridor
Figure 2, 3 and 4

The data of this exceptionally situated dwelling are not suited for a generally useful evaluation of the energy consumption caused by ventilation. Therefore, the measured values can only be seen as one of many possibilities occuring in practice.

3. Measurements

3.1 Measuring programme

Measurements made on this flat during several months:

- pressure differences:between the inside of the flat and
  the outside of the three walls mentioned
  outlet of the shafts on the roof
  outside of the frontdoor
- temperatures:at the external walls
  on the roof
  in the staircase
  in the corridor of the flat
- position of windows and doors (closed or opened).

Total time of measurements about 300 hours.

Ventilation rates : The flat was considered to be one room.
(all doors in the flat open).

In total, 21 ventilation rate measurements (of which 7x with open windows) were carried out with a total measurement time of about 70 hours.
For the situation of the measuring points, see figure 2.
All data was recorded by an incremental data recorder and off line processed with a computer. (fig. 5).

The air tightness of cracks of windows and doors etc. in the walls, and the outlet openings of natural ventilating shafts above the roof, was also determined. (fig. 6 and 7).
During one week, the relative humidity in kitchen, corridor, living-room and at one external wall was measured. The humidity data have not yet been analysed and will not yet be considered.

4. Results

Not all measuring data have been worked out and analysed yet. We now shall discuss the data which have been processed.
Often the results have been considered in relation to the meteorological conditions. The data for these conditions came from the weatherstation of the Royal Dutch Meteor-Institute (KNMI) in Hook of Holland.

This station has about the same position to the coastline as the building in question. The distance between the meteorological station and the building is about 15 km.

4.1 Pressure measurements

The results of the pressure measurements are give in figures 8 to 12. The pressure differences are all considered in relation to the pressure outside the SE wall on which the living-room is located. This figures lead to the following remarks:

- the pressure strongly depends on the wind direction;
- the minima, and maxima of the pressure differences can clearly be explained by the form of the building;
- the flow direction can be determined from the pressure differences between wall or roof and the inside pressure of the flat.

4.2 Air leakage measurements

The results of the air leakage measurements of the external wall and the shafts are represented in figures 13 to 19. Remarks:

- Not only the cracks of the movable parts in the walls but also the joints between the window-frame and the wall highly determine the airtightness.
- There are only small differences in the leakage with windows and doors pressed against the windowframe and pressed from the windowframe.
- The cracks of the ventilation windows and of the doors may be considered as very tight, according to Dutch standard.

4.3 Ventilation rate measurements

In figure 20, the ventilation rates are plotted against the meteorological wind velocity. There is no clear linear relationship between the meteorological wind velocity and the measured ventilation rate. In figure 21, the ventilation rates are plotted against a wind velocity corrected for the local roughness of the building in Kijkduin. With this correction the influence of surrounding buildings and dunes to the wind velocity at the location has been taken into account.

Remarks with the figures:

- the variation in the measured ventilation rates is rather large,
- if the roughness of the surroundings and the wind direction are taken into consideration, there is a clear linear relationship with the wind velocity,

Remark: the influence of the thermal forces has not yet been taken into consideration.

4.4 Window-opening habit

It is tried to find relationships between the position of windows and doors and the wind velocity, the wind direction and the outdoor temperature. The influence of the tenant habit on the pressure differences can be deduced from figure 22.
The pressure difference between the kitchen-wall and inside the flat is nearly zero at wind directions from North to South-West. This means that the pressure difference is zero if this wall is on the leewardside This may be explained by the nearly constantly opened bathroomwindow, except when the wind is strong and blows from directions between Southwest and North.

4.5 Relationship

In this paragraph we will discuss the relationship between the air-volume flow calculated from the pressure and air leakagemeasurements and the air volume flow to be calculated from the measured ventilation rate. To this end, the flat was modelled as given in figure 23. This relationship has been plotted for a period of 65 hours in figure 24. The air volume flow through joints and cracks in the walls into the flat as calculated from the pressure difference and air leakage is compared with the air-volume flow as calculated from the ventilation rate. From the figure it appears that the variation is rather large. It must be noted, however, that this variation is calculated with only one pressure measuring point for each external surface of a wall, whereas the openings in the walls, contrary to the expectation, were distributed all over the surface of the walls.

5. Provisional Conclusions.

- The pressure differences vary strongly and are highly dependent on the wind direction.
- The untightness of the walls is not limited to the cracks of the movable parts of the windows and doors in the walls. Windowframe joints seem to be also an important part.
- It appears to be possible to predict the ventilation rate fairly accurately from the wind velocity (see figure 21). Then, however, the wind velocity must be corrected thus that the influence of the surroundings of the building concerned are taken into account.
- The infiltration of air to the flat through the openings in the walls calculated from the measured pressure differences and the measured tightness agree rather well with the volume flow calculated from the measured ventilation rate.
- The tenant habitation though not yet completely analysed, must be considered as very important.
- For the prediction of the enery consumption of a house by ventilation, it is not correct to assume a linear relationship with the meteorological wind velocity.

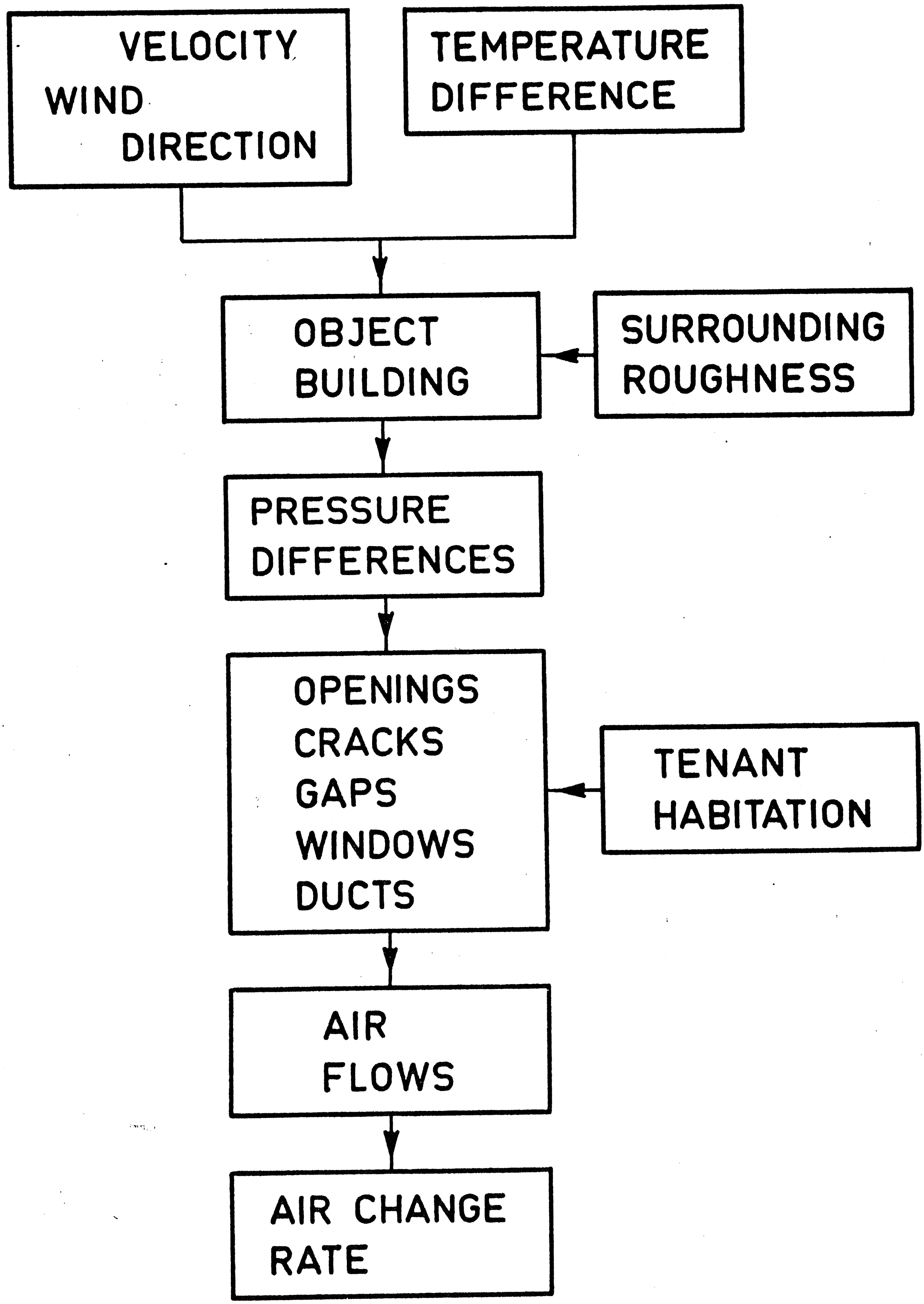
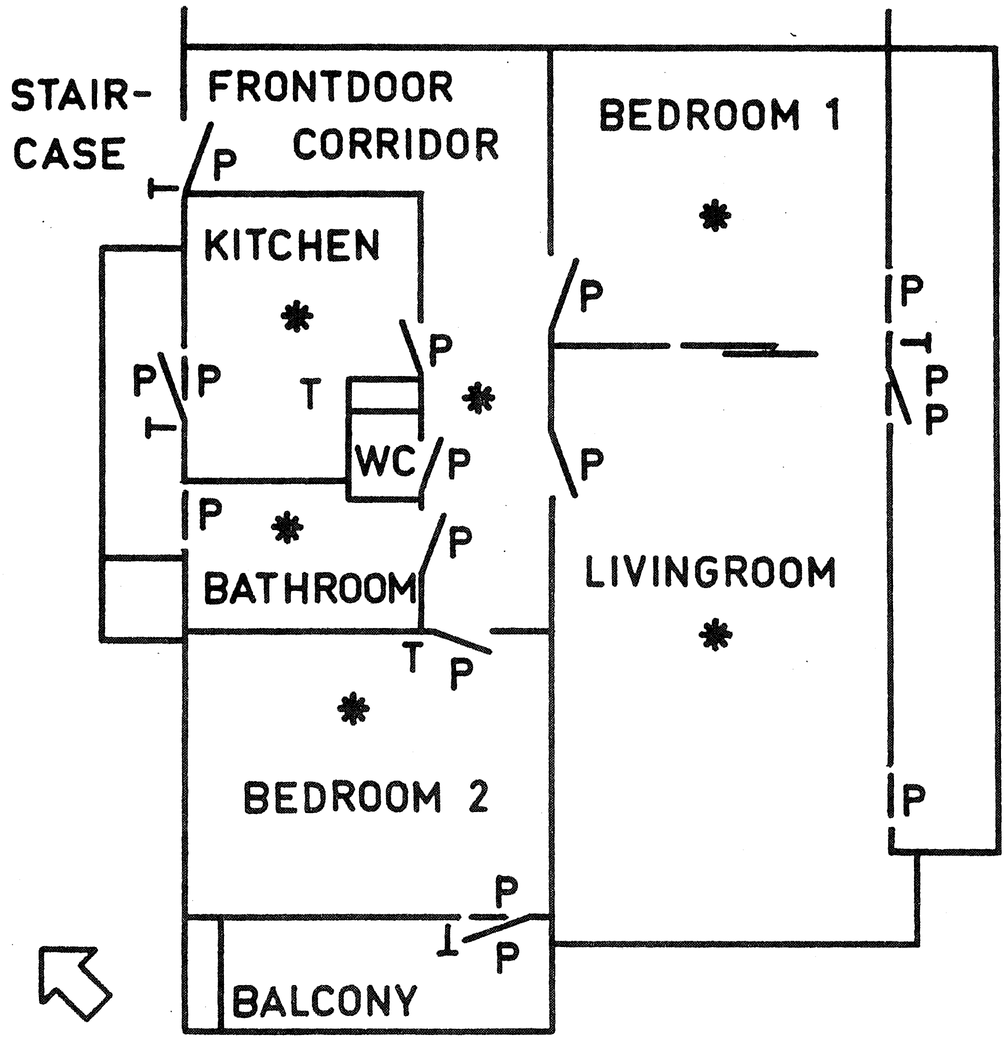

VELOCITY
WIND
DIRECTION
TEMPERATURE
DIFFERENCE
OBJECT
BUILDING
SURROUNDING
ROUGHNESS
PRESSURE
DIFFERENCES
OPENINGS
CRACKS
GAPS
WINDOWS
DUCTS
TENANT
HABITATION
AIR
FLOWS
AIR CHANGE
RATE

Fig. 1

FLOORPLAN OF THE APARTMENT



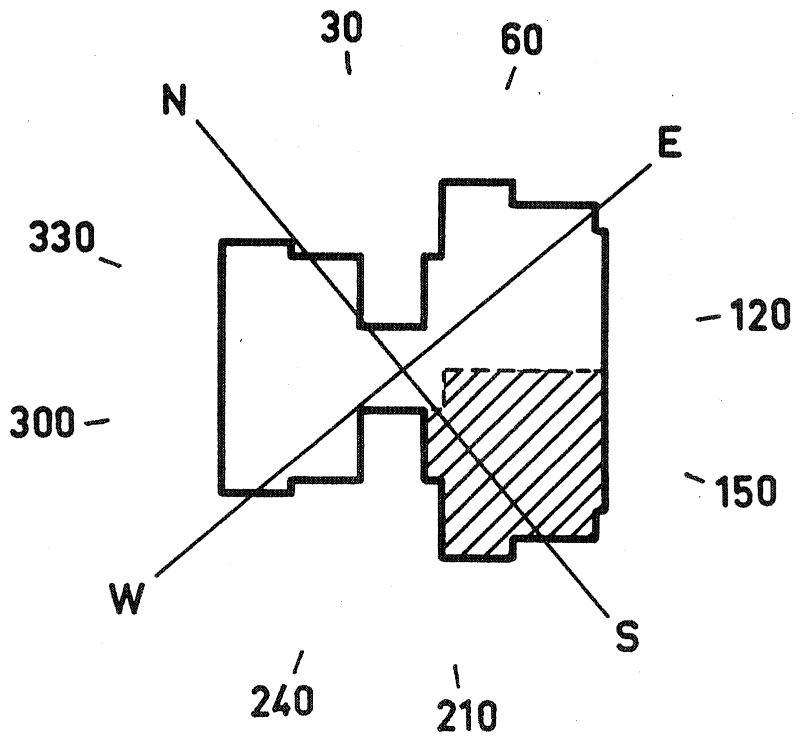
INTERIEURHEIGHT : 2.6 m

* KATHAROMETERS FOR AIR CHANGE RATE MEASUREMENTS

T PRESSURE AND TEMPERATURE MEASUREMENT

P MICROSWITCH

Fig. 2



Position of the building

Fig. 3

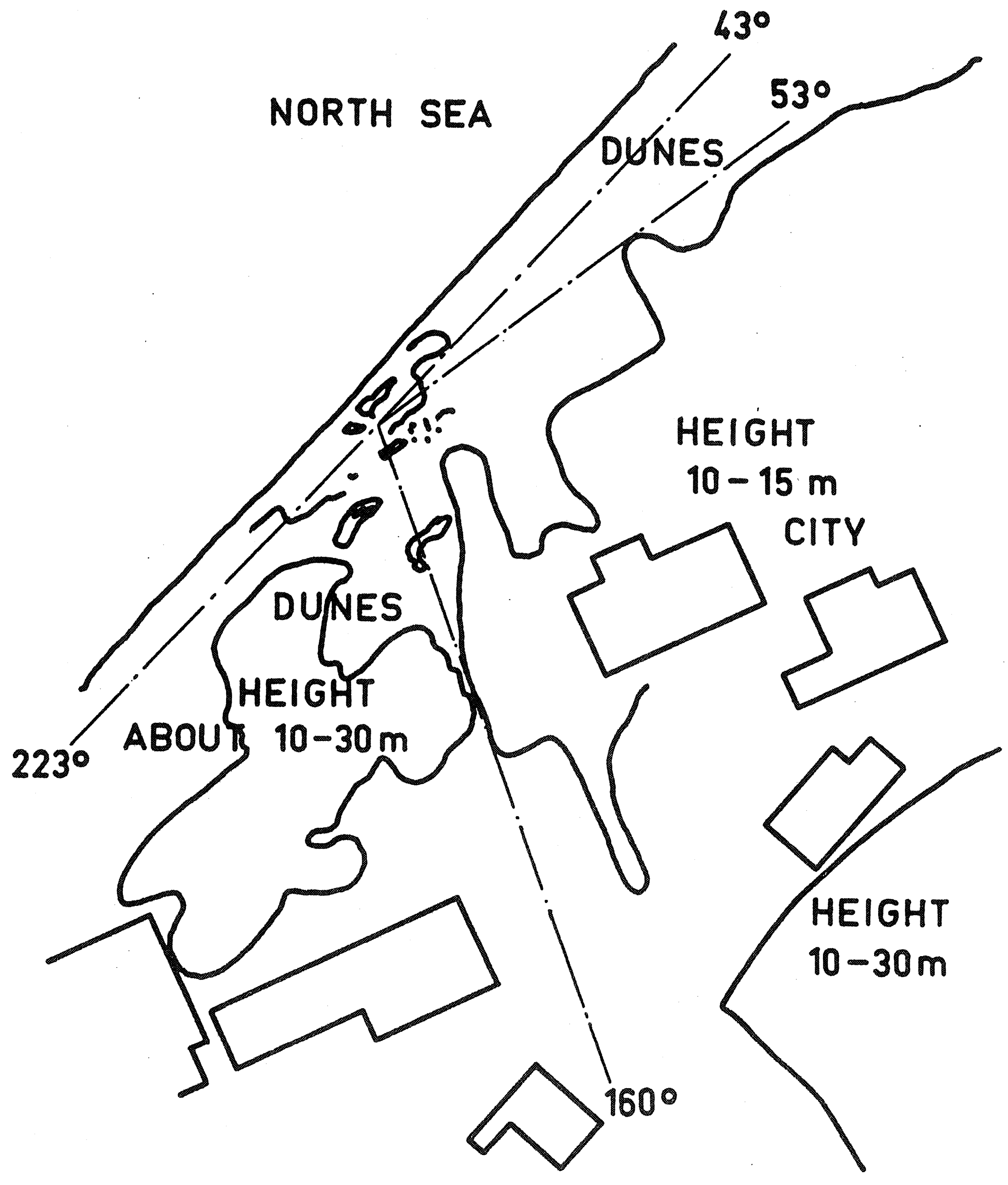

43°
53°
NORTH SEA
DUNES
HEIGHT
10 – 15 m
CITY
DUNES
HEIGHT
ABOUT 10–30 m
223°
HEIGHT
10 –30 m
160°

Fig. 4

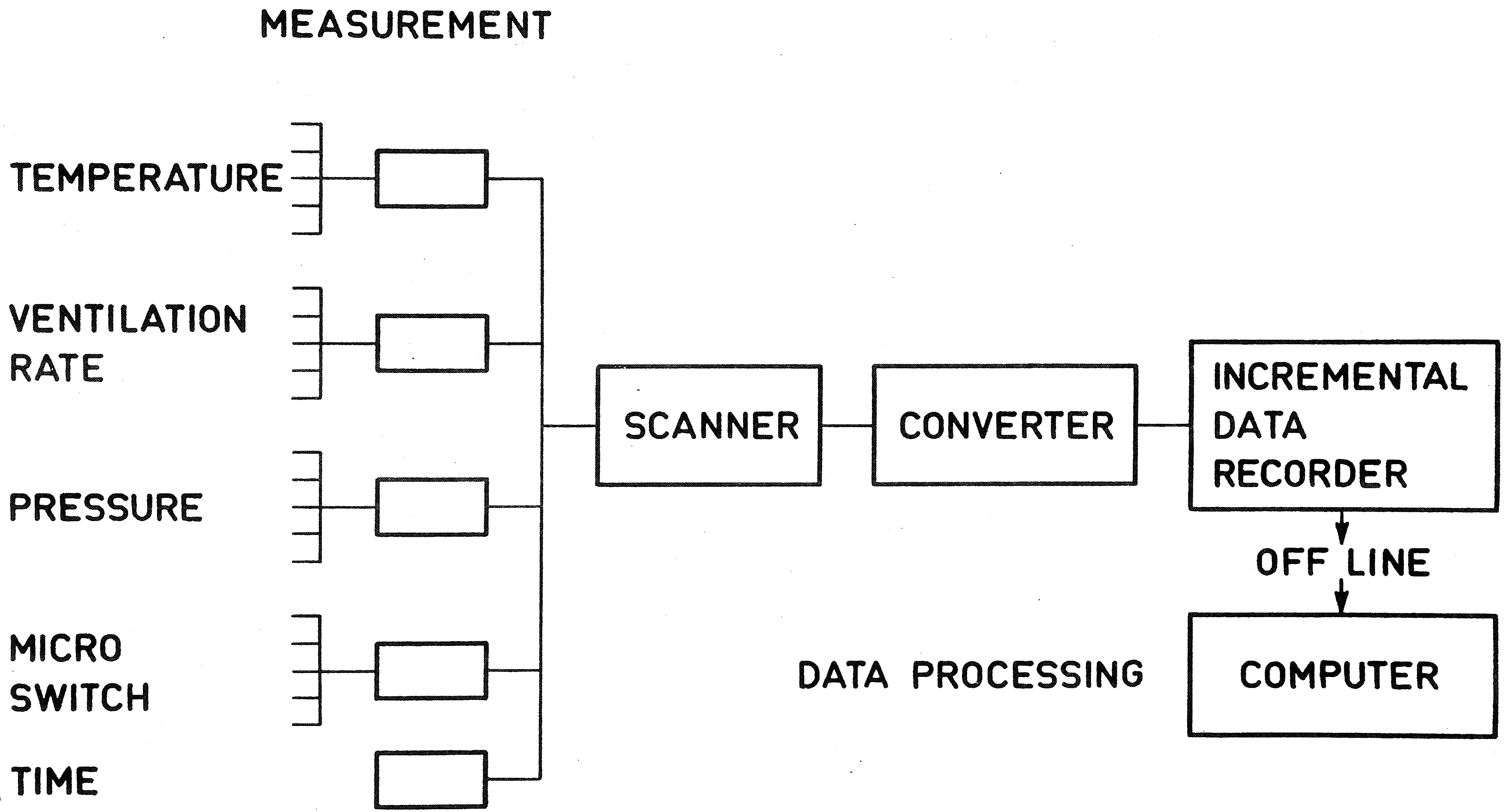

MEASUREMENT
TEMPERATURE
VENTILATION RATE
PRESSURE
MICRO SWITCH
TIME
SCANNER
CONVERTER
INCREMENTAL DATA RECORDER
OFF LINE
DATA PROCESSING
COMPUTER

Fig. 5

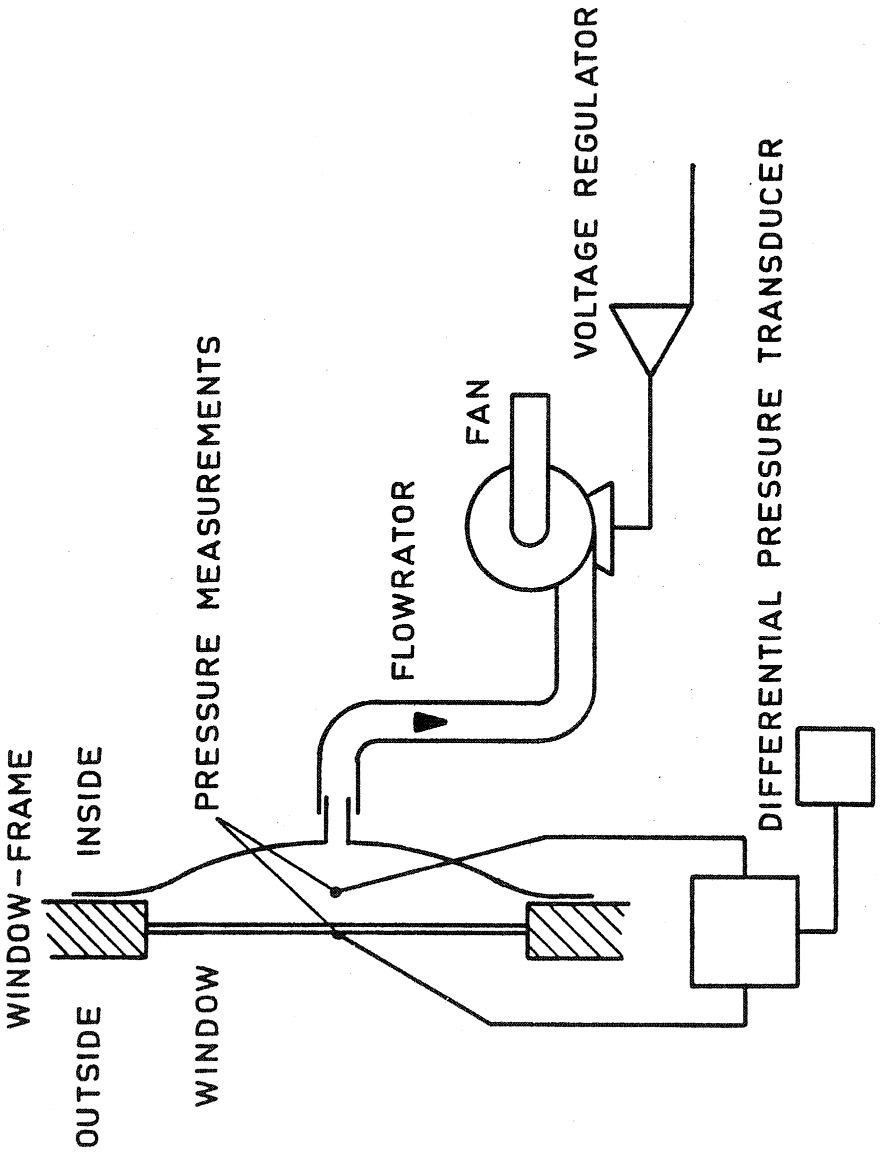

WINDOW-FRAME
OUTSIDE
INSIDE
WINDOW
PRESSURE MEASUREMENTS
FLOWRATOR
FAN
VOLTAGE REGULATOR
DIFFERENTIAL PRESSURE TRANSDUCER

Fig. 6

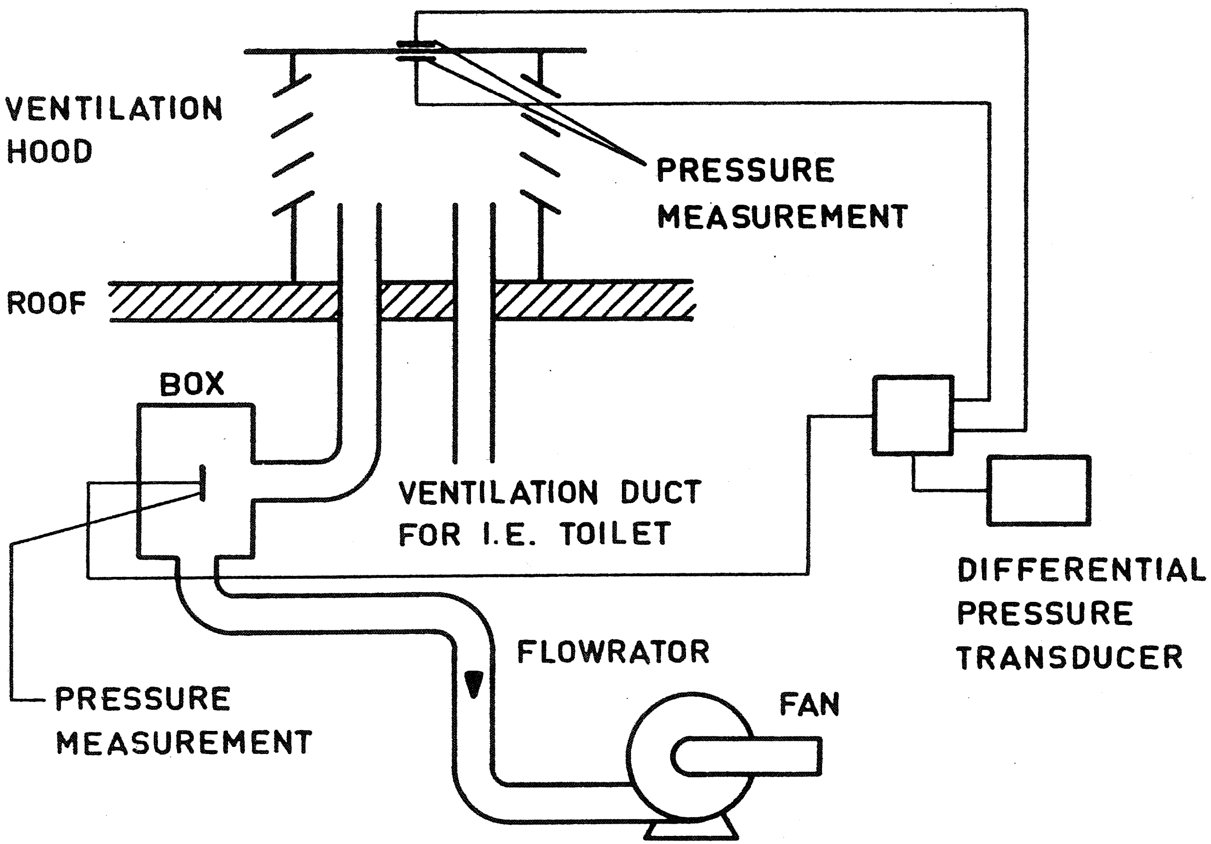

VENTILATION
HOOD
PRESSURE
MEASUREMENT
ROOF
BOX
VENTILATION DUCT
FOR I.E. TOILET
DIFFERENTIAL
PRESSURE
TRANSDUCER
FLOWRATOR
FAN
PRESSURE
MEASUREMENT

Fig. 7

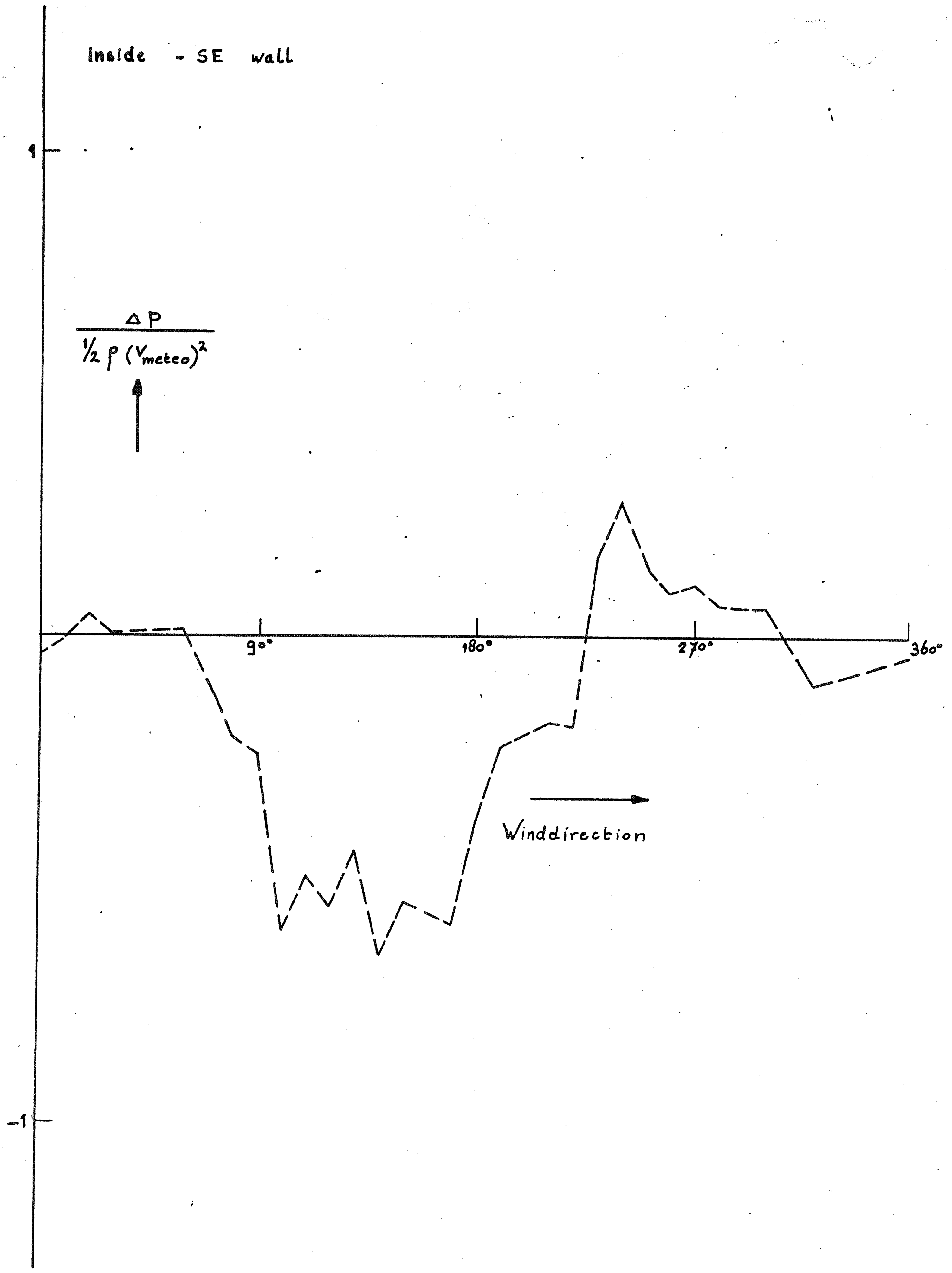

inside - SE wall
1
$\frac{\Delta P}{\frac{1}{2}\rho (V_{meteo})^2}$
90°
180°
270°
360°
Winddirection
-1

Fig. 8

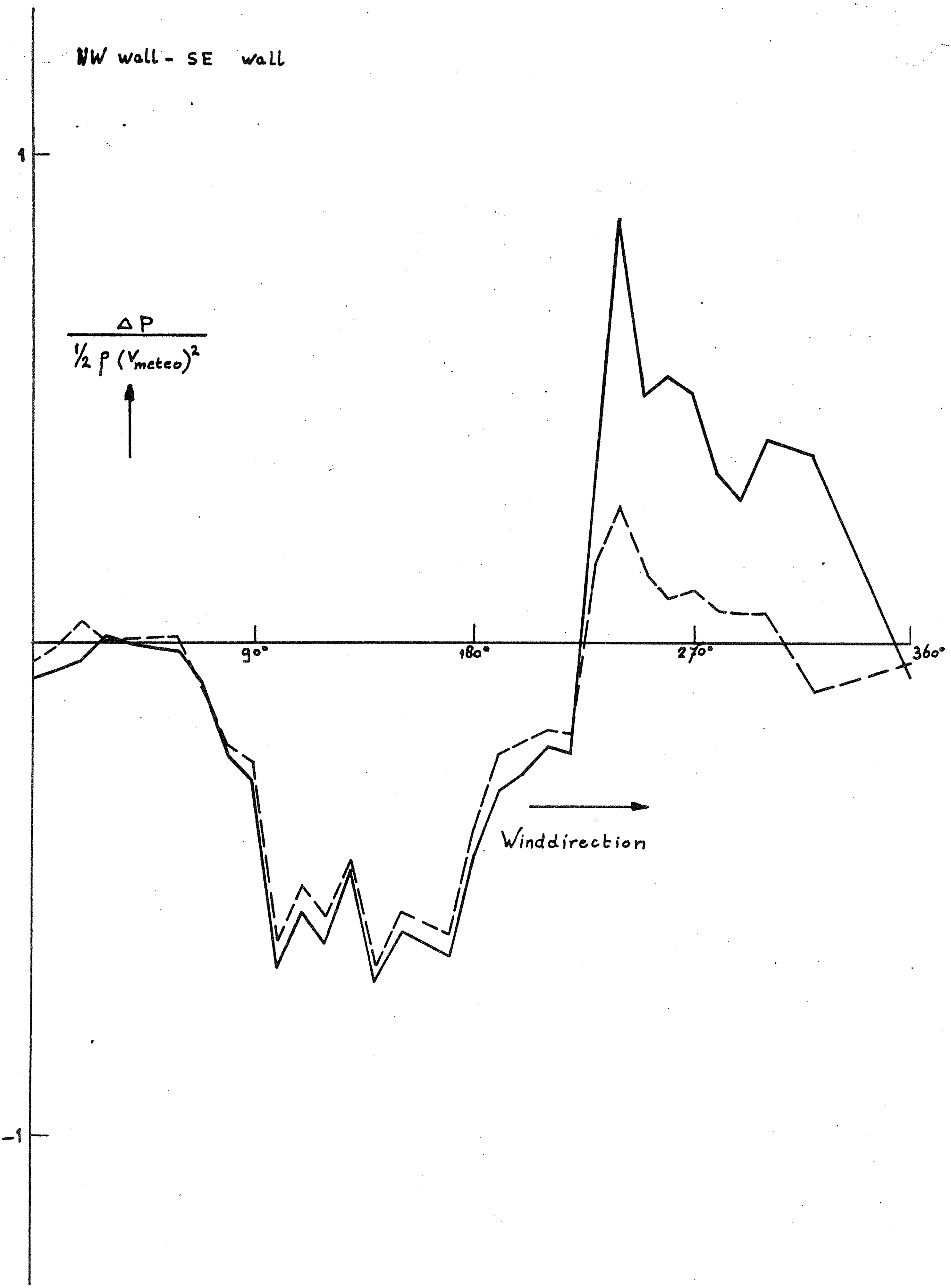


Fig. 9

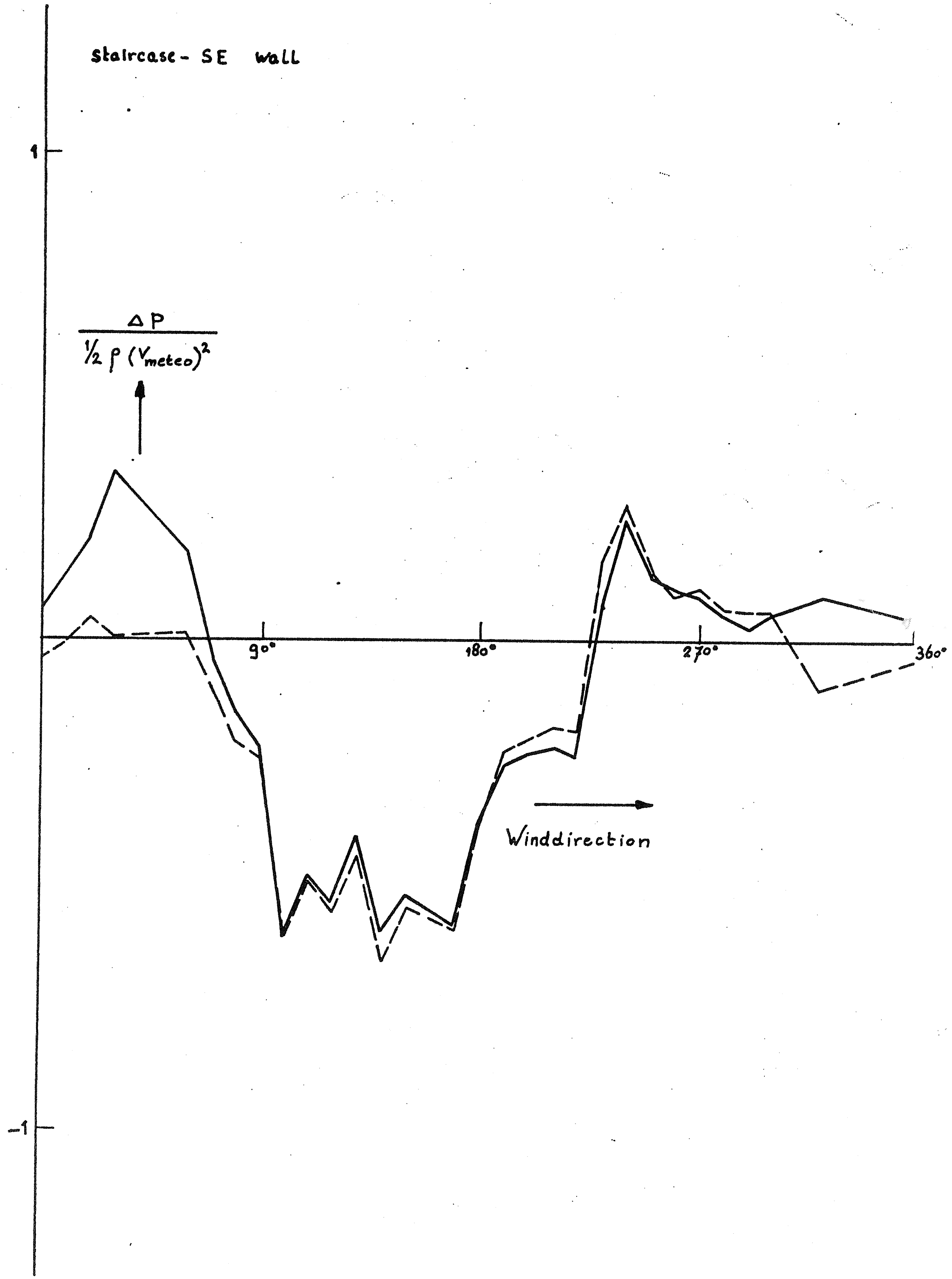

Staircase - SE wall
1
$\frac{\Delta P}{\frac{1}{2}\rho (V_{meteo})^2}$
90°
180°
270°
360°
Winddirection
-1

Fig. 10

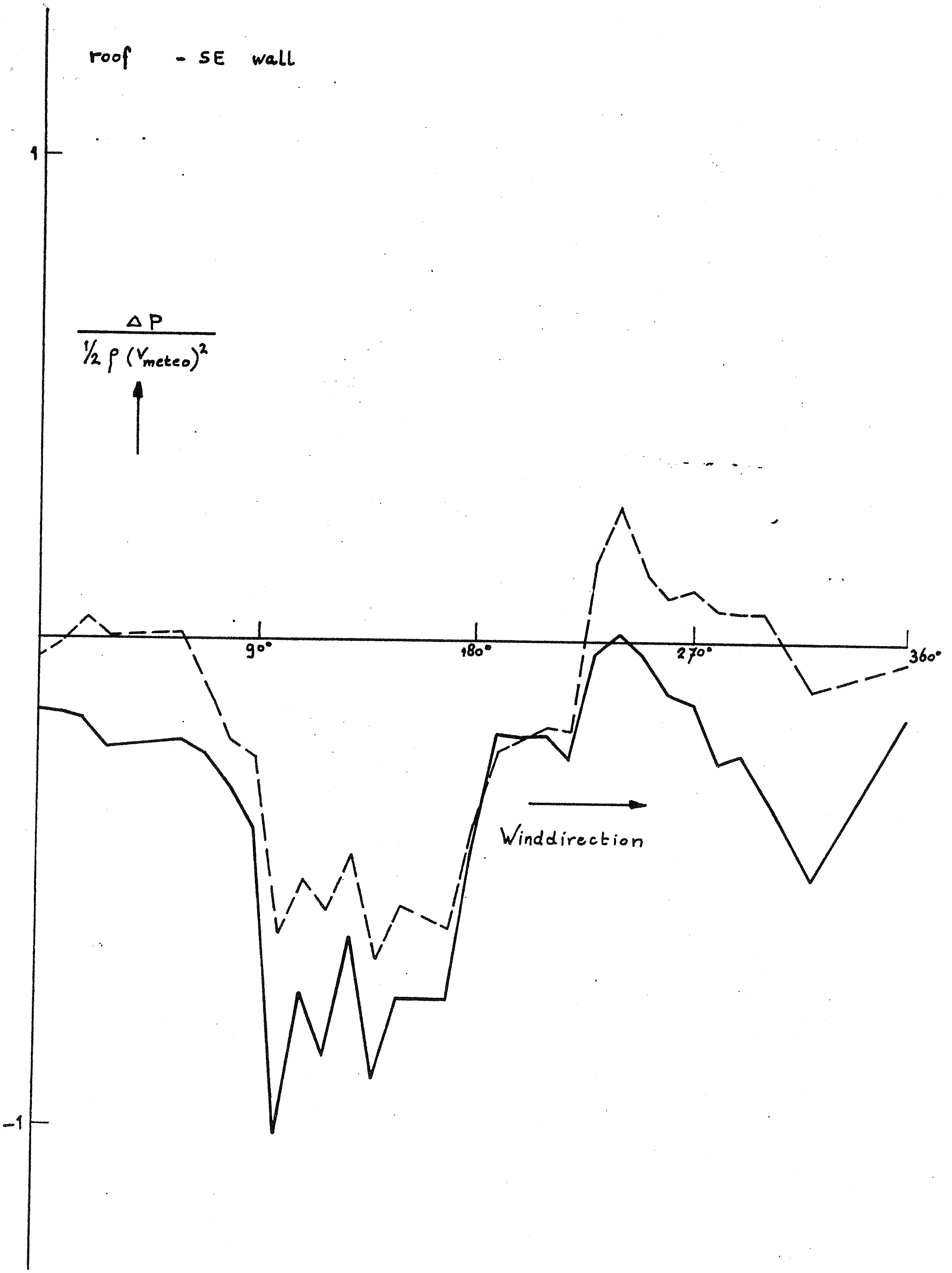

roof - SE wall
1
$\frac{\Delta P}{\frac{1}{2}\rho (V_{meteo})^2}$
90°
180°
270°
360°
Winddirection
-1

Fig. 11

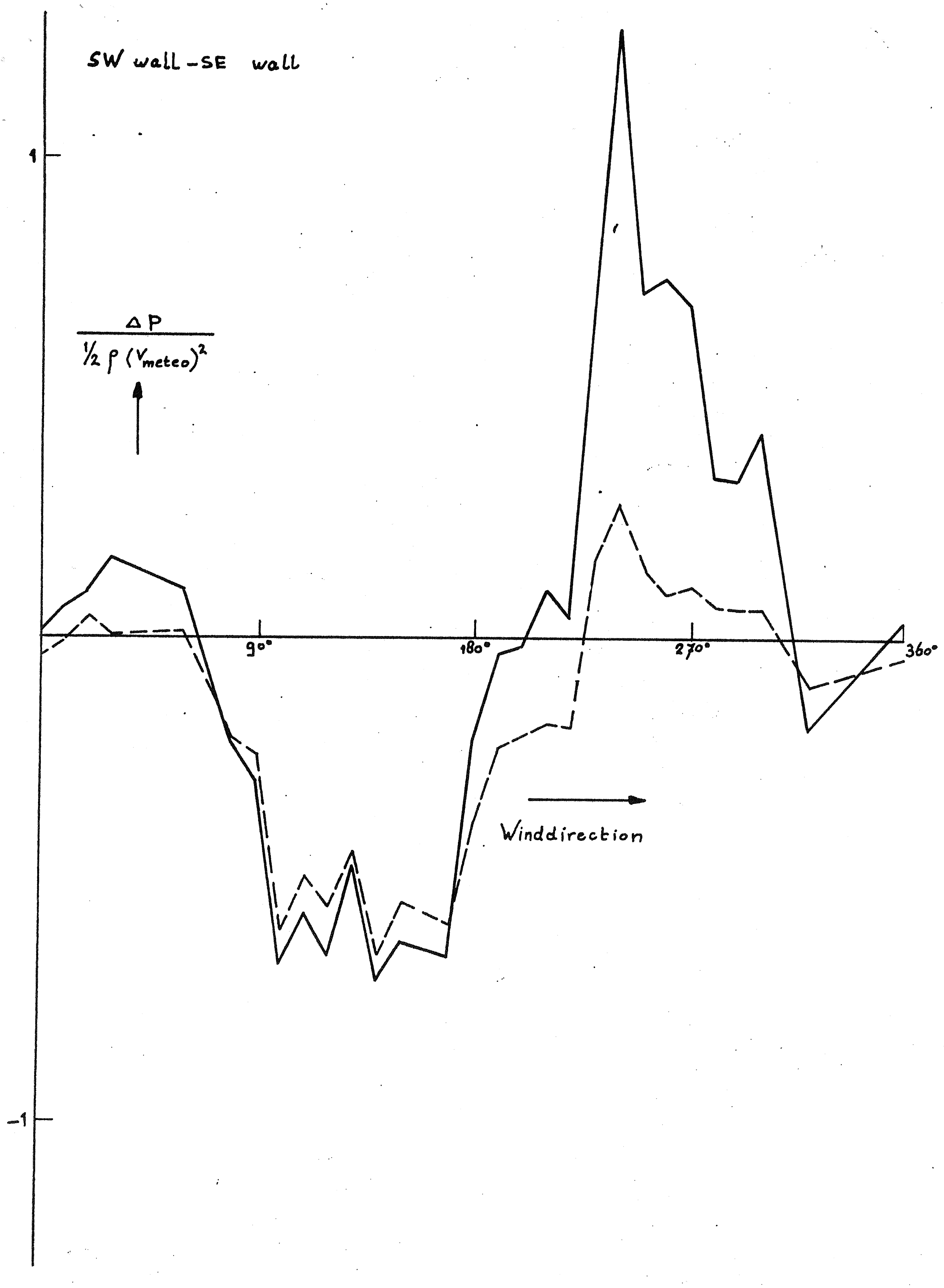


Fig. 12

SE wall

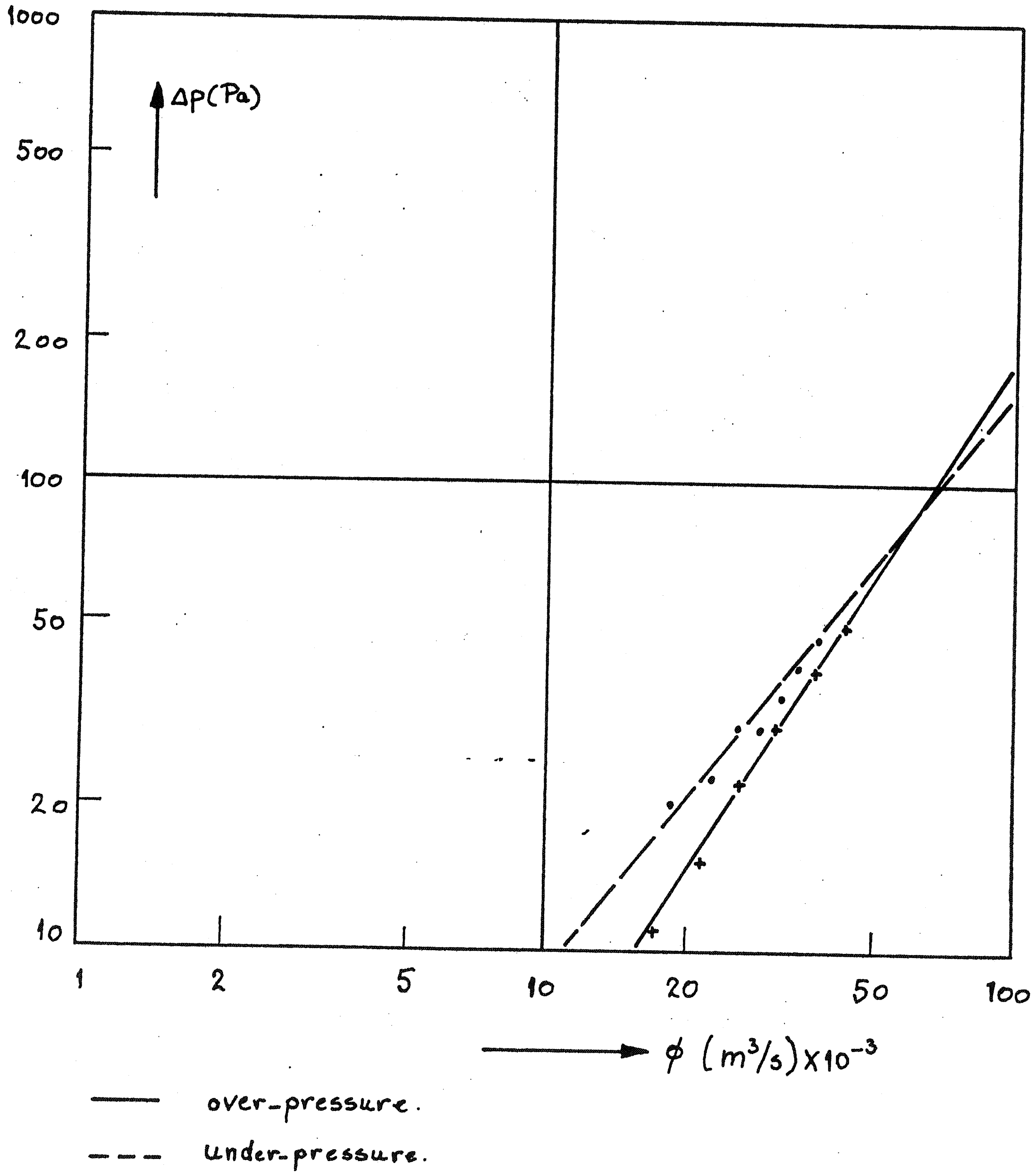


Fig. 13

SW wall

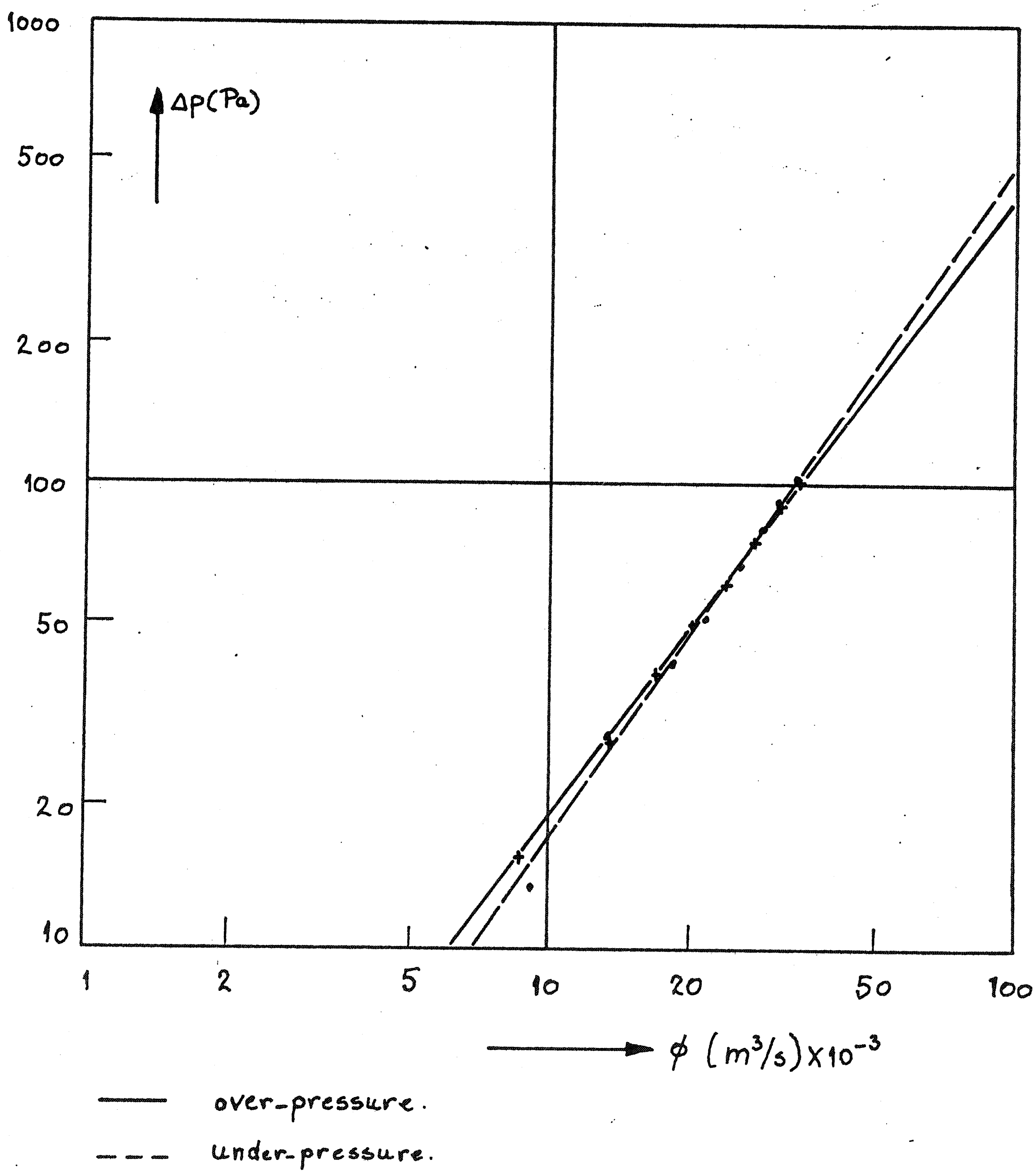


Fig. 14

NW wall (bathroom)

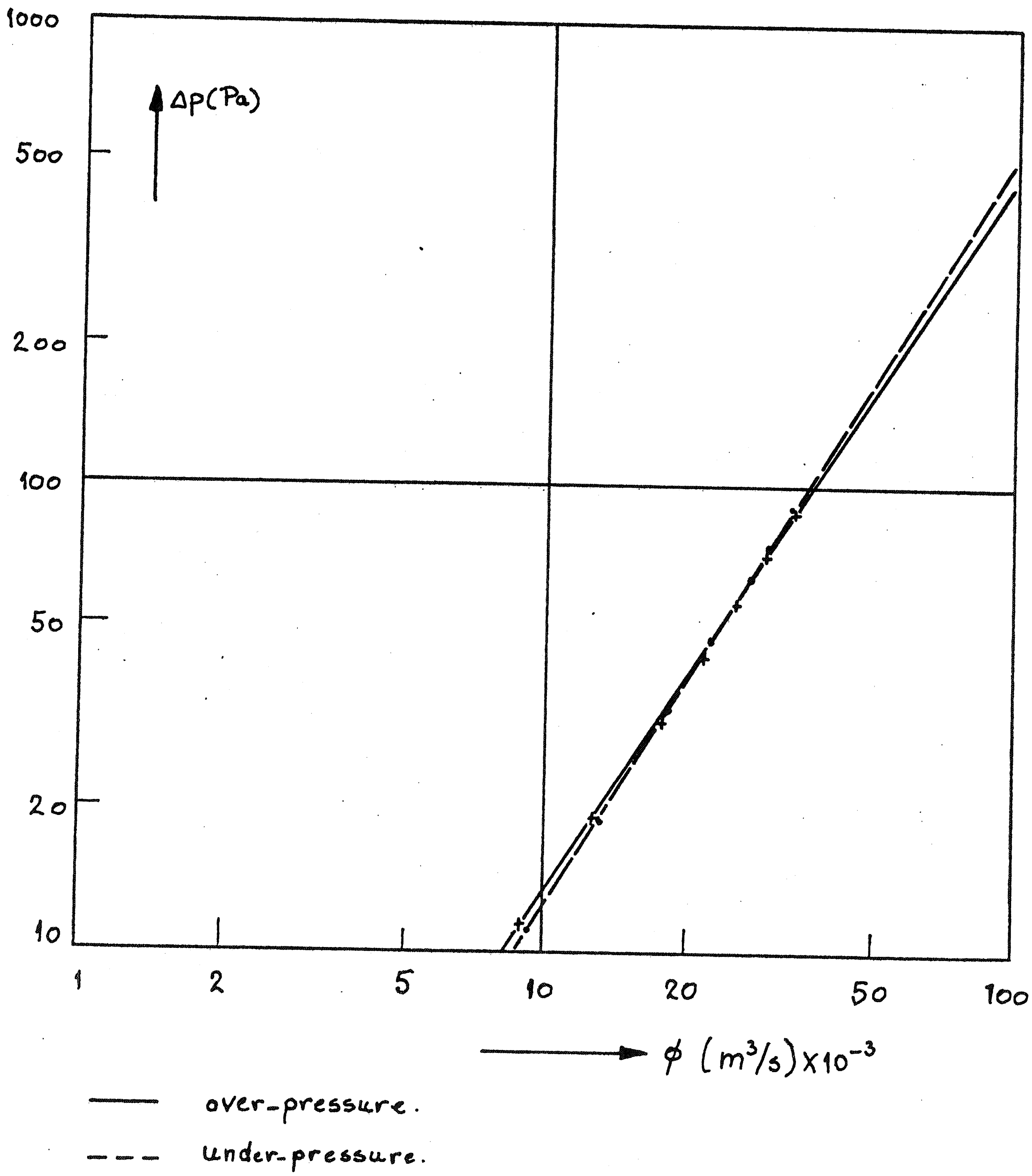


Fig. 15

NW wall (kitchen)

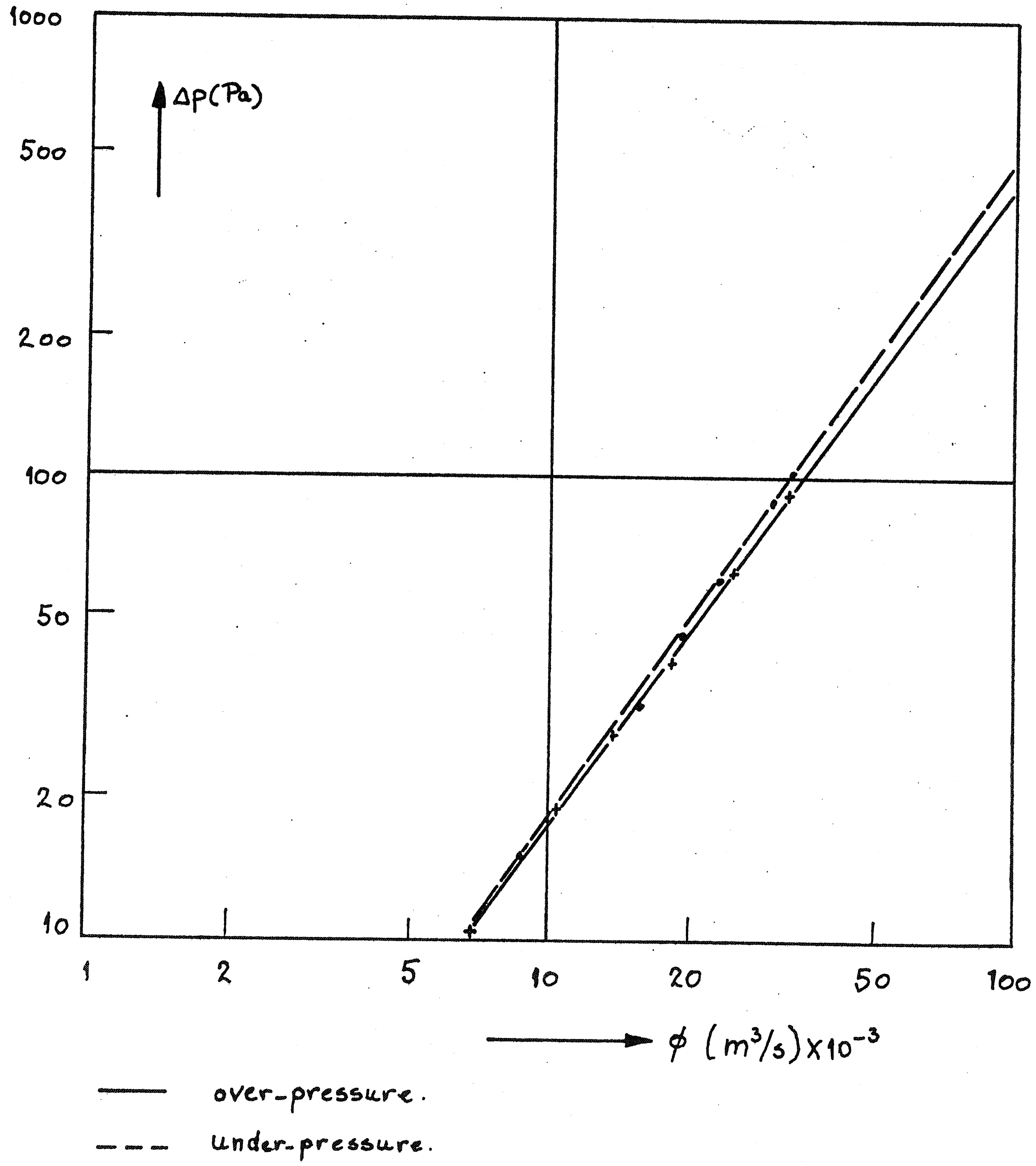


Fig. 16

Ventilationduct bathroom

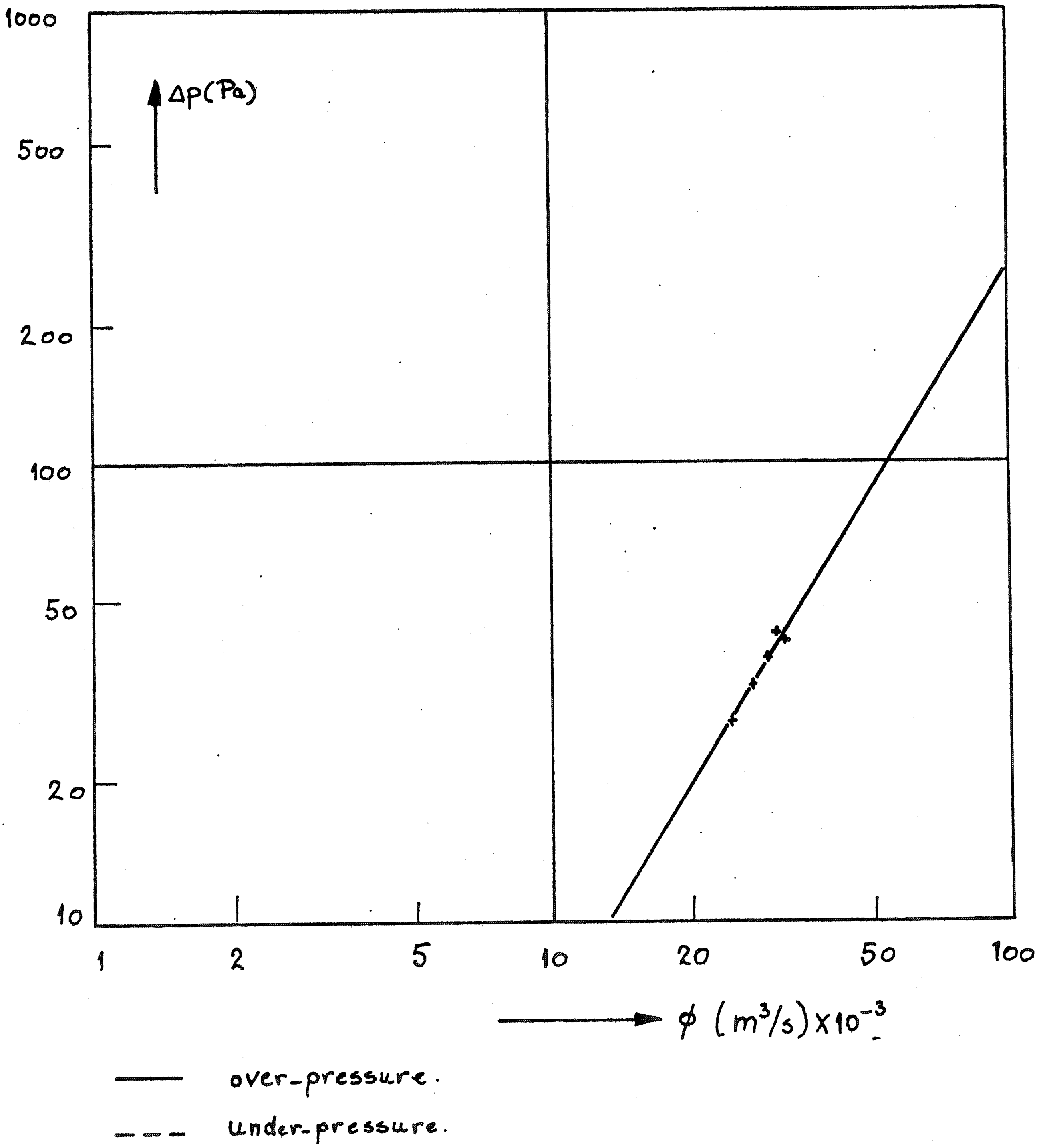


Fig. 17

Ventilation duct toilet

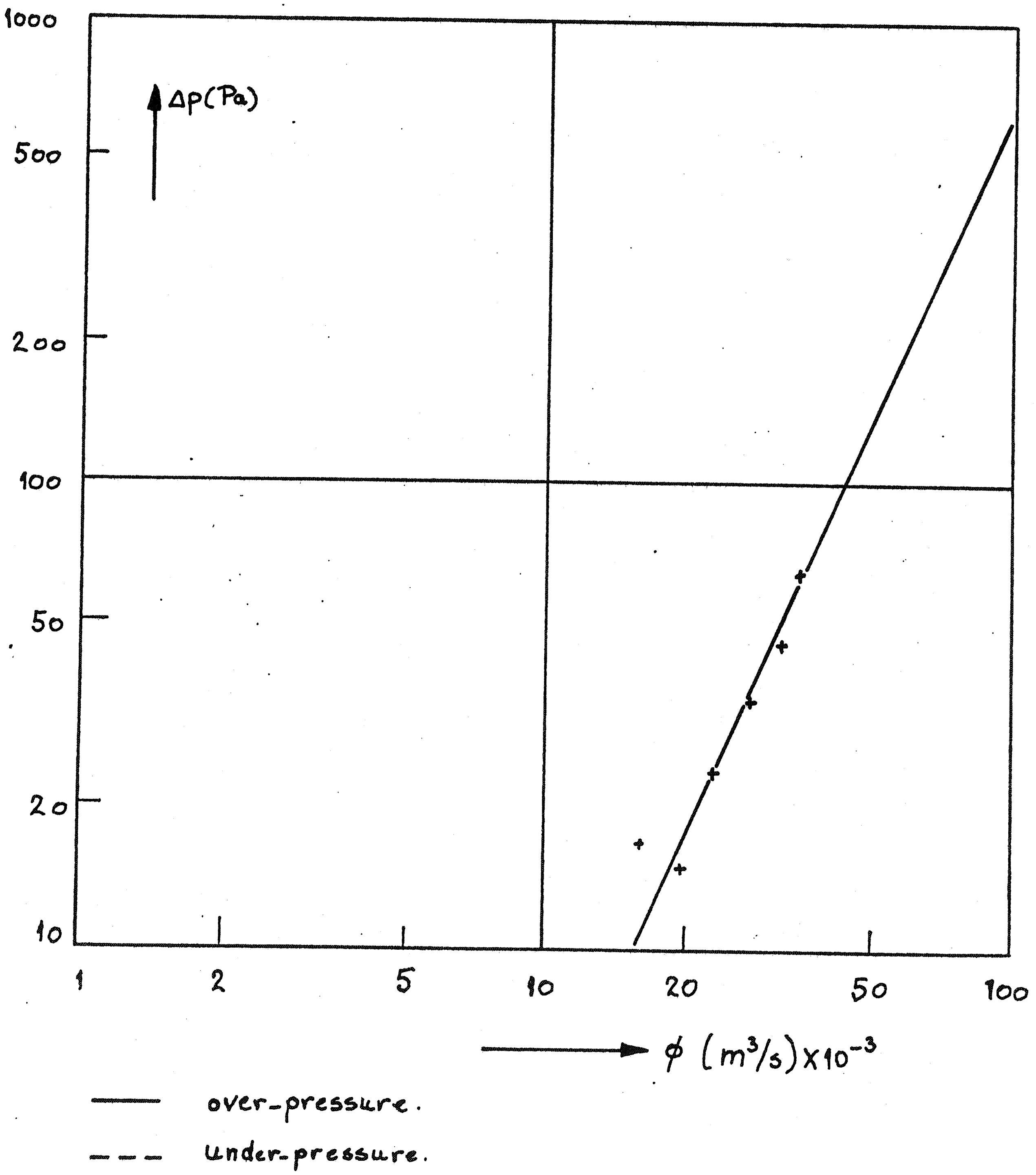
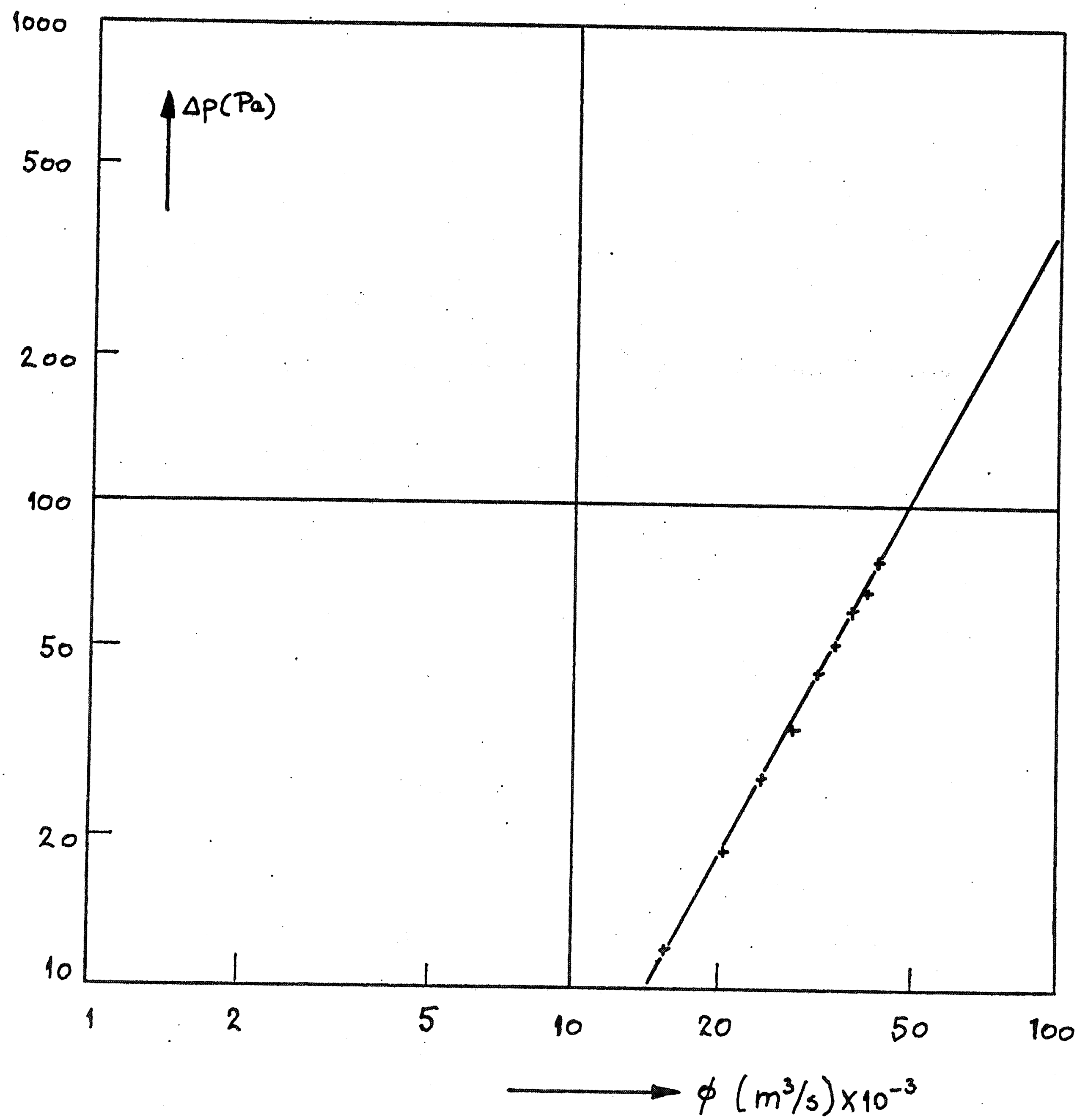


Fig. 18

Ventilationduct Kitchen



—— over-pressure.

– – – under-pressure.

Fig. 19

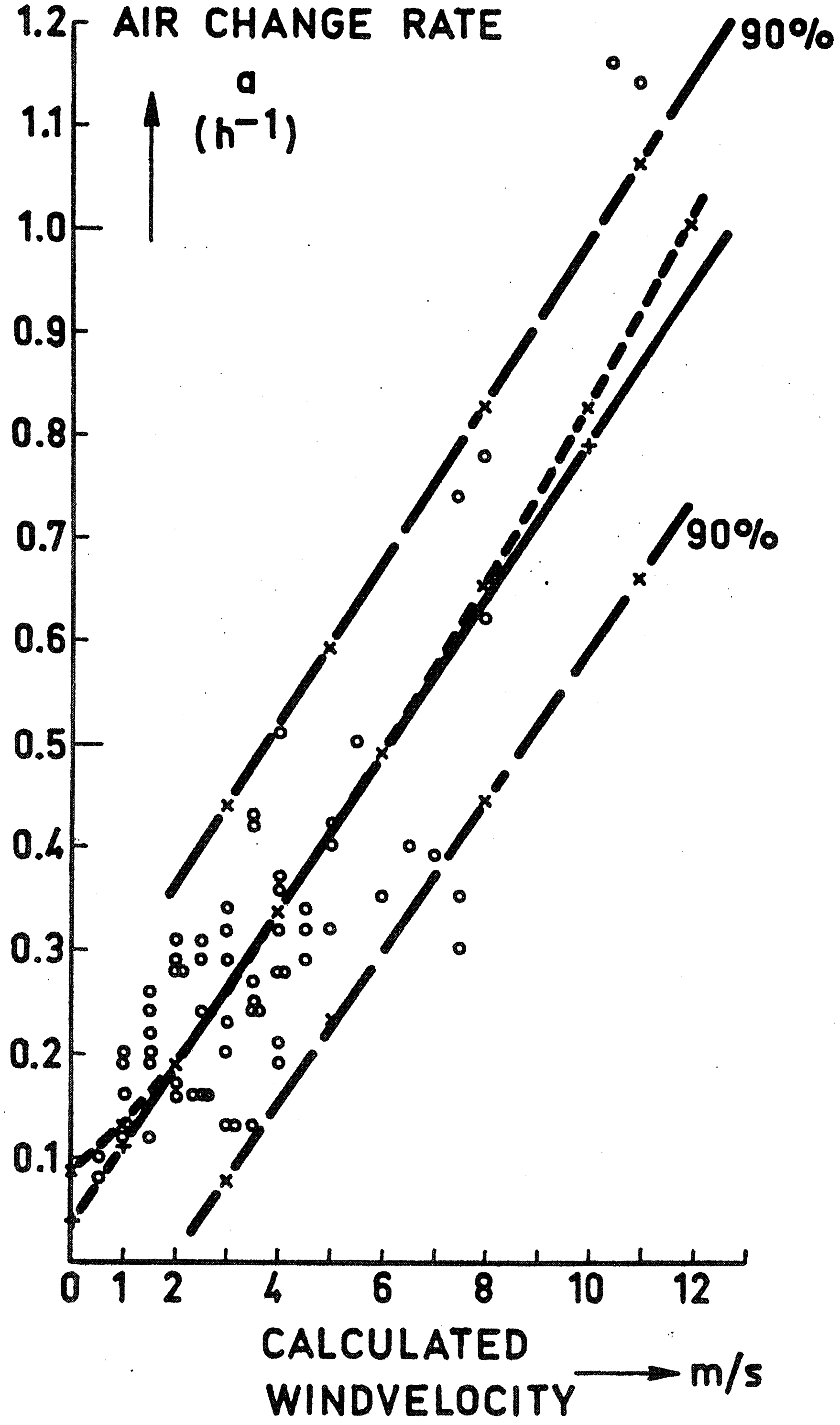

1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
AIR CHANGE RATE
a
(h^{-1})
90%
90%
0
1
2
4
6
8
10
12
CALCULATED
WINDVELOCITY
m/s

Fig. 21

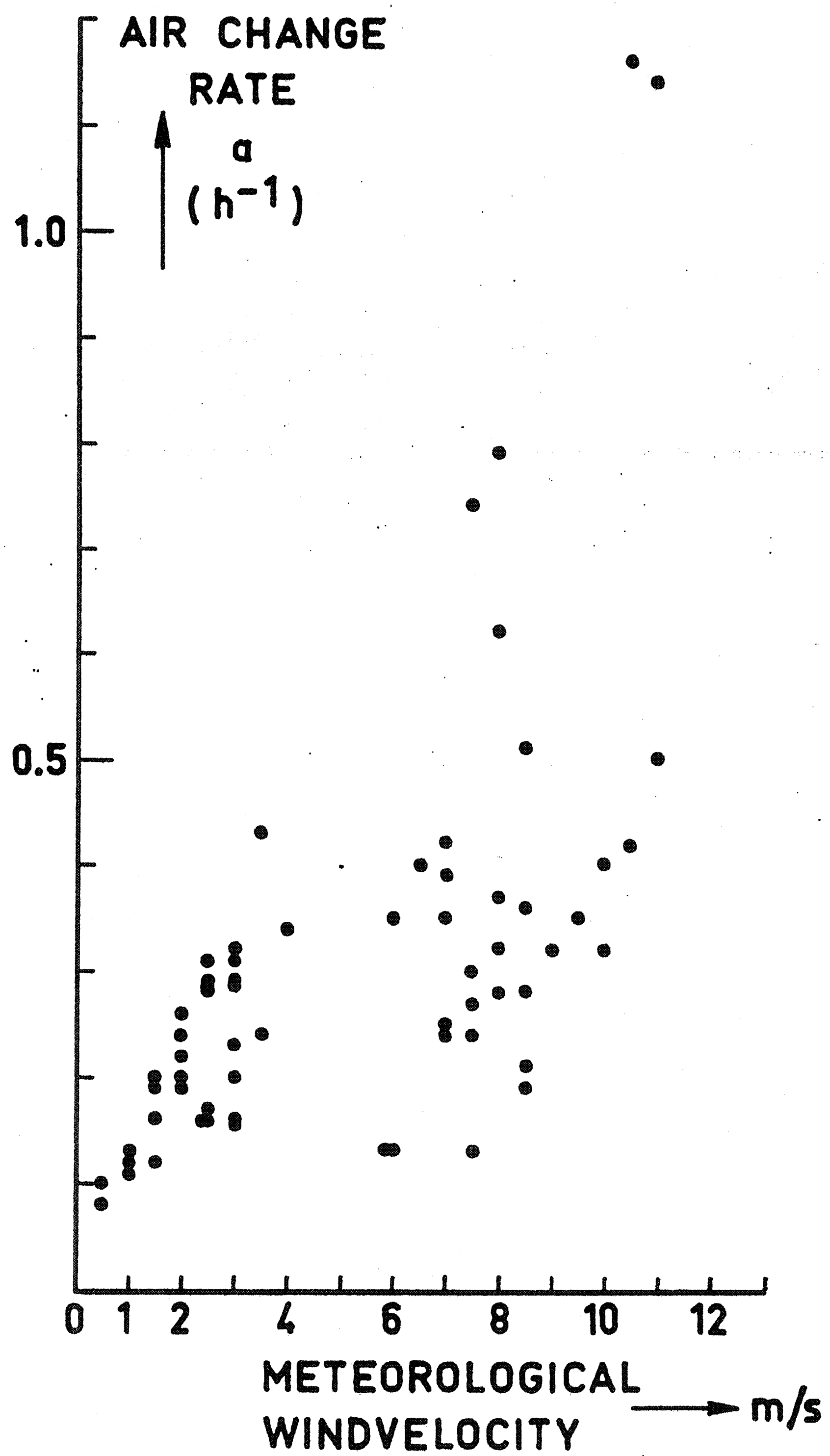

AIR CHANGE
RATE
a
(h⁻¹)
1.0
0.5
0
1
2
4
6
8
10
12
METEOROLOGICAL
WINDVELOCITY
m/s

Fig. 20

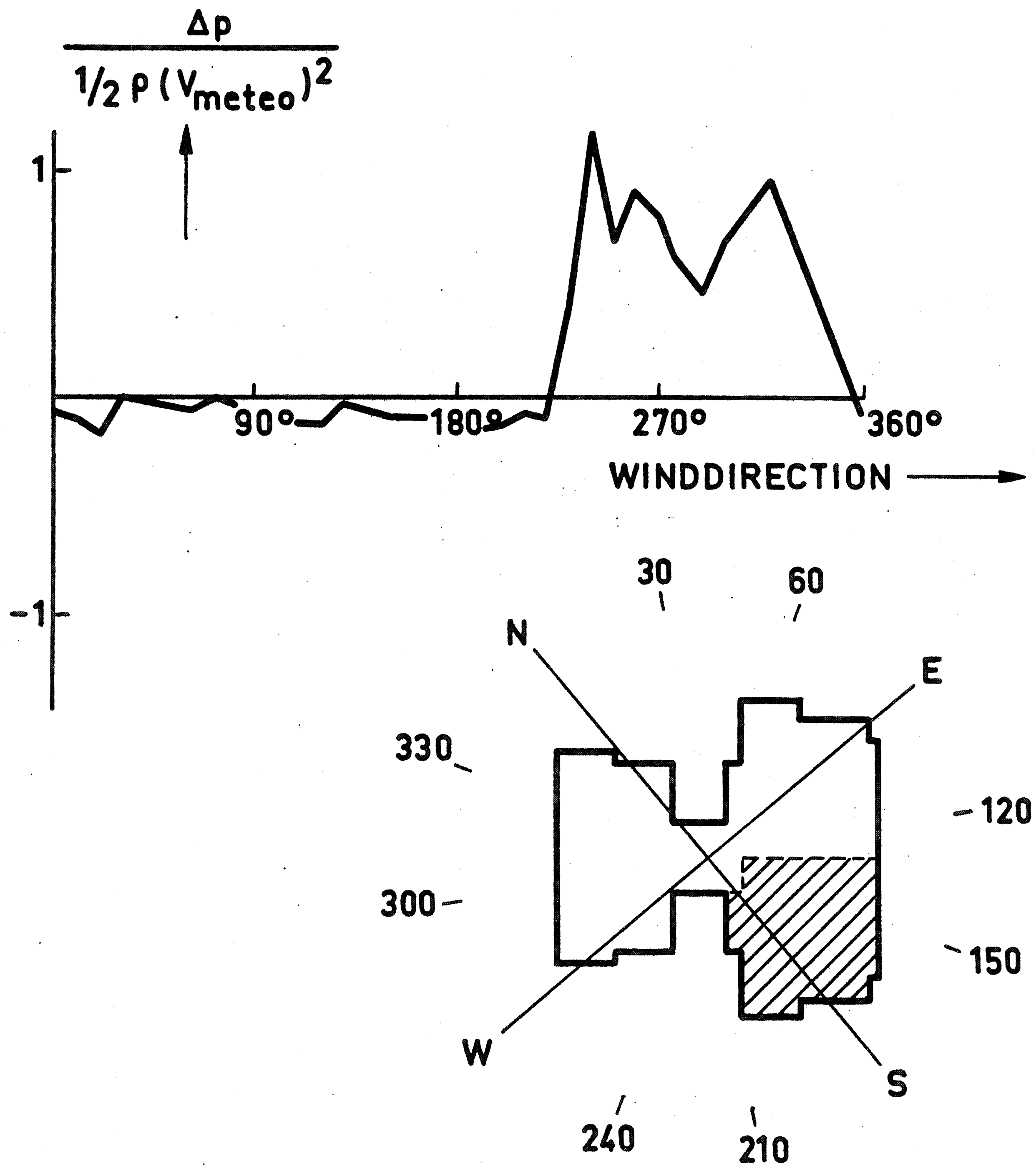
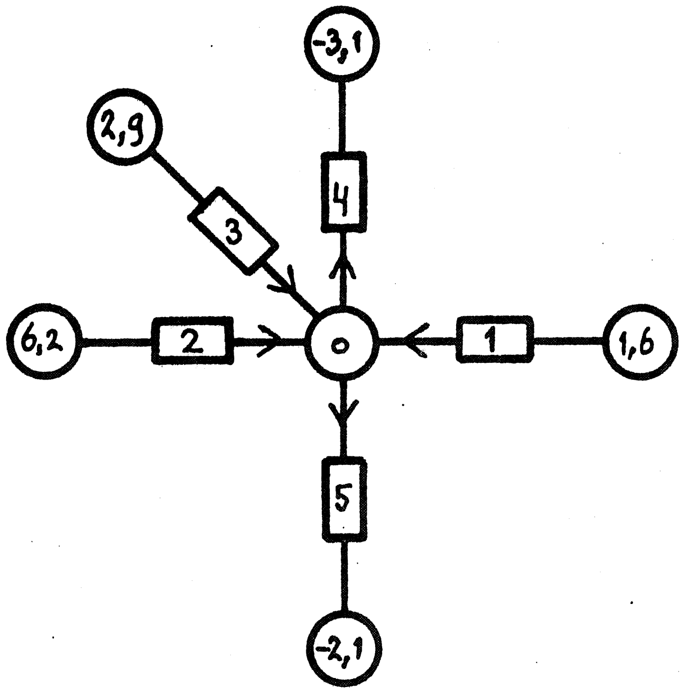

Δp
1/2 ρ (Vmeteo)²
1
-1
90°
180°
270°
360°
WINDDIRECTION
30
60
N
E
330
120
300
150
W
S
240
210

Fig. 22

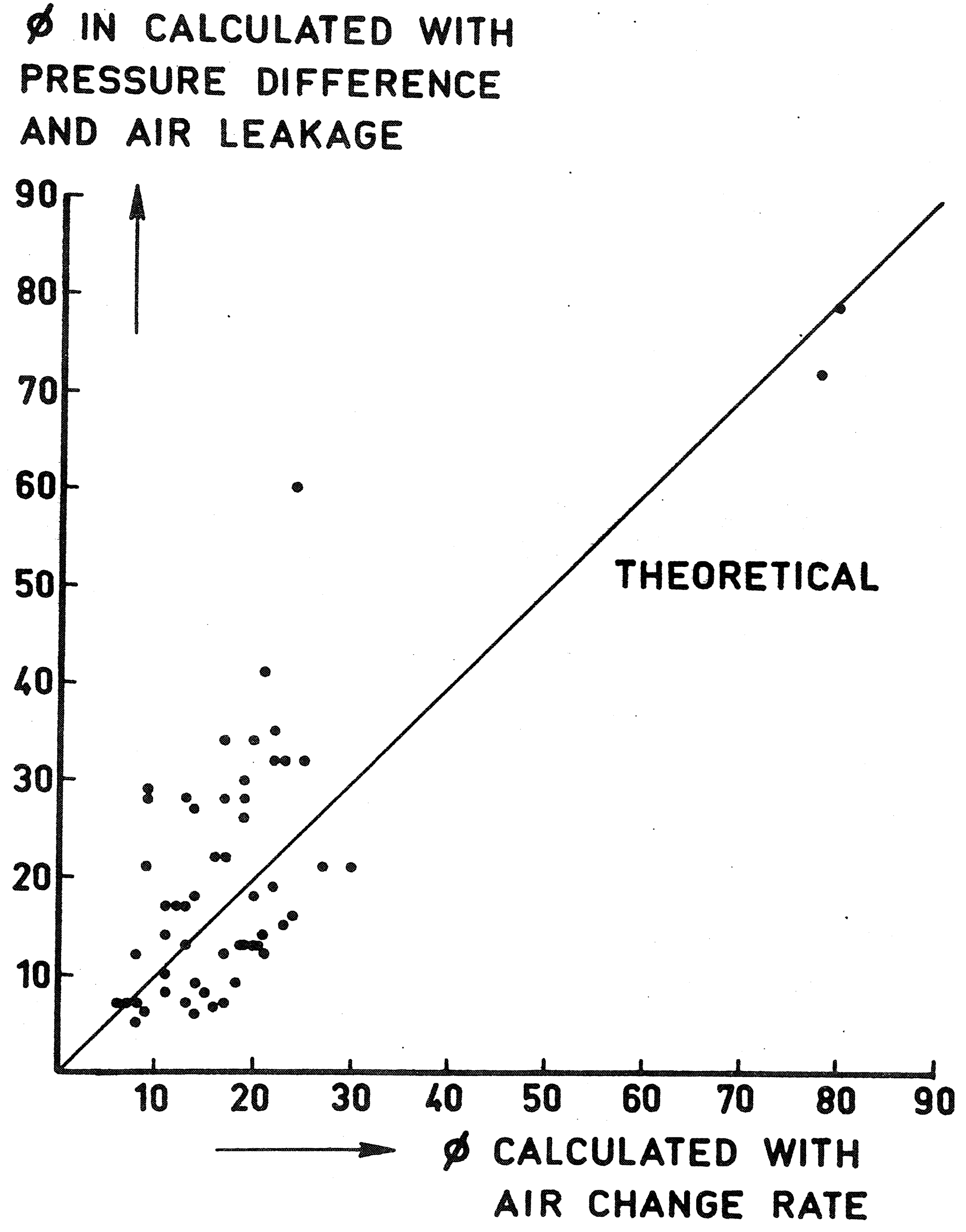
Ventilation rate (h^{-1})	$V_{meteo_{KNMI}}$ (m/s)	Direction (°)
0,32	3	300



IN			OUT		
ϕ_1	=	3,7	ϕ_4	=	23,8
ϕ_2	=	11,1	ϕ_5	=	2,1
ϕ_3	=	4,5			
$\phi_{tot_{in}}$		19,3	$\phi_{tot_{out}}$		25,9

$$\phi_{vent.rate} = 22{,}0 \ (m^3/s) \times 10^{-3}$$

Fig. 23



Ø IN CALCULATED WITH
PRESSURE DIFFERENCE
AND AIR LEAKAGE
90
80
70
60
50
40
30
20
10
THEORETICAL
10 20 30 40 50 60 70 80 90
Ø CALCULATED WITH
AIR CHANGE RATE

Fig. 24